TerraMatrix

MONTGOMERY WATSON
Natural Resource Group

December 12, 1997

Mr. Dale Gandy
Gandy Marley, Inc.
P.O. Box 827
Tatum, New Mexico 88267

Re: Transmittal of *Part A and Part B Permit Application for Triassic Park Hazardous Waste Facility* dated December 1997

Dear Dale:

On behalf of TerraMatrix/Montgomery Watson, S. M. Stoller and DelHart LLC, we are pleased to present three (3) hard copies and one (1) electronic copy of the above referenced document. This document supersedes all previous Part A and Part B permit submittals for the Triassic Park facility. In addition, this document addresses comments provided by ATK and NMED on the previous application submittals.

In accordance with State of New Mexico requirements, the engineering report, design drawings, specifications, construction quality assurance plan, and design calculations have been prepared by professional engineers registered in the State of New Mexico (Patrick Corser - No. 12236 and John Pellicer - No. 13547) with assistance from other engineering and technical staff.

We have enjoyed working with you and Larry Gandy on this project and look forward to the successful development of the Triassic Park Facility. If you have any questions please contact us.

Sincerely,

TerraMatrix/Montgomery Watson

Patrick Corser

Patrick Corser, P.E.
Vice President

DelHart, LLC

Hart M Greenwood

Hart M. Greenwood, REM
President

attachments

cc: J. Bonner - S.M. Stoller
J. Kendall - TerraMatrix

Volume I + II Missing

PART A AND PART B PERMIT APPLICATION

FOR THE

TRIASSIC PARK HAZARDOUS WASTE FACILITY

Volume IV

Appendix B - Construction Quality Assurance Plan
Appendix C - Construction Specifications

December 1997

Prepared By:

established 1959

The S.K. Phillips Corporation
[illegible]
Albuquerque, New Mexico [illegible]
(505) [illegible]

and

TerraMatrix
MONTGOMERY WATSON
Natural Resources Group

14175 Pine Grove Road
P.O. Box 774018
Steamboat Springs, Colorado 80477

FEB 1998

Appendices

NEW MEXICO ENVIRONMENTAL DEPARTMENT
RCRA PART B PERMIT APPLICATION

CONSTRUCTION QUALITY ASSURANCE PLAN

FOR

LANDFILL, SURFACE IMPOUNDMENT AND ASSOCIATED FACILITIES CONSTRUCTION

TRIASSIC PARK WASTE DISPOSAL FACILITY
CHAVES COUNTY, NEW MEXICO

EPA IDENTIFICATION NUMBER NM 0001002484

FINAL

December 1997

PATRICK G. CORSER
NEW MEXICO
12236
REGISTERED PROFESSIONAL ENGINEER

Patrick Corser, P.E
New Mexico Registration 12236

Note:	This document presents a construction quality assurance plan for various elements of the Triassic Park Waste Disposal Facility landfill, surface impoundment and associated facilities Modifications to the plan may be required prior to construction. Any revisions required will be submitted to NMED for approval prior to construction.

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SECTION I - GENERAL

1.0 INTRODUCTION

Triassic Park Waste Disposal Facility will consist of a landfill, evaporation pond, stabilization facility drum handling facility, liquid waste storage area, truck roll-off area and truck wash. This Construction Quality Assurance plan is intended to be used in conjunction with the design drawings and construction specifications.

The CQA Plan addresses the construction quality assurance of the soils, geosynthetics, and related liner system components for the facilities listed above at the Triassic Park Facility. The CQA Plan is divided into the following sections:

- Section I: General;
- Section II: Soils CQA;
- Section III: Geosynthetic Clay Liner CQA;
- Section IV: Geomembrane CQA;
- Section V: Geotextile CQA;
- Section VI: Geocomposite CQA;
- Section VII: Geonet CQA;
- Section VIII: Polyethylene Pipe and Fittings CQA; and,
- Section IX: ADS Slotted CPT CQA;
- Section X: Corrugated Metal Pipe CQA;
- Section XI: Carbon Steel and Stainless Steel Pipe CQA;
- Section XII: Polyethylene Tank CQA;
- Section XIII: Concrete Formwork CQA;
- Section XIV: Reinforcement Steel CQA;
- Section XV: Joints in Concrete CQA;
- Section XVI: Miscellaneous Metalwork CQA;
- Section XVII: Cast in Place Concrete CQA; abnd
- Section XVIII: CQA Documentation.

2.0 DEFINITIONS RELATING TO CONSTRUCTION QUALITY ASSURANCE

2.1 Construction Quality Assurance and Construction Quality Control

The CQA Plan is a site-specific document which addresses the following: (i) CQA personnel responsibilities, authorities, and qualifications; (ii) inspection, monitoring, and testing activities necessary to document that the facility is constructed to meet or exceed design criteria, plans, and specifications; and (iii) CQA documentation requirements.

Construction Quality Assurance (CQA) - A planned and systematic pattern of the means and actions designed to provide adequate confidence that items or services meet contractual and regulatory requirements, and will perform satisfactorily in service.

Construction Quality Control (CQC) -Those actions which provide a means to measure and control the characteristics of an item or service to meet contractual and regulatory requirements.

2.2 Use of the Terms in This Plan

In the context of this document:

- Construction Quality Assurance (CQA) refers to means and actions employed by the CQA Engineer to assure conformity of liner system preparation, production, and installation with this CQA Plan, the General Specifications, and the Construction Drawings. CQA is provided by a party independent from the product Manufacturer and Contractor.

- Construction Quality Control (CQC) refers to those actions taken by Manufacturers, Suppliers, Contractors, or Owners, including their designated representatives, to ensure that the materials and the workmanship meet the requirements of the General Specifications, and the Construction Drawings. In the case of soils, and within this CQA Plan, CQC is typically made a part of the CQA requirements and is provided by the CQA Engineer. In the case of geosynthetic and other non-soil components, CQC is provided by the Manufacturers and installers of the various geosynthetics.

3.0 PARTIES TO CONSTRUCTION QUALITY ASSURANCE

3.1 Organization Chart

A typical project organization chart for construction of landfills, surface impoundments and associated facilities is provided in Figure I-1.

3.2 Description of the Parties

3.2.1 Design Engineer

The Design Engineer is the individual, firm or corporation having direct responsibility for the design of the landfill or surface impoundment structure. During construction, the Design Engineer must approve any significant deviation from the design requirements of the Contract Documents. The Design Engineer may be an employee of the Owner. An individual representing the Design Engineer directly responsible for the project must be registered as a Professional Engineer in the State of New Mexico.

3.2.2 Contractor

The individual, firm, or corporation undertaking the execution of the work under the terms of the Contract Documents. The Contractor may be responsible for constructing the entire liner system (earthwork and geosynthetics), or only selected components of the liner system. The reference to Contractor refers to the General Contractor and all subcontractors which the General Contractor may employ in meeting the requirements of the Contract Documents.

3.2.3 Drainage Gravel Supplier

The drainage gravel Supplier excavates (or manufactures) and delivers drainage gravel to the Contractor at the Triassic Park Facility.

3.2.4 Road Base Material Supplier

The road base Supplier excavates (or manufactures) and road base material to the Contractor at the Triassic Park Facility.

3.2.5 Select Subbase Supplier

The select subbase Supplier excavates (or manufactures) and delivers select subbase to the contractor at the Triassic Park Facility.

3.2.6 Resin Supplier

The Resin Supplier produces and delivers resin to the Manufacturer of geosynthetic materials or polymer based products such as pipe.

3.2.7 Manufacturer

The Manufacturer manufactures a specific component (e.g., geomembrane, geosynthetic clay liner, geotextile, geocomposite, geonet or pipe) of the proposed liner system and delivers the component to the Contractor at the site. In the General Specifications, the term Manufacturer may refer to the geomembrane Manufacturer, geotextile Manufacturer, geocomposite/geonet Manufacturer, GCL Manufacturer, or pipe Manufacturer.

3.2.8 Construction Quality Assurance Engineer

The CQA Engineer is an individual, firm, or corporation, independent from the Owner, Contractor, and Manufacturer, that observes, tests, and documents activities related to the CQA of the earthworks at the site, and observes, tests, and documents activities related to the CQA of the installation of the geosynthetic components of the liner system. The CQA Engineer observes, tests, and documents activities related to the CQA of pipes and other liner system components. The CQA Engineer must provide an engineer which directly manages the CQA activities who is a Professional Engineer registered in the State of New Mexico. The CQA Engineer may be the same as the Design Engineer, but must be independent from the Owner.

3.2.9 Soils Construction Quality Assurance Laboratory

The Soils CQA Laboratory is independent from the Owner, Gravel Supplier, Granular Material Supplier, and Contractor. The Soils CQA Laboratory conducts tests in the laboratory (which may be on site or off site) on samples of soil taken from the borrow pits, stockpiles, or the liner system.

3.2.10 Geosynthetic CQA Laboratory

The Geosynthetics CQA Laboratory is independent from the Owner, Resin Supplier, Manufacturer, and Contractor. The Geosynthetics CQA Laboratory conducts tests on samples of geosynthetics taken from the site. The Geosynthetics CQA Laboratory may also conduct tests on pipes or other liner system components. The Geosynthetics CQA Laboratory service cannot be provided by any party involved with the manufacture or installation of any of the geosynthetic components.

3.2.11 Owner

The Owner owns and operates the landfill or surface impoundment. In this CQA Plan, the term "Owner" refers specifically to the Triassic Park Waste Disposal Facility.

3.3 Qualifications of the Parties

3.3.1 Design Engineer

The representative of the Design Engineer, who is directly responsible for the project, will be a qualified Professional Engineer registered in the State of New Mexico. The Design Engineer will have a history which demonstrates familiarity with all liner system components, including detailed design methods and procedures.

3.3.2 Geomembrane Installer

The Geomembrane Installer (who may be either the Contractor or a subcontractor to the Contractor) will be trained and qualified to install geosynthetics, as well as other liner system components such as pipe, if necessary.

All personnel performing seaming operations will be qualified by experience (i.e., each seamer will have installed no less than 100,000 square feet of geomembrane using the same methods of seaming that will be used on this project). At least one seamer will have experience seaming a minimum of 1,000,000 square feet of geomembrane using the same method of seaming that will be used on this project. The most experienced seamer, the "master seamer", will provide direct supervision, as required, over less experienced seamers. Field seaming may not take place without an approved master seamer being present.

The Contractor will provide the Owner and CQA Engineer with a list of proposed seaming personnel and their professional records. Any proposed seaming personnel deemed insufficiently experienced will not be accepted by the Owner or will be required to pass a seaming test prior to working on the Project.

3.3.3 Construction Quality Assurance Engineer Personnel

Personnel representing the CQA Engineer shall be properly trained and qualified to test and inspect soils, including high- and low-permeability soils, geosynthetics, including geomembranes, geotextiles, geocomposites, GCLs, and pipe. The CQA Engineer will predominately be represented by a Resident Engineer who has direct responsibility for management of the CQA activities. The CQA Resident Engineer will be experienced in construction, CQA of soils; CQA of geosynthetics and pipe; and preparation of CQA documentation including CQA forms, reports, and plans.

As a minimum, CQA Monitors will have a high school diploma and at least two years of construction related experience and one year of experience conducting CQA monitoring for landfill construction involving both soil and geosynthetic components, or a Bachelor of Science degree from a four year college or university and one year of experience conducting CQA monitoring for landfill construction involving both soil and geosynthetic components. In additions, the lead CQAM's shall be certified in geosynthetic by the National Institute for certification in Engineering technologies (NICET). The number of NICET certified monitors assigned to the work shall comply with the recommendation of EPA as indicated in Table I-1.

TABLE I-1
RECOMENDED IMPLEMENTATION PROGRAM
FOR CONSTRUCTION QUALITY ASSURANCE
(CQA) FOR GEOSYNTHETICS*
(Beginning January 1, 1993)

No. of Field Crews at Each Site	End of 18 Months (i.e., June 30, 1994)	End of 36 Months (i.e., January 1, 1996)
1-2	1 - Level II	1 - Level III ***
3-4	1 - Level II 1 - Level I	1 - Level III *** 1 - Level I
≥5	1 - Level II 2 - Level I	1 - Level III*** 1 - Level II 1 - Level I

* Certification for natural materials is under development as of this writing
** Performing a Critical Operation; Typically 4 to 6 People/Crew
*** Or PE with applicable experience

Reference: EPA Technical Guidance Document: Quality Assurance and Quality Control for Waste Containment Facilities. EPA/600/R-93/182, September 1993.

Qualification of CQA Personnel shall be documented by training records and professional resumes, shall be reviewed by the Project Manager.

3.3.4 Soils Construction Quality Assurance Laboratory

The Soils CQA Laboratory will have experience with the physical testing of soils, meet all applicable regulatory requirements, and be familiar with ASTM and other required test standards. The Soils CQA Laboratory will be capable of providing test results in accordance with the specifications.

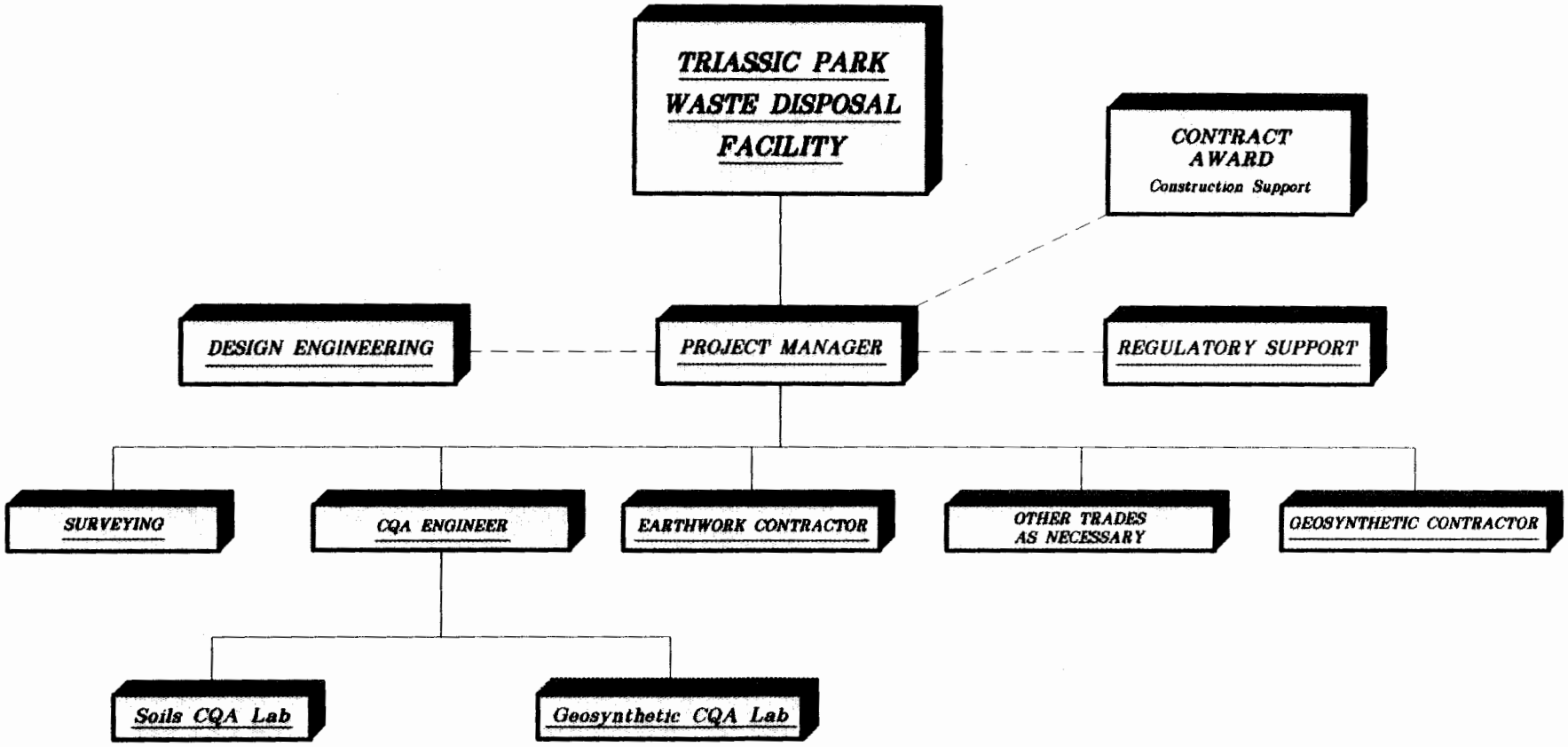
3.3.5 Geosynthetics Construction Quality Assurance Laboratory

The Geosynthetics CQA Laboratory will have experience in testing geosynthetics and other relevant liner system components and be familiar with ASTM and other applicable test standards.

3.4 Duties of Construction Quality Assurance Engineer

The overall responsibility of the CQA Engineer is to perform those activities specified in the CQA Plan (e.g., inspection, sampling, testing and documentation final certification). At a minimum, the CQA Engineer will be represented by a CQA Resident Engineer and the necessary supporting CQA inspection personnel. Specific responsibilities of the CQA Resident Engineer may include:

- Reviewing design criteria, plans, and specifications for clarity and completeness so that the CQA Plan can be implemented.
- Educating CQA personnel on CQA requirements and procedures.
- Scheduling and coordinating CQA activities.



REV No	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND SIGNED BY
0	Part B Permit	11/12/97	J Pellicer	J Bever	J Pellicer

TerraMatrix
MONTGOMERY WATSON
Mining Group

PROJECT No 602-0200
AutoCAD FILE TPORG.DWG
SCALE Not to Scale
FIGURE No I-1

Triassic Park Waste Disposal Facility

TYPICAL PROJECT ORGANIZATION

- Directing and supporting the CQA personnel in performing observations and tests by:
  - confirming that regular calibration of testing equipment is properly conducted and recorded;
  - confirming that the testing equipment, personnel, and procedures do not change adversely over time and verifying that changes do not adversely impact the inspection process;
  - confirming that the test data are accurately recorded and maintained; and,
  - verifying that the raw data are properly recorded, validated, reduced, summarized, and interpreted.
- Providing to the Owner reports on the observation results including:
  - review and interpretation of data sheets and reports;
  - identification of work that the CQA Resident Engineer believes should be accepted, rejected, or uncovered for observation, or that may require special testing, observation, or approval; and,
  - rejection of defective work and verification that corrective measures are implemented.
- Verifying that the Contractor's construction quality control plan, if required, is in accordance with the site-specific CQA Plan.
- At the Owner's request, reporting to the Contractor results of observations and tests as the work progresses and interacting with the Contractor to provide assistance in modifying the materials and work to comply with the specified design.
- Providing the final report and certifications required by the CQA Plan.

For the supporting CQA personnel, specific responsibilities may include:

- Performing independent on-site observation of the work in progress to verify conformance with the facility design criteria, plans, and specifications;
- Verifying that the equipment used in testing meets the test requirements and that the tests are conducted according to the standardized procedures defined by the CQA plan; and,
- Reporting to the CQA Resident Engineer results of all observation including work that is not of acceptable quality or that fails to meet the specified design.

4.0 SCOPE OF CONSTRUCTION QUALITY ASSURANCE

The scope of this CQA Plan includes the CQA of the subgrade, preparation and soil, pipe, concrete and geosynthetic components of the liner and cover system. This CQA Plan does not address design

guidelines, installation specifications, or selection of soils, geosynthetics, pipe or other liner system components, which are all described in the General Specifications.

The CQA Plan does not provide for Construction Quality Control which the Contractor may independently undertake to facilitate the Contractor's achieving his requirements under the General Specifications.

5.0 UNITS

In this CQA Plan, all properties and dimensions are expressed in customary U.S. units.

6.0 REFERENCES

6.1 Applicable Organizations

Organizations whose standards are referenced in the CQA Plan and the General Specifications are as follows:

- NMSH - New Mexico State Highway and Transportation Department of Highways (Standard Specifications for Road and Bridge Construction);
- ASTM - American Society for Testing and Materials;
- GRI - Geosynthetic Research Institute;
- OSHA - Occupational Safety and Health Administration; and,
- USEPA - United States Environmental Protection Agency.

6.2 Applicable Standards

Any reference to standards of any society, institute, association, or governmental agency will pertain to the edition in effect as of the date of this CQA Plan, unless stated otherwise.

6.3 Specific Standards

Specific test standards which may be cited in the CQA Plan and the General Specifications are given in Table I-2. These standards may be modified due to technological advances since compilation of Table I-2. All such modifications are to be approved by the Owner.

TABLE I-2
TEST METHODS CITED IN GENERAL SPECIFICATIONS AND CQA PLAN

AMERICAN SOCIETY OF TESTING AND MATERIALS		
1.	ASTM A 307	Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength
2.	ASTM A 726	Standard Specification for Cold-Rolled Carbon Steel sheet, Magnetic Laminated Quality, types 1, 2, and 2S
3.	ASTM C 88	Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate
4.	ASTM C 131	Resistance to Degradation of Small-size coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

TABLE I-2
TEST METHODS CITED IN GENERAL SPECIFICATIONS AND CQA PLAN

5.	ASTM D 374C or D 1777	Method for Measuring Thickness of Geotextile Materials.
6.	ASTM D 413	Standard Test Method for Rubber Property Adhesion to Flexible Substrate.
7.	ASTM D 422	Standard Method for Particle-Size Analysis of Soils.
8.	ASTM D 570	Standard Test Method for Water Absorption of Plastics.
9.	ASTM D 638	Standard Test Method for Tensile Properties of Plastics.
10.	ASTM D 698	Standard Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop.
11.	ASTM D 746	Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact.
12.	ASTM D 751	Standard Methods of Testing Coated Fabrics.
13.	ASTM D 792	Standard Test Methods for Specific Gravity (Relative density) and Density of Plastics by Displacement.
14.	ASTM D 882	Standard Test Methods for Tensile Properties of Thin Plastic Sheeting.
15.	ASTM D 1004	Standard Test Method of Initial Tear Resistance of Plastic film and Sheeting.
16.	ASTM D 1204	Standard Plastics Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature.
17.	ASTM D 1238	Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.
18.	ASTM D 1248	Standard Specification for Polyethylene Plastic Molding and extrusion Metals.
19.	ASTM D 1505	Standard Test Methods for Density of Plastics by Density-Gradient Technique.
20.	ASTM D 1556	Standard Test Method for Density of Soil In Place by the Sand-Cone Method.
21.	ASTM D 1593	Standard Specification for Nonrigid Vinyl Chloride Plastic Sheeting.
22.	ASTM D 1603	Standard Test Method for Carbon Black in Olefin Plastics.
23.	ASTM D 2167	Standard Test Method for Density and Unit Weight of Soils in Place by Rubber Balloon Method.
24.	ASTM D 2216 or D 4643	Standard Method for Laboratory Determination of water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures.
25.	ASTM D 2434	Standard Test Method for Permeability of Granular Soils (Constant Head).
26.	ASTM D 2487	Standard Test Method for Classification of Soils for Engineering Purposes.
27.	ASTM D 2657	Standard Practice for Heat-Joining for Polyolefin Pipe and Fittings.
28.	ASTM D 2663	Carbon-Black Dispersion in Rubber.
29.	ASTM D 2837	Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials.
30.	ASTM D 2922	Standard Test Method for Density of Soil and Soil-Aggregate In Place by Nuclear Methods (Shallow Depth).
31.	ASTM D 3015	Recommended Practice for Microscopical Examination of Pigment Dispersion in Plastic Compounds.
32.	ASTM D 3017	Standard Test Method for Moisture Content of Soil and Rock In Place by Nuclear Methods (Shallow Depth).
33.	ASTM D 3083	Standard Specification for Flexible Poly (Vinyl Chloride) Plastic Sheeting for Pond, Canal, and Reservoir Lining.
34.	ASTM D 3350	Standard Specifications for Polyethylene Plastic Pipe and Fittings Materials.
35.	ASTM D 3776	Mass Per Unit Area (Weight) of Woven Fabric.
36.	ASTM D 4253	Standard Test Method for Maximum Index Testing of Soils Using a Vibratory Table.
37.	ASTM D 4254	Standard test Method for Minimum Index Density of Soils and Calculations of Relative Density.

TABLE I-2
TEST METHODS CITED IN GENERAL SPECIFICATIONS AND CQA PLAN

38. ASTM D 4318	Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
39. ASTM D 4373	Standard Test Method for Calcium Carbonate Content of Soils.
40. ASTM D 4437	Standard Test Methods for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Geomembranes.
41. ASTM D 4491	Standard Test Method for Water Permeability of Geotextiles by the Permittivity Method.
42. ASTM D 4533	Standard Test Method for Trapezoid Tearing Strength of Geotextiles.
43. ASTM D 4632	Standard Test Method for Breaking Load and Elongation of Geotextiles (Grab Elongation Method and Peel Strength).
44. ASTM D 4643	Determination of Water (Moisture) Content of Soil by the Microwave Oven Method.
45. ASTM D 4716	Standard Test Method for Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products.
46. ASTM D 4751	Standard Test Method for Determining Apparent Opening Size of a Geotextile
47. ASTM D 4833	Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
48. ASTM D 5084	Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.
49. ASTM D 5261	Measuring Mass Per Unit Area of Geotextile
50. ASTM D 5321	Coefficient of Soil and Geosynthetics or Geosynthetics and Geosynthetics Friction by Direct Shear.
51. ASTM D 5890	Standard Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners.
52. ASTM 5891	Standard Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners.
53. ASTM E 11	Specification for Wire-Cloth Sieves for Testing Purposes.
54. ASTM F 714	Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter.
55. ASTM F 904	Standard Test Method for Comparison of Bond Strength or Ply Adhesion of Similar Laminates Made from Flexible Materials.
GEOSYNTHETIC RESEARCH INSTITUTE	
1. GRI-GMI	Standard Test Method for Ductile/Brittle Transition Time for Notched Polyethylene Specimen under Constant Stress.
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY	
1. USEPA Method 9090 Compatibility Test for Wastes and Membrane Liners.	

SECTION II - SOILS CONSTRUCTION QUALITY ASSURANCE

1.0 INTRODUCTION

This section of the CQA Plan addresses the soils components of the liner and cover systems and specifies the soils CQA program to be implemented with regard to materials selection and evaluation, laboratory test requirements, field test requirements, and treatment of problems.

This section of the CQA Plan also addresses for construction of the foundation subgrade, clay liners, clay covers, granular drainage layers, sump and pipe bedding gravel, the protective soil layer, and cover soil.

2.0 EXCAVATED SUBGRADE

2.1 Verification of Subgrade Continuity

When the excavation of the landfill or surface impoundment is completed, the CQA Engineer will:

- Inspect the subgrade on the side slopes and base of the landfill or surface impoundment and note areas of weak or excessively weathered subgrade materials; and,
- Observe the proof rolling of the base of the landfill or surface impoundment and note areas that exhibit excessive rutting, heaving, or softening.

Backfill material in the excavation will be structural fill or clay liner material that will be placed and compacted. The CQA Engineer will observe any excavation and backfilling operations.

The CQA Engineer will report any problems or deviations from the above requirements to the Owner.

2.2 Structural Fill Placement and Compaction

The General Specifications will be followed for the placement and compaction of structural fill. The CQA Engineer will monitor the fill placement and compaction to verify and document the following:

- The soil being placed meets the General Specification requirements for fill as determined by the test methods and frequencies specified within this CQA Plan;
- The compacted lift thickness is in accordance with the requirements of the General Specifications;
- The previous lift is scarified as specified in the General Specifications before placing the next lift;
- Fill is moisture conditioned, as required in the General Specifications; and,
- The compacted moisture content and dry unit weight of the fill meets specifications as determined by the test methods and frequencies described below.

2.3 Construction Quality Assurance Evaluation

The minimum frequency of soils testing for CQA purposes will conform to the minimum frequencies presented in Table II-1.

Nuclear density meter test methods will be used for the field testing of the in-situ dry unit weight and moisture content of the in-place, compacted fill. Standard Count Calibration, Sand Cone tests and/or Rubber Balloon tests and oven moisture content tests will be conducted to calibrate the results of the nuclear density meter and in cases of uncertainty with the nuclear density meter test results. Any conflict over the test results will be resolved by the CQA Engineer and the Owner. All perforations in the fill will be backfilled in accordance with the General Specifications.

If an in-place density test result fails to meet specifications, a confirmatory test will be performed immediately adjacent to the failed test. If the confirmatory test meets or exceeds specifications then a second confirmatory test will be performed at a second location immediately next to the failed test. If the second confirmatory test also meets or exceeds specifications then the area will be declared as meeting project specifications and the confirmatory tests will be reported. In the event that either confirmatory test fails to meet specifications, then additional testing will be performed to identify the limits of the area that does not meet project specifications.

If a defective area is discovered in the fill, the CQA Engineer will determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Engineer will determine the extent of the defective area by additional tests, observations, a review of records, or other means that the CQA Engineer deems appropriate. If the defect is related to adverse site conditions, such as excessively wet soils or surface desiccation, the CQA Engineer will define the limits and nature of the defect by testing or observation. After the extent and nature of a defect is determined, the CQA Engineer will notify the Owner, and verify that the deficiency is corrected by the Contractor before any additional work is performed in the area of the deficiency.

2.4 Surveying

A Professional Land Surveyor registered in the State of New Mexico will perform the CQA survey. The CQA Surveyor will independently survey the excavation to confirm that the grades and elevations in the field agree with those shown on the Construction Drawings. CQA Surveys will be conducted in accordance with the requirements described in Part 14 of Section II.

The results of the survey conducted by the CQA Surveyor will be compiled in a report signed by the CQA Surveyor and the CQA Engineer. The CQA Engineer and the Owner will review and approve the survey results before the next phase of the lining system is constructed.

3.0 PREPARED SUBGRADE

3.1 Prepared Subgrade Placement and Compaction

The CQA Engineer will verify and document that the prepared subgrade is constructed to the elevations, grades, and thicknesses shown on the Construction Drawings, with material meeting the requirements of the General Specifications as determined by the test methods and frequencies specified within this CQA Plan.

Prior to the placement of the prepared subgrade, the CQA Engineer will verify and document that:

- All or an approved portion of the excavation are complete, and that a survey has been conducted to verify that the subgrade grades and elevations conform to the Construction Drawings;
- The subgrade meets specifications as determined by the test requirements of this CQA Plan;
- The surface of the subgrade is free of debris, wet and soft areas, ponded water, vegetation, mud, ice or frozen material; and,
- If frozen subgrade material is encountered, it is removed and replaced in accordance with the General Specifications.

During placement and compaction of the prepared subgrade, the CQA Engineer will verify and document that:

- Close inspection of the placement and compaction of the prepared subgrade with earthmoving equipment is performed by the CQA Engineer;
- The prepared subgrade material meets the requirements of the General Specifications as determined by the CQA testing methods and frequency in Table II-2;
- The prepared subgrade is placed in accordance with the conditions and minimum requirements of the General Specifications;
- Each lift is compacted to the required thickness and minimum dry unit weight within the range of moisture contents established by the General Specifications as determined by the CQA testing methods and frequency in Table II-2;
- The Contractor uses the compaction equipment and the number of passes specified in the General Specifications;
- Perforations in the prepared subgrade at testing and sampling locations are backfilled in accordance with the General Specifications; and,
- The CQA Engineer will document the properties of the prepared subgrade as determined by the test methods and frequency prescribed by this CQA Plan and will report any nonconformance with the General Specifications to the Owner.

3.2 Construction Quality Assurance Evaluation

Construction quality assurance testing is required of the prepared subgrade, and the Contractor must take quality assurance testing into account when planning his construction schedule. Nuclear density meter test methods will be used for testing the in-situ compacted dry unit weight and moisture content of the materials. Standard Count Calibration, Sand Cone and/or Rubber Balloon tests and oven moisture content tests will be used to calibrate the reading of the nuclear density meter and in cases of uncertainty with the nuclear density meter readings. Any discrepancies between test results

will be resolved by the CQA Engineer and the Owner. The CQA Engineer will conduct moisture, and density tests as specified in Table II-2.

The testing frequency during prepared subgrade construction may be increased or modified at the discretion of the CQA Engineer when visual observations of construction performance indicate potential problems.

During construction, the frequency of testing may be increased by the CQA Engineer during adverse weather conditions, if equipment breaks down, at the start and finish of grading, if the material fails to meet the requirements of the General Specifications, or the extent of the work area is reduced.

If an in-place density test result fails to meet specifications, a confirmatory test will be performed immediately adjacent to the failed test. If the confirmatory test meets or exceeds specifications then a second confirmatory test will be performed at a second location immediately next to the failed test. If the second confirmatory test also meets or exceeds specifications then the area will be declared as meeting project specifications and the confirmatory tests will be reported. In the event that either confirmatory test fails to meet specifications, then additional testing will be performed to identify the limits of the area that does not meet project specifications.

If a defective area is discovered in the prepared subgrade, the CQA Engineer will determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Engineer will determine the extent of the defective area by additional tests, observations, a review of records, or other means that the CQA Engineer deems appropriate. If the defect is related to adverse site conditions, such as excessively wet soils or surface desiccation, the CQA Engineer will define the limits and nature of the defect by testing or observation. After the extent and nature of a defect is determined and has been remedied by the Contractor, the CQA Engineer will verify that the deficiency is corrected by retesting repaired areas before any additional work is performed by the Contractor in the area of the deficiency.

Based on the requirements of the General Specifications, the Contractor will be required to use all means necessary to protect all prior work, as well as all materials and completed work of other Sections. In the event of damage, the Contractor will be required to immediately make all repairs and replacements necessary. The CQA Engineer will verify and document that all damages are repaired.

3.3 Surveying

A Professional Land Surveyor registered in the State of New Mexico will perform the CQA surveys. The CQA Surveyor will independently survey the elevations and grades of the clay liner surfaces, and to confirm that the lines and elevations in the field agree with those shown on the Construction Drawings. CQA surveys will be conducted in accordance with the requirements described in Part 14 of Section II.

The results of the survey conducted by the CQA Surveyor will be compiled in a report signed by the CQA Surveyor and the CQA Engineer, and will be reviewed by the Owner. The owner and the CQA Engineer will approve the survey results before the next phase of the liner system (geomembrane installation) is constructed.

4.0 CLAY LINERS

4.1 Clay Liner Placement and Compaction

The CQA Engineer will verify and document that the clay liner is constructed to the elevations, grades, and thicknesses shown on the Construction Drawings, with material meeting the requirements of the General Specifications as determined by the test methods and frequencies specified within this CQA Plan.

Prior to the placement of the clay liner, the CQA Engineer will verify and document that:

- That a test fill has been constructed with the proposed liner material and production scale equipment to confirm processing and placement procedures. In addition, field and laboratory testing shall be completed on the test fill to confirm clay placement specifications will achieve the specified permeability. A test fill plan is presented in Appendix A.

- All or an approved portion of the excavation are complete, and that a survey has been conducted to verify that the subgrade grades and elevations conform to the Construction Drawings;

- The subgrade meets specifications as determined by the test requirements of this CQA Plan;

- The surface of the subgrade is free of debris, wet and soft areas, ponded water, vegetation, mud, ice or frozen material; and,

- If frozen subgrade material is encountered, it is removed and replaced in accordance with the General Specifications.

During placement and compaction of the clay liner, the CQA Engineer will verify and document that:

- Close observation of the placement and compaction of clay liner material with earthmoving equipment is performed by the CQA Engineer;

- The clay liner material meets the requirements of the General Specifications as determined by the CQA testing methods and frequency in Table II-3;

- The clay liner is placed in accordance with the conditions and minimum requirements of the General Specifications;

- Each lift is compacted to the required thickness and minimum dry unit weight within the range of moisture contents established by the General Specifications as determined by the CQA testing methods and frequency in Table II-3;

- The Contractor uses the compaction equipment and the number of passes specified in the General Specifications;

- Thin-walled (i.e., Shelby tube) samples of clay liner material are collected and laboratory permeability testing is performed at the frequency specified in Table II-3;

- Perforations in the clay liner at testing and sampling locations are backfilled in accordance with the General Specifications; and,

- Excessive wrinkles in the geosynthetic components underlying the clay have been "worked" out.

The CQA Engineer will document the properties of the clay soil as determined by the test methods and frequency prescribed by this CQA Plan and will report any nonconformance with the General Specifications to the Owner.

4.2 Construction Quality Assurance Evaluation

Extensive construction quality assurance testing is required of the clay liners, and the Contractor must take quality assurance testing into account when planning his construction schedule. Nuclear density meter test methods will be used for testing the in-situ compacted dry unit weight and moisture content of the clay materials. Standard Count Calibration, Sand Cone and/or Rubber Balloon tests and oven moisture content tests will be used to calibrate the reading of the nuclear density meter and in cases of uncertainty with the nuclear density meter readings. Any discrepancies between test results will be resolved by the CQA Engineer and the Owner. Thin-walled (i.e., Shelby) tube samples will be collected for hydraulic conductivity testing. At the request of the CQA Engineer, on-site construction equipment operated by the Contractor will be used to slowly push the sample tube through the clay layer. The CQA Engineer will conduct moisture, density, and hydraulic conductivity tests as specified in Table II-3.

The testing frequency during clay liner construction may be increased or modified at the discretion of the CQA Engineer when visual observations of construction performance indicate potential problems.

During construction, the frequency of testing may be increased by the CQA Engineer during adverse weather conditions, if equipment breaks down, at the start and finish of grading, if the material fails to meet the requirements of the General Specifications, or the extent of the work area is reduced.

All perforations in the clay liner at nuclear density test probe locations will be backfilled by the CQA Engineer with clay liner material and compacted by hand tamping. All perforations at sand cone or rubber balloon test locations, Shelby tube sample locations, and test pit locations will be backfilled by the Contractor with clay liner material and compacted in accordance with the specifications for clay liner.

If an in-place density test results fail to meet specifications, a confirmatory test will be performed immediately adjacent to the failed test. If the confirmatory test meets or exceeds specifications then a second confirmatory test will be performed at a second location immediately next to the failed test. If the second confirmatory test also meets or exceeds specifications then the area will be declared as meeting project specifications and the confirmatory tests will be reported. In the event that either confirmatory test fails to meet specifications, then additional testing will be performed to identify the limits of the area that does not meet project specifications.

If a defective area is discovered in the clay liner, the CQA Engineer will determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Engineer will determine the extent of the defective area by additional tests, observations, a review of records, or

other means that the CQA Engineer deems appropriate. If the defect is related to adverse site conditions, such as excessively wet soils or surface desiccation, the CQA Engineer will define the limits and nature of the defect by testing or observation. After the extent and nature of a defect is determined and has been remedied by the Contractor, the CQA Engineer will verify that the deficiency is corrected by retesting repaired areas before any additional work is performed by the Contractor in the area of the deficiency.

Based on the requirements of the General Specifications, the Contractor will be required to use all means necessary to protect all prior work, as well as all materials and completed work of other Sections. In the event of damage, the Contractor will be required to immediately make all repairs and replacements necessary. The CQA Engineer will verify and document that all damages are repaired.

4.3 Surveying

A Professional Land Surveyor registered in the State of New Mexico will perform the CQA surveys. The CQA Surveyor will independently survey the elevations and grades of the clay liner surfaces, and to confirm that the lines and elevations in the field agree with those shown on the Construction Drawings. CQA surveys will be conducted in accordance with the requirements described in Part 14 of Section II.

The results of the survey conducted by the CQA Surveyor will be compiled in a report signed by the CQA Surveyor and the CQA Engineer, and will be reviewed by the Owner. The Owner and the CQA Engineer will approve the survey results before the next phase of the liner system (geomembrane installation) is constructed.

5.0 DRAINAGE GRAVEL

5.1 Supplier

The Contractor will require that the drainage gravel Supplier provide the CQA Engineer with quality control test results and a written certification signed by a responsible party of the Supplier that the tests required by the General Specifications have been performed on the material to be delivered to the site.

The CQA Engineer will examine the tests results and report any deviations to the Owner. If the drainage gravel supplier cannot provide test results required by the general specifications, then the CQA Engineer may perform or arrange to perform the tests.

5.2 Conformance Evaluation

The test methods and frequency for CQA conformance testing of the drainage gravel are specified in Table II-4.

If the material fails to meet the requirements of the General Specifications, the CQA Engineer will perform sufficient sampling and testing to identify the extent of the nonconforming material at the expense of the Contractor. Nonconforming material will be removed from the site.

5.3 Placement and Compaction

The CQA Engineer will verify and document that the drainage gravel is constructed to the elevations, grades, and thicknesses shown on the Construction Drawings, with material meeting the requirements of the General Specifications as determined by the test methods and frequencies specified within this CQA Plan.

Prior to the placement of the drainage gravel, the CQA Engineer will verify and document that:

- The underlying geosynthetic layers are free of holes, tears, excessive wrinkles, or foreign objects; and,
- All work on underlying layers is complete and accepted by the Owner.

During placement and compaction of the drainage gravel, the CQA Engineer will verify and document that:

- Drainage gravel material satisfies the requirements of the General Specifications as determined by the testing prescribed within the CQA Plan;
- Drainage gravel material is spread before 12:00 noon, unless otherwise approved by the Owner;
- The equipment wheel ground pressure versus the material thickness requirements given in the General Specifications are complied with;
- The drainage gravel is placed in a manner so that the maximum material drop height is in accordance with the General Specifications;
- Close observation of the placement and compaction of drainage gravel with earth moving equipment is performed; and,
- The drainage gravel is compacted utilizing the equipment and number of passes specified in the General Specifications.

5.4 Construction Quality Assurance Evaluation

No density tests will be conducted on the drainage gravel. If the CQA Engineer suspects damage to pipes or underlying geosynthetic, the contractor will be required to expose the potentially damaged materials and repair any observed damage.

5.5 Surveying

A Professional Land Surveyor registered in the State of New Mexico will perform CQA surveys. The CQA surveyor will independently survey the elevations and grades of the top of the drainage gravel, and to confirm that the grades and elevations in the field agree with those shown on the Construction Drawings. The CQA surveys will be performed in accordance with the requirements described in Part 14 of Section II.

The results of the survey conducted by the CQA Surveyor will be compiled in a report signed by the CQA Surveyor and the CQA Engineer, and will be reviewed by the Owner. The Owner and CQA Engineer will approve the survey results before the next phase of the lining system is constructed.

6.0 ROAD BASE

6.1 Supplier

The Contractor will provide the CQA Engineer with quality control test results and a written certification signed by a responsible party of the road base Supplier that the tests required by the General Specifications have been performed on material representative of that which is to be delivered to the site.

The CQA Engineer will examine the tests results and report any deviations from the General Specifications to the Owner. If the road base Supplier cannot provide test results required by the General Specifications, then the CQA Engineer may perform or arrange to perform the tests.

6.2 Conformance Evaluation

The test methods and frequency for CQA testing of the road base is specified in Table II-5.

If the gravel fails to meet the requirements of the General Specifications, the CQA Engineer will perform sufficient sampling and testing to identify the extent of the nonconforming material with the cost of such tests borne by the Contractor. Nonconforming material will be removed from the site.

6.3 Placement

The CQA Engineer will verify and document that the road base is constructed to the elevations, grades, and thicknesses shown on the Construction Drawings, with material meeting the requirements of the General Specifications as determined by the test methods and frequencies specified within this CQA Plan.

Prior to the placement of the road base, the CQA Engineer will verify and document that:

- The underlying geotextile is free of holes, tears, excessive wrinkles, or foreign objects; and,
- All work on underlying layers is complete and accepted by the Owner.

During placement of the road base, the CQA Engineer will verify and document that:

- Close observation of the placement of road base with earth-moving equipment is performed;
- The road base is suitable and meets the requirements of the General Specifications as determined by the test methods and frequency prescribed within this CQA Plan; and,
- The road base is placed in accordance with the General Specifications.

6.4 Construction Quality Assurance Evaluation

Nuclear density tests will be used for testing the in-situ dry unit weight and moisture content of the road base. If the CQA Engineer suspects damage to underlying geosynthetics, the Contractor will be required to expose the potentially damaged materials and repair any observed damage.

7.0 COVER SOIL

7.1 Placement and Compaction

The CQA Engineer will verify and document that the cover soil is constructed to the elevations, grades, and thicknesses shown on the Construction Drawings, with material meeting the requirements of the General Specifications as determined by the test methods and frequencies specified within this CQA Plan.

Prior to the placement of the cover soil, the CQA Engineer will verify and document that:

- All or an approved portion of the waste filling plan is complete, and that a survey has been conducted to verify that the waste grades and elevations conform to the Construction Drawings;
- The surface of the subgrade is free of debris, wet and soft areas, ponded water, vegetation, mud, ice or frozen material; and,

During placement and compaction of the cover soil, the CQA Engineer will verify and document that:

- Close observation of the placement and compaction of cover soil with earthmoving equipment is performed by the CQA Engineer;
- The cover soil meets the requirements of the General Specifications as determined by the CQA testing methods and frequency in Table II-6;
- The cover soil is placed in accordance with the conditions and minimum requirements of the General Specifications;
- Each lift is compacted to the required thickness and minimum dry unit weight within the range of moisture contents established by the General Specifications as determined by the CQA testing methods and frequency in Table II-6;
- The Contractor uses the compaction equipment and the number of passes specified in the General Specifications; and,
- The CQA Engineer will document the properties of the cover soil as determined by the test methods and frequency prescribed by this CQA Plan and will report any nonconformance with the General Specifications to the Owner.

7.2 Construction Quality Assurance Evaluation

Nuclear density tests will be used for testing the in-situ unit weight and moisture content of the cover soil.

The Contractor will be required to use all means necessary to protect all prior work, as well as all material and completed work of other Sections. In the event of damage, the Contractor will be required to immediately make all repairs and replacements necessary. The CQA Engineer will verify and document that all damages are repair.

7.3 Surveying

A Professional Land Surveyor registered in the State of New Mexico will perform the CQA surveys. The CQA Surveyor will independently survey the elevations and grades of the cover soil to confirm that the lines and elevations in the field agree with those shown on the Construction Drawings. CQA surveys will be conducted in accordance with the requirements described in Part 14 of Section II.

The results of the survey conducted by the CQA Surveyor will be compiled in a report signed by the CQA Surveyor and the CQA Engineer, and will be reviewed by the Owner. The Owner and the CQA Engineer will approve the survey results before the next phase of construction.

8.0 VEGETATIVE COVER

8.1 Placement and Compaction

The CQA Engineer will verify and document that the vegetative cover is constructed to the elevations, grades, and thicknesses shown on the Construction Drawings, with material meeting the requirements of the General Specifications as determined by the test methods and frequencies specified within this CQA Plan.

Prior to the placement of the vegetative cover, the CQA Engineer will verify and document that:

- All work on underlying layers is complete and accepted by Owner; and,
- The underlying geocomposite is free of holes, team, excessive wrinkles, or foreign objects.

During placement and compaction of the vegetative cover, the CQA Engineer will verify and document that:

- Close observation of the placement and compaction of vegetative cover with earthmoving equipment is performed;
- The vegetative cover meets the requirements of the General Specifications as determined by the CQA testing methods and frequency in Table II-7;
- The vegetative cover is placed in accordance with the conditions and minimum requirements of the General Specifications;

- The Contractor uses the compaction equipment and the number of passes specified in the General Specifications; and,

- The CQA Engineer will document the properties of the vegetative cover as determined by the test methods and frequency prescribed by this CQA Plan and will report any nonconformance with the General Specifications to the Owner.

8.2 Construction Quality Assurance Evaluation

The Contractor will be required to use all means necessary to protect all prior work, as well as all material and completed work of other Sections. In the event of damage, the Contractor will be required to immediately make all repairs and replacements necessary. The CQA Engineer will verify and document that all damages are repair.

8.3 Surveying

A Professional Land Surveyor registered in the State of New Mexico will perform the CQA surveys. The CQA Surveyor will independently survey the elevations and grades of the vegetative cover to confirm that the lines and elevations in the field agree with those shown on the Construction Drawings. CQA surveys will be conducted in accordance with the requirements described in Part 14 of Section II.

The results of the survey conducted by the CQA Surveyor will be compiled in a report signed by the CQA Surveyor and the CQA Engineer, and will be reviewed by the Owner. The Owner and the CQA Engineer will approve the survey results before the next phase of construction.

9.0 PIPE BEDDING SAND

9.1 Placement and Compaction

The CQA Engineer will verify and document that the pipe bedding is constructed to the elevations, grades, and thicknesses shown on the Construction Drawings, with material meeting the requirements of the General Specifications as determined by the test methods and frequencies specified within this CQA Plan.

Prior to the placement of the pipe bedding sand, the CQA Engineer will verify and document that:

- All work on underlying layers is complete and accepted by the Owner; and,

- The underlying geotextile is free of holes, tears, excessive wrinkles, or foreign objects.

During placement and compaction of the pipe bedding sand, the CQA Engineer will verify and document that:

- Close observation of the placement and compaction of pipe bedding with earthmoving equipment is performed;

- The pipe bedding sand meets the requirements of the General Specifications as determined by the CQA testing methods and frequency in Table II-8;

- The pipe bedding sand is placed in accordance with the conditions and minimum requirements of the General Specifications;

- The Contractor uses the compaction equipment and the number of passes specified in the General Specifications; and,

- The CQA Engineer will document the properties of the pipe bedding sand as determined by the test methods and frequency prescribed by this CQA Plan and will report any nonconformance with the General Specifications to the Owner.

9.2 Construction Quality Assurance Evaluation

The Contractor will be required to use all means necessary to protect all prior work, as well as all material and completed work of other Sections. In the event of damage, the Contractor will be required to immediately make all repairs and replacements necessary. The CQA Engineer will verify and document that all damages are repair.

9.3 Surveying

A Professional Land Surveyor registered in the State of New Mexico will perform the CQA surveys. The CQA Surveyor will independently survey the elevations and grades of the pipe bedding sand to confirm that the lines and elevations in the field agree with those shown on the Construction Drawings. CQA surveys will be conducted in accordance with the requirements described in Part 14 of Section II.

The results of the survey conducted by the CQA Surveyor will be compiled in a report signed by the CQA Surveyor and the CQA Engineer, and will be reviewed by the Owner. The Owner and the CQA Engineer will approve the survey results before the next phase of construction.

10.0 SELECT SUBBASE

10.1 Placement and Compaction

Prior to the placement of the select subbase, the CQA Engineer will verify and document that:

- All work on underlying layers is complete and accepted by the Owner; and,

- The underlying geocomposite is free of holes, tears, excessive wrinkles, or foreign objects.

During placement and compaction of the select subbase, the CQA Engineer will verify and document that:

- Close observation of the placement and compaction of select subbase with earthmoving equipment is performed by the CQA Engineer;

- The select subbase meets the requirements of the General Specifications as determined by the CQA testing methods and frequency in Table II-9;

- The select subbase is placed in accordance with the conditions and minimum requirements of the General Specifications;

- Each lift is compacted to the required thickness and minimum dry unit weight within the range of moisture contents established by the General Specifications as determined by the CQA testing methods and frequency in Table II-9;

- The Contractor uses the compaction equipment and the number of passes specified in the General Specifications; and,

- The CQA Engineer will document the properties of the select subbase as determined by the test methods and frequency prescribed by this CQA Plan and will report any nonconformance with the General Specifications to the Owner.

10.2 Construction Quality Assurance Evaluation

Nuclear density tests will be used for testing the in-situ unit weight and moisture content of the select subbase.

The Contractor will be required to use all means necessary to protect all prior work, as well as all material and completed work of other Sections. In the event of damage, the Contractor will be required to immediately make all repairs and replacements necessary. The CQA Engineer will verify and document that all damages are repair.

10.3 Surveying

A Professional Land Surveyor registered in the State of New Mexico will perform the CQA surveys. The CQA Surveyor will independently survey the elevations and grades of the select subbase to confirm that the lines and elevations in the field agree with those shown on the Construction Drawings. CQA surveys will be conducted in accordance with the requirements described in Part 14 of Section II.

The results of the survey conducted by the CQA Surveyor will be compiled in a report signed by the CQA Surveyor and the CQA Engineer, and will be reviewed by the Owner. The Owner and the CQA Engineer will approve the survey results before the next phase of construction.

11.0 SUBBASE

11.1 Placement and Compaction

The CQA Engineer will verify and document that the subbase is constructed to the elevations, grades, and thicknesses shown on the Construction Drawings, with material meeting the requirements of the General Specifications as determined by the test methods and frequencies specified within this CQA Plan.

Prior to the placement of subbase, the CQA Engineer will verify and document that:

- All work on underlying layers is complete and accepted by the Owner.

During placement and compaction of the subbase, the CQA Engineer will verify and document that:

- Close observation of the placement and compaction of subbase with earthmoving equipment is performed by the CQA Engineer;
- The subbase meets the requirements of the General Specifications as determined by the CQA testing methods and frequency in Table II-10;
- The subbase is placed in accordance with the conditions and minimum requirements of the General Specifications;
- Each lift is compacted to the required thickness and minimum dry unit weight within the range of moisture contents established by the General Specifications as determined by the CQA testing methods and frequency in Table II-10; and,
- The Contractor uses the compaction equipment and the number of passes specified in the General Specifications;
- The CQA Engineer will document the properties of the subbase as determined by the test methods and frequency prescribed by this CQA Plan and will report any nonconformance with the General Specifications to the Owner.

11.2 Construction Quality Assurance Evaluation

Nuclear density tests will be used for testing the in-situ unit weight and moisture content of the subbase.

The Contractor will be required to use all means necessary to protect all prior work, as well as all material and completed work of other Sections. In the event of damage, the Contractor will be required to immediately make all repairs and replacements necessary. The CQA Engineer will verify and document that all damages are repair.

11.3 Surveying

A Professional Land Surveyor registered in the State of New Mexico will perform the CQA surveys. The CQA Surveyor will independently survey the elevations and grades of the subbase to confirm that the lines and elevations in the field agree with those shown on the Construction Drawings. CQA surveys will be conducted in accordance with the requirements described in Part 14 of Section II.

The results of the survey conducted by the CQA Surveyor will be compiled in a report signed by the CQA Surveyor and the CQA Engineer, and will be reviewed by the Owner. The Owner and the CQA Engineer will approve the survey results before the next phase of construction.

12.0 FOUNDATION SAND

12.1 Placement and Compaction

The CQA Engineer will verify and document that the foundation sand is constructed to the elevations, grades, and thicknesses shown on the Construction Drawings, with material meeting the

requirements of the General Specifications as determined by the test methods and frequencies specified within this CQA Plan.

Prior to the placement of the foundation sand, the CQA Engineer will verify and document that:

- All work on underlying layers is complete and accepted by the Owner; and,
- The underlying geomembrane is free of holes, tears, excessive wrinkles, or foreign objects.

During placement and compaction of the foundation sand, the CQA Engineer will verify and document that:

- Close observation of the placement and compaction of foundation sand with earthmoving equipment is performed;
- The foundation sand meets the requirements of the General Specifications as determined by the CQA testing methods and frequency in Table II-11;
- The foundation sand is placed in accordance with the conditions and minimum requirements of the General Specifications;
- Each lift is compacted to the required thickness and minimum dry unit weight within the range of moisture contents established by the General Specifications as determined by the CQA testing methods and frequency in Table II-11;
- The Contractor uses the compaction equipment and the number of passes specified in the General Specifications; and,
- The CQA Engineer will document the properties of the foundation sand as determined by the test methods and frequency prescribed by this CQA Plan and will report any nonconformance with the General Specifications to the Owner.

12.2 Construction Quality Assurance Evaluation

Nuclear density tests will be used for testing the in-situ unit weight and moisture content of the foundation sand.

The Contractor will be required to use all means necessary to protect all prior work, as well as all material and completed work of other Sections. In the event of damage, the Contractor will be required to immediately make all repairs and replacements necessary. The CQA Engineer will verify and document that all damages are repair.

12.3 Surveying

A Professional Land Surveyor registered in the State of New Mexico will perform the CQA surveys. The CQA Surveyor will independently survey the elevations and grades of the foundation sand to confirm that the lines and elevations in the field agree with those shown on the Construction Drawings. CQA surveys will be conducted in accordance with the requirements described in Part 14 of Section II.

The results of the survey conducted by the CQA Surveyor will be compiled in a report signed by the CQA Surveyor and the CQA Engineer, and will be reviewed by the Owner. The Owner and the CQA Engineer will approve the survey results before the next phase of construction.

13.0 PROTECTIVE SOIL LAYER

13.1 Placement and Compaction

The CQA Engineer will verify and document that the protective soil layer is constructed to the elevations, grades, and thicknesses shown on the Construction Drawings, with material meeting the requirements of the General Specifications as determined by the test methods and frequencies specified within this CQA Plan.

Prior to the placement of the protective soil layer, the CQA Engineer will verify and document that:

- The underlying geocomposite is free of holes, tears, excessive wrinkles, or foreign objects; and,
- All work on underlying layers is complete and accepted by the Owner.

During placement of the protective soil layer, the CQA Engineer will verify and document that:

- The soil is suitable and satisfies the requirements of the General Specifications as determined by the test methods and frequencies prescribed in Table 11-12;
- The protective soil is placed in accordance with the General Specifications;
- The lift thicknesses and total thickness of the protective soil layer agree with the requirements of the General Specifications;
- If excessive wrinkles begin to develop in the underlying geosynthetics during material placement or spreading, the wrinkles are worked out prior to continued placement operations;
- The protective soil layer is lightly compacted as described in the General Specifications;
- The protective soil is placed on the side slopes to the limits shown on the construction drawings; and,
- No protective soil layer material is placed or compacted during periods of unfavorable weather conditions.

13.2 Conformance Evaluation

There are no CQA testing requirements for the protective soil layer, other than thickness requirements.

If damage to underlying geosynthetics is expected, the CQA Engineer will require that the overlying protective soil layer material be removed to expose the geosynthetics.

The Contractor will be required to use all means necessary to protect all prior work, as well as all materials and completed work of other Sections. In the event of damage, the Contractor will be required to immediately make all repairs and replacements necessary. The CQA Engineer will verify and document that all damages are repaired.

13.3 Surveying

A Professional Land Surveyor registered in the State of New Mexico will perform the CQA surveys. The CQA surveyor will independently survey the elevations and grades of the top of the protective soil layer on the base and side-slopes of the landfill, and to confirm that the grades and elevations in the field agree with those shown on the Construction Drawings. The CQA surveys will be performed in accordance with the requirements described in Part 14 of Section II. The results of the survey conducted by the CQA Surveyor will be compiled in a report signed by the CQA Surveyor and the CQA Engineer, and will be reviewed by the Owner.

14.0 SURVEYING

The Surveyor will be required to survey each soil layer of the liner system and cover system (except the vegetative soil cover) for the landfill or surface impoundment in accordance with the requirements of the General Specifications. If required by the Owner, a Record Drawing will be submitted by the Surveyor before the placement of the next liner system layer. The surveys will be conducted at a 100 foot grid for slopes greater than 25 percent and at 50 foot grid for slopes less than 25 percent. All pipes for leachate detection, collection and/or removal will be surveyed at start and end points and at 50 foot intervals in between. The CQA survey will include enough information to confirm that the following features of the landfill or surface impoundment are constructed in accordance with the Construction Drawings:

- Toe of slope;
- Crest of slope;
- Grade breaks;
- Anchor trench;
- Leachate collection sump Leak detection sump;
- Permanent sump (landfills only); and,
- Perimeter drainage ditches.

The CQA results will be submitted to the Owner for final approval to proceed on the liner system construction.

TABLE II-1
MINIMUM FREQUENCY OF TESTING FOR CQA EVALUATION OF STRUCTURAL FILL

Test	Frequency	Standard Test Method
Material Properties		
Modified Proctor	1 per 5,000 cy placed (minimum 1 per source)	ASTM D 1557
Sieve Analysis	1 per 5,000 cy placed (minimum 1 per source)	ASTM D 422
Atterberg Limits	1 per 5,000 cy placed (minimum 1 per source)	ASTM D 4318
IN PLACE		
Nuclear Density Meter (50 ft. Grid)		
In-Situ Moisture Content	1 per 2,500 ft^2 per lift	ASTM D 3017
In-Situ Dry Unit Weight	1 per 2,500 ft^2 per lift	ASTM D 2922
Calibration And Check		
Standard Count Calibration or Sandstone	1 per day of fill placement	ASTM D 1556/D2922
Oven Moisture Contents (In-Situ Moisture Content)	1 per day of fill placement	ASTM D 2216

TABLE II-2
MINIMUM FREQUENCY OF TESTING FOR CQA EVALUATION OF PREPARED SUBGRADE

Test	Frequency	Standard Test Method
Modified Proctor	**1 per 250,000 SF**	**ASTM D 1557**
IN PLACE		
Nuclear Density Meter (50 ft. Grid)		
In-Situ Moisture Content	1 per 2,500 ft^2 per lift	ASTM D 3017
In-Situ Dry Unit Weight	1 per 2,500 ft^2 per lift	ASTM D 2922
Calibration and Check		
Sand Cone (In-Situ Density)	1 per day of fill placement	ASTM D 1556
Oven Moisture Content (In-Situ Moisture Content)	1 per day of fill placement	ASTM D 2216

TABLE II-3
MINIMUM FREQUENCY OF TESTING FOR CQA EVALUATION OF CLAY LINER

Test	Frequency	Standard Test Method
Material Properties		
Recompacted Permeability (moisture content and dry density inside placement window)	1 per 5,000 cy placed (minimum 1 per source)	ASTM D 5084
Sieve Analysis	1 per 3,000 cy placed (minimum 1 per source)	ASTM D 422
Atterberg Limits	1 per 3,000 cy placed (minimum 1 per source)	ASTM D 4318
IN PLACE		
Lift Thickness Before Compaction	1 per 2,500 ft^2 per lift	Field Measurement
Nuclear Density Meter[1] (50 ft. Grid)		
In-Situ Moisture Content	1 per 300 ccy	ASTM D 3017
In-Situ Dry Unit Weight	1 per 300 ccy	ASTM D 2922
Calibration and Check		
Standard Count Calibration, Sand Cone or Rubber Balloon (In-Situ Density)	1 per day of fill placement	ASTM D 1556/D 2167/D2922
Oven Moisture Contents (In-situ Moisture Content)	1 per day of fill placement	ASTM D 2216
Permeability		
Shelby tube Samples	1 for every 1,000 cu. yd. placed	ASTM D 5084

TABLE II-4
MINIMUM FREQUENCY OF TESTING
FOR CQA EVALUATION OF DRAINAGE GRAVEL

Test	Frequency	Standard Test Method
Material Properties		
Sieve Analysis	1 per 500 cy placed (minimum 1 per source)	ASTM D 422
Permeability	1 per source	ASTM D 2434

TABLE II-5
MINIMUM FREQUENCY OF TESTING FOR CQA EVALUATION OF ROAD BASE

Test	Frequency	Standard Test Method
Material Properties		
Sieve Analysis	1 per 1000 cy placed (minimum 1 per source)	ASTM D 422
Modified Proctor	1 per 1000 cy placed (minimum 1 per source)	ASTM D 1557
IN PLACE		
In-Situ Moisture Content	1 per 300 cy	ASTM D 3017
In-Situ Dry Unit Weight	1 per 300 cy	ASTM D 2922

TABLE II-6
MINIMUM FREQUENCY OF TESTING FOR CQA EVALUATION OF SOIL COVER

Test	Frequency	Standard Test Method
Material Properties		
Sieve Analysis	1 per 3000 cy placed (minimum 1 per source)	ASTM D 422
Atterberg Limits	1 per 3000 cy placed (minimum 1 per source)	ASTM D 4318
IN PLACE		
In-Situ Moisture Content	1 per 300 ft^2 per lift	ASTM D 3017
In-Situ Dry Unit Weight	1 per 300 ft^2 per lift	ASTM D 2922

TABLE II-7
MINIMUM FREQUENCY OF TESTING FOR CQA EVALUATION OF VEGETATIVE COVER

Test	Frequency	Standard Test Method
Material Properties		
Sieve Analysis	1 per 3000 cy placed (minimum 1 per source)	ASTM D 422
Atterberg Limits	1 per 3000 cy placed (minimum 1 per source)	ASTM D 4318

TABLE 11-8
MINIMUM FREQUENCY OF TESTING FOR CQA EVALUATION OF PIPE BEDDING SAND

Test	Frequency	Standard Test Material
Material Properties		
Sieve Analysis	1 per 500 cy placed	ASTM D 422
Atterberg Limits	1 per 500 cy placed	ASTM D 4318

TABLE II-9
MINIMUM FREQUENCY OF TESTING FOR CQA EVALUATION OF SELECT SUBBASE

Test	Frequency	Standard Test Method
Material Properties		
Sieve Analysis	1 per 1,000 cy placed (minimum 1 per source)	ASTM D 422
Modified Proctor	1 per 1,000 cy placed (minimum 1 per source)	ASTM D 1557
IN PLACE		
In-Situ Moisture Content	1 per 300 cy	ASTM D 3017
In-Situ Dry Unit Weight	1 per 300 cy	ASTM D 2922

TABLE II-10
MINIMUM FREQUENCY OF TESTING FOR CQA EVALUATION OF SUBBASE

Test	Frequency	Standard Test Method
Material Properties		
Sieve Analysis	1 per 1,000 cy placed (minimum 1 per source)	ASTM D 422
Modified Proctor	1 per 1,000 cy placed (minimum 1 per source)	ASTM D 1557
IN PLACE		
In-Situ Moisture Content	1 per 300 cy	ASTM D 3017
In-Situ Dry Unit Weight	1 per 300 cy	ASTM D 2922

TABLE II-11
MINIMUM FREQUENCY OF TESTING FOR CQA EVALUATION OF FOUNDATION SAND

Test	Frequency	Standard Test Method
Material Properties		
Sieve Analysis	1 per 1000 cy placed (minimum 1 per source)	ASTM D 422
Modified Proctor	1 per 1000 cy placed(minimum 1 per source)	ASTM D 1557
IN PLACE		
In-Situ Moisture Content	1 per 300 cy	ASTM D 3017
In-Situ Dry Unit Weight	1 per 300 cy	ASTM D 2922

TABLE II-12
MINIMUM FREQUENCY OF TESTING FOR CQA EVALUATION OF PROTECTIVE SOIL

Test	Frequency	Standard Test Method
Material Properties		
Sieve Analysis	1 per 5,000 cy placed (minimum 1 per source)	ASTM D 422
Atterberg Limits	1 per 5,000 cy placed (minimum 1 per source)	ASTM D 4318

SECTION III - GEOSYNTHETIC CLAY LINER CONSTRUCTION QUALITY ASSURANCE

1.0 GEOSYNTHETIC CLAY LINER MANUFACTURE AND DELIVERY

1.1 Manufacture and Quality Control

Prior to the installation of the Geosynthetic Clay Liner (GCL), the Contractor will be required to provide the CQA Engineer with the following information from the GCL Manufacturer:

- The certification required by the General Specifications signed by a responsible party employed by the GCL Manufacturer based on sampling interval of 1/ 50,000 ft^2; and,

- The manufacturing quality control certificates for each shift's production of GCL, signed by a responsible party employed by the GCL Manufacturer (such as the production manager). The quality control certificates will include:

  - Roll numbers and identification; and,

  - Sampling procedures and results of quality control tests specified by the General Specifications including descriptions of the test methods used for GCL rolls assigned to the Triassic Park project.

The CQA Engineer will verify and document that:

- The property values certified by the GCL Manufacturer meet all of the specified values listed in the General Specifications;

- The measurements of properties by the GCL Manufacturer are properly documented and the test methods used are in accordance with the General Specifications; and,

- The quality control certificates have been provided at the specified frequency for GCL rolls, and each certificate identifies the rolls or batch number related to that certificate.

The CQA Engineer will report deviations from the above requirements to the Owner prior to installation of the GCL.

1.2 Labeling

The CQA Engineer will verify and document that the GCL Manufacturer has labeled each roll of GCL as specified in the General Specifications.

The CQA Engineer will examine GCL rolls upon delivery and deviation from the above requirements will be reported to the Owner prior to installation of the GCL.

1.3 Transportation and Handling

The CQA engineer will observe and document the type of GCL handling equipment used by the installer is consistent with handling equipment identified in the general specifications.

Upon delivery at the site, the CQA Engineer will conduct a visual inspection of all rolls for defects and for damage. This examination will be conducted without unrolling rolls unless visible defects or damages are found. The CQA Engineer will indicate to the Owner:

- Any rolls that should be unrolled to allow for their inspection;
- Any rolls, or portions thereof, which should be rejected and removed from the site because they have severe flaws; and,
- Any rolls which include minor repairable flaws.

1.4 Storage

The CQA Engineer will verify and document that storage of the GCL is in accordance with the General Specifications.

1.5 Quality Assurance Conformance Testing

Either at the Manufacture's plant or upon delivery of the rolls of GCL, the CQA Engineer will ensure that samples are removed at the specified frequency and forwarded to the Geosynthetics CQA Laboratory for testing to verify and document conformance with the General Specifications.

Unless otherwise specified, samples will be taken at a rate of one per lot or one per 100,000 ft^2 whichever is greater. These samples will be tested for:

- Bentonite Moisture Content ASTM D 4643
- GCL Grab Strength, Elongation, Per Strength ASTM D 4632
- GCL Permeability ASTM D 5084
- GCL Interface Shear Strength ASTM D 5321

Conformance samples will be taken across the entire width of the roll and will not include the first 3 feet along the length of the roll. Unless otherwise specified, samples will be 1.5 feet (minimum) long by the roll width. The CQA Engineer will mark the machine direction on the samples with an arrow.

The CQA Engineer will examine all results from laboratory conformance testing and will compare the results to the specifications presented in Table 02780-1 of the Specifications. In addition, the CQA Engineer will report any nonconformance to the Owner as soon as practical after the test results become available.

The following procedure will apply whenever a sample fails a conformance test that is conducted by the Geosynthetics CQA Laboratory:

- The Contractor will be required to replace the roll (or rolls) of GCL that is not in conformance with the specifications with a roll that meets the requirements of the General Specifications.
- The CQA Engineer will ensure that conformance samples are removed for testing by the Geosynthetics CQA Laboratory from the closest numerical roll on both sides of the roll from which the failing sample was obtained. These two samples must pass the above

conformance tests. If either of these samples fail to meet the requirements, samples will be collected from the five numerically closest untested rolls on both sides of the failed samples and tested by the Geosynthetics CQA Laboratory. These ten samples must pass the above conformance tests. If any of these samples fail, a sample from every roll of GCL on site and a sample from every roll that is subsequently delivered from the same Manufacturer must be conformance tested by the Geosynthetics CQA Laboratory. The cost of all such tests are to be borne by the Contractor.

The CQA Engineer will document actions taken in conjunction with conformance test failures and report all actions to the Owner.

2.0 GEOSYNTHETIC CLAY LINER INSTALLATION

2.1 Earthworks

2.1.1 Surface Preparation

The Contractor or subcontractor responsible for GCL installation will be required to certify in writing that the surface on which the GCL will be installed is acceptable. The certificate of acceptance will be required to be given by the Contractor to the CQA Engineer, who will then verify to the Owner that the subgrade and/or clay liner installation is accepted immediately prior to commencement of GCL installation in the area under consideration.

After the surface on which the GCL is to be installed has been accepted by the Contractor responsible for GCL installation, it will be the CQA Engineer's responsibility to indicate to the Owner any change in the underlying layer that may, in accordance with the General Specifications, require repair work. If the Owner requires repair work, then it will be the responsibility of the Contractor to repair the underlying layer.

2.1.2 Anchor Trenches

The CQA Engineer will verify and document that the anchor trench backfill meets the requirements of the General Specifications and that the backfill is placed in accordance with the General Specifications.

2.2 Geosynthetic Clay Liner Deployment

2.2.1 Field Panel Identification

A field panel is the unit area of GCL which is to be placed in the field, i.e., a field panel is a roll or a portion of roll cut in the field.

The CQA Engineer will verify that each field panel is given an identification code (number or letter-number) consistent with the layout plan. This identification code will be agreed upon by the Owner, and the Contractor. This field panel identification code should be as simple and logical as possible. (Note: manufacturing plant roll numbers are usually cumbersome and are not related to location in the field.) It will be the responsibility of the Contractor to ensure that each field panel placed is marked with the manufacturing plant roll number. The roll number will be marked in the center of the panel in a color to allow for easy inspection.

The CQA Engineer will establish a table or chart showing correspondence between manufacturing plant roll numbers and field panel identification codes. The field panel identification code will be used for all CQA records.

2.2.2 Field Panel Placement

2.2.2.1 Installation Schedule

The CQA Engineer will evaluate significant changes in the schedule proposed by the Contractor and advise the Owner on the acceptability of that change. The CQA Engineer will verify and document that the condition of the underlying layer has not changed detrimentally during installation. Any damage to the surface of the underlying layer will be repaired by the Contractor in accordance with the General Specifications.

The CQA Engineer will record the identification code, location, and date of installation of each field panel.

2.2.2.2 Weather Conditions

The CQA Engineer will verify and document that GCL is not placed during inclement weather conditions as specified within the General Specifications.

Additionally, the CQA Engineer will verify and document that the underlying layer has not been damaged by weather conditions.

2.2.2.3 Damage

The CQA Engineer will visually observe each panel, after placement, for damage. The CQA Engineer will advise the Owner which panels, or portions of panels, should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels which have been rejected by the Owner will be marked, and their removal from the work area will be documented by the CQA Engineer.

2.2.2.4 Seam Overlap and Bentonite Seal

The CQA engineer will observe and document that the seam overlaps and bentonite material placed between panels along the seams meet specification guidelines. The CQA engineer will verify overlap width and will observe bentonite seal placement.

2.3 Defects and Repairs

2.3.1 Identification

All seams and non-seam areas of the GCL will be inspected by the CQA Engineer for evidence of defects, holes, contamination of geotextiles, displaced panels, premature hydration, and any sign of contamination by foreign matter. The CQA Engineer will observe and document repair procedures described below.

2.3.2 Repair Procedures

Prior to cover material placement, damage to the GCL shall be identified and repaired by the installer.

2.3.2.1 Rip and Tear Repair (Flat Surfaces)

Rips or tears may be repaired by completely exposing the affected area, removing all foreign objects or soil, and by then placing a patch cut from unused GCL over the damage (damaged material may be left in place), with a minimum overlap of 12 inches on all edges.

Accessory bentonite should be placed between the patch edges and the repaired material at a rate of a quarter pound per lineal foot of edge spread in a continuous six inch fillet.

2.3.2.2 Rip and Tear Repair (Slopes)

Damaged GCL material on slopes shall be repaired by the same procedures above, however, the overlapped edges of the patch should be wide enough to ensure the patch will keep its position during backfill or cover operations.

2.3.2.3 Displaced Panels

Displaced panels shall be adjusted to the correct position and orientation. The adjusted panel shall then be inspected for any geotextile damage or bentonite loss. Damage shall be repaired by the above procedure.

2.3.2.4 Premature Hydration

If the GCL is subjected to premature hydration, the GCL installer shall notify the CQA Engineer and Design Engineer for a site specific determination as to whether the material is acceptable or if alternative measures must be taken to ensure the quality of the design dependent upon the degree of damage.

SECTION IV - GEOMEMBRANE CONSTRUCTION QUALITY ASSURANCE

1.0 GEOMEMBRANE MANUFACTURE AND DELIVERY

1.1 Resin

Prior to the installation of the HDPE geomembrane material, the Contractor will be required to provide the CQA Engineer with the following information from the geomembrane Manufacturer:

- A copy of the quality control certificates issued by the resin Supplier that includes the origin (resin Supplier's name and resin production plant), identification (brand name, number) the production date of the resin used in the manufacture of the geomembrane shipped to the site, and the results of tests conducted to verify that the quality of the resin used to manufacture the geomembrane rolls assigned to the project meets the General Specifications; and

- Certification from the geomembrane Manufacturer that no reclaimed polymer is added to the resin during the manufacture of the geomembrane to be used in this project; the use of polymer recycled during the manufacturing process is permitted if the recycled polymer does not exceed 2 percent by weight of the total polymer weight.

The CQA Engineer will review these documents and report any discrepancies with the above requirements to the Owner.

1.2 Geomembrane Manufacturing Quality Control

Prior to the installation of the HDPE geomembrane, the Contractor will be required to provide the CQA Engineer with the following information from the geomembrane Manufacturer:

- The certification required by the General Specifications signed by a responsible party employed by the geomembrane Manufacturer based on sampling interval of 1/50,000 ft^2; and,

- The manufacturing quality control certificates for each shift's production of geomembrane, signed by a responsible party employed by the geomembrane Manufacturer (such as the production manager). The quality control certificates will include:

  - Roll numbers and identification; and,

  - Sampling procedures and results of quality control tests specified by the General Specifications including descriptions of the test methods used for geomembrane rolls assigned to the Triassic Park project.

The CQA Engineer will verify and document that:

- The property values certified by the geomembrane Manufacturer meet all of the specified values listed in the General Specifications;

- The measurements of properties by the geomembrane Manufacturer are properly documented and the test methods used are in accordance with the General Specifications; and,

- The quality control certificates have been provided at the specified frequency for geomembrane rolls, and each certificate identifies the rolls or batch number related to that certificate.

The CQA Engineer will report deviations from the above requirements to the Owner prior to installation of the geomembrane.

1.3 Labeling

The CQA Engineer will verify and document that the geomembrane Manufacturer has labeled each roll of geomembrane as specified in the General Specifications.

The CQA Engineer will examine geomembrane rolls upon delivery and deviation from the above requirements will be reported to the Owner prior to installation of the geomembrane.

1.4 Transportation and Handling

Upon delivery at the site, the CQA Engineer will conduct a visual inspection of all rolls for defects and for damage. This examination will be conducted without unrolling rolls unless visible defects or damages are found. The CQA Engineer will indicate to the Owner:

- Any rolls that should be unrolled to allow for their inspection;

- Any rolls, or portions thereof, which should be rejected and removed from the site because they have severe flaws; and,

- Any rolls which include minor repairable flaws.

1.5 Storage

The CQA Engineer will verify and document that storage of the geomembrane is in accordance with the General Specifications.

1.6 Quality Assurance Conformance Testing

Either at the Manufacture's plant or upon delivery of the rolls of geomembrane, the CQA Engineer will ensure that samples are removed at the specified frequency and forwarded to the Geosynthetics CQA Laboratory for testing to verify and document conformance with the General Specifications.

Conformance samples will be taken by the CQA Engineer across the entire width of the roll and will not include the first 3 feet. Unless otherwise specified, samples will be 1.5 feet (minimum) long by the roll width. The CQA Engineer will mark the direction of the machine used to cut the samples with an arrow.

Unless otherwise specified, samples will be taken at a rate of one per lot or one per 100,000 ft^2 whichever is greater. These samples will be tested for:

- Specific gravity
- Thickness
- Yield strength and yield elongation
- Tensile strength and tensile elongation at break
- Carbon black content
- Carbon black dispersion
- Puncture Resistance

Test shall be conducted in accordance with the test procedure presented in the specification.

The CQA Engineer will examine all results from laboratory conformance testing and will report any nonconformance to the Owner as soon practical after the test results become available.

The following procedure will apply whenever a sample fails a conformance test that is conducted by the CQA Engineer:

- The Contractor will be required to replace the roll (or rolls) of geomembrane that is in nonconformance with the General Specifications with a roll that meets the General Specifications.
- The CQA Engineer will ensure that conformance samples are removed for testing by the Geosynthetics CQA Laboratory from the closest numerical roll on both sides of the failed roll. These two samples must pass the above conformance tests. If either of these samples fail, samples will be collected from the five numerically closest untested rolls on both sides of the failed sample and tested by the Geosynthetics CQA Laboratory. These ten samples must pass the above conformance tests. If any of these samples fail, a sample from every roll of geomembrane on site and every roll subsequently delivered from the same Manufacturer must be conformance tested by the Geosynthetics CQA Laboratory; the cost of all such additional tests are to be borne by the Contractor.

The CQA Engineer will document actions taken in conjunction with conformance test failures and report all actions to the Owner.

2.0 GEOMEMBRANE INSTALLATION

2.1 Earthwork

2.1.1 Surface Preparation

The Contractor or subcontractor responsible for geomembrane installation will be required to certify in writing that the surface on which the geomembrane will be installed is acceptable.

The certificate of acceptance will be required to be given by the Contractor to the CQA Engineer, who will then verify to the Owner that the subgrade is accepted immediately prior to commencement of geomembrane installation in the area under consideration.

After the surface on which the geomembrane is to be installed has been accepted by the Contractor responsible for geomembrane installation, it will be the CQA Engineer's responsibility to indicate to the Owner any change in the underlying layer that may, in accordance with the General Specifications, require repair work. If the Owner requires repair work, then it will be the responsibility of the Contractor to repair the underlying layer.

2.1.2 Anchor Trenches

The CQA Engineer will verify and document that the anchor trench backfill meets the requirements of the General Specifications and that the backfill is placed in accordance with the General Specifications.

2.2 Geomembrane Deployment

2.2.1 Layout Drawing

The Contractor will be required to produce layout drawings which show the geomembrane panel configuration, dimensions, details, seam locations, etc. The layout drawings must be approved by the Owner prior to the installation of the geomembrane. The layout drawings, as modified and/or approved by the Owner will be part of the specifications, and a copy will be furnished to the CQA Engineer. The CQA Engineer will become familiar with the layout drawings.

2.2.2 Field Panel Identification

A field panel is the unit area of geomembrane which is to be seamed in the field, i.e., a field panel is a roll or a portion of roll cut in the field.

The CQA Engineer will verify that each field panel is given an identification code (number or letter-number) consistent with the layout plan. This identification code will be agreed upon by the Owner, and the Contractor. This field panel identification code should be as simple and logical as possible. (Note: manufacturing plant roll numbers are usually cumbersome and are not related to location in the field.) It will be the responsibility of the Contractor to ensure that each field panel placed is marked with the manufacturing plant roll number. The roll number will be marked in the center of the panel in a color to allow for easy inspection.

The CQA Engineer will establish a table or chart showing correspondence between manufacturing plant roll numbers and field panel identification codes. The field panel identification code will be used for all CQA records.

2.2.3 Field Panel Placement

2.2.3.1 Location

The CQA Engineer will verify and document that field panels are installed at the locations and positions indicated in the Contractor's layout plan, as approved or modified by the Owner.

2.2.3.2 Installation Schedule

The CQA Engineer will evaluate significant changes in the schedule proposed by the Contractor and advise the Owner on the acceptability of that change. The CQA Engineer will verify and document that the condition of the underlying layer has not changed detrimentally during installation. Any damage to the surface of the underlying layer will be repaired by the Contractor in accordance with the General Specifications.

The CQA Engineer will record the identification code, location, and date of installation of each field panel.

2.2.3.3 Weather Conditions

The CQA Engineer will verify and document that geomembrane is not placed during inclement weather conditions as specified within the General Specifications.

Additionally, the CQA Engineer will verify and document that the underlying layer has not been damaged by weather conditions.

2.2.3.4 Damage

The CQA Engineer will visually observe each panel, after placement and prior to seaming, for damage (e.g., holes, blisters, creases). The CQA Engineer will advise the Owner which panels, or portions of panels, should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels which have been rejected by the Owner will be marked, and their removal from the work area will be documented by the CQA Engineer.

2.3 Field Seaming

2.3.1 Seam Layout

The CQA Engineer will verify and document that the seam layout shown on the Panel Layout Drawing (Part 2.2.1) is consistent with the General Specifications. No panels may be seamed in the field without the Owner's approval. In addition, seams not specifically shown on the seam layout drawing may not be made without the Owner's prior approval.

A seam numbering system compatible with the panel numbering system will be agreed upon by the Contractor, the Owner, and CQA Engineer.

2.3.2 Seaming Equipment and Products

Processes approved by the General Specifications for field seaming are: (i) extrusion seaming; and (ii) fusion seaming. Proposed alternate processes will be required to be documented and submitted to the Owner for approval. Only seaming apparatus which the Owner has specifically approved by make and model will be used. The Contractor will be required to use a pyrometer to ensure that accurate temperatures of the extrudate and seamer nozzle are being achieved.

The extrusion seaming apparatus will be equipped with gauges indicating the temperatures of the extrudate and nozzle. The Contractor will be required to provide to the CQA Engineer the

Manufacturer's certification that the extrudate is compatible with the General Specifications and is comprised of the same resin as the geomembrane.

The CQA Engineer will log ambient temperatures, seaming apparatus temperatures, and extrudate temperatures or fusion seaming apparatus speeds. Ambient temperatures will be measured as specified in the General Specifications.

2.3.3 Seam Preparation

The CQA Engineer will verify and document that:

- Prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris, and foreign material; and,
- Preparation of seams is in accordance with the General Specifications.

2.3.4 Weather Conditions for Seaming

The CQA Engineer will verify and document that weather conditions for seaming are within the limits specified in the General Conditions.

2.3.5 Trial Seams

The Contractor will be required to make trial seams on fragment pieces of geomembrane liner to verify that seaming conditions are adequate. The Contractor will be required to make and test trial seams at the frequency and in accordance with the methods specified in the General Specifications.

The CQA Engineer will observe all trial seam procedures. The successful trial seam sample will be assigned a number and marked accordingly by the CQA Engineer, who will log the date, hour, ambient temperature, number of seaming unit, name of seamer, and pass or fail description. The sample itself will be retained only until the construction of the liner is complete and the liner has been accepted by the Owner.

2.3.6 Nondestructive Seam Continuity Testing

2.3.6.1 Introduction

Except as otherwise noted in the General Specifications, the Contractor will nondestructively test all field seams over their full length in accordance with the General Specifications. The purpose of nondestructive tests is to check the continuity of seams. Continuity testing will be carried out as the seaming work progresses, not at the completion of all field seaming. Nondestructive testing will not be permitted before sunrise or after sunset unless the Contractor demonstrates to the Owner that the Contractor has the capabilities to perform continuity testing under reduced light conditions.
The CQA Engineer will:

- Observe the continuity testing;
- Record location, date, test unit number, name of tester, and outcome of all testing; and,
- Document and inform the Contractor of any required repairs.

The Contractor will be required to complete any required repairs in accordance with the General Specifications.

The CQA Engineer will:

- Observe the repair and re-testing of the repair;
- Mark on the geomembrane that the repair has been made; and,
- Document the results.

The CQA Engineer will verify and document the procedures specified in the General Specifications where seams cannot be nondestructively tested.

The location, date of visual observation, name of tester, and outcome of the test or observation will be recorded by the CQA Engineer and reported to the Owner.

2.3.7 Destructive Seam Testing

2.3.7.1 Concept

Destructive seam tests will be performed at selected locations. The purpose of these tests is to evaluate seam strength and integrity. Seam strength testing will be done as the seaming work progresses, not at the completion of all field seaming.

2.3.7.2 Location and Frequency

The CQA Engineer will select locations where seam samples will be cut out for laboratory testing. The test frequency and locations will be established as follows:

- Samples will be collected at a minimum frequency of one test location per 500 ft of seam length (this minimum frequency is to be determined as an average taken throughout the entire landfill or surface impoundment project); and,
- Test locations will be determined during seaming at the CQA Engineer's discretion; selection of such locations may be prompted by suspicion of excess crystallinity, contamination, offset seams, or any other potential cause of imperfect seaming.

The Contractor will not be informed in advance of the locations where the seam samples will be taken.

2.3.7.3 Sampling Procedure

The Contractor will be required to cut samples as directed by the CQA Engineer as the seaming progresses in order to have laboratory test results before the geomembrane is covered by another material. The CQA Engineer will:

- Observe sample cutting;
- Assign a number to each sample and mark it accordingly;

- Record the sample number and location on the panel layout drawing; and,
- Record the reason for taking the sample at this location (e.g., routine testing, suspicious feature of the geomembrane, etc.).

All holes in the geomembrane resulting from destructive seam sampling will be covered by the Contractor immediately after sampling and repaired in accordance with the repair procedures described in the General Specifications. The continuity of the new seams in the repaired area will be nondestructively tested according to the General Specifications.

2.3.7.4 Size of Samples

At a given sampling location, two types of samples will be required to be taken by the Contractor.

First, two specimens for field testing will be taken. Each of these specimens will be 1 inch wide by 6 to 12 inches long, with the seam centered parallel to the width. The distance between these two specimens will be approximately 42 inches. If both specimens pass the field test described in the General Specifications, a sample for laboratory testing will be taken.

The sample for laboratory testing will be required to be taken between the two specimens for field testing. The destructive sample will be 12 inches wide by 42 inches long with the seam centered lengthwise. The sample will be cut into three parts and distributed as follows:

- One portion to the Contractor, 12 inches long;
- One portion to the CQA Engineer for archive storage, 12 inches long; and,
- One portion to the CQA Engineer for CQA Laboratory testing, 18 inches long.

Final determination of the sample sizes will be made at the preconstruction meeting.

2.3.7.5 Field Testing

The two 1-inch wide specimens specified above will be required to be tested in the field, by the Contractor, by tensiometer for peel and should not fail in the seam. If any field test sample fails to pass, then the procedures outlined in the General Specifications will be required to be followed.

The CQA Engineer will observe field tests and mark all samples and portions with their number, date, and time.

2.3.7.6 Geosynthetic Construction Quality Assurance Laboratory Testing

Laboratory destructive test samples will be packaged and shipped to the CQA Laboratory by the CQA Engineer in a manner which will not damage the test sample. The CQA Engineer will store the archive samples until the completion of the project. Laboratory destructive test samples will be tested by the Geosynthetics CQA Laboratory.

Testing will include "Shear Strength", and "Peel Strength", (ASTM D 443) with 1-inch wide strip, tested at 2 inches per minute). The minimum acceptable values to be obtained in these tests are those indicated in Table 02775-2 of Section 02775 of the General Specifications. At least 5 specimens will

be tested for each test method. Specimens will be selected alternately by test from the samples (i.e., peel, shear, peel, shear). At least 4 out of 5 of the specimens must pass.

The Geosynthetics CQA Laboratory will provide test results verbally to the CQA Engineer in a timely manner after they receive the samples. The CQA Engineer will review laboratory test results as soon as they become available, and inform the Owner of the test results.

2.3.7.7 Procedures for Destructive Test Failure

The procedures specified within the General Specifications will be required whenever a sample fails a destructive test, whether that test is conducted by the Geosynthetics CQA Laboratory, the Contractor's laboratory (if required), or by field tensiometer. The CQA Engineer will verify and document that one of the options specified within the General Specifications is followed.

The CQA Engineer will document all actions taken in conjunction with destructive test failures.

2.4 Defects and Repairs

2.4.1 Identification

All seams and non-seam areas of the geomembrane will be inspected by the CQA Engineer for evidence of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane will be required to be clean at the time of examination. The geomembrane surface will be required to be broomed or washed by the Contractor if the amount of dust or mud inhibits examination.

2.4.2 Evaluation

Each suspect location both in seam and non-seam areas will be required to be either non-destructively tested using the methods described in the General Specifications, or repaired as appropriate as determined by the CQA Engineer. Each location which fails the non-destructive testing will be marked by the CQA Engineer and will be required to be repaired by the Contractor. Materials should not be placed over geomembrane locations that have been repaired until the CQA Engineer has approved the repair.

2.4.3 Large Wrinkles

When seaming of the geomembrane is completed (or when seaming of a large area of the geomembrane is completed) and prior to placing overlying materials, the CQA Engineer will visually inspect the geomembrane for wrinkles. The CQA Engineer will indicate to the Contractor which wrinkles, if any, should be cut and reseamed. The seam thus produced will be tested like any other seam.

2.4.4 Repair Procedures

Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test will be repaired by the Contractor in accordance with the applicable method specified within the General Specifications.

2.4.5 Testing of Repairs

Each repair will be located and logged by the CQA Engineer. Each repair will be non-destructively tested using the methods described in the General Specifications as appropriate. Repairs which pass the non-destructive test will be considered as an adequate repair. Large caps may be of sufficient extent to require destructive testing, at the discretion of the CQA Engineer. Failed tests will require the repair to be redone and retested until passing test results are obtained. The CQA Engineer will observe the non-destructive testing of repairs and will document the date of the repair and test outcome.

2.5. Appurtenances

The CQA Engineer will verify and document that:

- Installation of the geomembrane around, and connection of geomembrane to appurtenances have been made according to the General Specifications;
- Extreme care is taken while seaming around appurtenances since neither non-destructive nor destructive testing may be feasible in these areas; and,
- The geomembrane has not been visibly damaged while being connected to appurtenances.

The CQA Engineer will inform the Owner if the above conditions are not fulfilled.

3.0 SURVEYING

The CQA Engineer, in conjunction with the Surveyor, will be required to prepare an "as-built" Record Drawing for geomembrane installations. It will include the surveyed location of field panels, seams (factory and field), repairs, and test locations.

The CQA results (Record Drawing and certification of Contractor's work) will be submitted to the Owner for final review and approval prior to proceeding with construction of any subsequent liner system components.

SECTION V - FILTER OR CUSHION GEOTEXTILE CONSTRUCTION QUALITY ASSURANCE

1.0 GEOTEXTILES

1.1 Manufacturing

The Geosynthetics Contractor will be required to provide the CQA Engineer with the following information from the geotextile Manufacturer:

- Certification required by the General Specifications signed by a responsible party employed by the geotextile Manufacturer; and,

- The manufacturing quality control certificates for each shift's production of geotextile rolls, which include geotextile roll numbers and identification, sampling procedures, and descriptions and results of the quality control tests specified in the General Specifications signed by a responsible party employed by the geotextile Manufacturer.

The CQA Engineer will examine all geotextile Manufacturer's certifications to verify and document that the property values listed on the certifications meet or exceed those specified within the General Specifications and that proper and complete documentation has been provided by the geotextile Manufacturer for all geotextile used at the site. The CQA Engineer will report any deviations from the above requirements to the Owner prior to installation of the geotextile.

1.2 Labeling

The CQA Engineer will verify and document that the geotextile Manufacturer has labeled all rolls of geotextile with the information specified in the General Specifications.

The CQA Engineer will examine rolls upon delivery and any deviation from the above requirements will be reported to the Owner prior to installation of the geotextile.

1.3 Shipment and Storage

The CQA Engineer will observe rolls of geotextile upon delivery at the site and any deviation from the requirements specified within the General Specifications will be reported to the Owner. Any damaged rolls will be rejected by the CQA Engineer and required to be repaired or replaced by the Contractor.

1.4 Conformance Testing

Either at the Manufacturer's factory or upon delivery of the geotextile rolls, the CQA Engineer will ensure that samples are removed and forwarded to the Geosynthetics CQA Laboratory for testing to verify and document conformance with the requirements of the General Specifications.

Conformance samples will be taken across the entire width of the roll and will not include the first 3 feet along the length of the roll. Unless otherwise specified, samples will be 1.5 feet (minimum) long by the roll width. The CQA Engineer will mark the machine direction on the samples with an arrow.

Samples will be taken at a rate of one per lot or one per 100,000 ft^2, whichever is greater. These samples will be tested for:

- Mass per unit area
- Grab strength
- Tear strength
- Puncture strength
- Permittivity

(Note: All tests should be conducted in accordance with the test methods listed in the specification.)

If the geotextile is being used as a filter, cushion or separator, the samples will also be tested for apparent opening size.

The CQA Engineer will examine all results of laboratory conformance testing and report any nonconformance to the Owner as soon as results become available.

The following procedure will apply whenever a sample fails a conformance test that is conducted by the Geosynthetics CQA Laboratory:

- The Contractor will be required to replace the roll (or rolls) of geotextile that is not in conformance with the specifications with a roll that meets the requirements of the General Specifications.

- The CQA Engineer will ensure that conformance samples are removed for testing by the Geosynthetics CQA Laboratory from the closest numerical roll on both sides of the roll from which the failing sample was obtained. These two samples must pass the above conformance tests. If either of these samples fail to meet the requirements, samples will be collected from the five numerically closest untested rolls on both sides of the failed sample and tested by the Geosynthetics CQA Laboratory. These ten samples must pass the above conformance tests. If any of these samples fail, a sample from every roll of geotextile on site and a sample from every roll that is subsequently delivered from the same Manufacturer must be conformance tested by the Geosynthetics CQA Laboratory. The cost of all such tests are to be borne by the Contractor.

The CQA Engineer will document actions taken in conjunction with conformance test failures and report all actions taken to the Owner.

1.5 Handling and Placement

The Geosynthetics Contractor will be required to handle all geotextile in such a manner as to ensure the geotextile is not damaged in any way. The CQA Engineer will verify and document compliance with the following:

- Just prior to geotextile placement, the layer that underlies the geotextile, if it is a geosynthetic, is clean and free of excessive amounts of dust, dirt, stones, rocks, or other obstructions that could potentially damage the liner system.

- In the presence of excessive wind, the geotextile is weighted with sandbags (or equivalent weight approved by the CQA Engineer).

- Geotextile is kept under tension to minimize the presence of wrinkles in the geotextile. If necessary, the geotextile is positioned by hand after being unrolled to minimize wrinkles.

- Geotextiles are cut using a geotextile cutter approved by the geotextile Manufacturer and the CQA Engineer. If in place, special care is taken to protect other materials (such as underlying geosynthetics) from damage which could be caused by the cutting of the geotextiles.

- The Contractor takes any necessary precautions to prevent damage to the underlying layers during placement of the geotextile.

- During placement of geotextiles, care is taken not to entrap in the geotextile stones, excessive dust, or moisture that could damage the underlying layers, generate clogging of drains or filters, or hamper subsequent seaming.

- Geotextile is not left exposed for a period in excess of 30 days after placement unless a longer exposure period is approved by the CQA Engineer and Owner.

The CQA Engineer will document any noncompliance with the above requirements and report them to the Owner.

1.6 Seams and Overlaps

The CQA Engineer will verify and document that all geotextile seams are oriented, overlapped and sewn in accordance with the General Specifications.

The Contractor will be required to pay close attention at seams to ensure that no protective soil layer material could be inadvertently placed beneath the geotextile.

Sewing will be required to be performed as required in the General Specifications.

1.7 Repair

The CQA Engineer will verify and document that any holes or tears in the geotextile are repaired in accordance with the requirements of the General Specifications.

The CQA Engineer will document any noncompliance with the above requirements and report it to the Owner.

SECTION VI - GEOCOMPOSITE CONSTRUCTION QUALITY ASSURANCE

1.0 GEOCOMPOSITES

1.1 Manufacturing

The Geosynthetics Contractor will be required to provide the CQA Engineer with the following information from the geocomposite Manufacturer:

- Certification required by the General Specifications signed by a responsible party employed by the geocomposite Manufacturer;
- The certification from the geocomposite Manufacturer that no reclaimed polymer was added to the resin during the manufacture of the geonet component of the geocomposite rolls assigned this project; and,
- The manufacturing quality control certificates for each shift's production of geocomposite rolls which include geocomposite roll numbers and identification, sampling procedures, and descriptions and results of quality control tests for the geonet specified in the General Specifications signed by a responsible party employed by the geocomposite Manufacturer.

The CQA Engineer will examine all of the geocomposite Manufacturer certifications to verify and document that the property values listed on the certifications meet or exceed those specified within the General Specifications and that proper and complete documentation has been provided by the geocomposite Manufacturer for all geocomposite used at the site. The CQA Engineer will report any deviations from the above requirements to the Owner prior to installation of the geocomposite.

1.2 Labeling

The CQA Engineer will verify and document that the geocomposite Manufacturer has labeled all rolls of geocomposite as specified within the General Specifications.

The CQA Engineer will examine rolls upon delivery and any deviation from the above requirements will be reported to the Owner prior to installation of the geocomposite.

1.3 Shipment and Storage

The CQA Engineer will observe rolls of geocomposite upon delivery at the site and any deviation from the requirements of the General Specifications will be reported to the Owner. Any damaged rolls will be rejected by the CQA Engineer and required to be repaired or replaced by the Contractor.

1.4 Conformance Testing

Either at the Manufacturer's plant or upon delivery of the geocomposite rolls, the CQA Engineer will ensure that samples are removed and forwarded to the Geosynthetics CQA Laboratory for testing to verify and document conformance with the requirements of the General Specifications.

Conformance samples will be taken across the entire width of the roll and will not include the first 3 feet. Unless otherwise specified, samples will be 1.5 feet long (minimum) by the roll width. The CQA Engineer will mark the machine direction on the samples with an arrow.

Samples will be taken at a rate of one per lot or one per 100,000 ft^2, whichever is greater. These samples will be tested for: peel strength (ASTM F 904); and hydraulic transmissivity, in accordance with the text methods presented in the specification.

The CQA Engineer will examine all results from laboratory conformance testing and will report any nonconformance to the Owner as soon as the results are become available.

The following procedure will apply whenever a sample fails a conformance test that is conducted by the Geosynthetics CQA Laboratory:

- The Contractor will be required to replace the roll (or rolls) of geocomposite that is not in conformance with the specifications with a roll that meets the requirements of the General Specifications.

- The CQA Engineer will ensure that conformance samples are removed for testing by the Geosynthetics CQA Laboratory from the closest numerical roll on both sides of the failed roll. These two samples must pass the above conformance tests. If either of these samples fail, samples will be collected from the 5 numerically closest untested rolls on both sides of the failed sample and tested by the Geosynthetics CQA Laboratory. These ten samples must pass the above conformance tests. If any of these samples fail, a sample from every roll of geocomposite on site and a sample from every roll that is subsequently delivered from the same Manufacturer must be conformance tested by the Geosynthetics CQA Laboratory. The cost of such tests is to be borne by the Contractor.

The CQA Engineer will document actions taken in conjunction with conformance test failures and report all actions to the Owner.

1.5 Handling and Placement

The Contractor will be required to handle all geocomposite in such a manner as to ensure it is not damaged. The CQA Engineer will verify and document compliance with the following:

- Just prior to geocomposite placement, the layer that will underlie the geocomposite is clean and free of excessive amounts of dust, dirt, stones, rocks, or other obstructions that could potentially damage the underlying layers or clog the drainage system.

- In the presence of excessive wind, the geocomposite is weighted with sandbags (or equivalent weight approved by the CQA Engineer).

- Geocomposite is kept under tension to minimize the presence of wrinkles in the geocomposite. If necessary, the geocomposite is positioned by hand after being unrolled to minimize wrinkles.

- Geocomposites are cut using a geocomposite cutter approved by the geocomposite Manufacturer and the CQA Engineer. If in place, special care is taken to protect other materials from damage which could be caused by the cutting of the geocomposites.

- The Geosynthetics Contractor takes all necessary precautions to prevent damage to the underlying layers during placement of the geocomposite.

- Geocomposite is not welded to geomembranes.

- During placement of clean geocomposite, care is taken not to entrap stones, excessive dust, or moisture that could damage the underlying geomembrane, generate clogging of drains or filters, or hamper subsequent seaming.

- A visual examination of the geocomposite is carried out over the entire surface, after installation, to ensure that no potentially harmful foreign objects, such as needles, are present.

- Geocomposite is not left exposed for a period in excess of 30 days after placement unless a longer exposure period is approved by the CQA Engineer and the Owner.

The CQA Engineer will document any noncompliance with the above requirements and report it to the Owner.

1.6 Seams and Overlaps

The components of the geocomposite (e.g., geotextile-geonet-geotextile) are not bonded together at the ends and edges of the rolls. The CQA Engineer will document that the geocomposite is overlapped and secured or seamed in accordance with the General Specifications.

1.7 Repair

The CQA Engineer will verify that any holes or tears in the geocomposite are repaired in accordance with the General Specifications.

The CQA Engineer will observe any repair, document any noncompliance with the above requirements, and report the noncompliance to the Owner.

SECTION VII - GEONET CONSTRUCTION QUALITY ASSURANCE

1.0 GEONET

1.1 Manufacturing

The Geosynthetics Contractor will be required to provide the CQA Engineer with the following information from the geonet Manufacturer:

- Certifications required by the General Specifications signed by a responsible party employed by the geonet Manufacturer;
- The certification from the geonet Manufacturer that no reclaimed polymer was added to the resin during the manufacture of the geonet rolls assigned to this project; and,
- The manufacturing quality control certificates for each shift's production of geonet rolls, which include geonet roll numbers and identification, sampling procedures, and descriptions and results of quality control tests for polymer specified in the General Specifications signed by a responsible party employed by the geonet Manufacturer.

The CQA Engineer will examine all geonet Manufacturer's certifications to verify and document that the property values listed on the certifications meet or exceed those specified within the General Specifications and that proper and complete documentation has been provided by the geonet Manufacturer for all geonet used at the site. The CQA Engineer will report any deviations from the above requirements to the Owner.

1.2 Labeling

The CQA Engineer will verify and document that the geonet Manufacturer has labeled all rolls of geonet as specified within the General Specifications.

The CQA Engineer will examine rolls upon delivery and any deviation from the above requirements will be reported to the Owner prior to installation of the geonet.

1.3 Shipment and Storage

The CQA Engineer will observe the rolls of geonet upon delivery at the site and any deviations from the requirements specified within the General Specifications will be reported to the Owner. Any damaged rolls will be rejected by the CQA Engineer and will be required to be repaired or replaced by the Contractor.

1.4 Conformance Testing

Either at the Manufacturer's plant or upon delivery of the geonet rolls, the CQA Engineer will ensure that samples are removed and forwarded to the Geosynthetic CQA Laboratory for testing, to verify and document conformance with the requirements of the General Specifications.

Conformance samples will be taken across the entire width of the roll and will not include the first 3 feet. Unless otherwise specified, samples will be 1.5 feet long (minimum) by the roll width. The CQA Engineer will mark the machine direction on the samples with an arrow.

Samples will be taken at a rate of one per lot or one per 100,000 ft^2, whichever is greater. These samples will be tested for:

- Polymer specific gravity
- Carbon black
- Thickness
- Transmissivity
- Polymer melt index

Tests shall be conducted in accordance with the method indicated in the specification.

The CQA Engineer will examine all results from laboratory conformance testing and will report any nonconformance to the Owner as soon as the results become available.

The following procedure will apply whenever a sample fails a conformance test that is conducted by the Geosynthetics CQA Laboratory:

- The Contractor will be required to replace the roll (or rolls) of geonet that is not in conformance with the specifications with a roll that meets the requirements of the General Specifications.

- The CQA Engineer will ensure that conformance samples are removed for testing by the Geosynthetics CQA Laboratory from the closest numerical roll on both sides of the failed roll. These two samples must pass the above conformance tests. If either of these samples fail, samples will be collected from the five numerically closest untested rolls on both sides of the failed sample and tested by the Geosynthetics CQA Laboratory. These ten samples must pass the above conformance tests. If any of these samples fail, a sample from every roll of geonet on site and a sample from every roll that is subsequently delivered from the same Manufacturer must be conformance tested by the Geosynthetics CQA Laboratory. The cost of such tests is to be borne by the Contractor.

The CQA Engineer will document actions taken in conjunction with conformance test failures and report all actions taken to the Owner.

1.5 Handling and Placement

The Contractor will handle all geonet in such a manner as to ensure the geonet is not damaged. The CQA Engineer will verify and document compliance with the following:

- The geonet is free of dirt or excessive dust just before installation.

- Just prior to geonet placement, the geomembrane liner that will underlie the geonet is clean and free of excessive amounts of dust, dirt, stones, rocks, or other obstructions that could potentially damage the geomembrane or clog the drainage system.

- On side slopes, the geonet is secured at the top of the slope then rolled down the slope in such a manner as to keep the geonet sheet in tension. If necessary, the geonet is positioned by hand after being unrolled to minimize wrinkles. Geonet can be place in the horizontal direction (i.e., across the slope) in some special locations (e.g., at the toe of a slope). If an extra layer of geonet is required, this extra layer of geonet can be placed in the horizontal direction. Such locations will be identified on the Construction Drawings.

- In the presence of excessive wind, the geonet is weighted with sandbags or the equivalent.

- Unless otherwise specified, geonet is not welded to geomembrane.

- Geonet will only be cut using a cutter approved by the geonet Manufacturer and the CQA Engineer. If in place, special care is taken to protect underlying geosynthetics from damage that could be caused by cutting of the geonet.

- The Geosynthetics Contractor takes any necessary precautions to prevent damage to underlying layers during placement of the geonet.

- During placement of geonets, care is taken not to entrap in the geonet dirt or excessive dust that could cause clogging of the drainage system, and/or stones that could damage the adjacent geomembrane. If dirt or excessive dust is entrapped in the geonet, it is hosed clean prior to placement of the next material on top of it. In this regard, care should be taken with the handling or sandbags, to prevent rupture or damage of the sandbag.

- Geonet is not placed in direct contact with textured geomembrane liner unless specifically called for in the Construction Drawings.

The CQA Engineer will document any noncompliance with the above requirements and report it to the Owner.

1.6 Stacking and Joining

Geonet will be stacked and joined in accordance with the Construction Drawings and the General Specifications. As a minimum, the CQA Engineer will verify and document that staking, joining and overlapping is in accordance with the General Specifications.

The CQA Engineer will document any noncompliance with the above requirements and report it to the Owner.

1.7 Repair

The CQA Engineer will verify and document that any holes or tears in the geonet are repaired in accordance with the General Specifications.

The CQA Engineer will observe any repair, note any noncompliance with the above requirements and report them to the Owner.

SECTION VIII - POLYETHYLENE PIPE AND FITTINGS CONSTRUCTION QUALITY ASSURANCE

1.0 POLYETHYLENE PIPE MANUFACTURE AND DELIVERY

1.1 Manufacturing

Prior to incorporating the polyethylene pipe and fittings into the work the Contractor will be required to provide the CQA Engineer with the certifications required by the General Specifications signed by a responsible party employed by the pipe Manufacturer.

The CQA Engineer will verify and document that the property values certified by the pipe Manufacturer meet the requirements of the General Specifications based on a sampling interval of one sample per lot. The CQA Engineer will report any deviations from the above requirements to the Owner.

1.2 Labeling

The CQA Engineer will verify that the pipe is labeled with the information specified in the General Specification. Any deviations from the labeling requirements will be reported to the Owner prior to pipe installation.

1.3 Shipment and Storage

The CQA Engineer will verify and document that the pipe and fittings are stored in accordance with the General Specifications.

The CQA Engineer will visual inspect the pipe upon delivery at the site and any deviations from the requirements of the General Specifications will be reported to the Owner.

1.4 Conformance Testing

No conformance testing will be conducted on the materials delivered to the site.

2.0 PIPE INSTALLATION

2.1 Handling and Laying

The CQA Engineer will verify and document that the pipe is installed at the specified locations and grades and that placement of backfill around and over the pipe is conducted in accordance with the requirements of the General Specifications, and in a manner intended to prevent damage to the pipe.

The pipe and fittings will be carefully examined before installation by the CQA Engineer. The CQA Engineer will verify and document that cracks, damage or defects are not present in the pipe and fittings in excess of that allowed by the General Specifications.

The CQA Engineer will also note the condition of the interior of pipes and fittings. Foreign material shall be removed from the pipe interior before it is moved into final position. No pipe will be

permitted to be placed until the CQA Engineer has observed the condition of the pipe. The CQA Engineer will document any deviation from the above requirements and report it to the Owner.

2.2 Joints and Connections

Lengths of pipe will be required to be assembled into suitable installation lengths by the butt-fusion process. Butt-fusion refers to the butt-joining of the pipe by softening the aligned faces of the pipe ends in a suitable apparatus and pressing them together under controlled pressure.

The CQA Engineer will spot-monitor butt fusion welding operations to ensure that the Contractor follows the General Specifications.

The CQA Engineer will document any noncompliance with the above requirements and report it to the Owner.

2.3 Surveying

A Professional Land Surveyor registered in the State of New Mexico will provide the CQA Surveys. The CQA Surveyor will independently survey the final elevation of the invert of all polyethylene leachate collection pipe (excluding laterals).

The results of the survey will be compiled in a report signed by the CQA Surveyor and the CQA Engineer and will be reviewed by the Owner. The Owner and the CQA Engineer will approve the results contained in the report before any subsequent construction that completely covers the pipe occurs.

SECTION IX - ADS SLOTTED CPT AND N12 CONSTRUCTION QUALITY ASSURANCE

1.0 ADS SLOTTED CPT MANUFACTURE AND DELIVERY

1.1 Manufacturing

Prior to incorporating the slotted CPT into the work the Contractor will be required to provide the CQA Engineer with the certifications required by the General Specifications signed by a responsible party employed by the pipe Manufacturer.

The CQA Engineer will verify and document that the property values certified by the pipe Manufacturer meet the requirements of the General Specifications based on a sampling interval of one sample per lot. The CQA Engineer will report any deviations from the above requirements to the Owner.

1.2 Labeling

The CQA Engineer will verify that the pipe is labeled with the information specified in the General Specification. Any deviations from the labeling requirements will be reported to the Owner prior to pipe installation.

1.3 Shipment and Storage

The CQA Engineer will verify and document that the pipe and fittings are stored in accordance with the General Specifications.

The CQA Engineer will visual inspect the pipe upon delivery at the site and any deviations from the requirements of the General Specifications will be reported to the Owner.

1.4 Conformance Testing

No conformance testing will be conducted on the materials delivered to the site.

2.0 PIPE INSTALLATION

2.1 Handling and Laying

The CQA Engineer will verify and document that the pipe is installed at the specified locations and grades and that placement of backfill around and over the pipe is conducted in accordance with the requirements of the General Specifications, and in a manner intended to prevent damage to the pipe.

The pipe and fittings will be carefully examined before installation by the CQA Engineer. The CQA Engineer will verify and document that cracks, damage or defects are not present in the pipe and fittings in excess of that allowed by the General Specifications.

The CQA Engineer will also note the condition of the interior of pipes and fittings. Foreign material shall be removed from the pipe interior before it is moved into final position. No pipe will be permitted to be placed until the CQA Engineer has observed the condition of the pipe.

The CQA Engineer will document any deviation from the above requirements and report it to the Owner.

2.2 Joints and Connections

Lengths of pipe will be required to be assembled into suitable installation lengths by split couplers. The CQA Engineer will spot-monitor installation of the split couplers to ensure that the Contractor follows the General Specifications. The CQA Engineer will document any noncompliance with the above requirements and report it to the Owner.

2.3 Surveying

A Professional Land Surveyor registered in the State of New Mexico will provide the CQA Surveys. The CQA Surveyor will independently survey the final elevation of the invert of all slotted CPT.

The results of the survey will be compiled in a report signed by the CQA Surveyor and the CQA Engineer and will be reviewed by the Owner. The Owner and the CQA Engineer will approve the results contained in the report before any subsequent construction that completely covers the pipe occurs.

SECTION X - CORRUGATED METAL PIPE CONSTRUCTION QUALITY ASSURANCE

1.0 CORRUGATED METAL PIPE MANUFACTURE AND DELIVERY

1.1 Manufacturing

Prior to incorporating the corrugated metal pipe (CMP) into the work the Contractor will be required to provide the CQA Engineer with the certifications required by the General Specifications signed by a responsible party employed by the pipe Manufacturer.

The CQA Engineer will verify and document that the property values certified by the pipe Manufacturer meet the requirements of the General Specifications based on a sampling interval of one sample per lot. The CQA Engineer will report any deviations from the above requirements to the Owner.

1.2 Labeling

No labels required in specifications.

1.3 Shipment and Storage

The CQA Engineer will verify and document that the pipe and fittings are stored in accordance with the General Specifications.

The CQA Engineer will visual inspect the pipe upon delivery at the site and any deviations from the requirements of the General Specifications will be reported to the Owner.

1.4 Conformance Testing

No conformance testing will be conducted on the materials delivered to the site.

2.0 CMP INSTALLATION

2.1 Handling and Laying

The CQA Engineer will verify and document that the pipe is installed at the specified locations and grades and that placement of backfill around and over the pipe is conducted in accordance with the requirements of the General Specifications, and in a manner intended to prevent damage to the pipe.

The pipe and fittings will be carefully examined before installation by the CQA Engineer. The CQA Engineer will verify and document that cracks, damage or defects are not present in the pipe and fittings in excess of that allowed by the General Specifications.

The CQA Engineer will also note the condition of the interior of pipes and fittings. Foreign material shall be removed from the pipe interior before it is moved into final position. No pipe will be permitted to be placed until the CQA Engineer has observed the condition of the pipe.

The CQA Engineer will document any deviation from the above requirements and report it to the Owner.

2.2 Joints and Connections

Lengths of pipe will be required to be assembled into suitable installation lengths. The CMP will be joined using the manufacturer's recommended equipment and procedures. The CQA Engineer will spot-monitor joining operations to ensure that the Contractor follows the manufacturer's specifications. The CQA Engineer will document any noncompliance with the above requirements and report it to the Owner.

2.3 Surveying

A Professional Land Surveyor registered in the State of New Mexico will provide the CQA Surveys. The CQA Surveyor will independently survey the final elevation of the invert of all CMP.

The results of the survey will be compiled in a report signed by the CQA Surveyor and the CQA Engineer and will be reviewed by the Owner. The Owner and the CQA Engineer will approve the results contained in the report before any subsequent construction that completely covers the pipe occurs.

SECTION XI - CARBON AND STAINLESS STEEL PIPE CONSTRUCTION QUALITY ASSURANCE

1.0 STEEL PIPE MANUFACTURE AND DELIVERY

1.1 Manufacturing

Prior to incorporating the steel pipe into the work the Contractor will be required to provide the CQA Engineer with the certifications required by the General Specifications signed by a responsible party employed by the pipe Manufacturer.

The CQA Engineer will verify and document that the property values certified by the pipe Manufacturer meet the requirements of the General Specifications based on a sampling interval of one sample per lot. The CQA Engineer will report any deviations from the above requirements to the Owner.

1.2 Labeling

The CQA Engineer will verify that the pipe is labeled with the information specified in the General Specification. Any deviations from the labeling requirements will be reported to the Owner prior to pipe installation.

1.3 Shipment and Storage

The CQA Engineer will verify and document that the pipe and fittings are stored in accordance with the General Specifications.

The CQA Engineer will visual inspect the pipe upon delivery at the site and any deviations from the requirements of the General Specifications will be reported to the Owner.

1.4 Conformance Testing

No conformance testing will be conducted on the materials delivered to the site.

2.0 PIPE INSTALLATION

2.1 Handling and Laying

The CQA Engineer will verify and document that the pipe is installed at the specified locations and grades and that placement of backfill around the pipe is conducted in accordance with the requirements of the General Specifications, and in a manner intended to prevent damage to the pipe.

The pipe will be carefully examined before installation by the CQA Engineer. The CQA Engineer will verify and document that cracks, damage or defects are not present in the pipe fittings in excess of that allowed by the General Specifications.

The CQA Engineer will also note the condition of the interior of pipes. Foreign material shall be removed from the pipe interior before it is moved into final position. No pipe will be permitted to be placed until the CQA Engineer has observed the condition of the pipe.

The CQA Engineer will document any deviation from the above requirements and report it to the Owner.

2.2 Joints and Connections

Lengths of pipe will be required to be assembled into suitable installation lengths by butt welding.

The CQA Engineer will spot-monitor welding operations to ensure that the Contractor follows the General Specifications.

The CQA Engineer will document any noncompliance with the above requirements and report it to the Owner.

2.3 Surveying

A Professional Land Surveyor registered in the State of New Mexico will provide the CQA Surveys. The CQA Surveyor will independently survey the final elevation of the basal location of all steel pipe.

The results of the survey will be compiled in a report signed by the CQA Surveyor and the CQA Engineer and will be reviewed by the Owner. The Owner and the CQA Engineer will approve the results contained in the report before any subsequent construction that completely covers the pipe occurs.

SECTION XII - POLYETHYLENE TANK CONSTRUCTION QUALITY ASSURANCE

1.0 POLYETHYLENE TANK MANUFACTURE AND DELIVERY

1.1 Manufacturing

Prior to incorporating the polyethylene tank into the work the Contractor will be required to provide the CQA Engineer with the certifications required by the General Specifications signed by a responsible party employed by the polyethylene tank Manufacturer.

The CQA Engineer will verify and document that the property values certified by the polyethylene tank Manufacturer meet the requirements of the General Specifications based on a sampling interval of one sample per lot. The CQA Engineer will report any deviations from the above requirements to the Owner.

1.2 Labeling

The CQA Engineer will verify that the polyethylene tank is labeled with the information specified in the General Specification. Any deviations from the labeling requirements will be reported to the Owner prior to pipe installation.

1.3 Shipment and Storage

The CQA Engineer will verify and document that the polyethylene tanks are stored in accordance with the General Specifications.

The CQA Engineer will visual inspect the polyethylene tank upon delivery at the site and any deviations from the requirements of the General Specifications will be reported to the Owner.

1.4 Conformance Testing

No conformance testing will be conducted on the materials delivered to the site.

2.0 POLYETHYLENE TANK INSTALLATION

2.1 Handling and Laying

The CQA Engineer will verify and document that the polyethylene tank is installed at the specified locations, and in a manner intended to prevent damage to the polyethylene tank.

The polyethylene tank will be carefully examined before installation by the CQA Engineer. The CQA Engineer will verify and document that cracks, damage or defects are not present in the polyethylene tank in excess of that allowed by the General Specifications.

The CQA Engineer will document any deviation from the above requirements and report it to the Owner.

2.2 SURVEYING

A Professional Land Surveyor registered in the State of New Mexico will provide the CQA Surveys. The CQA Surveyor will independently survey the final locations and elevation of the base of the polyethylene tank.

The results of the survey will be compiled in a report signed by the CQA Surveyor and the CQA Engineer and will be reviewed by the Owner. The Owner and the CQA Engineer will approve the results contained in the report before any subsequent construction hinders surveying of the polyethylene tank.

SECTION XIII - CONCRETE FORMWORK CONSTRUCTION QUALITY ASSURANCE

1.0 CONCRETE FORMWORK MANUFACTURE

1.1 Manufacturing

Prior to incorporating the formwork into the work the Contractor will be required to provide the CQA Engineer with the requirements of the General Specifications.

The CQA Engineer will verify and document that the material properties meet the requirements of the General Specifications. The CQA Engineer will report any deviations from the above requirements to the Owner.

2.0 FORMWORK INSTALLATION

2.1 Handling and Laying

The CQA Engineer will verify and document that the formwork is installed at the specified locations, and in the manner intended by the General Specifications.

The CQA Engineer will document any deviation from the above requirements and report it to the Owner.

2.2 Surveying

A Professional Land Surveyor registered in the State of New Mexico will provide the CQA Surveys. The CQA Surveyor will independently survey the final locations and elevation of the formwork.

The results of the survey will be compiled in a report signed by the CQA Surveyor and the CQA Engineer and will be reviewed by the Owner. The Owner and the CQA Engineer will approve the results contained in the report before any subsequent construction hinders surveying of the formwork.

SECTION XIV - REINFORCEMENT STEEL CONSTRUCTION QUALITY ASSURANCE

1.0 REINFORCEMENT STEEL MANUFACTURE AND DELIVERY

1.1 Manufacturing

Prior to incorporating the reinforcement steel into the work, the Contractor will be required to provide the CQA Engineer with the material certifications required by the General Specifications signed by a responsible party employed by the reinforcement steel Manufacturer.

The CQA Engineer will verify and document that the property values certified by the reinforcement steel Manufacturer meet the requirements of the General Specifications. The CQA Engineer will report any deviations from the above requirements to the Owner.

1.2 Labeling

The CQA Engineer will verify that the reinforcement steel is labeled with the information specified in the General Specification. Any deviations from the labeling requirements will be reported to the Owner prior to pipe installation.

1.3 Shipment and Storage

The CQA Engineer will verify and document that the reinforcement steel is stored in accordance with the General Specifications.

1.4 Testing

If requested by the Engineer, testing outlined in the General Specifications will be conducted.

2.0 REINFORCEMENT STEEL INSTALLATION

2.1 Fabrication and Installation

The CQA Engineer will verify and document that the reinforcement steel is installed at the specified locations, and in a manner intended to prevent damage to the work.

The reinforcement steel will be examined to ensure that the requirements of the General Specifications are followed.

The CQA Engineer will document any deviation from the above requirements and report it to the Owner.

SECTION XV - JOINTS IN CONCRETE CONSTRUCTION QUALITY ASSURANCE

1.0 JOINT MATERIAL MANUFACTURE

1.1 Manufacturing

Prior to incorporating the joint materials into the work the Contractor will be required to provide the CQA Engineer with the certifications required by the General Specifications signed by a responsible party employed by the Manufacturer.

The CQA Engineer will verify and document that the property values certified by the Manufacturer meet the requirements of the General Specifications. The CQA Engineer will report any deviations from the above requirements to the Owner.

2.0 JOINT INSTALLATION

2.1 Handling and Laying

The CQA Engineer will verify and document that the joint materials, locations and installation procedures are in accordance with the General Specifications. The CQA Engineer will document any deviation from the above requirements and report it to the Owner.

SECTION XVI - MISCELLANEOUS METALWORK CONSTRUCTION QUALITY ASSURANCE

1.0 MISCELLANEOUS METALWORK SUBMITTALS

Prior to incorporating the miscellaneous metalwork into the work, the Contractor will be required to provide the CQA Engineer with the submittals required by the General Specifications.

2.0 FABRICATION AND INSTALLATION

The CQA Engineer will verify and document that the miscellaneous metalwork is fabricated and installed at the specified locations, and in a manner intended by the General Specifications.

SECTION XVII - CAST IN PLACE CONCRETE CONSTRUCTION QUALITY ASSURANCE

1.0 SUBMITTALS

Prior to incorporating the cast in place concrete into the work, the Contractor will be required to provide the CQA Engineer all submittals required by the General Specifications.

2.0 CONFERENCE

Prior to incorporating the cast in place concrete into the work, the Contractor will be required to hold a meeting to discuss items required in the General Specifications.

3.0 TESTING

The CQA Engineer will verify and document that material sampling and testing required in the General Specifications is completed.

SECTION XVIII - CONSTRUCTION QUALITY ASSURANCE DOCUMENTATION

1.0 DOCUMENTATION

1.1 Introduction

An effective CQA plan depends largely on recognition of all construction activities that should be monitored, and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of construction quality assurance activities. The CQA Engineer will document that all quality assurance requirements have been addressed and satisfied.

The CQA Engineer will provide the Owner with signed descriptive remarks, data sheets, and logs to verify and document that all monitoring activities have been carried out. The Owner will maintain at the site a complete file of Construction Drawings, the CAQ plan, the General Specifications, (test procedures, daily reports, testing logs, and other pertinent forms and documents. The forms to be used for CQA documentation should include, at a minimum, those presented in this CQA Plan. The forms presented in this CQA Plan may be revised as necessary by the CQA Engineer.

1.2 Daily Record Keeping

1.2.1 Overview

Daily records will be completed in the field documenting CQA project administration, soils CQA, geosynthetics CQA, and other required CQA activities. The forms to be completed that pertain to each of these categories of records are discussed below.

1.2.2 Project Administration Records

Most project administration records are completed daily by the CQA Engineer and submitted weekly to the Owner. Examples of these forms are included in Appendices B and are briefly described below.

Daily Field Report

The Daily Field Report will be prepared by the CQA Engineer and submitted weekly to the Owner. At a minimum, the Daily Field Report will include the following information:

- The date, project name, location, and other identification;
- A narrative of the events and activities, including meetings and observation which occurred during a given day;
- The weather conditions;
- Source and amount of water used to construct the clay liner, if any;

- The name of parties to any discussions;
- The relevant subject matter or issues;
- The activities planned and performed;
- The schedule; and,
- The signature of the CQA Engineer.

Weekly Field Report

On a weekly basis, the CQA Engineer will summarize in a Weekly Field Report the activities recorded on the Daily Field Reports. This report will be submitted each week to the Owner along with the Daily Field Reports, and will include, at a minimum, the following information:

- The date, project name, location, and other information;
- A summary of work activities during reporting period;
- A summary of construction situations, deficiencies, and/or defects occurring during the reporting period;
- A summary of actions taken to remedy such situations, deficiencies and or defects; and,
- The signature of the CQA Resident Engineer.

Since the weekly report is presented in a report format, a form is not presented in Appendix B.

1.2.3 Soils CQA Records

Records kept for soils related activities will be completed by the CQA Engineer. The information will be recorded as testing is done in the field or as results are received from the laboratory. The records will be available for review on site, and copies will be issued as part of the Final Report. Examples of the relevant forms are included in Appendix B and are briefly described below.

Field Laboratory Compaction Test Log (ASTM D 698 Method A, B, C, D and ASTM D 1557 Method A, B, C).

The results of field compaction tests will be recorded on the Field Laboratory Compaction Test Log. Separate forms are available for each test method used.

Standard Count, Field Sand Cone and Rubber Balloon Density Test Log

The results of the sand cone and or rubber balloon Density Test Log. The results will be used for comparison or calibration with nuclear density test results.

Summary of Sieve Analysis Test Data

This form will provide a summary of sieve analysis test results for soils.

Summary of Field Density Test

This form will provide a summary of field nuclear density test results and sand cone test results for soils.

Summary of Index Laboratory Test Data

This form will provide a summary of index test results performed as required for soils.

Summary of Permeability Laboratory Data

This form will provide a summary of laboratory permeability test data required for clay liners.

1.2.4 Geosynthetics CQA Records

Records for the installation of geosynthetics will be completed by the CQA Engineer. The information will be recorded as the work progresses. The records will be available for review on site and copies will be issued as part of the final CQA report. Examples of the CQA forms to be completed for geosynthetics are included in Appendix D and briefly described below.

Material Inventory

The identifying roll number and pertinent information of each roll of geosynthetic received at the site will be recorded on this form as the materials arrive at the site. This information will be used to track manufacturer's quality control information, conformance test samples, and other CQA documentation.

Nondestructive Test Log

This form will be used to record the time, date, equipment operator, and results of vacuum box or air pressure testing of production geomembrane seaming operations.

Panel Placement Monitoring Log

This form will be used to record geomembrane panel numbers as they are placed in the field and to cross-reference the assigned panel numbers with roll numbers. The weather conditions, time, and temperature at placement will be recorded on the log. Measured dimensions used to calculate the area of the geomembrane will be recorded on the log.

Repair Summary Log

Information on repairs to geomembrane panels and seams will be recorded on this form. The information recorded will include a code to describe the type of repair, the name of the operator making the repair, the location (i.e. seam or panel location) of the repair, nondestructive testing results of the repair, and initials of the CQA Engineer observing the repair.

Seam and Panel Location Log

The relative location of repairs to geomembrane panels and seams described in the Repair Summary Log will be recorded on this form. The results of destructive tests and nondestructive can be indicated in this log, as well as, location and results of thickness measurements taken for each panel.

Destructive Test Log

This form will be used to record the results from testing performed on geomembrane seams at the Geosynthetics CQA Laboratory (an independent testing laboratory). The results for both pep and shear will be recorded. The form will be completed as data becomes available.

Trail Seam and Seaming Log

This form will be used to record results of trial geomembrane seam testing and to track production seaming activities. The time, temperature, type of seaming equipment used, name of seamer, and length of seam will be recorded.

Certificate of Acceptance Subgrade Surface

The Certificate of Acceptance is required to be signed by the Contractor prior to the installation of the geomembrane. The area being accepted must be described on the certificate.

1.2.5 Survey Records

Record Drawings resulting from the surveying performed by the CQA Surveyor will be reviewed by the CQA Engineer and the Owner. The Record Drawings will be available for review onsite, and copies will be issued as part of the final CQA Report issued by the CQA Engineer. At a minimum, these Records Drawings will include as-built survey data for the following liner system components:

- Prepared subgrade;
- Structural fill
- Clay liner;
- Polyethylene pipe and fittings;
- Geomembrane liners;
- Drainage Gravel;
- Protective soil layer;
- Road Base;
- Cover Soil;
- Vegetative cover;
- Pipe bedding;
- Select Subbase;
- Subbase;
- Foundation sand;
- Geocomposite;
- Geonet;
- Geotextile;
- Polyvinyl Chloride Pipe;
- Geosynthetic Clay Liner

- Steel Pipe; and,
- Polyethylene Tank.

1.3 Photographic Documentation

Photographic documentation will serve as a pictorial record of work progress, problems, and mitigation activities. The basic file will contain color prints; negatives will also be stored in a separate file in chronological order. These photographs will be available for review by the Owner, the CQA Engineer, and other interested parties. Selected photographs will be reproduces as part of the Final Report. The remaining photographs will be transmitted to the Owner and archived by the Owner as part of the operating records.

1.4. Design and/or Specification Changes

Design and/or specification changes may be required during construction. In such cases, the CQA Engineer will notify the Owner. The Owner will notify NMED, and when necessary, the Design Engineer.

Major design and/or specifications changes will be made only with the written agreement of the Design Engineer and the Owner and will take the form of an addendum to the General Specifications.

1.5 Signatures and Final Reports

At the completion of the work, the CQA Engineer will submit a final CQA report to the Owner.

At a minimum, this report will include: (a) summaries of all construction activities; (b) sources and amounts of water used to construct the clay liners; (c) results of chemical quality analyses of construction water from each source; (d) observation logs and testing data sheets including sample location plans; (e) a discussion of any changes from design and material specifications; (f) CQA Record Drawings; and (g) a summary statement sealed and signed by a Professional Engineer registered in the State of New Mexico that construction quality assurance was conducted as provided in the CQA Plan and, based on visual observations and data generated in accordance with the CQA Plan, the landfill or surface impoundment was constructed in accordance with the Construction Drawings, the CQA Plan, and the General Specifications, except as properly authorized and documented in the CQA final report. The CQA Record Drawings will include the following: primary and secondary geomembrane panel layout drawings; all drawings (including cross-sections) depicting any deviations from the Construction Drawings; and all survey conformance data.

APPENDIX A

TEST FILL PLAN

1.0 PURPOSE AND SCOPE

The purpose of the test fill is to establish a sequential and logical approach for the development of placement and compaction procedures to be used during construction of cohesive soil liners as an indicator that the soil liners are constructed in a way that meets design performance specifications. The test fill program will allow the Contractor, the Design Engineer, and the Construction Quality Assurance (CQA) engineer to identify appropriate placement and compaction procedures by establishing relationships between various compaction parameters, density, water content, Atterberg limits, particle size distribution, and permeability of the fill.

Once the construction procedures have been established by the test fill program, the Contractor and the CQA Engineer will monitor the cohesive soil liner construction procedures as an indicator that the design performance specifications are being achieved, Test fill construction procedures will include measuring lift thickness, counting the number of compactor coverages, and performing in-place density and moisture content tests to verify that the specified degree of compaction is achieved.

The test fill will be constructed in uniform horizontal lifts of uniform thicknesses.

This test fill program documents the requirements for constructing the test fill. The test fill program will include:

- subgrade preparation
- construction of a 3-foot-thick test fill
- inspection and testing of the test fill
- sampling of portions of the test fill

The test fill program described in this appendix may be modified based on site specific design and construction considerations.

Feasibility testing of clay sources will have been performed before the start of the test fill. These tests should provide the basic relationship of permeability with varying density and moisture content.

2.0 CONSTRUCTION EQUIPMENT

The equipment to be used for the test fill shall be proposed by the Contractor, and approved by the CQA Engineer and Project Manager.

3.0 TEST FILL MATERIAL

Test fill material shall be approved by the CQA Engineer. The material shall meet the requirements of the Specification Section 02221. The Material shall be an inorganic cohesive soil with a plasticity index (PI) ranging between 10 and 40; at least 50 percent of the soil shall pass the No. 200 sieve. As approved by the CQA Engineer, small quantities of fill with PI greater than 40 may be allowed if such materials are thoroughly mixed with other less plastic soils. Other materials may be considered based upon laboratory testing and upon approval of the Project Manager. The maximum particle size shall be 2 inches before processing.No frozen material shall be used, and in-place material that becomes frozen prior to completion of operations shall be removed.

4.0 TEST FILL CONSTRUCTION

4.1 SUBGRADE PREPARATION

The area within the limits of the test fill shall be cleared and grubbed of all trees, debris, brushes, stumps, roots, trash, and any other vegetation or objectionable material. Following clearing and grubbing, the area shall be stripped of topsoil. Topsoil shall be stockpiled in an area designated by the Project Manager.

The surface of the subgrade shall be proof-rolled so as to be free of soft zones, irregularities, loose earth, and abrupt changes in grade. The subgrade and test fill shall be sloped at a 2 percent grade. No standing water or excessive moisture shall be allowed on the surface of the subgrade. The surface shall be inspected by the CQA Engineer prior to beginning construction of the test fill.

If placement and compaction of soil materials on slope areas is to be accomplished by the downslope compaction method rather than by horizontal benching, the test fill shall have a sloped area of similar grade to the intended liner installation where the downslope compaction method can be evaluated.

4.2 CONFIGURATION

The test fill shall be a rectangle approximately 60 feet long by 20 feet wide. The test fill shall be constructed to a thickness of 3 feet in uniform horizontal lifts. Lines and grades shall be controlled by survey.

4.3 FILL PLACEMENT

The test fill shall be constructed in uniform horizontal lifts to a total thickness of 3 feet after compaction in accordance with the procedures specified below. The procedures, which vary with the lift considered, are intended to allow determination of a relationship between soil compaction criteria, which include density and moisture content, permeability, and compaction method parameters. Compaction method parameters include: (1) compactor characteristics; (2) thickness of compacted/uncompacted layers; (3) number of compactor coverages; and, soils moisture content.

4.3.1 First Lift

1. The first lift of test fill material shall be placed to a thickness resulting in 6 inches after compaction.

2. Soils moisture content shall be maintained when the placement window defined in the Specifications (Section 02221). The contractor shall adjust the moisture content as necessary to obtain the specified density criteria.

3. The test fill material shall be compacted with two one-way coverages using the Contractor's proposed compaction equipment.

4. The Contractor shall permit the CQA Engineer to perform inplace density tests and collect soil samples as specified in 5-3..

5. QA Engineer to perform in-place density tests and collect soil samples as specified in Section 5.3.

6. Holes left in the lift shall be repaired in accordance with methods outlined in the CQA plan. The repairs shall be compacted using procedures which have been shown to meet the required moisture and density criteria.

7. The test fill material shall be compacted a second time by applying two more one-way coverages with the selected compactor.

8. Steps 4 and 5 shall be repeated. Second tests shall be taken near the original tests.

9. The test fill material shall be compacted a third time by applying two more one-way coverages with the selected compactor.

10. Steps 4 and 5 shall be repeated. Third tests shall be taken near the first and second tests.

11. Steps 8 and 9, respectively, shall be repeated and continued until specified compaction criteria are obtained as identified by the CQA Engineer.

4.3.2 Second Lift

1. The loose thickness of the second lift shall be such that the thickness of the lift will be 6 inches after compaction.

2. A competent bond with the first lift shall be achieved by the Contractor and approved by the CQA Engineer.

3. Steps 2 through 10 of Section 4.3.1 shall be repeated.

4.3.3 Remaining Lifts

1. The loose thickness of the remaining lifts shall be such that the thickness of the lifts will be 6 inches after compaction.

2. The procedures for compacting and testing the remaining lifts shall be those that have been tested and proven effective during the compaction of the second lift.

4.3.4 Final Surface Preparation

The surface of the test fill shall be rolled with a smooth steel drum or pneumatic rolled so as to be free of irregularities, loose earth, and abrupt changes in grade. All stones larger than 1 inch shall be removed. Stones which are smaller than 1 inch and are judged to be detrimental to a geomembrane liner will be removed. One-half of the prepared soil surface shall be protected against drying with temporary plastic sheets. The sheets shall be placed immediately after the completion of surface preparation. Observations and documentation of desiccation cracking versus time shall be made on the uncovered section of the test fill.

5.0 INSPECTION AND TESTING

5.1 TEST FILL MATERIAL

The CQA Engineer shall perform testing on the cohesive soil material prior to its use in the test fill. Testing, using the most recent ASTM method, will include at least the following:

- soil density/moisture content relationship using the Modified and Standard Proctor Compaction Method (ASTM D 698 and ASTM D 1557)
- natural water content (ASTM D 2216)
- particle size distribution (ASTM D 422)
- Atterberg limits (ASTM D 4318)
- soil classification (ASTM D 2487)

5.2 SUBGRADE PREPARATION

The CQA Engineer shall observe the prepared subgrade for firmness, smoothness, and absence of abrupt changes in grade.

5.3 TEST FILL CONSTRUCTION

5.3.1 Lift Compaction

For the first and second lifts, the CQA Engineer shall perform the following activities:

- estimate the thickness of the loose lifts
- count the number of compactor coverages and observe compactor coverage of the test fill (Figure 1)
- at every two (2) coverages, perform a minimum of eight nuclear gauge in-place density and moisture reading (ASTM D 2292); compute degree of compaction (i.e., in-place dry density divided by the Standard Proctor or Modified maximum dry density; collect four additional soil samples for moisture content determination (ASTM D 2216)
- observe the repair of holes left in the lift as a result of density testing and soil sample collection
- continue in-place density testing and moisture content determination to enable development of a curve giving in-lace dry density versus number of compactor coverages for each lift thickness

For each of the remaining lifts, the CQA engineer shall perform the following activities:

- verify that the thickness of the loose lift does not exceed the loose thickness determined from testing of the second lift
- count the number of compactor coverages, determined from testing of the second lift, which are necessary to achieve the specified density and observe compactor coverage of the test fill
- perform a minimum of eight nuclear density tests per lift to verify the adequacy of the construction procedures previously established

The CQA Engineer shall collect a minimum of six (6) undisturbed Shelby tube samples or 12 inch x 12 inch x 6 inch undisturbed block soil samples from varying depths of the completed test fill. The samples shall be waxed or otherwise protected to retain natural moisture and tested in the laboratory for the following:

- hydraulic conductivity (permeability) using water as the permeant (ASTM D 5084)
- dry density
- particle size distribution (ASTM D 422)
- Atterberg limits (ASTM D 4318)
- soil classification (ASTM D 2487)
- soil moisture content (ASTM D 2216)

The CQA Engineer shall observe the test fill to verify the adequacy of the bonding between adjacent lifts. Such observation shall be exercised on the portion of the test fill which has been excavated to permit removal of undisturbed soil block samples.

5.3.2 Final Surface Preparation

The CQA Engineer shall observe the prepared surface for firmness, smoothness, and absence of abrupt changes in grade.

5.3.3 Permeability Testing

The permeability of the test fill shall be assessed by performance of a minimum of six (6) laboratory tests on specimens trimmed form the undisturbed block of Shelby tube samples tested at a location selected by the CQA Engineer.

5.4 TEST RESULTS

The test results which will be used to verify that the specified construction procedures meet the design performance criteria shall be:

- compaction testing (i.e., degree of compaction, in-place dry density, and moisture content)
- results of laboratory permeability testing performed on undisturbed soils samples
- soil index testing to evaluate material suitability

5.5 LINES AND GRADES

The following surfaces shall be surveyed to verify that proper thicknesses have been constructed:

- prepared surface of the subgrade
- final surface of the test fill

6.0 DOCUMENTATION

The CQA Engineer shall document activities associated with the construction, monitoring, and testing of the test fill. Such documentation shall include daily reports of construction activities and

oral communications with the contractor. In addition, the following shall be documented for each of the section listed below:

6.1 TEST FILL MATERIAL

The CQA Engineer shall provide a moisture-density relationship for the test fill liner material and other and other test results as specified in Section 5.1.

6.2 TEST FILL CONSTRUCTION

6.2.1 Subgrade preparation

The CQA Engineer shall document observations on subgrade preparation, as specified in Section 5.2.

6.2.2 Test Fill Construction

The CQA Engineer shall document activities of the test fill construction, monitoring, and testing in a test fill summary report, which shall include but not be limited to:

- record of the compactor type, configuration, and weight; for sheepsfoot compactors, record the drum diameter and length, empty and ballasted weight, length and face area of feet, and yoking arrangement, if any
- record thicknesses of lifts prior to and after compaction
- record density versus number of compactor coverages for each lift thickness, as specified in Section 5.3.1
- record the number of compactor coverage which will provide the specified degree of compaction and permeability
- record the procedure to bond lifts
- results of moisture, in-place density and degree of compaction, as specified in Section 5.3.1
- repair of holes left in the lift as a result of density testing and soil sample collection, as specified in Section 5.3.1
- results of laboratory premeability testing and other soil properties tests performed on undisturbed soil samples
- as-built drawing of the test fill and locations of all test samples for each lift
- cross-section of the test fill showing number of lifts and lift thickness
- description of actual construction procedures
- observations of test fill excavation for removal of undisturbed soils samples and observations of layer bonding, as specified in Section 5.3.1

APPENDIX B

PROJECT ADMINISTRATION RECORDS

TerraMatrix

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

FIELD ENGINEER'S DAILY REPORT

PROJECT NAME: TRIASSIC PARK WASTE DISPOSAL FACILITY
PROJECT NUMBER: 602
PAGE ____ of ____
FIELD ENGINEER:_____

DATE:_____ S M T W T F S
AREA:_____
_____
WEATHER:_____

CONTRACTOR WORK PERFORMED.....

TESTING OR SURVEYING PERFORMED.....

DISCUSSIONS WITH CONTRACTOR OR CLIENT.....

COMMENTS.....

VISITORS:

Field Book Number ____ Pages ____ to ____
SIGNATURE:_____

APPENDIX B

PROJECT ADMINISTRATION RECORDS

TerraMatrix

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

FIELD ENGINEER'S DAILY REPORT

PROJECT NAME: TRIASSIC PARK WASTE DISPOSAL FACILITY
PROJECT NUMBER: 602
PAGE ___ of ___
FIELD ENGINEER:_____

DATE:_____ S M T W T F S
AREA:_____
_____
WEATHER:_____

CONTRACTOR WORK PERFORMED.....

TESTING OR SURVEYING PERFORMED.....

DISCUSSIONS WITH CONTRACTOR OR CLIENT.....

COMMENTS.....

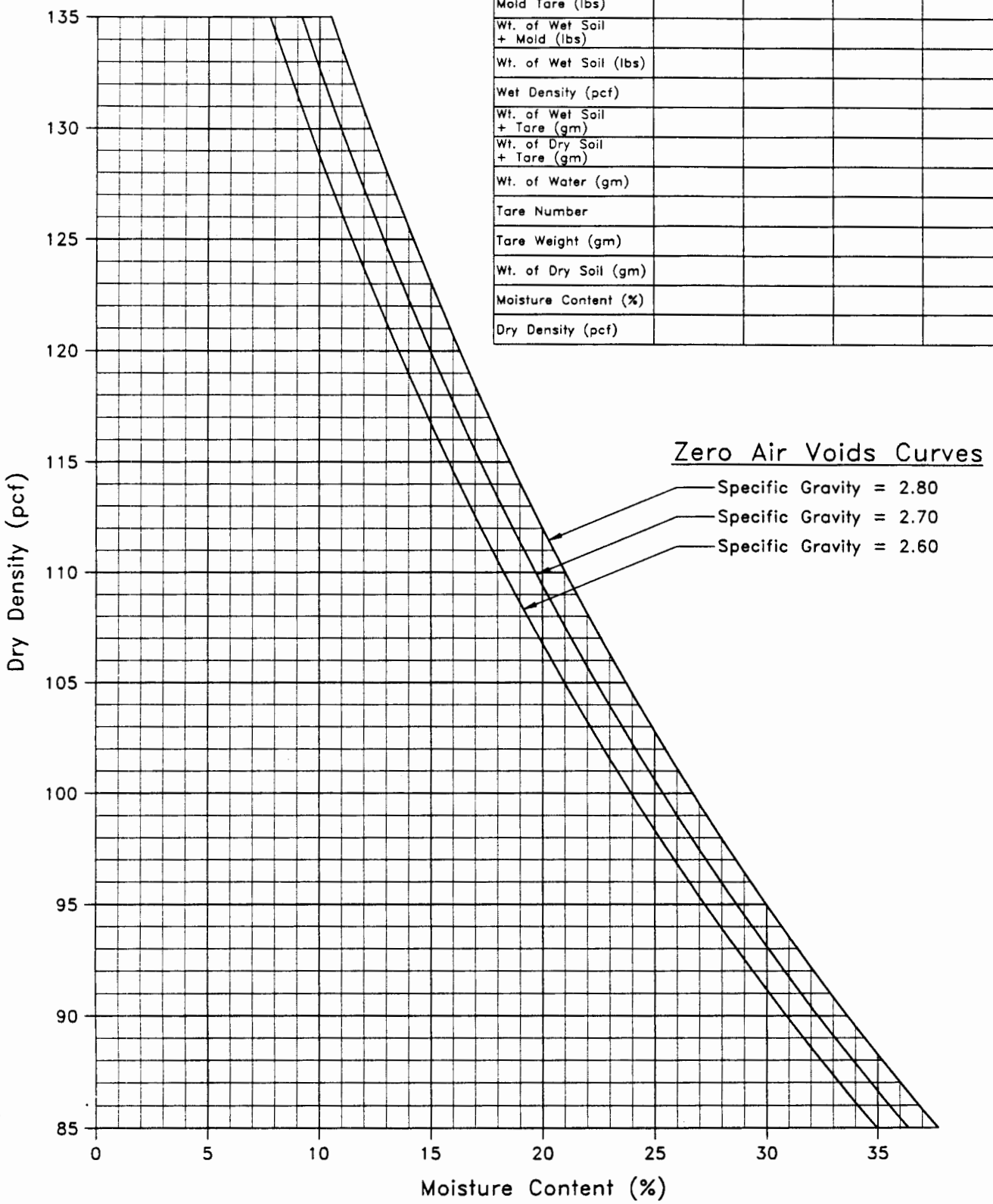
VISITORS:

Field Book Number ___ Pages ___ to ___
SIGNATURE:_____

APPENDIX C

SOILS CQA RECORDS

Point					
Mold Number					
Mold Tare (lbs)					
Wt. of Wet Soil + Mold (lbs)					
Wt. of Wet Soil (lbs)					
Wet Density (pcf)					
Wt. of Wet Soil + Tare (gm)					
Wt. of Dry Soil + Tare (gm)					
Wt. of Water (gm)					
Tare Number					
Tare Weight (gm)					
Wt. of Dry Soil (gm)					
Moisture Content (%)					
Dry Density (pcf)					



Project Name:			TerraMatrix
Sample Location:		Sample No.:	
Sample Source:		Technician:	
Sample Description:			MOISTURE-DENSITY RELATIONSHIP OF SOIL
Max. Dry Density (pcf):	Opt. Moisture (%):	Procedure:	
Liquid Limit (%):	Plasticity Index (%):	Natural Moisture (%):	Project No.:
% + 3/4 in.:	% − No. 4:	% − No. 200:	Date:

NUCLEAR GUAGE (ASTM D2922)
STANDARD COUNT LOG (ASTM D3017)

PROJECT NAME: TRIASSIC PARK WASTE DISPOSAL FACILITY **PROJECT NO. 602**

NUCLEAR GUAGE MODEL_____ **SERIAL NO.:**_____

DATE ARRIVED ON SITE:_____ **DATE DEPART SITE:**_____

DATE (day/mo)	QA ID	MOISTURE COUNT	DENSITY COUNT	PASS/ FAIL	PECENT CHANGE		DATE (day/mo)	QA ID	MOISTURE COUNT	DENSITY COUNT	PASS/ FAIL	PECENT CHANGE

IN-SITU DENSITY TESTS - RUBBER BALLOON METHOD (ASTM D 2167)
TRIASSIC PARK WASTE DISPOSAL FACILITY

OWNER: GANDY MARLEY INC.

PROJECT NUMBER: 602

DATE:_____ **MATERIAL TESTED:**_____ **OPTIMUM WATER CONTENT:**____ **MAX DRY DENSITY (pcf):**___

TESTED BY:_____ **REVIEWED BY:**_____ **WEATHER:**_____ **PAGE**___ **OF** ___

TEST NUMBER	RUBBER BALLOON	NUCLEAR DENSITY	RUBBER BALLOON	NUCLEAR DENSTIY	RUBBER BALLOON	NUCLEAR DENSITY
ELEVATION						
LOCATION						
FINAL READINGS (ft^3)						
AVERAGE FINAL READING (ft^3)						
INITIAL READING (ft^3)						
CORRECTED VOLUME (ft^3)						
SOIL WEIGHT + TARE (gm)						
TARE (gm)						
WEIGHT WET SOIL (gm)						
WET DENSITY (pcf)						
TIN NUMBER						
WEIGHT WET SOIL + TARE (gm)						
WEIGHT DRY SOIL + TARE (gm)						
WEIGHT OF WATER (gm)						
TARE (gm)						
WEIGHT DRY SOIL (gm)						
MOISTURE CONTENT						
DRY DENSITY (pcf)						
MAXIMUM DRY DENSITY (pcf)						
PERCENT COMPACTION						
CORRELATION TO TROXLER						

SAMPLE:_____

Sieve	Cumulative Weight Retained	Cumulative % Retained	Cumulative % Passing	Specification % Passing
3"				
2"				
1"				
3/4"				
3/8"				
#4				
#10				
#20				
#40				
#60				
#100				
#200				
PAN				

SAMPLE AND TARE WT: _____

TARE WT: _____ CONTAINER NO.:_____

WEIGHT BEFORE SIEVING:_____

UNIFORMITY COEFFICIENT, (D_{60}/D_{10}):_____
COEFFICIENT OF CURVATURE, $(D_{30})/(D_{10} \times D_{60})$:_____

SIEVE ANALYSIS FORM (ASTM D 422)

PROJECT: TRIASSIC PARK WASTE DISPOSAL FACILITY CQA

PROJECT NO. 602 DATE:_____ TESTED BY:_____

TERRAMATRIX
1475 Pine Grove Road
Steamboat Springs, Colorado 80477

NUCLEAR FIELD DEN[illegible]/MOISTURE TEST DATA
TRIASSIC PARK WA[illegible] DISPOSAL FACILITY
(ASTM 2922, D3017)

PROJECT NUMBER: 602
OWNER: GANDY MARLEY INC.
LOCATION:

CONTRACTOR:_____

SHEET NUMBER_____ OF_____

TROXLER MODEL _____ SERIAL NO.:_____STANDARD COUNT: DENSITY: _____ MOISTURE:_____ REQUIRED COMPACTION (%): _____

WEATHER: _____FIELD MONITOR: _____

TEST NUMBER													
GENERAL TEST LOCATION													
REFERENCE STAKE	I.D. NUMBER												
	NORTH COORDINATE												
	EAST COORDINATE												
	ELEVATION												
	BEARING (TO TEST)												
	DISTANCE												
MODE & DEPTH													
WET DENSITY (pcf)													
DRY DENSITY (pcf)		TROXLER	LAB	TROXLER	LAB	TROXLER	LAB	TROXLER	LAB	TROXLER	LAB	TROXLER	LAB
% MOISTURE													
% COMPACTION													
OPTIMUM MOISTURE (%)													
MAXIMUM DRY DENSITY (pcf)													
PASS/FAIL													

*TerraMatrix Inc. * P.O. Box 774018 * Steamboat Springs, Colorado 80477 * (303) 879 6260 * (303) 879 9048 (fax)*

SOILS TEST REQUEST SHEET

PROJECT NAME: TRIASSIC PARK WASTE DISPOSAL FACILITY **PROJECT NO. 602** **LAB NO.**_____

REQUESTED BY_____ **PROJECT MANAGER APPROVAL**_____ **PAGE**____ **OF** ____

SAMPLE NUMBER	SAMPLE DEPTH LOCATION AND/OR STATION	VISUAL USCS SYMBOL	MOISTURE CONTENT	DRY DENSITY	ATTERBERG LIMITS	SIEVE ANALYSIS	#200 WASH	HYDROMETER ANALYSIS	COMPACTION TEST	UNDISTURBED PERMEABILITY	DIRECT SEHAR	UNCONFINED COMPRESSION	REMOLDED PERMEABILITY	DATE REQUESTED	RESULTS DUE BY	DATE COMPLETED	DATE SAMPLE STORED	DATE SAMPLE DISPOSED OF

COMMENTS:

SPECIAL INSTRUCTIONS:

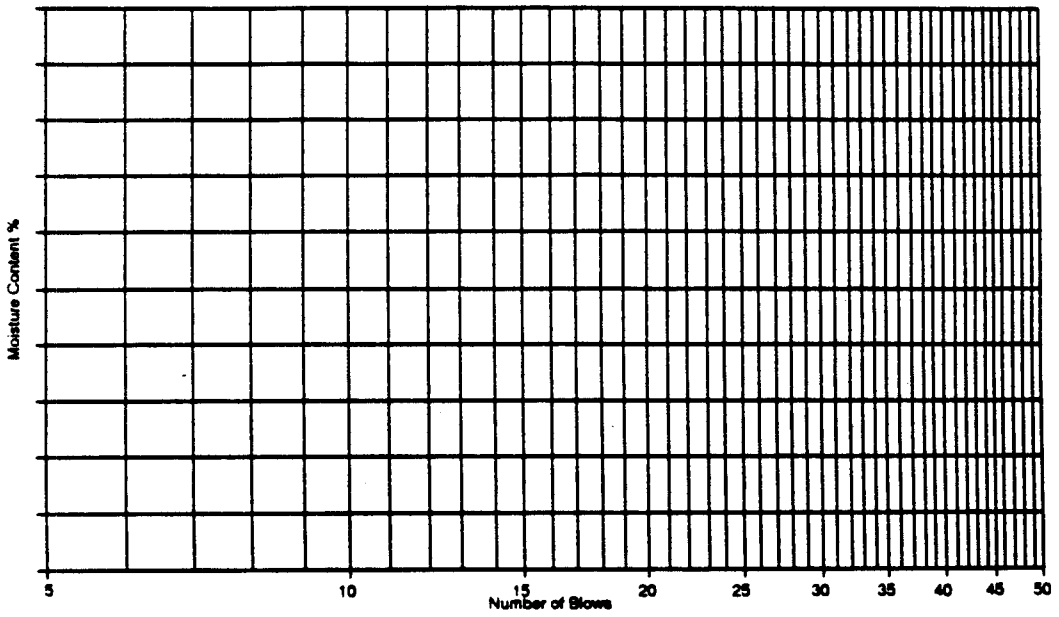
SAMPLES DELIVERED BY:_____

SAMPLES RECEIVED BY:_____

*TerraMatrix Inc. * P.O. Box 774018 * Steamboat Springs, Colorado 80477 * (303) 879-6260*

Type of Test	LL	LL	LL	LL	Nat. M.C.
Container #					
Tare Wt. (g)					
Number of Blows					
Wt. Sample Wet + Tare (g)					
Wt. Sample Dry + Tare (g)					
Weight of Water (g)					
Weight of Dry Soil (g)					
Moisture Content (%)					

Type of Test	PL	PL	Borehole #	
Container #			Sample #	
Tare (g)			Depth	
Wt. Sample Wet + Tare (g)			Liquid Limit	
Wt. Sample Dry + Tare (g)			Plastic Limit	
Weight of Water (g)			Plasticity Index	
Weight of Dry Soil (g)			Moisture Content	
Moisture Content (%)			Liquidity Index	



Sample Description: _____

_____

ATTERBERG LIMITS

Project: TRIASSIC PARK WASTE DISPOSAL FACILITY CQA

Project No.: DATE: TESTED BY: TERRAMATRIX

CONSTANT HEAD PERMEABILITY ON GRANULAR SOIL
GANDY MARLEY INC.
CHAVES COUNTY, NEW MEXICO

DATE:_____ SHEET____ OF ___

OWNER:_____ PROJECT NUMBER:_____

PROJECT NAME:_____LOCATION:_____

SAMPLE NO.:_____ TECH._____

DESCRIPTION:_____

HEIGHT BEFORE (H1):

(1) _____

(2) _____

(3) _____

(4) _____

HEIGHT AFTER (H2):

(1) _____

(2) _____

(3) _____

(4) _____

AVERAGE (H1) _____ AVERAGE (H2) _____

SAMPLE DIMENSIONS

HEIGHT, L=(H1-H2), cm: _____ HEAD, h, cm: _____

DIAMETER, cm:_____

AREA, A, sq. cm:_____

	QUANTITY OF WATER, Q (cubic cm)	TIME, t (sec)
TRIAL 1:	_____	_____
TRIAL 2:	_____	_____
TRIAL 3:	_____	_____
AVERAGE:	_____	_____

K= QL/Ath= _____ cm/sec

1 inch = 2.45 cm
1 gal = 3785.41 cubic cm

APPENDIX D

GEOSYNTHETICS CQA RECORDS

GEOSYNTHETICS INVENTORY, QUALITY CONTROL AND CONFORMANCE TESTING LOG

PROJECT NUMBE
PROJECT NAME:
OWNER:
INSTALLER:

DATE OF INVENTORY:_____
DATE OF DELIVERY: _____
TRUCK TYPE:_____
BILL OF LADING NUMBER:_____

QAM:_____
UNLOADING EQUIPMENT:_____
WEATHER CONDITIONS:_____
MANUFACTURER: _____

MATERIAL TYPE: GEOMEMBRANE GCL GEONET (COMPOSITE) GEOTEXTILE(CU) OTHER:_____

	INVENTORY LOG						QUALITY CONTROL CERTIFICATES AND CONFORMANCE TESTING VERIFICATION				
	ROLL NUMBER	LOT #	MON ID	ROLL. LXW (ftxft)	AREA (ft2)	DAMAGE REMARKS	QC CERT RECD Y/N	DATE CONF. SAMPLE CUT/ SENT OUT	DATE CONF. RESULTS RECD.	CONF. RESULTS REVIEWED BY/DATE	P/F
1.											
2.											
3.											
4.											
5.											
6.											
7.											
8.											
9.											
10.											
11.											
12.											
13.											
14.											
15.											
16.											
17.											
18.											
19.											
20.											

NCR#_____

TOTAL AREA THIS PAGE

REVIEWED BY: DATE:

GEOSYNTHETICS PANEL DEPLOYMENT LOG

PROJECT NUMBER:
OWNER:
INSTALLER:

DATE :_____
SHEET NUMBER____**of**____

GEOSYNTHETIC TYPE: **PRIMARY/SECONDARY/TERTIARY/CLOSURE**
GEOMEMBRANE **GCL** **GEONET(COMPOSITE)** **GEOTEXTILE(CU)**

OTHER/COMMENTS: _____
SUBGRADE CONDITION (Surface Compaction, Protrusions, Desiccation, Excessive Moisture): _____

PANEL NUMBER			
ROLL NUMBER			
DEPLOYED LENGTH (FT)			
*AMBIENT AIR TEMP (F)			
VISUAL OBSERVATION			
**OBSERVED OVERLAP			
MONITOR			
REMARKS			

SHEET THICKNESS (MILS)	LEAD	TRAIL	SPEC	P/F	LEAD	TRAIL	SPEC	P/F	LEAD	TRAIL	SPEC	P/F
			54				54				54	
			54				54				54	
			54				54				54	
			54				54				54	
			54				54				54	
AVERAGE			60				60				60	

PANEL NUMBER			
ROLL NUMBER			
DEPLOYED LENGTH (FT)			
*AMBIENT AIR TEMP (F)			
VISUAL OBSERVATION			
**OBSERVED OVERLAP			
MONITOR			
REMARKS			

SHEET THICKNESS (MILS	LEAD	TRAIL	SPEC	P/F	LEAD	TRAIL	SPEC	P/F	LEAD	TRAIL	SPEC	P/F
			54				54				54	
			54				54				54	
			54				54				54	
			54				54				54	
			54				54				54	
AVERAGE			60				60				60	

NCR REFERENCE NUMBER (IF REQUIRED)_____

INSTRUMENT ID#
THERMOMETER _____
MICROMETER _____
WIND GAUGE _____

REVIEWED BY_____ **DATE**_____

* Ambient air temperature must be between 40° and 100° F for HDPE deployment
** Observed overlap must conform to construction specifications for relevant material type

File: Paneldep.log
Printed: December 9, 1997 (10:01am)

TerraMatrix Inc. * P.O. Box 774018 * Steamboat Springs, Colorado 80477 * (970) 879-6260 * (970) 879-9048 (fax)

GEOMEMBRANE DEFECT LOG

PROJECT NUMBER:
OWNER:
LOCATION:
INSTALLER:

SHEET NUMBER: _____

DEFECT CODE	DEFECT LOCATION		DEFECT TYPE (SEE BELOW)	LOG DATE	CQA MON	REMARKS	REPAIR DATE*	TEST DATE*
	SEAM, PANEL OR REPAIR NO.	DEFECT LOCATION DESCRIPTION						
A								
B								
C								
D								
E								
F								
G								
H								
I								
J								
K								
M								
N								
P								
Q								
R								
S								
T								
W								
X								

AD ANIMAL RELATED DAMAGE
B UNDISPERSED RESIN BEAD
BO FUSION WELDER BURN
BS BOOT/SKIRT FOR FML PENETRATION
CO CHANGE OF OVERLAP
CR CREASE
D INSTALLATION DAMAGE
DF-# FUSION DESTRUCTIVE TEST NUMBER
DX-# EXTRUSION DESTRUCTIVE TEST NUMBER

EE EARTHWORKS DAMAGE
EXT EXTENSION
FM FISHMOUTH
FS FAILED SEAM LENGTH
FTS FIELD TEST STRIP
MT HEAT TRACK BURN
IO INSUFFICIENT OVERLAP (UNDER SPEC)
MO MANUFACTURER/DELIVERY DAMAGE

PT PRESSURE TEST CUT
SI SOIL IRREGULARITY
SL SLAG ON TEXTURED SHEET
T THREE PANEL INTERSECTION
VL VACUUM TEST LEAK
WR WRINKLE
WS WELDER RESTART
OTHER

NOTE: * COLUMNS TO BE USED BY THE DATA REVIEWER ONLY

REVIEWED BY:_____ DATE_____

NCR REFERENCE NUMBER (IF REQUIRED)_____

GEOMEMBRAN USION SEAM LOG

PROJECT NUMBER:)
OWNER:
LOCATION: DATE: _____
INSTALLER:
MACHINE NUMBER: M#_____ CARRYOVER: _____ CQA MONITOR: _____ SHEET NUMBER: _____of_____

PASSING TRIAL SEAM INFORMATION

NO.	TIME	TECH ID	WEDGE TEMP.	SPEED

SEAM NUMBER (1)	SEAM SECTION (2) FROM	TO	START TIME	TECH ID	TEMPERATURE/SPEED VERIFICATION WEDGE TEMP.(F)	SPEED	APPROX. LENGTH WELDED (ft)	DISTANCE FROM LAST DESTRUCTIVE (ft)	DESTRUCTIVE NUMBER	ENTIRE SEAM COMPLETE NO	YES	REMARKS	NON-DESTRUCT TEST DATE (reviewer only)
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												

(1) Indicate seam number by two adjacent panel numbers, with the lowest panel number indicated first.
(2)Reference seam endpoints from an End of Seam (EOS), a defect repair number or a point location on the seam (reference point, distance from reference point).

REVIEWED BY_____ DATE_____

(CIRCLE MACHINE USED)

TMI TENSIOMETER CALIBRATION: SERIAL NUMBER: 124 CALIBRATION DATE: 4/1/96 RECALIBRATION DATE: 4/1/97
NSC TENSIOMETER CALIBRATION: SERIAL NUMBER: 93021/91001 CALIBRATION DATE: 10/14/96 RECALIBRATION DATE: 10/14/97

NCR REFERENCE NUMBER (IF REQUIRED)_____

GEOMEMBRANE EXTRUSION SEAM/REPAIR LOG

PROJECT NUMBER:
OWNER:
LOCATION:
INSTALLER:

MACHINE NUMBER: MX_____ CARRYOVER: _____ CQA MONITOR: _____ DATE: _____

PASSING TRIAL SEAM INFORMATION

NO.	TIME	TECH ID	PRE-HEAT	BARREL

EXTRUDER PURGED OF HEAT DEGRADED EXTRUDATE (1)_____ SHEET NUMBER: ____of____

SEAM NUMBER (2)	SEAM SECTION (3) FROM	TO	DEFECT CODE	START TIME	TECH ID	TEMPERATURE VERIFICATION PRE-HEAT SETTING	BARREL TEMP. (F)	REPAIR SIZE (ft X ft)	APPROX. LENGTH WELDED (ft)	DISTANCE FROM LAST DESTRUCTIVE (ft)	DESTRUCTIVE NUMBER	ENTIRE SEAM COMPLETE No	Yes	REMARKS	NON-DEST TEST DATE (vacuum only)
/	-														
/	-														
/	-														
/	-														
/	-														
/	-														
/	-														
/	-														
/	-														
/	-														
/	-														
/	-														
/															

(1) Extruder must be purged when starting a seam and when welding stops for more than 1 minute.
(2) Indicate seam number by two adjacent panel numbers, with the lowest panel number indicated first.
(3) Reference seam endpoints from an End of Seam (EOS), a defect repair number or a point location on the seam (reference point, distance from reference point).

REVIEWED BY_____ DATE_____

(CIRCLE MACHINE USED)
TMI TENSIOMETER CALIBRATION: SERIAL NUMBER: 124 CALIBRATION DATE: 4/1/96 RE-CALIBRATION DATE: 4/1/97
NSC TENSIOMETER CALIBRATION: SERIAL NUMBER: 93021/91001 CALIBRATION DATE: 10/14/96 RE-CALIBRATION DATE: 10/14/97

NCR REFERENCE NUMBER (IF REQUIRED) _____

GEOMEMBRANE FUSION DESTRUCTIVE LOG

ROJECT NUMBER:
OWNER:
LOCATION:
INSTALLER:

DESTRUCTIVE MONITOR: _____

DATE TESTED:_____

DESTRUCTIVE SAMPLE NUMBER: _____(ASSIGNED BY QAM)

DESTRUCTIVE INFORMATION:

DEFECT NO.	SEAM NO.	LOCATION	TECH ID	MACHINE NUMBER	DATE	CQA MON ID

DESTRUCTIVE TEST DATA:

PEEL TEST RESULTS					
SAMPLE (INSIDE TRACK)	STRENGTH (lbs/in)	BREAK TYPE	SAMPLE (OUT. TRACK)	STRENGTH (lbs/in)	BREAK TYPE
A1			A2		
B1			B2		
C1			C2		
D1			D2		
E1			E2		
SPECIFICATION REQUIREMENTS	90	FTB		90	FTB

SHEAR TEST RESULTS						
SAMPLE	PEAK STRENGTH (lbs/in)	BREAK TYPE	WELD TO GRIP LENGTH (a)	WELD TO GRIP FAILING SIDE AT YIELD (b)	WELD TO GRIP FAILING SIDE AT BREAK (c)	SHEAR STRAIN (%) AT YIELD((b-a)/a)/ AT BREAK ((c-a)/a)
F						
G						
H						
I						
J						
SPECIFICATION REQUIREMENTS	119	FTB				AT YIELD - 10 % MIN AT BREAK - 50 % MIN

PASS/FAIL: _____

REMARKS:_____

REVIEWED BY_____ DATE_____

(CIRCLE MACHINE USED)

TMI TENSIOMETER CALIBRATION: SERIAL #: 124 CALIBRATION DATE: 4/1/96 RECALIBRATION DATE: 4/1/97

NSC TENSIOMETER CALIBRATION: SERIAL #'S: 93021/91001 CALIBRATION DATE: 10/14/96 RECALIBRATION DATE:10/14/97

NCR REFERENCE NUMBER (IF REQUIRED)_____

GEOMEMBRANE EXT SION TRIAL SEAM LOG

PROJECT NUMBER:
OWNER:
LOCATION:
INSTALLER:

DATE: _____

SHEET NUMBER: ____of____

TRIAL SEAM NUMBER (TSX-#)	TIME WELDED	AMBIENT TEMPERATURE (F)	TECH ID	MACHINE NUMBER (MX-#)	CQA MON ID	TEMPERATURE SETTINGS		PEEL TEST RESULTS			SHEAR TEST RESULTS			PASS/FAIL	REMARKS
						PRE-HEAT SETTING	BARREL TEMP. (F)	SAMPLE	STRENGTH (lbs/in)	BREAK TYPE	SAMPLE	STRENGTH (lbs/in)	BREAK TYPE		
								A			D				
								B			E				
								C							
								A			D				
								B			E				
								C							
								A			D				
								B			E				
								C							
								A			D				
								B			E				
								C							
								A			D				
								B			E				
								C							
								A			D				
								B			E				
								C							
SPECIFICATION REQUIREMENTS : 60 mil GEOMEMBRANE								PEEL		FTB	SHEAR		FTB		

(CIRCLE MACHINE USED)

TMI TENSIOMETER CALIBRATION: SERIAL #: 124 CALIBRATION DATE: 4/1/96 RECALIBRATION DATE: 4/1/97

NSC TENSIOMETER CALIBRATION: SERIAL #'S:93021/91001 CALIBRATION DATE: 10/14/96 RECALIBRATION DATE: 10/14/97

NCR REFERENCE NUMBER (IF REQUIRED)_____

REVIEWED BY_____ **DATE**_____

GEOMEMBRANE S[illegible]I VACUUM TEST LOG

PROJECT NUMBER:
OWNER:
LOCATION:
INSTALLER:

CQA MONITOR: _____
VACUUM BOX NUMBER_____

SHEET ____ **OF** ____

SEAMS								REPAIRS					
SEAM NUMBER*	SEAM SECTION ** FROM TO	TEST DATE	TECH ID	DEFECTS***	SEAM COMPLETE NO YES	OBS TEST	REMARKS	DEFECT CODE	TEST DATE	TECH ID	DEFECTS***	OBS TEST	REMARKS
/	-				/								
/	-				/								
/	-				/								
/	-				/								
/	-				/								
/	-				/								
/	-				/								
/	-				/								
/	-				/								
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/	-				/								
/	-				/								
/	-				/								
/	-												
/	-				/								
/	-				/								
/	-				/								

* Indicate seam number by two adjacent panel numbers, with the lowest panel number indicated first and proper layer (i.e., Tertiary, Secondary Primary).
** Reference seam endpoints from an End of Seam (EOS), a repair number or a point location on the seam (i.e., Reference point, distance from reference point).
*** Record quantity of leaks detected and reference new defect code in remarks column.

REVIEWED BY_____ **DATE**_____

NCR REFERENCE NUMBER (IF REQUIRED)_____

GEOMEMBRANE SE . PRESSURE TEST LOG

PROJECT NUMBER:
OWNER:
LOCATION:

INSTALLER:

DATE: _____

MACHINE NUMBER: _____ **CQA MONITOR:** _____ **SHEET NUMBER:** _____of_____

SEAM NUMBER*	SEAM SECTION** FROM	TO	TECH ID	START TIME	FINISH TIME	INITIAL PRESSURE	FINAL PRESSURE	PRESSURE DIFFERENCE	PASS/FAIL	OBS TEST Y/N	ENTIRE SEAM COMPLETE NO	YES	REMARKS
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												
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/	-												
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												
/	-												

* Indicate seam number by two adjacent panel numbers, with the lowest panel number indicated first.
** Reference seam endpoints from an End of Seam (EOS), a defect repair number or a point location on the seam (reference point, distance from reference point).

REVIEWED BY_____ DATE_____

NCR REFERENCE NUMBER (IF REQUIRED)_____

LETTER OF ACCEPTANCE
OF SOIL SUBGRADE SURFACE

PROJECT NUMBER:
OWNER:
LOCATION:
INSTALLER:

	Check Applicable
Pond 4	_____
Repository	_____

I, the Undersigned, the duly authorized representative of __TerraMatrix Inc. (TMI)__, have visually observed the soil subgrade surface within the area described below, and found that: 1.) all stones, rocks, debris, trash, roots, branches, and foreign matter, as well as pockets of soft or loose soil, and stones and rocks larger than ½ inch, have been removed from the surface; 2.) the surface is smooth and free of irregularities, sharp objects and abrupt changes in grade; and, 3.) the surface has been smooth-drum rolled.

This is a general acceptance for the area described below. The area of deployment for any given day will be reinspected by TerraMatrix to ensure that the subgrade surface continues to meet the above described criteria. The final inspection will be recorded in the TerraMatrix daily logs.

Area that has been observed is outlined on the attached drawing and is identified by:

_____

_____

_____

TMI REPRESENTATIVE

NAME	SIGNATURE	TITLE	DATE

LETTER RECEIVED BY

NAME	SIGNATURE	TITLE	DATE

NCR REFERENCE NUMBER (IF REQUIRED)_____

File: P:\SHELLY\FIELDFRM\SURFACCP.FRM
Printed: December 9, 1997 (10:07am)

Appendix

C

NEW MEXICO ENVIRONMENTAL DEPARTMENT
RCRA PART B PERMIT APPLICATION

SPECIFICATIONS FOR LANDFILL, SURFACE IMPOUNDMENT AND ASSOCIATED FACILITIES LINER AND COVER SYSTEM CONSTRUCTION

FINAL

TRIASSIC PARK HAZARDOUS WASTE FACILITY
CHAVES COUNTY, NEW MEXICO

EPA IDENTIFICATION NUMBER NM0001002484

December 1997

PATRICK G. CORSER
NEW MEXICO
12236
REGISTERED PROFESSIONAL ENGINEER

Patrick Corser, P.E., New Mexico Registration 12236

NOTE:	This document contains construction specifications for various elements of the Triassic Park Hazardous Waste Facility landfill, landfill cover, surface impoundment, and Associated Facilities. Modifications to the plan may be required prior to construction. Any revisions required will be submitted to NMED for approval prior to construction.

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SECTION 01010
GENERAL REQUIREMENTS

PART 1 GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary to construct the landfill or surface impoundment liner or cover systems at the Triassic Park hazardous waste treatment, storage, and disposal facility (TSDF) in Chaves County, New Mexico.

B. The work shall include those items identified in the Contract Documents which may include site preparation and earthwork, clay liner construction, geosynthetic clay liner installation, geomembrane liner/cover installation, drainage layer and drainage pipe installation, protective soil layer placement, quality control, surveying, and related work.

1.02 DEFINITIONS

A. The following list of definitions is provided for reference.

1. *Atterberg Limits*: The liquid limit, plastic limit, and shrinkage limit for soils as defined by (ASTM D 4318).

2. *NMED*: New Mexico Environmental Department (NMED)

3. *NMED and RCRA Part B Permit (Part B Permit):* New Mexico Environmental Department and Resource Conservation and Recovery Act (RCRA) Part B Permit for the Triassic Park Facility.

4. *Compaction*: The process of increasing the unit weight of soil by rolling, tamping, vibrating, or other mechanical means. As a result of compaction, the hydraulic conductivity of the soil may be decreased.

5. *Construction Drawings*: Design plans used to construct a facility; the plans must be signed and sealed by a Professional Engineer registered in the State of New Mexico.

6. *Construction Quality Assurance (CQA)*: A planned and systematic pattern of all means and actions designed to provide adequate confidence that items or services meet contractual and regulatory requirements.

7. *CQA Engineer*: The individual, firm or corporation, independent from the Owner, Contractor, Supplier, or Manufacturer, that is responsible

for observing, testing, and documenting construction activities under the terms of the contract. Provided that the Design Engineer and the Owner are not the same party, the CQA Engineer may be the same as the Design Engineer. The CQA Engineer will provide a Construction Quality Assurance Resident Engineer (CQA Resident Engineer). The CQA Engineer is responsible for certification of landfill construction according to the specifications contained herein and will be a Professional Engineer registered in the State of New Mexico.

8. *CQA Plan*: Site-specific document which addresses the following: (i) CQA personnel responsibilities, authorities, and qualifications; (ii) inspection, monitoring, and testing activities necessary to ensure that the facility is constructed to meet or exceed design criteria, plans, and specifications; and (iii) CQA documentation requirements.

9. *Contract Documents*: The contract documents for construction of the landfill or surface impoundment including the General Specifications, the Construction Drawings, the CQA Plan, any supplemental requirements, and the General Agreement.

10. *Contractor*: The individual, firm, or corporation undertaking the execution of the work under the terms of the contract.

11. *Design Engineer*: The individual, firm or corporation having direct responsibility for the design of the landfill or surface impoundment structure. The Design Engineer must provide a Professional Engineer registered in the State of New Mexico. The Design Engineer may be the same as the Owner.

12. *Dewatering:* Process of lowering ground water level(s) or removing storm water to permit construction activities to be made "in the dry" (not drying of fill material).

13. *General Specifications*: Specifications written which apply to the construction of all landfills and surface impoundments.

14. *Geocomposite:* A planar, polymeric drainage material consisting of a polyethylene geonet core and geotextile filter layers that have been heat-bonded to the top and bottom surfaces of the geonet.

15. *Geomembrane:* A nonporous polymeric membrane liner or barrier used in civil engineering projects.

16. *Geonet*: A net consisting of two sets of transverse polymeric strands which create high in-plane flow capacity; used as a drainage medium in civil engineering projects.

17. *Geosynthetics*: Polymeric materials used to perform various functions in construction projects (i.e., geomembranes, geonets, geocomposites, geotextiles, etc.).

18. *Geosynthetic Clay Liner (GCL)*: A factory manufactured, hydraulic barrier typically consisting of bentonite clay or other very low permeability material, supported by geotextiles and/or geomembranes which are held together by needling, stitching, or chemical adhesives.

19. *Geotextile:* A permeable textile material used with foundation, soil, rock, earth, or any other geotechnical engineering-related material that is an integral part of a man-made project, structure, or system.

20. *Gandy-Marley, Inc.*: owner and operator of the hazardous waste treatment, storage, and disposal facility under construction; referred to as the Owner.

21. *Hydraulic Conductivity*: The rate at which a fluid flows through a porous medium. It is a function of the physical characteristics of both the porous medium and the fluid.

22. *In-situ*: "As is", or as it exists in place naturally.

23. *Laboratory:* The individual, firm, or corporation, independent from the Owner, Manufacturer, Supplier, or Contractor, responsible for conducting tests on construction materials to assure conformance with the General Specifications.

24. *Leachate Collection System*: The drainage layer above the primary composite liner of the landfill and associated piping, risers, etc. that enable collection and removal of leachate from the landfill.

25. *Leak Detection System*: The drainage layer sandwiched between the primary and secondary liners of the landfill or surface impoundment and associated piping, risers, etc., that enable detection, collection, and removal of leachate, if any, that leaks through the primary liner.

26. *Liner System*: The system of natural and synthetic liners and drainage layers beneath the landfill or surface impoundment, used to contain leachate while allowing its collection and removal.

27. *Manufacturer*: The individual, firm, or corporation responsible for manufacturing a specific component (e.g., a geomembrane liner) used in surface impoundment or landfill construction.

28. *Moisture Content*: Ratio of quantity of water in the soil (by weight) to the weight of the soil solids (dry soil), expressed in percentage; also referred to as water content.

29. *Optimum Moisture Content (OMC)*: Moisture content corresponding to maximum dry unit weight as determined in the standard Proctor or modified Proctor compaction test (i.e., ASTM D 698 or D 1557).

30. *Owner:* The party known as Gandy-Marley, Inc., a New Mexico Corporation, and the operator of the hazardous waste treatment storage and disposal facility under construction. The Owner shall hire the Contractor(s) to execute the work under the terms of the General Agreement. The activities of the Owner in the General Specifications, any supplemental requirements, and CQA Plan may be performed by the Owner or other party representing the Owner such as, but not limited to, a representative of Triassic Park Hazardous Waste Facility, the Design Engineer, or CQA Engineer.

31. *Particle-Size Distribution*: Distribution of particle sizes within a soil; determined using ASTM D 422.

32. *Permanent Sump*: The drainage layer beneath the sump area of the secondary liner of the landfill that enables the detection, collection, and removal of leachate if any, that leaks through the secondary liner in that area.

33. *Permeability*: Ability of pore fluid to travel through a soil mass via interconnected voids. "High" permeability indicates relatively rapid flow, and vice versa. Rates of permeability are generally reported in centimeters per second.

34. *Plasticity*: Ability of soil mass to flow or be remolded without raveling or breaking apart. Generally that range of soil water content between the liquid and plastic limit.

35. *Primary Composite Liner*: Top composite liner in a double-liner system consisting of two or more low-permeability components of different materials in contact with each other.

36. *Primary Geomembrane Liner*: Top geomembrane liner in a double-liner system.

37. *Primary Soil Liner*: Top soil liner in a double-liner system.

38. *RCRA*: Resource Conservation and Recovery Act; Federal hazardous waste regulations.

39. *Secondary Composite Liner*: Bottom composite liner in a double-liner system consisting of two or more low-permeability components of different materials in contact with each other.

40. *Secondary Geomembrane Liner*: Bottom geomembrane liner in a double-liner system.

41. *Secondary Soil Liner*: Bottom soil liner in a double-liner system.

42. *Secondary Structure*: The macrostructure of a geologic stratum. Structural features in a soil or rock deposit which can be seen with little or no magnification, to include, but not be limited to, pockets, lenses, layers, seams, or partings of varying soil types, slickensided fissures, laminated structure, bedding planes, and/or mineral concretions or staining.

43. *Landfill Phase*: A discrete landfill cell designed and constructed to store industrial and/or hazardous wastes in an environmentally safe manner and in accordance with Federal, State, and local regulations.

44. *Sieve (200 Mesh)*: Refers to the soil particle size that passes (smaller than or equal to) the U.S. Sieve No. 200 (ASTM Specification E-11) which has a 75 micrometer (0.00295 inch) opening.

45. *Specifications*: Detailed descriptions of requirements, dimensions, materials, construction methods, etc., necessary for the construction of a landfill or surface impoundment.

46. *Subcontractor:* The individual, firm, or corporation that contracts to perform some service or provide some material necessary for the performance of another's contract.

47. *Supplier:* The individual, firm, or corporation responsible for supplying a contractor or a manufacturer with a specific material (e.g., gravel, granular material, resin, etc.) required for construction of a manufactured product or for the construction of the landfill or surface impoundment.

48. *Surface Impoundment:* A discrete impoundment designed and constructed to hold an accumulation of potentially contaminated rainwater and runoff from processing, hauling, or waste handling operations or designed and operated to contain hazardous waste during treatment of the waste.

49. *TSDF*: treatment, storage, and disposal facility.

50. *Unified Soil Classification System*: Soil classification system in accordance with ASTM D 2487.

51. *Unit Weight*: Weight of soil per unit volume; usually reported in pounds per cubic foot.

52. *"Walking Out"*: Continually rising effect experienced by a sheepsfoot roller during compaction of soil; an indication that the soil is approaching the proper degree of compaction.

PART 2: CONTRACT DOCUMENTS

2.01 INCLUDED DOCUMENTS

A. The Contract Documents for construction of the landfill or surface impoundment shall include, as applicable: (i) General Specifications, (ii) Supplemental Specifications; (iii) CQA Plan; (iv) Construction Drawings; and (v) General Agreement.

2.02 GENERAL SPECIFICATIONS

A. The landfill or surface impoundment shall be constructed in accordance with these General Specifications and other applicable Contract Documents.

2.03 SUPPLEMENTAL SPECIFICATION

A. The supplemental specifications provide additional requirements for construction of a specific landfill liner or cover or surface impoundment that relate to construction contractual considerations, and are not permit-related.

2.04 CQA PLAN

A. The materials, procedures, and test methods and frequencies used in the construction quality assurance of the landfill or surface impoundment construction shall conform to the requirements of the CQA Plan.

2.05 CONSTRUCTION DRAWINGS

A. The landfill or surface impoundment shall be constructed not only in accordance with the General Specifications but also in accordance with the Construction Drawings for the specific structure.

2.06 GENERAL AGREEMENT

A. The contractual agreement, and all terms and conditions thereof, between the Owner and the Contractor.

PART 3: PROJECT ORGANIZATION AND CONTROL

3.01 ORGANIZATION CHART

A. The project organization chart for the parties involved in construction of the landfill and surface impoundment is provided in Figure 01010-1.

3.02 RESPONSIBILITIES OF PARTIES

A. *Owner:* The Owner is the facility manager, responsible for facility administration, regulatory oversight, health and safety, accounting, purchasing, etc. The Owner has direct authority over the Contractor, CQA Engineer, and Design Engineer and coordinates activities by these parties.

B. *Contractor:* The Contractor is responsible for constructing various elements of the facility in accordance with the General Specifications, other applicable contract documents, Construction Drawings and CQA Plan. The Contractor may be responsible for earthwork, geosynthetics, and other components of landfill or surface impoundment construction. The contracting and administration of contract requirements for landfill or surface impoundment construction shall be the responsibility of the Owner. Different contractors may be used to construct different components of the landfill or surface impoundment.

C. *CQA Engineer*: The CQA Engineer is responsible for monitoring construction activities on-site and certifying that the facility is constructed in accordance with the plans and specifications. The CQA Engineer provides information, reports, test results, and observations to the Owner. The CQA Engineer may communicate directly with the Contractor and Design Engineer to coordinate activities and receive information. The CQA Engineer provides an on-site CQA Resident Engineer.

D. *Design Engineer:* The Design Engineer is responsible for the design of the landfill or surface impoundment. The Design Engineer reports to the Owner. The Design Engineer may communicate directly with the Contractor and CQA Engineer.

PART 4: SEQUENCE OF CONSTRUCTION

4.01 OVERALL SEQUENCE

A. The overall sequence of construction for a specific facility element shall be as described in the Construction Drawings for the specific structure and in accordance with the Contract Documents.

PART 5: REFERENCE STANDARDS

5.01 APPLICABLE ORGANIZATIONS

A. Organizations whose standards are referenced herein are as follows:

1. ASTM - American Society for Testing and Materials

2. New Mexico State Highway and Transportation Department (Standard Specifications for Highway and Bridge Construction)

3. GRI - Geosynthetics Research Institute

4. OSHA - Occupational Safety and Health Administration

5. USEPA - United States Environmental Protection Agency

5.02 APPLICABLE STANDARDS

A. Any reference to standards of any society, institute, association, or government agency shall be the edition in effect as of the date of the contract, unless stated otherwise.

5.03 SPECIFIC STANDARDS

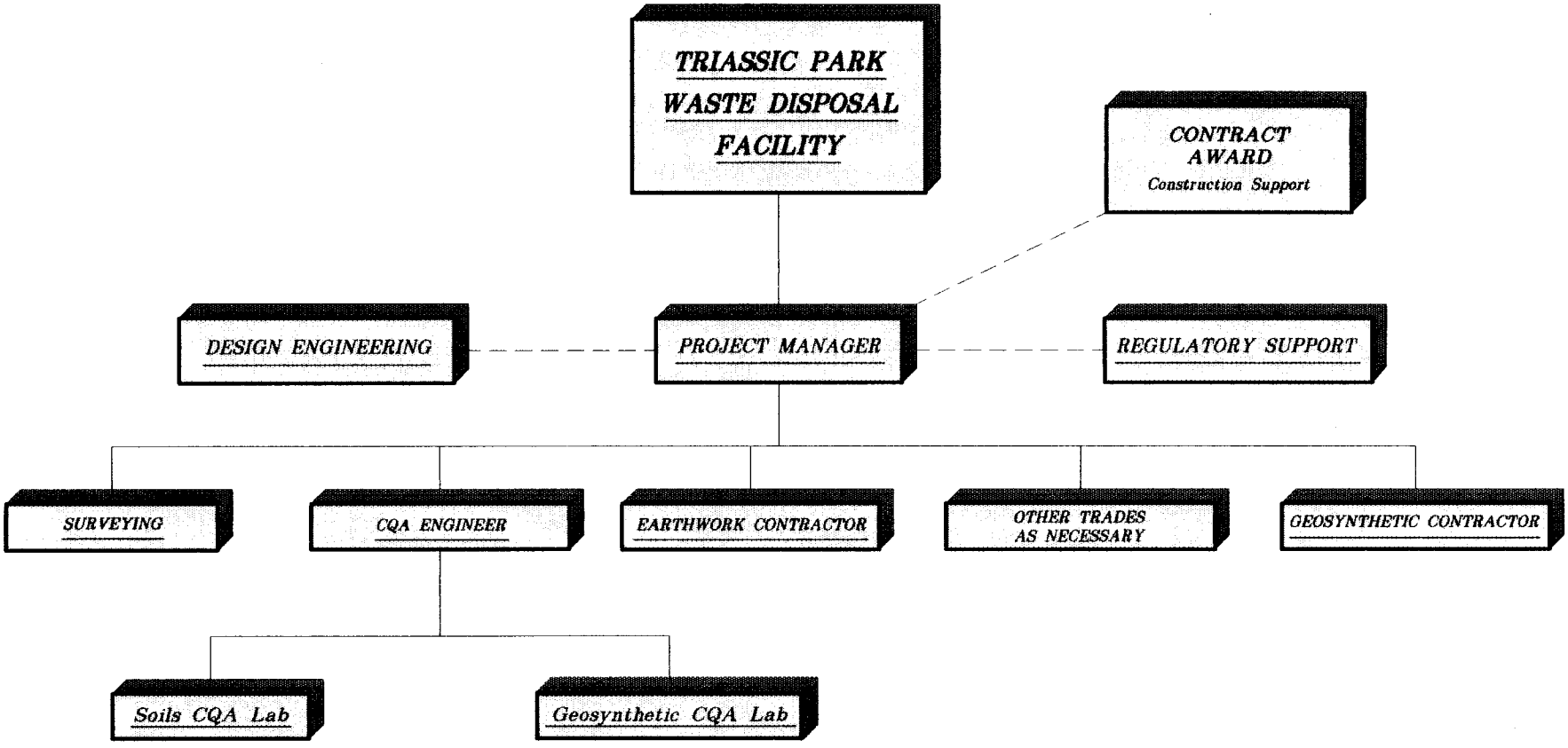
A. Specific test standards cited in the General Specifications are given in Table 01010-1.

PART 6: GENERAL REQUIREMENTS

A. *Reference Points*: Construction reference monuments and benchmarks have been established by the Owner for use in controlling the construction work. All work shall be constructed based on and in relation to these reference points. The Contractor shall be responsible for re-establishing any reference points disturbed during construction. Disturbed or destroyed points shall be re-established at the Contractor's expense, as directed by the Owner.

B. *Soils Investigation*: Site soil investigations will be performed by the Owner. Soil investigation reports will be available for the Contractor's use. The Contractor shall not assume that information within these reports accurately reflects the soil conditions at all locations within the project area, but that they only depict soil conditions at specific points where samples were taken.

C. *Surveying:* The Contractor shall perform all surveying required to lay out and control the work. Surveying shall be conducted such that all applicable standards required by the State of New Mexico are followed. Required Record Drawings shall be as specified in these General Specifications. All surveying shall be performed under the direction of a surveyor licensed to perform such work in the State of New Mexico. All Record Drawings shall be signed and sealed by the licensed surveyor who directed the survey work. Record drawings shall be at a scale not smaller than 1 inch = 50 feet. The required surveying of liner system elevations shall be carried out on a grid; approximately 50-foot square on slopes of 25 percent or less and 100-foot square on slopes greater than 25 percent. The survey locations shall be close enough to define the following features in the landfill or surface impoundment: toe of slope, crest of slope, anchor trench, leachate collection sump, leak detection sump, permanent sump, and perimeter drainage ditch. All surveys shall be referenced to the Owner's site coordinate grid system.



REV No	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND SIGNED BY
0	Part B Permit	11/12/97	J Pellicer	J Bever	J Pellicer

TerraMatrix
MONTGOMERY WATSON
Mining Group

PROJECT No: 602-0200
AutoCAD FILE: TPORG.DWG
SCALE: Not to Scale
FIGURE No: 01010-1

Triassic Park Waste Disposal Facility

TYPICAL PROJECT ORGANIZATION

D. *Construction Tolerances:* Unless otherwise stated herein and where practical, construction tolerances shall be " 0.2 feet horizontally, and, provided that minimum thickness requirements are met, " 0.1 feet vertically. All surfaces shall be reasonably free from irregularities with slopes or grades within " 10 percent of their nominal values. All liner and cover surfaces shall be free-draining with no standing water except at low points designated on the Construction Drawings.

E. *Permits:* The Contractor shall not be required to obtain any environmental or general construction permits applying to the general design of the facility. The Contractor shall be required to obtain permits, such as over-size haul permits, related to specific construction equipment or techniques he intends to employ to accomplish the work.

F. *Sedimentation, Erosion Control, and Dewatering*: Contractor shall comply with all requirements of the New Mexico State Highway and Transportation Department Standard Specifications for Highway and Bridge Construction for controlling erosion, water pollution, and dust emissions resulting from construction activities; the Contractor shall be responsible for any fines imposed due to noncompliance. Within the disturbed areas in which the Contractor is working, the Contractor shall seal-roll disturbed surfaces when required and maintain temporary grades and ditches to promote water drainage and prevent infiltration. The Contractor shall provide all equipment necessary to dewater excavations within 12 hours after a storm event.

G. *Work Limits*: All clearing, stripping, excavation, backfill and surfacing shall be done to the lines, grades, and dimensions called for on the Construction Drawings and General Specifications unless directed otherwise by the Owner. All work done beyond designated limits without prior approval shall be corrected to the Owner's satisfaction, at no additional cost to the Owner.

H. *Protection of Existing Services and Wells*: The Contractor shall exercise care to avoid disturbing or damaging existing monitor wells, electrical poles and lines, permanent below-ground utilities, permanent drainage structures, temporary utilities and structures, or items which the Owner has marked with red flagging. If the Contractor encounters any unexpected underground utilities during the course of the work, the Contractor shall immediately inform the Owner who will determine whether or not the utility is active. When the work requires the Contractor to be near or cross known utilities, the Contractor shall carefully uncover, support and protect these utilities and shall not cut, damage, or otherwise disturb them without prior authorization from the Owner. All utilities, wells, or other items damaged by the Contractor shall be immediately repaired or replaced by the Contractor to the satisfaction of the Owner at no additional cost to the Owner.

I. *Explosives*: The use of explosives for demolition or excavation is not expected to be required and will not be permitted without prior written approval of the Owner.

J. *Burning*: The use of open fires on site for any reason is prohibited.

K. *Temporary Roads*: The Contractor shall be responsible for constructing and maintaining all temporary roads and laydown areas which the Contractor may require in the execution of his work.

L. *Construction Water*: The quality of construction water used to accomplish construction work is crucial due to the nature of the facilities being constructed. The Owner will provide water for construction and dust control and will specify the source and periodically obtain water quality samples. The Contractor shall not add substances to construction water without the express written consent of the Owner. The Contractor shall utilize measuring devices that allow him to measure and record the volume of water used. Such usage records shall be maintained by the Contractor and provided to the Owner.

M. *Cooperation*: The Contractor shall cooperate with all other parties engaged in project-related activities to the greatest extent possible. Disputes or problems shall be referred to the Owner for resolution.

N. *Familiarization*: The Contractor is responsible for becoming familiar with all aspects of work prior to performing the work.

O. *Safeguards*: The Contractor shall provide and use all personnel safety equipment, barricades, guardrails, signs, lights, flares, and flagmen as required by OSHA, state, or local codes and ordinances. No excavations deeper than 4 feet with side slopes steeper than 2:1 (horizontal:vertical) shall be made without the prior approval of the Owner. When shoring is required, the design and inspection of such shoring shall be the Contractor's responsibility and subject to the review of the Owner prior to use. No personnel shall work within or next to an excavation requiring shoring until such shoring has been installed, inspected, and approved by an Engineer registered in the State of New Mexico provided by the Contractor. The Contractor shall be responsible for any fines imposed due to violation of any laws and regulations relating to the safety of the Contractor's personnel.

P *Construction Access Plan*: Prior to mobilization to the site, the Contractor shall submit a plan to the Owner showing where he intends to place staging areas, stockpile areas, temporary on-site access roads, temporary erosion control structures, etc. This plan must be approved by the Owner prior to mobilization.

Q. *Clean-up*: The Contractor shall be responsible for general house-keeping during construction. Upon completion of work, the Contractor shall remove all of his equipment, facilities, construction materials, and trash. All disturbed areas shall be revegetated or otherwise put into a condition satisfactory to the Owner. Revegetation shall be carried out in accordance with the requirements in Section 02900.

R. *Security*: The Contractor is responsible for the safety and condition of all of his tools and equipment. The Owner will not be responsible for lost or stolen materials or equipment.

S. *Acceptance of Work*: Except as otherwise provided within the General Conditions, the Contractor shall retain ownership and responsibility for all work until accepted by Owner. The Owner will accept ownership and responsibility for the liner system: (i) when all work is completed; (ii) after the Contractor has submitted all required documentation, including manufacturing quality control documentation, manufacturing certifications, and Record Drawings signed and sealed by a Professional Land Surveyor licensed in the State of New Mexico (if required by Owner); and (iii) after the CQA Engineer has submitted the Final CQA Report which certifies that the liner has been constructed in accordance with the Construction Drawings and these Specifications and Record Drawings signed and sealed by a Professional Engineer registered in the State of New Mexico.

T. *Health and Safety Training*: The Contractor shall provide necessary health and safety training for all of the Contractor's on-site personnel in accordance with the Site Health and Safety Plan. The Owner may require evidence of health and safety training at any time for any of the Contractor's personnel working on site.

U. *Exclusion Areas*: The Contractor's personnel shall not enter any areas on-site identified with signs as exclusion areas without approval of the Owner, and without proper personal protective equipment. The Contractor shall confine activities to the work limits shown on the Construction Drawings.

V. *Hazardous Waste Management Operations*: The Contractor shall not enter areas where active hazardous waste management operations are being performed.

W. *CQA Activities*: The Owner will utilize an independent CQA Engineer to perform CQA activities. The Contractor shall be aware of all CQA activities and shall allow sufficient time in his construction schedule to accommodate CQA activities. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of CQA activities.

X. All quality control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

TABLE 01010-1
TEST METHODS CITED IN GENERAL SPECIFICATIONS AND CQA PLAN

AMERICAN SOCIETY OF TESTING AND MATERIALS	
1. ASTM A 307	Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength.
2. ASTM A 726	Standard Specification for Cold-Rolled Carbon Steel Sheet, Magnetic Laminated Quality, Types 1, 2, and 2S.
3. ASTM C 88	Soundness of Aggregate by use of Sodium Sulfate or Magnesium Sulfate
4. ASTM C 131	Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
5. ASTM C 535	Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
6. ASTM D 422	Standard Method for Particle-Size Analysis of Soils.
7. ASTM D 570	Standard Test Method for Water Absorption of Plastics.
8. ASTM D 638	Standard Test Method for Tensile Properties of Plastics.
9. ASTM D 698	Standard Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop.
10. ASTM D 746	Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact.
11. ASTM D 751	Standard Methods of Testing Coated Fabrics.
12. ASTM D 792	Standard Test Methods for Specific Gravity (Relative Density) and Density of Plastics by Displacement.
13. ASTM D 882	Standard Test Methods for Tensile Properties of Thin Plastic Sheeting.
14. ASTM D 1004	Standard Test Method of Initial Tear Resistance of Plastic Film and Sheeting.
15. ASTM D 1204	Standard Plastics Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature.
16. ASTM D 1238	Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.
17. ASTM D 1248	Standard Specification for Polyethylene Plastic Molding and Extrusion Metals.
18. ASTM D 1505	Standard Test Methods for Density of Plastics by Density-Gradient Technique.
19. ASTM D 1556	Standard Test Method for Density of Soil In Place by the Sand-Cone Method.
20. ASTM D 1593	Standard Specification for Nonrigid Vinyl Chloride Plastic Sheeting.
21. ASTM D 1603	Standard Test Method for Carbon Black in Olefin Plastics.
22. ASTM D 2167	Standard Test Method for Density and Unit Weight of Soils in Place by the Rubber Balloon Method.
23. ASTM D 2216 or D 4643	Standard Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures.
24. ASTM D 2434	Standard Test Method for Permeability of Granular Soils (Constant Head).
25. ASTM D 2487	Standard Test Method for Classification of Soils for Engineering Purposes.
26. ASTM D 2657	Standard Practice for Heat-Joining for Polyolefin Pipe and Fittings.
27. ASTM D 2663	Carbon-Black Dispersion in Rubber.
28. ASTM D 2837	Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials.
29. ASTM D 2922	Standard Test Method for Density of Soil and Soil-Aggregate In Place by Nuclear Methods (Shallow Depth).
30. ASTM D 3015	Recommended Practice for Microscopical Examination of Pigment Dispersion in Plastic Compounds.
31. ASTM D 3017	Standard Test Method for Moisture Content of Soil and Rock In Place by Nuclear Methods (Shallow Depth).
32. ASTM D 3083	Standard Specification for Flexible Poly (Vinyl Chloride) Plastic Sheeting for Pond, Canal, and Reservoir Lining.
33. ASTM D 3350	Standard Specifications for Polyethylene Plastic Pipe and Fittings Materials.
34. ASTM D 3776	Mass Per Unit Area (Weight) of Woven Fabric.
35. ASTM D 4253	Standard Test Method for Maximum Index Density of Soils Using a Vibratory Table

TABLE 01010-1
TEST METHODS CITED IN GENERAL SPECIFICATIONS AND CQA PLAN

36. ASTM D 4254	Standard Test Method for Minimum Index Density of Soils and Calculations of Relative Density.
37. ASTM D 4318	Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
38. ASTM D 4373	Standard Test Method for Calcium Carbonate Content of Soils.
39. ASTM D 4437	Standard Test Methods for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Geomembranes.
40. ASTM D 4491	Standard Test Method for Water Permeability of Geotextiles by the Permittivity Method.
41. ASTM D 4533	Standard Test Method for Trapezoid Tearing Strength of Geotextiles.
42. ASTM D 4632	Standard Test Method for Breaking Load and Elongation of Geotextiles (Grab Elongation Method and Peel Strength).
43. ASTM D 4643	Determination of Water (Moisture) Content of Soil by the Microwave Oven Method
44. ASTM D 4716	Standard Test Method for Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products.
45. ASTM D 4751	Standard Test Method for Determining Apparent Opening Size of a Geotextile.
46. ASTM D 4716	Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
47. ASTM D 4833	Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.
48. ASTM D 5261	Measuring mass per unit area of geotextile.
49. ASTM D 5321	Coefficient of soil and geosynthetics or geosynthetics and geosynthetics friction by direct shear.
50. ASTM D 5890	Standard Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners
51. ASTM D 5891	Standard Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners
52. ASTM E 11	Specification for Wire-Cloth Sieves for Testing Purposes.
53. ASTM F 714	Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter.
54. ASTM C 31	Making and Curing Concrete Test Specimen in the Field.
55. ASTM C 39	Compressive Strength of Cylindrical Concrete Specimens.
56. ASTM C 143	Test Method for Slump of Hydraulic Cement Concrete.
57. ASTM C 173	Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method.
58. ASTM C 231	Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY	
1. USEPA Method 9090	Compatibility Test for Wastes and Membrane Liners.

[END OF SECTION]

SECTION 02110
SITE PREPARATION AND EARTHWORK

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary to perform all site preparation, excavation, backfilling, and grading required to construct the landfill or surface impoundment. The work shall be carried out in accordance with this General Specification, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02119 - Prepared Subgrade
B. Section 02221 - Clay Liner

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The Contractor shall be aware of all testing activities outlined in the CQA Plan and shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. Soil testing (both field and laboratory testing) required by the CQA Plan will be the responsibility of the CQA Engineer. All Quality Control testing required by the General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor. The Contractor shall cooperate with the CQA Engineer during all testing activities. The Contractor shall provide equipment and labor to assist the CQA Engineer in sampling and shall provide access to all areas requiring testing. The Contractor shall repair any damage to finished work caused by the CQA Engineer's sampling or testing activities, except when specifically not required by the General Specifications.

D. The CQA Engineer will coordinate independent surveying required by the CQA Plan. Surveying by the CQA Engineer does not relieve the Contractor of his responsibility to lay out, control, and document the work.

E. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at no cost to the Owner until acceptable test results are obtained.

PART 2: PRODUCTS

2.01 MATERIALS

A. Fill materials shall be obtained from the excavation of the landfill or surface impoundment, from the excavation of diversion ditches, or from borrow sources identified by the Owner.

B. Soil shall be classified as one of the following: (i) structural fill; (ii) clay liner material; (iii) topsoil; (iv) protective soil layer material; (v) cover soil; (vi) vegetative cover; (vii) pipe bedding; (viii) subbase; or (ix) spoil.

1. Soil that is classified according to the Unified Soil Classification System (USCS) as SM, CL, ML, SC or GM or GC (ASTM D 2487) and has a maximum particle size of 4 inches; or other material approved by the Owner, may be used as structural fill. Structural fill shall be placed at the locations shown on the Construction Drawings and in all areas requiring fill that are within 50 feet of the landfill or surface impoundment liner system. Beyond the 50 foot requirement structural fill material characteristics may be modified with the approval of the Owner.

2. Soil that meets the requirements of Section 02221 of these General Specifications may be used as clay liner material.

3. Soil classified as topsoil may be used for revegetation of disturbed areas or for other purposes shown on the Construction Drawings. All revegetation activities shall be carried out in accordance with this Section and Section 02900.

4. Soil that meets the requirements of Section 02716 of these General Specifications may be used as protective soil layer material.

5. Soil that meets the requirements of Section 02226 of these General Specifications may be used a cover soil.

6. Soil that meets the requirements of Section 02227 of these General Specifications may be used as vegetative cover material.

7. Soil that meets the requirements of Section 02228 of these General Specifications may be used as pipe bedding.

8. Soil that meets the requirements of Section 02230 of these General Specifications may be used as subbase.

9. Soil not classified as structural fill, clay liner material, protective soil layer material, cover soil, vegetative cover, or topsoil shall be classified as spoil material. Spoil may be used for purposes specified in the Construction Drawings or by the Owner, or it may be disposed of on site in a manner approved by the Owner.

PART 3: EXECUTION

3.01 SITE PREPARATION

A. The Contractor shall develop access to the construction area in accordance with the requirements of the Construction Drawings.

B. The Contractor shall install silt fences immediately down-slope of each area to be disturbed prior to the beginning of work in that area. The Contractor shall maintain the silt fences for the duration of construction. Accumulated sediment behind the silt fences shall be disposed of on-site by the Contractor in a manner approved by the Owner. The area around the top of landfills and surface impoundments shall be graded to direct surface water away from the structure, wherever possible.

C. All brush, vegetation, rubbish, and other objectionable material shall be removed from the construction area and disposed of in an area designated by the Owner.

D. All topsoil shall be removed from the construction area and stockpiled in areas designated by the Owner for subsequent use on site.

E. A 30-foot wide work area shall be maintained clear of objectionable materials around the edge of the landfill or surface impoundment construction area.

F. Diversion ditches, either permanent or temporary, shall be constructed in accordance with the Construction Drawings or as approved by the Owner. The Contractor shall be responsible for constructing diversion ditches as required to divert run-on around the construction area. The construction of temporary ditches not shown on the Construction Drawings shall not be undertaken until the Contractor's plan for constructing the ditches is approved by the Owner.

G. Temporary access roads to the construction area shall be constructed in accordance with the Construction Drawings or as approved by the Owner.

3.02 STOCKPILING

A. Prior to the start of excavation and if required by the Owner, the Contractor shall prepare a written excavation plan. The plan shall indicate the areas and sequence of excavation, and the anticipated classification of the excavated material (e.g., structural fill, clay liner material). This excavation plan must be reviewed and approved by the Owner. The Contractor shall take into account that the stockpiling portion of the excavation plan may be modified during construction based on the results of any conformance testing of the excavated material required by the CQA Plan.

B. Excavated fill materials (i.e., clay liner, cover soil, etc.) shall be stockpiled in designated areas free of incompatible soil, clearing debris, or other objectionable materials. Stockpile areas will be shown on the Construction Drawings or designated by the Owner.

C. Excavated material classified as spoil shall be segregated from fill and stockpiled or disposed of in the manner shown on the Construction Drawings or as specified by the Owner.

D. The CQA Engineer shall assist in the determination of what excavation material is select fill or spoil material.

E. Stockpiles of fill or spoil shall be no steeper than 3:1 (horizontal:vertical) or other slope approved by the Owner, graded to drain, sealed by tracking parallel to the slope with a dozer or other means approved by the Owner, and dressed daily during periods of active placement of fill taken from the stockpile. The Contractor may cover fill stockpiles with plastic sheeting or other material approved by the Owner in order to preserve the moisture content of the fill.

F. Stockpiles that will remain out of active use for a period greater than seven months shall either be covered as described in this section or stabilized by revegetation in accordance with the requirements for revegetation given in Section 02900.

G. The Contractor shall not remove fill material from the project site without the prior written approval of the Owner.

3.03 EXCAVATION

A. Upon completion of site preparation, the landfill or surface impoundment shall be excavated to the elevations and grades for the subgrade shown on the Construction Drawings. The excavation shall include provisions for any leakage detection system sump or permanent sump shown on the Construction Drawings. All excavation work shall be carried out in compliance with all applicable OSHA regulations.

B. During construction of the landfill or surface impoundment, the Contractor shall make excavations, as necessary, to ensure the drainage of water to a single area (i.e., a sump) to facilitate water collection and removal. A pump shall be provided for removing water from the sump. The pump shall have a capacity sufficient to meet the requirements of Section 01010 of these General Specifications. Water that accumulates in the sump shall be pumped to the on-site construction water tank or to such other location as designated by the Owner. The Contractor shall maintain the landfill or surface impoundment excavation in a dry and workable condition. Damaged work or delays caused by water from any source shall be the responsibility of the Contractor.

C. For subgrades on slopes steeper than 5:1 (horizontal:vertical) which will serve as foundations for structural fill, the subgrade shall be terraced or keyed to anchor the fill material and prevent slip failures. Each terrace shall be at least 10 feet wide with a maximum vertical elevation difference between terraces of 10 feet. Terraces shall generally run perpendicular to the fall line of the slope. Terraces shall have grades of not less than 2 percent or more than 5 percent away from the face of the embankment. Surface drainage shall be maintained at all times. This requirement does not apply to structural fills placed within the landfill or surface impoundment such as ramps or berms.

D. After excavation or stripping to final grade, the CQA Engineer will inspect the subgrade on the side slopes of the landfill or surface impoundment. The CQA Engineer will identify areas that require additional excavation of weak or excessively weathered subgrade materials on the slopes of the landfill or surface impoundment excavation. The Owner will direct the Contractor to excavate the soft areas identified by the CQA Engineer. Such excavations shall be backfilled with structural fill or clay liner material. Backfill shall be placed and compacted in accordance with the requirements for structural fill given in this section. If clay liner material is used to backfill these areas, it shall be placed in accordance with Section 02221 of these General Specifications. However, permeability tests will not be required.

E. After excavation to final grade, the CQA Engineer will inspect the subgrade on the base of the landfill or surface impoundment. The CQA Engineer may identify areas of the subgrade to be proofrolled. If proofrolling is necessary, the Contractor shall use a 20-ton pneumatic-tired roller or other equipment approved by the CQA Engineer. If soft spots or unsuitable materials are found, the Owner may direct the Contractor to excavate the soft material and either fill the excavated area with the same material (assuming the existing material will provide adequate support if recompacted) or structural fill material. Backfill shall be placed and compacted in accordance with the requirements for structural fill given in this section or clay liner material given in Section 02221.

F. The Contractor shall scarify the portion of the subgrade on the base of the landfill or surface impoundment that is comprised of soil and not treated for soft spots, to a depth of not less than 8 inches and compact it in accordance with the requirements for structural fill as directed by the Owner.

G. The subgrade surface shall be seal-rolled to prevent moisture infiltration unless fill is to be immediately placed on the subgrade.

H. Excavation of the landfill or surface impoundment shall not be considered complete, and no fill shall be placed on the subgrade, until the CQA Engineer confirms that the minimum elevations and grades shown on the Construction Drawings have been achieved in the field. The Contractor shall be responsible for notifying the CQA Engineer that the excavation (or a significant portion thereof) is complete and the Contractor shall plan for the time required for the CQA Engineer to confirm the elevations and grades of the excavation.

3.04 PLACEMENT AND COMPACTION OF STRUCTURAL FILL

A. Specific requirements for placement and compaction of structural fill shall be as specified herein unless other requirements are given on the Construction Drawings.

B. Fill lifts after compaction shall have an average thickness of no more than 6 inches and a maximum thickness of no more than 7 inches. The loose thickness shall be no greater than the length of the pad foot and drum groove of the compaction equipment (7 to 8 inches for a CAT 825).

C. The CQA Engineer must complete field testing of fill placed and compacted to determine compliance with these specifications in accordance with the CQA Plan. The Contractor shall not place a new lift of fill over a preceding lift until approval is given by the CQA Engineer. If the Contractor fails to comply with this requirement, he will be required to remove and replace all unauthorized work at his own expense.

D. Prior to placement of a lift of fill, the previous compacted lift shall be thoroughly scarified to provide good bonding between lifts. Scarification shall be accomplished by raking with a grader, discing, or an alternate method approved by the Owner.

E. The subgrade may be compacted at its natural moisture content.

F. Unless otherwise required by the Construction Drawings, structural fill shall be compacted at a moisture content between 3 percent dry to 3 percent wet of the optimum moisture content and to a minimum dry unit weight of 95 percent of the maximum dry unit weight determined in the modified Proctor compaction test (ASTM D 1557). If the moisture content of the structural fill is outside of the acceptable range, the soil shall be wetted or dried back, as appropriate.

During wetting or drying, the soil shall be regularly disced or otherwise mixed so that uniform moisture conditions are obtained.

G. The Contractor may moisture-condition fill in either the stockpile area or work area.

H. Compaction of lifts shall be performed with an appropriately heavy, properly ballasted, penetrating-foot compactor subject to the approval of the CQA Engineer.

I. The Contractor shall not place frozen fill, nor shall he place fill on frozen ground.

J. If fill freezes during construction, the Contractor shall remove the frozen fill, scarify the remaining unfrozen fill, and then place and compact new fill in accordance with these General Specifications. The frozen fill shall not be reused until it has thawed, and been thoroughly blended, and then reworked to an acceptable moisture content.

3.05 SURVEY CONTROL

A. The Surveyor shall survey the location and elevation of the excavation for the landfill or surface impoundment. He shall also survey the location and elevation of the top of subgrade shown on the Construction Drawings. Surveying shall be performed in general accordance with Section 01010 of these General Specifications.

B. The Surveyor shall provide Record Drawings of the location and elevation of the excavation and the top of prepared subgrade (or top of interim cover for cover systems) for the landfill or surface impoundment, in accordance with the requirements of Section 01010 of these General Specifications. The Surveyor shall submit this drawing to the Owner prior to the start of GCL placement or cover GCL placement unless otherwise approved by Owner and CQA Engineer. The Surveyor may submit a partial Record Drawing to obtain approval for a portion of work. The Owner will define the minimum requirements for a partial submittal.

3.06 FIELD QUALITY CONTROL

A. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

3.07 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all materials and all partially-completed and completed work of these General Specifications.

B. In the event of damage, the Owner will identify areas requiring repair, and the Contractor shall make all repairs and replacements necessary to the approval of the Owner at no additional cost to the Owner.

C. At the end of each day, the Contractor shall verify that the entire work area was left in a state that promotes surface drainage off and away from the area and from finished work. If threatening weather conditions are forecast, compacted surfaces shall be seal-rolled or covered with plastic sheeting to protect finished work.

3.08 REVEGETATION

A. At the end of construction, all disturbed areas with exposed soil (including borrow areas, soil stockpiles, material storage areas, Contractor access roads, etc.) shall be graded and revegetated in accordance with the requirements for revegetation in Specification 02900.

3.09 SEDIMENTATION AND EROSION CONTROL

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary for the installation of geotextiles for sedimentation and erosion control during construction. The work shall be carried out in accordance with the requirements of Section 603 of the New Mexico State Highway and Transportation Department Standard Specifications for Highway and Bridge Construction pertaining to erosion control and silt fences. Silt fences shall be placed as necessary downslope of all disturbed areas, and shall remain until such areas are successfully revegetated.

3.10 PERFORATIONS

A. Perforations in the subgrade or fill resulting from CQA activities will be filled. Such perforations may include, but are not limited to, the following:

1. Shelby tube sample locations; and,
2. Sand-cone or rubber balloon test locations.

B. All perforations resulting from construction and/or CQA activities shall be filled by the Contractor. The CQA Engineer will provide the Contractor with the locations of any perforations made as part of CQA activities.

C. Perforations from construction and/or CQA sampling activities (except nuclear density tests) shall be backfilled by the Contractor with structural fill material. The structural fill material shall be placed and compacted in accordance with the requirements of this section.

[END OF SECTION]

SECTION 02119
PREPARED SUBGRADE

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary for the construction of the prepared subgrade for the landfill or surface impoundment. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02110 - Site Preparation and Earthwork
B. Section 02221 - Clay Liner
C. Section 02714 - Geotextile filter of Cushion Layer
D. Section 02780 - Geosynthetic Clay Liner

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualifications and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The Contractor shall be aware of all testing activities outlined in the CQA Plan and shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. Soil testing (both field and laboratory testing) required by the CQA Plan will be the responsibility of the CQA Engineer. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor. The Contractor shall cooperate with the CQA Engineer during all testing activities. The Contractor shall provide equipment and labor to assist the CQA Engineer in sampling. The Contractor shall provide access to all areas requiring testing. The Contractor shall repair any damage to finished work caused by the CQA Engineer's sampling or testing activities.

D. The CQA Engineer will coordinate independent surveying. Surveying by the CQA Engineer does not relieve the Contractor of his responsibility to lay out, control, and document the work.

E. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at no cost to the Owner until acceptable test results are obtained.

PART 2: PRODUCTS

2.01 MATERIAL FOR PREPARED SUBGRADE

A. Prepared subgrade material shall be obtained from the landfill or surface impoundment excavation subgrade, borrow areas, or stockpiles identified by the Owner.

B. Prepared subgrade may require processing of in-situ materials, borrow areas, or stockpiles to achieve a maximum particle size of 1-inch.

C. The water used to increase the moisture content of the prepared subgrade shall be provided by the Owner. The Contractor shall maintain an accurate record of his water usage.

PART 3: EXECUTION

3.01 PREPARED SUBGRADE COMPACTION CRITERIA

A. The compaction moisture content of the prepared subgrade material shall be between 3 percent below and 3 percent above optimum moisture content determined in the modified Proctor compaction test (ASTM D1557). The minimum dry unit weight of the prepared subgrade shall be at least 90 percent of the maximum dry unit weight obtained from the modified Proctor compaction test (ASTM D1557).

3.02 PREPARED SUBGRADE MATERIAL PLACEMENT

A. Prepared subgrade shall be placed at the locations and to the thickness shown on the Construction Drawings.

B. Prepared subgrade placement shall begin only after completion of all, or an approved portion of, excavation, structural fill, or cover soil placement in the landfill or surface impoundment.

C. The Contractor shall not place prepared subgrade material on a surface or subgrade that contains debris, branches, vegetation, mud, ice, or frozen material. If frozen subgrade material is encountered, it shall be removed and replaced in accordance with these General Specifications.

D. Prepared subgrade material shall be placed and compacted in lifts parallel to the underlying surface.

E. If normal handling does not reduce the maximum clod size in the prepared subgrade material to an acceptable size, the Contractor shall use a Caterpillar SS250 soil stabilizer, mechanical mixer, or approved equivalent equipment to break up the clods. The prepared subgrade material shall be pulverized until the maximum soil clod size is reduced to 1 inches or less in largest dimension.

F. Moisture conditioning of the prepared subgrade material shall be accomplished in the processing area prior to prepared subgrade construction. The processing area location shall be approved by the Owner. Prepared subgrade material shall be moisture conditioned using a Caterpillar SS250 soil stabilizer or approved equivalent. If the prepared subgrade material is wetter than required, it shall be repeatedly mixed using a Caterpillar SS250 soil stabilizer, harrow, disc, grader, or equivalent to achieve drying.

G. Prepared subgrade material shall not be placed or compacted during a sustained period of temperature below 32°F that results in frozen material either in place or in the borrow area. Prepared subgrade material may be placed and compacted during periods of early morning freezing temperatures if above-freezing temperatures are anticipated during the day.

H. The Contractor shall not place frozen material nor shall the Contractor place material on frozen ground.

I. If prepared subgrade material freezes after compaction, the Contractor shall either rework the material after it thaws or remove the frozen material. The Contractor shall then place and compact new prepared subgrade or rework the prepared subgrade accordance with the General Specifications. Frozen prepared subgrade shall not be reused until it has thawed and been reworked to an acceptable moisture content. The Contractor shall be responsible for protecting compacted lifts of prepared subgrade material from freezing. If extended freezing conditions are anticipated, the Contractor shall prepare a plan for approval of the Owner which outlines the measures he will take to protect finished work.

J. Prepared subgrade material shall not be placed during periods of unfavorable weather conditions.

3.03 PREPARED SUBGRADE COMPACTION

A. The sequence of compaction of the prepared subgrade for the landfill or surface impoundment shall be as described in the General Specifications or as shown on the Construction Drawings.

B. Compaction of prepared subgrade on the landfill or surface impoundment shall be performed using a vibratory steel drum compactor. In areas where geomembranes will be installed on top of the prepared subgrade, Contractor shall prepare the surface in accordance with geomembrane surface preparation requirements identified in the geomembrane specifications.

C. The daily work area shall extend a sufficient distance so as to maintain soil moisture conditions within an acceptable range to allow continuous operations. Desiccation and crusting of the lift surface shall be avoided as much as possible.

D. The CQA Engineer will identify any areas of significant desiccation and crusting of a lift surface. The Contractor shall scarify the surface of such areas to a nominal depth of 1 to 2 inches or to the depth of desiccation identified by the CQA Engineer, and then water condition, disc or mix as necessary, and recompact the area.

E. Corners and other areas inaccessible to driven compaction equipment shall be compacted using hand operated equipment (such as a walk-behind roller) approved by the Owner.

3.04 SURVEY CONTROL

A. The Surveyor shall survey the final location and elevations of the top of the prepared subgrade. Surveying shall be performed in accordance with Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing to the Owner of the final location and elevation of the top of the prepared subgrade. The Surveyor shall submit this drawing prior to liner construction unless otherwise approved by the Owner and the CQA engineer. The Contractor may submit a partial record to obtain approval for a portion of the work. The Owner will define the minimum requirements for a partial submittal.

3.05 FIELD QUALITY CONTROL

A. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

B. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at his own expense until acceptable test results are obtained.

3.06 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all materials and partially completed work of these General Specifications.

B. In the event of damage, the CQA Engineer will identify areas requiring repair, and the Contractor shall make repairs and replacements necessary to the approval of the Owner and at no additional cost to the Owner.

C. The Contractor shall minimize, to the maximum extent feasible, desiccation cracking of prepared subgrade material. The Contractor shall sprinkle the prepared subgrade with water if cracking is observed or if directed by the Owner. The Contractor may seal roll the surface of the prepared subgrade to reduce drying and desiccation. The Contractor may protect exposed surfaces using light colored or translucent membranes, such as Visqueen, to inhibit drying of the prepared subgrade. The CQA Engineer will identify areas of significant cracking of the surface of the prepared subgrade and the Contractor shall repair the identified area to the satisfaction of the Owner and at no additional cost to the Owner.

D. Desiccation cracks larger than 0.2 feet deep or 0.25 inches wide shall be excavated to the full depth of the crack and repaired. Desiccation cracks on the prepared subgrade surface less than 0.2 feet deep and 0.25 inches wide shall be moistened and compacted with a smooth drum roller until the surfaces meet the requirements of the CQA plan.

3.07 PERFORATIONS

A. Perforations in the prepared subgrade resulting from construction and CQA activities shall be filled. Such perforations may include, but are not limited to, the following:

1. Nuclear density test probe locations;
2. Shelby tube sample locations;
3. Sand-cone or rubber-balloon test locations; and,
4. Survey stake locations.

B. Perforations in the prepared subgrade resulting from nuclear density tests will be filled by the CQA Engineer. All other perforations in the prepared subgrade resulting from construction and/or CQA sampling activities shall be filled by the Contractor. The CQA Engineer will provide the Contractor with the locations of any tests made as part of CQA activities, except nuclear density tests.

C. Perforations from construction and/or CQA sampling activities (except nuclear density tests) shall be backfilled by the Contractor with prepared subgrade material. The prepared subgrade material shall be placed and compacted (hand tamped) in accordance with the requirements of this section. Perforations in the prepared subgrade from nuclear density tests will be backfilled by the CQA Engineer with prepared subgrade material and compacted by hand tamping.

[END OF SECTION]

SECTION 02221
CLAY LINER

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary for the construction of the clay liner component of the liner system for the landfill or surface impoundment. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02110 - Site Preparation and Earthwork
B. Section 02710 - Geocomposite
C. Section 02714 - Filter or Cushion Geotextile
D. Section 02775 - Geomembrane Liners
E. Section 02780 - Geosynthetic Clay Liners

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualifications and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The Contractor shall be aware of all testing activities outlined in the CQA Plan and shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. Soil testing (both field and laboratory testing) required by the CQA Plan will be the responsibility of the CQA Engineer. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor. The Contractor shall cooperate with the CQA Engineer during all testing activities. The Contractor shall provide equipment and labor to assist the CQA Engineer in sampling. The Contractor shall provide access to all areas requiring testing. The Contractor shall repair any damage to finished work caused by the CQA Engineer's sampling or testing activities.

D. The CQA Engineer will coordinate independent surveying. Surveying by the CQA Engineer does not relieve the Contractor of his responsibility to lay out, control, and document the work.

E. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at no cost to the Owner until acceptable test results are obtained.

PART 2: PRODUCTS

2.01 MATERIALS

Clay liner material may only be used for construction if it has been shown to be suitable in a test fill program. The test fill program will have been performed prior to construction of the landfill or surface impoundment, and it is not part of the work included in this General Specification. These General Specifications may be modified per the results of the test fill.

A. Clay liner material shall be obtained from borrow areas or stockpiles identified by the Owner.

B. Clay liner material for landfill or surface impoundment construction shall:

1. Be classified according to the Unified Soil Classification System (USCS) as CL or CH (ASTM D 2487) and exhibit a minimum liquid limit of 30 and a minimum plasticity index of 11.

2. Have a percentage of gravel (i.e., dry weight retained on a U.S. No. 4 sieve) of less than 15 percent.

3. Have particles no larger than 2 inches (in largest dimension) after processing but prior to placement and no larger than 1 inch (in largest dimension) after placement and compaction.

4. Have a hydraulic conductivity of not more than 1×10^{-7} cm/sec when compacted in accordance with these General Specifications and tested in the laboratory in accordance with ASTM D 5084 at an average effective confining pressure of 5 psi.

C. The water used to increase the moisture content of the clay liner shall be provided by the Owner. The Contractor shall maintain an accurate record of his water usage.

PART 3: EXECUTION

The requirements of Part 3 may be modified based on the results of the test fill.

3.01 CLAY LINER COMPACTION CRITERIA

A. The compaction moisture content and the minimum dry unit weight of on-site clay, if used as clay liner material, shall plot within the placement window as shown on figure 02221-1.

3.02 CLAY LINER PLACEMENT

A. The clay liner shall be constructed to the elevations, grades, and thicknesses shown on the Construction Drawings. The thickness of the clay liner at any location shall be measured perpendicular to the plane of the slope at that location.

B. Clay liner placement shall begin only after completion of all, or an approved portion of excavation, structural fill placement, geosynthetic installation in the landfill or surface impoundment. Placement shall not begin until the Contractor has verified that prepared elevations and grades conform to the Construction Drawings and the CQA Engineer has completed testing and surveying required by the CQA Plan.

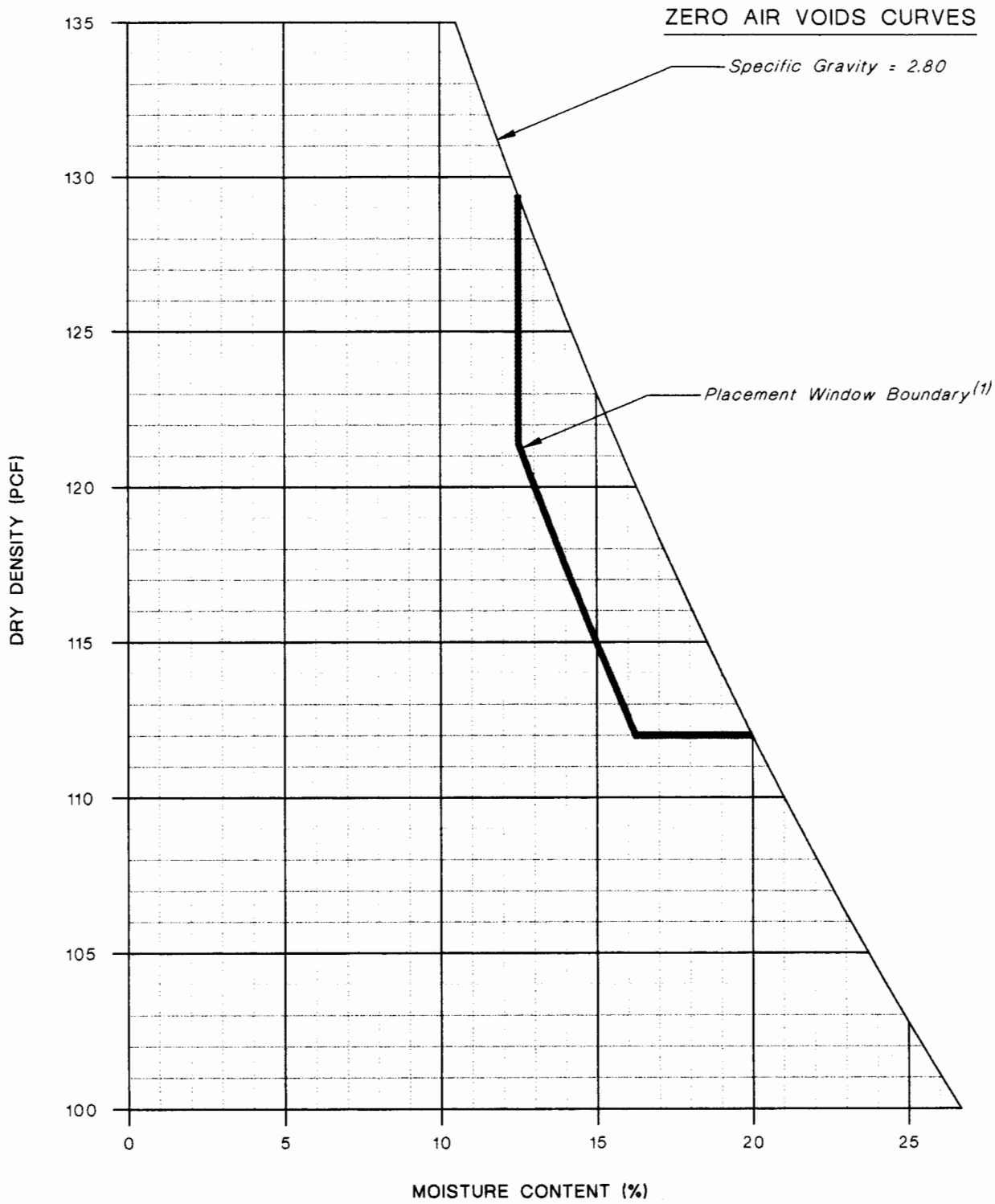
C. The Contractor shall not place clay liner material on a surface or subgrade that contains debris, branches, vegetation, mud, ice, or frozen material. If frozen material is encountered, it shall be removed and replaced in accordance with these General Specifications. Immediately prior to clay liner placement, any wet or soft areas shall be proof-rolled as directed by the Owner. Any excessively wet or soft areas shall be excavated and replaced with properly compacted structural fill.

D. The Contractor shall construct the clay liner in lifts. Each lift of the clay liner shall meet the minimum requirements of this General Specification.

E. The average lift thickness after compaction shall be no more than 6 inches, and the maximum lift thickness shall be 7 inches after compaction.

F. On slopes of 3:1 (horizontal:vertical) or flatter, clay liner material may either be placed and compacted in lifts that are parallel to the slope or in horizontal lifts. For steeper slopes, clay liner material shall be placed and compacted in horizontal lifts.

G. Prior to placement of a lift of clay liner material, Contractor shall allow the CQA Engineer to complete field testing in accordance with the CQA Plan. The Contractor shall not place a new lift of clay liner material over a preceding lift until approval is given by the CQA Engineer. If the Contractor fails to comply with this requirement, he will be required by the Owner to remove and replace all unauthorized work at no additional cost to the Owner.



(1) PLACEMENT WINDOW BOUNDARY MAY BE MODIFIED BASED ON RESULTS OF TEST FILL.

REV. No	REVISIONS	REV. DATE	DESIGN BY	DRAWN BY	REVIEWED AND SIGNED BY
0	Part B Permit	11/17/97	J.Pellicer	K.Conrath	J.Pellicer

TerraMatrix
MONTGOMERY WATSON
Mining Group

PROJECT No: 602-0200
AutoCAD FILE: PLACEWINDOW.DWG
SCALE: NA
FIGURE No: 02221-1

Triassic Park Waste Disposal Facility

CLAY LINER PLACEMENT WINDOW

H. Prior to placement of a lift of clay liner material, the previous lift shall be thoroughly scarified to a nominal depth of about 1 to 2 inches to provide good bonding between lifts. Scarification shall be accomplished by discing, ripping with a grader, penetration by a sheepsfoot compactor or an alternative method approved by the Owner.

I. The excessive trafficking of scarified surfaces by non-placement trucks or other equipment shall not be permitted during the period between scarification and placement of the following lift.

J. If normal handling does not reduce the maximum clod size in on-site clay to an acceptable size, the Contractor shall use a Caterpillar SS250 soil stabilizer, mechanical mixer, or approved equivalent equipment to break up the clods. The on-site clay material shall be pulverized until the maximum soil clod size is reduced to 2 inches or less in largest dimension.

K. Moisture conditioning of the clay liner material shall be accomplished in the processing area prior to clay liner construction. The processing area location shall be approved by the Owner. Clay liner material shall be moisture conditioned using a Caterpillar SS250 soil stabilizer or approved equivalent. If the clay liner material is wetter than required, it shall be repeatedly mixed using a Caterpillar SS250 soil stabilizer, harrow disc, grader, or equivalent to achieve drying.

L. No more than 3 percent moisture shall be added to the clay liner material at the time of compaction. Clay liner material requiring more than 3 percent moisture shall be removed, returned to the processing area, and conditioned until the proper moisture content is achieved. If the in-place moisture content is too high, the clay may be dozed, windrowed, disced, and/or otherwise mixed to facilitate drying.

M. Clay liner material shall not be placed or compacted during a sustained period of temperature below 32°F that results in frozen clay, either in place or in the borrow area. Clay liner material may be placed and compacted during periods of early morning freezing temperatures if above-freezing temperatures are anticipated during the day.

N. The Contractor shall not place frozen clay nor shall the Contractor place clay on frozen ground.

O. If clay liner material freezes after compaction, the Contractor shall remove the frozen material, scarify the remaining unfrozen clay, and then place and compact new clay in accordance with the General Specifications. Frozen clay shall not be reused until it has thawed and been reworked to an acceptable moisture content. The Contractor shall be responsible for protecting compacted lifts of clay liner material from freezing. If extended freezing conditions are anticipated, the Contractor shall prepare a plan for approval of the Owner which outlines the measures he will take to protect finished work.

P. Clay liner material shall not be placed during periods of unfavorable weather conditions.

Q. The first lift of clay liner material above any geosynthetics be constructed using a 12-inch thick loose lift. The lift shall be placed and spread using a low-ground pressure dozer (e.g., Caterpillar D6H LGP or other equipment approved by the Owner). Extreme care shall be taken during placement and spreading operations to ensure that the earthwork equipment does not damage the underlying geosynthetics.

3.03 CLAY LINER COMPACTION

A. The sequence of compaction of the clay liner for a landfill or surface impoundment shall be as described in the General Specifications or as shown on the Construction Drawings.

B. Compaction of the clay liner for the landfill or surface impoundment shall be performed using a Caterpillar 825 compactor or equal.

C. The daily work area shall extend a sufficient distance so as to maintain soil moisture conditions within an acceptable range to allow continuous operations. Desiccation and crusting of the lift surface shall be avoided as much as possible.

D. The CQA Engineer will identify any areas of significant desiccation and crusting of a lift surface. The Contractor shall scarify the surface of such areas to a nominal depth of 1 to 2 inches or to the depth of desiccation identified by the CQA Engineer, and then water condition, disc or mix as necessary, and recompact the area.

E. The transition from an existing full-depth section of clay liner to the beginning of an adjacent section that is to be constructed subsequently shall be accomplished by sloping (cutting back) the end of the full-depth section at 3:1 (horizontal:vertical) or flatter, scarifying the slope of the existing full-depth liner at the transition, and then immediately placing the adjacent lifts of clay liner.

F. If a dual-drum compactor which has the drums laterally separated by the operator's cab and the differential (such as a CAT 825) is used, one trip up and a staggered trip back, to cover the uncompacted area between the drums, shall be considered one pass. The minimum number of compactor passes on each lift of the secondary clay liner shall be as follows:

1. The clay liner shall be compacted with a minimum of 10 passes of the CAT 825 if the on-site clay is used or the number of passes determined during test fill construction.

It should be noted that more than the minimum number of passes may be necessary to satisfy the compaction criteria.

G. Corners and other areas inaccessible to driven compaction equipment shall be compacted using hand operated equipment (such as a walk-behind roller) approved by the Owner.

H. In areas where geomembranes will be installed on top of the clay liner, Contractor shall prepare the surface in accordance with geomembrane surface preparation requirements identified in the geomembrane specifications.

3.04 SURVEY CONTROL

A. The Surveyor shall survey the final location and elevation of the top of the clay liner. Surveying shall be performed in accordance with Section 01010 of these General Specifications. As part of this work, the Surveyor shall survey the location and elevation of the leak detection system sump. The survey will ensure:

1. The specified thickness of the clay liner has been achieved.

2. The top of the clay liner is at the grades and elevations specified on the contract drawings.

B. The Surveyor shall provide a Record Drawing to the Owner of the final location and elevation of the top of the clay liner, in accordance with the requirements of Section 01010 of these General Specifications. The Surveyor shall submit this drawing prior to additional construction unless otherwise approved by the Owner and the CQA engineer. The Contractor may submit a partial record to obtain approval for a portion of the work. The Owner will define the minimum requirements for a partial submittal.

3.05 FIELD QUALITY CONTROL

A. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

B. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at his own expense until acceptable test results are obtained.

3.06 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all materials and partially-completed and completed work of these General Specifications.

B. In the event of damage, the CQA Engineer will identify areas requiring repair, and the Contractor shall make repairs and replacements necessary to the approval of the Owner and at no additional cost to the Owner.

C. The Contractor shall minimize, to the maximum extent feasible, desiccation cracking of clay liner material. The Contractor shall sprinkle the clay with water if cracking is observed or if directed by the Owner. The Contractor may seal roll the surface of the clay to reduce drying and desiccation. The Contractor may protect exposed surfaces using light-colored or translucent membranes, such as Visqueen, to inhibit drying of the clay. The CQA Engineer will identify areas of significant cracking of the surface of the clay liner and the Contractor shall repair the identified area to the satisfaction of the Owner and at no additional cost to the Owner.

D. The clay liner surface shall be seal rolled and made smooth and free from ruts or indentations at the end of every working day when precipitation is forecast and/or at the completion of compaction operations in an area.

E. The Contractor shall maintain the clay liner surface in a condition suitable for geomembrane installation as specified in the CQA plan until the surface is covered. Desiccation cracks larger than 0.2 feet deep or 0.25 inches wide shall be excavated to the full depth of the crack and repaired. Desiccation cracks on the liner surface less than 0.2 feet deep and 0.25 inches wide shall be moistened and compacted with a smooth drum roller until the surfaces meet the requirements of the CQA Plan.

F. The layer of over-built material shall be removed prior to placement of overlying materials. The over-built material may be removed in sections to coordinate construction. Where the over-built material is removed, the finished surface shall be protected and maintained as required by the specifications.

G. No synthetic sealants or other chemical treatments may be applied to the clay liner material.

H. The CQA Engineer will issue an approval of the installation of the clay liner to the Owner prior to placement of material over the clay liner in accordance with the requirements of the CQA Plan.

3.07 PERFORATIONS

A. Perforations in the clay liner resulting from construction and CQA activities shall be filled. Such perforations may include, but are not limited to, the following:

1. Nuclear density test probe locations;
2. Shelby tube sample locations;
3. Sand-cone or rubber-balloon test locations; and,
4. Survey stake locations.

B. Perforations in the clay liner resulting from nuclear density tests will be filled by the CQA Engineer. All other perforations in the clay liner resulting from construction and/or CQA sampling activities shall be filled by the Contractor. The CQA Engineer will provide the Contractor with the locations of any tests made as part of CQA activities, except nuclear density tests.

C. Perforations from construction and/or CQA sampling activities (except nuclear density tests) shall be backfilled by the Contractor with clay liner material. The clay liner material shall be placed and compacted (hand tamped) in accordance with the requirements of this section. Perforations in the clay liner from nuclear density tests will be backfilled by the CQA Engineer with clay liner material and compacted by hand tamping.

[END OF SECTION]

SECTION 02224
DRAINAGE GRAVEL

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary for the placement of drainage gravel associated with the landfill and surface impoundment. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02710 - Geocomposite Detection or Collection Layer
B. Section 02714 - Geotextile Filter or Cushion Layer
C. Section 02718 - Polyethylene Pipe and Fittings
D. Section 02775 - Geomembrane Liners

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The Contractor shall be aware of all activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule.

C. On-site testing as specified in the CQA Plan for the drainage gravel (which does not include quality control testing at the source) will be the responsibility of the CQA Engineer. The Contractor shall cooperate with the CQA Engineer during all sampling and testing activities. The Contractor shall provide equipment and labor to assist the CQA Engineer in sampling. The Contractor shall provide access to all areas requiring testing. The Contractor will repair any damage to finished work caused by the CQA Engineer's sampling and testing activities.

D. Quality control testing (in accordance with Part 2.02 of this section) of the drainage gravel at the source shall be the responsibility of the Contractor.

PART 2: PRODUCTS

2.01 MATERIAL FOR DRAINAGE GRAVEL

A. Drainage gravel for the work shall consist of clean, hard, durable, non-carbonate, rounded, sub-rounded to sub-angular particles which are free of metals, roots, trees, stumps, concrete, construction debris, other organic matter, and deleterious materials and coatings.

B. The gravel shall be screened and washed to have a gradation (when tested in accordance with ASTM D 422) after placement equivalent to the following:

Sieve	Percent Passing
1"	100%
¾"	85-100%
3/8"	12-30%
4"	1-4%
40"	0-1%

C. Drainage gravel shall have a hydraulic conductivity of at least 1 cm/sec when hand compacted in the laboratory in 3 lifts and tested in accordance with ASTM D 2434.

D. Drainage gravel shall have less than 30% loss when tested in accordance with ASTM C 131 for abrasion and less than 12% loss when tested in accordance with ASTM C 88.

E. Drainage gravel shall have less than 5 percent loss of weight, when tested for calcium carbonate content in accordance with ASTM D 4373. This requirement may be waived by the Owner if it can be otherwise demonstrated that the material contains no significant carbonate content.

2.02 DRAINAGE GRAVEL SUPPLIER QUALITY CONTROL

A. The Contractor shall require that the drainage gravel Supplier sample and test the gravel to demonstrate that the material conforms to the requirements of Part 2.01 of this section. The Contractor shall require the gravel Supplier provide to the Owner written certification along with test results, that tests have been performed on representative samples of the gravel material that will be delivered to the Owner's site. The analysis shall demonstrate that tests (i.e., ASTM D 422, ASTM D 2434, ASTM D 4373, AASHTO T96, and AASHTO T104) have been performed and that acceptable results were obtained.

B. If a gravel sample fails to meet the quality control requirements of this General Specification, the Contractor shall require the gravel Supplier to perform sufficient sampling and testing to identify the extent of the nonconforming

material to the satisfaction of the CQA Engineer. The Contractor shall not use nonconforming material.

C. The Contractor shall require that the gravel Supplier comply with the certification and submittal requirements of the CQA Plan.

D. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

2.03 TRANSPORTATION

A. Transportation of gravel shall be the responsibility of the Contractor.

2.04 HANDLING AND STORAGE

A. Handling, stockpiling, and protection of the gravel prior to and following incorporation into the work is the responsibility of the Contractor. The Contractor shall be liable for contamination of the material incurred prior to final acceptance.

B. The Contractor shall be responsible for storage of the gravel at the site. The Contractor shall store the gravel at a location approved by the Owner and in such a manner so that it is not contaminated by dirt, mud, vegetation, or excessive dust. During stockpiling, the Contractor may elect to place the gravel on a protective sheet and/or to cover it to prevent contamination. The CQA Engineer will identify contaminated material which will be rejected by the Owner.

PART 3: EXECUTION

3.01 PLACEMENT AND COMPACTION

A. Gravel shall be placed at the locations and to the thicknesses shown on the Construction Drawings.

B. Gravel shall not be placed directly on the geomembrane liner. Gravel may be placed on top of a geotextile cushion layer, geonet, geocomposite drainage layer, or geomembrane rub sheet, as shown on the Construction Drawings. Gravel may be placed using a backhoe, front-end loader, belt conveyor, spreader box, or other method approved by the Owner, as long as the ground-pressure requirements of this Section are not exceeded. The maximum acceptable gravel drop height is 3 feet.

C. Final spreading of the gravel may be performed using a low ground-pressure dozer (Caterpillar D6H-LGP or other similar equipment approved by the CQA Engineer), low-ground pressure front-end loader, or by hand. The tracked

equipment shall operate only over previously-placed gravel or other soil. The Contractor shall not operate equipment directly on geosynthetics.

D. Unless otherwise specified by the Owner, the equipment used to spread gravel shall not exert ground pressures exceeding the following:

Allowable Equipment Ground Pressure (psi)	*Thickness of Gravel Above Geosynthetic (inches)*
<5	12
<10	18
<20	24
>20	36

The maximum allowable equipment ground pressure shall be 65 psi. The acceptability of equipment operating at ground pressures greater than 65 psi will be evaluated by the Owner at the Contractor's expense.

E. The Contractor shall operate equipment in a manner that is protective of polyethylene pipes and underlying geosynthetics. If it is suspected that damage to polyethylene pipes or underlying geosynthetics may have occurred, the Owner will instruct the Contractor to remove the overlying material to expose the potentially-damaged materials. The Contractor shall repair, at his own expense, any observed damage, in accordance with the requirements of these General Specifications.

F. Within 1 foot of the toe of a slope, gravel shall be spread by hand. Extreme care shall be taken when placing gravel to protect the installed components of the liner system.

G. Geotextile filter or cushion layers shall be placed as shown on the Construction Drawings. Geotextile filter and cushion layer placement shall be in accordance with Section 02714 of these General Specifications.

3.02 FIELD QUALITY CONTROL

A. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

B. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at his own expense until acceptable test results are obtained.

3.03 PROTECTION OF WORK

A. After the gravel has been incorporated into the work, the Contractor shall maintain it free of ruts, depressions, and damage resulting from the hauling and handling of any material, equipment, tools, etc.

B. The Contractor shall use all means necessary to protect all prior work, materials and completed and partially completed work of other Sections of these General Specifications.

C. In the event of damage, the CQA Engineer will identify areas requiring repair, and the Contractor shall make repairs and replacements necessary, to the approval of the Owner at no additional cost to the Owner.

3.04 SURVEY CONTROL

A. The Surveyor shall survey the final location and elevation of the top of the drainage gravel. Surveying shall be performed in accordance with of Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing to the Owner of the final location and elevation of the final surface of the drainage gravel, in accordance with the requirements of Section 01010 of these General Specifications.

[END OF SECTION]

SECTION 02225
ROAD BASE

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, testing, and installation services necessary for the installation of road base where shown on the Construction Drawings. The work shall be carried out in accordance with the Construction Drawings and the requirements of Section 304 of the New Mexico State Highway and Transportation Department Standard Specification for Road and Bridge Construction.

1.02 RELATED SECTIONS

A. Section 02230 - Subbase
B. Section 02714 - Filter or Cushion Geotextile

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The Contractor shall be aware of all activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule.

C. On-site testing as specified in the CQA Plan for the road base (which does not include quality control testing at the source) will be the responsibility of the CQA Engineer. The Contractor shall cooperate with the CQA Engineer during all sampling and testing activities. The Contractor shall provide equipment and labor to assist the CQA Engineer in sampling. The Contractor shall provide access to all areas requiring testing. The Contractor will repair any damage to finished work caused by the CQA Engineer's sampling and testing activities.

D. Quality control testing (in accordance with Part 2.02 of this section) of the road base at the source shall be the responsibility of the Contractor.

PART 2: PRODUCTS

2.01 MATERIAL FOR ROAD BASE AGGREGATE

A. Road base for the work shall consist of clean, hard, durable, non-carbonate, rounded, sub-rounded to sub-angular particles which are free of metals, roots, trees, stumps, concrete, construction debris, other organic matter, and deleterious materials and coatings.

B. The road base shall have a gradation (when tested in accordance with ASTM D 422) of Type II-B aggregate as defined in Section 304 of the New Mexico State Highway and Transportation Department Standard Specification for Road and Bridge Construction.

C. Road base shall have less than 5 percent loss of weight, when tested for calcium carbonate content in accordance with ASTM D 4373. This requirement may be waived by the owner if it can be otherwise demonstrated that the material contains no significant carbonate content.

2.02 ROAD BASE SUPPLIER QUALITY CONTROL

A. The Contractor shall require that the road base Supplier sample and test the road base to demonstrate that the material conforms to the requirements of Part 2.01 of this section. The Contractor shall require the road base Supplier provide to the Owner written certification along with test results, that tests have been performed on representative samples of the road base material that will be delivered to the Owner's site. The analysis shall demonstrate that tests (i.e., ASTM D 422, ASTM D 2434, ASTM D 4373, ASTM C 131, and ASTM C 88) have been performed and that acceptable results were obtained.

B. If a road base sample fails to meet the quality control requirements of this General Specification, the Contractor shall require the road base Supplier to perform sufficient sampling and testing to identify the extent of the nonconforming material to the satisfaction of the CQA Engineer. The Contractor shall not use nonconforming material.

C. The Contractor shall require that the road base Supplier comply with the certification and submittal requirements of the CQA Plan.

D. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

2.03 TRANSPORTATION

A. Transportation of road base shall be the responsibility of the Contractor.

2.04 HANDLING AND STORAGE

A. Handling, stockpiling, and protection of the road base prior to and following incorporation into the work is the responsibility of the Contractor. The Contractor shall be liable for contamination of the material incurred prior to final acceptance.

B. The Contractor shall be responsible for storage of the road base at the site. The Contractor shall store the road base at a location approved by the Owner and in such a manner so that it is not contaminated by dirt, mud, vegetation, or excessive dust. During stockpiling, the Contractor may elect to place the road base on a protective sheet and/or to cover it to prevent contamination. The CQA Engineer will identify contaminated material which will be rejected by the Owner.

PART 3: EXECUTION

3.01 GRAVEL COMPACTION CRITERIA

A. The compaction moisture content of the road base shall be between 3 percent below and 3 percent above optimum moisture content determined in the modified Proctor compaction test (ASTM D1557). The minimum dry unit weight of the road base aggregate shall be at least 95 percent of the maximum dry unit weight obtained from the modified Proctor compaction test (ASTM D1557).

3.02 PLACEMENT AND COMPACTION

A. Road base shall be placed at the locations and to the thicknesses shown on the Construction Drawings

B. Road base shall not be placed directly on geosynthetics unless required by the General Specifications or the Construction Drawings. Road base may be placed using a backhoe, front-end loader, belt conveyor, spreader box, or other method approved by the Owner in maximum 12-inch loose lifts.

C. Final spreading of the road base may be performed using a dozer or grader. Equipment shall operate only over previously-placed road base or other soil. The Contractor shall not operate equipment directly on geosynthetics.

D. Road base placed on top of geotextile shall have a first lift minimum thickness of 12 inches

E. The Contractor shall operate equipment in a manner that is protective of polyethylene pipes and underlying geosynthetics. If it is suspected that damage to polyethylene pipes or underlying geosynthetics may have occurred, the Owner will instruct the Contractor to remove the overlying material to expose the potentially-damaged materials. The Contractor shall repair, at his own

expense, any observed damage, in accordance with the requirements of these General Specifications.

F. Geotextile filter or cushion layers shall be placed as shown on the Construction Drawings. Geotextile filter and cushion layer placement shall be in accordance with Section 02714 of these General Specifications.

3.03 FIELD QUALITY CONTROL

A. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

B. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at his own expense until acceptable test results are obtained.

3.04 PROTECTION OF WORK

A. After the road base has been incorporated into the work, the Contractor shall maintain it free of ruts, depressions, and damage resulting from the hauling and handling of any material, equipment, tools, etc.

B. The Contractor shall use all means necessary to protect all prior work, materials and completed and partially completed work of other Sections of these General Specifications.

C. In the event of damage, the CQA Engineer will identify areas requiring repair, and the Contractor shall make repairs and replacements necessary, to the approval of the Owner at no additional cost to the Owner.

3.05 SURVEY CONTROL

A. The Surveyor shall survey the final location and elevation of the top of the road base. Surveying shall be performed in accordance with of Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing to the Owner of the final location and elevation of the final surface of the road base, in accordance with the requirements of Section 01010 of these General Specifications.

[END OF SECTION]

SECTION 02226
COVER SOIL

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary for the construction of the cover soil component of the landfill. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02119 - Prepared Subgrade
B. Section 02710 - Geocomposite Detection or Collection Layer

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The Contractor shall be aware of all testing activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. Soil testing (both field and laboratory testing) required by the CQA Plan will be the responsibility of the CQA Engineer. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor. The Contractor shall cooperate with the CQA Engineer during all testing activities. The Contractor shall provide equipment and labor to assist the CQA Engineer in sampling. The Contractor shall provide access to all areas requiring testing. The Contractor shall repair any damage to finished work caused by the CQA Engineer sampling or testing activities.

D. The CQA Engineer will coordinate independent surveying required by the CQA Plan. Surveying by the CQA Engineer does not relieve the Contractor of his responsibility to lay out, control, and document the work.

E. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at no cost to the Owner until acceptable test results are obtained.

PART 2: PRODUCTS

2.01 MATERIALS

A. Cover soil material shall be obtained from the landfill or surface impoundment excavation or from on-site or off-site borrow sources.

B. Cover soil layer material shall classify as CL, ML, SC, GC, SM, or GM according to the Unified Soil Classification System (ASTM D 2487) and shall have a maximum particle size not exceeding 3 inches.

PART 3: EXECUTION

3.01 COVER SOIL LAYER COMPACTION CRITERIA

A. The Contractor shall place and compact the soil as described in this Section.

3.02 PLACEMENT AND COMPACTION

A. Cover soil material shall be placed above the waste material at the locations and to the thicknesses shown on the Construction Drawings.

B. The Contractor shall not place the cover soil layer until the CQA Engineer confirms that the constructed grades and elevations of the waste meet the requirements of the Construction Drawings, all field testing is complete, and approved in accordance with the requirements of the CQA Plan.

C. The final in-place thickness of the cover soil layer shall be not less than 18 inches.

D. The cover soil material shall be spread in 2 lifts. The Contractor shall not operate equipment directly on geomembranes, geotextiles, GCL's, or geocomposites.

E. Unless otherwise specified by the Owner, the equipment used to haul and spread the cover soil layer in areas within 5 feet of geosynthetics shall not exert ground pressures exceeding the following:

Allowable Equipment Ground Pressure (psi)	*Minimum Thickness of Cover Soil Layer Above the Geosynthetic (inches)*
<5	12
<10	18
<20	24
>20	36

The maximum allowable equipment ground pressure shall be 65 psi. The acceptability of equipment operating at ground pressures greater than 65 psi will be evaluated by the Owner at the Contractor's expense.

F. Cover soil shall be compacted at a moisture content between 3 percent below to 3 percent above optimum moisture content and to a minimum dry unit weight of 90 percent of the maximum dry unit weight determined in the modified Proctor compaction test (ASTM D 1557).

G. In areas of heavy traffic, the thickness of the cover soil layer shall be increased at the direction of the Owner to satisfy the requirements of this Section. Heavy traffic areas shall be compacted with a smooth drum roller or other equipment approved by the Owner.

H. The Contractor shall operate equipment in a manner that is protective of underlying geosynthetics. If it is suspected that any damage to the underlying geosynthetics may have occurred, the Owner will instruct the Contractor to remove overlying cover soil layer material to expose the geosynthetics. The Contractor shall repair, at his own expense, any damage of the underlying geosynthetics in accordance with these General Specifications.

I. The Contractor shall minimize to the extent possible the generation of dust during placement of the cover soil layer. Water may be used for dust control if approved by the Owner. Chemical dust suppressants shall not be used.

J. No cover soil material shall be placed or compacted during a sustained period of temperature below 32°F that results in frozen material, either in-place or in the borrow area. With the approval of the Owner, cover soil material may be placed and compacted during periods of early morning freezing temperatures if above-freezing temperatures are anticipated during the day.

K. The Contractor shall not place frozen cover soil material nor shall he place cover soil material on frozen ground.

L. Cover soil material shall not be placed during periods of precipitation or unfavorable weather conditions.

3.03 SURVEY CONTROL

A. The Surveyor shall survey the final location and elevation of the top of the cover soil layer installed by the Contractor. Surveying shall be performed in accordance with Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing of the location and elevation of the top of the cover soil layer to the Owner in accordance with the requirements of Section 01010 of these General Specifications.

3.04 FIELD QUALITY CONTROL

A. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

B. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at his own expense until acceptable test results are obtained.

3.05 PROTECTION OF WORK

A. After the cover soil layer has been placed, the Contractor shall maintain it free of ruts, depressions, and damage resulting from the hauling and handling of any material, equipment, tools, etc.

B. The Contractor shall use all means necessary to protect all materials and partially-completed and completed work of these General Specifications.

C. In the event of damage, the CQA Engineer will identify any areas requiring repair, and the Contractor shall make repairs and replacements necessary, to the approval of the Owner and at no additional cost to the Owner.

[END OF SECTION]

SECTION 02227
VEGETATIVE COVER

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary for the construction of the vegetative cover component of the landfill. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02710 - Geocomposite
B. Section 02714 - Filter or Cushion Geotextile

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The Contractor shall be aware of all testing activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. Soil testing (both field and laboratory testing) required by the CQA Plan will be the responsibility of the CQA Engineer. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor. The Contractor shall cooperate with the CQA Engineer during all testing activities. The Contractor shall provide equipment and labor to assist the CQA Engineer in sampling. The Contractor shall provide access to all areas requiring testing. The Contractor shall repair any damage to finished work caused by the CQA Engineer sampling or testing activities.

D. The CQA Engineer will coordinate independent surveying required by the CQA Plan. Surveying by the CQA Engineer does not relieve the Contractor of his responsibility to lay out, control, and document the work.

E. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at no cost to the Owner until acceptable test results are obtained.

PART 2: PRODUCTS

2.01 MATERIALS

A. Vegetative cover material shall be obtained from the landfill or surface impoundment excavation or from on-site or off-site borrow sources.

B. Vegetative cover material shall classify as CL, ML, SC, GC, SM, or GM according to the Unified Soil Classification System (ASTM D 2487) and shall have a maximum particle size not exceeding 3 inches.

PART 3: EXECUTION

3.01 VEGETATIVE COVER LAYER COMPACTION CRITERIA

A. The Contractor shall place and compact the soil as described in of this Section.

3.02 PLACEMENT AND COMPACTION

A. Vegetative cover material shall be placed above the cover system geocomposite at the locations and to the thicknesses shown on the Construction Drawings.

B. The Contractor shall not place the vegetative soil layer until the CQA Engineer confirms that the constructed grades and elevations of the cover prepared subgrade meet the requirements of the Construction Drawings, all field testing is complete, and the geocomposite has been installed, tested, and approved in accordance with the requirements of the CQA Plan.

C. Prior to placing the vegetative cover layer, the CQA Engineer will verify that the underlying geosynthetic components are free of holes, tears, excessive wrinkles, or foreign objects. As instructed by the Owner, the Contractor shall "work out" or repair all excessive wrinkles to the satisfaction of the CQA Engineer prior to placement of the vegetative cover. In all cases, wrinkles in the geomembrane cover shall not be of a size that they could fold back on themselves.

D. The final in-place thickness of the vegetative cover layer shall be not less than 30 inches.

E. The vegetative cover material shall be spread in one lift using a low ground-pressure dozer (Caterpillar D6H-LGP, or other equipment approved by the Owner), low-ground pressure tracked front-end loader, or belt conveyor. Equipment shall operate only over previously-placed vegetative cover layer

material. The Contractor shall not operate equipment directly on geomembranes, geotextiles, gcls, or geocomposites.

F. Unless otherwise specified by the Owner, the equipment used to haul and spread the vegetative cover layer shall not exert ground pressures exceeding the following:

Allowable Equipment Ground Pressure (psi)	*Minimum Thickness of Protective Soil Layer Above the Geosynthetic (inches)*
<5	12
<10	18
<20	24
>20	36

The maximum allowable equipment ground pressure shall be 65 psi. The acceptability of equipment operating at ground pressures greater than 65 psi will be evaluated by the Owner at the Contractor's expense.

G. Vegetative cover material shall be compacted by two passes of tracked equipment such as a Caterpillar D6H-LGP or other equipment approved by the Owner.

H. In areas of heavy traffic, the thickness of the vegetative cover layer shall be increased at the direction of the Owner to satisfy the requirements of this Section. Heavy traffic areas shall be compacted with a smooth drum roller or other equipment approved by the Owner.

I. The Contractor shall operate equipment in a manner that is protective of underlying geosynthetics. If it is suspected that any damage to the underlying geosynthetics may have occurred, the Owner will instruct the Contractor to remove overlying vegetative cover material to expose the geosynthetics. The Contractor shall repair, at his own expense, any damage of the underlying geosynthetics in accordance with these General Specifications.

J. The Contractor shall minimize to the extent possible the generation of dust during placement of the vegetative cover layer. Water may be used for dust control if approved by the Owner. Chemical dust suppressants shall not be used.

K. No vegetative cover material shall be placed or compacted during a sustained period of temperature below 32°F that results in frozen material, either in-place or in the borrow area. With the approval of the Owner, vegetative cover material may be placed and compacted during periods of early morning freezing temperatures if above-freezing temperatures are anticipated during the day.

L. The Contractor shall not place frozen vegetative cover material nor shall he place vegetative cover material on frozen ground.

M. Vegetative cover material shall not be placed during periods of precipitation or unfavorable weather conditions.

3.03 SURVEY CONTROL

A. The Surveyor shall survey the final location and elevation of the top of the vegetative cover layer installed by the Contractor. Surveying shall be performed in accordance with Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing of the location and elevation of the top of the vegetative cover layer to the Owner in accordance with the requirements of Section 01010 of these General Specifications.

3.04 FIELD QUALITY CONTROL

A. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

B. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at his own expense until acceptable test results are obtained.

3.05 PROTECTION OF WORK

A. After the vegetative cover layer has been placed, the Contractor shall maintain it free of ruts, depressions, and damage resulting from the hauling and handling of any material, equipment, tools, etc.

B. The Contractor shall use all means necessary to protect all materials and partially-completed and completed work of these General Specifications.

C. In the event of damage, the CQA Engineer will identify any areas requiring repair, and the Contractor shall make repairs and replacements necessary, to the approval of the Owner and at no additional cost to the Owner.

[END OF SECTION]

SECTION 02228
PIPE BEDDING

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary for the construction of pipe bedding material. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02714 - Filter or Cushion Geotextile
B. Section 02718 - Polyethylene Pipe and Fittings

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The Contractor shall be aware of all testing activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. Soil testing (both field and laboratory testing) required by the CQA Plan will be the responsibility of the CQA Engineer. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor. The Contractor shall cooperate with the CQA Engineer during all testing activities. The Contractor shall provide equipment and labor to assist the CQA Engineer in sampling. The Contractor shall provide access to all areas requiring testing. The Contractor shall repair any damage to finished work caused by the CQA Engineer sampling or testing activities.

D. The CQA Engineer will coordinate independent surveying required by the CQA Plan. Surveying by the CQA Engineer does not relieve the Contractor of his responsibility to lay out, control, and document the work.

E. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at no cost to the Owner until acceptable test results are obtained.

PART 2: PRODUCTS

2.01 MATERIALS

A. Pipe bedding material shall be obtained from the landfill or surface impoundment excavation or from on-site or off-site borrow sources.

B. Pipe bedding material shall classify as ML, SM, SP, SW, or GM according to the Unified Soil Classification System (ASTM D 2487) and shall have a maximum particle size not exceeding 1 inches.

PART 3: EXECUTION

3.01 PIPE BEDDING COMPACTION CRITERIA

A. The Contractor shall place and compact the soil as described in of this Section.

3.02 PLACEMENT AND COMPACTION

A. Pipe bedding shall be placed at the locations and to the thicknesses shown on the Construction Drawings.

B. The Contractor shall not place the pipe bedding material until the CQA Engineer confirms that the constructed grades and elevations of the underlying materials meet the requirements of the Construction Drawings, all field testing is complete, and the underlying materials have been installed, tested, and approved in accordance with the requirements of the CQA Plan.

C. Prior to placing the pipe bedding material, the CQA Engineer will verify that the underlying geosynthetic components are free of holes, tears, excessive wrinkles, or foreign objects. As instructed by the Owner, the Contractor shall "work out" or repair all excessive wrinkles to the satisfaction of the CQA Engineer prior to placement of the pipe bedding. In all cases, wrinkles in the geomembrane shall not be of a size that they could fold back on themselves.

D. Pipe bedding may be placed using a backhoe, front-end loader, belt conveyor, spreader box, or other method approved by the Owner. The maximum drop height is 3 feet.

E. The pipe bedding material shall be shovel sliced into the haunches of the pipe.

F. Contractor shall not operate equipment directly on geosynthetics when placing pipe bedding material.

G. The Contractor shall operate equipment in a manner that is protective of underlying polyethylene pipes and geosynthetics. If it is suspected that any damage to the underlying polyethylene pipes or geosynthetics may have occurred, the Owner will instruct the Contractor to remove overlying pipe bedding material to expose the potentially damaged materials. The Contractor shall repair, at his own expense, any damage of the underlying materials in accordance with these General Specifications.

H. No pipe bedding material shall be placed or compacted during a sustained period of temperature below 32°F that results in frozen material, either in-place or in the borrow area. With the approval of the Owner, pipe bedding material may be placed and compacted during periods of early morning freezing temperatures if above-freezing temperatures are anticipated during the day.

I. The Contractor shall not place frozen pipe bedding material.

J. Pipe bedding material shall not be placed during periods of precipitation or unfavorable weather conditions.

K. Pipe bedding material shall be compacted with two passes of a hand operated vibrating compactor such as a hand tamper or walk-behind vibrating compactor or other method approved by the Owner.

3.03 SURVEY CONTROL

A. The Surveyor shall survey the final location and elevation of the top of the pipe bedding material installed by the Contractor. Surveying shall be performed in accordance with Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing of the location and elevation of the top of the pipe bedding material to the Owner in accordance with the requirements of Section 01010 of these General Specifications.

3.04 FIELD QUALITY CONTROL

A. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

B. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at his own expense until acceptable test results are obtained.

3.05 PROTECTION OF WORK

A. After the pipe bedding material has been placed, the Contractor shall maintain it free of ruts, depressions, and damage resulting from the hauling and handling of any material, equipment, tools, etc.

B. The Contractor shall use all means necessary to protect all materials and partially-completed and completed work of these General Specifications.

C. In the event of damage, the CQA Engineer will identify any areas requiring repair, and the Contractor shall make repairs and replacements necessary, to the approval of the Owner and at no additional cost to the Owner.

[END OF SECTION]

SECTION 02229
SELECT SUBBASE

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, testing, and installation services necessary for the installation of select subbase where shown on the Construction Drawings. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02710 - Geocomposite Detection or Collection Layer
B. Section 02714 - Filter or Cushion Geotextile

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The Contractor shall be aware of all activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule.

C. On-site testing as specified in the CQA Plan for the select subbase (which does not include quality control testing at the source) will be the responsibility of the CQA Engineer. The Contractor shall cooperate with the CQA Engineer during all sampling and testing activities. The Contractor shall provide equipment and labor to assist the CQA Engineer in sampling. The Contractor shall provide access to all areas requiring testing. The Contractor will repair any damage to finished work caused by the CQA Engineer's sampling and testing activities.

D. Quality control testing (in accordance with Part 2.02 of this section) of the select subbase at the source shall be the responsibility of the Contractor.

PART 2: PRODUCTS

2.01 MATERIAL FOR SELECT SUBBASE

A. Select subbase for the work shall consist of clean, hard, durable, non-carbonate, rounded, sub-rounded to sub-angular particles which are free of metals, roots, trees, stumps, concrete, construction debris, other organic matter, and deleterious materials and coatings.

B. The select subbase shall be screened and washed to have a gradation (when tested in accordance with ASTM D 422) after placement equivalent to the following:

Sieve	Percent Passing
¼"	100
#10	50-80
#20	30-60
#40	10-40
#60	0-30
#100	0-10
#200	0-2

C. Select subbase shall have less than 5 percent loss of weight, when tested for calcium carbonate content in accordance with ASTM D 4373. This requirement may be waived by the owner if it can be otherwise demonstrated that the material contains no significant carbonate content.

2.02 SELECT SUBBASE SUPPLIER QUALITY CONTROL

A. The Contractor shall require that the select subbase Supplier sample and test the select subbase to demonstrate that the material conforms to the requirements of Part 2.01 of this section. The Contractor shall require the select subbase Supplier provide to the Owner written certification along with test results, that tests have been performed on representative samples of the material that will be delivered to the Owner's site. The analysis shall demonstrate that tests (i.e., ASTM D 422, ASTM D 2434, ASTM D 4373, ASTM C 131, and ASTM C 88) have been performed and that acceptable results were obtained.

B. If a select subbase sample fails to meet the quality control requirements of this General Specification, the Contractor shall require the Supplier to perform sufficient sampling and testing to identify the extent of the nonconforming material to the satisfaction of the CQA Engineer. The Contractor shall not use nonconforming material.

C. The Contractor shall require that the gravel Supplier comply with the certification and submittal requirements of the CQA Plan.

D. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

2.03 TRANSPORTATION

A. Transportation of select subbase shall be the responsibility of the Contractor.

2.04 HANDLING AND STORAGE

A. Handling, stockpiling, and protection of the select subbase prior to and following incorporation into the work is the responsibility of the Contractor. The Contractor shall be liable for contamination of the material incurred prior to final acceptance.

B. The Contractor shall be responsible for storage of the select subbase at the site. The Contractor shall store the select subbase at a location approved by the Owner and in such a manner so that it is not contaminated by dirt, mud, vegetation, or excessive dust. During stockpiling, the Contractor may elect to place the select subbase on a protective sheet and/or to cover it to prevent contamination. The CQA Engineer will identify contaminated material which will be rejected by the Owner.

PART 3: EXECUTION

3.01 SELECT SUBBASE COMPACTION CRITERIA

A. The compaction moisture content of the select subbase shall be between 3 percent and 3 percent above optimum moisture content determined in the modified Proctor compaction test (ASTM D 1557). The minimum dry unit weight of the select subbase shall be at least 95 percent of the maximum dry unit weight obtained from the modified Proctor compaction test (ASTM D 1557).

3.02 PLACEMENT AND COMPACTION

A. Select subbase shall be placed at the locations and to the thicknesses shown on the Construction Drawings

B. Select subbase shall not be placed directly on geosynthetics unless required by the General Specifications or Construction Drawings. Select subbase may be placed using a backhoe, front-end loader, belt conveyor, spreader box, or other method approved by the Owner in maximum 12-inch loose lifts.

C. Final spreading of the select subbase may be performed using a low ground-pressure dozer (Caterpillar D6H-LGP or other similar equipment approved by the CQA Engineer), low-ground pressure front-end loader, or by hand. The tracked equipment shall operate only over previously-placed select

subbase or other soil. The Contractor shall not operate equipment directly on geosynthetics.

D. Unless otherwise specified by the Owner, the equipment used to spread select subbase shall not exert ground pressures exceeding the following:

Allowable Equipment Ground Pressure (psi)	*Thickness of Gravel Above Geosynthetic (inches)*
<5	12
<10	18
<20	24
>20	36

The maximum allowable equipment ground pressure shall be 65 psi. The acceptability of equipment operating at ground pressures greater than 65 psi will be evaluated by the Owner at the Contractor's expense.

E. The Contractor shall operate equipment in a manner that is protective of polyethylene pipes and underlying geosynthetics. If it is suspected that damage to polyethylene pipes or underlying geosynthetics may have occurred, the Owner will instruct the Contractor to remove the overlying material to expose the potentially-damaged materials. The Contractor shall repair, at his own expense, any observed damage, in accordance with the requirements of these General Specifications.

3.03 FIELD QUALITY CONTROL

A. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

B. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at his own expense until acceptable test results are obtained.

3.04 PROTECTION OF WORK

A. After the select subbase has been incorporated into the work, the Contractor shall maintain it free of ruts, depressions, and damage resulting from the hauling and handling of any material, equipment, tools, etc.

B. The Contractor shall use all means necessary to protect all prior work, materials and completed and partially completed work of other Sections of these General Specifications.

C. In the event of damage, the CQA Engineer will identify areas requiring repair, and the Contractor shall make repairs and replacements necessary, to the approval of the Owner at no additional cost to the Owner.

3.05 SURVEY CONTROL

A. The Surveyor shall survey the final location and elevation of the top of the select subbase. Surveying shall be performed in accordance with of Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing to the Owner of the final location and elevation of the final surface of the road base, in accordance with the requirements of Section 01010 of these General Specifications.

[END OF SECTION]

SECTION 02230
SUBBASE

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, testing, and installation services necessary for the installation of subbase where shown on the Construction Drawings. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02110 - Site Preparation and Earthwork
B. Section 02225 - Road Base

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The Contractor shall be aware of all activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. On-site testing as specified in the CQA Plan for the subbase (which does not include quality control testing at the source) will be the responsibility of the CQA Engineer. The Contractor shall cooperate with the CQA Engineer during all sampling and testing activities. The Contractor shall provide equipment and labor to assist the CQA Engineer in sampling. The Contractor shall provide access to all areas requiring testing. The Contractor will repair any damage to finished work caused by the CQA Engineer's sampling and testing activities.

D. Quality control testing of the subbase at the source shall be the responsibility of the Contractor.

E. The CQA Engineer will coordinate independent surveying required by the CQA Plan. Surveying by the CQA Engineer does not relieve the Contractor of his responsibility to lay out, control, and document the work.

F. If the CQA Engineer's tests indicate work does not meet the requirements of the specification, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at no cost to the Owner until acceptable test results area obtained.

PART 2: PRODUCTS

2.01 MATERIAL FOR SUBBASE

A. Subbase for the work shall obtained from the landfill or surface impoundment excavation or from on-site or off-site borrow sources. Subbase material shall be free of metals, roots, trees, stumps, concrete, construction debris, other organic matter, and deleterious materials and coatings.

B. The subbase shall classify as SM, SW, GM, or GW according to the Unified Soil Classification System (ASTM D2487) and shall have a maximum particle size of 3 inches.

PART 3: EXECUTION

3.01 SUBBASE COMPACTION CRITERIA

A. The compaction moisture content of the subbase shall be between 3 percent and 3 percent above optimum moisture content determined in the modified Proctor compaction test (ASTM D 1557). The minimum dry unit weight of the subbase shall be at least 95 percent of the maximum dry unit weight obtained from the modified Proctor compaction test (ASTM D 1557).

3.02 PLACEMENT AND COMPACTION

A. Subbase shall be placed at the locations and to the thicknesses shown on the Construction Drawings

B. Subbase shall not be placed directly on geosynthetics unless required by the General Specifications or Construction Drawings. Subbase may be placed using a backhoe, front-end loader, belt conveyor, spreader box, or other method approved by the Owner in maximum 12-inch loose lifts.

C. Final spreading of the subbase may be performed using a low ground-pressure dozer (Caterpillar D6H-LGP or other similar equipment approved by the CQA Engineer), low-ground pressure front-end loader, or by hand. The tracked equipment shall operate only over previously-placed subbase or other soil. The Contractor shall not operate equipment directly on geosynthetics.

D. Unless otherwise specified by the Owner, the equipment used to spread subbase shall not exert ground pressures exceeding the following:

Allowable Equipment Ground Pressure (psi)	*Thickness of Gravel Above Geosynthetic (inches)*
<5	12
<10	18
<20	24
>20	36

The maximum allowable equipment ground pressure shall be 65 psi. The acceptability of equipment operating at ground pressures greater than 65 psi will be evaluated by the Owner at the Contractor's expense.

E. The Contractor shall operate equipment in a manner that is protective of polyethylene pipes and underlying geosynthetics. If it is suspected that damage to polyethylene pipes or underlying geosynthetics may have occurred, the Owner will instruct the Contractor to remove the overlying material to expose the potentially-damaged materials. The Contractor shall repair, at his own expense, any observed damage, in accordance with the requirements of these General Specifications.

3.03 FIELD QUALITY CONTROL

A. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

B. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at his own expense until acceptable test results are obtained.

3.04 PROTECTION OF WORK

A. After the subbase has been incorporated into the work, the Contractor shall maintain it free of ruts, depressions, and damage resulting from the hauling and handling of any material, equipment, tools, etc.

B. The Contractor shall use all means necessary to protect all prior work, materials and completed and partially completed work of other Sections of these General Specifications.

C. In the event of damage, the CQA Engineer will identify areas requiring repair, and the Contractor shall make repairs and replacements necessary, to the approval of the Owner at no additional cost to the Owner.

3.05 SURVEY CONTROL

A. The Surveyor shall survey the final location and elevation of the top of the road base. Surveying shall be performed in accordance with of Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing to the Owner of the final location and elevation of the final surface of the road base, in accordance with the requirements of Section 01010 of these General Specifications.

[END OF SECTION]

SECTION 02231
FOUNDATION SAND

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, testing, and installation services necessary for the installation of foundation sand where shown on the Construction Drawings. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02110 - Site Preparation and Earthwork
B. Section 02718 - Polyethylene Pipe and Fittings
C. Section 02775 - Geomembrane Liners

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The Contractor shall be aware of all activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. On-site testing as specified in the CQA Plan for the foundation sand will be the responsibility of the CQA Engineer. The Contractor shall cooperate with the CQA Engineer during all sampling and testing activities. The Contractor shall provide equipment and labor to assist the CQA Engineer in sampling. The Contractor shall provide access to all areas requiring testing. The Contractor will repair any damage to finished work caused by the CQA Engineer's sampling and testing activities.

D. Quality control testing of the foundation sand at the source shall be the responsibility of the Contractor.

E. The CQA Engineer will coordinate independent surveying required by the CQA Plan. Surveying by the CQA Engineer does not relieve the Contractor of his responsibility to lay out, control, and document the work.

F. If the CQA Engineer's tests indicate work does not meet the requirements of the specification, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at no cost to the Owner until acceptable test results area obtained.

PART 2: PRODUCTS

2.01 MATERIAL FOR FOUNDATION SAND

A. Foundation sand for the work shall obtained from the landfill or surface impoundment excavation or from on-site or off-site borrow sources. Foundation sand material shall be free of metals, roots, trees, stumps, concrete, construction debris, other organic matter, and deleterious materials and coatings.

B. The foundation sand shall classify as SM or SW according to the Unified Soil Classification System (ASTM D2487) and shall have a maximum particle size of 1/4 inches.

PART 3: EXECUTION

3.01 FOUNDATION SAND COMPACTION CRITERIA

A. The compaction moisture content of the foundation sand shall be between 3 percent and 3 percent above optimum moisture content determined in the modified Proctor compaction test (ASTM D 1557). The minimum dry unit weight of the foundation shall be at least 95 percent of the maximum dry unit weight obtained from the modified Proctor compaction test (ASTM D 1557).

3.02 PLACEMENT AND COMPACTION

A. Foundation sand shall be placed at the locations and to the thicknesses shown on the Construction Drawings

B. Foundation sand shall not be placed directly on geosynthetics unless required by the General Specifications or Construction Drawings. Foundation sand may be placed using a backhoe, front-end loader, belt conveyor, spreader box, or other method approved by the Owner in maximum 12-inch loose lifts.

C. Final spreading of the foundation sand may be performed using a low ground-pressure dozer (Caterpillar D6H-LGP or other similar equipment approved by the CQA Engineer), low-ground pressure front-end loader, or by

hand. The tracked equipment shall operate only over previously-placed foundation sand or other soil. The Contractor shall not operate equipment directly on geosynthetics.

D. Unless otherwise specified by the Owner, the equipment used to spread subbase shall not exert ground pressures exceeding the following:

Allowable Equipment Ground Pressure (psi)	*Thickness of Gravel Above Geosynthetic (inches)*
<5	12
<10	18
<20	24
>20	36

The maximum allowable equipment ground pressure shall be 65 psi. The acceptability of equipment operating at ground pressures greater than 65 psi will be evaluated by the Owner at the Contractor's expense.

E. The Contractor shall operate equipment in a manner that is protective of polyethylene pipes and underlying geosynthetics. If it is suspected that damage to polyethylene pipes or underlying geosynthetics may have occurred, the Owner will instruct the Contractor to remove the overlying material to expose the potentially-damaged materials. The Contractor shall repair, at his own expense, any observed damage, in accordance with the requirements of these General Specifications.

3.03 FIELD QUALITY CONTROL

A. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

B. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at his own expense until acceptable test results are obtained.

3.04 PROTECTION OF WORK

A. After the foundation sand has been incorporated into the work, the Contractor shall maintain it free of ruts, depressions, and damage resulting from the hauling and handling of any material, equipment, tools, etc.

B. The Contractor shall use all means necessary to protect all prior work, materials and completed and partially completed work of other Sections of these General Specifications.

C. In the event of damage, the CQA Engineer will identify areas requiring repair, and the Contractor shall make repairs and replacements necessary, to the approval of the Owner at no additional cost to the Owner.

3.05 SURVEY CONTROL

A. The Surveyor shall survey the final location and elevation of the top of the road base. Surveying shall be performed in accordance with of Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing to the Owner of the final location and elevation of the final surface of the road base, in accordance with the requirements of Section 01010 of these General Specifications.

[END OF SECTION]

SECTION 02232
PROTECTIVE SOIL LAYER

PART 1 GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary for the construction of the protective soil layer component of the landfill. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

B. This specification shall also apply to polyethylene pipe and fitting installation in the truck roll off area, the drum handling facility, the truck wash facility, and the liquid waste storage area, unless otherwise indicated on the drawings.

1.02 RELATED SECTIONS

A. Section 02710 - Geocomposite
B. Section 02714 - Filter or Cushion Geotextile

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The Contractor shall be aware of all testing activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. Soil testing (both field and laboratory testing) required by the CQA Plan will be the responsibility of the CQA Engineer. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor. The Contractor shall cooperate with the CQA Engineer during all testing activities. The Contractor shall provide equipment and labor to assist the CQA Engineer in sampling. The Contractor shall provide access to all areas requiring testing. The Contractor shall repair any damage to finished work caused by the CQA Engineer sampling or testing activities.

D. The CQA Engineer will coordinate independent surveying required by the CQA Plan. Surveying by the CQA Engineer does not relieve the Contractor of his responsibility to lay out, control, and document the work.

E. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at no cost to the Owner until acceptable test results are obtained.

PART 2: PRODUCTS

2.01 MATERIALS

A. Protective soil layer material shall be obtained from the landfill or surface impoundment excavation or from on-site or off-site borrow sources identified by the Owner.

B. Protective soil layer material shall classify as CL, ML, SC, GC, SM, or GM according to the Unified Soil Classification System (ASTM D 2487) and shall have a maximum particle size not exceeding 2 inches.

PART 3: EXECUTION

3.01 PROTECTIVE SOIL LAYER COMPACTION CRITERIA

A. The Contractor shall place and compact the soil as described in of this Section.

3.02 PLACEMENT AND COMPACTION

A. Protective soil layer material shall be placed at the locations and to the thicknesses shown on the Construction Drawings.

B. The Contractor shall not place the protective soil layer until the CQA Engineer confirms that the constructed grades and elevations of the underlying materials meet the requirements of the Construction Drawings, all field testing is complete, the underlying materials have been installed, tested, and approved in accordance with the requirements of the CQA Plan.

C. Prior to placing the protective soil layer, the CQA Engineer will verify that the underlying geosynthetic components are free of holes, tears, excessive wrinkles, or foreign objects. As instructed by the Owner, the Contractor shall "work out" or repair all excessive wrinkles to the satisfaction of the CQA Engineer prior to placement of the protective soil layer.

D. The final in-place thickness of the protective soil layer shall be not less than 24 inches or as shown on the drawings.

E. The protective soil material shall be spread in one lift using a low ground pressure dozer (Caterpillar D6H-LGP, or other equipment approved by the Owner), low ground pressure tracked front-end loader, or belt conveyor. Equipment shall operate only over previously placed protective soil layer material. The Contractor shall not operate equipment directly on geosynthetics.

F. Unless otherwise specified by the Owner, the equipment used to haul and spread the protective soil layer shall not exert ground pressures exceeding the following:

Allowable Equipment Ground Pressure (psi)	*Minimum Thickness of Protective Soil Layer Above the Geosynthetic Liner (inches)*
<5	12
<10	18
<20	24
>20	36

The maximum allowable equipment ground pressure shall be 65 psi. The acceptability of equipment operating at ground pressures greater than 65 psi will be evaluated by the Owner at the Contractor's expense.

G. Protective soil layer material shall be compacted by two passes of tracked equipment such as a Caterpillar D6H-LGP or other equipment approved by the Owner.

H. In areas of heavy traffic, the thickness of the protective soil layer shall be increased at the direction of the Owner to satisfy the requirements of this Section. Heavy traffic areas shall be compacted with a smooth drum roller or other equipment approved by the Owner.

I. The Contractor shall operate equipment in a manner that is protective of underlying geosynthetics. If it is suspected that any damage to the underlying geosynthetics may have occurred, the Owner will instruct the Contractor to remove overlying protective soil layer material to expose the geosynthetics. The Contractor shall repair, at his own expense, any damage of the underlying geosynthetics in accordance with these General Specifications.

J. The Contractor shall minimize to the extent possible the generation of dust during placement of the protective soil layer. Water may be used for dust control if approved by the Owner. Chemical dust suppressants shall not be used.

K. No protective soil layer material shall be placed or compacted during a sustained period of temperature below 32°F that results in frozen material, either in-place or in the borrow area. With the approval of the Owner,

protective soil layer material may be placed and compacted during periods of early morning freezing temperatures if above freezing temperatures are anticipated during the day.

L. The Contractor shall not place frozen protective soil layer material nor shall he place protective soil layer material on frozen ground.

M. Protective soil layer material shall not be placed during periods of precipitation or unfavorable weather conditions.

3.03 SURVEY CONTROL

A. The Surveyor shall survey the final location and elevation of the top of the protective soil layer installed by the Contractor. Surveying shall be performed in accordance with Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing of the location and elevation of the top of the protective soil layer to the Owner in accordance with the requirements of Section 01010 of these General Specifications.

3.04 FIELD QUALITY CONTROL

A. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

B. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at his own expense until acceptable test results are obtained.

3.05 PROTECTION OF WORK

A. After the protective soil layer has been placed, the Contractor shall maintain it free of ruts, depressions, and damage resulting from the hauling and handling of any material, equipment, tools, etc.

B. The Contractor shall use all means necessary to protect all materials and partially-completed and completed work of these General Specifications.

C. In the event of damage, the CQA Engineer will identify any areas requiring repair, and the Contractor shall make repairs and replacements necessary, to the approval of the Owner and at no additional cost to the Owner.

[END OF SECTION]

SECTION 02710
GEOCOMPOSITE

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary for the installation of the geocomposite layer of the landfill or surface impoundment. The work shall be carried out in accordance with these General Specifications, Supplemental Specifications, the CQA Plan, and the Construction Drawings.

B. This specification shall also apply to geocomposite installation in the truck roll off area and truck wash facility, unless otherwise indicated on the drawings.

1.02 RELATED SECTIONS

A. Section 02221 - Clay Liner
B. Section 02229 - Select Subbase
C. Section 02714 - Filter or Cushion Geotextile
D. Section 02232 - Protective Soil Layer
E. Section 02775 - Geomembrane Liners

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The Contractor shall be aware of all activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. If testing is not completed prior to delivery to the site, the Contractor shall deliver geocomposite to the site at least 14 calendar days prior to installation to allow sufficient time for testing required by the CQA Plan.

D. Any geocomposite rolls that do not meet the requirements of these General Specifications will be rejected. The Contractor shall replace the rejected material with new material that conforms to the specification requirements, at no additional cost to the Owner.

E. If the CQA Engineer's test indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at no cost to the Owner until acceptable test results are obtained.

PART 2: PRODUCTS

2.01 GEOCOMPOSITE PROPERTIES

A. The Contractor shall require that the geocomposite Manufacturer furnish material with minimum average roll values, as defined by the Federal Highway Administration (FHWA), meeting or exceeding the criteria specified in Table 02710-1. The Contractor shall require that the Manufacturer provide results for tests performed using the procedures listed in Table 02710-1, as well as a certification that the material delivered to the site meets or exceeds the specified values.

B. In addition to the property values listed in Table 02710-1, the geocomposite shall:

1. Retain its structure during handling, placement, and long-term service.

2. Be capable of withstanding outdoor (i.e., ultra-violet light) exposure for a minimum of 30 days with no measurable degradation in the specified physical properties.

3. Meet any additional requirements of the Construction Drawings.

4. Be manufactured with a geonet that does not contain any reclaimed polymer, nor any foaming or blowing agents.

5. Consist of a geonet with a geotextile bonded to both sides of geonet.

2.02 MANUFACTURING QUALITY CONTROL

A. The Contractor shall require that the geocomposite Manufacturer sample and test the geocomposite to demonstrate that the material conforms to the requirements of these General Specifications. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor. Test results shall be provided to the Owner. Sampling shall, in general, be performed on sacrificial portions of the geocomposite material such that repair is not required. The Contractor shall require that the geocomposite Manufacturer sample and test the geocomposite at a minimum of once every 50,000 ft^2 and perform manufacturing quality control tests as indicated in Table 02710-1.

B. Any geocomposite sample that does not comply with these General Specifications shall result in rejection of the roll from which the sample was obtained. The Contractor shall replace any rejected rolls at no additional cost to the Owner.

C. If a geocomposite sample fails to meet the quality control requirements of this General Specification the Contractor shall require that the geocomposite Manufacturer sample and test each roll manufactured in the same lot, or at the same time, as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results as determined by the CQA Engineer is established.

D. Additional sample testing may be performed, at the geocomposite Manufacturer's discretion and expense, to more closely identify any non-complying rolls and/or to qualify individual rolls.

E. If required by the Owner, the Contractor shall require the geocomposite Manufacturer to retain a coupon of geocomposite (10 feet by 2 feet) provided for the project for every 20,000 ft^2 of geocomposite produced for the project until the work is accepted by the Owner.

F. The Contractor shall require that the geocomposite Manufacturer comply with the certification and submittal requirements of the CQA Plan.

2.03 LABELING

A. Geocomposite rolls shall be labeled with the following information.

1. Name of Manufacturer;
2. Product identification;
3. Lot number;
4. Roll number; and,
5. Roll dimensions.

B. If any special handling is required, it shall be so marked on the geocomposite itself, e.g., "This Side Up" or "This Side Against Soil To Be Retained".

2.04 TRANSPORTATION

A. Transportation of the geocomposite shall be the responsibility of the Contractor. The Contractor shall be liable for damage to the geocomposite incurred prior to and during transportation to the site. The Contractor shall replace damaged rolls at no additional cost to the Owner.

2.05 HANDLING AND STORAGE

A. Geocomposite shall be shipped and stored in watertight and opaque protective covers.

B. Handling, storage, and care of the geocomposite prior to and following incorporation into the work is the responsibility of the Contractor. The Contractor shall be liable for damage to the material incurred prior to final acceptance by the Owner. The Contractor shall repair damage in accordance with Part 3.03 of this section and at no additional cost the Owner.

C. The Contractor shall be responsible for storage of the geocomposite at the site. The geocomposite shall be stored off the ground and out of direct sunlight and shall be protected from puncture, cutting, and excessive heat, cold, moisture, mud, dirt, dust or any other damaging or deleterious condition. The geocomposite shall be stored in accordance with any additional requirements of the geocomposite Manufacturer.

PART 3: EXECUTION

3.01 HANDLING AND PLACEMENT

A. Geocomposite shall be installed at all locations shown on the Construction Drawings.

B. The Contractor shall handle the geocomposite in such a manner as to ensure the geocomposite is not damaged in any way.

C. When placing geocomposite on geomembrane, the geomembrane liner that will underlie the geocomposite shall be clean and free of excessive dust and dirt, stones, rocks, or other obstructions that could potentially damage the geomembrane. The geomembrane shall be swept clean prior to geocomposite placement. At the direction of the Owner, the Contractor shall clean the geomembrane with water.

D. The Contractor shall take all necessary precautions to prevent damage to underlying layers during placement of the geocomposite.

E. In the presence of excessive wind, the Contractor shall weight the geocomposite with sandbags or equivalent weight approved by the Owner.

F. On side slopes, the geocomposite shall be secured, by the Contractor, at the top of the slope and then rolled down the slope.

G. If necessary, the Contractor shall position the geocomposite by hand after it is unrolled to minimize wrinkles.

H. Geocomposite shall be clean when installed. During installation, care shall be taken by the Contractor not to entrap stones, excessive dirt, or moisture that could damage the underlying geomembrane, clog drains or filters, or hamper subsequent seaming.

I. Geocomposite shall not be welded to the geomembrane liners. Geocomposite shall only be cut using a cutter approved by the geocomposite Manufacturer and the Owner.

J. Tools shall not be left on or in the geocomposite.

K. After placing the geocomposite, the geocomposite shall not be left exposed for a period in excess of 30 days unless a longer exposure period is approved by the Owner based on a formal demonstration from the Contractor (e.g., a certification from the geocomposite Manufacturer) that the geotextile component of the geocomposite is stabilized against ultra-violet (UV) light degradation for a period in excess of 30 days.

L. If white colored geotextile is used in the geocomposite, precautions shall be taken against "snow blindness" of personnel.

3.02 SEAMS AND OVERLAPS

A. The components of the geocomposite (e.g., geotextile-geonet-geotextile) are not bonded together at the ends and edges of the rolls. Each component shall be secured or seamed to the like component at overlaps.

B. No horizontal seams shall be allowed on slopes steeper than 5:1 (horizontal:vertical), unless approved by the Owner.

C. *Geonet Components*

1. The geonet components shall be overlapped by at least 4 inches. These overlaps shall be secured by tying.

2. Tying shall be achieved by nylon strings, plastic fasteners, or polymer braid. Metallic devices shall not be used. Tying devices shall be provided in a color different than the geonet to allow easy inspection.

3. For slopes steeper than 5:1 (horizontal:vertical), tying shall be every 5 feet along the slope, every 2 feet across the slope, and every 6 inches in the anchor trench. For slopes flatter than 5:1 (horizontal:vertical), tying shall be every 10 feet in both directions and every 6 inches in the anchor trench.

4. In all cases, at least 2 ties per panel dimension shall be installed.

5. When more than one layer of geocomposite is installed, joints shall be staggered at least 1 foot.

6. The joints on adjacent geocomposite panels shall be staggered at least 1 foot.

D. *Geotextile Components*

1. The bottom layers of the geotextile shall be overlapped.

2. The top layers of geotextiles shall be continuously sewn (i.e., spot sewing is not allowed). Geotextiles shall be overlapped a minimum of 3 inches prior to sewing.

3. Polymeric thread shall be used for all sewing. The seam type shall be Federal Standard (No. 751.a) Type SSa. The seams shall be sewn using Stitch Type 401.

E. *Geocomposite Components*

1. The geocomposite shall be overlapped by at least 4 inches. These overlaps shall be secured by tying.

2. Cut geocomposite using scissors or other cutting tools, approved by the Owner. Do not damage underlying geosynthetics.

3. Tying shall be achieved by nylon strings, plastic fasteners, or polymer braid. Metallic devices shall not be used. Tying devices shall be provided in a color different than the geocomposite to allow easy inspection.

4. For slopes steeper than 5:1 (horizontal:vertical), tying shall be every 5 feet along the slope, every 2 feet across the slope, and every 6 inches in the anchor trench. For slopes flatter that 5:1 (horizontal:vertical), tying shall be every 10 feet in both directions and every 6 inches in the anchor trench.

5. In all cases, at least 2 ties per panel dimension shall be installed.

6. When more than one layer of geocomposite is installed, joints shall be staggered at least 1 foot.

7. The joints on adjacent geocomposite panels shall be staggered at least 1 foot.

8. In areas where this installation method is used, place geotextile over seams which overlap ties 1 foot on each side. This geotextile shall be heat sealed to the top of the geotextile component of the geocomposite.

3.03 REPAIR

A. Any holes or tears in the geocomposite shall be repaired by placing a patch extending 1 foot beyond the edges of the hole or tear. The patch shall be secured over the hole or tear by tying fasteners through the geocomposite patch, and through the top geotextile and geonet beneath the patch. The patch shall be secured every 6 inches with approved tying devices. A larger geotextile patch shall be placed over the geocomposite patch and shall be heat sealed to the top geotextile of the geocomposite needing repair. If the hole or tear width across the roll is more than 50 percent of the width of the roll, the damaged area shall be cut out and the two portions of the geocomposite shall be joined in accordance with Part 3.02 of this section.

3.04 PLACEMENT OF OVERLYING MATERIALS

A. Overlying materials as required by the Construction Drawings, shall be placed as soon as possible after placement and approval of the geocomposite. Placement of each overlying material shall be in accordance with the appropriate sections of these General Specifications.

B. The Contractor shall place overlying soil materials in such a manner as to ensure that:

1. The geocomposite and underlying geosynthetic materials are not damaged;

2. Minimal slippage occurs between the geocomposite and underlying layers; and,

3. Excessive stresses are not produced in the geocomposite.

C. Unless otherwise specified by the Owner, the equipment operating on soil material overlying a geocomposite shall comply with the following:

Maximum Allowable Equipment Ground Pressure (psi)	*Thickness of Soil Above Geocomposite (inches)*
<5	12
<10	18
<20	24
>20	36

The maximum allowable equipment ground pressure shall be 65 psi. The acceptability of equipment operating at ground pressures greater than 65 psi will be evaluated by the Owner at the Contractor's expense.

The requirements do not apply to equipment used to construct the sump secondary or primary clay liners; however, the Owner can restrict the use of equipment that, in the Owner's opinion, may be potentially damaging to the geocomposite.

D. The CQA Engineer will provide monitoring of the spreading of soils over the geocomposite in accordance with the CQA Plan.

3.05 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all materials and partially completed and completed work of these General Specifications.

B. The CQA Engineer will identify any areas requiring repair. The Contractor shall immediately make repairs and replacements necessary, to the approval of the Owner and at no additional cost to Owner.

C. The CQA Engineer will issue an approval of the geocomposite installation to the Owner prior to placement of material over the geocomposite in accordance with the CQA Plan.

TABLE 02710-1
REQUIRED GEOCOMPOSITE PROPERTIES

Properties	Units	Specified Values[4]	Test Method
Geonet Component:			
Polymer composition	%	95 polyethylene by weight	
Polymer specific gravity		0.92	ASTM D 1505
Polymer melt index	g/10 min.	0.1 - 0.5	ASTM D 1238
Carbon black content	%	2 - 3	ASTM D 1603
Nominal thickness	mm	5	ASTM D 374C or D1777
Geotextile Component (both sides of geonet):			
Polymer composition	%	95 polyester polypropylene, or polyethylene by weight	
Mass per unit area	oz/yd^2	7.1	ASTM D 3776
Apparent opening size	mm	$O_{95} < 0.210$ mm	ASTM D 4751
Permitivity	sec^{-1}	1.47	ASTM D 4491
Grab strength	lb	210	ASTM D 4632[1]
Tear strength	lb	75	ASTM D 4533[2]
Puncture strength	lb	95	ASTM D 4833[3]
Geocomposite:			
Transmissivity	m^2/s	2×10^{-4}	ASTM D 4716[5]
Peel Strength	lb/in.	2	ASTM D 413

NOTES:

(1) Minimum of values measured in machine and cross machine directions with 1 inch clamp on constant rate of extension (CRE) machine.

(2) Minimum value measured in machine and cross machine direction.

(3) Tension testing machine with a 1.75-inch diameter ring clamp, the steel ball being replaced with a 0.31-inch diameter solid steel cylinder with flat tip centered within the ring clamp.

(4) Values represent minimum average roll values (i.e., any roll in a lot should meet or exceed the values in this table). Where ranges of values are specified, the average roll value must be within the specified range. The apparent opening size specified is a maximum average roll value.

(5) The design transmissivity is the hydraulic transmissivity of the geocomposite measured using water at 68°F ± 3°F with a hydraulic gradient of 0.1, under a compressive stress of not less than 10,000 psf. For the test, the geocomposite shall be sandwiched between a layer of protective soil material representative of the material that will be used in the landfill and a 60-mil thick HDPE geomembrane. The minimum test duration shall be 24 hours and the report of results shall include measurements at intervals over the entire test duration.

[END OF SECTION]

SECTION 02712
GEONET

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary for the installation of the geonet for the landfill or surface impoundment. The work shall be carried out in accordance with this General Specification, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02221 - Clay Liner
B. Section 02775 - Geomembrane Liners

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

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

B. The Contractor shall be aware of all activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. If CQA testing is not completed prior to delivery at the site, the Contractor shall deliver geonet to the site at least 14 calendar days prior to installation to allow sufficient time for testing required by the CQA Plan.

D. Any geonet rolls that do not meet the requirements of these General Specifications will be rejected. The Contractor shall replace the rejected material with new material that conforms to the specification requirements, at no additional cost to the Owner.

E. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at no cost to the Owner until acceptable test results are obtained.

PART 2: PRODUCTS

2.01 GEONET PROPERTIES

A. The Contractor shall require that the geonet Manufacturer furnish material with minimum average roll values, as defined by the Federal Highway Administration (FHWA), meeting or exceeding the criteria specified in Table 02712-1. The Contractor shall require that the geonet Manufacturer provide results for tests performed using the procedures listed in Table 02712-1, as well as a certification that the material properties for the material delivered to the site will meet or exceed the specified values.

B. In addition to the property values listed in Table 02712-1, the geonet shall:

1. Retain its structure during handling, placement, and long-term service.

2. Meet any additional requirements of the Construction Drawings.

3. Not be manufactured from any reclaimed polymer, nor any foaming or blowing agents.

2.02 MANUFACTURING QUALITY CONTROL

A. The Contractor shall require that the geonet Manufacturer sample and test the geonet to demonstrate that the material conforms to the requirements of these General Specifications. All Quality Control testing required by the General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor. Test results shall be provided to the Owner. Sampling shall, in general, be performed on sacrificial portions of the geonet material such that repair is not required. The Contractor shall require that the geonet Manufacturer sample and test the geonet, at a minimum, once every 50,000 ft^2 and perform the manufacturing quality control tests indicated in Table 02712-1.

B. Any geonet sample that does not comply with these General Specifications shall result in rejection of the roll from which the sample was obtained. The Contractor shall replace any rejected rolls at no additional cost to the Owner.

C. If a geonet sample fails to meet the quality control requirements of these General Specifications, the Contractor shall require that the geonet Manufacturer sample and test each roll manufactured, in the same lot, or at the same time, as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established as specified within the CQA Plan.

D. Additional sample testing may be performed, at the geonet Manufacturer's discretion and expense, to more closely identify any non-complying rolls and/or to qualify individual rolls.

E. If requested by Owner, the Contractor shall require the geonet Manufacturer to retain a coupon of geonet (10 feet by 2 feet) provided for the project for every 20,000 ft^2 of geonet produced for the project until the work is accepted by the Owner.

F. The Contractor shall require that the geonet Manufacturer comply with the certification and submittal requirements of the CQA Plan.

2.03 LABELING

A. Geonet rolls shall be labeled with the following information.

1. Name of Manufacturer;
2. Product identification;
3. Lot number;
4. Roll number; and,
5. Roll dimensions.

2.04 TRANSPORTATION

A. Transportation of geonet shall be the responsibility of the Contractor. The Contractor shall be liable for damage to the geonet incurred prior to and during transportation to the site. The Contractor shall repair or replace damaged rolls at no additional cost to the Owner.

2.05 HANDLING AND STORAGE

A. Geonet shall be protected from damage during shipping and storage.

B. Handling, storage, and care of the geonet prior to and following incorporation into the work is the responsibility of the Contractor. The Contractor shall be liable for damage to the material incurred prior to final acceptance by the Owner. The Contractor shall repair damage in accordance with Part 3.03 of this Section and at no additional cost to the Owner.

C. The Contractor shall be responsible for storage of the geonet at the site. The geonet shall be stored off the ground and shall be protected from excessive heat or cold, moisture mud, dirt, dust, or any other damaging or deleterious condition. The geonet shall be stored in accordance with any additional requirements of the geonet Manufacturer.

PART 3: EXECUTION

3.01 HANDLING AND PLACEMENT

A. Geonet shall be installed at all locations shown on the Construction Drawings.

B. The Contractor shall handle the geonet in such a manner as to ensure the geonet is not damaged in any way.

C. Just prior to geonet placement, the geomembrane liner that will underlie the geonet shall be clean and free of dust, dirt, stones, rocks, or other obstructions that could potentially damage the geomembrane. The geomembrane shall be swept clean prior to geonet placement. At the direction of the Owner, the Contractor shall clean the geomembrane with water.

D. The Contractor shall take all necessary precautions to prevent damage to underlying layers during placement of the geonet.

E. In the presence of excessive wind, the geonet shall be weighted by the Contractor with sandbags or equivalent weight approved by the Owner.

F. On side slopes, the geonet shall be secured by the Contractor at the top of slope and then rolled down the slope.

G. If necessary, the Contractor shall position the geonet by hand after it is unrolled to minimize wrinkles.

H. Geonet shall be clean when installed. During installation, care shall be taken by the Contractor not to entrap stones and excessive dirt or moisture that could damage the underlying geomembrane or clog drains or filters.

I. Geonet shall not be welded to geomembrane liners. Geonet shall only be cut using a cutter approved by the geonet Manufacturer and the Owner.

J. Tools shall not be left on or in the geonet.

K. Geonet shall not be placed in direct contact with textured geomembrane liner unless specifically called for on the Construction Drawings.

3.02 STACKING AND JOINING

A. When two or more layers of geonets are stacked, care shall be taken to prevent the strands of one layer of geonet from penetrating the channels of an overlying or underlying layer.

B. A layer of geonet shall not be installed in a direction perpendicular to an underlying layer of geonet unless approved by the Owner.

C. In the corners of the side slopes, where overlaps between perpendicular geonet strips are required, an extra layer of geonet shall be provided on top of the previously installed geonets, from top to bottom of the slope, as shown on the Construction Drawings.

D. Adjacent rolls of geonet shall be overlapped by at least 4 inches. The overlaps shall be secured by tying.

E. Tying shall be achieved by nylon strings, plastic fasteners, or polymer braid. Metallic devices shall not be used. Tying devices shall be provided in a color different than the geonet to allow for easy inspection.

F. For slopes steeper than 5:1 (horizontal:vertical), tying shall be every 5 feet along the slope, every 2 feet across the slope, and every 6 inches in the anchor trench. For slopes flatter than 5:1 (horizontal:vertical), tying shall be every 10 feet in both directions, and every 6 inches in the anchor trench.

G. In all cases, at lease 2 ties per panel dimension shall be installed.

H. When more than one layer of geonet is installed, joints shall be staggered at least 1 foot.

I. The joints on adjacent geonet panels shall be staggered at least 1 foot.

J. No horizontal seams shall be allowed on slopes steeper than 5:1 (horizontal:vertical), unless approved by the Owner.

3.03 REPAIR

A. Any holes or tears in the geonet shall be repaired by placing a patch over the hole or tear extending 1 foot beyond the edges of the hole or tear. The patch shall be secured to the original geonet by tying every 6 inches with approved tying devices. If the hole or tear width across the roll is more than 50 percent of the width of the roll, the damaged area shall be cut out and the two portions of the geonet shall be joined in accordance with Part 3.02 of this section.

3.04 PLACEMENT OF OVERLYING MATERIALS

A. An installed layer of geonet shall be covered with an overlying layer (geotextile or geomembrane), as required by the Construction Drawings, as soon as possible after installation and approval to minimize the accumulation of dirt or dust in the geonet and the potential for damage to the geonet or the underlying geomembrane. If dust or dirt accumulates in the geonet layer prior to placement of the overlying layer, the Contractor shall clean the geonet by sweeping or washing with water. Placement of each overlying material shall be in accordance with these General Specifications.

B. Soil shall not be placed in direct contact with geonets. Geonets shall be separated from soil materials by a geotextile filter or other material, as indicated on the Construction Drawings. The only exception to this shall be at those locations shown on the Construction Drawings where sump or pipe bedding gravel directly overlies one or more layers of geonet.

C. The Contractor shall place soil above geonet layers (e.g., above a geotextile filter which overlies the geonet) in such a manner as to ensure that:

1. The geonet and underlying geomembrane are not damaged;

2. Minimal slippage occurs between the geonet and the underlying geomembrane; and,

3. Excessive stresses are not produced in the geonet.

D. Unless otherwise specified by the Owner, all equipment operating on soil material overlying a geonet shall comply with the following:

Maximum Allowable Equipment Ground Pressure (psi)	*Thickness of Soil Above Geonet (inches)*
<5	12
<10	18
<20	24
>20	36

The maximum allowable equipment ground pressure shall be 65 psi. The acceptability of equipment operating at ground pressures greater than 65 psi will be evaluated by the Owner at the Contractor's expense.

The equipment pressure requirements do not apply to equipment used to construct the secondary or primary clay liners; however, the Owner may restrict the use of equipment that, in the Owner's opinion, may be potentially damaging to the geonet.

E. The CQA Engineer will provide monitoring of the placement of soil materials over the geonet or overlying layer in accordance with the CQA Plan.

3.05 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all materials and partially completed and completed work of these General Specifications.

B. The CQA Engineer will identify any areas requiring repair. The Contractor shall make repairs and replacements as necessary, to the approval of the Owner and at no additional cost to the Owner.

C. The CQA Engineer will issue an approval of the geonet detection or collection layer installation to the Owner prior to placement of material over the geonet in accordance with the CQA Plan.

TABLE 02712-1
REQUIRED GEONET PROPERTIES

PROPERTIES	UNITS	SPECIFIED VALUES[2]	TEST METHOD
Polymer composition	%	95 polyethylene by weight	
Polymer specific gravity		0.92	ASTM D 1505[1]
Polymer melt index	g/10 min.	0.1 - 0.5	ASTM D 1238
Carbon black content	%	2-3	ASTM D 1603
Nominal thickness	mm	5	ASTM D 374C or D1777
Transmissivity	m^2/s	5×10^{-3}	ASTM D 4716[3]

NOTES:

(1) The specific gravity of the geonet polymer shall not exceed that of the geomembrane.

(2) Values represent minimum average roll values (i.e., any roll in a lot should meet or exceed the values in this table). Where ranges of values are specified, the average roll values must be within the specified range.

(3) The design transmissivity is the hydraulic transmissivity of the geonet measured using water at 68°F ± 3°F with a hydraulic gradient of not less than 0.1, nor more than 0.5, under a compressive stress of not less than 1000 psf. For the test, the geonet shall be sandwiched between a 60-mil thick HDPE geomembrane on bottom, and on top, and backed with soil representative of clay liner on one side. The minimum test duration shall be 24 hours and the report for the test results shall include measurements at intervals over the entire test duration.

[END OF SECTION]

SECTION 02714
FILTER AND CUSHION GEOTEXTILE

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary for the installation of the filter and cushion geotextile in the landfill or surface impoundment. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

B. This specification shall also apply to geotextile installation in the truck roll off area, the drum handling facility, and the truck wash facility unless otherwise indicated on the drawings.

1.02 RELATED SECTIONS

A. Section 02221 - Clay Liner
B. Section 02224 - Drainage Gravel
C. Section 02225 - Road Base
D. Section 02228 - Pipe Bedding
E. Section 02710 - Geocomposite
F. Section 02232 - Protective Soil Layer
G. Section 02775 - Geomembrane Liners

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with requirements of the CQA Plan.

B. The Contractor shall be aware of all activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. If CQA testing is not completed prior to delivery, the Contractor shall deliver geotextile to the site at least 14 calendar days prior to installation to allow sufficient time for testing required by the CQA Plan.

D. Any geotextile rolls that do not meet the requirements of these General Specifications will be rejected. The Contractor shall replace the rejected material with new material that conforms to the specification requirements, at no additional cost to the Owner.

E. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at no cost to the Owner until acceptable test results are obtained.

PART 2: PRODUCTS

2.01 GEOTEXTILE PROPERTIES

A. The Contractor shall require that the geotextile Manufacturer furnish geotextile with minimum average roll values, as defined by the Federal Highway Administration (FHWA), meeting or exceeding the criteria specified in Tables 02714-1 (for filter layers), or Table 02174-2 (for cushion layers). The Contractor shall require that the geotextile Manufacturer provide results for tests performed using the procedures in Table 02714-1, or 02714-2, as well as a certification that the material delivered to the site meets or exceeds the specified values.

B. Geotextile products shall be needle-punched, non-woven materials manufactured from continuous filaments or stapled fibers.

C. In addition to the property values listed in Table 02714-1 or 02714-2, the geotextile filter or cushion layer shall:

1. Retain its structure during handling, placement, and long-term service.

2. Be capable of withstanding outdoor (i.e., ultra-violet) light for a minimum of 30 days with no measurable degradation in the specified physical properties.

3. Meet any additional requirements of the Construction Drawings.

2.02 MANUFACTURING QUALITY CONTROL

A. The Contractor shall require that the geotextile Manufacturer sample and test the geotextile to demonstrate that the material conforms to the requirements of this General Specification. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor. Test results shall be provided to the Owner. Sampling shall, in general, be performed on sacrificial portions of the geotextile material such that repair is not required. The Contractor shall require that the geotextile Manufacturer sample and test the geotextile, at a

minimum, once every 50,000 ft^2 and perform the manufacturing quality control tests as indicated in Table 02714-1 and 02714-2.

B. Any geotextile sample that does not comply with this General Specification shall result in rejection of the roll from which the sample was obtained. The Contractor shall replace any rejected roll at no additional cost to the Owner.

C. If a geotextile sample fails to meet the quality control requirements of this General Specification, the Contractor shall require that geotextile Manufacturer sample and test each roll manufactured in the same lot, or at the same time, as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established in accordance with the CQA Plan.

D. Additional sample testing may be performed, at the geotextile Manufacturer's discretion and expense, to more closely identify any non-complying rolls and/or to qualify individual rolls.

E. If requested by the Owner, the Contractor shall require the geotextile Manufacturer to retain a coupon of geotextile (10 feet by 2 feet) provided for the project for every 20,000 ft^2 of geotextile produced for the project until the work is accepted by the Owner.

F. The Contractor shall require that the geotextile Manufacturer comply with the certification and submittal requirements of the CQA Plan.

2.03 LABELING

A. Geotextile rolls shall be marked or tagged with the following information:

1. Name of Manufacturer;
2. Product identification;
3. Lot number;
4. Roll number; and,
5. Roll dimensions.

B. If any special handling is required, it shall be so marked on the geotextile itself, e.g., "This Side Up" or "This Side Against Soil to be Retained".

2.04 TRANSPORTATION

A. Transportation of the geotextile is the responsibility of the Contractor. The Contractor shall be liable for damage to the geotextile incurred prior to and during transportation to the site. The Contractor shall repair or replace damaged rolls at no additional cost to the Owner.

2.05 HANDLING AND STORAGE

A. Geotextile shall be shipped and stored in watertight and opaque protective covers.

B. Handling, storage, and care of the geotextile prior to and following incorporation into the work is the responsibility of the Contractor. The Contractor shall be liable for damage to the geotextile incurred prior to final acceptance by the Owner. The Contractor shall repair damage in accordance with Part 3.03 of this section and at no additional cost to the Owner.

C. The Contractor shall be responsible for storage of the geotextile at the site. The geotextile shall be stored off the ground and out of direct sunlight and precipitation, and shall be protected from puncture, cutting, excessive heat, cold, moisture, mud, dirt, dust, or any other damaging or deleterious condition. The geotextile shall be stored in accordance with any additional requirements of the geotextile Manufacturer.

PART 3: EXECUTION

3.01 HANDLING AND PLACEMENT

A. Geotextile shall be installed at the locations shown on the Construction Drawings.

B. The Contractor shall handle the geotextile in such a manner as to ensure the geotextile is not damaged in any way.

C. The Contractor shall take all necessary precautions to prevent damage to underlying layers during placement of the geotextile.

D. After placing the geotextile, the geotextile shall not be left exposed for a period in excess of 30 days unless a longer exposure period is approved by the Owner, based on a demonstration from the Manufacturer (e.g., a certification from the geotextile Manufacturer) that the geotextile is stabilized against ultra-violet light (UV) degradation for a period in excess of 30 days. This requirement does not apply to material used as sacrificial geotextile.

E. If white colored geotextile is used, precautions shall be taken against "snow blindness" of personnel.

F. Just prior to geotextile placement, the layer that will underlie the geotextile, if it is a geosynthetic, shall be clean and free of dust, dirt, stones, rocks, or other obstructions that could potentially damage the liner system. At the direction of the Owner, the Contractor shall clean the underlying layer with water.

G. In the presence of excessive wind, the geotextile shall be weighted with sandbags or equivalent weight approved by the Owner.

H. On side slopes, the geotextile shall be secured at the top of the slope and then rolled down the slope.

I. If necessary, the Contractor shall position the geotextile by hand after it is unrolled to minimize wrinkles.

J. Geotextile shall be clean when installed. During installation, care shall be taken not to entrap stones, and excessive dirt or moisture that could damage the underlying layers, clog drains or filters, or hamper subsequent seaming.

K. Tools shall not be left in or on the geotextile.

L. The Contractor shall examine the entire geotextile surface after installation to ensure that no potentially harmful foreign objects (including broken sewing needles) are present. The Contractor shall remove any such foreign objects and shall replace any damaged geotextile Broken sewing needles may need to be located using a metal detector or other method approved by the Owner.

M. Geotextile shall only be cut using a cutter approved by the geotextile Manufacturer and the Owner.

3.02 SEAMS AND OVERLAPS

A. All geotextile overlaps shall be continuously sewn (i.e., spot sewing and thermal bonding are not allowed). Geotextiles shall be overlapped a minimum 3 inches prior to sewing. No horizontal seams shall be allowed on slopes steeper than 5:1 (horizontal:vertical) (i.e., seams shall be along, not across, the slopes), except as part of a patch, unless approved by the Owner.

B. Polymeric thread shall be used for all sewing. The seam type shall be Federal Standard Type (No. 751.a) SSa. The seams shall be sewn using Stitch Type 401.

3.03 REPAIR

A. Any holes or tears in the geotextile shall be repaired as follows:

1. On slopes steeper than 5:1 (horizontal:vertical), a patch made from the same geotextile shall be overlapped a minimum three inches and double seamed into place (with each seam approximately 0.5 inches apart and no closer than 1 inch from any edge). Should a tear exceed 10 percent of the width of the roll, that roll shall be removed from the work and replaced with new material, at no additional cost to the Owner.

2. On slopes equal to or flatter than 5:1 (horizontal:vertical), a patch made from the same geotextile shall be overlapped a minimum of 3 inches and stitched into place with a single seam.

B. Care shall be taken to remove soil or other material which may have penetrated the torn geotextile.

3.04 PLACEMENT OF OVERLYING MATERIALS

A. The Contractor shall place all overlying soil materials in such manner as to ensure that:

1. The geotextile and underlying geosynthetic materials are not damaged;

2. Minimum slippage occurs between the geotextile and underlying layers; and,

3. Excessive stresses are not produced in the geotextile.

B. The CQA Engineer will monitoring the spreading of soil materials over the geotextile in accordance with the CQA Plan.

C. Unless otherwise specified by the Owner, all equipment operating on soil material overlying the geotextile shall comply with the following (Note: a greater thickness shall be required as per Sections 02710, 02712, and 02775 if the geotextile is directly underlain by a geocomposite, geonet, or geomembrane):

Maximum Allowable Equipment Ground Pressure (psi)	*Thickness of Soil Above Geotextile (inches)*
<5	6
<10	12
<20	18
>20	24

The maximum allowable equipment ground pressure shall be 65 psi. The acceptability of equipment operating at ground pressures greater than 65 psi will be evaluated by the Owner at the Contractor's expense.

The equipment ground pressure requirements do not apply to separator geotextiles used below road base nor to equipment used to construct the clay liners; however, the Owner may restrict the use of equipment that, in the Owner's opinion, may potentially damage the underlying geotextiles.

3.05 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all prior work, materials and partially-completed and completed work of these General Specifications.

B. The CQA Engineer will identify any areas requiring repair. The Contractor shall make repairs and replacements as necessary, to the approval of the Owner, and at no additional cost to Owner.

C. The CQA Engineer will issue an approval of geotextile filter, cushion, separator, or sacrificial layer installation in accordance with the CQA Plan prior to placement of material over the geotextile.

TABLE 02714-1
REQUIRED FILTER GEOTEXTILE PROPERTIES

Properties	Units	Specified Values (4)	Test Method
Polymer composition	%	95 [polypropylene, polyester, or polyethylene by weight]	
Mass per unit area	oz/yd^2	7	ASTM D 3776
Apparent opening size	mm	$O_{95} < 0.210$ mm	ASTM D 4751
Permitivity	sec^{-1}	1.47	ASTM D 4491
Grab strength	lb	210	ASTM D 4632(1)
Tear strength	lb	75	ASTM D 4533(2)
Puncture strength	lb	95	ASTM D 4833 (3)

Notes:

(1) Minimum values for both machine and cross machine direction with 1 inch clamp on constant rate of extension (CRE) machine.
(2) Minimum value measured in machine and cross machine direction.
(3) Tension testing machine with a 1.75-inch diameter ring clamp, the steel ball being replaced with a 0.31-inch diameter solid steel cylinder with flat tip centered within the ring clamp.
(4) Values represent minimum average roll values (i.e., any roll in a lot should meet or exceed the values in this table). The specified apparent opening size is a maximum average roll value.

TABLE 02714-2
REQUIRED CUSHION GEOTEXTILE PROPERTIES

Properties	Qualifier	Units	Specified Values [4]	Test Method
Polymer composition	minimum	%	95 [polypropylene, polyester, or polyethylene by weight]	
Mass per unit area	minimum	oz/yd^2	12	ASTM D 3776
Grab strength	minimum	lb	300	ASTM D 4632[1]
Tear strength	minimum	lb	110	ASTM D 4533[2]
Puncture strength	minimum	lb	135	ASTM D 4833 [3]

Notes:

(1) Minimum values for both machine and cross machine direction with 1 inch clamp on constant rate of extension (CRE) machine.
(2) Minimum value measured in machine and cross machine direction.
(3) Tension testing machine with a 1.75-inch diameter ring clamp, the steel ball being replaced with a 0.31-inch diameter solid steel cylinder with flat tip centered within the ring clamp.
(4) All values represent minimum average roll values (i.e., any roll in a lot should meet or exceed the values in this table).

[END OF SECTION]

SECTION 02718
POLYETHYLENE PIPE AND FITTINGS

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary for the installation of all high density polyethylene (HDPE) pipes, pipe fittings, and appurtenances required for landfill or surface impoundment construction. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02221 - Clay Liner
B. Section 02224 - Pipe Bedding
C. Section 02710 - Geocomposite Detection or Collection Layer
D. Section 02714 - Filter or Cushion Geotextile
E. Section 02775 - Geomembrane Liners

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

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

B. The Contractor shall be aware of all activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. The CQA Engineer will coordinate independent surveying as required by the CQA Plan. Surveying by the CQA Engineer does not relieve the Contractor of his responsibility to lay out, control, and document the work.

D. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming materials. The nonconforming area shall be replaced by the Contractor at no cost to the Owner until acceptable test results are obtained.

PART 2: PRODUCTS

2.01 HDPE RESIN PROPERTIES

A. The HDPE pipe and fittings shall be manufactured from new, high molecular weight, HDPE resin conforming to ASTM D 1248 (Type III, Class C Category 5, Grade P 34), ASTM D 3350 (Cell Classification PE 345434C), and having a Plastic Pipe Institute (PPI) Rating of PE 3408. The resin shall be pre-compounded. In plant blending of non-compounded resins shall not be permitted. Pipe and fittings shall be manufactured from the same resin and by the same manufacturer.

B. The polyethylene compound shall contain a minimum of 2 percent carbon black to withstand outdoor exposure without loss of properties.

C. The polyethylene compound shall have minimum resistance of 5,000 hours when tested for environmental stress crack in accordance with requirements of GRI-GM5.

2.02 HDPE PIPE AND FITTINGS PROPERTIES

A. The Contractor shall provide pipe having the nominal diameters shown on the Construction Drawings.

B. All HDPE pipe and fittings shall have a minimum Standard Diameter Ratio (SDR) of 11 unless otherwise indicated on the Construction Drawings.

C. All HDPE pipe and fittings shall have a minimum hydrostatic design basis (HDB) of 1,600 pounds per square inch when determined in accordance with ASTM D 2837 unless otherwise indicated on the Construction Drawings.

D. All HDPE pipe and fittings shall comply with ASTM F 714.

E. HDPE pipe shall be supplied in standard laying lengths not exceeding 50 feet.

F. HDPE pipe shall be furnished non-perforated or perforated to meet the requirements of the Construction Drawings. Perforations, if required, shall be drilled into the pipe after manufacture. If approved by OWNER, perforations to pipe can be made after delivery to the project site.

G. HDPE pipes and fittings shall be homogeneous throughout and free of visible cracks, holes (other than intentional manufactured perforations), foreign inclusions, or other deleterious effects, and shall be uniform in color, density, melt index, and other physical properties.

H. Fittings at the ends of pipes shall be HDPE end caps unless otherwise indicated on the Construction Drawings.

I. Geomembrane boots shall be either field or shop-fabricated to the dimensions shown on the Construction Drawings. Pipe boots shall be fabricated from the same resin as the polyethylene geomembrane to which they are welded. Pipe boots shall be installed as indicated on the Construction Drawings.

2.03 MANUFACTURING QUALITY CONTROL

A. The Contractor shall submit to the Owner for approval within 14 days prior to the start of pipe work a complete list of materials to be furnished and the name of the pipe Manufacturer.

B. The Contractor shall submit to the Owner the pipe Manufacturer's certification of compliance with the product requirements of Part 2 of this section, including certification that stress regression testing has been performed in accordance with ASTM D 2837 on the pipe products representative of that delivered to the site. The Manufacturer's Certification must be based on a QC testing frequency of one sample per lot.

C. The Contractor shall submit to the Owner in writing the following documentation from the pipe Manufacturer on the raw materials used to manufacture the pipe and fittings:

1. Certificate identifying the specific resin used, its source, and the information required by ASTM D 1248.

2. Certificate stating that no recycled resin was used in manufacturing the pipe except for a small percentage (15 percent or less) of resin generated in the pipe Manufacturer's own plant from production using the same resin as the recycled material.

D. If requested by the Owner, the Contractor shall require the pipe manufacturer to retain one section of pipe (at least 5 feet in length) provided for the project for every 1,500 lineal feet of pipe produced for the project until the work is accepted by the Owner.

E. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

2.04 LABELING

A. The following shall be continuously indent-printed on the polyethylene pipe, or spaced at intervals not exceeding 10 feet:

1. Name and/or trademark of the pipe Manufacturer.
2. Nominal pipe size.
3. Standard dimension ratio (SDR).

4. The letters PE followed by the polyethylene grade per ASTM D 1248, followed by the hydrostatic design stress in 100's of psi (i.e., PE 3408).
5. Manufacturing Standard Reference (e.g., ASTM F 714-1).
6. A production code from which the date and place of manufacture can be determined.

2.05 TRANSPORTATION

A. Transportation of polyethylene pipe and fittings shall be the responsibility of the Contractor. The Contractor shall be liable for all damage to the polyethylene pipe and fittings incurred prior to and during transportation to the site.

2.06 HANDLING AND STORAGE

A. Handling, storage, and care of the polyethylene pipe and fittings, prior to and following installation at the site, is the responsibility of the Contractor. The Contractor shall be liable for all damage to the material incurred prior to final acceptance by the Owner.

B. The Contractor shall be responsible for storage of polyethylene pipe and fittings at the site. Pipe and fittings shall be stored on clean level ground, preferably turf or sand, free of sharp objects which could damage the pipe. Stacking shall be limited to a height that will not cause excessive deformation of the bottom layers of pipe under anticipated temperature conditions. Where necessary due to ground conditions, the pipe shall be stored on wooden sleepers that are spaced suitably and of such width as not to allow deformation of the pipe. The pipe shall be stored to minimize bowing.

2.07 PIPE BEDDING MATERIAL

A. Pipe bedding material shall meet the requirements of Section 02228 of this General Specification as well as any other requirements of the Construction Drawings.

2.08 HDPE FLAT STOCK

A. HDPE flat stock installed below polyethylene pipe shall consist of layers of HDPE furnished at the dimensions shown on the Construction Drawings. Flat stock shall be provided from the same resin as the pipe.

PART 3: EXECUTION

3.01 HANDLING AND PLACEMENT

A. Pipe, fittings, and HDPE flat stock shall be installed as indicated on the Construction Drawings.

B. The Contractor shall exercise care when transporting, handling and placing pipe and fittings, such that they will not be cut, kinked, twisted, or otherwise damaged.

C. The Contractor shall comply with the pipe Manufacturer's recommendations for handling, storage, and installation of all polyethylene pipe fittings.

D. Ropes, fabric, or rubber-protected slings and straps shall be used when handling pipe. Slings, straps, etc. shall not be positioned at butt-fused joints. Chains, cables or hooks shall not be inserted into the pipe ends as a means of handling pipe.

E. Pipe or fittings shall not be dropped onto rocky or unprepared ground. The pipe and fittings shall not be dropped into trenches or dragged over sharp objects.

F. The maximum allowable depth of cuts, gouges, or scratches on the exterior surface of pipe or fittings is 10 percent of the wall thickness. The interior of the pipe and fittings shall be free of cuts, gouges and scratches. The CQA Engineer will inspect the pipes in accordance with the CQA Plan. Sections of pipe with excessive cuts, gouges, or scratches will be rejected and the Contractor will be required to remove and replace the rejected pipe, at no additional cost to the Owner.

G. Whenever pipe laying is not actively in progress, the open end of pipe that has been placed shall be closed using a watertight plug.

H. Where pipes penetrate through geomembranes, an effective seal shall be established in accordance with these General Specifications as well as the details shown on the Construction Drawings.

3.02 INSTALLATION

A. All pipe and fittings shall be installed in accordance with these General Specifications and the pipe Manufacturer's instructions.

B. The Contractor shall carefully examine all pipe and fittings for cracks, damage or defect before installation. Defective materials shall be removed from the site and replaced with non-defective material at no additional cost to the Owner.

C. The interior of all pipe and fittings shall be inspected, and any foreign material shall be completely removed from the pipe interior before it is moved into final position.

D. Field cutting of pipe shall be carefully made, without damage to pipe or lining system components, so as to leave a smooth end at right angles to the axis of pipe. The method and device used to cut the pipes shall be approved of by the

Owner. Sharp edges of cut ends shall be filed off smooth. Flame cutting will not be allowed.

E. All pipe and fittings shall be laid or placed to the grades and elevations shown on the Construction Drawings with bedding and backfill as shown on the Construction Drawings.

F. Placement of overlying materials shall be carried out in accordance with these General Specifications.

G. No pipe shall be laid until the CQA Engineer has observed the condition of the pipe.

H. Blocking under piping shall not be permitting unless specifically accepted by the Owner.

I. The Contractor shall provide all necessary adapters and/or connection pieces required when connecting different types and sizes of pipe or when connecting pipe made by different manufacturers.

3.03 JOINTS AND CONNECTIONS

A. HDPE pipe shall be joined with thermal butt-fusion joints. All joints shall be made in accordance with ASTM D 2657 and the pipe Manufacturer's recommendations, and shall be made by trained personnel authorized by the pipe Manufacturer.

B. Mechanical connections of HDPE pipe to auxiliary equipment such as valves, flow meters, pumps and tanks shall consists of the following unless indicated otherwise on the Construction Drawings:

1. An HDPE flange connection, called a stub end, shall be butt-fused to the HDPE pipe. Outside diameter and drilling shall comply with the requirements indicated on the Construction Drawings.

2. A Type 316 stainless steel back-up flange. Outside diameter and drillings shall comply with the requirements indicated on the Construction Drawings.

3. Other mechanical couplings, such as 360 degree full circle clamps, shall only be used if approved by the Owner.

4. The stub ends shall be connected with corrosion-resistant bolts and nuts of Type 316 stainless steel, as specified in ASTM A 726 and ASTM A 307.

C. Polyethylene stub ends and flanges shall be at the ambient temperature of the surrounding soil at the time they are bolted tight to prevent relaxation of the flange bolts and loosening of the joint due to thermal contraction or expansion of the polyethylene pipe. Bolts shall be drawn up evenly and in line.

D. Pipe adjacent to joints and joints themselves shall be rigidly supported for a distance of at least one pipe diameter beyond the backup flanges.

E. Pipe boot connections shall be made in the field using viton rings and stainless steel clamps, or welded directly to pipe as shown on the Construction Drawings. The viton ring material shall have a thickness of 3/16 inch and shall have an inner diameter equal to the outer diameter of the pipe on which the viton ring is to be placed. The stainless steel clamps shall be made of 3/16 inch thick, 1/2 inch wide, Type 316 stainless steel. The clamps shall be joined around the pipe boot using a Type 316 stainless steel clasp, not thicker than 3/8 inch. These materials shall be chosen by the Contractor and approved by the Owner.

3.04 SURVEY CONTROL

A. The Surveyor shall survey the location and final elevation of the invert of all polyethylene leachate collection pipes (excluding laterals). The pipe shall be surveyed at its ends and at approximate 50-foot intervals between the ends. In addition, all joints, etc. shall be located horizontally and vertically and overall length measured. Surveying shall be performed in accordance with Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing of the location and final elevation of all pipes.

3.05 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all materials and all partially-complete and completed work of these General Specifications.

B. In the event of damage, the Contractor shall make all repairs and replacements necessary, to the approval of the Owner and at no additional cost to the Owner.

C. The CQA Engineer will issue an approval of pipe installation and inspection to the Owner prior to completely covering the pipe in accordance with the CQA Plan.

[END OF SECTION]

SECTION 02720
ADS N-12 PIPE

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary for the installation of all ADS N-12 pipe required for the landfill construction. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02224 - Drainage Gravel
B. Section 02714 - Geotextile Filter or Cushion Layer

1.03 QUALIFICATIONS AND SUBMITTALS

A. If "or equal" product is proposed, submit samples, technical data, test data, and specifications sufficient to allow evaluation by the Engineer.

1.04 CONSTRUCTION QUALITY ASSURANCE

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

B. The Contractor shall be aware of all activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. The CQA Engineer will coordinate independent surveying as required by the CQA Plan. Surveying by the CQA Engineer does not relieve the Contractor of his responsibility to lay out, control, and document the work.

D. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming materials. The nonconforming materials shall be removed by the Contractor at no cost to the Owner until acceptable materials are installed.

PART 2: PRODUCTS

2.01 ADS N-12 PIPE PROPERTIES

A. Smooth interior corrugated polyethylene pipe (ADS N-12) shall be high density polyethylene with a corrugated exterior and smooth interior. Pipe and fittings shall be made of polyethylene compounds.

2.03 MANUFACTURING QUALITY CONTROL

A. The Contractor shall submit to the Owner for approval within 14 days prior to the start of ADS N-12 pipe work a complete list of materials to be furnished and the name of the pipe Manufacturer.

B. The Contractor shall submit to the Owner the Manufacturer's certification of compliance with the product requirements of Part 2.

2.04 TRANSPORTATION

A. Transportation of ADS N-12 pipe shall be the responsibility of the Contractor. The Contractor shall be liable for all damage to the ADS N-12 pipe incurred prior to and during transportation to the site.

2.05 HANDLING AND STORAGE

A. Handling, storage, and care of the ADS N-12 pipe prior to and following installation at the site, is the responsibility of the Contractor. The Contractor shall be liable for all damage to the material incurred prior to final acceptance by the Owner.

B. The Contractor shall be responsible for storage of the ADS N-12 pipe at the site.

PART 3: EXECUTION

3.01 HANDLING AND PLACEMENT

A. Pipe shall be installed as indicated on the Construction Drawings.

B. The Contractor shall exercise care when transporting, handling and placing pipe and fittings, such that they will not be cut, kinked, twisted, or otherwise damaged.

C. The Contractor shall comply with the pipe Manufacturer's recommendations for handling, storage, and installation of all polyethylene pipe fittings.

D. Ropes, fabric, or rubber-protected slings and straps shall be used when handling pipe. Slings, straps, etc. shall not be positioned at butt-fused joints. Chains, cables or hooks shall not be inserted into the pipe ends as a means of handling pipe.

E. Pipe or fittings shall not be dropped onto rocky or unprepared ground. The pipe and fittings shall not be dropped into trenches or dragged over sharp objects.

F. The maximum allowable depth of cuts, gouges, or scratches on the exterior surface of pipe or fittings is 10 percent of the wall thickness. The interior of the pipe and fittings shall be free of cuts, gouges and scratches. The CQA Engineer will inspect the pipes in accordance with the CQA Plan. Sections of pipe with excessive cuts, gouges, or scratches will be rejected and the Contractor will be required to remove and replace the rejected pipe, at no additional cost to the Owner.

G. Whenever pipe laying is not actively in progress, the open end of pipe that has been placed shall be closed using a watertight plug.

H. Where pipes penetrate through geomembranes, an effective seal shall be established in accordance with these General Specifications as well as the details shown on the Construction Drawings.

3.02 INSTALLATION

A. All pipe and fittings shall be installed in accordance with these General Specifications and the pipe Manufacturer's instructions.

B. The Contractor shall carefully examine all pipe and fittings for cracks, damage or defect before installation. Defective materials shall be removed from the site and replaced with non-defective material at no additional cost to the Owner.

C. The interior of all pipe and fittings shall be inspected, and any foreign material shall be completely removed from the pipe interior before it is moved into final position.

D. Field cutting of pipe shall be carefully made, without damage to pipe or lining system components, so as to leave a smooth end at right angles to the axis of pipe. The method and device used to cut the pipes shall be approved of by the Owner. Sharp edges of cut ends shall be filed off smooth. Flame cutting will not be allowed.

E. All pipe and fittings shall be laid or placed to the grades and elevations shown on the Construction Drawings with bedding and backfill as shown on the Construction Drawings.

F. Placement of overlying materials shall be carried out in accordance with these General Specifications.

G. No pipe shall be laid until the CQA Engineer has observed the condition of the pipe.

H. Blocking under piping shall not be permitting unless specifically accepted by the Owner.

I. The Contractor shall provide all necessary adapters and/or connection pieces required when connecting different types and sizes of pipe or when connecting pipe made by different manufacturers.

3.04 JOINTS AND CONNECTIONS

A. HDPE pipe shall be joined with split couplers. All joints shall be made in accordance with the pipe Manufacturer's recommendations, and shall be made by trained personnel authorized by the pipe Manufacturer.

3.05 SURVEY CONTROL

A. The Surveyor shall survey the location and final elevation of the invert of all ADS N-12 pipe. The pipe shall be surveyed at its ends and at approximate 50-foot intervals between the ends. In addition, all joints, etc. shall be located horizontally and vertically and overall length measured. Surveying shall be performed in accordance with Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing of the location and final elevation of all pipes.

3.06 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all materials and all partially-complete and completed work of these General Specifications.

B. In the event of damage, the Contractor shall make all repairs and replacements necessary, to the approval of the Owner and at no additional cost to the Owner.

C. The CQA Engineer will issue an approval of pipe installation and inspection to the Owner prior to completely covering the pipe in accordance with the CQA Plan.

[END OF SECTION]

SECTION 02730
ADS SLOTTED CPT

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services necessary for the installation of all ADS corrugated polyethylene tubing (CPT) required for the landfill construction. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02224 - Drainage Gravel
B. Section 02714 - Geotextile Filter or Cushion Layer

1.03 QUALIFICATIONS AND SUBMITTALS

A. If "or equal" product is proposed, submit samples, technical data, test data, and specifications sufficient to allow evaluation by the Engineer.

1.04 CONSTRUCTION QUALITY ASSURANCE

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

B. The Contractor shall be aware of all activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. The CQA Engineer will coordinate independent surveying as required by the CQA Plan. Surveying by the CQA Engineer does not relieve the Contractor of his responsibility to lay out, control, and document the work.

D. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming materials. The nonconforming materials shall be removed by the Contractor at no cost to the Owner until acceptable materials are installed.

PART 2: PRODUCTS

2.01 SLOTTED CPT PROPERTIES

A. Slotted CPT shall conform to ASTM F405 and ASTM F667. Slot dimensions and locations shall be Manufacturer standard for the diameter pipe specified.

2.03 MANUFACTURING QUALITY CONTROL

A. The Contractor shall submit to the Owner for approval within 14 days prior to the start of ADS CPT work a complete list of materials to be furnished and the name of the pipe Manufacturer.

B. The Contractor shall submit to the Owner the Manufacturer's certification of compliance with the product requirements of Part 2.

2.04 TRANSPORTATION

A. Transportation of ADS CPT shall be the responsibility of the Contractor. The Contractor shall be liable for all damage to the ADS CPT incurred prior to and during transportation to the site.

2.05 HANDLING AND STORAGE

A. Handling, storage, and care of the ADS CPT prior to and following installation at the site, is the responsibility of the Contractor. The Contractor shall be liable for all damage to the material incurred prior to final acceptance by the Owner.

B. The Contractor shall be responsible for storage of the ADS CPT at the site.

PART 3: EXECUTION

3.01 HANDLING AND PLACEMENT

A. Pipe shall be installed as indicated on the Construction Drawings.

B. The Contractor shall exercise care when transporting, handling and placing pipe and fittings, such that they will not be cut, kinked, twisted, or otherwise damaged.

C. The Contractor shall comply with the pipe Manufacturer's recommendations for handling, storage, and installation of all polyethylene pipe fittings.

D. Ropes, fabric, or rubber-protected slings and straps shall be used when handling pipe. Slings, straps, etc. shall not be positioned at butt-fused joints. Chains, cables or hooks shall not be inserted into the pipe ends as a means of handling pipe.

E. Pipe or fittings shall not be dropped onto rocky or unprepared ground. The pipe and fittings shall not be dropped into trenches or dragged over sharp objects.

F. The maximum allowable depth of cuts, gouges, or scratches on the exterior surface of pipe or fittings is 10 percent of the wall thickness. The interior of the pipe and fittings shall be free of cuts, gouges and scratches. The CQA Engineer will inspect the pipes in accordance with the CQA Plan. Sections of pipe with excessive cuts, gouges, or scratches will be rejected and the Contractor will be required to remove and replace the rejected pipe, at no additional cost to the Owner.

G. Whenever pipe laying is not actively in progress, the open end of pipe that has been placed shall be closed using a watertight plug.

H. Where pipes penetrate through geomembranes, an effective seal shall be established in accordance with these General Specifications as well as the details shown on the Construction Drawings.

3.02 INSTALLATION

A. All pipe and fittings shall be installed in accordance with these General Specifications and the pipe Manufacturer's instructions.

B. The Contractor shall carefully examine all pipe and fittings for cracks, damage or defect before installation. Defective materials shall be removed from the site and replaced with non-defective material at no additional cost to the Owner.

C. The interior of all pipe and fittings shall be inspected, and any foreign material shall be completely removed from the pipe interior before it is moved into final position.

D. Field cutting of pipe shall be carefully made, without damage to pipe or lining system components, so as to leave a smooth end at right angles to the axis of pipe. The method and device used to cut the pipes shall be approved of by the Owner. Sharp edges of cut ends shall be filed off smooth. Flame cutting will not be allowed.

E. All pipe and fittings shall be laid or placed to the grades and elevations shown on the Construction Drawings with bedding and backfill as shown on the Construction Drawings.

F. Placement of overlying materials shall be carried out in accordance with these General Specifications.

G. No pipe shall be laid until the CQA Engineer has observed the condition of the pipe.

H. Blocking under piping shall not be permitting unless specifically accepted by the Owner.

I. The Contractor shall provide all necessary adapters and/or connection pieces required when connecting different types and sizes of pipe or when connecting pipe made by different manufacturers.

3.04 JOINTS AND CONNECTIONS

A. CPT shall be joined with split couplers. All joints shall be made in accordance with the pipe Manufacturer's recommendations, and shall be made by trained personnel authorized by the pipe Manufacturer.

3.05 SURVEY CONTROL

A. The Surveyor shall survey the location and final elevation of the invert of all ADS CPT. The pipe shall be surveyed at its ends and at approximate 50-foot intervals between the ends. In addition, all joints, etc. shall be located horizontally and vertically and overall length measured. Surveying shall be performed in accordance with Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing of the location and final elevation of all pipes.

3.06 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all materials and all partially-complete and completed work of these General Specifications.

B. In the event of damage, the Contractor shall make all repairs and replacements necessary, to the approval of the Owner and at no additional cost to the Owner.

C. The CQA Engineer will issue an approval of pipe installation and inspection to the Owner prior to completely covering the pipe in accordance with the CQA Plan.

[END OF SECTION]

SECTION 02740
CORRUGATED METAL PIPE

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation service necessary for the installation of all corrugated metal pipe (CMP) for construction. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. 02228 - Pipe Bedding

1.03 REFERENCES

A. American Association of State Highway and Transportation Officials (AASHTO) most current version:

1. AASHTO M36 - Specification for Corrugated Steel Pipe, Metallic-Coated, for Sewers and Drains

B. American Society for Testing and Materials (ASTM) most current version:

1. ASTM A27 - Specification for Steel Castings, Carbon, for General Application.

2. ASTM A36 - Specification for Structural Steel.

3. ASTM A123 - Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.

4. ASTM A536 - Specification for Ductile Iron Castings.

5. ASTM C478 - Specification for Precast Reinforced Concrete Manhole Sections.

6. ASTM D1557 - Test Methods for Moisture Density Relations of Soils and Soil Aggregate Mixtures Using 10-lb (4.54 kg) Hammer and 18-in. (457 mm) Drop.

7. ASTM D3776 - Test Methods for Mass per Unit Area (Weight) of Woven Fabric.

8. ASTM D3786 - Test Method for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics: Diaphragm Bursting Strength Tester Method.

9. ASTM D4355 - Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Zenon-Arc Type Apparatus).

10. ASTM D4533 - Test Method for Trapezoid Testing Strength of Geotextiles.

11. ASTM D4632 - Test Method for Breaking Load and Elongation of Geotextiles (Grab Method).

12. ASTM D4751 - Test Method for Determining Apparent Opening Size of a Geotextile.

13. ASTM D4833 - Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.

C. State of California Department of Transportation (CALTRANS), Standard Specifications, most current version.

1.04 SUBMITTALS

A. Submit manufacturer's and supplier's specifications and test data as required to demonstrate that materials conform to the requirements of this specification.

PART 2: PRODUCTS

2.01 CORRUGATED METAL PIPE (CMP)

A. CMP shall be galvanized steel conforming to AASHTO M36 Type I, with a nominal sheet thickness of 0.079 inches or greater. Diameters shall be as shown on the Construction Drawings.

B. Coupling bands shall be galvanized steel conforming to AASHTO M36 and shall be compatible with the type of CMP provided.

2.02 TRENCH BACKFILL

A. Trench backfill shall conform to the specifications for pipe bedding described in Section 02228.

PART 3: EXECUTION

3.01 CMP CULVERT INSTALLATION

A. Excavate trenches to the lines and grades shown on the Drawings. Overexcavate trenches so that at least 6 inches of pipe bedding material can be placed below the invert of the culvert. Conduct trenching operations in accordance with the applicable provisions of Section 02110.

B. Place a minimum 6-inch-thick layer of pipe bedding material in the trench prior to laying the culvert. Compact pipe bedding material with power tamper or equivalent means. The bottom of the trench shall support the culvert uniformly along its entire length.

C. Handle culvert using methods as recommended by the manufacturer. Join culvert sections using manufacturer's recommended equipment and procedures.

D. Place backfill around culvert in lifts no greater than 1 foot thick prior to compaction. Place soil around haunches of culvert manually or by other approved means so that no voids are present. Compact each lift with power tamper or equivalent means.

[END OF SECTION]

SECTION 02775
GEOMEMBRANE LINERS

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment supervision, transportation, and installation services necessary for the installation of the geomembrane liners for the landfill or surface impoundment. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

B. This specification shall also apply to geomembrane installation in the truck roll off area, the drum handling facility, and the truck wash facility unless otherwise indicated on the drawings.

1.02 RELATED SECTIONS

A. Section 02221 - Clay Liner
B. section 02231 - Foundation Sand
C. Section 02710 - Geocomposite
D. Section 02712 - Geonet
E. Section 02714 - Geotextile Filter, or Cushion, Layer
F. Section 02232 - Protective Soil Layer
G. Section 02718 - Polyethylene Pipe and Fittings
H. Section 02780 - Geosynthetic Clay Liners

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan. The Contractor shall require the geomembrane manufacturer to comply with the submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

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

B. The Contractor shall be aware of all activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. The Contractor shall deliver geomembrane to the site at least 14 calendar days prior to installation to allow sufficient time for testing required by the CQA Plan.

D. Geomembrane rolls that do not meet the requirements of this General Specification will be rejected. The Contractor shall replace rejected material with new material that conforms to the specification requirements, at no additional cost to the Owner.

E. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the nonconforming area. The nonconforming area shall be reworked by the Contractor at no cost to the Owner until acceptable test results are obtained.

PART 2: PRODUCTS

2.01 RESIN

A. Reclaimed polymer shall not be added to the resin; however, the use of polymer recycled during the manufacturing process will be permitted if the recycled polymer does not exceed 2 percent by weight of the total polymer weight. The product shall be manufactured specifically for use in geomembranes, using new, first-quality polyethylene resin.

B. The resin shall comply with the following properties for high density polyethylene (HDPE):

1. Specific Gravity: 0.94 to 0.96 (ASTM D 792 Method A or ASTM D 1505)

2. Melt Index: 0.1 - 0.3 g/10 min. (ASTM D 1238 Condition E 190/C, 2.16 kg)

3. Water absorption: 0.1% max (ASTM D 570)

2.02 GEOMEMBRANE PROPERTIES

A. Smooth or textured HDPE geomembrane shall be used based on the following schedule:

Facility	Textured/Smooth
Landfill (liner/cover)	Textured
Ditch liners	Smooth
Evaporation Pond and Collection Basin	Smooth
Truck Roll Off	Textured
Drum Storage	Smooth
Liquid Waste Storage	Smooth
Stabilization	NA
Truck Wash	Textured

B. The Contractor shall require that the geomembranes Manufacture furnish geomembrane with minimum average roll values, as defined by the Federal Highway Administration (FHWA), meeting or exceeding the criteria specified in Table 02775-1 and that meet the manufacturing quality control requirements of this section. The Contractor shall require the geomembrane Manufacturer to certify in writing as well as provide test results that demonstrate that the geomembrane delivered to the site complies with the properties listed in Table 02775-1.

C. In addition to the property values listed in Table 02775-1, the geomembrane material shall:

1. Contain a maximum of 1 percent by weight of additives, fillers, or extenders (not including carbon black).

2. Not have striations, roughness (except in the case of textured HDPE geomembranes where a roughened surface is characteristic), pinholes, or bubbles on the surface.

3. Be produced so as to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter.

4. Be manufactured in a single layer or coextruded.

2.03 MANUFACTURING QUALITY CONTROL

A. *Resin*:

1. The Contractor shall require the geomembrane Manufacturer to certify in writing that the resin used to manufacture the geomembrane delivered to the project site complies with the product specifications of this section. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor Any geomembrane manufactured from non-complying resin will be rejected.

2. The Contractor shall require the Manufacturer to supply quality control certificates from the resin Supplier that includes the origin (resin production plant), identification (brand name, number) the production date of the resin used in the manufacturer of the geomembrane shipped to the site, and the results of test conducted to verify that the resin used to manufacturer the geomembrane rolls assigned to the project meets the specifications of Part 2.01 of this section.

B. *Rolls*:

1. The Contractor shall require that the geomembrane Manufacturer continuously monitor the geomembrane during the manufacturing process for inclusions, bubbles, or other defects. Geomembrane that exhibits defects will not be accepted.

2. The Contractor shall require that the geomembrane Manufacturer monitor the geomembrane thickness during the manufacturing process. Geomembrane that fails to meet the specified minimum thickness will not be accepted.

3. The Contractor shall require that the geomembrane Manufacturer sample and test the geomembrane, at a minimum, once every 50,000 ft^2 and perform the tests indicated in Table 02775-1 to demonstrate that the geomembrane properties conform to the values specified in this section. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor. Samples shall be taken across the entire width of the roll and shall not include the first wrapping or outer layer of the roll (about 3.3 feet).

4. Geomembrane rolls that do not have acceptable manufacturing quality control test results shall be rejected by the Owner.

5. In the case of the rejection of a roll of geomembrane, the Contractor shall require that the geomembrane Manufacturer sample and test each roll manufactured in the same lot, or at the same time, as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established in accordance with the CQA Plan.

6. Additional testing may be performed at the geomembrane Manufacturer's discretion and expense, to more closely identify the non-complying rolls and/or to qualify individual rolls.

7. If requested by Owner, one coupon of geomembrane (at least 10 feet by 2 feet) for every 40,000 ft^2 of membrane produced shall be retained intact by the geomembrane Manufacturer until construction of landfill or surface impoundment components, for which the geomembrane is used, is complete and the Owner has accepted the completed work.

C. *Manufacturing Plant Visit:*

1. The Manufacturer shall permit the Owner or Owner's representative(s) to visit the manufacturing plant. Visits may be during the manufacturing of the geomembrane rolls for the specific project.

2. During the visit, the Owner or Owner's representative(s) may:

a. Review the manufacturing process, quality control procedures, laboratory facilities, and testing procedures;

b. Verify that properties guaranteed by the Manufacturer comply with the specifications;

c. Verify that the measurements of properties by the Manufacturer are properly documented and the test methods used are acceptable;

d. Inspect select geomembrane rolls for evidence of holes, blisters, or any sign of contamination by foreign matter;

e. Review packaging and transportation procedures;

f. Verify that roll packages are labeled in compliance with this Section; and

g. Take conformance samples from geomembrane rolls that are assigned to the project.

2.04 LABELING

A. The geomembrane shall be labeled with the following information:

1. Thickness of the material;
2. Length and width of the roll or factory panel;
3. Name of Manufacturer;
4. Product identification;
5. Lot number; and,
6. Roll or factory panel number.

2.05 TRANSPORTATION

A. Transportation of the geomembrane is the responsibility of the Contractor. The Contractor shall be liable for all damage to materials prior to and during transportation to the site. The Contractor shall replace any damaged rolls at no additional cost to the Owner.

2.06 HANDLING AND STORAGE

A. Handling, storage, and care of the geomembrane prior to and following incorporation in the work is the responsibility of the Contractor. The Contractor shall be liable for all damage to the material incurred prior to final acceptance of the installation by the Owner. The Contractor shall repair any damage in accordance with this Section and at no additional cost to the Owner.

B. The Contractor shall be responsible for storage of the geomembrane at the site. The geomembrane shall be protected from dirt, excessive heat or cold, puncture, cutting, or other damaging or deleterious conditions. The geomembrane shall also be stored in accordance with any additional requirements of the geomembrane Manufacturer.

PART 3: EXECUTION

3.01 EARTHWORK

A. *Surface Preparation*

1. Geomembrane liner shall be installed at all locations shown on the Construction Drawings.

2. The geomembrane liners and the cover geomembrane shall be installed as soon as practical after construction and CQA testing of the underlying materials. Prior to geomembrane liner installation, the Contractor shall verify, by surveying, that the elevations, thicknesses, and grades of the underlying materials conform to the requirements of the Construction Drawings. Installation of the geomembranes shall not begin until the CQA Engineer completes conformance testing and surveying of the appropriate portions of the underlying materials in accordance with the CQA Plan.

3. Areas to receive geomembrane liner shall be smooth and even, and free of ruts, voids, and protrusions or wrinkles. Any surface features, as determined by the CQA Engineer or Owner, which could damage the geomembrane shall be removed by the Contractor. For earth slopes of 3:1 (horizontal:vertical) or flatter, the final surface prior to receiving geomembrane shall be rolled smooth using a smooth drum roller. For slopes steeper than 3H:1V, dressing of the slopes shall be accomplished by back-dragging the surface with a dozer blade or by other methods approved by the Owner (such as raking the surface by hand) until the Owner is satisfied that the surface is smooth and even, and free of ruts, voids, obstructions, etc.. No vehicles shall be allowed on the final dressed surface without the approval of the Owner.

4. The Contractor shall provide written certification that the surface on which the geomembrane will be installed is acceptable. The certificate of acceptance for each area under consideration shall be given to the Owner as part of geomembrane installation in that area.

5. Special care shall be taken to maintain the prepared surface on which the geomembrane will be installed.

6. No geomembrane shall be placed in an area which has been softened by precipitation or which has excessively cracked due to desiccation.

7. Any damage to the surface caused by weather, installation activities, or other activities shall be repaired by the Contractor at no expense to the Owner.

B. *Anchor Trenches:*

1. The anchor trench shall be excavated prior to geomembrane placement to the elevations, grades, and width shown on the Construction Drawings.

2. No loose soil shall be allowed beneath the geomembrane in the anchor trench.

3. The anchor trench shall be backfilled as shown on the Construction Drawings. Care shall be taken when backfilling the anchor trench to prevent any damage to the geomembrane or other geosynthetics.

4. Clay liner material shall be placed in the anchor trench to the limits shown on the Construction Drawings. The clay liner material shall be compacted using suitable hand-operated compaction equipment. Clay shall be compacted to the requirements in the General Specifications.

5. Slightly rounded corners shall be provided at the top in-board side of the anchor trench to avoid sharp bends in the geomembrane.

3.02 GEOMEMBRANE DEPLOYMENT

A. *Layout Drawings*:

1. The Contractor shall provide at least 2 sets of geomembrane panel layout drawings to the Owner at least 14 days prior to geomembrane deployment. Drawings shall indicate the geomembrane panel configuration, dimensions, details, seam locations, etc. Field seams shall be differentiated from factory seams (if any). The layout drawings must be approved by the Owner prior to the installation of any geomembranes. These drawings shall not be modified without the prior approval of the Owner.

B. *Field Panel Identification*:

1. A geomembrane field panel is defined as a roll or a portion of a roll cut in the field.

2. Each field panel must be given an identification code (number or letter-number) consistent with the layout plan. This identification code shall be agreed upon by the Owner, and Contractor. The field panel

identification code shall be related, through a table or chart, to the original resin, and the constituent rolls and factory panels.

C. *Field Panel Placement:*

1. Field panels shall be installed at the location and positions indicated in the layout drawings.

2. Field panels shall be placed one at a time, and each field panel shall be seamed shortly after its placement.

3. Geomembrane shall not be placed when the ambient temperature is below 40°F unless the Contractor has previously submitted a geomembrane cold weather placement and seaming plan and such plan has been approved by the Owner.

4. Geomembranes shall not be placed during a precipitation event, in the presence of excessive moisture (e.g., fog, dew), in an area of ponded water, or in the presence of excessive winds.

5. The Contractor shall employ placement methods which ensure that:

   a. No vehicular traffic shall be allowed on the geomembrane.

   b. Equipment used shall not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons, or other means.

   c. Personnel working on the geomembrane shall not smoke, consume food or beverages (except for body fluid replenishment), wear damaging shoes, have cans, glass containers, or tools not required for liner placement on the geomembrane, or engage in other activities which could damage the geomembrane.

   d. The method used to unroll the panels shall not scratch or crimp the geomembrane and shall not damage the supporting soil.

   e. The method used to place the panels shall minimize wrinkles (especially differential wrinkles between adjacent panels).

   f. Temporary loads and/or anchors (e.g., sand bags), not likely to damage the geomembrane, shall be placed on the geomembrane to prevent uplift by wind.

6. On slopes, geomembranes shall be installed from the top of the slope to the bottom. The geomembrane shall be temporarily anchored at the

top of the slope prior to deployment. Unrestrained release of the geomembrane from the top of the slope is not acceptable.

7. Any field panel or portion thereof which becomes seriously damaged (torn, twisted, or crimped) shall be replaced with new material at no expense to the Owner. Less serious damage may be repaired with the approval of the Owner. Damaged panels or portions of damaged panels which have been rejected shall be removed from the work area at no expense to the Owner.

8. Adjacent geomembrane panels shall be overlapped as described in this Section. Larger overlaps shall be used if thermal contraction of the geomembrane is anticipated prior to seaming. Adjacent panels shall be placed under similar temperature conditions, preferably early in the day when temperatures are cooler, to minimize the potential for differential contraction.

9. If a textured geomembrane is placed over GCL, geotextile, or geocomposite a slip sheet (such as 20-mil smooth HDPE) shall first be placed over it in order to allow the geomembrane to slide into its proper position. Once the overlying geomembrane is properly positioned, the slip-sheet shall be carefully removed paying close attention to avoiding any movement to the geomembrane.

3.03 FIELD SEAMING

A. *Seam Layout:*

1. In general, seams shall be oriented parallel to the line of maximum slope, i.e., oriented down, not across, the slope. In corners and at odd-shaped geometric locations, the number of field seams shall be minimized. No horizontal seam shall be permitted less than 10 feet from the toe of the slope, except where approved by the Owner. No panels shall be seamed in the field without the Owner's approval.

B. *Personnel:*

1. All personnel performing seaming operations shall be qualified as required by the CQA Plan. At least one seamer shall have a minimum of 1,000,000 ft^2 of HDPE geomembrane experience. Seamers who don't have a minimum of 1 million ft^2 HDPE geomembrane experience will be considered inexperienced. Qualifications of the seamers shall be provided to the CQA Engineer prior to the start of construction. All personnel performing field seaming shall be qualified by experience or by passing seaming tests. The seaming tests shall require all inexperienced seamers to make 5 trial seams on-site prior to any actual field seams. The trial seams shall be tested according to this section and shall be performed under the supervision of an experienced seamer.

The CQA Engineer, or a designated representative, will observe and record the results of the tests. No seaming shall be performed unless a "master seamer" is present.

C. *Weather Conditions for Seaming*:

1. Seaming shall not be attempted at ambient temperatures below 40°F. At ambient temperatures between 40°F and 50°F, seaming will be allowed if the geomembrane is preheated either by the sun or a hot air device, and if there is no excessive cooling from wind. At ambient temperatures above 50°F, no preheating will be required. In all cases, the geomembrane shall be dry and protected from excessive wind.

2. If the Contractor wishes to perform seaming at ambient temperatures below 40°F, he shall demonstrate that the seam so produced is equivalent to those produced under normally approved conditions, and that the overall quality of the geomembrane is not adversely affected. The Contractor shall submit to the Owner for approval a geomembrane cold weather placement and seaming plan that details all aspects of the cold weather seaming operation.

3. To minimize geomembrane contraction stresses, seaming should ideally be carried out in the morning and late evening when the geomembrane is relatively contracted, and during the middle of the day if overcast conditions prevail. If the geomembrane is to be seamed in the middle of a sunny day, the Contractor shall ensure that there is sufficient slack in the geomembrane to prevent excessive stresses or trampolining when the geomembrane contracts as cooler temperatures prevail. The required amount of slack shall be determined by the Contractor and it should not be so much so as to cause excessive wrinkling of the geomembrane. If excessive trampolining or wrinkling of the geomembrane is observed, the Contractor will be required to make repairs to eliminate the problem at no additional cost to the Owner.

4. Ambient temperatures shall be measured near the crest of the landfill or surface impoundment.

D. *Overlapping and Temporary Bonding:*

1. Geomembrane panels shall be overlapped a minimum of 3 inches for extrusion welding and 4 inches for fusion welding or a greater amount if recommended by the geomembrane Manufacturer, but in any event, sufficient overlap shall be provided to allow peel tests to be performed on the seam.

2. The procedure used to temporarily bond adjacent panels together shall not damage the geomembrane. The temperature of the air at the nozzle

of a spot welding apparatus shall be controlled such that the geomembrane is not damaged.

3. No solvent or adhesive shall be used for cleaning or bonding of the geomembrane liner material.

E. *Seam Preparation:*

1. Prior to seaming, the seam area shall be cleaned so that it is free of moisture, dust, dirt, debris of any kind, and foreign material.

2. If seam overlap grinding is required, the process shall be completed according to the geomembrane Manufacturer's instructions and in a manner that does not damage the geomembrane.

3. Seams shall be aligned with the fewest possible number of wrinkles and "fishmouths".

F. *General Seaming Requirements:*

1. All geomembrane overlaps shall be continuously seamed using approved procedures.

2. Seaming shall extend to the outside edge of panels to be placed in the anchor trench.

3. If required, a firm substrate shall be provided by using a flat board, a conveyor belt, or similar hard surface, directly under the seam overlap to achieve proper support.

4. If seaming operations are carried out at night, adequate illumination shall be provided.

5. Fishmouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle to achieve a flat overlap. The cut fishmouths or wrinkles shall be seamed and any portion where the overlap is inadequate shall be patched with an oval or round patch of the same geomembrane that extends a minimum of 6 inches beyond the cut in all directions.

6. At the end of each day or installation segment, all exposed geomembrane edges shall be anchored by sandbags or other approved means. Sandbags securing the geomembrane on side slopes should be connected by a rope fastened at the top of the slope by a temporary anchor. If high winds are expected, boards with weighted sand bags on top may be used to keep wind from getting under the exposed edge of the geomembrane.

G. *Seaming Process:*

1. Approved processes for field seaming are extrusion welding and fusion welding using equipment that the Owner has approved by make and model. Alternate processes shall not be used unless a plan for their use has been submitted by the Contractor and approved by the Owner. Seaming equipment shall not damage the geomembrane.

2. Extrusion Equipment and Procedures:

   a. The Contractor shall maintain at least one spare operable seaming apparatus on site.

   b. The extrusion welding apparatus shall be equipped with gauges indicating the temperature in the apparatus and at the nozzle.

   c. Prior to beginning a seam, the extruder shall be purged until all heat-degraded extrudate has been removed from the barrel. Whenever the extruder is stopped, the barrel shall be purged of all heat-degraded extrudate.

   d. The Contractor shall provide documentation regarding the extrudate to the Owner and shall certify that the extrudate is compatible with the specifications, and consists of the same resin as the geomembrane.

   e. The electric generator for the extrusion welders shall be placed either outside the area to be lined or on a smooth base or other such manner that no damage occurs to the geomembrane.

3. Fusion Equipment and Procedures:

   a. The Contractor shall maintain at least one spare operable seaming apparatus on site.

   b. The fusion welding apparatus shall be an automated vehicular mounted device equipped with gauges indicating the applicable temperatures and pressures

   c. The edges of cross seams shall be abraded to a smooth incline (top and bottom) prior to welding.

   d. A movable protective layer shall be used directly below each geomembrane overlap to be seamed if deemed necessary by the Owner.

   e. The electric generator for the fusion welders shall be placed either outside the area to be lined or on a smooth base or other such manner that no damage occurs to the geomembrane.

f. All fusion welded seam intersections shall be patched in accordance with this Section.

H. *Trial Seams:*

1. Trial seams shall be made on fragment pieces of geomembrane to verify that seaming conditions are adequate. Such trial seams shall be made at the beginning of each seaming period (morning and afternoon). Each seamer shall make at least one trial seam each day. Trials seams shall also be made in the event that the ambient temperature varies more than 20°F since the last passing trial seam. Trial seams shall be made under the same conditions as actual seams. The trial seam sample shall be at least 5 feet long by 1 foot wide (after seaming) with the seam centered lengthwise for fusion trial seams and at least 3 feet long by 1 foot wide for extrusion trial seams. Seam overlap shall be as indicated in Part 3.03.D. of this Section.

2. Five specimens, each 1 inch wide, shall be cut from the trial seam sample by the Contractor. Two specimens shall be tested for shear strength and three specimens shall be tested for peel strength using a field tensiometer. Both tracks of double fusion welds will be tested for peel strength on each of the three specimens unless otherwise approved by the Owner. The test specimens shall not fail in the seam and shall meet or exceed the strength requirements in Table 02775-2. If a specimen fails, the entire operation shall be repeated. If the second trial seam fails, the seaming apparatus or seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved. Trial seam failure is defined as failure of any one of the five specimens.

3. The CQA Engineer will observe trial seam testing procedures. Successful trial seam samples will be assigned a number and marked accordingly by the CQA Engineer, who will also log the date, hour, ambient temperature, number of seaming unit, name of seamer, and pass or fail description. The sample itself will be retained only until the construction of the liner is complete, and the liner has been accepted by the Owner.

I. *Nondestructive Seam Continuity Testing:*

1. Except as noted below the Contractor shall nondestructively test for continuity all field seams over their full length, using the vacuum test (primarily for extrusion seams),or air pressure test (for double fusion seams only) methods. All other test methods must be approved by the Owner. These tests shall be carried out as the seaming work progresses, not at the completion of all field seaming. The Contractor shall complete any required repairs in accordance with this Section at no additional cost to the Owner.

2. If the seam cannot be nondestructively tested after final installation, the following procedures shall apply:

   a. Prior to seaming, the seamer shall make a new trial seam.

   b. The seam shall be capped with the same type of geomembrane if the seams of the cap can be nondestructively tested.

   c. If the seam is accessible to nondestructive testing prior to final installation but not after final installation, the seam shall be nondestructively tested prior to final installation.

   d. At the discretion of the Owner, vacuum testing of fusion welded seams may be allowed in lieu of capping fusion welded seams which cannot be air pressure tested.

   e. If none of the above techniques are practical the CQA Engineer will closely observe and document the seaming process.

3. <u>Vacuum Testing</u>

   a. The equipment for vacuum box testing shall comprise the following:

      i. A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly, and a vacuum gauge.

      ii. A steel vacuum tank and pump assembly equipped with a pressure controller and pipe connections.

      iii. A rubber pressure/vacuum hose with fittings and connections.

      iv. A bucket and applicator.

      v. A soapy solution.

   b. The following procedures shall be followed:

      i. Energize the vacuum pump and reduce the tank pressure to approximately 5 psi gauge.

      ii. Wet a strip of geomembrane seam approximately 4 inches by one and one half times the length (minimum) of the vacuum box with the soapy solution.

iii. Place the box over the wetted area.

iv. Close the bleed valve and open the vacuum valve.

v. Ensure that a leak tight seal is created as evidenced by a negative box pressure of a minimum 5 psi gauge.

vi. Examine the geomembrane through the viewing window for the presence of soap bubbles for not less than 10 seconds.

vii. If no bubbles appear after 10 seconds, close the vacuum valve and open the bleed valve, move the box to the next adjoining area with a minimum 3 inches overlap, and repeat the process.

viii. All areas where soap bubbles appear shall be marked with a marker that will not damage the geomembrane and repaired in accordance with Part 3.03.K. of this Section with no additional cost to the Owner.

4. Air Pressure Testing (For Double-Fusion Seams Only):

a. The following procedures are applicable to those processes which produce a double seam with an enclosed space.

b. The equipment shall comprise the following:

i. An air pump (manual or motor driven), equipped with a pressure gauge, capable of generating and sustaining a pressure between 25 and 30 psi, and mounted on a cushion to protect the geomembrane.

ii. A rubber hose with fittings and connections.

iii. A sharp hollow needle, or other approved pressure feed device.

c. The following procedures shall be followed:

i. Seal both ends of the seam to be tested.

ii. Insert needle, or other approved pressure feed device, into the tunnel created by the fusion weld.

iii. Insert a protective cushion between the air pump and the geomembrane.

iv. Energize the air pump to a gauge pressure between 25 and 30 psi, close valve, and sustain the pressure for not less than 5 minutes.

v. If the loss of pressure exceeds 2 psi, or does not stabilize, locate faulty area and repair in accordance with Part 3.03.K. of this Section.

vi. At the end of the test, cut the air channel at the end of the seam opposite the needle and verify air flow to ensure that the entire seam length was tested.

vii. Remove the needle, or other approved pressure feed device, and repair all test penetrations in accordance with Part 3.03.K. of this Section.

J. *Destructive Testing:*

1. Destructive seam tests shall be performed on samples collected from selected locations to evaluate seam strength and integrity. Destructive testing shall be carried out as the seaming work progresses, not at the completion of all field seaming.

2. Sampling:

a. Destructive test samples shall be collected at a minimum average frequency of one test location per 500 feet of seam length. Test locations shall be determined during seaming, and may be prompted by suspicion of excess crystallinity, contamination, offset seams, or any other potential cause of imperfect seaming. The CQA Engineer will be responsible for choosing the locations of destructive seam samples. The Contractor shall not be informed in advance of the locations where the seam samples will be taken. The CQA Engineer may increase the sampling frequency.

b. Samples shall be cut by the Contractor at the locations designated by the CQA Engineer as the seaming progresses in order to obtain laboratory test results before the geomembrane is covered by another material. Each sample shall be numbered and the sample number and location identified on the panel layout drawing. All holes in the geomembrane resulting from the destructive seam sampling shall be immediately covered. The holes shall be repaired in accordance with Part 3.03.K. of this Section. The continuity of the new seams in the repaired areas shall be tested according to this Section.

c. Two test specimens, each 1 inch wide and 6 to 12 inches long with the seam centered parallel to the width, shall be taken. The test specimens shall be spaced a clear distance of approximately 42 inches apart. These specimens shall be tested in the field in accordance with Part 3.03.J.3 of this Section. If these samples pass the field test, a laboratory sample shall be taken. The removed destructive sample shall be at least 12 inches wide by 42 inches long with the seam centered lengthwise. The sample shall be cut into three parts and distributed as follows:

i. One 12-inch long portion to the Contractor.

ii. One 18-inch long portion to the CQA Engineer for laboratory testing.

iii. One 12-inch long portion to the CQA Engineer for archive storage.

3. Field Testing:

a. The two 1 inch wide test specimens shall be tested in the field, using a tensiometer, for peel adhesion. Field testing shall be the responsibility of the Contractor and shall be observed by the CQA Engineer. The test specimens shall not fail in the weld more than 10 percent and shall meet the peel strength requirements of Table 02775-2. Both tracks of double fusion welded seams shall be tested in peel on each test specimen unless otherwise approved by the Owner. If any field test sample fails to pass, then the procedures outlined in Part 3.03.K. of this Section shall be followed.

4. Laboratory Testing:

a. Laboratory testing by the CQA Engineer, in accordance with the CQA Plan, shall include seam shear strength and shear strain at yield (ASTM D 3083) and peel adhesion (ASTM D 413). The minimum acceptable values to be obtained in these tests are those indicated in Table 02775-2. At least 5 specimens shall be tested for each test method. Specimens shall be selected alternately by test from the samples (i.e., peel, shear, peel, shear). A sample passes the laboratory tests when at least 4 out of 5 of the test specimens meet or exceed all of the test criteria. Both tracks of double fusion welded seams shall be tested in peel.

5. Destructive Test Failure:

a. The following procedures shall apply whenever a sample fails a destructive test, whether the test is conducted by the CQA Engineer's laboratory, the Contractor's laboratory, (if used) or by a field tensiometer. The Contractor shall have two options:

i. The Contractor can reconstruct the seam(s) (e.g., remove the old seam(s) and reseam, or cap the seam(s)) between any two passed test locations.

ii. The Contractor can trace the welding path to an intermediate location, a minimum of 10 feet from the location of the failed test (in each direction) and take test specimens for an additional field destructive tests at each location. If these field destructive tests pass, then full laboratory samples shall be taken. If these laboratory samples pass the tests, then the seam(s) shall be reconstructed between these locations. If either sample fails, then the process shall be repeated to establish the zone in which the seam shall be reconstructed. This will be done by following the chronological order in which the seaming apparatus welded the seam(s) prior to and after it welded the failing test location. In any case, all acceptable seams must be bounded by two locations from which samples passing laboratory destructive tests have been obtained. In cases exceeding 150 feet of reconstructed seam(s), a sample taken from within the reconstructed zone must pass destructive testing. Whenever a sample fails, the CQA Engineer may require additional tests for seams that were formed by the same seamer and/or seaming apparatus or seamed during the same time shift at no additional cost to the Owner.

iii. Should three consecutive failing destructives be performed on a single welding apparatus, the apparatus shall not be permitted to weld until the machine has been repaired and successfully passed three consecutive trial seams.

K. *Defects and Repairs:*

1. The geomembrane will be inspected before and after seaming for evidence of defects, holes, blisters, undispersed raw materials and any sign of contamination by foreign matter. The surface of the geomembrane shall be clean at the time of inspection. The

geomembrane surface shall be swept or washed by the Contractor if surface contamination inhibits inspection.

2. Each suspect location, both in seam and non-seam areas shall, at the discretion of the CQA Engineer, be either repaired or nondestructively tested using the methods described Part 3.03.I. of this section, as appropriate. Each location which fails nondestructive testing shall be marked by the CQA Engineer and repaired by the Contractor.

3. When geomembrane seaming is completed (or when seaming of a significant area of a geomembrane is completed) and prior to placing overlying materials, the CQA Engineer shall identify all excessive geomembrane wrinkles. The Contractor shall cut and reseam all wrinkles so identified. The seams thus produced shall be tested like any other seams.

4. Repair Procedures:

   a. Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, shall be repaired by the Contractor. Repairs to the geomembrane shall be completed to the base of the anchor trench but are not required across the base of the anchor trench. Several repair procedures exist. The final decision as to the appropriate repair procedure shall be agreed upon between the CQA Engineer and the Contractor. The procedures available include:

      i. Patching, used to repair holes, tears, intersections of fusion-welded seams, and undispersed raw materials;

      ii. Abrading and spot extrusion welding, used to repair small sections of extruded seams and air pressure test needle holes;

      iii. Spot seaming, used to repair areas where the geomembrane has been scratched, the geomembrane thickness has been reduced, or other minor, localized flaws exists;

      iv. Capping, used to repair failed seams; and,

      vi. Removing failing seams and replacing them with strips of new material seamed into place (used with long lengths of fusion seams).

   b. In addition, the following shall be satisfied:

i. Surfaces of the geomembrane which are to be repaired shall be abraded prior to the repair;

ii. All surfaces must be clean and dry at the time of repair;

iii. All seaming equipment used in repair procedures must be approved by the Owner;

iv. The repair procedures, materials, and techniques shall be approved in advance, for the specific repair, by the CQA Engineer;

v. Patches or caps shall extend at least 6 inches beyond the edge of the defect, and all corners of patches shall be rounded with a radius of at least 3 inches; and,

vi. The geomembrane below large caps shall be appropriately cut to avoid water or gas collection between the two sheets.

5. Repair Verification:

a. Each repair shall be located, logged, and nondestructively tested using the methods described in Part 3.03.I. of this Section, as appropriate. Repairs which pass the nondestructive test shall be taken as an indication of an adequate repair. Failed tests will require the repair to be redone and retested until a passing test results. At the discretion of the CQA Engineer, destructive testing may be required on large repairs.

3.04 MATERIALS IN CONTACT WITH THE LINER

A. The Contractor shall not leave any tools or equipment on the geomembrane.

B. The Contractor shall take all necessary precautions to ensure that the geomembrane is not damaged during its installation or during the installation of other components of the liner system or by other construction activities. Installation on rough surfaces shall be performed carefully. If approved by the Owner, additional loosely placed geotextile sections may be used by the Contractor to protect the geomembrane.

C. The CQA Engineer will provide monitoring of the placement and spreading of soil materials over the geomembrane as required by the CQA Plan.

D. Placement of sump and pipe bedding gravel on top of a geomembrane liner shall be carried out in accordance with Section 02224 and 02228 of these General Specifications.

E. Equipment shall not be driven directly on the geomembrane. Unless otherwise specified by the Owner, all equipment operating on materials overlying the geomembrane shall comply with the following:

Maximum Allowable Equipment Ground Pressure (psi)	*Thickness of Soil Above Geomembrane (inches)*
<5	12
<10	18
<20	24
>20	36

The maximum allowable equipment ground pressure shall be 65 psi. The acceptability of equipment operating at ground pressures greater than 65 psi will be evaluated by the Owner at the Contractor's expense.

These equipment ground pressure requirements do not apply to any equipment used to construct the secondary or primary clay liners. The Owner may restrict the use of equipment that may potentially damage the geomembrane.

F. *Appurtenances*:

1. Installation of the geomembrane in sump areas, and connection of the geomembrane to appurtenances shall be made according to the specifications. Extreme care shall be taken while seaming around sumps and appurtenances since neither nondestructive nor destructive testing may be feasible in these areas.

2. All clamps, slips, bolts, nuts, or other fasteners used to secure the geomembrane to each appurtenance shall be at least as durable as the geomembrane.

3. Geomembrane boots for pipe penetrations shall be factory fabricated and tested where practical. Geomembrane boots shall be installed as shown on the Construction Drawings and in accordance with any geomembrane Manufacturer recommendations.

3.05 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all materials and partially completed and completed work.

B. In the event of damage, the Contractor shall make repairs and replacements necessary to the approval of the Owner and at no additional cost to the Owner.

C. The CQA Engineer will issue an approval of the geomembrane liner installation to the Owner in accordance with the CQA Plan prior to placement of any material over the geomembrane.

3.06 RECORD DRAWINGS

A. Within 7 days of the completion of installation of any layer of geomembrane liner and unless otherwise approved by the Owner, the Contractor shall provide 2 copies of a complete "as-built" record drawing to the Owner. This record drawing shall be prepared by the Contractor and shall be at a scale of no less than 1 inch equals 30 feet.

B. Record drawings shall include the following:

1. The surveyed locations, dimensions, and elevations of anchor trenches.

2. The identification, size, and surveyed location of all deployed field panels of geomembrane liner (with date of deployment).

3. The identification, length, and surveyed location of all seams (both factory and field seams).

4. The location, and type of all repairs to seams and field panels.

5. The destructive test sample locations and pass/fail results.

C. The Owner will review the record drawing and either approve it or return it to the Contractor for revision. If the drawing is returned to the Contractor, he shall revise the drawing as requested by the Owner. No additional construction that would cover the installed geomembrane may be performed until the record drawing is approved by the Owner. The Contractor may submit a partial record to obtain approval for a portion of work.

TABLE 02775-1
REQUIRED GEOMEMBRANE

Property	Test Method	60 mil HDPE [1]
Thickness	ASTM D1593 Para 8.1.3 (Smooth)	60 mil
	ASTM D751 (Textured)	57 mil (min)
Specific Gravity	ASTM D1505	0.940
Elongation @ Yield	ASTM D638	13%
Elongation @ Break	ASTM D638 Speed C	500% Smooth 100% Textured
Tensile Strength @ Yield	ASTM D638 Test Specimen Type IV	132 lb/in
Tensile Strength @ Break	ASTM D638	228 lb/in Smooth 132 lb/in Textured
Carbon Black Content	ASTM D1603	2% to 3%
Carbon Black Dispersion	ASTM D3015 and ASTM D2663	A-1, A-2, B-1
Environmental Stress Crack	ASTM D1693	1,500 hrs
Low Temperature Brittleness	ASTM D746 Procedure B	-103°F
Dimensional Stability	ASTM D1204	<1.5% (max)
Puncture Resistance	FTMS 101C	78 lb Smooth 78 lb Textured

Note:
[1]Values represent minimum average roll values (i.e., any roll in a lot should meet or exceed the values in this table). Where ranges of values are given, the average roll values must be within the specified range. The specified dimensional stability is a maximum average roll value.

TABLE 02775-2
REQUIRED GEOMEMBRANE SEAM PROPERTIES[1]

ASTM D4437		60 Mil HDPE			
Shear	Fusion lbs/in	120	Smooth	113	Textured
	Extrusion lbs/in	120	Smooth	113	Textured
Peel	Fusion lbs/in	90	Smooth	90	Textured
	Extrusion lbs/in	80	Smooth	80	Textured

Note: (1) Specified properties are minimums.

[END OF SECTION]

SECTION 02780
GEOSYNTHETIC CLAY LINERS

PART 1: ENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment supervision, transportation, and installation services necessary for the installation of the geosynthetic clay liner (GCL) of the landfill or surface impoundment. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02119 - Prepared Subgrade
B. Section 02221 - Clay Liner
C. Section 02710 - Geocomposite
D. Section 02775 - Geomembrane Liners

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan. The Contractor shall require the GCL manufacturer to comply with the submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

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

B. The Contractor shall be aware of all activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. The Contractor shall deliver GCL to the site at least 14 calendar days prior to installation to allow sufficient time for testing required by the CQA Plan.

D. GCL rolls that do not meet the requirements of this General Specification will be rejected. The Contractor shall replace rejected material with new material that conforms to the specification requirements, at no additional cost to the Owner.

E. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extent of the

nonconforming area. The nonconforming area shall be reworked by the Contractor at no cost to the Owner until acceptable test results are obtained.

PART 2: PRODUCTS

2.01 GCL PROPERTIES

The GCL material shall be in accordance with the test methods, test frequencies and material physical properties as listed in Table 02780-1.

A. In addition to the property values listed in Table 02780-1, the GCL material shall:

1. The GCL shall be manufactured by mechanically bonding the geotextiles using a needle punching or stitching process to create frictional and shear strength characteristics.

2. In order to maintain these characteristics, no glues, adhesives or other non-mechanical bonding processes shall be used in lieu of the needle punch or stitching process. Their use to enhance the physical properties of the GCL is not permitted.

3. Interface Shear Testing of Proposed Equal Materials

   Interface shear tests (ASTM D 5321) shall be performed by the Geosynthetic Laboratory under the direction of the Design Engineer. Interface shear testing will be performed on fully hydrated GCL samples using a 12 inch by 12 inch shear box under test conditions described by the Design Engineer. The number of tests to be performed is based on a ratio of one test per 100,000 ft^2 of material. All costs related to testing and evaluation of proposed equal materials are the responsibility of the Contractor.

4. Interface Shear Testing for QA Conformance Samples

   Interface shear tests (ASTM D 5321) shall be performed by the Geosynthetic Laboratory under the direction of the CQA Engineer using test procedures determined by the Design Engineer. Tests will be performed at a frequency of one test per 100,000 ft^2 of material. All costs related to testing and evaluation of conformance samples is the responsibility of the CQA Engineer.

2.02 MANUFACTURING QUALITY CONTROL

A. The Contractor shall require that the GCL Manufacturer sample and test the GCL, at the frequencies outlined in Table 02780-1 the tests shall demonstrate that the GCL properties conform to the values specified in Table 02780-1. All Quality Control testing required by these General Specifications and/or

conducted at the discretion of the Contractor shall be the responsibility of the Contractor. GCL rolls that do not have acceptable manufacturing quality control test results shall be rejected by the Owner.

B. Quality Control certificates shall be issued by the GCL manufacturer to the project engineer, CQA inspector or other designated party for each delivery of material. The certifications shall be signed by the quality control manager of the GCL manufacturer or other responsible party and shall include the following information:

1. *Shipment Packing List* - A list indicating the rolls shipped on a particular truckload.

2. *Bill of Lading* - A list indicating the rolls shipped on a particular truckload.

3. *Letter of Certification* - The letter indicating the material is in conformance with the physical properties specified.

4. *Physical Properties Sheet* - The material specification for the GCL supplied in accordance with this specification.

C. Quality Control submittals shall be issued by the GCL manufacturer to the project engineer, CQA inspector or other designated party for each lot of material if necessary. The submittals shall include the following information:

1. *Bentonite Manufacturer Certification* - Bentonite manufacturer quality documentation for the particular lot of clay used in the production of the rolls delivered.

2. *Geotextile Manufacturer Certification* - Geotextile manufacturer quality control documentation for the particular lots of geotextiles used in the production of the rolls delivered.

3. *GCL Manufacturer Tracking List* - Cross referencing list delineating the corresponding geotextile and bentonite lots for the materials used in the production of the rolls delivered.

4. *Manufacturing Quality Control Data* - The manufacturing quality control test data indicating the actual test values obtained when tested at the appropriate frequencies for the properties specified in Table 02780-1.

D. *Manufacturing Plant Visit*:

1. The Manufacturer shall permit the Owner or Owner's representative(s) to visit the manufacturing plant. Visits may be during the manufacturing of the GCL rolls for the specific project.

2. During the visit, the Owner or Owner's representative(s) may:

   a. Review the manufacturing process, quality control procedures, laboratory facilities, and testing procedures;

   b. Verify that properties guaranteed by the Manufacturer comply with the specifications;

   c. Verify that the measurements of properties by the Manufacturer are properly documented and the test methods used are acceptable;

   d. Inspect select GCL rolls for evidence of holes, delamination, or any sign of contamination by foreign matter;

   e. Review packaging and transportation procedures;

   f. Verify that roll packages are labeled in compliance with this Section; and,

   g. Take conformance samples from GCL rolls that are assigned to the project.

E. Any accessory bentonite used for sealing seams, penetrations, or repairs, shall be the same granular bentonite as used in the production of the GCL itself.

2.03 LABELING

A. The geomembrane shall be labeled with the following information:

1. Length and width of the roll or factory panel;
2. Name of Manufacturer;
3. Product identification;
4. Lot number; and,
5. Roll or factory panel number.

2.04 TRANSPORTATION

A. Transportation of the GCL is the responsibility of the Contractor. The Contractor shall be liable for all damage to materials prior to and during transportation to the site. The Contractor shall replace any damaged rolls at no additional cost to the Owner.

2.05 HANDLING AND STORAGE

A. Handling, storage, and care of the GCL prior to and following incorporation in the work is the responsibility of the Contractor. The Contractor shall be liable

for all damage to the material incurred prior to final acceptance of the installation by the Owner. The Contractor shall repair any damage in accordance with this Section and at no additional cost to the Owner.

B. The Contractor shall be responsible for storage of the GCL at the site. The GCL shall be protected from water, dirt, puncture, cutting, or other damaging or deleterious conditions. The GCL shall also be stored in accordance with any additional requirements of the GCL Manufacturer, Owner, or CQA Engineer.

1. GCL should be stored no higher than three to four rolls high or limited to the height at which the handling apparatus may be safely handled by installation personnel. Stacks or tiers of rolls should be situated in a manner that prevents sliding or rolling by chocking the bottom layer of rolls.

2. Rolls shall not be stacked on uneven or discontinuous surfaces as this may cause bending or deformation of the rolls and in turn damage the GCL or cause difficulty inserting the core pipe.

3. An additional tarpaulin or plastic sheet shall be used over the stacked rolls to provide extra protection for GCL material stored outdoors.

4. Bagged bentonite material shall be stored and tarped next to GCL rolls unless other more protective measures are available. Bags shall be stored on pallets or other suitably dry surface which will prevent undue prehydration.

C. GCL must be supported during handling to ensure worker safety and prevent damage to the liner. Under no circumstances should the rolls be dragged, lifted from one end, lifted with only the forks of a lift truck or pushed to the ground from the delivery vehicle.

The CQA inspector shall verify that suitable handling equipment exists which does not pose any danger to installation personnel or risk of damage or deformation to the GCL material itself. Typical handling equipment is described below:

1. *Spreader Bar Assembly* - A spreader bar assembly shall include both a core pipe or bar and a spreader bar beam. The core pipe shall be used to uniformly support the roll when inserted through the GCL core while the spreader bar beam will prevent chains or straps from chafing the roll edges.

2. *Stinger* - A stinger is a rigid pipe or rod with one end directly connected to a forklift or other handling equipment. If a stinger is used, it should be fully inserted to its full length into the roll to prevent excessive bending of the roll when lifted.

3. *Roller Cradles* - Roller cradles consist of two larger diameter rollers spaced approximately 3 inches apart which both support the GCL roll and allow it to be freely unrolled. The use of roller cradles shall be permitted if the rollers support the entire width of the GCL roll.

4. *Straps* - Straps may be used to support the ends of the spreader bars *but are not recommended as the primary support mechanism.* As straps may damage the GCL where around the roll and generally do not provide sufficient uniform support to prevent roll bending or deformation, great care must be exercised when this option is used.

PART 3: EXECUTION

3.01 EARTHWORK

The surface upon which the GCL material will be installed shall be inspected by the CQA inspector and certified by the Earthwork Contractor to be in accordance with the requirements of this specification.

A. Site specific compaction requirements should be followed in accordance with the project drawings and specifications. At a minimum, the level of compaction should be such that no rutting is caused by installation equipment or other construction vehicles which traffic the area of deployment.

B. The surfaces to be lined shall be smooth and free of any debris, vegetation, roots, sticks, sharp rocks, or other deleterious materials larger than two inches as well as free of any voids, large cracks or standing water or ice.

C. Directly prior to deployment of the GCL, the subgrade shall be final graded to fill remaining voids or desiccation cracks, and smooth drum rolled to eliminate sharp irregularities or abrupt elevation changes. The surfaces to be lined shall be maintained in this smooth condition.

3.02 GEOSYNTHETIC SUBGRADE

Prior to GCL deployment on another geosynthetic surface shall be inspected and approved by the third party CQA inspector in accordance with the requirements of the project specification documents.

3.03 ANCHOR TRENCH

An anchor trench shall be excavated by the earthwork contractor or liner installer to the lines and grades shown on the project drawings.

A. The anchor trench shall be constructed free of sharp edges or corners and maintained in a dry condition. No loose soil shall be permitted beneath the GCL within the trench.

B. The anchor trench shall be inspected as well as approved by the CQA inspector prior to the GCL placement, back-filling and compaction of the anchor key material.

3.04 SUBGRADE INSPECTION

The earthen or geosynthetic subgrade shall be continuously inspected, approved and certified by the CQA inspector prior to GCL placement.

Upon approval by the CQA inspector, it shall be the installer's responsibility to indicate to the Engineer any change in the condition of the subgrade that could cause it to be out of compliance with any of the requirements of this section or the project specific specification.

3.05 GCL DEPLOYMENT

A. *GCL Orientation* - In the absence of specific guidelines, GCL panels should be placed with the non-woven side up on slopes to maximize the shear strength characteristics.

B. *GCL Panel Position* - Where possible, all slope panels should be installed parallel to the maximum slope while panels installed in flat areas require no particular orientation. No horizontal GCL panel seams shall be allowed on slopes steeper than 5%.

C. *Panel Deployment* - GCL materials shall be installed in general accordance with the procedures set forth in this section, subject to site specific conditions which would necessitate modifications.

Reinforced GCL shall be used on both slopes as well as the flat areas to ensure the GCL withstands the rigors of the installation and subsequent low load hydration.

1. Deployment should proceed from the highest elevation to the lowest to facilitate drainage in the event of precipitation.

2. The GCL may be deployed on slopes by pulling the material from a suspended roll, or securing a roll end into an anchor trench and unrolling each panel as the handling equipment slowly moves backwards.

3. Deployment on flat areas shall be conducted in the same manner as that for the slopes, however, care should be taken to minimize dragging the GCL. Slip-sheet may be used to facilitate positioning of the liner while ensuring the GCL is not damaged from underlying sources.

4. Overlaps shall be a minimum of 6 inches and be free of wrinkles, folds or fishmouths.

5. The Contractor shall only install as much GCL that can be covered at the end of the day. No GCL shall be left exposed overnight. The exposed edge of the GCL shall be covered by a temporary tarpaulin or other such water resistant sheeting until the next working day.

D. *Anchoring* - All GCL material installed on slopes greater than 7H:1V shall be anchored to prevent potential GCL panel movement.

1. Standard Anchor - The GCL shall be placed into and across the base of the excavated trench, stopping at the back wall of the excavation as shown on the drawing.

E. *Seaming* - A 6-inch lap line and a 9-inch match line shall be imprinted on both edges of the upper geotextile component of the GCL to assist in installation overlap quality control. Lines shall be printed as continuous dashes in easily observable non-toxic ink.

1. Overlap seams shall be a minimum of six inches on panel edges and one foot on panel ends.

2. Loose granular bentonite should be placed between panels at a rate of 1/4 pound per linear foot of seam.

F. *Detailing* - Detail work, defined as the sealing of the liner to pipe penetrations, foundation walls, drainage structures, spillways, and other appurtenances, shall be performed as recommended by the Design Engineer and the GCL Manufacturer.

G. *Damage Repair* - Prior to geomembrane material placement, damage to the GCL shall be identified and repaired by the installer. Damage is defined as any rips or tears in the geotextiles, delamination of geotextiles or a displaced panel.

1. Rip and Tear Repair (Flat Surfaces) - Rips or tears may be repaired by completely exposing the affected area, removing all foreign objects or soil and by then placing a patch cut from unused GCL over the damage (damaged material may be left in place), with a minimum of overlap of 12 inches on all edges.

2. Rip and Tear Repair (Slopes) - Damaged GCL material on slopes shall be repaired by the same procedures above. The minimum overlap of 12 inches on all edges may be increased as recommended by the CQA Engineer.

3. Displaced Panels - Displaced panels shall be adjusted to the correct position an orientation. The adjusted panel shall then be inspected for any geotextile damage or bentonite loss. Damage shall be repaired by the above procedure.

4. Premature Hydration - If the GCL is subjected to premature hydration, the GCL installer shall notify the CQA Engineer for a site specific determination as to whether the material is acceptable or if alternative measures must be taken to ensure the quality of the design-dependent upon the degree of damage.

3.06 MATERIALS IN CONTACT WITH THE GCL

A. The Contractor shall not leave any tools or equipment on the GCL.

B. The Contractor shall take all necessary precautions to ensure that the GCL is not damaged during its installation or during the installation of other components of the landfill or by other construction activities. Installation on rough surfaces shall be performed carefully.

C. The CQA Engineer will provide monitoring of the placement and spreading of soil materials over the GCL. Equipment shall not be driven directly on the GCL. Unless otherwise specified by the Owner, all equipment operating on materials overlying the GCL shall comply with the following:

Maximum Allowable Equipment Ground Pressure (psi)	*Thickness of Soil Above GCL (inches)*
<5	12
<10	18
<20	24
>20	36

The maximum allowable equipment ground pressure shall be 65 psi. The acceptability of equipment operating at ground pressures greater than 65 psi will be evaluated by the Owner at the Contractor's expense.

D. Installation of the overlying geosynthetic component can be accomplished through the use of *lightweight*, rubber-tired equipment such as a 4-wheel all-terrain vehicle (ATV). This vehicle can be driven directly on the GCL, provided the ATV makes no sudden stops, starts, or turns.

E. Smooth HDPE may be dragged across the GCL surface with equipment or by hand labor during positioning. Similarly, the HDPE may be unrolled with the use of low ground pressure equipment.

F. If a textured geomembrane is placed over the GCL, a slip sheet (such as 20-mil smooth HDPE) shall first be placed over the GCL in order to allow the geomembrane to slide into its proper position. Once the overlying geomembrane is properly positioned, the slip-sheet shall be carefully removed paying close attention to avoiding any movement to the geomembrane.

3.07 PROTECTION OF THE WORK

A. The Contractor shall use all means necessary to protect all materials and partially completed and completed work.

B. In the event of damage, the Contractor shall make repairs and replacements necessary to the approval of the Owner and at no additional cost to the Owner.

C. The CQA Engineer will issue an approval of the GCL liner installation to the Owner in accordance with the CQA Plan prior to placement of any material over the GCL.

TABLE 02780-1
REQUIRED GCL PROPERTIES[4]

Geotextile Properties	Test Method	Manufacturer's QC Minimum Test Frequency	Value -English-	Value -SI-
Nonwoven Mass/Unit Area	ASTM D 5261	1/ 200,000 sq. ft (1/20,000 sq. m)	7.4 oz./yd^2 Typical 6.0 oz./yd^2 MARV	250 g/m^2 Typical 200 g/m^2 MARV
Woven	ASTM D 5261	1/ 200,000 sq. ft (1/20,000 sq. m)	3.4 oz./yd^2 Typical 3.1 oz./yd^2 MARV	115 g/m^2 Typical 105 g/m^2 MARV
BENTONITE				
Swell Index	ASTM D 5890	1/100,000 lbs. (50,000 kg)	24 ml/2g min.	24 ml/2g min.
Moisture Content	ASTM D 4643	1/100,000 lbs. (50,000 kg)	12% max.	12% max.
Fluid Loss	ASTM D 5891	1/100,000 lbs. (50,000 kg)	18 ml max.	18 ml max.
FINISHED GCL [4]				
Bentonite Mass Per Unit Area[1]	ASTM D 5261	1/ 50,000 sq. ft (1/5,000 sq. m)	0.90 lb./sq. Ft MARV	4.39 kg/m^2 MARV
Grab Strength[2]	ASTM D 4362	1/ 50,000 sq. ft (1/5,000 sq. m)	95 lbs MARV	422 N MARV
Grab Elongation[2]	ASTM D 4632	1/ 50,000 sq. ft (1/5,000 sq. m)	75% Typical	75% Typical
Peel Strength	ASTM D 4632	1/ 50,000 sq. ft (1/5,000 sq. m)	15 lbs. min.	66 N min.
Permeability[3]	ASTM D 5084	1/100,000 sq. ft (1/10,000 sq. m)	5×10^{-9} cm/sec max	5×10^{-9} cm/sec max
Interface Shear[5]	ASTM 5321	1/100,000 sq.ft. 1/10,000 sq. m)	$\phi = 2°$, C = 440 psf	$\phi = 2°$, C = 21.1 Kpa

Notes:

1. Oven-dried measurement reflecting a moisture content of zero.
2. Measured at maximum peak, in the weakest principal direction.
3. De-Aired Tap Water @ 5 psi maximum effective confining stress and 2 psi head.
4. Internal shear strength testing (ASTM D 5321) of QA conformance samples or proposed equal material will be performed by the CQA Engineer as described in this specification.
5. Residual strength values tested under saturated undrained conditions at normal loads representative of design conditions.

[END OF SECTION]

SECTION 02900
VEGETATION AND SEEDING

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, and installation services for establishing vegetation on the surface of disturbed areas.

1.02 RELATED SECTIONS

A. Section 02227 Vegetative Cover

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualifications and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION AND QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The CQA Engineer will coordinate independent surveying required by the CQA Plan. Surveying by the CQA Engineer does not relieve the Contractor of his responsibility to lay out, control and document the work.

C. If the CQA Engineer's tests indicate work does not meet the requirements of the specifications, the CQA Engineer will establish the extend of the nonconforming area. The nonconformance area shall be reworked by the Contractor at no cost to the Owner until acceptable test results are obtained.

PART 2: PRODUCTS

2.01 MATERIALS

A. Seed mixture for planting shall be as specified by the New Mexico SCS.

PART 3: EXECUTION

3.01 SITE PREPARATION

A. Remove all weeds from areas to be planted. Roughen seed bed to a depth of 2 to 4 inches by scarifying, disking, harrowing, or equivalent methods.

3.02 PLANTING

A. Plant seed using equipment and procedures appropriate for seed type at recommended by the seed supplier.

[END SECTION]

SECTION 03100
CONCRETE FORMWORK

PART 1: GENERAL

1.01 THE REQUIREMENT

A. The Contractor shall furnish all materials for concrete form work, bracing, shoring, and supports and shall design and construct all falsework, all in accordance with the provisions of the General Specifications, the CQA Plan, and the Construction Drawings.

1.02 REFERENCE SPECIFICATIONS, CODES, AND STANDARDS

A. Codes: All codes, as referenced herein.

B. Government Standards:

PS 1 Construction and Industrial Plywood

PS 20 American Softwood Lumber Standard

C. Commercial Standards:

ACI 117 Standard Tolerances for Concrete Construction and Materials

ACI 347 Guide to Formwork for Concrete

1.03 CONTRACTOR SUBMITTALS

A. The Contractor shall submit the following.

1. Form ties and all related accessories, including taper tie plugs, if taper ties are used.

2. Form gaskets.

1.04 QUALITY ASSURANCE

A. Tolerances: The variation from established grade or lines shall not exceed 1/4-inch in 10 feet and there shall be no offsets or visible waviness in the finished surface. All other tolerances shall be within the tolerances of ACI 117.

PART 2: PRODUCTS

2.01 GENERAL

A. Except as otherwise expressly accepted by the Engineer, all lumber brought on the job site for use as forms, shoring, or bracing shall be new material. All forms shall be smooth surface forms and shall be of the following materials:

Walls	-	Steel or plywood panel
Columns	-	Steel, plywood or fiber glass
Roof and floor	-	Plywood
All other work	-	Steel panels, plywood or tongue and groove lumber

B. Form materials which may remain or leave residues on or in the concrete shall be classified as acceptable for potable water use by the Environmental Protection Agency within 30 days of application or use.

2.02 FORM AND FALSEWORK MATERIALS

A. Materials for concrete forms, formwork, and falsework shall conform to the following requirements:

1. Lumber shall be Douglas Fir or Southern Yellow Pine, construction grade or better, in conformance with U.S. Product Standard PS 20.

2. Plywood for concrete formwork shall be new, waterproof, synthetic resin bonded, exterior type Douglas Fir or Southern Yellow Pine plywood manufactured especially for concrete formwork and shall conform to the requirements of PS 1 for Concrete Forms, Class I, and shall be edge sealed.

3. Form materials shall be metal, wood, plywood, or other approved material that will not adversely affect the concrete and will facilitate placement of concrete to the shape, form, line, and grade shown. Metal forms shall be an approved type that will accomplish such results. Wood forms for surfaces to be painted shall be Medium Density Overlaid plywood, MDO Ext. Grade.

B. Unless otherwise shown, exterior corners in concrete members shall be provided with 3/4-inch chamfers. Re-entrant corners in concrete members shall not have fillets unless otherwise shown.

C. Forms and falsework to support the roof and floor slabs shall be designed for the total dead load, plus a live load of 50 psf (minimum). The minimum design load for combined dead and live loads shall be 100 psf.

2.03 FORM TIES

A. Form ties shall be provided with a plastic cone or other suitable means for forming a conical hole to insure that the form tie may be broken off back of the face of the concrete. The maximum diameter of removable cones for rod ties, or of other removable form-tie fasteners having a circular cross-section, shall not exceed 1-1/2 inches; and all such fasteners shall be such as to leave holes of regular shape for reaming. Form ties for water-retaining structures shall have integral waterstops. Integral waterstops shall tightly fit the form tie so that they cannot be moved from mid-point of the tie. Form ties shall be Burke Penta-Tie System by The Burke Company; Richmond Snap-Tys by the Richmond Screw Anchor Company; or equal.

B. Removable taper ties may be used when approved by the Engineer. A preformed neoprene or polyurethane tapered plug sized to seat at the center of the wall shall be inserted in the hole left by the removal of the taper tie. Use Burke Taper-Tie System by The Burke Company; Taper-Ty by the Richmond Screw Anchor Company; or equal.

PART 3: EXECUTION

3.01 GENERAL

A. Forms to confine the concrete and shape it to the required lines shall be used wherever necessary. The Contractor shall assume full responsibility for the adequate design of all forms, and any forms which are unsafe or inadequate in any respect shall promptly be removed from the WORK and replaced at the Contractor's expense. Provide worker protection from protruding reinforcement bars in accordance with applicable safety codes. A sufficient number of forms of each kind shall be provided to permit the required rate of progress to be maintained. The design and inspection of concrete forms, falsework, and shoring shall comply with applicable local, state and Federal regulations. Plumb and string lines shall be installed before concrete placement and shall be maintained during placement. Such lines shall be used by Contractor's personnel and by the Engineer and shall be in sufficient number and properly installed. During concrete placement, the Contractor shall continually monitor plumb and string line form positions and immediately correct deficiencies.

B. Concrete forms shall conform to the shape, lines, and dimensions of members as called for on the Drawings, and shall be substantial, free from surface defects, and sufficiently tight to prevent leakage. Forms shall be properly braced or tied together to maintain their position and shape under a load of freshly-placed concrete. If adequate foundation for shores cannot be secured, trussed supports shall be provided.

3.02 FORM DESIGN

A. All forms shall be true in every respect to the required shape and size, shall conform to the established alignment and grade, and shall be of sufficient strength and rigidity to maintain their position and shape under the loads and operations incident to placing and vibrating the concrete. Suitable and effective means shall be provided on all forms for holding adjacent edges and ends of panels and sections tightly together and in accurate alignment so as to prevent the formation of ridges, fins, offsets, or similar surface defects in the finished concrete. Plywood, 5/8-inch and greater in thickness, may be fastened directly to studding if the studs are spaced close enough to prevent visible deflection marks in the concrete. The forms shall be tight so as to prevent the loss of water, cement and fines during placing and vibrating of the concrete. Specifically, the bottom of wall forms that rest on concrete footings or slabs shall be provided with a gasket to prevent loss of fines and paste during placement and vibration of concrete. Such gasket may be a 1- to 1-1/2-inch diameter polyethylene rod held in position to the underside of the wall form. Adequate clean-out holes shall be provided at the bottom of each lift of forms. The size, number, and location of such clean-outs shall be as acceptable to the Engineer. Whenever concrete cannot be placed from the top of a wall form in a manner that meets the requirements of the General Specifications, form windows shall be provided in the size and spacing needed to allow placement of concrete to the requirements of Section 03300, Cast-in-Place Concrete. The size, number, and location of such form windows shall be as acceptable to the Engineer.

3.01 CONSTRUCTION

A. Vertical Surfaces: All vertical surfaces of concrete members shall be formed, except where placement of the concrete against the ground is shown. Not less than 1-inch of concrete shall be added to the thickness of the concrete member as shown where concrete is permitted to be placed against trimmed ground in lieu of forms. Such permission will be granted only for members of comparatively limited height and where the character of the ground is such that it can be trimmed to the required lines and will stand securely without caving or sloughing until the concrete has been placed.

B. Construction Joints: Concrete construction joints will not be permitted at locations other than those shown or specified, except as may be acceptable to the Engineer. When a second lift is placed on hardened concrete, special precautions shall be taken in the way of the number, location, and tightening of ties at the top of the old lift and bottom of the new to prevent any unsatisfactory effect whatsoever on the concrete. Pipe stubs and anchor bolts shall be set in the forms where required.

C. Form Ties:

1. Embedded Ties: Holes left by the removal of form tie cones shall be reamed with suitable toothed reamers so as to leave the surface of the holes clean and rough before being filled with mortar as specified for "Finish of Concrete Surfaces" in Section 03300 - Cast-in-Place Concrete. Wire ties for holding forms will not be permitted. No form-tying device or part thereof, other than metal, shall be left embedded in the concrete. Ties shall not be removed in such manner as to leave a hole extending through the interior of the concrete members. The use of snap-ties which cause spalling of the concrete upon form stripping or tie removal will not be permitted. If steel panel forms are used, rubber grommets shall be provided where the ties pass through the form in order to prevent loss of cement paste. Where metal rods extending through the concrete are used to support or to strengthen forms, the rods shall remain embedded and shall terminate not less than 1-inch back from the formed face or faces of the concrete.

2. Removable Ties: Where taper ties are approved for use, the larger end of the taper tie shall be on the wet side of walls in water retaining structures. After the taper tie is removed, the hole shall be thoroughly cleaned and roughened for bond. A precast neoprene or polyurethane tapered plug shall be located at the wall centerline. The hole shall be completely filled with non-shrink grout for water bearing and below-grade walls. The hole shall be completely filled with non-shrink or regular cement grout for above-grade walls which are dry on both sides. Exposed faces of walls shall have the outer 2 inches of the exposed face filled with a cement grout which shall match the color and texture of the surrounding wall surface.

3.02 REUSE OF FORMS

A. Forms may be reused only if in good condition and only if acceptable to the Engineer. Light sanding between uses will be required wherever necessary to obtain uniform surface texture on all exposed concrete surfaces. Exposed concrete surfaces are defined as surfaces which are permanently exposed to view. In the case of forms for the inside wall surfaces of hydraulic/water retaining structures, unused tie rod holes in forms shall be covered with metal caps or shall be filled by other methods acceptable to the Engineer.

3.03 REMOVAL OF FORMS

A. Careful procedures for the removal of forms shall be strictly followed, and this work shall be done with care so as to avoid injury to the concrete. No heavy loading on green concrete will be permitted. In the case of roof slabs and above-ground floor slabs, forms shall remain in place until test cylinders for the roof concrete attain a minimum compressive strength of 75 percent of the 28-day strength specified in Section 03300 - Cast-in-Place Concrete; provided, that

no forms shall be disturbed or removed under an individual panel or unit before the concrete in the adjacent panel or unit has attained 75 percent of the specified 28-day strength and has been in place for a minimum of 7 days. The time required to establish said strength shall be as determined by the Engineer who will make several test cylinders for this purpose from concrete used in the first group of roof panels placed. If the time so determined is more than the 7-day minimum, then that time shall be used as the minimum length of time. Forms for all vertical walls of waterholding structures shall remain in place at least 36 hours after the concrete has been placed. Forms for all parts of the work not specifically mentioned herein shall remain in place for periods of time as recommended in ACI 347.

3.04 MAINTENANCE OF FORMS

A. Forms shall be maintained at all times in good condition, particularly as to size, shape, strength, rigidity, tightness, and smoothness of surface. Forms, when in place, shall conform to the established alignment and grades. Before concrete is placed, the forms shall be thoroughly cleaned. The form surfaces shall be treated with a nonstaining mineral oil or other lubricant acceptable to the Engineer. Any excess lubricant shall be satisfactorily removed before placing the concrete. Where field oiling of forms is required, the Contractor shall perform the oiling at least two weeks in advance of their use. Care shall be exercised to keep oil off the surfaces of steel reinforcement and other metal items to be embedded in concrete.

3.05 FALSEWORK

A. All falsework shall be designed and constructed to provide the necessary rigidity and to support the loads. Falsework for the support of a superstructure shall be designed to support the loads that would be imposed if the entire superstructure were placed at one time.

B. Falsework shall be placed upon a solid footing, safe against undermining, and protected from softening. When the falsework is supported on timber piles, the maximum calculated pile loading shall not exceed 20 tons. When falsework is supported on any portion of the structure which is already constructed, the load imposed by the falsework shall be spread, distributed, and braced in such a way as to avoid any possibility of damage to the structure.

[END OF SECTION]

SECTION 03200 - REINFORCEMENT STEEL

PART 1: GENERAL

1.01 THE REQUIREMENT

A. The Contractor shall furnish, fabricate, and place all concrete reinforcement steel, welded wire fabric, couplers, and concrete inserts for use in reinforced concrete and masonry construction and shall perform all appurtenant work, including all the wires, clips, supports, chairs, spacers, and other accessories, all in accordance with the General Specifications, the CQA Plan, and the Construction Drawings.

1.02 REFERENCE SPECIFICATIONS, CODES, AND STANDARDS

A. Codes: All codes, as referenced herein.

B. Commercial Standards

ACI 315	Details and Detailing of Concrete Reinforcement
ACI 318	Building Code Requirements for Reinforced Concrete
CRSI MSP-1	Concrete Reinforcing Steel Institute Manual of Standard Practice
WRI	Manual of Standard Practice for Welded Wire Fabric
AWS D1.4	Structural Welding Code - Reinforcing Steel
ASTM A 82	Specification for Steel Wire, Plain, for Concrete Reinforcement
ASTM A 185	Specification for Welded Steel Wire Fabric, Plain, for Concrete Reinforcement
ASTM A 615	Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
ASTM A 775	Specification for Epoxy-Coated Reinforcing Steel Bars

1.03 CONTRACTOR SUBMITTALS

A. The Contractor shall furnish shop bending diagrams, placing lists, and drawings of all reinforcement steel prior to fabrication.

B. Details of the concrete reinforcement steel and concrete inserts shall be submitted by the Contractor at the earliest possible date after receipt by the Contractor of the Notice to Proceed. Said details of reinforcement steel for

fabrication and erection shall conform to ACI 315 and the requirements specified and shown. The shop bending diagrams shall show the actual lengths of bars, to the nearest inch measured to the intersection of the extensions (tangents for bars of circular cross section) of the outside surface. The shop drawings shall include bar placement diagrams which clearly indicate the dimensions of each bar splice.

C. Where mechanical couplers are required or permitted to be used to splice reinforcement steel, the Contractor shall submit manufacturer's literature which contains instructions and recommendations for installation for each type of coupler used; certified test reports which verify the load capacity of each type and size of coupler used; and shop drawings which show the location of each coupler with details of how they are to be installed in the formwork.

D. If reinforcement steel is spliced by welding at any location, the Contractor shall submit mill test reports which shall contain the information necessary for the determination of the carbon equivalent as specified in AWS D1.4. The Contractor shall submit a written welding procedure for each type of weld for each size of bar which is to be spliced by welding; merely a statement that AWS procedures will be followed is not acceptable.

1.4 QUALITY ASSURANCE

A. If requested by the Engineer, the Contractor shall provide samples from each heat of reinforcement steel delivered in a quantity adequate for testing. Costs of initial tests will be paid by the Owner. Costs of additional tests due to material failing initial tests shall be paid by the Contractor.

B. If reinforcement steel is spliced by welding at any location, the Contractor shall submit certifications of procedure qualifications for each welding procedure used and certification of welder qualifications, for each welding procedure, and for each welder performing the work. Such qualifications shall be as specified in AWS D1.4.

C. If requested by the Engineer, the Contractor shall provide samples of each type of welded splice used in the work in a quantity and of dimensions adequate for testing. At the discretion of the Engineer, radiographic testing of direct butt welded splices will be performed. The Contractor shall provide assistance necessary to facilitate testing. The Contractor shall repair any weld which fails to meet the requirements of AWS D1.4. The costs of testing will be paid by the Owner; except, the costs of all tests which fail to meet specified requirements shall be paid by the Contractor.

PART 2: PRODUCTS

2.01 MATERIAL REQUIREMENTS

A. Materials specified in this Section which may remain or leave residues on or within the concrete shall be classified as acceptable for potable water use by the Environmental Protection Agency within 30 days of application or use.

2.02 REINFORCEMENT STEEL

A. Reinforcement Steel for all cast-in-place reinforced concrete construction shall conform to the following requirements:

1. Bar reinforcement shall conform to the requirements of ASTM A 615 for Grade 60 Billet Steel Reinforcement or as otherwise shown.

2. Welded wire fabric reinforcement shall conform to the requirements of ASTM A 185 and the details shown; provided, that welded wire fabric with longitudinal wire of W4 size wire and smaller shall be either furnished in flat sheets or in rolls with a core diameter of not less than 10 inches; and provided further, that welded wire fabric with longitudinal wires larger than W4 size shall be furnished in flat sheets only.

3. Spiral reinforcement shall be cold-drawn steel wire conforming to the requirements of ASTM A 82.

B. Accessories

1. Accessories shall include all necessary chairs, slab bolsters, concrete blocks, tie wires, dips, supports, spacers, and other devices to position reinforcement during concrete placement. All bar supports shall meet the requirements of the CRSI Manual of Standard Practice including special requirements for supporting epoxy coated reinforcing bars. Wire bar supports shall be CRSI Class 1 for maximum protection with a 1/8-inch minimum thickness of plastic coating which extends at least 1/2-inch from the concrete surface. Plastic shall be gray in color.

2. Concrete blocks (dobies), used to support and position reinforcement steel, shall have the same or higher compressive strength as specified for the concrete in which it is located. Wire ties shall be embedded in concrete block bar supports.

C. Epoxy coating for reinforcing and accessories, where specified or shown, shall conform to ASTM A 775.

2.03 MECHANICAL COUPLERS

A. Mechanical couplers shall be provided where shown and where approved by the Engineer. The couplers shall develop a tensile strength which exceeds 125 percent of the yield strength of the reinforcement bars being spliced at each splice.

B. Where the type of coupler used is composed of more than one component, all components required for a complete splice shall be supplied. This shall apply to all mechanical splices, including those splices intended for future connections.

C. The reinforcement steel and coupler used shall be compatible for obtaining the required strength of the connection. Straight threaded type couplers shall require the use of the next larger size reinforcing bar or shall be used with reinforcing bars with specially forged ends which provide upset threads which do not decrease the basic cross section of the bar.

D. Couplers shall be Lenton Form Saver as manufactured by Erico Products; Dowel Bar Splicer System as manufactured by Richmond Screw Anchor Company; or equal.

2.04 WELDED SPLICES

A. Welded splices shall be provided where shown and where approved by the Engineer. All welded splices of reinforcement steel shall develop a tensile strength which exceeds 125 percent of the yield strength of the reinforcement bars which are connected.

B. All materials required to conform the welded splices to the requirements of AWS D1.4 shall be provided.

2.05 EPOXY GROUT

A. Epoxy for grouting reinforcing bars shall be specifically formulated for such application, for the moisture condition, application temperature, and orientation of the hole to be filled.

PART 3: EXECUTION

3.01 GENERAL

A. All reinforcement steel, welded wire fabric, couplers, and other appurtenances shall be fabricated, and placed in accordance with the requirements of the Building Code and the supplementary requirements specified herein.

3.02 FABRICATION

A. General

1. Reinforcement steel shall be accurately formed to the dimensions and shapes shown, and the fabricating details shall be prepared in accordance with ACI 315 and ACI 318, except as modified by the Drawings. Stirrups and tie bars shall be bent around a pin having a diameter not less than 1-1/2-inch for No. 3 bars, 2-inch for No. 4 bars, and 2-1/2-inch for No. 5 bars. Bends for other bars shall be made around a pin having a diameter not less than 6 times the bar diameter, except for bars larger than 1 inch, in which case the bends shall be made around a pin of 8 bar diameters. Bars shall be bent cold.

2. The Contractor shall fabricate reinforcement bars for structures in accordance with bending diagrams, placing lists, and placing drawings. Said drawings, diagrams, and lists shall be prepared by the Contractor.

B. Fabricating Tolerances: Bars used for concrete reinforcement shall meet the following requirements for fabricating tolerances:

1. Sheared length: ± 1 inch

2. Depth of truss bars: + 0, - 1/2 inch

3. Stirrups, ties, and spirals: ±1/2 inch

4. All other bends: ±1 inch

3.03 PLACING

A. Reinforcement steel shall be accurately positioned as shown, and shall be supported and wired together to prevent displacement, using annealed iron wire ties or suitable clips at intersections. All reinforcement steel shall be supported by concrete, plastic or metal supports, spacers or metal hangers which are strong and rigid enough to prevent any displacement of the reinforcement steel. Where concrete is to be placed on the ground, supporting concrete blocks (or dobies) shall be used, in sufficient numbers to support the bars without settlement, but in no case shall such support be continuous. All concrete blocks used to support reinforcement steel shall be tied to the steel with wire ties which are embedded in the blocks. For concrete over formwork, the Contractor shall furnish concrete, metal, plastic, or other acceptable bar chairs and spacers.

B. Limitations on the use of bar support materials shall be as follows.

1. Concrete Dobies: permitted at all locations except where architectural finish is required.

2. Wire Bar Supports: permitted only at slabs over dry areas, interior dry wall surfaces, and exterior wall surfaces.

3. Plastic Bar Supports: permitted at all locations except on grade.

C. Tie wires shall be bent away from the forms in order to provide the specified concrete coverage.

D. Bars additional to those shown which may be found necessary or desirable by the Contractor for the purpose of securing reinforcement in position shall be provided by the Contractor at its own expense.

E. Unless otherwise specified, reinforcement placing tolerances shall be within the limits specified in Section 7.5 of ACI 318 except where in conflict with the requirements of the Building Code.

F. Bars may be moved as necessary to avoid interference with other reinforcement steel, conduits, or embedded items. If bars are moved more than one bar diameter, or enough to exceed the above tolerances, the resulting arrangement of bars shall be as acceptable to the Engineer.

G. Welded wire fabric reinforcement placed over horizontal forms shall be supported on slab bolsters. Slab bolsters shall be spaced not more than 30 inches on centers, shall extend continuously across the entire width of the reinforcement mat, and shall support the reinforcement mat in the plane shown.

H. Welded wire fabric placed over the ground shall be supported on wired concrete blocks (dobies) spaced not more than 3 feet on centers in any direction. The construction practice of placing welded wire fabric on the ground and hooking into place in the freshly placed concrete shall not be used.

I. Epoxy coated reinforcing bars shall be stored, transported, and placed in such a manner as to avoid chipping of the epoxy coating. Non-abrasive slings made of nylon and similar materials shall be used. Specially coated bar supports shall be used. All chips or cracks in the epoxy coating shall be repaired with a compatible epoxy repair material prior to placing concrete.

J. Accessories supporting reinforcing bars shall be spaced such that there is no deflection of the accessory from the weight of the supported bars. When used to space the reinforcing bars from wall forms, the forms and bars shall be located so that there is no deflection of the accessory when the forms are tightened into position.

3.04 SPACING OF BARS

A. The clear distance between parallel bars (except in columns and between multiple layers of bars in beams) shall be not less than the nominal diameter of the bars nor less than 1-1/3 times the maximum size of the coarse aggregate, nor less than one inch.

B. Where reinforcement in beams or girders is placed in 2 or more layers, the clear distance between layers shall be not less than one inch.

C. In columns, the clear distance between longitudinal bars shall be not less than 1-1/2 times the bar diameter, nor less than 1-1/2 times the maximum size of the coarse aggregate, nor less than 1-1/2 inches.

D. The clear distance between bars shall also apply to the distance between a contact splice and adjacent splices or bars.

3.05 SPLICING

A. General

1. Reinforcement bar splices shall only be used at locations shown. When it is necessary to splice reinforcement at points other than where shown, the character of the splice shall be as acceptable to the Engineer.

2. Unless otherwise indicated, dowels shall match the size and spacing of the spliced bar.

B. Splices of Reinforcement

1. The length of lap for reinforcement bars, unless otherwise shown shall be in accordance with ACI 318-89, Section 12.15.1 for a Class B splice.

2. Laps of welded wire fabric shall be in accordance with the ACI 318. Adjoining sheets shall be securely tied together with No. 14 tie wire, one tie for each 2 running feet. Wires shall be staggered and tied in such a manner that they cannot slip.

3. Splices in column spiral reinforcement, when necessary, shall be made by welding or by a lap of 1-1/2 turns.

C. Bending or Straightening

1. Reinforcement shall not be straightened or rebent in a manner which will injure the material. Bars with kinks or bends not shown shall not be used. All bars shall be bent cold, unless otherwise permitted by the Engineer. No bars partially embedded in concrete shall be field-bent except as shown or specifically permitted by the Engineer.

D. Couplers which are located at a joint face shall be a type which can be set either flush or recessed from the face as shown. The couplers shall be sealed during concrete placement to completely eliminate concrete or cement paste from entering. Couplers intended for future connections shall be recessed a minimum of 1/2 inch from the concrete surface. After the concrete is placed, the coupler shall be plugged with plastic plugs which have an O-ring seal and the recess filled with sealant to prevent any contact with water or other corrosive materials. Threaded couplers shall be plugged .

E. Unless noted otherwise, mechanical coupler spacing and capacity shall match the spacing and capacity of the reinforcing shown for the adjacent section.

3.06 CLEANING AND PROTECTION

A. Reinforcement steel shall at all times be protected from conditions conducive to corrosion until concrete is placed around it.

B. The surfaces of all reinforcement steel and other metalwork to be in contact with concrete shall be thoroughly cleaned of all dirt, grease, loose scale and rust, grout, mortar and other foreign substances immediately before the concrete is placed. Where there is delay in depositing concrete, reinforcement shall be reinspected and, if necessary recleaned.

3.07 EMBEDMENT OF DRILLED REINFORCING STEEL DOWELS

A. Hole Preparation

1. The hole diameter shall be as recommended by the epoxy manufacturer but shall be no larger than 0.25 inch greater than the diameter of the outer surface of the reinforcing bar deformations.

2. The depth of the hole shall be as recommended by the epoxy manufacturer to fully develop the bar but shall not be less than 12 bar diameters, unless noted otherwise.

3. The hole shall be drilled by methods which do not interfere with the proper bonding of epoxy.

4. Existing reinforcing steel in the vicinity of proposed holes shall be located prior to drilling. The location of holes to be drilled shall be adjusted to avoid drilling through or nicking any existing reinforcing bars.

5. The hole shall be blown clean with clean, dry compressed air to remove all dust and loose particles.

6. Epoxy shall be injected into the hole through a tube placed to the bottom of the hole. The tube shall be withdrawn as epoxy is placed but

kept immersed to prevent formation of air pockets. The hole shall be filled to a depth that insures that excess material will be expelled from the hole during dowel placement.

7. Dowels shall be twisted during insertion into the partially filled hole so as to guarantee full wetting of the bar surface with epoxy. The bar shall be inserted slowly enough to avoid developing air pockets.

[END OF SECTION]

SECTION 03290
JOINTS IN CONCRETE

PART 1: GENERAL

1.01 THE REQUIREMENT

A. The Contractor shall construct all joints in concrete at the locations shown on the Construction Drawings. Joints required in concrete structures are of various types and will be permitted only where shown, unless specifically accepted by the Engineer.

1.02 REFERENCE SPECIFICATIONS, CODES, AND STANDARDS

A. Federal Specifications:

TT-S-0227E(3) Sealing Compound, elastomeric type, Multi-component for Caulking, Sealing, and Glazing Buildings and Other Structures).

B. U.S. Army Corps of Engineers Specifications:

CRD-C572 PVC Waterstop.

C. Commercial Standards:

ASTM A 775 Specification for Epoxy-Coated Reinforcing Steel Bars

ASTM C 920 Specification for Elastomeric Joint Sealants

ASTM D 412 Test Methods for Rubber Properties in Tension

ASTM D 624 Test Method for Rubber Property – Tear Resistance

ASTM D 638 Test Method for Tensile Properties of Plastics

ASTM D 746 Test Method for Brittleness Temperature of Plastics and Elastomers by Impact

ASTM D 747 Test Method for Apparent Bending Modulus of Plastics by Means of a Cantilever Beam

ASTM D 1056 Specification for Flexible Cellular Materials – Sponge or Expanded Rubber

ASTM D 1752 Specification for Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction

ASTM D 2240 Test Method for Rubber Property – Durometer Hardness

ASTM D 2241 Specification for Poly (Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR-Series)

1.03 TYPES OF JOINTS

A. **Construction Joints:** When fresh concrete is placed against a hardened concrete surface, the joint between the two pours is called a construction joint. Unless otherwise specified, all joints in water bearing members shall be provided with a waterstop and/or sealant groove of the shape specified and shown. The surface of the first pour may also be required to receive a coating of bond breaker as shown.

B. **Contraction Joints:** Contraction joints are similar to construction joints except that the fresh concrete shall not bond to the hardened surface of the first pour, which shall be coated with a bond breaker. The slab reinforcement shall be stopped 4-1/2 inches from the joint; which is provided with a sleeve-type dowel, to allow shrinkage of the concrete of the second pour. Waterstop and/or sealant groove shall also be provided when specified or shown.

C. **Expansion Joints:** To allow the concrete to expand freely, a space is provided between the two pours, the joint shall be formed as shown. This space is obtained by placing a filler joint material against the first pour, which acts as a form for the second pour. Unless otherwise specified, all expansion joints in water bearing members shall be provided with a center-bulb type waterstop as shown.

C. Premolded expansion joint material shall be installed with the edge at the indicated distance below or back from finished concrete surface, and shall have a slightly tapered, dressed, and oiled wood strip secured to or placed at the edge thereof during concrete placement, which shall later be removed to form space for sealing material.

D. The space so formed shall be filled with a joint sealant material as specified in the Paragraph in Part 2 entitled "Joint Sealant." In order to keep the two wall or slab elements in line the joint shall also be provided with a sleeve-type dowel as shown.

E. **Control Joints:** The function of the control joint is to provide a weaker plane in the concrete, where shrinkage cracks will probably occur. A groove, of the shape and dimensions shown, is formed or saw-cut in the concrete. This groove is afterward filled with a joint sealant material as specified in the Paragraph in Part 2 entitled "Joint Sealant."

1.04 CONTRACTOR SUBMITTALS

A. **Waterstops:** Prior to production of the material required under this contract, qualification samples shall be submitted. Such samples shall consist of extruded or molded sections of each size or shape to be used, and shall be accomplished so that the material and workmanship represents in all respects the material to be

furnished under this contract. The balance of the material to be used under this contract shall not be produced until after the Engineer has reviewed the qualification samples. Waterstop manufacturer shall certify waterstop material is suitable for chemicals Berog used in containment areas.

B. **Joint Sealant:** Prior to ordering the sealant material, the Contractor shall submit to the Engineer for the Engineer's review, sufficient data to show general compliance with the requirements of the Contract Documents.

C. Certified test reports from the sealant manufacturer on the actual batch of material being supplied indicating compliance with the above requirements shall be furnished the Engineer before the sealant is used on the job.

D. **Shipping Certification:** The Contractor shall provide written certification from the manufacturer as an integral part of the shipping form, to show that all of the material shipped to this project meets or exceeds the physical property requirements of the Contract Documents. Supplier certificates are not acceptable.

E. **Joint Location:** The Contractor shall submit placement shop drawings showing the location and type of all joints for each structure.

1.05 QUALITY ASSURANCE

A. **Waterstop Inspection:** It is required that all waterstop field joints shall be subject to rigid inspection, and no such work shall be scheduled or started without having made prior arrangements with the Engineer to provide for the required inspections. Not less than 24 hours' notice shall be provided to the Engineer for scheduling such inspections.

B. All field joints in waterstops shall be subject to rigid inspection for misalignment, bubbles, inadequate bond, porosity, cracks, offsets, and other defects which would reduce the potential resistance of the material to water pressure at any point. All defective joints shall be replaced with material which shall pass said inspection, and all faulty material shall be removed from the site and disposed of by the Contractor at its own expense.

C. The following waterstop defects represent a partial list of defects which shall be grounds for rejection:

1. Offsets at joints greater than 1/16-inch or 15 percent of material thickness, at any point, whichever is less.

2. Exterior crack at joint, due to incomplete bond, which is deeper than 1/16-inch or 15 percent of material thickness, at any point, whichever is less.

3. Any combination of offset or exterior crack which will result in a net reduction in the cross section of the waterstop in excess of 1/16-inch or 15 percent of material thickness at any point, whichever is less.
4. Misalignment of joint which result in misalignment of the waterstop in excess of 1/2-inch in 10 feet.

5. Porosity in the welded joint as evidenced by visual inspection.

6. Bubbles or inadequate bonding which can be detected with a penknife test. (If, while prodding the entire joint with the point of a pen knife, the knife breaks through the outer portion of the weld into a bubble, the joint shall be considered defective.)

D. **Waterstop Samples:** Prior to use of the waterstop material in the field, a sample of a fabricated mitered cross and a tee constructed of each size or shape of material to be used shall be submitted to the Engineer for review. These samples shall be fabricated so that the material and workmanship represent in all respects the fittings to be furnished under this contract. Field samples of fabricated fittings (crosses, tees, etc.) will be selected at random by the Engineer for testing by a laboratory at the Owner's expense. When tested, they shall have a tensile strength across the joints equal to at least 600 psi.

E. **Construction Joint Sealant:** The Contractor shall prepare adhesion and cohesion test specimens as specified herein, at intervals of 5 working days while sealants are being installed.

F. The sealant material shall show no signs of adhesive or cohesive failure when tested in accordance with the following procedure in laboratory and field tests:

1. Sealant specimen shall be prepared between 2 concrete blocks (1-inch by 2-inch by 3-inch). Spacing between the blocks shall be 1-inch. Coated spacers (2-inch by 1-1/2-inch by 1/2-inch) shall be used to insure sealant cross-sections of 1/2-inch by 2 inches with a width of 1-inch.

2. Sealant shall be cast and cured according to manufacturer's recommendations except that curing period shall be not less than 24 hours.

3. Following curing period, the gap between blocks shall be widened to 1-1/2-inch. Spacers shall be used to maintain this gap for 24 hours prior to inspection for failure.

1.06 GUARANTEE

A. The Contractor shall provide a 5-year written guarantee of the entire sealant installation against faulty and/or incompatible materials and workmanship, together with a statement that it agrees to repair or replace, to the satisfaction of

the Owner, at no additional cost to the Owner, any such defective areas which become evident within said 5-year guarantee period.

PART 2: PRODUCTS

2.07 GENERAL

B. All joint materials specified herein shall be classified as acceptable for potable water use, by the Environmental Protection Agency, within 30 days of application.

2.08 PVC WATERSTOPS

A. **General:** Waterstops shall be extruded from an elastomeric polyvinyl chloride compound containing the plasticizers, resins, stabilizers, and other materials necessary to meet the requirements of these Specifications. No reclaimed or scrap material shall be used. The Contractor shall obtain from the waterstop manufacturer and shall furnish to the Engineer for review, current test reports and a written certification of the manufacturer that the material to be shipped to the job meets the physical requirements as outlined in the U.S. Army Corps of Engineers Specification CRD-C572 and those listed herein.

B. **Flatstrip and Center-Bulb Waterstops:** Flatstrip and center-bulb waterstops shall be as detailed and as manufactured by: Kirkhill Rubber Co., Brea, California; Water Seals, Inc., Chicago, Illinois; Progress Unlimited, Inc., New York, New York; Greenstreak Plastic Products Co., St. Louis, Missouri; or equal; provided, that at no place shall the thickness of flat strip waterstops, including the center bulb type, be less than 3/8-inch.

C. **Multi-Rib Waterstops:** Multi-rib waterstops, where required, shall be as detailed and as manufactured by Water Seals, Inc., Chicago, Illinois; Progress Unlimited, Inc., New York, New York; Greenstreak Plastic Products Co., St. Louis, Missouri; or equal. Prefabricated joint fittings shall be used at all intersections of the ribbed-type waterstops.

D. **Other Types of Waterstops:** When other types of waterstops, not listed above are required and shown, they shall be subjected to the same requirements as those listed herein.

E. **Waterstop Testing Requirements:** When tested in accordance with the specified test standards, the waterstop material shall meet or exceed the following requirements:

PHYSICAL PROPERTY SHEET MATERIAL	VALUE	ASTM STD.
Tensile Strength-min (psi)	1750	D 638, Type IV
Ultimate elongation-min (percent)	350	D 638, type IV
Low Temp Brittleness-max (degrees F)	-35	D 746
Stiffness in flexure-min (psi	400	D 747
Accelerated Extraction (CRD-C572)		
Tensile Strength 0min (psi)	1500	D 638, Type IV
Ultimate Elongation-min (percent)	300	D 638, Type IV
Effect of Alkalies (CRD-C572)		
Change in Weight (percent)	+0.25/-0.10	-----
Change in Durometer, Shore A	+5	D 2240
Finish Waterstop		
Tensile Strength-min (psi)	1400	D 638, Type IV
Ultimate Elongation-min (percent)	280	D 638, Type IV

2.09 JOINT SEALANT

A. Joint sealant shall be polyurethane polymer designed for bonding to concrete which is continuously submerged in water. No material will be acceptable which has an unsatisfactory history as to bond or durability when used in the joints of water retaining structures.

B. Joint sealant material shall meet the following requirements (73 degrees F and 50 percent R.H.):

Work Life	45 - 180 minutes
Time to Reach 20 Shore "A" Hardness (at 77 degrees F, 200 gr quantity)	24 hours, maximum
Ultimate Hardness (ASTM D 2240)	20 - 45 Shore "A"
Tensile Strength (ASTM D 412) 175 psi, minimum	
Ultimate Elongation (ASTM D 412)	400 percent, minimum
Tear Resistance (Die C ASTM D 624)	75 pounds per inch of thickness, minimum
Color	Light Gray

C. All polyurethane sealants for waterstop joints in concrete shall conform to the following requirements:

1. Sealant shall be 2-part polyurethane with the physical properties of the cured sealant conforming to or exceeding the requirements of ANSI/ASTM C 920 or Federal Specification TT-S-0227 E(3) for 2-part material, as applicable.

2. For vertical joints and overhead horizontal joints, only "non-sag" compounds shall be used; all such compounds shall conform to the requirements of ANSI/ASTM C 920 Class 25, Grade NS, or Federal Specification TT-S-0227 E(3), Type II, Class A.

3. For plane horizontal joints, the self-leveling compounds which meet the requirements of ANSI/ASTM C 920 Class 25, Grade P, or Federal Specification TT-S-0227 E(3), Type I shall be used. For joints subject to either pedestrian or vehicular traffic, a compound providing non-tracking characteristics, and having a Shore "A" hardness range of 35 to 45, shall be used.

4. Primer materials, if recommended by the sealant manufacturer, shall conform to the printed recommendations of the sealant manufacturer.

D. All sealants, wherever shown, or required hereunder shall be PSI-270 as manufactured by Polymeric Systems Inc.; Elastothane 227R as manufactured by Pacific Polymers; Sikaflex 2C, as manufactured by Sika Corporation; or equal.

E. Sealants for non-waterstop joints in concrete shall conform to the requirements of Section [07920], "Sealants and Caulking."

2.10 JOINT MATERIALS

A. **Bearing Pad:** Bearing pad to be neoprene conforming to ASTM D 2000 BC 420, 40 durometer hardness unless otherwise noted.

B. **Neoprene Sponge:** Sponge to be neoprene, closed-cell, expanded, conforming to ASTM D 1056, type 2C3-E1.

C. **Joint Filler:**

1. Joint filler for expansion joints in waterholding structures shall be neoprene conforming to ASTM D1056, type 2C5-E1.

2. Joint filler material in other locations shall be of the preformed non-extruding type joint filler constructed of cellular neoprene sponge rubber or polyurethane of firm texture. Bituminous fiber type will not be permitted. All non-extruding and resilient-type preformed expansion joint fillers shall conform to the requirements and tests set forth in ASTM D 1752 for Type I, except as otherwise specified herein.

2.11 BACKING ROD

A. Backing rod shall be an extruded closed-cell, polyethylene foam rod. The material shall be compatible with the joint sealant material used and shall have a tensile strength of not less than 40 psi and a compression deflection of approximately 25 percent at 8 psi. The rod shall be 1/8-inch larger in diameter

than the joint width except that a one-inch diameter rod shall be used for a 3/4-inch wide joint.

2.12 BOND BREAKER

A. Bond breaker shall be Super Bond Breaker as manufactured by Burke Company, San Mateo, California; Select Cure CRB as manufactured by Select Products Co., Upland, California; or equal. It shall contain a fugitive dye so that areas of application will be readily distinguishable.

2.13 BENTONITE WATERSTOP

A. Where called for in the Contract Documents, bentonite type waterstop, which shall expand in the presence of water to form a watertight joint seal without damaging the concrete in which it is cast, shall be provided.

B. The bentonite waterstop shall be composed of 75 percent bentonite. The balance of the material shall be butyl rubber-hydrocarbon with less than 1.0 percent volatile matter. The waterstop shall contain no asbestos fibers or asphaltics.

C. The manufacturer's rated application temperature range shall be from 5 to 125 degrees F. The service temperature range shall be from -40 to 212 degrees F.

D. The cross sectional dimensions of the unexpanded waterstop shall be one inch by 3/4-inch.

E. The waterstop shall be provided with an adhesive backing which will provide excellent adhesion to concrete surfaces.

2.14 SLIP DOWELS

A. Slip dowels in joints shall be A36 smooth epoxy-coated bars, conforming to ASTM A 775.

2.15 PVC TUBING

A. PVC tubing in joints shall be Sch. SDR 13.5, conforming to ASTM D 2241.

PART 3: EXECUTION

3.01 GENERAL

A. Waterstops of the type specified herein shall be embedded in the concrete across joints as shown. All waterstops shall be fully continuous for the extent of the joint. Splices necessary to provide such continuity shall be accomplished in conformance to printed instructions of manufacturer of the waterstops. The Contractor shall take suitable precautions and means to support and protect the waterstops during the progress of the work and shall repair or replace at its own

expense any waterstops damaged during the progress of the work. All waterstops shall be stored so as to permit free circulation of air around the waterstop material.

B. When any waterstop is installed in the concrete on one side of a joint, while the other half or portion of the waterstop remains exposed to the atmosphere for more than 2 days, suitable precautions shall be taken to shade and protect the exposed waterstop from direct rays of the sun during the entire exposure and until the exposed portion of the waterstop is embedded in concrete.

3.02 SPLICES IN WATERSTOPS

A. Splices in waterstops shall be performed by heat sealing the adjacent waterstop sections in accordance with the manufacturer's printed recommendations. It is essential that:

1. The material not be damaged by heat sealing.

2. The splices have a tensile strength of not less than 60 percent of the unspliced materials tensile strength.

3. The continuity of the waterstop ribs and of its tubular center axis be maintained.

B. Butt joints of the ends of 2 identical waterstop sections may be made while the material is in the forms.

C. All joints with waterstops involving more than 2 ends to be jointed together, and all joints which involve an angle cut, alignment change, or the joining of 2 dissimilar waterstop sections shall be prefabricated by the Contractor prior to placement in the forms, allowing not less than 24-inch long strips of waterstop material beyond the joint. Upon being inspected and approved, such prefabricated waterstop joint assemblies shall be installed in the forms and the ends of the 24-inch strips shall be butt welded to the straight run portions of waterstop in place in the forms.

D. Where a centerbulb waterstop intersects and is jointed with a non-centerbulb waterstop, care shall be taken to seal the end of the centerbulb, using additional PVC material if needed.

3.03 JOINT CONSTRUCTION

A. **Setting Waterstops:** In order to eliminate faulty installation that may result in joint leakage, particular care shall be taken of the correct positioning of the waterstops during installation. Adequate provisions must be made to support and anchor the waterstops during the progress of the work and to insure the proper embedment in the concrete. The symmetrical halves of the waterstops shall be equally divided between the concrete pours at the joints. The center axis of the

waterstops shall be coincident with the joint openings. Maximum density and imperviousness of the concrete shall be insured by thoroughly working it in the vicinity of all joints.

B. In placing flat-strip waterstops in the forms, means shall be provided to prevent them from being folded over by the concrete as it is placed. Unless otherwise shown, all waterstops shall be held in place with light wire ties on 12-inch centers which shall be passed through the edge of the waterstop and tied to the curtain of reinforcing steel. Horizontal waterstops, with their flat face in a vertical plane, shall be held in place with continuous supports to which the top edge of the waterstop shall be tacked. In placing concrete around horizontal waterstops, with their flat face in a horizontal plane, concrete shall be worked under the waterstops by hand so as to avoid the formation of air and rock pockets.

C. In placing centerbulb waterstops in expansion joints, the centerbulb shall be centered on the joint filler material.

D. Waterstop in vertical wall joints shall stop 6 inches from the top of the wall where such waterstop does not connect with any other waterstop and is not to be connected to for a future concrete placement.

E. **Joint Location:** Construction joints, and other types of joints, shall be provided where shown. When not shown, construction joints shall be provided at 25-foot maximum spacing for all concrete construction, unless noted otherwise. Where joints are shown spaced greater than 40 feet apart, additional joints shall be provided to maintain the 25-foot maximum spacing. The location of all joints, of any type, shall be submitted for acceptance by the Engineer.

F. **Joint Preparation:** Special care shall be used in preparing concrete surfaces at joints where bonding between 2 sections of concrete is required. Unless otherwise shown, such bonding will be required at all horizontal joints in walls. Surfaces shall be prepared in accordance with the requirements of Section [03300] [03310], "Cast-in-Place Concrete." Except on horizontal wall construction joints, wall to slab joints or where otherwise shown or specified, at all joints where waterstops are required, the joint face of the first pour shall be coated with a bond breaker as specified herein.

G. **Construction Joint Sealant:** Construction joints in water-bearing floor slabs, and elsewhere as shown, shall be provided with tapered grooves which shall be filled with a construction joint sealant. The material used for forming the tapered grooves shall be left in the grooves until just before the grooves are cleaned and filled with joint sealant. After removing the forms from the grooves, all laitance and fins shall be removed, and the grooves shall be sand-blasted. The grooves shall be allowed to become thoroughly dry, after which they shall be blown out; immediately thereafter, they shall be primed, bond breaker tape placed in the bottom of the groove, and filled with the construction joint sealant. The primer used shall be supplied by the same manufacturer supplying the sealant. No sealant will be permitted to be used without a primer. Care shall be used to

completely fill the sealant grooves. Areas designated to receive a sealant fillet shall be thoroughly cleaned, as outlined for the tapered grooves, prior to application of the sealant.

H. The primer and sealant shall be placed strictly in accordance with the printed recommendations of the manufacturer, taking special care to properly mix the sealant prior to application. The sides of the sealant groove shall not be coated with bond breaker, curing compound, or any other substance which would interfere with proper bonding of the sealant. All sealant shall achieve final cure at least 7 days before the structure is filled with water.

I. All sealant shall be installed by a competent waterproofing specialty contractor who has a successful record of performance in similar installations. Before work is commenced, the crew shall be instructed as to the proper method of application by a representative of the sealant manufacturer.

J. Thorough, uniform mixing of 2-part, catalyst-cured materials is essential; special care shall be taken to properly mix the sealer before its application. Before any sealer is placed, the Contractor shall arrange to have the crew doing the work carefully instructed as to the proper method of mixing and application by a representative of the sealant manufacturer.

K. Any joint sealant which, after the manufacturer's recommended curing time for the job conditions of the work hereunder, fails to fully and properly cure shall be completely removed; the groove shall be thoroughly sandblasted to remove all traces of the uncured or partially cured sealant and primer, and shall be re-sealed with the specified joint sealant. All costs of such removal, joint treatment, re-sealing, and appurtenant work shall be at the expense of the Contractor.

L. **Bentonite Waterstop:**

1. Where a bentonite waterstop is called for, it shall be installed with the manufacturer's instructions and recommendations; except, as modified herein.

2. When requested by the Engineer, the manufacturer shall provide technical assistance in the field.

3. Bentonite waterstop shall only be used where complete confinement by concrete is provided. Bentonite waterstop shall not be used in expansion or contraction joints nor in the first 6 inches of any intersecting joint.

4. The bentonite waterstop shall be located as near as possible to the center of the joint and it shall be continuous around the entire joint. The minimum distance from the edge of the waterstop to the face of the member shall be 5 inches.

5. Where the thickness of the concrete member to be placed on the bentonite waterstop is less than 12 inches, the waterstop shall be placed in grooves formed or ground into the concrete. The groove shall be at least 3/4 inch deep and 1-1/4 inches wide. When placed in the groove, the minimum distance from the edge of the waterstop to the face of the member shall be 2.5 inches.

6. Where a bentonite waterstop is used in combination with PVC waterstop, the bentonite waterstop shall overlap the PVC waterstop for a minimum of 6 inches and shall be placed in contact with the PVC waterstop.

7. The bentonite waterstop shall not be placed when the temperature of the waterstop material is below 40 degrees F. The waterstop material may be warmed so that it shall remain above 40 degrees F during placement; however, means used to warm the material shall in no way harm the material or its properties. The waterstop shall not be installed where the air temperature falls outside the manufacturer's recommended range.

8. The concrete surface under the bentonite waterstop shall be smooth and uniform. The concrete shall be ground smooth if needed. Alternately, the bentonite waterstop shall be bonded to the surface using an epoxy grout which completely fills all voids and irregularities beneath the waterstop material. Prior to installation, the concrete surface shall be wire brushed to remove any laitance or other materials that may interfere with the bonding of epoxy.

9. The bentonite waterstop shall be secured in place with concrete nails and washers at 12-inch maximum spacing. This shall be in addition to the adhesive backing provided with the waterstop.

[END OF SECTION]

SECTION 03300
CAST-IN-PLACE CONCRETE

PART 1: GENERAL

1.01 THE REQUIREMENT

A. The Contractor shall furnish all materials for concrete in accordance with the provisions of this Section and shall form, mix, place, cure, repair, finish, and do all other work as required to produce finished concrete, in accordance with the requirements of the General Specifications, the CQA Plan, and the Construction Drawings.

B. The following types of concrete are covered in this Section:

1. Structural Concrete: Concrete to be used in all cases except where indicated otherwise.

2. Sitework Concrete: Concrete to be used for curbs, gutters, catch basins, sidewalks, pavements, fence and guard post embedment, underground duct bank encasement and all other concrete appurtenant to electrical facilities unless otherwise indicated.

3. Lean Concrete: Concrete to be used for thrust blocks, pipe trench cut-off blocks and cradles that are detailed on the Drawings as unreinforced. Lean concrete shall be used as protective cover for dowels intended for future connection.

C. The term "hydraulic structure" used in these specifications means environmental engineering concrete structures for the containment, treatment, or transmission of water, wastewater, or other fluids.

1.02 REFERENCE SPECIFICATIONS, CODES, AND STANDARDS

A. **Federal Specifications:**

UU-B-790A (1) (2)	Building Paper, Vegetable Fiber (Kraft, water-proofed, Water Repellent and Fire Resistant)

B. **Commercial Standards:**

ACI 117	Standard Tolerances for Concrete Construction and Materials
ACI 214	Recommended Practice for Evaluation of Strength Test Results of Concrete

ACI 301	Structural Concrete for Buildings
ACI 306.1	Cold Weather Concreting
ACI 309	Consolidation of Concrete
ACI 315	Details and Detailing of Concrete Reinforcement
ACI 318	Building Code Requirements for Reinforced Concrete
ASTM C 31	Practices for Making and Curing Concrete Test Specimens in the Field
ASTM C 33	Concrete Aggregates
ASTM C 39	Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C 94	Ready-Mixed Concrete
ASTM C 136	Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C 143	Test Method for Slump of Hydraulic Cement Concrete
ASTM C 150	Portland Cement
ASTM C 156	Test Methods for Water Retention by Concrete Curing Materials
ASTM C 157	Test Method for Length Change of Hardened Hydraulic Cement Mortar and Concrete
ASTM C 192	Practice for Making and Curing Concrete Test Specimens in the Laboratory
ASTM C 260	Air-Entraining Admixtures for Concrete
ASTM C 309	Liquid Membrane-Forming Compounds for Curing Concrete
ASTM C 494	Chemical Admixtures for Concrete

ASTM C 1077	Practice for Laboratories Testing Concrete and Concrete Aggregates for use in Construction & Criteria for Laboratory Evaluation
ASTM D 175	Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Non-extruding and Resilient Bituminous Types)
ASTM D 2419	Test Method for Sand Equivalent Value of Soils and Fine Aggregate
ASTM E 119	Method for Fire Tests of Building Construction and Materials

1.03 CONTRACTOR SUBMITTALS

A. **Mix Designs:** Prior to beginning work and within 14 days of the notice to proceed, the Contractor shall submit to the Engineer, for review, preliminary concrete mix designs which shall show the proportions and gradations of all materials proposed for each class and type of concrete specified herein. The mix designs shall be checked by an independent testing laboratory acceptable to the Engineer. All costs related to such checking shall be borne by the Contractor. Since laboratory trial batches require 35 calendar days to complete, the Contractor may consider testing more than one mix design for each class of concrete.

B. **Delivery Tickets:** Where ready-mix concrete is used, the Contractor shall furnish delivery tickets at the time of delivery of each load of concrete. Each ticket shall show the state certified equipment used for measuring and the total quantities, by weight, of cement, sand, each class of aggregate, admixtures, and the amounts of water in the aggregate added at the batching plant, and the amount allowed to be added at the site for the specific design mix. In addition, each ticket shall state the mix number, total yield in cubic yards, and the time of day, to the nearest minute, corresponding to the times when the batch was dispatched, when it left the plant, when it arrived at the site, when unloading began, and when unloading was finished.

C. Furnish the following submittals in accordance with ACI 301:

1. Mill tests for cement.

2. Admixture certification. Chloride ion content must be included.

3. Aggregate gradation and certification.

4. Materials and methods for curing.

1.04 CONCRETE CONFERENCE

A. A meeting to review the detailed requirements of the Contractor's proposed concrete design mixes and to determine the procedures for producing proper concrete construction shall be held no later than 14 days after the notice to proceed.

B. All parties involved in the concrete work shall attend the conference, including the following at a minimum:

Contractor's representative
Testing laboratory representative
Concrete subcontractor
Reinforcing steel subcontractor and detailer
Concrete supplier
Admixture manufacturer's representative

C. The conference shall be held at a mutually agreed upon time and place. The Engineer shall be notified no less than 5 days prior to the date of the conference.

1.05 QUALITY ASSURANCE

A. General

1. Tests on component materials and for compressive strength and shrinkage of concrete shall be performed as indicated herein. Test for determining slump will be in accordance with the requirements of ASTM C 143.

2. The cost of all laboratory tests on cement, aggregates, and concrete, will be borne by the Owner. However, the Contractor shall pay the cost of any additional tests and investigation on work performed which does not meet the specifications. The laboratory will meet or exceed the requirements of ASTM C 1077.

3. Concrete for testing shall be supplied by the Contractor at no additional cost to the Owner, and the Contractor shall assist the Engineer in obtaining samples, and disposal and cleanup of excess material.

B. Field Compression Tests:

1. Compression test specimens will be taken during construction from the first placement of each class of concrete specified herein and at intervals thereafter as selected by the Engineer to insure continued compliance with these specifications. Each set of test specimens will be a minimum of 5 cylinders.

2. Compression test specimens for concrete shall be made in accordance with section 9.2 of ASTM C 31. Specimens shall be 6-inch diameter by 12-inch high cylinders.

3. Compression tests shall be performed in accordance with ASTM C 39. One test cylinder will be tested at 7 days and 2 at 28 days. The remaining cylinders will be held to verify test results, if needed.

C. Evaluation and Acceptance of Concrete:

1. Evaluation and acceptance of the compressive strength of concrete will be according to the requirements of ACI 318, Chapter 5 "Concrete Quality," and as indicated herein.

2. A statistical analysis of compression test results will be performed according to the requirements of ACI 214. The standard deviation of the test results shall not exceed 640 psi, when ordered at equivalent water content as estimated by slump.

3. If any concrete fails to meet these requirements, immediate corrective action shall be taken to increase the compressive strength for all subsequent batches of the type of concrete affected.

4. When the standard deviation of the test results exceeds 640 psi, the average strength for which the mix is designed shall be increased by an amount necessary to satisfy the statistical requirement that the probability of any test being more than 500 psi below or the average of any 3 consecutive tests being below the required compressive strength is 1 in 100. The required average strength shall be calculated by Criterion No. 3 of ACI 214 using the actual standard of deviation.

5. All concrete which fails to meet the ACI requirements and these specifications, is subject to removal and replacement at no additional cost to the Owner.

D. **Shrinkage Tests:**

1. Drying shrinkage tests shall be performed for the trial batch indicated in the Paragraph in Part 2 entitled "Trial Batch and Laboratory Tests," the first placement of each class of concrete, and during construction to insure continued compliance with these Specifications.

2. Drying shrinkage specimens shall be 4-inch by 4-inch by 11-inch prisms with an effective gage length of 10 inches; fabricated, cured, dried, and measured in accordance with ASTM C 157 modified as follows: specimens shall be removed from molds at an age of 23 plus or minus 1 hours after trial batching, shall be placed immediately in water at 70

degrees F plus or minus 3 degrees F for at least 30 minutes, and shall be measured within 30 minutes thereafter to determine original length and then submerged in saturated lime water at 73 degrees F plus or minus 3 degrees F. Measurement to determine expansion expressed as a percentage of original length shall be made at age 7 days. This length at age 7 days shall be the base length for drying shrinkage calculations ("0" days drying age). Specimens then shall be stored immediately in a humidity control room maintained at 73 degrees F plus or minus 3 degrees F and 50 percent plus or minus 4 percent relative humidity for the remainder of the test. Measurements to determine shrinkage expressed as percentage of base length shall be made and reported separately for 7, 14, 21, and 28 days of drying after 7 days of moist curing.

3. The drying shrinkage deformation of each specimen shall be computed as the difference between the base length (at "0" days drying age) and the length after drying at each test age. The average drying shrinkage deformation of the specimens shall be computed to the nearest 0.0001 inch at each test age. If the drying shrinkage of any specimen departs from the average of that test age by more than 0.0004-inch, the results obtained from that specimen shall be disregarded. Results of the shrinkage test shall be reported to the nearest 0.001 percent of shrinkage. Compression test specimens shall be taken in each case from the same concrete used for preparing drying shrinkage specimens. These tests shall be considered a part of the normal compression tests for the project. Allowable shrinkage limitations shall be as indicated in Part 2 below.

E. **Construction Tolerances:** The Contractor shall set and maintain concrete forms and perform finishing operations to ensure that the completed work is within tolerances. Surface defects and irregularities are defined as finishes and are to be distinguished from tolerances. Tolerance is the permissible variation from lines, grades, or dimensions indicated on the Drawings. Where tolerances are not stated in the specifications, permissible deviations will be in accordance with ACI 117.

1. The following construction tolerances apply to finished walls and slab unless otherwise indicated:

Item	*Tolerance*
Variation of the constructed linear outline from the established position in plan.	In 10 feet: 1/4-inch; In 20 feet or more: 1/2-inch
Variation from the level or from the grades shown. In 20 feet or more: 1/2-inch	In 10 feet: 1/4-inch;
Variation from the plumb	In 10 feet: 1/4-inch;

In 20 feet or more: 1/2-inch

Variation in the thickness of slabs and walls.	Minus 1/4-inch; Plus 1/2-inch
Variation in the locations and sizes of slabs and wall openings	Plus or minus 1/4-inch

F. Floor Slab Hardener

1. Job Mockup: In a location designated by the Engineer, the Contractor shall place a 100 square foot floor mockup using the materials and procedures proposed for the work. Materials and procedures may be revised as necessary to obtain an acceptable surface, but the same materials and procedures shall be used in the work.

2. Field Service: The Contractor shall obtain onsite proper usage advice from the surface hardener manufacturer while the job mockup is being placed and during initial placement of the work. Notify the surface hardener manufacturer at least 3 days prior to initial use of the product.

3. Installer Qualifications: Installer shall have a minimum of 3 years experience and shall be specialized in application of dry shake surface hardeners.

PART 2: PRODUCTS

2.01 CONCRETE MATERIALS

A. **General:**

1. All materials shall be classified as acceptable for potable water use by the Environmental Protection Agency within 30 days of application.

2. Materials shall be delivered, stored, and handled so as to prevent damage by water or breakage. Cement reclaimed from cleaning bags or leaking containers shall not be used. All cement shall be used in the sequence of receipt of shipments.

B. All materials shall comply with the requirements of Sections 201, 203, and 204 of ACI 301, as applicable.

C. Storage of materials shall conform to the requirements of Section 205 of ACI 301.

D. Materials for concrete shall conform to the following requirements:

1. Cement shall be standard brand portland cement conforming to ASTM C 150 for Type II or Type V, including Table 2 optional requirements. A minimum of 85 percent of cement by weight shall pass a 325 screen. A single brand of cement shall be used throughout the work, and prior to its use, the brand shall be acceptable to the Engineer. The cement shall be suitably protected from exposure to moisture until used. Cement that has become lumpy shall not be used. Sacked cement shall be stored in such a manner so as to permit access for inspection and sampling. Certified mill test reports, including fineness, for each shipment of cement to be used shall be submitted to the Engineer, if requested, regarding compliance with these Specifications.

2. Water for mixing and curing shall be potable, clean, and free from objectionable quantities of silty organic matter, alkali, salts, and other impurities. The water shall be considered potable, for the purposes of this Section only, if it meets the requirements of the local governmental agencies. Agricultural water with high total dissolved solids (over 1000 mg/l TDS) shall not be used.

3. Aggregates shall be obtained from pits acceptable to the Engineer, shall be non-reactive, and shall conform to ASTM C 33. Maximum size of coarse aggregate shall be as indicated herein. Lightweight sand for fine aggregate will not be permitted.

    a. Coarse aggregates shall consist of clean, hard, durable gravel, crushed gravel, crushed rock, or a combination thereof. The coarse aggregates shall be prepared and handled in two or more size groups for combined aggregates with a maximum size greater than 3/4-inch. When the aggregates are proportioned for each batch of concrete, the two size groups shall be combined. See the Paragraph in Part 2 entitled "Trial Batch and Laboratory Tests" for the use of the size groups.

    b. Fine aggregates shall be natural sand or a combination of natural and manufactured sand that are hard and durable. When tested in accordance with ASTM D 2419, the sand equivalency shall not be less than 75 percent for an average of three samples, nor less than 70 percent for an individual test. Gradation of fine aggregate shall conform to ASTM C 33. The fineness modulus of sand used shall not be over 3.00.

    c. Combined aggregates shall be well graded from coarse to fine sizes and shall be uniformly graded between screen sizes to produce a concrete that has optimum workability and consolidation characteristics. Where a trial batch is required for a mix design, the final combined aggregate gradations will be established during the trial batch process.

d. When tested in accordance with ASTM C 33, the ratio of silica released to reduction in alkalinity shall not exceed 1.0.

e. When tested in accordance with ASTM C 33, the fine aggregate shall produce a color in the supernatant liquid no darker than the reference standard color solution.

f. When tested in accordance with ASTM C 33, the coarse aggregate shall show a loss not exceeding 42 percent after 500 revolutions, or 10.5 percent after 100 revolutions.

g. When tested in accordance with ASTM C 33, the loss resulting after five cycles shall not exceed 10 percent for fine or coarse aggregate when using sodium sulfate.

4. Ready-mix concrete shall conform to the requirements of ASTM C 94.

5. Admixtures: All admixtures shall be compatible and be furnished by a single manufacturer capable of providing qualified field service representation. Admixtures shall be used in accordance with manufacturer's recommendations. If the use of an admixture is producing an inferior end result, the Contractor shall discontinue use of the admixture. Admixtures shall not contain thiocyanates nor more than 0.05 percent chloride ion, and shall be non-toxic after 30 days.

a. Air-entraining agent meeting the requirements of ASTM C 260 shall be used. Sufficient air-entraining agent shall be used to provide a total air content of 3 to 5 percent. The Owner reserves the right, at any time, to sample and test the air-entraining agent. The air-entraining agent shall be added to the batch in a portion of the mixing water. The solution shall be batched by means of a mechanical batcher capable of accurate measurement. Air content shall be tested at the point of placement. Air entraining agent shall be Micro-Air by Master Builders; Daravair by W.R. Grace; Sika AEA-15 by Sika Corporation; or equal.

b. Set controlling and water reducing admixtures: Admixtures may be added at the Contractor's option, subject to the Engineer's approval, to control the set, effect water reduction, and increase workability. The addition of an admixture shall be at the Contractor's expense. Concrete containing an admixture shall be first placed at a location determined by the Engineer. Admixtures shall conform to the requirements of ASTM C 494. The required quantity of cement shall be used in the mix regardless of whether or not an admixture is used.

(1) Concrete shall not contain more than one water reducing admixture.

(2) Set controlling admixture may be either with or without water-reducing properties. Where the air temperature at the time of placement is expected to be consistently greater than 80 degrees F, a set retarding admixture such as Plastocrete by Sika Corporation; Pozzolith 300R by Master Builders; Daratard by W.R. Grace; or equal shall be used. Where the air temperature at the time of placement is expected to be consistently less than 40 degrees F, a non-corrosive set accelerating admixture such as Plastocrete 161FL by Sika Corporation; Pozzutec 20 by Master Builders; Daraset by W.R. Grace; or equal shall be used.

(3) Normal range water reducer shall conform to ASTM C 494, Type A. WRDA 79 by W.R. Grace; Pozzolith 322-N by Master Builders; Plastocrete 161 by Sika Corporation; or equal. The quantity of admixture used and the method of mixing shall be in accordance with the Manufacturer's instructions and recommendations.

(4) High range water reducer shall conform to ASTM C 494, Type F or G. Daracem 100 or WDRA 19 by W.R. Grace; Sikament FF or Sikament 86 by Sika Corporation; Rheobuild 1000 or Rheobuild 716 by Master Builders; or equal. High range water reducer shall be added to the concrete after all other ingredients have been mixed and initial slump has been verified. No more than 14 ounces of water reducer per sack of cement shall be used. Water reducer shall be considered as part of the mixing water when calculating water cement ratio.

(5) If the high range water reducer is added to the concrete at the job site, it may be used in conjunction with the same water reducer added at the batch plant. Concrete shall have a slump of 3 inches plus or minus 1/2-inch prior to adding the high range water reducing admixture at the job site. The high range water reducing admixture shall be accurately measured and pressure injected into the mixer as a single dose by an experienced technician. A standby system shall be provided and tested prior to each day's operation of the job site system.

(6) Concrete shall be mixed at mixing speed for a minimum of 30 mixer revolutions after the addition of the high range water reducer.

(7) **Flyash:** Flyash shall not be used.

2.02 CURING MATERIALS

A. Materials for curing concrete as indicated herein shall conform to the following requirements and ASTM C 309:

1. All curing compounds shall be white pigmented and resin based. Sodium silicate compounds shall not be allowed. Concrete curing compound shall be Kurez by Euclid Chemical Company; MB-429 as manufactured by Master Builders; L&M Cure R; or equal. Water based resin curing compounds shall be used only where local air quality regulations prohibit the use of a solvent based compound. Water based curing compounds shall be Aqua-Cure by Euclid Chemical Company; Masterkure-W by Master Builders; L&M Cure R-2; or equal.

2. Polyethylene sheet for use as concrete curing blanket shall be white and shall have a nominal thickness of 6 mils. The loss of moisture when determined in accordance with the requirements of ASTM C 156 shall not exceed 0.055 grams per square centimeter of surface.

3. Polyethylene-coated waterproof paper sheeting for use as concrete curing blanket shall consist of white polyethylene sheeting free of visible defects, uniform in appearance, have a nominal thickness of 2 mils, and be permanently bonded to waterproof paper conforming to the requirements of Federal Specification UU-B-790A (1) (2). The loss of moisture, when determined in accordance with the requirements of ASTM C 156, shall not exceed 0.055 gram per square centimeter of surface.

4. Polyethylene-coated burlap for use as concrete curing blanket shall be 4-mil thick, white opaque polyethylene film impregnated or extruded into one side of the burlap. Burlap shall weigh not less than 9 ounces per square yard. The loss of moisture, when determined in accordance with the requirements of ASTM C 156, shall not exceed 0.055 grams per square centimeter of surface.

5. Curing mats for use in Curing Method 6 as indicated below, shall be heavy shag rugs or carpets or cotton mats quilted at 4 inches on center. Curing mats shall weigh a minimum of 12 ounces per square yard when dry.

6. Evaporation retardant shall be a material such as Confilm as manufactured by Master Builders; Eucobar as manufactured by Euclid Chemical Company; E-CON as manufactured by L & M Construction Chemicals, Inc. or equal.

2.03 NON-WATERSTOP JOINT MATERIALS

A. Materials for non-waterstop joints in concrete shall conform to the following requirements:

1. Preformed joint filler shall be a non-extruding, resilient, bituminous type conforming to the requirements of ASTM D 1751.

2. Elastomeric joint sealer shall conform to the requirements of Section 07920 - Sealants and Caulking.

3. Mastic joint sealer shall be a material that does not contain evaporating solvents; that will tenaciously adhere to concrete surfaces; that will remain permanently resilient and pliable; that will not be affected by continuous presence of water and will not in any way contaminate potable water; and that will effectively seal the joints against moisture infiltration even when the joints are subject to movement due to expansion and contraction. The sealer shall be composed of special asphalts or similar materials blended with lubricating and plasticizing agents to form a tough, durable mastic substance containing no volatile oils or lubricants and shall be capable of meeting the test requirements set forth below, if testing is required by the Engineer.

2.04 MISCELLANEOUS MATERIALS

A. Dampproofing agent shall be an asphalt emulsion, such as Hydrocide 600 by Sonneborn; Damp-proofing Asphalt Coating by Euclid Chemical Company; Sealmastic by W. R. Meadows Inc., or equal.

B. Bonding agents shall be epoxy adhesives conforming to the following:

1. For bonding freshly-mixed, plastic concrete to hardened concrete, Sikadur 32 Hi-Mod Epoxy Adhesive, as manufactured by Sika Corporation; Concresive Liquid (LPL), as manufactured by Master Builders; BurkEpoxy MV as manufactured by The Burke Company; or equal.

2. For bonding hardened concrete or masonry to steel, Sikadur 31 Hi-Mod Gel as manufactured by Sika Corporation; BurkEpoxy NS as manufactured by The Burke Company; Concresive Paste (LPL) as manufactured by Master Builders; or equal.

C. Chemical protection agent shall be a coal tar epoxy, coal CAT 97-640/641 , as manufactured by Pittsburgh Paints. Coal tar shall be used a shown on the construction Drawings. Material shall be applied as directed by the manufacturer specification.

2.05 CONCRETE DESIGN REQUIREMENTS

A. **General:** Concrete shall be composed of cement, admixtures, aggregates, and water of the qualities indicated. The exact proportions in which these materials are to be used for different parts of the work will be determined during the trial batch. In general, the mix shall be designed to produce a concrete capable of being deposited so as to obtain maximum density and minimum shrinkage, and, where deposited in forms, to have good consolidation properties and maximum smoothness of surface. The aggregate gradations shall be formulated to provide fresh concrete that will not promote rock pockets around reinforcing steel or embedded items. The proportions shall be changed whenever necessary or desirable to meet the required results at no additional cost to the Owner. All changes shall be subject to review by the Engineer.

B. **Fine Aggregate Composition:** In mix designs for structural concrete, the percentage of fine aggregate in total aggregate by weight, shall be as indicated in the following table.

FINE AGGREGATE	
Fineness Modulus	**Maximum Percent**
2.7 or less	41
2.7 to 2.8	42
2.8 to 2.9	43
2.9 to 3.0	44

For other concrete, the maximum percentage of fine aggregate of total aggregate, by weight, shall not exceed 50.

C. **Water-Cement Ratio and Compressive Strength:** Concrete shall have the following minimum properties:

TYPE OF WORK	MIN 28-DAY COMPR. STRENGTH (PSI)	MAX SIZE AGGREGATE (IN)	MINIMUM CEMENT PER CU YD (LBS)	MAX W/C RATIO (BY WEIGHT)
Structural Concrete:				
Roof, floor slabs, columns, walls and all other concrete items not specified elsewhere.	4,000	1	564	0.45
12-inch and thicker walls, slabs on grade and footings. (optional)	4,000	1-1/2	564	0.45
Pea Gravel Mix. Thin sections and areas with congested reinforcing, at the Contractor's option and with the written approval of the Engineer for the specific location. Maximum fine aggregate 50% by weight of aggregate.	4,000	3/8	752	0.40
Sitework concrete	3,000	1	470	0.50

Lean concrete	2,000	1	376	0.60
NOTE: The Contractor is cautioned that the limiting parameters above are not a mix design. Additional cement or water reducing agent may be required to achieve workability required by the Contractor's construction methods and aggregates. The Contractor is responsible for providing concrete with the required workability.				

D. **Adjustments to Mix Design:** The mixes shall be changed whenever such change is necessary or desirable to secure the required strength, density, workability, and surface finish, and the Contractor shall be entitled to no additional compensation because of such changes.

2.06 CONSISTENCY

A. The quantity of water in a batch of concrete shall be just sufficient, with a normal mixing period, to produce a concrete which can be worked properly into place without segregation and which can be compacted by vibratory methods to give the desired density, impermeability, and smoothness of surface. The quantity of water shall be changed as necessary, with variations in the nature or moisture content of the aggregates, to maintain uniform production of a desired consistency. The consistency of the concrete in successive batches shall be determined by slump tests in accordance with ASTM C 143. The slumps shall be as follows:

Part of Work	*Slump (in)*
All concrete, unless indicated otherwise	3 inches plus or minus 1 inch
With high range water reducer added	7 inches plus or minus 2 inches
Pea gravel mix	7 inches plus or minus 2 inches
Ductbanks	5 inches plus or minus 1 inch

2.07 TRIAL BATCH AND LABORATORY TESTS

B. Before placing any concrete, a testing laboratory selected by the Engineer shall prepare a trial batch of each class of structural concrete, based on the preliminary concrete mixes submitted by the Contractor. During the trial batch the aggregate proportions may be adjusted by the testing laboratory using the two coarse aggregate size ranges to obtain the required properties. If one size range produces an acceptable mix, a second size range need not be used. Such adjustments will be considered refinements to the mix design and will not be the basis for extra compensation to the Contractor. All concrete shall conform to the requirements of this Section, whether the aggregate proportions are from the Contractor's preliminary mix design, or whether the proportions have been adjusted during the trial batch process. The trial batch shall be prepared using the aggregates, cement and admixture proposed for the project. The trial batch materials shall be of a quantity such that the testing laboratory

can obtain 3 drying shrinkage, and 6 compression test specimens from each batch.

C. The determination of compressive strength will be made by testing 6-inch diameter by 12-inch high cylinders; made, cured and tested in accordance with ASTM C 192 and ASTM C 39. Three compression test cylinders will be tested at 7 days and 3 at 28 days. The average compressive strength for the 3 cylinders tested at 28 days for any given trial batch shall not be less than 125 percent of the specified compressive strength.

D. A sieve analysis of the combined aggregate for each trial batch shall be performed according to the requirements of ASTM C 136. Values shall be given for percent passing each sieve.

2.08 SHRINKAGE LIMITATION

A. The maximum concrete shrinkage for specimens cast in the laboratory from the trial batch, as measured at 21-day drying age or at 28-day drying age shall be 0.036 percent or 0.042 percent, respectively. The Contractor shall only use a mix design for construction that has first met the trial batch shrinkage requirements. Shrinkage limitations apply only to structural concrete.

B. The maximum concrete shrinkage for specimens cast in the field shall not exceed the trial batch maximum shrinkage requirement by more than 25 percent.

C. If the required shrinkage limitation is not met during construction, the Contractor shall take any or all of the following actions at no additional cost to the Owner, for securing the specified shrinkage requirements. These actions may include changing the source or aggregates, cement and/or admixtures; reducing water content; washing of aggregate to reduce fines; increasing the number of construction joints; modifying the curing requirements; or other actions designed to minimize shrinkage or the effects of shrinkage.

2.09 MEASUREMENT OF CEMENT AND AGGREGATE

A. The amount of cement and of each separate size of aggregate entering into each batch of concrete shall be determined by direct weighing equipment furnished by the Contractor and acceptable to the Engineer.

B. Weighing tolerances:

Material	Percent of Total Weight
Cement	1
Aggregates	3
Admixtures	3

2.10 MEASUREMENT OF WATER

E. The quantity of water entering the mixer shall be measured by a suitable water meter or other measuring device of a type acceptable to the Engineer and capable of measuring the water in variable amounts within a tolerance of one percent. The water feed control mechanism shall be capable of being locked in position so as to deliver constantly any specified amount of water to each batch of concrete. A positive quick-acting valve shall be used for a cut-off in the water line to the mixer. The operating mechanism shall prevent leakage when the valves are closed.

2.11 READY-MIXED CONCRETE

F. At the Contractor's option, ready-mixed concrete may be used if it meets the requirements as to materials, batching, mixing, transporting, and placing as indicated herein and is in accordance with ASTM C 94, including the following supplementary requirements.

G. Ready-mixed concrete shall be delivered to the site of the work, and discharge shall be completed within one hour after the addition of the cement to the aggregates or before the drum has been revolved 250 revolutions, whichever is first.

H. Truck mixers shall be equipped with electrically-actuated counters by which the number of revolutions of the drum or blades may be readily verified. The counter shall be of the resetable, recording type, and shall be mounted in the driver's cab. The counters shall be actuated at the time of starting mixers at mixing speeds.

I. Each batch of concrete shall be mixed in a truck mixer for not less than 70 revolutions of the drum or blades at the rate of rotation designated by the manufacturer of equipment. Additional mixing, if any, shall be at the speed designated by the manufacturer of the equipment as agitating speed. All materials including mixing water shall be in the mixer drum before actuating the revolution counter for determining the number of revolution of mixing.

J. Truck mixers and their operation shall be such that the concrete throughout the mixed batch as discharged is within acceptable limits of uniformity with respect to consistency, mix, and grading. If slump tests taken at approximately the 1/4 and 3/4 points of the load during discharge give slumps differing by more than one inch when the required slump is 3 inches or less, or if they differ by more than 2 inches when the required slump is more than 3 inches, the mixer shall not be used on the work unless the causing condition is corrected and satisfactory performance is verified by additional slump tests. All mechanical details of the mixer, such as water measuring and discharge apparatus, condition of the blades, speed of rotation, general mechanical condition of the unit, and clearance of the drum, shall be checked before a further attempt to use the unit will be permitted.

K. Each batch of ready-mixed concrete delivered at the job site shall be accompanied by a delivery ticket furnished to the Engineer in accordance with the Paragraph in Part 1 entitled "Delivery Tickets."

L. The use of non-agitating equipment for transporting ready-mixed concrete will not be permitted. Combination truck and trailer equipment for transporting ready-mixed concrete will not be permitted. The quality and quantity of materials used in ready-mixed concrete and in batch aggregates shall be subject to continuous inspection at the batching plant by the Engineer.

2.11 FLOOR HARDENER (SURFACE APPLIED)

A. Surface hardener shall be a light reflective non-oxidizing metallic aggregate dry shake material that is premeasured, premixed, and packaged at the factory. Surface hardener shall be applied at the rate of 1.8 to 2.5 lbs/ft^2.

B. Curing compound shall meet the moisture retention requirements of ASTM C 309 and the manufacturer recommendations.

C. Monomolecular film shall maintain concrete moisture during the early placement stages of plastic concrete as recommended by the manufacturer.

D. Manufacturer: Floor hardener shall be "Lumiplate" by Master Builders, or equal.

PART 3: EXECUTION

3.01 PROPORTIONING AND MIXING

A. **Proportioning:** Proportioning of the mix shall conform to the requirements of Chapter 3 "Proportioning" of ACI 301.

B. **Mixing:** Mixing shall conform to the requirements of Chapter 7 of said ACI 301 Specifications.

C. **Slump:** Slumps shall be as indicated herein.

D. **Retempering:** Retempering of concrete or mortar which has partially hardened shall not be permitted.

3.02 PREPARATION OF SURFACES FOR CONCRETING

A. **General:** Earth surfaces shall be thoroughly wetted by sprinkling prior to the placing of any concrete, and these surfaces shall be kept moist by frequent sprinkling up to the time of placing concrete thereon. The surface shall be free from standing water, mud, and debris at the time of placing concrete.

B. **Joints in Concrete:** Concrete surfaces upon or against which concrete is to be placed, where the placement of the concrete has been stopped or interrupted so that, as determined by the Engineer, the new concrete cannot be incorporated integrally with that previously placed, are defined as construction joints. The surfaces of horizontal joints shall be given a compacted, roughened surface for good bonding. Except where the Drawings call for joint surfaces to be coated, the joint surfaces shall be cleaned of all laitance, loose or defective concrete, foreign material, and be roughened to a minimum 1/4-inch amplitude. Such cleaning and roughening shall be accomplished by hydroblasting or sandblasting (exposing aggregate) followed by thorough washing. All pools of water shall be removed from the surface of construction joints before the new concrete is placed.

C. After the surfaces have been prepared, all approximately horizontal construction joints shall be covered with a 6-inch lift of a pea gravel mix. The mix shall be placed and spread uniformly. Wall concrete shall follow immediately and shall be placed upon the fresh pea gravel mix.

D. **Placing Interruptions:** When placing of concrete is to be interrupted long enough for the concrete to take a set, the working face shall be given a shape by the use of forms or other means, that will secure proper union with subsequent work; provided that construction joints shall be made only where acceptable to the ENGINEER.

E. **Embedded Items:** No concrete shall be placed until all formwork, installation of parts to be embedded, reinforcement steel, and preparation of surfaces involved in the placing have been completed and accepted by the Engineer at least 4 hours before placement of concrete. All surfaces of forms and embedded items that have become encrusted with dried grout from previous work shall be cleaned before the surrounding or adjacent concrete is placed.

F. All inserts or other embedded items shall conform to the requirements herein.

G. All reinforcement, anchor bolts, sleeves, inserts, and similar items shall be set and secured in the forms at locations indicated on the Drawings or shown by shop drawings and shall be acceptable to the Engineer before any concrete is placed. Accuracy of placement is the responsibility of the Contractor.

H. **Casting New Concrete Against Old:** Where concrete is to be cast against old concrete (any concrete which is greater than 60 days of age), the surface of the old concrete shall be thoroughly cleaned and roughened by hydro-blasting or sandblasting (exposing aggregate). The joint surface shall be coated with an epoxy bonding agent unless indicated otherwise by the Engineer.

I. No concrete shall be placed in any structure until all water entering the space to be filled with concrete has been properly cut off or has been diverted by pipes, or other means, and carried out of the forms, clear of the work. No concrete shall be deposited underwater nor shall the Contractor allow still water to rise

on any concrete until the concrete has attained its initial set. Water shall not be permitted to flow over the surface of any concrete in such manner and at such velocity as will injure the surface finish of the concrete. Pumping or other necessary dewatering operations for removing ground water, if required, shall be subject to the review of the Engineer.

J. **Corrosion Protection:** Pipe, conduit, dowels, and other ferrous items required to be embedded in concrete construction shall be so positioned and supported prior to placement of concrete that there will be a minimum of 2 inches clearance between said items and any part of the concrete reinforcement. Securing such items in position by wiring or welding them to the reinforcement will not be permitted.

K. Openings for pipes, inserts for pipe hangers and brackets, and anchors shall, where practicable, be provided during the placing of concrete.

L. Anchor bolts shall be accurately set and shall be maintained in position by templates while being embedded in concrete.

M. **Cleaning:** The surfaces of all metalwork to be in contact with concrete shall be thoroughly cleaned of all dirt, grease, loose scale and rust, grout, mortar, and other foreign substances immediately before the concrete is placed.

3.03 HANDLING, TRANSPORTING, AND PLACING

A. **General:** Placing of concrete shall conform to the applicable requirements of Chapter 8 of ACI 301 and the requirements of this Section. No aluminum materials shall be used in conveying any concrete.

B. **Non-Conforming Work or Materials:** Concrete which during or before placing is found not to conform to the requirements indicated herein shall be rejected and immediately removed from the work. Concrete which is not placed in accordance with these Specifications, or which is of inferior quality, shall be removed and replaced by the Contractor at no additional cost to the Owner.

C. **Unauthorized Placement:** No concrete shall be placed except in the presence of a duly authorized representative of the Engineer. The Contractor shall notify the Engineer in writing at least 24 hours in advance of placement of any concrete.

D. **Placement in Wall and Column Forms:** Concrete shall not be dropped through reinforcement steel or into any deep form, nor shall concrete be placed in any form in such a manner as to leave accumulation of mortar on the form surfaces above the placed concrete. In such cases, means such as hoppers and, if necessary, vertical ducts of canvas, rubber, or metal shall be used for placing concrete in the forms in a manner that it may reach the place of final deposit without separation. In no case shall the free fall of concrete exceed 4 feet in

walls and 8 feet in columns below the ends of ducts, chutes, or buggies. Concrete shall be uniformly distributed during the process of depositing and in no case after depositing shall any portion be displaced in the forms more than 6 feet in horizontal direction. Concrete in wall forms shall be deposited in uniform horizontal layers not deeper than 2 feet; and care shall be taken to avoid inclined layers or inclined construction joints except where such are required for sloping members. Each layer shall be placed while the previous layer is still soft. The rate of placing concrete in wall forms shall not exceed 5 feet of vertical rise per hour. Sufficient illumination shall be provided in the interior of all forms so that the concrete at the places of deposit is visible from the deck or runway.

E. **Casting New Concrete Against Old:** Epoxy adhesive bonding agent shall be applied to the old surfaces according to the manufacturer's written recommendations. This provision shall not apply to joints where waterstop is provided. See Section 03290 - Joints in Concrete.

F. **Conveyor Belts and Chutes:** All ends of chutes, hopper gates, and all other points of concrete discharge throughout the Contractor's conveying, hoisting, and placing system shall be designed and arranged so that concrete passing from them will not fall separated into whatever receptacle immediately receives it. Conveyor belts, if used, shall be of a type acceptable to the Engineer. Chutes longer than 50 feet will not be permitted. Minimum slopes of chutes shall be such that concrete of the indicated consistency will readily flow in them. If a conveyor belt is used, it shall be wiped clean by a device operated in such a manner that none of the mortar adhering to the belt will be wasted. All conveyor belts and chutes shall be covered.

G. **Placement in Slabs:** Concrete placed in sloping slabs shall proceed uniformly from the bottom of the slab to the top, for the full width of the placement. As the work progresses, the concrete shall be vibrated and carefully worked around the slab reinforcement, and the surface of the slab shall be screeded in an up-slope direction.

H. **Temperature of Concrete:** The temperature of concrete when it is being placed shall be not more than 90 degrees F nor less than 55 degrees F for sections less than 12 inches thick nor less than 50 degrees for all other sections. Concrete ingredients shall not be heated to a temperature higher than that necessary to keep the temperature of the mixed concrete, as placed, from falling below the minimum temperature. When the temperature of the concrete is 85 degrees F or above, the time between the introduction of the cement to the aggregates and discharge shall not exceed 45 minutes. If concrete is placed when the weather is such that the temperature of the concrete would exceed 90 degrees F, the Contractor shall employ effective means, such as precooling of aggregates and mixing water using ice or placing at night, as necessary to maintain the temperature of the concrete, as it is placed, below 90 degrees F. The Contractor shall be entitled to no additional compensation on account of the foregoing requirements.

I. **Cold Weather Placement:**

1. Placement of concrete shall conform to ACI 306.1 - Cold Weather Concreting, and the following.

2. Remove all snow, ice, and frost from the surfaces, including reinforcement, against which concrete is to be placed. Before beginning concrete placement, thaw the subgrade to a minimum depth of 6 inches. All reinforcement and embedded items shall be warmed to above 32 degrees F prior to concrete placement.

3. Maintain the concrete temperature above 50 degrees F for at least 3 days after placement.

3.04 PUMPING OF CONCRETE

A. **General:** If the pumped concrete does not produce satisfactory end results, the Contractor shall discontinue the pumping operation and proceed with the placing of concrete using conventional methods.

B. **Pumping Equipment:** The pumping equipment shall have 2 cylinders and be designed to operate with one cylinder in case the other one is not functioning. In lieu of this requirement, the Contractor may have a standby pump on the site during pumping.

C. The minimum diameter of the hose conduits shall be in accordance with ACI 304.2R.

D. Pumping equipment and hose conduits that are not functioning properly shall be replaced.

E. Aluminum conduits for conveying the concrete shall not be permitted.

F. **Field Control:** Concrete samples for slump, air content, and test cylinders will be taken at the placement end of the hose.

3.05 ORDER OF PLACING CONCRETE

A. The order of placing concrete in all parts of the work shall be acceptable to the Engineer. In order to minimize the effects of shrinkage, the concrete shall be placed in units as bounded by construction joints at the indicated locations. The placing of units shall be done by placing alternate units in a manner such that each unit placed shall have cured at least 5 days for hydraulic structures and 2 days for all other structures before the contiguous unit or units are placed, except that the corner sections of vertical walls shall not be placed until the 2 adjacent wall panels have cured at least 10 days for hydraulic structures and 4 days for all other structures.

B. The surface of the concrete shall be level whenever a run of concrete is stopped. To insure a level, straight joint on the exposed surface of walls, a wood strip at least 3/4-inch thick shall be tacked to the forms on these surfaces. The concrete shall be carried about 1/2-inch above the underside of the strip. About one hour after the concrete is placed, the strip shall be removed and any irregularities in the edge formed by the strip shall be leveled with a trowel and all laitance shall be removed.

3.06 TAMPING AND VIBRATING

C. As concrete is placed in the forms or in excavations, it shall be thoroughly settled and compacted, throughout the entire depth of the layer which is being consolidated, into a dense, homogeneous mass, filling all corners and angles, thoroughly embedding the reinforcement, eliminating rock pockets, and bringing only a slight excess of water to the exposed surface of concrete. Vibrators shall be Group 3 per ACI 309, high speed power vibrators (8000 to 12,000 rpm) of an immersion type in sufficient number and with at least one standby unit as required. Group 2 vibrators may be used only at specific locations when accepted by the Engineer.

D. Care shall be used in placing concrete around waterstops. The concrete shall be carefully worked by rodding and vibrating to make sure that all air and rock pockets have been eliminated. Where flat-strip type waterstops are placed horizontally, the concrete shall be worked under the waterstops by hand, making sure that all air and rock pockets have been eliminated. Concrete surrounding the waterstops shall be given additional vibration over and above that used for adjacent concrete placement to assure complete embedment of the waterstops in the concrete.

E. Concrete in walls shall be internally vibrated and at the same time rammed, stirred, or worked with suitable appliances, tamping bars, shovels, or forked tools until it completely fills the forms or excavations and closes snugly against all surfaces. Subsequent layers of concrete shall not be placed until the layers previously placed have been worked thoroughly. Vibrators shall be provided in sufficient numbers, with standby units as required, to accomplish the required results within 15 minutes after concrete of the prescribed consistency is placed in the forms. The vibrating head shall not contact the surfaces of the forms. Care shall be taken not to vibrate concrete excessively or to work it in any manner that causes segregation of its constituents.

3.07 FINISHING CONCRETE SURFACES

F. **General:** Surfaces shall be free from fins, bulges, ridges, offsets, honeycombing, or roughness of any kind, and shall present a finished, smooth, continuous hard surface. Allowable deviations from plumb or level and from the alignment, profiles, and dimensions shown are defined as tolerances and are indicated in

Part 1, above. These tolerances are to be distinguished from irregularities in finish as described herein. Aluminum finishing tools shall not be used.

NTS: Acceptable surface finish of basin walls is difficult to define and can vary radically from Owner to Owner. If possible, discuss the issue with the Owner to define the finish they wish to buy. It is better to get the desired finish as part of the original bid than as a change order.

G. **Formed Surfaces:** No treatment is required after form removal except for curing, repair of defective concrete, and treatment of surface defects. Where architectural finish is required, it shall be as indicated.

NTS: Chose one of the following:

[1. Surface holes larger than [1/2]-inch in diameter or deeper than [1/4]-inch are defined as surface defects in basins and exposed walls.]

[2. The Owner has identified an acceptable wall finish on an identified panel at an existing structure to be used as a comparative sample for formed finish without architectural treatment. This panel is located [ ]. At walls which are exposed to view or in contact with water, surface roughness or surface holes (considering both size and number per unit surface area as separate criteria) greater than the identified panel shall be considered to have surface defects and shall be repaired to match or exceed the sample finish.]

[3. Basins and exposed walls shall be given a smooth finish as indicated below.]

[4. Basins and exposed walls shall be given two coats of cement based paint as indicated.]

H. **Unformed Surfaces:** After proper and adequate vibration and tamping, all unformed top surfaces of slabs, floors, walls, and curbs shall be brought to a uniform surface with suitable tools. Immediately after the concrete has been screeded, it shall be treated with a liquid evaporation retardant. The retardant shall be used again after each work operation as necessary to prevent drying shrinkage cracks. The classes of finish specified for unformed concrete surfaces are designated and defined as follows:

1. Finish U1 - Sufficient leveling and screeding to produce an even, uniform surface with surface irregularities not to exceed 3/8-inch. No further special finish is required.

2. Finish U2 - After sufficient stiffening of the screeded concrete, surfaces shall be float finished with wood or metal floats or with a finishing machine using float blades. Excessive floating of surfaces while the concrete is plastic and dusting of dry cement and sand on the concrete

surface to absorb excess moisture will not be permitted. Floating shall be the minimum necessary to produce a surface that is free from screed marks and is uniform in texture. Surface irregularities shall not exceed 1/4-inch. Joints and edges shall be tooled where indicated or as determined by the Engineer.

3. Finish U3 - After the finish U2 surface has hardened sufficiently to prevent excess of fine material from being drawn to the surface, steel troweling shall be performed with firm pressure such as will flatten the sandy texture of the floated surface and produce a dense, uniform surface free from blemishes, ripples, and trowel marks. The finish shall be smooth and free of all irregularities.

4. Finish U4 - Trowel the Finish U3 surface to remove local depressions or high points. In addition, the surface shall be given a light hairbroom finish with brooming perpendicular to drainage unless otherwise indicated. The resulting surface shall be rough enough to provide a nonskid finish.

I. Unformed surfaces shall be finished according to the following schedule:

UNFORMED SURFACE FINISH SCHEDULE

Area	Finish
Grade slabs and foundations to be covered with concrete or fill material	U1
Floors to be covered with grouted tile or topping grout	U2
Water bearing slabs with slopes 10 percent and less	U3
Water bearing slabs with slopes greater than 10 percent	U4
Slabs not water bearing	U4
Slabs to be covered with built-up roofing	U2
Interior slabs and floors to receive architectural finish	U3
Top surface of walls	U3

J. Floor Hardener (Surface Applied)

1. The following additional requirements apply to the substrate concrete in areas indicated to be under floor hardener:

a. Slump shall be no greater than 4 inches when peak ambient temperatures are expected to exceed 65 degrees F and no greater than 3 inches when temperatures will not exceed 65 degrees F.

b. Air content shall not exceed 3 percent.

c. No calcium chloride or set accelerating admixture containing calcium chloride shall be used.

d. Do not use admixtures that increase bleeding.

e. Do not use fly ash.

2. The Contractor shall finish areas indicated to receive hardener in conformance with the manufacturer's recommendations and the following. After leveling the concrete surface and as soon as the concrete will support an operator and machine without disturbing the level or working up excessive fines, the Contractor shall float the surface of the slab with a mechanical float fitted with detachable float shoes. Then apply 1/2 to 2/3 of the total amount of dry shake surface hardener uniformly to the surface. A mechanical spreader is recommended. Float the surface once the shake has absorbed sufficient moisture, as indicated by darkening of the shake. Immediately apply the remainder of the shake and allow it to absorb moisture. Do not apply shake when bleed water is present.

3. Perform a third floating if time and setting characteristics of the concrete will allow, but do not add water to the surface.

4. As the surface stiffens further and loses sheen, trowel with blades set relatively flat, using hand or mechanical methods. Remove all marks and pinholes in a final raised trowel operation.

5. Cure the finished surface using the fill-forming curing compound recommended by the manufacturer at a coverage rate which will provide moisture retention in excess of the requirements of ASTM C 309. Maintain ambient temperatures above 50 degrees F during the curing period.

6. Keep floors covered and prohibit traffic and loads for 10 days minimum after completion.

3.08 ARCHITECTURAL FINISH

K. **General:** Architectural finishes shall be provided only where specifically indicated on the Drawings. In all other locations, the paragraph entitled Finishing Concrete Surfaces, shall apply.

7. Immediately after the forms have been stripped, the concrete surface shall be inspected and any poor joints, voids, rock pockets, or other defective areas shall be repaired and all form-tie holes filled as indicated herein.

8. Architectural finishes shall not be applied until the concrete surface has been repaired as required and the concrete has cured at least 14 days.

9. All architecturally treated concrete surfaces shall conform to the accepted sample in texture, color, and quality. It shall be the Contractor's responsibility to maintain and protect the concrete finish.

L. Smooth Concrete Finish

1. The concrete surface shall be wetted, and a grout shall be applied with a brush. The grout shall be made by mixing one part portland cement and one part of fine sand that will pass a No. 16 sieve with sufficient water to give it the consistency of thick paint. The cement used in said grout shall be 1/2 gray and 1/2 white portland cement, or other proportion as determined by the Engineer. White portland cement shall be Atlas white, or equal. Calcium chloride at 5 percent by volume of the cement shall be used in the brush coat. The freshly applied grout shall be vigorously rubbed into the concrete surface with a wood float filling all small air holes. After all the surface grout had been removed with a steel trowel, the surface shall be allowed to dry and, when dry, shall be vigorously rubbed with burlap to remove completely all surface grout so that there is no visible paint-like film of grout on the concrete. The entire cleaning operation for any area shall be completed the day it is started, and no grout shall be left on the surface overnight.

2. Cleaning operations for any given day shall be terminated at panel joints. It is required that the various operations be carefully timed to secure the desired effect which is a light-colored concrete surface of uniform color and texture without any appearance of a paint or grout film.

3. In the event that improper manipulation results in an inferior finish, the Contractor shall rub such inferior areas with carborundum bricks.

4. Before beginning any of the final treatment on exposed surfaces, the Contractor shall treat in a satisfactory manner a trial area of at least 200 square feet in some inconspicuous place selected by the Engineer and shall preserve said trial area undisturbed until the completion of the job.

M. Sandblasted Concrete Finish.

1. Sandblasting shall be done in a safe manner acceptable to local authorities and per OSHA requirements. The sandblasting shall be a

light sandblast to remove laitance and to produce a uniform fine aggregate surface texture with approximately 1/32- to 1/16-inch of surface sandblasted off. Corners, patches, form panel joints, and soft spots shall be sandblasted with care.

2. A 3-sq ft sample panel of the sandblasted finish shall be provided by the Contractor for acceptance by the Engineer prior to starting the sandblasting work. The sample panel shall include a corner, plugs, and joints and shall be marked after approval. All other sandblasting shall be equal in finish to the sample panel.

3. Protection against sandblasting shall be provided on all adjacent surfaces and materials not requiring sandblasting. After sandblasting, the concrete surfaces shall be washed with clean water and excess sand removed.

3.09 CURING AND DAMPPROOFING

A. **General:** All concrete shall be cured for not less than 7 days after placing, in accordance with the methods indicated below for the different parts of the work.

Surface to be Cured or Dampproofed	Method
Unstripped forms	1
Wall sections with forms removed	6
Construction joints between footings and walls, and between floor slab and columns	2
Encasement concrete and thrust blocks	3
All concrete surfaces not specifically indicated in this Paragraph	4
Floor slabs on grade in hydraulic structures	5
Slabs not on grade	6

B. **Method 1:** Wooden forms shall be wetted immediately after concrete has been placed and shall be kept wet with water until removal. If steel forms are used the exposed concrete surfaces shall be kept continuously wet until the forms are removed. If forms are removed within 7 days of placing the concrete, curing shall be continued in accordance with Method 6 below.

C. **Method 2:** The surface shall be covered with burlap mats which shall be kept wet with water for the duration of the curing period, until the concrete in the walls has been placed. No curing compound shall be applied to surfaces cured under Method 2.

D. **Method 3:** The surface shall be covered with moist earth not less than 4 hours nor more than 24 hours after the concrete is placed. Earthwork operations that may damage the concrete shall not begin until at least 7 days after placement of concrete.

E. **Method 4:** The surface shall be sprayed with a liquid curing compound.

1. It shall be applied in accordance with the manufacturer's printed instructions at a maximum coverage rate of 200 square feet per gallon and in such a manner as to cover the surface with a uniform film which will seal thoroughly.

2. Where the curing compound method is used, care shall be exercised to avoid damage to the seal during the 7-day curing period. If the seal is damaged or broken before the expiration of the curing period, the break shall be repaired immediately by the application of additional curing compound over the damaged portion.

3. Wherever curing compound has been applied by mistake to surfaces against which concrete subsequently is to be placed and to which it is to adhere, compound shall be entirely removed by wet sandblasting just prior to the placing of new concrete.

4. Curing compound shall be applied as soon as the concrete has hardened enough to prevent marring on unformed surfaces and within 2 hours after removal of forms. Repairs to formed surfaces shall be made within the 2-hour period; provided, however, that any such repairs which cannot be made within the said 2-hour period shall be delayed until after the curing compound has been applied. When repairs are to be made to an area on which curing compound has been applied, the area involved shall first be wet-sandblasted to remove the curing compound.

5. At all locations where concrete is placed adjacent to a panel which has been coated with curing compound, the panel shall have curing compound reapplied to an area within 6 feet of the joint and to any other location where the curing membrane has been disturbed.

6. Prior to final acceptance of the work, all visible traces of curing compound shall be removed from all surfaces in such a manner that does not damage the surface finish.

F. **Method 5:**

1. Until the concrete surface is covered with curing compound, the entire surface shall be kept damp by applying water using nozzles that atomize the flow so that the surface is not marred or washed. The concrete shall be given a coat of curing compound in accordance with Method 4 above. Not less than one hour nor more than 4 hours after the curing compound has been applied, the surface shall be wetted with water delivered through a fog nozzle, and concrete-curing blankets shall be placed on the slabs. The curing blankets shall be polyethylene sheet, polyethylene-coated waterproof paper sheeting, or polyethylene-coated burlap. The blankets shall be laid with the edges butted together and with the joints between strips sealed with 2-inch wide strips of sealing tape or with edges lapped not less than 3 inches and fastened together with a waterproof cement to form a continuous watertight joint.

2. The curing blankets shall be left in place during the 7-day curing period and shall not be removed until after concrete for adjacent work has been placed. If the curing blankets become torn or otherwise ineffective, the Contractor shall replace damaged sections. During the first 3 days of the curing period, no traffic of any nature and no depositing, temporary or otherwise, of any materials shall be permitted on the curing blankets. During the remainder of the curing period, foot traffic and temporary depositing of materials that impose light pressure will be permitted only on top of plywood sheets 5/8-inch minimum thickness, laid over the curing blanket. The Contractor shall add water under the curing blanket as often as necessary to maintain damp concrete surfaces at all times.

G. **Method 6:** This method applies to both walls and slabs.

1. The concrete shall be kept continuously wet by the application of water for a minimum period of at least 7 consecutive days beginning immediately after the concrete has reached final set or forms have been removed.

2. Until the concrete surface is covered with the curing medium, the entire surface shall be kept damp by applying water using nozzles that atomize the flow so that the surface is not marred or washed.

3. Heavy curing mats shall be used as a curing medium to retain the moisture during the curing period. The curing medium shall be weighted or otherwise held substantially in contact with the concrete surface to prevent being dislodged by wind or any other causes. All edges shall be continuously held in place.

4. The curing blankets and concrete shall be kept continuously wet by the use of sprinklers or other means both during and after normal working hours.

5. Immediately after the application of water has terminated at the end of the curing period, the curing medium shall be removed, any dry spots shall be rewetted, and curing compound shall be immediately applied in accordance with Method 4 above.

6. The Contractor shall dispose of excess water from the curing operation to avoid damage to the work.

H. **Dampproofing**

1. The exterior surface of all buried roof slabs shall be dampproofed as follows.

2. Immediately after completion of curing the surface shall be sprayed with a dampproofing agent consisting of an asphalt emulsion. Application shall be in 2 coats. The first coat shall be diluted to 1/2 strength by the addition of water and shall be sprayed on so as to provide a maximum coverage rate of 100 square feet per gallon of dilute solution. The second coat shall consist of an application of the undiluted material, and shall be sprayed on so as to provide a maximum coverage rate of 100 square feet per gallon. Dampproofing material shall be as indicated above.

3. As soon as the material has taken an initial set, the entire area thus coated shall be coated with whitewash. Any formula for mixing the whitewash may be used if it produces a uniformly coated white surface and remains until placing of the backfill. If the whitewash fails to remain on the surface until the backfill is placed, the Contractor shall apply additional whitewash.

3.10 PROTECTION

A. The Contractor shall protect all concrete against injury until final acceptance.

B. Fresh concrete shall be protected from damage due to rain, hail, sleet, or snow. The Contractor shall provide such protection while the concrete is still plastic and whenever precipitation is imminent or occurring.

3.11 CURING IN COLD WEATHER

A. Water curing of concrete may be reduced to 6 days during periods when the mean daily temperature in the vicinity of the Site is less than 40 degrees F; provided that, during the prescribed period of water curing, when temperatures

are such that concrete surfaces may freeze, water curing shall be temporarily discontinued.

B. Concrete cured by an application of curing compound will require no additional protection from freezing if the protection at 50 degrees F for 72 hours is obtained by means of approved insulation in contact with the forms or concrete surfaces; otherwise the concrete shall be protected against freezing temperatures for 72 hours immediately following 72 hours protection at 50 degrees F. Concrete cured by water shall be protected against freezing temperatures for 3 days immediately following the 72 hours of protection at 50 degrees F.

C. Discontinuance of protection against freezing temperatures shall be such that the drop in temperature of any portion of the concrete will be gradual and will not exceed 40 degrees F in 24 hours. In the spring, when the mean daily temperature rises above 40 degrees F for more than 3 successive days, the specified 72-hour protection at a temperature not lower than 50 degrees F may be discontinued for as long as the mean daily temperature remains above 40 degrees F; provided, that the concrete shall be protected against freezing temperatures for not less than 48 hours after placement.

D. Where artificial heat is employed, special care shall be taken to prevent the concrete from drying. Use of unvented heaters will be permitted only when unformed surfaces of concrete adjacent to the heaters are protected for the first 24 hours from an excessive carbon dioxide atmosphere by application of curing compound; provided, that the use of curing compound for such surfaces is otherwise permitted by these Specifications.

3.12 TREATMENT OF SURFACE DEFECTS

A. As soon as forms are removed, all exposed surfaces shall be carefully examined and any irregularities shall be immediately rubbed or ground in a satisfactory manner in order to secure a smooth, uniform, and continuous surface. Plastering or coating of surfaces to be smoothed will not be permitted. No repairs shall be made until after inspection by the Engineer. In no case will extensive patching of honeycombed concrete be permitted. Concrete containing minor voids, holes, honeycombing, or similar depression defects shall be repaired as indicated below. Concrete containing extensive voids, holes, honeycombing, or similar depression defects shall be completely removed and replaced. All repairs and replacements herein required shall be promptly executed at no increased cost to the Owner.

B. Defective surfaces to be repaired shall be cut back from trueline a minimum depth of 1/2-inch over the entire area. Feathered edges will not be permitted. Where chipping or cutting tools are not required in order to deepen the area properly, the surface shall be prepared for bonding by the removal of all laitance or soft material, plus not less than 1/32-inch depth of the surface film from all hard portions by means of an efficient sandblast. After cutting and

sandblasting, the surface shall be wetted sufficiently in advance of shooting with shotcrete or with cement mortar so that while the repair material is being applied, the surfaces underneath will remain moist but not so wet as to overcome the suction upon which a good bond depends. The material used for repair proposed shall consist of a mixture of one sack of cement to 3 cubic feet of sand. For exposed walls, the cement shall contain such a proportion of Atlas white portland cement as is required to make the color of the patch match the color of the surrounding concrete.

C. Holes left by tie-rod cones shall be reamed with suitable toothed reamers so as to leave the surfaces of the holes clean and rough. Holes then shall be repaired in an approved manner with dry-packed cement grout. Holes left by form-tying devices having a rectangular cross-section and other imperfections having a depth greater than their least surface dimension shall not be reamed but shall be repaired in an approved manner with dry-packed cement grout.

D. All repairs shall be built up and shaped in such a manner that the completed work will conform to the requirements of this Section, as applicable, using approved methods which will not disturb the bond, cause sagging, or cause horizontal fractures. Surfaces of repairs shall receive the same kind and amount of curing treatment as required for the concrete in the repaired section.

E. Prior to filling any structure with water, all cracks that may have developed shall be "vee'd" as indicated and filled with sealant conforming to the requirements of Section 03290 - Joints in Concrete. This repair method shall be done on the water bearing face of members. Prior to backfilling, faces of members in contact with fill which are not covered with a waterproofing membrane shall also have cracks repaired as indicated herein.

3.13 PATCHING HOLES IN CONCRETE

A. **Patching Small Holes:**

4. Holes which are less than 12 inches in the least dimension and extend completely through concrete members shall be filled.

5. Small holes in members which are water-bearing or in contact with soil or other fill material shall be filled with non-shrink grout. Where a face of the member is exposed to view, the non-shrink grout shall be held back 2 inches from the finished surface. The remaining 2 inches shall then be patched according to the Paragraph entitled "Treatment of Surface Defects."

6. Small holes through all other concrete members shall be filled with non-shrink grout, with exposed faces treated as above.

B. **Patching Large Holes:**

1. Holes which are larger than 12 inches in the least dimension shall have a keyway chipped into the edge of the opening all around, unless a formed keyway exists. The holes shall then be filled with concrete as indicated herein.

2. Holes which are larger than 24 inches in the least dimension and which do not have reinforcing steel extending from the existing concrete, shall have reinforcing steel set in grout in drilled holes. The reinforcing added shall match the reinforcing in the existing wall unless indicated otherwise.

3. Large holes in members which are water bearing or in contact with soil or other fill shall have a bentonite type waterstop material placed around the perimeter of the hole in accordance with Section 03290 - Joints in Concrete, unless there is an existing waterstop in place.

3.14 CARE AND REPAIR OF CONCRETE

A. The Contractor shall protect all concrete against injury or damage from excessive heat, lack of moisture, overstress, or any other cause until final acceptance. Particular care shall be taken to prevent the drying of concrete and to avoid roughening or otherwise damaging the surface. Any concrete found to be damaged, or which may have been originally defective, or which becomes defective at any time prior to the final acceptance of the completed work, or which departs from the established line or grade, or which, for any other reason, does not conform to the requirements of the General Specifications, the CQA Plan, and the Construction Drawings, shall be satisfactorily repaired or removed and replaced with acceptable concrete at no additional cost to the Owner.

[END OF SECTION]

SECTION 03410
STRUCTURAL PRECAST CONCRETE

PART 1: GENERAL

1.01 SUMMARY

A. Description of Work

1. This section applies to construction of the vertical riser foundation for the landfill as shown on the Drawings.

2. This section applies to precast catch basins and similar items used for surface water drainage.

B. Related Sections

1. 03100 - Concrete Form Work

2. 02718 - Polyethylene Pipe

3. 15600 - Carbon Steel Pipe

4. 15700 - Stainless Steel Pipe

1.02 REFERENCES

A. American Concrete Institute (ACI) most current version:

1. ACI 318 - Building Code Requirements for Reinforced Concrete.

B. American Society for Testing and Materials (ASTM) most current version:

1. ASTM 184 - Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement.

2. ASTM A307 - Specification for Carbon Steel Externally Threaded Standard Fasteners.

3. ASTM A615 - Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement.

4. ASTM A775 - Specification for Epoxy-Coated Reinforcing Steel Bars.

5. ASTM C31 - Making and Curing Concrete Test Specimens in the Field.

6. ASTM C33 - Specification for Concrete Aggregates.

7. ASTM C39 - Test Method for Compressive Strength of Cylindrical Concrete Specimens.

8. ASTM C150 - Specification for Portland Cement.

9. ASTM C171 - Specification for Sheet Materials for Curing Concrete.

10. ASTM C185 - Test Method for Air Content of Hydraulic Cement Mortar.

11. ASTM C260 - Specification for Air-Entraining Admixtures for Concrete.

12. ASTM C309 - Specification for Liquid Membrane-Forming Compounds for Curing Concrete.

13. ASTM C330 - Specification for Lightweight Aggregates for Structural Concrete.

14. ASTM C494 - Specification for Chemical Admixtures for Concrete.

C. Prestressed Concrete Institute (PCI) most current version:

1. PCI MNL-116 - Manual for Quality Control for Plants and Productions of Precast Prestressed Concrete Products.

1.03 SUBMITTALS

A. Shop Drawings and Product Data

1. Content:

a. Dimensions.

b. Details of inserts, anchors, connections, accessories, formed openings, scheduled field cut openings, anchor bolt layout plan, and fabrication detail.

c. Lifting positions or devices.

d. Reinforcement.

2. Manufacturer's instructions for handling, transporting, and erecting.

B. Certificates

1. Manufacturer's certificates that material and/or procedures are in compliance with specifications.

2. When requested by OWNER, evidence of certification and/or experience qualifications.

C. Test Reports: Reports of tests on concrete.

1.04 QUALITY ASSURANCE

A. Testing

1. Conduct testing in accordance with PCI (Prestressed Concrete Institute) MNL-116.

2. CQA ENGINEER to verify testing.

B. Source Quality Control: In general compliance with applicable provisions of PCI MNL-116.

1. Concrete Compression Tests:

a. ASTM C39.

b. Make one compression test for each day's production of each type of member.

2. Specimens:

a. Provide four test specimens for each compression test.

b. Obtain concrete for specimens from actual production batch.

c. Concrete Cylinders, 6 inch by 12 inch, ASTM C31.

C. Other requirements:

1. Design, fabricate, and install precast sections to meet requirements of ACI 318.

1.05 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Follow manufacturer's instructions for handling and transporting.

B. Lift members at designated points only, and use lifting inserts if provided.

C. Use lifting slings or spreader bars to keep angle between lifted member and cable greater than 45°.

D. Do not place members in position which will cause overstress, warp, or twist.

E. Handle members to protect from dirt and damage.

F. Place stored items so that identification marks are discernable.

G. Separate stacked items by battens across full width of each bearing surface.

H. Stack items so that lifting points/devices are accessible and undamaged.

PART 2: PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Firms specializing in providing precast concrete products and services normally associated with industry for at least 3 years.

B. Manufacturers meeting requirements of PCI MNL-116.

C. Manufacturers may be required to submit written evidence showing experience; qualifications; and adequacy of plant capability, facilities, and ability to perform work in accordance with these specifications.

1. Evidence shall consist of PCI plant certification or results of tests performed by independent testing laboratory to monitor conformance to provisions of PCI MNL-116 and requirements herein.

2.02 MATERIALS

A. Portland Cement

1. ASTM C150, Type II.

B. Admixtures

1. Air-Entraining: ASTM C260.

2. Water Reduction and Set Retardation: ASTM C494, Type A.

3. Super Plasticizer: ASTM C494, Type A.

C. Aggregates

1. ASTM C33 or C330.

2. Material: Natural.

3. Maximum 1 inch.

D. Water

1. Potable or free from foreign materials in amounts harmful to concrete.

E. Reinforcing Steel

1. Deformed Steel Bars: ASTM A615, including supplementary requirements S1, Grade 60.

2. Epoxy coat reinforcing steel conforming to ASTM A775.

F. Curing Materials

1. Liquid membrane forming compound, ASTM C309, or sheet materials, ASTM C171.

G. Coating

1. Coating shall be Coal Cat Coal Tar epoxy 97-6401/641 or approved equal.

2.03 MIX DESIGN

A. Mix design to be per manufacturer's recommendations.

B. Concrete properties

1. Water-Cement Ratio: Maximum 40 pounds water to 100 pounds cement.

2. Air-Entrainment: Amount produced by adding dosage of air-entraining agent providing 19% ±3% entrained air in standard 1:4 sand mortar as tested according to ASTM C185.

3. Twenty-eight-day Compressive Strength:

a. Minimum 4000 psi.

4. Do not use calcium chloride or other salts.

2.04 FABRICATION

A. Formwork

1. Securely attach anchorage devices to formwork in locations not affecting position of main reinforcement or placing of concrete.

2. Form treatments or curing compounds shall not contain any ingredients which might stain through or otherwise inure concrete or reduce bond with subsequent coatings, finishes, or caulking.

B. Reinforcement

1. Provide reinforcement necessary to resist stresses from handling and erecting stresses as required, in addition to any shown on the Drawings.

2. Place and anchor reinforcement in position.

C. Concrete Placement

1. Batch, mix, and handle concrete in accordance with ACI and PCI recommended practices.

2. Place concrete in continuous operation to prevent formation of seams.

3. Consolidate placed concrete by vibration without dislocation or damage to reinforcement and built-in items.

D. Provide permanent markings in precast units to identify pick-up point.

E. Cure units in accordance with PCI MNL-116.

F. Finishes

1. All exposed surfaces shall have PCI commercial finish.

2. Coat all exposed areas of riser pipe foundation with coal tar epoxy per Article 2-2 G and manufacturer's recommendations.

2.05 HOLES

A. Eight-inch diameter and over shall be formed during manufacture of units.

PART 3: EXECUTION

3.01 ERECTION

A. Align, place, and level units in final position on accepted bearing surfaces.

B. Place no warped, cracked, or broken units.

C. Remove lifting devices and grout surfaces flush with concrete.

D. Refinish damaged surfaces to match adjacent areas.

[END OF SECTION]

SECTION 05100
STRUCTURAL STEEL FRAMING

PART 1: GENERAL

1.01 THE REQUIREMENT

A. The Contractor shall provide structural steel framing and appurtenant metal parts required for permanent connection of the structural steel system, complete and in place, in accordance with the General Specifications, the CQA Plan, and the Construction Drawings.

1.02 REFERENCE SPECIFICATIONS, CODES, AND STANDARDS

A. References herein to "Building Code" or UBC shall mean the [Uniform Building Code of the International Conference of Building Officials (ICBO)]. The edition of the codes adopted as of the date of award of this contract shall apply to the work herein.

B. Federal Specifications and Commercial Standards:

AISC	Code of Standard Practice for Steel Buildings and Bridges
AISC	Structural Steel Buildings-Allowable Stress Design and Plastic Design
AISC	Allowable Stress Design Specifications for Structural Joints Using ASTM A325 and A490 Bolts approved by the Research Council on Structural Connections of the Engineering Foundation
ASTM A 36	Structural Steel
ASTM A 53	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
ASTM A 307	Carbon Steel Bolts and Studs
ASTM A 325	Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
ASTM A 500	Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
ASTM A 501	Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
AWS D1.1	Structural Welding Code - Steel

1.03 CONTRACTOR SUBMITTALS

A. Shop drawings shall conform to AISC recommendations and specifications and shall show all holes, etc. required for other work. Drawings shall include complete details showing all members and their connections, anchor bolt layouts, schedules for fabrication procedures, and diagrams showing the sequence of erection.

B. Testing laboratory certifications for shop and field welders shall be submitted in triplicate directly to the Engineer with copies to the Contractor and others as required.

PART 2: PRODUCTS

2.01 MATERIALS

A. All structural steel shapes, plates, bars and their products shall be ASTM A36 unless otherwise indicated.

B. Structural steel pipe shall be ASTM A501, or ASTM A53, Type E or S, Grade B.

C. Structural tubing shall be ASTM A500, Grade B. All members shall be furnished full length without splices unless otherwise indicated or approved by the Engineer.

D. Bolts for connections shall be ASTM A325, unless indicated otherwise. Bolts used to connect dissimilar metals shall be ASTM A193 and A194, Type 316 stainless steel.

E. Welded anchor studs shall be headed concrete anchor studs (HAS), or deformed bar anchors (DBA), or threaded studs (TAS), as indicated on the Drawings and as supplied by Nelson Stud Welding Company, Lorain, OH; Omark Industries, KSM Fastening Systems Division, Seattle, WA, or Portland, OR; or equal.

F. Structural steel shall be cleaned and coated in accordance with Section 09800 - Protective Coating.

G. All steel members in contact with aluminum shall be galvanized per Section 05500 - Miscellaneous Metalwork, unless indicated otherwise.

H. All structural members shall be furnished full length without splices unless otherwise indicated or approved by the Engineer.

2.02 INSPECTION AND TESTING

A. Shop inspection may be required by the Owner at its own expense. The Contractor shall give ample notice to the Engineer prior to the beginning of any fabrication work so that inspection may be provided. The Contractor shall

furnish all facilities for the inspection of materials and workmanship in the shop, and inspectors shall be allowed free access to the necessary parts of the work. Inspectors shall have the authority to reject any materials or work which does not meet the requirements of these Specifications. Inspection at the shop is intended as a means of facilitating the work and avoiding errors, but it is expressly understood that it will in no way relieve the Contractor from responsibility for proper materials or workmanship under this Specification.

B. The Owner may engage inspectors to inspect welded connections and high-strength bolted connections, and to perform tests and prepare test reports.

1. Ten percent of all butt and bevel welds which extend continuously for 24 inches or less shall be completely tested in accordance with AWS D1.1, Part B, Radiographic Testing of Welds, Chapter 6. All butt and bevel welds which extend continuously for more than 24 inches shall be spot tested at intervals not exceeding 36 inches.

2. Welds that are required by the Engineer to be corrected shall be corrected or redone and retested as directed, at the Contractor's expense and to the satisfaction of the Engineer and/or approved independent testing lab.

3. The Contractor shall test to failure three bolts from each heat lot of bolts furnished to the job to verify compliance with this Specification. The testing laboratory shall be approved by the Engineer and all test reports shall be supplied to the Engineer. In addition, high-strength bolts shall be inspected using one of the methods set forth in the AISC Specification "Structural Joints Using ASTM A325 or A490 Bolts".

C. The costs for all initial testing will be paid by the Owner. However, the Contractor shall pay for all costs for any additional testing and investigation on work which does not meet Specifications. The Contractor shall supply material for testing at no cost to the Owner and shall assist the Engineer in obtaining material for test samples.

PART 3: EXECUTION

3.01 MEASUREMENT

A. The Contractor shall verify all dimensions and shall make any field measurements necessary and shall be fully responsible for accuracy and layout of work. The Contractor shall review the Drawings, and any discrepancies shall be reported to the Engineer for clarification prior to starting fabrication.

3.02 FABRICATION

A. Structural steel shall be fabricated in accordance with the Drawings, AISC Specifications, and as shown on the shop drawings.

B. Materials shall be properly marked and match-marked for field assembly.

C. Where finishing is required, assembly shall be completed including bolting and welding of units, before start of finishing operations.

3.03 CONNECTIONS

A. Shop and field connections shall be bolted or welded as shown or specified. All connections shall develop full strength of members joined and shall conform to AISC standard connections.

3.04 WELDED CONSTRUCTION

A. The Contractor shall comply with the current AWS D1.1 Code for procedures, appearance, and quality of welds and welders, and methods used in correcting welding work. All welded architectural metal work where exposed to view shall have welds ground smooth. Shielded metal are welding method or gas metal arc welding methods shall be used for welding structural steel.

B. Unless otherwise shown, all butt and bevel welds shall be complete penetration.

3.05 HOLES FOR OTHER WORK

A. Holes shall be provided as necessary or as indicated for securing other work to structural steel framing, and for the passage of other work through steel framing members. No torch cut holes will be permitted.

3.06 SHOP PAINT PRIMER

A. Shop paint primer shall be applied in accordance with the manufacturer specification. Omit shop applied primer at field weld locations, for the portion of a member to be embedded in concrete, and where galvanizing with no further coating is required.

3.07 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Structural members shall be loaded in such a manner that they may be transported and unloaded without being excessively stressed, deformed, or otherwise damaged.

B. Structural steel members and packaged materials shall be protected from corrosion and deterioration. Material shall be stored in a dry area and shall not be placed in direct contact with the ground. Materials shall not be placed on the structure in a manner that might cause distortion or damage to the members or the supporting structures. Repair or replace damaged materials or structures as directed.

3.08 ERECTION

A. The Contractor shall comply with the AISC Specifications and Code of Standard Practice, and with specified requirements.

NTS: Bearing type connections are less costly than friction type connections and should be noted on the drawings wherever they are appropriate. Bearing type connections shall not be used for lateral force resisting frames and elements.

B. High-strength bolts shall be installed in accordance with the AISC Specification for Structural Joints using ASTM A325 Bolts. The connections shall be the friction type, unless noted otherwise.

C. Anchor bolts and other connectors required for securing structural steel to in-place work and templates and other devices for presetting bolts and other anchors to accurate locations shall be furnished by the Contractor.

D. The Contractor shall be responsible for designing and installing any temporary bracing required for the safe erection of all structural steel members.

3.09 SETTING BASES AND BEARING PLATES

A. Prior to the placement of non-shrink grout beneath base and bearing plates, the bottom surface of the plates shall be cleaned of all bond-reducing materials, and concrete and masonry bearing surface shall also be cleaned of all bond-reducing materials and roughened to improve bonding.

B. Loose and attached baseplates, and bearing plates for structural members shall be set on wedges, leveling nuts, or other adjustable devices.

C. Anchor bolts shall be tightened after the supported members have been positioned and plumbed and the non-shrink grout has attained its indicated strength.

D. Baseplates shall be grouted with non-shrink grout to assure full uniform bearing. Grouting shall be done prior to placing loads on the structure.

3.10 FIELD ASSEMBLY

A. Structural frames shall be set accurately to the lines and elevations indicated. The various members shall be aligned and adjusted to form a part of a complete frame or structure before permanently fastening. Bearing surfaces and other surfaces which will be in permanent contact shall be cleaned before assembly. Necessary adjustments to compensate for discrepancies in elevations and alignments shall be performed.

B. Individual members of the structure shall be leveled and plumbed within AISC tolerances.

C. Required leveling and plumbing measurements shall be established on the mean operating temperature of the structure.

3.11 MISFITS AT BOLTED CONNECTIONS

A. Where misfits in erection bolting are encountered, the Engineer shall be immediately notified. The Contractor shall submit a method to remedy the misfit for review by the Engineer. The Engineer will determine whether the remedy is acceptable or if the member must be refabricated.

B. Incorrectly sized or misaligned holes in members shall not be enlarged by burning or by the use of drift pins.

C. The Contractor shall pay for all costs associated with repairing misfits at no increased cost to the Owner.

3.12 GAS CUTTING

A. Gas cutting torches shall not be used in the field for correcting fabrication errors in the structural framing, except when approved by the Engineer. Gas-cut sections shall be finished equal to a sheared appearance.

3.13 TOUCH-UP PAINTING

A. Immediately after erection, field welds, bolted connections, and abraded areas shall be cleaned of the shop paint primer. Touch-up paint primer shall be applied by brush or spray which is the same thickness and material as that used for the shop paint. Galvanized surfaces which have been field welded or damaged shall be repaired in accordance with Section 05500 - Miscellaneous Metalwork.

[END OF SECTION]

SECTION 05500
MISCELLANEOUS METALWORK

PART 1: GENERAL

1.01 THE REQUIREMENT

A. The Contractor shall provide miscellaneous metalwork and appurtenances, complete, in accordance with the General Specifications, the CQA Plan, and the Construction Drawings.

1.02 REFERENCE SPECIFICATIONS, CODES, AND STANDARDS

A. **Federal Specifications:**

MIL-G-18015 A (3) (Ships) Aluminum Planks. (6063-T6)
MIL-A-907E Antiseize Thread Compound, High Temperature

B. **Commercial Standards:**

AA-M32C22A41	Aluminum Assn.
AASHTO HS-20	Truck Loading
AISC	Specifications and Commentary
AISI	Design of Light Gauge, Cold-Formed Steel Structural Members
ASTM A 36	Structural Steel
ASTM A 48	Gray Iron Castings
ASTM A 53	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
ASTM A 123	Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A 125	Steel Springs, Helical, Heat Treated
ASTM A 153	Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A 193	Alloy Steel and Stainless Steel Bolting Materials for High Temperature Service
ASTM A 194	Carbon and Alloy Steel Nuts for Bolts for High Pressure and High Temperature Services
ASTM A 307	Carbon Steel Bolts and Studs, 60,000 psi Tensile
ASTM A 500	Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
ASTM A 563	Carbon and Alloy Steel Nuts
ASTM A 575	Steel Bars, Carbon, Merchant Quality, M-Grades
ASTM A 786	Rolled Steel Floor Plates
ASTM B 98	Copper-Silicon Alloy Rod, Bar, and Shapes
ASTM B 438	Sintered Bronze Bearings (Oil-Impregnated)
ANSI/AWS D1.1	Structural Welding Code - Steel
ANSI/AWS D1.2	Structural Welding Code - Aluminum

ANSI/AWS QC1	Qualification and Certification of Welding Inspectors
NFPA 101	Life Safety Code
NAAMM	Metal Stairs Manual

1.03 CONTRACTOR SUBMITTALS

A. **Shop Drawings:** Shop drawings of all miscellaneous metalwork shall be submitted to the Engineer for review.

B. Layout drawings for grating shall be submitted showing the direction of span, type and depth of grating, size and shape of grating panels, seat angle details, and details of grating hold down fasteners. Load and deflection tables shall be submitted for each style and depth of grating used.

C. An ICBO report listing the ultimate load capacity in tension and shear for each size and type of concrete anchor used shall be submitted to the Engineer for review. Contractor shall submit manufacturer's recommended installation instructions and procedures for all adhesive anchors for Engineer's review. Upon review, by Engineer, these instructions shall be followed specifically.

D. No substitution for the indicated adhesive anchors will be considered unless accompanied with ICBO report verifying strength and material equivalency, including temperature at which load capacity is reduced to 90 percent of that determined at 75 degrees F.

1.04 QUALITY ASSURANCE

A. All weld procedures and welder qualification shall be available in the Contractors field office for Engineers review.

B. All welding shall be inspected by a Contractor-provided inspector qualified in accordance with AWS requirements and approved by the Engineer.

PART 2: PRODUCTS

2.01 GENERAL REQUIREMENTS

A. **Steel:**

1.	Shapes, Plates, Bars	ASTM A 36
2.	Pipe, Pipe Columns, Bollards	ASTM A 53, Type E or S, Grade B Standard weight unless noted otherwise
3.	Tubes	ASTM A 500 Grade B

B. **Corrosion Protection:** Unless otherwise indicated, miscellaneous metalwork of fabricated steel, which will be used in a corrosive environment and/or will be

submerged in water/wastewater shall be coated in accordance with Section 09800 -Protective Coating and shall not be galvanized prior to coating. All other miscellaneous steel metalwork shall be hot-dip galvanized after fabrication as specified herein.

C. **Stainless Steel:** Unless otherwise indicated, stainless steel metalwork and bolts shall be of Type 316 stainless steel and shall not be galvanized.

D. **Aluminum:** Unless otherwise indicated, aluminum metalwork shall be of Alloy 6061-T6. Aluminum in contact with concrete, masonry, wood, porous materials, or dissimilar metals shall have contact surfaces coated in accordance with the Section 09800 - Protective Coating.

E. **Cast Iron:** Unless otherwise indicated, iron castings shall conform to the requirements of ASTM A 48, Class 50B or better.

F. **Chemical protection:** Chemical protection agent shall be a coal tar epoxy, Coal Cat 97-640/641, as manufactured by Pittsburgh Parts. Coal tar epoxy shall be used as shown on the construction Drawings. Material shall be applied as directed by the manufacturer specification.

2.02 LADDERS

A. Ladders which may be partially or wholly submerged, or which are located inside a hydraulic structure, shall be entirely of Type 316 stainless steel. All other ladders shall be of [aluminum], [carbon steel, hot-dip galvanized after fabrication] or [as indicated].

B. Every ladder that does not have an exterior handhold shall be equipped with a pop-up extension. Pop-up extension device shall be manufactured of the same material and finish as the ladder with telescoping tubular section that locks automatically when fully extended. Upward and downward improvement shall be controlled by stainless steel spring balancing mechanisms. Units shall be completely assembled with fasteners for securing to the ladder rungs in accordance with the manufacturers instructions.

2.03 METAL GRATING

A. **General:** Metal grating shall be of the design, sizes and types indicated. All grating shall be completely banded at all edges and cutouts using material and cross section equivalent to the bearing bars. Such banding shall be welded to each cut bearing bar. Grating shall be supported on all sides of an opening by support members. Where grating is supported on concrete, embedded support angles matching grating material shall be used on all sides, unless shown otherwise. Such angles shall be mitered and welded at corners.

1. All pieces of grating shall be fastened in two locations to each support.

2. Where grating forms the landing at the top of a stairway, the edge of the grating, which forms the top riser, shall have an integral non-slip nosing, width equal to that of the stairway.

3. Where grating depth is not given, grating shall be provided which will be within allowable stress levels, and which shall not exceed a deflection of 1/4 inch or the span divided by 180, whichever is less. For heavy duty grating, the loading used for determining stresses and deflections shall be AASHTO HS-20, or a 5-ton fork lift, whichever is greater.

B. **Material:**

1. Except where indicated otherwise, bar grating shall be fabricated entirely of galvanized steel.

C. **Standard-Duty Grating:**

1. No single piece of grating shall weigh more than 80 pounds, unless indicated otherwise. Standard duty grating shall be serrated bar grating.

2. Cross bars shall be welded or mechanically locked tightly into position so that there is no movement allowed between bearing and cross bars.

D. **Safety Grating:**

1. Safety grating shall be made of sheet metal punched into an open serrated diamond pattern and formed into plank sections. The open diamond shapes shall be approximately 1-7/8 inch by 11/16 inch in size. Safety grating shall be Grip Strut by Metal Products Division, United States Gypsum Company; Deck Span by IKG Industries, or equal.

E. **Heavy-Duty Grating:** Heavy-duty grating shall be of welded steel, galvanized after fabrication. Cross bars shall be welded in position.

2.04 CHECKERED PLATE

A. Checkered plate shall be not less than 1/4-inch thick, and shall have a pattern of raised lugs on one face and shall be smooth on the opposite face. Lugs shall be a minimum of one inch in length and raised a minimum of 0.050 inch above the surface. The lugs shall be located in a pattern in which the lugs are oriented at 90 degrees from the adjacent lugs in two orthogonal directions. The rows of lugs shall be oriented at 45 degrees from the edges of the plates.

B. Where no plate material is indicated on the drawings, aluminum shall be provided. Unless noted otherwise on the drawings, the minimum plate thickness shall be as required to limit deflection, resulting from a live load of 100 psf, to 1/4-inch or the span divided by 240, whichever is less.

2.05 BOLTS AND ANCHORS

A. **Standard Service (Non-Corrosive Application):** Unless otherwise indicated, bolts, anchor bolts, washers, and nuts shall be steel, galvanized after fabrication as indicated herein. Threads on galvanized bolts and nuts shall be formed with suitable taps and dies such that they retain their normal clearance after hot-dip galvanizing. Except as otherwise indicated, steel for bolts, anchor bolts and cap screws shall be in accordance with the requirements of ASTM A 193 Grade B-7.

NTS: In the list of corrosive service locations below, project-specific trouble areas are not covered, such as (1) all outdoor locations, (2) all locations subject to continuous or intermittent wetting or spraying other than weather. If stainless steel nuts, bolts, and washes are to be provided there, call these areas out on the Drawings.

B. **Corrosive Service:** All bolts, nuts, and washers in the locations listed below shall be stainless steel as indicated below.

1. All buried locations.
2. All submerged locations.
3. All locations subject to seasonal or occasional flooding.
4. Inside hydraulic structures below the top of the structure.
5. Inside buried vaults, manholes, and structures which do not drain through a gravity sewer or to a sump with a pump.
6. All chemical handling areas.
7. Inside trenches, containment walls, and curbed areas.
8. Locations indicated by the Contract Documents or designated by the Engineer to be provided with stainless steel bolts.

NTS: *In cases where the galling characteristics of stainless steel bolts and nuts would present a serious problem, use the subparagraph C in this NTS instead of the subparagraph C below the NTS. It should be recognized, however, that the bronze nuts are more expensive and more difficult to obtain in some areas.):*

C. Stainless steel bolts, nuts, anchor bolts, and washers shall be of Type 316 stainless steel, with bronze nuts, or cap screws (where screwed into stainless steel), of copper-silicon alloy, conforming to ASTM B 98, alloy C 65100, designation H04, or alloy C 65500, designation H04. Wherever stainless steel bolts and nuts are indicated, it shall refer to the above material combination, unless specifically excluded.

C. Unless otherwise indicated, stainless steel bolts, anchor bolts, nuts, and washers shall be Type 316 stainless steel, class 2, conforming to ASTM A 193 for bolts and

to ASTM A 194 for nuts. All threads on stainless steel bolts shall be protected with an antiseize lubricant suitable for submerged stainless steel bolts, to meet government specification MIL-A-907E. Buried bolts in poorly drained soil shall be coated the same as the buried pipe.

1. Antiseize lubricant shall be classified as acceptable for potable water use by the NSF.

2. Antiseize lubricant shall be "PURE WHITE" by Anti-Seize Technology, Franklin Park, IL, 60131, AS-470 by Dixon Ticonderoga Company, Lakehurst, NJ, 08733, or equal.

D. **Bolt Requirements:**

1. The bolt and nut material shall be free-cutting steel.

2. The nuts shall be capable of developing the full strength of the bolts. Threads shall be Coarse Thread Series conforming to the requirements of the American Standard for Screw Threads. All bolts and cap screws shall have hexagon heads and nuts shall be Heavy Hexagon Series.

3. All bolts and nuts shall be installed with washers fabricated of material matching the base material of bolts, except that hardened washers for high strength bolts shall conform to the requirements of the AISC Specification. Lock washers shall be installed with washers where indicated and shall be fabricated of material matching the bolts.

4. The length of all bolts shall be such that after joints are made up, each bolt shall extend through the entire nut, but in no case more than 1/2-inch beyond the nut.

E. **Adhesive Anchors:** Unless otherwise indicated, all drilled, concrete or masonry anchors shall be adhesive anchors. No substitutions will be considered unless accompanied with ICBO report verifying strength and material equivalency.

1. Epoxy adhesive anchors are required for drilled anchors where exposed to weather, in submerged, wet, splash, overhead, and corrosive conditions, and for anchoring handrails, pumps, mechanical equipment, and reinforcing bars. Epoxy anchor grout shall comply with Section 03315 - Grout. Threaded rod shall be stainless steel Type 316.

2. Unless otherwise indicated, glass capsule, polyester resin adhesive anchors will be permitted in locations not indicated above and shall be Hilti HVA or Molly Parabond. Threaded rod shall be galvanized steel.

F. **Expanding-Type Anchors**: Expanding-type anchors if indicated or permitted, shall be steel expansion type ITW Ramset/Redhead "Trubolt" anchors; McCullock Industries "Kwick-Bolt;" or equal. Lead caulking anchors will not be

permitted. Size shall be as indicated. Expansion type anchors which are to be embedded in grout may be steel. Non-embedded buried or submerged anchors shall be stainless steel.

2.06 POWDER-DRIVEN PINS

A. **Materials:** Powder-driven pins for installation in concrete or steel shall be heat-treated steel alloy. If the pins are not inherently sufficiently corrosion-resistant for the conditions to which they are to be exposed, they shall be protected in an acceptable manner. Pins shall have capped or threaded heads capable of transmitting the loads the shanks are required to support. Pins that are connected to steel shall have longitudinal serrations around the circumference of the shank.

2.07 IMPACT ANCHOR

A. Impact anchors shall be an expansion type anchor in which a nail type pin is driven to produce the expansive force. It shall have a zinc sleeve with a mushroom style head and stainless steel nail pin. Anchors shall be Metal Hit Anchors, manufactured by Hilti, Inc., Rawl Zamac Nailin, manufactured by the Rawlplug Company; or equal.

PART 3: EXECUTION

3.01 FABRICATION AND INSTALLATION REQUIREMENTS

A. **Fabrication and Erection:** Except as otherwise indicated, the fabrication and erection of structural steel shall conform to the requirements of the American Institute of Steel Construction "Manual of Steel Construction."

B. **Power-Driven Pins:** Power-driven pins shall be installed by a craftsman who is certified by the manufacturer as being qualified to install the manufacturer's pins. Pins shall be driven in one initial movement by an instantaneous force that has been carefully selected to attain the required penetration. Driven pins shall conform to the following requirements where "D" = Pin's shank diameter:

Material Penetrated by Pin	Material's Minimum thickness	Pin's Shank Penetration in Supporting Material	Minimum Space from Pin's CL to Edge of Penetrated Material	Minimum Pin Spacing
Concrete	16D	6D minimum	14D	20D
Steel	¼-inch	steel thickness	4D	7D

3.02 WELDING

A. **Method:** All welding shall be by the metal-arc method or gas-shielded arc method as described in the American Welding Society's "Welding Handbook" as supplemented by other pertinent standards of the AWS. Qualification of welders shall be in accordance with the AWS Standards governing same.

B. **Quality:** In assembly and during welding, the component parts shall be adequately clamped, supported and restrained to minimize distortion and for control of dimensions. Weld reinforcement shall be as indicated by the AWS Code. Upon completion of welding, all weld splatter, flux, slag, and burrs left by attachments shall be removed. Welds shall be repaired to produce a workmanlike appearance, with uniform weld contours and dimensions. All sharp corners of material which is to be painted or coated shall be ground to a minimum of 1/32-inch on the flat.

3.03 GALVANIZING

C. All structural steel plates shapes, bars and fabricated assemblies required to be galvanized shall, after the steel has been thoroughly cleaned of rust and scale, be galvanized in accordance with the requirements of ASTM A 123. Any galvanized part that becomes warped during the galvanizing operation shall be straightened. Bolts, anchor bolts, nuts and similar threaded fasteners, after being properly cleaned, shall be galvanized in accordance with the requirements of ASTM A 153. Field repairs to galvanizing shall be made using "Galvinox," "Galvo-Weld," or equal.

3.04 DRILLED ANCHORS

A. Drilled anchors and reinforcing bars shall be installed in strict accordance with the manufacturer's instructions. Holes shall be roughened with a brush on a power drill, cleaned and dry. Drilled anchors shall not be installed until the concrete has reached the specified 28-day compressive strength. Adhesive anchors shall not be loaded until the adhesive has reached its indicated strength in accordance with the manufacturer's instructions.

[END OF SECTION]

SECTION 07920
SEALANTS AND CAULKING

NTS: This Section has "M" status: it has been through the process of technical discipline review, manufacturer review, and construction experience feedback. Upgrading was completed in November, 1995. Bill Brumm has been a major contributor toward technical upgrading of this Section and is aware of the details of its contents. Bill Brumm may be a resource to answer questions.

The Section cross references the following sections:

Use professional care in customizing this master Section for use in project specifications. Not only are there square brackets to address, the Specifier must also consider whether the rest of the text is appropriate for the unique needs of the project, making additions and deletions if necessary to make it so.

Section 07920 specifies joint sealants and caulking, joint fillers, compressible seals and other joint sealers for a variety of applications. Moisture barrier film is also included.

PART 1: GENERAL

1.01 THE REQUIREMENT

A. The CONTRACTOR shall provide caulking, sealing, and appurtenant work, complete and in place, in accordance with the Contract Documents.

1.02 REFERENCE STANDARDS

A. General: Portions of the following standards are incorporated into this Section by references below. The standards are listed here for convenience.

B. Federal Specifications:

TT-S-001543A	Sealing Compound, Silicone Rubber Base, (For Caulking, Sealing and Glazing in Buildings and Other Structures)
SS-S-200D	Sealants, Joint, Two Compound, Jet Blast Resistant, Cold Applied for Portland Cement Concrete Pavement.
TT-S-00227E	Sealing Compound, Elastomeric Type, Multi-Component, (For Caulking, Sealing and Glazing in Buildings and Other Structures).

TT-S-00230C	Sealing Compound, Elastomeric Type, Single Component, (For Caulking, Sealing, and Glazing in Buildings and Other Structures)

C. Commercial Standards:

ASTM C 557	Adhesives for Fastening Cypsum Wallboard to Wood Framing.
ASTM C 834	Latex Sealing Compounds.
ASTM C 919	Practice for Use of Sealants in Acoustical Applications.
ASTM C 920	Elastomeric Joint Sealants.
ASTM C 1056	Flexible Cellular Material-Sponge or Expanded Rubber.
ASTM D 1752	Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction.
ASTM E 84	Surface Burning Characteristics of Building Materials.
ASTM E 814	Methods for Fire Tests of Through Penetrations: Firestops.
UL 1479	Underwriter's Laboratory Standard for Safety Fire Tests of Through Penetrations Firestops.

1.03 CONTRACTOR SUBMITTALS

D. General: Submittals shall be in accordance with Section 01300 - Contractor Submittals.

E. Technical Data: A complete materials list along with the manufacturer's technical data and literature, specifications, joint width and depth tables, and installation instructions.

F. Samples: Samples (including color samples) of all the caulking and sealant materials and other materials proposed for use on the WORK. The samples shall be clearly marked with the manufacturer's name and product identification.

G. Certificates: If requested by the ENGINEER, certificates from an independent testing laboratory approved by the ENGINEER, certifying that the submitted materials meet all the requirements of the ASTM and Federal Specifications cited.

H. Warranty: A copy of the manufacturer's warranty covering all sealants, caulking materials, and other materials against defects in materials.

PART 2: PRODUCTS

2.01 SEALANTS AND CAULKING MATERIALS

A. General:

1. Manufacturer's Standards: In addition to the standards listed below, the sealants and caulking products and application shall be in accordance with the manufacturer's published recommendations and specifications.

2. Wherever manufacturer's names and products are listed in this Section, "or equal" products will be considered in accordance with Section 01300 - Contractor Submittals.

B. Materials shall conform to the following requirements:

1. Significant Movement Sealants (plus or minus 25% movement capability)

a. For expansion wall joints; masonry and metal curtainwall joints; precast concrete joints and concrete panels; perimeter sealing (windows, doors, and panels); control joints; interior and non-traffic horizontal joints.

(1) Two component, non-sag, polyurethane or polysulfide sealant conforming to Federal Specification TT-S-227E, Class A, Type II, and ASTM C 920, Type M, Class 25, Grade NS.

Products Research & Chemical Corp. "RC-2"
Progress Unlimited "Iso-Flex 2000"

(2) One component, non-sag, low modulus, polyurethane or polysulfide sealant conforming to Federal Specification TT-S230C, Class A, Type II, and ASTM C 920, Type S, Class 25, Grade NS.

Products Research & Chemical Corp. "RC-1"
Tremco "Dymonic"

(3) One component, non-sag, medium modulus, neutral cure, silicone sealant conforming to Federal Specification TT-S-1543A, Class A, and ASTM C 920, Type S, Class 25, Grade NS.

Products Research & Chemical Corp. "PRC-4000"
Dow Corning "795"

[b. For horizontal joints exposed to fuel spillage.

(4) Two component, self-leveling, fuel resistant, polyurethane or polysulfide sealant conforming to Federal Specification SS-S-200D, Type H, and ASTM C 920, Type M, Class 25, Grade P.

Products Research & Chemical Corp. "3105-S"
Pacific Polymere Inc. "ElastoThane 200"

c. For horizontal joints not exposed to fuel spillage.

(5) Two component, self-leveling, polyurethane or polysulfide sealant conforming to Federal Specification TT-S-227E, Class A, Type I, and ASTM C 920, Type M, Class 25, Grade P.

Products Research & Chemical Corp. "RC-2SL"
Bostic "Chem-Calk 550"

(6) One component, self-leveling, polyurethane or polysulfide sealant conforming to Federal Specification TT-S-230C, Class A, Type I, and ASTM C 920, Type S, Class 25, Grade P.

Products Research & Chemical Corp. "6006"
Mameco "Vulkem 45"]

2. Glazing Sealants

a. For non-structural applications

(1) One component non-sag, medium modulus, neutral cure, silicone sealant conforming to Federal Specification TT-S-1543A, Class A, and ASTM C 920, Type S, Class 25, Grade NS.

Products Research & Chemical Corp. "4000"
Dow Corning "795"

(2) One component, non-sag, high modulus, acetoxy cure, silicone sealant conforming to Federal Specification TT-S-1543A, Class A, and ASTM C 920, Type S, Class 25, Grade NS.

3. Interior Sealant and Caulking

a. For general applications

(1) One component, acrylic latex caulking conforming to ASTM C 834

Pecora Corp. "AC-20"
Bostic "Chem-Calk 600"

b. For non-exposed acoustical applications

(1) One component, non-drying, non-hardening, non-shrinking, acoustical caulking conforming to ASTM C 557 and ASTM C 919.

Inmont Company "Prestite 579.64"
Tremco, "Acoustical Sealant"
United States Gypsum, "Acoustical Sealant"
W.W. Henry, "Type 313, Acoustical Sealant"

4. Acoustic Sheet Caulking: For use on all outlet boxes including intercoms, telephone or other services that require penetrations in the walls, acoustic sheet caulking shall be resilient synthetic polymer, self-adhesive, 1/8-inch thick, 6-inch x 8-inch, sheet acoustic sealer. Pads shall be Lowry's Electrical Box Pads as manufactured by Harry A. Lowry & Associates, Inc., 11176 Penrose Street, Sun Valley, CA 91352, (818) 768-4661, (213) 875-0225; or equal.

5. Firestop Sealant: Where piping, conduit, wire, or other materials pass through fire rated walls, floors, ceilings or roofs, provide a [1] [3]-hour fire rated sealant in accordance with ASTM E 814 and UL 1479. Fire-resistant penetration sealant shall be a medium density fire-resistant foam that retains form and stability at high temperature. Fire-resistant sealant shall be Dow-Corning Corporation "3-6548 Silicone RTV" foam; 3M Corporation "Fire Barrier Caulk CP25N, No-sag "or "CP25 S/L, Self-Leveling", as appropriate for the use intended. Equivalent products of General Electric and Metalines, Inc. will also be considered.

6. Preformed Sealants: Preformed sealant shall be polybutylene or isoprene-butylene based pressure sensitive weather resistant tape or bead sealant capable of sealing out moisture, air, and dust when installed as recommended by the manufacturer. At temperatures from minus 30 to plus 160 degrees F, the sealant shall be non-bleeding and shall have no loss of adhesion.

7. Tape sealant: Dimensions shall be as required for application conditions. Tape sealants shall be type recommended by tape manufacturer for connecting and bonding to surfaces.

8. Filler material shall be resilient, closed-cell polyethylene foam conforming to ASTM D 1752, Type II or III, and/or bond breakers of proper size for joint widths. Filler shall be compatible with sealant manufacturer's product and shall not stain the sealant nor the materials to which applied.

9. Primer: Primers shall be as recommended in the manufacturer's printed instructions for caulking and sealants, and shall not stain the sealant nor the materials to which applied. Manufacturer shall be consulted for all surfaces not specifically covered in submittal application instructions. Primer shall be used in accordance with manufacturer's instructions with all primers being applied prior to the installation of any backer rod or bond breaker tape.

10. Cleaning and cleanup solvents, agents, and accessory materials shall be as recommended in the manufacturer's printed instructions for cleaning up.

2.02 COLOR OF SEALANTS

A. Color of sealants that are visible after installation shall match adjacent building finish. If in doubt of color match, obtain color approval from ENGINEER.

2.03 SUB-SLAB MEMBRANE

A. Sub-slab membrane shall be 6-mil, odorless, nontoxic, polyethylene film without holes, complying with FHA requirements for below-slab moisture barrier, and shall be Sisalkraft "Moisture-stop"; Dampproof "XX"; or equal.

PART 3: EXECUTION

3.01 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Delivery of Materials: Manufactured materials shall be delivered in original, unbroken packages or containers bearing the manufacturer's label. Packages or containers shall be delivered to the site with seals unbroken.

B. Shelf Life: Materials whose shelf life dates have expired shall not be used in the WORK. Such materials shall be promptly removed from the project site.

C. Storage: All materials shall be carefully stored in accordance with the manufacturer's instructions, in an area that is protected from deleterious elements, and in a manner that will prevent damage to the product. Materials shall be stored at temperatures between 40 and 90 degrees unless otherwise specified by the manufacturer.

3.02 INSTALLATION

A. Manufacturer's Recommendations: All work under this Section and all testing, where applicable, shall be performed in accordance with manufacturer's printed recommendations, specifications, and installation instructions except where more stringent requirements are indicated herein; and, except where project conditions require extra precautions or provisions to assure performance of the waterproofing system.

B. Authorized Installers: Caulking and sealants shall be complete systems and be installed only by installers authorized and approved by the respective manufacturers.

C. Surface Preparation

1. General: The surfaces of joints to be sealed shall be dry. Oil, grease, dirt, chalk, particles of mortar, dust, loose rust, loose mill scale, and other foreign substances shall be removed from surfaces of joints which will be in contact with the sealant. Ferrous metal surfaces shall be cleaned of all rust, mill scale, and other coatings by wire brush, grinding, or sandblasting. Oil and grease shall be removed by cleaning in accordance with sealant manufacturer's printed recommendations. Protective coatings shall be removed from all aluminum surfaces against which caulking or sealing compound is to be placed. Bituminous or resinous materials shall be removed from surfaces to receive caulking or sealants.

2. Concrete and Masonry Surfaces: Where surfaces have been treated with curing compounds, oil, or other such materials, the materials shall be removed by sandblasting or wire brushing. Laitance, efflorescence, and loose mortar shall be removed from the joint cavity.

3. Steel Surfaces: Steel surfaces to be in contact with sealant shall be sandblasted or, if sandblasting would not be practical or would damage adjacent finish work, the metal shall be scraped and wire brushed to remove loose mill scale. Protective coatings on steel surfaces shall be removed by sandblasting or by a solvent that leaves no residue.

4. Aluminum Surfaces: Aluminum surfaces to be in contact with sealants shall be cleaned of temporary protective coatings. When masking tape is used for a protective cover, the tape and any residual adhesive shall be removed just prior to applying the sealant. Solvents used to remove protective coating shall be as recommended by the manufacturer of the aluminum work and shall be non-staining.

5. Wood Surfaces: Wood surfaces to be in contact with sealants shall be free of splinters and sawdust or other loose particles.

D. Joint Types and Sizes: Joint shapes and sizes shall be as indicated or as necessary for job conditions where not indicated. Joints to be caulked or sealed include through-bolt holes, door frames, louver and ventilator frames, joints between openings where items pass through exterior walls, concrete masonry, or combination of these surfaces, and as otherwise indicated or required for watertightness, weatherproofing, or airtightness. Use sealing compound at both exterior and interior surfaces of exterior wall penetrations.

3.03 SEALANT FILLED JOINTS

A. Manufacturer's Representative: The CONTRACTOR shall furnish the on-site services of the sealant manufacturer's representative prior to sealant work for inspection of the joints to be sealed and for instructing the installer in the proper use of the materials[.] [if requested by the ENGINEER.]

B. Sealant: Sealant shall be used before expiration of shelf life. Multi-component sealants shall be mixed according to manufacturer's printed instructions. Sealant in guns shall be applied with a nozzle of proper size to fit the width of joint. Sealant shall be installed to the required depth without displacing the backing. Unless otherwise indicated or recommended by the manufacturer, the installed sealant shall be tooled so that the surface is uniformly smooth and free of wrinkles and to assure full adhesion to the sides of the joint. Sealants shall be installed free of air pockets, foreign embedded matter, ridges, and sags. Sealer shall be applied over the sealant if recommended by the sealant manufacturer.

C. Sealant Depth: Sealant depth in joints shall be 1/2 the width of joint, but not less than 1/8-inch deep and 1/4-inch wide nor more than 1/2-inch deep and 1-inch wide. All joints shall have a rigid filler material installed to proper depth prior to application of sealant.

D. Masking Tape: Masking tape shall be placed on the finish surface on one or both sides of a joint cavity to protect adjacent finish surfaces from primer or sealant smears. Masking tape shall be removed within 10 minutes after joint has been filled and tooled.

E. Backing: Backing shall be installed to provide the indicated sealant depth. The installation tool shall be shaped to avoid puncturing the backing.

F. Bond-Breaker: Bond-breaker shall be applied to fully cover the bottom of the joint without contaminating the sides where sealant adhesion is required.

G. Primer: Primer shall be used on concrete masonry units, wood, or other porous surfaces in accordance with instructions furnished with the sealant. Primer shall be applied to the joint surfaces to be sealed. Surfaces adjacent to joints shall not be primed.

H. Applications: A full bead of sealant shall be applied into the joint under sufficient pressure, with the nozzle drawn across sealant, to completely fill the void space and to ensure complete wetting of contact area to obtain uniform adhesion. During application, the tip of the nozzle shall be kept at the bottom of the joint thereby forcing the sealant to fill from the bottom to the top. Sealants shall be tooled immediately after exposure with a caulking tool or soft bristled brush moistened with solvent. The finished sealant-filled joint shall be slightly concave unless otherwise indicated.

I. Acoustic Partition Joints: Acoustic partition joints shall be made air and sound-tight with acoustic caulking material.

1. Partitions shall be sealed where indicated on the Drawings. Gypsum panels may have joint treatment applied in the normal manner over sealed joints, or panels may be finished with base or trim as required.

2. A 1/4-inch minimum round bead of sealant shall be applied around all cut-outs, such as at electrical boxes and air conditioning ducts, sufficient to seal the openings.

3.04 ACOUSTIC CAULKING

A. Preparation: Joints and surfaces to be sealed shall be clean, dry, and free of loose materials.

B. Concealed Joints: Concealed joints in acoustic partitions including perimeters and intersections of walls and penetrations through finish work and at conduit ends with boxes shall be sealed with acoustic caulking compound. Backs of electrical boxes shall be sealed with acoustic sheet caulking, covering all holes and knock-outs.

3.05 SUB-SLAB MEMBRANE

A. A sub-slab membrane shall be installed under floor slabs over which a finish flooring system will be installed and at other locations as indicated.

3.06 CLEANING

A. After application of sealant and caulking materials, adjacent materials which have been soiled shall be cleaned and left in a neat, clean, undamaged, or unstained condition. On porous surfaces, excess sealant shall be removed per sealant or caulking manufacturer's printed instructions.

[END OF SECTION]

SECTION 11210
LEACHATE PUMPS

PART 1: GENERAL

1.01 SUMMARY

A. Description of Work

1. This section includes supply and installation of leachate removal pumps for the Landfill. The following pumps are included:

   a. The submersible pump in the Primary Leachate Collection System. This will be the principal pump used to remove leachate from the landfill.

   b. The self-priming pump in the vertical riser of the Primary Leachate Collection System. This higher capacity pump will be used to remove storm water from the primary sump.

   c. The submersible pump in the Secondary Leachate Collection System. This pump will be used to remove leachate that leaks through the primary system into the secondary collection system.

   d. The submersible pump in the Vadose Sump. This pump will be used to remove leachate that leaks through the secondary lining system.

B. Related Sections

1. 15600 - Welded Steel Pipe

2. 15700 - Stainless Steel Pipe

1.02 SUBMITTALS

A. Submit detailed information on proposed pumps, motors, materials, connections, and electrical requirements.

B. If "or equal" product is proposed, submit technical data and specifications sufficient to allow evaluation by the ENGINEER.

1.03 QUALITY ASSURANCE

A. Prior to installing, test pumps and demonstrate their operation to the satisfaction of the CQA ENGINEER.

PART 2: PRODUCTS

2.01 GENERAL

A. Pumps shall be constructed such that all wetted parts are type 316 stainless steel, or other highly corrosion resistent materials.

B. Submersible pumps and their motors shall have bearings which permit the pump to be operated in continuous or intermittent service in the horizontal position.

C. The external portions of the case shall be free of sharp edges or burrs which might prevent the free sliding of the pump along the enclosing pipe.

D. Electrical characteristics of pump motors shall be compatible with power available at the site.

2.02 SUBMERSIBLE PUMPS

A. The submersible pump for the Primary Leachate Collection System shall be a Grundfos Model 40S30-9 or equal as approved by the ENGINEER.

B. The submersible pumps for the Secondary Leachate Collection System and Vadose Sump shall be Grundfos Model 25S15-9 or equal as approved by the ENGINEER.

2.03 SELF-PRIMING SUMP PUMP

A. The larger capacity sump pump to be installed in the vertical riser shall be a self-priming type, capable of drawing water 10 ft or more at sea level. The pump shall be a Gorman Rupp Model S4C18 or equal as approved by the ENGINEER.

PART 3: EXECUTION

3.01 PUMP INSTALLATION

A. The OWNER shall install all pumps and motors in accordance with manufacturers' instructions, at locations as shown on the Drawings.

B. Installation shall include all discharge piping and wiring.

C. Install pumps in side slope riser pipes prior to placing backfill over the pipes, in order to confirm pump installation location. When pump is in correct position as determined by visual inspection through holes in perforated pipe section, mark discharge tube or support cable as appropriate at top of riser pipe. Survey location (coordinates and elevation) of pump prior to trench backfilling.

[END OF SECTION]

PART 2: PRODUCTS

2.01 POLYETHYLENE TANK PROPERTIES

A. The polythylene tank shall be Model Number 10 VCT 09K manufactured by Central California Cntainer and conform to the following specifications or equal:

Item	*Primart Tank Description*	*Secondary Tank Description*
Diameter	10 feet	12 feet
Height	16 feet 1 inch	21 feet 3 inches
Material	Cross Linked Polyethylene Resin	Cross linked polyethylene resin
Type	Enclosed Top Containment Tank	Ethylene Resin
Primary Tank Volume	9,000 gallons	Enclosed top tank
Secondary Tank		15,500 gallons

2.03 MANUFACTURING QUALITY CONTROL

A. The Contractor shall submit to the Owner for approval within 14 days prior to the start of polyethylene tank work a complete list of materials to be furnished and the name of the polyethylene tank Manufacturer.

B. The Contractor shall submit to the Owner the polyethylene tank Manufacturer's certification of compliance with the product requirements of Part 2.

C. All Quality Control testing required by these General Specifications and/or conducted at the discretion of the Contractor shall be the responsibility of the Contractor.

2.04 TRANSPORTATION

A. Transportation of polyethylene tanks shall be the responsibility of the Contractor. The Contractor shall be liable for all damage to the polyethylene tanks incurred prior to and during transportation to the site.

2.05 HANDLING AND STORAGE

A. Handling, storage, and care of the steel pipe prior to and following installation at the site, is the responsibility of the Contractor. The Contractor shall be liable for all damage to the material incurred prior to final acceptance by the Owner.

B. The Contractor shall be responsible for storage of the polyethylene tanks at the site. Polyethylene tanks shall be stored on clean level ground, preferably turf or sand, free of sharp objects which could damage the polyethylene tanks.

PART 3: EXECUTION

3.01 HANDLING AND PLACEMENT

A. Polyethylene tanks shall be installed as indicated on the Construction Drawings.

B. The Contractor shall exercise care when transporting, handling and placing polyethylene tanks, such that they will not be damaged.

C. The Contractor shall comply with the polyethylene tanks Manufacturer's recommendations for handling, storage, and installation of all tanks.

D. Polyethylene tanks shall not be dropped onto rocky or unprepared ground.

F. The exterior of the polyethylene tanks shall be free of cuts, gouges and scratches. The CQA Engineer will inspect the polyethylene tanks in accordance with the CQA Plan. Polyethylene tanks with excessive cuts, gouges, or scratches will be rejected and the Contractor will be required to remove and replace the rejected polyethylene tanks, at no additional cost to the Owner.

3.02 INSTALLATION

A. All polyethylene tanks shall be installed in accordance with these General Specifications and the polyethylene tanks Manufacturer's instructions.

B. The Contractor shall carefully examine all polyethylene tanks for cracks, damage or defect before installation. Defective materials shall be removed from the site and replaced with non-defective material at no additional cost to the Owner.

C. All polyethylene tanks shall be placed to the grades and elevations shown on the Construction Drawings.

3.04 SURVEY CONTROL

A. The Surveyor shall survey the location and final elevation of all polyethylene tanks. Surveying shall be performed in accordance with Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing of the location all polyethylene tanks.

3.05 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all materials and all partially-complete and completed work of these General Specifications.

B. In the event of damage, the Contractor shall make all repairs and replacements necessary, to the approval of the Owner and at no additional cost to the Owner.

C. The CQA Engineer will issue an approval of polyethylene tank installation and inspection to the Owner following installation of the polyethylene tank in accordance with the CQA Plan.

[END OF SECTION]

2. The Contractor shall provide specimens for weld tests to the CQA Engineer for testing by an independent testing laboratory if the CQA Engineer suspects unsatisfactory welding.

3. Use of back-up welding strips or rings for welds is not permitted.

3.04 SURVEY CONTROL

A. The Surveyor shall survey the location and final elevation of all steel pipe. The pipe shall be surveyed at its ends. In addition, all joints, etc. shall be located horizontally and vertically and overall length measured. Surveying shall be performed in accordance with Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing of the location and final elevation of all steel pipe.

3.05 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all materials and all partially-complete and completed work of these General Specifications.

B. In the event of damage, the Contractor shall make all repairs and replacements necessary, to the approval of the Owner and at no additional cost to the Owner.

C. The CQA Engineer will issue an approval of pipe installation and inspection to the Owner prior to completely covering the pipe in accordance with the CQA Plan.

[END OF SECTION]

PART A AND PART B PERMIT APPLICATION

FOR THE

TRIASSIC PARK HAZARDOUS WASTE FACILITY

Volume V

Appendix D - Laboratory Test Results
Appendix E - Engineering Calculations

December 1997

Prepared By:

established 1959

and

TerraMatrix
MONTGOMERY WATSON
Natural Resources Group

1475 Pine Grove Road
P.O. Box 774018
Steamboat Springs, Colorado 80477

DEC 1997

LIST OF APPENDICES

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C	Lithology Logs
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H	Example Waste Profile Sheet
I	Example Inspection Sheet
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Volume III

Engineering Report

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Appendix B - Construction Quality Assurance Plan
Appendix C - Construction Specifications

Volume V - Engineering Report - Appendices

Appendix D - Laboratory Test Results
Appendix E - Engineering Calculations

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Appendix D

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

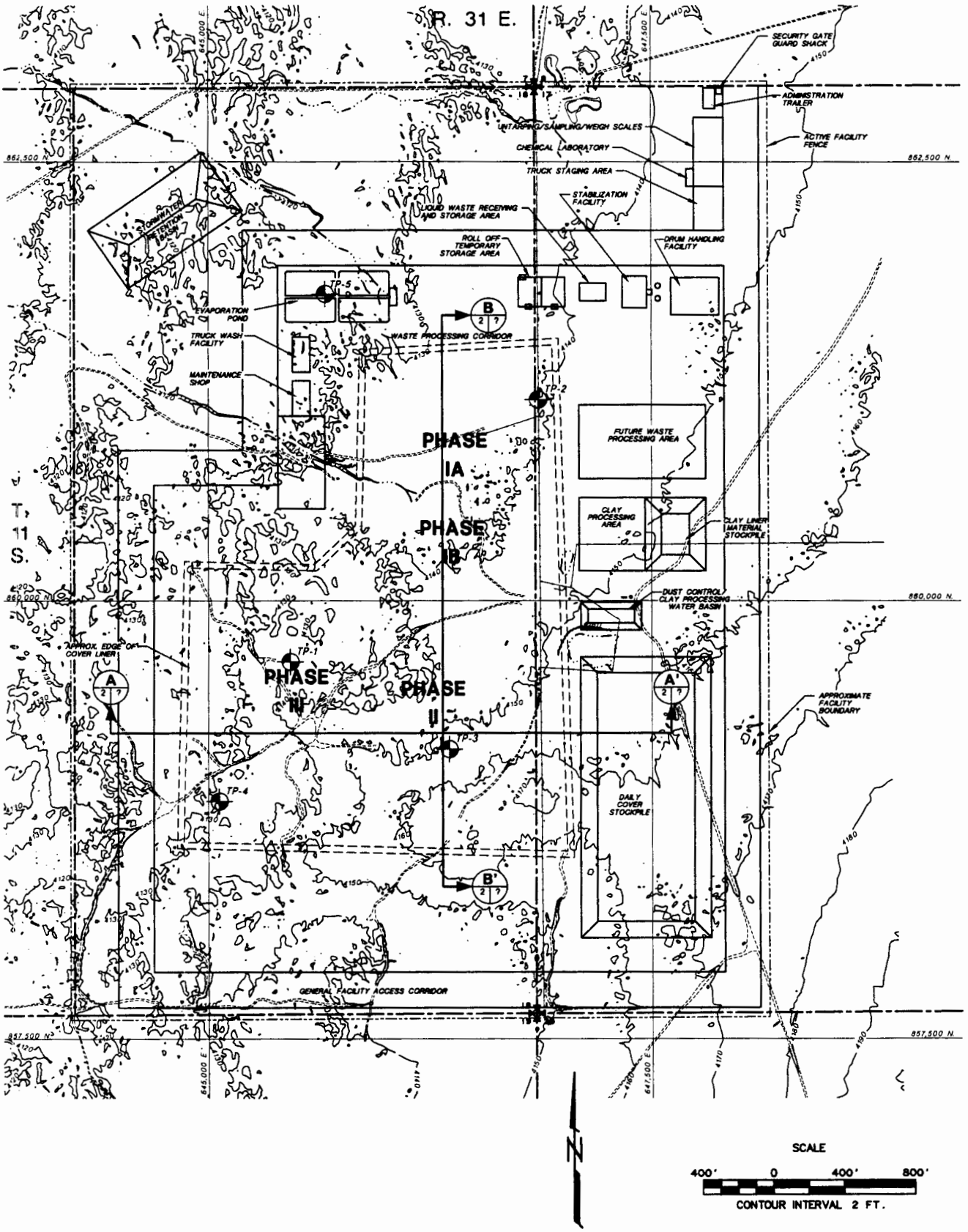
SUMMARY OF LABORATORY TEST RESULTS

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

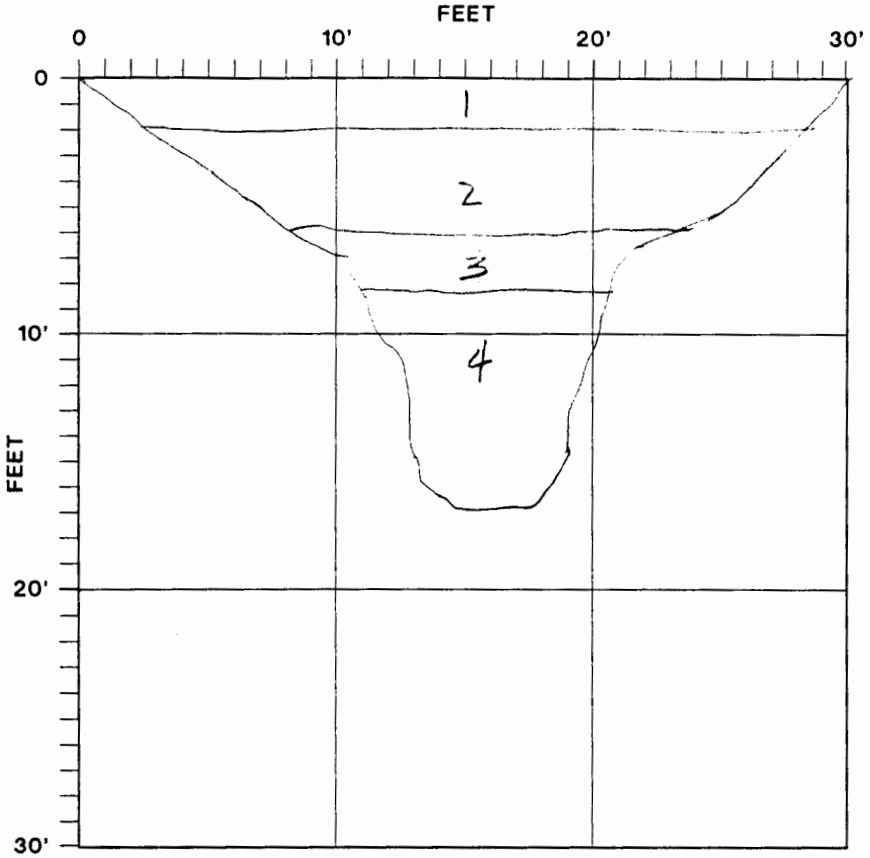
TerraMatrix
Engineering & Materials Testing Services
80560 Moffat Avenue
Steamboat Springs, Colorado 80487

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 lense
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

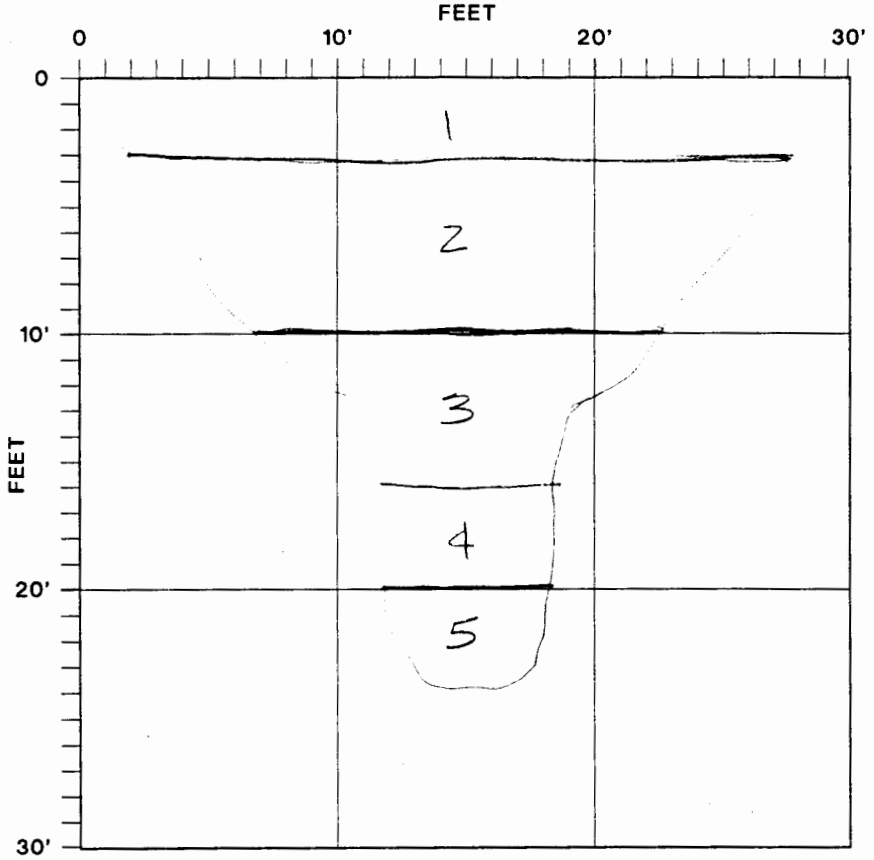
SPECIAL NOTES:

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		TEST PIT #1
	Figure No.		

GENERAL LOCATION: TP-2 DATE: 8/18/97

PIT TREND: 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 lenses, slightly moist
4	16'-20' Slightly stiff to stiff, brown, silty CLAY, moist
5	20'-24' Hard, brown, clayey, sandy, SILT, moist

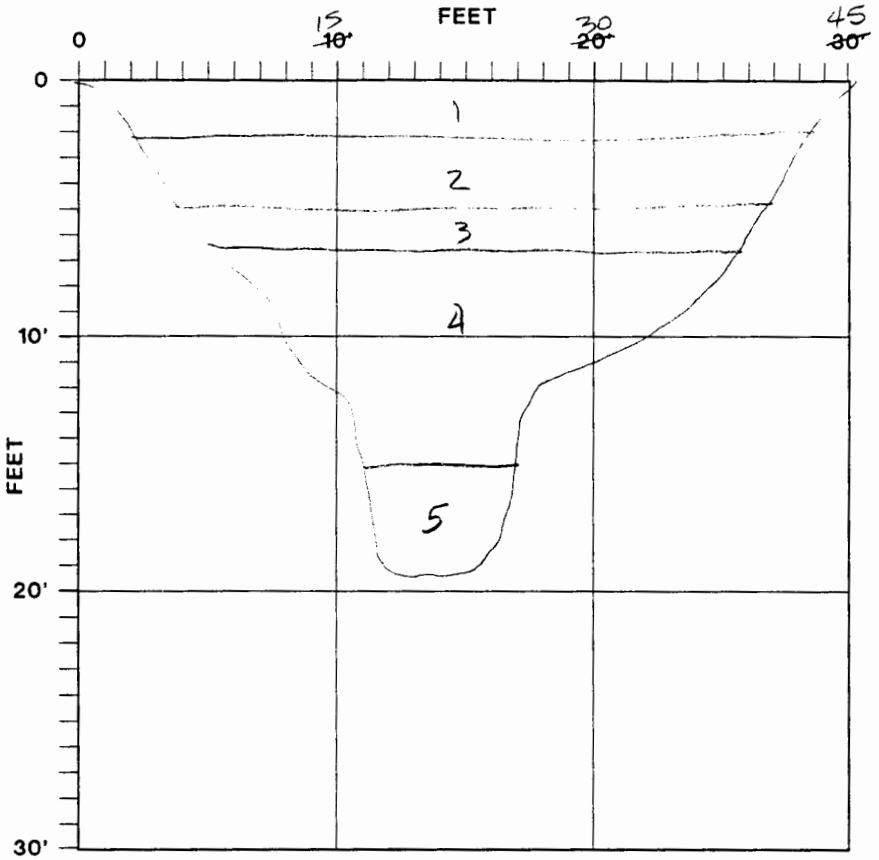
SPECIAL NOTES:

No water encountered

Project No: 602	Design By:	Scale:	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: 2	Figure No.	TEST PIT # 2

GENERAL LOCATION: TP-3 DATE: 8/18/97

PIT TREND: _____ 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'

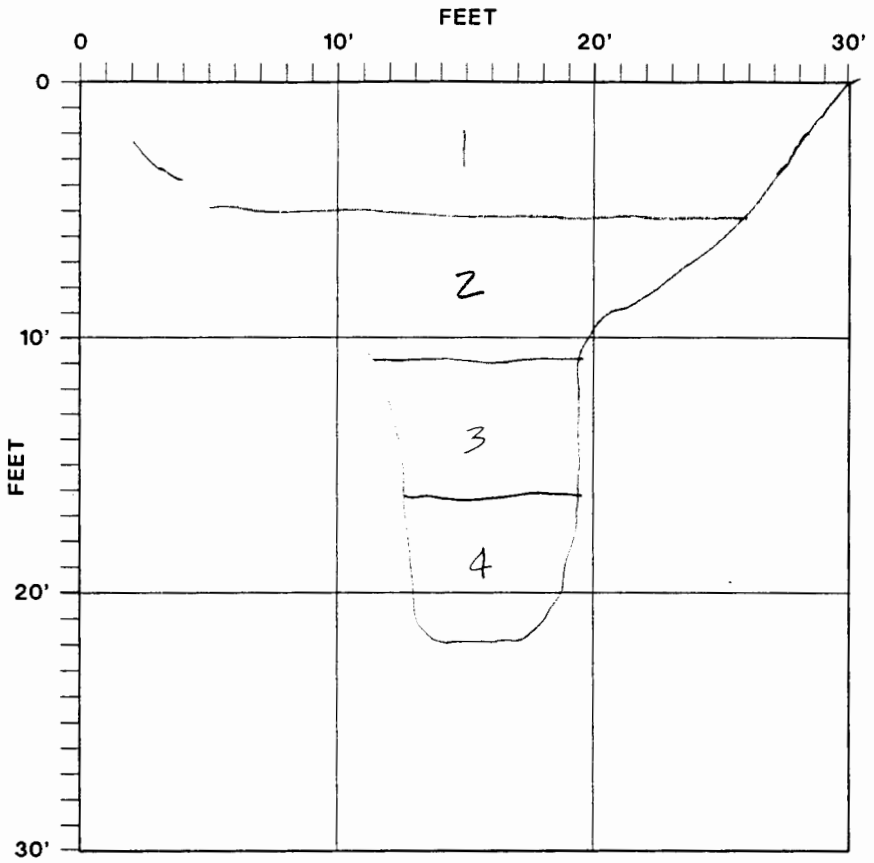
Project No: 602	Design By:	Scale:	Triassic Park Landfill
File:	Drawn By:	Date:	
TerraMatrix Engineering & Environmental Services, 1475 Pine Grove Road, P.O. Box 774018, Steamboat Springs, Colorado 80477	Test Pit No: 3	Figure No.	TEST PIT # 3

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 [illegible], 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

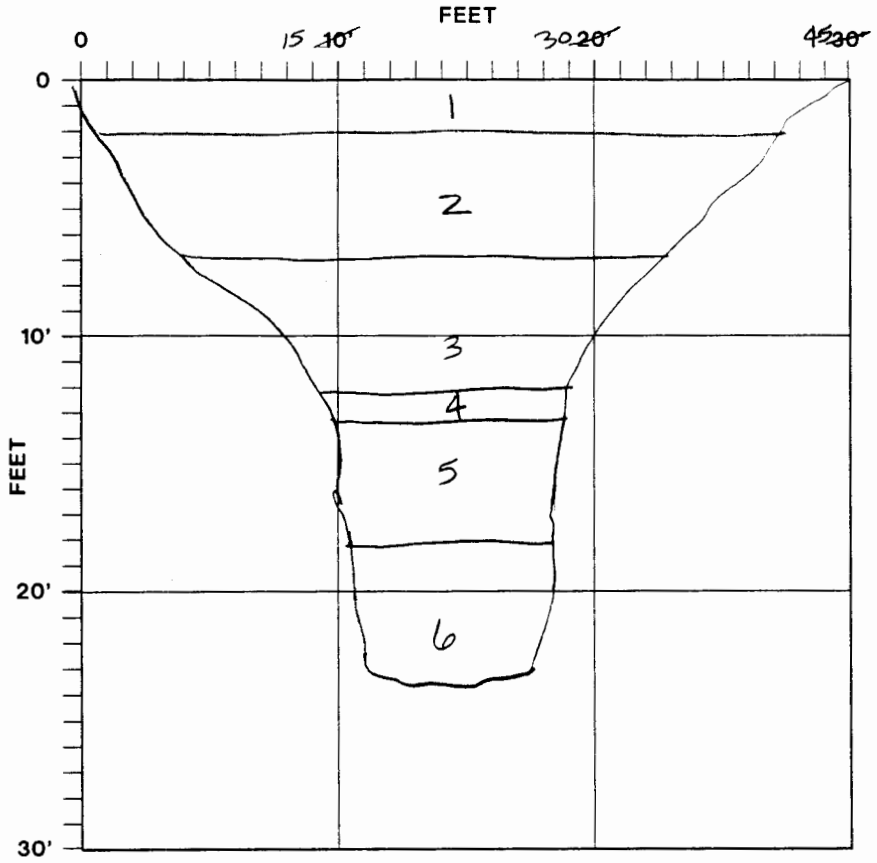
TEST PIT #4

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
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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).

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.

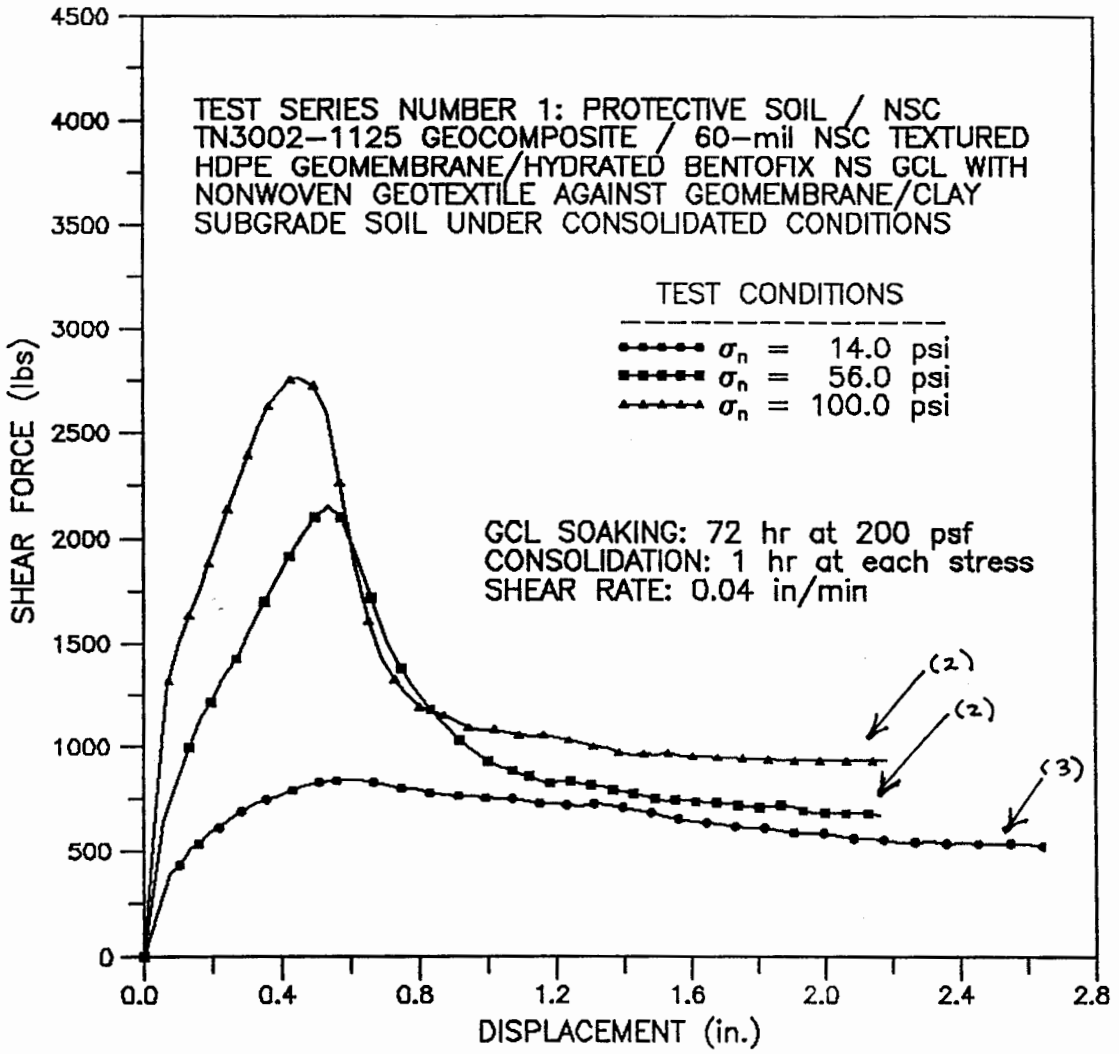
Test Procedures for Each Normal Stress Condition:

- 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.

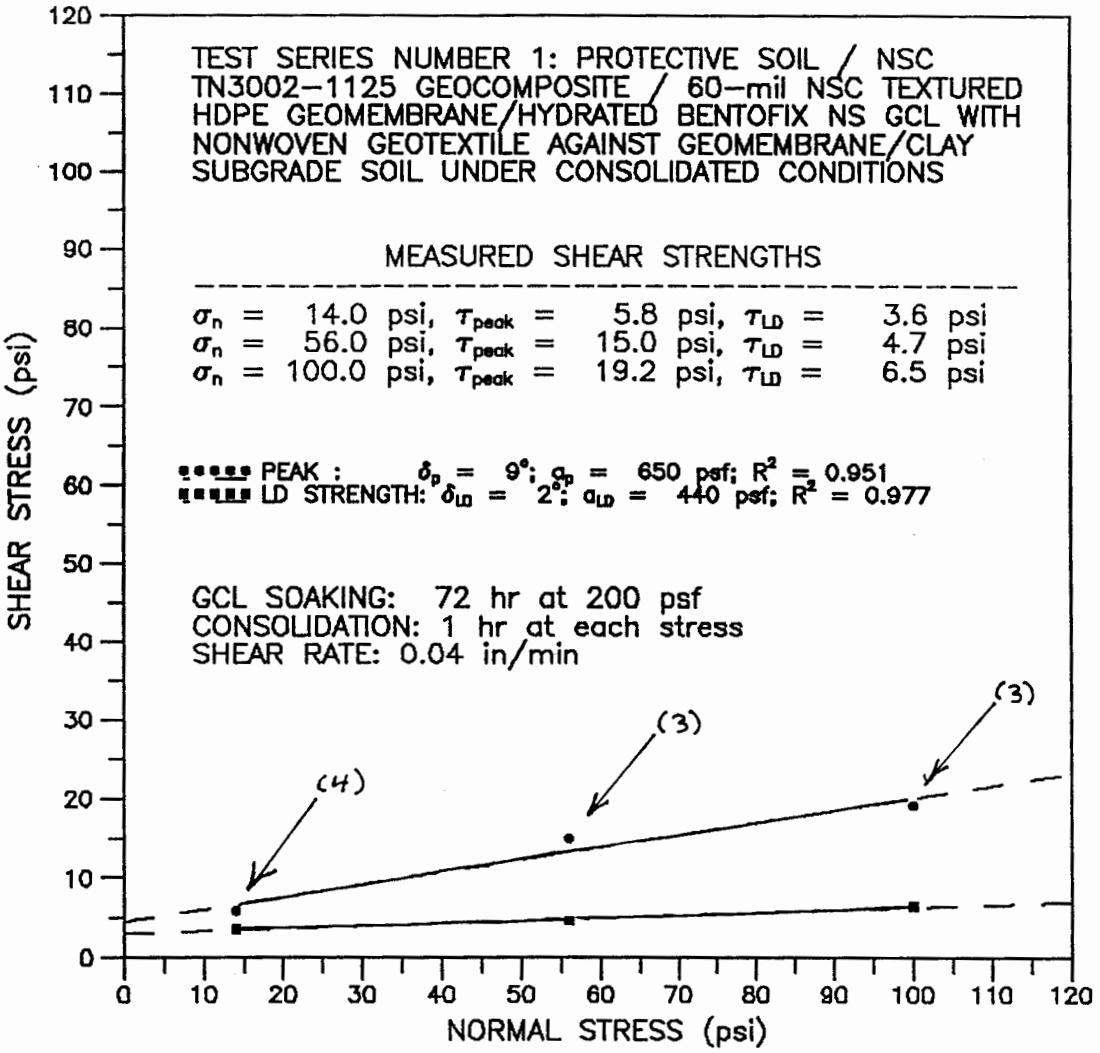
DATE TESTED: 4 TO 7 OCTOBER 1997

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.

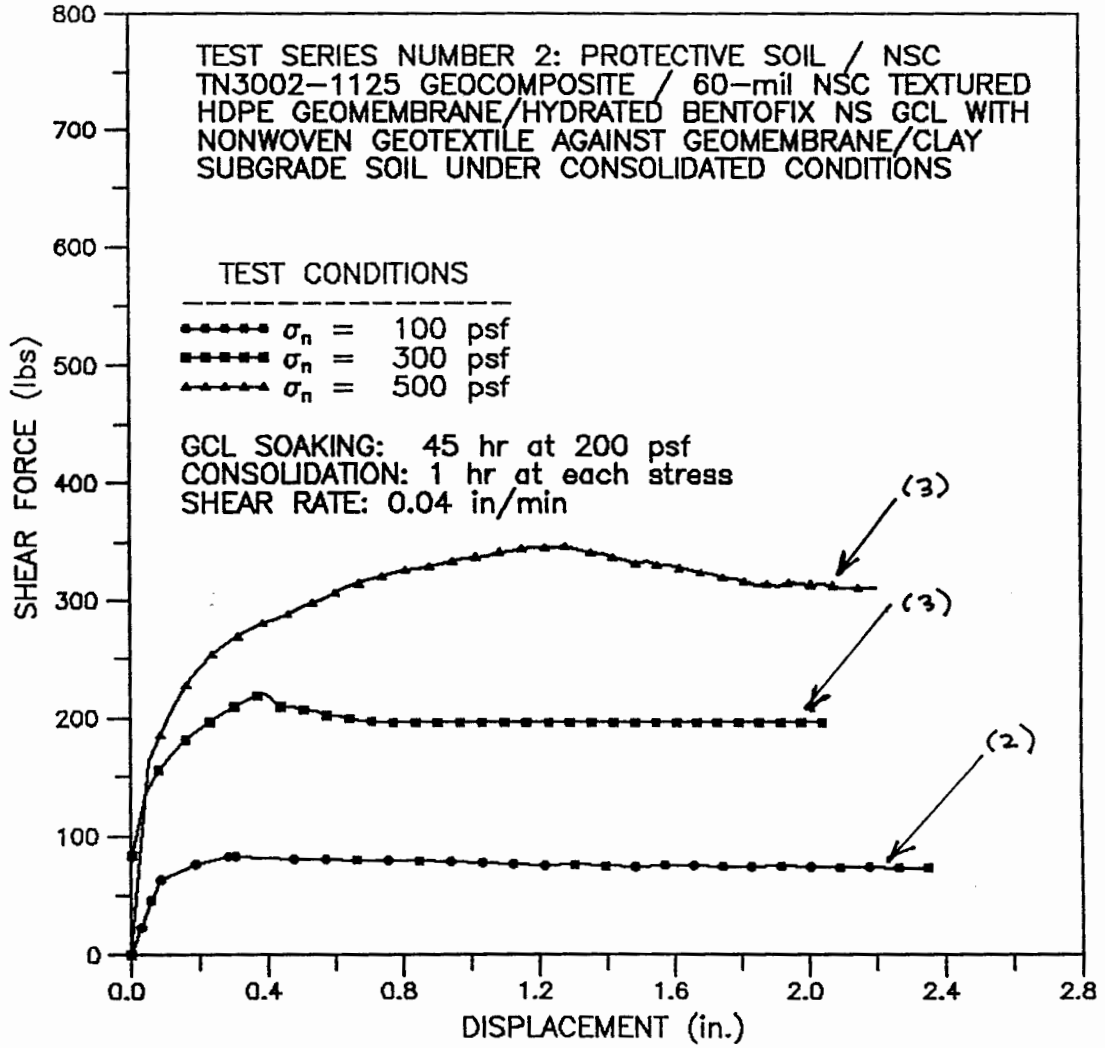
DATE TESTED: 4 TO 7 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	C-2
PROJECT NO.	GL10406
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.

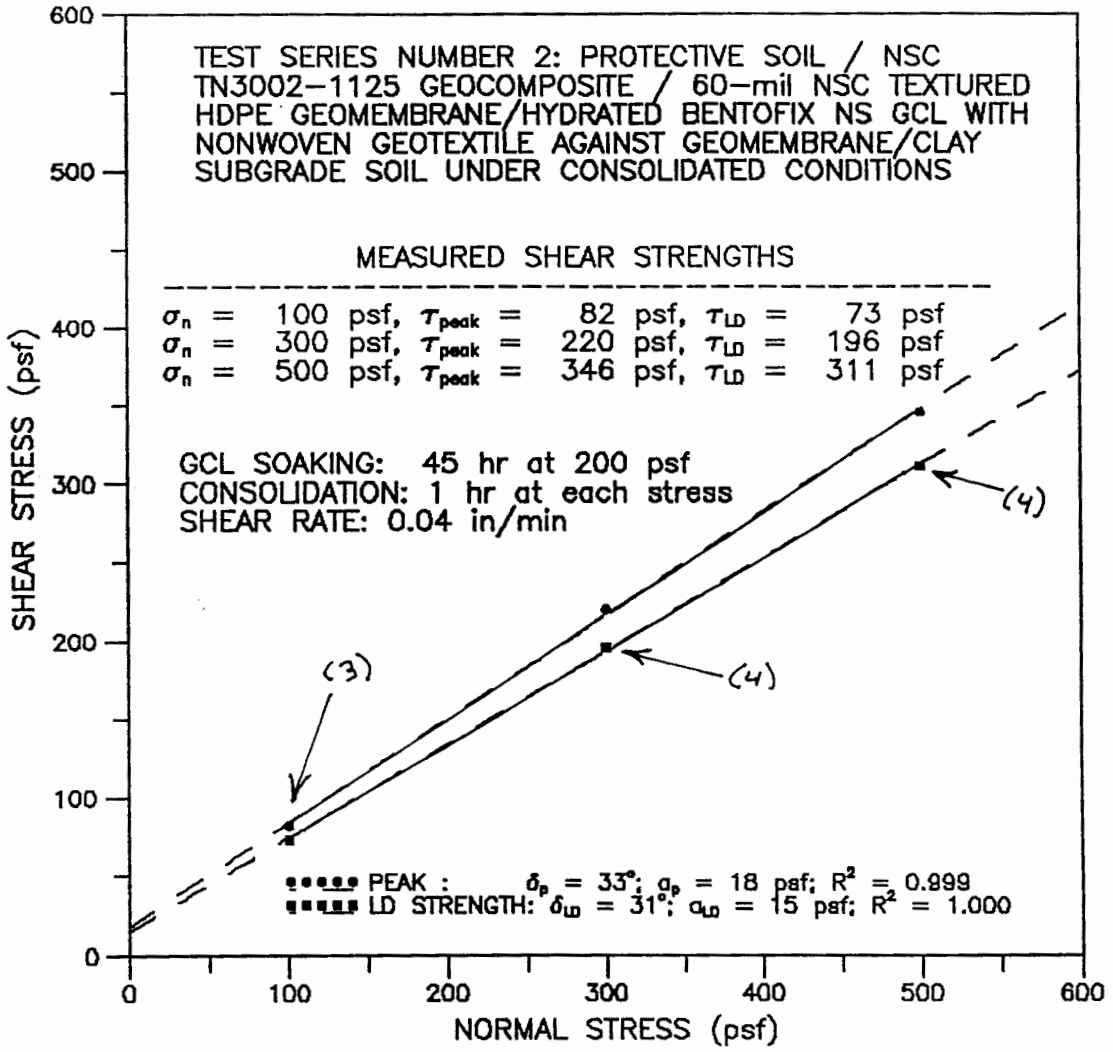
DATE TESTED: 7 TO 9 OCTOBER 1997

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

FIGURE NO.	C-3
PROJECT NO.	GL10406
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.	GLI0406
DOCUMENT NO.	SGI97133
FILE NO.	

Appendix

E

E-1

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Cut Slope Stability

	Name	Date
Prepared By:	Paul Pellicer	11/3/97
Checked By:	John Pellicer	12-Nov-97
Reviewed By:	P. Closser	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602 Sheet: 1 Of 34
Prepared By: P. Pellizer Date: Nov 3, 1997
Checked By: J. Pellicer Date: 12-Nov-97

Cut Slope Stability

Objective: Evaluate Cut Slope stability for 3H:1V Side slopes.

Method: Use XSTABL (ver 5.200) to analyze cut slope stability.

Assumptions:
- Cut slopes are unsaturated
- Cut slopes are in the Upper Dockum
- Strength properties for the Upper Dockum will be used for the Lower Dockum which is a tighter formation (therefore Conservative)
- The upper silty sands will be assumed to be Upper Dockum since this is primarely Driving force only.

Calculation: Use Cross-section cut through the North end of the Cell (see pg. 3+4).

C/P RATIO IS FOR NORMALLY CONSOLIDATED SOIL THEREFORE, THESE SHEAR STRENGTHS ARE CONSERVATIVE. ALSO, FIELD TESTING W/ POCKET PENETROMETER INDICATED C = 2,000-3,000 PSF

Using an average plasticity index for the Upper Dockum = 27 (see pg 5) use figure 18.11 from Terzagh. + peck (pg 6) to corralate to a c/p value for the upper Dockum material = 0.2.

Next the slope was layered using an arbitrary layer thickness of 20 ft to below the base of the excavation. (see pg 4)

The average Normal stress for each slice was then determined assuming an in-situ unit weight of the upper dockum of 110 pcf and an average c was calculated for each layer.

average layer Depth	Normal Stress ($\bar{\sigma}$)	c
10'	1100 psf	220 psf
30'	3300 psf	660 psf
50'	5500 psf	1100 psf
70'	7700 psf	1540 psf
90'	9900 psf	1980 psf
110'	12,100 psf	2420 psf
130'	14300 psf	2860 psf

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these strength parameters were entered into the XSTABL program and a Janbu Circular failure search was initiated.

The Minimum Static factor of safety found = 1.4 (see pg 9-21)

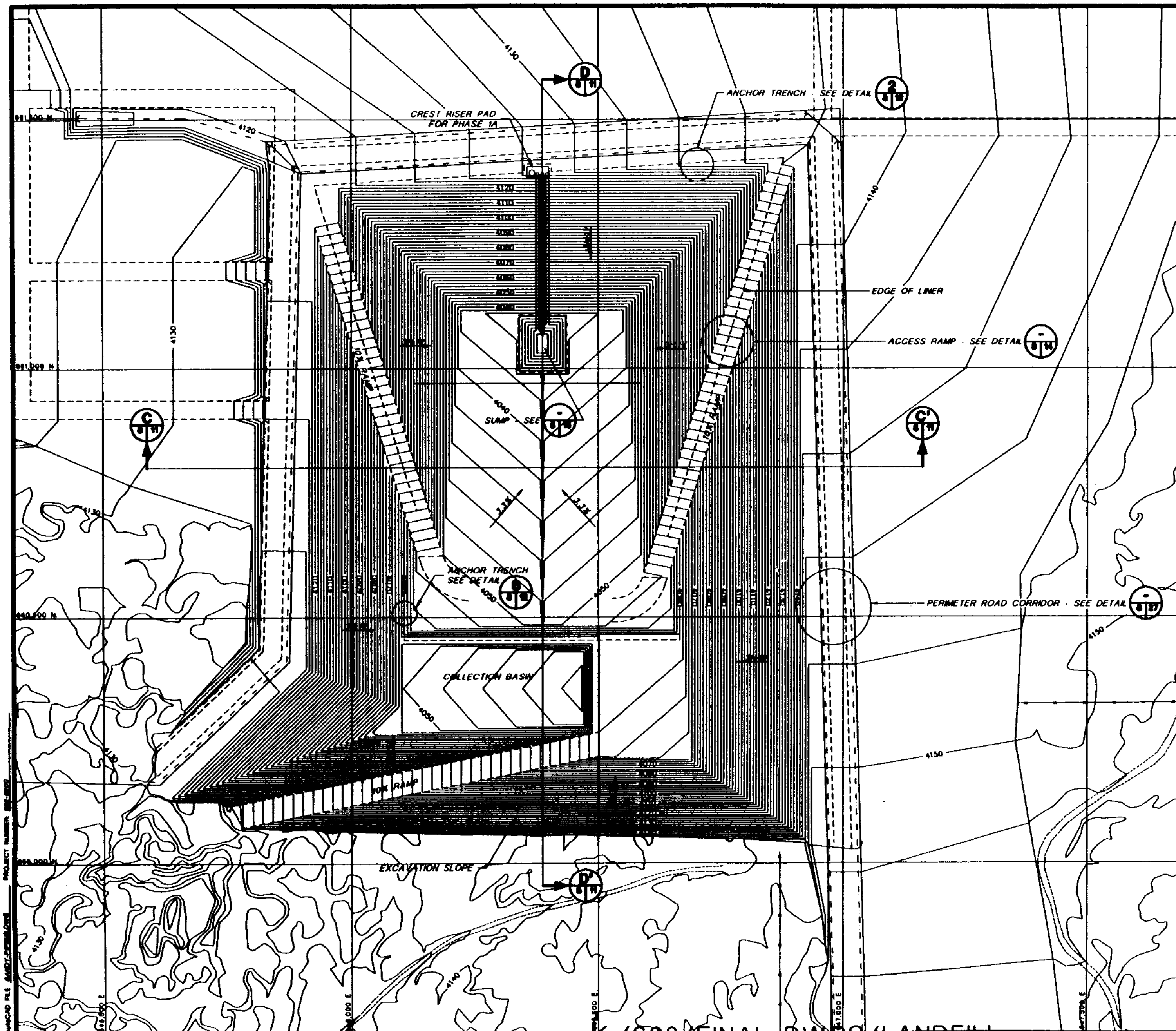
Dynamic analysis.

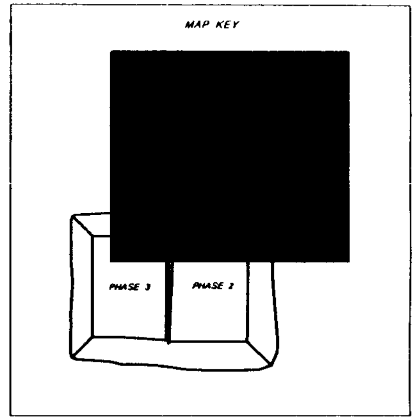
Using the United States Department of the interior Geological Survey "Probabilistic estimates of Maximum Acceleration and velocity in rock in the contiguous united states" Algermissen S.T. et. al, 1982 (see pg 7+8)

The Maximum ground acceleration for the site associated w/ 90% Probability of not being exceeded in 250 yrs earthquake = 0.04 g.

Using a ground acceleration = 0.04 g Results in a pseudo-Static factor of safety = 1.2. (see pg 22-34)

Conclusion: The parameters in this calculation are very conservative. The static F.S. = 1.4 and the pseudo static F.S. = 1.2. Therefore the cut slopes should be considerd stable. Due to the temporary nature of the cut slope, a safety less than 1.5 was accepted.





NOTES:
1. FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2, "INDEX, LEGEND AND GENERAL NOTES".
2. TOPOGRAPHY FROM AERIAL SURVEYS PERFORMED AUGUST 1997 BY KOOGLE AND POULS ENGINEERING.

PATRICK G. CORSER NEW MEXICO 12236 REGISTERED PROFESSIONAL ENGINEER

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Corser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date — Patrick G. Corser, NM P.E. 12236

SCALE 100' 0 100' 200'
CONTOUR INTERVAL 2 FT.

Not For Construction

REV No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	10/10/97	PGC/PP	T.Bate	P.Corser

TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE:
DETAILED EXCAVATION PLAN - PHASE 1A

TerraMatrix MONTGOMERY WATSON Mining Group

Sheet 1 Of 1 Sheets
SCALE AS NOTED
DRAWING No. 8

K:/602/FINAL DWGS/LANDFILL
GANDY-P1PSUB.dwg
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0.200
0.149
0.151

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		upper Dockum	
2	17	12.1		54	40		27	73		upper Dockum	
3	7.5	9.7		36	20		2	98		upper Dockum	
4	14	8.6		39	27		13	87		upper Dockum	
~~4~~	~~20~~	~~7.0~~					~~1~~	~~99~~			
5	18	12.3		46	32		35	65		upper Dockum	
				Avg =	27.6						

Project Name: Gandy
Project Location:
Project No.: 790-12101 | Technician: DCP | Date: 9-10-97

TerraMatrix
Engineering & Materials Testing Services
50000 Moffat Avenue
Steamboat Springs, Colorado 80487

SUMMARY OF LABORATORY TEST RESULTS

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(602-024)
PMP
3-NOV-97

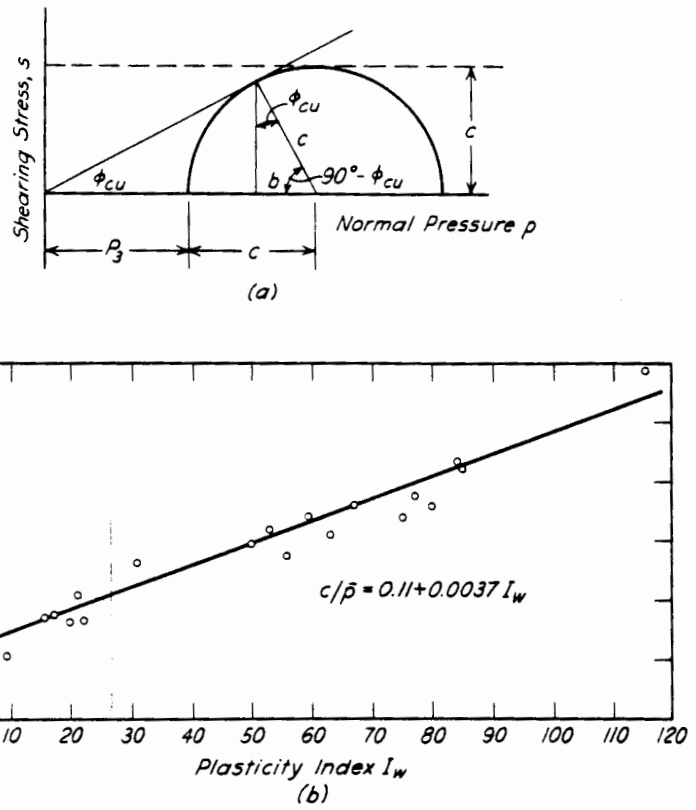

Fig. 18.4. (*a*) **Mohr rupture diagram for calculating relation between** c **and** $\bar{p}_3$ **for consolidated-undrained test.** (*b*) **Statistical relation between** $c/\bar{p}$ **ratio and plasticity index (after Skempton 1957).**

tivity. Some natural clay deposits, moreover, consist of a mixture of particles of fairly uniform fine sand and clay. While sedimentation proceeds, the simultaneous deposition of the flaky constituents of the finest fraction and of the equidimensional sand grains interferes with the rolling of the sand grains into stable arrangements. Therefore, if the sand grains touch each other, their configuration may be as metastable as that of true quicksands. However, the interstices between the sand grains are occupied by the clay-size materials which acquire, as a result of such physico-chemical processes as thixotropy and syneresis, appreciable strength as sedimentation proceeds. As a consequence, although the clay is sensitive, it does not exhibit the properties of true quicksands. In many respects, the states of transition from loose sand

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United States Department of the Interior

Geological Survey

PROBABILISTIC ESTIMATES OF MAXIMUM ACCELERATION AND VELOCITY IN ROCK IN THE CONTIGUOUS UNITED STATES

by

S. T. Algermissen, D. M. Perkins, P. C. Thenhaus,
S. L. Hanson and B. L. Bender

U.S. GEOLOGICAL SURVEY
DENVER
NOV 15 1982
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Open-File Report 82-1033

1982

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

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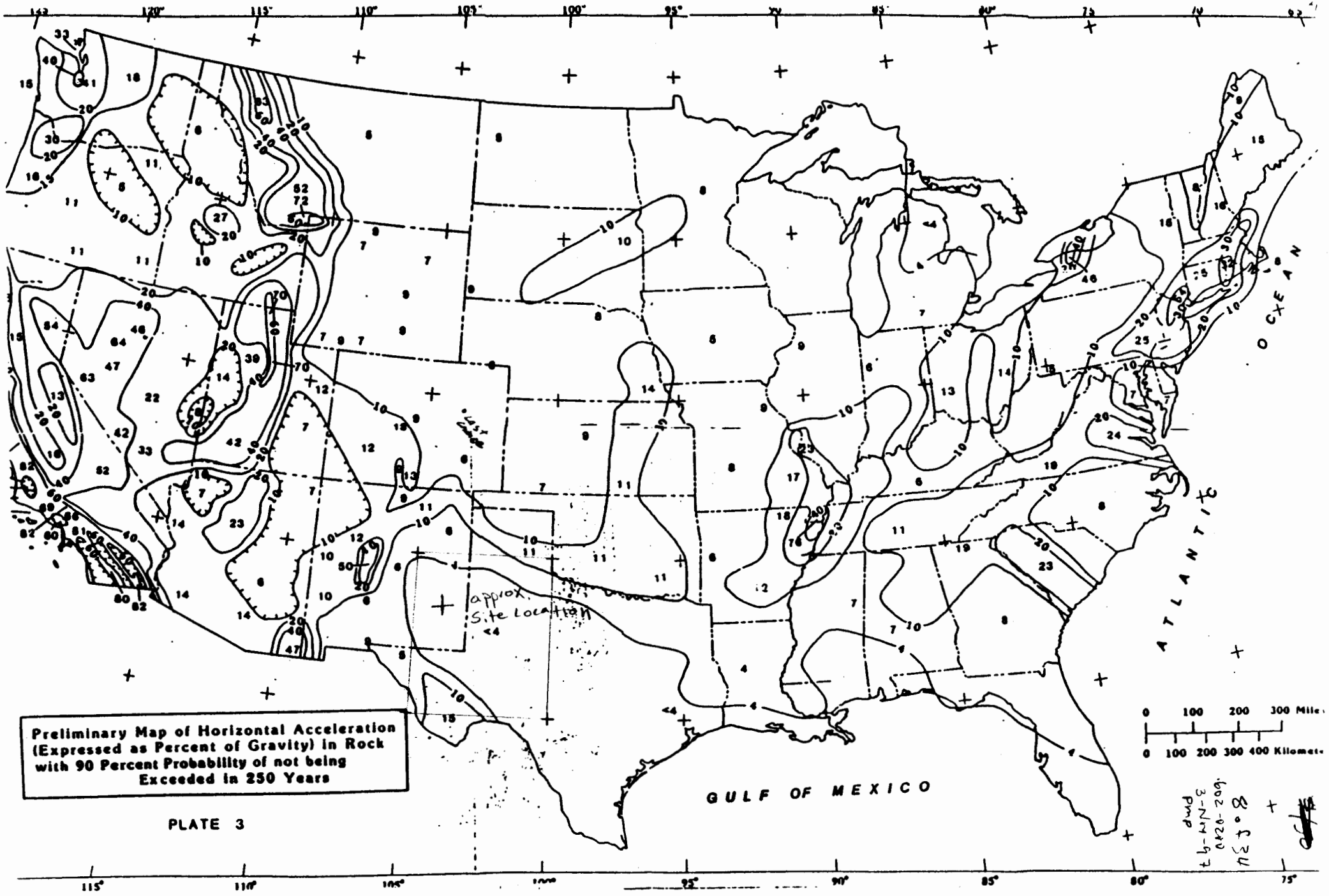
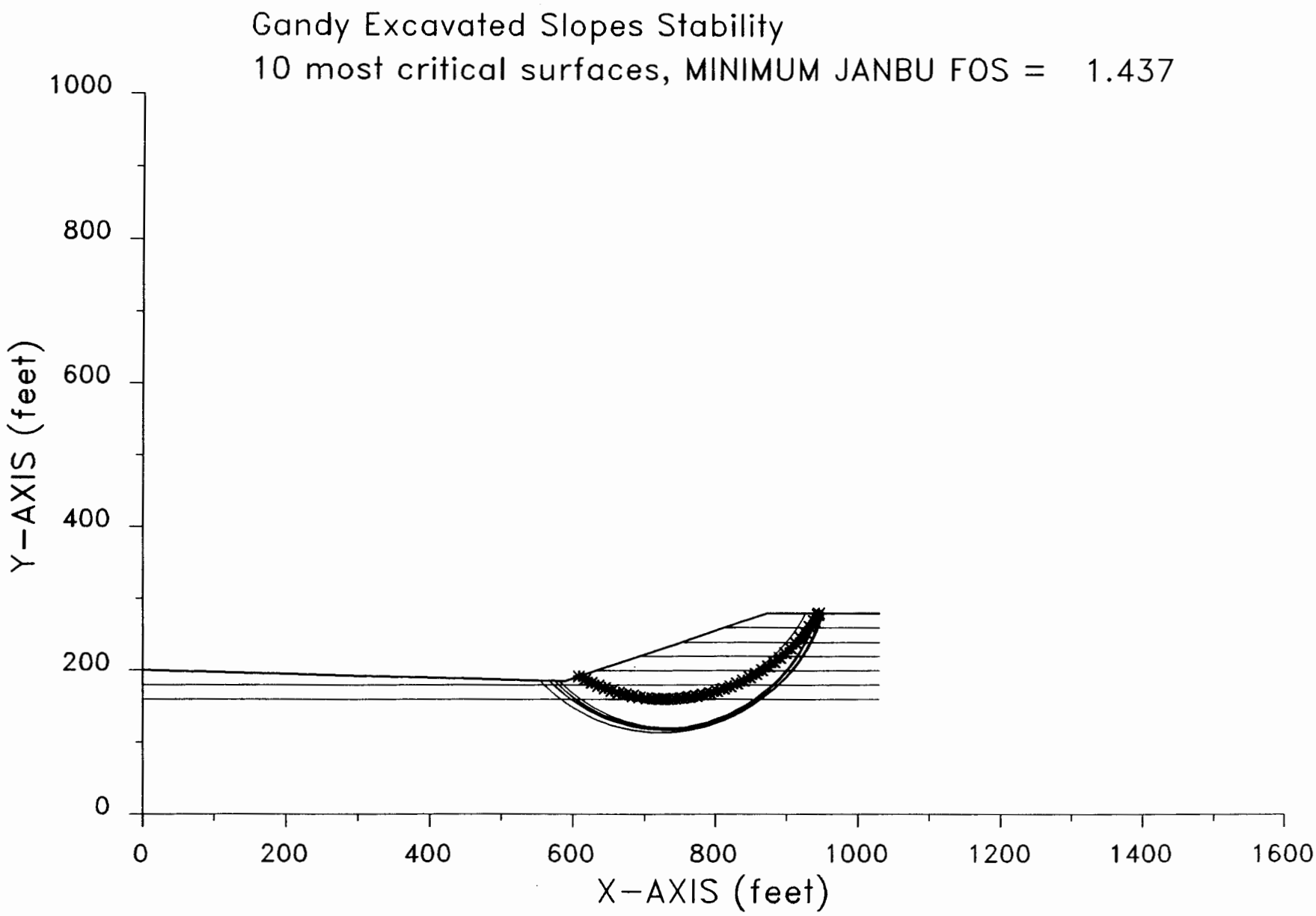


Preliminary Map of Horizontal Acceleration (Expressed as Percent of Gravity) in Rock with 90 Percent Probability of not being Exceeded in 250 Years

PLATE 3

GANSUB2 11-04-97 10:13



9 of 34
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602-0210
PMP
3-Nov-97

XSTABL File: GANSUB2 11-04-97 10:13

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.200                96 á 1216  *
*****************************************
```

Problem Description : Gandy Excavated Slopes Stability

SEGMENT BOUNDARY COORDINATES
---

7 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	200.0	589.1	185.0	5
2	589.1	185.0	632.0	199.3	5
3	632.0	199.3	692.0	219.3	4
4	692.0	219.3	752.0	239.3	3
5	752.0	239.3	812.0	259.3	2
6	812.0	259.3	872.0	279.3	1
7	872.0	279.3	1029.2	279.3	1

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	812.0	259.3	1029.2	259.3	2
2	752.0	239.3	1029.2	239.3	3
3	692.0	219.3	1029.2	219.3	4
4	632.0	199.3	1029.2	199.3	5
5	.0	179.3	1029.2	179.3	6
6	.0	159.3	1029.2	159.3	7

ISOTROPIC Soil Parameters
---

7 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	220.0	.00	.000	.0	0
2	110.0	110.0	660.0	.00	.000	.0	0
3	110.0	110.0	1100.0	.00	.000	.0	0
4	110.0	110.0	1540.0	.00	.000	.0	0
5	110.0	110.0	1980.0	.00	.000	.0	0
6	110.0	110.0	2420.0	.00	.000	.0	0
7	110.0	110.0	2860.0	.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

900 trial surfaces will be generated and analyzed.

30 Surfaces initiate from each of 30 points equally spaced along the ground surface between x = 450.0 ft
and x = 650.0 ft

Each surface terminates between x = 800.0 ft
and x = 950.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

10.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

****
-- WARNING -- WARNING -- WARNING -- WARNING -- (# 48)
****
Negative effective stresses were calculated at the base of a slice.

This warning is usually reported for cases where slices have low self weight and a relatively high "c" shear strength parameter. In such cases, this effect can only be eliminated by reducing the "c" value.
****

USER SELECTED option to maintain strength greater than zero

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 40 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	608.62	191.51
2	617.47	186.84
3	626.49	182.53
4	635.68	178.58
5	645.01	175.01
6	654.49	171.80
7	664.08	168.98
8	673.78	166.54
9	683.56	164.48
10	693.43	162.82
11	703.35	161.55
12	713.31	160.68
13	723.30	160.21
14	733.30	160.13
15	743.29	160.45
16	753.26	161.17
17	763.20	162.28
18	773.09	163.79
19	782.90	165.70
20	792.64	167.99
21	802.27	170.66
22	811.80	173.72
23	821.19	177.16
24	830.43	180.96
25	839.52	185.13
26	848.44	189.66
27	857.17	194.54
28	865.69	199.76
29	874.01	205.32
30	882.09	211.21
31	889.94	217.41
32	897.53	223.92
33	904.85	230.73
34	911.90	237.82
35	918.66	245.19

36	925.13	252.82
37	931.28	260.70
38	937.12	268.82
39	942.62	277.17
40	943.91	279.30

** Corrected JANBU FOS = 1.437 ** (Fo factor = 1.099)

Failure surface No. 2 specified by 39 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	615.52	193.81
2	624.16	188.78
3	633.01	184.13
4	642.06	179.87
5	651.29	176.01
6	660.67	172.56
7	670.20	169.52
8	679.85	166.90
9	689.61	164.71
10	699.45	162.94
11	709.36	161.60
12	719.32	160.70
13	729.31	160.23
14	739.31	160.20
15	749.30	160.61
16	759.27	161.45
17	769.18	162.72
18	779.04	164.43
19	788.81	166.57
20	798.47	169.13
21	808.02	172.11
22	817.43	175.50
23	826.67	179.30
24	835.75	183.50
25	844.63	188.09
26	853.31	193.07
27	861.75	198.42
28	869.96	204.14
29	877.91	210.20
30	885.59	216.61
31	892.98	223.35
32	900.07	230.40
33	906.84	237.76
34	913.29	245.40
35	919.40	253.32
36	925.15	261.50
37	930.54	269.92
38	935.56	278.57
39	935.95	279.30

** Corrected JANBU FOS = 1.438 ** (Fo factor = 1.103)

Failure surface No. 3 specified by 38 coordinate points

Point	x-surf	y-surf

No.	(ft)	(ft)
1	615.52	193.81
2	624.11	188.69
3	632.93	183.97
4	641.95	179.67
5	651.17	175.78
6	660.55	172.32
7	670.08	169.29
8	679.74	166.71
9	689.51	164.57
10	699.36	162.88
11	709.29	161.65
12	719.26	160.88
13	729.25	160.56
14	739.25	160.71
15	749.23	161.31
16	759.18	162.37
17	769.06	163.89
18	778.87	165.86
19	788.57	168.28
20	798.15	171.14
21	807.59	174.44
22	816.87	178.16
23	825.97	182.32
24	834.87	186.88
25	843.54	191.85
26	851.98	197.21
27	860.17	202.96
28	868.08	209.07
29	875.71	215.54
30	883.02	222.36
31	890.02	229.50
32	896.68	236.96
33	903.00	244.72
34	908.94	252.75
35	914.52	261.06
36	919.70	269.61
37	924.49	278.39
38	924.94	279.30

** Corrected JANBU FOS = 1.439 ** (Fo factor = 1.105)

Failure surface No. 4 specified by 49 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	567.24	185.56
2	574.40	178.57
3	581.86	171.91
4	589.60	165.58
5	597.61	159.60
6	605.87	153.96
7	614.37	148.70
8	623.10	143.81
9	632.03	139.31
10	641.14	135.20
11	650.43	131.49

12	659.87	128.19
13	669.45	125.31
14	679.14	122.85
15	688.93	120.81
16	698.80	119.20
17	708.73	118.03
18	718.70	117.29
19	728.70	116.98
20	738.70	117.12
21	748.68	117.68
22	758.63	118.69
23	768.53	120.13
24	778.35	122.00
25	788.08	124.29
26	797.71	127.01
27	807.20	130.14
28	816.55	133.69
29	825.74	137.64
30	834.74	141.99
31	843.55	146.73
32	852.14	151.85
33	860.50	157.34
34	868.61	163.19
35	876.46	169.38
36	884.03	175.92
37	891.31	182.77
38	898.28	189.94
39	904.93	197.41
40	911.25	205.16
41	917.23	213.18
42	922.85	221.45
43	928.10	229.96
44	932.98	238.69
45	937.47	247.62
46	941.57	256.75
47	945.26	266.04
48	948.54	275.48
49	949.69	279.30

** Corrected JANBU FOS = 1.442 ** (Fo factor = 1.118)

Failure surface No. 5 specified by 48 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	574.14	185.38
2	581.32	178.43
3	588.81	171.80
4	596.59	165.51
5	604.64	159.58
6	612.94	154.00
7	621.48	148.80
8	630.25	143.99
9	639.22	139.57
10	648.38	135.55
11	657.70	131.95
12	667.18	128.76
13	676.79	126.00

14	686.52	123.67
15	696.33	121.77
16	706.23	120.31
17	716.18	119.29
18	726.16	118.71
19	736.16	118.58
20	746.15	118.89
21	756.12	119.65
22	766.05	120.85
23	775.92	122.49
24	785.70	124.57
25	795.38	127.07
26	804.94	130.01
27	814.36	133.37
28	823.62	137.14
29	832.70	141.32
30	841.59	145.90
31	850.27	150.88
32	858.71	156.23
33	866.92	161.95
34	874.85	168.03
35	882.51	174.46
36	889.88	181.22
37	896.94	188.31
38	903.68	195.69
39	910.08	203.38
40	916.14	211.34
41	921.83	219.55
42	927.15	228.02
43	932.10	236.71
44	936.65	245.62
45	940.80	254.71
46	944.54	263.99
47	947.87	273.42
48	949.65	279.30

** Corrected JANBU FOS = 1.443 ** (Fo factor = 1.118)

Failure surface No. 6 specified by 40 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	608.62	191.51
2	617.53	186.97
3	626.61	182.78
4	635.84	178.94
5	645.22	175.45
6	654.72	172.33
7	664.33	169.58
8	674.04	167.19
9	683.84	165.18
10	693.70	163.54
11	703.62	162.29
12	713.59	161.41
13	723.57	160.92
14	733.57	160.81
15	743.57	161.09
16	753.55	161.74

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17	763.49	162.78
18	773.39	164.20
19	783.23	166.00
20	792.99	168.17
21	802.66	170.71
22	812.23	173.63
23	821.67	176.91
24	830.99	180.55
25	840.16	184.54
26	849.17	188.88
27	858.00	193.56
28	866.65	198.58
29	875.10	203.92
30	883.34	209.59
31	891.36	215.57
32	899.14	221.85
33	906.68	228.42
34	913.96	235.28
35	920.97	242.41
36	927.70	249.80
37	934.15	257.45
38	940.29	265.34
39	946.13	273.46
40	950.00	279.30

** Corrected JANBU FOS = 1.444 ** (Fo factor = 1.098)

Failure surface No. 7 specified by 47 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	574.14	185.38
2	581.22	178.32
3	588.61	171.59
4	596.31	165.20
5	604.29	159.18
6	612.55	153.54
7	621.05	148.27
8	629.79	143.41
9	638.74	138.95
10	647.89	134.91
11	657.21	131.30
12	666.69	128.11
13	676.31	125.37
14	686.04	123.07
15	695.87	121.23
16	705.77	119.84
17	715.73	118.90
18	725.72	118.42
19	735.72	118.41
20	745.71	118.85
21	755.66	119.76
22	765.57	121.12
23	775.41	122.94
24	785.14	125.20
25	794.77	127.92
26	804.26	131.07
27	813.59	134.66

28	822.75	138.67
29	831.72	143.10
30	840.47	147.94
31	848.99	153.17
32	857.26	158.80
33	865.26	164.79
34	872.98	171.15
35	880.40	177.86
36	887.50	184.90
37	894.27	192.26
38	900.69	199.93
39	906.75	207.88
40	912.44	216.10
41	917.75	224.58
42	922.66	233.29
43	927.16	242.22
44	931.25	251.35
45	934.91	260.65
46	938.14	270.12
47	940.81	279.30

** Corrected JANBU FOS = 1.444 ** (Fo factor = 1.119)

Failure surface No. 8 specified by 50 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	553.45	185.91
2	560.52	178.84
3	567.89	172.08
4	575.53	165.63
5	583.45	159.52
6	591.61	153.74
7	600.01	148.32
8	608.64	143.26
9	617.47	138.57
10	626.49	134.26
11	635.69	130.33
12	645.04	126.80
13	654.54	123.67
14	664.16	120.94
15	673.89	118.62
16	683.71	116.72
17	693.60	115.24
18	703.54	114.17
19	713.52	113.53
20	723.52	113.31
21	733.52	113.52
22	743.50	114.15
23	753.44	115.20
24	763.33	116.68
25	773.15	118.57
26	782.88	120.88
27	792.50	123.59
28	802.00	126.71
29	811.36	130.24
30	820.56	134.15
31	829.59	138.46

32	838.43	143.14
33	847.06	148.19
34	855.47	153.60
35	863.64	159.37
36	871.56	165.47
37	879.21	171.91
38	886.58	178.67
39	893.66	185.73
40	900.44	193.08
41	906.89	200.72
42	913.02	208.62
43	918.81	216.78
44	924.24	225.17
45	929.32	233.79
46	934.02	242.61
47	938.35	251.63
48	942.29	260.82
49	945.83	270.17
50	948.86	279.30

** Corrected JANBU FOS = 1.445 ** (Fo factor = 1.118)

Failure surface No. 9 specified by 48 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	567.24	185.56
2	574.44	178.62
3	581.94	172.00
4	589.73	165.73
5	597.79	159.82
6	606.11	154.27
7	614.67	149.09
8	623.45	144.31
9	632.44	139.92
10	641.61	135.94
11	650.95	132.37
12	660.44	129.22
13	670.06	126.49
14	679.80	124.20
15	689.62	122.35
16	699.52	120.94
17	709.48	119.97
18	719.46	119.45
19	729.46	119.37
20	739.46	119.74
21	749.42	120.56
22	759.34	121.82
23	769.20	123.52
24	778.97	125.66
25	788.63	128.24
26	798.17	131.24
27	807.56	134.67
28	816.79	138.51
29	825.85	142.76
30	834.70	147.41
31	843.33	152.45
32	851.74	157.88

33	859.89	163.67
34	867.77	169.82
35	875.38	176.31
36	882.68	183.14
37	889.67	190.29
38	896.34	197.75
39	902.67	205.49
40	908.64	213.51
41	914.25	221.79
42	919.48	230.31
43	924.33	239.05
44	928.79	248.01
45	932.84	257.15
46	936.48	266.47
47	939.69	275.93
48	940.67	279.30

** Corrected JANBU FOS = 1.445 ** (Fo factor = 1.118)

Failure surface No.10 specified by 47 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	581.03	185.21
2	588.21	178.24
3	595.70	171.61
4	603.48	165.33
5	611.54	159.42
6	619.87	153.88
7	628.44	148.72
8	637.23	143.97
9	646.24	139.62
10	655.43	135.68
11	664.80	132.17
12	674.31	129.10
13	683.96	126.46
14	693.71	124.27
15	703.56	122.52
16	713.48	121.23
17	723.44	120.39
18	733.43	120.01
19	743.43	120.08
20	753.42	120.62
21	763.37	121.61
22	773.26	123.05
23	783.08	124.95
24	792.81	127.29
25	802.41	130.07
26	811.88	133.29
27	821.19	136.94
28	830.32	141.02
29	839.26	145.50
30	847.98	150.39
31	856.47	155.68
32	864.71	161.35
33	872.68	167.38
34	880.37	173.78
35	887.75	180.52

36	894.82	187.60
37	901.56	194.98
38	907.95	202.67
39	913.99	210.65
40	919.65	218.89
41	924.93	227.38
42	929.82	236.10
43	934.30	245.04
44	938.37	254.18
45	942.02	263.49
46	945.24	272.96
47	947.08	279.30

** Corrected JANBU FOS = 1.445 ** (Fo factor = 1.119)

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Excavated Slopes Stability

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	1.437	1.099	608.62	943.91	7.264E+05
2.	1.438	1.103	615.52	935.95	7.035E+05
3.	1.439	1.105	615.52	924.94	6.830E+05
4.	1.442	1.118	567.24	949.69	1.117E+06
5.	1.443	1.118	574.14	949.65	1.095E+06
6.	1.444	1.098	608.62	950.00	7.332E+05
7.	1.444	1.119	574.14	940.81	1.079E+06
8.	1.445	1.118	553.45	948.86	1.162E+06
9.	1.445	1.118	567.24	940.67	1.087E+06
10.	1.445	1.119	581.03	947.08	1.069E+06

* * * END OF FILE * * *

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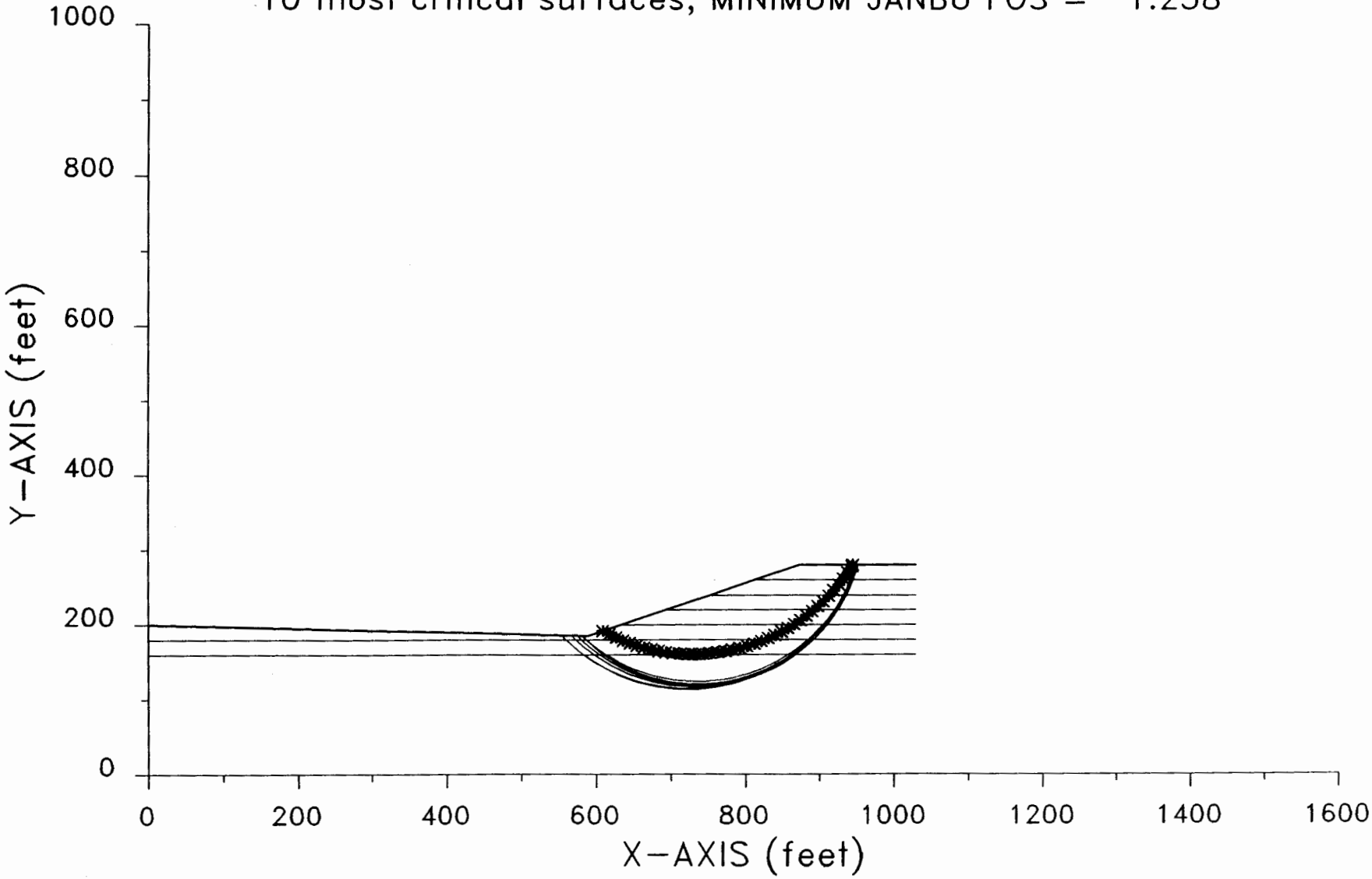
Gandy Excavated Slopes Stability Q

10 most critical surfaces, MINIMUM JANBU FOS = 1.258



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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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*  Ver. 5.200                96 á 1216  *
*****************************************
```

Problem Description : Gandy Excavated Slopes Stability Q

SEGMENT BOUNDARY COORDINATES
---

7 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	200.0	589.1	185.0	5
2	589.1	185.0	632.0	199.3	5
3	632.0	199.3	692.0	219.3	4
4	692.0	219.3	752.0	239.3	3
5	752.0	239.3	812.0	259.3	2
6	812.0	259.3	872.0	279.3	1
7	872.0	279.3	1029.2	279.3	1

6 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	812.0	259.3	1029.2	259.3	2
2	752.0	239.3	1029.2	239.3	3
3	692.0	219.3	1029.2	219.3	4
4	632.0	199.3	1029.2	199.3	5
5	.0	179.3	1029.2	179.3	6
6	.0	159.3	1029.2	159.3	7

ISOTROPIC Soil Parameters
---

7 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	220.0	.00	.000	.0	0
2	110.0	110.0	660.0	.00	.000	.0	0
3	110.0	110.0	1100.0	.00	.000	.0	0
4	110.0	110.0	1540.0	.00	.000	.0	0
5	110.0	110.0	1980.0	.00	.000	.0	0
6	110.0	110.0	2420.0	.00	.000	.0	0
7	110.0	110.0	2860.0	.00	.000	.0	0

A horizontal earthquake loading coefficient
of .040 has been assigned

A vertical earthquake loading coefficient
of .000 has been assigned

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

900 trial surfaces will be generated and analyzed.

30 Surfaces initiate from each of 30 points equally spaced along the ground surface between x = 450.0 ft
and x = 650.0 ft

Each surface terminates between x = 800.0 ft
and x = 950.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

* * * * * DEFAULT SEGMENT LENGTH SELECTED BY XSTABL * * * * *

10.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

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```
*************************************************************************
    --  WARNING  --  WARNING  --  WARNING  --  WARNING  --  (# 48)
*************************************************************************
Negative effective stresses were calculated at the base of a slice.
This warning is usually reported for cases where slices have low self
weight and a relatively high "c" shear strength parameter.  In such
cases, this effect can only be eliminated by reducing the "c" value.
*************************************************************************
```

USER SELECTED option to maintain strength greater than zero

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 40 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	608.62	191.51
2	617.47	186.84
3	626.49	182.53
4	635.68	178.58
5	645.01	175.01
6	654.49	171.80
7	664.08	168.98
8	673.78	166.54
9	683.56	164.48
10	693.43	162.82
11	703.35	161.55
12	713.31	160.68
13	723.30	160.21
14	733.30	160.13
15	743.29	160.45
16	753.26	161.17
17	763.20	162.28
18	773.09	163.79
19	782.90	165.70
20	792.64	167.99
21	802.27	170.66
22	811.80	173.72
23	821.19	177.16
24	830.43	180.96
25	839.52	185.13
26	848.44	189.66
27	857.17	194.54

28	865.69	199.76
29	874.01	205.32
30	882.09	211.21
31	889.94	217.41
32	897.53	223.92
33	904.85	230.73
34	911.90	237.82
35	918.66	245.19
36	925.13	252.82
37	931.28	260.70
38	937.12	268.82
39	942.62	277.17
40	943.91	279.30

** Corrected JANBU FOS = 1.258 ** (Fo factor = 1.099)

Failure surface No. 2 specified by 49 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	567.24	185.56
2	574.40	178.57
3	581.86	171.91
4	589.60	165.58
5	597.61	159.60
6	605.87	153.96
7	614.37	148.70
8	623.10	143.81
9	632.03	139.31
10	641.14	135.20
11	650.43	131.49
12	659.87	128.19
13	669.45	125.31
14	679.14	122.85
15	688.93	120.81
16	698.80	119.20
17	708.73	118.03
18	718.70	117.29
19	728.70	116.98
20	738.70	117.12
21	748.68	117.68
22	758.63	118.69
23	768.53	120.13
24	778.35	122.00
25	788.08	124.29
26	797.71	127.01
27	807.20	130.14
28	816.55	133.69
29	825.74	137.64
30	834.74	141.99
31	843.55	146.73
32	852.14	151.85
33	860.50	157.34
34	868.61	163.19
35	876.46	169.38
36	884.03	175.92
37	891.31	182.77
38	898.28	189.94

39	904.93	197.41
40	911.25	205.16
41	917.23	213.18
42	922.85	221.45
43	928.10	229.96
44	932.98	238.69
45	937.47	247.62
46	941.57	256.75
47	945.26	266.04
48	948.54	275.48
49	949.69	279.30

** Corrected JANBU FOS = 1.261 ** (Fo factor = 1.118)

Failure surface No. 3 specified by 40 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	608.62	191.51
2	617.53	186.97
3	626.61	182.78
4	635.84	178.94
5	645.22	175.45
6	654.72	172.33
7	664.33	169.58
8	674.04	167.19
9	683.84	165.18
10	693.70	163.54
11	703.62	162.29
12	713.59	161.41
13	723.57	160.92
14	733.57	160.81
15	743.57	161.09
16	753.55	161.74
17	763.49	162.78
18	773.39	164.20
19	783.23	166.00
20	792.99	168.17
21	802.66	170.71
22	812.23	173.63
23	821.67	176.91
24	830.99	180.55
25	840.16	184.54
26	849.17	188.88
27	858.00	193.56
28	866.65	198.58
29	875.10	203.92
30	883.34	209.59
31	891.36	215.57
32	899.14	221.85
33	906.68	228.42
34	913.96	235.28
35	920.97	242.41
36	927.70	249.80
37	934.15	257.45
38	940.29	265.34
39	946.13	273.46
40	950.00	279.30

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** Corrected JANBU FOS = 1.261 ** (Fo factor = 1.098)

Failure surface No. 4 specified by 48 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	574.14	185.38
2	581.32	178.43
3	588.81	171.80
4	596.59	165.51
5	604.64	159.58
6	612.94	154.00
7	621.48	148.80
8	630.25	143.99
9	639.22	139.57
10	648.38	135.55
11	657.70	131.95
12	667.18	128.76
13	676.79	126.00
14	686.52	123.67
15	696.33	121.77
16	706.23	120.31
17	716.18	119.29
18	726.16	118.71
19	736.16	118.58
20	746.15	118.89
21	756.12	119.65
22	766.05	120.85
23	775.92	122.49
24	785.70	124.57
25	795.38	127.07
26	804.94	130.01
27	814.36	133.37
28	823.62	137.14
29	832.70	141.32
30	841.59	145.90
31	850.27	150.88
32	858.71	156.23
33	866.92	161.95
34	874.85	168.03
35	882.51	174.46
36	889.88	181.22
37	896.94	188.31
38	903.68	195.69
39	910.08	203.38
40	916.14	211.34
41	921.83	219.55
42	927.15	228.02
43	932.10	236.71
44	936.65	245.62
45	940.80	254.71
46	944.54	263.99
47	947.87	273.42
48	949.65	279.30

** Corrected JANBU FOS = 1.261 ** (Fo factor = 1.118)

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Failure surface No. 5 specified by 39 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	615.52	193.81
2	624.16	188.78
3	633.01	184.13
4	642.06	179.87
5	651.29	176.01
6	660.67	172.56
7	670.20	169.52
8	679.85	166.90
9	689.61	164.71
10	699.45	162.94
11	709.36	161.60
12	719.32	160.70
13	729.31	160.23
14	739.31	160.20
15	749.30	160.61
16	759.27	161.45
17	769.18	162.72
18	779.04	164.43
19	788.81	166.57
20	798.47	169.13
21	808.02	172.11
22	817.43	175.50
23	826.67	179.30
24	835.75	183.50
25	844.63	188.09
26	853.31	193.07
27	861.75	198.42
28	869.96	204.14
29	877.91	210.20
30	885.59	216.61
31	892.98	223.35
32	900.07	230.40
33	906.84	237.76
34	913.29	245.40
35	919.40	253.32
36	925.15	261.50
37	930.54	269.92
38	935.56	278.57
39	935.95	279.30

** Corrected JANBU FOS = 1.262 ** (Fo factor = 1.103)

Failure surface No. 6 specified by 50 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	553.45	185.91
2	560.52	178.84
3	567.89	172.08
4	575.53	165.63
5	583.45	159.52
6	591.61	153.74

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7	600.01	148.32
8	608.64	143.26
9	617.47	138.57
10	626.49	134.26
11	635.69	130.33
12	645.04	126.80
13	654.54	123.67
14	664.16	120.94
15	673.89	118.62
16	683.71	116.72
17	693.60	115.24
18	703.54	114.17
19	713.52	113.53
20	723.52	113.31
21	733.52	113.52
22	743.50	114.15
23	753.44	115.20
24	763.33	116.68
25	773.15	118.57
26	782.88	120.88
27	792.50	123.59
28	802.00	126.71
29	811.36	130.24
30	820.56	134.15
31	829.59	138.46
32	838.43	143.14
33	847.06	148.19
34	855.47	153.60
35	863.64	159.37
36	871.56	165.47
37	879.21	171.91
38	886.58	178.67
39	893.66	185.73
40	900.44	193.08
41	906.89	200.72
42	913.02	208.62
43	918.81	216.78
44	924.24	225.17
45	929.32	233.79
46	934.02	242.61
47	938.35	251.63
48	942.29	260.82
49	945.83	270.17
50	948.86	279.30

** Corrected JANBU FOS = 1.263 ** (Fo factor = 1.118)

Failure surface No. 7 specified by 48 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	581.03	185.21
2	588.11	178.14
3	595.51	171.41
4	603.20	165.02
5	611.18	158.99
6	619.42	153.33
7	627.92	148.06

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8	636.65	143.18
9	645.59	138.70
10	654.73	134.64
11	664.04	130.99
12	673.51	127.78
13	683.12	125.01
14	692.84	122.67
15	702.66	120.79
16	712.56	119.35
17	722.51	118.37
18	732.49	117.84
19	742.49	117.77
20	752.49	118.16
21	762.45	119.01
22	772.37	120.30
23	782.21	122.06
24	791.97	124.26
25	801.61	126.90
26	811.12	129.98
27	820.49	133.49
28	829.68	137.43
29	838.68	141.78
30	847.48	146.54
31	856.04	151.70
32	864.37	157.25
33	872.43	163.17
34	880.21	169.45
35	887.69	176.08
36	894.87	183.04
37	901.72	190.33
38	908.23	197.92
39	914.38	205.80
40	920.17	213.96
41	925.58	222.37
42	930.60	231.02
43	935.22	239.88
44	939.43	248.96
45	943.21	258.21
46	946.58	267.63
47	949.50	277.19
48	950.05	279.30

** Corrected JANBU FOS = 1.263 ** (Fo factor = 1.119)

Failure surface No. 8 specified by 47 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	581.03	185.21
2	588.45	178.50
3	596.16	172.13
4	604.14	166.10
5	612.38	160.44
6	620.87	155.15
7	629.58	150.24
8	638.51	145.73
9	647.62	141.61
10	656.91	137.91

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11	666.35	134.62
12	675.93	131.75
13	685.63	129.31
14	695.43	127.30
15	705.30	125.74
16	715.24	124.61
17	725.21	123.92
18	735.21	123.68
19	745.21	123.88
20	755.19	124.53
21	765.13	125.62
22	775.01	127.15
23	784.82	129.11
24	794.52	131.51
25	804.11	134.34
26	813.57	137.60
27	822.87	141.26
28	832.00	145.34
29	840.94	149.82
30	849.68	154.70
31	858.18	159.95
32	866.45	165.58
33	874.45	171.57
34	882.19	177.91
35	889.63	184.59
36	896.77	191.59
37	903.59	198.91
38	910.08	206.51
39	916.23	214.40
40	922.02	222.56
41	927.44	230.96
42	932.48	239.60
43	937.13	248.45
44	941.39	257.50
45	945.24	266.73
46	948.68	276.12
47	949.68	279.30

** Corrected JANBU FOS = 1.264 ** (Fo factor = 1.117)

Failure surface No. 9 specified by 50 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	553.45	185.91
2	560.57	178.89
3	567.98	172.17
4	575.67	165.78
5	583.62	159.71
6	591.82	153.99
7	600.25	148.62
8	608.91	143.61
9	617.77	138.97
10	626.81	134.70
11	636.03	130.83
12	645.40	127.35
13	654.92	124.26
14	664.55	121.58

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15	674.29	119.31
16	684.12	117.46
17	694.01	116.02
18	703.96	115.00
19	713.94	114.40
20	723.94	114.22
21	733.94	114.47
22	743.92	115.14
23	753.86	116.23
24	763.74	117.74
25	773.55	119.66
26	783.28	122.00
27	792.89	124.74
28	802.38	127.89
29	811.73	131.44
30	820.92	135.38
31	829.94	139.71
32	838.77	144.41
33	847.39	149.48
34	855.78	154.91
35	863.94	160.69
36	871.85	166.81
37	879.49	173.26
38	886.86	180.03
39	893.93	187.10
40	900.69	194.46
41	907.14	202.10
42	913.26	210.01
43	919.04	218.17
44	924.48	226.57
45	929.55	235.19
46	934.25	244.01
47	938.57	253.03
48	942.52	262.22
49	946.06	271.57
50	948.63	279.30

** Corrected JANBU FOS = 1.264 ** (Fo factor = 1.118)

Failure surface No.10 specified by 47 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	581.03	185.21
2	588.21	178.24
3	595.70	171.61
4	603.48	165.33
5	611.54	159.42
6	619.87	153.88
7	628.44	148.72
8	637.23	143.97
9	646.24	139.62
10	655.43	135.68
11	664.80	132.17
12	674.31	129.10
13	683.96	126.46
14	693.71	124.27
15	703.56	122.52

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16	713.48	121.23
17	723.44	120.39
18	733.43	120.01
19	743.43	120.08
20	753.42	120.62
21	763.37	121.61
22	773.26	123.05
23	783.08	124.95
24	792.81	127.29
25	802.41	130.07
26	811.88	133.29
27	821.19	136.94
28	830.32	141.02
29	839.26	145.50
30	847.98	150.39
31	856.47	155.68
32	864.71	161.35
33	872.68	167.38
34	880.37	173.78
35	887.75	180.52
36	894.82	187.60
37	901.56	194.98
38	907.95	202.67
39	913.99	210.65
40	919.65	218.89
41	924.93	227.38
42	929.82	236.10
43	934.30	245.04
44	938.37	254.18
45	942.02	263.49
46	945.24	272.96
47	947.08	279.30

** Corrected JANBU FOS = 1.264 ** (Fo factor = 1.119)

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Excavated Slopes Stability Q

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	1.258	1.099	608.62	943.91	7.264E+05
2.	1.261	1.118	567.24	949.69	1.117E+06
3.	1.261	1.098	608.62	950.00	7.332E+05
4.	1.261	1.118	574.14	949.65	1.095E+06
5.	1.262	1.103	615.52	935.95	7.035E+05
6.	1.263	1.118	553.45	948.86	1.162E+06
7.	1.263	1.119	581.03	950.05	1.087E+06
8.	1.264	1.117	581.03	949.68	1.054E+06
9.	1.264	1.118	553.45	948.63	1.157E+06
10.	1.264	1.119	581.03	947.08	1.069E+06

* * * END OF FILE * * *

E-2

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602

Calculation Title: Protective Soil layer Stability

	Name	Date
Prepared By:	Paul Pellicer	Nov 3 1997
Checked By:	John Pellicer	13-Nov-97
Reviewed By:	P. Gold	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602 Sheet: 1 Of 16
Prepared By: P. Pellicer Date: Nov 3, 1997
Checked By: J. Pellicer Date: 13-Nov-97

Protective Soil Layer Stability

Objective: Determine the stability of the protective soil layer over the Geocomposite Slopes.

Assumptions:
- D6 Dozer will be used to place and operate on the slopes.
- A Dozer will not be on the slope for pseudo-static conditions.

Calculation:

Use infinite slope analysis to evaluate the stability of the protective soil cover.

Controlling strength of the slope liner system as determined by direct shear test is:
$a = 15$ psf, $\delta = 31°$ (residual strengths) (see pg 3)
(Saturated condition)

Dozer load was simulated by increasing the thickness of the protective soil

- D6 Dozer (Cat handbook see pg 4)

Track pressure = 9.8 psi = 1411 psf

equivalent soil thickness = $\frac{1411 \text{ psf}}{110 \text{ pcf}}$ = 12.8 ft.

Maximum ground acceleration = 0.04g (see pg 5+6)

Static F.S. = 2.0 (see pg. 7)

Pseudo-static F.S. = 1.8 (see pg 8)

Static F.S. w/ simulated Dozer on slope = 1.8 (see pg. 9)
XSTABL w/ surcharg equal to Doze ⇒ Static F.S. = 1.8

Conclusions: Protective Soil layer on 3H:1V side slopes should be stable. Assuming saturated strength for the side slopes is very conservative.
DOZER WILL NOT OPERATE ON SLOPES DURING RAIN STORM
THEREFORE, SATURATED CONDITIONS WERE NOT CONSIDERED.

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602-0200
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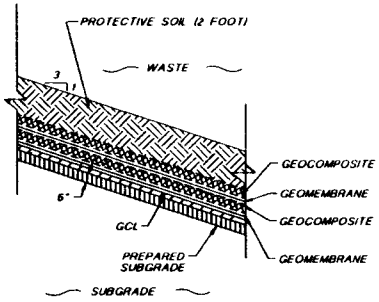
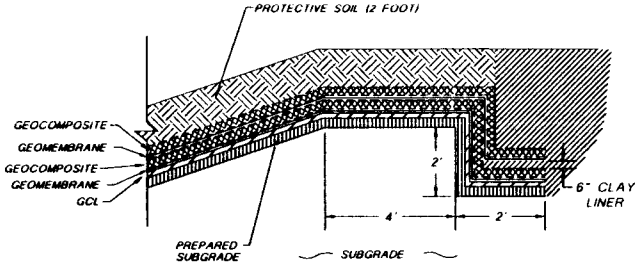
E-2



1 (7|12) SLOPE DETAIL
Not To Scale



2 (8|12) 2 (9|12) 2 (10|12) 2 (23|12) 2 (24|12) LINER ANCHOR TRENCH DETAIL
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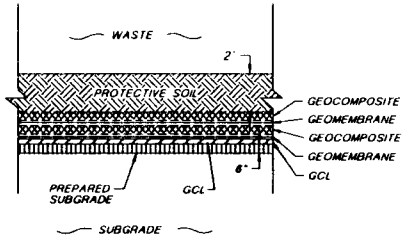
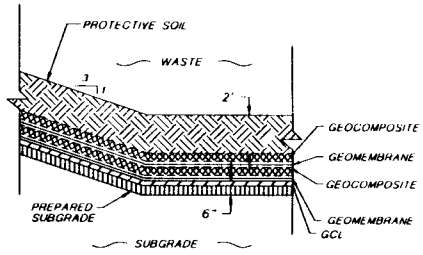
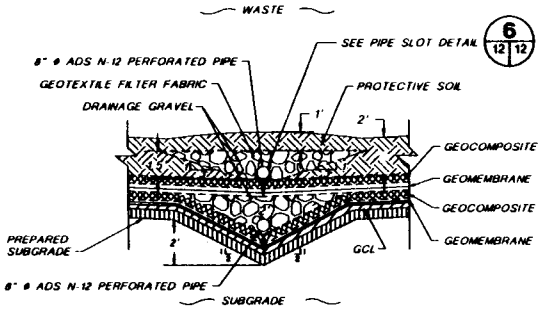


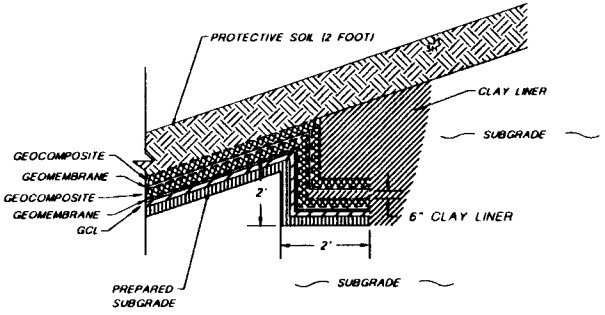
3 (7|12) 3 (24|12) FLOOR DETAIL
Not To Scale



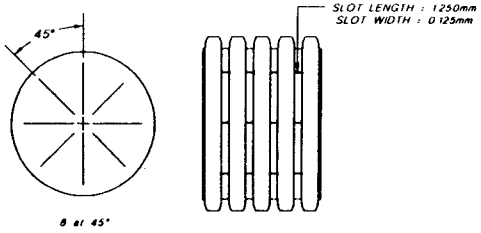
4 (7|12) TOE OF SLOPE DETAIL
Not To Scale



5 (9|12) FLOOR PIPE DETAIL
Not To Scale



6 (8|12) 6 (13|12) SLOPE ANCHOR TRENCH
Not To Scale



6 (12|12) ADS N-12 PIPE SLOT DETAIL
Not To Scale

Not For Construction

REV No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND SIGNED BY
0	PART B PERMIT APPLICATION	12/18/91	PGC/JPP	K.Carson	P.Carver

TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE:
LINER DETAILS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE: As Shown
DRAWING No: 12

PATRICK G. CARVER
NEW MEXICO
12236
REGISTERED PROFESSIONAL ENGINEER

PROFESSIONAL ENGINEER'S STATEMENT
I, Patrick G. Carver, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date *Patrick G. Carver, NM P.E. 12236*

NOTE:
FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2, "INDEX, LEGEND AND GENERAL NOTES".

K:/602/FINAL DWGS/LANDFILL
LNRDTLS.dwg
2,273,903
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GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

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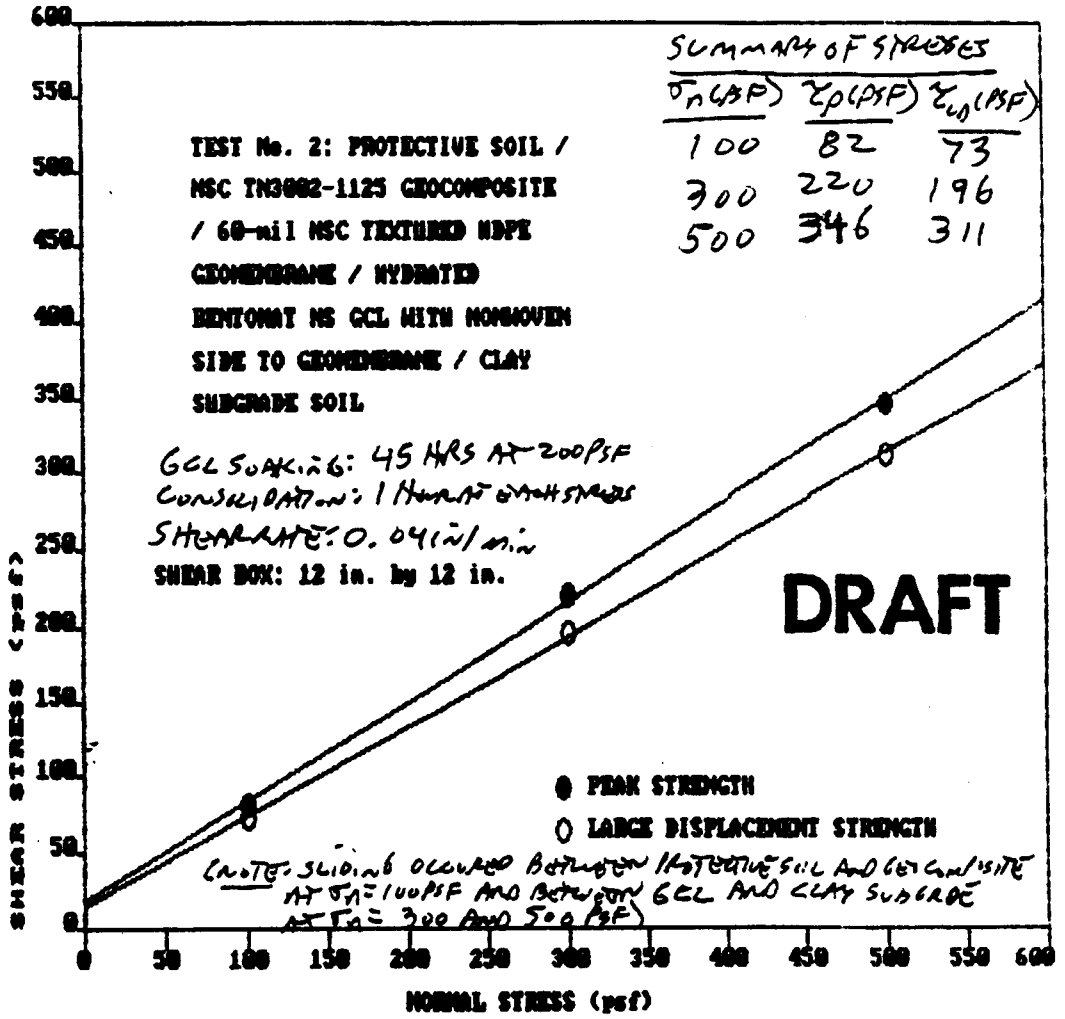
602-0200
PMP
3-Nov-97

TERRAMATRIX MONTGOMERY WATSON - ASTM D 5321 TESTS



SUMMARY OF STRESSES

σ_n (PSF)	τ_p (PSF)	τ_{LD} (PSF)
100	82	73
300	220	196
500	346	311

THE REGRESSION POLYNOMIAL OF LINE 9 - PEAK STRENGTH

(1.800E+01) + (6.600E-01)*X $a = 18$ PSF $\delta = 33°$
THE VARIANCE - 8.000E+00

THE REGRESSION POLYNOMIAL OF LINE 10 - LARGE DISPLACEMENT STRENGTH

(1.483E+01) + (5.950E-01)*X $a = 15$ PSF $\delta = 31°$
THE VARIANCE - 3.556E+00

Reviewed By: Robert H Swan Jr Date: 10-10-97

1. Trans.
D7H

/h	MPH
2.7	1.7
3.5	2.2
4.6	2.8
5.8	3.6
7.6	4.7
10.0	6.2
3.3	2.1
4.3	2.7
5.6	3.5
7.1	4.4
9.2	5.7
12.2	7.6

ted for transmission
nechanical efficiency
ents, and weight and

t Rated RPM kg	lb
16 380	37,110
12 857	28,350
9700	21,390
7433	16,390
5519	12,170
3940	8,690
Max. at Lug	
22 158	48,860
16 993	37,470
12 884	28,410
9941	21,920
7451	16,430
5392	11,890

Pressures computed from operating weights given earlier in this section in the specifications tables.

MODEL	SHOE WIDTH mm	SHOE WIDTH in.	CONTACT AREA m^2	CONTACT AREA Sq. in.	GROUND PRESSURE kPa	GROUND PRESSURE psi
D3B** ***	305	12◄	1.11	1723	59	8.6
	356	14	1.30	2010	51	7.4
	406	16*	1.48	2298	44	6.4
D3B LGP	635	25◄	2.61	4050	29	4.2
D4E** standard undercarriage	406	16◄	1.49	2304	59	8.6
	457	18	1.67	2592	52	7.6
	508	20	1.86	2880	47	6.9
D4E*** standard undercarriage	406	16◄	1.49	2304	60	8.7
	457	18	1.67	2592	53	7.7
	508	20	1.86	2880	47	6.9
D4E LGP**	762	30◄	3.37	5220	29.5	4.28
D4E LGP***	762	30◄	3.37	5220	29.7	4.31
D5B***	406	16◄	1.79	2784	67	9.8
	457	18	2.02	3132	60	8.7
	508	20	2.24	3480	54	7.8
	559	22	2.47	3828	49	7.1
D5B LGP	864	34◄	4.87	7548	30	4.3

*D3B Custom 75 standard shoe.
**Direct drive.
***Power shift.
◄Standard shoe.

NOTE: Ground contact area = width of track shoe × length of track on ground × 2.

$$\text{Ground pressure} = \frac{\text{operating weight}}{\text{ground contact area}}$$

MODEL	SHOE WIDTH mm	SHOE WIDTH in.	CONTACT AREA m^2	CONTACT AREA Sq. in.	GROUND PRESSURE kPa	GROUND PRESSURE psi
D6D***	457	18◄	2.16	3348	67	9.8
	508	20	2.40	3720	60	8.8
	559	22	2.64	4092	55	8.0
	610	24	2.88	4464	51	7.4
D6D LGP	914	36◄	5.25	8136	32	4.6
D7G***	508	20◄	2.76	4280	73	10.6
	559	22	3.04	4708	66	9.6
	610	24	3.31	5136	60	8.8
D7G LGP	864	34◄	5.26	8160	44	6.4
D7H***	508	20◄	2.94	4565	75	10.9
	559	22	3.24	5022	68	9.9
	610	24	3.53	5478	62	9.0
	660	26	3.83	5935	61	8.9
D7H LGP	914	36◄	5.82	9030	42	6.1
D8L	560	22◄	3.59	5566	101	14.7
	610	24	3.92	6072	93	13.5
	660	26	4.24	6578	86	12.5
	710	28	4.57	7084	80	11.6
D9L	610	24◄	4.32	6696	118	17.1
	686	27	4.86	7533	105	15.2
	762	30	5.40	8370	94	13.7
D10	711	28◄	5.56	8624	139	20.2
	810	32	6.36	9856	122	17.7

**Direct drive.
***Power shift.
◄Standard shoe.

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8-Nov-97

United States Department of the Interior

Geological Survey

PROBABILISTIC ESTIMATES OF MAXIMUM ACCELERATION AND VELOCITY IN ROCK IN THE CONTIGUOUS UNITED STATES

by

S. T. Algermissen, D. M. Perkins, P. C. Thenhaus,
S. L. Hanson and B. L. Bender

U.S. GEOLOGICAL SURVEY
DENVER
NOV 15 1982
LIBRARY
GEOLOGIC DIVISION

Open-File Report 82-1033

1982

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

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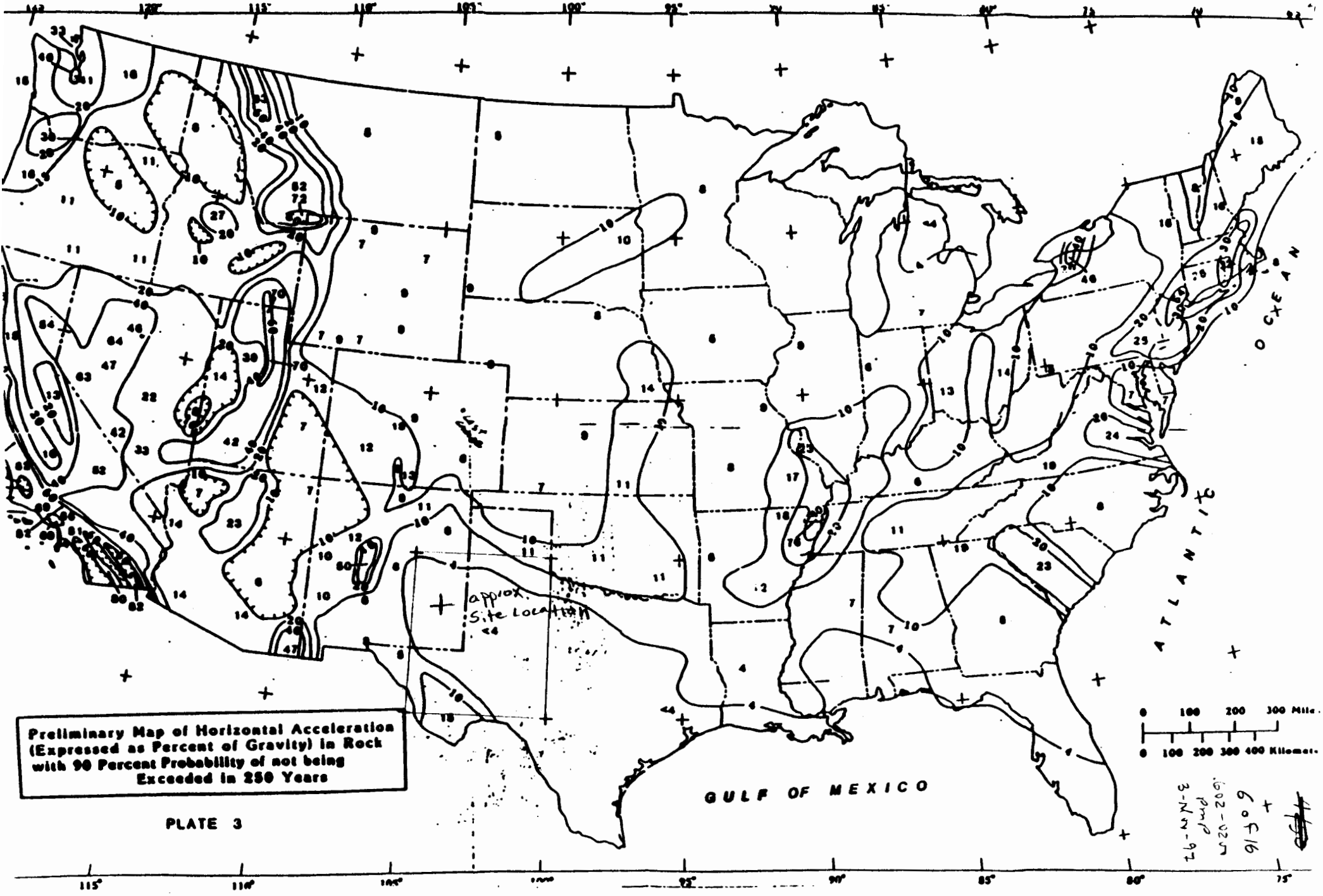
10 NOV 19



Preliminary Map of Horizontal Acceleration (Expressed as Percent of Gravity) in Rock with 90 Percent Probability of not being Exceeded in 250 Years

PLATE 3

6 of 16
602-027
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3-22-97

602-0200
3-Nov-97
PMP

Infinite slope analysis spreadsheet
Date: 03-Nov-97
By: Paul Pellicer
Filename: Protective cover stability.wq1

Soil Parameters

Cohesion:	15 psf		0.07185535
Friction Angle:	31 degrees	tangent	0.600860619
Gamma Moist:	110 pcf		

Slope Geometry:

Slope Angle:	18.4 degrees	cosine	0.948876012 sine
Failure Plane Depth:	2 ft		

Groundwater Parameters

Height of water in failure mass:	0 ft
Pore Pressure Ratio:	0 no units

Seismic Parameters

Ground Acceleration:	0 g's

Safety Factor: 2.0339

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602-0200
PMP
3-Nov-97

Infinite slope analysis spreadsheet
Date: 04-Nov-97
By: Paul Pellicer
Filename: Protective cover stability.wq1

Soil Parameters

Cohesion:	15 psf		0.07185535
Friction Angle:	31 degrees	tangent	0.600860619
Gamma Moist:	110 pcf		

Slope Geometry:

Slope Angle:	18.4 degrees	cosine	0.948876012 sine
Failure Plane Depth:	2 ft		

Groundwater Parameters

Height of water in failure mass:	0 ft
Pore Pressure Ratio:	0 no units

Seismic Parameters

Ground Acceleration:	0.04 g's

Safety Factor: 1.79413

602-0200
PMP
3-Nov-97

Infinite slope analysis spreadsheet
Date: 13-Nov-97
By: Paul Pellicer
Filename: Protective cover stability.wq1

Soil Parameters

Cohesion:	15 psf		0.009710182
Friction Angle:	31 degrees	tangent	0.600860619
Gamma Moist:	110 pcf		

Slope Geometry:

Slope Angle:	18.4 degrees	cosine	0.948876012 sine
	14.8 ft		

Groundwater Parameters

Height of water in failure mass:	0 ft
Pore Pressure Ratio:	0 no units

Seismic Parameters

Ground Acceleration:	0 g's

Safety Factor: 1.83702

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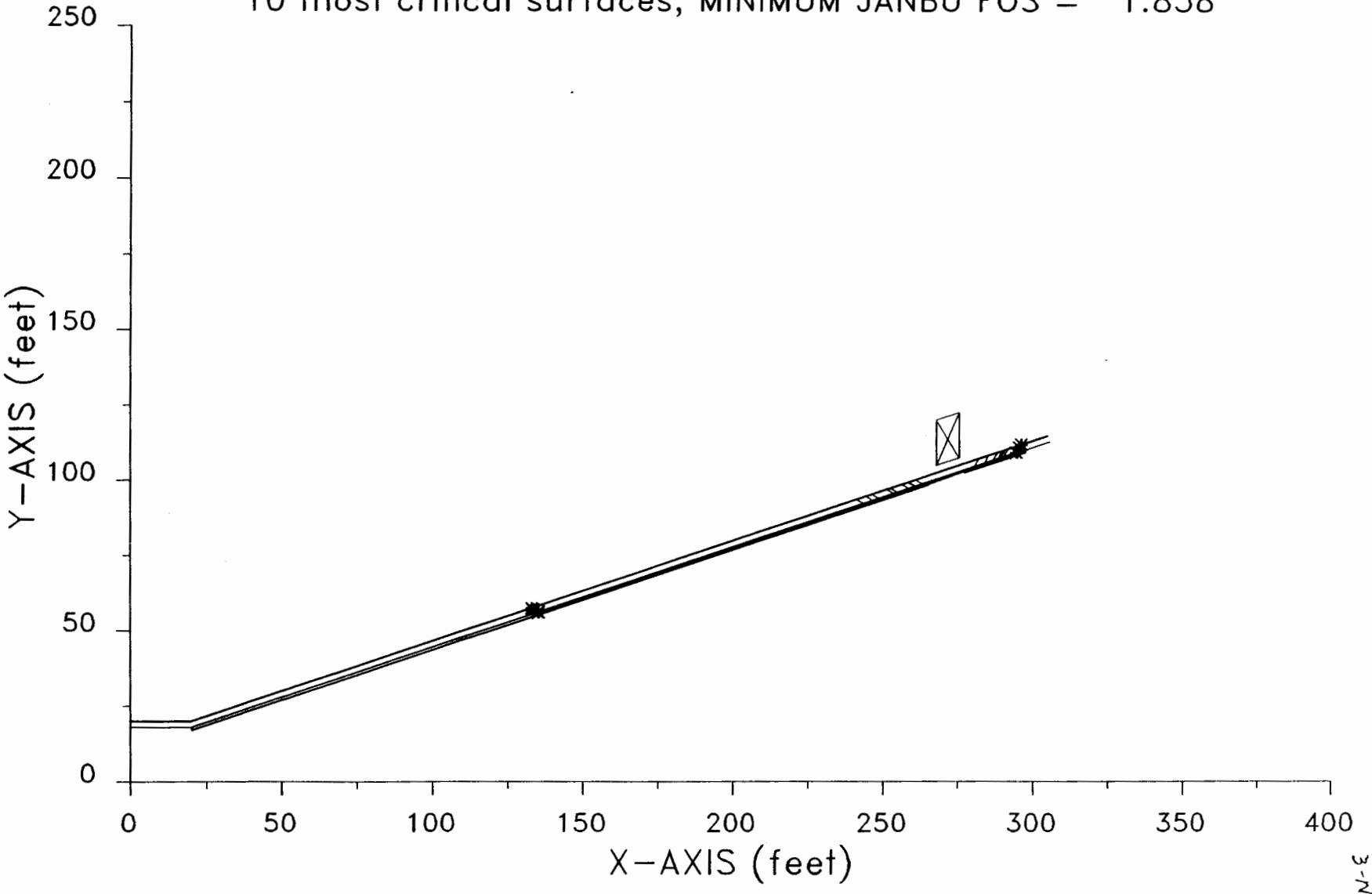
Protective soil with Dozer

10 most critical surfaces, MINIMUM JANBU FOS = 1.858



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1 of 16
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XSTABL File: GPSWD 11-13-97 12:27

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.200                96 á 1216  *
*****************************************
```

Problem Description : Protective soil with Dozer

SEGMENT BOUNDARY COORDINATES
---

2 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	20.0	20.0	20.0	1
2	20.0	20.0	304.6	114.7	1

2 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	18.0	20.3	18.0	2
2	20.3	18.0	305.3	112.8	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	15.0	31.00	.000	.0	0

BOUNDARY LOADS
---

1 load(s) specified

Load No.	x-left (ft)	x-right (ft)	Intensity (psf)	Direction (deg)
1	267.6	275.2	1411.0	.0

NOTE - Intensity is specified as a uniformly distributed force acting on a HORIZONTALLY projected surface.

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

1000 trial surfaces will be generated and analyzed.

2 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 2.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	20.3	17.5	265.1	98.9	1.0
2	277.1	102.9	297.1	109.6	1.0

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 7 coordinate points

Point No.	x-surf (ft)	y-surf (ft)

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1	132.91	57.57
2	133.48	57.24
3	135.20	56.22
4	135.24	56.20
5	294.26	109.15
6	295.28	110.87
7	295.81	111.77

** Corrected JANBU FOS = 1.858 ** (Fo factor = 1.006)

Failure surface No. 2 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	244.20	94.60
2	244.78	94.26
3	246.50	93.24
4	247.64	92.60
5	280.30	104.44
6	280.33	104.49
7	281.34	106.22
8	281.89	107.14

** Corrected JANBU FOS = 1.933 ** (Fo factor = 1.034)

Failure surface No. 3 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	260.57	100.05
2	261.15	99.70
3	262.88	98.69
4	263.43	98.38
5	283.48	105.46
6	283.53	105.56
7	284.54	107.28
8	285.09	108.21

** Corrected JANBU FOS = 1.936 ** (Fo factor = 1.042)

Failure surface No. 4 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	258.41	99.33
2	259.00	98.99
3	260.72	97.97
4	261.84	97.34
5	287.86	106.77
6	288.03	107.05
7	289.04	108.78
8	289.59	109.70

** Corrected JANBU FOS = 1.938 ** (Fo factor = 1.039)

Failure surface No. 5 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	246.20	95.27
2	246.78	94.92
3	248.50	93.91
4	249.53	93.33
5	286.38	106.43
6	286.43	106.52
7	287.44	108.25
8	287.99	109.17

** Corrected JANBU FOS = 1.948 ** (Fo factor = 1.030)

Failure surface No. 6 specified by 7 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	258.05	99.21
2	258.63	98.86
3	260.35	97.85
4	260.83	97.58
5	294.34	109.17
6	295.35	110.90
7	295.89	111.80

** Corrected JANBU FOS = 1.948 ** (Fo factor = 1.028)

Failure surface No. 7 specified by 7 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	252.35	97.31
2	252.94	96.97
3	254.66	95.96
4	254.90	95.82
5	294.15	109.11
6	295.17	110.83
7	295.70	111.74

** Corrected JANBU FOS = 1.958 ** (Fo factor = 1.023)

Failure surface No. 8 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	250.97	96.86
2	251.56	96.51
3	253.28	95.50
4	253.87	95.17

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5	289.81	107.58
6	289.85	107.66
7	290.87	109.39
8	291.41	110.31

** Corrected JANBU FOS = 1.961 ** (Fo factor = 1.027)

Failure surface No. 9 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	256.02	98.53
2	256.60	98.19
3	258.33	97.18
4	259.07	96.75
5	288.08	106.86
6	288.23	107.12
7	289.25	108.85
8	289.79	109.77

** Corrected JANBU FOS = 1.961 ** (Fo factor = 1.033)

Failure surface No.10 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	241.08	93.56
2	241.66	93.22
3	243.38	92.20
4	244.39	91.63
5	288.59	107.10
6	288.69	107.27
7	289.70	109.00
8	290.25	109.92

** Corrected JANBU FOS = 1.962 ** (Fo factor = 1.026)

The following is a summary of the TEN most critical surfaces

Problem Description : Protective soil with Dozer

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	1.858	1.006	132.91	295.81	2.809E+04
2.	1.933	1.034	244.20	281.89	1.273E+04
3.	1.936	1.042	260.57	285.09	9.955E+03
4.	1.938	1.039	258.41	289.59	1.168E+04
5.	1.948	1.030	246.20	287.99	1.340E+04
6.	1.948	1.028	258.05	295.89	1.197E+04
7.	1.958	1.023	252.35	295.70	1.256E+04

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3-Nov-97

8.	1.961	1.027	250.97	291.41	1.265E+04
9.	1.961	1.033	256.02	289.79	1.182E+04
10.	1.962	1.026	241.08	290.25	1.481E+04

* * * END OF FILE * * *

E-3

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Trassic Park

Project No. 602-0200

Calculation Title: Phase 1A Filling Plan Stability

	Name	Date
Prepared By:	P. Pellicer	7-Nov-97
Checked By:	J. Pellicer	13-Nov-97
Reviewed By:	P. [illegible]	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Phase 1a Filling Plan Stability

Objective: Evaluate the stability of the phase 1a filling plan.

Method: Use both SARMA and XSTABL Computer programs to evaluate block mode failures along the liner interface and through the waste.

Assumptions: · The Waste was assigned a typical friction angle for a relatively loose silty Sand (see pg 3) (Relative density = 25% ⇒ $\phi = 29°$)

Analysis: Two Cross Sections were cut for analysis. (See pg 7) Cross Section A-A' is Normal to the 3H:1V side slope and has the minimal Base grade (see pg 8) Cross Section B-B' is oriented to reduce a portion of the base grade even Further (See pg 9)

These Cross Sections were entered into both SARMA and XSTABL. Liner interface strengths of a = 440 psf and $\delta = 2°$ were used (see pg 4)

SARMA indicates a static F.S. = 1.51 for Section A-A' and F.S = 1.94 for Section B-B'. (see pg 10-11)

XSTABL indicates a static F.S. = 1.52 for Section A-A' and F.S. = 1.91 for Section B-B' (See pg 12-19, 26-32)

Using a ground acceleration = 0.04g (see pg 5-6) XSTABL indicates a pseudo-static F.S. = 1.01 for Section A-A' and a F.S. = 1.19 for Section B-B' (see pg 19-25, 33-39). SARMA indicates ground accelerations = 0.0411 and 0.0615 to a F.S. = 1.0 for both Sections Respectively. (see pg 10-11)

In addition to Failure along the entire liner interface XSTABL was used to search for Critical failure planes running along Part of the liner interface and up through the waste. The Most Critical failure plane found from this Search has a static

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602 Sheet: 2 Of 47
Prepared By: P. Pellicer Date: Nov 7 1997
Checked By: J. Pellicer Date: 12-Nov-97

F.S. = 1.70 and a pseudo-static F.S = 1.37. (see pg 40-55)

Sarma was used to check the critical failure surface found by XSTABL for this failure mode. A static F.S. = 1.66 and a ground acceleration = 0.09g is required to reach a pseudo-static F.S. = 1, These values correspond well w/ XSTABL. (see pg 57)

Conclusions: Statically the prase 1a filling plan has an adequate Factor of Safety. The pseudo-static factors of safety are a little low but for the short time phase 1a will be at its ultimate capacity it should be O.K.

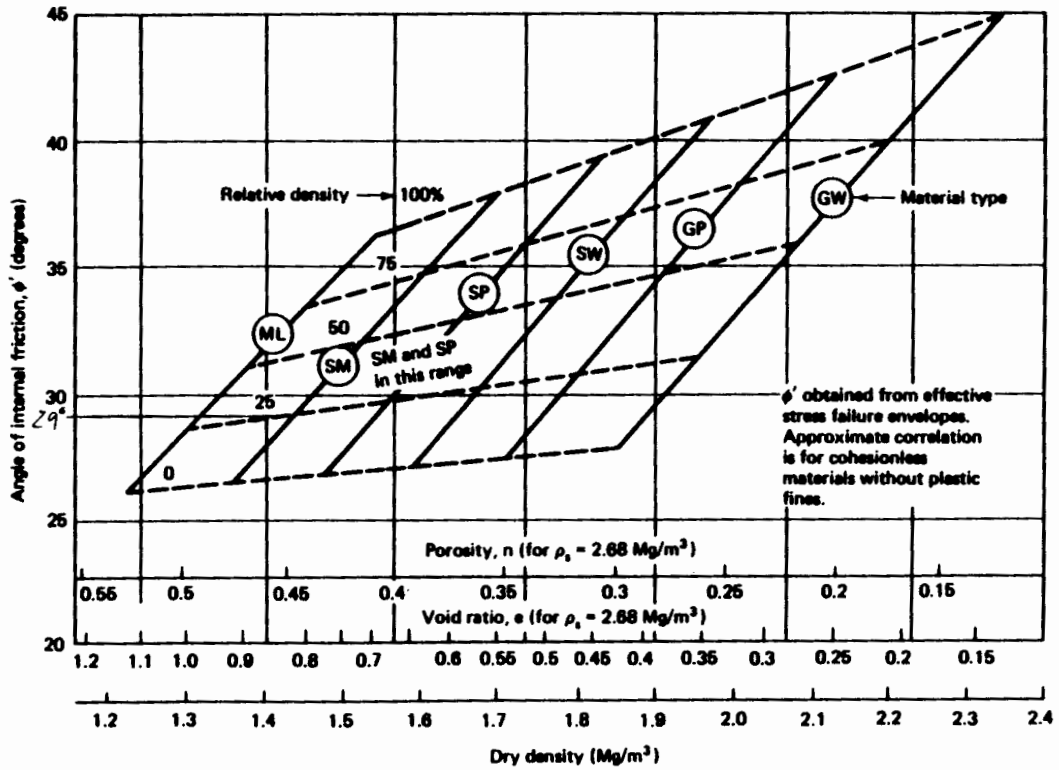

Fig. 11.13 Correlations between the effective friction angle in triaxial compression and the dry density, relative density, and soil classification

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7 Nov-97

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

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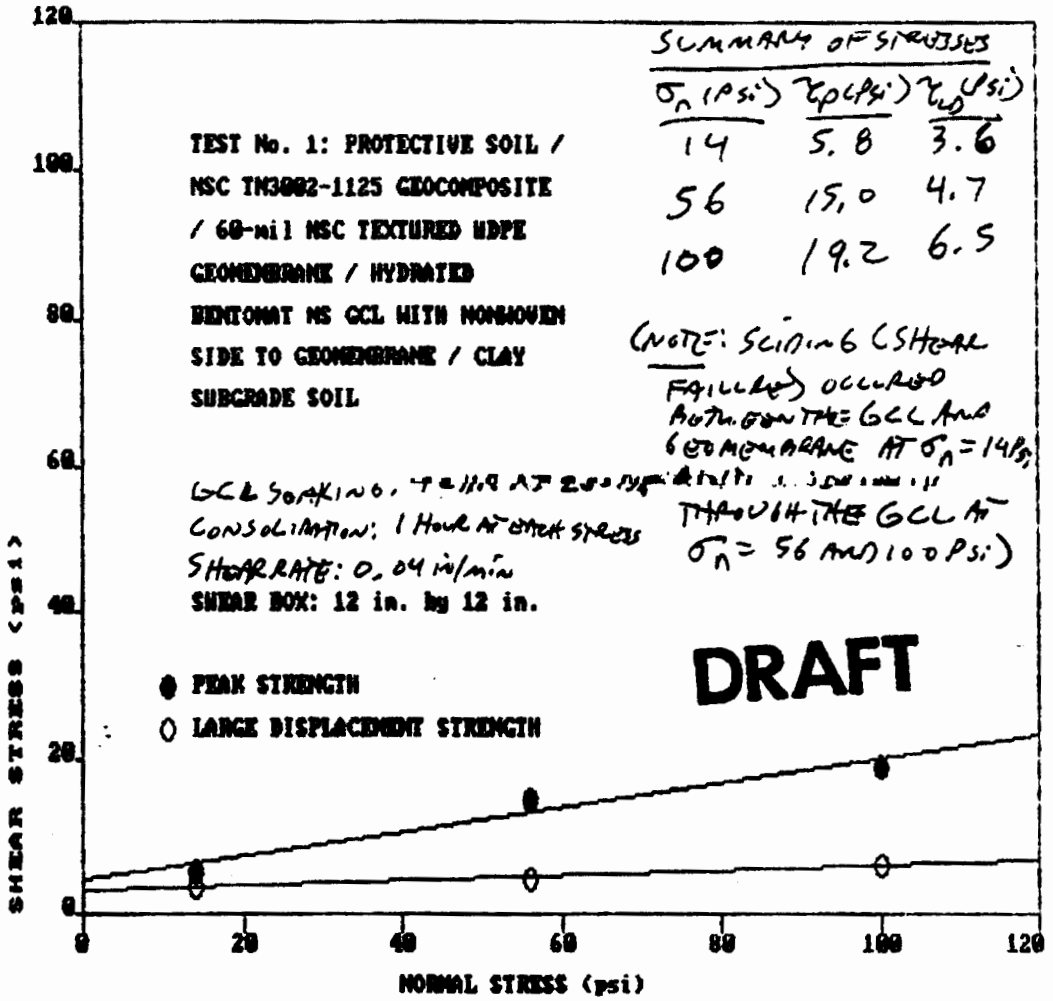
PMP
7-Nov-97

TERRAMATRIX MONTGOMERY WATSON - ASTM D 5321 TESTS



SUMMARY OF STRESSES

σ_n (psi)	τ_p (psi)	τ_{LD} (psi)
14	5.8	3.6
56	15.0	4.7
100	19.2	6.5

(NOTE: SLIPPING (SHEAR FAILURE) OCCURRED BOTH ON THE GCL AND GEOMEMBRANE AT σ_n = 14 psi; THROUGH THE GCL AT σ_n = 56 AND 100 psi)

THE REGRESSION POLYNOMIAL OF LINE 9 - PEAK STRENGTH

(4.534E+00) + (1.551E-01)*X
THE VARIANCE - 1.532E+00

a = 650 PSF δ = 9°

THE REGRESSION POLYNOMIAL OF LINE 10 - LARGE DISPLACEMENT STRENGTH

(3.045E+00) + (3.321E-02)*X
THE VARIANCE - 3.240E-02

a = 440 PSF δ = 2°

Reviewed By: Robert H. Swan Jr. Date: 10-8-97

3/50
3 1819 00069223 2
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pmp.
7-Nov-97

United States Department of the Interior

Geological Survey

PROBABILISTIC ESTIMATES OF MAXIMUM ACCELERATION AND VELOCITY IN ROCK IN THE CONTIGUOUS UNITED STATES

by

S. T. Algermissen, D. M. Perkins, P. C. Thenhaus,
S. L. Hanson and B. L. Bender

U.S. GEOLOGICAL SURVEY
DENVER
NOV 15 1982
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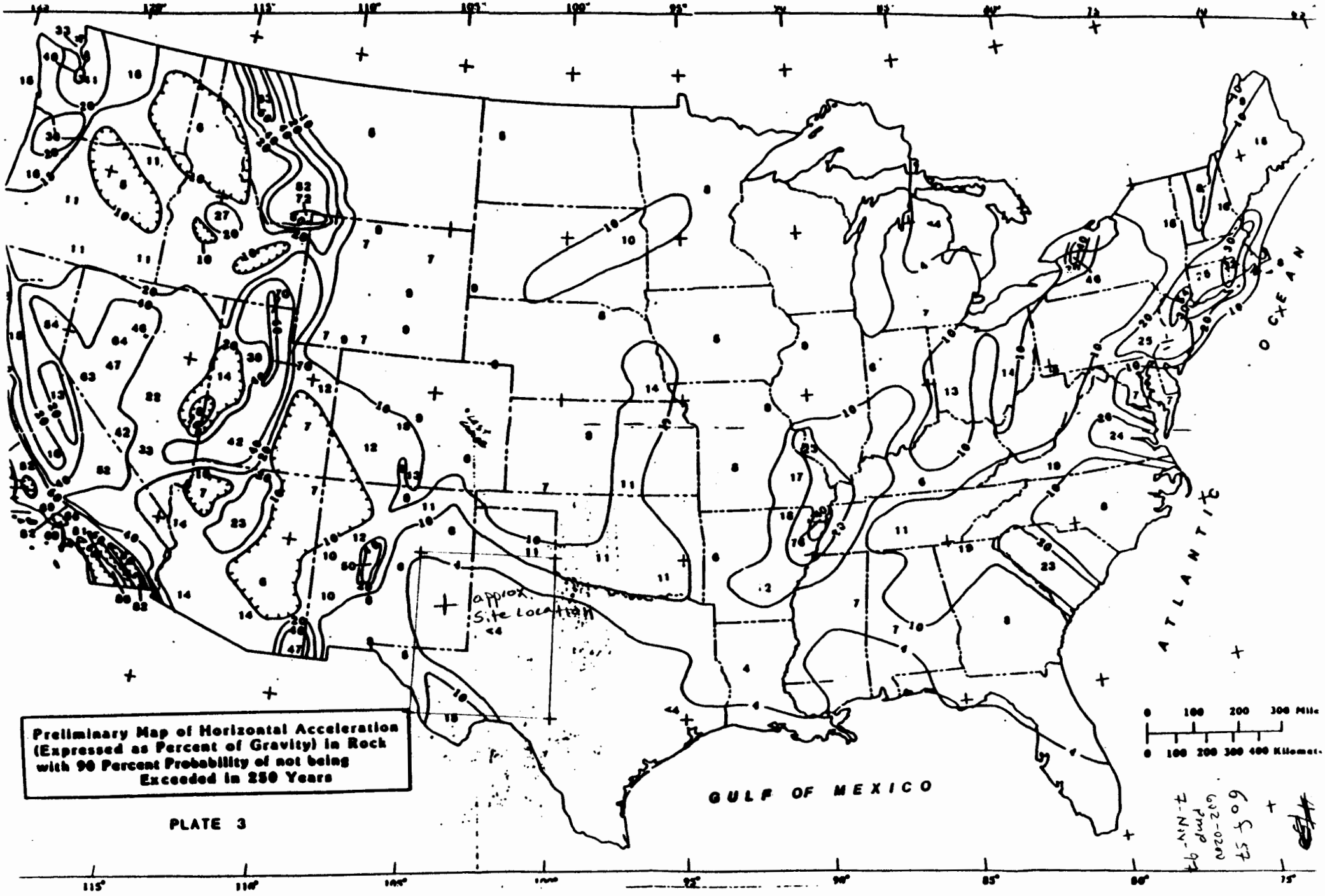
Open-File Report 82-1033

1982

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

JUL 27 1994
10 NOV 199



Preliminary Map of Horizontal Acceleration (Expressed as Percent of Gravity) in Rock with 90 Percent Probability of not being Exceeded in 250 Years

PLATE 3

4b MAY-E
Pond
0020-2009
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pwp
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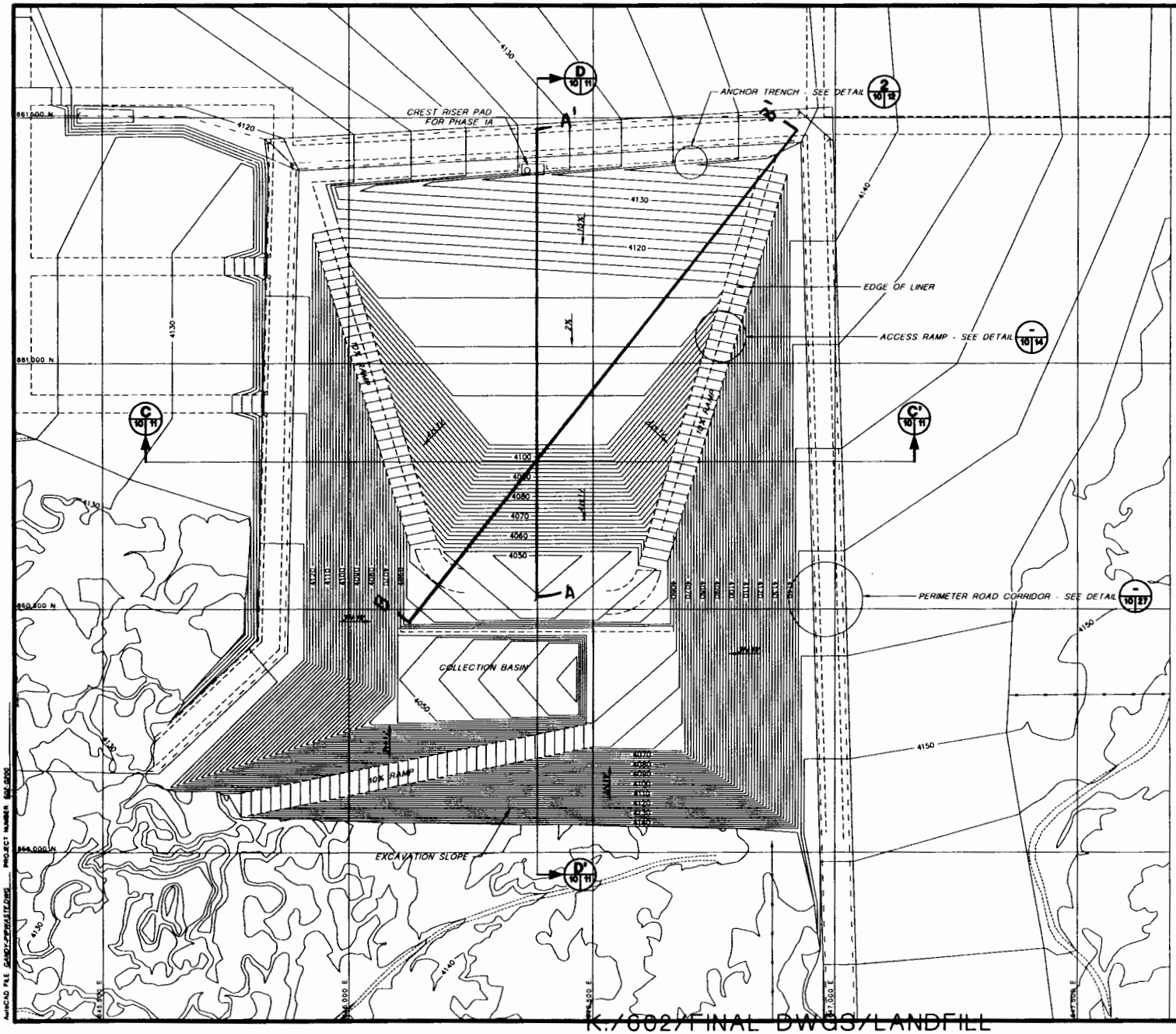
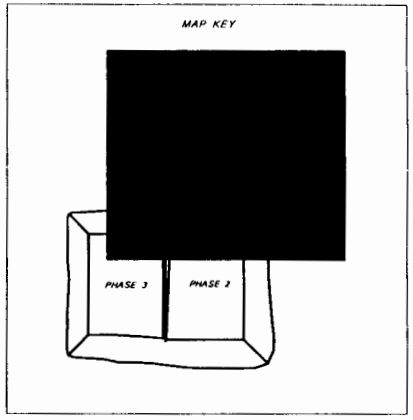
E-3





NOTES:
1. FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2, "INDEX, LEGEND AND GENERAL NOTES".
2. TOPOGRAPHY FROM AERIAL SURVEYS PERFORMED AUGUST 1997 BY KOOGLE AND POULS ENGINEERING.
3. WASTE FILL VOLUME FOR PHASE 1A: 553,200 CY

PATRICK G. CORSER NEW MEXICO 12236 REGISTERED PROFESSIONAL ENGINEER

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Corser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Corser, NM P.E. 12236

SCALE
100' 0 100' 200'
CONTOUR INTERVAL 2 FT.

Not For Construction

REV. No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	10/10/97	PBC/JPF	T.Smith	P.Corser

TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE:
FILLING PLAN - PHASE 1A

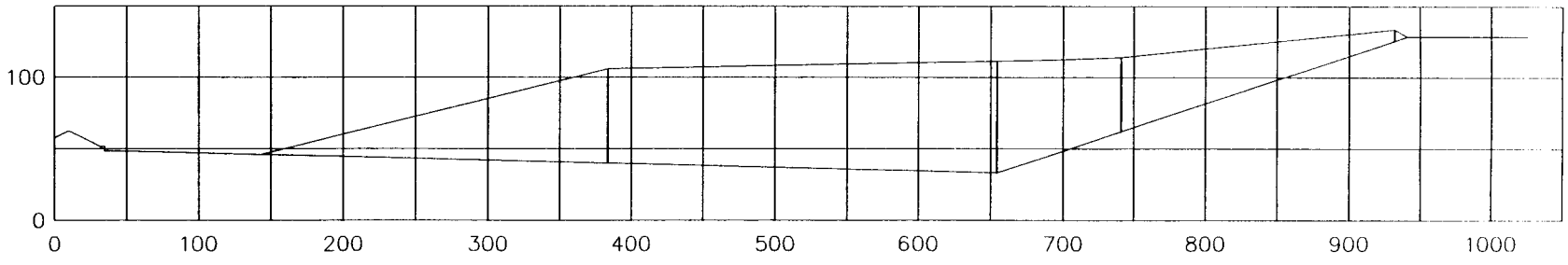
TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE: AS NOTED
DRAWING No. 10

AutoCAD FILE GANDY-P1WASTE.DWG PROJECT NUMBER 602-0200

K:/602/FINAL DWGS/LANDFILL
GANDY-P1PWASTE.dwg
2,683,081
12/09/97 12:06p

8 of 17
602-0200
pmp
7 Nov 97



Section A-A'

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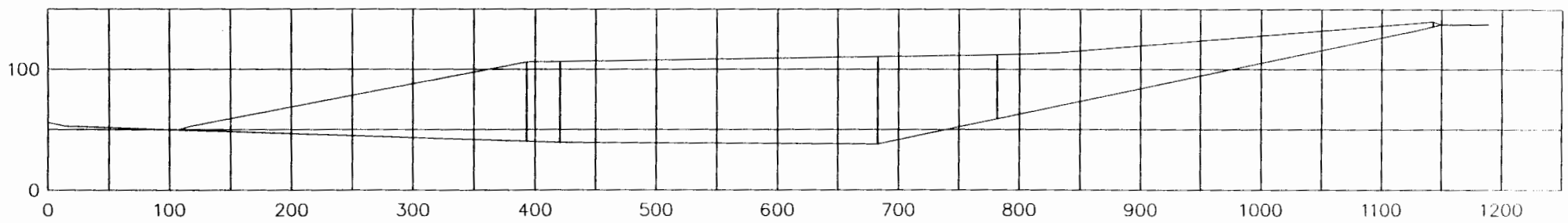

Section B - B'

602-0200
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7-Nov-97

SARMA NON-VERTICAL SLICE ANALYSIS

Analysis no. gp1a3

Unit weight of water = 62.4

Side number	1	2	3	4	5	6
Coordinate xt	143.33	383.61	654.57	741.12	931.94	941.00
Coordinate yt	45.93	106.00	111.42	114.00	133.58	128.66
Coordinate xw	143.33	383.61	654.57	741.12	931.94	941.00
Coordinate yw	45.93	39.94	38.18	62.03	125.64	128.66
Coordinate xb	143.33	383.61	654.57	741.12	931.94	941.00
Coordinate yb	45.93	39.94	38.18	62.03	125.64	128.66
Friction angle	0.00	0.00	0.00	0.00	0.00	0.00
Cohesion	0.00	0.00	0.00	0.00	0.00	0.00

Slice number	1	2	3	4	5
Rock unit weight	110.00	110.00	110.00	110.00	110.00
Friction angle	2.00	2.00	2.00	2.00	2.00
Cohesion	440.00	440.00	440.00	440.00	440.00
Force T	0.00	0.00	0.00	0.00	0.00
Angle theta	0.00	0.00	0.00	0.00	0.00

fective normal stresses

se	3642.68	7664.55	6763.00	3173.30	336.85
Side	0.00	1698.72	3453.25	2509.96	-213.70

Acceleration Kc = 0.0411 Factor of Safety = 1.51

Negative effective normal stresses - solution unacceptable

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PMP
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SARMA NON-VERTICAL SLICE ANALYSIS

Analysis no. gp1b3

Unit weight of water = 62.4

Side number	1	2	3	4	5	6
Coordinate xt	106.80	393.05	420.55	683.00	781.70	1143.00
Coordinate yt	49.76	106.00	106.42	110.48	112.00	139.79
Coordinate xw	106.80	393.05	420.55	683.00	781.70	1143.00
Coordinate yw	49.76	40.32	39.41	38.04	58.95	135.83
Coordinate xb	106.80	393.05	420.55	683.00	781.70	1143.00
Coordinate yb	49.76	40.32	39.41	38.04	58.95	135.83
Friction angle	0.00	0.00	0.00	0.00	0.00	0.00
Cohesion	0.00	0.00	0.00	0.00	0.00	0.00

Slice number	1	2	3	4	5	6
Rock unit weight	110.00	110.00	110.00	110.00	110.00	110.00
Friction angle	2.00	2.00	2.00	2.00	2.00	2.00
Cohesion	440.00	440.00	440.00	440.00	440.00	440.00
Force T	0.00	0.00	0.00	0.00	0.00	0.00
Angle theta	0.00	0.00	0.00	0.00	0.00	0.00

Effective normal stresses

Base	3622.05	7309.84	7671.66	6827.70	3075.37	158.58
Side	0.00	1796.93	2008.10	3329.17	2507.60	-295.57

Side number	7
Coordinate xt	1149.18
Coordinate yt	137.42
Coordinate xw	1149.18
Coordinate yw	137.42
Coordinate xb	1149.18
Coordinate yb	137.42
Friction angle	0.00
Cohesion	0.00

Slice number
Rock unit weight
Friction angle
Cohesion
Force T
Angle theta

Effective normal stresses
Base
Side

Acceleration Kc = 0.0615 Factor of Safety = 1.94

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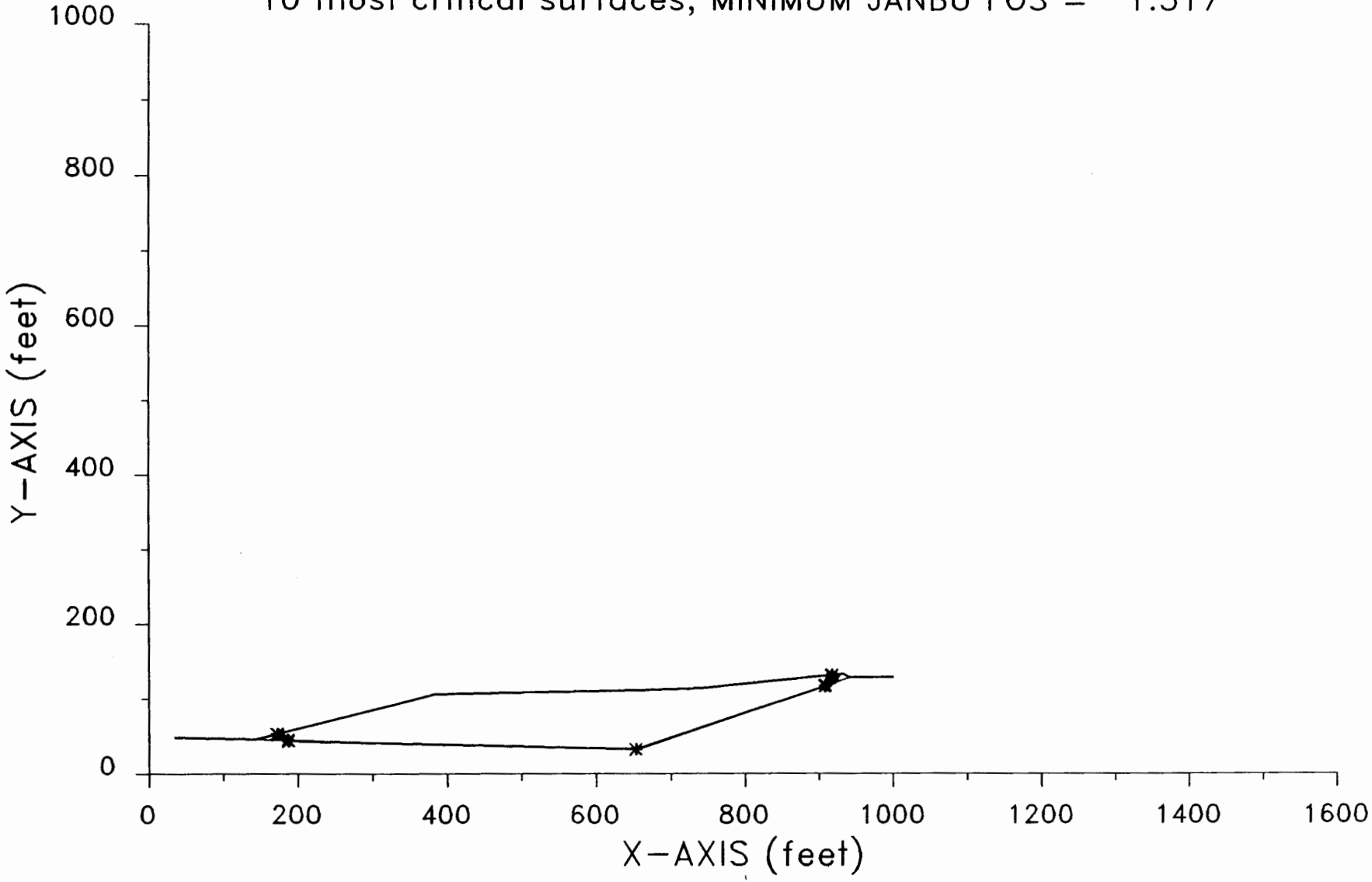
Gandy Interem Stability A-A

10 most critical surfaces, MINIMUM JANBU FOS = 1.517



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130 of 57
GB2-02rv
PMP
7-Nov-97

XSTABL File: GB1XA 11-08-97 19:59

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.200                 96 á 1216 *
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```

Problem Description : Gandy Interem Stability A-A

SEGMENT BOUNDARY COORDINATES
---

7 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	34.9	48.6	143.3	45.9	2
2	143.3	45.9	383.6	106.0	1
3	383.6	106.0	654.6	111.4	1
4	654.6	111.4	741.1	114.0	1
5	741.1	114.0	931.9	133.6	1
6	931.9	133.6	941.0	128.7	1
7	941.0	128.7	1000.0	128.7	2

5 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	143.3	45.9	383.6	39.9	2
2	383.6	39.9	654.6	33.2	2
3	654.6	33.2	741.1	62.3	2
4	741.1	62.3	931.9	125.6	2
5	931.9	125.6	941.0	128.7	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

500 trial surfaces will be generated and analyzed.

3 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 15.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	183.3	44.4	233.3	43.2	1.0
2	629.6	33.3	655.6	32.7	1.0
3	901.0	114.8	921.0	121.5	1.0

****
ERROR # 38
****
The program calculated a point for the PASSIVE wedge that is outside the defined slope geometry. The analysis will continue, but the user should adjust the search box or slope geometry to allow a passive wedge to be formed from all points within first box.
****

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 9 coordinate points

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Point No.	x-surf (ft)	y-surf (ft)
1	172.64	53.24
2	174.02	52.42
3	186.94	44.81
4	187.88	43.90
5	653.42	32.65
6	907.06	116.52
7	908.25	117.75
8	915.86	130.68
9	916.66	132.03

** Corrected JANBU FOS = 1.517 ** (Fo factor = 1.041)

Failure surface No. 2 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	170.78	52.77
2	171.25	52.49
3	184.18	44.88
4	184.80	44.28
5	653.27	32.68
6	914.72	119.17
7	915.76	120.25
8	923.09	132.70

** Corrected JANBU FOS = 1.522 ** (Fo factor = 1.041)

Failure surface No. 3 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	171.03	52.83
2	171.62	52.48
3	184.55	44.87
4	184.73	44.69
5	653.09	32.42
6	907.80	116.58
7	909.25	118.09
8	916.87	131.01
9	917.52	132.12

** Corrected JANBU FOS = 1.525 ** (Fo factor = 1.041)

Failure surface No. 4 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	173.73	53.51
2	175.64	52.38
3	188.56	44.77
4	189.16	44.19

5	654.16	32.79
6	901.02	115.16
7	901.30	115.45
8	908.91	128.37
9	910.71	131.42

** Corrected JANBU FOS = 1.526 ** (Fo factor = 1.042)

Failure surface No. 5 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	178.23	54.64
2	182.34	52.22
3	195.26	44.60
4	196.29	43.61
5	655.27	32.26
6	919.87	120.86
7	920.93	121.96
8	927.52	133.15

** Corrected JANBU FOS = 1.527 ** (Fo factor = 1.041)

Failure surface No. 6 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	175.08	53.85
2	177.66	52.33
3	190.58	44.72
4	190.99	44.32
5	653.67	32.25
6	912.86	118.52
7	913.94	119.64
8	921.54	132.54

** Corrected JANBU FOS = 1.528 ** (Fo factor = 1.041)

Failure surface No. 7 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	178.53	54.71
2	182.79	52.20
3	195.71	44.59
4	196.60	43.73
5	655.22	32.88
6	919.66	120.91
7	920.56	121.84
8	927.21	133.12

** Corrected JANBU FOS = 1.532 ** (Fo factor = 1.041)

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Failure surface No. 8 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	175.03	53.83
2	177.57	52.33
3	190.50	44.72
4	190.62	44.60
5	652.68	32.35
6	904.82	116.37
7	905.17	116.73
8	912.79	129.66
9	914.03	131.76

** Corrected JANBU FOS = 1.534 ** (Fo factor = 1.042)

Failure surface No. 9 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	177.45	54.44
2	181.18	52.24
3	194.11	44.63
4	194.55	44.21
5	652.41	32.30
6	916.17	120.03
7	916.67	120.55
8	923.88	132.78

** Corrected JANBU FOS = 1.535 ** (Fo factor = 1.041)

Failure surface No.10 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	175.78	54.02
2	178.69	52.31
3	191.62	44.69
4	191.80	44.51
5	653.15	32.60
6	918.41	120.18
7	919.75	121.57
8	926.51	133.05

** Corrected JANBU FOS = 1.536 ** (Fo factor = 1.041)

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Interem Stability A-A

Modified	Correction	Initial	Terminal	Available

602-0244
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7-Nov-92

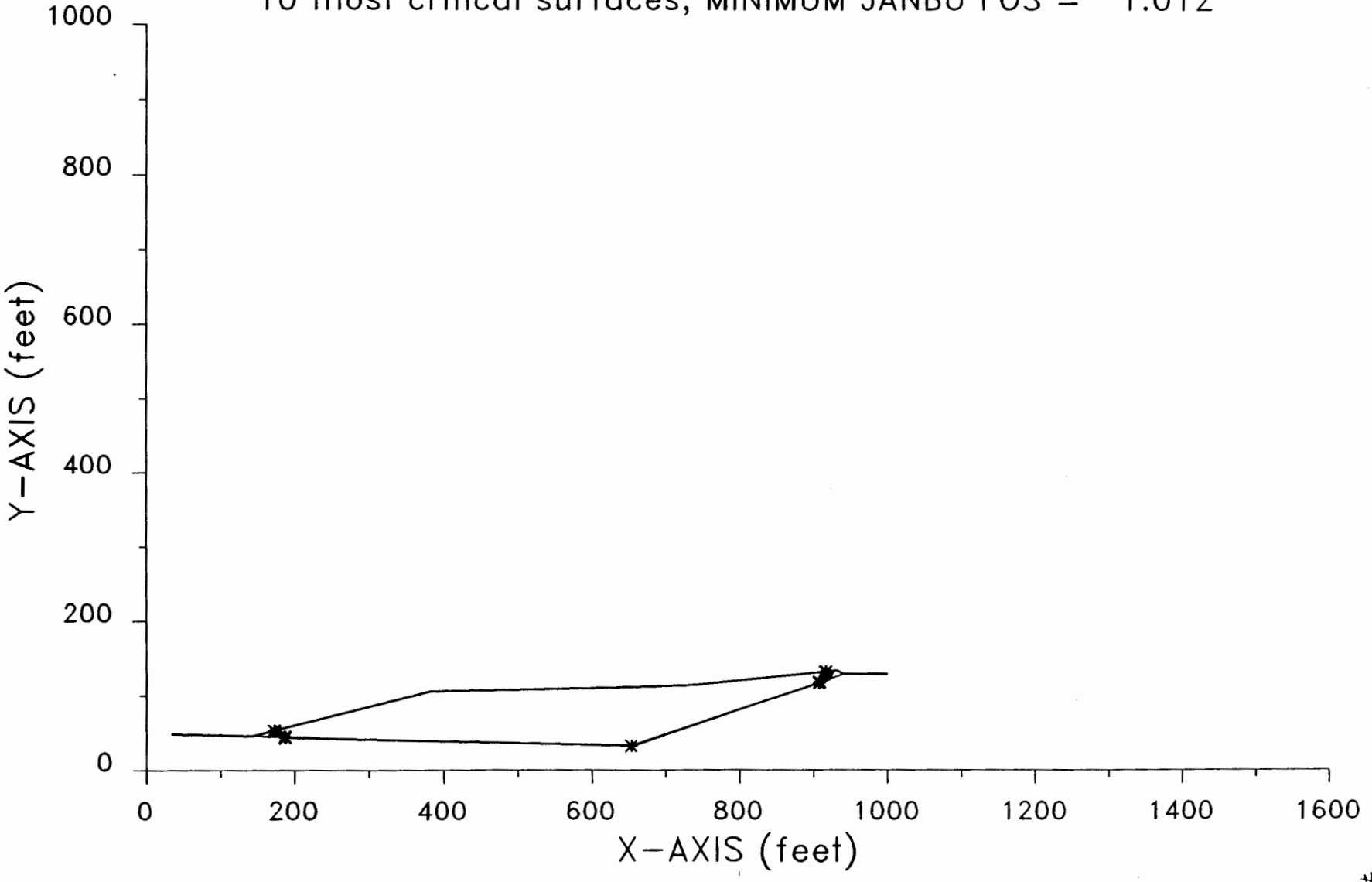
	JANBU FOS	Factor	x-coord (ft)	x-coord (ft)	Strength (lb)
1.	1.517	1.041	172.64	916.66	4.860E+05
2.	1.522	1.041	170.78	923.09	4.888E+05
3.	1.525	1.041	171.03	917.52	4.864E+05
4.	1.526	1.042	173.73	910.71	4.824E+05
5.	1.527	1.041	178.23	927.52	4.910E+05
6.	1.528	1.041	175.08	921.54	4.878E+05
7.	1.532	1.041	178.53	927.21	4.896E+05
8.	1.534	1.042	175.03	914.03	4.836E+05
9.	1.535	1.041	177.45	923.88	4.880E+05
10.	1.536	1.041	175.78	926.51	4.892E+05

* * * END OF FILE * * *

GbiXAQ 11-08-97 20:00

Gandy Interem Stability A-A Q

10 most critical surfaces, MINIMUM JANBU FOS = 1.012



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GOZ-020
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7-NOV-97

2 of 57
602-0200
pmp
7-Nov-97

XSTABL File: GB1XAQ 11-08-97 20:00

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.200                 96 á 1216 *
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Problem Description : Gandy Interem Stability A-A Q

SEGMENT BOUNDARY COORDINATES
---

7 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	34.9	48.6	143.3	45.9	2
2	143.3	45.9	383.6	106.0	1
3	383.6	106.0	654.6	111.4	1
4	654.6	111.4	741.1	114.0	1
5	741.1	114.0	931.9	133.6	1
6	931.9	133.6	941.0	128.7	1
7	941.0	128.7	1000.0	128.7	2

5 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	143.3	45.9	383.6	39.9	2
2	383.6	39.9	654.6	33.2	2
3	654.6	33.2	741.1	62.3	2
4	741.1	62.3	931.9	125.6	2
5	931.9	125.6	941.0	128.7	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

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GRZ-02W
PMP

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A horizontal earthquake loading coefficient
of .040 has been assigned

A vertical earthquake loading coefficient
of .000 has been assigned

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

500 trial surfaces will be generated and analyzed.

3 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 15.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	183.3	44.4	233.3	43.2	1.0
2	629.6	33.3	655.6	32.7	1.0
3	901.0	114.8	921.0	121.5	1.0

****
ERROR # 38
****
The program calculated a point for the PASSIVE wedge that is outside the defined slope geometry. The analysis will continue, but the user should adjust the search box or slope geometry to allow a passive wedge to be formed from all points within first box.
****

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	172.64	53.24
2	174.02	52.42
3	186.94	44.81
4	187.88	43.90
5	653.42	32.65
6	907.06	116.52
7	908.25	117.75
8	915.86	130.68
9	916.66	132.03

** Corrected JANBU FOS = 1.012 ** (Fo factor = 1.041)

Failure surface No. 2 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	170.78	52.77
2	171.25	52.49
3	184.18	44.88
4	184.80	44.28
5	653.27	32.68
6	914.72	119.17
7	915.76	120.25
8	923.09	132.70

** Corrected JANBU FOS = 1.015 ** (Fo factor = 1.041)

Failure surface No. 3 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	171.03	52.83
2	171.62	52.48
3	184.55	44.87
4	184.73	44.69
5	653.09	32.42
6	907.80	116.58
7	909.25	118.09
8	916.87	131.01
9	917.52	132.12

** Corrected JANBU FOS = 1.015 ** (Fo factor = 1.041)

Failure surface No. 4 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	173.73	53.51
2	175.64	52.38
3	188.56	44.77
4	189.16	44.19
5	654.16	32.79
6	901.02	115.16
7	901.30	115.45
8	908.91	128.37
9	910.71	131.42

** Corrected JANBU FOS = 1.016 ** (Fo factor = 1.042)

Failure surface No. 5 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	175.08	53.85
2	177.66	52.33
3	190.58	44.72
4	190.99	44.32
5	653.67	32.25
6	912.86	118.52
7	913.94	119.64
8	921.54	132.54

** Corrected JANBU FOS = 1.018 ** (Fo factor = 1.041)

Failure surface No. 6 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	178.23	54.64
2	182.34	52.22
3	195.26	44.60
4	196.29	43.61
5	655.27	32.26
6	919.87	120.86
7	920.93	121.96
8	927.52	133.15

** Corrected JANBU FOS = 1.019 ** (Fo factor = 1.041)

Failure surface No. 7 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	175.03	53.83
2	177.57	52.33
3	190.50	44.72
4	190.62	44.60

5	652.68	32.35
6	904.82	116.37
7	905.17	116.73
8	912.79	129.66
9	914.03	131.76

** Corrected JANBU FOS = 1.020 ** (Fo factor = 1.042)

Failure surface No. 8 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	178.53	54.71
2	182.79	52.20
3	195.71	44.59
4	196.60	43.73
5	655.22	32.88
6	919.66	120.91
7	920.56	121.84
8	927.21	133.12

** Corrected JANBU FOS = 1.023 ** (Fo factor = 1.041)

Failure surface No. 9 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	177.45	54.44
2	181.18	52.24
3	194.11	44.63
4	194.55	44.21
5	652.41	32.30
6	916.17	120.03
7	916.67	120.55
8	923.88	132.78

** Corrected JANBU FOS = 1.023 ** (Fo factor = 1.041)

Failure surface No.10 specified by 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	175.78	54.02
2	178.69	52.31
3	191.62	44.69
4	191.80	44.51
5	653.15	32.60
6	918.41	120.18
7	919.75	121.57
8	926.51	133.05

** Corrected JANBU FOS = 1.023 ** (Fo factor = 1.041)

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Interem Stability A-A Q

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	1.012	1.041	172.64	916.66	4.861E+05
2.	1.015	1.041	170.78	923.09	4.889E+05
3.	1.015	1.041	171.03	917.52	4.863E+05
4.	1.016	1.042	173.73	910.71	4.824E+05
5.	1.018	1.041	175.08	921.54	4.883E+05
6.	1.019	1.041	178.23	927.52	4.919E+05
7.	1.020	1.042	175.03	914.03	4.839E+05
8.	1.023	1.041	178.53	927.21	4.905E+05
9.	1.023	1.041	177.45	923.88	4.888E+05
10.	1.023	1.041	175.78	926.51	4.898E+05

* * * END OF FILE * * *

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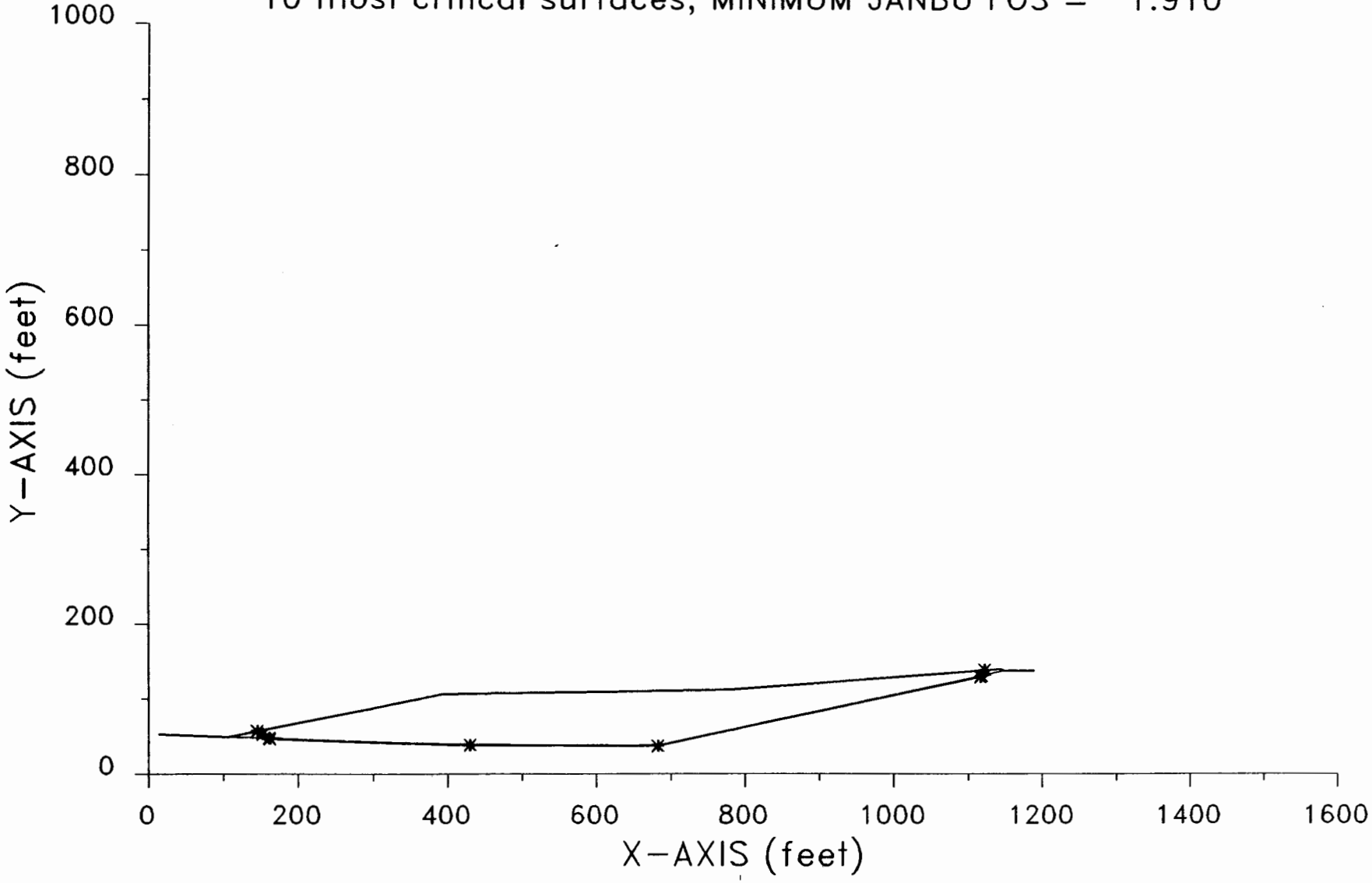
Gandy Interem Stability BB

10 most critical surfaces, MINIMUM JANBU FOS = 1.910



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26 of 57

220457
612-0200
PMP
7-Nov-97

XSTABL File: GB1BB 11-08-97 20:15

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
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*          All Rights Reserved          *
*                                       *
*  Ver. 5.200                96 á 1216  *
*****************************************
```

Problem Description : Gandy Interem Stability BB

SEGMENT BOUNDARY COORDINATES
---

6 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	14.0	52.8	106.8	49.8	2
2	106.8	49.8	393.0	106.0	1
3	393.0	106.0	781.7	112.0	1
4	781.7	112.0	1143.0	139.8	1
5	1143.0	139.8	1149.2	137.4	1
6	1149.2	137.4	1189.0	137.4	2

3 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	106.8	49.8	420.5	39.4	2
2	420.5	39.4	683.0	38.0	2
3	683.0	38.0	1149.2	137.4	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit	Unit Weight Moist	Unit Weight Sat.	Cohesion Intercept	Friction Angle	Pore Pressure Parameter	Pore Pressure Constant	Water Surface

7-Nov-97 28.557 612-12W No. pmp

No.	(pcf)	(pcf)	(psf)	(deg)	Ru	(psf)	No.
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

500 trial surfaces will be generated and analyzed.

4 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 10.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	156.8	47.6	176.8	46.8	1.0
2	410.5	39.2	430.5	38.8	1.0
3	658.0	37.6	684.0	37.5	1.0
4	1109.2	127.8	1129.2	132.0	1.0

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	145.07	57.31
2	152.25	53.08
3	160.87	48.01
4	161.99	46.92
5	430.24	38.35
6	682.53	37.25
7	1116.21	129.27
8	1117.54	130.65
9	1121.98	138.18

** Corrected JANBU FOS = 1.910 ** (Fo factor = 1.030)

Failure surface No. 2 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	141.58	56.63
2	147.33	53.25
3	155.94	48.17
4	156.96	47.19
5	426.92	38.80
6	683.31	37.37
7	1116.29	129.28
8	1117.63	130.67
9	1122.06	138.19

** Corrected JANBU FOS = 1.911 ** (Fo factor = 1.030)

Failure surface No. 3 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	143.53	57.01
2	150.08	53.15
3	158.70	48.08
4	159.65	47.16
5	427.60	38.77
6	681.59	37.26
7	1112.97	128.37
8	1114.56	130.01
9	1119.25	137.97

** Corrected JANBU FOS = 1.911 ** (Fo factor = 1.030)

Failure surface No. 4 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	145.88	57.47
2	153.40	53.04
3	162.02	47.97
4	163.11	46.92
5	424.25	38.50
6	682.82	37.91
7	1115.99	129.21
8	1117.35	130.61
9	1121.80	138.17

** Corrected JANBU FOS = 1.912 ** (Fo factor = 1.030)

Failure surface No. 5 specified by 10 coordinate points

Point	x-surf	y-surf

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No.	(ft)	(ft)
1	149.47	58.18
2	149.85	57.95
3	158.47	52.88
4	167.08	47.80
5	168.02	46.89
6	412.94	38.75
7	681.70	37.14
8	1112.24	128.16
9	1113.90	129.87
10	1118.64	137.93

** Corrected JANBU FOS = 1.912 ** (Fo factor = 1.030)

Failure surface No. 6 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	145.73	57.44
2	153.18	53.05
3	161.80	47.98
4	162.66	47.14
5	428.62	38.75
6	680.32	37.17
7	1109.99	127.54
8	1111.81	129.43
9	1116.73	137.78

** Corrected JANBU FOS = 1.912 ** (Fo factor = 1.030)

Failure surface No. 7 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	143.27	56.96
2	149.70	53.17
3	158.32	48.09
4	159.27	47.18
5	423.37	38.54
6	682.65	37.43
7	1121.04	130.15
8	1122.56	131.72
9	1126.58	138.54

** Corrected JANBU FOS = 1.913 ** (Fo factor = 1.030)

Failure surface No. 8 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	142.05	56.72
2	147.99	53.22
3	156.60	48.15

4	157.59	47.19
5	423.03	38.57
6	683.93	37.51
7	1123.36	130.78
8	1124.71	132.18
9	1128.54	138.69

** Corrected JANBU FOS = 1.913 ** (Fo factor = 1.029)

Failure surface No. 9 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	142.78	56.87
2	149.02	53.19
3	157.64	48.11
4	158.60	47.19
5	423.37	38.56
6	683.51	37.47
7	1122.37	130.51
8	1123.79	131.98
9	1127.70	138.62

** Corrected JANBU FOS = 1.914 ** (Fo factor = 1.029)

Failure surface No.10 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	144.73	57.25
2	151.77	53.10
3	160.39	48.02
4	161.28	47.16
5	424.05	38.53
6	681.79	37.36
7	1119.05	129.60
8	1120.72	131.33
9	1124.89	138.41

** Corrected JANBU FOS = 1.914 ** (Fo factor = 1.030)

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Interem Stability BB

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	1.910	1.030	145.07	1121.98	6.139E+05
2.	1.911	1.030	141.58	1122.06	6.144E+05
3.	1.911	1.030	143.53	1119.25	6.126E+05

4.	1.912	1.030	145.88	1121.80	6.127E+05
5.	1.912	1.030	149.47	1118.64	6.114E+05
6.	1.912	1.030	145.73	1116.73	6.108E+05
7.	1.913	1.030	143.27	1126.58	6.163E+05
8.	1.913	1.029	142.05	1128.54	6.176E+05
9.	1.914	1.029	142.78	1127.70	6.170E+05
10.	1.914	1.030	144.73	1124.89	6.151E+05

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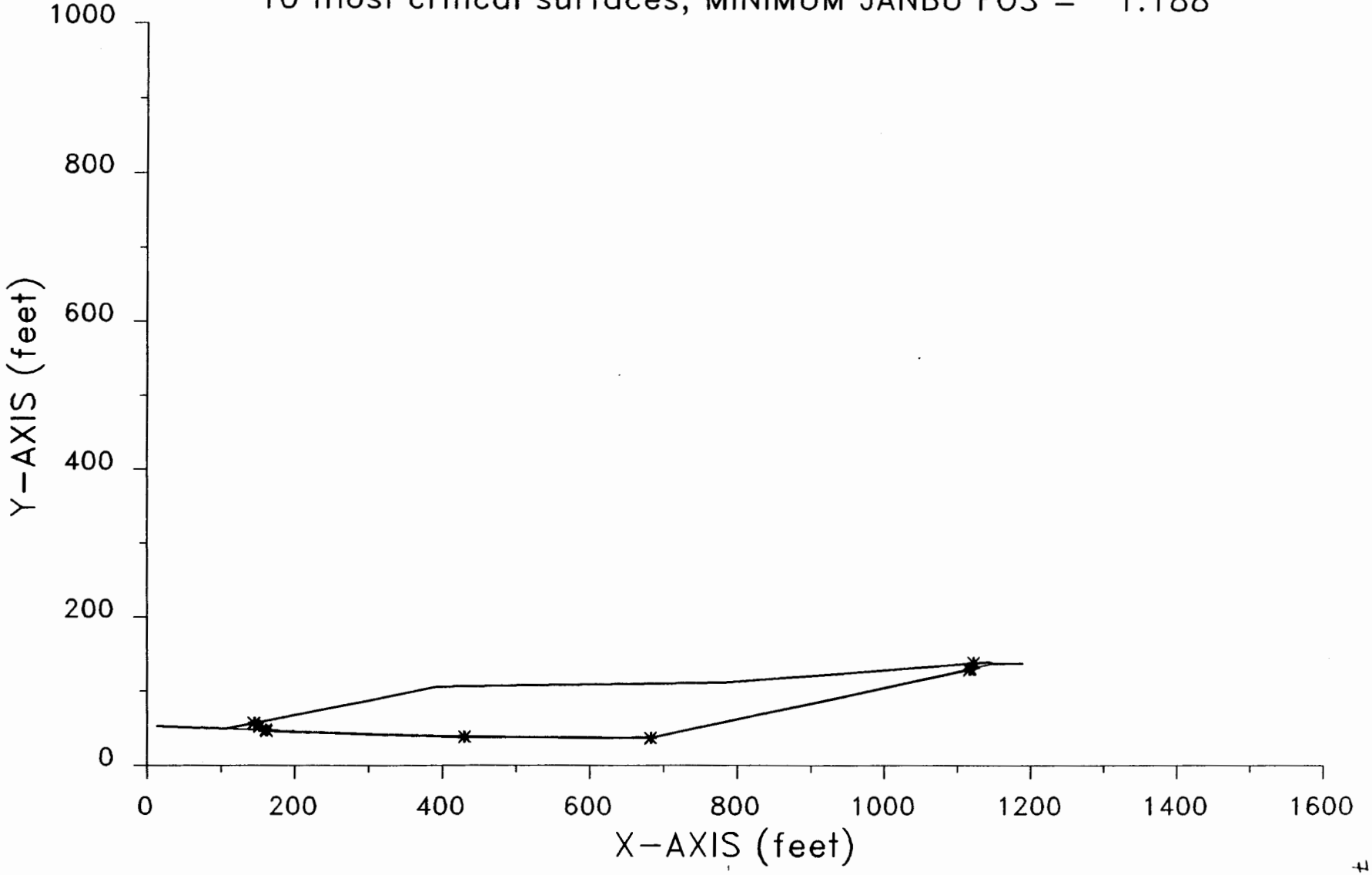
Gandy Interem Stability BB Q

10 most critical surfaces, MINIMUM JANBU FOS = 1.188



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0020-209
33 of 53

602-0200
PMP
7-Nov-97

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*****************************************
*              X S T A B L              *
*                                       *
*       Slope Stability Analysis        *
*              using the                *
*           Method of Slices            *
*                                       *
*        Copyright (C) 1992 á 96        *
*   Interactive Software Designs, Inc.  *
*       Moscow, ID 83843, U.S.A.        *
*                                       *
*         All Rights Reserved           *
*                                       *
*  Ver. 5.200                96 á 1216  *
*****************************************
```

Problem Description : Gandy Interem Stability BB Q

SEGMENT BOUNDARY COORDINATES
---

6 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	14.0	52.8	106.8	49.8	2
2	106.8	49.8	393.0	106.0	1
3	393.0	106.0	781.7	112.0	1
4	781.7	112.0	1143.0	139.8	1
5	1143.0	139.8	1149.2	137.4	1
6	1149.2	137.4	1189.0	137.4	2

3 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	106.8	49.8	420.5	39.4	2
2	420.5	39.4	683.0	38.0	2
3	683.0	38.0	1149.2	137.4	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit	Unit Weight Moist	Unit Weight Sat.	Cohesion Intercept	Friction Angle	Pore Pressure Parameter	Pore Pressure Constant	Water Surface

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GRZ-02W
No. PMP
7-Nov-97

No.	(pcf)	(pcf)	(psf)	(deg)	Ru	(psf)	
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A horizontal earthquake loading coefficient
of .040 has been assigned

A vertical earthquake loading coefficient
of .000 has been assigned

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

500 trial surfaces will be generated and analyzed.

4 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 10.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	156.8	47.6	176.8	46.8	1.0
2	410.5	39.2	430.5	38.8	1.0
3	658.0	37.6	684.0	37.5	1.0
4	1109.2	127.8	1129.2	132.0	1.0

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	145.07	57.31
2	152.25	53.08

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3	160.87	48.01
4	161.99	46.92
5	430.24	38.35
6	682.53	37.25
7	1116.21	129.27
8	1117.54	130.65
9	1121.98	138.18

** Corrected JANBU FOS = 1.188 ** (Fo factor = 1.030)

Failure surface No. 2 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	143.53	57.01
2	150.08	53.15
3	158.70	48.08
4	159.65	47.16
5	427.60	38.77
6	681.59	37.26
7	1112.97	128.37
8	1114.56	130.01
9	1119.25	137.97

** Corrected JANBU FOS = 1.189 ** (Fo factor = 1.030)

Failure surface No. 3 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	145.73	57.44
2	153.18	53.05
3	161.80	47.98
4	162.66	47.14
5	428.62	38.75
6	680.32	37.17
7	1109.99	127.54
8	1111.81	129.43
9	1116.73	137.78

** Corrected JANBU FOS = 1.189 ** (Fo factor = 1.030)

Failure surface No. 4 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	141.58	56.63
2	147.33	53.25
3	155.94	48.17
4	156.96	47.19
5	426.92	38.80
6	683.31	37.37
7	1116.29	129.28
8	1117.63	130.67

9	1122.06	138.19

** Corrected JANBU FOS = 1.189 ** (Fo factor = 1.030)

Failure surface No. 5 specified by 10 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	149.47	58.18
2	149.85	57.95
3	158.47	52.88
4	167.08	47.80
5	168.02	46.89
6	412.94	38.75
7	681.70	37.14
8	1112.24	128.16
9	1113.90	129.87
10	1118.64	137.93

** Corrected JANBU FOS = 1.189 ** (Fo factor = 1.030)

Failure surface No. 6 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	145.25	57.35
2	152.51	53.07
3	161.13	48.00
4	161.98	47.17
5	429.27	38.80
6	682.90	37.29
7	1113.31	128.44
8	1114.90	130.09
9	1119.56	138.00

** Corrected JANBU FOS = 1.190 ** (Fo factor = 1.030)

Failure surface No. 7 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	145.88	57.47
2	153.40	53.04
3	162.02	47.97
4	163.11	46.92
5	424.25	38.50
6	682.82	37.91
7	1115.99	129.21
8	1117.35	130.61
9	1121.80	138.17

** Corrected JANBU FOS = 1.191 ** (Fo factor = 1.030)

Failure surface No. 8 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	143.27	56.96
2	149.70	53.17
3	158.32	48.09
4	159.27	47.18
5	423.37	38.54
6	682.65	37.43
7	1121.04	130.15
8	1122.56	131.72
9	1126.58	138.54

** Corrected JANBU FOS = 1.191 ** (Fo factor = 1.030)

Failure surface No. 9 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	144.73	57.25
2	151.77	53.10
3	160.39	48.02
4	161.28	47.16
5	424.05	38.53
6	681.79	37.36
7	1119.05	129.60
8	1120.72	131.33
9	1124.89	138.41

** Corrected JANBU FOS = 1.191 ** (Fo factor = 1.030)

Failure surface No.10 specified by 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	145.91	57.48
2	153.44	53.04
3	162.05	47.97
4	162.88	47.17
5	416.61	39.08
6	683.48	37.64
7	1113.54	128.49
8	1115.12	130.13
9	1119.76	138.01

** Corrected JANBU FOS = 1.191 ** (Fo factor = 1.030)

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Interem Stability BB Q

GV2-02W
PMP 7-Nov-9

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	1.188	1.030	145.07	1121.98	6.144E+05
2.	1.189	1.030	143.53	1119.25	6.129E+05
3.	1.189	1.030	145.73	1116.73	6.113E+05
4.	1.189	1.030	141.58	1122.06	6.147E+05
5.	1.189	1.030	149.47	1118.64	6.122E+05
6.	1.190	1.030	145.25	1119.56	6.128E+05
7.	1.191	1.030	145.88	1121.80	6.132E+05
8.	1.191	1.030	143.27	1126.58	6.167E+05
9.	1.191	1.030	144.73	1124.89	6.156E+05
10.	1.191	1.030	145.91	1119.76	6.123E+05

* * * END OF FILE * * *

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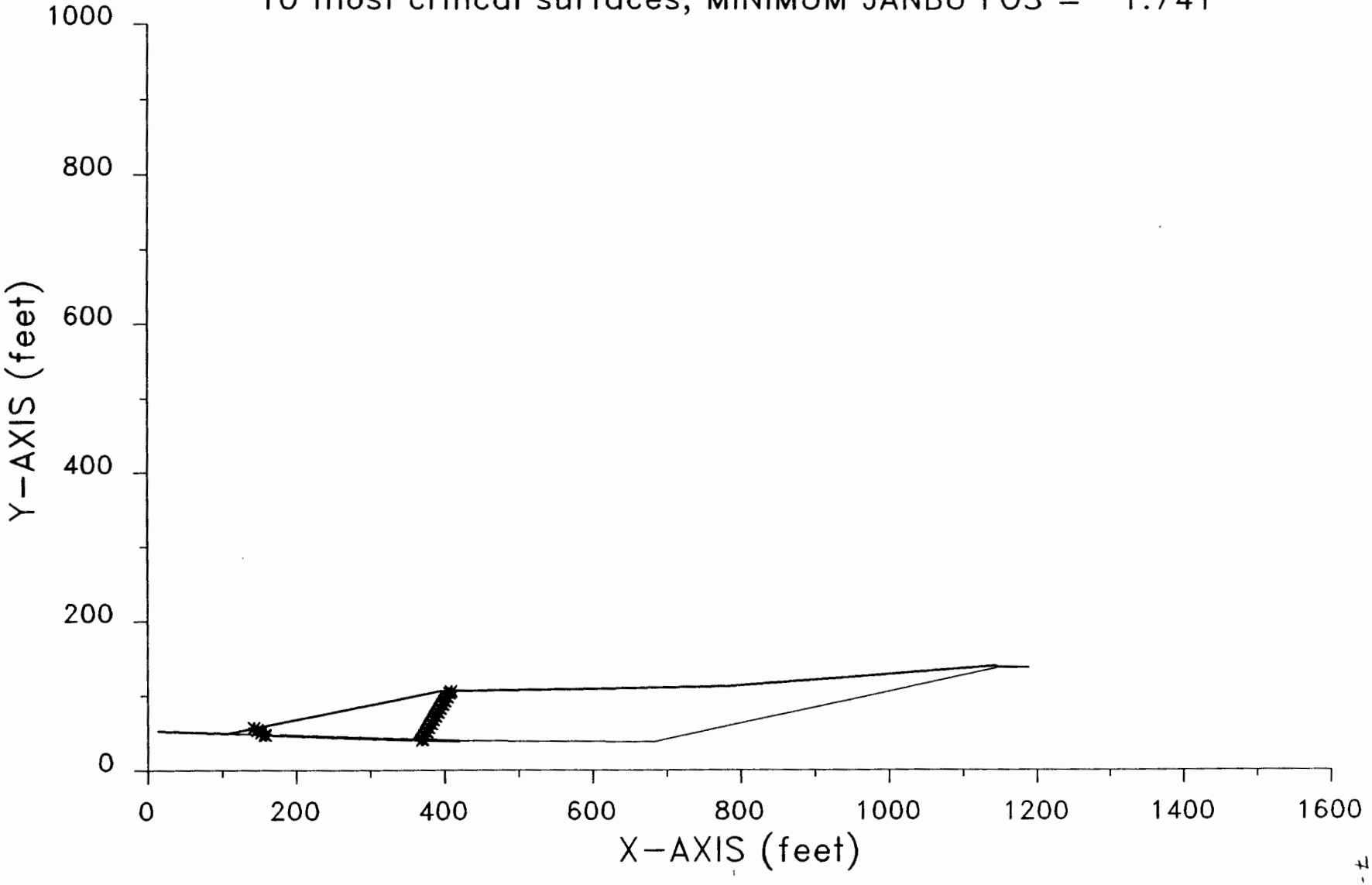
Gandy Interem Stability ~~BB~~AA a

10 most critical surfaces, MINIMUM JANBU FOS = 1.741



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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
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*  Ver. 5.200                96 á 1216  *
*****************************************
```

Problem Description : Gandy Interem Stability ~~BBa~~ AA

SEGMENT BOUNDARY COORDINATES
---

6 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	14.0	52.8	106.8	49.8	2
2	106.8	49.8	393.0	106.0	1
3	393.0	106.0	781.7	112.0	1
4	781.7	112.0	1143.0	139.8	1
5	1143.0	139.8	1149.2	137.4	1
6	1149.2	137.4	1189.0	137.4	2

3 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	106.8	49.8	420.5	39.4	2
2	420.5	39.4	683.0	38.0	2
3	683.0	38.0	1149.2	137.4	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit	Unit Weight Moist	Unit Weight Sat.	Cohesion Intercept	Friction Angle	Pore Pressure Parameter	Pore Pressure Constant	Water Surface

No.	(pcf)	(pcf)	(psf)	(deg)	Ru	(psf)	
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

500 trial surfaces will be generated and analyzed.

2 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 6.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	156.8	47.6	166.8	47.3	1.0
2	179.0	46.7	420.5	38.9	1.0

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	143.03	56.91
2	147.64	54.19
3	152.81	51.15
4	157.98	48.10
5	158.90	47.22
6	369.64	40.32
7	370.36	41.06
8	373.40	46.23
9	376.45	51.40
10	379.49	56.57
11	382.54	61.74
12	385.58	66.91

13	388.63	72.08
14	391.67	77.25
15	394.72	82.42
16	397.76	87.59
17	400.81	92.76
18	403.85	97.93
19	406.90	103.10
20	408.75	106.24

** Corrected JANBU FOS = 1.741 ** (Fo factor = 1.075)

Failure surface No. 2 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	143.71	57.05
2	148.61	54.16
3	153.78	51.12
4	158.95	48.07
5	160.02	47.04
6	369.31	40.52
7	369.85	41.08
8	372.89	46.25
9	375.94	51.42
10	378.98	56.59
11	382.03	61.76
12	385.07	66.93
13	388.12	72.10
14	391.16	77.27
15	394.21	82.44
16	397.25	87.61
17	400.30	92.78
18	403.34	97.95
19	406.39	103.12
20	408.23	106.24

** Corrected JANBU FOS = 1.742 ** (Fo factor = 1.075)

Failure surface No. 3 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	141.64	56.64
2	145.68	54.26
3	150.85	51.21
4	156.02	48.17
5	156.99	47.24
6	356.95	40.50
7	357.90	41.48
8	360.94	46.65
9	363.99	51.82
10	367.03	56.98
11	370.08	62.15
12	373.12	67.32
13	376.17	72.49
14	379.21	77.66

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15	382.26	82.83
16	385.30	88.00
17	388.35	93.17
18	391.39	98.34
19	394.44	103.51
20	395.93	106.05

** Corrected JANBU FOS = 1.743 ** (Fo factor = 1.076)

Failure surface No. 4 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	143.77	57.06
2	148.69	54.16
3	153.86	51.11
4	159.03	48.07
5	159.98	47.16
6	370.19	40.50
7	370.72	41.05
8	373.76	46.22
9	376.81	51.39
10	379.85	56.56
11	382.90	61.73
12	385.94	66.90
13	388.99	72.07
14	392.03	77.24
15	395.08	82.41
16	398.12	87.58
17	401.17	92.75
18	404.22	97.92
19	407.26	103.09
20	409.12	106.25

** Corrected JANBU FOS = 1.745 ** (Fo factor = 1.075)

Failure surface No. 5 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	141.81	56.67
2	145.92	54.25
3	151.09	51.21
4	156.26	48.16
5	156.87	47.57
6	359.59	40.43
7	360.51	41.39
8	363.56	46.56
9	366.60	51.73
10	369.65	56.90
11	372.69	62.07
12	375.74	67.24
13	378.78	72.41
14	381.83	77.58
15	384.87	82.75
16	387.92	87.92

17	390.96	93.09
18	394.01	98.26
19	397.05	103.43
20	398.62	106.09

** Corrected JANBU FOS = 1.745 ** (Fo factor = 1.076)

Failure surface No. 6 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	142.23	56.76
2	146.52	54.23
3	151.69	51.19
4	156.86	48.14
5	157.79	47.25
6	367.86	40.92
7	368.07	41.14
8	371.12	46.31
9	374.17	51.48
10	377.21	56.65
11	380.26	61.82
12	383.30	66.99
13	386.35	72.16
14	389.39	77.33
15	392.44	82.50
16	395.48	87.67
17	398.53	92.84
18	401.57	98.01
19	404.62	103.18
20	406.40	106.21

** Corrected JANBU FOS = 1.748 ** (Fo factor = 1.075)

Failure surface No. 7 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	141.80	56.67
2	145.91	54.25
3	151.08	51.21
4	156.25	48.16
5	156.94	47.49
6	359.93	40.67
7	360.62	41.39
8	363.67	46.55
9	366.72	51.72
10	369.76	56.89
11	372.81	62.06
12	375.85	67.23
13	378.90	72.40
14	381.94	77.57
15	384.99	82.74
16	388.03	87.91
17	391.08	93.08
18	394.12	98.25

19	397.17	103.42
20	398.74	106.09

** Corrected JANBU FOS = 1.748 ** (Fo factor = 1.076)

Failure surface No. 8 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	143.83	57.07
2	148.78	54.16
3	153.95	51.11
4	159.12	48.07
5	160.12	47.10
6	357.02	40.59
7	357.88	41.48
8	360.92	46.65
9	363.97	51.82
10	367.01	56.99
11	370.06	62.16
12	373.10	67.32
13	376.15	72.49
14	379.19	77.66
15	382.24	82.83
16	385.29	88.00
17	388.33	93.17
18	391.38	98.34
19	394.42	103.51
20	395.91	106.04

** Corrected JANBU FOS = 1.749 ** (Fo factor = 1.076)

Failure surface No. 9 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	144.07	57.12
2	149.12	54.14
3	154.29	51.10
4	159.46	48.05
5	159.97	47.57
6	368.52	40.29
7	369.30	41.10
8	372.34	46.27
9	375.39	51.44
10	378.43	56.61
11	381.48	61.78
12	384.52	66.95
13	387.57	72.12
14	390.61	77.29
15	393.66	82.46
16	396.70	87.63
17	399.75	92.80
18	402.79	97.97
19	405.84	103.13
20	407.66	106.23

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** Corrected JANBU FOS = 1.749 ** (Fo factor = 1.075)

Failure surface No.10 specified by 21 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	145.38	57.38
2	145.80	57.13
3	150.97	54.08
4	156.14	51.04
5	161.31	47.99
6	162.30	47.03
7	367.32	40.96
8	367.52	41.16
9	370.56	46.33
10	373.61	51.50
11	376.65	56.67
12	379.70	61.84
13	382.74	67.01
14	385.79	72.18
15	388.83	77.35
16	391.88	82.51
17	394.92	87.68
18	397.97	92.85
19	401.01	98.02
20	404.06	103.19
21	405.83	106.20

** Corrected JANBU FOS = 1.753 ** (Fo factor = 1.075)

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Interem Stability BBa

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	1.741	1.075	143.03	408.75	2.226E+05
2.	1.742	1.075	143.71	408.23	2.218E+05
3.	1.743	1.076	141.64	395.93	2.081E+05
4.	1.745	1.075	143.77	409.12	2.228E+05
5.	1.745	1.076	141.81	398.62	2.112E+05
6.	1.748	1.075	142.23	406.40	2.199E+05
7.	1.748	1.076	141.80	398.74	2.113E+05
8.	1.749	1.076	143.83	395.91	2.075E+05
9.	1.749	1.075	144.07	407.66	2.211E+05
10.	1.753	1.075	145.38	405.83	2.186E+05

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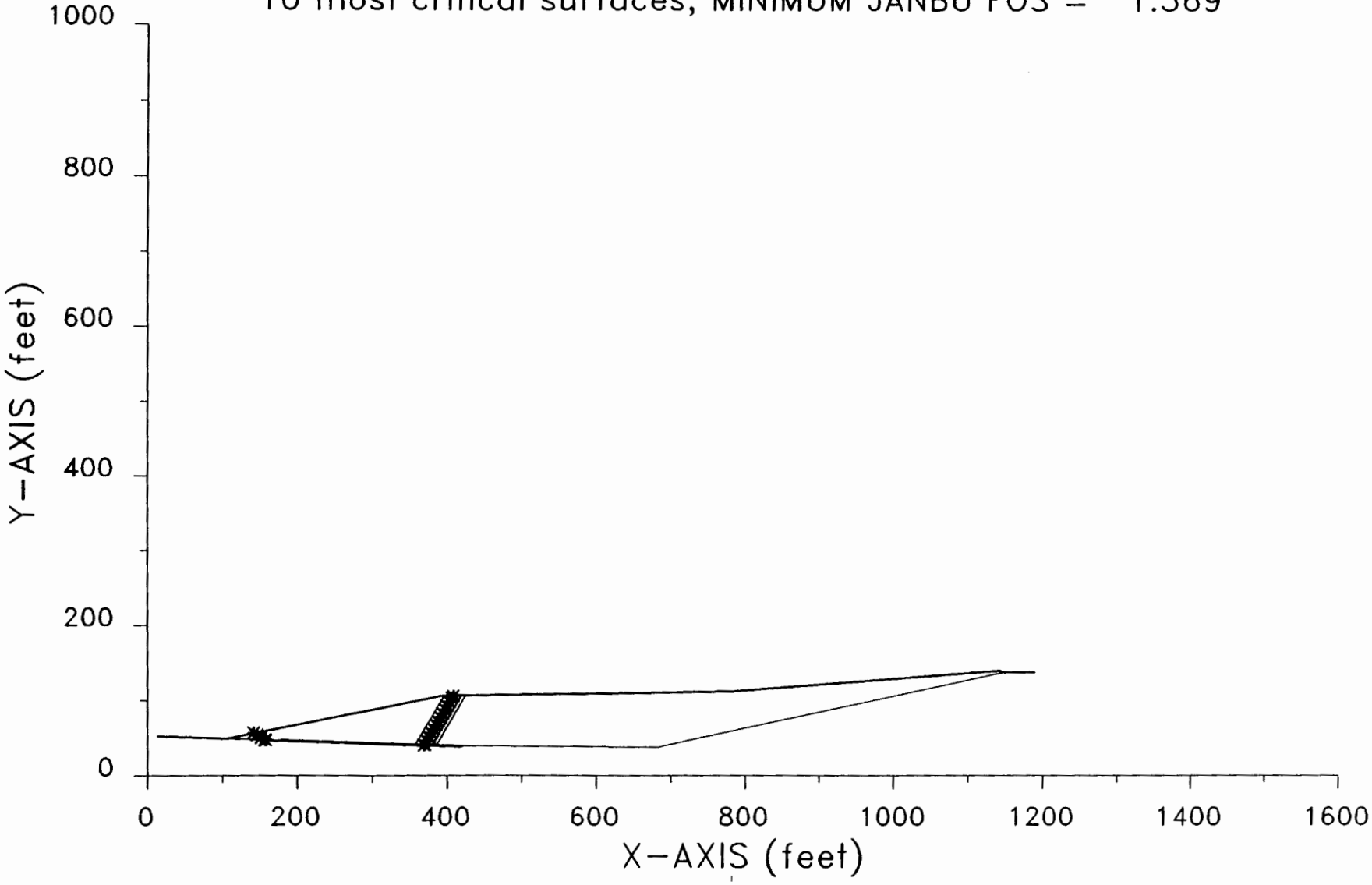
Gandy Interem Stability ~~BB~~AA a Q

10 most critical surfaces, MINIMUM JANBU FOS = 1.369



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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
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*                                       *
*  Ver. 5.200                 96 á 1216 *
*****************************************
```

Problem Description : Gandy Interem Stability ~~BB~~AA a Q

SEGMENT BOUNDARY COORDINATES
---

6 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	14.0	52.8	106.8	49.8	2
2	106.8	49.8	393.0	106.0	1
3	393.0	106.0	781.7	112.0	1
4	781.7	112.0	1143.0	139.8	1
5	1143.0	139.8	1149.2	137.4	1
6	1149.2	137.4	1189.0	137.4	2

3 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	106.8	49.8	420.5	39.4	2
2	420.5	39.4	683.0	38.0	2
3	683.0	38.0	1149.2	137.4	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit	Unit Weight Moist	Unit Weight Sat.	Cohesion Intercept	Friction Angle	Pore Pressure Parameter	Pore Pressure Constant	Water Surface

No.	(pcf)	(pcf)	(psf)	(deg)	Ru	(psf)	
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A horizontal earthquake loading coefficient
of .040 has been assigned

A vertical earthquake loading coefficient
of .000 has been assigned

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

500 trial surfaces will be generated and analyzed.

2 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 6.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	156.8	47.6	166.8	47.3	1.0
2	179.0	46.7	420.5	38.9	1.0

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	143.03	56.91
2	147.64	54.19
3	152.81	51.15
4	157.98	48.10

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5	158.90	47.22
6	369.64	40.32
7	370.36	41.06
8	373.40	46.23
9	376.45	51.40
10	379.49	56.57
11	382.54	61.74
12	385.58	66.91
13	388.63	72.08
14	391.67	77.25
15	394.72	82.42
16	397.76	87.59
17	400.81	92.76
18	403.85	97.93
19	406.90	103.10
20	408.75	106.24

** Corrected JANBU FOS = 1.369 ** (Fo factor = 1.075)

Failure surface No. 2 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	143.71	57.05
2	148.61	54.16
3	153.78	51.12
4	158.95	48.07
5	160.02	47.04
6	369.31	40.52
7	369.85	41.08
8	372.89	46.25
9	375.94	51.42
10	378.98	56.59
11	382.03	61.76
12	385.07	66.93
13	388.12	72.10
14	391.16	77.27
15	394.21	82.44
16	397.25	87.61
17	400.30	92.78
18	403.34	97.95
19	406.39	103.12
20	408.23	106.24

** Corrected JANBU FOS = 1.371 ** (Fo factor = 1.075)

Failure surface No. 3 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	143.77	57.06
2	148.69	54.16
3	153.86	51.11
4	159.03	48.07
5	159.98	47.16
6	370.19	40.50

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7	370.72	41.05
8	373.76	46.22
9	376.81	51.39
10	379.85	56.56
11	382.90	61.73
12	385.94	66.90
13	388.99	72.07
14	392.03	77.24
15	395.08	82.41
16	398.12	87.58
17	401.17	92.75
18	404.22	97.92
19	407.26	103.09
20	409.12	106.25

** Corrected JANBU FOS = 1.373 ** (Fo factor = 1.075)

Failure surface No. 4 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	142.72	56.85
2	147.21	54.21
3	152.38	51.16
4	157.54	48.12
5	158.04	47.64
6	379.78	39.85
7	380.62	40.72
8	383.67	45.89
9	386.71	51.06
10	389.76	56.23
11	392.81	61.40
12	395.85	66.57
13	398.90	71.74
14	401.94	76.91
15	404.99	82.08
16	408.03	87.25
17	411.08	92.42
18	414.12	97.59
19	417.17	102.76
20	419.32	106.41

** Corrected JANBU FOS = 1.375 ** (Fo factor = 1.074)

Failure surface No. 5 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	142.30	56.77
2	146.62	54.23
3	151.79	51.18
4	156.96	48.14
5	157.82	47.31
6	385.06	39.72
7	385.86	40.55
8	388.90	45.72

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9	391.95	50.89
10	394.99	56.06
11	398.04	61.23
12	401.08	66.40
13	404.13	71.57
14	407.17	76.74
15	410.22	81.91
16	413.26	87.08
17	416.31	92.25
18	419.35	97.42
19	422.40	102.59
20	424.70	106.49

** Corrected JANBU FOS = 1.375 ** (Fo factor = 1.073)

Failure surface No. 6 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	142.23	56.76
2	146.52	54.23
3	151.69	51.19
4	156.86	48.14
5	157.79	47.25
6	367.86	40.92
7	368.07	41.14
8	371.12	46.31
9	374.17	51.48
10	377.21	56.65
11	380.26	61.82
12	383.30	66.99
13	386.35	72.16
14	389.39	77.33
15	392.44	82.50
16	395.48	87.67
17	398.53	92.84
18	401.57	98.01
19	404.62	103.18
20	406.40	106.21

** Corrected JANBU FOS = 1.376 ** (Fo factor = 1.075)

Failure surface No. 7 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	144.07	57.12
2	149.12	54.14
3	154.29	51.10
4	159.46	48.05
5	159.97	47.57
6	368.52	40.29
7	369.30	41.10
8	372.34	46.27
9	375.39	51.44
10	378.43	56.61

11	381.48	61.78
12	384.52	66.95
13	387.57	72.12
14	390.61	77.29
15	393.66	82.46
16	396.70	87.63
17	399.75	92.80
18	402.79	97.97
19	405.84	103.13
20	407.66	106.23

** Corrected JANBU FOS = 1.377 ** (Fo factor = 1.075)

Failure surface No. 8 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	142.67	56.84
2	147.15	54.21
3	152.32	51.16
4	157.49	48.12
5	158.26	47.38
6	372.84	40.77
7	373.04	40.97
8	376.08	46.14
9	379.13	51.31
10	382.17	56.48
11	385.22	61.65
12	388.26	66.82
13	391.31	71.99
14	394.35	77.16
15	397.40	82.33
16	400.44	87.50
17	403.49	92.67
18	406.53	97.84
19	409.58	103.01
20	411.51	106.29

** Corrected JANBU FOS = 1.378 ** (Fo factor = 1.074)

Failure surface No. 9 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	143.14	56.94
2	147.81	54.19
3	152.98	51.14
4	158.14	48.10
5	158.89	47.38
6	379.73	40.31
7	380.14	40.74
8	383.19	45.91
9	386.23	51.08
10	389.28	56.25
11	392.33	61.42
12	395.37	66.59

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13	398.42	71.76
14	401.46	76.93
15	404.51	82.10
16	407.55	87.27
17	410.60	92.44
18	413.64	97.61
19	416.69	102.78
20	418.82	106.40

** Corrected JANBU FOS = 1.378 ** (Fo factor = 1.074)

Failure surface No.10 specified by 20 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	141.64	56.64
2	145.68	54.26
3	150.85	51.21
4	156.02	48.17
5	156.99	47.24
6	356.95	40.50
7	357.90	41.48
8	360.94	46.65
9	363.99	51.82
10	367.03	56.98
11	370.08	62.15
12	373.12	67.32
13	376.17	72.49
14	379.21	77.66
15	382.26	82.83
16	385.30	88.00
17	388.35	93.17
18	391.39	98.34
19	394.44	103.51
20	395.93	106.05

** Corrected JANBU FOS = 1.378 ** (Fo factor = 1.076)

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Interem Stability BBa Q

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	1.369	1.075	143.03	408.75	2.150E+05
2.	1.371	1.075	143.71	408.23	2.143E+05
3.	1.373	1.075	143.77	409.12	2.152E+05
4.	1.375	1.074	142.72	419.32	2.256E+05
5.	1.375	1.073	142.30	424.70	2.309E+05
6.	1.376	1.075	142.23	406.40	2.124E+05
7.	1.377	1.075	144.07	407.66	2.136E+05
8.	1.378	1.074	142.67	411.51	2.177E+05

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7-Nov-97

9.	1.378	1.074	143.14	418.82	2.250E+05
10.	1.378	1.076	141.64	395.93	2.012E+05

* * * END OF FILE * * *

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Nov 7, 1997

SARMA NON-VERTICAL SLICE ANALYSIS

Analysis no. gancomb

Unit weight of water = 62.4

Side number	1	2	3	4	5
Coordinate xt	143.02	164.44	369.62	393.00	408.75
Coordinate yt	56.91	61.12	101.41	106.00	106.24
Coordinate xw	143.02	164.44	369.62	393.00	408.91
Coordinate yw	56.91	45.40	40.29	79.50	106.51
Coordinate xb	143.02	164.44	369.62	393.00	408.75
Coordinate yb	56.91	45.40	40.29	79.50	106.24
Friction angle	0.00	0.00	0.00	0.00	0.00
Cohesion	0.00	0.00	0.00	0.00	0.00

Slice number	1	2	3	4
Rock unit weight	110.00	110.00	110.00	110.00
Friction angle	29.00	2.00	29.00	29.00
Cohesion	0.00	440.00	0.00	0.00
Force T	0.00	0.00	0.00	0.00
Angle theta	0.00	0.00	0.00	0.00

Effective normal stresses

Base	1054.35	4235.05	3085.83	929.83
Side	0.00	1256.37	1908.49	759.38

Acceleration Kc = 0.0899 Factor of Safety = 1.66

E-4

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Ultimate Filling Plan Waste Stability

	Name	Date
Prepared By:	P. Pellicer	7-Nov-97
Checked By:	J. Pellicer	12-Nov-97
Reviewed By:	P. Corsel	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602 Sheet: 1 Of 81
Prepared By: P. Pellicer Date: Nov 7, 1997
Checked By: J. Pellicer Date: 12-Nov 97

Ultimate Filling Plan Waste Stability

Objective: Evaluate the overall stability of the waste body once the ultimate filling plan has been reached.

Method: Use the XSTABL (ver 5.200) computer program to evaluate basal failure evelopes.

Assumptions: The waste was assigned a strength associated with a relatively loose silty sand. (25% relative density ⇒ $\phi = 29°$) (see pg 5)

Calculations: Two Cross Sections were evaluated (see pg 3), Section B-B' running North South and section A-A' running East West. (see pg. 4)

Phase berms were taken out of the crossections or given the same properties as the liner interface so they have no impact on stability (conservative).

Two different failure geometries were checked on both cross sections. Geometry 1 checked failure planes running the entire length of the cross sections through the liner systems weakest interface. This mode of failure was checked both staticly and pseudo-staticly using a maximum ground acceleration = 0.04g.

Analysis of Section B-B' resulted in a static F.S. = 6.4 and a pseudo-static F.S. = 1.6. (see pg 9-24)
Analysis of Section A-A' resulted in a static F.S. = 8.5 and a pseudo-static F.S. = 1.5 (See pg 25-40)

Geometry 2 checked failure planes running through the liner system and up through the waste, daylighting somewhere in the middle of the cell. The entire length of the cross-section was searched to find where the most critical failure plane daylighted.

TerraMatrix
Engineering & Environmental Services
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Phone 970.879.6260 Fax 970.879.9048

With Geometry 2 Section B-B's most critical failure plane has a Static F.S. = 4.8 and a pseudo-static F.S. = 2.0, (see Pg. 41 - 61)
Section A-A's most critical failure plane has a static F.S. = 3.7 and a pseudo-static F.S. = 1.6. (see pg 62 - 81)

Conclusions: This stability analysis used undrained unconsolidated strength from the interface testing program. This is very conservative for this analysis, since the filling time to reach the ultimate geometry will allow most of the waste and liner system to drain and consolidate.

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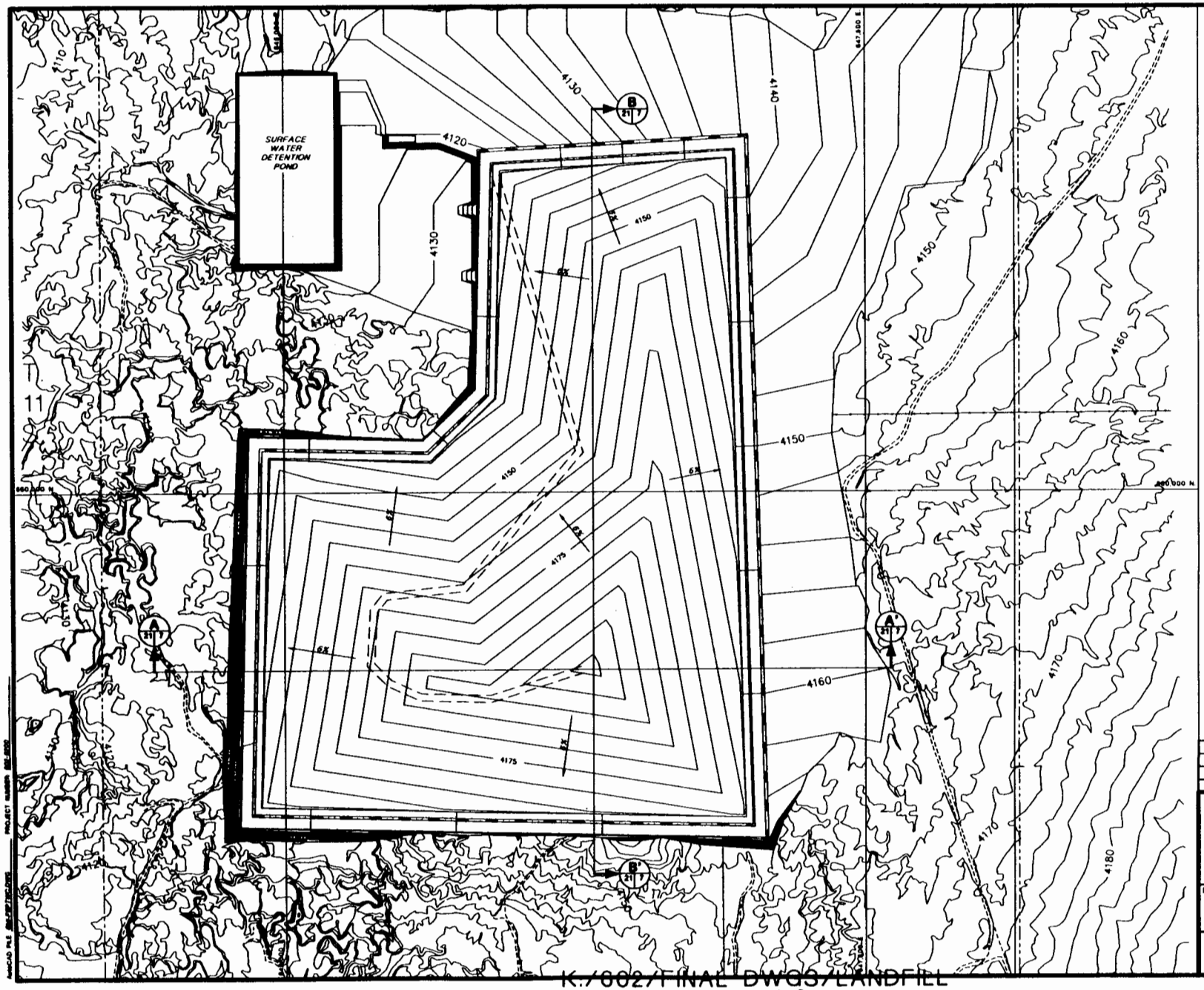
PWP
7-NOV-97

E-4



NOTES
1. FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No 2, "INDEX, LEGEND AND GENERAL NOTES".
2. TOPOGRAPHY FROM AERIAL SURVEYS PERFORMED AUGUST 1997 BY KOOGLE AND POULS ENGINEERING.

PATRICK G. CORNER NEW MEXICO 10236 REGISTERED PROFESSIONAL ENGINEER

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Corner, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date *Patrick G. Corner, NM P.E. 10236*

N

SCALE
200' 0 200' 400'
CONTOUR INTERVAL 5 FT.
SURFACE TOPOGRAPHY CONTOUR INTERVAL 2 FT

Not For Construction

REV No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	9/18/97	PGC/JFF	T Smith	P Corner

TRIASSIC PARK WASTE DISPOSAL FACILITY

DRAWING TITLE:
FINAL GRADING PLAN - TOP OF WASTE CONTOURS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE: AS NOTED
DRAWING No. 21

PROJECT NUMBER 96E-0200

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12/10/97 11:29a

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602-0200
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7-NOV-97

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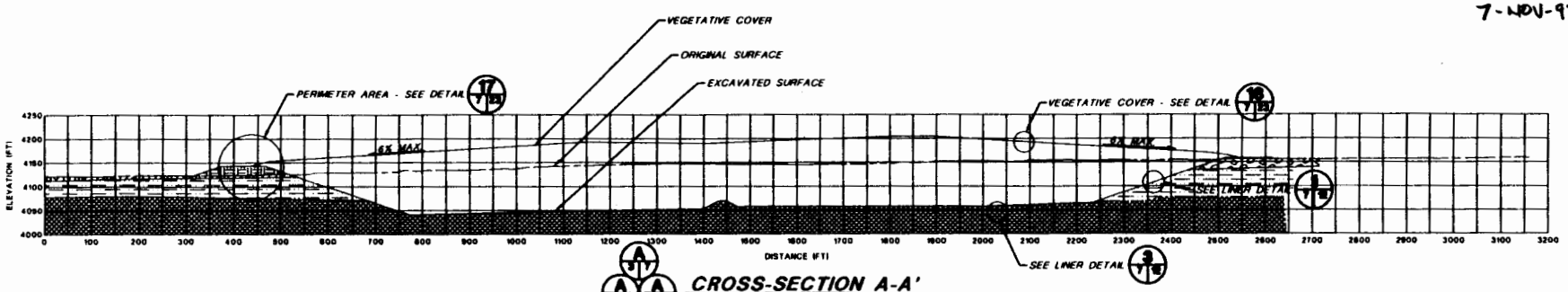
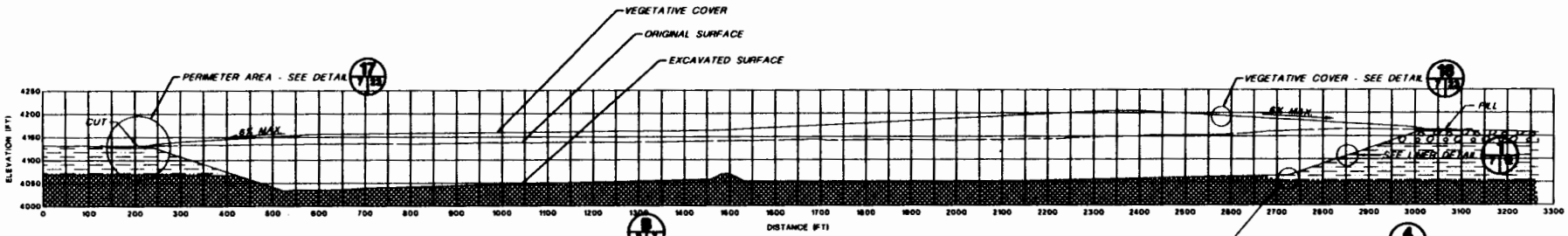


CROSS-SECTION A-A'

HORIZONTAL SCALE
0 120' 240'

VERTICAL SCALE
0 120' 240'



CROSS-SECTION B-B'

HORIZONTAL SCALE
0 120' 240'

VERTICAL SCALE
0 120' 240'

LEGEND

- DRAINAGE GRAVEL
- ALLUVIAL DEPOSITS
- UPPER DOCKUM
- LOWER DOCKUM
- WASTE

NOTE:
FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2, "INDEX, LEGEND AND GENERAL NOTES".

Not For Construction

REV. No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	10/15/97	PGC/JFP	T.Smith	P.Carver

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Carver, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Carver, NM P.E. 10830

TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE:
LANDFILL CROSS-SECTIONS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE: As noted
DRAWING No. 7

AutoCAD FILE: GANDY-TXSEC2.DWG PROJECT NUMBER: 602-0200

K:/602/FINAL DWGS/LANDFILL
gandy-txsec2.dwg
5,5 668
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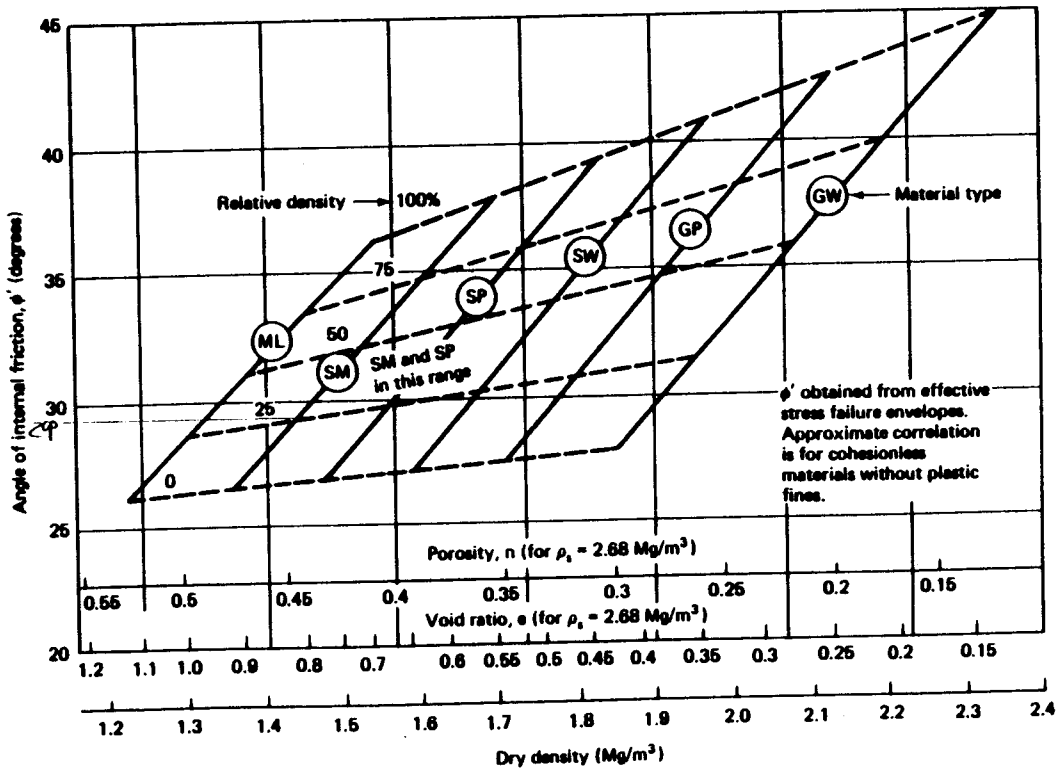

Fig. 11.13 Correlations between the effective friction angle in triaxial compression and the dry density, relative density, and soil classification

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SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

605 81
602-0270
pmp
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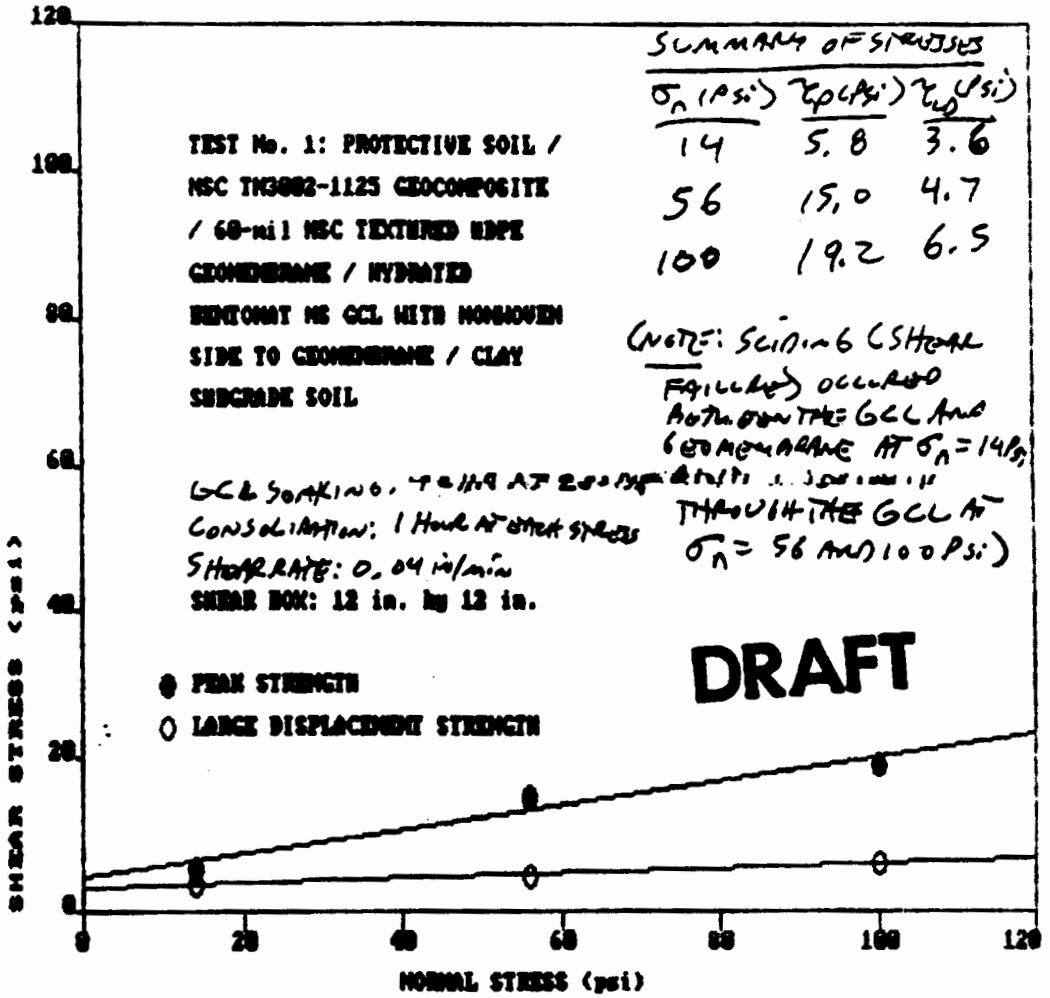
TERRAMATRIX MONTGOMERY WATSON - ASTM D 5321 TESTS



SUMMARY OF STRESSES

σ_n (psi)	τ_p (psi)	τ_{ld} (psi)
14	5.8	3.6
56	15.0	4.7
100	19.2	6.5

(NOTE: SLIPPING (SHEAR FAILURE) OCCURRED BOTH ON THE GCL AND GEOMEMBRANE AT σ_n = 14 psi; THROUGH THE GCL AT σ_n = 56 AND 100 psi)

THE REGRESSION POLYNOMIAL OF LINE 9 - PEAK STRENGTH

(4.534E+00) + (1.551E-01)*X
THE VARIANCE - 1.532E+00

a = 650 PSF δ = 9°

THE REGRESSION POLYNOMIAL OF LINE 10 - LARGE DISPLACEMENT STRENGTH

(3.045E+00) + (3.321E-02)*X
THE VARIANCE - 3.240E-02

a = 440 PSF δ = 2°

Reviewed By: Robert H. Swan Jr. Date: 10-8-97

SGI FORM-14/GEL94351

94.08.23
TOTAL P.02

3 1819 00069223 2
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pmf
7-Nov-97

United States Department of the Interior

Geological Survey

PROBABILISTIC ESTIMATES OF MAXIMUM ACCELERATION AND VELOCITY IN ROCK IN THE CONTIGUOUS UNITED STATES

by

S. T. Algermissen, D. M. Perkins, P. C. Thenhaus,
S. L. Hanson and B. L. Bender

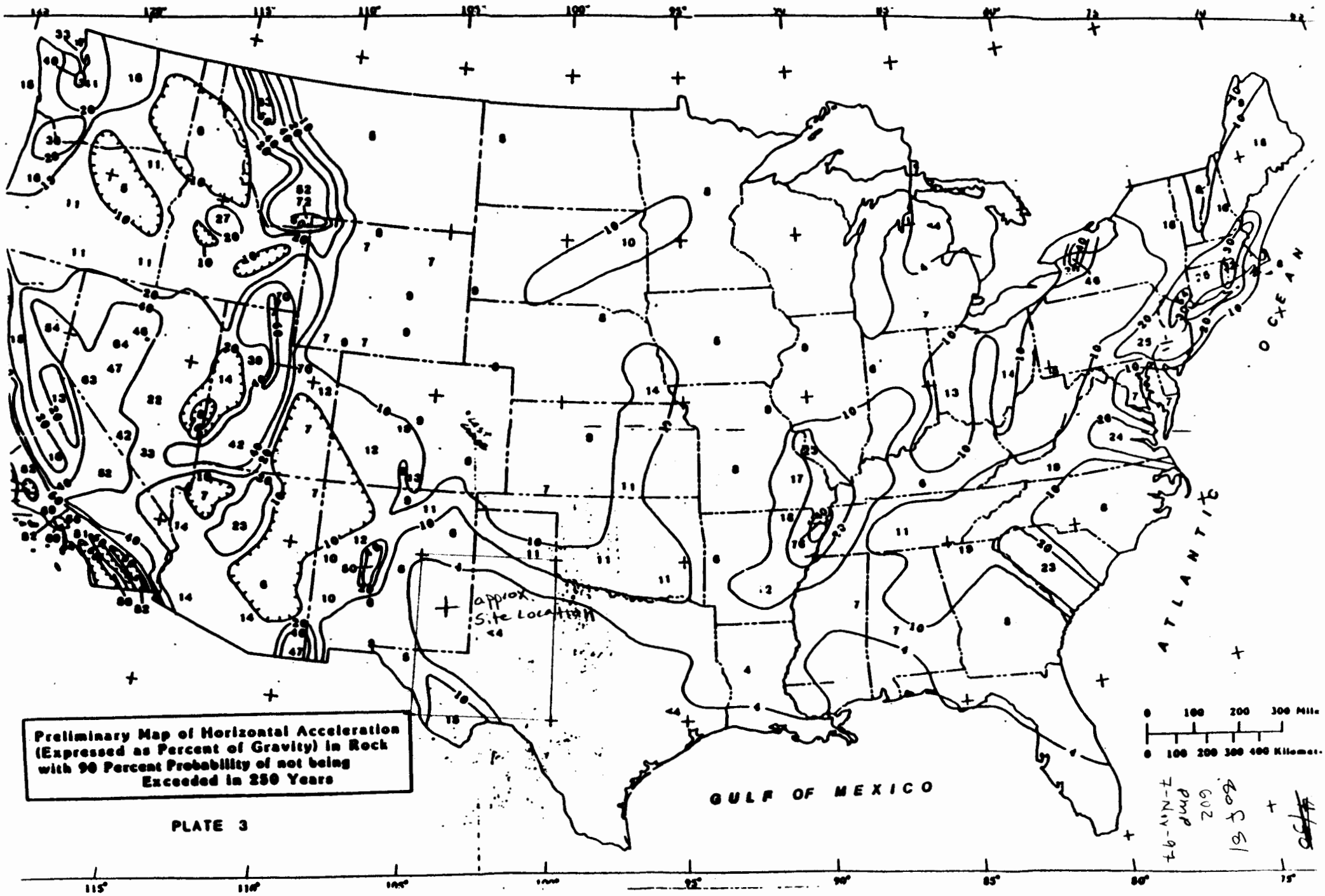
U.S. GEOLOGICAL SURVEY
DENVER
NOV 15 1982
LIBRARY
GEOLOGIC DIVISION

Open-File Report 82-1033

1982

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

JUL 27 1990
10 NOV 199

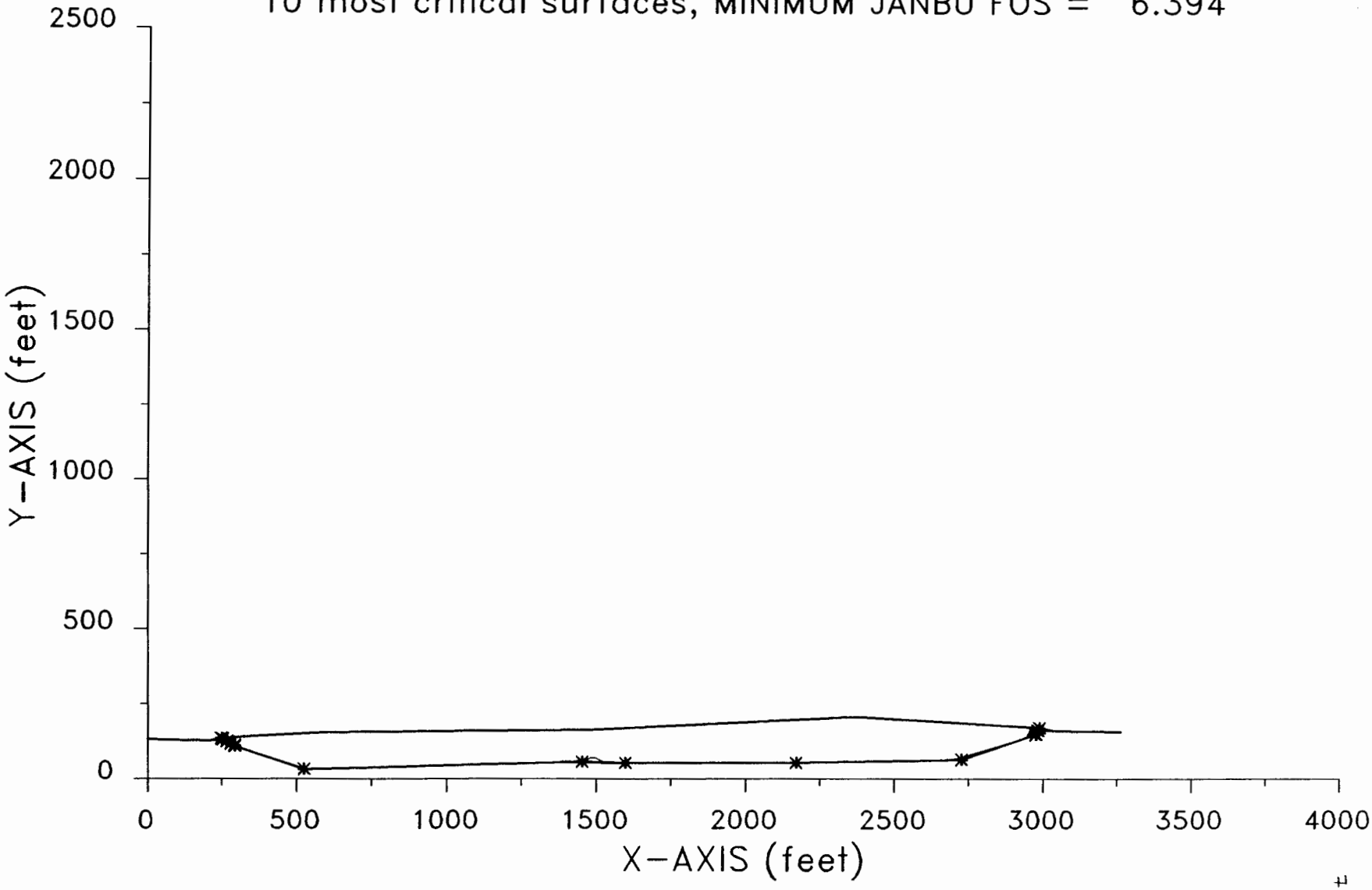


Preliminary Map of Horizontal Acceleration (Expressed as Percent of Gravity) in Rock with 90 Percent Probability of not being Exceeded in 250 Years

PLATE 3

Gandy Total Basal Failue

10 most critical surfaces, MINIMUM JANBU FOS = 6.394



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7-Nov-97

XSTABL File: GTB1 11-05-97 19:00

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*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.200                 96 á 1216 *
*****************************************
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Problem Description : Gandy Total Basal Failue

SEGMENT BOUNDARY COORDINATES
---

9 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	131.9	213.0	127.5	2
2	213.0	127.5	243.3	135.0	1
3	243.3	135.0	590.6	155.8	1
4	590.6	155.8	1473.6	163.6	1
5	1473.6	163.6	2338.5	204.8	1
6	2338.5	204.8	2394.6	205.0	1
7	2394.6	205.0	2985.4	170.0	1
8	2985.4	170.0	3036.6	160.0	1
9	3036.6	160.0	3266.9	157.0	2

10 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	213.0	127.5	241.3	127.4	2
2	241.3	127.4	525.9	32.6	2
3	525.9	32.6	1459.4	57.9	2
4	1459.4	57.9	1483.7	70.0	2
5	1483.7	70.0	1498.7	70.0	2
6	1498.7	70.0	1531.4	53.7	2
7	1531.4	53.7	2159.5	53.7	2
8	2159.5	53.7	2725.7	65.0	2
9	2725.7	65.0	3009.3	159.7	2
10	3009.3	159.7	3036.6	160.0	2

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ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

500 trial surfaces will be generated and analyzed.

7 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 15.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	261.3	120.3	311.3	103.6	1.0
2	524.9	32.1	575.9	33.4	1.0
3	1359.4	54.7	1459.4	57.4	1.0
4	1531.4	53.2	1631.4	53.2	1.0
5	2134.5	53.2	2184.5	53.7	1.0
6	2675.7	63.5	2726.7	64.5	1.0
7	2939.3	135.8	2989.3	152.5	1.0

```
*************************************************************
**     Factor of safety calculation for surface #   217    **
**     failed to converge within FIFTY iterations          **
**                                                         **
**    The last calculated value of the FOS was  22.9377    **
**    This will be ignored for final summary of results    **
*************************************************************
```

The trial failure surface in question is defined by the following 14 coordinate points

Point	x-surf	y-surf

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Point No.	x-surf (ft)	y-surf (ft)
1	246.32	135.18
2	257.41	128.65
3	270.34	121.04
4	283.26	113.42
5	284.13	112.58
6	552.99	33.11
7	1446.77	56.92
8	1596.15	53.68
9	2155.89	53.80
10	2680.97	63.74
11	2984.13	150.39
12	2985.42	151.73
13	2993.04	164.65
14	2995.07	168.11

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	250.19	135.41
2	254.30	132.99
3	267.22	125.38
4	280.15	117.77
5	293.07	110.15
6	294.09	109.17
7	526.03	32.28
8	1454.46	57.25
9	1597.73	53.42
10	2170.29	53.62
11	2726.55	64.58
12	2975.75	148.14
13	2976.26	148.67
14	2983.87	161.59
15	2988.47	169.40

** Corrected JANBU FOS = 6.394 ** (Fo factor = 1.018)

Failure surface No. 2 specified by 14 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	243.11	134.95
2	249.11	131.41

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3	262.04	123.80
4	274.96	116.19
5	274.97	116.18
6	525.46	32.32
7	1368.25	54.51
8	1570.87	53.32
9	2142.09	53.00
10	2722.39	64.03
11	2968.02	145.74
12	2968.26	146.00
13	2975.88	158.92
14	2982.50	170.17

** Corrected JANBU FOS = 6.877 ** (Fo factor = 1.018)

Failure surface No. 3 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	253.72	135.62
2	263.25	130.01
3	276.17	122.40
4	289.10	114.79
5	302.02	107.17
6	302.82	106.41
7	526.62	31.73
8	1361.54	54.34
9	1566.29	53.41
10	2179.75	53.66
11	2722.22	64.27
12	2985.59	151.27
13	2986.33	152.03
14	2993.94	164.95
15	2995.73	167.98

** Corrected JANBU FOS = 7.087 ** (Fo factor = 1.018)

Failure surface No. 4 specified by 16 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	251.81	135.51
2	258.39	131.63
3	271.31	124.02
4	284.24	116.41
5	297.16	108.79
6	297.38	108.58
7	525.09	32.07
8	1388.63	55.37
9	1579.03	52.84
10	2173.39	53.71
11	2714.08	63.81
12	2953.76	140.14
13	2955.22	141.64
14	2962.83	154.57
15	2970.44	167.49

16	2972.38	170.77

** Corrected JANBU FOS = 7.443 ** (Fo factor = 1.019)

Failure surface No. 5 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	245.85	135.15
2	256.22	129.05
3	269.14	121.43
4	282.07	113.82
5	282.57	113.33
6	528.40	32.65
7	1397.91	55.48
8	1557.75	52.72
9	2180.81	53.37
10	2723.06	63.93
11	2947.29	138.94
12	2947.37	139.02
13	2954.98	151.94
14	2962.60	164.87
15	2966.28	171.13

** Corrected JANBU FOS = 7.549 ** (Fo factor = 1.019)

Failure surface No. 6 specified by 16 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	256.07	135.76
2	256.28	135.64
3	269.21	128.03
4	282.13	120.41
5	295.06	112.80
6	307.98	105.19
7	308.30	104.88
8	529.57	31.83
9	1451.03	57.07
10	1561.70	52.89
11	2158.20	53.32
12	2725.93	64.17
13	2975.52	147.56
14	2976.74	148.83
15	2984.35	161.75
16	2988.82	169.33

** Corrected JANBU FOS = 7.603 ** (Fo factor = 1.019)

Failure surface No. 7 specified by 16 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	248.34	135.30

2	249.61	134.56
3	262.54	126.94
4	275.46	119.33
5	288.39	111.72
6	289.87	110.28
7	535.00	32.19
8	1409.17	56.14
9	1567.35	53.06
10	2134.78	53.23
11	2726.26	64.30
12	2949.59	139.00
13	2950.68	140.13
14	2958.30	153.05
15	2965.91	165.98
16	2968.86	170.98

** Corrected JANBU FOS = 7.643 ** (Fo factor = 1.019)

Failure surface No. 8 specified by 14 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	246.97	135.22
2	259.05	128.10
3	271.98	120.49
4	284.90	112.88
5	286.39	111.44
6	526.73	31.77
7	1428.14	57.02
8	1532.61	53.45
9	2179.44	53.19
10	2704.76	64.30
11	2968.34	145.03
12	2969.75	146.49
13	2977.36	159.42
14	2983.65	170.10

** Corrected JANBU FOS = 7.695 ** (Fo factor = 1.018)

Failure surface No. 9 specified by 17 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	256.92	135.82
2	258.44	134.92
3	271.36	127.31
4	284.29	119.70
5	297.21	112.08
6	310.14	104.47
7	311.08	103.55
8	525.99	32.11
9	1375.86	54.95
10	1629.49	52.79
11	2152.47	53.25
12	2702.32	63.57
13	2940.53	136.06

14	2941.49	137.06
15	2949.11	149.98
16	2956.72	162.91
17	2961.72	171.40

** Corrected JANBU FOS = 7.706 ** (Fo factor = 1.019)

Failure surface No.10 specified by 14 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	243.02	134.93
2	248.83	131.51
3	261.76	123.89
4	274.68	116.28
5	275.19	115.79
6	525.45	31.94
7	1389.99	55.55
8	1569.92	52.82
9	2174.72	53.44
10	2698.76	64.18
11	2966.85	144.67
12	2968.07	145.93
13	2975.68	158.86
14	2982.35	170.18

** Corrected JANBU FOS = 7.721 ** (Fo factor = 1.018)

```
*********************************************************************
**                                                                 **
**  Out of the    500 surfaces generated and analyzed by XSTABL,   **
**        3 surfaces were found to have MISLEADING FOS values.     **
**                                                                 **
*********************************************************************
```

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Total Basal Failue

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	6.394	1.018	250.19	2988.47	2.800E+06
2.	6.877	1.018	243.11	2982.50	3.013E+06
3.	7.087	1.018	253.72	2995.73	3.074E+06
4.	7.443	1.019	251.81	2972.38	3.257E+06
5.	7.549	1.019	245.85	2966.28	3.298E+06
6.	7.603	1.019	256.07	2988.82	3.286E+06
7.	7.643	1.019	248.34	2968.86	3.323E+06
8.	7.695	1.018	246.97	2983.65	3.399E+06
9.	7.706	1.019	256.92	2961.72	3.396E+06

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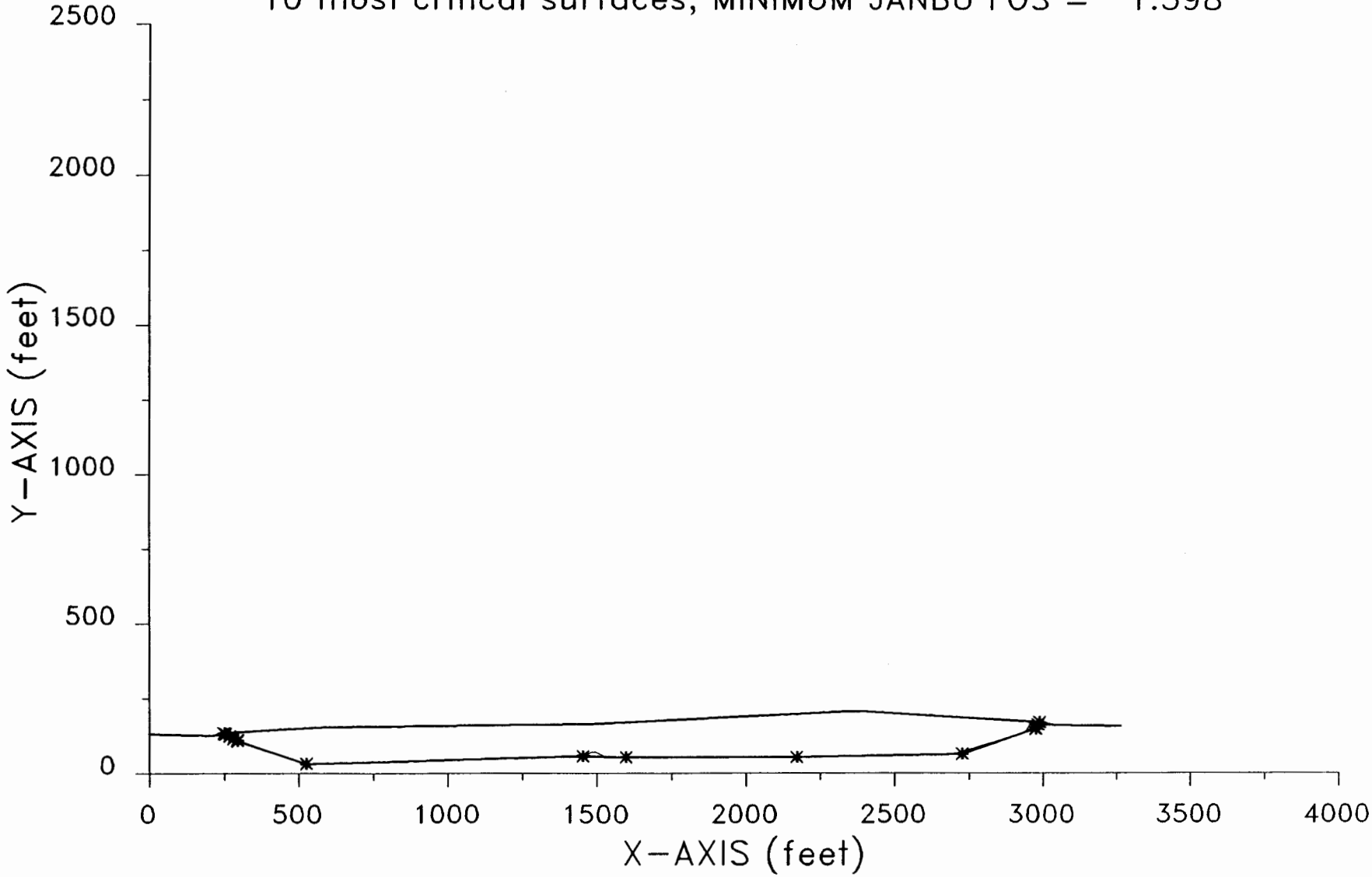
Gandy Total Basal Failue Q

10 most critical surfaces, MINIMUM JANBU FOS = 1.598



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GS2-0220
18 SOIL

602-02W
PMP
7-Nov-97

XSTABL File: GTB1Q 11-05-97 19:02

```
*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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```

Problem Description : Gandy Total Basal Failue Q

SEGMENT BOUNDARY COORDINATES
---

9 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	131.9	213.0	127.5	2
2	213.0	127.5	243.3	135.0	1
3	243.3	135.0	590.6	155.8	1
4	590.6	155.8	1473.6	163.6	1
5	1473.6	163.6	2338.5	204.8	1
6	2338.5	204.8	2394.6	205.0	1
7	2394.6	205.0	2985.4	170.0	1
8	2985.4	170.0	3036.6	160.0	1
9	3036.6	160.0	3266.9	157.0	2

10 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	213.0	127.5	241.3	127.4	2
2	241.3	127.4	525.9	32.6	2
3	525.9	32.6	1459.4	57.9	2
4	1459.4	57.9	1483.7	70.0	2
5	1483.7	70.0	1498.7	70.0	2
6	1498.7	70.0	1531.4	53.7	2
7	1531.4	53.7	2159.5	53.7	2
8	2159.5	53.7	2725.7	65.0	2
9	2725.7	65.0	3009.3	159.7	2
10	3009.3	159.7	3036.6	160.0	2

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ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A horizontal earthquake loading coefficient
of .040 has been assigned

A vertical earthquake loading coefficient
of .000 has been assigned

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

500 trial surfaces will be generated and analyzed.

7 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 15.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	261.3	120.3	311.3	103.6	1.0
2	524.9	32.1	575.9	33.4	1.0
3	1359.4	54.7	1459.4	57.4	1.0
4	1531.4	53.2	1631.4	53.2	1.0
5	2134.5	53.2	2184.5	53.7	1.0
6	2675.7	63.5	2726.7	64.5	1.0
7	2939.3	135.8	2989.3	152.5	1.0

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

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The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	250.19	135.41
2	254.30	132.99
3	267.22	125.38
4	280.15	117.77
5	293.07	110.15
6	294.09	109.17
7	526.03	32.28
8	1454.46	57.25
9	1597.73	53.42
10	2170.29	53.62
11	2726.55	64.58
12	2975.75	148.14
13	2976.26	148.67
14	2983.87	161.59
15	2988.47	169.40

** Corrected JANBU FOS = 1.598 ** (Fo factor = 1.018)

Failure surface No. 2 specified by 14 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	243.11	134.95
2	249.11	131.41
3	262.04	123.80
4	274.96	116.19
5	274.97	116.18
6	525.46	32.32
7	1368.25	54.51
8	1570.87	53.32
9	2142.09	53.00
10	2722.39	64.03
11	2968.02	145.74
12	2968.26	146.00
13	2975.88	158.92
14	2982.50	170.17

** Corrected JANBU FOS = 1.693 ** (Fo factor = 1.018)

Failure surface No. 3 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	253.72	135.62
2	263.25	130.01

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3	276.17	122.40
4	289.10	114.79
5	302.02	107.17
6	302.82	106.41
7	526.62	31.73
8	1361.54	54.34
9	1566.29	53.41
10	2179.75	53.66
11	2722.22	64.27
12	2985.59	151.27
13	2986.33	152.03
14	2993.94	164.95
15	2995.73	167.98

** Corrected JANBU FOS = 1.736 ** (Fo factor = 1.018)

Failure surface No. 4 specified by 16 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	251.81	135.51
2	258.39	131.63
3	271.31	124.02
4	284.24	116.41
5	297.16	108.79
6	297.38	108.58
7	525.09	32.07
8	1388.63	55.37
9	1579.03	52.84
10	2173.39	53.71
11	2714.08	63.81
12	2953.76	140.14
13	2955.22	141.64
14	2962.83	154.57
15	2970.44	167.49
16	2972.38	170.77

** Corrected JANBU FOS = 1.836 ** (Fo factor = 1.019)

Failure surface No. 5 specified by 14 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	246.97	135.22
2	259.05	128.10
3	271.98	120.49
4	284.90	112.88
5	286.39	111.44
6	526.73	31.77
7	1428.14	57.02
8	1532.61	53.45
9	2179.44	53.19
10	2704.76	64.30
11	2968.34	145.03
12	2969.75	146.49
13	2977.36	159.42

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14	2983.65	170.10

** Corrected JANBU FOS = 1.907 ** (Fo factor = 1.018)

Failure surface No. 6 specified by 16 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	255.78	135.75
2	268.47	128.27
3	281.39	120.66
4	294.32	113.05
5	307.24	105.43
6	308.04	104.67
7	525.86	31.76
8	1381.43	55.31
9	1540.90	53.55
10	2161.09	53.66
11	2714.09	64.69
12	2954.98	141.33
13	2955.31	141.67
14	2962.93	154.60
15	2970.54	167.52
16	2972.45	170.77

** Corrected JANBU FOS = 1.915 ** (Fo factor = 1.019)

Failure surface No. 7 specified by 17 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	256.92	135.82
2	258.44	134.92
3	271.36	127.31
4	284.29	119.70
5	297.21	112.08
6	310.14	104.47
7	311.08	103.55
8	525.99	32.11
9	1375.86	54.95
10	1629.49	52.79
11	2152.47	53.25
12	2702.32	63.57
13	2940.53	136.06
14	2941.49	137.06
15	2949.11	149.98
16	2956.72	162.91
17	2961.72	171.40

** Corrected JANBU FOS = 1.917 ** (Fo factor = 1.019)

Failure surface No. 8 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)

1	241.00	134.43
2	242.22	133.71
3	255.15	126.10
4	268.07	118.48
5	268.63	117.95
6	525.65	32.26
7	1415.01	56.35
8	1597.36	52.86
9	2161.86	53.04
10	2715.21	64.36
11	2950.85	139.44
12	2951.91	140.54
13	2959.52	153.46
14	2967.13	166.38
15	2969.81	170.92

** Corrected JANBU FOS = 1.921 ** (Fo factor = 1.019)

Failure surface No. 9 specified by 14 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	243.02	134.93
2	248.83	131.51
3	261.76	123.89
4	274.68	116.28
5	275.19	115.79
6	525.45	31.94
7	1389.99	55.55
8	1569.92	52.82
9	2174.72	53.44
10	2698.76	64.18
11	2966.85	144.67
12	2968.07	145.93
13	2975.68	158.86
14	2982.35	170.18

** Corrected JANBU FOS = 1.921 ** (Fo factor = 1.018)

Failure surface No.10 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	244.27	135.06
2	252.22	130.38
3	265.14	122.77
4	278.07	115.15
5	278.17	115.05
6	525.85	31.93
7	1374.48	55.40
8	1560.34	53.26
9	2150.67	53.02
10	2699.92	63.97
11	2954.28	141.09
12	2954.62	141.44

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13	2962.24	154.37
14	2969.85	167.29
15	2971.92	170.80

** Corrected JANBU FOS = 1.925 ** (Fo factor = 1.019)

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Total Basal Failue Q

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	1.598	1.018	250.19	2988.47	2.807E+06
2.	1.693	1.018	243.11	2982.50	2.962E+06
3.	1.736	1.018	253.72	2995.73	3.029E+06
4.	1.836	1.019	251.81	2972.38	3.195E+06
5.	1.907	1.018	246.97	2983.65	3.329E+06
6.	1.915	1.019	255.78	2972.45	3.323E+06
7.	1.917	1.019	256.92	2961.72	3.330E+06
8.	1.921	1.019	241.00	2969.81	3.353E+06
9.	1.921	1.018	243.02	2982.35	3.362E+06
10.	1.925	1.019	244.27	2971.92	3.360E+06

* * * END OF FILE * * *

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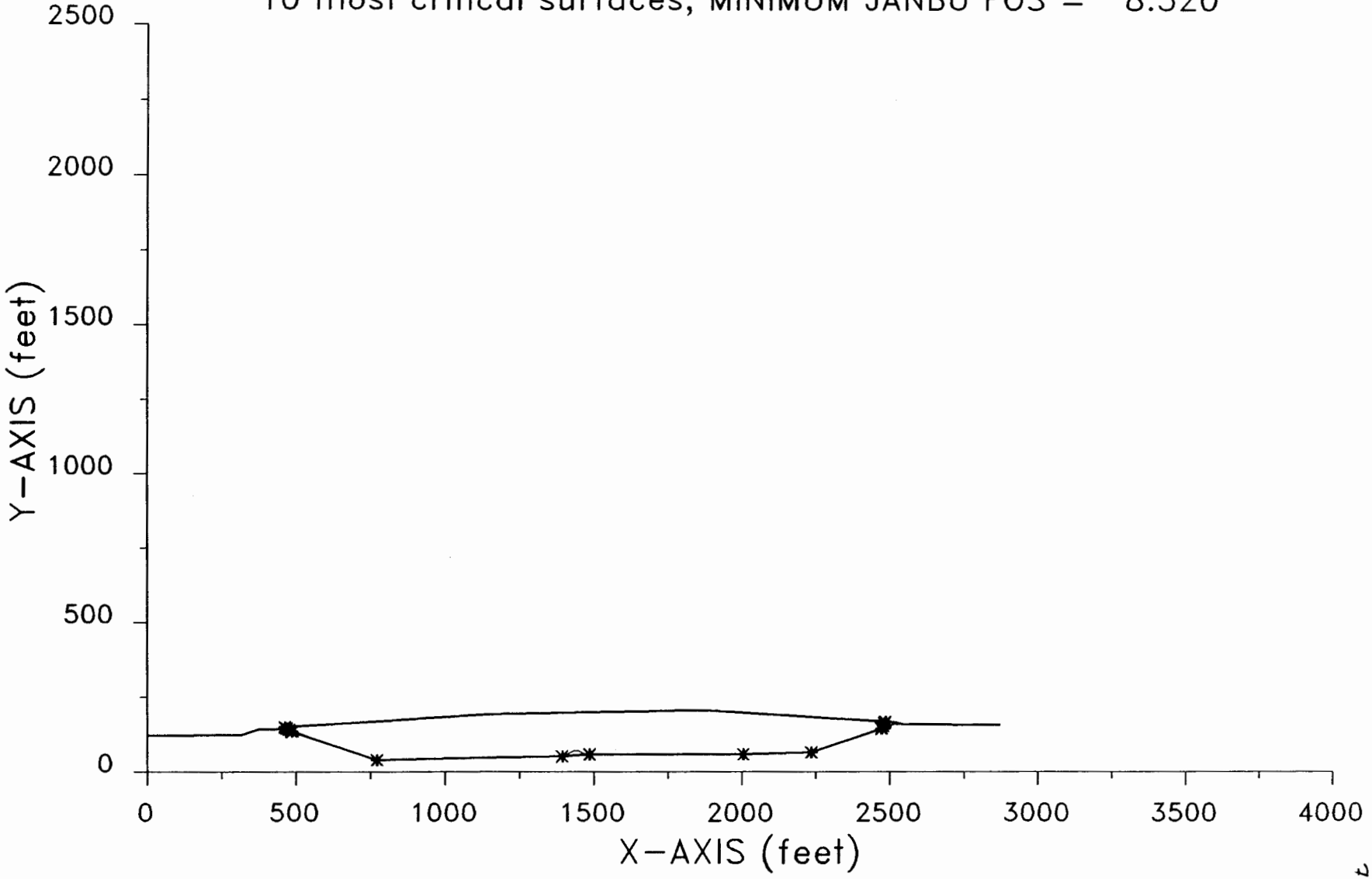
Gandy Basal Failure aa

10 most critical surfaces, MINIMUM JANBU FOS = 8.520



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602-0200
PMP
7-Nov-97

XSTABL File: GTBA1 11-06-97 8:45

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*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
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*****************************************
```

Problem Description : Gandy Basal Failure aa

SEGMENT BOUNDARY COORDINATES
---

10 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.0	122.0	315.6	123.8	2
2	315.6	123.8	375.2	143.6	2
3	375.2	143.6	436.8	143.6	2
4	436.8	143.6	474.5	153.0	1
5	474.5	153.0	1146.0	192.8	1
6	1146.0	192.8	1813.7	204.9	1
7	1813.7	204.9	1884.7	205.0	1
8	1884.7	205.0	2519.5	165.0	1
9	2519.5	165.0	2543.7	159.0	1
10	2543.7	159.0	2872.9	156.7	2

10 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	436.8	143.6	465.1	143.6	2
2	465.1	143.6	772.5	41.1	2
3	772.5	41.1	1399.3	52.9	2
4	1399.3	52.9	1433.2	69.8	2
5	1433.2	69.8	1448.8	69.9	2
6	1448.8	69.9	1472.6	58.0	2
7	1472.6	58.0	2008.1	58.3	2
8	2008.1	58.3	2233.9	65.1	2
9	2233.9	65.1	2515.4	159.0	2

10	2515.4	159.0	2543.7	159.0	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

500 trial surfaces will be generated and analyzed.

7 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 10.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	485.1	136.5	535.1	119.8	1.0
2	771.5	40.6	772.5	40.6	1.0
3	1374.3	51.9	1399.3	52.4	1.0
4	1472.6	57.5	1497.6	57.5	1.0
5	1998.1	57.8	2018.1	58.1	1.0
6	2233.9	64.6	2234.9	64.6	1.0
7	2470.4	143.5	2495.4	151.8	1.0

```
*************************************************************
**     Factor of safety calculation for surface #    14    **
**     failed to converge within FIFTY iterations          **
**                                                         **
**    The last calculated value of the FOS was  24.1013    **
**    This will be ignored for final summary of results    **
*************************************************************
```

The trial failure surface in question is defined by the following 17 coordinate points

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6	518.34	128.05
7	526.96	122.97
8	527.27	122.67
9	772.45	40.43
10	1389.84	52.11
11	1474.50	57.87
12	2015.50	58.52
13	2234.79	64.33
14	2479.57	146.59
15	2480.21	147.26
16	2485.29	155.88
17	2490.36	164.49
18	2491.69	166.75

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.15	150.17
2	469.09	146.67
3	477.71	141.60
4	486.32	136.52
5	487.29	135.59
6	772.40	40.13
7	1393.41	51.80
8	1485.69	57.85
9	2006.10	57.83
10	2234.85	65.02
11	2471.94	144.45
12	2472.01	144.53
13	2477.09	153.14
14	2482.17	161.76
15	2485.34	167.15

** Corrected JANBU FOS = 8.520 ** (Fo factor = 1.026)

Failure surface No. 2 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.91	150.11
2	468.30	146.94
3	476.92	141.86
4	485.53	136.79
5	486.48	135.87
6	772.31	40.12

7	1383.52	51.68
8	1479.38	57.79
9	2006.15	58.09
10	2234.88	64.70
11	2484.73	148.57
12	2485.01	148.86
13	2490.08	157.48
14	2495.16	166.10
15	2495.41	166.52

** Corrected JANBU FOS = 8.561 ** (Fo factor = 1.026)

Failure surface No. 3 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.95	150.37
2	471.72	145.80
3	480.33	140.72
4	488.95	135.65
5	489.83	134.79
6	771.82	40.61
7	1382.69	51.61
8	1489.81	57.19
9	2003.49	57.89
10	2234.20	64.99
11	2478.90	146.38
12	2479.54	147.04
13	2484.62	155.65
14	2489.69	164.27
15	2491.17	166.78

** Corrected JANBU FOS = 8.587 ** (Fo factor = 1.026)

Failure surface No. 4 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.67	150.05
2	467.51	147.20
3	476.13	142.12
4	484.75	137.05
5	485.97	135.87
6	772.41	40.28
7	1391.97	51.80
8	1488.01	57.64
9	2002.09	57.55
10	2234.24	64.34
11	2477.25	145.96
12	2477.70	146.42
13	2482.77	155.04
14	2487.85	163.66
15	2489.74	166.87

** Corrected JANBU FOS = 8.592 ** (Fo factor = 1.026)

Failure surface No. 5 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.48	150.00
2	466.87	147.42
3	475.48	142.34
4	484.10	137.26
5	485.50	135.91
6	772.37	40.47
7	1381.45	51.74
8	1484.86	57.41
9	1998.79	57.56
10	2234.71	64.37
11	2471.18	143.60
12	2472.11	144.56
13	2477.18	153.18
14	2482.26	161.79
15	2485.41	167.15

** Corrected JANBU FOS = 8.602 ** (Fo factor = 1.026)

Failure surface No. 6 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	464.16	150.42
2	472.40	145.57
3	481.01	140.50
4	489.63	135.42
5	489.76	135.29
6	771.80	40.46
7	1392.89	51.81
8	1488.45	57.78
9	2008.72	58.26
10	2234.22	64.77
11	2476.23	145.20
12	2477.28	146.28
13	2482.36	154.90
14	2487.43	163.52
15	2489.42	166.90

** Corrected JANBU FOS = 8.603 ** (Fo factor = 1.026)

Failure surface No. 7 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	464.06	150.40
2	472.07	145.68
3	480.69	140.60
4	489.31	135.53
5	490.44	134.44
6	772.11	40.29

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7	1391.42	52.41
8	1486.08	57.54
9	2012.77	57.55
10	2234.06	64.79
11	2471.15	143.66
12	2471.97	144.51
13	2477.05	153.13
14	2482.12	161.75
15	2485.31	167.15

** Corrected JANBU FOS = 8.615 ** (Fo factor = 1.026)

Failure surface No. 8 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.23	150.19
2	469.33	146.60
3	477.94	141.52
4	486.56	136.45
5	487.63	135.41
6	772.44	40.42
7	1386.64	51.99
8	1487.94	57.87
9	2008.46	58.25
10	2234.66	64.43
11	2476.27	144.99
12	2477.63	146.40
13	2482.71	155.02
14	2487.79	163.64
15	2489.70	166.88

** Corrected JANBU FOS = 8.621 ** (Fo factor = 1.026)

Failure surface No. 9 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.66	150.05
2	467.49	147.21
3	476.10	142.13
4	484.72	137.06
5	485.90	135.92
6	772.11	40.95
7	1382.25	51.80
8	1490.13	57.59
9	2011.03	57.93
10	2234.28	64.79
11	2481.52	147.24
12	2482.17	147.92
13	2487.24	156.53
14	2492.32	165.15
15	2493.21	166.66

** Corrected JANBU FOS = 8.629 ** (Fo factor = 1.025)

Failure surface No.10 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.26	150.20
2	469.44	146.56
3	478.06	141.48
4	486.67	136.41
5	486.99	136.10
6	771.60	40.80
7	1397.94	51.94
8	1475.88	57.05
9	2009.02	57.66
10	2234.31	64.52
11	2477.48	146.27
12	2477.60	146.39
13	2482.68	155.01
14	2487.75	163.62
15	2489.67	166.88

** Corrected JANBU FOS = 8.637 ** (Fo factor = 1.025)

```
*********************************************************************
**                                                                 **
**  Out of the    500 surfaces generated and analyzed by XSTABL,   **
**        6 surfaces were found to have MISLEADING FOS values.     **
**                                                                 **
*********************************************************************
```

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Basal Failure aa

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	8.520	1.026	463.15	2485.34	1.862E+06
2.	8.561	1.026	462.91	2495.41	1.862E+06
3.	8.587	1.026	463.95	2491.17	1.863E+06
4.	8.592	1.026	462.67	2489.74	1.863E+06
5.	8.602	1.026	462.48	2485.41	1.862E+06
6.	8.603	1.026	464.16	2489.42	1.862E+06
7.	8.615	1.026	464.06	2485.31	1.863E+06
8.	8.621	1.026	463.23	2489.70	1.862E+06
9.	8.629	1.025	462.66	2493.21	1.861E+06
10.	8.637	1.025	463.26	2489.67	1.862E+06

* * * END OF FILE * * *

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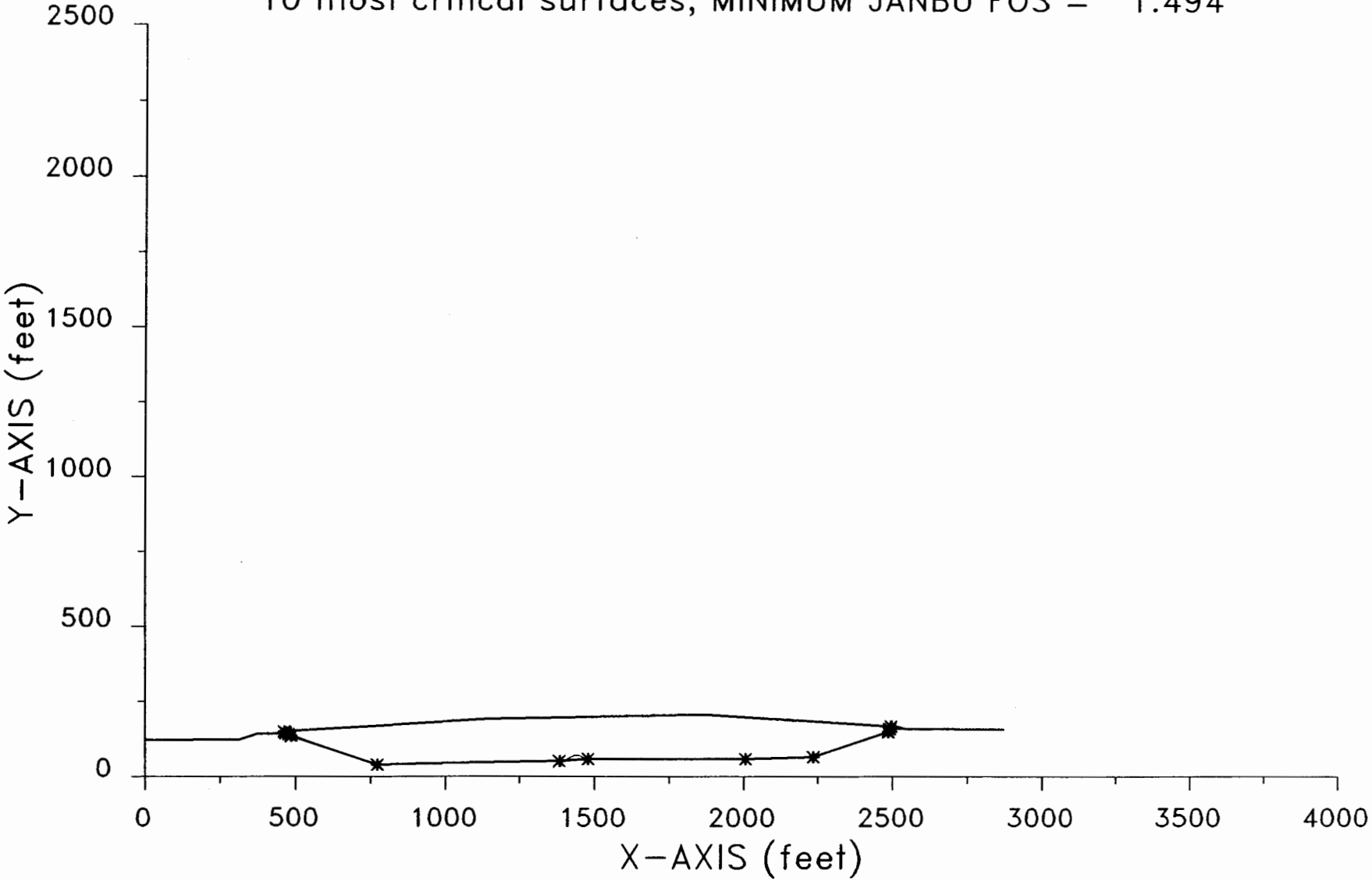
Gandy Basal Failure aa Q

10 most critical surfaces, MINIMUM JANBU FOS = 1.494



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```
*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.200                 96 á 1216 *
*****************************************
```

Problem Description : Gandy Basal Failure aa Q

SEGMENT BOUNDARY COORDINATES
---

10 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.0	122.0	315.6	123.8	2
2	315.6	123.8	375.2	143.6	2
3	375.2	143.6	436.8	143.6	2
4	436.8	143.6	474.5	153.0	1
5	474.5	153.0	1146.0	192.8	1
6	1146.0	192.8	1813.7	204.9	1
7	1813.7	204.9	1884.7	205.0	1
8	1884.7	205.0	2519.5	165.0	1
9	2519.5	165.0	2543.7	159.0	1
10	2543.7	159.0	2872.9	156.7	2

10 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	436.8	143.6	465.1	143.6	2
2	465.1	143.6	772.5	41.1	2
3	772.5	41.1	1399.3	52.9	2
4	1399.3	52.9	1433.2	69.8	2
5	1433.2	69.8	1448.8	69.9	2
6	1448.8	69.9	1472.6	58.0	2
7	1472.6	58.0	2008.1	58.3	2
8	2008.1	58.3	2233.9	65.1	2
9	2233.9	65.1	2515.4	159.0	2

10	2515.4	159.0	2543.7	159.0	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A horizontal earthquake loading coefficient
of .040 has been assigned

A vertical earthquake loading coefficient
of .000 has been assigned

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

500 trial surfaces will be generated and analyzed.

7 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 10.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	485.1	136.5	535.1	119.8	1.0
2	771.5	40.6	772.5	40.6	1.0
3	1374.3	51.9	1399.3	52.4	1.0
4	1472.6	57.5	1497.6	57.5	1.0
5	1998.1	57.8	2018.1	58.1	1.0
6	2233.9	64.6	2234.9	64.6	1.0
7	2470.4	143.5	2495.4	151.8	1.0

****
ERROR # 38
****

The program calculated a point for the PASSIVE wedge that is outside the defined slope geometry. The analysis will continue, but the user should adjust the search box or slope geometry to allow a passive wedge to be formed from all points within first box.
****

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.91	150.11
2	468.30	146.94
3	476.92	141.86
4	485.53	136.79
5	486.48	135.87
6	772.31	40.12
7	1383.52	51.68
8	1479.38	57.79
9	2006.15	58.09
10	2234.88	64.70
11	2484.73	148.57
12	2485.01	148.86
13	2490.08	157.48
14	2495.16	166.10
15	2495.41	166.52

** Corrected JANBU FOS = 1.494 ** (Fo factor = 1.026)

Failure surface No. 2 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.15	150.17
2	469.09	146.67
3	477.71	141.60
4	486.32	136.52
5	487.29	135.59
6	772.40	40.13
7	1393.41	51.80
8	1485.69	57.85
9	2006.10	57.83
10	2234.85	65.02
11	2471.94	144.45
12	2472.01	144.53
13	2477.09	153.14

14	2482.17	161.76
15	2485.34	167.15

** Corrected JANBU FOS = 1.495 ** (Fo factor = 1.026)

Failure surface No. 3 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.67	150.05
2	467.51	147.20
3	476.13	142.12
4	484.75	137.05
5	485.97	135.87
6	772.41	40.28
7	1391.97	51.80
8	1488.01	57.64
9	2002.09	57.55
10	2234.24	64.34
11	2477.25	145.96
12	2477.70	146.42
13	2482.77	155.04
14	2487.85	163.66
15	2489.74	166.87

** Corrected JANBU FOS = 1.495 ** (Fo factor = 1.026)

Failure surface No. 4 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.48	150.00
2	466.87	147.42
3	475.48	142.34
4	484.10	137.26
5	485.50	135.91
6	772.37	40.47
7	1381.45	51.74
8	1484.86	57.41
9	1998.79	57.56
10	2234.71	64.37
11	2471.18	143.60
12	2472.11	144.56
13	2477.18	153.18
14	2482.26	161.79
15	2485.41	167.15

** Corrected JANBU FOS = 1.496 ** (Fo factor = 1.026)

Failure surface No. 5 specified by 14 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.63	150.04

2	467.37	147.25
3	475.99	142.17
4	484.61	137.10
5	485.32	136.41
6	771.68	40.44
7	1375.07	51.57
8	1483.66	57.47
9	2010.87	57.67
10	2234.07	64.61
11	2493.87	150.81
12	2495.31	152.30
13	2500.38	160.91
14	2503.39	166.02

** Corrected JANBU FOS = 1.496 ** (Fo factor = 1.025)

Failure surface No. 6 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.66	150.05
2	467.49	147.21
3	476.10	142.13
4	484.72	137.06
5	485.90	135.92
6	772.11	40.95
7	1382.25	51.80
8	1490.13	57.59
9	2011.03	57.93
10	2234.28	64.79
11	2481.52	147.24
12	2482.17	147.92
13	2487.24	156.53
14	2492.32	165.15
15	2493.21	166.66

** Corrected JANBU FOS = 1.496 ** (Fo factor = 1.025)

Failure surface No. 7 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.34	150.22
2	469.71	146.47
3	478.33	141.39
4	486.94	136.32
5	487.69	135.59
6	772.14	40.61
7	1394.22	51.87
8	1490.96	57.03
9	1998.34	57.90
10	2234.42	64.44
11	2482.28	147.09
12	2483.50	148.36
13	2488.58	156.98
14	2493.65	165.59

15	2494.24	166.59

** Corrected JANBU FOS = 1.497 ** (Fo factor = 1.025)

Failure surface No. 8 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.95	150.37
2	471.72	145.80
3	480.33	140.72
4	488.95	135.65
5	489.83	134.79
6	771.82	40.61
7	1382.69	51.61
8	1489.81	57.19
9	2003.49	57.89
10	2234.20	64.99
11	2478.90	146.38
12	2479.54	147.04
13	2484.62	155.65
14	2489.69	164.27
15	2491.17	166.78

** Corrected JANBU FOS = 1.497 ** (Fo factor = 1.026)

Failure surface No. 9 specified by 15 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.17	150.17
2	469.13	146.66
3	477.75	141.58
4	486.37	136.51
5	486.53	136.35
6	772.40	40.26
7	1382.80	51.58
8	1486.63	57.24
9	2000.54	57.44
10	2234.81	64.23
11	2474.20	144.48
12	2475.30	145.63
13	2480.38	154.24
14	2485.46	162.86
15	2487.89	166.99

** Corrected JANBU FOS = 1.497 ** (Fo factor = 1.026)

Failure surface No.10 specified by 14 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.88	150.10
2	468.19	146.98

3	476.80	141.90
4	485.42	136.82
5	486.10	136.16
6	771.84	40.55
7	1388.28	51.92
8	1494.96	57.76
9	2016.15	57.80
10	2234.37	64.30
11	2491.07	150.44
12	2491.70	151.10
13	2496.78	159.71
14	2500.59	166.19

** Corrected JANBU FOS = 1.497 ** (Fo factor = 1.025)

The following is a summary of the TEN most critical surfaces

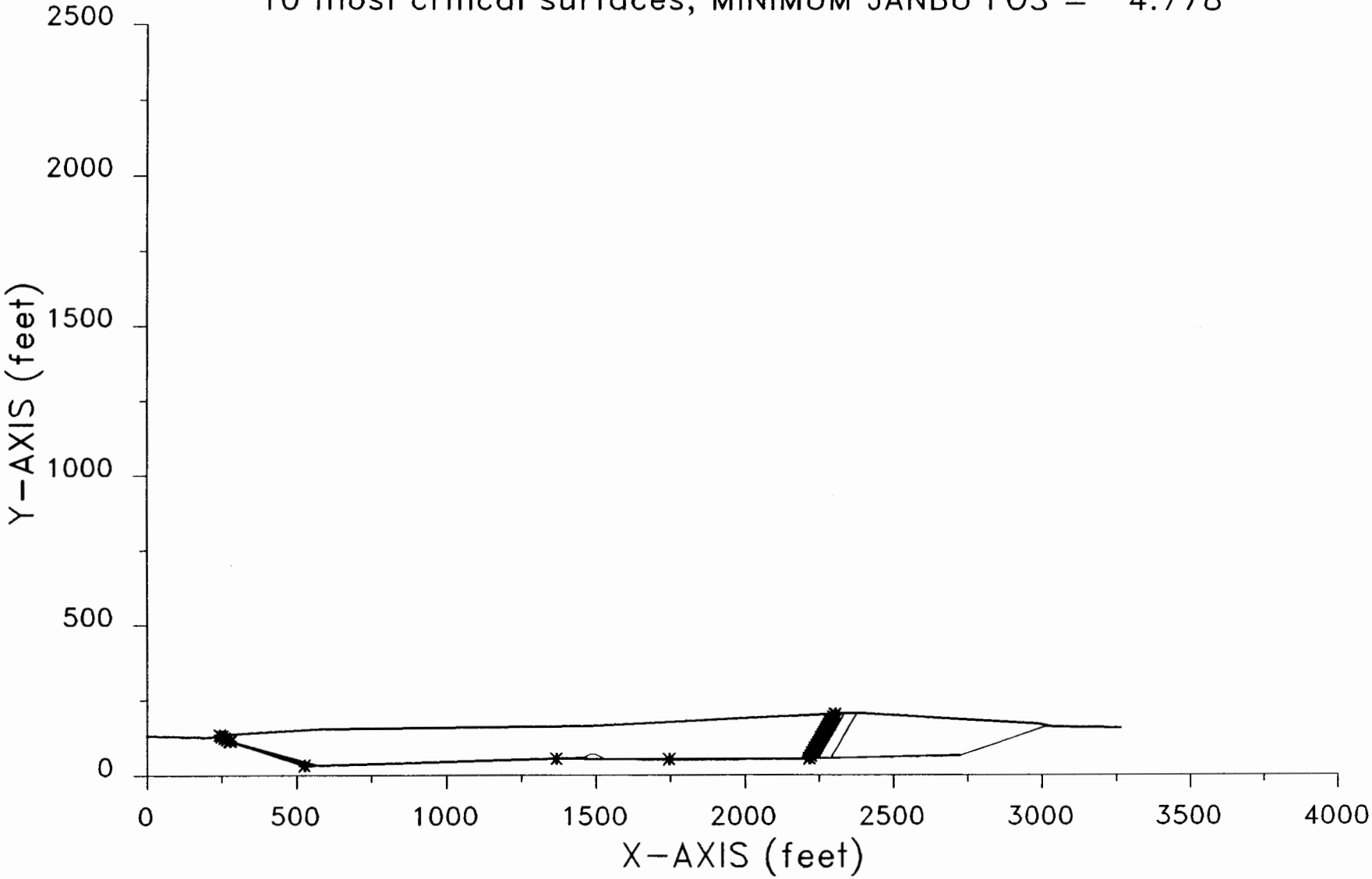
Problem Description : Gandy Basal Failure aa Q

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	1.494	1.026	462.91	2495.41	1.862E+06
2.	1.495	1.026	463.15	2485.34	1.860E+06
3.	1.495	1.026	462.67	2489.74	1.862E+06
4.	1.496	1.026	462.48	2485.41	1.860E+06
5.	1.496	1.025	462.63	2503.39	1.865E+06
6.	1.496	1.025	462.66	2493.21	1.860E+06
7.	1.497	1.025	463.34	2494.24	1.863E+06
8.	1.497	1.026	463.95	2491.17	1.863E+06
9.	1.497	1.026	463.17	2487.89	1.863E+06
10.	1.497	1.025	462.88	2500.59	1.864E+06

* * * END OF FILE * * *

Gandy Total Basal Failue Q

10 most critical surfaces, MINIMUM JANBU FOS = 4.778



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7-Nov-97
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XSTABL File: GTB2 11-06-97 6:34

```
*****************************************
*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.200                 96 á 1216 *
*****************************************
```

Problem Description : Gandy Total Basal Failue Q

SEGMENT BOUNDARY COORDINATES
---

9 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	131.9	213.0	127.5	2
2	213.0	127.5	243.3	135.0	1
3	243.3	135.0	590.6	155.8	1
4	590.6	155.8	1473.6	163.6	1
5	1473.6	163.6	2338.5	204.8	1
6	2338.5	204.8	2394.6	205.0	1
7	2394.6	205.0	2985.4	170.0	1
8	2985.4	170.0	3036.6	160.0	1
9	3036.6	160.0	3266.9	157.0	2

10 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	213.0	127.5	241.3	127.4	2
2	241.3	127.4	525.9	32.6	2
3	525.9	32.6	1459.4	57.9	2
4	1459.4	57.9	1483.7	70.0	2
5	1483.7	70.0	1498.7	70.0	2
6	1498.7	70.0	1531.4	53.7	2
7	1531.4	53.7	2159.5	53.7	2
8	2159.5	53.7	2725.7	65.0	2
9	2725.7	65.0	3009.3	159.7	2
10	3009.3	159.7	3036.6	160.0	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

500 trial surfaces will be generated and analyzed.

5 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 10.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	261.3	120.3	311.3	103.6	1.0
2	524.9	32.1	575.9	33.4	1.0
3	1359.4	54.7	1459.4	57.4	1.0
4	1531.4	53.2	2159.5	52.7	1.0
5	2184.5	53.7	2726.7	64.5	1.0

```
*************************************************************
**     Factor of safety calculation for surface #    64    **
**     failed to converge within FIFTY iterations          **
**                                                         **
**    The last calculated value of the FOS was  21.2076    **
**    This will be ignored for final summary of results    **
*************************************************************
```

The trial failure surface in question is defined by the following 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)

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The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 29 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	243.98	135.04
2	251.47	130.63
3	260.09	125.55
4	268.70	120.48
5	277.32	115.40
6	278.63	114.14
7	527.07	31.99
8	1367.24	54.58
9	1746.80	52.70
10	2216.16	54.07
11	2216.91	54.85
12	2221.99	63.46
13	2227.07	72.08
14	2232.14	80.69
15	2237.22	89.31
16	2242.29	97.93
17	2247.37	106.54
18	2252.44	115.16
19	2257.52	123.78
20	2262.59	132.39
21	2267.67	141.01
22	2272.74	149.63
23	2277.82	158.24
24	2282.90	166.86
25	2287.97	175.47
26	2293.05	184.09
27	2298.12	192.71
28	2303.20	201.32
29	2304.28	203.17

** Corrected JANBU FOS = 4.778 ** (Fo factor = 1.032)

Failure surface No. 2 specified by 31 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	255.62	135.74
2	263.75	130.95
3	272.37	125.87
4	280.99	120.80
5	289.60	115.72
6	298.22	110.65
7	306.84	105.57
8	306.89	105.52
9	560.85	32.94
10	1376.54	55.51
11	1656.88	53.39

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12	2191.25	53.45
13	2192.12	54.35
14	2197.20	62.97
15	2202.27	71.58
16	2207.35	80.20
17	2212.42	88.82
18	2217.50	97.43
19	2222.57	106.05
20	2227.65	114.67
21	2232.72	123.28
22	2237.80	131.90
23	2242.87	140.51
24	2247.95	149.13
25	2253.03	157.75
26	2258.10	166.36
27	2263.18	174.98
28	2268.25	183.60
29	2273.33	192.21
30	2278.40	200.83
31	2279.07	201.97

** Corrected JANBU FOS = 6.261 ** (Fo factor = 1.032)

Failure surface No. 3 specified by 30 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	246.97	135.22
2	250.43	133.18
3	259.04	128.11
4	267.66	123.03
5	276.28	117.96
6	284.89	112.88
7	285.29	112.49
8	548.51	32.85
9	1360.20	54.32
10	1743.27	53.48
11	2188.01	53.68
12	2188.59	54.28
13	2193.66	62.90
14	2198.74	71.51
15	2203.81	80.13
16	2208.89	88.75
17	2213.96	97.36
18	2219.04	105.98
19	2224.11	114.59
20	2229.19	123.21
21	2234.26	131.83
22	2239.34	140.44
23	2244.42	149.06
24	2249.49	157.68
25	2254.57	166.29
26	2259.64	174.91
27	2264.72	183.52
28	2269.79	192.14
29	2274.87	200.76
30	2275.48	201.80

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** Corrected JANBU FOS = 6.418 ** (Fo factor = 1.032)

Failure surface No. 4 specified by 30 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	245.82	135.15
2	247.53	134.15
3	256.14	129.07
4	264.76	124.00
5	273.38	118.92
6	281.99	113.85
7	282.25	113.59
8	573.03	33.60
9	1362.45	54.55
10	2097.66	52.41
11	2245.43	55.08
12	2245.76	55.42
13	2250.84	64.04
14	2255.91	72.65
15	2260.99	81.27
16	2266.06	89.89
17	2271.14	98.50
18	2276.21	107.12
19	2281.29	115.74
20	2286.36	124.35
21	2291.44	132.97
22	2296.51	141.58
23	2301.59	150.20
24	2306.67	158.82
25	2311.74	167.43
26	2316.82	176.05
27	2321.89	184.67
28	2326.97	193.28
29	2332.04	201.90
30	2333.61	204.57

** Corrected JANBU FOS = 6.430 ** (Fo factor = 1.032)

Failure surface No. 5 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	240.14	134.22
2	248.04	129.57
3	256.66	124.49
4	265.27	119.41
5	266.38	118.34
6	568.42	32.89
7	1387.20	55.01
8	1697.66	53.02
9	2203.86	53.83
10	2204.61	54.60
11	2209.68	63.22
12	2214.76	71.83
13	2219.84	80.45

14	2224.91	89.07
15	2229.99	97.68
16	2235.06	106.30
17	2240.14	114.91
18	2245.21	123.53
19	2250.29	132.15
20	2255.36	140.76
21	2260.44	149.38
22	2265.51	158.00
23	2270.59	166.61
24	2275.67	175.23
25	2280.74	183.84
26	2285.82	192.46
27	2290.89	201.08
28	2291.77	202.57

** Corrected JANBU FOS = 6.443 ** (Fo factor = 1.032)

Failure surface No. 6 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	240.36	134.27
2	248.76	129.33
3	257.38	124.25
4	265.99	119.17
5	267.17	118.03
6	526.25	31.81
7	1364.70	55.23
8	2004.20	52.87
9	2192.36	54.07
10	2192.64	54.36
11	2197.71	62.98
12	2202.79	71.59
13	2207.86	80.21
14	2212.94	88.83
15	2218.01	97.44
16	2223.09	106.06
17	2228.16	114.68
18	2233.24	123.29
19	2238.32	131.91
20	2243.39	140.52
21	2248.47	149.14
22	2253.54	157.76
23	2258.62	166.37
24	2263.69	174.99
25	2268.77	183.61
26	2273.84	192.22
27	2278.92	200.84
28	2279.60	201.99

** Corrected JANBU FOS = 6.454 ** (Fo factor = 1.032)

Failure surface No. 7 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)

1	239.21	133.99
2	245.00	130.58
3	253.61	125.50
4	262.23	120.43
5	262.91	119.78
6	527.33	32.54
7	1366.35	54.92
8	2151.22	52.22
9	2196.27	53.67
10	2197.02	54.45
11	2202.10	63.07
12	2207.17	71.68
13	2212.25	80.30
14	2217.32	88.91
15	2222.40	97.53
16	2227.48	106.15
17	2232.55	114.76
18	2237.63	123.38
19	2242.70	132.00
20	2247.78	140.61
21	2252.85	149.23
22	2257.93	157.84
23	2263.00	166.46
24	2268.08	175.08
25	2273.15	183.69
26	2278.23	192.31
27	2283.30	200.93
28	2284.06	202.21

** Corrected JANBU FOS = 6.503 ** (Fo factor = 1.032)

Failure surface No. 8 specified by 29 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	244.55	135.07
2	252.91	130.15
3	261.52	125.07
4	270.14	120.00
5	278.76	114.92
6	280.21	113.52
7	544.74	32.45
8	1422.26	56.72
9	1731.78	52.90
10	2193.15	53.56
11	2193.95	54.39
12	2199.03	63.00
13	2204.11	71.62
14	2209.18	80.24
15	2214.26	88.85
16	2219.33	97.47
17	2224.41	106.09
18	2229.48	114.70
19	2234.56	123.32
20	2239.63	131.93
21	2244.71	140.55
22	2249.78	149.17

23	2254.86	157.78
24	2259.94	166.40
25	2265.01	175.02
26	2270.09	183.63
27	2275.16	192.25
28	2280.24	200.86
29	2280.94	202.06

** Corrected JANBU FOS = 6.529 ** (Fo factor = 1.032)

Failure surface No. 9 specified by 30 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	249.58	135.38
2	257.06	130.97
3	265.67	125.90
4	274.29	120.82
5	282.91	115.75
6	291.52	110.67
7	291.62	110.57
8	553.55	32.82
9	1400.64	56.22
10	1770.45	52.57
11	2196.42	53.60
12	2197.24	54.45
13	2202.31	63.07
14	2207.39	71.69
15	2212.47	80.30
16	2217.54	88.92
17	2222.62	97.53
18	2227.69	106.15
19	2232.77	114.77
20	2237.84	123.38
21	2242.92	132.00
22	2247.99	140.62
23	2253.07	149.23
24	2258.14	157.85
25	2263.22	166.46
26	2268.30	175.08
27	2273.37	183.70
28	2278.45	192.31
29	2283.52	200.93
30	2284.28	202.22

** Corrected JANBU FOS = 6.540 ** (Fo factor = 1.032)

Failure surface No.10 specified by 29 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	240.47	134.30
2	240.50	134.28
3	249.11	129.21
4	257.73	124.13
5	266.35	119.06

6	267.68	117.77
7	528.89	32.33
8	1374.04	55.47
9	2089.03	52.34
10	2288.19	56.06
11	2288.40	56.27
12	2293.47	64.89
13	2298.55	73.51
14	2303.62	82.12
15	2308.70	90.74
16	2313.77	99.35
17	2318.85	107.97
18	2323.92	116.59
19	2329.00	125.20
20	2334.07	133.82
21	2339.15	142.44
22	2344.23	151.05
23	2349.30	159.67
24	2354.38	168.28
25	2359.45	176.90
26	2364.53	185.52
27	2369.60	194.13
28	2374.68	202.75
29	2375.96	204.93

** Corrected JANBU FOS = 6.582 ** (Fo factor = 1.031)

```
*********************************************************************
**                                                                 **
**  Out of the    500 surfaces generated and analyzed by XSTABL,   **
**       10 surfaces were found to have MISLEADING FOS values.     **
**                                                                 **
*********************************************************************
```

The following is a summary of the TEN most critical surfaces

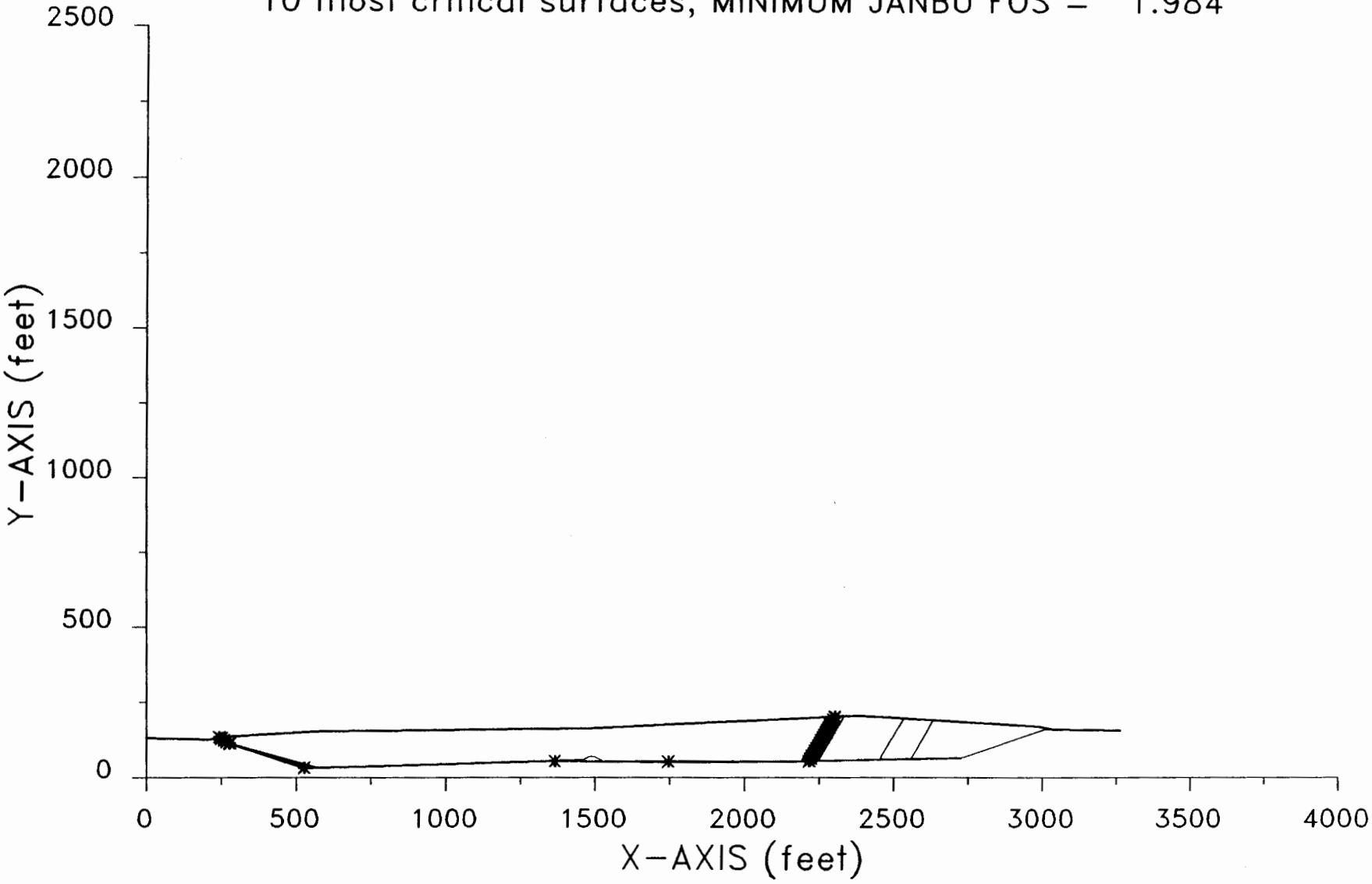
Problem Description : Gandy Total Basal Failue Q

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	4.778	1.032	243.98	2304.28	3.077E+06
2.	6.261	1.032	255.62	2279.07	3.964E+06
3.	6.418	1.032	246.97	2275.48	4.090E+06
4.	6.430	1.032	245.82	2333.61	4.330E+06
5.	6.443	1.032	240.14	2291.77	4.165E+06
6.	6.454	1.032	240.36	2279.60	4.233E+06
7.	6.503	1.032	239.21	2284.06	4.254E+06
8.	6.529	1.032	244.55	2280.94	4.210E+06
9.	6.540	1.032	249.58	2284.28	4.211E+06
10.	6.582	1.031	240.47	2375.96	4.707E+06

* * * END OF FILE * * *

Gandy Total Basal Failue Q

10 most critical surfaces, MINIMUM JANBU FOS = 1.984



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*****************************************
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*                                       *
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*               using the               *
*            Method of Slices           *
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```

Problem Description : Gandy Total Basal Failue Q

SEGMENT BOUNDARY COORDINATES
---

9 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	131.9	213.0	127.5	2
2	213.0	127.5	243.3	135.0	1
3	243.3	135.0	590.6	155.8	1
4	590.6	155.8	1473.6	163.6	1
5	1473.6	163.6	2338.5	204.8	1
6	2338.5	204.8	2394.6	205.0	1
7	2394.6	205.0	2985.4	170.0	1
8	2985.4	170.0	3036.6	160.0	1
9	3036.6	160.0	3266.9	157.0	2

10 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	213.0	127.5	241.3	127.4	2
2	241.3	127.4	525.9	32.6	2
3	525.9	32.6	1459.4	57.9	2
4	1459.4	57.9	1483.7	70.0	2
5	1483.7	70.0	1498.7	70.0	2
6	1498.7	70.0	1531.4	53.7	2
7	1531.4	53.7	2159.5	53.7	2
8	2159.5	53.7	2725.7	65.0	2
9	2725.7	65.0	3009.3	159.7	2
10	3009.3	159.7	3036.6	160.0	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A horizontal earthquake loading coefficient
of .040 has been assigned

A vertical earthquake loading coefficient
of .000 has been assigned

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

500 trial surfaces will be generated and analyzed.

5 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 10.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	261.3	120.3	311.3	103.6	1.0
2	524.9	32.1	575.9	33.4	1.0
3	1359.4	54.7	1459.4	57.4	1.0
4	1531.4	53.2	2159.5	52.7	1.0
5	2184.5	53.7	2726.7	64.5	1.0

****
ERROR # 38
****
The program calculated a point for the PASSIVE wedge that is outside the defined slope geometry. The analysis will continue, but the user should adjust the search box or slope geometry to allow a passive

wedge to be formed from all points within first box.
****

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 29 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	243.98	135.04
2	251.47	130.63
3	260.09	125.55
4	268.70	120.48
5	277.32	115.40
6	278.63	114.14
7	527.07	31.99
8	1367.24	54.58
9	1746.80	52.70
10	2216.16	54.07
11	2216.91	54.85
12	2221.99	63.46
13	2227.07	72.08
14	2232.14	80.69
15	2237.22	89.31
16	2242.29	97.93
17	2247.37	106.54
18	2252.44	115.16
19	2257.52	123.78
20	2262.59	132.39
21	2267.67	141.01
22	2272.74	149.63
23	2277.82	158.24
24	2282.90	166.86
25	2287.97	175.47
26	2293.05	184.09
27	2298.12	192.71
28	2303.20	201.32
29	2304.28	203.17

** Corrected JANBU FOS = 1.984 ** (Fo factor = 1.032)

Failure surface No. 2 specified by 31 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	255.62	135.74
2	263.75	130.95

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3	272.37	125.87
4	280.99	120.80
5	289.60	115.72
6	298.22	110.65
7	306.84	105.57
8	306.89	105.52
9	560.85	32.94
10	1376.54	55.51
11	1656.88	53.39
12	2191.25	53.45
13	2192.12	54.35
14	2197.20	62.97
15	2202.27	71.58
16	2207.35	80.20
17	2212.42	88.82
18	2217.50	97.43
19	2222.57	106.05
20	2227.65	114.67
21	2232.72	123.28
22	2237.80	131.90
23	2242.87	140.51
24	2247.95	149.13
25	2253.03	157.75
26	2258.10	166.36
27	2263.18	174.98
28	2268.25	183.60
29	2273.33	192.21
30	2278.40	200.83
31	2279.07	201.97

** Corrected JANBU FOS = 2.671 ** (Fo factor = 1.032)

Failure surface No. 3 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	245.44	135.13
2	246.55	134.47
3	255.16	129.40
4	263.78	124.32
5	272.39	119.25
6	281.01	114.17
7	281.87	113.35
8	539.35	32.88
9	1364.46	54.59
10	2118.96	52.56
11	2452.08	58.87
12	2452.73	59.55
13	2457.81	68.17
14	2462.89	76.78
15	2467.96	85.40
16	2473.04	94.02
17	2478.11	102.63
18	2483.19	111.25
19	2488.26	119.87
20	2493.34	128.48
21	2498.41	137.10
22	2503.49	145.72

23	2508.56	154.33
24	2513.64	162.95
25	2518.71	171.56
26	2523.79	180.18
27	2528.87	188.80
28	2533.56	196.77

** Corrected JANBU FOS = 2.738 ** (Fo factor = 1.027)

Failure surface No. 4 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	240.36	134.27
2	248.76	129.33
3	257.38	124.25
4	265.99	119.17
5	267.17	118.03
6	526.25	31.81
7	1364.70	55.23
8	2004.20	52.87
9	2192.36	54.07
10	2192.64	54.36
11	2197.71	62.98
12	2202.79	71.59
13	2207.86	80.21
14	2212.94	88.83
15	2218.01	97.44
16	2223.09	106.06
17	2228.16	114.68
18	2233.24	123.29
19	2238.32	131.91
20	2243.39	140.52
21	2248.47	149.14
22	2253.54	157.76
23	2258.62	166.37
24	2263.69	174.99
25	2268.77	183.61
26	2273.84	192.22
27	2278.92	200.84
28	2279.60	201.99

** Corrected JANBU FOS = 2.739 ** (Fo factor = 1.032)

Failure surface No. 5 specified by 30 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	246.97	135.22
2	250.43	133.18
3	259.04	128.11
4	267.66	123.03
5	276.28	117.96
6	284.89	112.88
7	285.29	112.49
8	548.51	32.85

9	1360.20	54.32
10	1743.27	53.48
11	2188.01	53.68
12	2188.59	54.28
13	2193.66	62.90
14	2198.74	71.51
15	2203.81	80.13
16	2208.89	88.75
17	2213.96	97.36
18	2219.04	105.98
19	2224.11	114.59
20	2229.19	123.21
21	2234.26	131.83
22	2239.34	140.44
23	2244.42	149.06
24	2249.49	157.68
25	2254.57	166.29
26	2259.64	174.91
27	2264.72	183.52
28	2269.79	192.14
29	2274.87	200.76
30	2275.48	201.80

** Corrected JANBU FOS = 2.741 ** (Fo factor = 1.032)

Failure surface No. 6 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	240.14	134.22
2	248.04	129.57
3	256.66	124.49
4	265.27	119.41
5	266.38	118.34
6	568.42	32.89
7	1387.20	55.01
8	1697.66	53.02
9	2203.86	53.83
10	2204.61	54.60
11	2209.68	63.22
12	2214.76	71.83
13	2219.84	80.45
14	2224.91	89.07
15	2229.99	97.68
16	2235.06	106.30
17	2240.14	114.91
18	2245.21	123.53
19	2250.29	132.15
20	2255.36	140.76
21	2260.44	149.38
22	2265.51	158.00
23	2270.59	166.61
24	2275.67	175.23
25	2280.74	183.84
26	2285.82	192.46
27	2290.89	201.08
28	2291.77	202.57

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** Corrected JANBU FOS = 2.756 ** (Fo factor = 1.032)

Failure surface No. 7 specified by 30 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	245.82	135.15
2	247.53	134.15
3	256.14	129.07
4	264.76	124.00
5	273.38	118.92
6	281.99	113.85
7	282.25	113.59
8	573.03	33.60
9	1362.45	54.55
10	2097.66	52.41
11	2245.43	55.08
12	2245.76	55.42
13	2250.84	64.04
14	2255.91	72.65
15	2260.99	81.27
16	2266.06	89.89
17	2271.14	98.50
18	2276.21	107.12
19	2281.29	115.74
20	2286.36	124.35
21	2291.44	132.97
22	2296.51	141.58
23	2301.59	150.20
24	2306.67	158.82
25	2311.74	167.43
26	2316.82	176.05
27	2321.89	184.67
28	2326.97	193.28
29	2332.04	201.90
30	2333.61	204.57

** Corrected JANBU FOS = 2.772 ** (Fo factor = 1.032)

Failure surface No. 8 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	251.53	135.49
2	253.39	134.40
3	262.01	129.32
4	270.63	124.25
5	279.24	119.17
6	287.86	114.10
7	296.48	109.02
8	297.97	107.58
9	532.87	32.49
10	1362.40	54.69
11	2103.14	52.67
12	2556.40	60.88
13	2557.13	61.64

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14	2562.21	70.25
15	2567.28	78.87
16	2572.36	87.48
17	2577.43	96.10
18	2582.51	104.72
19	2587.58	113.33
20	2592.66	121.95
21	2597.73	130.57
22	2602.81	139.18
23	2607.88	147.80
24	2612.96	156.41
25	2618.04	165.03
26	2623.11	173.65
27	2628.19	182.26
28	2633.25	190.86

** Corrected JANBU FOS = 2.785 ** (Fo factor = 1.025)

Failure surface No. 9 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	239.21	133.99
2	245.00	130.58
3	253.61	125.50
4	262.23	120.43
5	262.91	119.78
6	527.33	32.54
7	1366.35	54.92
8	2151.22	52.22
9	2196.27	53.67
10	2197.02	54.45
11	2202.10	63.07
12	2207.17	71.68
13	2212.25	80.30
14	2217.32	88.91
15	2222.40	97.53
16	2227.48	106.15
17	2232.55	114.76
18	2237.63	123.38
19	2242.70	132.00
20	2247.78	140.61
21	2252.85	149.23
22	2257.93	157.84
23	2263.00	166.46
24	2268.08	175.08
25	2273.15	183.69
26	2278.23	192.31
27	2283.30	200.93
28	2284.06	202.21

** Corrected JANBU FOS = 2.786 ** (Fo factor = 1.032)

Failure surface No.10 specified by 29 coordinate points

Point No.	x-surf (ft)	y-surf (ft)

1	244.55	135.07
2	252.91	130.15
3	261.52	125.07
4	270.14	120.00
5	278.76	114.92
6	280.21	113.52
7	544.74	32.45
8	1422.26	56.72
9	1731.78	52.90
10	2193.15	53.56
11	2193.95	54.39
12	2199.03	63.00
13	2204.11	71.62
14	2209.18	80.24
15	2214.26	88.85
16	2219.33	97.47
17	2224.41	106.09
18	2229.48	114.70
19	2234.56	123.32
20	2239.63	131.93
21	2244.71	140.55
22	2249.78	149.17
23	2254.86	157.78
24	2259.94	166.40
25	2265.01	175.02
26	2270.09	183.63
27	2275.16	192.25
28	2280.24	200.86
29	2280.94	202.06

** Corrected JANBU FOS = 2.797 ** (Fo factor = 1.032)

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Total Basal Failue Q

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	1.984	1.032	243.98	2304.28	2.959E+06
2.	2.671	1.032	255.62	2279.07	3.918E+06
3.	2.738	1.027	245.44	2533.56	4.544E+06
4.	2.739	1.032	240.36	2279.60	4.137E+06
5.	2.741	1.032	246.97	2275.48	4.043E+06
6.	2.756	1.032	240.14	2291.77	4.116E+06
7.	2.772	1.032	245.82	2333.61	4.281E+06
8.	2.785	1.025	251.53	2633.25	4.625E+06
9.	2.786	1.032	239.21	2284.06	4.193E+06
10.	2.797	1.032	244.55	2280.94	4.162E+06

* * * END OF FILE * * *

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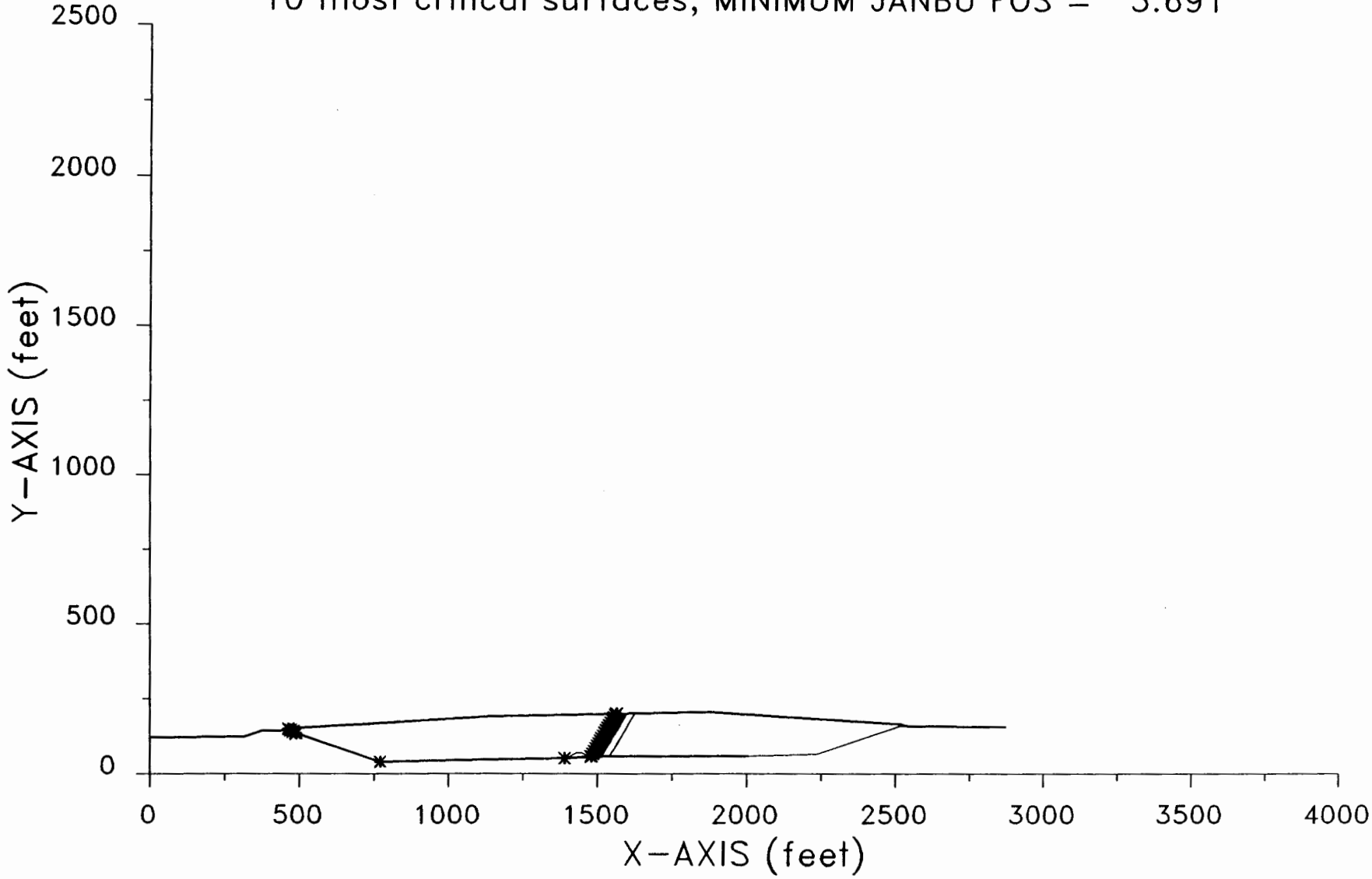
Gandy Basal Failure aa 2

10 most critical surfaces, MINIMUM JANBU FOS = 3.691



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*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
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Problem Description : Gandy Basal Failure aa 2

SEGMENT BOUNDARY COORDINATES
---

10 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.0	122.0	315.6	123.8	2
2	315.6	123.8	375.2	143.6	2
3	375.2	143.6	436.8	143.6	2
4	436.8	143.6	474.5	153.0	1
5	474.5	153.0	1146.0	192.8	1
6	1146.0	192.8	1813.7	204.9	1
7	1813.7	204.9	1884.7	205.0	1
8	1884.7	205.0	2519.5	165.0	1
9	2519.5	165.0	2543.7	159.0	1
10	2543.7	159.0	2872.9	156.7	2

10 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	436.8	143.6	465.1	143.6	2
2	465.1	143.6	772.5	41.1	2
3	772.5	41.1	1399.3	52.9	2
4	1399.3	52.9	1433.2	69.8	2
5	1433.2	69.8	1448.8	69.9	2
6	1448.8	69.9	1472.6	58.0	2
7	1472.6	58.0	2008.1	58.3	2
8	2008.1	58.3	2233.9	65.1	2
9	2233.9	65.1	2515.4	159.0	2

10	2515.4	159.0	2543.7	159.0	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

500 trial surfaces will be generated and analyzed.

4 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 10.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	485.1	136.5	535.1	119.8	1.0
2	771.5	40.6	772.5	40.6	1.0
3	1374.3	51.9	1399.3	52.4	1.0
4	1472.6	57.5	2008.1	57.5	1.0

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)

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1	463.87	150.35
2	471.45	145.89
3	480.06	140.81
4	488.68	135.74
5	489.64	134.81
6	771.93	40.40
7	1390.88	51.83
8	1480.58	57.64
9	1480.94	58.00
10	1486.01	66.62
11	1491.09	75.24
12	1496.16	83.85
13	1501.24	92.47
14	1506.31	101.09
15	1511.39	109.70
16	1516.46	118.32
17	1521.54	126.94
18	1526.61	135.55
19	1531.69	144.17
20	1536.77	152.78
21	1541.84	161.40
22	1546.92	170.02
23	1551.99	178.63
24	1557.07	187.25
25	1562.14	195.87
26	1564.81	200.39

** Corrected JANBU FOS = 3.691 ** (Fo factor = 1.052)

Failure surface No. 2 specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.04	150.14
2	468.71	146.80
3	477.33	141.72
4	485.95	136.65
5	486.71	135.91
6	771.56	40.87
7	1382.20	51.82
8	1484.94	57.82
9	1485.12	58.01
10	1490.20	66.62
11	1495.27	75.24
12	1500.35	83.86
13	1505.42	92.47
14	1510.50	101.09
15	1515.57	109.70
16	1520.65	118.32
17	1525.72	126.94
18	1530.80	135.55
19	1535.88	144.17
20	1540.95	152.79
21	1546.03	161.40
22	1551.10	170.02
23	1556.18	178.64
24	1561.25	187.25

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25	1566.33	195.87
26	1569.04	200.47

** Corrected JANBU FOS = 3.695 ** (Fo factor = 1.052)

Failure surface No. 3 specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.90	150.11
2	468.25	146.95
3	476.87	141.88
4	485.49	136.80
5	485.82	136.48
6	771.56	40.38
7	1385.46	52.08
8	1505.19	57.81
9	1505.39	58.02
10	1510.46	66.63
11	1515.54	75.25
12	1520.61	83.87
13	1525.69	92.48
14	1530.76	101.10
15	1535.84	109.72
16	1540.92	118.33
17	1545.99	126.95
18	1551.07	135.57
19	1556.14	144.18
20	1561.22	152.80
21	1566.29	161.41
22	1571.37	170.03
23	1576.44	178.65
24	1581.52	187.26
25	1586.59	195.88
26	1589.51	200.84

** Corrected JANBU FOS = 3.697 ** (Fo factor = 1.051)

Failure surface No. 4 specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.64	150.29
2	470.70	146.14
3	479.31	141.06
4	487.93	135.99
5	488.48	135.46
6	772.25	40.88
7	1393.45	52.38
8	1480.05	57.58
9	1480.46	58.00
10	1485.53	66.62
11	1490.61	75.24
12	1495.68	83.85
13	1500.76	92.47
14	1505.83	101.09

15	1510.91	109.70
16	1515.99	118.32
17	1521.06	126.93
18	1526.14	135.55
19	1531.21	144.17
20	1536.29	152.78
21	1541.36	161.40
22	1546.44	170.02
23	1551.51	178.63
24	1556.59	187.25
25	1561.66	195.87
26	1564.32	200.38

** Corrected JANBU FOS = 3.701 ** (Fo factor = 1.052)

Failure surface No. 5 specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.22	150.19
2	469.32	146.60
3	477.94	141.52
4	486.55	136.45
5	487.63	135.40
6	771.92	40.90
7	1385.81	51.93
8	1506.73	57.31
9	1507.41	58.02
10	1512.49	66.64
11	1517.56	75.25
12	1522.64	83.87
13	1527.71	92.48
14	1532.79	101.10
15	1537.86	109.72
16	1542.94	118.33
17	1548.01	126.95
18	1553.09	135.57
19	1558.17	144.18
20	1563.24	152.80
21	1568.32	161.42
22	1573.39	170.03
23	1578.47	178.65
24	1583.54	187.26
25	1588.62	195.88
26	1591.56	200.87

** Corrected JANBU FOS = 3.705 ** (Fo factor = 1.051)

Failure surface No. 6 specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.74	150.07
2	467.73	147.13
3	476.35	142.05
4	484.97	136.98

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5	485.82	136.16
6	772.25	40.41
7	1378.23	51.66
8	1540.79	57.56
9	1541.25	58.04
10	1546.33	66.65
11	1551.41	75.27
12	1556.48	83.89
13	1561.56	92.50
14	1566.63	101.12
15	1571.71	109.74
16	1576.78	118.35
17	1581.86	126.97
18	1586.93	135.59
19	1592.01	144.20
20	1597.08	152.82
21	1602.16	161.43
22	1607.23	170.05
23	1612.31	178.67
24	1617.39	187.28
25	1622.46	195.90
26	1625.76	201.49

** Corrected JANBU FOS = 3.708 ** (Fo factor = 1.050)

Failure surface No. 7 specified by 27 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	465.80	150.83
2	469.15	148.86
3	477.76	143.78
4	486.38	138.71
5	495.00	133.63
6	496.13	132.53
7	771.69	40.47
8	1395.06	52.29
9	1490.66	57.08
10	1491.56	58.01
11	1496.63	66.63
12	1501.71	75.24
13	1506.79	83.86
14	1511.86	92.48
15	1516.94	101.09
16	1522.01	109.71
17	1527.09	118.32
18	1532.16	126.94
19	1537.24	135.56
20	1542.31	144.17
21	1547.39	152.79
22	1552.46	161.41
23	1557.54	170.02
24	1562.62	178.64
25	1567.69	187.25
26	1572.77	195.87
27	1575.54	200.58

** Corrected JANBU FOS = 3.710 ** (Fo factor = 1.052)

Failure surface No. 8 specified by 27 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	464.73	150.56
2	465.64	150.03
3	474.25	144.95
4	482.87	139.88
5	491.49	134.80
6	491.67	134.62
7	771.64	40.45
8	1386.72	52.14
9	1514.26	57.82
10	1514.47	58.02
11	1519.54	66.64
12	1524.62	75.26
13	1529.69	83.87
14	1534.77	92.49
15	1539.84	101.10
16	1544.92	109.72
17	1549.99	118.34
18	1555.07	126.95
19	1560.14	135.57
20	1565.22	144.19
21	1570.30	152.80
22	1575.37	161.42
23	1580.45	170.04
24	1585.52	178.65
25	1590.60	187.27
26	1595.67	195.88
27	1598.69	201.00

** Corrected JANBU FOS = 3.712 ** (Fo factor = 1.051)

Failure surface No. 9 specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	464.31	150.46
2	472.88	145.41
3	481.49	140.34
4	490.11	135.26
5	490.83	134.56
6	772.32	40.46
7	1379.07	51.70
8	1540.94	57.54
9	1541.42	58.04
10	1546.49	66.65
11	1551.57	75.27
12	1556.65	83.89
13	1561.72	92.50
14	1566.80	101.12
15	1571.87	109.74
16	1576.95	118.35
17	1582.02	126.97

18	1587.10	135.59
19	1592.17	144.20
20	1597.25	152.82
21	1602.32	161.43
22	1607.40	170.05
23	1612.48	178.67
24	1617.55	187.28
25	1622.63	195.90
26	1625.92	201.50

** Corrected JANBU FOS = 3.718 ** (Fo factor = 1.050)

Failure surface No.10 specified by 27 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	466.93	151.11
2	472.86	147.62
3	481.48	142.54
4	490.09	137.47
5	498.71	132.39
6	499.76	131.38
7	772.41	40.51
8	1395.76	51.99
9	1493.74	57.08
10	1494.64	58.01
11	1499.72	66.63
12	1504.79	75.24
13	1509.87	83.86
14	1514.94	92.48
15	1520.02	101.09
16	1525.09	109.71
17	1530.17	118.33
18	1535.24	126.94
19	1540.32	135.56
20	1545.39	144.18
21	1550.47	152.79
22	1555.55	161.41
23	1560.62	170.02
24	1565.70	178.64
25	1570.77	187.26
26	1575.85	195.87
27	1578.66	200.64

** Corrected JANBU FOS = 3.719 ** (Fo factor = 1.052)

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Basal Failure aa 2

Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)

1.	3.691	1.052	463.87	1564.81	1.493E+06
2.	3.695	1.052	463.04	1569.04	1.495E+06
3.	3.697	1.051	462.90	1589.51	1.519E+06
4.	3.701	1.052	463.64	1564.32	1.490E+06
5.	3.705	1.051	463.22	1591.56	1.521E+06
6.	3.708	1.050	462.74	1625.76	1.560E+06
7.	3.710	1.052	465.80	1575.54	1.508E+06
8.	3.712	1.051	464.73	1598.69	1.532E+06
9.	3.718	1.050	464.31	1625.92	1.563E+06
10.	3.719	1.052	466.93	1578.66	1.514E+06

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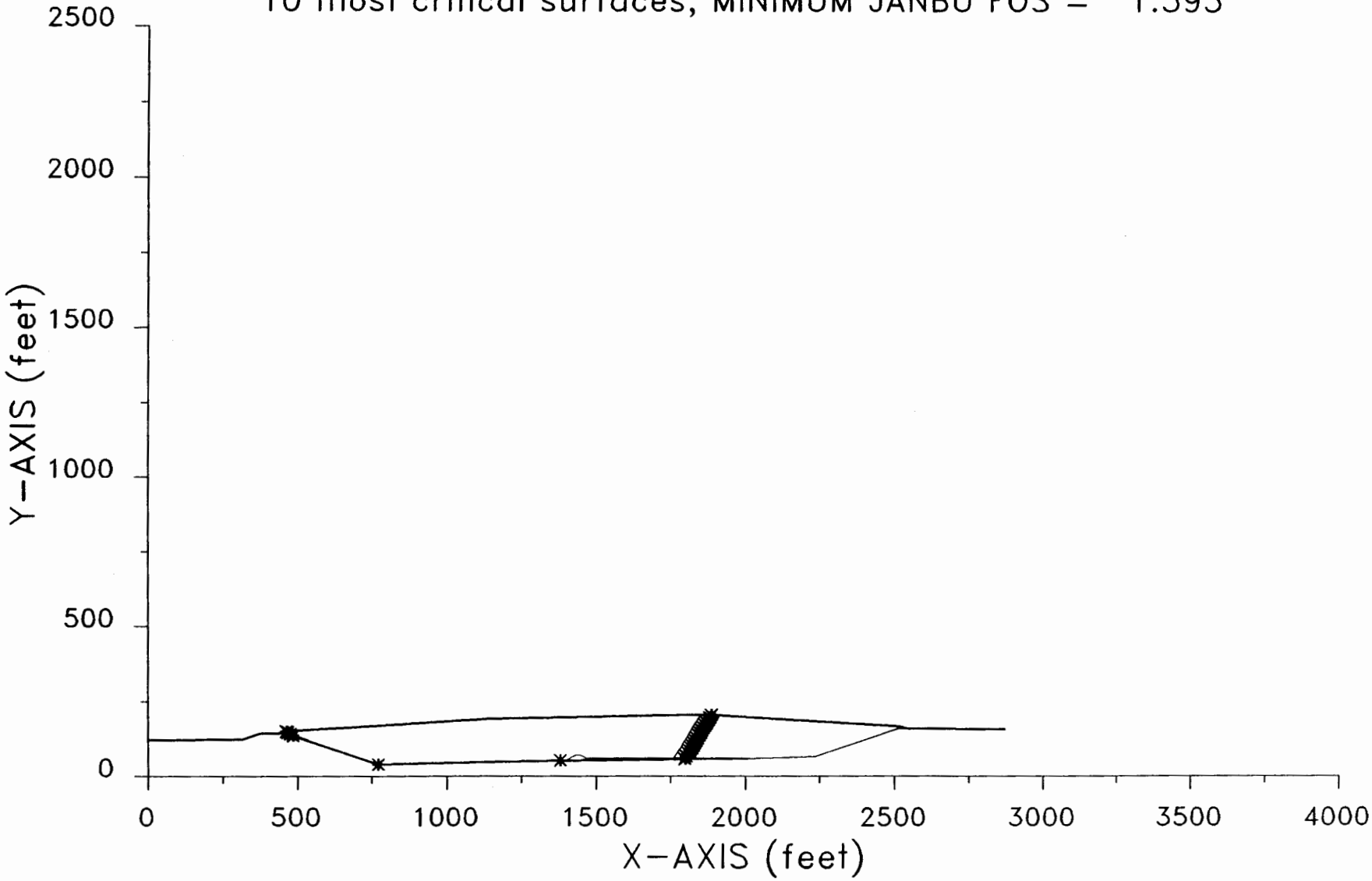
Gandy Basal Failure aa 2 Q

10 most critical surfaces, MINIMUM JANBU FOS = 1.595



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PMP
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*              X S T A B L              *
*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
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*  Ver. 5.200                 96 á 1216 *
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```

Problem Description : Gandy Basal Failure aa 2 Q

SEGMENT BOUNDARY COORDINATES
---

10 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	5.0	122.0	315.6	123.8	2
2	315.6	123.8	375.2	143.6	2
3	375.2	143.6	436.8	143.6	2
4	436.8	143.6	474.5	153.0	1
5	474.5	153.0	1146.0	192.8	1
6	1146.0	192.8	1813.7	204.9	1
7	1813.7	204.9	1884.7	205.0	1
8	1884.7	205.0	2519.5	165.0	1
9	2519.5	165.0	2543.7	159.0	1
10	2543.7	159.0	2872.9	156.7	2

10 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	436.8	143.6	465.1	143.6	2
2	465.1	143.6	772.5	41.1	2
3	772.5	41.1	1399.3	52.9	2
4	1399.3	52.9	1433.2	69.8	2
5	1433.2	69.8	1448.8	69.9	2
6	1448.8	69.9	1472.6	58.0	2
7	1472.6	58.0	2008.1	58.3	2
8	2008.1	58.3	2233.9	65.1	2
9	2233.9	65.1	2515.4	159.0	2

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10	2515.4	159.0	2543.7	159.0	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A horizontal earthquake loading coefficient
of .040 has been assigned

A vertical earthquake loading coefficient
of .000 has been assigned

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

The active and passive portions of the sliding surfaces are generated according to the Rankine theory.

500 trial surfaces will be generated and analyzed.

4 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 10.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	485.1	136.5	535.1	119.8	1.0
2	771.5	40.6	772.5	40.6	1.0
3	1374.3	51.9	1399.3	52.4	1.0
4	1472.6	57.5	2008.1	57.5	1.0

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 27 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.63	150.04
2	467.37	147.25
3	475.99	142.17
4	484.60	137.10
5	485.42	136.30
6	772.40	40.15
7	1380.63	52.28
8	1798.39	57.73
9	1798.83	58.18
10	1803.90	66.80
11	1808.98	75.42
12	1814.05	84.03
13	1819.13	92.65
14	1824.21	101.26
15	1829.28	109.88
16	1834.36	118.50
17	1839.43	127.11
18	1844.51	135.73
19	1849.58	144.35
20	1854.66	152.96
21	1859.73	161.58
22	1864.81	170.19
23	1869.88	178.81
24	1874.96	187.43
25	1880.03	196.04
26	1885.11	204.66
27	1885.29	204.96

** Corrected JANBU FOS = 1.595 ** (Fo factor = 1.043)

Failure surface No. 2 specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.22	150.19
2	469.32	146.60
3	477.93	141.52
4	486.55	136.45
5	486.62	136.38
6	772.10	40.19
7	1376.04	51.56
8	1823.15	57.89
9	1823.44	58.20
10	1828.52	66.81
11	1833.60	75.43
12	1838.67	84.05
13	1843.75	92.66
14	1848.82	101.28
15	1853.90	109.89

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16	1858.97	118.51
17	1864.05	127.13
18	1869.12	135.74
19	1874.20	144.36
20	1879.27	152.98
21	1884.35	161.59
22	1889.43	170.21
23	1894.50	178.82
24	1899.58	187.44
25	1904.65	196.06
26	1909.02	203.47

** Corrected JANBU FOS = 1.595 ** (Fo factor = 1.042)

Failure surface No. 3 specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.78	150.33
2	471.13	145.99
3	479.75	140.92
4	488.37	135.84
5	489.59	134.66
6	772.14	40.22
7	1398.82	52.36
8	1825.22	57.44
9	1825.95	58.20
10	1831.02	66.81
11	1836.10	75.43
12	1841.17	84.05
13	1846.25	92.66
14	1851.32	101.28
15	1856.40	109.90
16	1861.47	118.51
17	1866.55	127.13
18	1871.63	135.74
19	1876.70	144.36
20	1881.78	152.98
21	1886.85	161.59
22	1891.93	170.21
23	1897.00	178.83
24	1902.08	187.44
25	1907.15	196.06
26	1911.43	203.32

** Corrected JANBU FOS = 1.597 ** (Fo factor = 1.042)

Failure surface No. 4 specified by 27 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.88	150.10
2	468.18	146.98
3	476.80	141.90
4	485.41	136.83
5	485.71	136.54

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PMP
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6	772.40	40.14
7	1388.55	52.41
8	1783.57	57.03
9	1784.67	58.17
10	1789.75	66.79
11	1794.82	75.41
12	1799.90	84.02
13	1804.97	92.64
14	1810.05	101.26
15	1815.12	109.87
16	1820.20	118.49
17	1825.27	127.11
18	1830.35	135.72
19	1835.43	144.34
20	1840.50	152.95
21	1845.58	161.57
22	1850.65	170.19
23	1855.73	178.80
24	1860.80	187.42
25	1865.88	196.04
26	1870.95	204.65
27	1871.15	204.98

** Corrected JANBU FOS = 1.598 ** (Fo factor = 1.044)

Failure surface No. 5 specified by 27 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.60	150.03
2	467.28	147.28
3	475.89	142.20
4	484.51	137.13
5	485.94	135.75
6	772.07	40.64
7	1391.26	52.30
8	1780.11	57.97
9	1780.31	58.17
10	1785.39	66.79
11	1790.46	75.40
12	1795.54	84.02
13	1800.61	92.64
14	1805.69	101.25
15	1810.76	109.87
16	1815.84	118.49
17	1820.91	127.10
18	1825.99	135.72
19	1831.06	144.34
20	1836.14	152.95
21	1841.22	161.57
22	1846.29	170.18
23	1851.37	178.80
24	1856.44	187.42
25	1861.52	196.03
26	1866.59	204.65
27	1866.78	204.97

** Corrected JANBU FOS = 1.598 ** (Fo factor = 1.044)

Failure surface No. 6 specified by 27 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.77	150.32
2	471.10	146.00
3	479.71	140.93
4	488.33	135.85
5	489.23	134.98
6	772.12	40.18
7	1394.94	52.56
8	1791.58	57.93
9	1791.83	58.18
10	1796.90	66.80
11	1801.98	75.41
12	1807.05	84.03
13	1812.13	92.64
14	1817.20	101.26
15	1822.28	109.88
16	1827.35	118.49
17	1832.43	127.11
18	1837.51	135.73
19	1842.58	144.34
20	1847.66	152.96
21	1852.73	161.57
22	1857.81	170.19
23	1862.88	178.81
24	1867.96	187.42
25	1873.03	196.04
26	1878.11	204.66
27	1878.31	204.99

** Corrected JANBU FOS = 1.598 ** (Fo factor = 1.044)

Failure surface No. 7 specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	464.04	150.39
2	472.01	145.70
3	480.62	140.63
4	489.24	135.55
5	490.62	134.22
6	772.16	40.23
7	1387.85	52.48
8	1824.26	57.66
9	1824.78	58.20
10	1829.85	66.81
11	1834.93	75.43
12	1840.00	84.05
13	1845.08	92.66
14	1850.15	101.28
15	1855.23	109.90
16	1860.31	118.51
17	1865.38	127.13

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18	1870.46	135.74
19	1875.53	144.36
20	1880.61	152.98
21	1885.68	161.59
22	1890.76	170.21
23	1895.83	178.83
24	1900.91	187.44
25	1905.98	196.06
26	1910.30	203.39

** Corrected JANBU FOS = 1.599 ** (Fo factor = 1.042)

Failure surface No. 8 specified by 27 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	464.30	150.46
2	472.84	145.42
3	481.46	140.35
4	490.07	135.27
5	491.28	134.11
6	772.14	40.20
7	1398.00	52.30
8	1789.67	57.36
9	1790.46	58.18
10	1795.53	66.79
11	1800.61	75.41
12	1805.68	84.03
13	1810.76	92.64
14	1815.83	101.26
15	1820.91	109.88
16	1825.98	118.49
17	1831.06	127.11
18	1836.13	135.72
19	1841.21	144.34
20	1846.29	152.96
21	1851.36	161.57
22	1856.44	170.19
23	1861.51	178.81
24	1866.59	187.42
25	1871.66	196.04
26	1876.74	204.66
27	1876.93	204.99

** Corrected JANBU FOS = 1.599 ** (Fo factor = 1.044)

Failure surface No. 9 specified by 27 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	462.96	150.12
2	468.45	146.89
3	477.06	141.81
4	485.68	136.74
5	485.80	136.62
6	772.05	40.12

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7	1398.97	51.92
8	1760.83	57.76
9	1761.21	58.16
10	1766.29	66.78
11	1771.36	75.39
12	1776.44	84.01
13	1781.51	92.63
14	1786.59	101.24
15	1791.67	109.86
16	1796.74	118.48
17	1801.82	127.09
18	1806.89	135.71
19	1811.97	144.32
20	1817.04	152.94
21	1822.12	161.56
22	1827.19	170.17
23	1832.27	178.79
24	1837.34	187.41
25	1842.42	196.02
26	1847.50	204.64
27	1847.68	204.95

** Corrected JANBU FOS = 1.599 ** (Fo factor = 1.044)

Failure surface No.10 specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	463.99	150.38
2	471.82	145.76
3	480.44	140.69
4	489.06	135.61
5	490.02	134.69
6	771.81	40.71
7	1390.15	52.34
8	1811.88	57.58
9	1812.47	58.19
10	1817.54	66.81
11	1822.62	75.42
12	1827.70	84.04
13	1832.77	92.66
14	1837.85	101.27
15	1842.92	109.89
16	1848.00	118.50
17	1853.07	127.12
18	1858.15	135.74
19	1863.22	144.35
20	1868.30	152.97
21	1873.37	161.59
22	1878.45	170.20
23	1883.53	178.82
24	1888.60	187.43
25	1893.68	196.05
26	1898.44	204.13

** Corrected JANBU FOS = 1.599 ** (Fo factor = 1.043)

602-0240
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7Nov-97

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Basal Failure aa 2 Q

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	1.595	1.043	462.63	1885.29	1.725E+06
2.	1.595	1.042	463.22	1909.02	1.750E+06
3.	1.597	1.042	463.78	1911.43	1.754E+06
4.	1.598	1.044	462.88	1871.15	1.711E+06
5.	1.598	1.044	462.60	1866.78	1.705E+06
6.	1.598	1.044	463.77	1878.31	1.719E+06
7.	1.599	1.042	464.04	1910.30	1.753E+06
8.	1.599	1.044	464.30	1876.93	1.720E+06
9.	1.599	1.044	462.96	1847.68	1.687E+06
10.	1.599	1.043	463.99	1898.44	1.740E+06

* * * END OF FILE * * *

E-5

E-6

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Cover Stability

	Name	Date
Prepared By:	P. Pellicer	4-Nov-97
Checked By:	J. Pellicer	12-Nov-97
Reviewed By:	P. Corbett	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602 Sheet: 1 Of 48
Prepared By: P. Pellicer Date: Nov 4, 1997
Checked By: J. Pellicer Date: 12-Nov-97

Cover Stability

Objective: Analyze the stability of the cover system

Method: The stability of the cover slopes + cover system were analyzed three ways. First the cover system was analyzed using infinite slope failure methods, Next the cover slope stability was analyzed using XSTABL (ver 5.200) to check both Circular and Block Modes of failure.

Assumptions:

- Waste strength was assumed to be associated with a loose (25% relative density) Silty Sand (SM), The onsite Silty Sand will be used as daily cover. This should also be a conservative estimate of most soil, solidified waste, and debris placed in the cell. $\phi = 29°$ (see pg 6)
- Underlaying foundation soil were assigned a medial undrained strength, C = 1100 psf. (conservative)

Calculations: Cross-section C (see pg 3+4) was cut through the longest cover slope. The cover slope is 6%.

Infinite slope stability methods were used to assess a failure of the cover system with the failure plane running through the liner system. Using an interface shear strength: a = 15 psf + δ = 39 (see pg 8) the cover system has a static F.S. = 10.9 and a pseudo-static F.S = 6.5 using a ground acceleration = 0.04g (see pg 10-12)

XSTABL (ver 5.200) was used to assess Circular failure modes associated w/ the cover slope. The static F.S. for circular failures = 3.0. However the critical failure surfaces were failing through the foundation soil. This is very unlikely and is probably due to the very conservative foundation soil strength assumed. (see pg 13-27)

(See pg 13)

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Therefore a more likely failure mode was analyzed. A Block type failure running Through the waste and along the liner system was analyzed. A waste strength of 29°, and liner interface strength of a = 440 psf, δ = 2° (see pg 7) were used. The basal grade was adjusted to remove a phasing berm and create a worst case scenario (conservative) (see pg 4). The Block failure analysis resulted in a static F.S. = 2.8 (see pg 22-38) and a psuedo-static F.S. = 1.5 (see pg 39-48) useing a ground acceleration = 0.04g (see pg 10).

Conclusions: Both the cover system and the cover waste slopes have adequate factors of safety both staticly + pseudo-staticly.

Addendum: Infinite slope analysis was completed for static and pseudostatic conditions assuming a fully saturated cover. This is to model periods after intense rainstorms.

Static SF = 5.25

Pseudostatic SF = 3.13

Cover system is stable under saturated conditions

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602-0200
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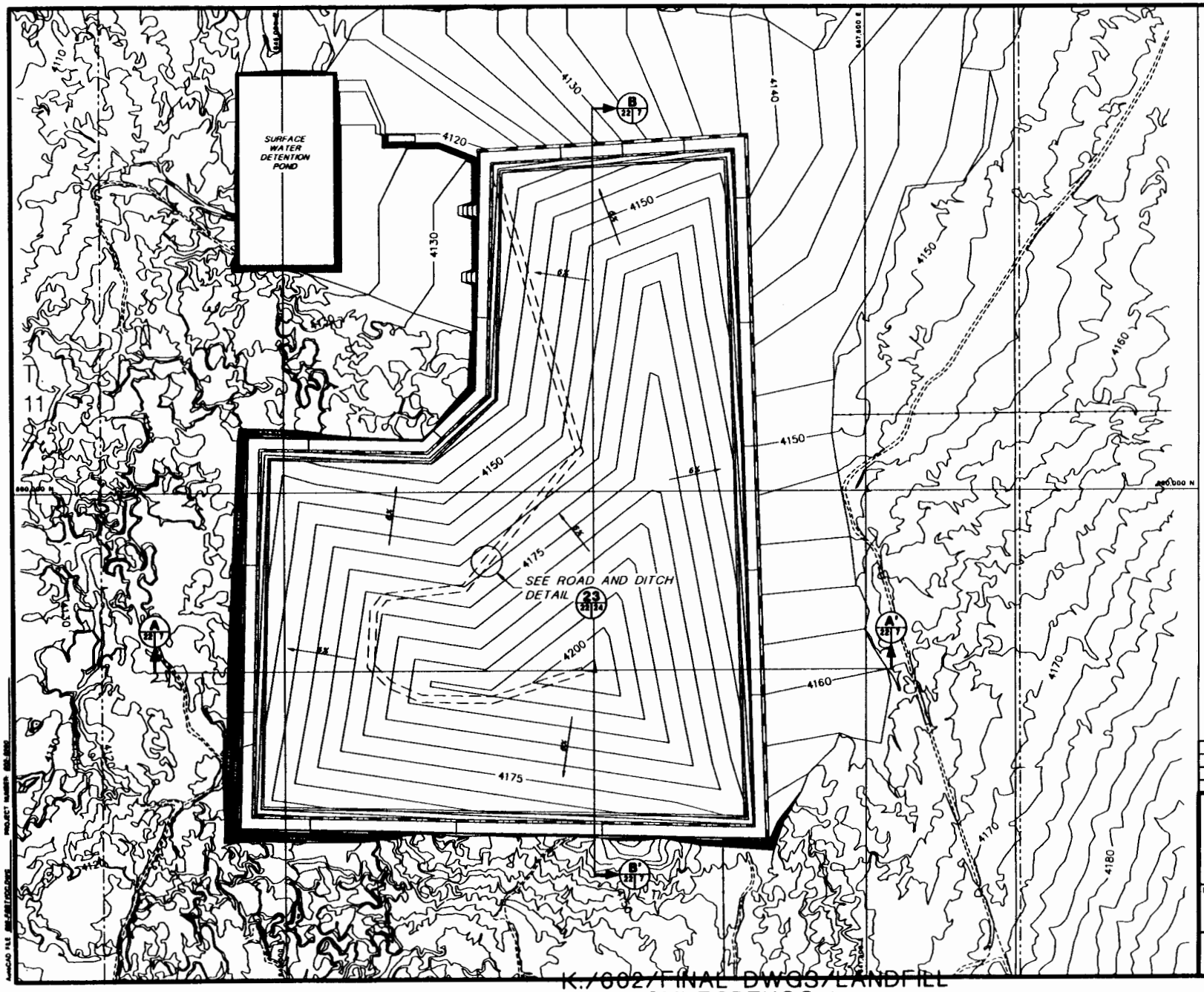
4-Nov-97

E-5



NOTES
1. FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No 2, "INDEX, LEGEND AND GENERAL NOTES"
2. TOPOGRAPHY FROM AERIAL SURVEYS PERFORMED AUGUST 1997 BY KOOGLE AND POULS ENGINEERING

PATRICK G. CORSER NEW MEXICO 12236 REGISTERED PROFESSIONAL ENGINEER

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Corser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Corser, NM P.E. 12236

SCALE
500' 0 500' 1000'
CONTOUR INTERVAL 5 FT.
SURFACE TOPOGRAPHY CONTOUR INTERVAL 2 FT

Not For Construction

REV. No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	10/10/97	PGC/JFP	T.Smith	P.Corser

TRIASSIC PARK WASTE DISPOSAL FACILITY

DRAWING TITLE
FINAL GRADING PLAN - TOP OF VEGETATIVE COVER CONTOURS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE: AS NOTED
DRAWING No 22

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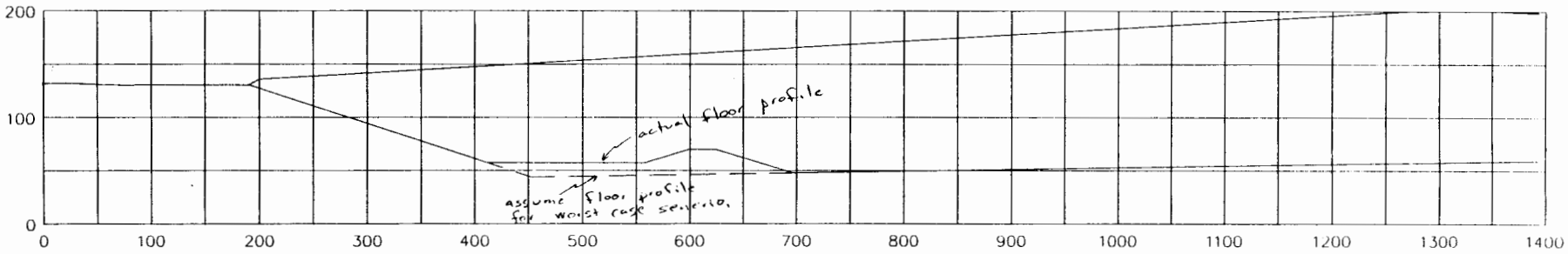
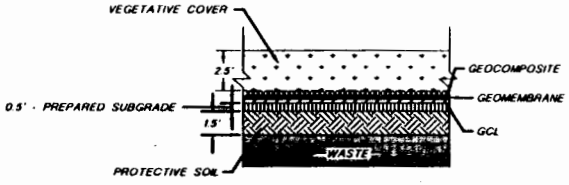
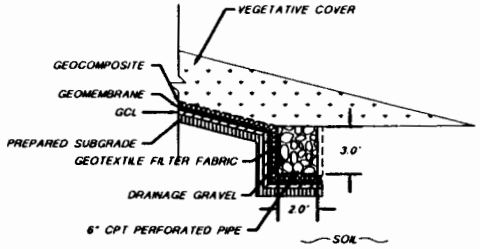
4 of 16
692-V200
PMP
4 Nov-97



5 of 78
602-0200
PMP
4-NOV-97



18 / 23 | 23 COVER DETAIL
NOT TO SCALE



19 / 23 | 23 COVER ANCHOR TRENCH DETAIL
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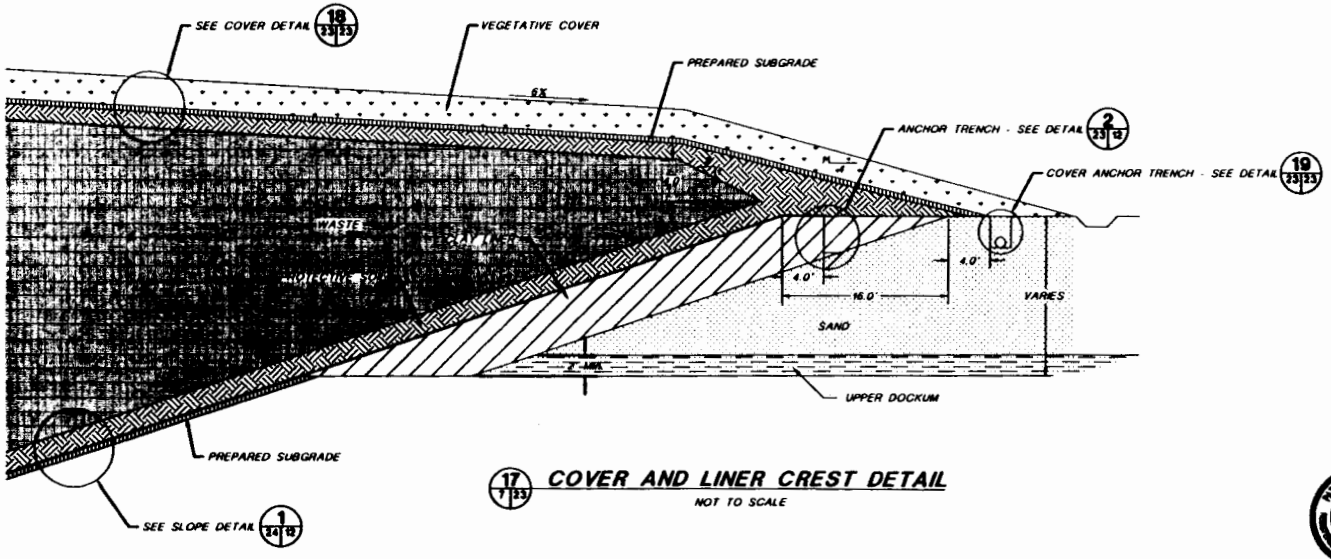

17 / 7 | 23 COVER AND LINER CREST DETAIL
NOT TO SCALE

NOTE:
FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2, "INDEX, LEGEND AND GENERAL NOTES".

PROFESSIONAL ENGINEER'S STATEMENT
I, Patrick G. Carver, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Carver, NM P.E. 10250

Not For Construction

REV. No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND SIGNED BY
0	PART B PERMIT APPLICATION	10/10/97	PGC/JPP	T Smith	P Carver

TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE:
FINAL COVER DETAILS

TerraMatrix
MONTGOMERY WATSON
Sibley Group

Sheet 1 Of 1 Sheets
SCALE: As noted
DRAWING No. 23

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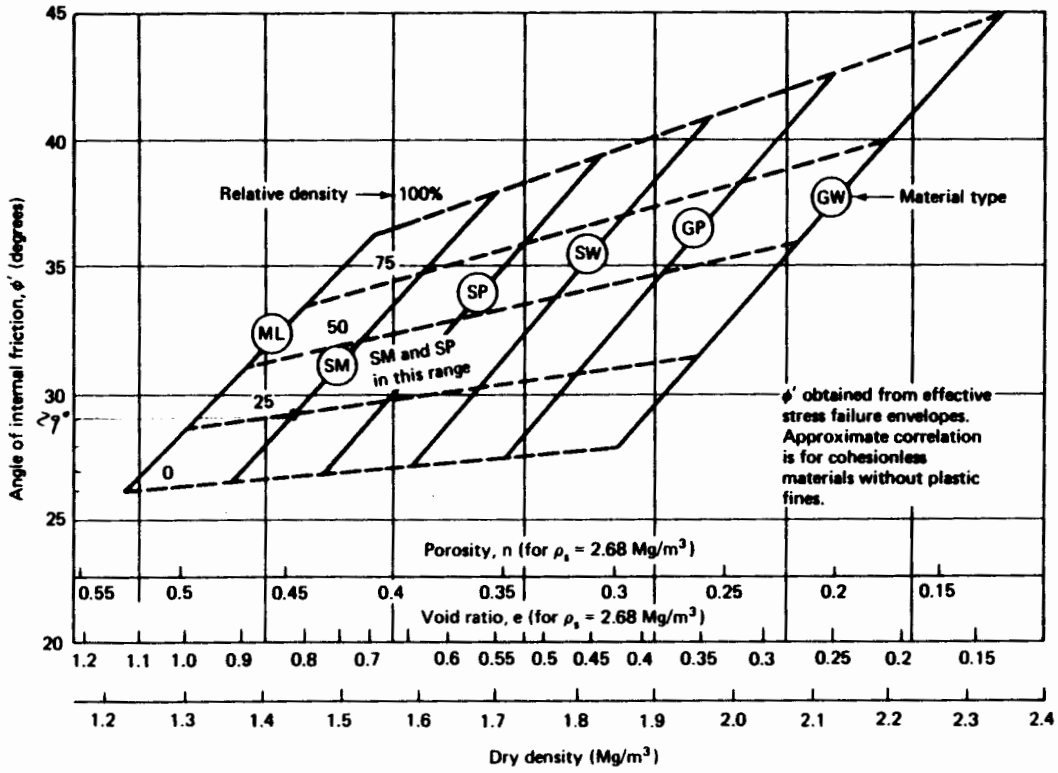

Fig. 11.13 Correlations between the effective friction angle in triaxial compression and the dry density, relative density, and soil classification (after U.S. Navy, 1971).

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GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

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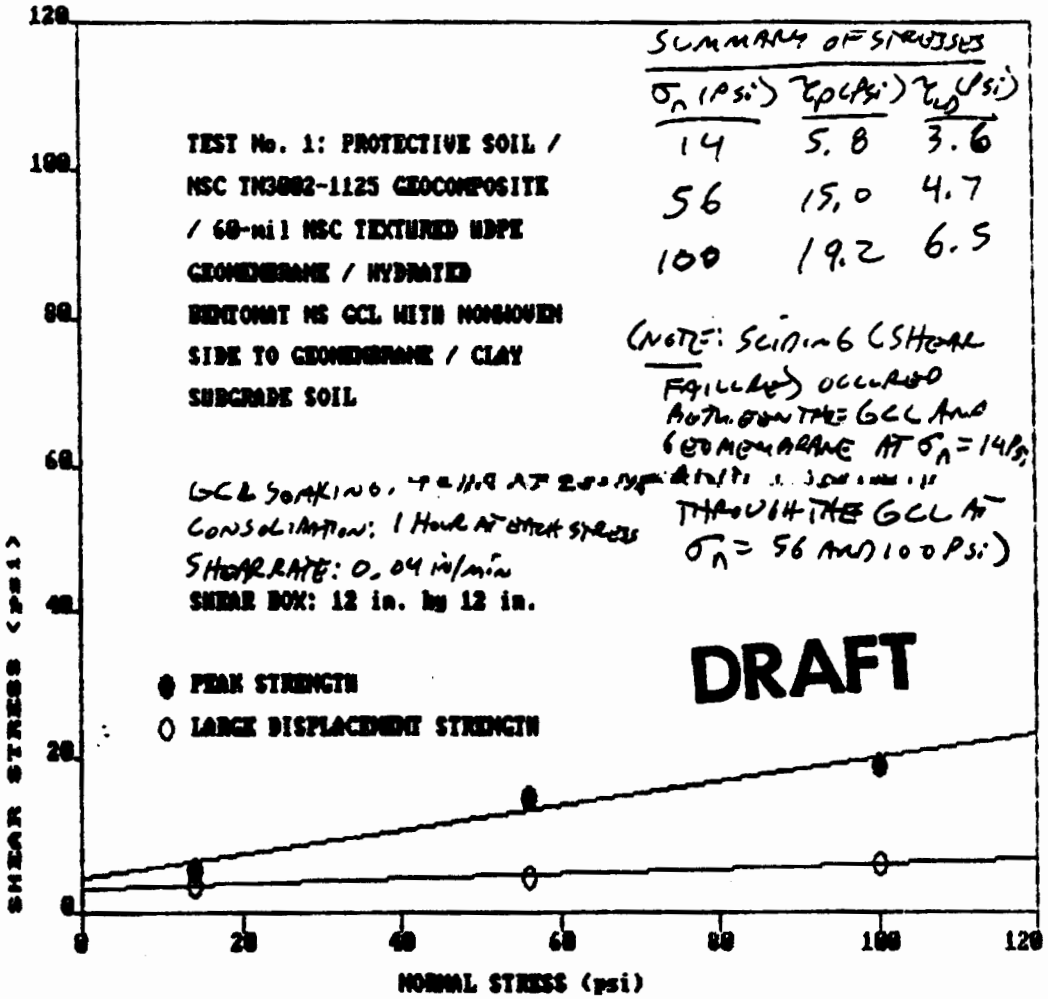
602-0200
PMP
4-Nov-97

TERRAMATRIX MONTGOMERY WATSON - ASTM D 5321 TESTS



THE REGRESSION POLYNOMIAL OF LINE 9 - PEAK STRENGTH

(4.534E+00) + (1.551E-01)*X
THE VARIANCE - 1.532E+00

a = 650 PSF δ = 9°

THE REGRESSION POLYNOMIAL OF LINE 10 - LARGE DISPLACEMENT STRENGTH

(3.045E+00) + (3.321E-02)*X
THE VARIANCE - 3.240E-02

a = 440 PSF δ = 2°

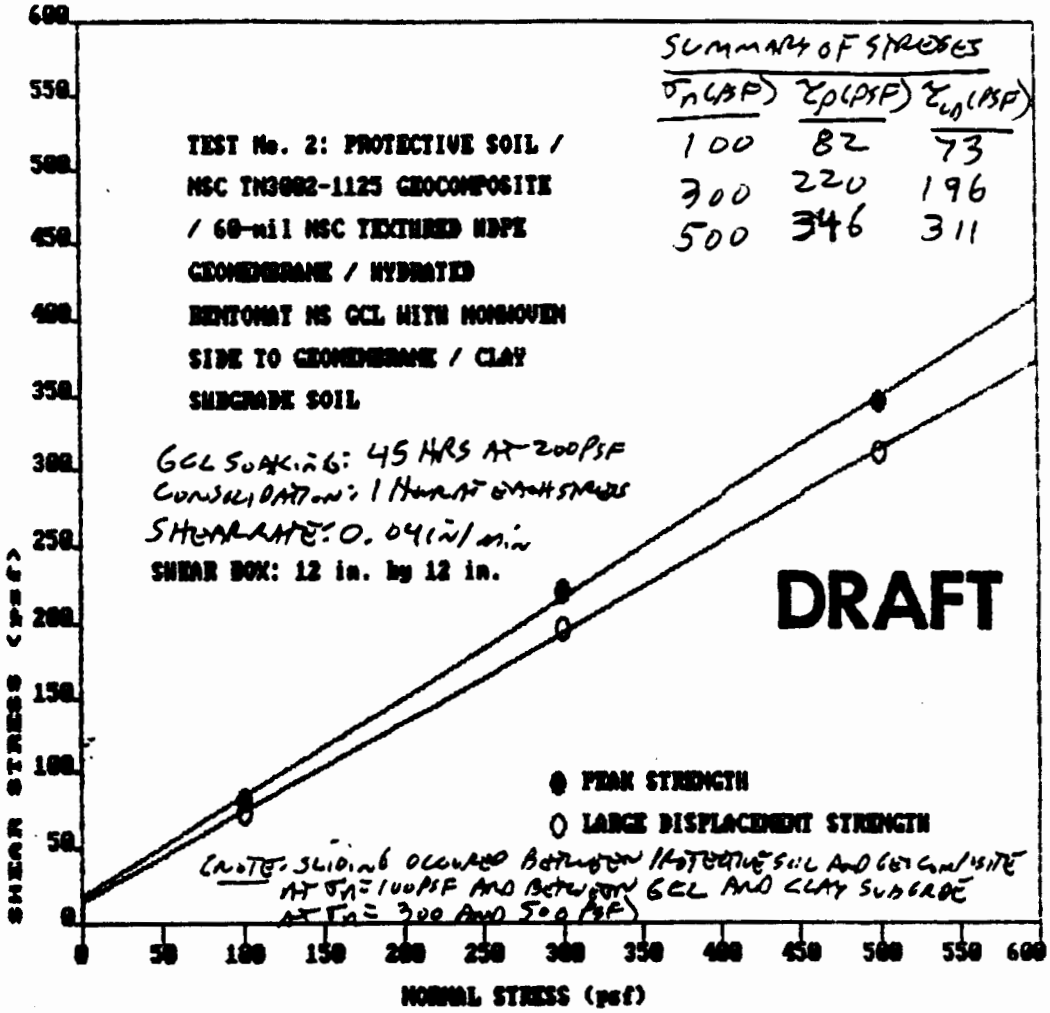
Reviewed By: Robert H. Swan Jr. Date: 10-8-97

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

8 of 48
602-0200
pmp
4-Nov-97

TERRAMATRIX MONTGOMERY WATSON - ASTM D 5321 TESTS



THE REGRESSION POLYNOMIAL OF LINE 9 - PEAK STRENGTH

(1.800E+01) + (6.600E-01)*X a = 18 PSF δ = 33°
THE VARIANCE - 8.000E+00

THE REGRESSION POLYNOMIAL OF LINE 10 - LARGE DISPLACEMENT STRENGTH

(1.483E+01) + (5.950E-01)*X a = 15 PSF δ = 31°
THE VARIANCE - 3.556E+00

Reviewed By: Robert H Swan Jr Date: 10-10-97

9 of 48 ~~3/50~~
3 1819 00069223 2
602-0200
PMP
4-Nov-97

United States Department of the Interior

Geological Survey

PROBABILISTIC ESTIMATES OF MAXIMUM ACCELERATION AND VELOCITY IN ROCK IN THE CONTIGUOUS UNITED STATES

by

S. T. Algermissen, D. M. Perkins, P. C. Thenhaus,
S. L. Hanson and B. L. Bender

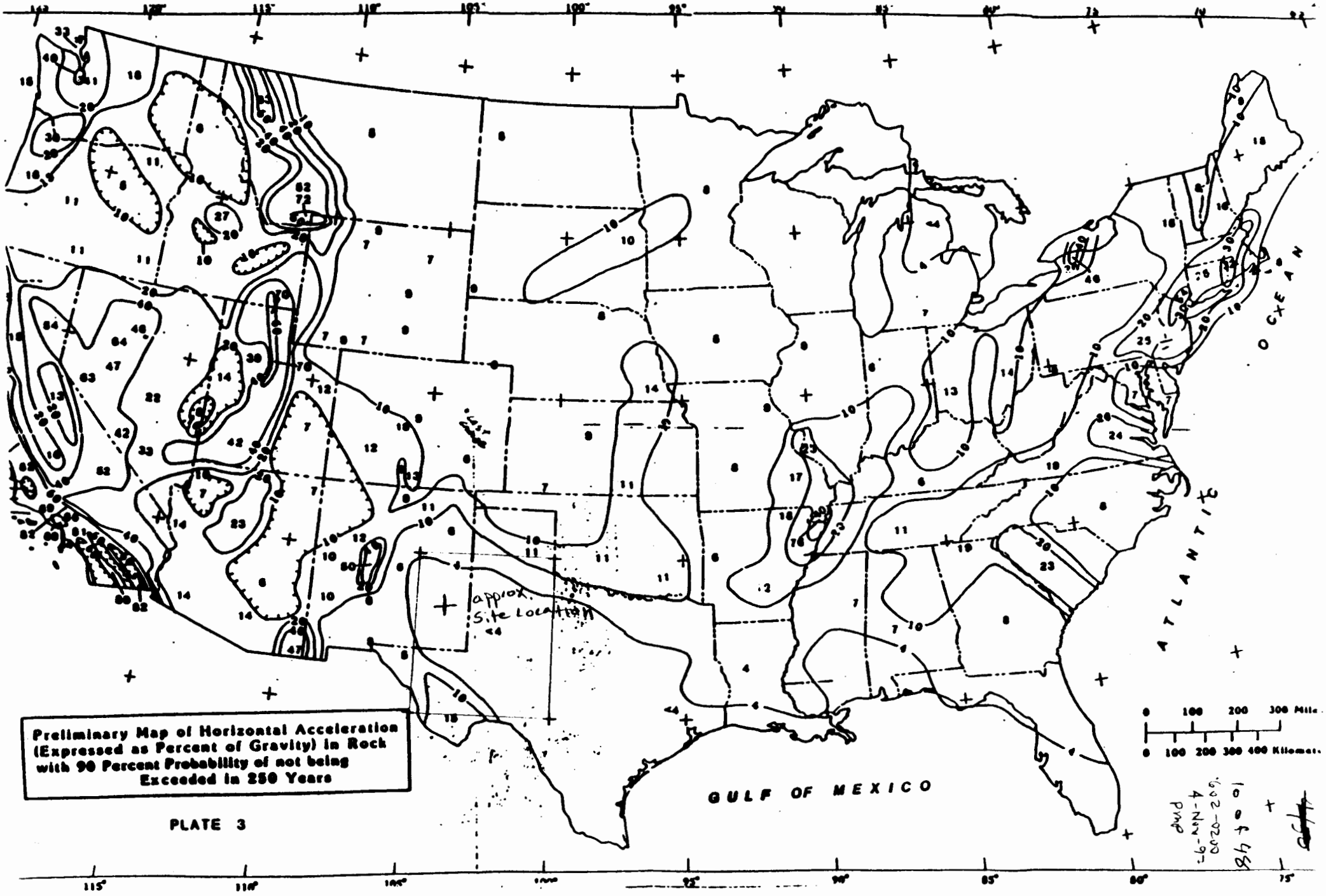
U.S. GEOLOGICAL SURVEY
DENVER
NOV 15 1982
LIBRARY
GEOLOGIC DIVISION

Open-File Report 82-1033

1982

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

JUL 27 1990
10 NOV 199



Preliminary Map of Horizontal Acceleration (Expressed as Percent of Gravity) in Rock with 90 Percent Probability of not being Exceeded in 250 Years

PLATE 3

C02-0250
PMP
4-Nov-97

Infinite slope analysis spreadsheet
Date: 04-Nov-97
By: Paul Pellicer
Filename: Cover system stability .wq1

Soil Parameters

Cohesion:	15 psf		0.054643341
Friction Angle:	31 degrees	tangent	0.600860619
Gamma Moist:	110 pcf		

Slope Geometry:

Slope Angle:	3.43 degrees	cosine	0.998208638 sine
Failure Plane Depth:	2.5 ft		

Groundwater Parameters

Height of water in failure mass:	0 ft
Pore Pressure Ratio:	0 no units

Seismic Parameters

Ground Acceleration:	0 g's

Safety Factor: 10.9383 ✓

612-0200
PMP
4-Nov-97

Infinite slope analysis spreadsheet
Date: 04-Nov-97
By: Paul Pellicer
Filename: Cover system stability Q.wq1

Soil Parameters

Cohesion:	15 psf		0.054643341
Friction Angle:	31 degrees	tangent	0.600860619
Gamma Moist:	110 pcf		

Slope Geometry:

Slope Angle:	3.43 degrees	cosine	0.998208638 sine
Failure Plane Depth:	2.5 ft		

Groundwater Parameters

Height of water in failure mass:	0 ft
Pore Pressure Ratio:	0 no units

Seismic Parameters

Ground Acceleration:	0.04 g's

Safety Factor: 6.54578 ✓

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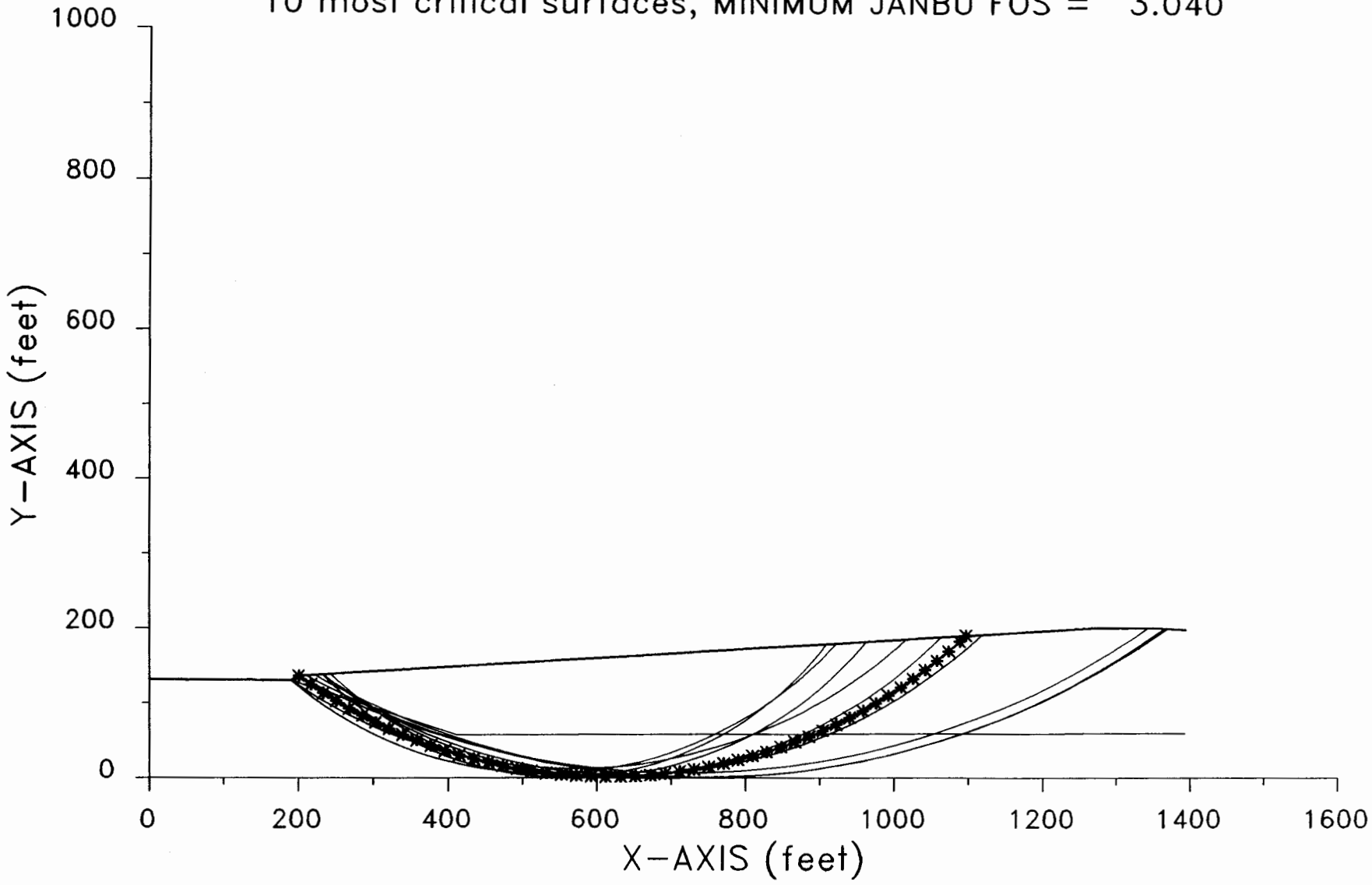
Gandy Cover Circular Failure

10 most critical surfaces, MINIMUM JANBU FOS = 3.040



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PMP

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*                                       *
*        Slope Stability Analysis       *
*               using the               *
*            Method of Slices           *
*                                       *
*         Copyright (C) 1992 á 96       *
*   Interactive Software Designs, Inc.  *
*        Moscow, ID 83843, U.S.A.       *
*                                       *
*          All Rights Reserved          *
*                                       *
*  Ver. 5.200                 96 á 1216 *
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Problem Description : Gandy Cover Circular Failure

SEGMENT BOUNDARY COORDINATES
---

5 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	131.7	190.1	130.5	2
2	190.1	130.5	200.1	135.9	1
3	200.1	135.9	1270.7	200.0	1
4	1270.7	200.0	1355.5	200.0	1
5	1355.5	200.0	1393.4	198.4	1

2 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	190.1	130.5	411.8	57.5	2
2	411.8	57.5	1393.4	59.4	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.

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1	110.0	110.0	.0	29.00	.000	.0
2	110.0	110.0	1100.0	.00	.000	.0

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

900 trial surfaces will be generated and analyzed.

30 Surfaces initiate from each of 30 points equally spaced along the ground surface between x = 190.0 ft
and x = 500.0 ft

Each surface terminates between x = 600.0 ft
and x = 1370.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

20.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

```
*************************************************************
**     Factor of safety calculation for surface #   858    **
**     failed to converge within FIFTY iterations          **
**                                                         **
**    The last calculated value of the FOS was  11.7258    **
**    This will be ignored for final summary of results    **
*************************************************************
```

The trial failure surface in question is defined by the following 9 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	489.31	153.22
2	503.74	139.36
3	521.26	129.72
4	540.68	124.95

5	560.68	125.38
6	579.88	130.98
7	596.97	141.37
8	610.79	155.83
9	613.42	160.65

```
*************************************************************
**     Factor of safety calculation for surface #   874    **
**     failed to converge within FIFTY iterations          **
**                                                         **
**    The last calculated value of the FOS was  11.7428    **
**    This will be ignored for final summary of results    **
*************************************************************
```

The trial failure surface in question is
defined by the following 8 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	500.00	153.86
2	514.82	140.43
3	532.99	132.06
4	552.83	129.52
5	572.51	133.04
6	590.24	142.31
7	604.38	156.46
8	606.34	160.22

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined
are displayed below - the most critical first

Failure surface No. 1 specified by 50 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	200.69	135.94
2	217.07	124.45
3	233.76	113.44
4	250.76	102.90
5	268.04	92.84
6	285.61	83.28
7	303.44	74.21
8	321.51	65.65
9	339.82	57.61
10	358.35	50.09
11	377.09	43.09
12	396.02	36.62
13	415.12	30.69
14	434.38	25.30

15	453.78	20.46
16	473.32	16.17
17	492.96	12.43
18	512.71	9.25
19	532.54	6.62
20	552.43	4.56
21	572.37	3.05
22	592.35	2.11
23	612.35	1.74
24	632.35	1.93
25	652.33	2.69
26	672.29	4.00
27	692.20	5.89
28	712.05	8.33
29	731.82	11.33
30	751.50	14.89
31	771.08	19.00
32	790.52	23.67
33	809.83	28.88
34	828.99	34.63
35	847.97	40.92
36	866.77	47.75
37	885.37	55.10
38	903.76	62.98
39	921.91	71.37
40	939.82	80.27
41	957.47	89.67
42	974.85	99.57
43	991.95	109.95
44	1008.74	120.81
45	1025.22	132.14
46	1041.37	143.93
47	1057.19	156.18
48	1072.65	168.86
49	1087.75	181.98
50	1095.97	189.54

** Corrected JANBU FOS = 3.040 ** (Fo factor = 1.067)

Failure surface No. 2 specified by 63 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	211.38	136.58
2	228.99	127.09
3	246.76	117.93
4	264.71	109.09
5	282.81	100.58
6	301.06	92.41
7	319.46	84.57
8	338.00	77.07
9	356.67	69.90
10	375.47	63.08
11	394.39	56.60
12	413.43	50.47
13	432.58	44.69
14	451.83	39.26
15	471.17	34.18

16	490.61	29.46
17	510.12	25.09
18	529.72	21.08
19	549.38	17.42
20	569.11	14.13
21	588.89	11.20
22	608.72	8.62
23	628.60	6.41
24	648.52	4.57
25	668.46	3.09
26	688.43	1.97
27	708.42	1.22
28	728.41	.83
29	748.41	.81
30	768.41	1.15
31	788.40	1.86
32	808.37	2.93
33	828.32	4.37
34	848.23	6.17
35	868.12	8.33
36	887.96	10.86
37	907.75	13.75
38	927.48	17.00
39	947.15	20.61
40	966.75	24.58
41	986.28	28.90
42	1005.73	33.58
43	1025.08	38.62
44	1044.34	44.01
45	1063.50	49.75
46	1082.55	55.84
47	1101.49	62.27
48	1120.30	69.05
49	1138.99	76.17
50	1157.55	83.63
51	1175.97	91.43
52	1194.24	99.57
53	1212.36	108.03
54	1230.32	116.83
55	1248.12	125.95
56	1265.75	135.40
57	1283.20	145.16
58	1300.47	155.25
59	1317.56	165.64
60	1334.45	176.35
61	1351.14	187.36
62	1367.63	198.68
63	1368.70	199.44

** Corrected JANBU FOS = 3.076 ** (Fo factor = 1.057)

Failure surface No. 3 specified by 62 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	200.69	135.94
2	218.43	126.71
3	236.34	117.81

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4	254.41	109.23
5	272.63	100.98
6	291.00	93.06
7	309.50	85.48
8	328.14	78.23
9	346.91	71.33
10	365.81	64.76
11	384.81	58.54
12	403.93	52.66
13	423.15	47.13
14	442.47	41.95
15	461.87	37.11
16	481.37	32.64
17	500.94	28.51
18	520.58	24.74
19	540.28	21.33
20	560.05	18.27
21	579.87	15.58
22	599.73	13.24
23	619.63	11.26
24	639.57	9.64
25	659.53	8.39
26	679.51	7.49
27	699.50	6.96
28	719.50	6.79
29	739.50	6.99
30	759.49	7.54
31	779.47	8.46
32	799.43	9.74
33	819.36	11.38
34	839.26	13.38
35	859.12	15.74
36	878.93	18.46
37	898.70	21.54
38	918.40	24.98
39	938.04	28.77
40	957.60	32.92
41	977.09	37.42
42	996.49	42.28
43	1015.80	47.48
44	1035.01	53.03
45	1054.12	58.93
46	1073.12	65.18
47	1092.01	71.77
48	1110.77	78.70
49	1129.40	85.97
50	1147.90	93.57
51	1166.25	101.51
52	1184.46	109.78
53	1202.52	118.38
54	1220.42	127.31
55	1238.15	136.55
56	1255.72	146.12
57	1273.10	156.00
58	1290.31	166.20
59	1307.33	176.71
60	1324.15	187.52
61	1340.78	198.64
62	1342.74	200.00

** Corrected JANBU FOS = 3.158 ** (Fo factor = 1.056) 602-0204 pmp 4-Nov-97

Failure surface No. 4 specified by 62 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	222.07	137.22
2	239.61	127.60
3	257.32	118.31
4	275.20	109.36
5	293.25	100.74
6	311.46	92.47
7	329.82	84.54
8	348.32	76.95
9	366.97	69.71
10	385.74	62.82
11	404.64	56.28
12	423.66	50.10
13	442.80	44.27
14	462.04	38.81
15	481.38	33.71
16	500.81	28.97
17	520.32	24.59
18	539.91	20.58
19	559.58	16.94
20	579.31	13.67
21	599.10	10.77
22	618.94	8.24
23	638.82	6.08
24	658.74	4.29
25	678.69	2.88
26	698.67	1.84
27	718.65	1.18
28	738.65	.89
29	758.65	.98
30	778.65	1.44
31	798.63	2.27
32	818.59	3.48
33	838.53	5.06
34	858.43	7.02
35	878.30	9.35
36	898.11	12.05
37	917.88	15.12
38	937.58	18.56
39	957.21	22.37
40	976.77	26.55
41	996.25	31.09
42	1015.64	35.99
43	1034.93	41.26
44	1054.12	46.89
45	1073.21	52.88
46	1092.17	59.22
47	1111.02	65.92
48	1129.73	72.97
49	1148.32	80.37
50	1166.75	88.12
51	1185.05	96.21
52	1203.18	104.64

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53	1221.16	113.41
54	1238.96	122.52
55	1256.60	131.95
56	1274.05	141.72
57	1291.32	151.81
58	1308.39	162.22
59	1325.27	172.95
60	1341.94	184.00
61	1358.41	195.36
62	1364.36	199.63

** Corrected JANBU FOS = 3.194 ** (Fo factor = 1.058)

Failure surface No. 5 specified by 47 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	232.76	137.86
2	248.62	125.67
3	264.86	114.00
4	281.47	102.87
5	298.43	92.27
6	315.73	82.22
7	333.33	72.73
8	351.23	63.81
9	369.41	55.47
10	387.85	47.72
11	406.52	40.56
12	425.42	34.01
13	444.52	28.07
14	463.80	22.75
15	483.24	18.05
16	502.82	13.97
17	522.52	10.53
18	542.32	7.72
19	562.20	5.55
20	582.14	4.01
21	602.12	3.12
22	622.12	2.87
23	642.12	3.27
24	662.09	4.31
25	682.02	5.98
26	701.89	8.30
27	721.67	11.25
28	741.34	14.84
29	760.89	19.06
30	780.30	23.90
31	799.54	29.37
32	818.59	35.45
33	837.44	42.14
34	856.06	49.43
35	874.44	57.31
36	892.56	65.78
37	910.39	74.83
38	927.93	84.45
39	945.15	94.63
40	962.03	105.35
41	978.56	116.61

42	994.72	128.40
43	1010.49	140.70
44	1025.86	153.49
45	1040.81	166.78
46	1055.32	180.54
47	1062.22	187.52

** Corrected JANBU FOS = 3.210 ** (Fo factor = 1.070)

Failure surface No. 6 specified by 50 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	232.76	137.86
2	249.08	126.30
3	265.73	115.22
4	282.70	104.62
5	299.95	94.52
6	317.50	84.91
7	335.31	75.82
8	353.37	67.23
9	371.68	59.17
10	390.21	51.64
11	408.94	44.65
12	427.87	38.20
13	446.98	32.29
14	466.25	26.93
15	485.67	22.13
16	505.21	17.89
17	524.87	14.22
18	544.63	11.11
19	564.47	8.57
20	584.37	6.60
21	604.32	5.20
22	624.30	4.38
23	644.30	4.13
24	664.30	4.45
25	684.28	5.35
26	704.22	6.83
27	724.12	8.87
28	743.95	11.49
29	763.69	14.68
30	783.34	18.43
31	802.87	22.74
32	822.26	27.62
33	841.51	33.05
34	860.60	39.03
35	879.50	45.55
36	898.21	52.62
37	916.71	60.22
38	934.98	68.35
39	953.02	77.00
40	970.79	86.17
41	988.30	95.84
42	1005.52	106.01
43	1022.44	116.68
44	1039.05	127.82
45	1055.33	139.44

46	1071.27	151.52
47	1086.85	164.05
48	1102.07	177.03
49	1116.91	190.43
50	1117.31	190.82

** Corrected JANBU FOS = 3.234 ** (Fo factor = 1.067)

Failure surface No. 7 specified by 42 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	190.00	130.50
2	205.52	117.88
3	221.50	105.86
4	237.92	94.45
5	254.77	83.67
6	272.01	73.54
7	289.63	64.06
8	307.59	55.27
9	325.87	47.16
10	344.45	39.74
11	363.29	33.04
12	382.38	27.06
13	401.67	21.80
14	421.15	17.28
15	440.79	13.50
16	460.56	10.47
17	480.43	8.18
18	500.37	6.66
19	520.36	5.89
20	540.36	5.87
21	560.34	6.62
22	580.29	8.12
23	600.16	10.38
24	619.93	13.38
25	639.58	17.14
26	659.07	21.64
27	678.37	26.87
28	697.46	32.83
29	716.31	39.51
30	734.90	46.89
31	753.19	54.98
32	771.16	63.75
33	788.79	73.20
34	806.05	83.31
35	822.91	94.07
36	839.35	105.46
37	855.35	117.46
38	870.88	130.06
39	885.92	143.24
40	900.45	156.98
41	914.45	171.26
42	921.57	179.10

** Corrected JANBU FOS = 3.235 ** (Fo factor = 1.072)

Failure surface No. 8 specified by 40 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	232.76	137.86
2	246.92	123.73
3	261.70	110.26
4	277.08	97.47
5	293.01	85.38
6	309.47	74.03
7	326.43	63.42
8	343.85	53.60
9	361.70	44.56
10	379.93	36.34
11	398.51	28.95
12	417.41	22.41
13	436.59	16.72
14	456.00	11.90
15	475.61	7.97
16	495.37	4.91
17	515.25	2.76
18	535.22	1.50
19	555.21	1.14
20	575.20	1.68
21	595.15	3.12
22	615.02	5.47
23	634.75	8.70
24	654.32	12.82
25	673.69	17.81
26	692.81	23.68
27	711.65	30.39
28	730.16	37.96
29	748.32	46.34
30	766.08	55.54
31	783.41	65.53
32	800.27	76.29
33	816.63	87.79
34	832.45	100.03
35	847.71	112.96
36	862.36	126.56
37	876.39	140.82
38	889.77	155.69
39	902.46	171.15
40	907.79	178.27

** Corrected JANBU FOS = 3.302 ** (Fo factor = 1.078)

Failure surface No. 9 specified by 42 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	243.45	138.50
2	258.14	124.93
3	273.38	111.97
4	289.13	99.65
5	305.37	87.98
6	322.08	76.99

7	339.22	66.68
8	356.77	57.09
9	374.70	48.22
10	392.97	40.09
11	411.56	32.72
12	430.44	26.11
13	449.57	20.28
14	468.92	15.23
15	488.47	10.98
16	508.17	7.53
17	527.99	4.89
18	547.91	3.06
19	567.88	2.05
20	587.88	1.86
21	607.87	2.48
22	627.82	3.92
23	647.69	6.17
24	667.46	9.23
25	687.08	13.10
26	706.53	17.77
27	725.77	23.23
28	744.77	29.47
29	763.50	36.48
30	781.93	44.25
31	800.02	52.77
32	817.76	62.02
33	835.10	71.98
34	852.01	82.65
35	868.48	94.00
36	884.47	106.01
37	899.96	118.67
38	914.91	131.95
39	929.31	145.83
40	943.14	160.28
41	956.35	175.29
42	961.37	181.48

** Corrected JANBU FOS = 3.327 ** (Fo factor = 1.076)

Failure surface No.10 specified by 46 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	190.00	130.50
2	206.63	119.39
3	223.58	108.78
4	240.85	98.69
5	258.41	89.11
6	276.25	80.07
7	294.35	71.57
8	312.70	63.61
9	331.28	56.21
10	350.08	49.37
11	369.07	43.10
12	388.24	37.39
13	407.57	32.27
14	427.04	27.73
15	446.65	23.77

16	466.36	20.40
17	486.17	17.63
18	506.05	15.45
19	525.99	13.87
20	545.96	12.88
21	565.96	12.50
22	585.96	12.71
23	605.94	13.53
24	625.89	14.94
25	645.79	16.95
26	665.62	19.56
27	685.36	22.76
28	705.00	26.55
29	724.52	30.93
30	743.89	35.89
31	763.11	41.44
32	782.15	47.55
33	801.00	54.23
34	819.64	61.48
35	838.06	69.28
36	856.23	77.63
37	874.15	86.52
38	891.79	95.94
39	909.14	105.89
40	926.18	116.36
41	942.90	127.33
42	959.29	138.79
43	975.32	150.75
44	990.99	163.18
45	1006.28	176.07
46	1015.97	184.75

** Corrected JANBU FOS = 3.344 ** (Fo factor = 1.066)

```
*********************************************************************
**                                                                 **
**  Out of the    900 surfaces generated and analyzed by XSTABL,   **
**        2 surfaces were found to have MISLEADING FOS values.     **
**                                                                 **
*********************************************************************
```

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Cover Circular Failure

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	3.040	1.067	200.69	1095.97	1.660E+06
2.	3.076	1.057	211.38	1368.70	2.329E+06
3.	3.158	1.056	200.69	1342.74	2.291E+06
4.	3.194	1.058	222.07	1364.36	2.385E+06
5.	3.210	1.070	232.76	1062.22	1.589E+06

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6.	3.234	1.067	232.76	1117.31	1.731E+06
7.	3.235	1.072	190.00	921.57	1.343E+06
8.	3.302	1.078	232.76	907.79	1.252E+06
9.	3.327	1.076	243.45	961.37	1.369E+06
10.	3.344	1.066	190.00	1015.97	1.571E+06

* * * END OF FILE * * *

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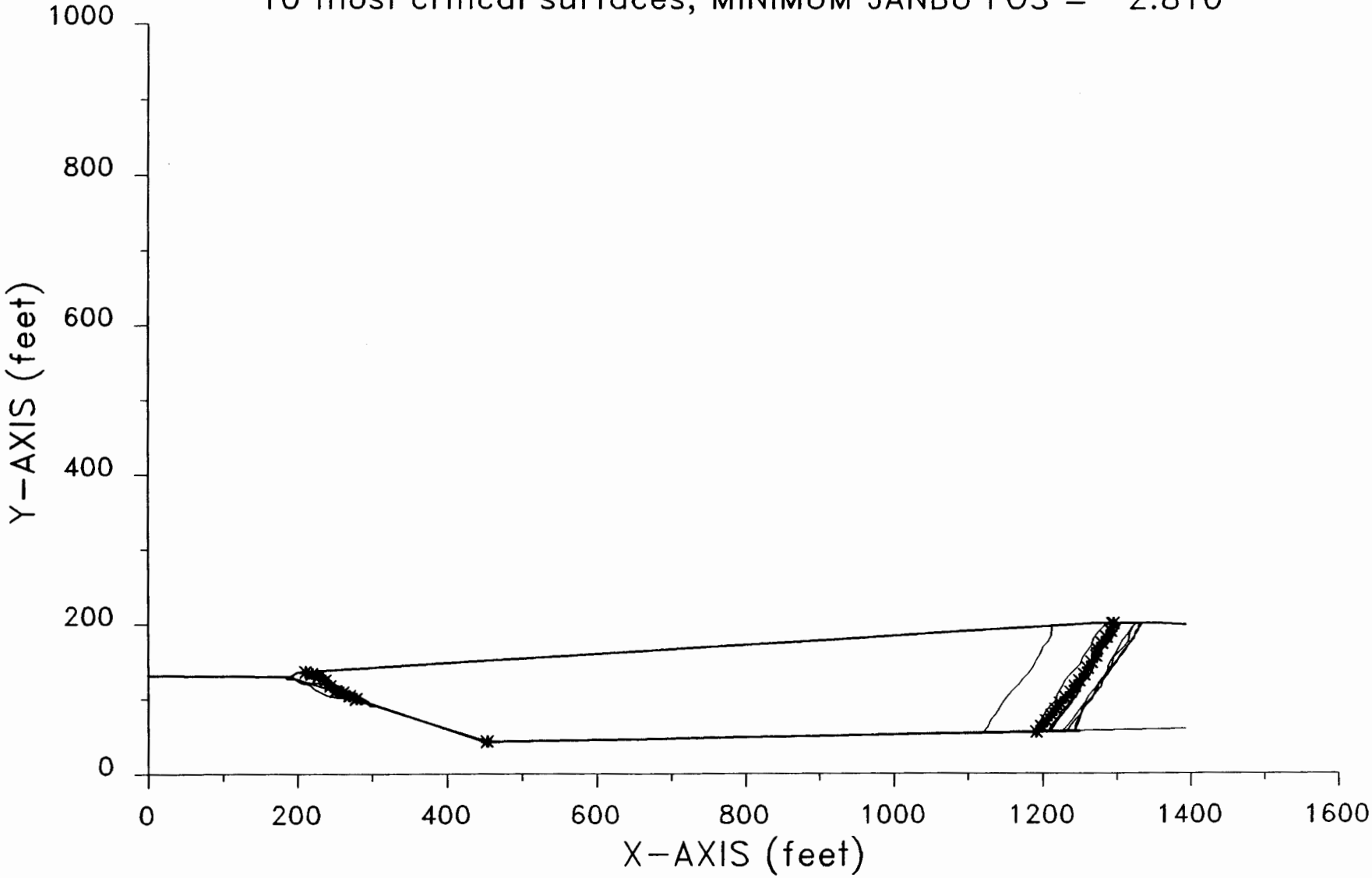
Gandy Cover Block Failure

10 most critical surfaces, MINIMUM JANBU FOS = 2.810



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*****************************************
*              X S T A B L              *
*                                       *
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*               using the               *
*            Method of Slices           *
*                                       *
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*  Ver. 5.200                 96 á 1216 *
*****************************************
```

Problem Description : Gandy Cover Block Failure

SEGMENT BOUNDARY COORDINATES
---

5 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	131.7	190.1	130.5	2
2	190.1	130.5	200.1	135.9	1
3	200.1	135.9	1270.7	200.0	1
4	1270.7	200.0	1355.5	200.0	1
5	1355.5	200.0	1393.4	198.4	1

2 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	190.1	130.5	453.1	43.8	2
2	453.1	43.8	1393.4	59.4	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.

1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

500 trial surfaces will be generated and analyzed.

3 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 10.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	269.1	103.6	344.9	78.6	1.0
2	450.0	42.8	470.0	43.1	1.0
3	1100.0	53.6	1250.0	56.1	1.0

```
*************************************************************
**     Factor of safety calculation for surface #   387    **
**     failed to converge within FIFTY iterations          **
**                                                         **
**    The last calculated value of the FOS was   9.6297    **
**    This will be ignored for final summary of results    **
*************************************************************
```

The trial failure surface in question is defined by the following 29 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	216.72	136.90
2	219.36	134.26
3	227.03	127.84
4	234.10	120.77
5	244.09	120.30
6	254.08	120.15
7	263.14	115.92
8	271.15	109.92
9	279.62	104.60
10	286.73	97.58
11	467.65	43.47
12	1114.11	53.36
13	1114.33	63.35
14	1115.17	73.32
15	1120.88	81.53
16	1121.19	91.52
17	1125.15	100.71
18	1129.17	109.87

19	1131.14	119.67
20	1131.79	129.65
21	1137.07	138.14
22	1144.14	145.21
23	1148.86	154.03
24	1154.95	161.95
25	1161.51	169.51
26	1168.57	176.59
27	1175.49	183.80
28	1182.51	190.93
29	1186.48	194.96

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 30 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	210.78	136.54
2	219.25	134.15
3	228.70	130.88
4	236.86	125.10
5	244.12	118.22
6	251.19	111.15
7	261.06	109.57
8	269.72	104.56
9	278.77	100.32
10	453.41	43.18
11	1191.28	55.21
12	1198.18	62.45
13	1204.84	69.90
14	1211.33	77.51
15	1217.47	85.41
16	1223.53	93.36
17	1230.55	100.48
18	1237.62	107.55
19	1242.65	116.19
20	1249.72	123.26
21	1255.89	131.14
22	1260.50	140.01
23	1266.42	148.07
24	1272.49	156.02
25	1273.41	165.98
26	1280.09	173.41
27	1285.99	181.49
28	1292.14	189.37
29	1294.37	199.12
30	1295.08	200.00

** Corrected JANBU FOS = 2.810 ** (Fo factor = 1.052)

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Failure surface No. 2 specified by 30 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	218.35	136.99
2	222.80	133.29
3	230.53	126.94
4	238.53	120.94
5	245.73	113.99
6	255.71	113.38
7	262.86	106.39
8	272.17	102.74
9	281.40	98.90
10	291.10	96.46
11	453.34	42.53
12	1207.47	55.58
13	1212.13	64.43
14	1218.81	71.87
15	1225.71	79.10
16	1232.75	86.21
17	1237.89	94.79
18	1244.96	101.86
19	1249.07	110.98
20	1253.70	119.84
21	1257.09	129.25
22	1259.97	138.83
23	1266.43	146.46
24	1269.84	155.86
25	1276.41	163.40
26	1283.47	170.48
27	1285.16	180.33
28	1290.27	188.93
29	1294.68	197.91
30	1295.99	200.00

** Corrected JANBU FOS = 2.848 ** (Fo factor = 1.053)

Failure surface No. 3 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	218.48	137.00
2	224.02	134.07
3	232.86	129.40
4	240.00	122.39
5	248.38	116.93
6	255.51	109.92
7	265.50	109.51
8	272.58	102.45
9	454.90	42.73
10	1209.31	55.03
11	1214.83	63.37
12	1220.24	71.77
13	1223.80	81.12
14	1230.86	88.20

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15	1237.73	95.47
16	1241.21	104.84
17	1248.23	111.96
18	1253.81	120.27
19	1260.88	127.34
20	1266.17	135.82
21	1268.73	145.49
22	1274.75	153.47
23	1278.17	162.87
24	1285.24	169.95
25	1291.62	177.65
26	1296.50	186.37
27	1302.01	194.72
28	1304.52	200.00

** Corrected JANBU FOS = 2.859 ** (Fo factor = 1.053)

Failure surface No. 4 specified by 31 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	192.53	131.81
2	199.08	125.82
3	208.87	123.76
4	218.65	121.68
5	228.65	121.60
6	238.47	119.73
7	248.39	118.48
8	256.27	112.32
9	264.17	106.19
10	273.98	104.25
11	282.55	99.10
12	450.02	42.41
13	1224.73	55.25
14	1231.78	62.34
15	1238.54	69.71
16	1244.15	77.98
17	1250.26	85.90
18	1256.51	93.70
19	1261.02	102.63
20	1267.70	110.07
21	1274.64	117.28
22	1281.69	124.36
23	1287.18	132.72
24	1287.98	142.69
25	1292.84	151.43
26	1298.24	159.84
27	1302.79	168.75
28	1307.08	177.78
29	1313.98	185.02
30	1318.96	193.69
31	1325.14	200.00

** Corrected JANBU FOS = 2.871 ** (Fo factor = 1.051)

Failure surface No. 5 specified by 33 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	206.98	136.31
2	211.40	134.77
3	219.80	129.36
4	229.80	129.05
5	236.90	122.00
6	245.40	116.74
7	252.47	109.67
8	262.33	108.03
9	270.45	102.19
10	280.05	99.37
11	289.81	97.23
12	297.64	91.00
13	307.63	90.67
14	453.91	43.03
15	1241.72	55.54
16	1246.59	64.27
17	1249.81	73.74
18	1252.11	83.47
19	1258.91	90.81
20	1265.86	98.00
21	1269.91	107.14
22	1273.41	116.51
23	1280.47	123.59
24	1287.38	130.82
25	1292.80	139.22
26	1299.24	146.87
27	1303.44	155.95
28	1309.35	164.02
29	1315.57	171.85
30	1322.62	178.94
31	1324.41	188.78
32	1331.45	195.88
33	1333.13	200.00

** Corrected JANBU FOS = 2.926 ** (Fo factor = 1.051)

Failure surface No. 6 specified by 34 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	182.53	130.55
2	186.08	127.21
3	196.06	126.60
4	204.83	121.78
5	214.67	120.03
6	222.57	113.90
7	231.27	108.97
8	240.50	105.11
9	250.27	102.99
10	260.25	102.39
11	269.83	99.51
12	279.79	98.68
13	289.56	96.53
14	299.05	93.39
15	451.02	43.08

16	1231.97	56.10
17	1238.20	63.93
18	1244.27	71.87
19	1251.34	78.95
20	1254.15	88.54
21	1261.13	95.70
22	1267.86	103.10
23	1274.63	110.46
24	1274.92	120.46
25	1281.69	127.82
26	1286.87	136.38
27	1293.23	144.10
28	1295.31	153.88
29	1302.27	161.06
30	1309.27	168.20
31	1314.86	176.49
32	1316.78	186.30
33	1321.31	195.21
34	1326.09	200.00

** Corrected JANBU FOS = 2.934 ** (Fo factor = 1.050)

Failure surface No. 7 specified by 32 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	205.47	136.22
2	206.47	135.25
3	213.68	128.33
4	223.65	127.54
5	233.07	124.20
6	242.14	119.99
7	251.03	115.40
8	258.91	109.25
9	267.52	104.16
10	276.15	99.11
11	285.26	94.98
12	295.25	94.63
13	455.06	42.90
14	1208.48	55.31
15	1214.56	63.25
16	1220.60	71.22
17	1226.80	79.07
18	1233.01	86.91
19	1239.51	94.50
20	1240.82	104.42
21	1244.21	113.83
22	1250.99	121.17
23	1255.99	129.84
24	1257.78	139.67
25	1264.85	146.75
26	1268.12	156.20
27	1272.54	165.17
28	1279.57	172.29
29	1286.01	179.93
30	1291.99	187.95
31	1298.56	195.49
32	1300.68	200.00

** Corrected JANBU FOS = 2.958 ** (Fo factor = 1.052)

Failure surface No. 8 specified by 30 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	229.86	137.68
2	233.15	135.14
3	240.91	128.83
4	248.09	121.87
5	255.32	114.96
6	264.59	111.21
7	274.41	109.34
8	283.06	104.31
9	291.74	99.35
10	300.03	93.76
11	456.02	42.52
12	1188.34	55.31
13	1192.52	64.40
14	1198.66	72.29
15	1203.00	81.30
16	1209.39	89.00
17	1216.23	96.29
18	1219.09	105.87
19	1224.45	114.31
20	1228.92	123.26
21	1235.77	130.54
22	1242.78	137.67
23	1249.80	144.80
24	1253.26	154.18
25	1259.15	162.26
26	1265.06	170.32
27	1267.85	179.93
28	1273.85	187.92
29	1280.91	195.01
30	1285.44	200.00

** Corrected JANBU FOS = 2.964 ** (Fo factor = 1.054)

Failure surface No. 9 specified by 31 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	228.11	137.58
2	233.60	132.73
3	240.92	125.92
4	248.05	118.90
5	257.82	116.77
6	265.22	110.05
7	275.08	108.35
8	282.34	101.48
9	290.33	95.47
10	299.49	91.45
11	309.41	90.15
12	453.79	42.51

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13	1119.67	54.29
14	1126.53	61.57
15	1130.47	70.76
16	1136.83	78.48
17	1141.95	87.07
18	1147.04	95.68
19	1153.00	103.71
20	1160.04	110.80
21	1166.89	118.09
22	1172.99	126.02
23	1180.02	133.13
24	1185.73	141.34
25	1190.17	150.30
26	1195.77	158.59
27	1198.98	168.06
28	1206.05	175.13
29	1210.26	184.20
30	1211.15	194.16
31	1211.45	196.45

** Corrected JANBU FOS = 2.979 ** (Fo factor = 1.056)

Failure surface No.10 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	228.82	137.62
2	232.86	133.59
3	239.96	126.54
4	248.22	120.90
5	257.60	117.45
6	264.72	110.43
7	273.71	106.04
8	281.34	99.58
9	451.60	43.25
10	1242.47	56.37
11	1244.78	66.10
12	1248.94	75.19
13	1253.60	84.04
14	1258.56	92.72
15	1265.13	100.26
16	1271.58	107.91
17	1278.60	115.02
18	1281.31	124.65
19	1286.49	133.21
20	1293.24	140.58
21	1298.20	149.26
22	1305.11	156.49
23	1311.26	164.38
24	1316.82	172.69
25	1322.04	181.21
26	1327.92	189.30
27	1328.99	199.24
28	1329.44	200.00

** Corrected JANBU FOS = 2.980 ** (Fo factor = 1.052)

```
*****************************************************************
**                                                             **
**  Out of the    500 surfaces generated and analyzed by XSTABL,  **
**        1 surfaces were found to have MISLEADING FOS values.   **
**                                                             **
*****************************************************************
```

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Cover Block Failure

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	2.810	1.052	210.78	1295.08	1.526E+06
2.	2.848	1.053	218.35	1295.99	1.472E+06
3.	2.859	1.053	218.48	1304.52	1.489E+06
4.	2.871	1.051	192.53	1325.14	1.566E+06
5.	2.926	1.051	206.98	1333.13	1.488E+06
6.	2.934	1.050	182.53	1326.09	1.471E+06
7.	2.958	1.052	205.47	1300.68	1.459E+06
8.	2.964	1.054	229.86	1285.44	1.497E+06
9.	2.979	1.056	228.11	1211.45	1.416E+06
10.	2.980	1.052	228.82	1329.44	1.492E+06

* * * END OF FILE * * *

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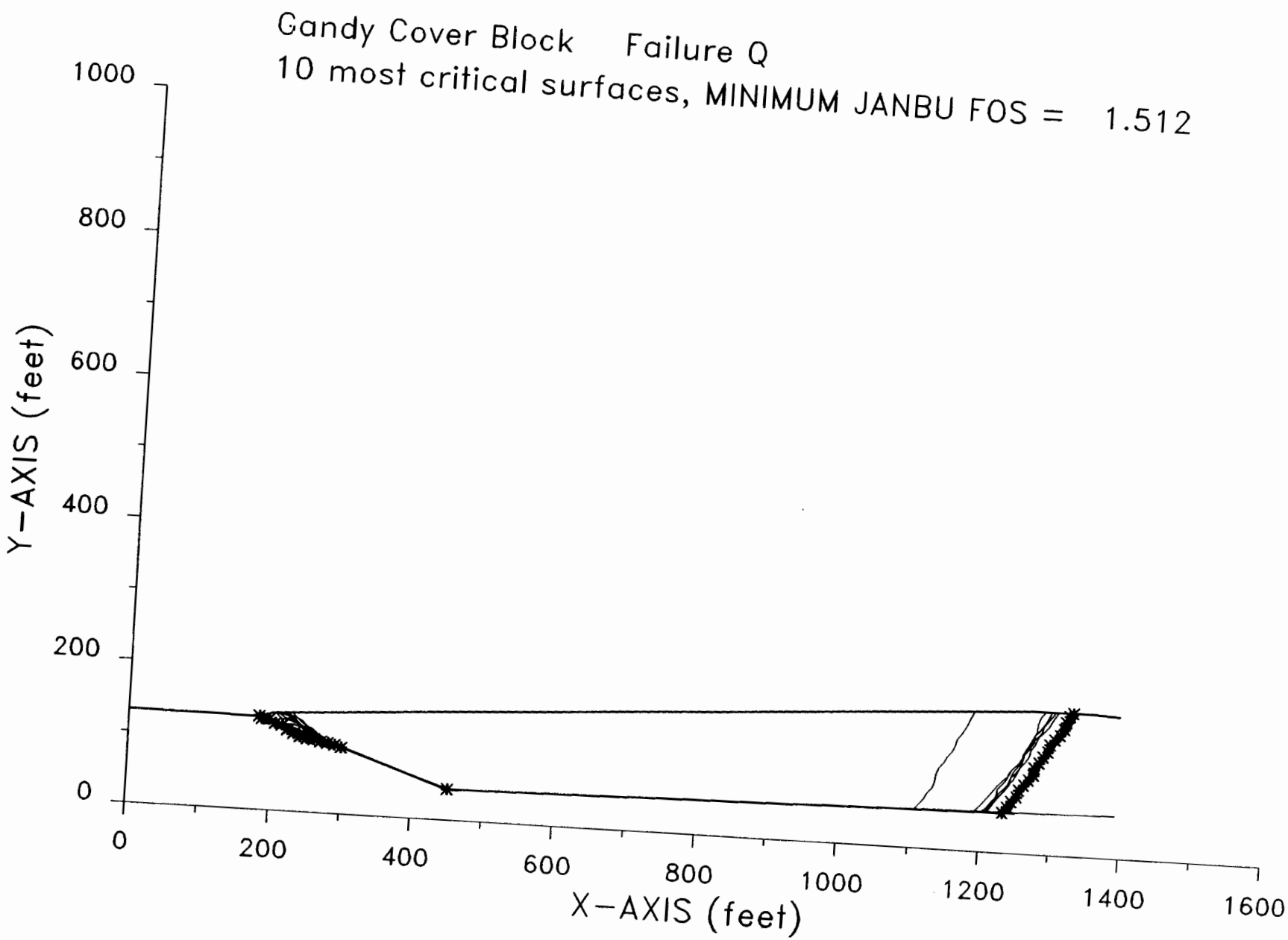

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```
*****************************************
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*                                       *
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```

Problem Description : Gandy Cover Block Failure Q

SEGMENT BOUNDARY COORDINATES
---

5 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	.0	131.7	190.1	130.5	2
2	190.1	130.5	200.1	135.9	1
3	200.1	135.9	1270.7	200.0	1
4	1270.7	200.0	1355.5	200.0	1
5	1355.5	200.0	1393.4	198.4	1

2 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	190.1	130.5	453.1	43.8	2
2	453.1	43.8	1393.4	59.4	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.

1	110.0	110.0	.0	29.00	.000	.0	0
2	110.0	110.0	440.0	2.00	.000	.0	0

A horizontal earthquake loading coefficient
of .040 has been assigned

A vertical earthquake loading coefficient
of .000 has been assigned

A critical failure surface searching method, using a random technique for generating sliding BLOCK surfaces, has been specified.

500 trial surfaces will be generated and analyzed.

3 boxes specified for generation of central block base

Length of line segments for active and passive portions of sliding block is 10.0 ft

Box no.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Width (ft)
1	269.1	103.6	344.9	78.6	1.0
2	450.0	42.8	470.0	43.1	1.0
3	1100.0	53.6	1250.0	56.1	1.0

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED JANBU METHOD * * * * *

The 10 most critical of all the failure surfaces examined are displayed below - the most critical first

Failure surface No. 1 specified by 34 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	182.53	130.55
2	186.08	127.21
3	196.06	126.60
4	204.83	121.78
5	214.67	120.03
6	222.57	113.90
7	231.27	108.97
8	240.50	105.11
9	250.27	102.99

10	260.25	102.39
11	269.83	99.51
12	279.79	98.68
13	289.56	96.53
14	299.05	93.39
15	451.02	43.08
16	1231.97	56.10
17	1238.20	63.93
18	1244.27	71.87
19	1251.34	78.95
20	1254.15	88.54
21	1261.13	95.70
22	1267.86	103.10
23	1274.63	110.46
24	1274.92	120.46
25	1281.69	127.82
26	1286.87	136.38
27	1293.23	144.10
28	1295.31	153.88
29	1302.27	161.06
30	1309.27	168.20
31	1314.86	176.49
32	1316.78	186.30
33	1321.31	195.21
34	1326.09	200.00

** Corrected JANBU FOS = 1.512 ** (Fo factor = 1.050)

Failure surface No. 2 specified by 30 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	218.35	136.99
2	222.80	133.29
3	230.53	126.94
4	238.53	120.94
5	245.73	113.99
6	255.71	113.38
7	262.86	106.39
8	272.17	102.74
9	281.40	98.90
10	291.10	96.46
11	453.34	42.53
12	1207.47	55.58
13	1212.13	64.43
14	1218.81	71.87
15	1225.71	79.10
16	1232.75	86.21
17	1237.89	94.79
18	1244.96	101.86
19	1249.07	110.98
20	1253.70	119.84
21	1257.09	129.25
22	1259.97	138.83
23	1266.43	146.46
24	1269.84	155.86
25	1276.41	163.40
26	1283.47	170.48

27	1285.16	180.33
28	1290.27	188.93
29	1294.68	197.91
30	1295.99	200.00

** Corrected JANBU FOS = 1.552 ** (Fo factor = 1.053)

Failure surface No. 3 specified by 30 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	210.78	136.54
2	219.25	134.15
3	228.70	130.88
4	236.86	125.10
5	244.12	118.22
6	251.19	111.15
7	261.06	109.57
8	269.72	104.56
9	278.77	100.32
10	453.41	43.18
11	1191.28	55.21
12	1198.18	62.45
13	1204.84	69.90
14	1211.33	77.51
15	1217.47	85.41
16	1223.53	93.36
17	1230.55	100.48
18	1237.62	107.55
19	1242.65	116.19
20	1249.72	123.26
21	1255.89	131.14
22	1260.50	140.01
23	1266.42	148.07
24	1272.49	156.02
25	1273.41	165.98
26	1280.09	173.41
27	1285.99	181.49
28	1292.14	189.37
29	1294.37	199.12
30	1295.08	200.00

** Corrected JANBU FOS = 1.553 ** (Fo factor = 1.052)

Failure surface No. 4 specified by 31 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	192.53	131.81
2	199.08	125.82
3	208.87	123.76
4	218.65	121.68
5	228.65	121.60
6	238.47	119.73
7	248.39	118.48
8	256.27	112.32

9	264.17	106.19
10	273.98	104.25
11	282.55	99.10
12	450.02	42.41
13	1224.73	55.25
14	1231.78	62.34
15	1238.54	69.71
16	1244.15	77.98
17	1250.26	85.90
18	1256.51	93.70
19	1261.02	102.63
20	1267.70	110.07
21	1274.64	117.28
22	1281.69	124.36
23	1287.18	132.72
24	1287.98	142.69
25	1292.84	151.43
26	1298.24	159.84
27	1302.79	168.75
28	1307.08	177.78
29	1313.98	185.02
30	1318.96	193.69
31	1325.14	200.00

** Corrected JANBU FOS = 1.558 ** (Fo factor = 1.051)

Failure surface No. 5 specified by 33 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	206.98	136.31
2	211.40	134.77
3	219.80	129.36
4	229.80	129.05
5	236.90	122.00
6	245.40	116.74
7	252.47	109.67
8	262.33	108.03
9	270.45	102.19
10	280.05	99.37
11	289.81	97.23
12	297.64	91.00
13	307.63	90.67
14	453.91	43.03
15	1241.72	55.54
16	1246.59	64.27
17	1249.81	73.74
18	1252.11	83.47
19	1258.91	90.81
20	1265.86	98.00
21	1269.91	107.14
22	1273.41	116.51
23	1280.47	123.59
24	1287.38	130.82
25	1292.80	139.22
26	1299.24	146.87
27	1303.44	155.95
28	1309.35	164.02

29	1315.57	171.85
30	1322.62	178.94
31	1324.41	188.78
32	1331.45	195.88
33	1333.13	200.00

** Corrected JANBU FOS = 1.560 ** (Fo factor = 1.051)

Failure surface No. 6 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	218.48	137.00
2	224.02	134.07
3	232.86	129.40
4	240.00	122.39
5	248.38	116.93
6	255.51	109.92
7	265.50	109.51
8	272.58	102.45
9	454.90	42.73
10	1209.31	55.03
11	1214.83	63.37
12	1220.24	71.77
13	1223.80	81.12
14	1230.86	88.20
15	1237.73	95.47
16	1241.21	104.84
17	1248.23	111.96
18	1253.81	120.27
19	1260.88	127.34
20	1266.17	135.82
21	1268.73	145.49
22	1274.75	153.47
23	1278.17	162.87
24	1285.24	169.95
25	1291.62	177.65
26	1296.50	186.37
27	1302.01	194.72
28	1304.52	200.00

** Corrected JANBU FOS = 1.566 ** (Fo factor = 1.053)

Failure surface No. 7 specified by 32 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	205.47	136.22
2	206.47	135.25
3	213.68	128.33
4	223.65	127.54
5	233.07	124.20
6	242.14	119.99
7	251.03	115.40
8	258.91	109.25
9	267.52	104.16

10	276.15	99.11
11	285.26	94.98
12	295.25	94.63
13	455.06	42.90
14	1208.48	55.31
15	1214.56	63.25
16	1220.60	71.22
17	1226.80	79.07
18	1233.01	86.91
19	1239.51	94.50
20	1240.82	104.42
21	1244.21	113.83
22	1250.99	121.17
23	1255.99	129.84
24	1257.78	139.67
25	1264.85	146.75
26	1268.12	156.20
27	1272.54	165.17
28	1279.57	172.29
29	1286.01	179.93
30	1291.99	187.95
31	1298.56	195.49
32	1300.68	200.00

** Corrected JANBU FOS = 1.574 ** (Fo factor = 1.052)

Failure surface No. 8 specified by 28 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	228.82	137.62
2	232.86	133.59
3	239.96	126.54
4	248.22	120.90
5	257.60	117.45
6	264.72	110.43
7	273.71	106.04
8	281.34	99.58
9	451.60	43.25
10	1242.47	56.37
11	1244.78	66.10
12	1248.94	75.19
13	1253.60	84.04
14	1258.56	92.72
15	1265.13	100.26
16	1271.58	107.91
17	1278.60	115.02
18	1281.31	124.65
19	1286.49	133.21
20	1293.24	140.58
21	1298.20	149.26
22	1305.11	156.49
23	1311.26	164.38
24	1316.82	172.69
25	1322.04	181.21
26	1327.92	189.30
27	1328.99	199.24
28	1329.44	200.00

** Corrected JANBU FOS = 1.590 ** (Fo factor = 1.052)

Failure surface No. 9 specified by 30 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	186.85	130.52
2	192.21	127.57
3	201.72	124.49
4	210.38	119.50
5	219.88	116.36
6	229.86	115.63
7	238.40	110.43
8	248.11	108.04
9	257.98	106.45
10	267.03	102.20
11	276.93	100.82
12	451.38	42.94
13	1106.11	53.43
14	1113.10	60.58
15	1119.85	67.96
16	1123.83	77.13
17	1130.88	84.22
18	1134.62	93.49
19	1135.75	103.43
20	1139.15	112.83
21	1146.19	119.94
22	1150.36	129.03
23	1157.39	136.14
24	1161.14	145.41
25	1163.82	155.04
26	1169.78	163.07
27	1175.42	171.33
28	1179.22	180.58
29	1183.40	189.66
30	1185.10	194.88

** Corrected JANBU FOS = 1.608 ** (Fo factor = 1.055)

Failure surface No.10 specified by 31 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	214.74	136.78
2	215.63	136.39
3	225.43	134.41
4	235.02	131.57
5	243.74	126.68
6	250.99	119.79
7	258.63	113.33
8	267.51	108.74
9	275.87	103.26
10	283.27	96.53
11	293.21	95.40
12	454.35	42.48

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4-Nov-97

13	1201.92	55.28
14	1208.99	62.36
15	1214.93	70.40
16	1221.43	78.00
17	1222.85	87.90
18	1229.49	95.38
19	1235.95	103.01
20	1238.82	112.59
21	1245.54	120.00
22	1252.55	127.12
23	1257.59	135.76
24	1261.05	145.14
25	1266.53	153.51
26	1271.22	162.34
27	1275.85	171.20
28	1276.78	181.16
29	1279.60	190.76
30	1286.25	198.22
31	1287.86	200.00

** Corrected JANBU FOS = 1.610 ** (Fo factor = 1.053)

The following is a summary of the TEN most critical surfaces

Problem Description : Gandy Cover Block Failure Q

	Modified JANBU FOS	Correction Factor	Initial x-coord (ft)	Terminal x-coord (ft)	Available Strength (lb)
1.	1.512	1.050	182.53	1326.09	1.376E+06
2.	1.552	1.053	218.35	1295.99	1.392E+06
3.	1.553	1.052	210.78	1295.08	1.451E+06
4.	1.558	1.051	192.53	1325.14	1.486E+06
5.	1.560	1.051	206.98	1333.13	1.403E+06
6.	1.566	1.053	218.48	1304.52	1.412E+06
7.	1.574	1.052	205.47	1300.68	1.375E+06
8.	1.590	1.052	228.82	1329.44	1.412E+06
9.	1.608	1.055	186.85	1185.10	1.194E+06
10.	1.610	1.053	214.74	1287.86	1.388E+06

* * * END OF FILE * * *

4BA

612-0270
PMP
12-Nov-97

Infinite slope analysis spreadsheet
Date: 12-Nov-97
By: Paul Pellicer
Filename: Cover system stability .wq1

Soil Parameters

Cohesion:	15 psf		0.054643341
Friction Angle:	31 degrees	tangent	0.600860619
Gamma Moist:	110 pcf		

Slope Geometry:

Slope Angle:	3.43 degrees	cosine	0.998208638 sine
Failure Plane Depth:	2.5 ft		

Groundwater Parameters

Height of water in failure mass:	2.5	ft
Pore Pressure Ratio:	0.567272727	no units

Seismic Parameters

Ground Acceleration:	0	g's

Safety Factor: 5.2514

4BB
602-020V
pmp
12-Nov-97

Infinite slope analysis spreadsheet
Date: 12-Nov-97
By: Paul Pellicer
Filename: Cover system stability .wq1

Soil Parameters

Cohesion:	15 psf		0.054643341
Friction Angle:	31 degrees	tangent	0.600860619
Gamma Moist:	110 pcf		

Slope Geometry:

Slope Angle:	3.43 degrees	cosine	0.998208638 sine
Failure Plane Depth:	2.5 ft		

Groundwater Parameters

Height of water in failure mass:	2.5 ft
Pore Pressure Ratio:	0.567272727 no units

Seismic Parameters

Ground Acceleration:	0.04 g's

Safety Factor: 3.13509

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602 - 0200

Calculation Title: Ramp Stability

	Name	Date
Prepared By:	P. Pellicer	14-Nov-97
Checked By:	J. Pellicer	14-Nov-97
Reviewed By:	P. Gober	15 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
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Steamboat Springs, Colorado 80477
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Ramp Stability

Objective: Evaluate Stability of Ramp Select Subbase and Road Base on the Ramp, Statically, pseudo-statically, and w/ a loaded Scraper.

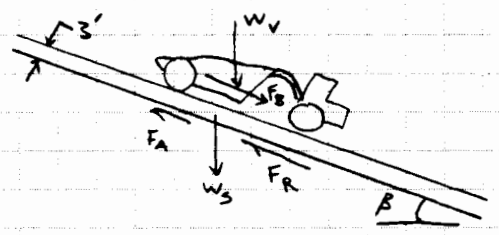
Assumptions: - use a fully loaded 631 scraper applying brakes for scraper load.

Calculations:

Evaluate static + pseudo-static using Infinite Slope Spread sheat.

γ for select subbase and Road Base = 125 pcf
assume failur plane runs through liner system
Liner system strength = $a = 18$ psf (see pg 3)
$\delta = 31°$
Road grade = 10% (Residual strength from Sina Pacific Testing)
Infinite slope analysis indicate a static F.S. = 6.4 and a pseudo-static F.S. = 4.6 using a ground acceleration of 0.04g (see pg 4 - 7)

Evaluate static stability of ramp with a loaded 631 scraper breaking on the Ramp.



Length of Scraper ≈ 50' (see pg 10)
width of access Ramp ≈ 47 ft (subgrade) (see pg 9)

Weakest interface ⇒ $\delta_{min} = 31°$, $a_{min} = 15$ psf (see pg 3)

Evaluate stability of ramp w/ scraper just for one length of the scraper (conservative)

Define Resisting Forces:
F_R = Frictional Force @ Base of Roadway.

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Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

$F_R = (W_V + W_S) * \cos\beta * \tan\delta_{min}$

W_V = wt of Scraper
= GVW + Rated load
= 93410 lb + 75000 lb (from Cat Handbook see pg 10)
= 168410 lbs

W_S = wt of Soil
= $(W \times L \times T)\gamma_S$ W = 47 ft, L = 50 ft, T = 3 ft (see pg 9)
= (47ft × 50ft × 3ft) 125pcf, γ_S = 125pcf (assumed)
= 881250 lbs

β = 10% ⇒ 5.71° (see pg 8)

F_R = (168410 lbs + 881250 lbs) * cos 5.71 * tan 31°
= 627570 lbs

F_A = Adhesion Force
= $WL * a_{min}$
= (47 ft * 50 ft) * 15 psf
= 35250 lbs

$F_{R_{total}}$ = $F_R + F_A$
= 662820 lbs

Define Diving Forces:

F_{SD} = Soil and vehicle driving Force
= $(W_S + W_V)\sin\beta$
= (168410 + 881250) sin 5.71
= 104,434 lbs

F_b = Braking Force from Scraper
= $0.3\ W_V$
= 0.3 (168410 lbs) =
= 50523 lbs

$F_{D_{total}}$ = $F_{SD} + F_b$ = 154957

$F.S. = \frac{F_{R\,total}}{F_{D\,total}} = \frac{662820}{154957} = 4.3$ o.k.

Conclusion: The Ramp is stable for the conditions analyzed.

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

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14-Nov-97
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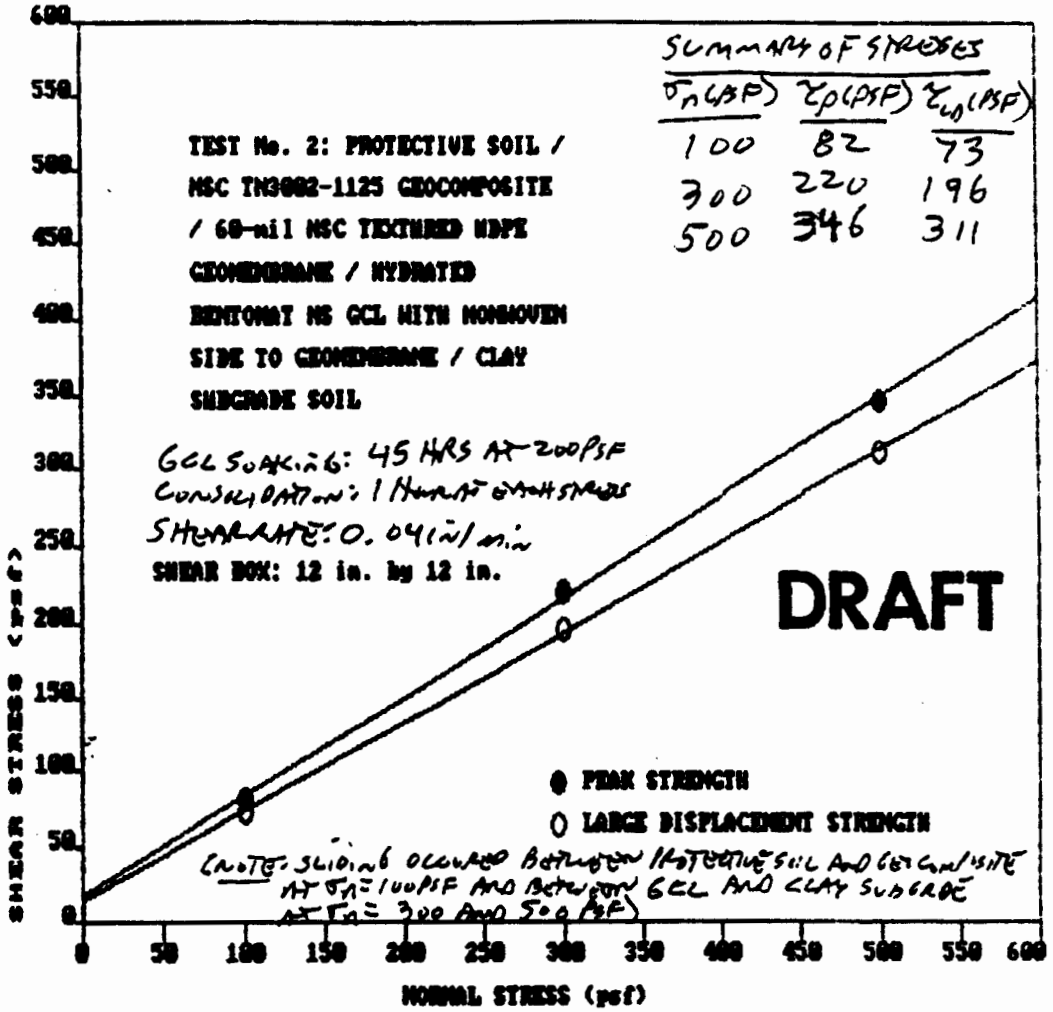
TERRAMATRIX MONTGOMERY WATSON - ASTM D 5321 TESTS



THE REGRESSION POLYNOMIAL OF LINE 9 - PEAK STRENGTH

(1.800E+01) + (6.600E-01)*X a = 18 PSF δ = 33°
THE VARIANCE - 8.000E+00

THE REGRESSION POLYNOMIAL OF LINE 10 - LARGE DISPLACEMENT STRENGTH

(1.483E+01) + (5.950E-01)*X a = 15 PSF δ = 31°
THE VARIANCE - 3.556E+00

Reviewed By: Robert H Swan Jr Date: 10-10-97

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602-0200
14-Nov-97
PMP

United States Department of the Interior

Geological Survey

PROBABILISTIC ESTIMATES OF MAXIMUM ACCELERATION AND VELOCITY IN ROCK IN THE CONTIGUOUS UNITED STATES

by

S. T. Algermissen, D. M. Perkins, P. C. Thenhaus,
S. L. Hanson and B. L. Bender

U.S. GEOLOGICAL SURVEY
DENVER
NOV 15 1982
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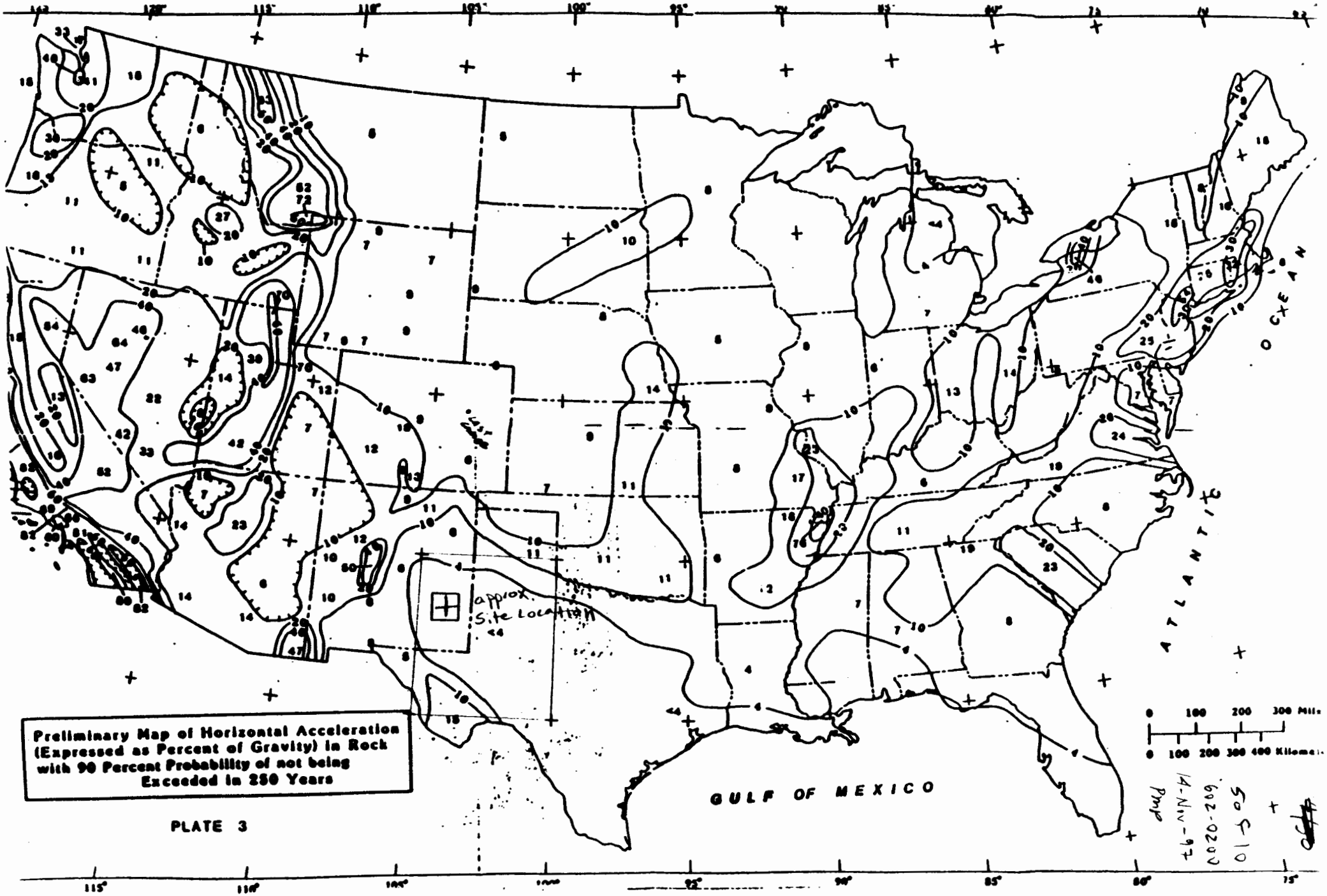
Open-File Report 82-1033

1982

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

JUL 27 199
10 NOV 19



Preliminary Map of Horizontal Acceleration (Expressed as Percent of Gravity) in Rock with 90 Percent Probability of not being Exceeded in 250 Years

PLATE 3

602-0200
14-Nov-97
PMP

Infinite slope analysis spreadsheet
Date: 13-Nov-97
By: Paul Pellicer
Filename: ~~Protective cover stability~~.wq1
Ramp Stability

Soil Parameters

Cohesion:	15 psf		0.040199461
Friction Angle:	31 degrees	tangent	0.600860619
Gamma Moist:	125 pcf		

Slope Geometry:

Slope Angle:	5.71 degrees	cosine	0.99503822 sine
Failure Plane Depth:	3 ft		

Groundwater Parameters

Height of water in failure mass:	0 ft
Pore Pressure Ratio:	0 no units

Seismic Parameters

Ground Acceleration:	0 g's

Safety Factor: 6.41328

14-Nov-97
602-0200
PMP

Infinite slope analysis spreadsheet
Date: 13-Nov-97
By: Paul Pellicer
Filename: Protective cover stability.wq1

Soil Parameters

Cohesion:	15 psf		0.040199461
Friction Angle:	31 degrees	tangent	0.600860619
Gamma Moist:	125 pcf		

Slope Geometry:

Slope Angle:	5.71 degrees	cosine	0.99503822 sine
Failure Plane Depth:	3 ft		

Groundwater Parameters

Height of water in failure mass:	0 ft
Pore Pressure Ratio:	0 no units

Seismic Parameters

Ground Acceleration:	0.04 g's

Safety Factor: 4.56361

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14-NOV-97
PMP

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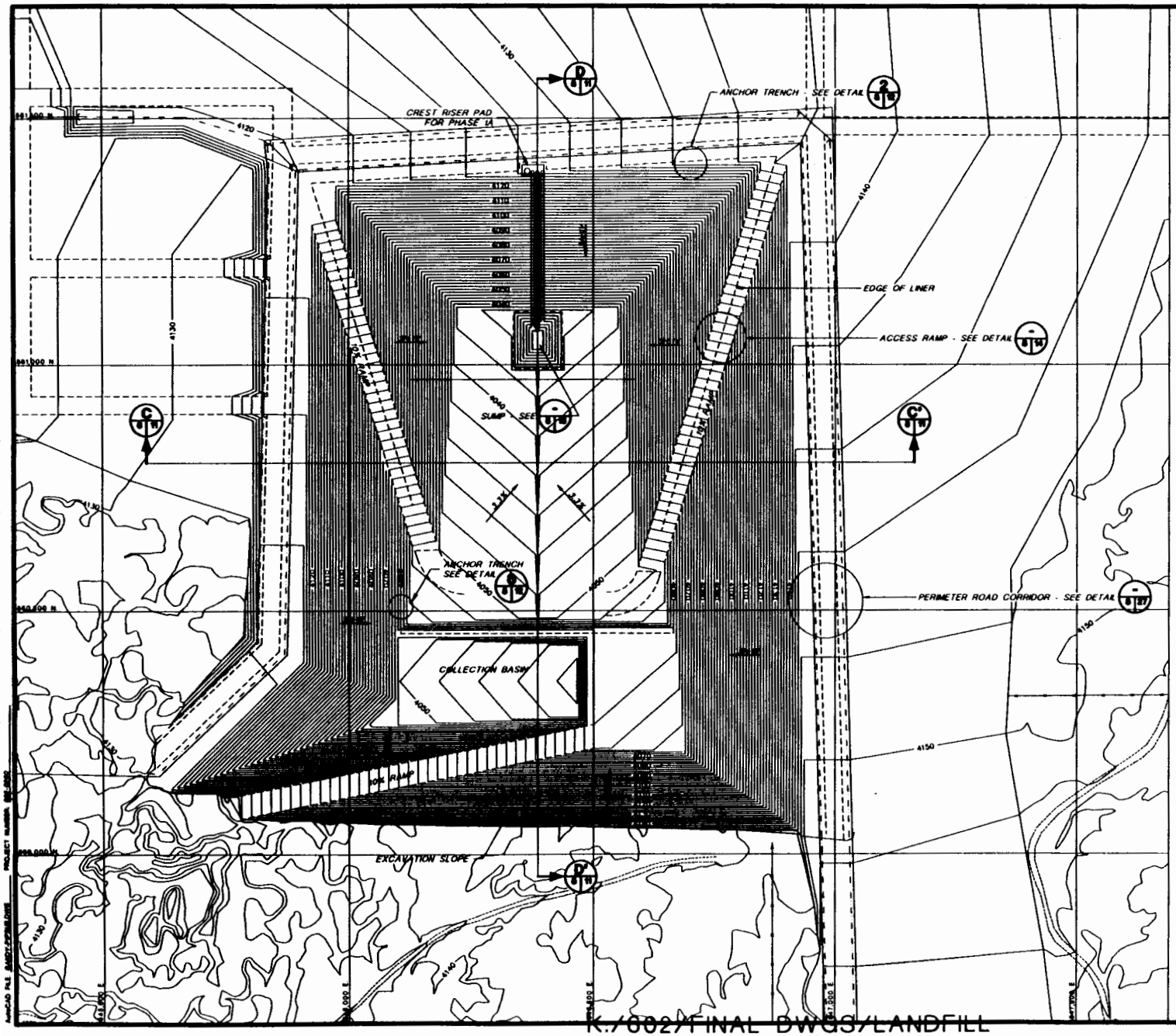

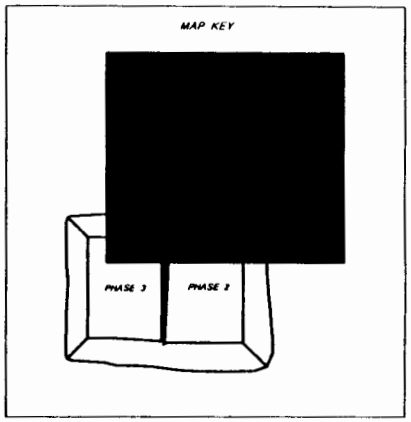

NOTES:
1. FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No 2. "INDEX, LEGEND AND GENERAL NOTES"
2. TOPOGRAPHY FROM AERIAL SURVEYS PERFORMED AUGUST 1997 BY KOOGLE AND POULS ENGINEERING

PATRICK G. CORSER NEW MEXICO 12236 REGISTERED PROFESSIONAL ENGINEER

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Corser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Corser, NM P.E. 12236

SCALE
100' 0 100' 200'
CONTOUR INTERVAL 2 FT.

Not For Construction

REV	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED BY	NO.
6	PART B PERMIT APPLICATION	10/10/97	PGC/JPF	T.Smith	P.Corser	

TRIASSIC PARK WASTE DISPOSAL FACILITY

DRAWING TITLE:
DETAILED EXCAVATION PLAN - PHASE 1A

TerraMatrix
MONTGOMERY WATSON
Rising Group

Sheet 1 Of 1 Sheets
SCALE: AS NOTED
DRAWING No. 8

K:/602/FINAL DWGS/LANDFILL
GANDY-P1PSUB.dwg
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12/09/97 11:49a

E-6

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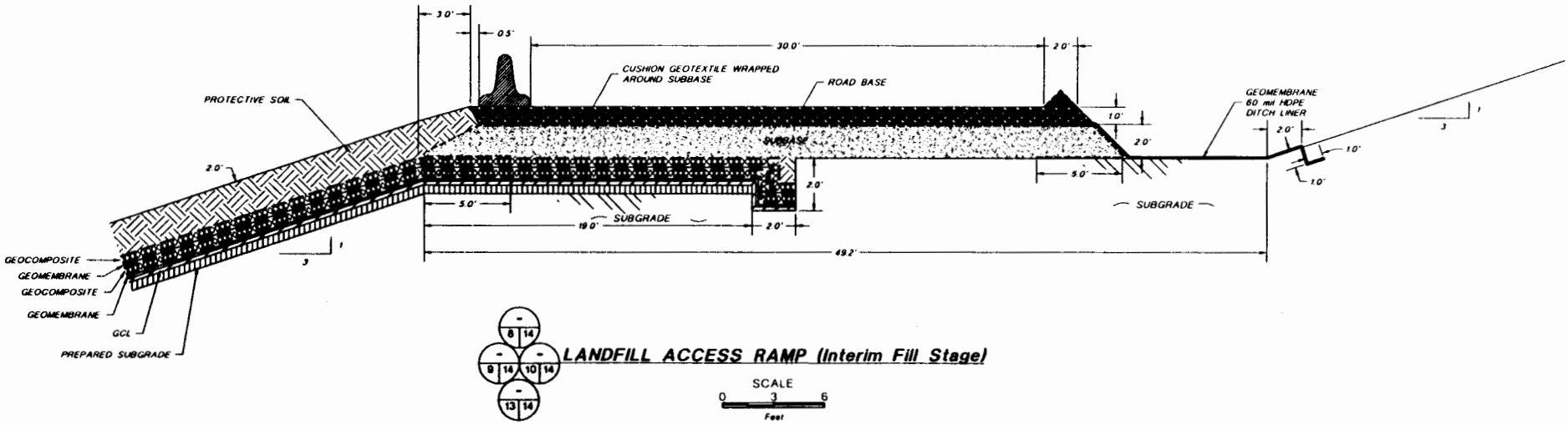
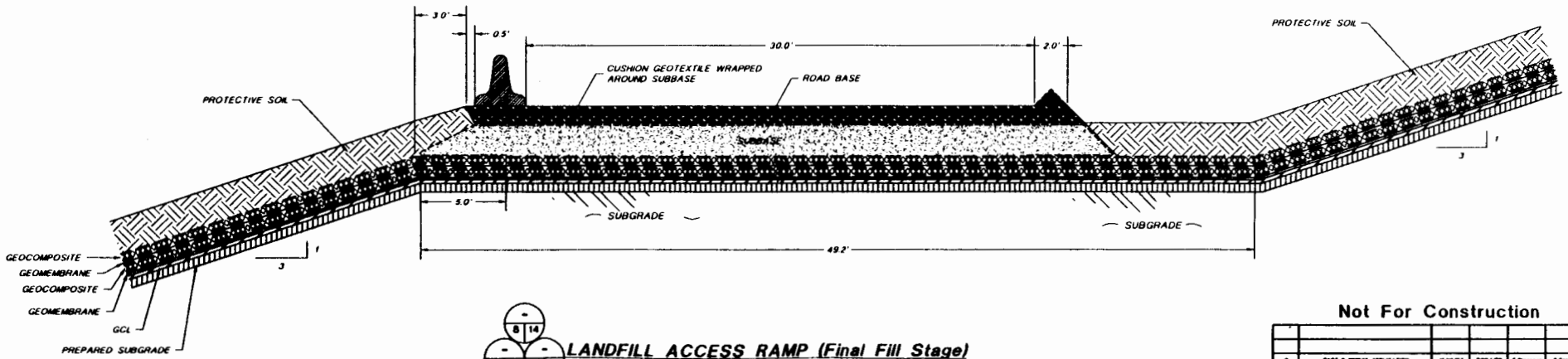
602-0200
14-NOV-97
pmp



8 14 | 9 14 | 10 14 | 13 14

LANDFILL ACCESS RAMP (Interim Fill Stage)

SCALE
0 3 6
Feet



8 14 | 9 14 | 10 14 | 13 14

LANDFILL ACCESS RAMP (Final Fill Stage)

SCALE
0 3 6
Feet

NOTE
FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2 "INDEX, LEGEND AND GENERAL NOTES"

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Corser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Corser, NM P.E. 12236

Not For Construction

REV No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	11/6/97	PGC/PP	E.Simonson	P.Corser

TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE
TYPICAL LANDFILL ACCESS RAMP DETAILS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE AS NOTED
DRAWING No. 14

AUTOCAD FILE RAMP-DETAIL.DWG PROJECT NUMBER 602-0200

Specifications
• Standard Scrapers

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PMP
14-Nov-97

	621B		631D		651E	
Flywheel power	246 kW	330 HP	336 kW	450 HP	410 kW	550 H
Operating weight (empty)◄	30 205 kg	66,590 lb	42 370 kg	93,410 lb	59 420 kg	131,00
Scraper capacity —						
Struck	10.7 m^3	14 yd^3	16 m^3	21 yd^3	24.5 m^3	32 yc
Heaped	15.3 m^3	20 yd^3	23.7 m^3	31 yd^3	33.6 m^3	44 yc
Rated load	21 770 kg	48,000 lb	34 000 kg	75,000 lb	47 170 kg	104,00
Weight distribution — Empty						
Drive	70%		69%		69%	
Rear	30%		31%		31%	
Weight distribution — Loaded						
Drive	55%		54%		54%	
Rear	45%		46%		46%	
Engine model	3406		3408		3412	
Rated engine RPM	1900		2000		1900	
Displacement	14.6 L	893 in^3	18.0 L	1099 in^3	27.0 L	1649 i
Top speed (loaded)	48 km/h	30 mph	50 km/h	31 mph	50 km/h	31 mp
Non-stop turning circle	11.1 m	36'6"	12.2 m	40'1"	13.6 m	44'7'
With ROPS restriction	—		—		14.5 m	47'7'
Tires — Tractor drive	29.5-29, 28 PR (E-3)		33.25-35, 38 PR (E-3)		37.5R39 Radial ★ ★ (E	
Scraper	29.5-29, 28 PR (E-3)		33.25-35, 38 PR (E-3)		37.5R39 Radial ★ ★ (E	
Width of cut	3.02 m	9'11"	3.50 m	11'6"	3.68 m	12'1'
Maximum depth of cut	340 mm	13.4"	483 mm	19"	440 mm	17.3"
Maximum depth of spread	460 mm	18"	425 mm	16.7"	660 mm	26"
Fuel tank refill capacity	511 L	135 gal	760 L	200 gal	1083 L	286 ga
GENERAL DIMENSIONS:						
Height to top of scraper	3.63 m	11'11"	4.17 m	13'8"	4.70 m	15'5"
Wheelbase	7.72 m	25'4"	8.74 m	28'8"	9.96 m	32'8"
Overall length	12.7 m	41'7"	14.25 m	46'9"	16.13 m	52'11"
Overall width	3.45 m	11'4"	3.96 m	13'	4.34 m	14'3"
Shipping width (draft arm on inside of bowl)	—		3.66 m	12'0"	3.91 m	12'10"
Scraper tread	2.18 m	7'2"	2.46 m	8'1"	2.82 m	9'3"
Tractor tread	2.21 m	7'3"	2.46 m	8'1"	2.64 m	8'8"

◄**Operating weight** includes coolant, lubricants, full fuel tank, ROPS canopy and operator.

E-7

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Evaporation Pond Slope Stability

	Name	Date
Prepared By:	J. Pellicer	14-Nov-97
Checked By:	P. Pellizer	14-Nov-97
Reviewed By:	P. Good	14Nov97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of
Prepared By: J. Pellicer Date: 14-Nov-97
Checked By: D. Pellicer Date: 14-Nov-97

Evaporation Pond Slope Stability

OBJECTIVE: Determine slope stability of evaporation pond slopes.

METHOD: Use XSTABL (Ver. 5.200) to analyze cut slope stability.

ASSUMPTIONS: Cut slopes are unsaturated
Cut slopes are primarily in the Upper Dockum

GEOMETRY: See attached plan view and section.

SOIL STRENGTH: Pocket Penetrometer data indicate an unconfined compressive strength in excess of 5 tsf. Therefore $c \geq 5{,}000$ psf.

GROUND ACCELERATION: 0.04g see attached pg.

STATIC SAFETY FACTOR (2H:1V): 19.18

PSEUDOSTATIC SAFETY FACTOR (2H:1V): 15.73

STATIC SAFETY FACTOR (3H:1V): 15.90

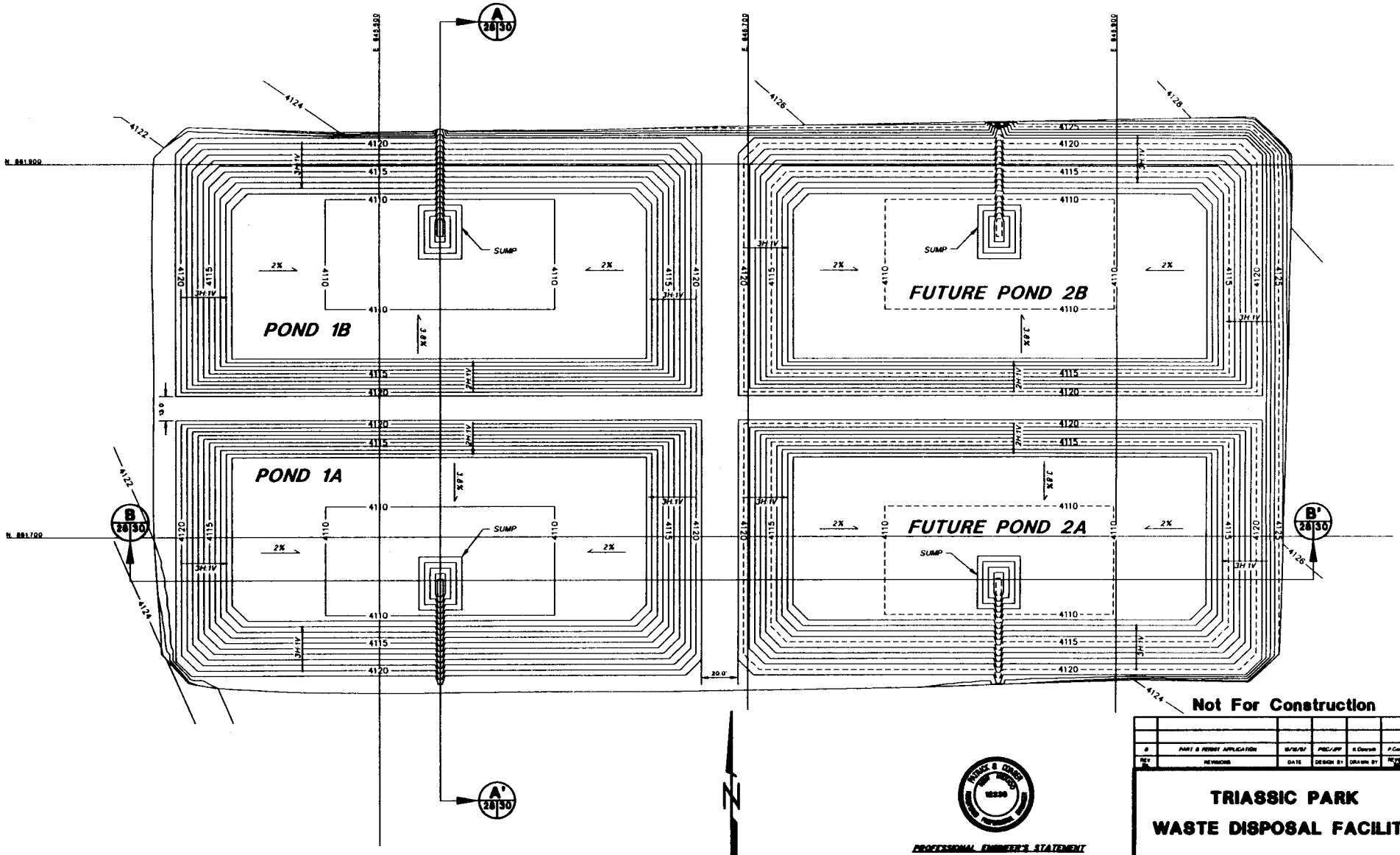
PSEUDOSTATIC SAFETY FACTOR (3H:1V): 13.30

CONCLUSION: Pond slopes are stable both statically and pseudostatically.

602-0200
JJP
14-NOV-97

2 of 30

E-7



NOTE:
FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2, "INDEX, LEGEND AND GENERAL NOTES".

SCALE
25' 0 25' 50'
CONTOUR INTERVAL 1 FT. – INSIDE OF POND
CONTOUR INTERVAL 2 FT. – OUTSIDE OF POND

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Carver, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Carver, NM P.E. 10236

REV. No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	9/16/97	PGC/JPP	K.Conrad	P.Carver

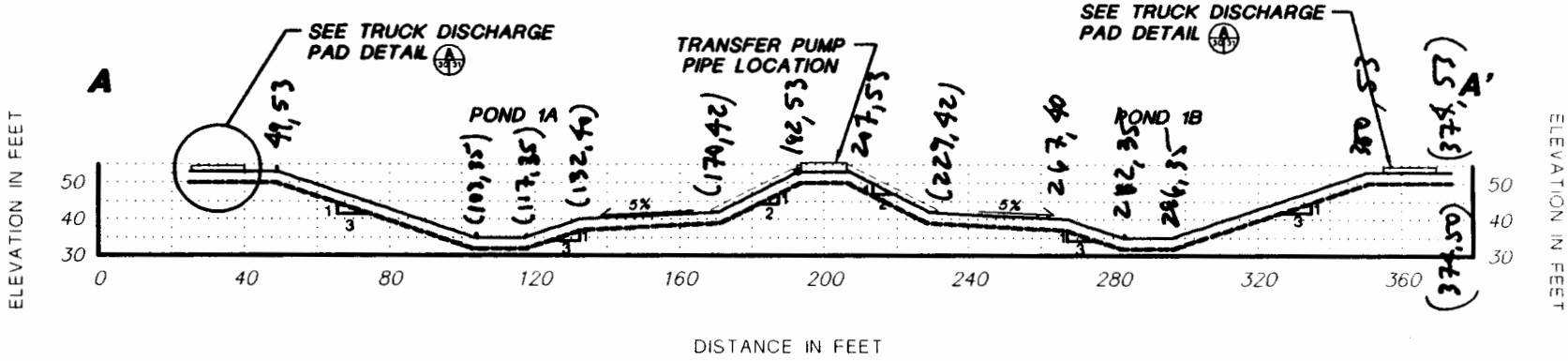
TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE:
EVAPORATION POND
SUBGRADE CONTOURS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE: As Shown
DRAWING No. 26

K:/602/FINAL DWGS/Evaporation Pond
SUBGRD-CONT2.dwg
796,365
12/09/97 04:15p



CROSS-SECTION A-A'

HORIZONTAL SCALE
0 25' 50'

VERTICAL SCALE
0 25' 50'

DOCUMENT DRAFT - REVIEW TABLE					
REVIEW ISSUE	DESCRIPTION	DRAFT DATE	DESIGN BY	DRAWN BY	REVIEWED BY

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

TerraMatrix
MONTGOMERY WATSON
Mining Group

PROJECT No.:
AutoCAD FILE evaporation pond dwg
SCALE
FIGURE No.

3 of 3
Revision
602-0220
14-Nov-02

TP-4

0-3' Topsoil, silty sand, Tan, moist.

3'-5' Tan very fine sand, slightly moist medium hard

5'-6.5' white calcareous, caliche, some gravels and cobbles, hard to very hard

maxed out pen 5 tsf

6.5'-11' white calcareous, caliche, no cobbles or gravel, very hard, with clay

11'-16' Reddish brown, slightly cemented to well cemented siltstone-sandstone, hard very hard to dig @ 18'

16'-22' Reddish brown, claystone-mudstone, hard to very hard, slightly moist.

TP-5

0-2' Sand, silty topsoil, tan, moist

2'-7' Brown To red silty sand, slight moist

7'-12' Brown, calcareous clay w/sand slightly moist.

12'-13' Gravely clay lense

13'-17' Dark brown mudstone, slightly moist, hard to very hard

pocket pen maxed 5 tsf

17'-23' Reddish brown, sandy siltstone hard to very hard

TP-1

0-2.5' Topsoil - silty fine sand, reddish brown, roots, moist,

2.5'-6.0' Gravelly silty sand, some clay, caliche, brownish red, slightly moist

6.0-8.0'* Red weathered claystone - mudstone chunky, hard

8'-17' Red claystone - mudstone w/ traces of olive claystone, hard, slightly moist. To very hard

*pocket pen @ 7-8', moved out

5 tsf

Dozer D6H

Already dozed out, veiwed side cuts to identify material, same for TP-2, TP-4 + TP-5

310D John Deere backhoe extended boom

TP-2

0-3' Topsoil - Tan sand w/ silt, moist, fine

3'-10' Light brown calcareous clay w/ silt and sands, ~~and sand lenses (moist)~~

10'-16' Brown silty sand (moist), trace coarse sand lenses

16'-20' Brown slightly silty clay, moist hard to very hard

20'-24' Brown clayey sandy silt, moist, fine

TP-3

0-1' Topsoil - silty sand, Tan moist roots, ~~medium to~~ fine in size.

1'-2.5' Sand, trace silt, fine, tan some roots

2.5'-5' Light tan to white, chiefly calcareous caliche, some cobbles and gravel

5'-6.5' Reddish brown, sandy clay, some silt

6.5'-15' Reddish brown, claystone-siltstone, slightly weathered, slightly moist, blocky hard to very hard, ~~water out penetrates~~ greenish grey lenses of siltstone 5 tsf

15'-19' Reddish siltstone, very hard

Bucket sample @ 7.5'
Bag sample at 6.5'

NOV 14 '97 15:52 NO.005 P.04
6 of 20
J. Rehrer
6020200
14-NOV-97

7 of 30
J. Pellizza
602-0200
14-Nov-97

TP-4

0-3' Topsoil, silty sand, Tan, moist.

3'-5' Tan very fine sand, slightly moist medium hard

5'-6.5' White calcareous, caliche, some gravels and cobbles, hard to very hard

maxed out pen 5 tsf

6.5'-11' white calcareous, caliche, no cobbles or gravel, very hard, with clay

11'-16' Reddish brown, slightly cemented to well cemented siltstone-sandstone, hard very hard to dig @ 18'

16'-22' Reddish brown, claystone-mudstone, hard to very hard, slightly moist.

TP-5

0-2' Sand, silty topsoil, tan, moist

2'-7' Brown To red silty sand, slight moist

7'-12' Brown, calcareous clay w/sand slightly moist.

12'-13' Gravely clay lense

13'-17' Dark brown mudstone, slightly moist, hard to very hard

(pocket pen maxed) 5 tsf

17'-23' Reddish brown, sandy siltstone hard to very hard

TP-1

0-2.5' Topsoil - silty fine sand, reddish brown, roots, moist,

2.5'-6.0' Gravelly silty sand, some clay, calichi, brownish red, slightly moist

6.0-8.0'* Red weathered claystone - mudstone chunky, hard

8'-17' Red claystone - mudstone w/ traces of olive claystone, hard, slightly moist. To very hard

*pocket pen @ 7-8', moved out

5 tsf

Dozer D6H

Already dozed out, veiwed side cuts to identify material, same for TP-2, TP-4 + TP-5

310D John Deere backhoe extended boom

ID:3037638003 NOV 14'97 15:51 No.003 P.03

9.C 30
J. Pellicer
602-2009
14-Nov-97

TP-2

0-3' Topsoil - Tan sand w/ silt, moist, fine

3'-10' Light brown calcareous clay w/ silt and sands, ~~and sand lenses (moist)~~

10'-16' Brown silty sand (moist), trace coarse sand lenses

16'-20' Brown slightly silty clay, moist hard to very hard

20'-24' Brown clayey sandy silt, moist, fine

TP-3

0-1' Topsoil - silty sand, Tan moist roots, ~~medium to~~ fine in size.

1'-2.5' Sand, trace silt, fine, tan some roots

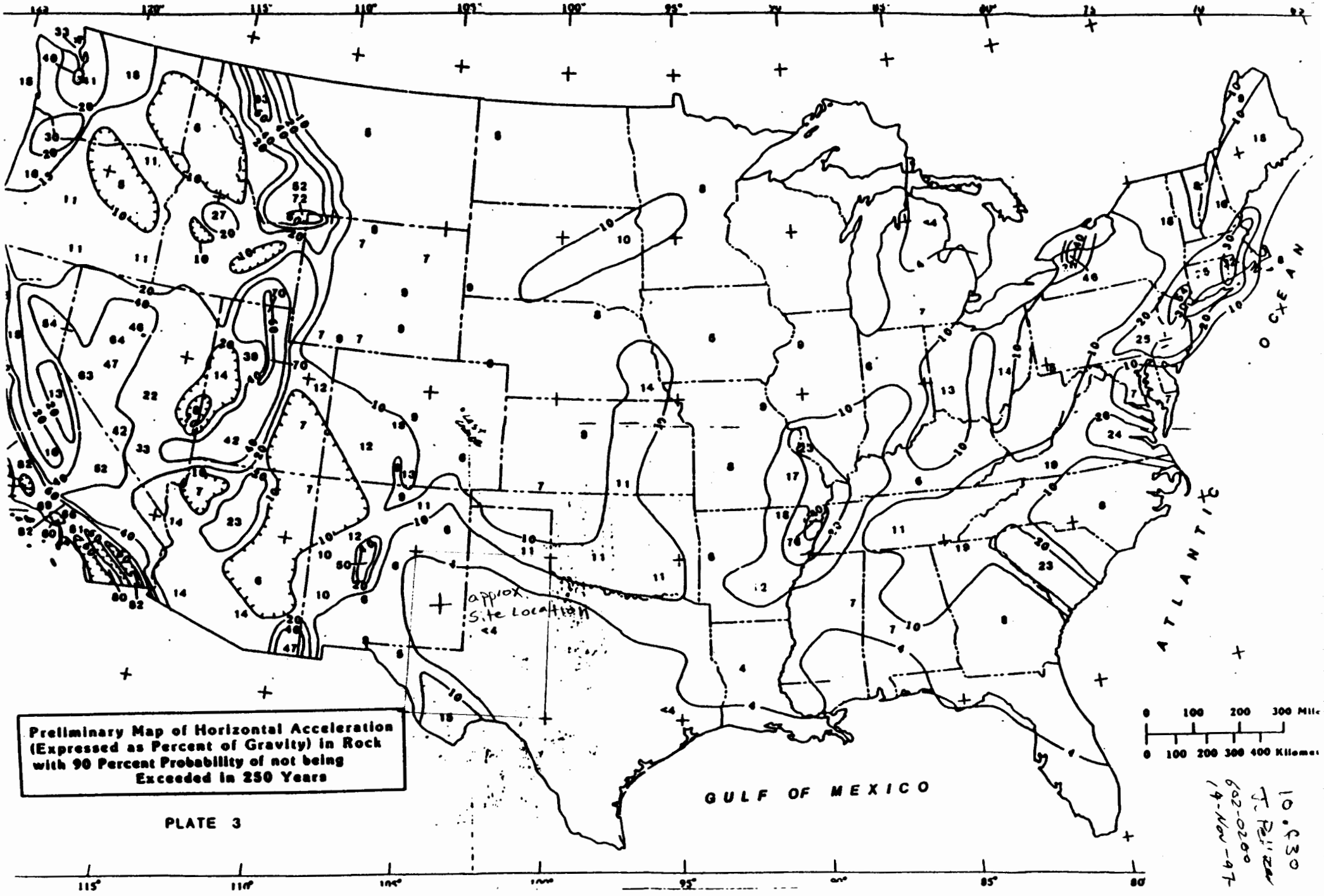
2.5'-5' Light tan to white, clayey calcareous caliche, some cobbles and gravel

5'-6.5' Reddish brown, sandy clay, some silt

6.5'-15' Reddish brown, claystone-siltstone, slightly weathered, slightly moist. blocked hard to very hard, ~~water out penetrates~~ greenish grey lenses of siltstone 5 tsf

15'-17' Reddish siltstone, very hard

Bucket sample @ 7.5'
Bag sample at 6.5'

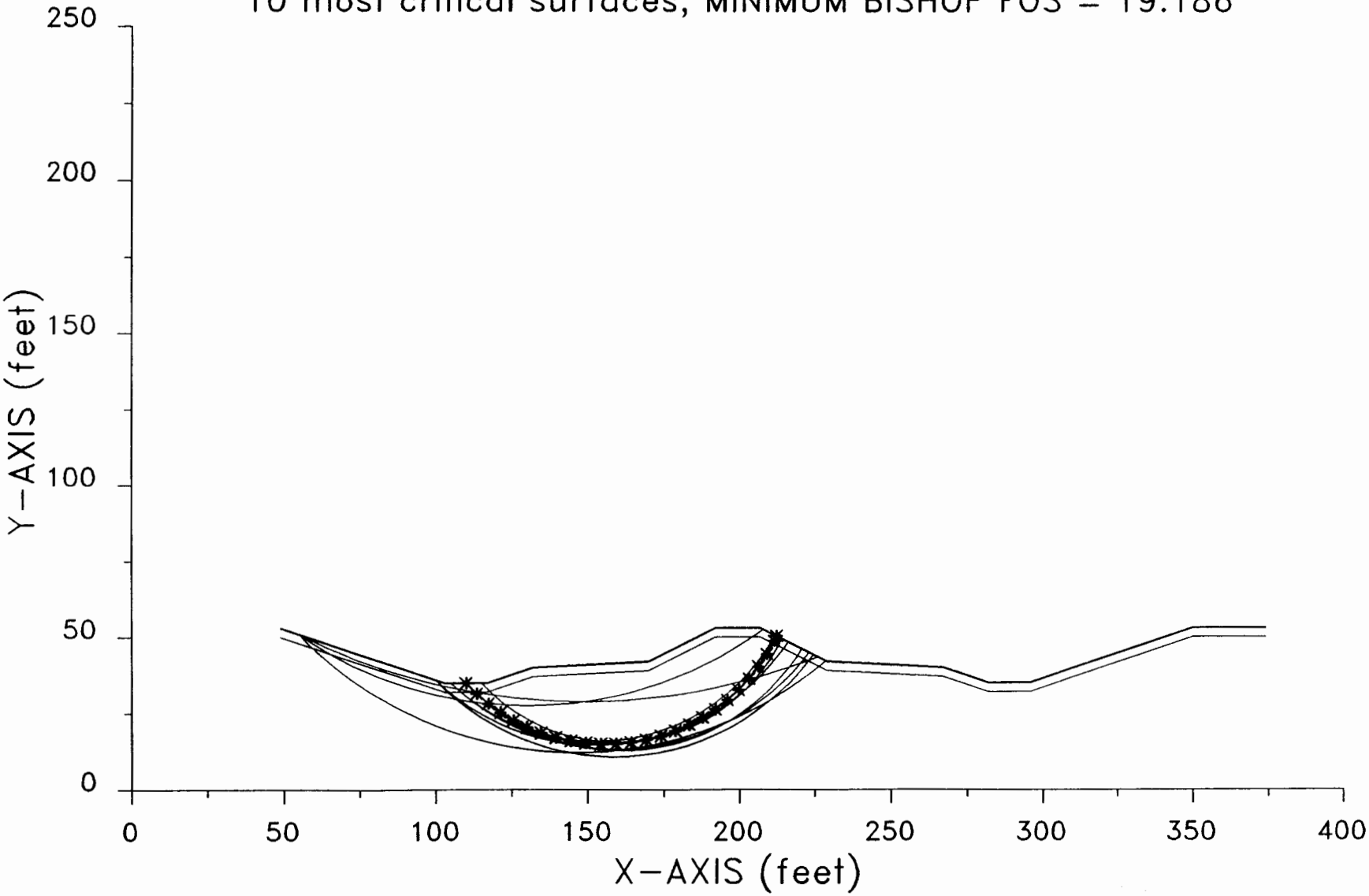


Preliminary Map of Horizontal Acceleration (Expressed as Percent of Gravity) in Rock with 90 Percent Probability of not being Exceeded in 250 Years

PLATE 3

10.230
J. Pelizza
602-0200
14-Nov-97

Triassic park evap pond, static
10 most critical surfaces, MINIMUM BISHOP FOS = 19.186



11 of 30
J. Pellmer
602-0200
14-Nov-97

12 of 30
J. Pellwer
602-0200
14-Nov-97

XSTABL File: POND1 11-14-97 15:22

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*          X S T A B L                  *
*                                       *
*     Slope Stability Analysis          *
*          using the                    *
*        Method of Slices               *
*                                       *
*     Copyright (C) 1992 Ä 96           *
*  Interactive Software Designs, Inc.   *
*     Moscow, ID 83843, U.S.A.          *
*                                       *
*      All Rights Reserved              *
*                                       *
* Ver. 5.200              96 Ä 1216     *
*****************************************
```

Problem Description : riassic park evap pond, static

SEGMENT BOUNDARY COORDINATES

---

12 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	49.0	53.0	103.0	35.0	1
2	103.0	35.0	117.0	35.0	1
3	117.0	35.0	132.0	40.0	1
4	132.0	40.0	170.0	42.0	1
5	170.0	42.0	192.0	53.0	1
6	192.0	53.0	207.0	53.0	1
7	207.0	53.0	229.0	42.0	1
8	229.0	42.0	267.0	40.0	1
9	267.0	40.0	282.0	35.0	1
10	282.0	35.0	296.0	35.0	1
11	296.0	35.0	350.0	53.0	1
12	350.0	53.0	374.0	53.0	1

12 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	49.0	50.0	103.0	32.0	2

2	103.0	32.0	117.0	32.0	2
3	117.0	32.0	132.0	37.0	2
4	132.0	37.0	170.0	39.0	2
5	170.0	39.0	192.0	50.0	2
6	192.0	50.0	207.0	50.0	2
7	207.0	50.0	229.0	39.0	2
8	229.0	39.0	267.0	37.0	2
9	267.0	37.0	282.0	32.0	2
10	282.0	32.0	296.0	32.0	2
11	296.0	32.0	350.0	50.0	2
12	350.0	50.0	374.0	50.0	2

ISOTROPIC Soil Parameters

---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Constant (psf)	Water Surface No.
1	110.0	110.0	5000.0	.00	.000	.0	0
2	110.0	110.0	5000.0	.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

400 trial surfaces will be generated and analyzed.

20 Surfaces initiate from each of 20 points equally spaced along the ground surface between x = 55.0 ft
and x = 150.0 ft

Each surface terminates between x = 170.0 ft
and x = 230.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

5.0 ft line segments define each trial failure surface.

---

14 of 30
J. Peterson
602-0200
14-Nov-97

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

***** SIMPLIFIED BISHOP METHOD *****

The most critical circular failure surface is specified by 26 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	110.00	35.00
2	113.54	31.47
3	117.35	28.23
4	121.40	25.30
5	125.68	22.71
6	130.15	20.47
7	134.78	18.59
8	139.55	17.09
9	144.43	15.98
10	149.37	15.25
11	154.36	14.93
12	159.36	15.00
13	164.34	15.47
14	169.26	16.34
15	174.10	17.60
16	178.83	19.24
17	183.40	21.25
18	187.81	23.62
19	192.00	26.34
20	195.97	29.38
21	199.69	32.73
22	203.12	36.36
23	206.25	40.26
24	209.06	44.39
25	211.54	48.74
26	212.29	50.35

**** Simplified BISHOP FOS = 19.186 ****

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J. Pelkey
602-0200
14-Nov-97

```
*****************************************************************
**                                                             **
** Out of the    400 surfaces generated and analyzed by XSTABL, **
**     393 surfaces were found to have MISLEADING FOS values.   **
**                                                             **
*****************************************************************
```

The following is a summary of the TEN most critical surfaces

Problem Description : riassic park evap pond, static

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	19.186	155.95	77.49	62.58	110.00	212.29	3.811E+07
2.	19.397	152.45	83.98	68.19	105.00	211.87	4.249E+07
3.	19.445	152.86	90.95	76.25	100.00	216.11	5.072E+07
4.	19.468	159.58	76.10	60.64	115.00	214.01	3.569E+07
5.	19.614	161.07	82.69	69.88	110.00	220.62	4.492E+07
6.	20.171	159.58	92.42	79.22	105.00	223.01	5.299E+07
7.	20.260	158.77	91.94	81.14	100.00	224.41	5.770E+07
8.	500.000	146.47	139.40	127.21	55.00	228.54	1.217E+08
9.	500.000	130.36	160.60	133.00	55.00	207.89	1.083E+08
10.	500.000	148.88	239.63	210.70	55.00	225.93	1.856E+08

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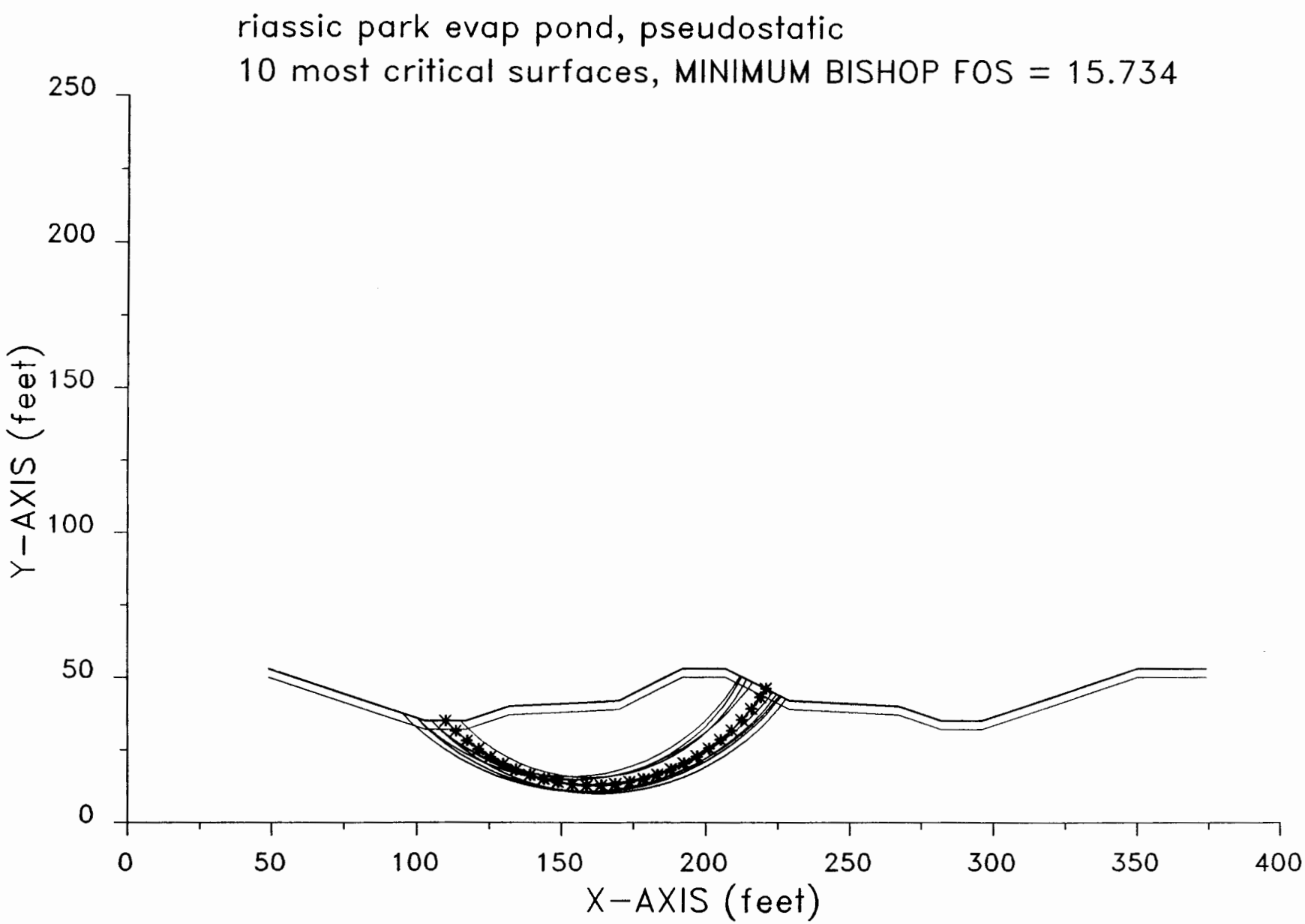

16of 30
T. Pellrey
602-0200
14-Nov. 97

17 of 30
J. Pettiner
802-0200
14-Nov-97

XSTABL File: POND1Q 11-14-97 15:23

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*          X S T A B L                  *
*                                       *
*     Slope Stability Analysis          *
*          using the                    *
*        Method of Slices               *
*                                       *
*     Copyright (C) 1992 Ä 96           *
*  Interactive Software Designs, Inc.   *
*     Moscow, ID 83843, U.S.A.          *
*                                       *
*      All Rights Reserved              *
*                                       *
* Ver. 5.200              96 Ä 1216     *
*****************************************
```

Problem Description : riassic park evap pond, pseudostatic

SEGMENT BOUNDARY COORDINATES

---

12 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	49.0	53.0	103.0	35.0	1
2	103.0	35.0	117.0	35.0	1
3	117.0	35.0	132.0	40.0	1
4	132.0	40.0	170.0	42.0	1
5	170.0	42.0	192.0	53.0	1
6	192.0	53.0	207.0	53.0	1
7	207.0	53.0	229.0	42.0	1
8	229.0	42.0	267.0	40.0	1
9	267.0	40.0	282.0	35.0	1
10	282.0	35.0	296.0	35.0	1
11	296.0	35.0	350.0	53.0	1
12	350.0	53.0	374.0	53.0	1

12 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	49.0	50.0	103.0	32.0	2

2	103.0	32.0	117.0	32.0	2
3	117.0	32.0	132.0	37.0	2
4	132.0	37.0	170.0	39.0	2
5	170.0	39.0	192.0	50.0	2
6	192.0	50.0	207.0	50.0	2
7	207.0	50.0	229.0	39.0	2
8	229.0	39.0	267.0	37.0	2
9	267.0	37.0	282.0	32.0	2
10	282.0	32.0	296.0	32.0	2
11	296.0	32.0	350.0	50.0	2
12	350.0	50.0	374.0	50.0	2

ISOTROPIC Soil Parameters
---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	5000.0	.00	.000	.0	0
2	110.0	110.0	5000.0	.00	.000	.0	0

A horizontal earthquake loading coefficient
of .040 has been assigned

A vertical earthquake loading coefficient
of .000 has been assigned

A critical failure surface searching method, using a random
technique for generating CIRCULAR surfaces has been specified.

400 trial surfaces will be generated and analyzed.

20 Surfaces initiate from each of 20 points equally spaced
along the ground surface between x = 55.0 ft
and x = 150.0 ft

Each surface terminates between x = 170.0 ft
and x = 230.0 ft

Unless further limitations were imposed, the minimum elevation

at which a surface extends is y = .0 ft

5.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED BISHOP METHOD * * * * *

The most critical circular failure surface is specified by 27 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	110.00	35.00
2	113.54	31.47
3	117.33	28.20
4	121.33	25.21
5	125.55	22.52
6	129.94	20.13
7	134.49	18.07
8	139.18	16.33
9	143.98	14.93
10	148.87	13.89
11	153.82	13.19
12	158.81	12.85
13	163.81	12.87
14	168.80	13.24
15	173.74	13.97
16	178.62	15.05
17	183.42	16.48
18	188.09	18.25
19	192.63	20.34
20	197.01	22.76
21	201.20	25.48
22	205.19	28.50

20 of 30
J. Pelletier
602-0200
14-Nov-97

23	208.95	31.79
24	212.47	35.35
25	215.72	39.14
26	218.70	43.16
27	220.62	46.19

**** Simplified BISHOP FOS = 15.734 ****

```
*****************************************************************
**                                                             **
** Out of the   400 surfaces generated and analyzed by XSTABL, **
**     325 surfaces were found to have MISLEADING FOS values.  **
**                                                             **
*****************************************************************
```

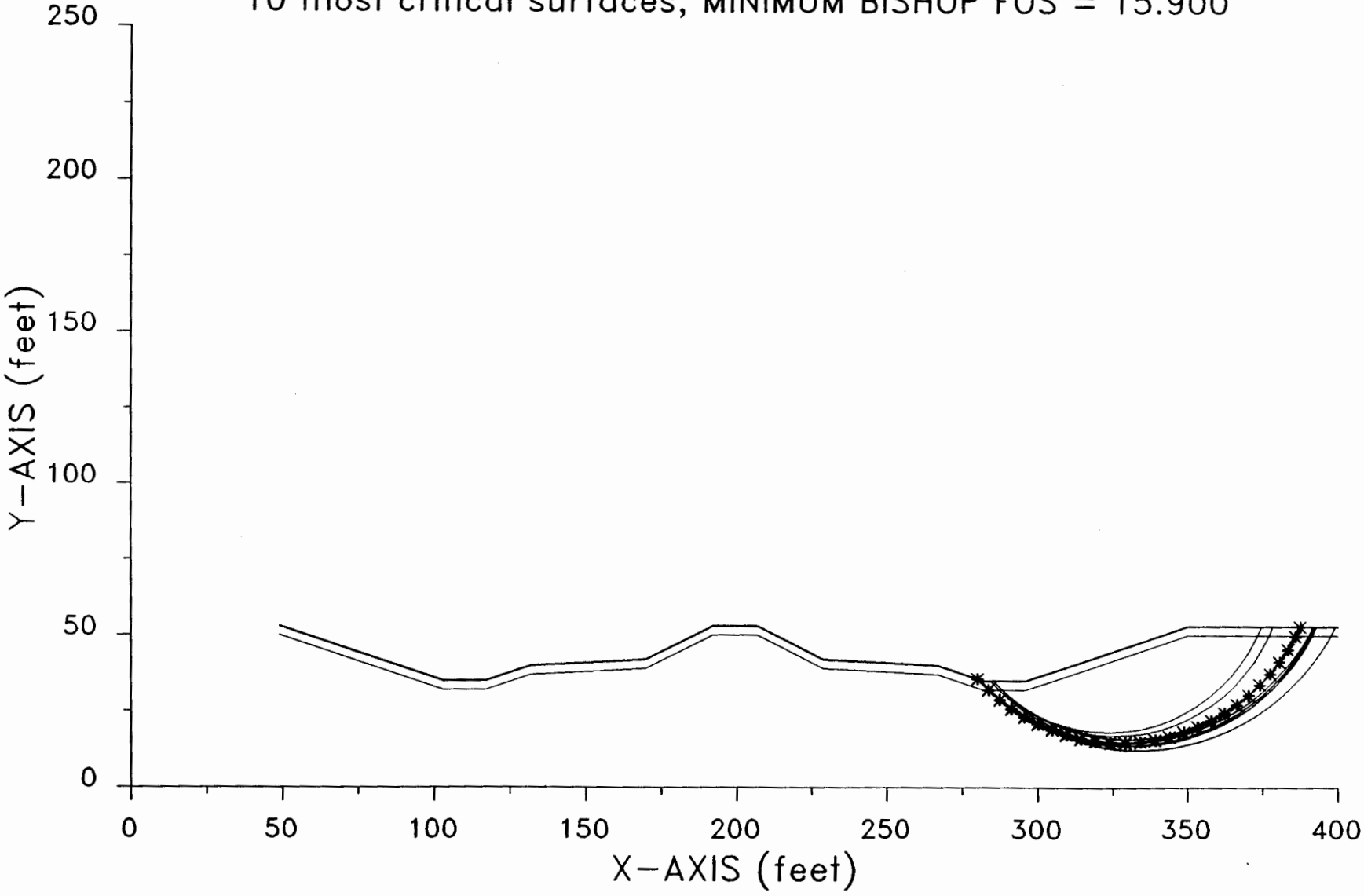
The following is a summary of the TEN most critical surfaces

Problem Description : riassic park evap pond, pseudostatic

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	15.734	161.07	82.69	69.88	110.00	220.62	4.492E+07
2.	15.814	152.86	90.95	76.25	100.00	216.11	5.072E+07
3.	15.856	158.77	91.94	81.14	100.00	224.41	5.770E+07
4.	15.870	155.95	77.49	62.58	110.00	212.29	3.811E+07
5.	15.933	159.58	92.42	79.22	105.00	223.01	5.299E+07
6.	16.010	152.45	83.98	68.19	105.00	211.87	4.249E+07
7.	16.052	159.58	76.10	60.64	115.00	214.01	3.569E+07
8.	16.085	159.76	93.24	82.75	100.00	225.89	5.934E+07
9.	16.362	157.57	96.71	86.03	95.00	225.38	6.374E+07
10.	16.402	163.11	90.22	80.16	105.00	227.66	5.612E+07

* * * END OF FILE * * *

riassic park evap pond, static
10 most critical surfaces, MINIMUM BISHOP FOS = 15.900



21 of 30
J. Pellman
602-0200
14-Nov-97

22 of 30
J. Pelrea
602-0200
14-Nov-97

XSTABL File: POND2 11-14-97 15:20

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*          X S T A B L                  *
*                                       *
*      Slope Stability Analysis         *
*            using the                  *
*         Method of Slices              *
*                                       *
*      Copyright (C) 1992 Ä 96          *
*  Interactive Software Designs, Inc.   *
*      Moscow, ID 83843, U.S.A.         *
*                                       *
*       All Rights Reserved             *
*                                       *
* Ver. 5.200              96 Ä 1216     *
*****************************************
```

Problem Description : riassic park evap pond, static

SEGMENT BOUNDARY COORDINATES

---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	49.0	53.0	103.0	35.0	1
2	103.0	35.0	117.0	35.0	1
3	117.0	35.0	132.0	40.0	1
4	132.0	40.0	170.0	42.0	1
5	170.0	42.0	192.0	53.0	1
6	192.0	53.0	207.0	53.0	1
7	207.0	53.0	229.0	42.0	1
8	229.0	42.0	267.0	40.0	1
9	267.0	40.0	282.0	35.0	1
10	282.0	35.0	296.0	35.0	1
11	296.0	35.0	350.0	53.0	1
12	350.0	53.0	374.0	53.0	1
13	374.0	53.0	400.0	53.0	1

13 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment

1	49.0	50.0	103.0	32.0	2
2	103.0	32.0	117.0	32.0	2
3	117.0	32.0	132.0	37.0	2
4	132.0	37.0	170.0	39.0	2
5	170.0	39.0	192.0	50.0	2
6	192.0	50.0	207.0	50.0	2
7	207.0	50.0	229.0	39.0	2
8	229.0	39.0	267.0	37.0	2
9	267.0	37.0	282.0	32.0	2
10	282.0	32.0	296.0	32.0	2
11	296.0	32.0	350.0	50.0	2
12	350.0	50.0	374.0	50.0	2
13	374.0	50.0	400.0	50.0	2

ISOTROPIC Soil Parameters

---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Constant (psf)	Water Surface No.
1	110.0	110.0	5000.0	.00	.000	.0	0
2	110.0	110.0	5000.0	.00	.000	.0	0

A critical failure surface searching method, using a random technique for generating CIRCULAR surfaces has been specified.

400 trial surfaces will be generated and analyzed.

20 Surfaces initiate from each of 20 points equally spaced along the ground surface between x = 280.0 ft
and x = 300.0 ft

Each surface terminates between x = 310.0 ft
and x = 399.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

5.0 ft line segments define each trial failure surface.

24 of 30
J. Reitzer
602-0200
14-Nov-97

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED BISHOP METHOD * * * * *

The most critical circular failure surface is specified by 27 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	280.00	35.67
2	283.54	32.13
3	287.33	28.88
4	291.36	25.92
5	295.61	23.28
6	300.05	20.98
7	304.65	19.02
8	309.38	17.41
9	314.23	16.18
10	319.15	15.32
11	324.13	14.83
12	329.13	14.73
13	334.12	15.01
14	339.08	15.67
15	343.97	16.71
16	348.77	18.12
17	353.44	19.89
18	357.97	22.02
19	362.32	24.48
20	366.47	27.27
21	370.39	30.37
22	374.07	33.76
23	377.48	37.42
24	380.59	41.33
25	383.40	45.46
26	385.89	49.80
27	387.40	53.00

25 of 30
J. Pelkey
602-0200
14-Nov-97

**** Simplified BISHOP FOS = 15.900 ****

```
*****************************************************************
**                                                             **
** Out of the   400 surfaces generated and analyzed by XSTABL, **
**     281 surfaces were found to have MISLEADING FOS values.  **
**                                                             **
*****************************************************************
```

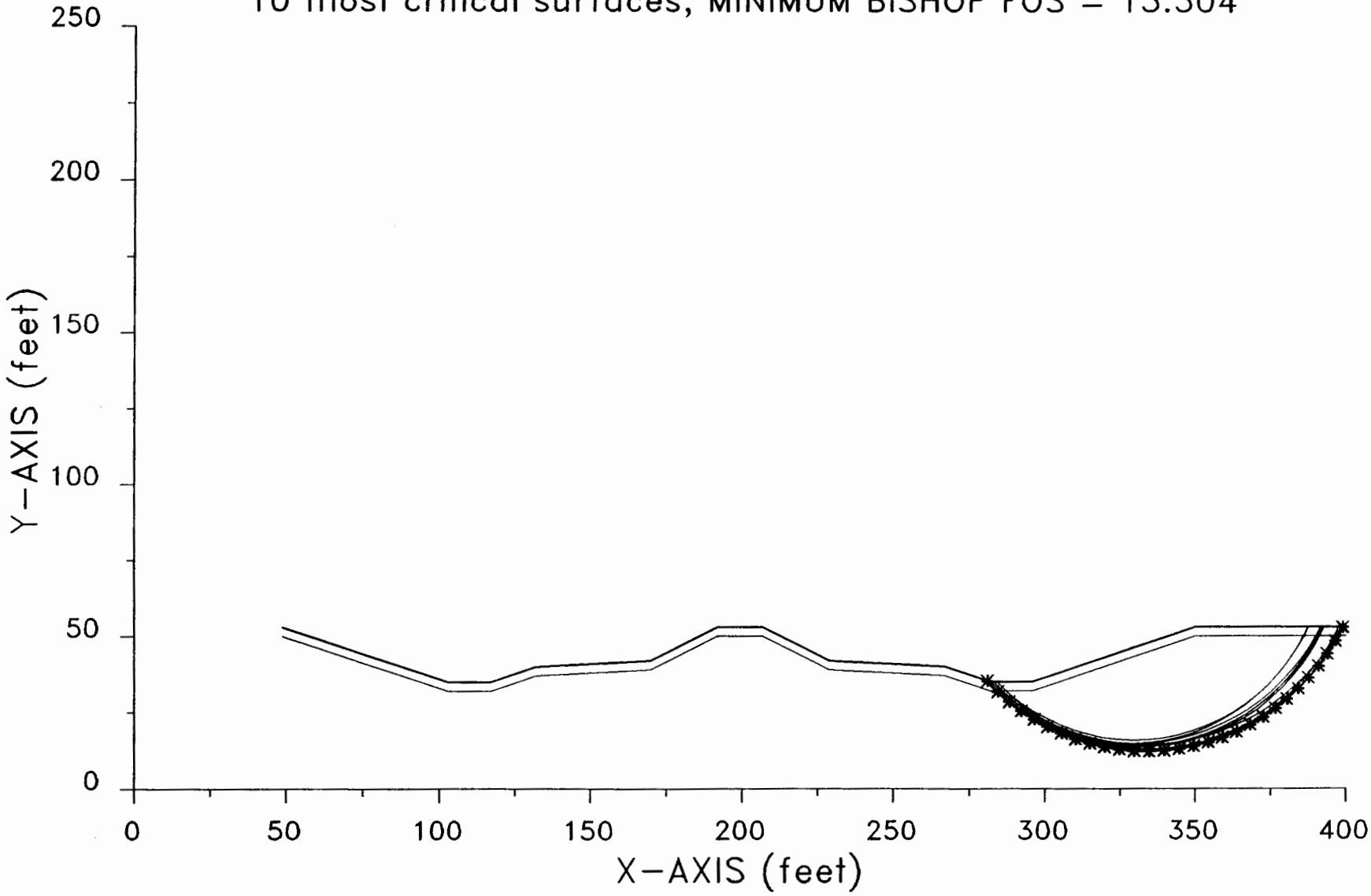
The following is a summary of the TEN most critical surfaces

Problem Description : riassic park evap pond, static

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	15.900	327.96	80.09	65.37	280.00	387.40	4.201E+07
2.	15.958	330.22	82.40	68.60	280.00	392.17	4.585E+07
3.	15.971	330.32	82.70	68.88	280.00	392.42	4.610E+07
4.	15.998	326.20	72.43	55.47	285.26	378.09	3.141E+07
5.	16.051	329.72	79.75	63.83	284.21	387.62	3.934E+07
6.	16.052	329.70	84.27	69.51	280.00	391.72	4.590E+07
7.	16.070	332.56	79.81	65.92	284.21	392.76	4.290E+07
8.	16.073	330.07	77.78	61.95	285.26	386.81	3.775E+07
9.	16.082	333.97	84.71	72.39	281.05	399.05	5.075E+07
10.	16.082	323.62	72.66	54.51	284.21	374.43	2.985E+07

*** END OF FILE ***

riassic park evap pond, pseudostatic
10 most critical surfaces, MINIMUM BISHOP FOS = 13.304



2 of 30
J. Pelkey
602-0200
14-Nov-97

XSTABL File: POND2Q 11-14-97 15:21

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****************************************
*          X S T A B L                 *
*                                      *
*     Slope Stability Analysis         *
*          using the                   *
*        Method of Slices              *
*                                      *
*     Copyright (C) 1992 Ä 96          *
*  Interactive Software Designs, Inc.  *
*     Moscow, ID 83843, U.S.A.         *
*                                      *
*      All Rights Reserved             *
*                                      *
* Ver. 5.200              96 Ä 1216    *
****************************************
```

Problem Description : riassic park evap pond, pseudostatic

SEGMENT BOUNDARY COORDINATES

---

13 SURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment
1	49.0	53.0	103.0	35.0	1
2	103.0	35.0	117.0	35.0	1
3	117.0	35.0	132.0	40.0	1
4	132.0	40.0	170.0	42.0	1
5	170.0	42.0	192.0	53.0	1
6	192.0	53.0	207.0	53.0	1
7	207.0	53.0	229.0	42.0	1
8	229.0	42.0	267.0	40.0	1
9	267.0	40.0	282.0	35.0	1
10	282.0	35.0	296.0	35.0	1
11	296.0	35.0	350.0	53.0	1
12	350.0	53.0	374.0	53.0	1
13	374.0	53.0	400.0	53.0	1

13 SUBSURFACE boundary segments

Segment No.	x-left (ft)	y-left (ft)	x-right (ft)	y-right (ft)	Soil Unit Below Segment

1	49.0	50.0	103.0	32.0	2
2	103.0	32.0	117.0	32.0	2
3	117.0	32.0	132.0	37.0	2
4	132.0	37.0	170.0	39.0	2
5	170.0	39.0	192.0	50.0	2
6	192.0	50.0	207.0	50.0	2
7	207.0	50.0	229.0	39.0	2
8	229.0	39.0	267.0	37.0	2
9	267.0	37.0	282.0	32.0	2
10	282.0	32.0	296.0	32.0	2
11	296.0	32.0	350.0	50.0	2
12	350.0	50.0	374.0	50.0	2
13	374.0	50.0	400.0	50.0	2

ISOTROPIC Soil Parameters

---

2 Soil unit(s) specified

Soil Unit No.	Unit Weight Moist (pcf)	Unit Weight Sat. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Parameter Ru	Pore Pressure Constant (psf)	Water Surface No.
1	110.0	110.0	5000.0	.00	.000	.0	0
2	110.0	110.0	5000.0	.00	.000	.0	0

A horizontal earthquake loading coefficient
of .040 has been assigned

A vertical earthquake loading coefficient
of .000 has been assigned

A critical failure surface searching method, using a random
technique for generating CIRCULAR surfaces has been specified.

400 trial surfaces will be generated and analyzed.

20 Surfaces initiate from each of 20 points equally spaced
along the ground surface between x = 280.0 ft
and x = 300.0 ft

Each surface terminates between x = 310.0 ft
and x = 399.0 ft

Unless further limitations were imposed, the minimum elevation at which a surface extends is y = .0 ft

5.0 ft line segments define each trial failure surface.

ANGULAR RESTRICTIONS

The first segment of each failure surface will be inclined within the angular range defined by :

Lower angular limit := -45.0 degrees
Upper angular limit := (slope angle - 5.0) degrees

Factors of safety have been calculated by the :

* * * * * SIMPLIFIED BISHOP METHOD * * * * *

The most critical circular failure surface is specified by 30 coordinate points

Point No.	x-surf (ft)	y-surf (ft)
1	281.05	35.32
2	284.59	31.78
3	288.36	28.50
4	292.35	25.48
5	296.54	22.75
6	300.90	20.31
7	305.43	18.18
8	310.09	16.37
9	314.86	14.89
10	319.73	13.73
11	324.66	12.92
12	329.64	12.45
13	334.64	12.32
14	339.63	12.54
15	344.60	13.10
16	349.52	14.01
17	354.36	15.25
18	359.11	16.82
19	363.73	18.72
20	368.22	20.93

21	372.54	23.44
22	376.67	26.25
23	380.61	29.34
24	384.32	32.69
25	387.79	36.29
26	391.00	40.12
27	393.95	44.16
28	396.60	48.40
29	398.96	52.81
30	399.05	53.00

**** Simplified BISHOP FOS = 13.304 ****

```
*****************************************************************
**                                                             **
** Out of the    400 surfaces generated and analyzed by XSTABL, **
**     239 surfaces were found to have MISLEADING FOS values.   **
**                                                             **
*****************************************************************
```

The following is a summary of the TEN most critical surfaces

Problem Description : riassic park evap pond, pseudostatic

	FOS (BISHOP)	Circle Center x-coord (ft)	Circle Center y-coord (ft)	Radius (ft)	Initial x-coord (ft)	Terminal x-coord (ft)	Resisting Moment (ft-lb)
1.	13.304	333.97	84.71	72.39	281.05	399.05	5.075E+07
2.	13.370	334.90	83.23	70.73	283.16	398.79	4.875E+07
3.	13.371	330.22	82.40	68.60	280.00	392.17	4.585E+07
4.	13.375	330.32	82.70	68.88	280.00	392.42	4.610E+07
5.	13.437	327.96	80.09	65.37	280.00	387.40	4.201E+07
6.	13.454	334.85	82.35	69.32	284.21	397.65	4.691E+07
7.	13.455	332.56	79.81	65.92	284.21	392.76	4.290E+07
8.	13.459	329.70	84.27	69.51	280.00	391.72	4.590E+07
9.	13.475	333.42	88.78	74.33	282.11	398.55	5.056E+07
10.	13.568	329.72	79.75	63.83	284.21	387.62	3.934E+07

*** END OF FILE ***

E-8

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602 - 0200

Calculation Title: Prepared Subgrade Settlement

	Name	Date
Prepared By:	P. Pellicer	12-Nov-97
Checked By:	J. Pellicer	13-Nov-97
Reviewed By:	P. Corser	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Prepared Subgrade Settlement.

Objective: Determine the amount of settlement of the 6 in prepared subgrade.

Assumptions:
- $\gamma_{waste} = 110$ pcf
- Waste Thickness$_{max}$ = 140 ft.
- $C = 1100$ psf for recompacted prepared subgrade (conservative)
- σ_p' for prepared subgrade is due to compactive effort during placement and is greater than the actual overburden load from the protective soil.
- $\gamma_{protective\ soil} = 90$ pcf

Calculations:

Primary Consolidation:

$$S_c = C_{r\epsilon} H_o \log \frac{\sigma_p'}{\sigma_{v_o}} + C_{c\epsilon} H_o \log \frac{\sigma_{v_o}' + \Delta\sigma_v}{\sigma_p'}$$

$$C_{r\epsilon} = \frac{C_r}{1+e_o}$$

$$C_{c\epsilon} = \frac{C_c}{1+e_o}$$

H_o = Thickness of Prepared subgrade = 6"

σ_{v_o} = initial overburden pressure = $\underbrace{(2\text{ ft})(90\text{ pcf})}_{\text{protective soil}} = 180$ psf

$\Delta\sigma_v$ = change in overburden pressure = $\underbrace{(140\text{ ft})(110\text{ pcf})}_{\text{waste}} = 15{,}400$ psf

σ_p' = Maximum past pressure.

estimate σ_p' using C/P ratios (from figure 18.4 p117 Terzaghi and Peck 1967) (see pg 4)

Using the Avg PI = 28 (see pg 3) enter the C/P vs. PI plot (pg 4) ⇒ $C/P = 0.22$ using $C = 1100$ psf (conservative) ⇒ $P = 5000$ psf $= \sigma_p'$

e_o = initial void ratio = $\frac{G_s \gamma_w}{\gamma_d} - 1$

assume $G_s = 2.7$
$\gamma_w = 62.4$ pcf
Soil is to be placed at 90% of Modified proctor.

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Project Name: Triessic Park
Project Number: 602-0200 Sheet: 2 Of 6
Prepared By: P. Pellitzer Date: Nov 12, 1997
Checked By: J. Pellitzer Date: 13-Nov-97

Modified proctor Max. Dry density = 127 pcf (see pg 6)

$\gamma_d = (0.9)(127 pcf) = 114.3$ pcf say 114

$e_o = \frac{(2.7)(62.4)}{114} - 1 = 0.478$ ✓

$C_c = 0.007(LL-7)$ (Empirical eq. p 341 Holz + Kovacs)
(see pg 5)

$LL_{Avg} = 42$ (see pg 3)

$C_c = 0.007(42-7) = 0.245$ ✓

Assume $C_r = 0.05 C_c = 0.0123$ ✓ (see pg 5)

$C_{r\epsilon} = \frac{0.0123}{1+0.478} = 0.0083$ ✓

$C_{c\epsilon} = \frac{0.245}{1+0.478} = 0.1658$ ✓

$S_c = (0.0083)(6 in) \log \frac{5000 psf}{180 psf} + (0.1658)(6 in) \log \frac{180 psf + 15,400 psf}{5000 psf}$

$S_c = 0.072 in + .491 in = \underline{\underline{0.56 in}}$ ✓

Since primary Consolidation is so small secondary Consolidation should be considered negligible. ✓

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			CL
2	17	12.1		54	40		27	73			CH
3	7.5	9.7		36	20		2	98			CL
4	14	8.6		39	27		13	87			CL
4	~~20~~	~~7.0~~					~~1~~	~~99~~	Caliche not applicable		
5	18	12.3		46	32		35	65			CL
			Avg =	42.4	27.6			83			

Project Name: Gandy - Triassic Park Waste Disposal Facility		
Project Location: New Mexico		
Project No.: 790-12101	Technician: DCP	Date: 9-10-97

TerraMatrix
Engineering & Materials Testing Services
50200 Moffat Avenue
Steamboat Springs, Colorado 80487

SUMMARY OF LABORATORY TEST RESULTS

12-Nov-97
GW2-0200
pmd

3 of 6

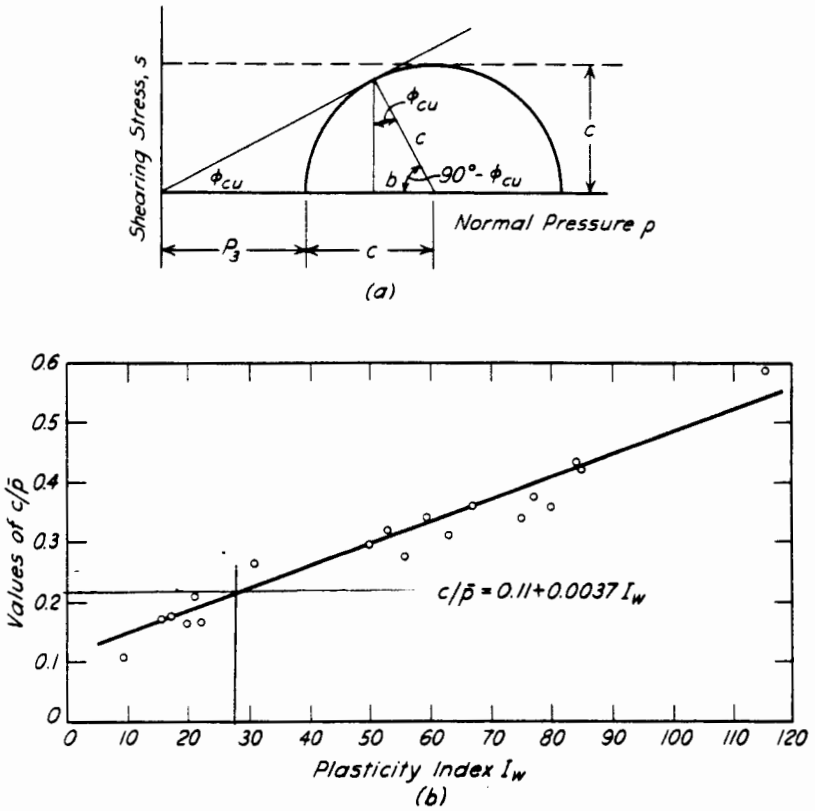
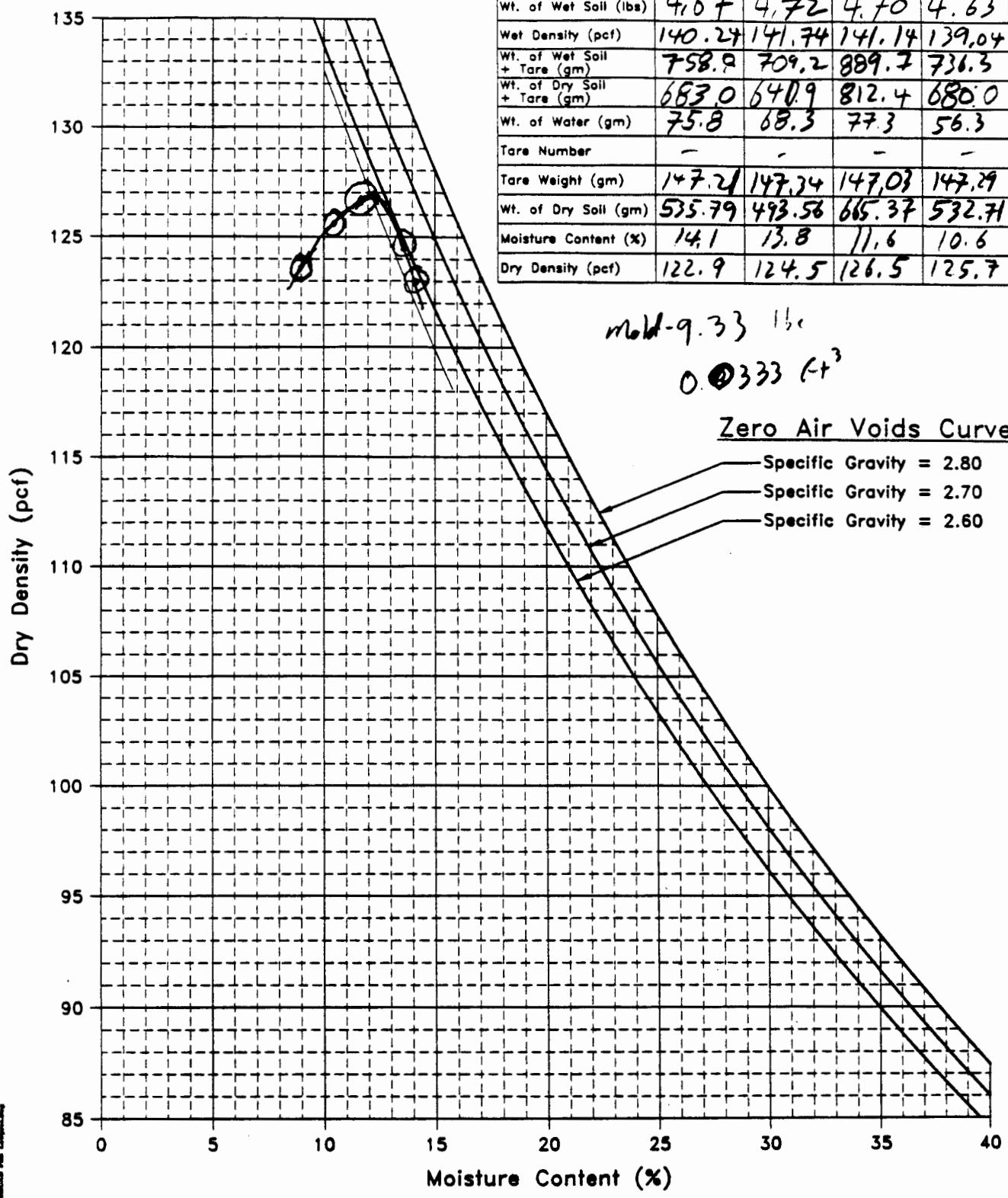


Fig. 18.4. (*a*) Mohr rupture diagram for calculating relation between *c* and $\bar{p}$, for consolidated-undrained test. (*b*) Statistical relation between $c/\bar{p}$ ratio and plasticity index (after Skempton 1957).

tivity. Some natural clay deposits, moreover, consist of a mixture of particles of fairly uniform fine sand and clay. While sedimentation proceeds, the simultaneous deposition of the flaky constituents of the finest fraction and of the equidimensional sand grains interferes with the rolling of the sand grains into stable arrangements. Therefore, if the sand grains touch each other, their configuration may be as metastable as that of true quicksands. However, the interstices between the sand grains are occupied by the clay-size materials which acquire, as a result of such physico-chemical processes as thixotropy and syneresis, appreciable strength as sedimentation proceeds. As a consequence, although the clay is sensitive, it does not exhibit the properties of true quicksands. In many respects, the states of transition from loose sand

Mod 12 Nov 97 602 zero pmp 6 of 6

~~Water (ml)~~ #7	1	2	3	4	5
Wt. of Wet Soil + Mold (lbs)	14.00	14.05	14.03	13.96	13.81
Wt. of Wet Soil (lbs)	4.67	4.72	4.70	4.63	4.48
Wet Density (pcf)	140.24	141.74	141.14	139.04	134.53
Wt. of Wet Soil + Tare (gm)	758.9	709.2	889.7	736.3	704.8
Wt. of Dry Soil + Tare (gm)	683.0	640.9	812.4	680.0	659.4
Wt. of Water (gm)	75.8	68.3	77.3	56.3	45.4
Tare Number	–	–	–	–	–
Tare Weight (gm)	147.21	147.34	147.03	147.29	147.0
Wt. of Dry Soil (gm)	535.79	493.56	665.37	532.71	512.40
Moisture Content (%)	14.1	13.8	11.6	10.6	8.9
Dry Density (pcf)	122.9	124.5	126.5	125.7	123.6



Project Name: Gandy			TerraMatrix MONTGOMERY WATSON Mining Group
Sample Location:		Sample No.: Composite	MOISTURE-DENSITY RELATIONSHIP OF SOIL
Sample Source:		Technician: DCP	
Sample Description: Red Clay			
Max. Dry Density (pcf): 127	Opt. Moisture (%): 12.2	Procedure: D1557	
Liquid Limit (%):	Plasticity Index (%):	Natural Moisture (%):	Project No.:
% + 3/4 in.:	% – No. 4:	% – No. 200:	Date: 9-16-97

E-9

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Subgrade Settlement

	Name	Date
Prepared By:	P. Pellicer	12-Nov-97
Checked By:	J. Pellicer	12-Nov-97
Reviewed By:	P. Gore	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

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Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of 9
Prepared By: P. Pellicer Date: Nov 12, 1997
Checked By: J. Pellicer Date: 12-Nov-97

Subgrade Settlement.

Objective: Determine the Maximum amount of potential Settlement for the subgrade. To be used for determining Induced stresses in the liner geomembrane.

Assumptions:
- Simplified Geometry, No side slopes, uniform waste thickness (associated w/ deepest part of land fill 140 ft)
- Unit weight of waste = 110 pcf
- Waste behaves as a flexible mat.
- foundation Soil is of infinite depth (conservative).

Calculations: Divide cell foot print into rectangles with a Common Corner "O" at the deepest section of the land fill. (see pg 3)

Use Elastic Settlement Theory. (pp. 169-172 - Fang 1991) (see pg 4-7) $S_i = C_s q B \left(\frac{1-\nu^2}{E_u}\right)$

Estimate physical Parameters of Foundation Soil Lower Dockum ⇒ $\nu = 0.3$, $E_u = 72{,}000$ ksf (see pg 7-9) (conservative estimates.)

$q = (110\,pcf)(140\,ft) = 15400\,psf.$

$\frac{1-\nu^2}{E_u} = \frac{1-(.3)^2}{72{,}000{,}000\,psf} = 1.264 \times 10^{-8}\,\frac{ft^2}{lb}$

$q \times \frac{1-\nu^2}{E_u} = 1.946 \times 10^{-4}$

Area	L (ft)	B (ft)	L/B	C_s*	S_i (ft)
A	2143	610	3.5	.9	.107
B	2143	422	5.1	1.05	.086
C	999	906	1.1	.56	.099
D	1421	626	2.3	.79	.096
E	626	610	1.0	.56	.066
F	906	422	2.1	.76	.062

* interpolated from table 5.3 (see pg 6)

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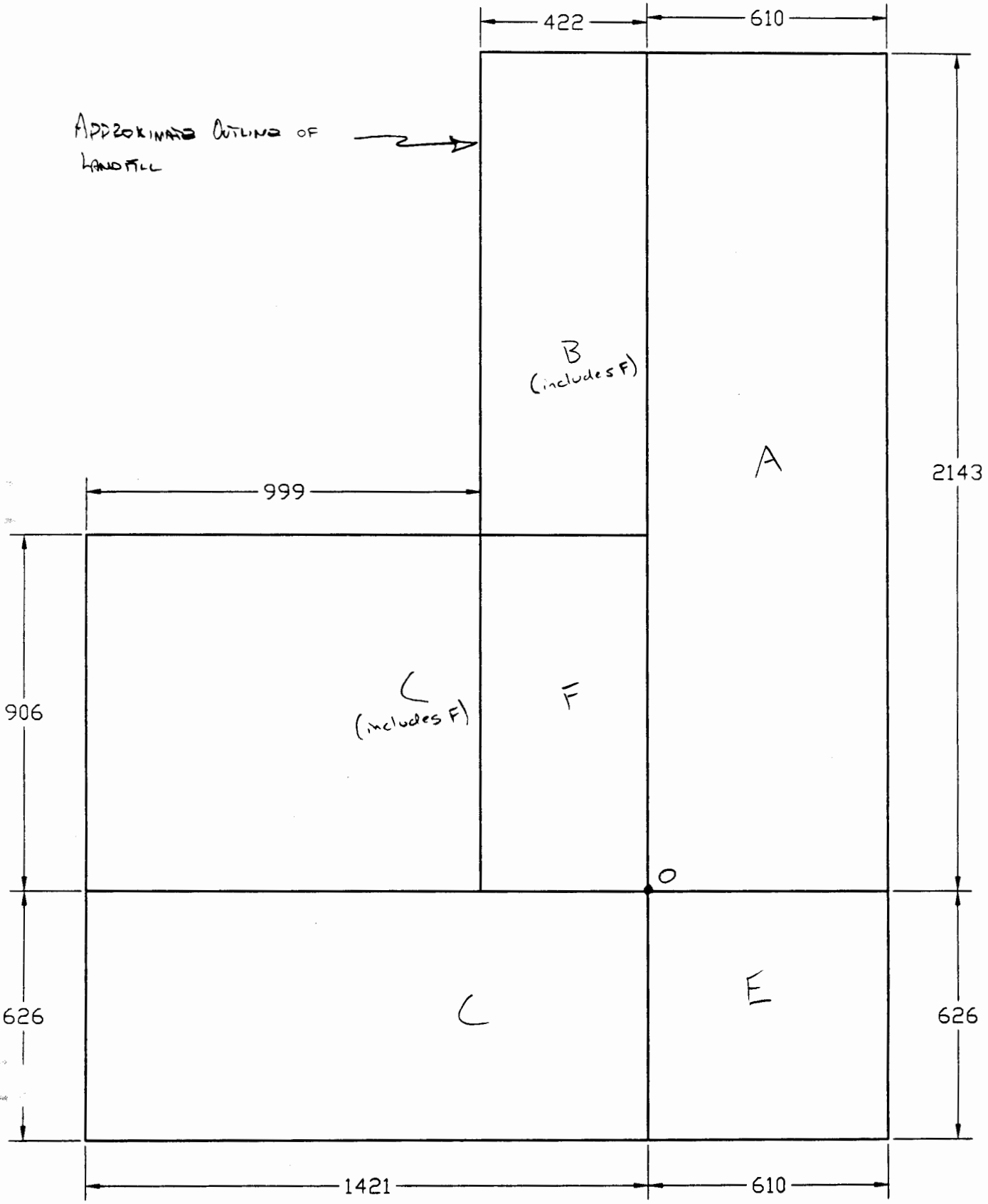
Phone 970.879.6260 Fax 970.879.9048

$\Sigma S_i = 0.39$ ft $\Rightarrow$ Say 5"

Conclusions: The assumptions used in this calculation are extremely conservative and were used to achieve a worst case settlement for induced stress in the Geomembrane. Actual subgrade settlement will not be this large for two reasons

- The waste thickness is less than what was assumed exspecially on the side slopes.
- The base of the cell has already been loaded by overburden that will be excavated out and therefore will not behave in a fully elastic manner, and the net change of effective stress in the foundation soils is minimal.

NOTE: A specific calculation was not completed for the evaporation pond. The estimated settlement for the landfill is not considered harmful. The evaporation is smaller than the landfill; therefore, the subgrade will settle less. Therefore subgrade settlement in the evaporation pond will not be a problem.


422
610
APPROXIMATE OUTLINE OF LANDFILL
B
(includes F)
A
2143
999
906
C
(includes F)
F
O
626
C
E
626
1421
610

4 of 9
6V2-0200
PMP
12-NOV-92

FOUNDATION ENGINEERING HANDBOOK

Second Edition

Edited by

HSAI-YANG FANG Ph.D.

1991

Professor of Civil Engineering and Director, Geotechnical Engineering Division, Fritz Engineering Laboratory, Lehigh University

VNR VAN NOSTRAND REINHOLD
New York

and less than at the edges (Fig. 5.2b). Contact stress distributions are important for the design of foundations and footings (Bowles, 1975a). For the structural design of footings, a linear contact stress distribution is often assumed although this is obviously incorrect from a soil mechanics point of view.

5.4.2 Immediate Settlement of Cohesive Foundations

For soils that are predominately cohesive, linear theory of elasticity is used to estimate the magnitude of initial settlements. Soil profiles are typically simplified, although some solutions involving multiple layer theory are available. Homogeneity and isotropy are implicitly assumed so that only two elastic parameters, the modulus of elasticity E and Poisson's ratio ν are needed. This approach works reasonably well on clay soils if the applied stress level is low; that is, if the factor of safety is large and we do not have plastic yielding in the foundation. If foundation yielding is likely to occur, another approach is recommended, which will be described below.

In many foundations on cohesive soils, the immediate or distortion settlement is a relatively small part of the total vertical movement and, thus, rough estimates are acceptable. A discussion of relative importance of immediate and consolidation settlement will be given later in this section.

A Distributed Load at or Near the Surface of a Deep Layer When the foundation problem can be approximated as one or more uniformly distributed loads acting on circular or rectangular areas near the surface of a relatively deep stratum, the vertical settlement can be estimated by

$$s_i = C_s q B \left(\frac{1 - \nu^2}{E_u} \right) \tag{5.2}$$

where

s_i = settlement of a point on the surface
C_s = shape and rigidity factor
q = magnitude of the uniformly distributed load
B = characteristic dimension of the loaded area as shown in Figure 5.3
E_u = Young's modulus (undrained)
ν = Poisson's ratio

The coefficient C_s accounts for the shape and rigidity of the loaded area and for the position of the point for which the settlement is being calculated. Values of C_s are given in Table 5.3.

EXAMPLE 5.1

A structure is to be supported on a stiff reinforced concrete mat foundation whose dimensions are 20 m by 50 m. The load on the mat is to be uniformly distributed; its magnitude is 65 kPa. The mat rests on a deep saturated deposit of saturated clay for which the average undrained Young's modulus is approximately 40 MPa. Estimate the immediate settlement at the center and corner of the mat.

Solution

Since the mat is stiff, use the rigid factors from Table 5.3a. With $L/B = 50/20 = 2.5$, the shape factors for both the center and corner are determined by interpolation to be $C_s = 1.20$. Thus from Equation 5.2 the immediate surface settlement at both the center and corner of the mat is $s_i = 1.20(65)(20)\,[(1 - 0.5^2)]$ divided by $[(40 \times 10^3)] = 0.029$ m = 29 mm.

For comparison, the shape factors for a flexible mat would be determined by interpolation to be

At the center $C_s = 1.63$
At the corner $C_s = 0.81$

Thus, the immediate surface settlements are

At the center $s_i = 40$ mm
At the corner $s_i = 20$ mm

A mat foundation is usually neither completely flexible nor completely rigid, depending on its size and thickness and how heavily reinforced it is. If it is large, the distribution of contact pressure may be nearly uniform over its center portion. At the corners and edges, however, the rigidity of the mat may be significant (owing to its thickness and the amount of reinforcing), and settlements are likely to be less than predicted. In a saturated clay, because of settlement in the middle portion of the foundation, some heave may occur in the outer portions because of undrained (constant volume) loading and shear.

Effect of Layered Systems In actuality, most soil profiles are not homogeneous and deep. If the thickness of the top layer is large relative to the dimensions of the loaded area, immediate surface settlement may be calculated as if the soil were a homogeneous layer of infinite depth. However, if the upper stratum is relatively thin, the effect of layering must be taken into consideration. This is likely to be especially important when a soft compressible stratum is underlain by rock or very hard or dense soils. This special case may be approximated by a layer of elastic material of finite thickness underlain by a rigid base. Settlements for this case may be determined by Equation 5.2, but using a shape factor C_s that accounts for the presence of the rigid base. Values for these shape factors C_s are tabulated in Table 5.3b for the settlement under the center of a rigid circular area and under the corner of flexible rectangular areas. These shape factors depend upon both the shape of the loaded area and the thickness of the compressible stratum relative to the width of the loaded area, as illustrated in Figure 5.3.

Examination of Table 5.3 indicates the importance of the presence of a rigid boundary. When $H/B = 0.5$, the reduction in surface displacements of the center of the loaded area relative to that for the halfspace is greater than 50 percent.

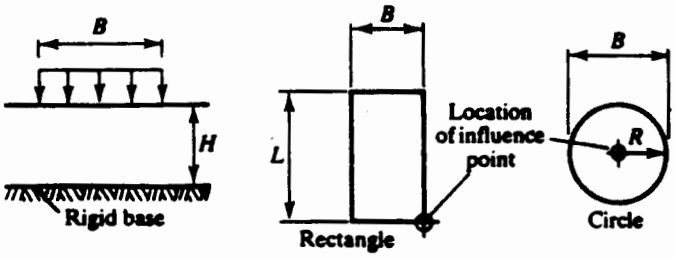


Fig. 5.3 Notation for loaded areas, shown in plan view. (*U.S. Navy, 1982.*)

EXAMPLE 5.2

Compute the immediate settlement at the center of the uniformly loaded (flexible) area measuring 6 m × 6 m. The applied surface stress is 200 kPa and the depth to firm bottom is 3 m. Assume the undrained elastic modulus is 10 000 kPa and $\nu = 0.5$.

Solution

Use the C_s values for the corners of four equally sided rectangles 3 m × 3 m. In this case, $H/B = 1$, $L/B = 1$, and,

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TABLE 5.3 SHAPE AND RIGIDITY FACTORS, C_s, FOR CALCULATING SETTLEMENTS OF POINTS ON LOADED AREAS AT THE SURFACE OF AN ELASTIC HALFSPACE[a].

a. Infinite Depth

Shape and Rigidity	*Center*	*Corner*	*Edge/Middle of Long Side*	*Average*
Circle (flexible)	1.00		0.64	0.85
Circle (rigid)	0.79		0.79	0.79
Square (flexible)	1.12	0.56	0.76	0.95
Square (rigid)	0.82	0.82	0.82	0.82
Rectangle:				
(flexible)				
length/width				
2	1.53	0.76	1.12	1.30
5	2.10	1.05	1.68	1.82
10	2.56	1.28	2.10	2.24
Rectangle:				
(rigid)				
length/width				
2	1.12	1.12	1.12	1.12
5	1.6	1.6	1.6	1.6
10	2.0	2.0	2.0	2.0

b. Limited Depth Over a Rigid Base

H/B	*Center of Rigid Circular Area Diameter = B*	*Corner of Flexible Rectangular Area*				
		L/B = 1	*L/B = 2*	*L/B = 5*	*L/B = 10*	*L/B = ∞ (strip)*
			ν = 0.50			
0	0.00	0.00	0.00	0.00	0.00	0.00
0.5	0.14	0.06	0.04	0.04	0.04	0.04
1.0	0.35	0.15	0.12	0.10	0.10	0.10
1.5	0.48	0.23	0.22	0.18	0.18	0.18
2.0	0.54	0.29	0.29	0.27	0.26	0.26
3.0	0.62	0.36	0.40	0.39	0.38	0.37
5.0	0.69	0.44	0.52	0.55	0.54	0.52
10.0	0.74	0.48	0.64	0.76	0.77	0.73
			ν = 0.33			
0	0.00	0.00	0.00	0.00	0.00	0.00
0.5	0.20	0.09	0.08	0.08	0.08	0.08
1.0	0.40	0.19	0.18	0.16	0.16	0.16
1.5	0.51	0.27	0.28	0.25	0.25	0.25
2.0	0.57	0.32	0.34	0.34	0.34	0.34
3.0	0.64	0.38	0.44	0.46	0.45	0.45
5.0	0.70	0.46	0.56	0.60	0.61	0.61
10.0	0.74	0.49	0.66	0.80	0.82	0.81

[a] After U.S. Navy (1982).

from Table 5.3, $C_s = 0.15$:

$$S_i = 0.15(200)(3)\left(\frac{1-0.5^2}{10\,000}\right) \times 4 = 27 \text{ mm}$$

If the soil profile consists of a relatively thin stiffer layer underlain by a less stiff layer of greater depth, then the stresses from the surface load must be distributed to the top of the less compressible layer. Use the stress distribution techniques discussed in Section 5.6.

Analytical and/or numerical methods for the determination of displacements in multilayered systems are available for cases other than those in Table 5.3 (see Poulos and Davis, 1974). A number of multilayer solutions are now available in computer codes. Except for pavements and special foundations, however, the use of multilayered computer analyses is generally not justified, because the material parameters are not accurately determined, the boundary conditions and interface conditions between the strata are not that well known, and, finally, approximations may be required to fit the geometry of the real problem to that for which the solution is available. In many situations an approximate analysis of the intermediate settlement is sufficient, as illustrated in the following two examples.

EXAMPLE 5.3

The mat foundation of Example 5.1, 20 m × 50 m supporting a uniform normal load of 65 kPa, is founded on a soil profile shown in Figure 5.4. The profile indicates a layer of stiff clay over a more compressible layer that is in turn underlain by shale. Assume these conditions are representative of the entire site. Estimate the immediate surface settlement at the center of the mat.

Solution

Assume the shale acts as a rigid base and above it a *single* stratum of thickness $H = 15$ m. Thus,

$$\frac{H}{B} = \frac{15}{10} = 1.5 \quad \frac{L}{B} = \frac{25}{10} = 2.5$$

The shape factor C_s obtained from Table 5.3b by linear

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Professor Emeritus of Rutgers University
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USA

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4-24. Modulus of Elasticity of Rocks

Knowledge about the modulus of elasticity of rocks is an important factor in evaluating rock deformation under various loading conditions. It is also necessary in studies of seismics in rocks. The modulus of elasticity of rock varies from one geologic region to another because of the existence of various types of rock formation. For this reason alone, different values of the modules of elasticity of different rocks can be anticipated. Hence, there exists a need for the determination of the numerical values of the modulus of elasticity of rocks.

Generally, the modulus of elasticity of rock is affected by rock type, porosity, particle size, and water content. The variation in the values of the modulus of elasticity is more pronounced in clayey shales than in sandstone, for example.

The modulus of elasticity is greater perpendicular to stratification and fissure than that determined parallel to the bedding planes and fissures.

The various modes of genesis or formation of rocks also affect the magnitude of the modulus of elasticity.

The reason for high modulus of elasticity values of some rocks probably lies in their structures themselves, as well as in their mineral chemical compounds. The known values of the modulus of elasticity of various rocks may suggest that eruptive igneous rocks of basic nature—like basalts, for example—have a larger modulus value than acidic rocks—such as granite, for example.

Technically, the modulus of elasticity of a rock can be increased considerably by means of rock grouting.

Elasticity constants E and μ of rocks are determined by:

1. static tests
2. longitudinal resonance tests
3. electrical resistance (strain gauge) tests
4. ultrasonic velocity measurements on laboratory rock test specimens, and
5. dynamic tests, in which velocities of propagated energy waves in situ are measured. Measurements of the primary wave (P-wave) and secondary wave (S-wave) velocities thus afford the indirect determination of E and μ of geologic materials in situ.

TABLE 4-13
Elasticity Constants E and μ of Some Rocks

Rock	Young's modulus of elasticity E		Poisson's ratio	References
	kg/cm²	N/m²	μ	
	Multiply by 10^6	Multiply by 10^{10}	Average values	
1	2	3	4	5
Igneous rocks				
Basalt	2.0–10.0	1.96–9.81	0.14–0.25	37, 63, 68, 107
		4.85–11.15	0.22–0.25	18
Diabase	3.0–9.0	2.94–8.83	0.125–0.25	42, 63
		–	0.333	68
		2.20–11.40	0.103–0.184	68
		8.00–10.75	–	18
Gabbro	6.0–11.0	5.88–10.78	0.125–0.25	37, 63, 68
		5.84–8.71	0.154–0.48	18
Granite	2.6–7.0	2.55–6.86	0.125–0.25	37, 63
		–	0.155–0.338	18
		–	0.150–0.240	112, 68
		2.13–7.05	–	18
Syenite	6.0–8.0	5.88–7.85	0.25	37
		6.29–8.63	0.17–0.319	18
			0.15–0.34	68
Sedimentary rocks				
Dolomite	2.0–8.4	1.96–8.24	0.08–0.20	37, 63
		7.10–9.30	0.08–0.20	68, 107
		–	0.32–0.37	18
Limestone	1.0–8.0	0.98–7.85	0.10–0.20	63, 107
		–	0.16–0.23	68
		–	0.33 –	63
		0.80–2.10	0.14–0.30	18
Sandstone	0.5–8.6	0.49–8.43	0.066–0.125	112
		–	0.230–0.300	56
		–	0.17	63, 68
			0.07	112
	163,848,000 psf.	163,970,000	0.62	56
Shale (clay)	0.8–3.0	0.78–2.94	0.11–0.54	37, 68
		0.98–2.35	0.10	56
		1.20–4.40	0.23–0.30	107
		–	0.04–0.12	18
Sandstone	4.5–5.2	4.41–5.10	0.21–0.24	63

TABLE 12-3
Properties of Various Rocks as Foundation Materials

Type	Rock	Typical dry unit weight, p.c.f.	Range of modulus of elasticity, k.s.i.	Range of compressive strength, k.s.i.	Structural characteristics
Igneous:					
Intrusive (coarse grained).	Feldspar predominates, light colored:				
	Granite (abundant quartz)	168	4,000 to 7,000	10 to 25	Generally present as intrusion of great mass. May contain fracture system, closed except where weathering has proceeded downward from the surface. Deep localized weathering may occur at intersection of major fracture systems.
	Diorite (little quartz)	176	5,000 to 8,000		
	Iron, magnesium predominate, dark colored Gabbro.	180	7,000 to 12,000	15 to 30	
Extrusive (fine grained).	Feldspar predominates, light colored:				
	Rhyolite (abundant quartz)	162	5,000 to 8,000	10 to 25	Formed in sheet-like masses characterized by extensive joint system, more open in basalt than rhyolite or andesite. May contain holes, voids, layers of volcanic ash or pumice resulting from vulcanism concurrent with extrusion.
	Andesite (little quartz)	166	6,000 to 9,000		
	Iron, magnesium predominate, dark colored Basalt.	178	7,000 to 13,000	25 to 40	
	Glassy Obsidian	140	1,000 to 4,000	2 to 8	Exhibits flow structures, may be highly vesicular.
	Fragmental Tuff	100	200 to 1,000	0.2 to 1	Light and relatively porous structure formed in volcanic discharge.
Metamorphic:					
Foliated (platy) ...	Medium grained, abundant mica Schist.	167	2,000 to 5,000	5 to 15	Often intricately folded and distorted. Fracturing, softening, weathering or deep erosion occurs in zones of intense movement. Weathering produces clayey, micaceous residue.
	Fine grained, dark colored Slate	168	5,000 to 8,000	10 to 20	
Banded (imperfectly foliated).	Coarse grained, abundant quartz Gneiss.	169	4,000 to 8,000	10 to 20	Less distortion than in the highly foliated rocks. Weathered residue is gritty with resistant silica particles.
Massive	Hard and brittle:				
	Quartzite (mainly quartz)	166	6,000 to 8,000	15 to 35	Quartzite and marble may be extremely hard with only fine fracture system. Some serpentines are soft to great depths.
	Marble (mainly calcite)	168	7,000 to 10,000	12 to 30	
	Relatively soft Serpentine	158	1,000 to 5,000	1 to 10	
Sedimentary:					
Argillaceous (clay minerals predominate).	Fine grained, laminated:				
	Shale (clay size)	100 to 140	500 to 2,000	0.1 to 5	Wide variation in engineering properties between materials formed by compaction alone or with cementation. Compaction shales may soften, slake and swell on exposure. Cementation types (argillite) are not sensitive to exposure.
	Siltstone (silt size)	110 to 150	500 to 2,000	0.1 to 5	
Siliceous (silica predominates).	Medium grained Sandstone	147	1,000 to 3,000	4 to 12	Strength and permeability depends on type and degree of cementation. Fracturing, folding and jointing leads to deterioration of cementing materials.
	Coarse grained:				
	Conglomerate (rounded particles) ...	155	1,000 to 5,000	5 to 15	
	Breccia (angular fragments)	150	1,000 to 5,000	5 to 15	

72,000 ksf

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E-10

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Effect of Differential Settlement on Base Grades

	Name	Date
Prepared By:	P. Pellicer	13-Nov-97
Checked By:	J. Pellicer	13-Nov-97
Reviewed By:	P. Cobbe	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
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Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of 2
Prepared By: P. Pellicer Date: 13-Nov-1997
Checked By: J. Pellicer Date: 13-Nov-97

Effect of Differential settlement on Base Grades.

Objective: Evaluate the effect of differential settlement on the cell base grades for phase 1

Calculations:

Maximum amount of settlement = 5.56" (from Subgrade Settlement + prepared Subgrade settlement Calculations).

Maximum amount of settlement occurs at pt A. (See pg 2)
No Settlement occurs at Pt B (conservative) (see pg 2)

Distance between Pt A + B = 581'

Change in grade $= \left(\frac{-5.56''}{12''/ft}\right)(581') = -0.0008 \Rightarrow -0.08\%$

Current Minimum grade in phase 1 = 2.5%

Minimum grade in phase 1 after differential settlement
= 2.5% − 0.08% = 2.42% > 2% (Minimum recomended by EPA)

Conclusion: Even w/ extremely conservative assumptions differential settlement has a negligable effect on the base grades.

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13-NOV-97

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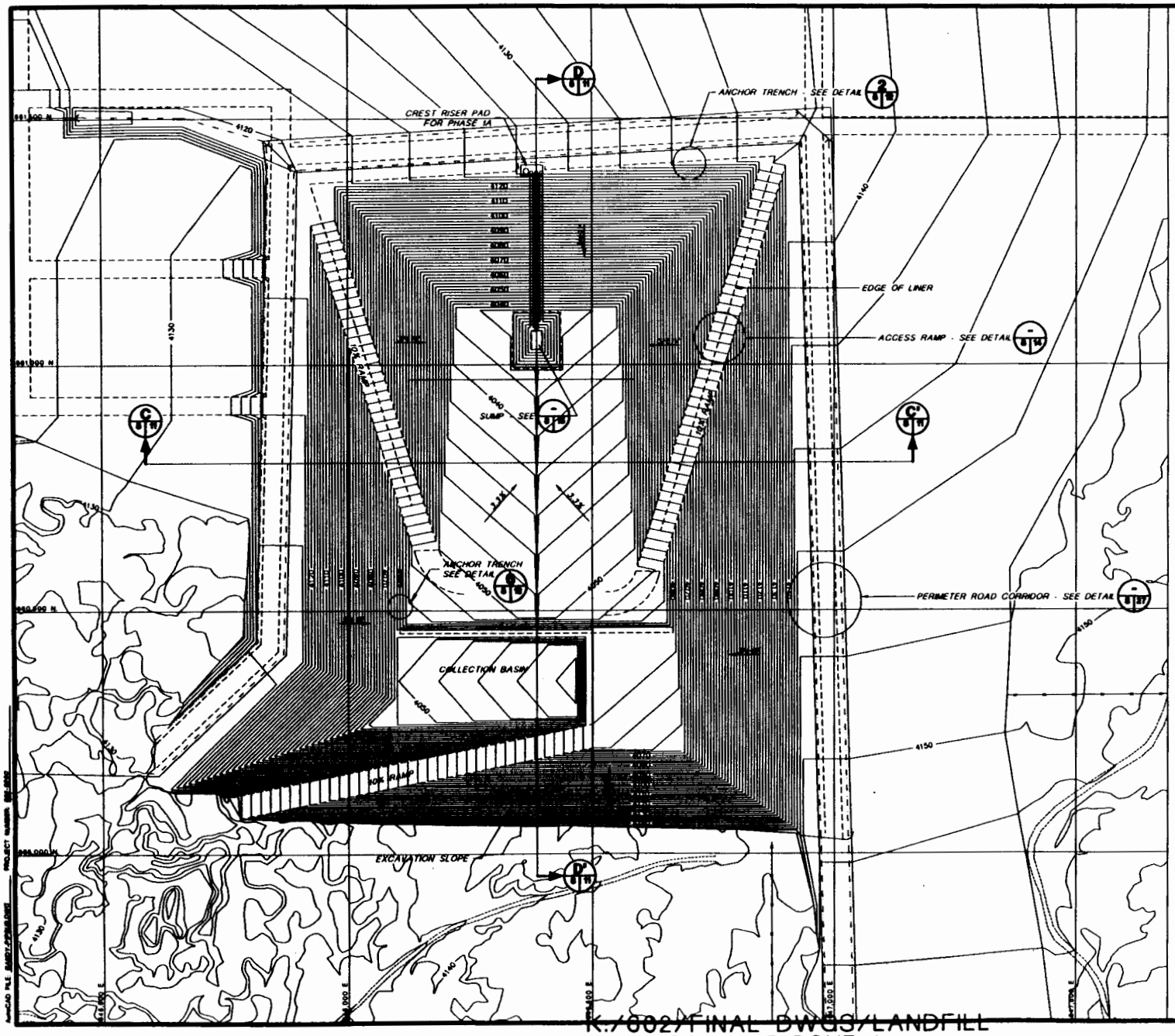

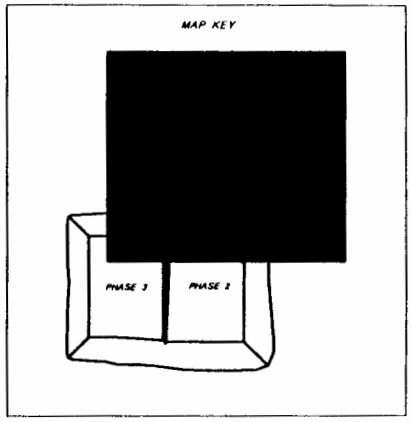

NOTES:
1. FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2 "INDEX, LEGEND AND GENERAL NOTES".
2. TOPOGRAPHY FROM AERIAL SURVEYS PERFORMED AUGUST 1997 BY KOOGLE AND POULS ENGINEERING.

PATRICK G. CORSER NEW MEXICO 12236 REGISTERED PROFESSIONAL ENGINEER

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Corser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Corser, NM P.E. 12236

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100' 0 100' 200'
CONTOUR INTERVAL 2 FT.

Not For Construction

REV. No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	10/30/97	PGC/JEF	T.Smith	P.Corser

TRIASSIC PARK WASTE DISPOSAL FACILITY

DRAWING TITLE
DETAILED EXCAVATION PLAN - PHASE 1A

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
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DRAWING No. 8

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TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Waste Settlement

	Name	Date
Prepared By:	P. Pellicer	11-Nov-97
Checked By:	J. Pellicer	12-Nov-97
Reviewed By:	P. Gorski	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

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Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of 13
Prepared By: P. Pellizer Date: Nov 1997
Checked By: J. Pellizer Date: 12-Nov-97

Waste Settlement.

Objective: Calculate amount of waste settlement and how the settlement will affect surface grades.

Assumptions:
- Waste settlement is uniform
- Primary settlement has occurred prior to placement of the cover system. Monitoring of the settlement should be conducted.

Calculations:
- take all cross sections perpendicular to cover grades to show true grades. (see pg 2)
- Divide crossections into segments determined by changes in slope of either the cell base or cover. (see pg 3-5)

Results: Total waste settlement up to 7% is acceptable to maintain a minimum cove grade of 3%. (see pg 6-8)

Conclutions: The EPA recomends using 11.5% settlement for design purposes. However this is considered the Maximum amount of settlement possible. Two methods were used to estimate a range of settlements, These two methods were the Power Creep Law and Sowers Method for Secondary Compression. These Two methods resulted in an estimated range of settlement of 2% → 7.8% (see pg 9-11). ∴ the 7% settlement used in this calculation is not unreasonable. Prior to placement of final cover, waste settlement will be monitored and compared to the estimated 7% settlement used for calculation. If settlement is larger than 7% cover grades will be adjusted to accomodate settlement and maintain minimum 3% grade.

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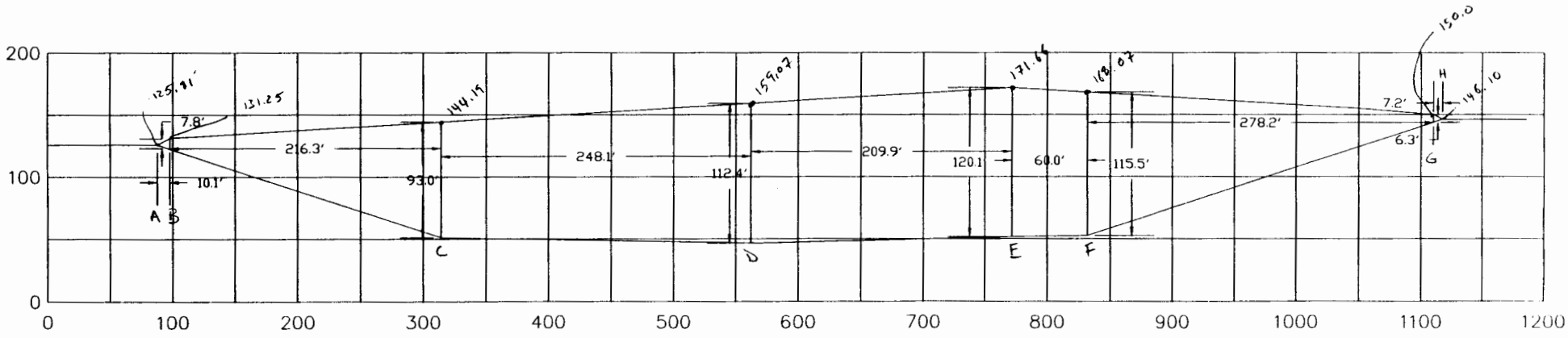

Section A A'

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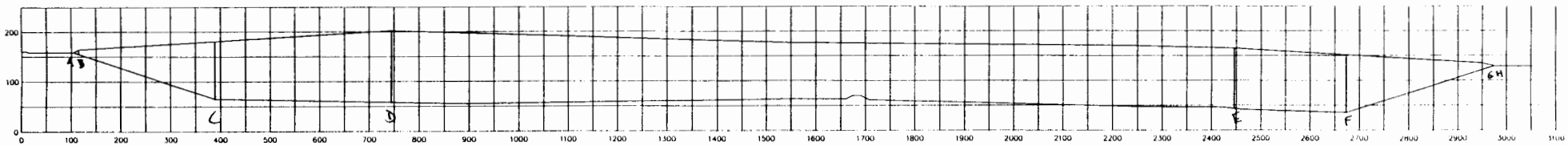

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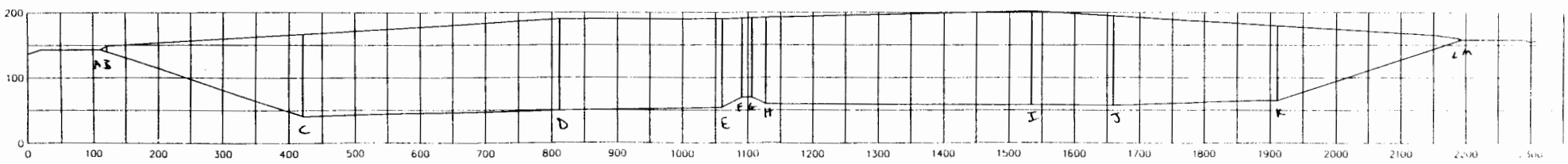

Section C-C'

Project Name: Gandy Marley Inc.
Project Number: 602-0200
Prepared By: Paul Pellicer Checked By:
Filename: Gandy waste Settlement xseca.xls

Station	Waste Depth (ft)	Settlement Factor	Maximum Settlement (ft)	Original Elevation (ft)	Post Settlement Elevation (ft)	Slope Segment	Horizontal Distance (ft)	Original Grade (%)	Post Settlement Grade (%)	Minimum Required Slope (%)
A	0	0.07	0	125.81	125.81					
B	7.8	0.07	0.546	131.25	130.70	A-B	10.1	54%	48.5%	3.0%
C	93	0.07	6.51	144.19	137.68	B-C	216.3	6%	3.2%	3.0%
D	112.4	0.07	7.868	159.07	151.20	C-D	248.1	6%	5.5%	3.0%
E	120.1	0.07	8.407	171.66	163.25	D-E	209.9	6%	5.7%	3.0%
F	115.5	0.07	8.085	168.07	159.99	E-F	60	6%	5.4%	3.0%
G	6.3	0.07	0.441	150.00	149.56	F-G	278.2	6%	3.7%	3.0%
H	0	0.07	0	146.10	146.10	G-H	7.2	54%	48.0%	3.0%

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11-Nov-97

Project Name: Gandy Marley Inc.
Project Number: 602-0200
Prepared By: Paul Pellicer Checked By:
Filename: Gandy waste Settlement xsecc.xls
B

Station	Waste Depth (ft)	Settlement Factor	Maximum Settlement (ft)	Original Elevation (ft)	Post Settlement Elevation (ft)	Slope Segment	Horizontal Distance (ft)	Original Grade (%)	Post Settlement Grade (%)	Minimum Required Slope (%)
A	0	0.07	0	158.82	158.82					
B	8.67	0.07	0.6069	164.27	163.66	A-B	10.08	54%	48.0%	3.0%
C	115.76	0.07	8.1032	180.74	172.64	B-C	274.49	6%	3.3%	3.0%
D	144.06	0.07	10.0842	202.07	191.99	C-D	355.65	6%	5.4%	3.0%
E	121.68	0.07	8.5176	165.00	156.48	D-E	NA	NA	NA	NA
F	116.18	0.07	8.1326	151.36	143.23	E-F	227.31	6%	5.8%	3.0%
G	2.47	0.07	0.1729	130.00	129.83	F-G	297.81	7%	4.5%	3.0%
H	0	0.07	0	128.45	128.45	G-H	2.97	52%	46.4%	3.0%

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602-0200
Pmd
11-Nov-97

Project Name: Gandy Marley Inc.
Project Number: 602-0200
Prepared By: Paul Pellicer Checked By:
Filename: Gandy waste Settlement xsecc.xls

Station	Waste Depth (ft)	Settlement Factor	Maximum Settlement (ft)	Original Elevation (ft)	Post Settlement Elevation (ft)	Slope Segment	Horizontal Distance (ft)	Original Grade (%)	Post Settlement Grade (%)	Minimum Required Slope (%)
A	0	0.07	0	143.15	143.15					
B	8.76	0.07	0.6132	148.60	147.99	A-B	10.08	54%	48.0%	3.0%
C	125.2	0.07	8.764	166.55	157.79	B-C	299.26	6%	3.3%	3.0%
D	140.58	0.07	9.8406	190.00	180.16	C-D	390.9	6%	5.7%	3.0%
E	135.16	0.07	9.4612	190.00	180.54	D-E	248.3	0%	0.2%	NA
F	121.09	0.07	8.4763	191.09	182.61	E-F	30.7	4%	6.8%	NA
G	121.54	0.07	8.5078	191.54	183.03	F-G	15.42	3%	2.7%	NA
H	132.4	0.07	9.268	192.12	182.85	G-H	21.21	3%	0.8%	NA
I	144.1	0.07	10.087	202.11	192.02	H-I	406.6	2%	2.3%	NA
J	137.05	0.07	9.5935	194.58	184.99	I-J	125.49	6%	5.6%	3.0%
K	114.34	0.07	8.0038	179.48	171.48	J-K	251.67	6%	5.4%	3.0%
L	3.56	0.07	0.2492	160	159.75	K-L	278.74	7%	4.2%	3.0%
M	0	0.07	0	157.68	157.68	L-M	3.79	61%	54.6%	3.0%

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602-0200
PMP
11-Nov-97

9.5 13
602-92N
PMP
11-Nov-97

Power Creep Law Settlement

Waste Depth (ft)	Slice Thickness (m)	Over Burden Pressure (kPa)	Slice Settlement (m)	Culmative Settlement (ft)	Percent Settlement
0-5	1.524	13.15	0.002	0.007	0.14%
5-10	1.524	39.45	0.007	0.0289	0.29%
10-15	1.524	65.75	0.011	0.0650	0.43%
15-20	1.524	92.05	0.015	0.1156	0.58%
20-25	1.524	118.35	0.020	0.1807	0.72%
25-30	1.524	144.65	0.024	0.2602	0.87%
30-35	1.524	170.95	0.029	0.3541	1.01%
35-40	1.524	197.25	0.033	0.4625	1.16%
40-45	1.524	223.55	0.037	0.5853	1.30%
45-50	1.524	249.85	0.042	0.7226	1.45%
50-55	1.524	276.15	0.046	0.8744	1.59%
55-60	1.524	302.45	0.051	1.0406	1.73%
60-65	1.524	328.75	0.055	1.2213	1.88%
65-70	1.524	355.05	0.059	1.4164	2.02%
70-75	1.524	381.35	0.064	1.6260	2.17%
75-80	1.524	407.65	0.068	1.8500	2.31%
80-85	1.524	433.95	0.073	2.0884	2.46%
85-90	1.524	460.25	0.077	2.3414	2.60%
90-95	1.524	486.55	0.081	2.6088	2.75%
95-100	1.524	512.85	0.086	2.8906	2.89%
100-105	1.524	539.15	0.090	3.1869	3.04% = Cumulative total settlement

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GW2 D20V
PMP
11-Nov-97

Sowers Method Secondary Compression

Waste Depth (ft)	Slice Thickness (ft)	Slice Settlement (ft)	Culmative Settlement (ft)	Percent Settlement
0-5	5	0.111	0.111	2.22%
5-10	5	0.111	0.2222	2.22%
10-15	5	0.111	0.3333	2.22%
15-20	5	0.111	0.4444	2.22%
20-25	5	0.111	0.5556	2.22%
25-30	5	0.111	0.6667	2.22%
30-35	5	0.111	0.7778	2.22%
35-40	5	0.111	0.8889	2.22%
40-45	5	0.111	1.0000	2.22%
45-50	5	0.111	1.1111	2.22%
50-55	5	0.111	1.2222	2.22%
55-60	5	0.111	1.3333	2.22%
60-65	5	0.111	1.4444	2.22%
65-70	5	0.111	1.5556	2.22%
70-75	5	0.111	1.6667	2.22%
75-80	5	0.111	1.7778	2.22%
80-85	5	0.111	1.8889	2.22%
85-90	5	0.111	2.0000	2.22%
90-95	5	0.111	2.1111	2.22%
95-100	5	0.111	2.2222	2.22%
100-105	5	0.111	2.3333	2.22% = Cumulative Total Settlement.

602-02W
PMP
11-Nov-97

Sowers Method Secondary Compression

Waste Depth (ft)	Slice Thickness (ft)	Slice Settlement (ft)	Culmative Settlement (ft)	Percent Settlement
0-5	5	0.389	0.389	7.78%
5-10	5	0.389	0.7778	7.78%
10-15	5	0.389	1.1667	7.78%
15-20	5	0.389	1.5556	7.78%
20-25	5	0.389	1.9444	7.78%
25-30	5	0.389	2.3333	7.78%
30-35	5	0.389	2.7222	7.78%
35-40	5	0.389	3.1111	7.78%
40-45	5	0.389	3.5000	7.78%
45-50	5	0.389	3.8889	7.78%
50-55	5	0.389	4.2778	7.78%
55-60	5	0.389	4.6667	7.78%
60-65	5	0.389	5.0556	7.78%
65-70	5	0.389	5.4444	7.78%
70-75	5	0.389	5.8333	7.78%
75-80	5	0.389	6.2222	7.78%
80-85	5	0.389	6.6111	7.78%
85-90	5	0.389	7.0000	7.78%
90-95	5	0.389	7.3889	7.78%
95-100	5	0.389	7.7778	7.78%
100-105	5	0.389	8.1667	7.78% = Cumulative total Settlement

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602 024H
pmP
11-Nov-97

SECTION 7

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Conclusions reached as a result of the study are:

a. The dominant mechanisms of settlement of the fill and subsidence of the covers of horizontally layered hazardous waste landfills are expected to be closing of the inherent drum-placement void spaces and compression of cell contents including intermediate cover soils, waste, and waste containers. Cavity related piping and sinkhole phenomena are not expected to play a major role in predicted subsidence. This conclusion is based on review of representative active waste disposal practices in industry and government and analysis of documented and theoretical subsidence mechanisms reported in other, related activities.

b. The maximum postclosure subsidence of the cover (cap) of a simulated hazardous waste landfill operating under interim RCRA guidelines, from compressibility alone, is predicted to be about 11-1/2 percent of the total height of the fill and cover at the center of the landfill. For a 62.5-ft-thick fill and cover the maximum expected subsidence, after deterioration of the waste containers, was 87 in. The final cover slope with that subsidence would be about 2 percent, which is undesirable under current RCRA guidelines. An additional 8 to 9 percent subsidence must be considered if waste drums are assumed to contain the maximum allowable 10 percent void space when placed in the fill.

c. Actual landfill settlement and cover subsidence may be less than the worst-case maximum predicted 11-1/2 percent because more of the voids between containers will probably be filled as a result of less than optimum (tight) stacking of containers during placement. The 11-1/2 percent figure is considered an effective value for design purposes.

RECOMMENDATIONS

Cover subsidence from settlement of compressible fill is expected to occur. Therefore, to minimize the severity of subsidence, managers of hazardous waste landfills should continue at least those operational methods that are being practiced at representative RCRA-guided secure landfills as determined from field observations of this study. Recommended operational methods include:

a. Landfill operators should make an effort to reduce voids when placing wastes and fill within the cell by insuring that intermediate cover soils are allowed to sift between waste containers and debris.

Drums or other containers of wastes should be filled to minimize the volume of void within the containers. Much of the potential settlement from compressibility can be eliminated by preventing the inclusion of cavities in the waste placement process in the typical hazardous waste landfill.

b. Layering of waste and intermediate cover in thin lifts so that some compactive effort is achieved during filling.

c. Control of liquids by installation of efficient leachate collection systems and stabilization of liquid wastes to prevent saturation of the fill and to allow consolidation to occur as rapidly as possible.

d. Installation and monitoring of cover settlement plates so that the subsiding surface can be maintained at the proper slope. Hazardous waste landfills should be documented, instrumented, and monitored after closure. Subsidence of the cover as well as the settlement of internal waste layers should be monitored with time in an effort to gain understanding of postclosure internal changes, how they occur, and how they affect the overall behavior of the landfill. Many of the mechanisms at work within these landfill cells can be understood only by study and experience with representative landfill cells. The data obtained by field monitoring will permit evaluation and improvement of settlement/subsidence prediction models developed in this study. Landfill operators should remember that, while the cover surface can be maintained at a proper runoff slope by the addition of soil or other material, the internal cover liner, whether a clay layer or a flexible membrane liner or both, may have been deformed and stressed by subsidence. Internal cover liner damage or deformation cannot be remedied by simple cover surface cosmetic actions.

e. Placement of a buffer thickness of intermediate cover soils above the uppermost waste layer and beneath the final cover to lessen the potential for collapse of the cover directly above locally compressible zones such as deteriorating drums.

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TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Settlement Induced Stresses in Geomembrane

	Name	Date
Prepared By:	P. Pellicer	12-Nov-97
Checked By:	J. Pellicer	13-Nov-97
Reviewed By:	P. Gorser	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

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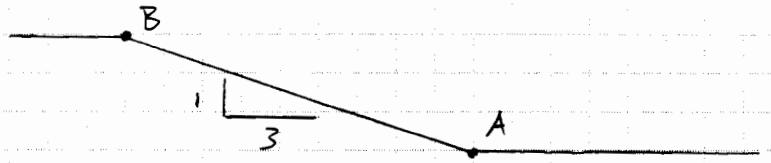
Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of 5
Prepared By: P. Pellicer Date: Nov 12, 1997
Checked By: J. Pellicer Date: 13-Nov-97

Settlement Induced Stress in Geomembrane

Objective: Estimate the stress induced in the Geomembrane liner due to settlement of the subgrade and prepared subgrade.

Assumptions: Use NSC 60 mil textured liner

Calculations:



Settlement at point "A" is the sum of subgrade settlement and prepared subgrade settlement.

$= 5\,in + .56\,in = 5.56\,in$ (very conservative)

From subgrade settlement calc package

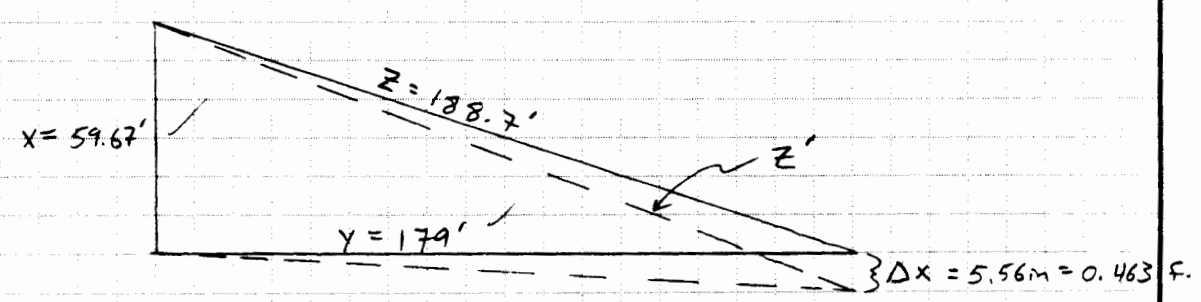
From prepared subgrade settlement calc. package.

Assume settlement at Point "B" = 0

The shortest slope length will experience the greatest strain and therefore the Maximum induced stress.

The shortest slope length is at C-C' (see pg 3) = 188.7 ft

w/ 3H:1V slope this results in the following Geometry.



$$Z' = \left((x+x')^2 + (y)^2\right)^{1/2}$$
$$= \left((59.67' + 0.463')^2 + (179')^2\right)^{1/2}$$
$$= 188.83'$$

$$\epsilon = \frac{\Delta l}{l_0} = \frac{188.83 - 188.7}{188.7'} = 6.9 \times 10^{-4}$$

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Project Name: Triassic Park
Project Number: 602-0200 Sheet: 2 Of 5
Prepared By: P. Pellizer Date: Nov 12, 1997
Checked By: J. Pellicer Date: 13-Nov-97

$\sigma = E\epsilon$

$E = 94{,}000$ psi (see pg 4)

$\sigma = (94{,}000 \text{ psi})(6.9 \times 10^{-4}) = 64.9$ psi

σ_{yield} for 60 mil THDPE = 2200 psi (see pg 5)

2200 psi >> 64.9 psi F.S. = 34

Conclusions: Based on the calculations, the settlement of the subgrade + prepared subgrade will have no detrimental effect on the liner.

NOTE: No specific calculation was done to estimate stresses induced in the evaporation pond lining system. Since the evaporation pond is substantially smaller than the landfill, it is expected the induced stresses on the liner system will be less. Since the calculated stresses for the landfill are less than the yield strength of the geomembrane, the stresses for the evaporation pond will be less than the geomembrane yield strength also.

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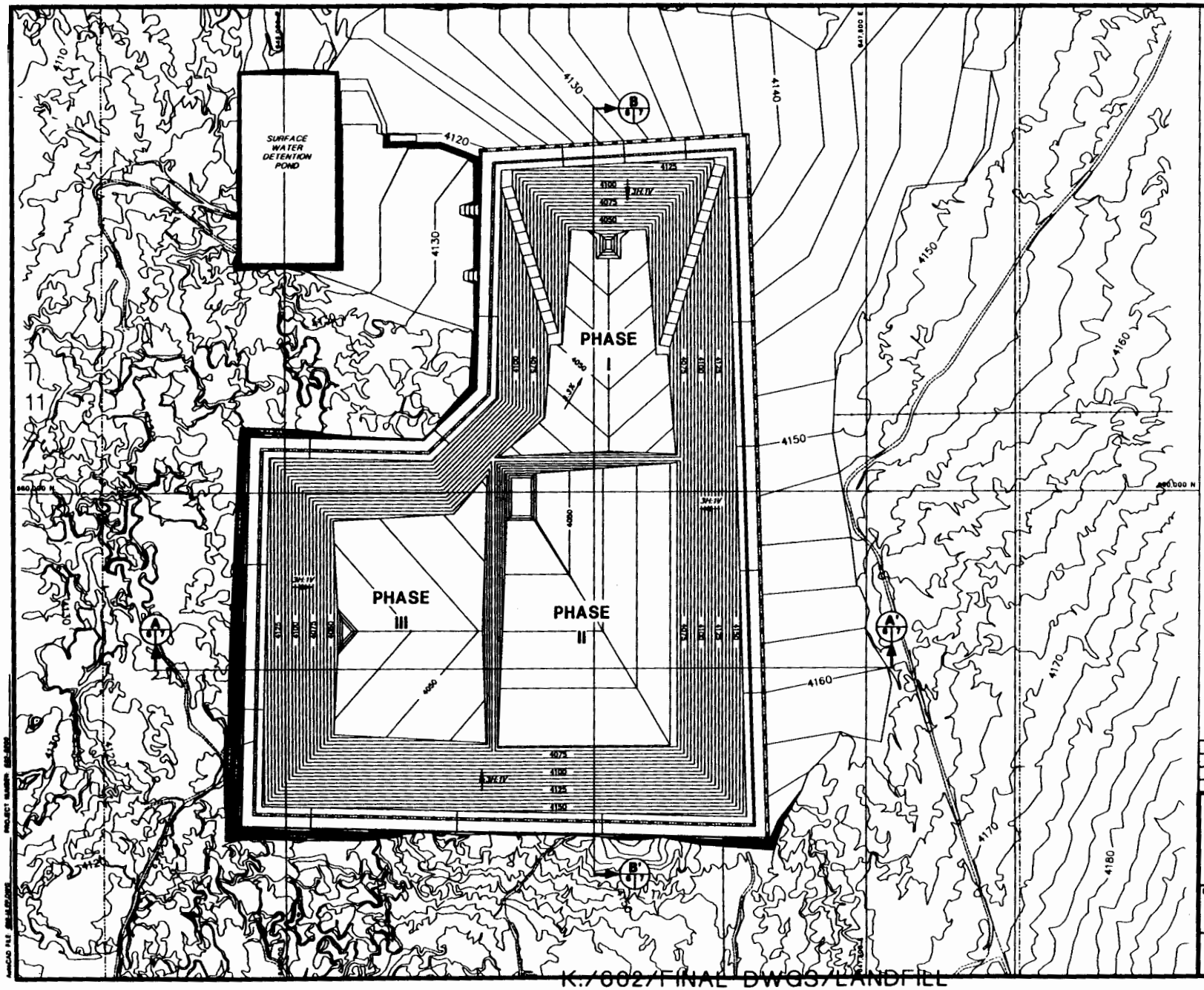
602-0200
pump
12-NOV-97

E-12



NOTES:
1. FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2, "INDEX, LEGEND AND GENERAL NOTES"
2. TOPOGRAPHY FROM AERIAL SURVEYS PERFORMED AUGUST 1997 BY KOOGLE AND POULS ENGINEERING
3. BASE GRADES FOR PHASES II AND III TO BE MODIFIED PRIOR TO CONSTRUCTION TO ACHIEVE A MINIMUM OF 2%

PATRICK G. CORSER — NEW MEXICO — REGISTERED PROFESSIONAL ENGINEER

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Corser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date — Patrick G. Corser, NM P.E. 12236

SCALE
800' 0 800' 400'
CONTOUR INTERVAL 5 FT.
SURFACE TOPOGRAPHY CONTOUR INTERVAL 2 FT

Not For Construction

REV. No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PMIT & PERMIT APPLICATION	10/16/97	PGC/JPF	EWB	P Corser

TRIASSIC PARK WASTE DISPOSAL FACILITY

DRAWING TITLE:
ULTIMATE LANDFILL EXCAVATION PLAN

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE: AS NOTED
DRAWING No. 8

K:/002/FINAL DWGS/LANDFILL
GMI-ULEP.dwg
10,199,158
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TABLE 5.3 TENSILE BEHAVIOR PROPERTIES OF 30-MIL PVC, 36-MIL CSPE, AND 30-MIL HDPE

Property		Dumbbell shape (Fig. 5.2)			Narrow-width (1.0-in. [25 mm]) shape (Fig. 5.3)			Wide-width (8.0-in. [100-mm]) shape (Fig. 5.3)			Three-dimensional shape (Fig. 5.5)		
		PVC	CSPE-R	HDPE	PVC	CSPE-R	HDPE	PVC	CSPE-R	HDPE	PVC	CSPE-R	HDPE
maximum stress*	(lb./in.^{2})	3400	5700	3200	2900	5100	3000	2800	4300	2800	1200	3300	2300
	(megapascals)	23	39	22	20	35	21	19	30	19	8.3	23	16
maximum strain*	(%)	300	17	11	300	35	13	300	30	15	120+	100	47
modulus	(lb./in.^{2})	9000	33,000	94,000	9000	15,000	40,000	9000	14,000	33,000	4000	5000	25,000
	(megapascals)	62	227	648	62	103	275	62	96	227	28	34	172
ultimate stress	(lb./in.^{2})	3400	1300	≅4000	2700	1200	≅3500	2800	1100	≅3000	d.n.f.	3300	2300
	(megapascals)	23	9.0	28	19	8.3	24	19	7.6	21		23	16
ultimate strain	(%)	300	100	≅700	300	58	≅600	300	51	≅500	d.n.f.	100	47

*Notes:

PVC values are at ultimate

CSPE-R values are at scrim break

HDPE values are at yield

d.n.f. = did not fail

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GCL-020

pmo

12-Mar-97

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602-1210
pmp
12-Nov-97

FRICTION SEAL™ HD GEOMEMBRANE
QUALITY CONTROL SPECIFICATIONS
60 mil

FRICTION SEAL HD, National Seal Company's advanced textured high density polyethylene (HDPE) geomembrane, is manufactured by attaching a friction surface to NSC's high quality HDPE geomembrane. The friction surface is made from high molecular weight polyethylene resin compounded specifically for use in NSC geomembranes. The resin has been formulated to provide stress crack, chemical and ultraviolet resistance for fluid containment. NSC produces FRICTION SEAL HD with a textured surface on one or both sides of the parent sheet.

The following properties are tested as a part of NSC's quality control program. Certified test results for properties on this page are available upon request. Refer to NSC's Quality Control Manual for exact test methods and frequencies.

RESIN PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Melt Flow Index[2]	ASTM D 1238	g/10 min	0.50	0.25
Oxidative Induction Time	ASTM D 3895, Al pan, 200°C, 1 atm O_2	minutes	100	120

SHEET PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Mass per Unit Area[3]	ASTM D 3776	lb/ft^2	0.31	0.32
Thickness[4]	ASTM D 751, NSF mod.			
Average		mils	60.0	61.5
Individual		mils	57.0	59.7
Density[4]	ASTM D 1505	g/cm^3	0.940	0.948
Carbon Black Content[4]	ASTM D 1603	percent	2.0-3.0	2.35
Carbon Black Dispersion[4]	ASTM D 3015, NSF mod.	rating	A1, A2, B1	A1
Tensile Properties[5]	ASTM D 638			
Stress at Yield		psi	2200	2750
		ppi	132	169
Stress at Break		psi	2200	3240
		ppi	132	199
Strain at Yield	1.3" gage length (NSF)	percent	13.0	17.5
Strain at Break	2.0" gage or extensometer	percent	200	540
	2.5" gage length (NSF)	percent	160	432
Dimensional Stability[2,4]	ASTM D 1204, NSF mod.	percent	1.5.	0.4
Tear Resistance	ASTM D 1004	ppi	750	1000
		lbs	45	62
Puncture Resistance	ASTM D 4833	ppi	1800	2276
		lbs	108	140
Constant Load ESCR, Single Point[4]	GRI, GM-5a	hours	200	>400
Friction Angle, Index	GRI, GS-7	degrees	40	56

1 This value represents the minimum acceptable test value for a roll as tested according to NSC's Manufacturing Quality Control Manual. Individual test specimen values are not addressed in this specification except thickness.

2 Indicates Maximum Value

3 Friction Coating on both sides of base sheet

4 Testing performed on base sheet

5 Stress and strength values are normalized to the nominal base sheet thickness. NSC certifies properties based on values calculated using nominal thickness only. Stress values calculated using actual product thickness is not guaranteed due to the lack of industry accepted thickness test procedures for friction sheet.

E-13

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Geomembrane Stress Induced by Waste Settlement

	Name	Date
Prepared By:	P. Pellicer	14-Nov-97
Checked By:	J. Pellicer	14-Nov-97
Reviewed By:	R. Gold	15 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

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Engineering & Environmental Services
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Phone 970.879.6260 Fax 970.879.9048

Project Name: Treasure Park
Project Number: 602-0200 Sheet: 1 Of
Prepared By: A. Pellicer Date: 14-Nov-97
Checked By: J. Pellicer Date: 14-Nov-97

Geomembrane Stress Induced by waste Settlement.

Objective: Assess stresses developed in the slope Geomembrane due to waste settlement.

Method: Any stress induced in the liner system will be transfered to the subgrade until the internal strength of the liner system is over come. Once the internal strength is exceeded the stress will be transfered to the anchor trench system through one or both of the geomembranes. The anchor trench system is designed to let the liner syster pull out before the yield stress of the geomembrane is reached.

∴ Stresses Induced in the liner system due to waste settlement is not critical and will not damage the liner system.

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TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Evaporation Pond Clay Liner Settlement

	Name	Date
Prepared By:	J. Pellicer	14-Nov-97
Checked By:	P. Pellicer	14-Nov-97
Reviewed By:	P. Corser	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

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Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of 2
Prepared By: J. Pellicer Date: 14-Nov-97
Checked By: P. Pellicer Date: 14-Nov-97

Evaporation Pond Clay Liner Settlement

Depth of the pond is 12ft

Pressure on top of clay liner: (12 ft)(624 pcf) = 748 psf

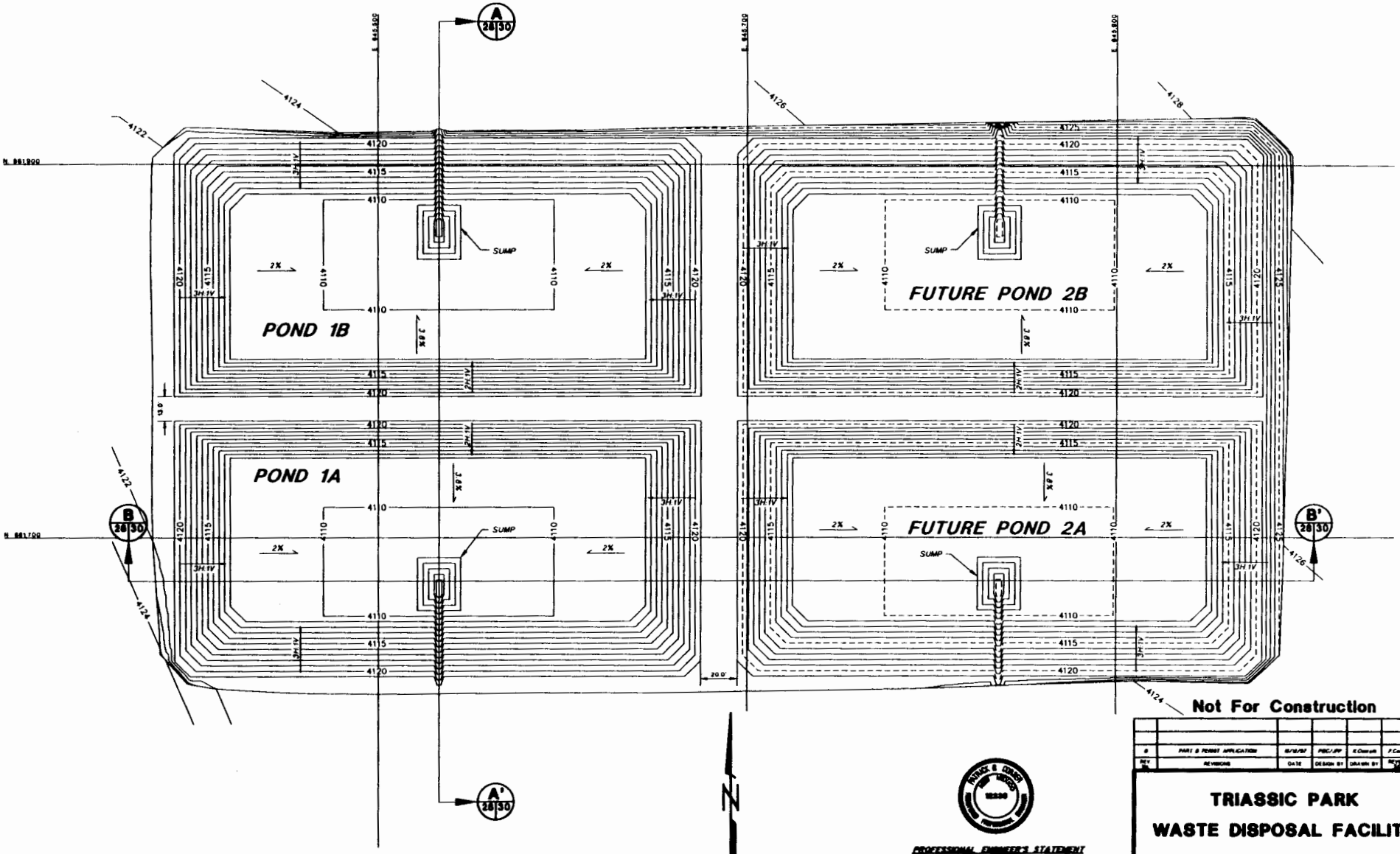
The normal stress exerted by the fluid in comparison to the maximum past pressure imparted to the clay liner from compaction will be negligible. Therefore settlement of the material will be negligible.

CONCLUSION: Clay liner settlement will be so minimal it will not damage overlying liner system.

602-0200
JPP
14-NOV-97

2 of 2

E-14



NOTE:
FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2, "INDEX, LEGEND AND GENERAL NOTES".

SCALE

CONTOUR INTERVAL 1 FT. – INSIDE OF POND
CONTOUR INTERVAL 2 FT. – OUTSIDE OF POND

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Carver, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Carver, NM P.E. 12530

REV. No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	12/12/97	PBC/JPP	K.Cassell	P.Carver

TRIASSIC PARK WASTE DISPOSAL FACILITY

DRAWING TITLE:
EVAPORATION POND SUBGRADE CONTOURS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE: As Shown
DRAWING No. 28

K:/602/FINAL DWGS/Evaporation Pond
SUBGRD-CONT2.dwg
796,365
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E-15

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Anchor Trench Pullout Capacity

	Name	Date
Prepared By:	P. Pellicer	8-Nov-97
Checked By:	J. Pellicer	12-Nov-97
Reviewed By:	P. Gobel	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
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Anchor Trench Pullout Capacity.

Objective: Determine Pullout Capacity of anchor trench and check to make sure it pulls out before the HDPE yields.

Assumptions: Geosynthetics will pull out of anchor trench with single sided shear. Single sided failure will occur rather than double sided shear because there is less shearing resistance. Shearing failures occur along the path of least resistance.

Calculations: There are Two anchor trench systems to evaluate.
1. Perimeter liner anchor trench.
2. Temporary anchor trench on ramps

Perimeter liner anchor trench: (see pg 5)

Use Peak Shear strength; $a = 18\,psf$ $\delta = 33°$ (see pg 3)

$\gamma_{m_1} = 100\,pcf$ (assumed) protective soil

$P_R = (\sigma_N \tan\delta + a)L$

$\gamma_{m_2} = 120\,pcf$ (assumed) anchor trench backfill

$\phi_{soil} = 30°$ (assumed)

Runout:

$$P_{R_1} = (\sigma_N \tan 33° + 18\,psf)\,4\,ft$$

$$\sigma_N = (100\,lb/ft^3)(2\,ft) = 200\,lbs/ft^2$$

$$P_{R_1} = ((200\,lbs/ft^2)(\tan 33) + 18\,psf))\,4\,ft$$

$$P_{R_1} = 591\,lb/ft\left(\frac{1\,ft}{12\,in}\right) = \underline{\underline{49}}\,lb/in \checkmark$$

Bottom of anchor trench:

$$\sigma_N = (120\,pcf)(2\,ft) + (100\,pcf)(2\,ft) = 440\,psf \checkmark$$

$$P_{R2} = ((440\,psf)(\tan 33°) + 18\,psf))\,2\,ft$$

$$P_{R2} = 607\,lb/ft\left(\frac{1\,ft}{12\,in}\right) = 50\,lb/in \checkmark$$

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Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Anchor trench sidewall:

$\overline{\sigma_H} = k_o \overline{\sigma_N}$

$k_o = 1 - \sin\phi = 1 - \sin 30 = 0.5$

$\overline{\sigma_H} = ((2ft)(100pcf) + (1ft)(120pcf))(0.5) = 160 psf$ ✓

$P_{R3} = (\overline{\sigma_H} \tan\delta + a) L$

$= ((160pcf)(\tan 33) + 18psf)\ 2ft = 244 lb/ft$ ✓

$P_{R3} = 244 lb/ft \left(\frac{1ft}{12in}\right) = 20 lb/in$ ✓

$\Sigma P_R = 49 lb/in + 50 lb/in + 20 lb/in = 119 lb/in$ ✓

60 mil THDPE @ Yield = 132 lb/in (see pg 4)

132 lb/in > 119 lb/in ∴ HDPE will pullout rather than tear. O.k.

Temporary anchor trenchs on ramps:
The anchor trenches on the ramps exceed the Geometry (pg 6) (pullout resistance) of the perimeter anchor trench. However the critical failure geometry does not involve these anchor trenches and since they are temporary there should be minimal risk of tearing the liner.

EVAPORATION POND ANCHOR TRENCH

Evaporation Pond Slope Length = 60 ft (pg 7)

Weight of Liner Acting Downslope = $(60ft)(1ft)\left(\frac{60mil}{1}\right)\left(\frac{1in}{1000mil}\right)\left(\frac{ft}{12in}\right)(.94)(62.4pcf) = 5.56 lbs$

Neglect frictional force of geomembrane on slope (conservative)

Anchor Trench is 2 ft by 2 ft (pg 8)

Pullout Resistance of Base of Trench = $(2ft)(100pcf)(1ft)(2ft)\tan 7$ ($\delta = 7°$, see pg 9 + 10)
= 49 lb

Neglect sidewall resistance (conservative)
SF = 49 lb / 5.5 lb = 8.9 okay

CONCLUSION: Anchor trench will hold up geosynthetics. Since the evaporation pond has smooth HDPE, the liner will pull out of the anchor trench more readily than the textured HDPE used for the landfill. Textured HDPE pulls out before yield; therefore, smooth HDPE will pull out before yielding. okay

GEOSYNTEC CONSULTANTS

SOIL-GEOSYNTHETIC INTERACTION TESTING LABORATORY

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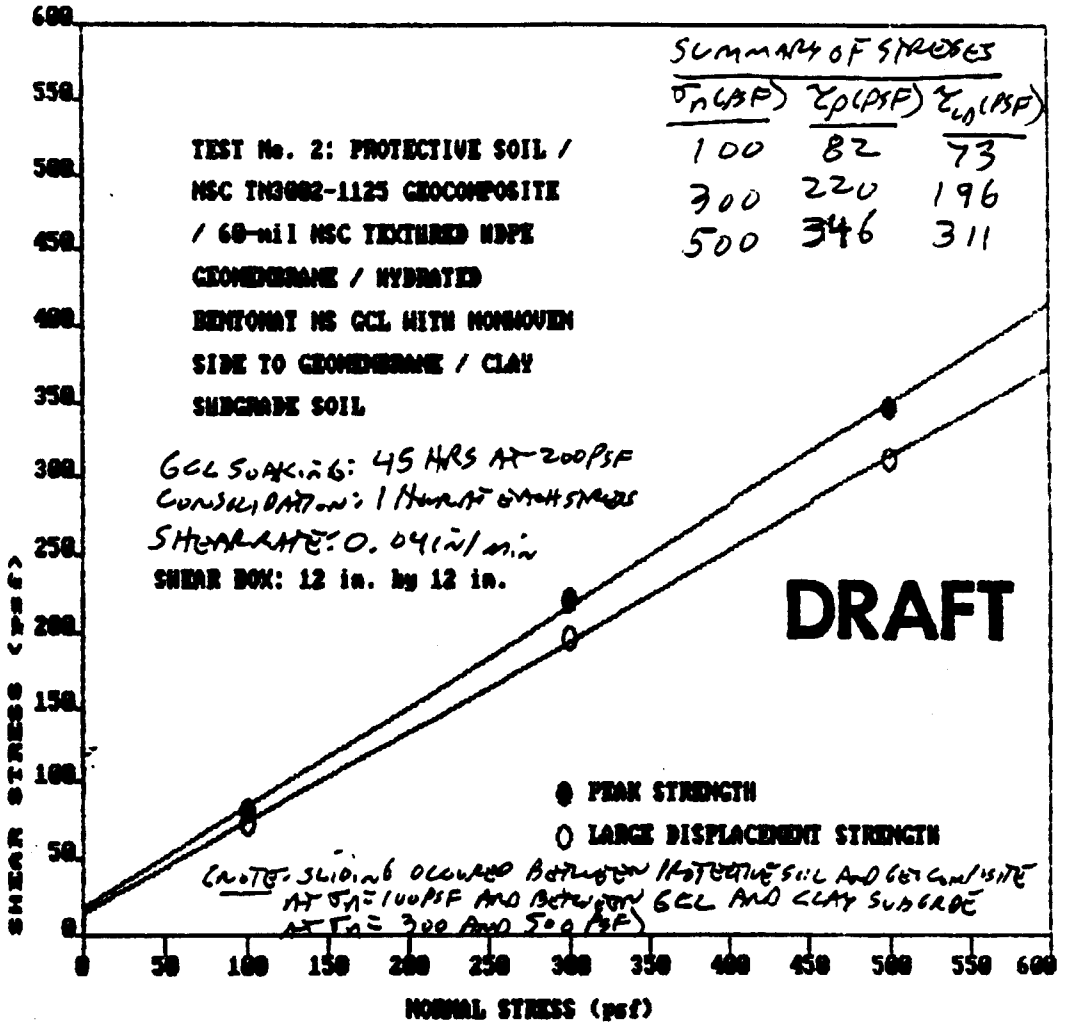
602-0200
PMP
8-Nov-97

TERRAMATRIX MONTGOMERY WATSON - ASTM D 5321 TESTS



SUMMARY OF STRESSES

σ_n (PSF)	τ_p (PSF)	τ_{LD} (PSF)
100	82	73
300	220	196
500	346	311

THE REGRESSION POLYNOMIAL OF LINE 9 - PEAK STRENGTH

(1.800E+01) + (6.600E-01)*X $a = 18$ PSF $\delta = 33°$
THE VARIANCE - 8.000E+00

THE REGRESSION POLYNOMIAL OF LINE 10 - LARGE DISPLACEMENT STRENGTH

(1.483E+01) + (5.950E-01)*X $a = 15$ PSF $\delta = 31°$
THE VARIANCE - 3.556E+00

Reviewed By: Robert H. Swan Jr Date: 10-10-97

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602-0200
PMP
8-Nov-97

FRICTION SEAL™ HD GEOMEMBRANE
QUALITY CONTROL SPECIFICATIONS
60 mil

FRICTION SEAL HD, National Seal Company's advanced textured high density polyethylene (HDPE) geomembrane, is manufactured by attaching a friction surface to NSC's high quality HDPE geomembrane. The friction surface is made from high molecular weight polyethylene resin compounded specifically for use in NSC geomembranes. The resin has been formulated to provide stress crack, chemical and ultraviolet resistance for fluid containment. NSC produces FRICTION SEAL HD with a textured surface on one or both sides of the parent sheet.

The following properties are tested as a part of NSC's quality control program. Certified test results for properties on this page are available upon request. Refer to NSC's Quality Control Manual for exact test methods and frequencies.

RESIN PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Melt Flow Index[2]	ASTM D 1238	g/10 min	0.50	0.25
Oxidative Induction Time	ASTM D 3895, Al pan, 200°C, 1 atm O_2	minutes	100	120

SHEET PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Mass per Unit Area[3]	ASTM D 3776	lb/ft^2	0.31	0.32
Thickness[4]	ASTM D 751, NSF mod.			
Average		mils	60.0	61.5
Individual		mils	57.0	59.7
Density[4]	ASTM D 1505	g/cm^3	0.940	0.948
Carbon Black Content[4]	ASTM D 1603	percent	2.0-3.0	2.35
Carbon Black Dispersion[4]	ASTM D 3015, NSF mod.	rating	A1, A2, B1	A1
Tensile Properties[5]	ASTM D 638			
Stress at Yield		psi	2200	2750
		ppi	132 ←	169
Stress at Break		psi	2200	3240
		ppi	132	199
Strain at Yield	1.3" gage length (NSF)	percent	13.0	17.5
Strain at Break	2.0" gage or extensometer	percent	200	540
	2.5" gage length (NSF)	percent	160	432
Dimensional Stability[2,4]	ASTM D 1204, NSF mod.	percent	1.5.	0.4
Tear Resistance	ASTM D 1004	ppi	750	1000
		lbs	45	62
Puncture Resistance	ASTM D 4833	ppi	1800	2276
		lbs	108	140
Constant Load ESCR, Single Point[4]	GRI, GM-5a	hours	200	>400
Friction Angle, Index	GRI, GS-7	degrees	40	56

[1] This value represents the minimum acceptable test value for a roll as tested according to NSC's Manufacturing Quality Control Manual. Individual test specimen values are not addressed in this specification except thickness.

[2] Indicates Maximum Value

[3] Friction Coating on both sides of base sheet

[4] Testing performed on base sheet

[5] Stress and strength values are normalized to the nominal base sheet thickness. NSC certifies properties based on values calculated using nominal thickness only. Stress values calculated using actual product thickness is not guaranteed due to the lack of industry accepted thickness test procedures for friction sheet.

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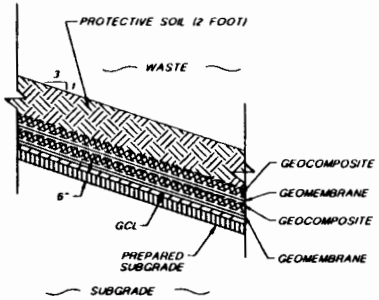

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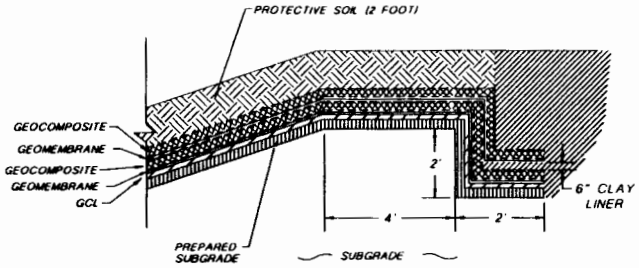
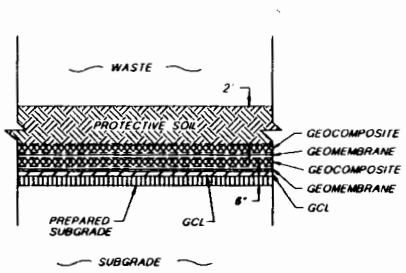
Not To Scale



2 (8|12) 2 (9|12) 2 (10|12) 2 (23|12) 2 (24|12) **LINER ANCHOR TRENCH DETAIL**
Not To Scale



3 (7|12) 3 (24|12) **FLOOR DETAIL**
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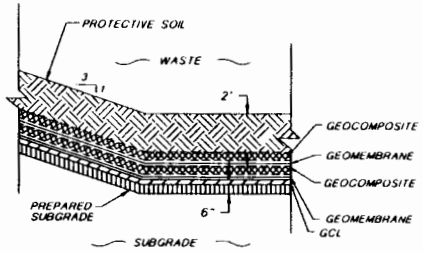

4 (7|12) **TOE OF SLOPE DETAIL**
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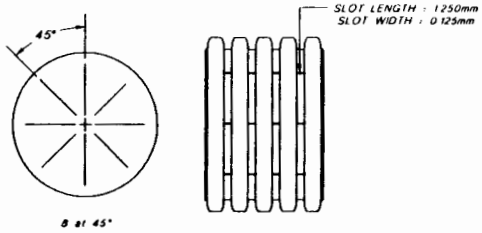
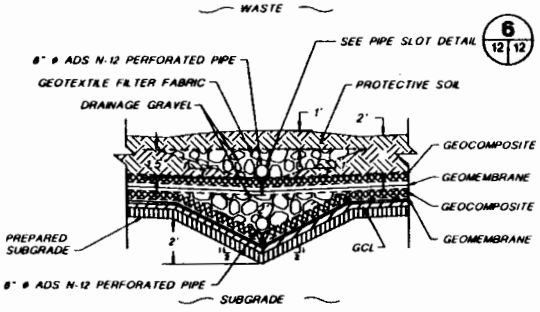
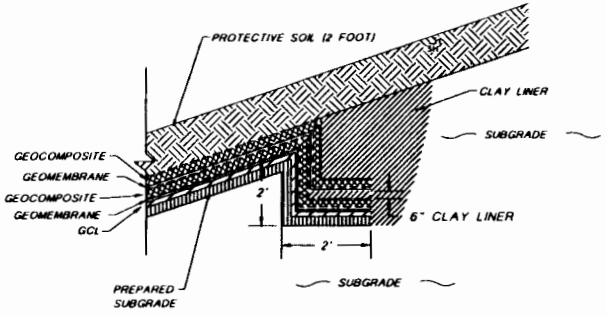


6 (12|12) **ADS N-12 PIPE SLOT DETAIL**
Not To Scale



5 (9|12) **FLOOR PIPE DETAIL**
Not To Scale



6 (8|12) 6 (13|12) **SLOPE ANCHOR TRENCH**
Not To Scale

NOTE:
FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2, "INDEX, LEGEND AND GENERAL NOTES".

PATRICK G. CARVER
10330
MISSOURI
PROFESSIONAL ENGINEER

PROFESSIONAL ENGINEER'S STATEMENT
I, Patrick G. Carver, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date _____ Patrick G. Carver, Mo P.E. 10330

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REV No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	10/10/97	PGC/JPP	K Carver	P Carver

TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE:
LINER DETAILS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE: As Shown
DRAWING No. 12

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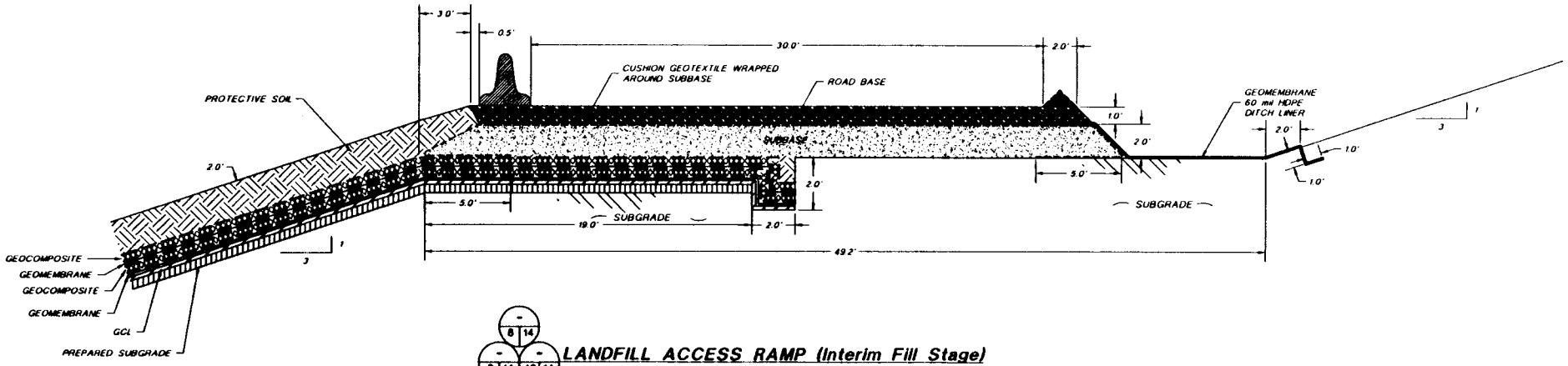
6 of 10
pmp
602-0200

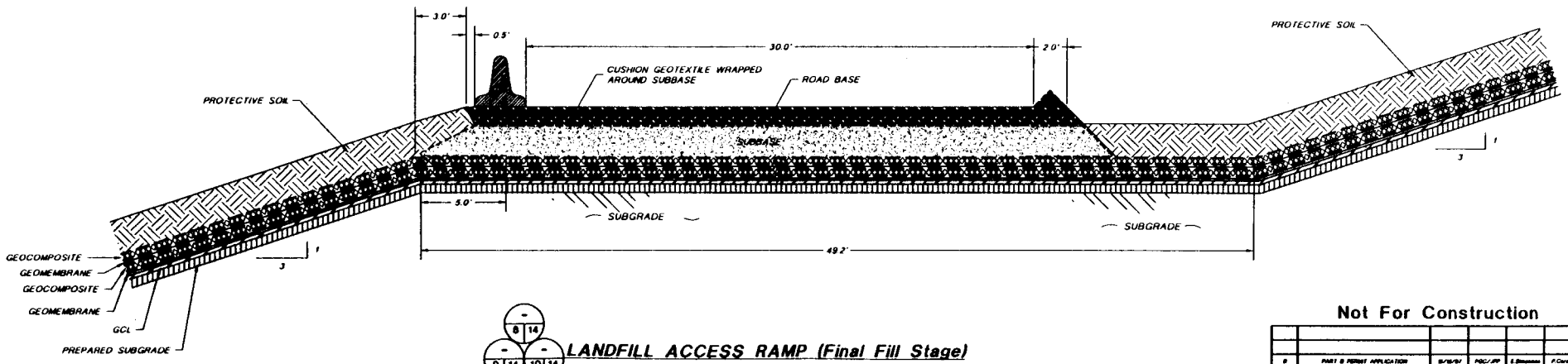
E-15



8 14 9 14 10 14 13 14

LANDFILL ACCESS RAMP (Interim Fill Stage)

SCALE
0 3 6
Feet



8 14 9 14 10 14 13 14

LANDFILL ACCESS RAMP (Final Fill Stage)

SCALE
0 3 6
Feet

NOTE
FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No 2, "INDEX, LEGEND AND GENERAL NOTES"

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I, Patrick G. Corser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information

Date Patrick G. Corser, NM P.E. 12236

Not For Construction

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B	PART B PERMIT APPLICATION	9/18/97	RGC/PP	E.Simonson	P.Corser

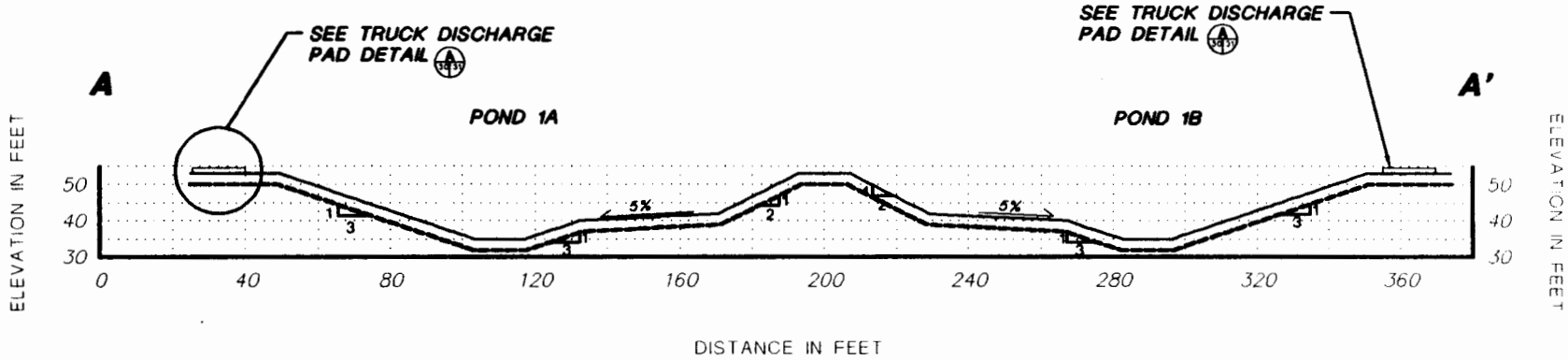
TRIASSIC PARK WASTE DISPOSAL FACILITY

DRAWING TITLE
TYPICAL LANDFILL ACCESS RAMP DETAILS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE AS NOTED
DRAWING No 3d

AutoCAD R14 RAMP-DETAILS.DWG PROJECT NUMBER 602-0200



A 28/30 CROSS-SECTION A-A'

HORIZONTAL SCALE
0 25' 50'

VERTICAL SCALE
0 25' 50'

DOCUMENT DRAFT - REVIEW TABLE					
REVIEW ISSUE	DESCRIPTION	DRAFT DATE	DESIGN BY	DRAWN BY	REVIEWED BY

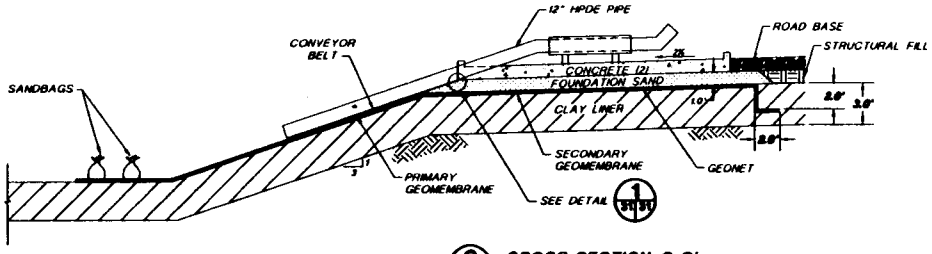
REV No	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND SIGNED BY

TerraMatrix
MONTGOMERY WATSON
Mining Group

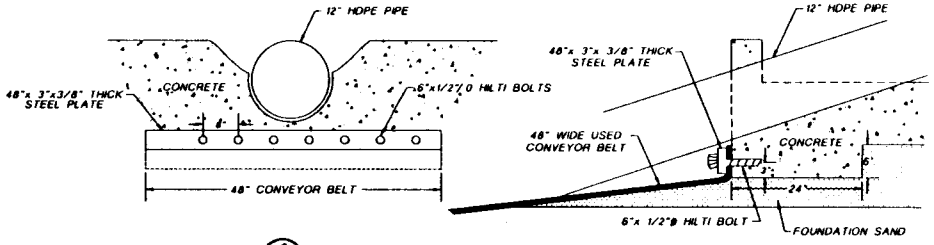
PROJECT No.
AutoCAD FILE evaporation pond dwg
SCALE
FIGURE No.

8 of 10
602-0200
8-NOV-97

E-15



C CROSS-SECTION C-C'
Not To Scale



1 DETAIL CONVEYOR BELT CONNECTION
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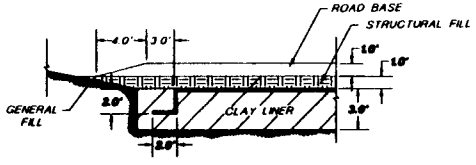

E CROSS-SECTION E-E' ACCESS RAMP
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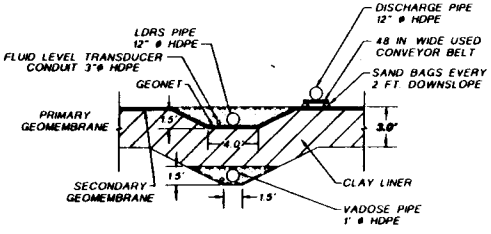

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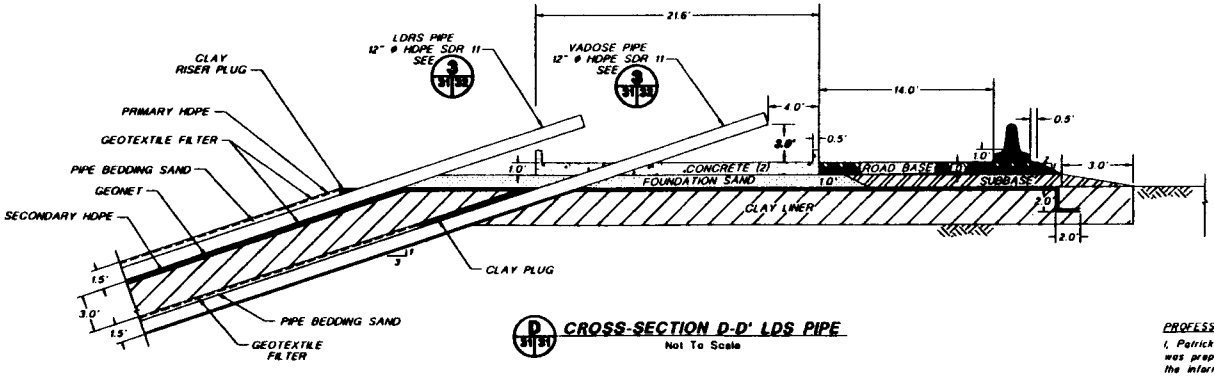

D CROSS-SECTION D-D' LDS PIPE
Not To Scale

NOTE:
FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2, "INDEX, LEGEND AND GENERAL NOTES".

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Corser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Corser, NM P.E. 12236

PATRICK G. CORSER NEW MEXICO 12236 REGISTERED PROFESSIONAL ENGINEER

Not For Construction

REV. No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	09/05/97	PGC/JPP	K.Conrad	P.Corser

TRIASSIC PARK WASTE DISPOSAL FACILITY

DRAWING TITLE:
EVAPORATION POND TRUCK DISCHARGE STATION

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 2 Of 2 Sheets
SCALE: As Shown
DRAWING No. 31

PROJECT NUMBER 602-0200
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8-Nov-97
JPP
9/10

SLOPE STABILITY FAILURE INVESTIGATION: LANDFILL UNIT B-19, PHASE I-A, KETTLEMAN HILLS, CALIFORNIA

by

Raymond B. Seed

James K. Mitchell

and

H. Bolton Seed

REPORT NO. UCB/GT/88-01

July, 1988

College of Engineering
Department of Civil Engineering
University of California
Berkeley, California

Table 2.14: Summary of Interface Shear Strength Tests: Kettleman Hills Repository

Interface Components	Conditions	DIRECT SHEAR TESTS Residual Friction Angle: ϕ_r	PULLOUT BOX TESTS Residual Friction Angle: ϕ_r	Values Proposed for Stability Analyses
HDPE Liner/Geotextile	Dry, Unpolished Dry, Part. Polished Dry, Polished	9.5° to 12.5° 9.0° to 11.0° 8.5° to 10.5°	9.5° (1 Test) --- 8.0° (1 Test)	ϕ = 9° ± 1°
	Wet, Unpolished Wet, Polished	8.0° to 10.0° 7.0° to 9.5°	7.0° to 10.5° 6.5° to 9.0°	ϕ = 8° ± 1°
HDPE Liner/Clay	Dry (As-Compacted)	11.0° to 14.0°	---	ϕ = 12° ± 1°
	Saturated (U-U)	(τ_r = 800 to 1000 psf)	---	τ = 900 psf ± 250 psf
HDPE Liner/Geonet (Transverse Shear)	Dry	7.0° to 8.0°(+)	---	ϕ = 8.5° ± 1°
	Submerged	7.0° to 10.0°	8.0° to 9.0°	ϕ = 8.5° ± 1°
HDPE Liner/Geonet (Aligned Shear)	Submerged	5.0° to 8.0°	6.0° to 8.0°	ϕ = 7.0° ± 1.5°
Geotextile/Clay	Saturated (U-U)	~ 24°	---	$\phi \approx$ 24°
Geotextile/Geonet	Dry	> 20°	---	ϕ > 20°
	Submerged	10° to 14°(+)	---	ϕ > 12°
HDPE Liner/HDPE Liner	Dry	6.0° to 13.0°	7.0° to 13.5°	ϕ = 9.5° ± 3°
	Submerged	6.0° to 11.0°	---	ϕ = 8.5° ± 2.5°

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TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602 - 0200

Calculation Title: Geomembrane Survivability

	Name	Date
Prepared By:	P. Pellicer	14-Nov-97
Checked By:	J. Pellicer	15-Nov-97
Reviewed By:	R. Corzo	15 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of 8
Prepared By: P. Pellicer Date: 14-Nov-97
Checked By: J. Pellicer Date: 15-Nov-97

Geomembrane Survivability

Objective: Assess the survivability of 60 mil THDPE liner.

Method: Utilize guidelines for assessing survivability in "Designing with Geosynthetics" R.M. Koerner 1994. (see pg 2-4)

Minimum Properties	High Survivibility	Very High Survivibility	NSC 60 THDPE	NSC 60 mil smooth HDPE
Thickness (mils)	35	40	60	60
Tensile (lb/in)	60	70	132	132
Tear (lb)	15	20	45	45
Puncture (lb)	35	40	108	108
Impact (ft-lb)	20	25	NV	NV

Conclusions: 60 mil THDPE exceeds all criteria for Very High Survivibility except for the impact value which is not specified by the manufacture.

Note: This calculation is applicable to all the site facilities that use geomembrane.

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602 0270
14-Nov-017
PMP

If the 196°C reaction took 1000 hours to complete, the comparable 90°C reaction would take

$$R_{90°C} = 6587(1000)$$
$$= 6{,}587{,}000 \text{ hours}$$
$$= 752 \text{ years}$$

Thus the predicted values for this particular polymer to reach 50% of its original impact strength at 90°C is approximately 700 years (i.e., its predicted lifetime).

5.1.6 Summary

This relatively long section on properties and test methods has illustrated the wealth of test methods available for use and characterization purposes of geomembranes. Most of the established tests and standardized test methods have come by way of the plastics and rubber industries for non-geotechnical-related uses. This is fortunate, for it gives a base or reference plane to work from. However, many have some variation required for use in below-ground construction. Still other demands require completely new tests and test methods. With ASTM in the United States (as well as standard institutes over the entire world), there is an awareness and vibrant activity to develop such test methods and standards. Until they are available, however, we must act on intuition and develop procedures that model the required design information as closely as possible. Many of the tests and information presented in this section were done in that light. It should be obvious that the complexity of the tests progressed from the simple thickness test to the complex degradation tests. Indeed, a wide range of test methods are available.

Finally, a rather lengthy treatise on durability and aging gave insight into the potential service lifetime of geomembranes. In my experience with geosynthetics over the past 15 years, my original thoughts were that geosynthetics were easy to place but wouldn't last very long. My current thoughts have shifted dramatically, and I argue for extremely long service lifetimes, but I have very real concerns about the proper placement of geosynthetics. Clearly, the geosynthetic must survive its placement if these long predicted lifetimes are to be achieved.

5.2 SURVIVABILITY REQUIREMENTS

For any of the design methods presented in this chapter to function properly, it is necessary that the geomembrane survive the packaging, transportation, handling, and installation demands that are placed on it. This aspect of design cannot be taken lightly or assumed to take care of itself. Yet there is a decided problem in formulating a generalized survivability design for every application, since each

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14-Nov-97

situation is unique. Some of the major variables affecting a given situation are the following:

pmp

- Storage at the manufacturing facility
- Handling at the manufacturing facility
- Transportation from the factory to the site
- Offloading at the site
- Storage conditions at the site
- Temperature extremes at the site
- Subgrade conditions at the site
- Deployment at the approximate location
- Movement into final seaming location
- Treatment at the site during seaming
- Treatment at the site after seaming
- Placement of the cover material or soil backfill on the completed geomembrane

Note that each of these topics is largely out of the hands of the designer. Only by rigid specifications and a complementary construction quality assurance (CQA) document, competent full-time inspection by CQA personnel, and the cooperation of a knowledgeable manufacturer's manufacturing quality control (MQC) and contractor's construction quality control (CQC) can the geomembrane survive to the point of beginning to function as designed. Although each situation is different, some empirical guidelines are necessary, and the following properties and their minimum values are offered.

While being packaged, transported, handled, and installed, geomembranes are often vulnerable to tear, puncture, and impact. Such events often come about accidentally, by vandalism, or by poor quality of work. Typical situations are the dropping of tools on the liner, the driving of autos or pickup trucks on the unprotected liner, high winds getting beneath the liner during placement, the awkwardness of moving large sheets of the liner into position, and so on. The geomembrane property most involved with resistance or susceptibility to tear, puncture, and impact damage is thickness. At least a linear, and sometimes exponential, increase in resistance to the aforementioned actions is seen as thickness increases. For this reason many agencies require a minimum thickness under any circumstance. For example, the U.S. Bureau of Reclamation requires a minimum thickness of 20 mils (0.50 mm) for canal liners, while the U.S. Environmental Protection Agency requires a minimum thickness for geomembranes for solid waste liners of 30 mils (0.75 mm). For similar applications in Germany, it is necessary to use an 80-mil (2.0-mm)-thick geomembrane. Rather than use a single regulated value for all conditions, however, the minimum thickness and its subsequent properties should be related to site-specific conditions. Using a concept similar to the placement of geotextiles, Table 5.11 is offered at four different required survivability levels. Note

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602-0200
14-Nov-97
PMP

Table 5.11 Recommended minimum properties for general geomembrane installation survivability

Property and Test Method	*Required Degree of Survivability*			
	Low[a]	*Medium*[b]	*High*[c]	*Very High*[d]
Thickness (D5199) mils (mm)	25 (0.63)	30 (0.75)	35 (0.88)	40 (1.00)
Tensile D882 (1.0 in. [25 mm] strip) lb./in. (kN/m)	40 (7.0)	50 (8.7)	60 (10.5)	70 (12.2)
Tear (D1004 Die C) lb. (N)	7.5 (33)	10 (45)	15 (67)	20 (90)
Puncture (D4833 modified) lb. (N)	25 (110)	30 (130)	35 (160)	40 (180)
Impact (D1424 modified) ft.-lb. (J)	12 (9)	15 (11)	20 (15)	25 (19)

[a]*Low* refers to careful hand placement on very uniform well-graded subgrade with light loads of a static nature—typical of vapor barriers beneath building floor slabs.

[b]*Medium* refers to hand or machine placement on machine-graded subgrade with medium loads—typical of canal liners.

[c]*High* refers to hand or machine placement on machine-graded subgrade of poor texture with high loads—typical of landfill liners and covers.

[d]*Very high* refers to hand or machine placement on machine-graded subgrade of very poor texture with high loads—typical of reservoir covers and liners for heap leach pads.

that these values are not to be used in place of design, but as a check on design to see that installation can be properly assured.

5.3 LIQUID CONTAINMENT (POND) LINERS

The U.S. EPA estimates that there are over 200,000 surface impoundments storing hazardous and nonhazardous liquids, the vast majority of which are unlined. This total does not include potable water and non-EPA-regulated reservoirs and impoundments. Certainly a major use of geomembranes is in the area of liquid containment via a surface impoundment. In fact, the name *geomembrane* is actually one that supersedes the name *pond liner,* reflecting the original use of the polymeric materials to which this section is devoted. Certainly, the agriculture industry has a desperate need to store water, and hence both the U.S. Department of Agriculture and the U.S. Bureau of Reclamation were involved in early research into synthetic pond liners. Staff [36] suggests that thermoset (rubber) liners may have been used prior to the 1930s, and cites the use of polyvinyl chloride sheeting for liners in the 1940s. When covered with a minimum of 12 in. (30 cm) of soil, these PVC liners have performed admirably. Uncovered, however, there was a tendency for progressive brittleness and cracking. This condition was found to be caused by the loss of the plasticizer (used to make it flexible to begin with) from the vinyl due

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FRICTION SEAL™ HD GEOMEMBRANE
QUALITY CONTROL SPECIFICATIONS
60 mil

FRICTION SEAL HD, National Seal Company's advanced textured high density polyethylene (HDPE) geomembrane, is manufactured by attaching a friction surface to NSC's high quality HDPE geomembrane. The friction surface is made from high molecular weight polyethylene resin compounded specifically for use in NSC geomembranes. The resin has been formulated to provide stress crack, chemical and ultraviolet resistance for fluid containment. NSC produces FRICTION SEAL HD with a textured surface on one or both sides of the parent sheet.

The following properties are tested as a part of NSC's quality control program. Certified test results for properties on this page are available upon request. Refer to NSC's Quality Control Manual for exact test methods and frequencies.

RESIN PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Melt Flow Index[2]	ASTM D 1238	g/10 min	0.50	0.25
Oxidative Induction Time	ASTM D 3895, Al pan, 200°C, 1 atm O_2	minutes	100	120

SHEET PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Mass per Unit Area[3]	ASTM D 3776	lb/ft^2	0.31	0.32
Thickness[4]	ASTM D 751, NSF mod.			
Average		mils	60.0	61.5
Individual		mils	57.0	59.7
Density[4]	ASTM D 1505	g/cm^3	0.940	0.948
Carbon Black Content[4]	ASTM D 1603	percent	2.0-3.0	2.35
Carbon Black Dispersion[4]	ASTM D 3015, NSF mod.	rating	A1, A2, B1	A1
Tensile Properties[5]	ASTM D 638			
Stress at Yield		psi	2200	2750
		ppi	132	169
Stress at Break		psi	2200	3240
		ppi	132	199
Strain at Yield	1.3" gage length (NSF)	percent	13.0	17.5
Strain at Break	2.0" gage or extensometer	percent	200	540
	2.5" gage length (NSF)	percent	160	432
Dimensional Stability[2,4]	ASTM D 1204, NSF mod.	percent	1.5.	0.4
Tear Resistance	ASTM D 1004	ppi	750	1000
		lbs	45	62
Puncture Resistance	ASTM D 4833	ppi	1800	2276
		lbs	108	140
Constant Load ESCR, Single Point[4]	GRI, GM-5a	hours	200	>400
Friction Angle, Index	GRI, GS-7	degrees	40	56

[1] This value represents the minimum acceptable test value for a roll as tested according to NSC's Manufacturing Quality Control Manual. Individual test specimen values are not addressed in this specification except thickness.

[2] Indicates Maximum Value

[3] Friction Coating on both sides of base sheet

[4] Testing performed on base sheet

[5] Stress and strength values are normalized to the nominal base sheet thickness. NSC certifies properties based on values calculated using nominal thickness only. Stress values calculated using actual product thickness is not guaranteed due to the lack of industry accepted thickness test procedures for friction sheet.

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FRICTION SEAL™ HD GEOMEMBRANE
PHYSICAL PROPERTIES

60 mil

The properties on this page are not part of NSC's Manufacturing Quality Control program and are not included on the material certifications. Seam testing is the responsibility of the installer and/or CQC personnel.

PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Multi-Axial Tensile Elongation	GRI, GM-4	percent	20.0	22.3
Critical Cone Height	GRI, GM-3, NSC mod.	cm	1.0	1.5
Wide Width Tensile	ASTM D 4885			
Stress at Yield		psi	2000	2110
Strain at Yield		%	15.0	20.0
Brittleness Temp. by Impact[2]	ASTM D 746	°C	-75	<-90
Coef. of Linear Thermal Exp.[2]	ASTM D 696	$°C^{-1}$	1.5×10^{-4}	1.2×10^{-4}
ESCR, Bent Strip	ASTM D 1693	hours	1500	>10,000
Hydrostatic Resistance	ASTM D 751	psi	450	550
Modulus of Elasticity	ASTM D 638	psi	80,000	116,000
Ozone Resistance[4]	ASTM D 1149, 168 hrs	P/F	P	P
Permeability[2,4]	ASTM E 96	cm/sec · Pa	2.3×10^{-14}	8.1×10^{-15}
Puncture Resistance	FTMS 101, method 2065	ppi	1300	1570
		lbs	78	97
Soil Burial Resistance[2]	ASTM D 3083, NSF mod.	% change	10	0
Tensile Impact	ASTM D 1822	ft lbs/in^2	130	160
Volatile Loss[2]	ASTM D 1203, A	percent	0.10	0.08
Water Absorption[2,4]	ASTM D 570, 23°C	percent	0.10	0.04
Water Vapor Transmission[2,4]	ASTM E 96	g/day · m^2	0.024	0.009

SEAM PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Shear Strength	ASTM D 4437, NSF mod.	psi	2000	2700
		ppi	120	166
Peel Strength	ASTM D 4437, NSF mod.	psi	1500	1870
(hot wedge fusion)		ppi	90	115
Peel Strength	ASTM D 4437, NSF mod.	psi	1300	1590
(fillet extrusion)		ppi	78	98

STANDARD ROLL DIMENSIONS

Length	850 feet	Area	12,750 ft^2
Width	15 feet	Weight	3,950 lbs

This information contained herein has been compiled by National Seal Company and is, to the best of our knowledge, true and accurate. All suggestions and recommendations are offered without guarantee. Final determination of suitability for use based on any information provided, is the sole responsibility of the user. There is no implied or expressed warranty of merchantability of fitness of the product for the contemplated use.

NSC reserves the right to update the information contained herein in accordance with technological advances in the material properties.

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HDPE GEOMEMBRANE
QUALITY CONTROL SPECIFICATIONS

60 mil

National Seal Company's High Density Polyethylene (HDPE) Geomembranes are produced from virgin, first quality, high molecular weight resins and are manufactured specifically for containment in hydraulic structures. NSC HDPE geomembranes have been formulated to be chemically resistant, free of leachable additives and resistant to ultraviolet degradation.

The following properties are tested as a part of NSC's quality control program. Certified test results for properties on this page are available upon request. Refer to NSC's Quality Control Manual for exact test methods and frequencies.

All properties meet or exceed NSF Standard Number 54.

RESIN PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Melt Flow Index[2]	ASTM D 1238	g/10 min	0.50	0.25
Oxidative Induction Time	ASTM D 3895, Al pan, 200°C, 1 atm O_2	minutes	100	120

SHEET PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Thickness	ASTM D 751, NSF mod.			
Average		mils	60.0	61.5
Individual		mils	57.0	59.7
Density	ASTM D 1505	g/cm^3	0.940	0.948
Carbon Black Content	ASTM D 1603	percent	2.0-3.0	2.35
Carbon Black Dispersion	ASTM D 3015, NSF mod.	rating	A1, A2, B1	A1
Tensile Properties	ASTM D 638			
Stress at Yield		psi	2200	2550
		ppi	132	157
Stress at Break		psi	3800	4850
		ppi	228	298
Strain at Yield	1.3" gage length (NSF)	percent	13.0	16.9
Strain at Break	2.0" gage or extensometer	percent	700	890
	2.5" gage length (NSF)	percent	560	710
Dimensional Stability[2]	ASTM D 1204, NSF mod.	percent	1.5	0.4
Tear Resistance	ASTM D 1004	ppi	750	860
		lbs	45	53
Puncture Resistance	ASTM D 4833	ppi	1800	2130
		lbs	108	131
Constant Load ESCR, Single Point	GRI, GM-5a	hours	200	>400

[1] This value represents the minimum acceptable test value for a roll as tested according to NSC's Manufacturing Quality Control Manual. Individual test specimen values are not addressed in this specification except thickness.

[2] Indicates Maximum Value

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HDPE GEOMEMBRANE
PHYSICAL PROPERTIES

60 mil

The properties on this page are not part of NSC's Manufacturing Quality Control program and are not included on the material certifications. Seam testing is the responsibility of the installer and/or CQA personnel.

PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Multi-Axial Tensile Elongation	GRI, GM-4	percent	20.0	28.0
Critical Cone Height	GRI, GM-3, NSC mod.	cm	1.0	1.5
Wide Width Tensile	ASTM D 4885			
Stress at Yield		psi	2000	2110
Strain at Yield		%	15.0	20.0
Brittleness Temp. by Impact[2]	ASTM D 746	°C	-75	<-90
Coef. of Linear Thermal Exp.[2]	ASTM D 696	$°C^{-1}$	1.5×10^{-4}	1.2×10^{-4}
ESCR, Bent Strip	ASTM D 1693	hours	1500	>10,000
Hydrostatic Resistance	ASTM D 751	psi	450	510
Modulus of Elasticity	ASTM D 638	psi	80,000	135,000
Ozone Resistance	ASTM D 1149, 168 hrs	P/F	P	P
Permeability[2]	ASTM E 96	cm/sec · Pa	2.3×10^{-14}	8.1×10^{-15}
Puncture Resistance	FTMS 101, method 2065	ppi	1300	1700
		lbs	78	105
Soil Burial Resistance[2]	ASTM D 3083, NSF mod.	% change	10	0
Tensile Impact	ASTM D 1822	ft lbs/in^2	250	420
Volatile Loss[2]	ASTM D 1203, A	percent	0.10	0.06
Water Absorption[2]	ASTM D 570, 23°C	percent	0.10	0.04
Water Vapor Transmission[2]	ASTM E 96	g/day · m^2	0.024	0.009

SEAM PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Shear Strength	ASTM D 4437, NSF mod.	psi	2000	2700
		ppi	120	166
Peel Strength	ASTM D 4437, NSF mod.	psi	1500	1870
(hot wedge fusion)		ppi	90	115
Peel Strength	ASTM D 4437, NSF mod.	psi	1300	1590
(fillet extrusion)		ppi	78	98

STANDARD ROLL DIMENSIONS

Length	1110 feet	Area	16,650 ft^2
Width	15 feet	Weight	5,000 lbs

This information contained herein has been compiled by National Seal Company and is, to the best of our knowledge, true and accurate. All suggestions and recommendations are offered without guarantee. Final determination of suitability for use based on any information provided, is the sole responsibility of the user. There is no implied or expressed warranty of merchantability of fitness of the product for the contemplated use.

NSC reserves the right to update the information contained herein in accordance with technological advances in the material properties.

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TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Geomembrane Puncture Resistance In landfill

	Name	Date
Prepared By:	P. Pellicer	14-Nov-97
Checked By:	J. Pellicer	14-Nov-97
Reviewed By:	P. Gobel	14Nov97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triasic Park
Project Number: 602-0200 Sheet: 1 Of 1
Prepared By: P. Pellicer Date: 14-Nov-97
Checked By: J. Pellicer Date: 14-Nov-97

Geomembrane Puncture Resistance

Objective: Evaluate Puncture resistance of the Geomembrane Liner and cover.

Method: All geomembranes in the landfill liner system and cover system are protected by at least one layer of Geotextile (Geocomposite or GCL)
Review of the Puncture resistance of Geotextile / Geocomposite calculation indicate that for worst case scenerio the geotextile has a minimum F.S. = 3.5 (11/200 Geotextile)
∴ the threat of puncture of the geomembrane is Negligible.

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TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Geomembrane Puncture Resistance

	Name	Date
Prepared By:	P. Pellicer	14-Nov-97
Checked By:	J. Pellicer	15-Nov-97
Reviewed By:	P. Gobel	15 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of 8
Prepared By: P. Pellicer Date: 14-Nov-97
Checked By: J. Pullen Date: 15-Nov-97

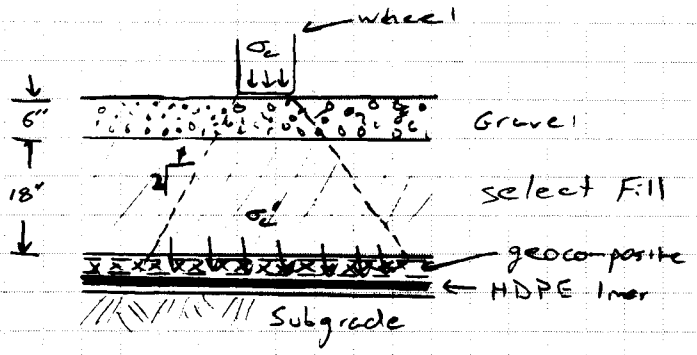
Geomembrane Puncture Resistance

Objective: Assess the Risk of Puncture of the Geomembrane for the Evap. Pond, Drum handling area and Truck roll off.

Method: The critical contact for these three facilities is between the prepared subgrade (or clay liner) and the HDPE liner. Apply Method outlined in R.M. Koerners "Designing with Geosynthetics" 1994 for determining Puncture resistance of Geotextiles.

Calculations: Of these three facilities the Truck roll off will have the largest pressures on the Geomembrane. These pressures were determined using a HS20 axle load of 32 kips (this is a large semi-truck load used for highway design, see pg 3).

Determine pressure on geomembrane:



assume 1:2 Distribution

σ_c = Tire contact pressure = 70 psi

σ_c' = Pressure at Depth = $\sigma_c \left[\frac{R^2}{(R+D)^2}\right] + D\,\gamma_{soil}$, assume γ_{soil} = 125pcf

D = Cover Thickness = 24"

R = effective Radius of tire Contact = $\left[P/\pi\sigma_c\right]^{1/2}$

P = axle load = 32 kips

$R = \left[32000\,lb/\pi * 70\,psi\right]^{1/2} = 12\,in$ ✓

$\sigma_c' = 70\,psi\left[\frac{12\,in^2}{(12+24)^2}\right] + \left[2\,ft * 125\,pcf * \frac{1\,ft^2}{144\,in^2}\right] = \underline{9.5\,psi}$ ✓

TerraMatrix
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From the specifications the largest particle size for the clay liner and prepared subgrade = 1 in

Determine required puncture resistance:

$$F_{reqd} = p' d_a^2 S_1 S_2 S_3 \quad \text{(see pg 4-5)}$$

F_{reqd} = required vertical force to be resisted.
p' = pressure exerted on geomembrane = 9.5 psi
d_a = average particle size (will use maximum size = 1", very conservative)
S_1 = protrusion factor = h_n / d_a
h_n = protrusion height $\leq d_a$
S_2 = Scale factor = $0.31 / d_a$
S_3 = Shape factor = $1 - A_p / A_c$
A_p/A_c = 0.4 for crushed rock (see pg 5) (conservative)

Set $h_n = 1'' \Rightarrow S_1 = 1''/1'' = 1$

$S_2 = 0.31/1 = 0.31$
$S_3 = 1 - 0.4 = 0.6$

$$F_{reqd} = (9.5\,psi)(1'')^2(1)(.31)(0.6) = 1.8 \text{ lbs}$$

From HDPE Spec Sheet (see pg 8) Puncture resistance for 60 mil HDPE = 108 lbs

$$F.S. = \frac{108 \text{ lbs}}{1.8 \text{ lbs}} = 60$$

Conclusions: Puncture of the HDPE membrane at these facilities is very minimal. In addition to this calculation which assumes a 1" protrusion height, it is recommended that the CQA personel and liner installer walk the subgrade for acceptance purposed. Recomended acceptance criteria typically suggest that the maximum allowable size stone protruding from or lying on the subgrade surface is 1/2" in diameter or less. (see pg 6-7)

Forces resulting from elastic deformations, including rib shortening R

Forces resulting from thermal deformations T, including shrinkage S

Highway Bridge Loads ▪ *Vehicular live load* of highway bridges is expressed in terms of design lanes and lane loadings. The number of design lanes depends on the width of the roadway.

Each lane load is represented by a standard truck with trailer (Fig. 17-3) or, alternatively

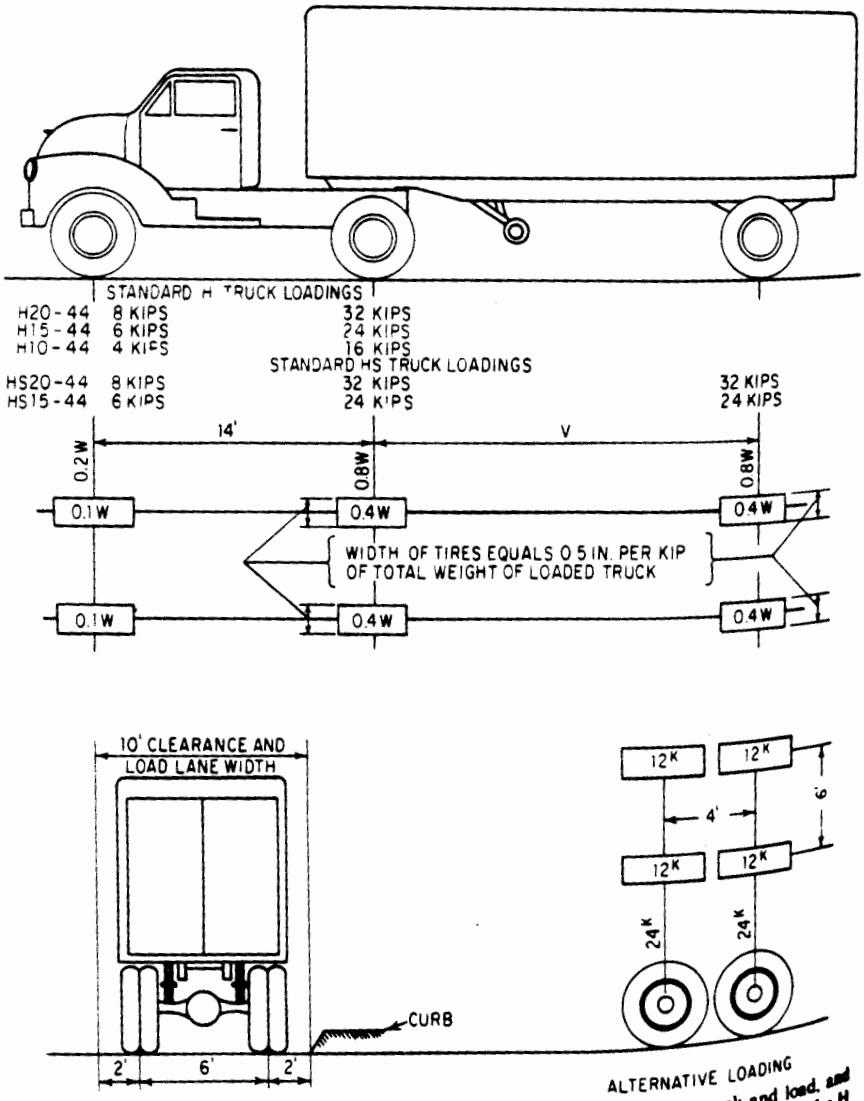

Fig. 17-3. Standard truck loading. For H trucks, W = total weight of truck and load, and for HS trucks, W = combined weight on the first two axles, which is the same weight as for H trucks. V indicates a variable spacing from 14 to 30 ft that should be selected to produce maximum stress.

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Solution: (a) Using a maximum strain of 33%, the value of $f(\epsilon) = 0.52$. Thus the required grab tensile strength is as follows:

$$\begin{aligned} T_{reqd} &= p'(d_v)^2(0.52) \\ &= p'(0.33\ d_a)^2(0.52) \\ &= 0.057\ p'd_a^2 \\ &= 0.057(100)(2.0)^2 \\ &= 22.6 \text{ lb.} \end{aligned}$$

(b) The global factor of safety on a 125-lb. ultimate grab tensile geotextile with partial factors of safety of 2.5 is as follows:

$$\begin{aligned} FS &= \frac{T_{allow}}{T_{reqd}} \\ &= \frac{125/2.5}{22.6} \\ &= 2.2, \text{ which is acceptable.} \end{aligned}$$

2.5.4 Puncture Resistance

Although not only related to the separation function, the geotextile during its placement must survive the installation process. Indeed, fabric survivability is critical in all types of applications; without it, the best of designs are futile (recall Section 2.2.5.1). In this regard, sharp stones, tree stumps, roots, miscellaneous debris, and other things on the ground beneath the geotextile could puncture through the geotextile after stone base and traffic loads are imposed above it. The design method suggested for this situation is shown schematically in Figure 2.29. For these conditions, the vertical force exerted on the geotextile (which is gradually tightening around the protruding object) is as follows:

$$F_{reqd} = p'd_a^2 S_1 S_2 S_3 \tag{2.30}$$

where F_{reqd} = the required vertical force to be resisted,
p' = the pressure exerted on the geotextile (approximately 100% of tire inflation pressure at the ground surface for small stone thicknesses),
d_a = the average diameter of the puncturing aggregate or sharp object,
S_1 = protrusion factor = h_h/d_a,
h_h = protrusion height $\leq d_a$,
S_2 = scale factor to adjust ASTM D4833 test value using 5/16-in.-diameter puncture probe to actual puncturing object = $0.31/d_a$,
S_3 = shape factor to adjust flat puncture probe of ASTM D4833 to actual shape of puncturing object = $1 - A_p/A_c$ (values of A_p/A_c to be used

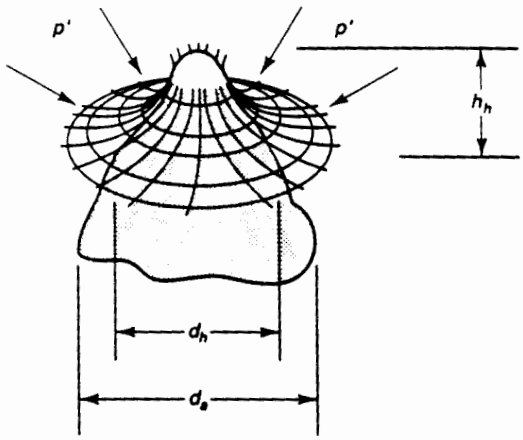

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Figure 2.29 Visualization of a stone puncturing a geotextile as pressure is applied from above.

range from 0.8 for Ottawa sand, 0.7 for run-of-bank gravel, 0.4 for crushed rock, and 0.3 for shot rock),

A_p = projected area of particle, and

A_c = area of smallest circumscribed circle.

Example:

What is the factor of safety against puncture of a geotextile from a 2.0-in. stone by a loaded truck with tire inflation pressure of 80 lb./in.^{2} traveling on the surface of the stone base? The geotextile has an ultimate puncture strength of 45 lb. according to ASTM D4833.

Solution: Using the full stress on the geotextile of 80 lb./in.^{2} and factors of 0.33, 0.155, and 0.6 for S_1, S_2, and S_3, respectively,

$$\begin{aligned} F_{\text{reqd}} &= p' d_a^2 S_1 S_2 S_3 \\ &= 80 \times (2.0)^2(0.33)(0.155)(0.6) \\ &= 9.82 \text{ lb.} \end{aligned}$$

Assuming that the cumulative partial factor of safety is 2.0, the global factor of safety is as follows:

$$\begin{aligned} FS &= \frac{F_{\text{allow}}}{F_{\text{reqd}}} \\ &= \frac{45/2.0}{9.82} \\ &= 2.3, \text{ which is acceptable.} \end{aligned}$$

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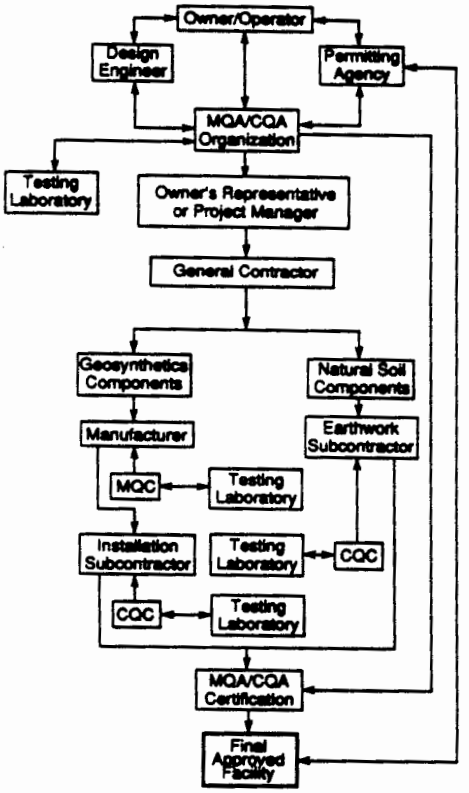
David E. Daniel and Robert M. Koerner

Waste Containment Facilities



Guidance for Construction, Quality Assurance and Quality Control of Liner and Cover Systems

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Some items recommended for a specification or CQA document include the following:

- The soil subgrade shall be of the specified grading, moisture content, density and surface finish as required by the installer and as approved by the CQA engineer for placement of the geomembrane. See Chapter 3 for these details for compacted clay liner subgrades.
- Construction equipment deploying the rolls or pallets shall not deform or rut the soil subgrade excessively. Tire or track deformations beneath the geomembrane should not be greater than 25 mm (1 in.) in depth. The geomembrane shall not be deployed on frozen subgrade where ruts are greater than 12 mm (0.5 in.) in depth.
- The plans, specifications, and/or QA documents should be very specific about the maximum allowable size stone protruding from the soil subgrade, or alternatively, lying on the surface of the subgrade. This issue is related to the type of geomembrane, with HDPE and CSPE-R being the most sensitive [maximum size generally being 12 mm (0.5 in.)], and VLDPE and PVC being less sensitive in this regard.
- When placing the geomembrane on another geosynthetic material (geotextile, geonet, etc.), construction equipment should not be permitted to ride directly on the lower geosynthetic material. In cases where rolls must be moved over previously placed geosynthetics it is necessary to move materials by hand or by using small pneumatic tired lifting units. Tire inflation pressures should be limited to a maximum value of 40 kPa (6 psi).
- Underlying geosynthetic materials (such as geotextiles or geonets) should have all folds, waves and other undulations removed before placement of the geomembrane.
- Care, and planning, should be taken to unroll or unfold the geomembrane close to its intended, and final, position.

4.3.4.2 Temperature Effects—Sticking/Cracking High temperatures can cause geomembrane surfaces on rolls, or accordion folded on pallets, to stick together, a process commonly called "blocking." At the other extreme, low temperatures can cause geomembrane sheets to crack when unrolled or unfolded. Comments on unrolling, or unfolding of geomembranes at each of these temperature extremes follow.

When preparing a specification or CQA document, some items to consider include the following:

FRICTION SEAL™ HD GEOMEMBRANE
PHYSICAL PROPERTIES

60 mil

The properties on this page are not part of NSC's Manufacturing Quality Control program and are not included on the material certifications. Seam testing is the responsibility of the installer and/or CQC personnel.

PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Multi-Axial Tensile Elongation	GRI, GM-4	percent	20.0	22.3
Critical Cone Height	GRI, GM-3, NSC mod.	cm	1.0	1.5
Wide Width Tensile	ASTM D 4885			
Stress at Yield		psi	2000	2110
Strain at Yield		%	15.0	20.0
Brittleness Temp. by Impact[2]	ASTM D 746	°C	-75	<-90
Coef. of Linear Thermal Exp.[2]	ASTM D 696	$°C^{-1}$	1.5×10^{-4}	1.2×10^{-4}
ESCR, Bent Strip	ASTM D 1693	hours	1500	>10,000
Hydrostatic Resistance	ASTM D 751	psi	450	550
Modulus of Elasticity	ASTM D 638	psi	80,000	116,000
Ozone Resistance[4]	ASTM D 1149, 168 hrs	P/F	P	P
Permeability[2,4]	ASTM E 96	cm/sec · Pa	2.3×10^{-14}	8.1×10^{-15}
Puncture Resistance	FTMS 101, method 2065	ppi	1300	1570
		lbs	78	97
Soil Burial Resistance[2]	ASTM D 3083, NSF mod.	% change	10	0
Tensile Impact	ASTM D 1822	ft lbs/in^2	130	160
Volatile Loss[2]	ASTM D 1203, A	percent	0.10	0.08
Water Absorption[2,4]	ASTM D 570, 23°C	percent	0.10	0.04
Water Vapor Transmission[2,4]	ASTM E 96	g/day · m^2	0.024	0.009

SEAM PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Shear Strength	ASTM D 4437, NSF mod.	psi	2000	2700
		ppi	120	166
Peel Strength	ASTM D 4437, NSF mod.	psi	1500	1870
(hot wedge fusion)		ppi	90	115
Peel Strength	ASTM D 4437, NSF mod.	psi	1300	1590
(fillet extrusion)		ppi	78	98

STANDARD ROLL DIMENSIONS

Length	850 feet	Area	12,750 ft^2
Width	15 feet	Weight	3,950 lbs

This information contained herein has been compiled by National Seal Company and is, to the best of our knowledge, true and accurate. All suggestions and recommendations are offered without guarantee. Final determination of suitability for use based on any information provided, is the sole responsibility of the user. There is no implied or expressed warranty of merchantability of fitness of the product for the contemplated use.

NSC reserves the right to update the information contained herein in accordance with technological advances in the material properties.

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TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Geotextile / Geocomposite Survivability

	Name	Date
Prepared By:	P. Pellicer	14-Nov-97
Checked By:	J. Pellicer	14-Nov-97
Reviewed By:	P. Corser	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

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Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of 5
Prepared By: P. Pellizer Date: 14-Nov-97
Checked By: J. Pellicer Date: 14-Nov-97

Geotextile/Geocomposite Survivability

Objective: Determine Min. Geotextile properties to survive Installation and Operational stresses.

Analysis: Follow Recommendations By R.M. Koerner "Designing with Geosynthetics" 1994

See Attached Recommendations for Medium to High Survivability and compare w/ min Geotextile values.

	High Survivability	Medium Survivability	trevira 011/200	trevira 011/250
grab strength	180 lb	115 lb	160	210
Puncture resistance	75 lb	40 lb	80	95
Trapezoid Tear	75 lb	40 lb	60	75
			ok Medium	ok. High

Conclusions: Geotextile properties should meet or exceed those listed for 011/200 textile for medium surviveability

Geotetextile properties should meet or exceed Those listed for 011/250 textile for High surviveability

THE GEOTEXTILE PROPERTIES SPEC. FOR USE AS FILTER OR CUSHION WILL MEET OR EXCEED HIGH SURVIVABILITY CRITERIA. (SEE ATTACHED SPEC. SHEETS.

Table 2.20 Required degree of survivability as a function of subgrade conditions and construction equipment*

Subgrade conditions	*Construction equipment and 6 to 12 in. of cover material: initial lift thickness*		
	Low ground-pressure equipment (≤4 lb./in.)	*Medium ground-pressure equipment (>4 lb./in.², ≤8 lb./in.²)*	*High ground-pressure equipment (>8 lb./in.²)*
Subgrade has been cleared of all obstacles except grass, weeds, leaves, and fine wood debris. Surface is smooth and level such that any shallow depressions and humps do not exceed 6 in. in depth or height. All larger depressions are filled. Alternatively a smooth working table may be placed.	Low	Moderate	High
Subgrade has been cleared of obstacles larger than small to moderate-sized tree limbs and rocks. Tree trunks and stumps should be removed or covered with a partial working table. Depressions and humps should not exceed 1 in. in depth or height. Larger depressions should be filled.	Moderate	High	Very high
Minimal site preparation is required. Trees may be felled, delimbed, and left in place. Stumps should be cut to project not more than 6 in. ± above subgrade. Fabric may be draped directly over the tree trunks, stumps, large depressions and humps, holes, stream channels, and large boulders. Items should be removed only if placing the fabric and cover material over them will distort the finished road surface.	High	Very high	Not recommended

*Recommendations are for 6 to 12 in. initial lift thickness. For other initial lift thicknesses:
12 to 18 in.: reduce survivability requirement one level;
18 to 24 in.: reduce survivability requirement two levels;
>24 in.: reduce survivability requirement three levels.
Survivability levels are in increasing order: low, moderate, high, and very high.
For special construction techniques such as prerutting, increase fabric survivability requirement one level.
Placement of excessive initial cover material thickness may cause bearing failure of soft subgrade.

Source: After Christopher and Holtz [146].

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14-Nov-97

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602-0200 PMP
14-Nov-97

Table 2.21 AASHTO-AGC-ARBTA Joint Committee minimum geotextile properties recommended for survivability (reference 4)

	Physical Property Requirements[a] Geotextiles < 50% Elongation/Geotextiles > 50% Elongation[b,c]		
Survivability Level	*Grab Strength ASTM D4632 (lb.)*	*Puncture Resistance ASTM D4833 (lb.)*	*Trapezoid Tear Strength ASTM D4533 (lb.)*
Medium	180/115	70/40	70/40
High	270/180	100/75	100/75

[a]Values shown are minimum average roll values. Strength values are in the weaker principal direction.

[b]Elongation (strain) at failure as determined by ASTM D4632, Grab Tensile.

[c]The values of geotextile elongation do not imply the allowable consolidation properties of the subgrade soil. These must be determined by a separate investigation.

price indexes, site and climate variations, type and quantity of geotextile, and so on, a few comments are in order.

The cost of the geotextile itself is reasonably related to its mass per unit area. Heavier geotextiles cost proportionately more than lighter ones. Note, however, that the installation cost may not be significantly higher for the heavier geotextiles. The type of manufacture is also a factor, with woven slit film generally being the least expensive, then nonwoven heat bonded and needle-punched nonwoven, and then woven monofilament, which is the most expensive on the basis of an equivalent mass per unit area. These comments, however, should in no way sway a design toward preference of one geotextile over another. They are offered only to give a feeling for the costs involved. As of this writing, these costs ranged from \$0.40 to \$1.50/yd.^{2} for geotextiles in the range 4.0 to 16.0 oz./yd.^{2}, with installation costs being an additional \$0.15 to \$0.60/yd.^{2} depending on the site conditions, quantity involved, and particular application.

Geotextile availability is sometimes very important. In aggressively marketed areas, many geotextiles are available and the free-market system will sort things out. In more remote areas, however, where only one or two geotextiles are available, design must necessarily reflect this situation. It is unrealistic to think that manufacturers will "tailor-make" a geotextile to your design specification if it involves only a small quantity for a remote area.

In a similar vein, union situations have been known to affect costs, as has patent infringement in certain select areas.

2.11.4 Summary

At the heart of any well-designed facility is its proper and careful construction. In my personal investigations of geotextile-related failures, only nine failures were design related (five were clogging problems, two retention problems, and two low-strength problems); all the others (approximately 25) were construction related. Of the latter group, two were loss of strength due to excessive UV exposure, two were from lack of proper overlap on soft soils (sewing would have undoubtedly

3.05 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all prior work, materials and partially-completed and completed work of these General Specifications.

B. The CQA Engineer will identify any areas requiring repair. The Contractor shall make repairs and replacements as necessary, to the approval of the Owner, and at no additional cost to Owner.

C. The CQA Engineer will issue an approval of geotextile filter, cushion, separator, or sacrificial layer installation in accordance with the CQA Plan prior to placement of material over the geotextile.

TABLE 02714-1
REQUIRED FILTER GEOTEXTILE PROPERTIES

Properties	Units	Specified Values [4]	Test Method
Polymer composition	%	95 [polypropylene, polyester, or polyethylene by weight]	
Mass per unit area	oz/yd^2	8	ASTM D 3776
Apparent opening size	mm	O_{95} < 0.212mm	ASTM D 4751
Permitivity	sec^{-1}	0.1	ASTM D 4491
Grab strength	lb	200	ASTM D 4632[1]
Tear strength	lb	85	ASTM D 4533[2]
Puncture strength	lb	100	ASTM D 4833 [3]

Notes:

1. Minimum values for both machine and cross machine direction with 1 inch clamp on constant rate of extension (CRE) machine.
2. Minimum value measured in machine and cross machine direction.
3. Tension testing machine with a 1.75-inch diameter ring clamp, the steel ball being replaced with a 0.31-inch diameter solid steel cylinder with flat tip centered within the ring clamp.
4. Values represent minimum average roll values (i.e., any roll in a lot should meet or exceed the values in this table). The specified apparent opening size is a maximum average roll value.

TABLE 02714-2
REQUIRED CUSHION GEOTEXTILE PROPERTIES

Properties	Qualifier	Units	Specified Values [4]	Test Method
Polymer composition	minimum	%	95 [polypropylene, polyester, or polyethylene by weight]	
Mass per unit area	minimum	oz/yd^2	12	ASTM D 3776
Grab strength	minimum	lb	300	ASTM D 4632[1]
Tear strength	minimum	lb	110	ASTM D 4533[2]
Puncture strength	minimum	lb	135	ASTM D 4833 [3]

PART A AND PART B PERMIT APPLICATION

FOR THE

TRIASSIC PARK HAZARDOUS WASTE FACILITY

Volume VI

Appendix E - Engineering Calculations (Con't.)
Appendix F - Surface Water Control Plan
Appendix G - Landfill Action Leakage Rate and Response Action Plan

December 1997

Prepared By:

established 1959

and

TerraMatrix
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LIST OF APPENDICES

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C	Lithology Logs
D	Geophysical Logs
E	Geotechnical Laboratory Results
F	Grain Size Analyses
G	Cross-Sections
H	Example Waste Profile Sheet
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Volume III

Engineering Report

Appendix A - Drawings

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Appendix B - Construction Quality Assurance Plan
Appendix C - Construction Specifications

Volume V - Engineering Report - Appendices

Appendix D - Laboratory Test Results
Appendix E - Engineering Calculations

Volume VI - Engineering Report - Appendices

Appendix E - Engineering Calculations - Continued
Appendix F - Surface Water Control Plan
Appendix G - Landfill Action Leakage Rate and Response Action Plan

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TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Geotextile / Geocomposite Filtration

	Name	Date
Prepared By:	P. Pellicer	14-Nov-97
Checked By:	J. Pellicer	14-Nov-97
Reviewed By:	P. Lorser	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

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Project Name: Trassic Park
Project Number: 602-0200 Sheet: 1 Of 2
Prepared By: P. Pellicer Date: 14-Nov-97
Checked By: J. Pellicer Date: 14-Nov-97

Geotextile / Geocomposite Filtration

Objective: Determine the ability of Geotextile/Geocomposite to filter on site silty sands and Upper dockum.

Analysis: The two critical soils that Geotextiles/Geocomposites will need to Retain are the onsite silty sands (used as protective soil layer and vegetative cover) and the upper dockum (clay liner, in sump area)

According to Task Force 25 the soil retention criteria is as Fallows.

1. If soil has ≤ 50% passing the #200 sieve Then the A.O.S. of Fabric ≥ No 30 sieve (≤ 0.6 mm)

2. If soil has > 50% Passing the # 200 sieve Then the A.O.S of Fabric ≥ #50 sieve (≤ 0.3 mm)

The onsite silty sand has < 50% passing the # 200 sieve and the upper doccum has > 50% passing the # 200 sieve

∴ Geotextiles Fabric should have
A.O.S. ≥ #50 sieve or ≤ 0.3 mm

Minimum A.O.S. of Trevira products. (see pg 2)

011/120	#50 sieve	0.3 mm	borderline
011/140	#50 sieve	0.3 mm	borderline
011/200	#70 sieve	0.21 mm	O.K.
011/250	#70 sieve	0.21 mm	O.K.
011/280	#70 sieve	0.21 mm	O.K.

Conclusion: 1) Use Trevira 011/200 (equivalant or better) for geotextile and on geocomposites.

2) Use any Geotextile with AOS of 0.21m (#70 Sieve) or Less.

Trevira® Spunbond nonwoven engineering products are highly needled fabrics with excellent tensile properties, high filtration potential and outstanding permeability.

Trevira® Spunbond Type 11 products are 100% continuous filament polyester nonwoven needlepunched engineering fabrics. They deliver a combination of advantages unmatched by any other spunbonded geotextiles. They're resistant to freeze-thaw, soil chemicals and ultraviolet light exposure.

Trevira® Spunbond nonwoven engineering fabrics offer excellent performance where the requirement is tensile reinforcement, planar flow, filtration, or separation. They are ideal for roadways, railbeds, drainage systems, lining systems, retaining walls. And much more.

TYPICAL PHYSICAL PROPERTIES OF TREVIRA® TYPE 11 PROPERTIES

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fabric Weight	oz/yd²	ASTM D-5261	3.5	4.2	6.0	7.5	8.5	10.5	12.4	13.5	16.5
Fabric Thickness, t	mils	ASTM D-5199	60	70	90	110	120	140	165	170	210
Grab Strength (MD/CD)[1]	lbs	ASTM D-4632	120/105	150/125	230/180	300/235	320/260	420/350	475/400	540/450	650/570
Grab Elongation (MD/CD)[1]	%	ASTM D-4632	75/85	75/85	75/85	75/80	75/80	75/80	75/80	80/80	85/85
Trapezoid Tear Strength (MD/CD)[1]	lbs	ASTM D-4533	50/40	55/50	80/75	105/95	110/100	140/125	170/145	180/165	225/200
Puncture Resistance	lbs	ASTM D-4833	55	65	95	115	125	155	170	185	225
Mullen Burst Strength	psi	ASTM D-3786	195	225	330	400	435	560	600	700	855
Water Flow Rate	gpm/ft²	ASTM D-4491	195	190	170	150	130	120	105	100	80
Permittivity, Ψ	sec⁻¹	ASTM D-4491	2.61	2.54	2.27	2.01	1.76	1.6	1.47	1.34	1.07
Permeability, k = Ψxt	cm/sec	ASTM D-4491	.40	.45	.52	.56	.53	.57	.62	.58	.57
AOS	Sieve Size mm	ASTM D-4751	70-100 .210-.149	70-100 .210-.149	70-100 .210-.149	70-100 .210-.149	70-120 .210-.125	100-120 .149-.125	100-140 .149-.106	120-140 .125-.106	140-170 .106-.088
Standard Roll Widths[2]	ft		12.5 and 15.0								
Standard Roll Lengths[2]	ft		400	400	300	300	300	300	300	300	300

[1]MD = Machine Direction, CD = Cross Machine Direction.

[2]Other width and length rolls are available upon request.

MINIMUM† PHYSICAL PROPERTIES OF TREVIRA® TYPE 11 PROPERTIES

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fabric Weight	oz/yd²	ASTM D-5261	3.3	4.0	5.7	7.1	8.0	10.0	12.0	13.0	16.0
Fabric Thickness, t	mils	ASTM D-5199	50	55	75	95	105	125	145	150	185
Grab Strength	lbs	ASTM D-4632	90	110	160	210	230	305	350	390	500
Grab Elongation	%	ASTM D-4632	60	60	60	60	60	60	60	65	70
Trapezoid Tear Strength	lbs	ASTM D-4533	30	40	60	75	80	100	120	130	150
Puncture Resistance	lbs	ASTM D-4833	45	50	80	95	100	130	150	155	195
Mullen Burst Strength	psi	ASTM D-3786	170	190	285	360	380	510	550	640	780
Water Flow Rate	gpm/ft²	ASTM D-4491	155	150	130	110	90	80	65	60	40
Permittivity, Ψ	sec⁻¹	ASTM D-4491	2.07	2.01	1.74	1.47	1.20	1.07	0.87	0.80	0.53
Permeability, k = Ψxt	cm/sec	ASTM D-4491	.26	.28	.33	.35	.32	.34	.32	.31	.25
AOS	Sieve Size mm	ASTM D-4751	50 .300	50 .300	70 .210	70 .210	70 .210	70 .210	70 .210	100 .149	100 .149

†These minimum values represent minimum test values as determined from Quality Control (Q.C.) testing.

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TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic

Project No. 602-0200

Calculation Title: Puncture Resistance of Geotextile/Geocomposite

	Name	Date
Prepared By:	P. Pellicer	14-Nov-97
Checked By:	J. Pellicer	14-Nov-97
Reviewed By:	R. Corsel	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

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Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of 5
Prepared By: P. Pellicer Date: 14-Nov-97
Checked By: J. Pellicer Date: 14-Nov-97

Puncture Resistance of Geotextile / GeoComposite

Objective: Determine puncture resistance of geotextile

Calculation:

Use formula outlined in "Designing with Geosynthetics" 3rd Ed. Koerner, 1995, pg 165 (see pg 4)

$$F_{Req} = p' d_a^2 S_1 S_2 S_3$$

F_R = required vertical force to be resisted
p' = pressure exerted on geotextile
d_a = average diameter of puncturing aggregate
S_1 = protrusion factor, h_h/d_a
h_h = protrusion height $\leq d_a$
S_2 = scale factor to adjust ASTM D4833 test value using 5/16" dia. puncture probe to actual puncturing object = $0.31 d_a$
S_3 = shape factor to adjust flat puncture probe of ASTM D4833 to actual shape of puncturing object = $1 - A_p/A_c$
A_p = projected area of particle
A_c = area of smallest circumscribed circle.

Worst Case Scenario occurs in sump area w/ sump drainage gravel (see specification for grain size) and ≈ 160 ft of waste (conservative)

Sump Gravel is 1" minus to be conservative set d_a = 1" (Largest grain size)

$p' = (160\ ft)(110\ psf) = 17{,}600\ psf \left(\frac{1\ ft^2}{144\ in^2}\right) = 122\ psi$ ✓

$S_1 = h_h/d_a$, assume $h_h = d_a$, $\Rightarrow S_1 = 1$ (conservative) ✓

$S_2 = 0.31 d_a = (0.31)(1") = 0.31"$ ✓

$S_3 = 1 - A_p/A_c$, assume $A_p/A_c = 0.4$ (crushed rock see pg 5)
$= 1 - .4 = .6$ ✓

$F_R = (122\ psi)(1")^2(1)(0.31)(.6) = 22.7\ lbs.$ ✓

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Project Name: Triassic Park
Project Number: 602-0200 Sheet: 2 Of 5
Prepared By: P. Pellizer Date: 14-Nov-97
Checked By: J. Pellicer Date: 14-Nov-97

See attached spec. sheet for geotextile minimum Puncture Resistance (see pg 3).

Trevira Geotextile	Min. Puncture Resistance (lb)	F_R (lb)	S.F.	
011/120	45	22.7	2.0	Low
011/140	50	22.7	2.2	Low
011/200	80	22.7	3.5	o.k.
011/250	95	22.7	4.2	o.k.
011/280	100	22.7	4.4	o.k.

NSC Geocomposite comes w/ Trevira 011/250 geotextile standard. from the table above this has a F.S. = 3.6 against puncture. o.k.

Conclusion: Trevira 011/200 or better (or equivelent) will be o.k. to use anywhere on the site where it comes in contact w/ soils w/ a $d_a \leq 1''$ and has a contact pressure $p' \leq 122$ psi.

Trevira® Spunbond nonwoven engineering products are highly needled fabrics with excellent tensile properties, high filtration potential and outstanding permeability.

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Trevira® Spunbond nonwoven engineering fabrics offer excellent performance where the requirement is tensile reinforcement, planar flow, filtration, or separation. They are ideal for roadways, railbeds, drainage systems, lining systems, retaining walls. And much more.

TYPICAL PHYSICAL PROPERTIES OF TREVIRA® TYPE 11 PRODUCTS

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fabric Weight	oz/yd²	ASTM D-5261	3.5	4.2	6.0	7.5	8.5	10.5	12.4	13.5	16.5
Fabric Thickness, t	mils	ASTM D-5199	60	70	90	110	120	140	165	170	210
Grab Strength (MD/CD)[1]	lbs	ASTM D-4632	120/105	150/125	230/180	300/235	320/260	420/350	475/400	540/450	650/570
Grab Elongation (MD/CD)[1]	%	ASTM D-4632	75/85	75/85	75/85	75/80	75/80	75/80	75/80	80/80	85/85
Trapezoid Tear Strength (MD/CD)[1]	lbs	ASTM D-4533	50/40	55/50	80/75	105/95	110/100	140/125	170/145	180/165	225/200
Puncture Resistance	lbs	ASTM D-4833	55	65	95	115	125	155	170	185	225
Mullen Burst Strength	psi	ASTM D-3786	195	225	330	400	435	560	600	700	855
Water Flow Rate	gpm/ft²	ASTM D-4491	195	190	170	150	130	120	105	100	80
Permittivity, Ψ	sec⁻¹	ASTM D-4491	2.61	2.54	2.27	2.01	1.76	1.6	1.47	1.34	1.07
Permeability, k = Ψxt	cm/sec	ASTM D-4491	.40	.45	.52	.56	.53	.57	.62	.58	.57
AOS	Sieve Size mm	ASTM D-4751	70-100 .210-.149	70-100 .210-.149	70-100 .210-.149	70-100 .210-.149	70-120 .210-.125	100-120 .149-.125	100-140 .149-.106	120-140 .125-.106	140-170 .106-.088
Standard Roll Widths[2]	ft		12.5 and 15.0								
Standard Roll Lengths[2]	ft		400	400	300	300	300	300	300	300	300

[1]MD = Machine Direction, CD = Cross Machine Direction.

[2]Other width and length rolls are available upon request.

MINIMUM† PHYSICAL PROPERTIES OF TREVIRA® TYPE 11 PRODUCTS

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fabric Weight	oz/yd²	ASTM D-5261	3.3	4.0	5.7	7.1	8.0	10.0	12.0	13.0	16.0
Fabric Thickness, t	mils	ASTM D-5199	50	55	75	95	105	125	145	150	185
Grab Strength	lbs	ASTM D-4632	90	110	160	210	230	305	350	390	500
Grab Elongation	%	ASTM D-4632	60	60	60	60	60	60	60	65	70
Trapezoid Tear Strength	lbs	ASTM D-4533	30	40	60	75	80	100	120	130	150
Puncture Resistance	lbs	ASTM D-4833	45	50	80	95	100	130	150	155	195
Mullen Burst Strength	psi	ASTM D-3786	170	190	285	360	380	510	550	640	780
Water Flow Rate	gpm/ft²	ASTM D-4491	155	150	130	110	90	80	65	60	40
Permittivity, Ψ	sec⁻¹	ASTM D-4491	2.07	2.01	1.74	1.47	1.20	1.07	0.87	0.80	0.53
Permeability, k = Ψxt	cm/sec	ASTM D-4491	.26	.28	.33	.35	.32	.34	.32	.31	.25
AOS	Sieve Size mm	ASTM D-4751	50 .300	50 .300	70 .210	70 .210	70 .210	70 .210	70 .210	100 .149	100 .149

†These minimum values represent minimum test values as determined from Quality Control (Q.C.) testing.

The information contained herein is offered free of charge, and is, to our best knowledge, true and accurate; however, all recommendations or suggestions are made without guarantee, since the conditions of use are beyond our control. There is no expressed warranty and no implied warranty of merchantability or of fitness for purpose of the product or products described herein. In submitting this information, no liability is assumed or license or other rights implied given with respect to any existing or pending patent, patent applications or trademarks. The observance of all legal regulations and patents is the responsibility of the user.

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Solution: (a) Using a maximum strain of 33%, the value of $f(\epsilon) = 0.52$. Thus the required grab tensile strength is as follows:

$$
\begin{aligned}
T_{reqd} &= p'(d_v)^2(0.52) \\
&= p'(0.33\ d_a)^2(0.52) \\
&= 0.057\ p'd_a^2 \\
&= 0.057(100)(2.0)^2 \\
&= 22.6 \text{ lb.}
\end{aligned}
$$

(b) The global factor of safety on a 125-lb. ultimate grab tensile geotextile with partial factors of safety of 2.5 is as follows:

$$
\begin{aligned}
FS &= \frac{T_{allow}}{T_{reqd}} \\
&= \frac{125/2.5}{22.6} \\
&= 2.2, \text{ which is acceptable.}
\end{aligned}
$$

2.5.4 Puncture Resistance

Although not only related to the separation function, the geotextile during its placement must survive the installation process. Indeed, fabric survivability is critical in all types of applications; without it, the best of designs are futile (recall Section 2.2.5.1). In this regard, sharp stones, tree stumps, roots, miscellaneous debris, and other things on the ground beneath the geotextile could puncture through the geotextile after stone base and traffic loads are imposed above it. The design method suggested for this situation is shown schematically in Figure 2.29. For these conditions, the vertical force exerted on the geotextile (which is gradually tightening around the protruding object) is as follows:

$$F_{reqd} = p'd_a^2 S_1 S_2 S_3 \tag{2.30}$$

where F_{reqd} = the required vertical force to be resisted,
p' = the pressure exerted on the geotextile (approximately 100% of tire inflation pressure at the ground surface for small stone thicknesses),
d_a = the average diameter of the puncturing aggregate or sharp object,
S_1 = protrusion factor = h_h/d_a,
h_h = protrusion height $\leq d_a$,
S_2 = scale factor to adjust ASTM D4833 test value using 5/16-in.-diameter puncture probe to actual puncturing object = $0.31/d_a$,
S_3 = shape factor to adjust flat puncture probe of ASTM D4833 to actual shape of puncturing object = $1 - A_p/A_c$ (values of A_p/A_c to be used

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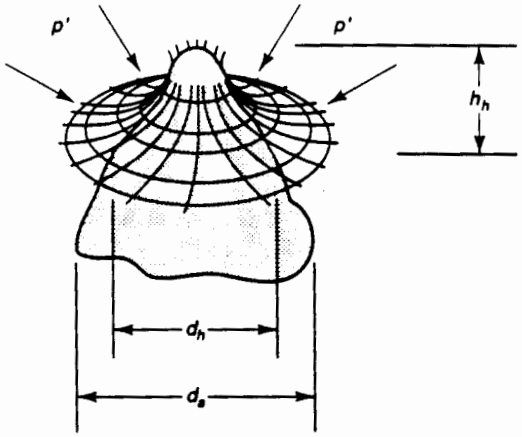

Figure 2.29 Visualization of a stone puncturing a geotextile as pressure is applied from above.

range from 0.8 for Ottawa sand, 0.7 for run-of-bank gravel, 0.4 for crushed rock, and 0.3 for shot rock),

A_p = projected area of particle, and

A_c = area of smallest circumscribed circle.

Example:

What is the factor of safety against puncture of a geotextile from a 2.0-in. stone by a loaded truck with tire inflation pressure of 80 lb./in.^{2} traveling on the surface of the stone base? The geotextile has an ultimate puncture strength of 45 lb. according to ASTM D4833.

Solution: Using the full stress on the geotextile of 80 lb./in.^{2} and factors of 0.33, 0.155, and 0.6 for S_1, S_2, and S_3, respectively,

$$\begin{aligned} F_{\text{reqd}} &= p' d_a^2 S_1 S_2 S_3 \\ &= 80 \times (2.0)^2(0.33)(0.155)(0.6) \\ &= 9.82 \text{ lb.} \end{aligned}$$

Assuming that the cumulative partial factor of safety is 2.0, the global factor of safety is as follows:

$$\begin{aligned} FS &= \frac{F_{\text{allow}}}{F_{\text{reqd}}} \\ &= \frac{45/2.0}{9.82} \\ &= 2.3, \text{ which is acceptable.} \end{aligned}$$

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TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Trissie Park

Project No. 602-0200

Calculation Title: GCL Material Properties

	Name	Date
Prepared By:	J. Pellicer	14-Nov-97
Checked By:	P. Pellicer	14-Nov-97
Reviewed By:	P. Carr	14Nov97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

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Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of 2
Prepared By: J. Pellicer Date: 14 Nov-97
Checked By: P. Pellicer Date: 14-Nov-97

GCL Material Properties

The material properties for the GCL are presented in the construction specifications. A copy of the required GCL properties are attached (pg 2).

The GCL material strengths are given in the attached specification. Shear strength characteristics of the material are addressed in the slope stability calculations. For further information regarding shear strength of slope, reference slope stability calculations.

Foundation and cover material associated with placement of the GCL are presented in the construction specifications.

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3.07 PROTECTION OF THE WORK

A. The Contractor shall use all means necessary to protect all materials and partially completed and completed work.

B. In the event of damage, the Contractor shall make repairs and replacements necessary to the approval of the Owner and at no additional cost to the Owner.

C. The CQA Engineer will issue an approval of the GCL liner installation to the Owner in accordance with the CQA Plan prior to placement of any material over the GCL.

TABLE 02780-1
REQUIRED GCL PROPERTIES[4]

Geotextile Properties	Test Method	Manufacturer's QC Minimum Test Frequency	Value -English-	Value -SI-
Nonwoven Mass/Unit Area	ASTM D 5261	1/ 200,000 sq. ft (1/20,000 sq. m)	7.4 oz./yd^2 Typical 6.0 oz./yd^2 MARV	250 g/m^2 Typical 200 g/m^2 MARV
Woven	ASTM D 5261	1/ 200,000 sq. ft (1/20,000 sq. m)	3.4 oz./yd^2 Typical 3.1 oz./yd^2 MARV	115 g/m^2 Typical 105 g/m^2 MARV
BENTONITE				
Swell Index	ASTM D 5890	1/100,000 lbs. (50,000 kg)	24 ml/2g min.	24 ml/2g min.
Moisture Content	ASTM D 4643	1/100,000 lbs. (50,000 kg)	12% max.	12% max.
Fluid Loss	ASTM D 5891	1/100,000 lbs. (50,000 kg)	18 ml max.	18 ml max.
FINISHED GCL [4]				
Bentonite Mass Per Unit Area[1]	ASTM D 5261	1/ 40,000 sq. ft (1/4,000 sq. m)	0.90 lb./sq. Ft MARV	4.39 kg/m^2 MARV
Grab Strength[2]	ASTM D 4362	1/ 40,000 sq. ft (1/4,000 sq. m)	95 lbs MARV	422 N MARV
Grab Elongation[2]	ASTM D 4632	1/ 40,000 sq. ft (1/4,000 sq. m)	75% Typical	75% Typical
Peel Strength	ASTM D 4632	1/ 40,000 sq. ft (1/4,000 sq. m)	15 lbs. min.	66 N min.
Permeability[3]	ASTM D 5084	1/100,000 sq. ft (1/10,000 sq. m)	5 x 10^{-9} cm/secec max	5 x 10^{-9} cm/secec max

Notes:
1. Oven-dried measurement reflecting a moisture content of zero.
2. Measured at maximum peak, in the weakest principal direction.
3. De-Aired Tap Water @ 5 psi maximum effective confining stress and 2 psi head.
4. Internal shear strength testing (ASTM D 5321) of QA conformance samples or proposed equal material will be performed by the CQA Engineer as described in this specification.

[END OF SECTION]

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TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Clay Liner Properties

	Name	Date
Prepared By:	J. Pellicer	14-Nov-97
Checked By:	P. Pellicer	14-Nov-97
Reviewed By:	P. Gore	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

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Project Name: Triassic Park
Project Number: 692-0200 Sheet: 1 Of 1
Prepared By: J. Pellicer Date: 14-Nov-97
Checked By: P. Pellicer Date: 14-Nov-97

Clay Liner Properties

Clay Liner Borrow Area: Clay liner material will be obtained from the landfill or evaporation pond excavation in Upper Dockum material.

Placement Specificat Window: Refer to the Construction Specifications for material placement window.

THE PLACEMENT SPECIFICATION WINDOW IS BASED ON SITE SPECIFIC TESTING OF CLAY LINER MATERIALS OBTAINED FROM THE SITE. THE RECOMPACTED PERMEABILITY TESTS ARE PRESENTED IN THE APPENDIX TO THE ENGINEERING REPORT.

COMPATIBILITY OF CLAY + WASTE: SINCE SAMPLES OF THE ACTUAL SITE LEACHATE IS NOT AVAILABLE, ACTUAL COMPATIBILITY TESTS COULD NOT BE CONDUCTED. HOWEVER, PREVIOUS TESTING OF CLAY LINER MATERIALS WITH TYPICAL HAZARDOUS WASTE LANDFILL ~~LIQUIDS~~ LEACHATES DOES NOT INDICATES SUBSTANTIAL CHANGES IN PERMEABILITY.

TYPICAL CHARACTERISTICS OF CLAY:

- USCS CLASSIFICATION - CL to CH
- PLASTICITY INDEX - 27%
- % LT #200 SIEVE - 83%
- RE-COMPACTED PERMEABILITY - 4.1×10^{-7} cm/sec

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TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Wheel Loading on Access Ramp

	Name	Date
Prepared By:	P. Pellicer	13-Nov-97
Checked By:	J. Pellicer	13-Nov-97
Reviewed By:	P-Cooper	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

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Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of 7
Prepared By: P. Pellizer Date: 13-Nov, 1997
Checked By: J. Pellicer Date: 13-Nov-97

Wheel Loading on Access Ramp.

Objective: verify that wheel loading will not Damage Geomembrane.

Assumptions: 631 Scraper will generate the largest pressure on the Geomembrane.

Calculations: Define contact stress on liner.

Assume 2:1 Distribution slope

$$\sigma_c' = \sigma_c \left[\frac{R^2}{(R+D)^2} \right]$$

σ_c' = Contact stress on liner
σ_c = Tire contact pressure
R = effective Radius of tire contact = $[P/\pi\sigma_c]^{1/2}$
P = Axle load.
D = Roadway Thickness = 3' (see pg 3)

631 Scraper wt = 93,410 lb
Rated load = 75,000 lb
Total = 168,410 lb
wt distribution loaded ⇒ drive axle = 54%
} Cat handbook see pg 4

P = Axle load = 168,410 lb (.54) = 90,941 lb ✓

Tire Pressure 80 psi (see pg 5)

$$R = [90{,}941\ lb / \pi\ 80]^{1/2} = 19\ in \checkmark$$

$$\sigma_c' = 80\,psi \left[\frac{(19\,in)^2}{(19\,in + 36\,in)^2} \right] = 9.5\ psi \checkmark$$

Estimate Puncture pressure for 60 mil THDPE Liner

Puncture Resistance load = 108 lb (see pg 6)
Puncture Resistance specimen area = $\frac{d^2\pi}{4}$

d = diameter of specimen = 45 mm = 1.77 in (see pg 7)

$$area = \frac{(1.77)^2\pi}{4} = 2.46\ in^2 \checkmark$$

Puncture resistance pressure = $108\ lb / 2.46\ in^2$ = 44 psi

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$$F.S. = \frac{44\,psi}{9.5\,psi} = 4.6 \quad o.k.$$

Conclusions: wheel loading on the ramp should have no detrimental effects on the liner system. This calculation is conservative because the cushioning effect of the Geosynthetics over the Geomembrane was not utilized.

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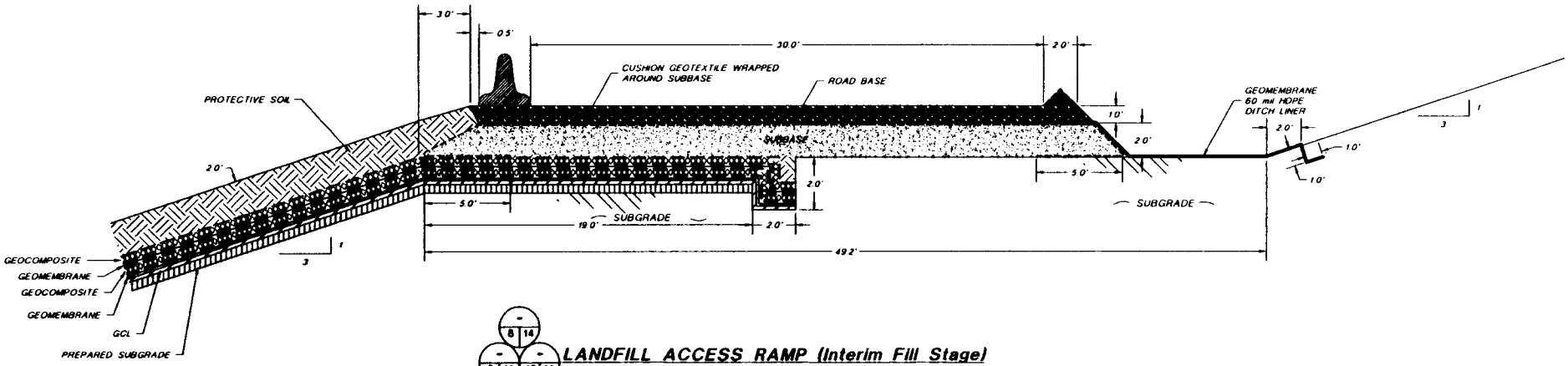
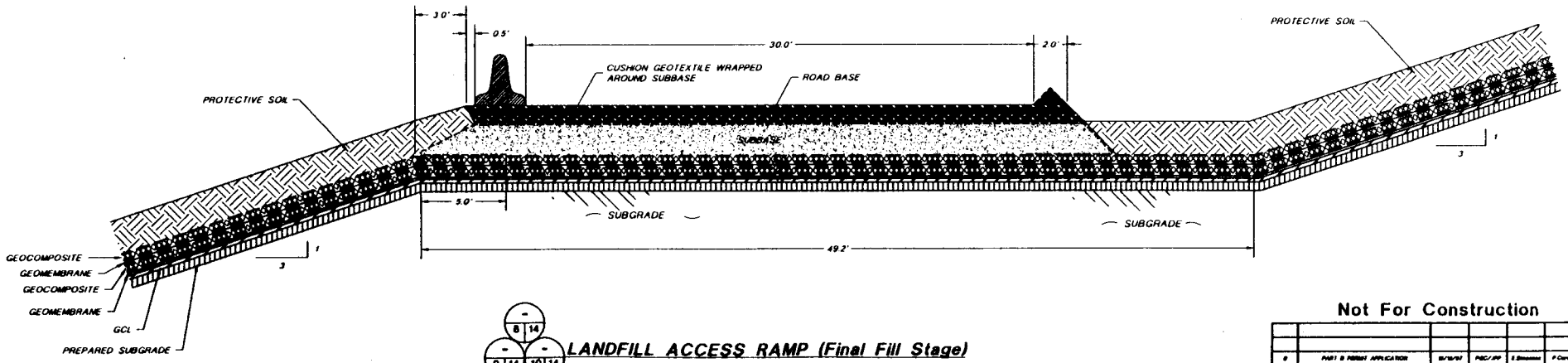


LANDFILL ACCESS RAMP (Interim Fill Stage)

SCALE 0 3 6 Feet



LANDFILL ACCESS RAMP (Final Fill Stage)

SCALE 0 3 6 Feet

NOTE
FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2 "INDEX, LEGEND AND GENERAL NOTES"

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Corser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Corser, NM P.E. 12236

Not For Construction

REV No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	8/15/97	PGC/PP	E Simonson	P Corser

TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE
TYPICAL LANDFILL ACCESS RAMP DETAILS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE AS NOTED
DRAWING No. 14

AutoCAD FILE RAMP_DETAIL.DWG PROJECT NUMBER 602-0200

Specifications
• Standard Scrapers

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	621B		631D		651E	
Flywheel power	246 kW	330 HP	336 kW	450 HP	410 kW	550 HP
Operating weight (empty)◄	30 205 kg	66,590 lb	42 370 kg	93,410 lb	59 420 kg	131,000 lb
Scraper capacity —						
Struck	10.7 m^3	14 yd^3	16 m^3	21 yd^3	24.5 m^3	32 yd^3
Heaped	15.3 m^3	20 yd^3	23.7 m^3	31 yd^3	33.6 m^3	44 yd^3
Rated load	21 770 kg	48,000 lb	34 000 kg	75,000 lb	47 170 kg	104,000 lb
Weight distribution — Empty						
Drive	70%		69%		69%	
Rear	30%		31%		31%	
Weight distribution — Loaded						
Drive	55%		54%		54%	
Rear	45%		46%		46%	
Engine model	3406		3408		3412	
Rated engine RPM	1900		2000		1900	
Displacement	14.6 L	893 in^3	18.0 L	1099 in^3	27.0 L	1649 in^3
Top speed (loaded)	48 km/h	30 mph	50 km/h	31 mph	50 km/h	31 mph
Non-stop turning circle	11.1 m	36'6"	12.2 m	40'1"	13.6 m	44'7"
With ROPS restriction	—		—		14.5 m	47'7"
Tires — Tractor drive	29.5-29, 28 PR (E-3)		33.25-35, 38 PR (E-3)		37.5R39 Radial ★★ (E-3)	
Scraper	29.5-29, 28 PR (E-3)		33.25-35, 38 PR (E-3)		37.5R39 Radial ★★ (E-3)	
Width of cut	3.02 m	9'11"	3.50 m	11'6"	3.68 m	12'1"
Maximum depth of cut	340 mm	13.4"	483 mm	19"	440 mm	17.3"
Maximum depth of spread	460 mm	18"	425 mm	16.7"	660 mm	26"
Fuel tank refill capacity	511 L	135 gal	760 L	200 gal	1083 L	286 gal
GENERAL DIMENSIONS:						
Height to top of scraper	3.63 m	11'11"	4.17 m	13'8"	4.70 m	15'5"
Wheelbase	7.72 m	25'4"	8.74 m	28'8"	9.96 m	32'8"
Overall length	12.7 m	41'7"	14.25 m	46'9"	16.13 m	52'11"
Overall width	3.45 m	11'4"	3.96 m	13'	4.34 m	14'3"
Shipping width (draft arm on inside of bowl)	—		3.66 m	12'0"	3.91 m	12'10"
Scraper tread	2.18 m	7'2"	2.46 m	8'1"	2.82 m	9'3"
Tractor tread	2.21 m	7'3"	2.46 m	8'1"	2.64 m	8'8"

◄**Operating weight** includes coolant, lubricants, full fuel tank, ROPS canopy and operator.

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600 . . . WHEEL TRACTOR-SCRAPERS — Bias and Bias Belted Tires

Model	Tire Size	Ply Rating	Pressure Front kPa	Pressure Front psi	Pressure Rear kPa	Pressure Rear psi
613C	18.00-25*	16	345	50	379	55
	23.5-25	16	241	35	276	40
615	26.5-25*	26	413	60	345	50
	29.5-25	22	276	40	241	35
621B	29.5-29*	28	413	60	276	40
	29.5-29	34	413	60	276	40
	29.5-35	28	345	50	241	35
	33.25-29	26	310	45	207	30
623B	29.5-29*	28	448	65	345	50
	29.5-29	34	448	65	345	50
	29.5-35	28	379	55	310	45
627B	29.5-29*	28	413	60	413	60
	29.5-29	34	413	60	413	60
	29.5-35	28	345	50	345	50
	33.25-29	26	310	45	310	45
631D	33.25-35*	38	482	70	379	55
	37.25-35	30	345	50	276	40
633D	33.25-35*	38	517	75	448	65
	37.25-35	30	379	55	310	45
637D	33.25-35*	38	517	75	482	70
	37.25-35	30	379	55	345	50
651E	37.5-39	36	482	70	413	60
	37.5-39	44	482	70	413	60
657E	37.5-39	44	517	75	551	80
	37.5-39	52	517	75	551	80

*Standard tire and ply rating.

600 . . . WHEEL TRACTOR-SCRAPERS — Radial Tires

Model	Tire Size	Strength Index	Michelin Front kPa	Michelin Front psi	Michelin Rear kPa	Michelin Rear psi	Goodyear Front kPa	Goodyear Front psi	Goodyear Rear kPa	Goodyear Rear psi	Firestone Front kPa	Firestone Front psi	Firestone Rear kPa	Firestone Rear p
613C	18.00R25		413	60	448	65	—	—	—	—	—	—	—	
	23.5R25	*	310	45	345	50	310	45	345	50	—	—	—	
615	26.5R25	**	413	60	379	55	—	—	—	—	—	—	—	
	29.5R25	**	345	50	310	45	—	—	—	—	—	—	—	
621B	29.5R29	**	448	65	379	55	482	70	345	50	—	—	—	
	29.5R35	**	448	65	379	55	—	—	—	—	—	—	—	
	33.25R29	**	413	60	345	50	—	—	—	—	—	—	—	
623B	29.5R29	**	482	70	413	60	517	75	413	60	—	—	—	
	29.5R35	**	448	65	379	55	—	—	—	—	—	—	—	
627B	29.5R29	**	413	60	413	60	448	65	448	65	—	—	—	
	29.5R35	**	413	60	413	60	—	—	—	—	—	—	—	
	33.25R29	**	379	55	379	55	—	—	—	—	—	—	—	
631D	33.25R35	**	551	80	517	75	551	80	448	65	551	80	517	
	37.25R35	**	517	75	413	60	—	—	—	—	—	—	—	
633D	33.25R35	**	551	80	517	75	586	85	517	75	586	85	517	
	37.25R35	**	517	75	482	70	—	—	—	—	—	—	—	
637D	33.25R35	**	551	80	551	80	586	85	551	80	586	85	517	
	37.25R35	**	517	75	517	75	—	—	—	—	—	—	—	
651E	37.5R39*	**	689	100	551	80	551	80	482	70	551	80	51	
	40.5/75R39	**	517	75	482	70	482	70	482	70	—	—	—	
657E	37.5R39*	**	689	100	689	100	586	85	620	90	586	85	6	
	40.5/75R39	**	517	75	517	75	517	75	517	75	—	—		

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FRICTION SEAL™ HD GEOMEMBRANE
QUALITY CONTROL SPECIFICATIONS
60 mil

FRICTION SEAL HD, National Seal Company's advanced textured high density polyethylene (HDPE) geomembrane, is manufactured by attaching a friction surface to NSC's high quality HDPE geomembrane. The friction surface is made from high molecular weight polyethylene resin compounded specifically for use in NSC geomembranes. The resin has been formulated to provide stress crack, chemical and ultraviolet resistance for fluid containment. NSC produces FRICTION SEAL HD with a textured surface on one or both sides of the parent sheet.

The following properties are tested as a part of NSC's quality control program. Certified test results for properties on this page are available upon request. Refer to NSC's Quality Control Manual for exact test methods and frequencies.

RESIN PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Melt Flow Index[2]	ASTM D 1238	g/10 min	0.50	0.25
Oxidative Induction Time	ASTM D 3895, Al pan, 200°C, 1 atm O_2	minutes	100	120

SHEET PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Mass per Unit Area[3]	ASTM D 3776	lb/ft^2	0.31	0.32
Thickness[4]	ASTM D 751, NSF mod.			
Average		mils	60.0	61.5
Individual		mils	57.0	59.7
Density[4]	ASTM D 1505	g/cm^3	0.940	0.948
Carbon Black Content[4]	ASTM D 1603	percent	2.0-3.0	2.35
Carbon Black Dispersion[4]	ASTM D 3015, NSF mod.	rating	A1, A2, B1	A1
Tensile Properties[5]	ASTM D 638			
Stress at Yield		psi	2200	2750
		ppi	132	169
Stress at Break		psi	2200	3240
		ppi	132	199
Strain at Yield	1.3" gage length (NSF)	percent	13.0	17.5
Strain at Break	2.0" gage or extensometer	percent	200	540
	2.5" gage length (NSF)	percent	160	432
Dimensional Stability[2,4]	ASTM D 1204, NSF mod.	percent	1.5.	0.4
Tear Resistance	ASTM D 1004	ppi	750	1000
		lbs	45	62
Puncture Resistance	ASTM D 4833	ppi	1800	2276
		lbs	108	140
Constant Load ESCR, Single Point[4]	GRI, GM-5a	hours	200	>400
Friction Angle, Index	GRI, GS-7	degrees	40	56

1 This value represents the minimum acceptable test value for a roll as tested according to NSC's Manufacturing Quality Control Manual. Individual test specimen values are not addressed in this specification except thickness.

2 Indicates Maximum Value

3 Friction Coating on both sides of base sheet

4 Testing performed on base sheet

5 Stress and strength values are normalized to the nominal base sheet thickness. NSC certifies properties based on values calculated using nominal thickness only. Stress values calculated using actual product thickness is not guaranteed due to the lack of industry accepted thickness test procedures for friction sheet.

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stant-rate-of extension (CRE) type, with autographic recorder conforming to the requirements of Specification D 76. See Fig. 1.

6.2 *Ring Clamp Attachment*, consisting of concentric plates with an open internal diameter of 45 ± 0.025 mm (1.772 ± 0.001 in.), capable of clamping the test specimen without slippage. A suggested clamping arrangement is shown in Figs. 1 and 2. The external diameter is suggested to be 100 ± 0.025 mm (3.937 ± 0.001 in.). The diameter of the six holes used for securing the ring clamp assembly is suggested to be 8 mm (0.135 in.) and equally spaced at a radius of 37 mm (2.95 in.). The surfaces of these plates can consist of grooves with O-rings or coarse sandpaper bonded onto opposing surfaces.

6.3 *Solid Steel Rod*, with a diameter of 8 ± 0.01 mm (0.35 ± 0.005 in.) having a flat end with a 45° = 0.8 mm (0.315 in.) chamfered edge contacting the test specimen's surface. See Figs. 1 and 3.

7. Sampling

7.1 *Lot Sample*—Divide the product into lots and take the lot sample as directed in Practice D 4354.

7.2 *Laboratory Sample*—For the laboratory sample take a swatch extending the full width of the geotextile, of sufficient length along the selvage from each sample roll so that the requirements of 7.3 and 8.1 can be met. Take a sample that will exclude material from the outer wrap and inner wrap around the core unless the sample is taken at the production site, then inner and outer wrap material may be used.

7.3 *Test Specimens*—Select from the laboratory sample the number of specimens directed in Section 8. Minimum specimen diameter is 100 mm (4 in.) to facilitate clamping. Space the specimens along a diagonal on the unit of the

FIG. 1 Photographs of Test Setup and Fixture

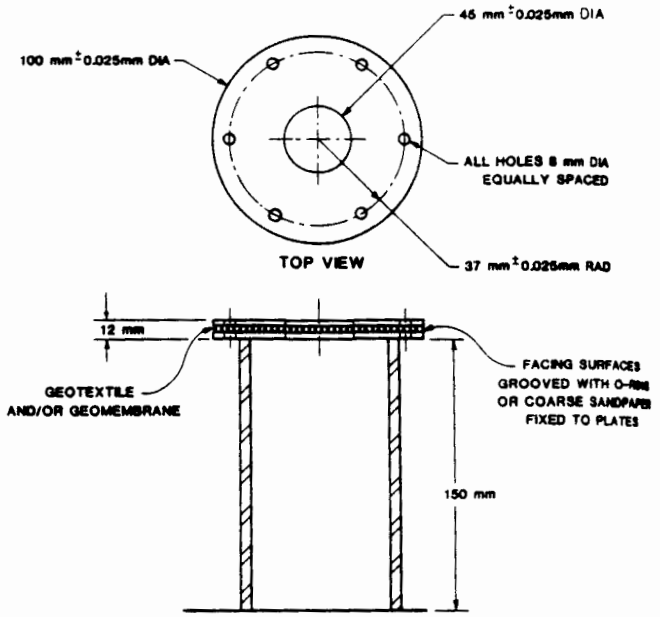

FIG. 2 Test Fixture Detail (Not to Scale)

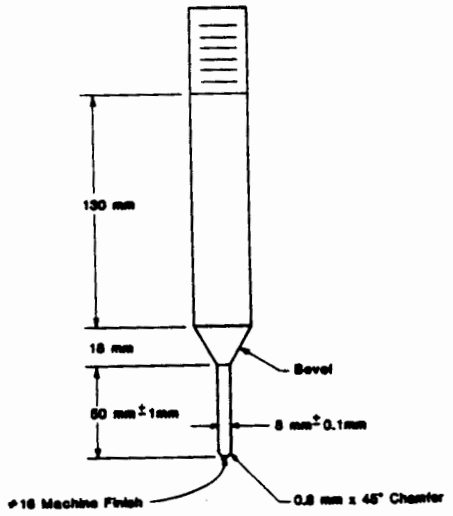

FIG. 3 Test Probe Detail (Not to Scale)

E-25

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Frost Penetration

	Name	Date
Prepared By:	J. Pellicer	24-Oct-97
Checked By:	P. Corser	29-Oct-97
Reviewed By:	P. Corser	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Gandy/Triassic Park
Project Number: 602 Sheet: 1 Of
Prepared By: J. Pellicer Date: 4-OCT-97
Checked By: RCL Date: 29 Oct 97

OBJECTIVE: Determine depth of freeze for protective/cover soils which will be placed over the liner/cover system.

METHODOLOGY: Modified Berggren Equation

DATA: Use coldest high and low temperatures from historical data. Data obtained from the Utah Climate Center

REFERENCE: Departments of the Army and the Air Force, 1966 "Calculation Methods for Determination of Depths of Freeze and Thaw in Soils" - TM 5-852C

See attached spreadsheet for calculation.

RESULT: Based on the most conservative temperature. Frost is expected to penetrate 2.3 ft into the ground. Vegatative Soil cover is 2.5 ft Thick.

CONCLUSION: Antisipated frost penetration does not exceed the depth of the vegetative cover therefore frost should not affect the cover GCL. The protective soil on the liner slopes should be sufficient protection for the liner GCL's due to limited length of exposure.

TITLE: DEPTH OF FREEZE CALCULATIONS FOR MULTIPLE LAYERED SOIL
JOB NAME: GANDY/TRIASSIC PARK LANDFILL
JOB NUMBER: 602
PREPARED BY: JOHN PELLICER
DATE PREPARED: 24 OCT 1997
FILENAME: H:\JOHN PELLICER\GANDY\SPREAD\FROST DEPTH CALCULATION FOR TRIASSIC PARK LANDFILL 2

REF: CALCULATION METHODS FOR DETERMINATION
OF DEPTHS OF FREEZE AND THAW IN SOILS
DEPARTMENT OF THE ARMY TECHNICAL MANUAL TM 5-852-6
JANUARY 1966

MULTI-LAYERED SOLUTION OF MODIFIED B

Air Temperature Data
Bitter Lakes Wildlife Refuge, New Mexico
1950 - 1997

MEAN ANNUAL TEMPERATURE:	59	
n-factor:	0.5	
air freezing index (F):	1138	
SURFACE FREEZING INDEX nF =	**569**	
Length of Freezing Season (t):	136	(days)
Vs (nF/t)	4.2	
Vo, |Tmean-T(32)|	27	
"Alpha" (Vo/Vs) =	6.46	

Freezing n-factor	Surface Type
1	Snow
0.9	Pavement (ice/snow-free)
0.9	Sand & gravel
0.7	Pavement (II)
0.5	Turf

Material	UW Unit Weight pcf	w Water Content %	d Thickness Ft	Sd Sum Thick. Ft	C Volumetric Heat Capacity BTU/Ft^3-F	K Thermal Conduct. unfrozen	K Thermal Conduct. frozen	Kave Thermal Cond. BTU/Ft-Hr-F	L Vol. Latent Heat of Fusion BTU/Ft^3	L*d BTU/Ft^2	Σ(L*d) BTU/Ft^2	Lave Ave. BTU/Ft^3	C*d	Σ(C*d)	Cave	μ [(C/L)*Vs]	α (Vo/Vs)	λ	λ^2	Rn (d/K)	ΣRn	ΣRn+Rn/2	nI	Σnl
Vegetative Cover	100.00	10.00	2.3220	2.32	24.50	0.92	0.90	0.91	1440.00	3343.68	3343.68	1440.00	56.89	56.89	24.50	0.07	6.46	0.56	0.31	2.56	2.56	1.28	569.27	**569**

THE DEPTH OF FROST IS DETERMINED WHEN THE SUM OF THE FROST INDICES IS EQUAL TO THE FREEZE INDEX.
THE THICKNESS OF THE LAYERS CAN BE MANIPULATED TO DETERMINE THE EXACT DEPTH OF FROST.

MEASURED DAILY TEMPERATURES BITTER LAKES WILDLIFE REFUGE, NEW MEXICO 1950 to 1997

	DAY	MONTH	DAY	AIR TEMPERATURE HIGH	LOW	MEAN	FREEZE INDEX	SUM FREEZE INDEX		
OCTOBER	1	10	1	62	35	49	16.5	17	0	0
	2	10	2	67	35	51	19	36	0	0
	3	10	3	59	30	45	12.5	48	0	0
	4	10	4	61	31	46	14	62	0	0
	5	10	5	59	30	45	12.5	75	0	0
	6	10	6	62	30	46	14	89	0	0
	7	10	7	62	30	46	14	103	0	0
	8	10	8	59	19	39	7	110	0	0
	9	10	9	62	24	43	11	121	0	0
	10	10	10	57	27	42	10	131	0	0
	11	10	11	57	29	43	11	142	0	0
	12	10	12	58	28	43	11	153	0	0
	13	10	13	56	30	43	11	164	0	0
	14	10	14	56	30	43	11	175	0	0
	15	10	15	53	30	42	9.5	184	0	0
	16	10	16	53	25	39	7	191	0	0
	17	10	17	56	27	42	9.5	201	0	0
	18	10	18	59	21	40	8	209	0	0
	19	10	19	58	19	39	6.5	215	0	0
	20	10	20	55	17	36	4	219	0	0
	21	10	21	56	21	39	6.5	226	0	0
	22	10	22	55	24	40	7.5	233	0	0
	23	10	23	52	23	38	5.5	239	0	0
	24	10	24	56	25	41	8.5	247	0	0
	25	10	25	50	23	37	4.5	252	0	0
	26	10	26	51	25	38	6	258	0	0
	27	10	27	51	25	38	6	264	0	0
	28	10	28	52	17	35	2.5	266	0	0
	29	10	29	49	17	33	1	267	0	0
	30	10	30	49	20	35	2.5	270	0	0
	31	10	31	51	10	31	-1.5	268	0	0
NOVEMBER	32	11	1	54	13	34	1.5	270	0	0
	33	11	2	54	14	34	2	272	0	0
	34	11	3	56	13	35	2.5	274	0	0
	35	11	4	53	12	33	0.5	275	0	0
	36	11	5	51	22	37	4.5	279	36	0
	37	11	6	46	10	28	-4	275	0	0
	38	11	7	45	11	28	-4	271	0	0
	39	11	8	48	13	31	-1.5	270	0	0
	40	11	9	48	16	32	0	270	0	0
	41	11	10	45	17	31	-1	269	0	0
	42	11	11	45	15	30	-2	267	0	0
	43	11	12	45	15	30	-2	265	0	0
	44	11	13	49	9	29	-3	262	0	0

	45	11	14	49	11	30	-2	260	0	0	40
	46	11	15	50	-3	24	-8.5	251	0	0	
	47	11	16	43	-1	21	-11	240	0	0	
	48	11	17	49	4	27	-5.5	235	0	0	
	49	11	18	43	9	26	-6	229	0	0	
	50	11	19	42	9	26	-6.5	222	0	0	
	51	11	20	50	13	32	-0.5	222	0	0	
	52	11	21	44	9	27	-5.5	216	0	0	
	53	11	22	45	7	26	-6	210	0	0	
	54	11	23	45	5	25	-7	203	0	0	
	55	11	24	48	10	29	-3	200	0	0	
	56	11	25	45	13	29	-3	197	0	0	
	57	11	26	47	1	24	-8	189	0	0	
	58	11	27	42	3	23	-9.5	180	0	0	
	59	11	28	42	8	25	-7	173	0	0	
	60	11	29	44	2	23	-9	164	0	0	
	61	11	30	43	8	26	-6.5	157	0	0	
DECEMBER	62	12	1	44	7	26	-6.5	151	0	0	
	63	12	2	43	10	27	-5.5	145	0	0	
	64	12	3	38	8	23	-9	136	0	0	
	65	12	4	42	8	25	-7	129	0	0	
	66	12	5	39	4	22	-10.5	119	0	0	
	67	12	6	49	2	26	-6.5	112	0	0	
	68	12	7	47	6	27	-5.5	107	0	0	
	69	12	8	37	12	25	-7.5	99	0	0	
	70	12	9	39	-11	14	-18	81	0	0	
	71	12	10	49	-11	19	-13	68	0	0	
	72	12	11	36	7	22	-10.5	58	0	0	
	73	12	12	38	-3	18	-14.5	43	0	0	
	74	12	13	40	2	21	-11	32	0	0	
	75	12	14	38	3	21	-11.5	21	0	0	
	76	12	15	37	-8	15	-17.5	3	0	0	
	77	12	16	32	-7	13	-19.5	-17	0	0	
	78	12	17	38	4	21	-11	-28	0	0	
	79	12	18	41	0	21	-11.5	-39	0	0	
	80	12	19	40	1	21	-11.5	-51	0	0	
	81	12	20	38	-4	17	-15	-66	0	0	
	82	12	21	36	0	18	-14	-80	0	0	
	83	12	22	38	3	21	-11.5	-91	0	0	
	84	12	23	44	-5	20	-12.5	-104	0	0	
	85	12	24	48	-10	19	-13	-117	0	0	
	86	12	25	46	3	25	-7.5	-124	0	0	
	87	12	26	42	-3	20	-12.5	-137	0	0	
	88	12	27	36	1	19	-13.5	-150	0	0	
	89	12	28	39	-6	17	-15.5	-166	0	0	
	90	12	29	42	2	22	-10	-176	0	0	
	91	12	30	50	-7	22	-10.5	-186	0	0	
	92	12	31	54	-2	26	-6	-192	0	0	
JANUARY	93	1	1	41	5	23	-9	-201	0	0	

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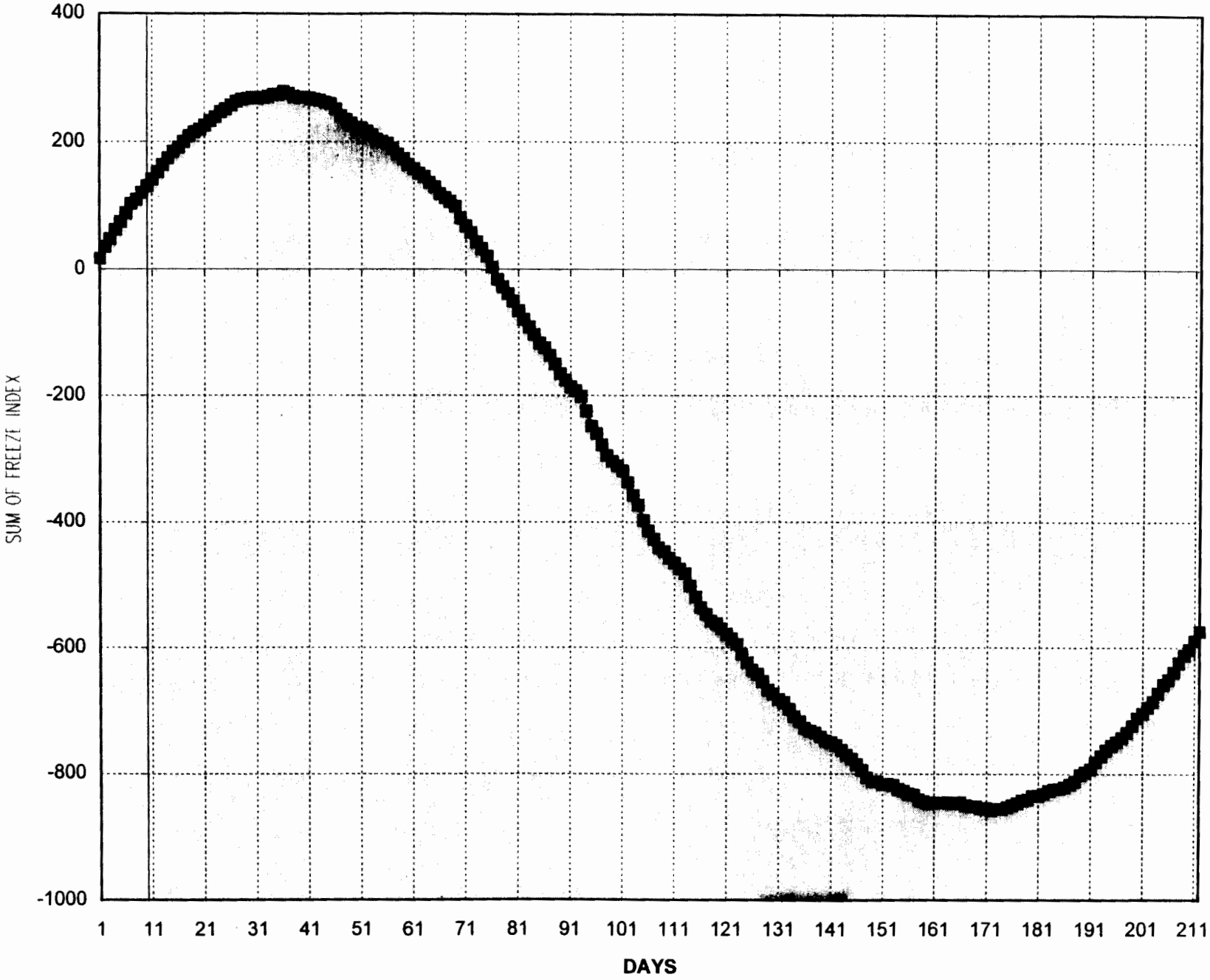
	94	1	2	34	-18	8	-24	-225	0	0
	95	1	3	34	-18	8	-24	-249	0	0
	96	1	4	42	-1	21	-11.5	-261	0	0
	97	1	5	38	-9	15	-17.5	-278	0	0
	98	1	6	32	-4	14	-18	-296	0	0
	99	1	7	49	-3	23	-9	-305	0	0
	100	1	8	49	2	26	-6.5	-312	0	0
	101	1	9	49	-2	24	-8.5	-320	0	0
	102	1	10	32	-4	14	-18	-338	0	0
	103	1	11	44	-22	11	-21	-359	0	0
	104	1	12	44	-11	17	-15.5	-375	0	0
	105	1	13	38	-22	8	-24	-399	0	0
	106	1	14	45	-14	16	-16.5	-415	0	0
	107	1	15	43	-4	20	-12.5	-428	0	0
	108	1	16	32	3	18	-14.5	-442	0	0
	109	1	17	53	0	27	-5.5	-448	0	0
	110	1	18	41	2	22	-10.5	-458	0	0
	111	1	19	49	0	25	-7.5	-466	0	0
	112	1	20	39	5	22	-10	-476	0	0
	113	1	21	42	7	25	-7.5	-483	0	0
	114	1	22	37	-12	13	-19.5	-503	0	0
	115	1	23	35	-6	15	-17.5	-520	0	0
	116	1	24	36	-5	16	-16.5	-537	0	0
	117	1	25	41	0	21	-11.5	-548	0	0
	118	1	26	38	5	22	-10.5	-559	0	0
	119	1	27	49	8	29	-3.5	-562	0	0
	120	1	28	44	3	24	-8.5	-571	0	0
	121	1	29	42	5	24	-8.5	-579	0	0
	122	1	30	41	8	25	-7.5	-587	0	0
	123	1	31	40	7	24	-8.5	-595	0	0
FEBRUARY	124	2	1	44	-12	16	-16	-611	0	0
	125	2	2	48	-12	18	-14	-625	0	0
	126	2	3	43	-1	21	-11	-636	0	0
	127	2	4	41	9	25	-7	-643	0	0
	128	2	5	41	0	21	-11.5	-655	0	0
	129	2	6	36	2	19	-13	-668	0	0
	130	2	7	48	2	25	-7	-675	0	0
	131	2	8	43	5	24	-8	-683	0	0
	132	2	9	50	4	27	-5	-688	0	0
	133	2	10	40	1	21	-11.5	-699	0	0
	134	2	11	40	2	21	-11	-710	0	0
	135	2	12	42	6	24	-8	-718	0	0
	136	2	13	45	-2	22	-10.5	-729	0	0
	137	2	14	49	6	28	-4.5	-733	0	0
	138	2	15	50	8	29	-3	-736	0	0
	139	2	16	45	8	27	-5.5	-742	0	0
	140	2	17	41	9	25	-7	-749	0	0
	141	2	18	44	16	30	-2	-751	0	0
	142	2	19	41	13	27	-5	-756	0	0

	143	2	20	44	6	25	-7	-763	0	0
	144	2	21	42	4	23	-9	-772	0	0
	145	2	22	45	7	26	-6	-778	0	0
	146	2	23	43	4	24	-8.5	-786	0	0
	147	2	24	50	-5	23	-9.5	-796	0	0
	148	2	25	46	-5	21	-11.5	-807	0	0
	149	2	26	46	6	26	-6	-813	0	0
	150	2	27	49	15	32	0	-813	0	0
	151	2	28	46	9	28	-4.5	-818	0	0
MARCH	152	3	1	48	17	33	0.5	-817	0	0
	153	3	2	48	13	31	-1.5	-819	0	0
	154	3	3	47	5	26	-6	-825	0	0
	155	3	4	45	12	29	-3.5	-828	0	0
	156	3	5	45	11	28	-4	-832	0	0
	157	3	6	50	9	30	-2.5	-835	0	0
	158	3	7	43	6	25	-7.5	-842	0	0
	159	3	8	47	12	30	-2.5	-845	0	0
	160	3	9	49	8	29	-3.5	-848	0	0
	161	3	10	51	16	34	1.5	-847	0	0
	162	3	11	49	15	32	0	-847	0	0
	163	3	12	54	10	32	0	-847	0	0
	164	3	13	49	17	33	1	-846	0	0
	165	3	14	49	11	30	-2	-848	0	0
	166	3	15	49	17	33	1	-847	0	0
	167	3	16	43	14	29	-3.5	-850	0	0
	168	3	17	44	16	30	-2	-852	0	0
	169	3	18	46	16	31	-1	-853	0	0
	170	3	19	47	11	29	-3	-856	0	0
	171	3	20	55	11	33	1	-855	0	0
	172	3	21	44	13	29	-3.5	-859	0	172
	173	3	22	52	16	34	2	-857	0	0
	174	3	23	52	12	32	0	-857	0	0
	175	3	24	49	20	35	2.5	-854	0	0
	176	3	25	51	20	36	3.5	-851	0	0
	177	3	26	53	18	36	3.5	-847	0	0
	178	3	27	50	21	36	3.5	-844	0	0
	179	3	28	54	14	34	2	-842	0	0
	180	3	29	55	20	38	5.5	-836	0	0
	181	3	30	57	9	33	1	-835	0	0
	182	3	31	52	17	35	2.5	-833	0	0
APRIL	183	4	1	53	20	37	4.5	-828	0	0
	184	4	2	51	18	35	2.5	-826	0	0
	185	4	3	47	19	33	1	-825	0	0
	186	4	4	54	16	35	3	-822	0	0
	187	4	5	52	20	36	4	-818	0	0
	188	4	6	52	22	37	5	-813	0	0
	189	4	7	60	24	42	10	-803	0	0
	190	4	8	52	21	37	4.5	-798	0	0
	191	4	9	55	19	37	5	-793	0	0

192	4	10	58	28	43	11	-782	0	0
193	4	11	60	23	42	9.5	-773	0	0
194	4	12	61	23	42	10	-763	0	0
195	4	13	57	20	39	6.5	-756	0	0
196	4	14	57	19	38	6	-750	0	0
197	4	15	52	26	39	7	-743	0	0
198	4	16	54	26	40	8	-735	0	0
199	4	17	55	30	43	10.5	-725	0	0
200	4	18	58	31	45	12.5	-712	0	0
201	4	19	52	26	39	7	-705	0	0
202	4	20	58	25	42	9.5	-696	0	0
203	4	21	56	28	42	10	-686	0	0
204	4	22	59	30	45	12.5	-673	0	0
205	4	23	62	30	46	14	-659	0	0
206	4	24	56	24	40	8	-651	0	0
207	4	25	57	31	44	12	-639	0	0
208	4	26	63	30	47	14.5	-625	0	0
209	4	27	60	28	44	12	-613	0	0
210	4	28	57	27	42	10	-603	0	0
211	4	29	63	27	45	13	-590	0	0
212	4	30	64	30	47	15	-575	0	0

MAXIMUM	279
MINIMUM	-859
FREEZING INDEX:	1138
FREEZING SEASON:	136

BITTER LAKES WILDLIFE REFUGE, NEW MEXICO
FREEZING INDEX



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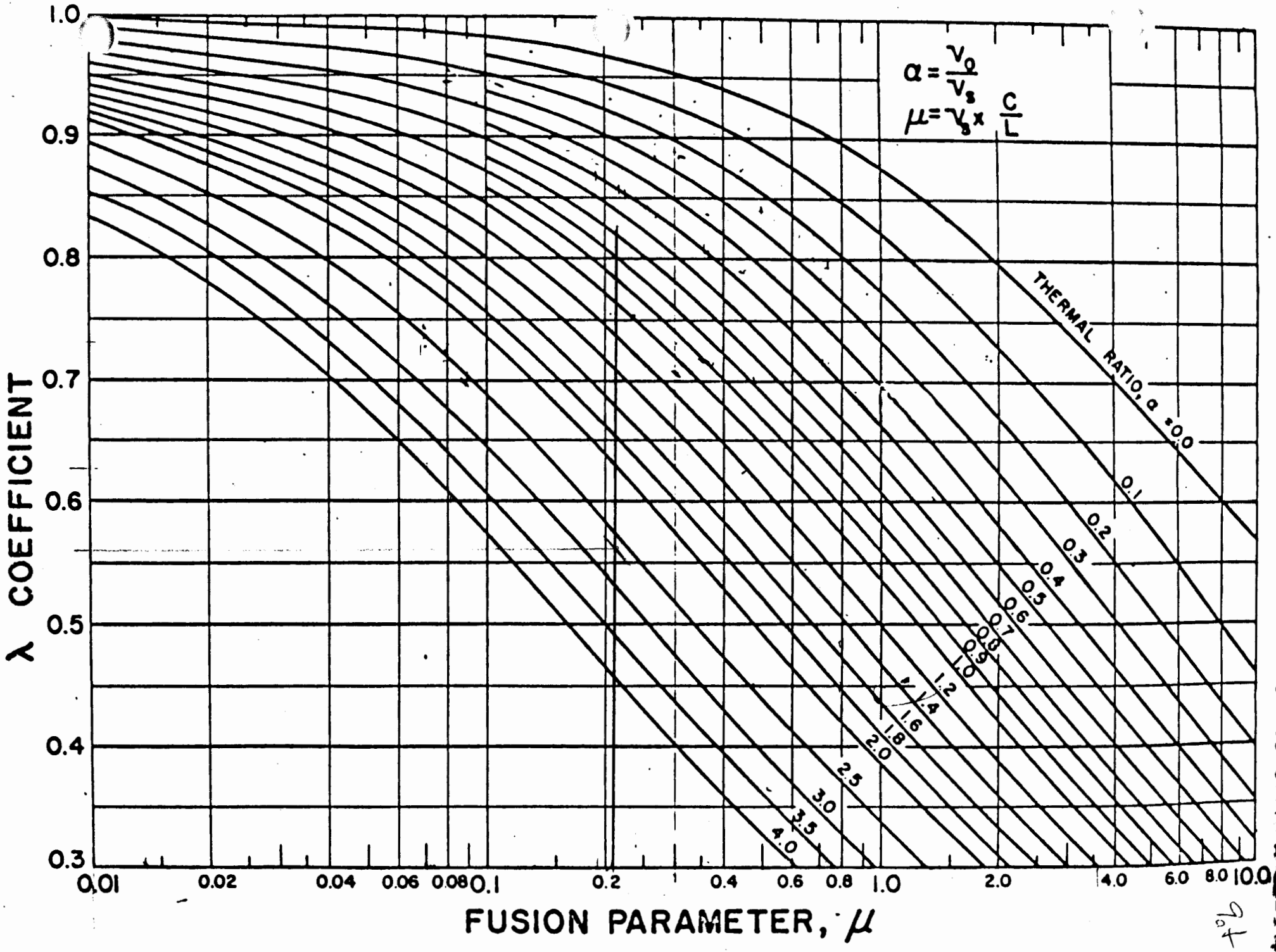

Figure 13. λ coefficient in the modified Berggren formula

10 of

BITTER LAKES WL REFUGE, NEW MEXICO (290992)

Period of Record Monthly Climate Summary

Period of Record : 12/1/1950 to 6/30/1997

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	56.7	62.6	69.9	79.1	86.9	95.1	95.7	93.8	87.1	78.2	65.7	57.9	77.4
Average Min. Temperature (F)	20.5	25.1	31.2	40.2	49.6	59.0	63.2	61.5	53.8	40.6	28.3	21.0	41.2
Average Total Precipitation (in.)	0.41	0.43	0.32	0.47	1.06	1.36	2.18	2.22	1.79	1.17	0.50	0.44	12.35
Average Total SnowFall (in.)	2.2	2.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	1.7	7.4
Average Snow Depth (in.)	0	0	0	0	0	0	0	0	0	0	0	0	0

Western Regional Climate Center, Greg McCurdy, gmwrcc@sage.dri.edu

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BITTER LAKES WL REFUGE, NEW MEXICO

NCDC 1961-1990 Monthly Normals

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Max. Temperature (F)	55.7	61.1	69.3	78.4	86.4	94.1	95.2	92.9	85.6	77.5	65.4	56.9	76.5
Highest Mean Max. Temperature (F)	64.8	69.9	78.5	83.0	92.1	102.5	102.0	97.7	91.5	84.0	71.6	67.0	79.3
Year Highest Occurred	1967	1962	1967	1986	1962	1980	1980	1983	1983	1963	1981	1970	1963
Lowest Mean Max. Temperature (F)	46.4	53.0	57.9	71.0	82.3	89.9	88.6	87.1	76.3	71.2	55.5	48.5	74.5
Year Lowest Occurred	1979	1964	1969	1983	1976	1986	1975	1971	1974	1984	1961	1983	1978
Mean Temperature (F)	37.6	42.6	50.3	59.4	67.8	76.4	79.2	77.2	69.9	59.0	47.3	38.7	58.8
Highest Mean Temperature (F)	44.5	49.0	56.5	64.1	72.3	83.7	83.6	81.6	74.6	62.6	51.4	45.7	60.1
Year Highest Occurred	1969	1962	1967	1967	1989	1990	1980	1969	1983	1963	1965	1970	1967
Lowest Mean Temperature (F)	31.1	35.0	42.1	53.3	62.7	72.8	73.6	73.4	63.1	52.3	40.9	32.3	56.3
Year Lowest Occurred	1966	1964	1969	1983	1975	1979	1975	1974	1974	1976	1976	1989	1975
Mean Min. Temperature (F)	19.4	24.1	31.1	40.3	49.3	58.6	63.2	61.5	54.2	40.4	29.1	20.5	41.0
Highest Mean Min. Temperature (F)	24.8	28.4	35.7	45.9	53.4	65.5	67.2	65.6	59.0	46.7	37.4	27.6	42.9
Year Highest Occurred	1965	1987	1985	1967	1989	1990	1966	1969	1990	1983	1978	1984	1986
Lowest Mean Min. Temperature (F)	9.4	17.0	26.3	34.0	41.2	53.4	56.6	56.1	48.1	32.8	22.4	12.8	36.7
Year Lowest Occurred	1963	1964	1969	1975	1975	1975	1988	1975	1975	1976	1975	1989	1975
Mean Precipitation (in.)	0.43	0.48	0.33	0.46	0.97	1.75	1.89	2.52	1.96	1.10	0.62	0.49	13.00
Highest Precipitation (in.)	2.15	1.54	1.63	2.41	3.81	5.96	5.15	7.19	5.68	5.61	2.02	2.11	23.72
Year Highest Occurred	1968	1975	1968	1966	1981	1978	1968	1977	1974	1983	1961	1969	1986

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BITTER LAKES WL REFUGE, NEW MEXICO

Period of Record Daily Climate Summary

Daily Records for station 290992 BITTER LAKES WL REFUGE state: nm

For temperature and precipitation, multi-day accumulations
are not considered either for records or averages.
The year given is the year of latest occurrence.

Period requested -- Begin : 1/ 1/1890 -- End : 12/31/2000
Period used -- Begin : 12/ 1/1950 -- End : 6/30/1997

Cooling degree threshold = 65.00 Heating degree threshold = 65.00

AVG Multi-year unsmoothed average of the indicated quantity
HI Highest value of indicated quantity for this day of year
LO Lowest value of indicated quantity for this day of year
YR Latest year of occurrence of the extreme value
NO Number of years with data for this day of year.
Units: English (inches and degrees F)

		Maximum Temperature						Minimum Temperature						Precipitation				
MO	DY	AVG	NO	HI	YR	LO	YR	AVG	NO	HI	YR	LO	YR	AVG	NO	HIGH	YR	AVG
1	1	55	37	78	1966	24	1979	20	38	41	1952	5	1990	0.002	46	0.07	1979	0.10
1	2	52	39	81	1997	20	1979	19	39	34	1952	-18	1979	0.010	45	0.19	1973	0.10
1	3	54	44	86	1997	26	1979	17	44	34	1997	-18	1979	0.012	47	0.13	1973	0.02
1	4	53	46	70	1954	26	1971	19	45	42	1997	-1	1974	0.016	47	0.56	1958	0.09
1	5	53	44	70	1989	22	1971	19	45	38	1989	-9	1971	0.020	46	0.62	1958	0.04
1	6	55	46	82	1994	24	1971	20	46	32	1982	-4	1970	0.011	46	0.50	1997	0.11
1	7	57	41	80	1969	25	1971	21	41	49	1965	-3	1971	0.032	46	0.53	1986	0.17
1	8	54	42	85	1969	27	1971	22	42	49	1965	2	1971	0.010	46	0.36	1968	0.11
1	9	55	45	77	1969	31	1979	18	45	49	1957	-2	1964	0.008	47	0.14	1974	0.05
1	10	53	46	77	1953	13	1962	18	46	32	1991	-4	1977	0.017	47	0.66	1973	0.00
1	11	53	46	73	1953	11	1962	18	46	44	1960	-22	1962	0.011	47	0.31	1960	0.01
1	12	54	46	74	1953	13	1963	20	46	44	1960	-11	1962	0.005	46	0.17	1963	0.08
1	13	55	45	79	1976	20	1997	20	45	38	1980	-22	1963	0.022	46	0.70	1982	0.26
1	14	58	41	79	1957	38	1963	20	42	45	1952	-14	1963	0.010	46	0.25	1960	0.23
1	15	58	40	77	1980	32	1984	19	41	43	1969	-4	1982	0.000	47	0.00	1997	0.00
1	16	57	41	74	1967	30	1992	19	42	32	1969	3	1964	0.005	47	0.22	1960	0.05
1	17	57	45	80	1974	25	1982	21	46	53	1996	0	1957	0.000	47	0.01	1991	0.00
1	18	58	44	83	1974	29	1981	21	45	41	1952	2	1957	0.020	47	0.39	1979	0.06
1	19	57	45	83	1953	26	1984	21	45	49	1952	0	1984	0.030	47	0.66	1990	0.11
1	20	56	44	75	1985	32	1984	23	45	39	1983	5	1963	0.028	47	0.50	1968	0.08
1	21	55	43	80	1953	28	1978	22	43	42	1969	7	1976	0.042	45	0.95	1968	0.16
1	22	57	43	80	1974	23	1966	22	45	37	1974	-12	1966	0.030	45	0.88	1980	0.20
1	23	57	43	73	1971	30	1966	20	45	35	1977	-6	1980	0.004	46	0.17	1980	0.00
1	24	60	44	83	1972	36	1966	19	42	36	1967	-5	1980	0.008	45	0.32	1961	0.03
1	25	60	44	82	1952	31	1978	20	45	41	1962	0	1980	0.013	46	0.34	1962	0.00
1	26	62	46	79	1969	33	1961	23	47	38	1954	5	1966	0.006	47	0.08	1976	0.01
1	27	60	44	84	1975	32	1961	24	45	49	1953	8	1963	0.013	46	0.32	1989	0.04
1	28	61	43	80	1956	29	1961	22	43	44	1968	3	1963	0.000	46	0.00	1996	0.00
1	29	63	42	78	1986	42	1966	23	41	42	1969	5	1961	0.000	46	0.00	1996	0.00
1	30	61	43	80	1963	29	1951	23	43	41	1954	8	1951	0.010	46	0.48	1964	0.00
1	31	59	44	83	1963	29	1951	23	45	40	1954	7	1977	0.011	46	0.42	1978	0.10
2	1	57	44	84	1963	11	1985	24	44	44	1963	-12	1951	0.003	47	0.06	1990	0.00
2	2	59	45	79	1963	20	1985	22	45	48	1963	-12	1951	0.015	47	0.52	1975	0.03
2	3	57	44	78	1987	19	1956	22	44	43	1992	-1	1972	0.015	47	0.45	1964	0.17
2	4	60	42	80	1963	18	1956	24	41	41	1957	9	1956	0.039	47	1.30	1956	0.33
2	5	59	42	80	1963	27	1982	24	41	41	1958	0	1956	0.031	47	1.43	1988	0.36

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										HI	YR	LO						
2	6	59	45	80	1995	20	1982	22	44	36	1951	2	1956	0.007	47	0.29	1979	0.08
2	7	58	46	84	1963	18	1989	22	45	48	1957	2	1956	0.010	47	0.39	1997	0.00
2	8	61	47	85	1957	28	1989	22	46	43	1966	5	1956	0.015	47	0.41	1973	0.15
2	9	62	46	86	1957	28	1980	24	46	50	1960	4	1967	0.010	47	0.29	1980	0.11
2	10	61	43	86	1957	29	1973	23	44	40	1976	1	1956	0.007	47	0.26	1986	0.07
2	11	64	43	83	1962	33	1986	24	44	40	1976	2	1981	0.016	47	0.29	1963	0.04
2	12	62	43	85	1962	29	1986	24	44	42	1957	6	1981	0.030	47	0.62	1968	0.18
2	13	63	42	84	1962	30	1986	26	43	45	1991	-2	1963	0.018	46	0.41	1997	0.00
2	14	67	43	86	1967	37	1951	27	44	49	1962	6	1966	0.021	46	0.44	1962	0.00
2	15	64	44	86	1979	31	1978	26	44	50	1967	8	1951	0.001	46	0.04	1978	0.02
2	16	64	45	80	1986	45	1990	25	45	45	1986	8	1990	0.010	47	0.18	1975	0.05
2	17	63	45	78	1982	29	1979	27	45	41	1986	9	1990	0.006	47	0.25	1989	0.07
2	18	64	43	86	1970	33	1980	27	43	44	1955	16	1966	0.009	46	0.32	1957	0.02
2	19	63	42	85	1986	42	1978	28	42	41	1994	13	1964	0.016	46	0.39	1987	0.00
2	20	63	43	88	1986	39	1987	27	42	44	1980	6	1953	0.019	46	0.26	1964	0.13
2	21	62	42	89	1986	34	1971	25	42	42	1958	4	1964	0.019	47	0.45	1997	0.05
2	22	63	44	84	1996	42	1966	24	45	45	1958	7	1987	0.062	47	1.04	1973	0.13
2	23	63	46	87	1996	27	1975	25	46	43	1958	4	1976	0.006	47	0.14	1975	0.25
2	24	63	45	82	1982	37	1953	26	45	50	1951	-5	1965	0.009	47	0.19	1992	0.02
2	25	65	44	82	1976	36	1997	26	43	46	1951	-5	1960	0.006	46	0.19	1951	0.01
2	26	67	43	87	1986	37	1982	28	43	46	1996	6	1952	0.000	46	0.00	1997	0.00
2	27	67	42	88	1986	43	1984	29	42	49	1981	15	1964	0.006	45	0.11	1997	0.00
2	28	67	43	79	1976	48	1990	28	43	46	1981	9	1962	0.023	46	0.34	1968	0.00
2	29	67	12	85	1972	42	1996	27	12	42	1952	14	1984	0.000	12	0.00	1996	0.00
3	1	65	45	84	1972	31	1960	29	46	48	1973	17	1984	0.009	47	0.22	1993	0.00
3	2	67	45	84	1967	34	1995	29	47	48	1976	13	1962	0.000	47	0.01	1971	0.02
3	3	66	46	89	1974	35	1965	29	47	47	1986	5	1971	0.001	47	0.04	1958	0.00
3	4	65	44	86	1974	29	1978	27	45	45	1974	12	1971	0.007	47	0.19	1981	0.00
3	5	64	42	86	1956	34	1969	27	42	45	1983	11	1953	0.010	46	0.18	1958	0.03
3	6	66	44	85	1991	34	1984	28	43	50	1991	9	1989	0.029	46	1.13	1958	0.00
3	7	69	43	86	1972	52	1984	29	45	43	1968	6	1996	0.001	47	0.03	1996	0.01
3	8	69	43	87	1972	48	1996	29	45	47	1962	12	1967	0.009	47	0.19	1994	0.00
3	9	70	46	86	1986	36	1996	29	44	49	1986	8	1996	0.004	46	0.11	1994	0.00
3	10	70	44	86	1954	44	1994	31	46	51	1990	16	1964	0.038	47	1.35	1973	0.00
3	11	69	43	85	1982	40	1969	32	44	49	1980	15	1979	0.024	46	0.52	1968	0.00
3	12	69	43	88	1972	41	1958	31	44	54	1982	10	1959	0.004	46	0.07	1981	0.03
3	13	69	43	89	1972	37	1993	30	44	49	1990	17	1959	0.003	47	0.12	1975	0.00
3	14	69	45	85	1971	40	1962	30	46	49	1967	11	1988	0.006	47	0.16	1982	0.01
3	15	70	45	86	1972	49	1969	31	46	49	1972	17	1988	0.003	47	0.09	1969	0.02
3	16	69	44	89	1974	36	1969	31	46	43	1987	14	1976	0.006	47	0.19	1969	0.04
3	17	70	45	86	1984	48	1969	30	45	44	1953	16	1959	0.004	46	0.13	1961	0.00
3	18	71	41	90	1974	45	1988	30	43	46	1994	16	1980	0.003	46	0.12	1958	0.00
3	19	72	44	89	1982	39	1965	32	44	47	1994	11	1965	0.014	46	0.55	1961	0.00
3	20	72	43	88	1995	46	1965	32	44	55	1994	11	1965	0.049	47	0.81	1957	0.06
3	21	70	43	86	1988	37	1968	31	44	44	1979	13	1965	0.023	47	0.42	1974	0.16
3	22	73	45	92	1995	46	1952	33	46	52	1954	16	1955	0.008	47	0.22	1958	0.00
3	23	74	46	86	1978	51	1952	33	47	52	1972	12	1952	0.003	47	0.08	1958	0.00
3	24	73	46	88	1971	53	1957	34	47	49	1994	20	1980	0.006	47	0.13	1958	0.00
3	25	71	45	84	1993	40	1990	33	45	51	1995	20	1996	0.003	47	0.14	1958	0.00
3	26	72	42	88	1976	49	1987	34	42	53	1953	18	1959	0.004	47	0.12	1987	0.00
3	27	73	46	90	1967	50	1982	34	47	50	1972	21	1955	0.009	47	0.37	1977	0.00
3	28	74	46	95	1971	38	1994	35	46	54	1985	14	1994	0.016	47	0.45	1966	0.00
3	29	73	45	90	1967	35	1975	35	45	55	1985	20	1975	0.005	46	0.14	1987	0.02
3	30	71	45	86	1989	30	1987	35	45	57	1968	9	1987	0.013	46	0.19	1975	0.04
3	31	73	45	92	1974	50	1991	35	45	52	1956	17	1972	0.005	46	0.11	1992	0.00
4	1	76	44	91	1986	59	1992	36	44	53	1964	20	1955	0.004	47	0.11	1988	0.00
4	2	76	44	91	1959	44	1988	35	44	51	1965	18	1970	0.004	47	0.18	1992	0.00
4	3	75	45	88	1959	51	1987	35	46	47	1997	19	1987	0.026	47	0.94	1997	0.00
4	4	74	44	92	1961	53	1973	35	43	54	1985	16	1979	0.005	47	0.22	1995	0.00
4	5	74	44	92	1959	36	1983	35	44	52	1953	20	1973	0.004	47	0.11	1983	0.00
4	6	76	44	93	1954	41	1987	35	45	52	1967	22	1994	0.016	47	0.29	1983	0.00
4	7	79	46	98	1972	42	1983	40	46	60	1967	24	1971	0.002	47	0.08	1983	0.00
4	8	78	46	96	1963	35	1983	38	46	52	1967	21	1973	0.012	47	0.18	1984	0.00
4	9	77	45	92	1963	42	1973	38	45	55	1967	19	1973	0.004	47	0.09	1997	0.00
4	10	76	44	94	1963	55	1997	38	44	58	1972	28	1988	0.003	47	0.09	1997	0.00

										HI	YR	LO						
4	11	78	45	93	1972	50	1989	39	45	60	1967	23	1995	0.027	47	0.48	1969	0.00
4	12	77	47	93	1972	43	1997	39	46	61	1960	23	1953	0.015	47	0.48	1980	0.00
4	13	76	46	96	1972	40	1980	39	46	57	1981	20	1959	0.026	47	0.52	1958	0.00
4	14	79	46	93	1986	52	1980	39	46	57	1992	19	1959	0.021	47	0.52	1977	0.00
4	15	79	46	95	1963	51	1981	39	46	52	1971	26	1996	0.021	47	0.50	1981	0.00
4	16	81	47	96	1962	58	1981	40	47	54	1979	26	1961	0.002	47	0.07	1976	0.00
4	17	81	47	92	1978	63	1988	43	47	55	1979	30	1960	0.007	46	0.22	1958	0.00
4	18	81	45	94	1987	49	1990	42	45	58	1979	31	1953	0.016	47	0.39	1952	0.00
4	19	82	45	95	1987	51	1990	44	45	52	1977	26	1953	0.006	47	0.22	1992	0.00
4	20	80	46	93	1954	57	1992	42	46	58	1962	25	1995	0.009	47	0.22	1992	0.00
4	21	80	45	97	1965	58	1982	40	45	56	1965	28	1964	0.012	47	0.57	1959	0.00
4	22	81	46	100	1965	56	1987	43	46	59	1957	30	1967	0.023	47	0.50	1990	0.00
4	23	80	44	98	1965	47	1982	43	45	62	1958	30	1963	0.014	46	0.62	1953	0.00
4	24	82	46	98	1989	49	1982	42	46	56	1965	24	1995	0.026	47	0.79	1966	0.00
4	25	83	44	97	1996	67	1980	45	44	57	1955	31	1995	0.063	47	1.53	1997	0.00
4	26	83	45	96	1996	46	1997	45	45	63	1951	30	1980	0.033	47	0.95	1965	0.00
4	27	82	46	93	1974	64	1973	45	46	60	1959	28	1973	0.007	47	0.16	1997	0.00
4	28	81	46	96	1996	64	1995	43	45	57	1993	27	1975	0.028	47	1.26	1985	0.00
4	29	83	46	96	1996	60	1957	46	46	63	1990	27	1975	0.013	47	0.21	1985	0.00
4	30	82	45	95	1962	59	1994	44	45	64	1955	30	1968	0.021	47	0.33	1955	0.00
5	1	82	41	93	1995	59	1974	45	41	60	1981	32	1970	0.026	47	0.48	1976	0.00
5	2	80	43	95	1992	62	1990	44	42	61	1986	25	1967	0.037	47	1.07	1981	0.00
5	3	82	45	97	1964	48	1978	45	45	57	1986	28	1983	0.043	47	1.40	1981	0.00
5	4	82	43	97	1971	57	1979	46	42	61	1965	30	1979	0.004	45	0.13	1980	0.00
5	5	85	44	99	1962	67	1953	46	44	61	1977	32	1953	0.019	46	0.58	1976	0.00
5	6	84	44	98	1962	63	1976	46	45	58	1952	24	1959	0.056	47	1.22	1981	0.00
5	7	85	43	98	1979	67	1951	48	44	60	1979	27	1975	0.021	47	1.01	1959	0.00
5	8	87	44	100	1952	60	1976	48	44	60	1996	32	1984	0.010	47	0.24	1959	0.00
5	9	86	44	104	1989	60	1976	48	43	58	1985	31	1975	0.000	47	0.01	1992	0.00
5	10	87	43	101	1962	71	1981	50	43	64	1991	36	1981	0.018	47	0.45	1955	0.00
5	11	86	45	102	1974	69	1994	48	44	67	1991	36	1986	0.023	47	0.45	1972	0.00
5	12	87	44	102	1984	68	1997	49	45	60	1989	38	1957	0.041	47	0.70	1955	0.00
5	13	88	44	102	1996	60	1953	48	44	60	1995	37	1957	0.026	47	0.69	1977	0.00
5	14	87	40	100	1974	66	1996	49	42	61	1951	34	1975	0.009	47	0.38	1973	0.00
5	15	86	42	99	1988	52	1973	50	41	61	1960	34	1973	0.023	47	0.37	1959	0.00
5	16	88	40	101	1978	67	1973	50	39	61	1995	33	1983	0.033	46	1.10	1984	0.00
5	17	88	44	100	1996	67	1984	49	42	60	1996	40	1986	0.035	46	0.70	1979	0.00
5	18	85	45	100	1974	52	1986	50	45	62	1966	32	1986	0.085	47	1.33	1954	0.00
5	19	86	43	97	1991	63	1997	51	43	65	1972	34	1971	0.062	47	1.20	1963	0.00
5	20	88	41	100	1974	70	1988	51	42	61	1991	38	1963	0.050	46	1.22	1951	0.00
5	21	89	43	101	1953	74	1997	50	44	65	1991	35	1967	0.059	47	1.20	1992	0.00
5	22	90	44	106	1996	67	1979	52	42	64	1989	40	1974	0.122	47	3.14	1992	0.00
5	23	89	43	105	1996	68	1963	52	41	68	1984	40	1960	0.027	47	0.58	1992	0.00
5	24	89	45	103	1989	70	1992	52	44	64	1984	39	1975	0.022	47	0.52	1987	0.00
5	25	89	44	104	1989	62	1992	53	44	63	1984	42	1954	0.027	47	1.11	1992	0.00
5	26	90	44	101	1989	62	1997	52	44	60	1964	40	1960	0.043	47	1.04	1966	0.00
5	27	89	42	104	1951	66	1997	53	41	62	1989	40	1960	0.024	47	0.63	1964	0.00
5	28	90	41	102	1951	74	1986	54	40	68	1991	40	1973	0.019	46	0.37	1953	0.00
5	29	91	43	104	1951	67	1992	54	43	68	1989	39	1973	0.040	47	0.38	1972	0.00
5	30	90	40	103	1968	63	1992	53	39	69	1989	38	1975	0.014	47	0.45	1960	0.00
5	31	90	41	102	1977	70	1975	53	40	65	1985	32	1975	0.046	47	0.91	1986	0.00
6	1	89	45	103	1969	58	1983	54	43	62	1994	39	1964	0.016	47	0.29	1986	0.00
6	2	91	43	102	1993	71	1979	54	42	62	1994	44	1992	0.046	47	0.78	1989	0.00
6	3	91	45	102	1990	67	1978	55	44	63	1956	44	1970	0.044	47	1.35	1978	0.00
6	4	90	44	103	1990	64	1951	56	43	68	1990	42	1957	0.111	47	3.00	1967	0.00
6	5	92	44	104	1961	71	1970	56	43	71	1990	40	1962	0.055	47	1.29	1997	0.00
6	6	93	45	108	1990	71	1985	56	44	70	1956	45	1985	0.077	47	1.82	1985	0.00
6	7	94	45	110	1980	70	1983	57	45	65	1980	48	1971	0.019	46	0.55	1976	0.00
6	8	95	44	105	1980	81	1997	58	43	70	1980	48	1975	0.005	47	0.14	1992	0.00
6	9	94	44	110	1981	80	1997	56	42	67	1990	45	1993	0.063	47	0.76	1987	0.00
6	10	92	43	110	1981	76	1997	56	43	65	1980	44	1951	0.023	46	0.52	1985	0.00
6	11	93	42	105	1959	79	1991	57	41	68	1952	43	1979	0.074	46	1.19	1975	0.00
6	12	94	45	106	1981	77	1975	58	44	72	1958	44	1979	0.060	47	1.59	1985	0.00
6	13	94	45	103	1958	73	1985	60	44	69	1954	46	1979	0.057	47	0.74	1978	0.00
6	14	96	47	105	1980	81	1969	59	45	71	1990	49	1969	0.054	47	1.71	1984	0.00

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										HI	YR	LO						
6	15	96	46	107	1980	81	1996	59	44	70	1952	49	1969	0.010	47	0.29	1961	0.00
6	16	95	45	106	1980	69	1961	59	43	74	1960	45	1981	0.015	47	0.39	1967	0.00
6	17	96	42	109	1977	76	1997	59	40	71	1965	44	1997	0.019	47	0.48	1984	0.00
6	18	98	43	110	1960	82	1997	60	42	71	1990	45	1997	0.010	47	0.25	1953	0.00
6	19	98	44	106	1974	78	1984	61	42	69	1993	53	1975	0.037	47	0.55	1982	0.00
6	20	97	46	107	1996	79	1984	61	44	70	1993	48	1979	0.036	47	0.65	1984	0.00
6	21	98	45	109	1981	80	1982	61	44	70	1990	46	1953	0.025	47	0.50	1993	0.00
6	22	98	46	113	1981	77	1970	61	45	71	1996	50	1969	0.012	47	0.22	1993	0.00
6	23	97	45	107	1958	65	1989	62	44	72	1976	49	1973	0.015	47	0.38	1981	0.00
6	24	98	45	109	1980	69	1986	62	43	70	1972	51	1973	0.042	47	0.61	1986	0.00
6	25	97	44	110	1990	73	1986	62	43	69	1987	50	1973	0.094	47	1.67	1986	0.00
6	26	96	46	110	1990	79	1986	62	45	69	1990	52	1976	0.030	47	0.51	1987	0.00
6	27	97	46	112	1994	82	1966	62	46	72	1990	46	1983	0.030	47	0.77	1996	0.00
6	28	97	47	114	1994	78	1996	63	47	72	1991	48	1983	0.092	47	2.00	1978	0.00
6	29	98	45	112	1980	82	1966	63	45	71	1991	48	1983	0.031	47	0.72	1988	0.00
6	30	98	47	107	1957	84	1978	62	47	72	1993	41	1995	0.158	47	1.89	1989	0.00
7	1	96	45	108	1957	77	1970	63	45	72	1968	52	1975	0.026	46	0.34	1970	0.00
7	2	97	43	108	1994	84	1988	63	43	72	1955	53	1985	0.050	45	1.83	1986	0.00
7	3	97	42	109	1994	78	1986	64	42	74	1990	55	1975	0.032	45	0.63	1968	0.00
7	4	97	43	108	1980	75	1968	63	44	75	1990	40	1988	0.069	45	1.15	1976	0.00
7	5	96	44	109	1994	71	1968	63	44	69	1994	54	1995	0.107	46	2.96	1968	0.00
7	6	96	44	106	1971	75	1972	63	44	72	1966	56	1985	0.055	46	1.05	1960	0.00
7	7	97	45	106	1992	71	1960	63	45	72	1993	53	1958	0.095	46	2.46	1960	0.00
7	8	97	44	110	1951	72	1952	63	44	72	1993	54	1952	0.060	46	0.88	1952	0.00
7	9	96	42	109	1951	82	1952	64	42	72	1996	56	1985	0.078	46	2.25	1981	0.00
7	10	96	42	106	1951	78	1981	64	42	70	1991	57	1995	0.064	46	1.11	1988	0.00
7	11	96	42	106	1963	79	1988	64	42	71	1990	57	1994	0.049	46	0.88	1975	0.00
7	12	96	46	106	1970	83	1975	64	46	71	1951	56	1975	0.063	46	0.96	1959	0.00
7	13	95	46	112	1958	74	1991	63	46	71	1996	53	1975	0.088	45	1.04	1959	0.00
7	14	95	45	112	1958	73	1991	63	45	71	1958	54	1962	0.063	45	1.43	1976	0.00
7	15	95	45	106	1958	78	1991	62	45	70	1970	52	1959	0.158	45	1.42	1993	0.00
7	16	96	44	106	1980	85	1991	63	44	73	1970	53	1975	0.061	44	1.42	1993	0.00
7	17	96	45	108	1980	83	1975	63	45	73	1983	50	1955	0.104	46	1.30	1959	0.00
7	18	95	43	108	1978	84	1984	63	43	71	1996	52	1988	0.020	46	0.48	1953	0.00
7	19	95	45	105	1978	84	1984	64	45	73	1965	49	1988	0.025	44	0.24	1984	0.00
7	20	96	44	106	1963	80	1979	64	44	74	1970	48	1988	0.092	45	1.22	1988	0.00
7	21	95	45	105	1951	75	1988	63	45	69	1966	43	1988	0.049	46	1.38	1989	0.00
7	22	95	44	105	1996	78	1975	63	44	73	1996	55	1988	0.103	45	1.57	1953	0.00
7	23	95	45	108	1963	82	1976	63	45	69	1979	57	1988	0.063	45	0.65	1978	0.00
7	24	95	44	108	1963	81	1978	63	44	72	1963	51	1961	0.104	45	1.13	1978	0.00
7	25	96	44	106	1963	77	1991	63	43	73	1969	54	1975	0.088	46	1.90	1991	0.00
7	26	95	45	106	1995	77	1991	62	45	73	1969	46	1988	0.092	46	1.63	1985	0.00
7	27	96	45	109	1995	83	1973	63	45	71	1966	47	1988	0.037	46	0.41	1992	0.00
7	28	95	45	110	1995	85	1955	63	45	75	1954	51	1988	0.117	46	1.15	1981	0.00
7	29	95	45	104	1983	84	1981	63	45	73	1966	48	1988	0.049	46	0.62	1962	0.00
7	30	95	45	106	1995	81	1990	63	45	70	1966	56	1953	0.052	46	1.70	1971	0.00
7	31	95	46	104	1972	70	1971	64	46	77	1969	47	1988	0.071	45	2.03	1965	0.00
8	1	95	44	107	1966	83	1973	64	44	75	1972	55	1990	0.083	45	1.00	1971	0.00
8	2	95	45	103	1987	85	1995	64	45	73	1972	56	1971	0.062	46	2.05	1974	0.00
8	3	96	45	106	1980	83	1971	64	45	70	1970	56	1961	0.091	46	1.44	1984	0.00
8	4	95	44	103	1980	76	1974	63	44	72	1969	51	1988	0.087	46	2.54	1993	0.00
8	5	95	46	107	1977	78	1974	63	46	74	1989	51	1988	0.029	46	0.36	1991	0.00
8	6	97	45	103	1980	86	1971	62	44	67	1993	50	1975	0.017	46	0.35	1980	0.00
8	7	97	43	104	1985	73	1990	62	44	69	1996	48	1988	0.067	46	1.67	1972	0.00
8	8	95	44	105	1994	75	1990	62	44	70	1987	49	1990	0.070	46	1.68	1996	0.00
8	9	95	45	103	1977	71	1984	62	45	70	1995	53	1990	0.102	46	1.42	1984	0.00
8	10	94	44	105	1977	71	1984	61	43	70	1951	50	1988	0.155	46	2.02	1967	0.00
8	11	93	43	102	1992	74	1984	62	43	69	1983	48	1988	0.019	46	0.35	1955	0.00
8	12	92	46	100	1969	77	1981	60	46	69	1993	52	1988	0.148	46	2.80	1977	0.00
8	13	93	45	102	1969	72	1980	61	46	70	1989	48	1988	0.017	46	0.28	1980	0.00
8	14	94	45	103	1969	83	1981	62	44	67	1991	55	1960	0.051	45	1.10	1990	0.00
8	15	94	44	103	1962	81	1991	62	44	69	1986	54	1960	0.051	46	0.51	1980	0.00
8	16	94	45	104	1982	82	1991	62	45	70	1982	48	1988	0.050	46	1.17	1986	0.00
8	17	95	44	107	1978	80	1979	62	45	68	1991	50	1973	0.095	46	1.67	1981	0.00
8	18	95	41	105	1969	79	1979	62	42	70	1969	53	1962	0.040	46	0.69	1990	0.00

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										HI	YR	LO						
8	19	94	44	107	1969	82	1961	62	45	67	1994	55	1962	0.029	46	0.29	1961	0.00
8	20	93	44	104	1970	80	1961	62	44	71	1995	54	1979	0.111	46	2.80	1977	0.00
8	21	93	44	103	1986	82	1979	61	44	71	1982	47	1988	0.073	46	1.00	1977	0.00
8	22	93	43	104	1983	82	1958	61	43	69	1952	53	1967	0.156	46	2.02	1951	0.00
8	23	92	44	104	1985	66	1966	61	44	68	1952	53	1976	0.090	46	2.04	1966	0.00
8	24	92	44	102	1985	67	1974	60	44	68	1992	52	1960	0.079	45	0.83	1974	0.00
8	25	93	45	103	1985	74	1974	61	45	68	1969	51	1973	0.110	46	2.50	1971	0.00
8	26	92	46	103	1985	76	1974	60	46	67	1977	49	1975	0.053	46	2.16	1972	0.00
8	27	93	45	102	1985	74	1972	60	43	68	1977	49	1970	0.062	46	1.64	1986	0.00
8	28	93	42	104	1962	78	1980	61	42	69	1952	53	1980	0.103	46	2.00	1989	0.00
8	29	93	40	102	1962	82	1974	59	43	67	1969	40	1988	0.010	46	0.19	1951	0.00
8	30	92	45	103	1962	71	1963	60	44	68	1969	44	1988	0.038	46	0.97	1968	0.00
8	31	92	44	101	1964	74	1963	59	43	65	1989	41	1988	0.071	46	1.29	1963	0.00
9	1	91	42	103	1952	74	1993	60	42	69	1983	46	1988	0.050	44	0.85	1953	0.00
9	2	91	43	101	1982	80	1969	58	43	68	1989	48	1988	0.075	45	1.75	1962	0.00
9	3	92	41	101	1979	64	1972	59	41	68	1979	47	1955	0.038	46	0.65	1982	0.00
9	4	91	42	104	1983	69	1974	58	42	67	1983	42	1961	0.025	46	0.48	1991	0.00
9	5	91	43	102	1992	77	1967	57	43	67	1983	44	1961	0.117	46	1.40	1963	0.00
9	6	91	41	106	1983	70	1981	57	41	65	1990	43	1984	0.047	45	0.79	1981	0.00
9	7	90	42	105	1983	72	1973	57	42	66	1990	44	1952	0.088	45	1.04	1993	0.00
9	8	90	40	100	1970	65	1973	57	41	65	1979	45	1952	0.108	46	2.30	1969	0.00
9	9	89	44	101	1970	70	1981	57	44	66	1991	41	1953	0.058	46	1.10	1995	0.00
9	10	88	45	102	1992	57	1976	57	45	67	1983	42	1956	0.086	45	1.04	1990	0.00
9	11	89	43	99	1963	69	1980	56	42	64	1972	42	1960	0.030	46	0.42	1964	0.00
9	12	88	42	99	1974	75	1989	56	42	65	1993	40	1959	0.070	46	0.91	1961	0.00
9	13	87	45	98	1956	52	1975	55	45	63	1991	40	1959	0.075	46	0.83	1983	0.00
9	14	87	44	98	1960	55	1975	55	44	64	1986	37	1959	0.060	45	1.25	1980	0.00
9	15	86	43	104	1956	62	1979	54	43	63	1992	36	1959	0.065	45	0.66	1985	0.00
9	16	86	44	101	1956	64	1979	53	44	63	1985	41	1951	0.017	46	0.29	1995	0.00
9	17	88	43	99	1956	61	1979	53	43	63	1970	37	1951	0.030	46	0.75	1965	0.00
9	18	88	43	98	1983	59	1971	53	43	64	1995	37	1951	0.018	46	0.33	1991	0.00
9	19	87	43	99	1954	49	1971	54	43	66	1960	39	1968	0.075	46	0.94	1974	0.00
9	20	87	44	99	1951	49	1991	53	44	63	1990	34	1971	0.041	46	0.56	1985	0.00
9	21	85	44	98	1977	52	1991	52	44	63	1990	34	1983	0.057	46	0.95	1988	0.00
9	22	82	43	97	1959	50	1995	51	43	64	1990	33	1975	0.063	46	0.88	1974	0.00
9	23	82	44	97	1961	53	1974	51	44	67	1993	36	1975	0.058	45	1.02	1974	0.00
9	24	83	39	98	1953	54	1974	51	40	65	1993	39	1975	0.059	44	0.90	1971	0.00
9	25	84	42	97	1951	58	1974	49	41	59	1964	38	1975	0.081	46	0.97	1962	0.00
9	26	85	42	101	1953	62	1978	50	42	61	1967	40	1975	0.162	46	4.11	1955	0.00
9	27	84	42	99	1982	59	1980	48	41	59	1982	37	1989	0.071	46	1.80	1958	0.00
9	28	84	43	98	1953	62	1980	48	43	62	1982	33	1973	0.035	45	0.72	1984	0.00
9	29	84	43	98	1994	52	1984	48	43	60	1983	34	1976	0.025	46	0.65	1995	0.00
9	30	84	43	97	1994	54	1985	48	42	62	1983	34	1996	0.010	45	0.29	1990	0.00
10	1	84	38	99	1977	53	1985	48	38	62	1983	35	1963	0.034	46	1.45	1982	0.00
10	2	84	41	94	1969	56	1985	47	41	67	1954	35	1975	0.051	46	1.25	1955	0.00
10	3	83	42	95	1973	67	1959	47	42	59	1981	30	1961	0.044	46	0.72	1955	0.00
10	4	82	44	93	1991	69	1959	46	42	61	1955	31	1961	0.035	46	1.24	1984	0.00
10	5	82	42	94	1993	62	1966	46	43	59	1954	30	1959	0.014	46	0.28	1962	0.00
10	6	81	44	95	1967	62	1986	46	44	62	1977	30	1995	0.044	46	0.93	1954	0.00
10	7	80	45	94	1956	62	1986	44	46	62	1977	30	1952	0.117	46	3.92	1954	0.00
10	8	82	45	98	1979	54	1976	44	44	59	1968	19	1976	0.018	45	0.62	1994	0.00
10	9	83	42	98	1979	60	1970	44	42	62	1961	24	1970	0.032	46	0.37	1985	0.00
10	10	82	42	93	1969	62	1990	43	42	57	1954	27	1992	0.032	46	1.25	1986	0.00
10	11	83	43	93	1969	67	1982	42	44	57	1972	29	1976	0.017	46	0.37	1974	0.00
10	12	82	44	93	1996	58	1986	42	44	58	1972	28	1977	0.073	46	1.30	1974	0.00
10	13	81	45	95	1968	48	1986	42	44	56	1953	30	1977	0.016	46	0.28	1974	0.00
10	14	81	42	94	1996	57	1969	41	43	56	1996	30	1969	0.010	46	0.44	1974	0.00
10	15	79	42	94	1962	57	1974	40	41	53	1996	30	1952	0.033	46	0.90	1994	0.00
10	16	77	40	90	1989	42	1970	39	41	53	1981	25	1975	0.018	46	0.55	1960	0.00
10	17	78	41	95	1979	61	1969	40	41	56	1993	27	1976	0.093	46	3.53	1960	0.00
10	18	77	44	95	1988	53	1989	40	44	59	1972	21	1966	0.020	46	0.53	1956	0.00
10	19	77	44	88	1995	55	1989	39	45	58	1969	19	1989	0.033	46	0.42	1951	0.00
10	20	75	45	89	1979	42	1972	38	45	55	1986	17	1976	0.078	46	2.55	1983	0.00
10	21	76	44	92	1979	46	1972	38	44	56	1985	21	1989	0.071	46	0.85	1969	0.00
10	22	75	42	90	1961	52	1996	38	41	55	1985	24	1990	0.040	46	0.90	1969	0.00

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										HI	YR	LO						
10	23	75	41	90	1959	47	1984	37	41	52	1974	23	1996	0.050	46	1.15	1974	0.00
10	24	74	41	85	1973	43	1978	37	42	56	1992	25	1996	0.044	46	1.11	1978	0.00
10	25	75	42	94	1959	43	1984	38	42	50	1992	23	1993	0.017	46	0.29	1992	0.00
10	26	74	45	91	1959	50	1957	38	45	51	1951	25	1981	0.022	46	0.48	1951	0.00
10	27	74	45	89	1979	53	1993	37	45	51	1974	25	1953	0.032	46	1.17	1969	0.00
10	28	73	44	88	1988	38	1976	35	44	52	1977	17	1970	0.012	46	0.28	1969	0.07
10	29	73	42	87	1987	38	1976	35	42	49	1956	17	1980	0.026	46	0.34	1958	0.02
10	30	72	41	87	1968	43	1993	34	41	49	1977	20	1993	0.016	46	0.22	1979	0.00
10	31	71	44	86	1968	34	1991	33	44	51	1983	10	1991	0.025	46	0.50	1961	0.04
11	1	72	44	85	1975	45	1991	36	45	54	1987	13	1993	0.017	45	0.24	1963	0.00
11	2	68	44	89	1973	40	1951	33	45	54	1983	14	1989	0.017	45	0.48	1987	0.01
11	3	68	45	82	1988	33	1991	31	46	56	1994	13	1989	0.050	46	0.95	1983	0.00
11	4	67	44	80	1984	37	1991	32	44	53	1983	12	1991	0.033	46	0.84	1986	0.00
11	5	67	40	84	1973	50	1992	32	40	51	1983	22	1991	0.033	46	0.75	1983	0.00
11	6	68	41	87	1988	45	1961	30	40	46	1983	10	1959	0.002	46	0.04	1987	0.00
11	7	69	41	85	1975	50	1993	33	41	45	1977	11	1959	0.013	46	0.45	1977	0.00
11	8	67	41	86	1980	33	1990	32	42	48	1981	13	1993	0.003	46	0.07	1990	0.01
11	9	71	43	89	1980	49	1990	31	43	48	1965	16	1962	0.014	46	0.35	1961	0.00
11	10	69	43	84	1985	50	1957	30	43	45	1982	17	1953	0.000	46	0.02	1957	0.00
11	11	69	39	84	1956	52	1957	29	39	45	1982	15	1968	0.009	46	0.32	1978	0.00
11	12	69	42	82	1956	47	1991	30	42	45	1958	15	1987	0.010	46	0.37	1994	0.00
11	13	68	41	84	1955	34	1976	30	41	49	1958	9	1975	0.035	46	0.78	1961	0.11
11	14	68	41	84	1973	27	1976	30	42	49	1968	11	1975	0.026	46	0.59	1961	0.00
11	15	68	43	85	1988	35	1976	28	44	50	1962	-3	1961	0.002	46	0.04	1968	0.00
11	16	65	46	86	1963	38	1961	28	46	43	1971	-1	1961	0.046	46	1.24	1991	0.00
11	17	64	45	85	1981	33	1980	28	45	49	1967	4	1959	0.031	45	0.42	1957	0.00
11	18	64	45	82	1981	39	1980	27	45	43	1986	9	1959	0.011	46	0.14	1964	0.00
11	19	66	42	80	1981	44	1980	27	43	42	1992	9	1987	0.005	46	0.14	1962	0.00
11	20	65	42	87	1996	47	1991	26	42	50	1977	13	1987	0.002	45	0.07	1991	0.00
11	21	65	42	87	1996	40	1972	26	41	44	1978	9	1953	0.006	46	0.12	1972	0.00
11	22	64	43	77	1989	36	1992	26	43	45	1978	7	1953	0.003	46	0.08	1957	0.07
11	23	65	45	83	1965	42	1984	26	44	45	1978	5	1957	0.000	46	0.01	1992	0.00
11	24	62	43	79	1993	36	1952	27	43	48	1951	10	1979	0.014	45	0.29	1972	0.04
11	25	63	40	83	1959	30	1982	25	40	45	1978	13	1975	0.021	45	0.66	1980	0.00
11	26	65	40	83	1990	32	1980	25	40	47	1985	1	1975	0.037	45	0.18	1982	0.01
11	27	63	39	84	1995	34	1982	25	40	42	1977	3	1980	0.022	45	0.72	1982	0.15
11	28	57	37	77	1954	32	1976	23	38	42	1981	8	1992	0.010	45	0.25	1976	0.09
11	29	58	42	78	1966	26	1976	20	43	44	1981	2	1976	0.017	46	0.38	1976	0.09
11	30	58	44	76	1966	40	1976	23	44	43	1970	8	1976	0.011	46	0.29	1981	0.00
12	1	62	46	82	1970	37	1991	22	45	44	1962	7	1975	0.008	47	0.14	1971	0.00
12	2	62	47	78	1951	31	1991	22	46	43	1955	10	1991	0.011	46	0.19	1971	0.04
12	3	61	43	78	1973	35	1971	23	43	38	1955	8	1979	0.001	47	0.03	1964	0.00
12	4	62	42	85	1958	37	1964	24	43	42	1962	8	1990	0.007	47	0.18	1967	0.00
12	5	62	45	80	1958	32	1992	22	45	39	1969	4	1990	0.016	47	0.45	1992	0.10
12	6	62	45	75	1975	30	1992	22	46	49	1956	2	1950	0.021	47	0.97	1969	0.02
12	7	58	45	76	1981	29	1960	23	46	47	1980	6	1992	0.007	47	0.14	1961	0.03
12	8	61	45	78	1958	28	1978	23	45	37	1961	12	1978	0.039	47	0.48	1960	0.11
12	9	58	45	83	1950	17	1978	23	45	39	1965	-11	1978	0.029	47	0.71	1960	0.29
12	10	58	42	77	1970	29	1978	22	43	49	1965	-11	1978	0.011	47	0.26	1982	0.00
12	11	59	42	79	1950	31	1986	20	43	36	1965	7	1960	0.005	47	0.13	1986	0.01
12	12	57	41	84	1950	26	1972	20	42	38	1981	-3	1989	0.020	47	0.55	1991	0.09
12	13	61	45	82	1950	31	1985	22	47	40	1984	2	1989	0.007	47	0.19	1981	0.00
12	14	56	44	82	1950	31	1987	22	44	38	1951	3	1985	0.043	47	0.65	1984	0.41
12	15	56	43	74	1956	29	1987	19	44	37	1950	-8	1987	0.020	46	0.22	1970	0.09
12	16	55	44	74	1957	24	1967	18	45	32	1990	-7	1987	0.010	45	0.45	1959	0.00
12	17	56	40	75	1977	25	1989	20	41	38	1957	4	1979	0.006	46	0.18	1986	0.00
12	18	55	43	75	1980	32	1964	20	44	41	1962	0	1996	0.011	47	0.37	1986	0.00
12	19	57	44	81	1980	23	1983	20	43	40	1962	1	1996	0.007	47	0.33	1991	0.00
12	20	57	43	74	1994	19	1983	21	43	38	1991	-4	1973	0.012	47	0.31	1984	0.00
12	21	57	45	75	1981	34	1980	21	45	36	1962	0	1973	0.027	47	0.85	1967	0.00
12	22	56	45	83	1981	22	1989	20	46	38	1959	3	1963	0.022	46	0.58	1986	0.00
12	23	56	43	81	1964	21	1989	19	43	44	1965	-5	1990	0.005	47	0.19	1983	0.05
12	24	57	43	75	1969	33	1953	20	41	48	1964	-10	1953	0.000	47	0.00	1996	0.00
12	25	56	40	81	1955	21	1983	19	40	46	1959	3	1990	0.003	46	0.08	1962	0.00
12	26	55	40	74	1996	25	1987	20	40	42	1959	-3	1990	0.027	47	0.35	1982	0.19

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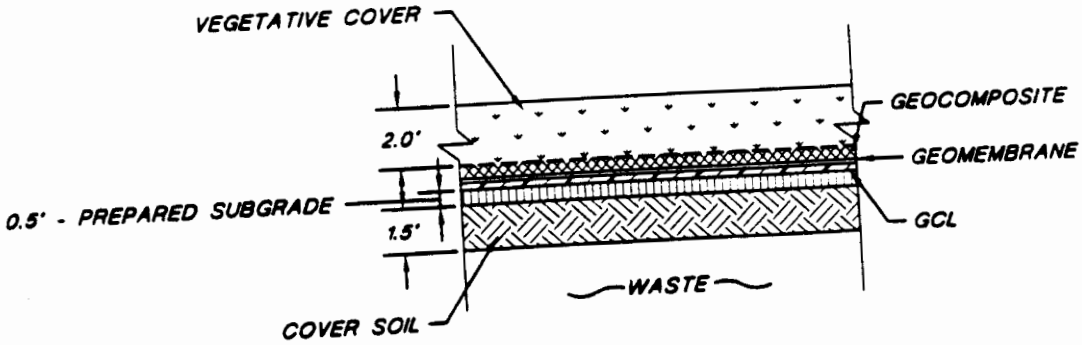
										HI	YR	LO						
12	27	55	42	75	1980	23	1983	20	42	36	1979	1	1973	0.008	47	0.19	1968	0.00
12	28	57	45	73	1980	35	1965	21	45	39	1984	-6	1987	0.005	47	0.19	1990	0.03
12	29	58	46	76	1980	29	1982	22	46	42	1984	2	1966	0.026	47	0.57	1969	0.16
12	30	56	44	80	1965	23	1983	20	44	50	1951	-7	1983	0.016	46	0.37	1969	0.08
12	31	57	41	75	1965	19	1969	20	41	54	1951	-2	1983	0.007	46	0.12	1974	0.03

Western Regional Climate Center, Greg McCurdy, gmwrcc@sage.dri.edu



COVER DETAIL

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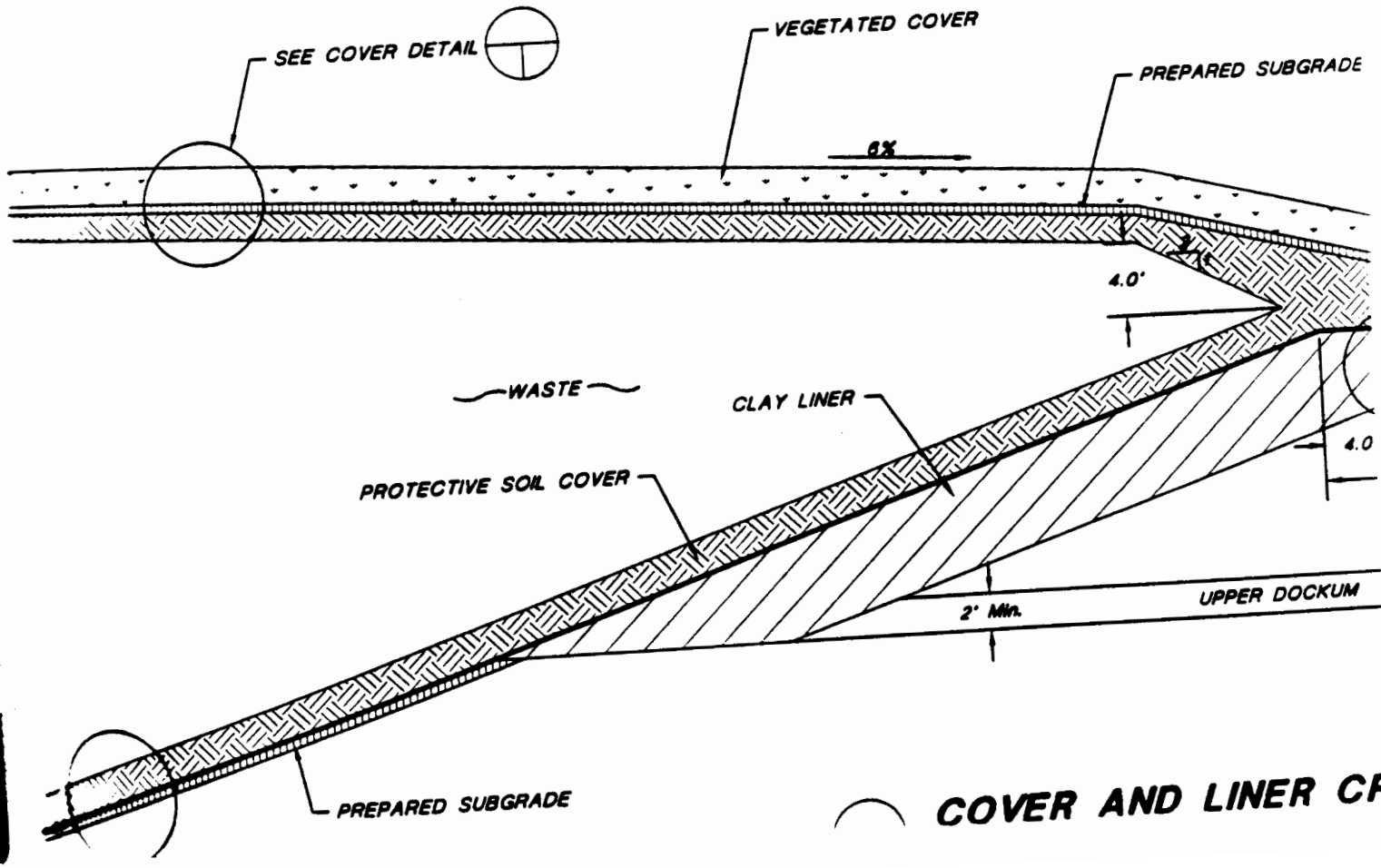

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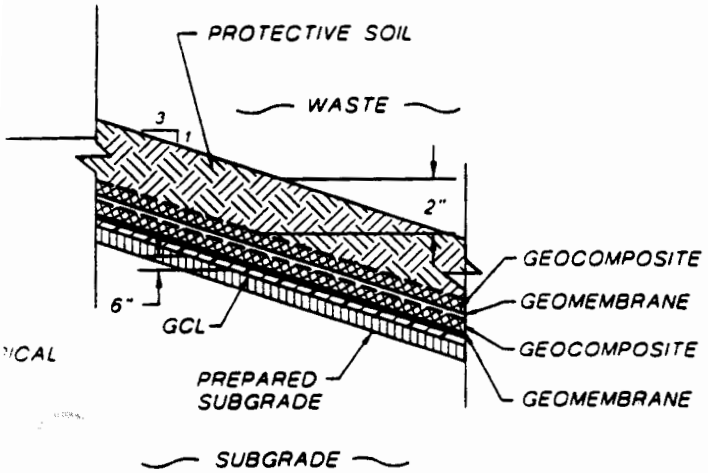

A 7 12 **SLOPE DETAIL**
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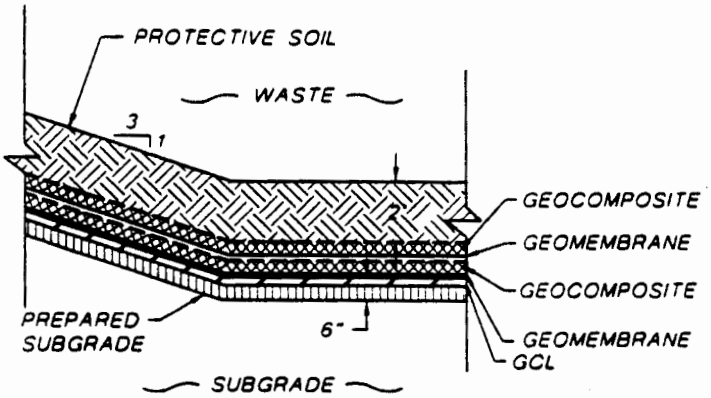
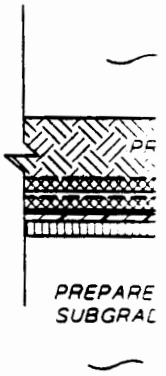
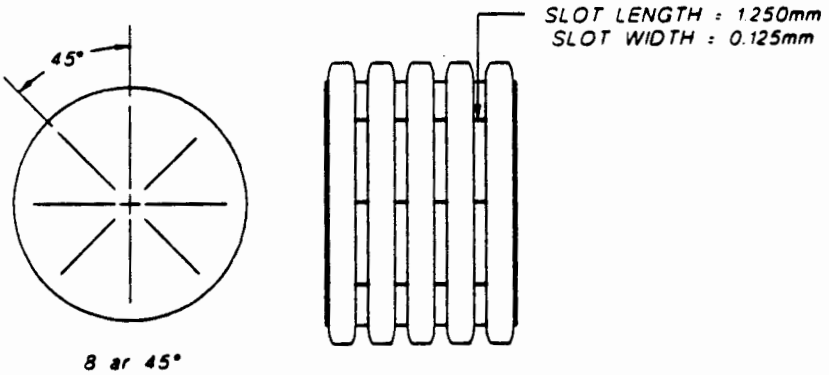


E 7 12 **TOE OF SLOPE DETAIL**
Not To Scale



D 7 12 **F**



G **PIPE PERFORATION DETAIL**

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TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Pipe Crushing

	Name	Date
Prepared By:	P. Pellicer	15-Nov-97
Checked By:	J. Pellicer	15-Nov-97
Reviewed By:	P. Gorski	15Nov97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Transit Park
Project Number: 602-0200 Sheet: 1 Of 8
Prepared By: P. Pellicer Date: 15-Nov-97
Checked By: J. Pellicer Date: 15-Nov-97

Pipe Crushing.

Objective: Evaluate adequacy of 12" + 18" SDR11 pipe against crushing.

Method: Compare Estimated Strains in the sump gravels placed around the sump pipes to allowable strains in the HDPE Pipe. Pipe should not strain more than than surrounding soils due to bridging.

$\sigma = E\epsilon$

σ = Stress (overburden pressure)
E = Modulus of Elasticity
ϵ = strain.

Worst case 18" pipe, 160 ft of waste.

Estimate strain in gravel:

Gravel Thickness Same as pipe diameter.

$\sigma = (160\ ft)(110\ pcf) = 17600\ psf \Rightarrow 122\ psi$ ✓

$\epsilon = \frac{\sigma}{E}$

$E = 4000\ ksf$ for gravel (see pg 2)
$= 27,7000\ psi$ ✓

$\epsilon_{gravel} = \frac{122}{27,700} = 0.004 \Rightarrow 0.4\%$

Allowable Ring deflection (ϵ_{pipe}) = 2.7% for SDR 11 pipe (see pg 3)

$S.F. = \frac{2.7\%}{0.4\%} = 6.75$

Conclusions: Pipes will not exceed recommended allowable deflections. Therefore pipe will be o.k. This is consistant w/ the attached paper (see pg 4-8) which suggests allowable burial depth are much greater than suggested burial depth. Our experience also suggests that HDPE pipes perform well at large burial depth.

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TABLE 2-7 Typical range of values for the static stress-strain modulus E_s for selected soils

Field values depend on stress history, water content, density, etc.

Soil	E_s ksf	E_s Mpa
Clay		
Very soft	50–250	2–15
Soft	100–500	5–25
Medium	300–1000	15–50
Hard	1000–2000	50–100
Sandy	500–5000	25–250
Glacial till		
Loose	200–3200	10–150
Dense	3000–15 000	150–720
Very dense	10 000–30 000	500–1440
Loess	300–1200	15–60
Sand		
Silty	150–450	5–20
Loose	200–500	10–25
Dense	1000–1700	50–81
Sand and gravel		
Loose	1000–3000	50–150
Dense	2000–4000 ←	100–200
Shale	3000–300 000	150–5000
Silt	40–400	2–20

The *modulus of subgrade reaction* k_s is defined as the ratio of stress to deformation as shown on Fig. 2-37*c*. The units of k_s are the same as unit weight.

The shear modulus G' (and may be subscripted) is defined as the ratio of shear stress to shear strain. It is related to E_s and μ as

$$G'_s = \frac{s}{\epsilon_s} = \frac{E_s}{2(1+\mu)} \qquad (b)$$

The shearing strain ϵ_s is the change in right angle at any corner of an element as in Fig. 2-37*b* such that

$$\epsilon_s = \text{angle } BCD - \text{angle } B'C'D' \qquad (c)$$

Another concept occasionally used is the volumetric strain, defined as

$$\epsilon_v = \frac{\Delta V}{V} = \epsilon_1 + \epsilon_2 + \epsilon_3 \qquad (d)$$

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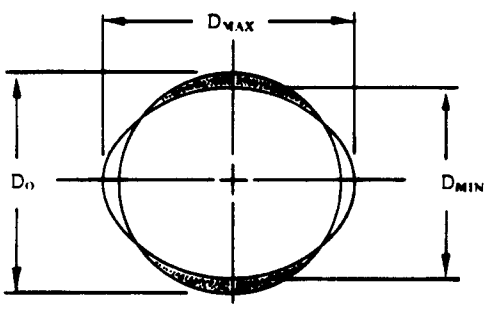
Design by Ring Deflection: Ring deflection is defined as the ratio of the vertical change in diameter to the original diameter. It is often expressed as a percentage. Ring deflection for buried Driscopipe is conservatively the same as (no more than) the vertical compression of the soil envelope around the pipe. Design by ring deflection matches the ability of Driscopipe to accommodate, without structural distress, the vertical compression of the soil enveloping the buried pipeline. *Design by ring deflection comprises a calculation of vertical soil strain to insure it will be less than the allowable ring deflection of the pipe.* See Chart 27. The tabulation shows that with lower values of SDR, the allowable deflection is less. For installations which require this thicker wall to resist the external soil pressure, actual ring deflection can easily be limited to the tabular values by proper compaction of the backfill around the pipe. The recommended allowable deflection for the various SDR's are:

CHART 27

SDR	ALLOWABLE RING DEFLECTION
32.5	8.1%
26.0	6.5%
21.0	5.2%
19.0	4.7%
17.0	4.2%
15.5	3.9%
13.5	3.4%
11.0	2.7%



$$\% \text{ RING DEFLECTION} = \left(1 - \frac{D_{MIN}}{D_O}\right) \times 100\%$$

NOTE: 5% deflection decreases flow-area by ¼%. 10% deflection decreases flow-area by 1%.

The allowable ring deflection of polyethylene pipe is a function of the allowable tangential strain in the outer surface of the pipe wall. A conservative limit of 1 - 1½% tangential strain in the outer surface of the pipe wall due to vertical deflection of the pipe "ring" by soil compression can be understood by comparing two pipes of the same diameter but different wall thickness.

Assume each of the pipes is equally deflected under loads required to achieve that result. The tangential surface strain developed in the thickwall pipe is much greater than the surface strain in the thinwall pipe. The tangential strain varies directly as the wall thickness (i.e.: distance from the neutral axis) and is proportional to the amount of ring deflection. For a given ring deflection, the thicker the wall, the higher the strain.

Alternately, assume that each of the pipes are subjected to loads such that the tangential surface strain in the pipe's wall surface is equal for both pipes. For equal surface strain, the degree of vertical deflection of the pipe ring is different for the two pipes. Under these circumstances, the degree of deflection would be less for the thickwall pipe and greater for the thinwall pipe.

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15-Nov-97
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K.C. PUBLIC WORKS
Solid Waste Division
ENGINEERING SECTION

Report on the

STRUCTURAL PERFORMANCE OF PERFORATED AND SLOTTED HIGH-DENSITY POLYETHYLENE PIPES UNDER HIGH SOIL COVER

Submitted to: King County Solid Waste
601 FX McRory Building
419 Occidental Avenue South

Attention: Mr. Gerald D. Walken , P.E., Senior Engineer

Submitted by: Department of Civil and Environmental Engineering
Utah State University
Logan, UT 84322

Principal Investigator: Reynold K. Watkins, Professor

Date: 1987 Aug 31

Introduction:

High density polyethylene pipes are an attractive alternative for the collection and transmission of fluids under sanitary land fills. Polyethylene pipes are classified as flexible. They do not have pipe stiffness equal to clay tile pipes, concrete pipes, ductile pipes, etc. Nevertheless, despite the low pipe stiffness, if polyethlene pipe is buried in a select granular soil backfill, it can provide a successful conduit by the interaction of pipe and soil. The height of sanitary land fills is often so great that pipes underneath are subjected to enormous soil pressure. The question has been raised as to the competence of polyethylene pipes to resist the external soil pressure. Soil pressure is the pressure caused by the high embankment of soil and refuse. Tests conducted at Utah State University reveal that when buried in well-compacted, select, pipe zone backfill, high density polyethylene pipes perform well under very high soil cover -- even into the hundreds of ft. Moreover, the polyethylene is not corroded by chemicals that percolate out of the sanitary land fill.

In order to collect and drain off the liquids and methane gas that is generated in the sanitary land fill, the pipes can be perforated or slotted. However, it is not known what effect perforations or slots may have on the structural performance of the pipe under high soil cover. Clearly, stress concentrations will occur, but the polyethylene may relax enough that fracture does not occur. The best investigation is actual testing. Therefore tests similar to the tests on non-perforated pipes, were conducted on samples of perforated and slotted pipes in the USU small soil cell. The pipe zone backfill was washed, pit-run gravel passing a three-fourths sieve. This is typical of soil used in most installations of polyethylene pipe.

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Objectives:

The primary objective of the tests was to observe the structural performance under high soil pressures of high-density polyethylene pipes that are perforated and slotted. Pipe zone backfill was shovel-sliced under the haunches of the pipes.

A secondary objective was to observe the structural performance of a non-perforated pipe under high soil pressure if pipe zone backfill is merely dumped over the pipe in a windrow with no attempt to place the soil under the haunches of the pipe.

Procedure:

Four specimens of six inch diameter, SDR 9.33, high density polyethylene pipes, each 5.5 ft long, were provided by King County Solid Waste. One of these pipes was unperforated. It served as a control for comparison of the other pipes. It also provided information as to the performance of the pipe if no soil is placed under the haunches. One of the other specimens was perforated and two were slotted as described in Appendix A. Soil was placed under the haunches of these pipes by shovel-slicing.

Tests were conducted in the USU small soil cell. The bedding was well-compacted soil on which the pipe specimen was laid. Pipe zone backfill was washed pit-run gravel that passed a three-fourths inch sieve. The pipe zone backfill was not compacted. Two different methods of pipe installation were used as shown on Figures 2 and 3. Both perforated and slotted pipe specimens were tested in a trench as shown in Figure 2. With the first lift of backfill placed to approximately the top of the pipe, a hand shovel was used to shovel-slice the soil under the haunches. After shovel-slicing, pipe zone backfill was placed over the pipe to a depth of about 1.25 ft. In the sanitary land fill, the overburden would be refuse and/or soil. In these tests, uncompacted soil was used. The unperforated pipe specimen was tested in an embankment as shown in Figure 3. After the pipe was placed on a compacted bedding, pipe zone backfill was poured onto the top of the pipe until a windrow reached a height of 1.0 ft above the top of the pipe. No effort was made to place soil under the haunches. This simulates a very typical method of installation of pipes. An embankment of overburden was then brought up to the top of the soil cell and leveled off. The overburden was uncompacted soil used in the test to simulate the refuse overburden in the sanitary land fill. Figures 4 and 5 are photographs of the soil cell as a pipe specimen is placed and backfilled for testing. After the cell was filled to the top with overburden, the loading beams were placed and load was applied to the overburden in increments. After each increment, the pipe was carefully observed for any evidence of distress. Vertical and horizontal diameters were measured near the mid-length of the pipe specimen.

Pipe Dimensions:

Nominal six inch diameter, SDR = 9.3
Measured: SDR = 8.5 standard dimension ratio
OD = 6.555 in average outside diameter
ID = 5.013 in average inside diameter
t = 0.771 in average wall thickness
s = 0.039 in standard deviation of wall thickness (plus or minus)
Minimum wall thickness = 0.731 in
Maximum wall thickness = 0.847 in

Perforations: Diameter = 0.475 in
Orientation when buried is such that two rows of slots are on the spring lines.

Slots: Widths = 0.106 in
Orientation when buried is such that the ends of the slots are at the spring line, i.e. at the horizontal diameter.

See Appendix A for location and orientation of perforations and slots. The reason for positioning two rows of perforations and one end of each row of slots on the spring lines is to assure the worst conditions for stress concentration. The maximum compressive stress occurs at the spring line, and the maximum stress concentration occurs at the side of a perforation and the corner of a sawed slot on the surface of the pipe wall.

Theoretical Stresses:

For plastics in general, and for polyethylene in particular, the stress theory of design is not appropriate. Even if stresses exceed the proportional limit, the material only yields, and creeps, and comes to equilibrium. Nevertheless, a theoretical stress analysis is possible as included in Appendix A. Assuming a height of cover of 200 ft at 50 lbs per cubic ft, the average compressive stress at the spring line is 2.6 ksi for perforations and for slots is 2.3 ksi for four slots per ft, and 2.5 ksi for fourteen slots per ft. This is the sum of both ring compression stress and flexural stress based on ring deflection. The ring deflection is assumed to be 3.5% These average stresses are close to yield point but are not excessive in light of the relaxation properties of polyethylene. Including stress concentrations, stress at the sides of the perforations would be 6.45 ksi if the material didn't yield. At the ends of the slots, the stress concentrations would not be significantly greater than the average stresses. If any stress were considered excessive, it would be the stress at the sides of the perforations. But no evidence of distress was observed from the physical tests.

Results:

Results of the tests are reported below for vertical soil pressure up to just over 10 kips per sq ft. 10 ksf is equivalent to 200 ft of cover at a unit weight of 50 lbs per cu ft.

1. There was no distress in any of the test specimens. No plastic flow could be detected adjacent to the perforations or at the ends of the slots. This can be explained in part by the very small, localized zones of high stress. Concentrated stresses develop only at sides of perforations and maybe at ends of slots. Moreover the zones occur only at or near the surfaced of the wall because the flexural stresses reverse themselves throughout the thickness of the wall and so are maximum only at the surfaces of the wall. Localized stresses cause the material to creep locally and come to equilibrium. The zone of creep is so small as to be invisible. From Appendix A, at 10 ksf soil pressure, the highest maximum average stress occurred at the spring line on the inside surface of the perforated pipe, and was 2.34 ksi. At this stress, the polyethylene creeps, but within a few hours comes to equilibrium at a lower stress.

2. Ring deflection was less than 3.3% for all of the tests. Ring deflection is defined as decrease in vertical diameter divided by the circular mean diameter of 5.784 inches. The diagrams plotted on Figures 6 to 10 show pipe deflection as a function of soil load. Pipe deflection is decrease in vertical diameter divided by the inside diameter of 5.013 inches. To convert from pipe deflection to ring deflection, multiply the pipe deflection by 0.8667. The maximum pipe deflection was 3.8%. Recorded on Figures 6 to 10 are the pipe deflections at vertical soil pressure of 10 kips per square ft. This allows comparison of pipe deflections for the four test specimens. No statistical conclusions are available because of the small number of samples.

3. Failure to shovel-slice gravel under the haunches does not make a significant difference in performance of the pipe when buried in loose gravel. A greater number of tests may reveal a statistical difference. The most important observation from these tests is the ability of the pipe to perform adequately whether or not gravel is shovel-sliced under the haunches. The explanation of this surprising observation is probably the ability of the heavy pipe cross section to compress the uncompacted topfill and even the compacted bedding in such a way that the pipe shapes its own soil support. Also circumferential creep allows the pipe cross section to adjust to the soil configuration without pipe fracture. This adjustment of pipe shape to soil and soil to pipe shape may be called conformation.

4. The effect of time on pipe performance is to allow creep and relaxation of stresses toward ultimate stress equilibrium. See Figure 9. This was confirmed on the pipe with four slots per ft. It was allowed to remain in the test cell long enough for pipe deflection to come to equilibrium. This occurred in less

than a day. As the pipe deflection comes to equilibrium, the stresses in the pipe relax, and the gravel backfill is forced to take a greater share of the load. Even loose gravel is able to support high vertical pressure with little compression.

5. Performance limits for the test specimens were not reached. Load limits were not achieved. Consequently, a sample of the perforated pipe was tested by parallel plate test to observe performance at high ring deflection. The results are shown in the load-deflection diagram of Figure 11. Localized stress at the sides of the perforations was not visible even at a ring deflection of 30%. It would be impossible for gravel to compress enough to allow 30% ring deflection without crushing of the gravel particles. Crushing could not occur for typical gravels at less than some 400 ksf which is equivalent to 4000 ft of soil cover at 100 pcf. This is far above any anticipated fill heights for sanitary land fills at present. Furthermore, yielding of polyethylene is not a performance limit. It does not forebode pipe failure. It allows pipe to conform with the soil.

Conclusions:

1. When buried in washed gravel, six inch SDR 9.33 polyethylene pipes perform satisfactorily under cover of 200 ft of fill at 50 lbs per cubic ft even though the gravel is not compacted. Shovel-slicing gravel under the haunches may be advisable. It assures a better bedding for the pipe, especially if the surface on which the pipe is laid is not a plane. Shovel-slicing could be specified. Nevertheless, pipe laid on a plane surface, without gravel being shovel-sliced under the haunches, still performs adequately. With the pipe on a firm plane surface, shovel-slicing only serves to increase the margin of safety by some small, unknown amount.

2. The upper limit of vertical soil pressure on six inch SDR 9.33 polyethylene pipe buried in gravel is unknown, but a parallel plate test on the perforated pipe indicates that the upper limit is many times greater than 200 ft at 50 pcf.

3. Ring deflection of six inch SDR 9.33 polyethylene pipe buried in loose, washed gravel is less than the vertical compression of the gravel. Under a fill height of 200 ft at 50 lbs per cubic ft, ring deflection is less than about 3.3%.

4. Distress, such as concentrated stress at the sides of perforations, is not a performance limit in these tests. There is no evidence of cracking or tearing, or even that cracking or tearing could occur if the pipe is confined by burial in gravel.

5. Six inch SDR 9.33 polyethylene pipes are an attractive alternative as drain pipes under sanitary land fills. Perforations and slots do not reduce load carrying capacity significantly except for the small reduction in cross sectional area of the pipe wall.

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TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 6DZ-0200

Calculation Title: Thermal Induced Stress in Evaporation Pond Liner

	Name	Date
Prepared By:	P. Pellicer	15-Nov-97
Checked By:	J. Pellicer	15-Nov-97
Reviewed By:	P. Cobb	15 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

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Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of 5
Prepared By: P. Pellicer Date: 15 Nov-97
Checked By: J. Pellicer Date: 15-Nov-97

Thermal Induced Stress in Evaporation Pond Liner

Objective: Assess potential stress induced in the Geomembrane liner due to temperature change.

Assumptions: -100°F Temperature change from when liner is installed to coldest temperature

Calculations:

Determine longest length of liner in Evaporation pond
$L_o = 287$ ft (see pg 2)

Thermal linear Expansivity for HDPE = $7 \times 10^{-5}/1°F$ (see pg 3)

$$\Delta L = L_o(\Delta Temp)\ 7\times10^{-5}/1°F$$
$$= (287\ ft)\left(\frac{12\ in}{1\ ft}\right)(-100°)(7\times10^{-5}/1°F) = -24 \text{ inches.}$$

Stress induced in liner by Temperature change

$\sigma = E\epsilon$
σ = stress in liner
E = Modulus of Elasticity = 80,000 psi (see pg 5)

$$\epsilon = \frac{\Delta L}{L_o} = \frac{24 \text{ inches}}{287\left(12\frac{in}{ft}\right)} = 0.007$$

$$\sigma = 80{,}000 \text{ psi}\ (0.007) = 560 \text{ psi}$$

σ_{yield} = 2200 psi (for 60 mil HDPE, see pg 4)

$$S.F._{for\ yeild} = \frac{2200}{560} = 3.9$$

Conclusions: Stress of this size will not damage the liner. If the pond is empty at time of extreme temperature some temporary bridging may occur at the toe of the slopes, this will induce very little stress in the liner if it allowed to move. If the pond has liquids in it this will insulate the liner system and the liner will not contract as much.

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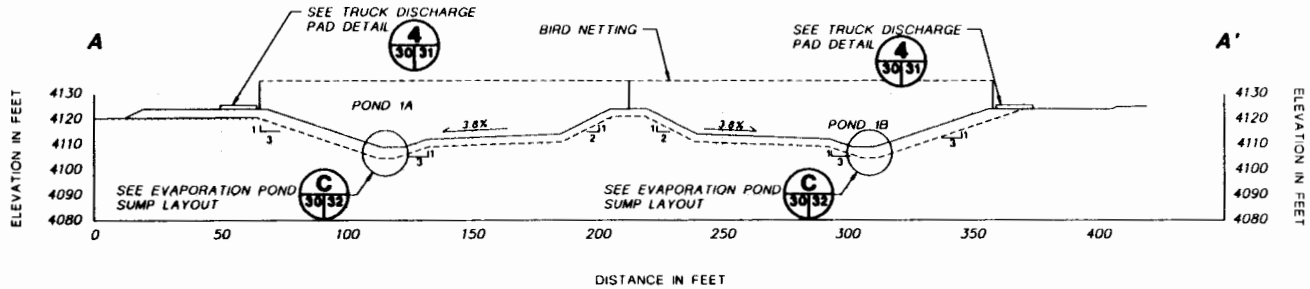
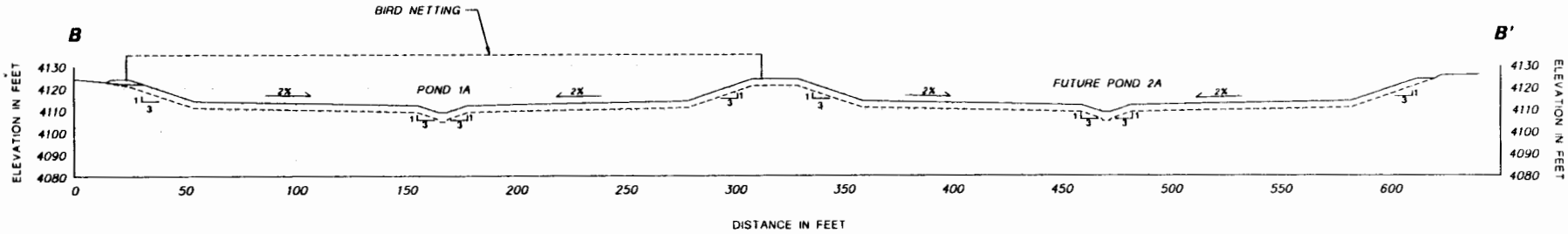


CROSS-SECTION A-A'

A 28 30 A 29 30

HORIZONTAL SCALE
0 25' 50'

VERTICAL SCALE
0 25' 50'



CROSS-SECTION B-B'

B 28 30 B 29 30

HORIZONTAL SCALE
0 25' 50'

VERTICAL SCALE
0 25' 50'

Not For Construction

REV No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	8/18/97	PGC/JPP	K Cassels	P Carver

TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE
EVAPORATION POND CROSS SECTIONS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE As Shown
DRAWING No 30

PATRICK G. CARVER 16230 REGISTERED PROFESSIONAL ENGINEER

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Carver, state that this map was prepared under my supervision and all the information presented herein is true and correct to the best of my knowledge and information.

Date *Patrick G. Carver, NM P.E. 16230*

NOTE:
FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2, "INDEX, LEGEND AND GENERAL NOTES".

AutoCAD FILE EPSECS2.DWG PROJECT NUMBER 602-0200

~~K:/602/FINAL DWGS/Evaporation Pond~~
EPSECS2.dwg
1,579,155
12/09/97 04:18p

difficult to make. The latter point is perhaps the most significant aspect of cold conditions. The proposed seaming method should be attempted at site-installation temperatures on test strips on simulated subgrades and evaluated to see that a satisfactory seam strength will indeed result. They are called "trial seams."

5.1.4.5.3 Coefficient of Thermal Expansion. There are a number of procedures that can be used to determine the coefficient of thermal contraction or expansion of a material; for example, ASTM D2102 and D2259 for contraction, and D1042 and D1204 for expansion and dimensional changes. All of them subject the test specimen to a constant source of cold (or heat) and carefully measure the separation distance between two given initial locations. Some typical data are presented in Table 5.10. An example using this data in adding slack during the installation of a geomembrane follows.

Example:

Calculate the amount of slack to be added during the installation of an MDPE liner for a surface impoundment anticipating a 100°F temperature change. Base the calculations on a 100-ft. side slope distance and a coefficient of thermal linear expansion of Table 5.10.

Solution:

$$\text{Minimum slack: } 8 \times 10^{-5}\,(100)(100)(12) = 9.6 \text{ in.}$$

$$\text{Maximum slack: } 9 \times 10^{-5}\,(100)(100)(12) = 10.8 \text{ in.}$$

The calculated amounts are very significant, and the importance of adding slack for temperature compensation cannot be overemphasized.

5.1.4.6 Oxidation Degradation Whenever a free radical is created (e.g., on a carbon atom in the polyethylene chain), oxygen can create progressive, long-term

Table 5.10 Coefficients of linear thermal expansion (Various references)

Polymer Type	*Thermal Linear Expansivity × 10^{-5}* per 1°F	per 1°C
Polyethylene		
High density	6–7 ←	11–13
Medium density	8–9	14–16
Low density	6–7	10–12
Very low density	8–14	15–25
Polypropylene	3–5	5–9
Polyvinyl chloride		
Unplasticized	3–6	5–10
35% plasticizer	4–14	7–25
Polyamide		
Nylon 6	4–5	7–9
Nylon 66	4–5	7–9
Polystyrene	2–4	3–7
Polyester	3–5	9–9

5 of 5

602-0200
15-Nov-97
pmp

FRICTION SEAL™ HD GEOMEMBRANE
PHYSICAL PROPERTIES

60 mil

The properties on this page are not part of NSC's Manufacturing Quality Control program and are not included on the material certifications. Seam testing is the responsibility of the installer and/or CQC personnel.

PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Multi-Axial Tensile Elongation	GRI, GM-4	percent	20.0	22.3
Critical Cone Height	GRI, GM-3, NSC mod.	cm	1.0	1.5
Wide Width Tensile	ASTM D 4885			
Stress at Yield		psi	2000	2110
Strain at Yield		%	15.0	20.0
Brittleness Temp. by Impact[2]	ASTM D 746	°C	-75	<-90
Coef. of Linear Thermal Exp.[2]	ASTM D 696	$°C^{-1}$	1.5×10^{-4}	1.2×10^{-4}
ESCR, Bent Strip	ASTM D 1693	hours	1500	>10,000
Hydrostatic Resistance	ASTM D 751	psi	450	550
Modulus of Elasticity	ASTM D 638	psi	80,000 ←	116,000
Ozone Resistance[4]	ASTM D 1149, 168 hrs	P/F	P	P
Permeability[2,4]	ASTM E 96	cm/sec · Pa	2.3×10^{-14}	8.1×10^{-15}
Puncture Resistance	FTMS 101, method 2065	ppi	1300	1570
		lbs	78	97
Soil Burial Resistance[2]	ASTM D 3083, NSF mod.	% change	10	0
Tensile Impact	ASTM D 1822	ft lbs/in^2	130	160
Volatile Loss[2]	ASTM D 1203, A	percent	0.10	0.08
Water Absorption[2,4]	ASTM D 570, 23°C	percent	0.10	0.04
Water Vapor Transmission[2,4]	ASTM E 96	g/day · m^2	0.024	0.009

SEAM PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Shear Strength	ASTM D 4437, NSF mod.	psi	2000	2700
		ppi	120	166
Peel Strength	ASTM D 4437, NSF mod.	psi	1500	1870
(hot wedge fusion)		ppi	90	115
Peel Strength	ASTM D 4437, NSF mod.	psi	1300	1590
(fillet extrusion)		ppi	78	98

STANDARD ROLL DIMENSIONS

Length	850 feet	Area	12,750 ft^2
Width	15 feet	Weight	3,950 lbs

This information contained herein has been compiled by National Seal Company and is, to the best of our knowledge, true and accurate. All suggestions and recommendations are offered without guarantee. Final determination of suitability for use based on any information provided, is the sole responsibility of the user. There is no implied or expressed warranty of merchantability of fitness of the product for the contemplated use.

NSC reserves the right to update the information contained herein in accordance with technological advances in the material properties.

6FH-0893

E-28

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 6
1445 ROSS AVENUE, SUITE 1200
DALLAS, TX 75202-2733

March 14, 1996

MAR 1996
RECEIVED

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

RE: Gandy Marley Inc., Triassic Park Hazardous Waste Facility, Part B Application and the Corresponding Revisions

Dear Mr. Garcia:

The Environmental Protection Agency (EPA) has completed a technical review of the landfill design for Gandy Marley Inc. and has determined that it meets the requirements of 40 CFR 264.300 thru 264.317. If you have any further questions, please contact Mr. Rich Mayer at (214) 665-7442.

Sincerely yours,

Rich Mayer

for David Neleigh, Section Chief
New Mexico - Federal Facilities

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State of New Mexico
ENVIRONMENT DEPARTMENT
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GARY E. JOHNSON
GOVERNOR

MARK E. WEIDLER
SECRETARY

EDGAR T. THORNTON, III
DEPUTY SECRETARY

DATE: March 11, 1996

MEMORANDUM

TO: Bob Sweeney, Hazardous Waste Bureau

FROM: Rich Stafford, Solid Waste Bureau

SUBJECT: Triassic Park liner and cover design
HELP model review

The HELP model output files dated February 28, 1996 submitted by TerraMatrix in a report dated March, 1996 in fulfillment of the requirements for an alternate liner demonstration show a leakage rate of 0.008 cubic feet per year and 0.002 cubic feet per year for the bottom and the slope, respectively. The comparable values for the §264.301(c)(1)(i)(B) liner are 2.587 and 0.042. This satisfies the "alternative design" requirement of §264.301(b).

Attached are the final cover HELP model output files submitted by TerraMatrix on March 8 and 9. The copy received by the Solid Waste Bureau by FAX dated March 9 is modeled with (1) a minimum grade of 5%, (2) a maximum drainage distance of 1000 feet, and (3) poor grass. This cover shows an infiltration rate through the FML of 0.001 cubic feet per year. This is less than the percolation rate through the alternate liner, 0.008 cubic feet per year through the bottom and 0.002 on the slope, and thus meets the requirements of §264.310(5).

Please note these comments are restricted to the demonstrations required by §264 and do not specifically address the other design items we discussed last week. It is my understanding the Solid Waste Bureau has no further outstanding issues pertaining to the Triassic Park facility.

xc: Dale Gandy, Gandy Marley, Inc.
John J. Kendall, TerraMatrix
Mark Weidler, NMED Secretary
Pete Maggiore
Ed Kelley
Gerald Silva
J. David Duran

attachments

Prepared for:

Gandy Marley, Inc.
P.O. Box 872
1109 E. Broadway
Tatum, NM 88267

Triassic Park Hazardous Waste Facility Landfill Alternative Liner System HELP Analysis
(Revision 1)

March 1996

Prepared By:

TerraMatrix Inc.
Engineering and Environmental Services
165 South Union Boulevard, Suite 460
Lakewood, Colorado 80228

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1.0 INTRODUCTION

In conjunction with engineering design and permitting tasks associated with the Gandy Marley Incorporated Triassic Park Hazardous Waste Facility RCRA Part B Permit Application, TerraMatrix Inc. has conducted a hydrologic evaluation of a potential landfill liner design alternative. This analysis was performed using the Hydrologic Evaluation of Landfill Performance (HELP) model, a computer program developed by the United States Environmental Protection Agency (EPA). Contained herein are descriptions of the liner alternatives, a discussion of the HELP program input parameters and modeling methodologies employed, and a discussion of the modeling results.

1.1 BACKGROUND

The proposed Triassic Park Facility is a full service hazardous waste treatment, storage, and disposal facility. Its primary disposal unit will be a large multi-phase lined landfill with an expected life of 30 years. A conceptual design for the proposed landfill liner system and a request and justification for a waiver from minimum technology requirements (MTR) was submitted in the RCRA Part B Permit Application. Per the request of Gandy Marley Inc., an additional waiver justification report was prepared and submitted to the New Mexico Environmental Department (NMED) to clarify hydrologic concerns related to the liner. Following review of these documents, NMED rejected the original proposed landfill liner presented in the Part B Application. TerraMatrix then prepared an analysis of five potential liner alternatives using EPA's HELP model, three of which were shown to provide equivalent leakage protection as the MTR liner system. This report, revision 1 of the above mentioned HELP analysis, presents the alternative landfill liner design selected by Gandy Marley, Inc. and the Revision 0 results of the hydrologic modeling conducted to compare its effectiveness in preventing leakage of hazardous constituents to that of the MTR liner system defined in 40 CFR 264.301(c). This report presents an alternative cover performance demonstration requested by NMED.

1.2 HELP PROGRAM DESCRIPTION

The HELP model is a computer program which models the water movement into, through, and out of landfills. The model accepts climatic, soil, and design data, and utilizes a solution technique that accounts for the effects of surface storage, run-off, infiltration, percolation, evapotranspiration, soil moisture storage, and lateral drainage. Landfill systems including various combinations of vegetation, cover soils, waste cells, special drainage layers, and low permeability barrier soils, as well as, special synthetic membrane covers and liners, may be modeled.

HELP was developed by the U.S. Army Corps of Engineers Waterways Experiment Station (WES) for the EPA Municipal Research Laboratory, Cincinnati, OH. HELP Version 3.04a dated July, 1995 was used in this analysis. HELP version 3.03 dated December 1994 was used in the Revision 0 analysis. The latest version, HELP Version 3.04a, incorporates new weather data handling capabilities , drainage layer routines, peak daily head routines, and evapotranspiration routines.

1.3 REPORT ORGANIZATION

Including this section, this report is organized into seven Sections. Section 2.0 presents the landfill liner designs including detailed descriptions of the construction materials contemplated. Section 3.0 discusses the HELP modeling methodologies used to evaluate the liner alternative and MTR. Section 4.0 presents the HELP inputs and selection rationale. Section 5.0 discusses the HELP analysis results. Section 6.0 presents the conclusions of the analysis and Section 7.0 presents report references. Summary tables, figures, and appendices follow the report.

2.0 TRIASSIC PARK LANDFILL LINER ALTERNATIVES

The liner designs considered in this analysis include the RCRA Subtitle C minimum technology liner system described in 40 CFR 301 and proposed alternative. Figures 1 and 2, following the text, illustrate the slope and floor liner material components for each design approach.

The MTR consists of primary and secondary liners with leachate collection and removal systems (LCRS) above and between the liners. The LCRS system between the liners is also referred to as a leak detection system (LDS). The LCRS and LDS drainage systems consist of a sand drainage layer surrounded by geotextile filter fabric where required. The primary barrier layer consists of a single flexible membrane liner (FML). The secondary barrier layer is a composite liner consisting of 3 feet of compacted clay overlain by an FML.

The proposed alternative is a double high density polyethylene (HDPE) liner design with LCRS and LDS which incorporate geocomposite drainage layers instead of sand geotextile layers. Additionally, a geosynthetic clay liner (GCL) and a 6 inch layer of prepared subgrade is used instead of 3 feet of compacted clay in the bottom barrier layer.

The cover design shown in Figure 3 consists of, from the top down, a vegetative cover, a geocomposite drainage layer, a HDPE flexible membrane cover (FMC), a GCL, 6 inches of prepared subgrade, and 1.5 feet of cover soil. It should be noted that a GCL in combination with 6 inches of prepared subgrade is substituted for a processed clay layer in the cover section.

The sections below present additional design details and discuss the materials contemplated for use in each alternative.

2.1 RCRA SUBTITLE C MINIMUM TECHNOLOGY LINER SYSTEM

40 CFR 301(1)(I) defines what is nominally referred to as the minimum technology liner system , or MTR. The liner system must include the following:

- A top liner (e.g., a geomembrane).
- A composite bottom liner, consisting of at least two components (e.g., a geomembrane upper component with a 3 foot thick clay bottom layer with a maximum hydraulic conductivity of $1x10^{-7}$cm/sec).
- A LCRS on top of the top liner and a leachate collection and detection system between the liners (also referred to as a LDS).

The MTR system presented in this analysis consists of the following components, from the top down:

- A 2 foot protective soil layer.
- LCRS: geotextile - 1 foot thickness of drainage sand - geotextile (optional) .
- FML top liner: HDPE.
- LDS: geotextile - 1 foot thickness of drainage sand - geotextile (optional).
- Composite bottom liner: HDPE - 3 foot clay layer ($1x10^{-7}$cm/sec).

2.2 PROPOSED ALTERNATIVE LINER SYSTEM

The proposed alternative is a double liner system similar to MTR with material substitutions made for the bottom clay barrier layer and the LCRS and LDS drainage layers. A GCL replaces the 3 foot thick clay layer in the MTR and 6 inches of prepared subgrade is included below the GCL for structural support. The sand/geotextile LCRS and LDS drainage layers are replaced with geotextile/geonet/geotextile materials. The protective soil and FMLs are as described above in the MTR design.

The geocomposite drainage material contemplated for all alternatives consists of a non-woven geotextile bonded to a geonet webbing. The geotextile component of this material acts as a filter allowing moisture to pass to the geonet while keeping soil sediments out. Moisture flows along the ribs of the geonet transporting water to the sump collection areas. The geocomposite provides an effective drainage medium with transmissivities in the order of $1x10^{-3}$ m^2/sec. Sand material can be processed to achieve hydraulic conductivities of $1x10^{-2}$cm/sec while gravels can achieve 10.0cm/sec. Because the geonet and geotextile materials are essentially inert, they offer greater resistance to clogging due to biological activity or chemical reactions with leachate than do sand and gravel materials which typically contain small factions of organic materials. Sand and gravel layers, however, offer a greater cushioning to the FML than do geocomposites which under very high loading conditions (which are not expected for the Triassic Park Landfill) can deform the FML.

2.3 COVER

40 CFR 264.310 outlines several performance criteria which landfill cover designs must meet once constructed. These criteria include the following:

- Provide long term minimization migration of liquids through the closed landfill;
- Function with minimum maintenance;
- Promote drainage and minimize erosion or abrasion of the cover;
- Accommodate settling and subsidence so that the cover's integrity is maintained; and,
- Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present

The cover design proposed here for the Triassic Park Landfill was used in this HELP analysis. It consists of the following components, from top down:

- 2 foot thick vegetative cover layer
- Geocomposite drainage layer: geotextile/geonet
- Flexible membrane cover: HDPE
- Geosynthetic clay liner (geotextile/bentonite/geotextile)
- 6 inches of prepared subgrade
- 1.5 foot thick cover soil

This cover section differs from the cover section originally presented in the Part B Application. In this case, a GCL and 6 inches of prepared subgrade replaces a 3 foot layer of processed clay. Because this clay is near to the surface in a cover application, it may be subject to desiccation and frost cracking. This problem is avoided with the use of a GCL.

3.0 HELP ANALYSIS METHODOLOGY

The HELP modeling approach used to evaluate the hydrologic performance of the proposed liner alternative and MTR follows the NMED's Draft Guidance Document for Performance Demonstration for an Alternative Liner Design Using the HELP Modeling Program Under the New Mexico Solid Waste Management Regulations (20 NMAC 9.1). This approach was selected because it allows a direct comparison between MTR and an alternative liner system, the results can be used to demonstrate performance equivalency required under 40 CFR 264.301(d). This methodology is paraphrased below. A complete version of these protocols is presented in Appendix C.

3.1 ALTERNATE LINER EQUIVALENCY DEMONSTRATION METHOD

1. In order to demonstrate that the alternative liner design provides equivalent protection as the MTR composite liner, a computer modeling analysis of the MTR and the proposed alternative liner must be performed. Equivalent protection in terms of leakage through the secondary liner must be demonstrated through a comparison of the alternative liner with the MTR.

2. Justification for all input parameters in the model must be provided. Characteristics of soils proposed for the construction and operation of the landfill and the parameter values used in the model must be consistent. Soil and waste moisture content parameters as well as geomembrane liner data and storm water run-off fraction must also be consistent with the expected conditions and materials contemplated for use.

3. Actual design conditions and operation development of the landfill must be simulated as closely as possible by doing a succession of model simulations. This succession must attempt to simulate moisture conditions in the landfill by using the previous simulation's moisture content output as the input for the following simulation. The duration of the simulation periods must be consistent with the landfill's expected filling rates as follows:

> 3.1 Initial simulation of the open landfill at start-up when landfill has little to no waste. The time period should extend for the anticipated duration of this condition, a minimum of one year and a probable maximum of five years.
>
> 3.2 A succeeding simulation to model conditions of the partially full landfill for some anticipated time period, most probably five years. This would incorporate daily cover and intermediate cover.
>
> 3.3 Perform subsequent computer simulations to model the landfill in the closed condition for the duration of the entire post-closure care period.
>
> > 3.3.1 Model bare ground for the time period expected until vegetation becomes established.
> >
> > 3.3.2 Model the vegetated condition for the remainder of the post-closure care period.

4. Compliance with the regulatory requirement of not exceeding a 12-inch hydraulic head on the bottom liner must be demonstrated given design drainage layer slopes and drainage distances.

5. If the infiltration through the alternative liner system for the simulation(s) is less than or equal to infiltration through the MTR liner system, then these HELP Model simulation(s) will serve to demonstrate equivalent performance of the alternative liner system compared to the MTR.

In addition to demonstrating performance equivalency with MTR, the performance of the proposed alternative liner must also be compared to the performance of the proposed final cover. 40 CFR 264.310 (a) (5) requires that the final cover must be designed and constructed to have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

3.2 ALTERNATE COVER DEMONSTRATION METHOD

As in the above case, a proposed alternate landfill cover must achieve the equivalent protection as the liner. If an alternative final cover is proposed for the landfill, it must be demonstrated that the proposed final cover design includes an infiltration layer that achieves an equivalent reduction in infiltration as the bottom liner. A HELP Model simulation comparison is acceptable for this demonstration for a 5 year period with vegetation. Precipitation, evapotranspiration, temperature, and solar radiation data must be site specific and identical for both liner and cover design simulations. Justification for all input parameters in the model must be provided. It is expected that the cover's design slopes and run-off distances will be modeled.

Further descriptions of the HELP program inputs for both of these modeling approaches is presented in Section 4.0.

4.0 HELP PROGRAM INPUTS

Inputs for the HELP program are made in a series of data files which the main program uses during its simulation runs. Default inputs are available for most data categories and these were used where appropriate. In certain cases default inputs were not used, for example, the initial soil moisture contents were manually set for each run as mentioned above. The following sections describe the inputs used and their selection rationale for both HELP modeling approaches. HELP input data sheets which summarize inputs for each run are presented in Appendix A, HELP Data Input Sheets.

4.1 CLIMATIC DATA

The HELP program provides a weather generator to simulate changing weather conditions over time for various locations in the United States based on historical weather data. The location selected for this analysis was Roswell, NM. Roswell is located 42 miles west of the Triassic Park site and is the closest default city available in the HELP program.

Once the default city has been selected, weather inputs for precipitation and temperature can be automatically assigned by the program or input by the user. For the original analysis in Revision 0 of this report, the default values for precipitation and temperature for Roswell, NM were used. For this analysis, weather inputs for precipitation and temperature for the Roswell, NM area were obtained from the National Oceanic and Atmospheric Association (NOAA). Thirty year averages (period 1964 to 1994) for precipitation and temperature were used instead of the HELP default values for Roswell. These weather records indicate a slightly wetter environment and inputting them would tend to make the results of HELP runs slightly higher, but would not change the relative performance of the various liner alternatives.

Evapotranspiration inputs to define the vegetation conditions and evaporative zone depth can also be input into the HELP model. For this analysis, these inputs were changed to represent likely vegetative conditions. During the operational period of the landfill when there is no cover present and for a short period immediately after the cover is installed there will be little vegetation present. The vegetation input used for this period was "bare ground". In selecting this option, the program provides Roswell area default values for an evaporative zone depth of 14 inches, growing season start and end on days 76 and 310, and maximum leaf area index of 0. After cover vegetation is established on the cover, typically after 1 year, the vegetative input was changed to "poor stand or grass". Vegetation at the Triassic Park site is sparse and this input was felt to best approximate the semi-arid site conditions. The evaporative zone depth was changed to 24 inches which corresponds to the design thickness of the vegetative cover layer and the maximum leaf area index was changed to 1 which was also felt to be appropriate for the site.

4.2 SOIL AND DESIGN DATA

Inputs for soil characteristics and design data include the percent run-off expected and the physical characteristics for each layer in the landfill model. In this analysis, 100 percent potential run-off was assumed when the landfill was covered and 0 percent run-off was assumed during the operational periods when the landfill cover was not in place. The layer characteristics are summarized below and in Appendix A .

4.2.1 Waste

The waste layer type, soil "texture" number, initial moisture content, and thickness define how moisture will percolate through waste layer and how much will be stored there. Because the waste layer is typically the thickest layer present, the outcome of landfill water flow analysis can be influenced greatly by its hydrologic properties.

The hydrologic properties of hazardous waste have not been studied to the same extent that municipal waste has been studied and therefore literature information is limited. The HELP model does not provide specific default values for hazardous waste and it is left to the program user to define these characteristics.

The waste was assigned soil texture numbers, initial moisture contents, and hydraulic conductivities which reflect expected actual conditions. The soil texture number of 7 corresponds to a silty sand material (SM) with default porosity of 0.473, field capacity of 0.222, wilting point of 0.104, and hydraulic conductivity of 5.4×10^{-4}cm/sec. The initial moisture content was set at 0.2055.

The hydraulic properties of the waste fill will depend on the characteristics of the incoming waste and the nature of the daily cover soil used. The physical characteristics of landfilled hazardous waste can vary widely from sludges to solids and debris. Contaminated soils and bulk solid materials, however, will make up a major proportion of these materials. Typically, the waste material is placed and compacted and covered with daily cover soil material. Since the surface of the waste fill must be trafficable to waste hauler trucks and other heavy earthmoving equipment, it is not an uncommon practice to increase the amount of daily cover soil placed when softer or sludgy type wastes are received. At the Triassic Park site sand and siltstone will be predominantly used as daily cover materials and incoming contaminated soils are also likely to have a high sand content. Bulk solid wastes such as filter cake material, bag house wastes, and other process wastes are fine grained with particle sizes in the silt range. Based on this, the soil texture corresponding to a sandy silt was selected for the waste material.

Based on previous experience at hazardous waste sites, the initial moisture contents of the waste for Years 0 through 1 were set at 0.2055 which corresponds to a moisture content of 15 percent.

4.2.2 Protective Soil

The protective soil layer placed on top of the liner prior to waste filling will be the same material used for daily soil cover with the exception that it will be screened to remove oversize rocks and cobbles. Based on evaluation of bulk samples taken at the site from the upper sand unit, a soil texture number of 4 corresponding to a silty sand was selected to model the protective soil layer. This soil texture has the following defaults: porosity of 0.473, field capacity of 0.0105, wilting point of 0.047, and hydraulic conductivity of 1.7×10^{-3}cm/sec. The initial moisture content for this layer was set at 0.0863 which is consistent with the average moisture contents of 5.9 percent for the site's silty sand samples.

4.2.3 Lateral Drainage (Sand)

The lateral drainage sand material considered for use at the site will have to meet minimum hydraulic conductivities of 1×10^{-2}cm/sec. Although no hydraulic testing of candidate site materials has been conducted, it is believed that this performance standard can be met with available material sources either in their natural state or with a minimal amount of screening and washing. The soil texture number of 1 which corresponds to a poorly graded sand was selected for this layer. This soil texture has the following defaults: porosity of 0.417, field capacity of 0.045, wilting point of 0.018, and hydraulic conductivity of 1×10^{-2}cm/sec. Initial moisture content for this layer was set at 0.045 which equals the field capacity and therefore does not allow for water storage in the lateral drainage layer. It should be noted that the geotextile components of the sand drainage layer were not included in the this evaluation. Transmissities of this material exceeds those of the sand material and therefore this assumption is conservative.

4.2.4 Lateral Drainage (Geocomposite)

The geocomposite drainage material used in this analysis was a geotextile bonded to a geonet. The HELP model does not have a specific default for geocomposites so the default for the geonet was selected for this layer. The added capacity of the geotextile in this case is ignored and, as above, this assumption is conservative. The soil

texture number of 20 which corresponds to a drainage net was selected for this layer. This soil texture has the following defaults: porosity of 0.850, field capacity of 0.010, wilting point of 0.005, and hydraulic conductivity of 10.0cm/sec. The initial moisture content for this layer was set at 0.010 which equals the field capacity and therefore does not allow for water storage in the lateral drainage

4.2.5 Barrier (FML: HDPE)

The FML barrier layer considered is a 60 mil HDPE geomembrane. HELP model defaults for this layer are thickness 0.06 inch and soil texture number 35. For geomembranes, the HELP model also provides input capabilities for pinhole density, installation defects, and installation quality assurance. Input values for these parameters are recommended in the HELP Manual. Values used in this analysis were pinhole density of 1.0, geomembrane defect number 3, and liner installation quality of 3. All of these inputs correspond to a good geomembrane installation under good construction quality control.

4.2.6 Barrier (Clay)

The clay barrier layer material considered is a typical fine grained clay material which when moisture conditioned and compacted under controlled conditions is capable of achieving an in-place hydraulic conductivity of 1×10^{-7} cm/sec. HELP program defaults for soil texture number 26 with porosity of 0.445, field capacity of 0.393, wilting point of 0.445, and modified hydraulic conductivity of 1×10^{-7}cm/sec were used for the clay layer. The moisture content was set equal to the porosity to allow for immediate saturated flow through the clay layer.

For the MTR case, the thickness of the clay barrier layer was set at 3 feet.

Permeability testing of the clay material samples gathered at the site indicate that hydraulic conductivities of 1×10^{-7}cm/sec can be achieved.

4.2.7 Barrier (GCL)

The GCL material considered is a composite geotextile/bentonite/geotextile layer. These liner products, although relatively new compared to geotextiles and geomembranes, have become popular substitutes for clay layers in cover systems and recently in liner systems. The soil texture number of 17 was selected for the GCL with a porosity of 0.750, field capacity of 0.747, wilting point of 0.400, and hydraulic conductivity of 3×10^{-9}cm/sec. The initial moisture content for this layer was set at 0.7500 which equals the porosity to allow for immediate saturated flow thought the clay layer.

4.2.8 Prepared Subgrade

The prepared subgrade material considered is essentially the same material considered for the clay barrier material described above. The difference between these materials is the level processing and moisture conditions prior to placement and the resultant increased permeability of the prepared subgrade. The primary function of this layer is to provide a smooth stable surface upon which to install the overlying geosynthetics but it is not envisaged that extensive moisture conditioning or processing will be done. However, because this material is the same material proposed for the clay barrier layer, it will exhibit some barrier layer characteristics by inhibiting flow through holes in the FML.

For the prepared subgrade layer, the same soil texture number and defaults were input as the clay layer described above including the conductivity. Permeability tests done on samples from the Upper Dockum Unit indicated hydraulic conductivities in this range.

4.3 LANDFILL COVER DATA

Landfill cover data inputs include the cover layer materials, the type of vegetative cover on the surface of the cover, the percentage of moisture that is subject to run-off, the slope of the cover and maximum drainage distance. Materials contemplated for the cover design are discussed above and their arrangement is illustrated in Figure 3. As discussed previously for covered conditions, 100 percent potential run-off was input, the vegetative condition for the newly installed cover assumed a "bare ground" and a 14 inch evaporative zone depth for the first year, and "poor stand of grass" with a 24 inch evaporative zone for the remaining years. A maximum drainage distance of 550 feet at 4H:1V slope (25 percent) was computed from conceptual drawings in the presented RCRA Permit Application for the Triassic Park Facility. The HELP soil texture classification number 6 was selected for the vegetative cover for the cover performance demonstration. This soil type is consistent with the Alma series soil found at the site. It should be noted that the vegetative soil type used in the Revision 0 HELP analysis has a soil texture number of 4 with a porosity of 0.4270, field capacity of 0.1050, wilting point of 0.0470, and hydraulic conductivity of 1.7×10^{-3} cm/sec. These lateral drainage values are consistent with the Roswell - Association also found at the Triassic Park site. The material is a silty sand with default porosity of 0.453, field capacity of 0.190, wilting point of 0.085, and saturated hydraulic conductivity of 7.2×10^{-4}. Initial moisture content for the vegetative soil was set at 0.0863.

5.0 HELP PROGRAM RESULTS

5.1 ALTERNATE LINER EQUIVALENCY DEMONSTRATION

Results for the individual HELP model runs are summarized in Tables 5 and 6. Actual printouts of the HELP model summary output files are presented in Appendix B. As previously mentioned, these results were originally presented in Revision 0 of this report. For completeness, they are also included in this revision.

Review of the results presented in the summary table below and Tables 5 and 6 indicates there is little difference in leakage rates between the various liner alternatives for the final closed landfill. Further inspection of the modeling results for the operational phase, Years 0 through 10, reveals insignificantly small leakage in the proposed alternate liner. For this period the proposed alternate and MTR liners are considered equivalent and leakages are rounded to three decimal points in the table below. For Years 11 though 40 with the landfill cover in place, very little precipitation enters the system and the waste mass begins to drain with this water being removed from the system in the LCRS layer. Bottom barrier layer leakage rates at this point become negligible for both the proposed liner alternative and MTR.

MODELING APPROACH LEAKAGE RATE SUMMARY
Operational Period (Years 0 - 10)

Alternatives	Floor Leakage (g/a/d)	Slope Leakage (g/a/d)
Proposed Alternate	0.000	0.000
MTR	0.000	0.000

NOTE: 1. Values shown are final leakage rates after period Years 0 through 10
2. Results shown are from Revision 0 of the Alternative Liner System HELP Analysis

MODELING APPROACH LEAKAGE RATE SUMMARY
Covered Period (Years 11 - 40)

Alternatives	Floor Leakage (g/a/d)	Slope Leakage (g/a/d)
Proposed Alternate	0	0
MTR	0	0

NOTE: 1. Values shown are final leakage rates after period Years 31 through 40
2. Results shown are from Revision 0 of the Alternative Liner System HELP Analysis

Review of Tables 5 and 6 show head values for both the proposed alternate and MTR indicate pressure development on the primary and secondary liners in the range of 0.000 to 0.001 inches which are well below the regulatory maximum of 12 inches.

5.2 ALTERNATE COVER DEMONSTRATION

Results of HELP model runs for the alternate cover demonstration of Years 0 through 5 are summarized in Tables 1 through 4. Actual printouts of the HELP model summary output are presented in Appendix B.

Review of these results indicated leakages through the proposed cover in the order of 0.00002 g/a/d while leakage through the proposed alternate liner are 0.000164 for the floor area and 0.000041 for the slope area. Once again, the difference between these two leakage rates is insignificantly small and the proposed cover can be considered at least as impermeable as the proposed alternate liner.

6.0 CONCLUSIONS

Based on the HELP model results, the following conclusions can be made:

- There is little difference between the proposed alternative and MTR in terms of percolation rates through the bottom liner over the life of the facility. The differences that exist in Years 0 through 10 are insignificantly small. The proposed alternate liner performance can therefore be considered equivalent to the MTR liner performance.

- Hydraulic pressure on the primary and secondary liners of both the MTR and proposed alternate liner system is well below the regulatory maximum of 12 inches.

- The cover system leakage is less than or equal to the leakage of the liner system. It effectively reduces precipitation infiltration which will the waste to drain once the cover is in place.

allow

7.0 REFERENCES

Gandy Marley Inc., *RCRA Permit Application for the Triassic Park Waste Disposal Facility*, November 1994. Prepared for Gandy Marley Inc. By S.M. Stoller Corporation and TerraMatrix Inc.

New Mexico Environment Department, Solid Waste Bureau, Permit Section. *Guidance Document for Performance Demonstration for an Alternative Cover Design Using the HELP Modeling Program Under the New Mexico Solid Waste Management Regulations (20 NMAC 9.1) and Performance Demonstration for an Alternative Liner Design Using the HELP Modeling Program Under the New Mexico Solid Waste Management Regulations (20 NMAC 9.1)*

Schroeder, P.R., Dozier, T.S., Zappi, P.A., McEnroe, B.M., Sjostrom, J.W., and Peyton, R.L. (1994). *The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation For Version 3* EPA/600/9-94/xxx, U.S. Environmental Protection Agency Risk Reduction Engineering Laboratory, Cincinnati, OH.

TABLES

TABLE 1

SUMMARY TABLES

TABLE 1

YEARS	LINER SECTION	PRIMARY LATERAL DRAINAGE (gal/acre/day)(1)	PRIMARY LINER LEAKAGE (gal/acre/day)(1)	SECONDARY LATERAL DRAINAGE (gal/acre/day)(1)	SECONDARY LINER LEAKAGE (gal/acre/day)(1)	COMMENTS
FLOOR						
	MTR	33.704579	64.212128	58.712736	0.053019	
0-5	2	48.011289	51.814221	51.801597	0.000164	
SLOPE						
	MTR	87.717213	11.815266	11.772023	0.000861	
0-5	2	544.995355	43.131039	43.131018	0.000041	
COVER						
0-5	COVER	18.240582	0.000020	NA	NA	

Notes:

(1) Values based on average annual totals.
(2) Liner section 2 is referred to as Proposed Alternate in the text.

TABLE 2

FLOOR/SLOPE LINER ALTERNATIVE 2 (PROPOSED ALTERNATE)

TABLE 2
GANDY LANDFILL FLOOR LINER ALTERNATIVE #2 (PROPOSED ALTERNATE)

YEARS	PRECIPITATION (gal/acre/day)(1)	LAYER	LAYER TYPE	THICKNESS (inches)	INITIAL M.C.(3) (vol/vol)	FINAL M.C.(3) (vol/vol)	LATERAL DRAINAGE (gal/acre/day)(1)	PERCOLATION (gal/acre/day)(1)	HEAD ON LAYER (inches)(1)	COMMENTS
0-5	963.716416	1	Soil	24	0.0863	0.1240	NA	NA	NA	
		2	Geocomposite	0.2	0.0100	0.0120	48.011289	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	51.814221	0.0010	
		4	Geocomposite	0.2	0.0100	0.0142	51.801597	NA	NA	
		5	Geomembrane	0.06	0.0000	0.0000	NA	NA	0.0001	
		6	GCL	0.24	0.7500	0.7500	NA	0.000164	NA	

Notes:
(1) Values based on average annual totals.
(2) Peak daily values may be higher due to storm events.

TABLE 2
GANDY LANDFILL SLOPE LINER ALTERNATIVE # 2 (PROPOSED ALTERNATE)

YEARS	PRECIPITATION (gal/acre/day)(1)	LAYER	LAYER TYPE	THICKNESS (inches)	INITIAL M.C.(3) (vol/vol)	FINAL M.C.(3) (vol/vol)	LATERAL DRAINAGE (gal/acre/day)(1)	PERCOLATION (gal/acre/day)(1)	HEAD ON LAYER (inches)(1)	COMMENTS
0-5	963.716416	1	Soil	24	0.0863	0.1007	NA	NA	NA	
		2	Geocomposite	0.2	0.0100	0.0112	544.995355	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	43.131039	0.0000	
		4	Geocomposite	0.2	0.0100	0.0100	43.131018	NA	NA	
		5	Geomembrane	0.06	0.0000	0.0000	NA	NA	0.0000	
		6	GCL	0.24	0.7500	0.7500	NA	0.000041	NA	

Notes:

(1) Values based on average annual totals.
(2) Peak daily values may be higher due to storm events.

TABLE 3

FLOOR/SLOPE MTR LINER SUMMARY TABLES

TABLE 3
GANDY LANDFILL FLOOR MTR LINER

YEARS	PRECIPITATION (gal/acre/day)(1)	LAYER	LAYER TYPE	THICKNESS (inches)	INITIAL M.C.(3) (vol/vol)	FINAL M.C.(3) (vol/vol)	LATERAL DRAINAGE (gal/acre/day)(1)	PERCOLATION (gal/acre/day)(1)	HEAD ON LAYER (inches)(1)	COMMENTS
0-5	963.716416	1	Soil	24	0.0863	0.1240	NA	NA	NA	
		2	Sand	12	0.0450	0.0557	33.704579	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	64.212128	0.5230	
		4	Sand	12	0.0450	0.0755	58.712736	NA	NA	
		5	Geomembrane	0.06	0.0000	0.0000	NA	NA	0.9120	
		6	Clay	36	0.4450	0.4450	NA	0.053019	NA	

Notes:
(1) Values based on average annual totals.
(2) Peak daily values may be higher due to storm events.

TABLE 3
GANDY LANDFILL SLOPE MTR LINER

YEARS	PRECIPITATION (gal/acre/day)(1)	LAYER	LAYER TYPE	THICKNESS (inches)	INITIAL M.C.(3) (vol/vol)	FINAL M.C.(3) (vol/vol)	LATERAL DRAINAGE (gal/acre/day)(1)	PERCOLATION (gal/acre/day)(1)	HEAD ON LAYER (inches)(1)	COMMENTS
0-5	963.716416	1	Soil	24	0.0863	0.1240	NA	NA	NA	
		2	Sand	12	0.0450	0.0467	87.717213	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	11.815266	0.0600	
		4	Sand	12	0.0450	0.0452	11.772023	NA	NA	
		5	Geomembrane	0.06	0.0000	0.0000	NA	NA	0.0080	
		6	Clay	36	0.4450	0.4450	NA	0.000861	NA	

Notes:
(1) Values based on average annual totals.
(2) Peak daily values may be higher due to storm events.

TABLE 4

COVER ALTERNATIVE

TABLE 4
GANDY LANDFILL COVER ALTERNATIVE

YEARS	PRECIPITATION (gal/acre/day)(1)	LAYER	LAYER TYPE	THICKNESS (inches)	INITIAL M.C.(3) (vol/vol)	FINAL M.C.(3) (vol/vol)	LATERAL DRAINAGE (gal/acre/day)(1)	PERCOLATION (gal/acre/day)(1)	HEAD ON LAYER (inches)(1)	COMMENTS
0-5	963.716416	1	Veg. Soil	24	0.0863	0.0866	NA	NA	NA	
		2	Geocomposite	0.2	0.0100	0.0150	18.240582	NA	0.0000	
		3	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		4	GCL	0.24	0.7500	0.7500	NA	0.000020	NA	
		5.00000	Soil	6	0.0863	0.0860	NA	NA	NA	
		6.00000	Soil	18	0.0863	0.0860	NA	NA	NA	

Notes:

(1) Values based on average annual totals.

(2) Peak daily values may be higher due to storm events.

TABLE 5

ALTERNATE 2 (PROPOSED ATERNATE)

FLOOR/SLOPE LINER SUMMARY TABLES

(ALTERNATIVE LINER SYSTEM HELP ANALYSIS REVISION 0)

TABLE 5
GANDY LANDFILL SLOPE LINER ALTERNATIVE #2 (PROPOSED ALTERNATE)

YEARS	PRECIPITATION (gal/acre/day)(1)	LAYER	LAYER TYPE	THICKNESS (inches)	INITIAL M.C.(3) (vol/vol)	FINAL M.C.(3) (vol/vol)	LATERAL DRAINAGE (gal/acre/day)(1)	PERCOLATION (gal/acre/day)(1)	HEAD ON LAYER (inches)(1)	COMMENTS
0-1	647.239184	1	Waste	60	0.2055	0.2080	NA	NA	NA	
		2	Soil	24	0.0863	0.1406	NA	NA	NA	
		3	Geocomposite	0.2	0.0100	0.0100	0.000000	NA	NA	
		4	Geomembrane	0.06	0.0000	0.0000	NA	0.000000	0.0000	
		5	Geocomposite	0.2	0.0100	0.0100	0.000000	NA	NA	
		6	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		7	GCL	0.24	0.7500	0.7500	NA	0.000000	0.0000	
2-5	718.472179	1	Waste	840	0.2080	0.2192	NA	NA	NA	
		2	Soil	24	0.1406	0.1131	NA	NA	NA	
		3	Geocomposite	0.2	0.0100	0.0100	6.574209	NA	NA	
		4	Geomembrane	0.06	0.0000	0.0000	NA	5.722065	0.0000	
		5	Geocomposite	0.2	0.0100	0.0100	5.770240	NA	NA	
		6	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		7	GCL	0.24	0.7500	0.7500	NA	0.000041	0.0000	
6-10	718.808290	1	Waste	1080	0.2192	0.2284	NA	NA	NA	
		2	Soil	24	0.1131	0.1488	NA	NA	NA	
		3	Geocomposite	0.2	0.0100	0.0102	25.495047	NA	NA	
		4	Geomembrane	0.06	0.0000	0.0000	NA	7.833662	0.0000	
		5	Geocomposite	0.2	0.0100	0.0100	7.833642	NA	NA	
		6	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		7	GCL	0.24	0.7500	0.7500	NA	0.000041	0.0000	

TABLE 5
GANDY LANDFILL SLOPE LINER ALTERNATIVE #2 (PROPOSED ALTERNATE)

	647.239184	1	Veg. Soil	24	0.0863	0.0938	NA	NA	NA	
		2	Geocomposite	0.2	0.0100	0.0110	539.163562	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		4	Clay	36	0.4450	0.4450	NA	0.000205	0.0010	
		5	Soil	24	0.0863	0.0863	NA	NA	NA	
		6	Waste	1440	0.2284	0.2269	NA	NA	NA	
11		7	Soil	24	0.1488	0.1712	NA	NA	NA	
		8	Geocomposite	0.2	0.0102	0.0100	116.866483	NA	NA	
		9	Geomembrane	0.06	0.0000	0.0000	NA	5.764161	0.0010	
		10	Geocomposite	0.2	0.0100	0.0100	5.764161	NA	NA	
		11	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		12	GCL	0.24	0.7500	0.7500	NA	0.000020	0.0000	
	673.203761	1	Veg. Soil	24	0.0938	0.0709	NA	NA	NA	
		2	Geocomposite	0.2	0.0110	0.0166	538.388928	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		4	Clay	36	0.4450	0.4450	NA	0.000246	0.0010	
		5	Soil	24	0.0863	0.0863	NA	NA	NA	
		6	Waste	1440	0.2269	0.2220	NA	NA	NA	
12-31		7	Soil	24	0.1712	0.1050	NA	NA	NA	
		8	Geocomposite	0.2	0.0100	0.0100	30.262782	NA	NA	
		9	Geomembrane	0.06	0.0000	0.0000	NA	1.893904	0.0000	
		10	Geocomposite	0.2	0.0100	0.0100	1.893883	NA	NA	
		11	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		12	GCL	0.24	0.7500	0.7500	NA	0.000000	0.0000	

TABLE 5
GANDY LANDFILL SLOPE LINER ALTERNATIVE #2 (PROPOSED ALTERNATE)

	699.481906	1	Veg. Soil	24	0.0709	0.0652	NA	NA	NA	
		2	Geocomposite	0.2	0.0166	0.0109	560.267933	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		4	Clay	36	0.4450	0.4450	NA	0.000266	0.0010	
		5	Soil	24	0.0863	0.0863	NA	NA	NA	
		6	Waste	1440	0.2220	0.2220	NA	NA	NA	
32-40		7	Soil	24	0.1050	0.1050	NA	NA	NA	
		8	Geocomposite	0.2	0.0100	0.0100	0.000000	NA	NA	
		9	Geomembrane	0.06	0.0000	0.0000	NA	0.000000	0.0000	
		10	Geocomposite	0.2	0.0100	0.0100	0.000000	NA	NA	
		11	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		12	GCL	0.24	0.7500	0.7500	NA	0.000000	0.0000	

Notes:
(1) Values based on average annual totals.
(2) Peak daily values may be higher due to storm events.
(3) Final moisture contents from each run were used as initial moisture contents for subsequent runs.
(4) Results from Alternative Liner System HELP Analysis Revision 0

TABLE 5
GANDY LANDFILL FLOOR LINER ALTERNATIVE #2 (PROPOSED ALTERNATE)

YEARS	PRECIPITATION (gal/acre/day)(1)	LAYER	LAYER TYPE	THICKNESS (inches)	INITIAL M.C.(3) (vol/vol)	FINAL M.C.(3) (vol/vol)	LATERAL DRAINAGE (gal/acre/day)(1)	PERCOLATION (gal/acre/day)(1)	HEAD ON LAYER (inches)(1)	COMMENTS
0-1	647.239184	1	Waste	60	0.2055	0.2080	NA	NA	NA	
		2	Soil	24	0.0863	0.1406	NA	NA	NA	
		3	Geocomposite	0.2	0.0100	0.0100	0.000000	NA	NA	
		4	Geomembrane	0.06	0.0000	0.0000	NA	0.000000	0.0000	
		5	Geocomposite	0.2	0.0100	0.0100	0.000000	NA	NA	
		6	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		7	GCL	0.24	0.7500	0.7500	NA	0.000000	0.0000	
2-5	718.472179	1	Waste	840	0.2080	0.2192	NA	NA	NA	
		2	Soil	24	0.1406	0.1131	NA	NA	NA	
		3	Geocomposite	0.2	0.0100	0.0100	1.239286	NA	NA	
		4	Geomembrane	0.06	0.0000	0.0000	NA	11.056946	0.0000	
		5	Geocomposite	0.2	0.0100	0.0103	11.055676	NA	NA	
		6	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		7	GCL	0.24	0.7500	0.7500	NA	0.000184	0.0000	
6-10	718.808290	1	Waste	1080	0.2192	0.2284	NA	NA	NA	
		2	Soil	24	0.1131	0.1488	NA	NA	NA	
		3	Geocomposite	0.2	0.0100	0.0122	10.902438	NA	NA	
		4	Geomembrane	0.06	0.0000	0.0000	NA	22.420307	0.0000	
		5	Geocomposite	0.2	0.0103	0.0144	22.408092	NA	NA	
		6	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		7	GCL	0.24	0.7500	0.7500	NA	0.000164	0.0000	

TABLE 5
GANDY LANDFILL FLOOR LINER ALTERNATIVE #2 (PROPOSED ALTERNATE)

	647.239184	1	Veg. Soil	24	0.0863	0.0938	NA	NA	NA	
		2	Geocomposite	0.2	0.0100	0.0110	539.163562	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		4	Clay	36	0.4450	0.4450	NA	0.000205	0.0010	
		5	Soil	24	0.0863	0.0863	NA	NA	NA	
		6	Waste	1440	0.2284	0.2269	NA	NA	NA	
11		7	Soil	24	0.1488	0.1712	NA	NA	NA	
		8	Geocomposite	0.2	0.0122	0.0149	50.885120	NA	NA	
		9	Geomembrane	0.06	0.0000	0.0000	NA	71.702075	0.0010	
		10	Geocomposite	0.2	0.0144	0.0165	71.670903	NA	NA	
		11	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		12	GCL	0.24	0.7500	0.7500	NA	0.000164	0.0010	
	673.203761	1	Veg. Soil	24	0.0938	0.0709	NA	NA	NA	
		2	Geocomposite	0.2	0.0110	0.0166	538.388928	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		4	Clay	36	0.4450	0.4450	NA	0.000246	0.0010	
		5	Soil	24	0.0863	0.0863	NA	NA	NA	
		6	Waste	1440	0.2269	0.2220	NA	NA	NA	
12-31		7	Soil	24	0.1712	0.1050	NA	NA	NA	
		8	Geocomposite	0.2	0.0149	0.0100	12.279714	NA	NA	
		9	Geomembrane	0.06	0.0000	0.0000	NA	19.880619	0.0000	
		10	Geocomposite	0.2	0.0165	0.0100	19.885333	NA	NA	
		11	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		12	GCL	0.24	0.7500	0.7500	NA	0.000123	0.0000	

TABLE 5
GANDY LANDFILL FLOOR LINER ALTERNATIVE #2 (PROPOSED ALTERNATE)

	699.481906	1	Veg. Soil	24	0.0709	0.0652	NA	NA	NA	
		2	Geocomposite	0.2	0.0166	0.0109	560.267933	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		4	Clay	36	0.4450	0.4450	NA	0.000266	0.0010	
		5	Soil	24	0.0863	0.0863	NA	NA	NA	
		6	Waste	1440	0.2220	0.2220	NA	NA	NA	
32-40		7	Soil	24	0.1050	0.1050	NA	NA	NA	
		8	Geocomposite	0.2	0.0100	0.0100	0.000000	NA	NA	
		9	Geomembrane	0.06	0.0000	0.0000	NA	0.000000	0.0000	
		10	Geocomposite	0.2	0.0100	0.0100	0.000000	NA	NA	
		11	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		12	GCL	0.24	0.7500	0.7500	NA	0.000000	0.0000	

Notes:
(1) Values based on average annual totals.
(2) Peak daily values may be higher due to storm events.
(3) Final moisture contents from each run were used as initial moisture contents for subsequent runs.
(4) Results from Alternative Liner System HELP Analysis Revision 0

TABLE 6

MTR

FLOOR/SLOPE LINER SUMMARY TABLES

(ALTERNATIVE LINER SYSTEM HELP ANALYSIS REVISION 0)

TABLE 6
GANDY LANDFILL FLOOR MTR LINER

YEARS	PRECIPITATION (gal/acre/day)(1)	LAYER	LAYER TYPE	THICKNESS (inches)	INITIAL M.C.(3) (vol/vol)	FINAL M.C.(3) (vol/vol)	LATERAL DRAINAGE (gal/acre/day)(1)	PERCOLATION (gal/acre/day)(1)	HEAD ON LAYER (inches)(1)	COMMENTS
0-1	0.000000	1	Waste	60	0.2055	0.2092	NA	NA	NA	
		2	Soil	24	0.0863	0.1065	NA	NA	NA	
		3	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		4	Geomembrane	0.06	0.0000	0.0000	NA	0.000000	0.0000	
		5	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		6	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		7	Clay	36	0.4450	0.4450	NA	0.000000	0.0000	
2-5	0.000000	1	Waste	840	0.2092	0.2128	NA	NA	NA	
		2	Soil	24	0.1065	0.1050	NA	NA	NA	
		3	Sand	12	0.0450	0.0450	0.084028	NA	NA	
		4	Geomembrane	0.06	0.0000	0.0000	NA	0.585530	0.0010	
		5	Sand	12	0.0450	0.0450	0.582927	NA	NA	
		6	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		7	Clay	36	0.4450	0.4450	NA	0.000902	0.0090	
6-10	0.000000	1	Waste	1080	0.2128	0.2164	NA	NA	NA	
		2	Soil	24	0.1050	0.1050	NA	NA	NA	
		3	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		4	Geomembrane	0.06	0.0000	0.0000	NA	0.000000	0.0000	
		5	Sand	12	0.0450	0.4500	0.000000	NA	NA	
		6	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		7	Clay	36	0.4450	0.4450	NA	0.000000	0.0000	

TABLE 6
GANDY LANDFILL FLOOR MTR LINER

	0.000000	1	Veg. Soil	24	0.0863	0.0938	NA	NA	NA	
		2	Geocomposite	0.2	0.0100	0.0110	539.163562	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		4	Clay	36	0.4450	0.4450	NA	0.000205	0.0010	
		5	Soil	24	0.0863	0.0863	NA	NA	NA	
		6	Waste	1440	0.2164	0.2164	NA	NA	NA	
11		7	Soil	24	0.1050	0.1050	NA	NA	NA	
		8	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		9	Geomembrane	0.06	0.0000	0.0000	NA	0.000000	0.0000	
		10	Sand	12	0.4500	0.0450	0.000000	NA	NA	
		11	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		12	Clay	36	0.4450	0.4450	NA	0.000000	0.0000	
	0.000000	1	Veg. Soil	24	0.0938	0.0709	NA	NA	NA	
		2	Geocomposite	0.2	0.0110	0.0166	538.388928	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		4	Clay	36	0.4450	0.4450	NA	0.000246	0.0010	
		5	Soil	24	0.0863	0.0863	NA	NA	NA	
		6	Waste	1440	0.2164	0.2164	NA	NA	NA	
12-31		7	Soil	24	0.1050	0.1050	NA	NA	NA	
		8	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		9	Geomembrane	0.06	0.0000	0.0000	NA	0.000000	0.0000	
		10	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		11	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		12	Clay	36	0.4450	0.4450	NA	0.000000	0.0000	

TABLE 6
GANDY LANDFILL FLOOR MTR LINER

	0.000000	1	Veg. Soil	24	0.0709	0.0652	NA	NA	NA	
		2	Geocomposite	0.2	0.0166	0.0109	560.267933	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		4	Clay	36	0.4450	0.4450	NA	0.000266	0.0010	
		5	Soil	24	0.0863	0.0863	NA	NA	NA	
		6	Waste	1440	0.2164	0.2164	NA	NA	NA	
32-40		7	Soil	24	0.1050	0.1050	NA	NA	NA	
		8	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		9	Geomembrane	0.06	0.0000	0.0000	NA	0.000000	0.0000	
		10	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		11	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		12	Clay	36	0.4450	0.4450	NA	0.000000	0.0000	

Nots:
(1) Values based on average annual totals.
(2) Peak daily values may be higher due to storm events.
(3) Final moisture contents from each run were used as initial moisture contents for subsequent runs.
(4) Results from Alternative Liner System HELP Analysis Revsision 0

TABLE 6
GANDY LANDFILL SLOPE MTR LINER

YEARS	PRECIPITATION (gal/acre/day)(1)	LAYER	LAYER TYPE	THICKNESS (inches)	INITIAL M.C.(3) (vol/vol)	FINAL M.C.(3) (vol/vol)	LATERAL DRAINAGE (gal/acre/day)(1)	PERCOLATION (gal/acre/day)(1)	HEAD ON LAYER (inches)(1)	COMMENTS
0-1	0.000000	1	Waste	60	0.2055	0.2092	NA	NA	NA	
		2	Soil	24	0.0863	0.1065	NA	NA	NA	
		3	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		4	Geomembrane	0.06	0.0000	0.0000	NA	0.000000	0.0000	
		5	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		6	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		7	Clay	36	0.4450	0.4450	NA	0.000000	0.0000	
2-5	0.000000	1	Waste	840	0.2092	0.2128	NA	NA	NA	
		2	Soil	24	0.1065	0.1050	NA	NA	NA	
		3	Sand	12	0.0450	0.0450	0.467215	NA	NA	
		4	Geomembrane	0.06	0.0000	0.0000	NA	0.202343	0.0000	
		5	Sand	12	0.0450	0.0450	0.202240	NA	NA	
		6	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		7	Clay	36	0.4450	0.4450	NA	0.000123	0.0000	
6-10	0.000000	1	Waste	1080	0.2128	0.2164	NA	NA	NA	
		2	Soil	24	0.1050	0.1050	NA	NA	NA	
		3	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		4	Geomembrane	0.06	0.0000	0.0000	NA	0.000000	0.0000	
		5	Sand	12	0.0450	0.4500	0.000000	NA	NA	
		6	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		7	Clay	36	0.4450	0.4450	NA	0.000000	0.0000	

TABLE 6
GANDY LANDFILL SLOPE MTR LINER

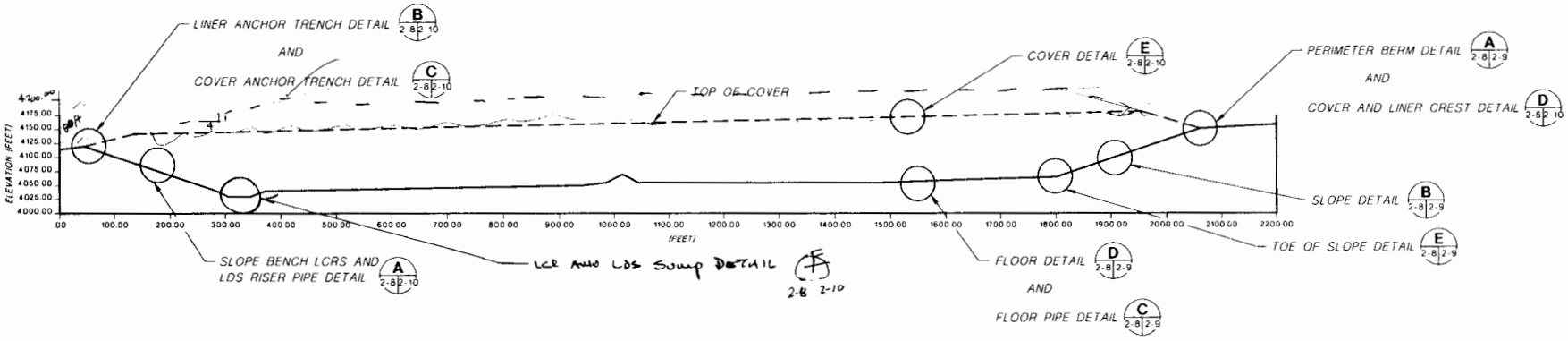
11	0.000000	1	Veg. Soil	24	0.0863	0.0938	NA	NA	NA	
		2	Geocomposite	0.2	0.0100	0.0110	539.163562	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		4	Clay	36	0.4450	0.4450	NA	0.000205	0.0010	
		5	Soil	24	0.0863	0.0863	NA	NA	NA	
		6	Waste	1440	0.2164	0.2164	NA	NA	NA	
		7	Soil	24	0.1050	0.1050	NA	NA	NA	
		8	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		9	Geomembrane	0.06	0.0000	0.0000	NA	0.000000	0.0000	
		10	Sand	12	0.4500	0.0450	0.000000	NA	NA	
		11	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		12	Clay	36	0.4450	0.4450	NA	0.000000	0.0000	
12-31	0.000000	1	Veg. Soil	24	0.0938	0.0709	NA	NA	NA	
		2	Geocomposite	0.2	0.0110	0.0166	538.388928	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		4	Clay	36	0.4450	0.4450	NA	0.000246	0.0010	
		5	Soil	24	0.0863	0.0863	NA	NA	NA	
		6	Waste	1440	0.2164	0.2164	NA	NA	NA	
		7	Soil	24	0.1050	0.1050	NA	NA	NA	
		8	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		9	Geomembrane	0.06	0.0000	0.0000	NA	0.000000	0.0000	
		10	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		11	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		12	Clay	36	0.4450	0.4450	NA	0.000000	0.0000	

TABLE 6
GANDY LANDFILL SLOPE MTR LINER

	0.000000	1	Veg. Soil	24	0.0709	0.0652	NA	NA	NA	
		2	Geocomposite	0.2	0.0166	0.0109	560.267933	NA	NA	
		3	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		4	Clay	36	0.4450	0.4450	NA	0.000266	0.0010	
		5	Soil	24	0.0863	0.0863	NA	NA	NA	
		6	Waste	1440	0.2164	0.2164	NA	NA	NA	
32-40		7	Soil	24	0.1050	0.1050	NA	NA	NA	
		8	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		9	Geomembrane	0.06	0.0000	0.0000	NA	0.000000	0.0000	
		10	Sand	12	0.0450	0.0450	0.000000	NA	NA	
		11	Geomembrane	0.06	0.0000	0.0000	NA	NA	NA	
		12	Clay	36	0.4450	0.4450	NA	0.000000	0.0000	

Notes:

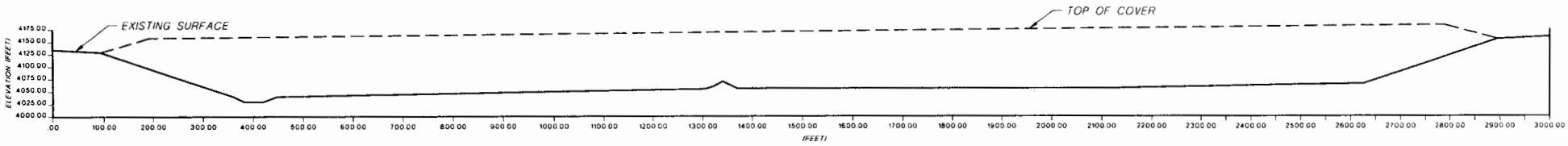
(1) Values based on average annual totals.
(2) Peak daily values may be higher due to storm events.
(3) Final moisture contents from each run were used as initial moisture contents for subsequent runs.
(4) Results from Alternative Liner System HELP Analysis Revision 0



A 2-7 2-8 CROSS-SECTION A-A'

SCALE

100' 0 100' 200'



B 2-7 2-8 CROSS-SECTION B-B'

SCALE

100' 0 100' 200'

A 6 6
DETAIL/SECTION NUMBER
DRAWING No. WHERE DETAIL/SECTION IS REFERENCED
DRAWING No. WHERE DETAIL/SECTION IS SHOWN

No.	REVISION	DATE	BY	CHKD
4				
3				
2				
1	REVISED CONCEPTUAL LINER DESIGN	3/96	JMB	JJK
0	CONCEPTUAL DESIGN FOR PART B APPLICATION	11/94	JGN	JJK

SCALE: SEE SCALE BAR
DESIGN BY: J.KENDALL
DRAWN BY: E.SIMONSEN
CHECK BY: P.CORSER
PROJECT No. 602-0100
FILE NAME: XS-GAND

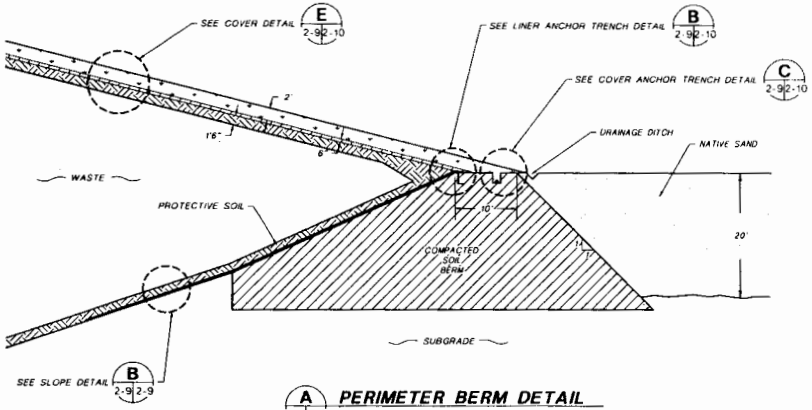
GM inc.

PROJECT: TRIASSIC PARK WASTE DISPOSAL FACILITY

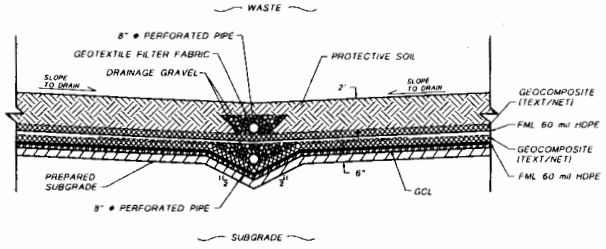
DRAWING TITLE: CONCEPTUAL LANDFILL FILL PLAN CROSS-SECTIONS

TerraMatrix

SHEET 1 OF 1
DRAWING No. 2-8
REV 1



A 2-8 2-9 PERIMETER BERM DETAIL
Not To Scale



C 2-8 2-9 FLOOR PIPE DETAIL
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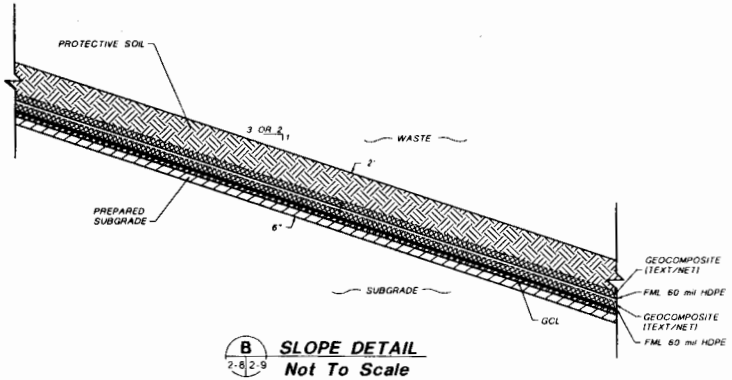
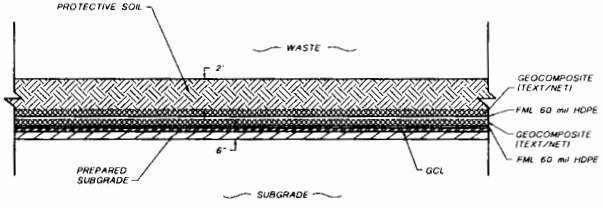


B 2-8 2-9 SLOPE DETAIL
Not To Scale



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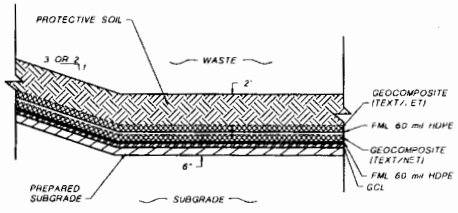


E 2-8 2-9 TOE OF SLOPE DETAIL
Not To Scale

NOTES:
1) PROTECTIVE SOIL CONSISTS OF SELECT SOILS
2) GEOMEMBRANE IS A MIN. 60 mil HDPE
3) GEOCOMPOSITE CONSISTS OF GEOTEXTILE BONDED TO GEONET

A 6 6
DETAIL/SECTION NUMBER
DRAWING No. WHERE DETAIL/SECTION IS REFERENCED
DRAWING No. WHERE DETAIL/SECTION IS SHOWN

No	REVISION	DATE	BY	CHK'D
4				
3				
2				
1	REVISED CONCEPTUAL LINER DESIGN	3/96	JMB	JJK
0	CONCEPTUAL DESIGN FOR PART B APPLICATION	11/94	JJN	JJK

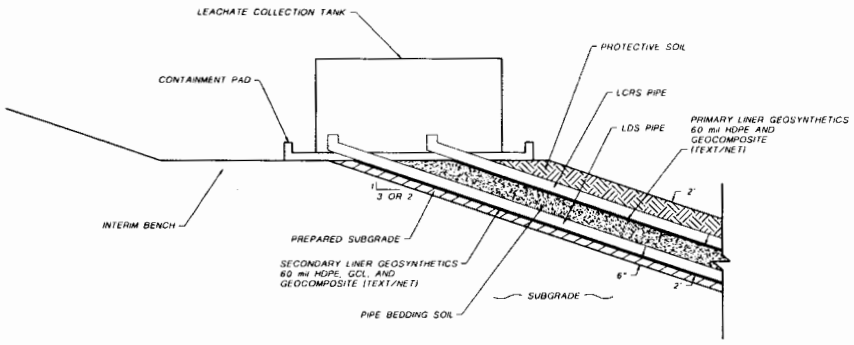
SCALE: AS NOTED
DESIGN BY: J. KENDALL
DRAWN BY: E. SIMONSEN
CHECK BY: P. CORSER
PROJECT No: 602-0100
FILE NAME: TLD-GAND.DWG

GM inc.

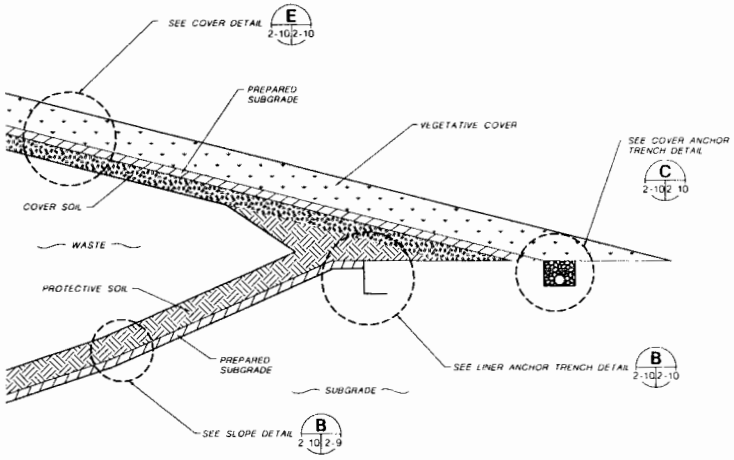
PROJECT: TRIASSIC PARK WASTE DISPOSAL FACILITY
DRAWING TITLE: CONCEPTUAL LANDFILL LINER DETAILS

TerraMatrix

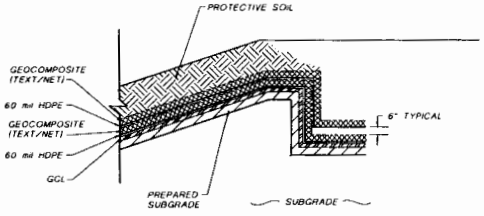
SHEET 1 OF 1
DRAWING No: FIG. 2-9
REV: 1



A 2-8 2-10 SLOPE BENCH LCRS AND LDS RISER PIPE DETAIL
Not To Scale



D 2-8 2-10 COVER AND LINER CREST DETAIL
Not To Scale



B 2-8 2-10 LINER ANCHOR TRENCH DETAIL
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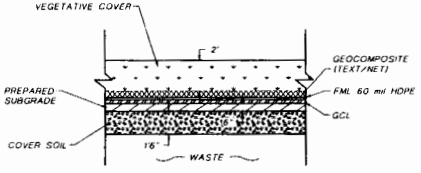
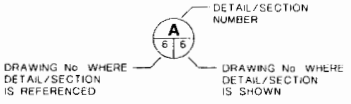
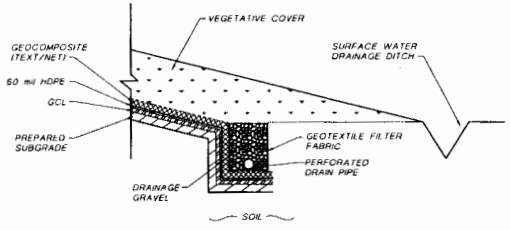


E 2-8 2-10 COVER DETAIL
Not To Scale





C 2-8 2-10 COVER ANCHOR TRENCH DETAIL
Not To Scale

NOTES:
1) PROTECTIVE SOIL CONSISTS OF SELECT SOILS
2) GEOMEMBRANE IS A MIN. 60 mil HDPE
3) GEOCOMPOSITE CONSISTS OF GEOTEXTILE BONDED TO GEONET
4) ACTUAL SIZE, LOCATION, TYPE AND ORIENTATION OF LCRS PIPES AND TANKS ON SLOPE BENCHES AND ON LANDFILL CREST TO BE DETERMINED DURING FINAL DESIGN

No	REVISION	DATE	BY	CHKD
4				
3				
2				
1	REVISED CONCEPTUAL LINER DESIGN	3/96	JMB	JJK
0	CONCEPTUAL DESIGN FOR PART B APLICAITON	11/94	JGN	JJK

SCALE: AS NOTED
DESIGN BY: J.KENDALL
DRAWN BY: E.SIMONSEN
CHECK BY: P.CORSER
PROJECT No: 602-0100
FILE NAME: TYLDGAND

GM inc.

PROJECT: TRIASSIC PARK WASTE DISPOSAL FACILITY

DRAWING TITLE: CONCEPTUAL LANDFILL LCRS DETAILS

TerraMatrix

SHEET 1 OF 1
DRAWING No: FIG. 2-10
REV: 1

APPENDIX A

HELP INPUT DATA SHEETS

TABLE 1
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
CLIMATOLOGICAL DATA		
city	Roswell, NM	Nearby City
precipitation & source of data (default or synthetic)	Synthetic	Only option for Roswell, NM
temperature & source of data	Synthetic	Roswell, NM
latitude	33.24	HELP default for Roswell, NM
maximum leaf area index	0	Bare Ground
evaporate zone depth	14 in.	HELP default for Roswell, NM
growing season start and end day	76/310	HELP default for Roswell, NM
LANDFILL COVER DATA		
type of vegetative cover	NA	Bare Ground
SCS runoff curve number	NA	0% allowable runoff CN does not affect results
active (uncovered)	Yes	
% of surface runoff that drains from landfill	0%	
surface area	1 acre	Unit area, (outputs to be converted to gallons/acre/day)
SOIL AND DESIGN DATA		
source of soil characteristics		HELP defaults, useing lab data for onsite soils
number of layers	6	
NOTES:		

PROJECT: Triassic Park Disposal Facility, Alternative #2 Floor Liner System

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 1		
layer type	1	Protective soil, (Vertical percolation layer)
thickness	24 in	See liner section
soil texture	4	HELP Default for a SM, (lab data indicates onsite soil to be a SM)
porosity	0.473	HELP default for texture 4
field capacity	0.0105	HELP default for texture 4
wilting point	0.047	HELP default for texture 4
moisture content	0.0863	Based on a avg. M.C. = 5.9% for Natural moisture contents of Silty Sands tested from the site.
saturated hydraulic conductivity	1.7E-3cm/s	HELP default for texture 4
Is layer compacted?	No	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, Alternative #2 floor liner system

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 2		
layer type	2	Geocomposite (lateral drainage layer)
thickness	0.2 in	HELP default thickness for texture 20(consistant w/ materials on the market)
soil texture	20	HELP Default for drainage net.(conservative, ignores added capacity of geotextile
porosity	0.850	HELP default for texture 20
field capacity	0.010	HELP default for texture 20
wilting point	0.005	HELP default for texture 20
moisture content	0.010	Moisture content equal to field capacity, does not allow for water storage in Lateral drainage layer
saturated hydraulic conductivity	1.0E1cm/s	HELP default for texture 20
Is layer compacted?	NA	
slope (if lateral drainage layer)	2.3%	Floor grade from cell layout drawing
maximum horizontal drainage distance (if lateral drainage layer)	550 ft	Maximum drainage length for phase 1 floor (scaled from drawings)
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, Alternative #2 floor Liner system

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 3		
layer type	4	FML, (HDPE Geomembrane)
thickness	0.06 in	60 mil (typical geomembrane thickness)
soil texture	35	HELP Default texture for HDPE geomembrane.
porosity	NA	
field capacity	NA	
wilting point	NA	
moisture content	NA	
saturated hydraulic conductivity	2.0E-13cm/s	HELP default for texture 35
Is layer compacted?	NA	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	1	Typical value recommended by HELP manual.
geomembrane installation defects	3	Typical value recommended by HELP manual for good installation.
liner installation quality (if geomembrane)	3	Good installation
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, Alternative #2 floor liner system

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 4		
layer type	2	Geocomposite (lateral drainage layer)
thickness	0.2 in	HELP default thickness for texture 20(consistant w/ materials on the market)
soil texture	20	HELP Default for drainage net.(conservative, ignores added capacity of geotextile
porosity	0.850	HELP default for texture 20
field capacity	0.010	HELP default for texture 20
wilting point	0.005	HELP default for texture 20
moisture content	0.010	Moisture content equal to field capacity, does not allow for water storage in Lateral drainage layer
saturated hydraulic conductivity	1.0E1cm/s	HELP default for texture 20
Is layer compacted?	NA	
slope (if lateral drainage layer)	2.3%	Floor grade from cell layout drawing
maximum horizontal drainage distance (if lateral drainage layer)	550 ft	Maximum drainage length for phase 1 floor (scaled from drawings)
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, Alternative #2 floor Liner system

TABLE 2
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
LAYER NUMBER: 5		
layer type	4	FML, (HDPE Geomembrane)
thickness	0.06 in	60 mil (typical geomembrane thickness)
soil texture	35	HELP Default texture for HDPE geomembrane.
porosity	NA	
field capacity	NA	
wilting point	NA	
moisture content	NA	
saturated hydraulic conductivity	2.0E-13cm/s	HELP default for texture 35
Is layer compacted?	NA	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	1	Typical value recommended by HELP manual.
geomembrane installation defects	3	Typical value recommended by HELP manual for good installation.
liner installation quality (if geomembrane)	3	Good installation
geotextile transmissivity	NA	

NOTES: (make additional copies for each layer as required)

PROJECT: Triassic Park Disposal Facility, Alternative #2 floor liner system

TABLE 2
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
LAYER NUMBER: 6		
layer type	3	GCL
thickness	0.24 in	HELP default thickness for bentonite mat
soil texture	17	HELP Default texture for bentonite mat
porosity	0.750	HELP default for texture 17
field capacity	0.747	HELP default for texture 17
wilting point	0.400	HELP default for texture 17
moisture content	0.750	Moisture content equal to porosity, allows for imediate saturated flow (HELP default).
saturated hydraulic conductivity	3.0E-9cm/s	HELP default for bentonite mat
Is layer compacted?	No	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	

NOTES: (make additional copies for each layer as required)

PROJECT: Triassic Park Disposal Facility, Alternative #2 floor liner system

TABLE 1
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
CLIMATOLOGICAL DATA		
city	Roswell, NM	Nearby City
precipitation & source of data (default or synthetic)	Synthetic	Only option for Roswell, NM
temperature & source of data	Synthetic	Roswell, NM
latitude	33.24	HELP default for Roswell, NM
maximum leaf area index	0	Bare Ground
evaporate zone depth	14 in.	HELP default for Roswell, NM
growing season start and end day	76/310	HELP default for Roswell, NM
LANDFILL COVER DATA		
type of vegetative cover	NA	Bare Ground
SCS runoff curve number	NA	0% allowable runoff CN does not affect results
active (uncovered)	Yes	
% of surface runoff that drains from landfill	0%	
surface area	1 acre	Unit area, (outputs to be converted to gallons/acre/day)
SOIL AND DESIGN DATA		
source of soil characteristics		HELP defaults, useing lab data for onsite soils
number of layers	6	
NOTES:		

PROJECT: Triassic Park Disposal Facility, Alternative #2 slope Liner System

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 1		
layer type	1	Protective soil, (Vertical percolation layer)
thickness	24 in	See liner section
soil texture	4	HELP Default for a SM, (lab data indicates onsite soil to be a SM)
porosity	0.473	HELP default for texture 4
field capacity	0.0105	HELP default for texture 4
wilting point	0.047	HELP default for texture 4
moisture content	0.0863	Based on a avg. M.C. = 5.9% for Natural moisture contents of Silty Sands tested from the site.
saturated hydraulic conductivity	1.7E-3cm/s	HELP default for texture 4
Is layer compacted?	No	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, Alternative #2 slope liner system

TABLE 2
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
LAYER NUMBER: 2		
layer type	2	Geocomposite (lateral drainage layer)
thickness	0.2 in	HELP default thickness for texture 20(consistant w/ materials on the market)
soil texture	20	HELP Default for drainage net.(conservative, ignores added capacity of geotextile
porosity	0.850	HELP default for texture 20
field capacity	0.010	HELP default for texture 20
wilting point	0.005	HELP default for texture 20
moisture content	0.010	Moisture content equal to field capacity, does not allow for water storage in Lateral drainage layer
saturated hydraulic conductivity	1.0E1cm/s	HELP default for texture 20
Is layer compacted?	NA	
slope (if lateral drainage layer)	33%	slope grade from cell layout drawing
maximum horizontal drainage distance (if lateral drainage layer)	316 ft	Maximum drainage length for phase 1 slope (scaled from drawings)
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	

NOTES: (make additional copies for each layer as required)

PROJECT: Triassic Park Disposal Facility, Alternative #2 slope Liner system

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 3		
layer type	4	FML, (HDPE Geomembrane)
thickness	0.06 in	60 mil (typical geomembrane thickness)
soil texture	35	HELP Default texture for HDPE geomembrane.
porosity	NA	
field capacity	NA	
wilting point	NA	
moisture content	NA	
saturated hydraulic conductivity	2.0E-13cm/s	HELP default for texture 35
Is layer compacted?	NA	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	1	Typical value recommended by HELP manual.
geomembrane installation defects	3	Typical value recommended by HELP manual for good installation.
liner installation quality (if geomembrane)	3	Good installation
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, Alternative #2 slope liner system

TABLE 2
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
LAYER NUMBER: 4		
layer type	2	Geocomposite (lateral drainage layer)
thickness	0.2 in	HELP default thickness for texture 20(consistant w/ materials on the market)
soil texture	20	HELP Default for drainage net.(conservative, ignores added capacity of geotextile
porosity	0.850	HELP default for texture 20
field capacity	0.010	HELP default for texture 20
wilting point	0.005	HELP default for texture 20
moisture content	0.010	Moisture content equal to field capacity, does not allow for water storage in Lateral drainage layer
saturated hydraulic conductivity	1.0E1cm/s	HELP default for texture 20
Is layer compacted?	NA	
slope (if lateral drainage layer)	33%	Slope grade from cell layout drawing
maximum horizontal drainage distance (if lateral drainage layer)	316 ft	Maximum drainage length for phase 1 slope (scaled from drawings)
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	

NOTES: (make additional copies for each layer as required)

PROJECT: Triassic Park Disposal Facility, Alternative #2 slope Liner system

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	VALUE	JUSTIFICATION
LAYER NUMBER: 5		
layer type	4	FML, (HDPE Geomembrane)
thickness	0.06 in	60 mil (typical geomembrane thickness)
soil texture	35	HELP Default texture for HDPE geomembrane.
porosity	NA	
field capacity	NA	
wilting point	NA	
moisture content	NA	
saturated hydraulic conductivity	2.0E-13cm/s	HELP default for texture 35
Is layer compacted?	NA	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	1	Typical value recommended by HELP manual.
geomembrane installation defects	3	Typical value recommended by HELP manual for good installation.
liner installation quality (if geomembrane)	3	Good installation
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, Alternative #2 slope liner system

TABLE 2
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
LAYER NUMBER: 6		
layer type	3	GCL
thickness	0.24 in	HELP default thickness for bentonite mat
soil texture	17	HELP Default texture for bentonite mat
porosity	0.750	HELP default for texture 17
field capacity	0.747	HELP default for texture 17
wilting point	0.400	HELP default for texture 17
moisture content	0.750	Moisture content equal to porosity, allows for imediate saturated flow (HELP default).
saturated hydraulic conductivity	3.0E-9cm/s	HELP default for bentonite mat
Is layer compacted?	No	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	

NOTES: (make additional copies for each layer as required)

PROJECT: Triassic Park Disposal Facility, Alternative #2 slope liner system

TABLE 1 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
CLIMATOLOGICAL DATA		
city	Roswell, NM	Nearby City
precipitation & source of data (default or synthetic)	Synthetic	Only option for Roswell, NM, using 30 yr mean monthly inputs
temperature & source of data	Synthetic	Roswell, NM using 30yr mean monthly inputs
latitude	33.24	HELP default for Roswell, NM
maximum leaf area index	1	Poor stand of grass
evaporate zone depth	24 in.	Maximum depth of vegetative soil
growing season start and end day	76/310	HELP default for Roswell, NM
LANDFILL COVER DATA		
type of vegetative cover	1	Poor stand of grass
SCS runoff curve number	74.9	HELP model generated, Soil texture 4, 25% slope, poor stand of grass
active (uncovered)	No	
% of surface runoff that drains from landfill	100%	
surface area	1 acre	Unit area, (outputs to be converted to gallons/acre/day)
SOIL AND DESIGN DATA		
source of soil characteristics		HELP defaults, useing lab data for onsite soils
number of layers	6	
NOTES;		

PROJECT: Triassic Park Disposal Facility, Cover Liner System

TABLE 2
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
LAYER NUMBER: 1		
layer type	1	Vegetative soil, (Vertical percolation layer)
thickness	24 in	See liner section
soil texture	6	HELP Default for a SM, (geologic data indicates some onsite soil to be a SM w/ a lower permeability than other SM's on site)
porosity	0.453	HELP default for texture 6
field capacity	0.190	HELP default for texture 6
wilting point	0.085	HELP default for texture 6
moisture content	0.0863	Based on a avg. M.C. = 5.9% for Natural moisture contents of Silty Sands tested from the site.
saturated hydraulic conductivity	7.2E-4cm/s	HELP default for texture 4
Is layer compacted?	No	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	

NOTES: (make additional copies for each layer as required)

PROJECT: Triassic Park Disposal Facility, Cover Alternative

TABLE 2
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
LAYER NUMBER: 2		
layer type	2	Geocomposite (lateral drainage layer)
thickness	0.2 in	HELP default thickness for texture 20(consistant w/ materials on the market)
soil texture	20	HELP Default for drainage net.(conservative, ignores added capacity of geotextile
porosity	0.850	HELP default for texture 20
field capacity	0.010	HELP default for texture 20
wilting point	0.005	HELP default for texture 20
moisture content	0.010	Moisture content equal to field capacity, does not allow for water storage in Lateral drainage layer
saturated hydraulic conductivity	1.0E1cm/s	HELP default for texture 20
Is layer compacted?	NA	
slope (if lateral drainage layer)	25%	See cover section
maximum horizontal drainage distance (if lateral drainage layer)	550 ft	Estimate
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	

NOTES: (make additional copies for each layer as required)

PROJECT: Triassic Park Disposal Facility, Cover Alternative

TABLE 2
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
LAYER NUMBER: 3		
layer type	4	FMC, (HDPE Geomembrane)
thickness	0.06 in	60 mil (typical geomembrane thickness)
soil texture	35	HELP Default texture for HDPE geomembrane.
porosity	NA	
field capacity	NA	
wilting point	NA	
moisture content	NA	
saturated hydraulic conductivity	2.0E-13cm/s	HELP default for texture 35
Is layer compacted?	NA	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	1	Typical value recommended by HELP manual.
geomembrane installation defects	3	Typical value recommended by HELP manual for good installation.
liner installation quality (if geomembrane)	3	Good installation
geotextile transmissivity	NA	

NOTES: (make additional copies for each layer as required)

PROJECT: Triassic Park Disposal Facility, Cover Alternative

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 4		
layer type	3	GCL
thickness	0.24 in	See Cover section
soil texture	17	HELP Default for bentonite mat
porosity	0.750	HELP default for texture 17
field capacity	0.747	HELP default for texture 17
wilting point	0.400	HELP default for texture 17
moisture content	0.750	Moisture content equal to porosity, allows for imediate saturated flow (HELP default).
saturated hydraulic conductivity	3.0E-9cm/s	HELP default for bentonite mat.
Is layer compacted?	No	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, Cover Alternative

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 5		
layer type	1	Protective soil, (Vertical percolation layer)
thickness	6 in	See cover section
soil texture	4	HELP Default for a SM, (lab data indicates onsite soil to be a SM)
porosity	0.473	HELP default for texture 4
field capacity	0.0105	HELP default for texture 4
wilting point	0.047	HELP default for texture 4
moisture content	0.0863	Based on a avg. M.C. = 5.9% for Natural moisture contents of Silty Sands tested from the site.
saturated hydraulic conductivity	1.7E-3cm/s	HELP default for texture 4
Is layer compacted?	Yes	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, Cover Alternative

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 6		
layer type	1	Protective soil, (Vertical percolation layer)
thickness	18 in	See cover section
soil texture	4	HELP Default for a SM, (lab data indicates onsite soil to be a SM)
porosity	0.473	HELP default for texture 4
field capacity	0.0105	HELP default for texture 4
wilting point	0.047	HELP default for texture 4
moisture content	0.0863	Based on a avg. M.C. = 5.9% for Natural moisture contents of Silty Sands tested from the site.
saturated hydraulic conductivity	1.7E-3cm/s	HELP default for texture 4
Is layer compacted?	No	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, Cover Alternative

TABLE 1
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
CLIMATOLOGICAL DATA		
city	Roswell, NM	Nearby City
precipitation & source of data (default or synthetic)	Synthetic	Only option for Roswell, NM Using 30yr avg mean monthly inputs
temperature & source of data	Synthetic	Roswell, NM using 30 yr avg. mean monthly inputs
latitude	33.24	HELP default for Roswell, NM
maximum leaf area index	0	Bare Ground
evaporate zone depth	14 in.	HELP default for Roswell, NM
growing season start and end day	76/310	HELP default for Roswell, NM
LANDFILL COVER DATA		
type of vegetative cover	NA	Bare Ground
SCS runoff curve number	NA	0% allowable runoff CN does not affect results
active (uncovered)	Yes	
% of surface runoff that drains from landfill	0%	
surface area	1 acre	Unit area, (outputs to be converted to gallons/acre/day)
SOIL AND DESIGN DATA		
source of soil characteristics		HELP defaults, useing lab data for onsite soils
number of layers	6	
NOTES:		

PROJECT: Triassic Park Disposal Facility, MTR Floor Liner System

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 1		
layer type	1	Protective soil, (Vertical percolation layer)
thickness	24 in	See liner section
soil texture	4	HELP Default for a SM, (lab data indicates onsite soil to be a SM)
porosity	0.473	HELP default for texture 4
field capacity	0.0105	HELP default for texture 4
wilting point	0.047	HELP default for texture 4
moisture content	0.0863	Based on avg moisture content of bulk samples taken from site
saturated hydraulic conductivity	1.7E-3cm/s	HELP default for texture 4
Is layer compacted?	No	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, MTR floor liner system

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 2		
layer type	2	Sand lateral drainage layer
thickness	12 in	See liner section, (ignore geotextile cushion & seperation layers)
soil texture	1	HELP Default for a poorly graded sand, (typical drainage material).
porosity	0.417	HELP default for texture 1
field capacity	0.045	HELP default for texture 1
wilting point	0.018	HELP default for texture 1
moisture content	0.045	Moisture content equal to field capacity (does not allow storage)
saturated hydraulic conductivity	1.0E-2cm/s	HELP default for texture 1 (also EPA minimum required value)
Is layer compacted?	No	
slope (if lateral drainage layer)	2.3%	Floor grade from cell layout drawing
maximum horizontal drainage distance (if lateral drainage layer)	550 ft	Maximum drainage length for phase 1 floor (scaled from drawings)
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, MTR floor liner system

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 3		
layer type	4	FML, (HDPE Geomembrane)
thickness	0.06 in	60 mil (typical geomembrane thickness)
soil texture	35	HELP Default texture for HDPE geomembrane.
porosity	NA	
field capacity	NA	
wilting point	NA	
moisture content	NA	
saturated hydraulic conductivity	2.0E-13cm/s	HELP default for texture 35
Is layer compacted?	NA	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	1	Typical value recommended by HELP manual.
geomembrane installation defects	3	Typical value recommended by HELP manual for good installation.
liner installation quality (if geomembrane)	3	Good installation
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, MTR floor liner system

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 4		
layer type	2	Sand lateral drainage layer
thickness	12 in	See liner section, (ignore geotextile cushion & seperation layers)
soil texture	1	HELP Default for a poorly graded sand, (typical drainage material).
porosity	0.417	HELP default for texture 1
field capacity	0.045	HELP default for texture 1
wilting point	0.018	HELP default for texture 1
moisture content	0.045	Moisture content equal to field capacity (does not allow storage)
saturated hydraulic conductivity	1.0E-2cm/s	HELP default for texture 1 (also EPA minimum required value)
Is layer compacted?	No	
slope (if lateral drainage layer)	2.3%	Floor grade from cell layout drawing
maximum horizontal drainage distance (if lateral drainage layer)	550 ft	Maximum drainage length for phase 1 floor (scaled from drawings)
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	
NOTES; (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, MTR floor liner system

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 5		
layer type	4	FML, (HDPE Geomembrane)
thickness	0.06 in	60 mil (typical geomembrane thickness)
soil texture	35	HELP Default texture for HDPE geomembrane.
porosity	NA	
field capacity	NA	
wilting point	NA	
moisture content	NA	
saturated hydraulic conductivity	2.0E-13cm/s	HELP default for texture 35
Is layer compacted?	NA	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	1	Typical value recommended by HELP manual.
geomembrane installation defects	3	Typical value recommended by HELP manual for good installation.
liner installation quality (if geomembrane)	3	Good installation
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, MTR floor liner system

TABLE 2
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
LAYER NUMBER: 6		
layer type	3	Compacted Clay Liner
thickness	36 in	See liner section
soil texture	0	HELP Default texture 26 (compacted CL) w/ a modified k value. (lab data indicates soil to be a CL)
porosity	0.445	HELP default for texture 26
field capacity	0.393	HELP default for texture 26
wilting point	0.445	HELP default for texture 26
moisture content	0.445	Moisture content equal to porosity (allows for immediate saturated flow)
saturated hydraulic conductivity	1.0E-7cm/s	Lab data indicates this permeability is possible w/ this soil.
Is layer compacted?	YES	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	

NOTES: (make additional copies for each layer as required)

PROJECT: Triassic Park Disposal Facility, MTR floor liner system

TABLE 1
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
CLIMATOLOGICAL DATA		
city	Roswell, NM	Nearby City
precipitation & source of data (default or synthetic)	Synthetic	Only option for Roswell, NM using 30 yr avg. mean monthly inputs
temperature & source of data	Synthetic	Roswell, NM using 30 yr avg. mean monthly inputs
latitude	33.24	HELP default for Roswell, NM
maximum leaf area index	0	Bare Ground
evaporate zone depth	14 in.	HELP default for Roswell, NM
growing season start and end day	76/310	HELP default for Roswell, NM
LANDFILL COVER DATA		
type of vegetative cover	NA	Bare Ground
SCS runoff curve number	NA	0% allowable runoff CN does not affect results
active (uncovered)	Yes	
% of surface runoff that drains from landfill	0%	
surface area	1 acre	Unit area, (outputs to be converted to gallons/acre/day)
SOIL AND DESIGN DATA		
source of soil characteristics		HELP defaults, useing lab data for onsite soils
number of layers	6	
NOTES:		

PROJECT: Triassic Park Disposal Facility, Slope MTR Liner System

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 1		
layer type	1	Protective soil, (Vertical percolation layer)
thickness	24 in	See liner section
soil texture	4	HELP Default for a SM, (lab data indicates onsite soil to be a SM)
porosity	0.473	HELP default for texture 4
field capacity	0.0105	HELP default for texture 4
wilting point	0.047	HELP default for texture 4
moisture content	0.0863	Based on a avg. M.C. = 5.9% for Natural moisture contents of Silty Sands tested from the site.
saturated hydraulic conductivity	1.7E-3cm/s	HELP default for texture 4
Is layer compacted?	No	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, MTR slope liner system

TABLE 2
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
LAYER NUMBER: 2		
layer type	2	Sand lateral drainage layer
thickness	12 in	See liner section, (ignore geotextile cushion & seperation layers)
soil texture	1	HELP Default for a poorly graded sand, (typical drainage material).
porosity	0.417	HELP default for texture 1
field capacity	0.045	HELP default for texture 1
wilting point	0.018	HELP default for texture 1
moisture content	0.045	Moisture content equal to field capacity, does not allow for water storage in lateral drainage layer.
saturated hydraulic conductivity	1.0E-2cm/s	HELP default for texture 1 (also EPA minimum required value)
Is layer compacted?	No	
slope (if lateral drainage layer)	33%	slope grade from cell layout drawing
maximum horizontal drainage distance (if lateral drainage layer)	316 ft	Maximum drainage length for phase 1 slope (scaled from drawings)
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	

NOTES: (make additional copies for each layer as required)

PROJECT: Triassic Park Disposal Facility, MTR slope liner system

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 3		
layer type	4	FML, (HDPE Geomembrane)
thickness	0.06 in	60 mil (typical geomembrane thickness)
soil texture	35	HELP Default texture for HDPE geomembrane.
porosity	NA	
field capacity	NA	
wilting point	NA	
moisture content	NA	
saturated hydraulic conductivity	2.0E-13cm/s	HELP default for texture 35
Is layer compacted?	NA	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	1	Typical value recommended by HELP manual.
geomembrane installation defects	3	Typical value recommended by HELP manual for good installation.
liner installation quality (if geomembrane)	3	Good installation
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, MTR slope liner system

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 4		
layer type	2	Sand lateral drainage layer
thickness	12 in	See liner section, (ignore geotextile cushion & seperation layers)
soil texture	1	HELP Default for a poorly graded sand, (typical drainage material).
porosity	0.417	HELP default for texture 1
field capacity	0.045	HELP default for texture 1
wilting point	0.018	HELP default for texture 1
moisture content	0.045	Moisture content equal to field capacity, does not allow for water storage in lateral drainage layer.
saturated hydraulic conductivity	1.0E-2cm/s	HELP default for texture 1 (also EPA minimum required value)
Is layer compacted?	No	
slope (if lateral drainage layer)	33%	Slope grade from cell layout drawing
maximum horizontal drainage distance (if lateral drainage layer)	316 ft	Maximum drainage length for phase 1 slope (scaled from drawings)
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, MTR slope liner system

TABLE 2 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS		
INPUT PARAMETER	**VALUE**	**JUSTIFICATION**
LAYER NUMBER: 5		
layer type	4	FML, (HDPE Geomembrane)
thickness	0.06 in	60 mil (typical geomembrane thickness)
soil texture	35	HELP Default texture for HDPE geomembrane.
porosity	NA	
field capacity	NA	
wilting point	NA	
moisture content	NA	
saturated hydraulic conductivity	2.0E-13cm/s	HELP default for texture 35
Is layer compacted?	NA	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	1	Typical value recommended by HELP manual.
geomembrane installation defects	3	Typical value recommended by HELP manual for good installation.
liner installation quality (if geomembrane)	3	Good installation
geotextile transmissivity	NA	
NOTES: (make additional copies for each layer as required)		

PROJECT: Triassic Park Disposal Facility, MTR slope liner system

TABLE 2
LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS

INPUT PARAMETER	VALUE	JUSTIFICATION
LAYER NUMBER: 6		
layer type	3	Compacted Clay Liner
thickness	36 in	See liner section
soil texture	0	HELP Default texture 26 (compacted CL) w/ a modified k value. (lab data indicates soil to be a CL)
porosity	0.445	HELP default for texture 26
field capacity	0.393	HELP default for texture 26
wilting point	0.445	HELP default for texture 26
moisture content	0.445	Moisture content equal to porosity, allows for imediate saturated flow (HELP default).
saturated hydraulic conductivity	1.0E-7cm/s	Lab data indicates this permeability is possible w/ this soil.
Is layer compacted?	YES	
slope (if lateral drainage layer)	NA	
maximum horizontal drainage distance (if lateral drainage layer)	NA	
geomembrane pinhole density	NA	
geomembrane installation defects	NA	
liner installation quality (if geomembrane)	NA	
geotextile transmissivity	NA	

NOTES: (make additional copies for each layer as required)

PROJECT: Triassic Park Disposal Facility, MTR slope liner system

APPENDIX B

HELP SIMULATION SUMMARY PRINTOUTS

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******************************************************************************
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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                 HELP MODEL VERSION 3.04a  (10 JULY 1995)                 **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     d:\602\in\flr.D4
TEMPERATURE DATA FILE:       d:\602\in\flr.D7
SOLAR RADIATION DATA FILE:   d:\602\in\flr.D13
EVAPOTRANSPIRATION DATA:     d:\602\in\flr.D11
SOIL AND DESIGN DATA FILE:   d:\602\in\ALT2FLR.D10
OUTPUT DATA FILE:            d:\602\out\alt2flr.OUT


TIME:  15: 5     DATE:   2/28/1996


******************************************************************************

    TITLE:  gandy alternative 2, year 0-5, floor

    ***************************************************************************


    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
             WERE SPECIFIED BY THE USER.


                                LAYER  1
                                --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER   4
        THICKNESS                    =     24.00   INCHES
        POROSITY                     =      0.4370 VOL/VOL
        FIELD CAPACITY               =      0.1050 VOL/VOL
        WILTING POINT                =      0.0470 VOL/VOL
        INITIAL SOIL WATER CONTENT   =      0.0863 VOL/VOL
        EFFECTIVE SAT. HYD. COND.    =  0.170000002000E-02 CM/SEC
```

```
                    LAYER  2
                    --------

          TYPE 2 - LATERAL DRAINAGE LAYER
            MATERIAL TEXTURE NUMBER  20
THICKNESS                    =      0.20    INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   10.0000000000      CM/SEC
SLOPE                        =      2.30    PERCENT
DRAINAGE LENGTH              =    550.0     FEET


                    LAYER  3
                    --------

          TYPE 4 - FLEXIBLE MEMBRANE LINER
            MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06    INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00    HOLES/ACRE
FML INSTALLATION DEFECTS     =      3.00    HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                    LAYER  4
                    --------

          TYPE 2 - LATERAL DRAINAGE LAYER
            MATERIAL TEXTURE NUMBER  20
THICKNESS                    =      0.20    INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   10.0000000000      CM/SEC
SLOPE                        =      2.30    PERCENT
DRAINAGE LENGTH              =    550.0     FEET
```

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	3.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.24	INCHES
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7470	VOL/VOL
WILTING POINT	=	0.4000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 4 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 550. FEET.

SCS RUNOFF CURVE NUMBER	=	80.50	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	14.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.208	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.118	INCHES

LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.658	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	2.255	INCHES
TOTAL INITIAL WATER	=	2.255	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
ROSWELL NEW MEXICO

STATION LATITUDE	=	33.24	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	76	
END OF GROWING SEASON (JULIAN DATE)	=	310	
EVAPORATIVE ZONE DEPTH	=	14.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	8.70	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	49.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	40.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	53.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	52.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.42	0.47	0.49	0.69	1.14	1.43
1.99	1.90	1.87	1.13	0.57	0.53

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	44.10	51.30	59.80	68.30	76.80
79.30	77.90	71.00	60.10	48.00	40.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO
AND STATION LATITUDE = 33.24 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.30	0.29	0.54	0.49	1.17	0.99
	2.39	1.68	1.79	0.90	1.44	0.97
STD. DEVIATIONS	0.34	0.07	0.47	0.39	1.10	1.20
	1.12	1.16	1.14	1.04	1.76	0.67
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
APOTRANSPIRATION						
TOTALS	0.438	0.303	0.412	0.280	1.097	0.882
	1.825	1.797	1.517	1.018	1.082	0.779
STD. DEVIATIONS	0.190	0.068	0.364	0.162	0.930	1.074
	0.881	1.256	0.771	0.663	0.810	0.425
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0416	0.0342	0.0209	0.0120	0.0095	0.0120
	0.0301	0.0626	0.0505	0.0703	0.2054	0.0964
STD. DEVIATIONS	0.0397	0.0333	0.0164	0.0092	0.0072	0.0110
	0.0406	0.0592	0.0375	0.0667	0.2849	0.1230
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0569	0.0502	0.0434	0.0307	0.0252	0.0237
	0.0399	0.0722	0.0681	0.0770	0.1117	0.0973

STD. DEVIATIONS	0.0402	0.0412	0.0311	0.0230	0.0179	0.0196
	0.0460	0.0552	0.0445	0.0424	0.0755	0.0673

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	0.0568	0.0505	0.0434	0.0308	0.0254	0.0237
	0.0396	0.0716	0.0685	0.0768	0.1109	0.0983
STD. DEVIATIONS	0.0400	0.0416	0.0312	0.0231	0.0180	0.0194
	0.0452	0.0549	0.0448	0.0424	0.0746	0.0684

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0006	0.0005	0.0003	0.0002	0.0001	0.0002
	0.0004	0.0009	0.0007	0.0010	0.0029	0.0013
STD. DEVIATIONS	0.0005	0.0005	0.0002	0.0001	0.0001	0.0002
	0.0006	0.0008	0.0005	0.0009	0.0040	0.0017

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0008	0.0008	0.0006	0.0004	0.0003	0.0003
	0.0005	0.0010	0.0010	0.0010	0.0016	0.0013
STD. DEVIATIONS	0.0005	0.0006	0.0004	0.0003	0.0002	0.0003
	0.0006	0.0007	0.0006	0.0006	0.0010	0.0009

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES	CU. FEET	PERCENT

PRECIPITATION	12.95	(2.076)	47023.0	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	11.431	(1.9467)	41494.45	88.243
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.64535	(0.56767)	2342.634	4.98189
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.69647	(0.36897)	2528.192	5.37650
AVERAGE HEAD ON TOP OF LAYER 3	0.001	(0.001)		
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.69630	(0.36874)	2527.576	5.37519
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00000	(0.00000)	0.008	0.00002
AVERAGE HEAD ON TOP OF LAYER 5	0.001	(0.000)		
CHANGE IN WATER STORAGE	0.181	(0.4414)	658.36	1.400

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	1.40	5082.000
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 2	0.10664	387.11032
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.022506	81.69557
AVERAGE HEAD ON TOP OF LAYER 3	0.045	
MAXIMUM HEAD ON TOP OF LAYER 3	0.088	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	11.6 FEET	
DRAINAGE COLLECTED FROM LAYER 4	0.02105	76.40586
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 5	0.009	
MAXIMUM HEAD ON TOP OF LAYER 5	0.025	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	1.36	4944.3652

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2317
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0470

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	2.9768	0.1240
2	0.0024	0.0120
3	0.0000	0.0000
4	0.0028	0.0142
5	0.0000	0.0000
6	0.1800	0.7500
SNOW WATER	0.000	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                 HELP MODEL VERSION 3.04a  (10 JULY 1995)                 **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
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PRECIPITATION DATA FILE:     d:\602\in\flr.D4
TEMPERATURE DATA FILE:       d:\602\in\flr.D7
SOLAR RADIATION DATA FILE:   d:\602\in\flr.D13
EVAPOTRANSPIRATION DATA:     d:\602\in\flr.D11
SOIL AND DESIGN DATA FILE:   d:\602\in\ALT2slp.D10
OUTPUT DATA FILE:            d:\602\out\alt2slp.OUT


TIME:  15: 6     DATE:   2/28/1996


******************************************************************************

   TITLE:  gandy alternative 2, year 0-5, slope

   ***************************************************************************


    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
             WERE SPECIFIED BY THE USER.


                                LAYER  1
                                --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER   4
         THICKNESS                  =     24.00   INCHES
         POROSITY                   =      0.4370 VOL/VOL
         FIELD CAPACITY             =      0.1050 VOL/VOL
         WILTING POINT              =      0.0470 VOL/VOL
         INITIAL SOIL WATER CONTENT =      0.0863 VOL/VOL
         EFFECTIVE SAT. HYD. COND.  =  0.170000002000E-02 CM/SEC
```

LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.20	INCHES
POROSITY	=	0.8500	VOL/VOL
FIELD CAPACITY	=	0.0100	VOL/VOL
WILTING POINT	=	0.0050	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000	CM/SEC
SLOPE	=	33.00	PERCENT
DRAINAGE LENGTH	=	316.0	FEET

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	3.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 4

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.20	INCHES
POROSITY	=	0.8500	VOL/VOL
FIELD CAPACITY	=	0.0100	VOL/VOL
WILTING POINT	=	0.0050	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000	CM/SEC
SLOPE	=	33.00	PERCENT
DRAINAGE LENGTH	=	316.0	FEET

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	3.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.24	INCHES
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7470	VOL/VOL
WILTING POINT	=	0.4000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 4 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 33.% AND A SLOPE LENGTH OF 316. FEET.

SCS RUNOFF CURVE NUMBER	=	82.40	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	14.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.208	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.118	INCHES

LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.658	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	2.255	INCHES
TOTAL INITIAL WATER	=	2.255	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
ROSWELL NEW MEXICO

STATION LATITUDE	=	33.24	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	76	
END OF GROWING SEASON (JULIAN DATE)	=	310	
EVAPORATIVE ZONE DEPTH	=	14.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	8.70	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	49.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	40.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	53.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	52.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.42	0.47	0.49	0.69	1.14	1.43
1.99	1.90	1.87	1.13	0.57	0.53

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	44.10	51.30	59.80	68.30	76.80
79.30	77.90	71.00	60.10	48.00	40.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO
AND STATION LATITUDE = 33.24 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.30	0.29	0.54	0.49	1.17	0.99
	2.39	1.68	1.79	0.90	1.44	0.97
STD. DEVIATIONS	0.34	0.07	0.47	0.39	1.10	1.20
	1.12	1.16	1.14	1.04	1.76	0.67
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
APOTRANSPIRATION						
TOTALS	0.223	0.121	0.144	0.096	0.318	0.413
	1.261	0.557	0.702	0.341	0.405	0.398
STD. DEVIATIONS	0.157	0.088	0.153	0.175	0.325	0.765
	0.644	0.326	0.848	0.432	0.413	0.439
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.2838	0.1530	0.3144	0.1666	0.7463	0.5542
	0.7122	1.3258	0.9034	0.5961	1.1245	0.4454
STD. DEVIATIONS	0.2299	0.1388	0.3029	0.0962	0.6884	0.5561
	0.5288	0.9396	0.3697	0.3540	1.3388	0.2356
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0338	0.0244	0.0337	0.0259	0.0528	0.0428
	0.0557	0.0793	0.0653	0.0540	0.0660	0.0459

STD. DEVIATIONS	0.0218	0.0167	0.0253	0.0152	0.0350	0.0287
	0.0235	0.0266	0.0129	0.0137	0.0312	0.0100

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	0.0338	0.0244	0.0337	0.0259	0.0528	0.0428
	0.0557	0.0793	0.0653	0.0540	0.0660	0.0459
STD. DEVIATIONS	0.0218	0.0167	0.0253	0.0152	0.0350	0.0287
	0.0235	0.0266	0.0129	0.0137	0.0312	0.0100

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0002	0.0001	0.0002	0.0001	0.0005	0.0003
	0.0004	0.0008	0.0006	0.0004	0.0007	0.0003
STD. DEVIATIONS	0.0001	0.0001	0.0002	0.0001	0.0004	0.0003
	0.0003	0.0006	0.0002	0.0002	0.0008	0.0001

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001
	0.0002	0.0003	0.0002	0.0002	0.0002	0.0001
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0000	0.0000	0.0001	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES	CU. FEET	PERCENT

PRECIPITATION	12.95	(2.076)	47023.0	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	4.979	(0.8403)	18074.46	38.437
LATERAL DRAINAGE COLLECTED FROM LAYER 2	7.32567	(2.24924)	26592.176	56.55140
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.57975	(0.16004)	2104.510	4.47549
AVERAGE HEAD ON TOP OF LAYER 3	0.000	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.57975	(0.16004)	2104.509	4.47549
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00000	(0.00000)	0.002	0.00000
AVERAGE HEAD ON TOP OF LAYER 5	0.000	(0.000)		
CHANGE IN WATER STORAGE	0.069	(0.3656)	251.88	0.536

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	1.40	5082.000
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 2	0.55831	2026.65674
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.010151	36.84814
AVERAGE HEAD ON TOP OF LAYER 3	0.010	
MAXIMUM HEAD ON TOP OF LAYER 3	0.094	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 4	0.01015	36.84814
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00001
AVERAGE HEAD ON TOP OF LAYER 5	0.001	
MAXIMUM HEAD ON TOP OF LAYER 5	0.000	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	1.36	4944.3652

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.1804

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0470

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	2.4179	0.1007
2	0.0022	0.0112
3	0.0000	0.0000
4	0.0020	0.0100
5	0.0000	0.0000
6	0.1800	0.7500
SNOW WATER	0.000	

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              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                 **
                 HELP MODEL VERSION 3.04a  (10 JULY 1995)                   **
**                DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     d:\602\in\cov.D4
TEMPERATURE DATA FILE:       d:\602\in\cov.D7
SOLAR RADIATION DATA FILE:   d:\602\in\cov.D13
EVAPOTRANSPIRATION DATA:     d:\602\in\cov.D11
SOIL AND DESIGN DATA FILE:   d:\602\in\coverU.D10
OUTPUT DATA FILE:            d:\602\out\coverU.OUT


TIME:   8:31     DATE:   2/29/1996


******************************************************************************

    TITLE:  gandy cover alternative, year 0-5

    ***************************************************************************


    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
             WERE SPECIFIED BY THE USER.


                                LAYER  1
                                --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER   6
        THICKNESS                    =     24.00   INCHES
        POROSITY                     =      0.4530 VOL/VOL
        FIELD CAPACITY               =      0.1900 VOL/VOL
        WILTING POINT                =      0.0850 VOL/VOL
        INITIAL SOIL WATER CONTENT   =      0.0863 VOL/VOL
        EFFECTIVE SAT. HYD. COND.    =  0.720000011000E-03 CM/SEC
```

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 1.80
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.20	INCHES
POROSITY	=	0.8500	VOL/VOL
FIELD CAPACITY	=	0.0100	VOL/VOL
WILTING POINT	=	0.0050	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000	CM/SEC
SLOPE	=	25.00	PERCENT
DRAINAGE LENGTH	=	550.0	FEET

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	3.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 4

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.24	INCHES
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7470	VOL/VOL
WILTING POINT	=	0.4000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.300000003000E-08	CM/SEC

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	6.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0863	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

LAYER 6

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 4

THICKNESS	=	18.00	INCHES
POROSITY	=	0.4370	VOL/VOL
FIELD CAPACITY	=	0.1050	VOL/VOL
WILTING POINT	=	0.0470	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0863	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000002000E-02	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 6 WITH A POOR STAND OF GRASS, A SURFACE SLOPE OF 25.% AND A SLOPE LENGTH OF 550. FEET.

SCS RUNOFF CURVE NUMBER	=	80.50	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	24.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.071	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	10.872	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.040	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	4.324	INCHES

TOTAL INITIAL WATER = 4.324 INCHES
TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
ROSWELL NEW MEXICO

STATION LATITUDE	=	33.24 DEGREES
MAXIMUM LEAF AREA INDEX	=	1.00
START OF GROWING SEASON (JULIAN DATE)	=	76
END OF GROWING SEASON (JULIAN DATE)	=	310
EVAPORATIVE ZONE DEPTH	=	24.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	8.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	49.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	40.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	53.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	52.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.42	0.47	0.49	0.69	1.14	1.43
1.99	1.90	1.87	1.13	0.57	0.53

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	44.10	51.30	59.80	68.30	76.80
79.30	77.90	71.00	60.10	48.00	40.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO
AND STATION LATITUDE = 33.24 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.30	0.29	0.54	0.49	1.17	0.99
	2.39	1.68	1.79	0.90	1.44	0.97
STD. DEVIATIONS	0.34	0.07	0.47	0.39	1.10	1.20
	1.12	1.16	1.14	1.04	1.76	0.67
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.001	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.001
	0.001	0.000	0.000	0.001	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.660	0.265	0.558	0.266	1.236	1.117
	2.254	1.850	1.519	0.938	1.055	0.987
STD. DEVIATIONS	0.399	0.087	0.467	0.422	1.021	1.293
	1.297	1.206	1.094	0.856	0.675	0.419
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0161	0.0040	0.0138	0.0068	0.0091	0.0063
	0.0347	0.0368	0.0203	0.0122	0.0433	0.0417
STD. DEVIATIONS	0.0295	0.0059	0.0168	0.0102	0.0110	0.0087
	0.0224	0.0189	0.0086	0.0077	0.0579	0.0250
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

RCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES		CU. FEET	PERCENT
PRECIPITATION	12.95	(2.076)	47023.0	100.00
RUNOFF	0.001	(0.0023)	4.94	0.011
EVAPOTRANSPIRATION	12.706	(1.7289)	46122.80	98.086
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.24518	(0.12170)	890.020	1.89273
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00000	(0.00000)	0.001	0.00000
AVERAGE HEAD ON TOP OF LAYER 3	0.000	(0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00153	(0.00028)	5.554	0.01181
CHANGE IN WATER STORAGE	0.000	(0.5820)	-0.29	-0.001

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	1.40	5082.000
RUNOFF	0.003	12.1114
DRAINAGE COLLECTED FROM LAYER 2	0.04743	172.17372
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 3	0.002	
MAXIMUM HEAD ON TOP OF LAYER 3	0.192	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000005	0.01711
SNOW WATER	1.36	4944.3652

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.2101

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0850

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	2.0774	0.0866
2	0.0030	0.0150
3	0.0000	0.0000
4	0.1800	0.7500
5	0.5159	0.0860
6	1.5477	0.0860
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                 HELP MODEL VERSION 3.04a  (10 JULY 1995)                 **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     d:\602\in\flr.D4
TEMPERATURE DATA FILE:       d:\602\in\flr.D7
SOLAR RADIATION DATA FILE:   d:\602\in\flr.D13
EVAPOTRANSPIRATION DATA:     d:\602\in\flr.D11
SOIL AND DESIGN DATA FILE:   d:\602\in\MTRFL.D10
OUTPUT DATA FILE:            d:\602\out\mtrfl.OUT


TIME:  14:59     DATE:   2/28/1996


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   TITLE:  Gandy Landfill  - MTR - Floor (0-5 yrs)

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    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
             WERE SPECIFIED BY THE USER.


                              LAYER  1
                              --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER   4
        THICKNESS                  =     24.00   INCHES
        POROSITY                   =      0.4370 VOL/VOL
        FIELD CAPACITY             =      0.1050 VOL/VOL
        WILTING POINT              =      0.0470 VOL/VOL
        INITIAL SOIL WATER CONTENT =      0.0863 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  =  0.170000002000E-02 CM/SEC
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                        LAYER  2
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            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   1
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4170 VOL/VOL
FIELD CAPACITY               =      0.0450 VOL/VOL
WILTING POINT                =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC
SLOPE                        =      2.30   PERCENT
DRAINAGE LENGTH              =    550.0    FEET


                        LAYER  3
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      3.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                        LAYER  4
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   1
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4170 VOL/VOL
FIELD CAPACITY               =      0.0450 VOL/VOL
WILTING POINT                =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC
SLOPE                        =      2.30   PERCENT
DRAINAGE LENGTH              =    550.0    FEET
```

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	3.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	36.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4450	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 4 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 550. FEET.

SCS RUNOFF CURVE NUMBER	=	80.50	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	14.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.208	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.118	INCHES

LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.658	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	19.171	INCHES
TOTAL INITIAL WATER	=	19.171	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
ROSWELL NEW MEXICO

STATION LATITUDE	=	33.24	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	76	
END OF GROWING SEASON (JULIAN DATE)	=	310	
EVAPORATIVE ZONE DEPTH	=	14.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	8.70	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	49.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	40.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	53.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	52.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.42	0.47	0.49	0.69	1.14	1.43
1.99	1.90	1.87	1.13	0.57	0.53

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	44.10	51.30	59.80	68.30	76.80
79.30	77.90	71.00	60.10	48.00	40.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO
AND STATION LATITUDE = 33.24 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.30	0.29	0.54	0.49	1.17	0.99
	2.39	1.68	1.79	0.90	1.44	0.97
STD. DEVIATIONS	0.34	0.07	0.47	0.39	1.10	1.20
	1.12	1.16	1.14	1.04	1.76	0.67
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.438	0.303	0.412	0.280	1.097	0.882
	1.825	1.797	1.517	1.018	1.082	0.779
STD. DEVIATIONS	0.190	0.068	0.364	0.162	0.930	1.074
	0.881	1.256	0.771	0.663	0.810	0.425
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0621	0.0457	0.0407	0.0298	0.0227	0.0161
	0.0169	0.0237	0.0320	0.0360	0.0495	0.0777
STD. DEVIATIONS	0.0705	0.0472	0.0388	0.0260	0.0188	0.0130
	0.0100	0.0158	0.0204	0.0216	0.0344	0.0772
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.1049	0.0816	0.0768	0.0603	0.0495	0.0378
	0.0402	0.0519	0.0652	0.0729	0.0922	0.1296

STD. DEVIATIONS	0.1025	0.0723	0.0638	0.0470	0.0373	0.0279
	0.0233	0.0328	0.0394	0.0399	0.0523	0.1029

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	0.0693	0.0661	0.0750	0.0716	0.0707	0.0638
	0.0611	0.0582	0.0568	0.0606	0.0623	0.0737
STD. DEVIATIONS	0.0625	0.0590	0.0659	0.0617	0.0598	0.0530
	0.0492	0.0428	0.0379	0.0375	0.0358	0.0413

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.8312	0.6892	0.5543	0.4196	0.3096	0.2268
	0.2301	0.3233	0.4497	0.4901	0.6959	1.0576
STD. DEVIATIONS	0.9305	0.7113	0.5279	0.3656	0.2563	0.1824
	0.1359	0.2155	0.2866	0.2939	0.4840	1.0507

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.9310	0.9967	1.0206	1.0072	0.9627	0.8973
	0.8323	0.7929	0.7990	0.8257	0.8757	1.0028
STD. DEVIATIONS	0.8338	0.8893	0.8971	0.8686	0.8136	0.7451
	0.6699	0.5832	0.5332	0.5109	0.5034	0.5618

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES	CU. FEET	PERCENT

PRECIPITATION	12.95	(2.076)	47023.0	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	11.431	(1.9467)	41494.45	88.243
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.45305	(0.31273)	1644.561	3.49735
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.86312	(0.52877)	3133.128	6.66297
AVERAGE HEAD ON TOP OF LAYER 3	0.523	(0.361)		
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.78920	(0.59140)	2864.794	6.09232
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00071	(0.00051)	2.587	0.00550
AVERAGE HEAD ON TOP OF LAYER 5	0.912	(0.683)		
CHANGE IN WATER STORAGE	0.280	(0.8130)	1016.64	2.162

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	1.40	5082.000
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 2	0.00669	24.27183
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.009581	34.77909
AVERAGE HEAD ON TOP OF LAYER 3	2.822	
MAXIMUM HEAD ON TOP OF LAYER 3	5.131	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	49.7 FEET	
DRAINAGE COLLECTED FROM LAYER 4	0.00517	18.76339
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000004	0.01610
AVERAGE HEAD ON TOP OF LAYER 5	2.181	
MAXIMUM HEAD ON TOP OF LAYER 5	4.028	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	41.9 FEET	
SNOW WATER	1.36	4944.3652

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2317
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0470

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	2.9768	0.1240
2	0.6687	0.0557
3	0.0000	0.0000
4	0.9060	0.0755
5	0.0000	0.0000
6	16.0200	0.4450
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                 HELP MODEL VERSION 3.04a  (10 JULY 1995)                 **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:     d:\602\in\flr.D4
TEMPERATURE DATA FILE:       d:\602\in\flr.D7
SOLAR RADIATION DATA FILE:   d:\602\in\flr.D13
EVAPOTRANSPIRATION DATA:     d:\602\in\flr.D11
SOIL AND DESIGN DATA FILE:   d:\602\in\MTRSLP.D10
OUTPUT DATA FILE:            d:\602\out\mtrslp.OUT


TIME:  15: 5     DATE:   2/28/1996


******************************************************************************

    TITLE:  Gandy Landfill  - MTR - Side Slope (0-5yrs)

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    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
             WERE SPECIFIED BY THE USER.


                              LAYER  1
                              --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER   4
        THICKNESS                    =     24.00   INCHES
        POROSITY                     =      0.4370 VOL/VOL
        FIELD CAPACITY               =      0.1050 VOL/VOL
        WILTING POINT                =      0.0470 VOL/VOL
        INITIAL SOIL WATER CONTENT   =      0.0863 VOL/VOL
        EFFECTIVE SAT. HYD. COND.    =  0.170000002000E-02 CM/SEC
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                    LAYER  2
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          TYPE 2 - LATERAL DRAINAGE LAYER
            MATERIAL TEXTURE NUMBER   1
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4170 VOL/VOL
FIELD CAPACITY               =      0.0450 VOL/VOL
WILTING POINT                =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC
SLOPE                        =     33.00   PERCENT
DRAINAGE LENGTH              =    316.0    FEET


                    LAYER  3
                    --------

          TYPE 4 - FLEXIBLE MEMBRANE LINER
            MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      3.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                    LAYER  4
                    --------

          TYPE 2 - LATERAL DRAINAGE LAYER
            MATERIAL TEXTURE NUMBER   1
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4170 VOL/VOL
FIELD CAPACITY               =      0.0450 VOL/VOL
WILTING POINT                =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0450 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC
SLOPE                        =     33.00   PERCENT
DRAINAGE LENGTH              =    316.0    FEET
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LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	3.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	36.00	INCHES
POROSITY	=	0.4450	VOL/VOL
FIELD CAPACITY	=	0.3930	VOL/VOL
WILTING POINT	=	0.2770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4450	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 4 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 316. FEET.

SCS RUNOFF CURVE NUMBER	=	81.00	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	14.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.208	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.118	INCHES

LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.658	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	19.171	INCHES
TOTAL INITIAL WATER	=	19.171	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
ROSWELL NEW MEXICO

STATION LATITUDE	=	33.24	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	76	
END OF GROWING SEASON (JULIAN DATE)	=	310	
EVAPORATIVE ZONE DEPTH	=	14.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	8.70	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	49.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	40.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	53.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	52.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.42	0.47	0.49	0.69	1.14	1.43
1.99	1.90	1.87	1.13	0.57	0.53

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	44.10	51.30	59.80	68.30	76.80
79.30	77.90	71.00	60.10	48.00	40.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ROSWELL NEW MEXICO
AND STATION LATITUDE = 33.24 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.30	0.29	0.54	0.49	1.17	0.99
	2.39	1.68	1.79	0.90	1.44	0.97
STD. DEVIATIONS	0.34	0.07	0.47	0.39	1.10	1.20
	1.12	1.16	1.14	1.04	1.76	0.67
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
APOTRANSPIRATION						
TOTALS	0.438	0.303	0.412	0.280	1.097	0.882
	1.825	1.797	1.517	1.018	1.082	0.779
STD. DEVIATIONS	0.190	0.068	0.364	0.162	0.930	1.074
	0.881	1.256	0.771	0.663	0.810	0.425
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0900	0.0779	0.0593	0.0394	0.0317	0.0282
	0.0550	0.1046	0.1121	0.1128	0.2302	0.2378
STD. DEVIATIONS	0.0779	0.0721	0.0454	0.0298	0.0225	0.0211
	0.0613	0.0858	0.0789	0.0732	0.2175	0.2939
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0130	0.0113	0.0096	0.0070	0.0060	0.0053
	0.0086	0.0144	0.0156	0.0159	0.0253	0.0268

STD. DEVIATIONS	0.0099	0.0093	0.0068	0.0048	0.0040	0.0036
	0.0082	0.0109	0.0101	0.0087	0.0188	0.0253

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	0.0143	0.0113	0.0103	0.0075	0.0063	0.0050
	0.0081	0.0128	0.0159	0.0151	0.0214	0.0300
STD. DEVIATIONS	0.0124	0.0091	0.0074	0.0052	0.0042	0.0033
	0.0066	0.0097	0.0103	0.0085	0.0156	0.0300

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0536	0.0521	0.0359	0.0246	0.0191	0.0176
	0.0332	0.0632	0.0700	0.0682	0.1437	0.1437
STD. DEVIATIONS	0.0456	0.0482	0.0275	0.0186	0.0136	0.0132
	0.0370	0.0519	0.0493	0.0442	0.1358	0.1776

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0085	0.0076	0.0062	0.0047	0.0038	0.0031
	0.0049	0.0077	0.0099	0.0091	0.0134	0.0181
STD. DEVIATIONS	0.0073	0.0061	0.0045	0.0032	0.0025	0.0020
	0.0040	0.0059	0.0064	0.0051	0.0097	0.0181

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES	CU. FEET	PERCENT

PRECIPITATION	12.95	(2.076)	47023.0	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	11.431	(1.9467)	41494.45	88.243
LATERAL DRAINAGE COLLECTED FROM LAYER 2	1.17907	(0.81329)	4280.021	9.10197
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.15882	(0.09008)	576.507	1.22601
AVERAGE HEAD ON TOP OF LAYER 3	0.060	(0.042)		
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.15824	(0.08907)	574.397	1.22152
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00001	(0.00001)	0.042	0.00009
AVERAGE HEAD ON TOP OF LAYER 5	0.008	(0.005)		
CHANGE IN WATER STORAGE	0.186	(0.4322)	674.12	1.434

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
*PRECIPITATION	1.40	5082.000
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 2	0.05930	215.27205
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.004617	16.76041
AVERAGE HEAD ON TOP OF LAYER 3	1.111	
MAXIMUM HEAD ON TOP OF LAYER 3	2.196	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 4	0.00353	12.80457
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00068
AVERAGE HEAD ON TOP OF LAYER 5	0.066	
MAXIMUM HEAD ON TOP OF LAYER 5	0.189	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	1.36	4944.3652

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.2317

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0470

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	2.9768	0.1240
2	0.5601	0.0467
3	0.0000	0.0000
4	0.5428	0.0452
5	0.0000	0.0000
6	16.0200	0.4450
SNOW WATER	0.000	

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APPENDIX C

NEW MEXICO ENVIRONMENTAL DEPARTMENT
DRAFT GUIDANCE DOCUMENT FOR PERFORMANCE DEMONSTRATION

DRAFT

Guidance Document

for

Performance Demonstration for an Alternative Cover Design Using the HELP Modeling Program Under the New Mexico Solid Waste Management Regulations (20 NMAC 9.1)

and

Performance Demonstration for an Alternative Liner Design Using the HELP Modeling Program Under the New Mexico Solid Waste Management Regulations (20 NMAC 9.1)

Prepared by the
New Mexico Environment Department
Solid Waste Bureau
Permit Section

DRAFT

Performance Demonstration for an Alternative Cover Design Using the HELP Modeling Program Under the New Mexico Solid Waste Management Regulations (20 NMAC 9.1)

1. Existing Solid Waste Landfills without a Liner System:

A prescriptive landfill cover system must in accordance with Section 502.A.1 consist of an infiltration layer comprised of a minimum of 18 inches of earthen material with the required hydraulic conductivity (K) and a minimum of 6 inches of soil that is capable of sustaining native plant growth as an erosion layer (Figure 1). The cover component of 18 inches of earthen material must be equivalent to the least hydraulically conductive natural subsoils or a saturated hydraulic conductivity of no greater than 1×10^{-5} cm/sec. For example, if the hydraulic conductivity of the natural subsoils is 1×10^{-6} cm/sec, then the K of the infiltration layer material must be equivalent to these soils. If the hydraulic conductivity of the natural subsoils is greater than 1×10^{-5} cm/sec (e.g., 1×10^{-4} cm/sec), the K of the infiltration layer material must equate to the 1×10^{-5} cm/sec requirement.

If the infiltration layer meets the minimum hydraulic conductivity of 1×10^{-5} cm/sec or that of the natural subsoils and the minimum 18 inch condition then a HELP Model simulation is not required. If an alternative cover design is proposed, it must achieve an equivalent reduction in infiltration as the infiltration layer specified in Section 502.A.1.a. Therefore, a HELP Model simulation is required to demonstrate that the design of such a cover provides equivalent reduction in infiltration as the prescriptive cover design. If the natural subsoils have a hydraulic conductivity of less than 1×10^{-5} cm/sec (e.g., 1×10^{-6} cm/sec), then the cover must achieve equivalent reduction in infiltration as that of the prescriptive cover but with an 18 inch infiltration layer with a hydraulic conductivity of 1×10^{-6} cm/sec.

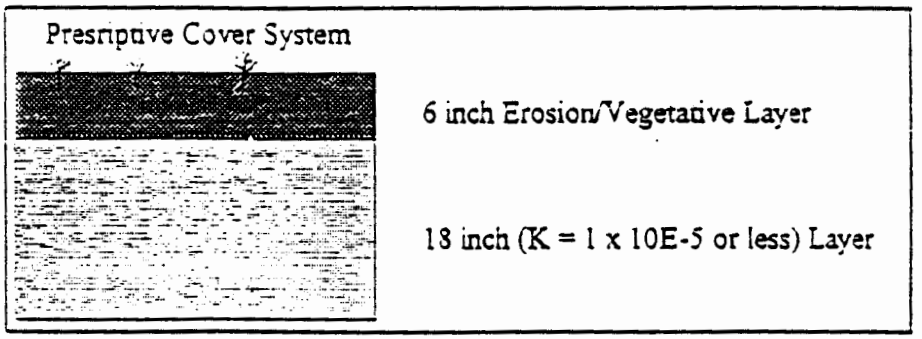

Figure 1. Prescriptive Cover System

A demonstration of equivalent reduction in infiltration is determined by using the EPA HELP Model. The HELP Model simulations need to compare the prescriptive cover and the alternative cover design (Figure 2). The simulation for the prescriptive cover must include the erosion, infiltration and intermediate layers. The alternative cover design simulation includes the

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intermediate and alternative cover layers. The two designs are to be simulated for years 1 through 5 with vegetation during the post-closure care period to demonstrate equivalency. Precipitation, evapotranspiration, temperature, and solar radiation data must be site specific and identical for both alternative and prescriptive cover designs simulations. Provide justification for all input parameters in the model utilizing the attached forms. Demonstrate the relationship of the characteristics of on-site or other sources of soil proposed for the construction of cover or liner and the parameter values in the model. It is anticipated that the entire area of the landfill or cell will be modelled.

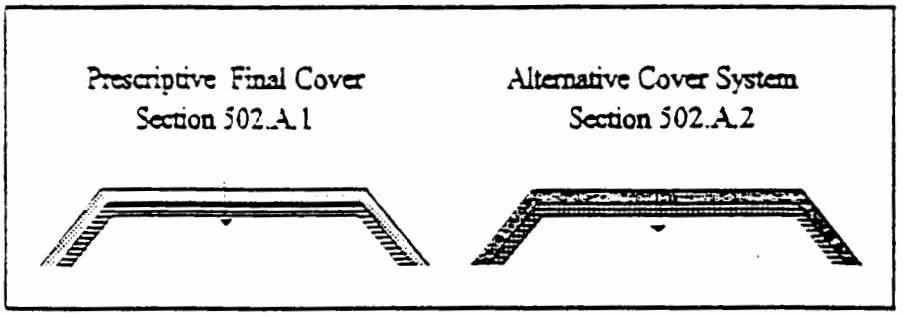

Figure 2.

For example, comparing the prescriptive cover of:

1) 6 inches of topsoil
2) 18 inches of compacted soil ($K = 5 \times 10^{-6}$; to meet natural subsoils $K = 5 \times 10^{-6}$)

with a proposed alternative cover system of:

1) 6 inches of topsoils
2) 30 inches of compacted ($K = 1 \times 10^{-5}$)
3) 12 inches of uncompacted intermediate cover

2. New Solid Waste Landfills:

As in the above case, the cover for the proposed landfill with a the prescriptive or alternative liner must achieve the equivalent protection as the liner. If an alternative final cover is proposed for the landfill, then a demonstration must be submitted to the Bureau for approval pursuant to Section 502.A.2.a. It must be determined by this demonstration that the proposed final cover design includes an infiltration layer that achieves an equivalent reduction in infiltration as the bottom liner (Figure 3). A HELP Model simulation comparison is acceptable for this demonstration for a 5 year period with vegetation. Precipitation, evapotranspiration, temperature, and solar radiation data must be site specific and identical for both liner and cover design simulations. Provide justification for all input parameters in the model utilizing the attached forms. Demonstrate the relationship of the characteristics of on-site or other sources of soil proposed for the construction of cover or liner and the parameter values in the model. It is anticipated that the entire area of the landfill or cell will be modelled.

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For example, the comparison must include a HELP Model simulation for the liner and the proposed final cover systems as below.

The simulation for an alternative liner system* could include:

1) the drainage/protective layer of the liner with leachate collection system,
2) the 60-mil HDPE FML,
3) the 0.2 inch ($K = 2 \times 10^{-9}$) GCL (geosynthetic clay liner),
4) ~~the~~ 6 inches of compacted in situ soil used as the prepared subgrade, and
5) with the solid waste cell open and no runoff.

*Any alternative liner system must meet the demonstration as described in the "Performance Demonstration For An Alternative Liner Design Using The HELP Modeling Program Under the New Mexico Solid Waste Management Regulations (20 NMAC 9.1)."

A liner system is compared with a HELP Model simulation for a proposed final cover:

1) 18 inches uncompacted material (6 inches of topsoil with poor grass and 12 inches of uncompacted soil),
2) the 0.2 inch GCL ($K = 2 \times 10^{-9}$),
3) 12 inches of intermediate cover (6 inches of compacted soil and 6 inches of uncompacted soil), and
4) with the solid waste cell closed and final placement of the cover to include runoff.

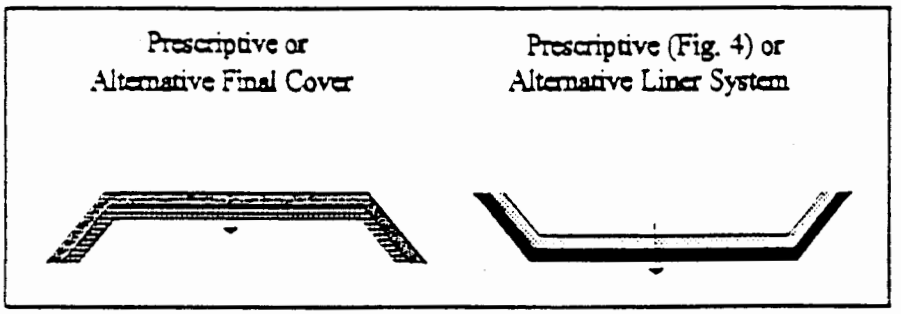

Figure 3.

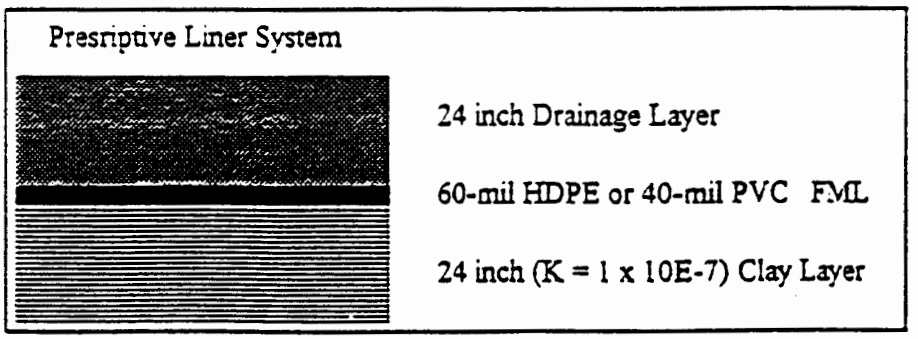

Figure 4.

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Performance Demonstration for an Alternative Liner Design Using the HELP Modeling Program Under the New Mexico Solid Waste Management Regulations (20 NMAC 9.1)

1. Section 306.A.2 of the regulations requires the design of the alternative liner must provide equivalent protection as the composite liner defined in Section 306.A.1. Two computer modeling analyses must be performed - an analysis of the composite liner specified in Section 306.A.1 and an analysis of the proposed alternative liner as specified in Section 306.A.2. Equivalent protection must be demonstrated through a comparison of the performance of the Section 306.A.2 alternative liner with the performance of Section 306.A.1 composite liner (Figure 5).

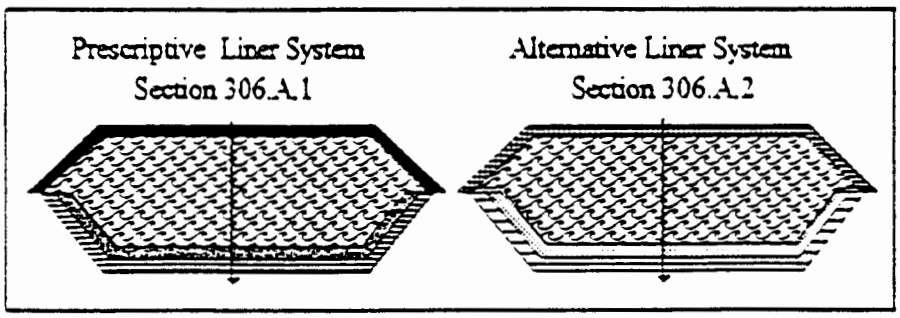

Figure 5.

2. Provide justification for all input parameters in the model utilizing the attached forms. Demonstrate the relationship of the characteristics of on-site or other sources of soil proposed for the construction and operation of the landfill and the parameter values used in the model. Show justification for the soil and waste moisture content parameters as well as geomembrane liner data and storm water runoff fraction.

3. Simulate actual design conditions and operational development of the landfill as closely as possible by doing a succession of model simulations. This succession must attempt to simulate moisture conditions in the landfill as closely as possible. To aid in accomplishing this, each successive computer simulation must use the previous simulation's moisture content output as the input for the following simulation. Describe the design approach modelled.

3.1 Initial simulation of the open landfill at start-up when landfill has little to no waste. The time period should extend for the anticipated duration of this condition, a minimum of one year and a probable maximum of five years.

3.2 A succeeding simulation to model conditions of the partially full landfill for some anticipated time period, most probably five years. This would incorporate daily cover and intermediate cover.

3.3. Perform subsequent computer simulations to model the landfill in the closed

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condition for the duration of the entire post-closure care period.

3.3.1 Model bare ground for the time period expected until vegetation becomes established.

3.3.2 Model the vegetated condition for the remainder of the post-closure care period.

4. Compliance with the regulatory requirement of not exceeding a 12 inch hydraulic head on the bottom liner must be demonstrated. Consequently, the area modeled must incorporated, at a minimum, one leachate collection "watershed" in order to simulate the leachate drainage distance. It is anticipated that the entire area of the landfill or cell will be modelled.

5. If there is no infiltration through the alternative liner system for the simulation(s), then these HELP Model simulation(s) will serve to demonstrate the concentration values listed in Section 1110 (Appendix K, EIB/SWMR-4) will not be exceeded in the uppermost aquifer or the relative point of compliance.

ATTACHMENT 1 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS11/23/94 sheet no. 1

rev.1 1/22/96

INPUT PARAMETER	VALUE	JUSTIFICATION
CLIMATOLOGICAL DATA		
city		
precipitation & source of data (default or synthetic)		
temperature & source of data		
latitude		
maximum leaf area index		
evaporative zone depth		
growing season start and end day		
LANDFILL COVER DATA		
type of vegetative cover		
SCS runoff curve number		
active (uncovered)?		
% of surface runoff that drains from landfill		
surface area		
SOIL AND DESIGN DATA		
source of soil charactersitics		
number of layers		

NOTES:

ATTA .iMENT 1 LANDFILL ALTERNATIVE LINER OR COVER DESIGN MODELING INPUT PARAMETERS 11/23/94 sheet no. 2

rev. 1 1/22/96

INPUT PARAMETER	VALUE	JUSTIFICATION
LAYER NUMBER:		
layer type		
thickness		
soil texture		
porosity		
field capacity		
wilting point		
moisture content		
saturated hydraulic conductivity		
Is layer compacted?		
slope (if lateral drainage layer)		
maximum horizontal drainage distance (if lateral drainage layer)		
geomembrane pinhole density		
geomembrane installation defects		
liner installation quality (if geomembrane)		
geotextile transmissivity		

(make additional copies for each layer as required)

E-29

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: TRIASSIC PARK HAZARDOUS WASTE FACILITY

Project No. 602-0200

Calculation Title: PERIMETER ROAD DESIGN EVALUATION

	Name	Date
Prepared By:	J. KENDALL	9-DEC-97
Checked By:	J. Pellicer	10-Dec-97
Reviewed By:	R. Gatzke	10-Dec-97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: TRIASSIC PARK HW FACILITY ROAD DESIGN
Project Number: 602-0200 Sheet: 1 Of 10
Prepared By: JJK Date: 12/9/97
Checked By: J. Pelliccer Date: 10-Dec-97

OBJECTIVE: EVALUATE PROPOSED PERIMETER ROAD DESIGN FOR OFF HIGHWAY EQUIPMENT LOADING

METHOD: USE CBR CURVES FOR OFF HIGHWAY VEHICLES TO EVALUATE ROAD SUBBASE AND GRAVEL ROAD BASE THICKNESSES

REFERENCES: (1) CHIRONIS, NICHOLAS P., "HOW TO BUILD BETTER HAUL ROADS", COAL AGE, JANUARY 1978, PP 122-124.

(2) TERRAMATRIX/MONTGOMERY WATSON, "ENGINEERING REPORT - TRIASSIC PARK HAZARDOUS WASTE FACILITY" DECEMBER 1997.

a) DESIGN DRAWING NO. 27, PERIMETER ROAD DETAILS
b) DESIGN DRAWING NO. 5, INITIAL SITE GRADING PLAN
c) SPECIFICATION NO 02230, SUBBASE
d) APPENDIX D LABORATORY TEST RESULTS

(3) CATERPILLAR HAND BOOK
(4) HOLTZ, RD, "GEOTECHNICAL ENGINEERING", 1981, PP 156

ASSUMPTIONS: (1) FILL AREAS WILL BE COMPACTED TO 95% ACCORDING TO SPECIFICATION NO (2c). THIS WILL PROVIDE A SUB GRADE BEARING CAPACITY OF CONSERVATIVELY 3,000 TO 5,000 PSF. (2b)

(2) CUT AREAS WILL GENERALLY REMOVE SOFT WIND BLOWN SURFICIAL SANDS AND WILL LIKELY BOTTOM OUT IN THE CALICHE LAYER, THE UPPER DOCKUM CLAY, OR HARDENED SANDS BENEATH THE SURFICIAL SANDS. (2b, 2d). BASED ON POCKET PENETROMETER DATA TAKEN DURING THE TEST PITTING INVESTIGATION (2d), THESE AREAS WILL PROVIDE A SUBGRADE BEARING CAPACITY OF CONSERVATIVELY 3,000 TO 5,000 PSF.

(3) ASSUME OFF HIGHWAY TRUCK IS A CAT 769 C WITH GROSS VEHICLE WEIGHT LOADED OF 130,000 lb AND 67% REAR WEIGHT DISTRIBUTION (3)

(4) SUBGRADE BEARING CAPACITIES BETWEEN 3,000 PSF AND 5,000 PSF GENERALLY CORRESPOND TO FIRM OR STIFF CLAY AND COMPACT SAND-CLAY MATERIALS, RESPECTIVELY IN TABLE 1 (REF 1). COMPARING THIS TO FIGURE 1 (REF 1) INDICATES A CBR VALUE OF BETWEEN 6 AND 10 FOR THE SUBGRADE. ASSUME AVG VALUE OF 8.

(5) ASSUME COMPACTION OF SUBBASE WILL ACHIEVE CBR = 20 TO 40.

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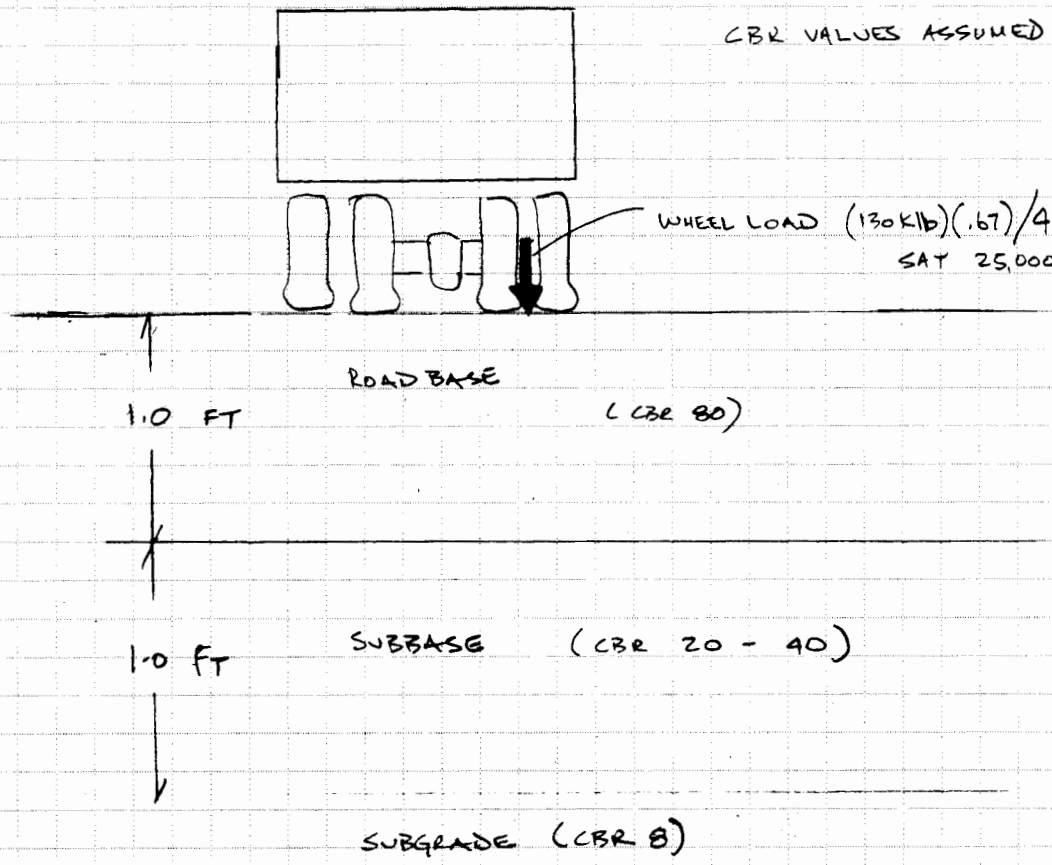
Project Name: TRIASSIC PARK HW FACILITY ROAD DESIGN
Project Number: 602-0200 Sheet: 2 Of 10
Prepared By: JJK Date: 12/9/97
Checked By: J. Pellicer Date: 10-Dec-97

CALCULATION

TYPICAL OFF HIGHWAY TRUCK: CAT 769C
GROSS VEHICLE WT (LOADED): 130,000
WT DISTRIBUTION: 67% REAR AXLE

(1) DETERMINE WHEEL LOAD AND SKETCH ROAD SECTION

CBR VALUES ASSUMED



(2) DETERMINE TOTAL SUBBASE AND ROADBASE THICKNESS REQ'D

FROM FIG 1, REQ'D SUBBASE THICKNESS IS 18 INCHES FOR SUBGRADE CBR=8.

FROM DESIGN, TOTAL SUBBASE AND ROAD BASE THICKNESS IS 29 INCHES
∴ OK

(3) DETERMINE TOTAL ROADBASE THICKNESS REQ'D

FROM FIG 1, REQ'D ROADBASE THICKNESS IS 10 INCHES FOR SUBBASE CBR = 20
FROM DESIGN, TOTAL ROADBASE THICKNESS IS 12 INCHES, ∴ OK

CONCLUSION:

(1) ROADBASE AND SUBBASE THICKNESSES WILL SUPPORT OFF HIGHWAY EQUIPMENT. ACTUAL ROADBASE THICKNESS REQUIRED WILL LIKELY BE LESS BASED ON ACTUAL SUBGRADE CONDITIONS DETERMINED DURING CONSTRUCTION. EVALUATE ROADBASE THICKNESSES LESS THAN 1 FT DURING CONSTRUCTION AND MODIFY DESIGN ACCORDINGLY.

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How to Build Better Haul Roads

Making sure the haul road is going to hold up under traffic planned for it means considering a variety of construction parameters, including subbase and surface materials, thicknesses, road-adhesion characteristics and hauling widths.

Nicholas P. Chironis, senior editor

Surface mine operators often avoid placing subbase materials under the haul-road surface in the interest of economy. They may believe it is less costly to permit some haul segments that hamper the flow of traffic rather than incur the cost of constructing a good road base. The eventual results, however, often lead to more costly operation.

If the sub-standard road is not constantly maintained, rutting, sinking and overall deterioration usually occurs, and vehicles must slow down considerably to negotiate these conditions. Over a period of time such slow-downs represent a considerable time loss to the production cycle, and can result in the need for additional vehicles and operators.

Need for good subbase

At some mine sites, the road surface is underlain by natural strata capable of supporting the weight of any haulage vehicle. For example, in the case of bedded stone formations, it is only necessary to place the desired road surface material directly on the bedded stone to have a good road. But frequently such base materials are not naturally available and the engineer building the road must look to the possibility of using other materials. The bearing capacity of potential subbase materials has been analyzed as part of a research study for the U.S. Bureau of Mines. The result is a table giving the bearing capacities of rock and other subsurface materials in terms of vehicle tire loads (Table 1).

To use this table, keep in mind that tire loading for most haulage vehicles, when inflated to recommended pressure, will rarely exceed 16,000 psi. Although the tire loading may be somewhat less depending on the number of tires and their size, this figure can be used with some confidence to determine subbase requirements. By checking the loading of 16,000 psi in the table it can be seen that any subgrade less consolidated than soft rock calls for additional material to establish a stable base. The question then is: How much additional material should be placed over the subgrade to adequately support the road surface?

CBR curves

The study engineers found that one of the best methods of making this road-thickness determination is through use of California bearing-ratio (CBR) curves, Fig. 1. In order to be completely accurate, the road designer should obtain CBR values from actual tests on both the subgrade and subbase materials the designer plans to use. These tests can be conducted by submitting the samples to a soils testing laboratory, a relatively minimal cost.

The CBR curves provide the subbase-thickness requirements for a wide range of wheel loads, soils and subbase materials. It must be emphasized, however, that the ranges in the CBR curves are not well defined. Actual test results, for example, may prove the bearing ratios for a specific soil group to be considerably better than the low value depicted on the chart. The CBR ranges reflected by the graph, therefore, should be used in lieu of actual test results when only general information is desired. In such cases, pick the lowest possible CBR value for a given soil type.

Table 1. Bearing Capacity of Soils

Material	Capacity in 1,000 lb per sq ft
Hard Sound Rock	120
Medium Hard Rock	80
Hard Pan Overlying Rock	24
Compact Gravel and Boulder-Gravel Formations; Very Compact Sandy Gravel	20
Soft Rock	16
Loose Gravel and Sandy Gravel; Compact Sand and Gravelly Sand; Very Compact Sand—Inorganic Silt Soils	12
Hard Dry Consolidated Clay	10
Loose Coarse to Medium Sand; Medium Compact Fine Sand	8
Compact Sand-Clay Soils	6
Loose Fine Sand; Medium Compact Sand—Inorganic Silt Soils	4
Firm or Stiff Clay	3
Loose Saturated Sand Clay Soils, Medium Soft Clay	2

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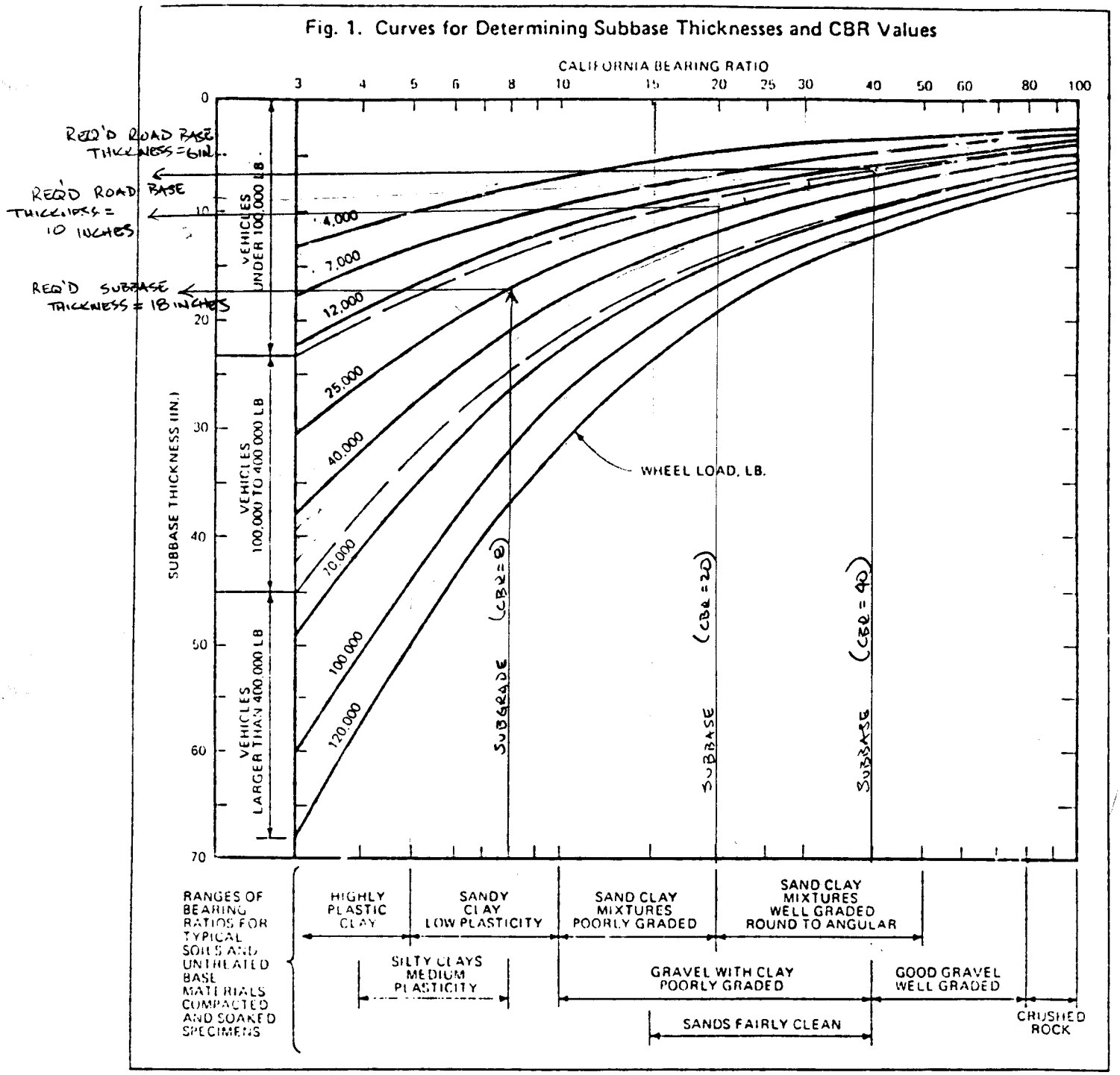
Fig. 1. Curves for Determining Subbase Thicknesses and CBR Values



As shown by the curves, final subbase thicknesses are influenced by vehicle wheel loads as well as soil type. Maximum wheel loadings for any haulage vehicle are easily computed from manufacturers specifications by dividing the loaded vehicle weight over each axle by the number of tires on that axle. In every case, use the highest wheel loading calculated for the subbase thickness determinations. In fact, when a wheel is mounted on a tandem axle, increase the value by 20%.

To provide a readily available indication of wheel loading characteristics of currently manufactured vehicles, the chart is divided into three categories. Each category represents the range of wheel loadings under fully loaded conditions that may be anticipated for vehicles in the given weight class.

Sample design problem

Here is how to compute subbase requirements, once the

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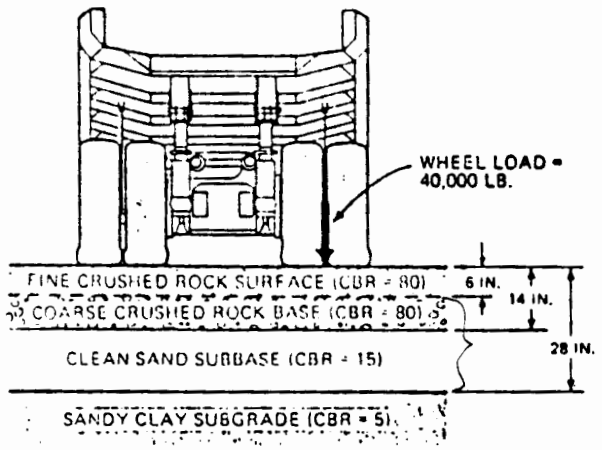
Fig. 2. Thicknesses of Subbase Materials



wheel loading and CBR values have been established. Let us assume the following conditions:

The haulroad is to be constructed over a silty clay of medium plasticity with a CBR of 5. The maximum wheel load for any vehicle using the road is 40,000 lb. Fairly clean sand is available with a CBR of 15 to serve as subbase material. Road surface is to be constructed of good gravel that has a CBR of 80. (If any of these actual CBR values are not known, pick off the CBR values from the chart, and then continue with these steps.)

- Step A. The 40,000-lb, wheel-load curve intersects the vertical line for a CBR of 5 at 28 in. This means that the final road surface must be at least this distance above the subgrade (Fig. 2).
- Step B. The value for a clean sand with a CBR of 15 intersects the 40,000-lb curve at 14 in. below road surface.
- Step C. The intersection of the 80-CBR line for gravel with the curve for the 40,000-lb wheel load occurs at 6 in. Because this thickness constitutes the final surface material, it should be placed at the upper 6-in. portion of the road.

For best results, subbase materials should exceed the final desired surface width by at least 2 ft and must be compacted while moist. Each 8-in. layer should be subjected to repeated passes.

Compaction is usually done best with heavy rollers. But as few surface-mine operators have rollers in their vehicle fleet, an alternative such as heavy-tracked equipment may be employed.

Surface materials

Skelly and Loy engineers conducting the Bureau study visited over 300 mining operations throughout the country to obtain practical information on haul-road construction. They report that at many of these mine sites, especially at small coal mining and quarry operations, the haulway was simply built by clearing a path over the existing terrain.

While this practice is undoubtedly inexpensive, the engineers find that the benefits were seldom long-lived. Because it is difficult to construct a bedded rock surface free of jagged edges, greater vehicle maintenance is required as a result of excessive tire scuffing and wear. Furthermore, unless thoroughly compacted and stabilized, such earth roads cause dust problems, especially during dry seasons. If it is not controlled, the dust contaminates air-filtration components, brakes, and moving parts, making frequent replacement of these items necessary.

Dust also represents a major safety hazard to the vehicle operator by reducing visibility. Eliminating the dust problem requires continual wetting of the surface, which represents yet another maintenance expenditure. When

Table 2. Road Adhesion Coefficients of Rubber Tired Vehicles

Road Surface	Road Adhesion Coefficients	Road Surface	Road Adhesion Coefficients
Concrete		**Rock**	
New	0.80 to 1.00	Crushed	0.55 to 0.75
Traveled	0.60 to 0.80	Wet	0.55 to 0.75
Polished	0.55 to 0.75		
Wet	0.45 to 0.80	**Cinders**	
		Packed	0.50 to 0.70
Asphalt		Wet	0.65 to 0.75
New	0.80 to 1.00		
Traveled	0.60 to 0.80	**Snow**	
Polished	0.55 to 0.75	Packed	0.30 to 0.55
Excess Tar	0.50 to 0.60	Loose	0.10 to 0.25
Wet	0.30 to 0.80	Wet	0.30 to 0.60
Gravel		**Ice**	
Packed & Oiled	0.55 to 0.85	Smooth	0.10 to 0.25
Loose	0.40 to 0.70	Wet	0.05 to 0.10
Wet	0.40 to 0.80		

TABLE 5-4 Continued

Major Divisions (1)	(2)	Symbol: Letter (3)	Hatching (4)	Color (5)	Drainage Characteristics (12)	Compaction Equipment (13)	Unit Dry Densities: lbf/ft³ (14)	Mg/m³ (15)	Typical Design Values: CBR (16)	Subgrade Modulus k (lbf/in.³) (17)
COARSE-GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW		Red	Excellent	Crawler-type tractor, rubber-tired roller, steel-wheeled roller	125-140	2.00-2.24	40-80	300-500
		GP		Red	Excellent	Crawler-type tractor, rubber-tired roller, steel-wheeled roller	110-140	1.76-2.24	30-60	300-500
		GM d		Yellow	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	125-145	2.00-2.32	40-60	300-500
		GM u		Yellow	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	115-135	1.84-2.16	20-30	200-500
		GC		Yellow	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	130-145	2.08-2.32	20-40	200-500
	SAND AND SANDY SOILS	SW		Red	Excellent	Crawler-type tractor, rubber-tired roller	110-130	1.76-2.08	20-40	200-400
		SP		Red	Excellent	Crawler-type tractor, rubber-tired roller	105-135	1.68-2.16	10-40	150-400
		SM d		Yellow	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	120-135	1.92-2.16	15-40	150-400
		SM u		Yellow	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	100-130	1.60-2.08	10-20	100-300
		SC		Yellow	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	100-135	1.60-2.16	5-20	100-300
FINE-GRAINED SOILS	SILTS AND CLAYS LL IS LESS THAN 50	ML		Green	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	90-130	1.44-2.08	15 or less	100-200
		CL		Green	Practically impervious	Rubber-tired roller, sheepsfoot roller	90-130	1.44-2.08	15 or less	50-150
		OL		Green	Poor	Rubber-tired roller, sheepsfoot roller	90-105	1.44-1.68	5 or less	50-100
	SILTS AND CLAYS LL IS GREATER THAN 50	MH		Blue	Fair to poor	Sheepsfoot roller, rubber-tired roller	80-105	1.28-1.68	10 or less	50-100
		CH		Blue	Practically impervious	Sheepsfoot roller, rubber-tired roller	90-115	1.44-1.84	15 or less	50-150
		OH		Blue	Practically impervious	Sheepsfoot roller, rubber-tired roller	80-110	1.28-1.76	5 or less	25-100
HIGHLY ORGANIC SOILS		Pt		Orange	Fair to poor	Compaction not practical				

SUBBASE CBR RANGES 20 - 40

HOLTZ, R.D. "GEOTECHNICAL ENGINEERING", 1981.

602 JTK 9-Dec-97 6/10

602
JJK
9-Dec-97 7/10

SECTION 02230
SUBBASE

PART 1: GENERAL

1.01 SCOPE OF WORK

A. The Contractor shall furnish all labor, materials, tools, equipment, supervision, transportation, testing, and installation services necessary for the installation of subbase where shown on the Construction Drawings. The work shall be carried out in accordance with these General Specifications, the CQA Plan, and the Construction Drawings.

1.02 RELATED SECTIONS

A. Section 02110 - Site Preparation and Earthwork
B. Section 02225 - Road Base

1.03 QUALIFICATIONS AND SUBMITTALS

A. The Contractor shall abide by all qualification and submittal requirements of the CQA Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Work will be monitored and tested in accordance with the requirements of the CQA Plan.

B. The Contractor shall be aware of all activities outlined in the CQA Plan, and the Contractor shall account for these activities in the construction schedule. No additional costs to the Owner shall be allowed by the Contractor as a result of the performance of the CQA activities.

C. On-site testing as specified in the CQA Plan for the subbase (which does not include quality control testing at the source) will be the responsibility of the CQA Engineer. The Contractor shall cooperate with the CQA Engineer during all sampling and testing activities. The Contractor shall provide equipment and labor to assist the CQA Engineer in sampling. The Contractor shall provide access to all areas requiring testing. The Contractor will repair any damage to finished work caused by the CQA Engineer's sampling and testing activities.

D. Quality control testing of the subbase at the source shall be the responsibility of the Contractor.

602
JJK
9-Dec-97

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3.05 SURVEY CONTROL

A. The Surveyor shall survey the final location and elevation of the top of the road base. Surveying shall be performed in accordance with of Section 01010 of these General Specifications.

B. The Surveyor shall provide a Record Drawing to the Owner of the final location and elevation of the final surface of the road base, in accordance with the requirements of Section 01010 of these General Specifications.

[END OF SECTION]

E-30

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Vertical Riser Bearing Capacity

	Name	Date
Prepared By:	J. Pellicer	13-Nov-97
Checked By:	P. Corser	14-Nov-97
Reviewed By:		
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602 Sheet: 1 Of 6
Prepared By: J. Pellicer Date: 13-Nov-97
Checked By: RL Date: 14 Nov 97

Vertical Riser Bearing Capacity

OBJECTIVE: Determine bearing capacity safety factor of vertical riser pipe.

METHOD: Treat the vertical riser pipe as a pile. Assume waste settlement will cause downdrag forces on the pipe. Use Vesic's Method outlined in Principles of Foundation Engineering.

ASSUMPTIONS: Waste $\phi = 29°$

Waste $\gamma = 110$ pcf

Riser Pipe Diameter = 24 in

Wrap 2 layers of HDPE around the perimeter of the riser pipe.

HDPE/HDPE $\delta = 10°$

Maximum Depth of Waste = 140 ft.

Downdrag: Pipe Area $= \pi d h = (\pi)(2\,ft)(140\,ft) = 879\,ft^2$

Avg. Pressure $= \left(0 + \frac{140\,ft}{2}\right)(110\,pcf)(1 - \sin 29)$

$= 3{,}967$ psf

Downdrag Load $= (879\,ft^2)(3{,}967\,psf)(\tan 10)$

$= 614{,}850$ lb

Weight of Pipe $= (140\,ft)(171\,lb/ft) = 23{,}940$ lbs

Weight of Soil on Pad $= (140\,ft)(110\,pcf)\left((60\,ft)^2 - \frac{\pi (2)^2}{4}\right)$

$= 506{,}044$ lb

Weight of Concrete $= \left((6\,ft)^2 - \pi \frac{(2\,ft)^2}{4}\right)(1.5\,ft)(150\,pcf) = 7{,}393$ lb (pg 3 of 4)

Total Weight = 1,152,227 lb

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602 Sheet: 2 Of 6
Prepared By: J. Pellicer Date: 13-Nov-97
Checked By: RCP Date: 14 Nov 97

Bearing Capacity = $A_p (cN_c + \sigma_o' N_\sigma)$

Strength of Bearing Soil = $c = 0$ psf ; $\phi = 30°$

$I_r = 100$ from pg 5

Use table of pg. 6 to obtain N_σ factor

$N_\sigma = 51.02$

$A_p = (6\,ft)^2 - \pi \frac{(2\,ft)^2}{4} = 32.9\ ft^2$

$\sigma_o' = (140\,ft)(110\,pcf) = 15{,}400\ psf$

$Q_p = (32.9\,ft^2)(\cancel{cN_c}^{\,0} + (51.02)(15{,}400\,psf))$

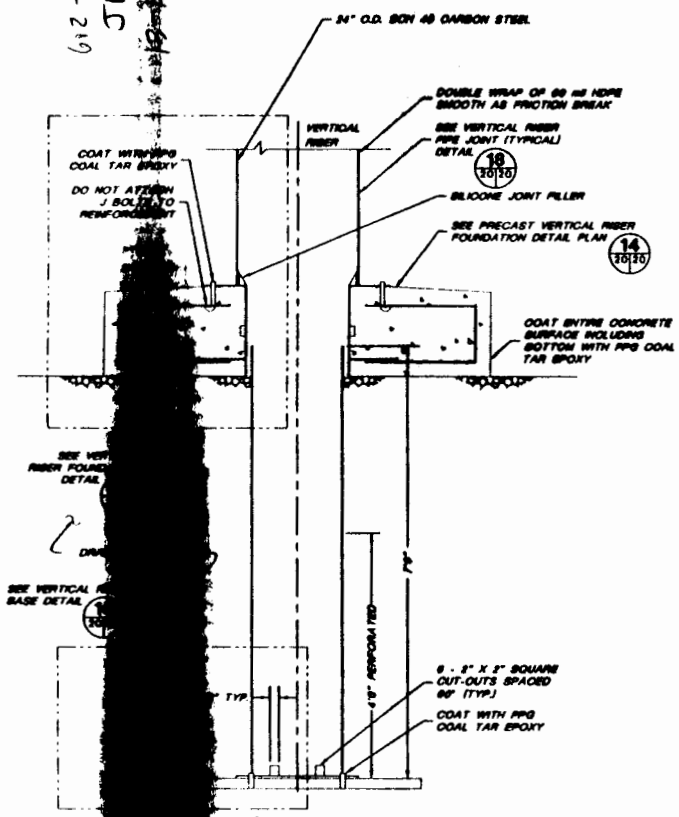
$= 25{,}849{,}793$ lbs

$SF = \frac{25{,}849{,}793\ lb}{1{,}152{,}227\ lb} = 22.4$ ok

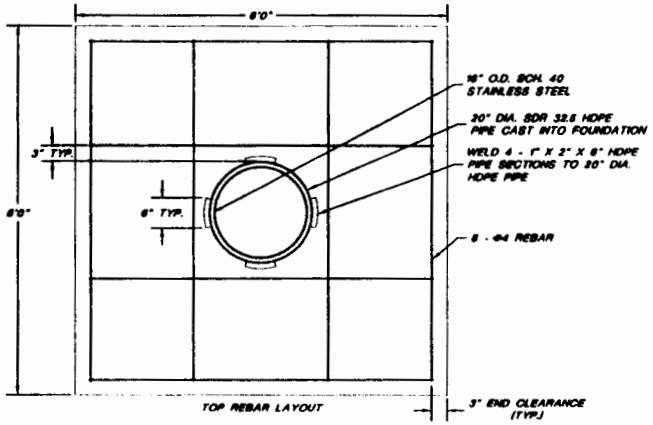
CONCLUSION: Bearing capacity of soil under vertical riser pipe is adequate.

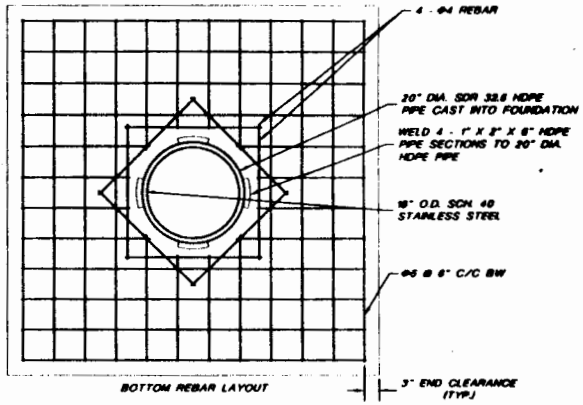
3/6

612-020
JPP

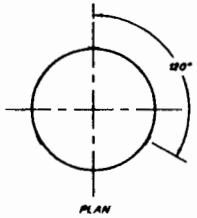


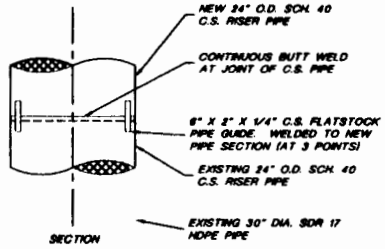
16/17/20 **SECTION**
Vertical Riser
SCALE 0 1' 2' Feet





?/20/20 **DETAIL PLAN**
Vertical Riser
Riser Foundation
SCALE 0 1' 2' Feet





18/20/20 **DETAIL**
Precast Vertical Pipe Joint (Typical)
SCALE 0 1' 2' Feet

PATRICK G. CARSER NEW MEXICO 12336 REGISTERED PROFESSIONAL ENGINEER

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Carser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Carser, NM P.E. 12336

NOTE: FOR GE[illegible] ED INFORMATION SEE DRAWING No. 2, "INDEX, [illegible] NOTES".

Not For Construction

REV No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND ISSUED BY
0	PART B PERMIT	11/1/91	JJP	EWS	PRC

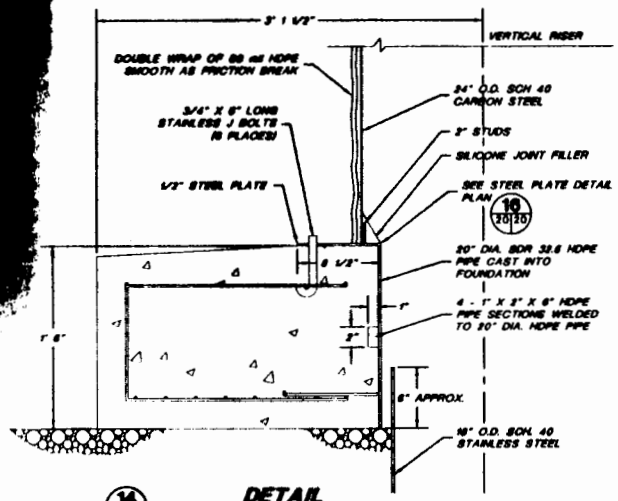
TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE
VERTICAL RISER DETAILS

TerraMatrix
MONTGOMERY WATSON
Mining Group

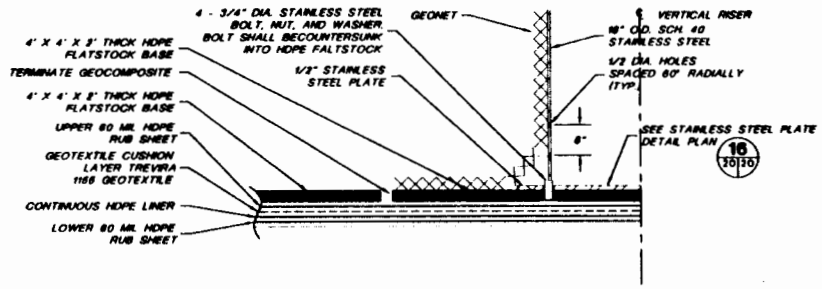
Sheet 1 Of 2 Sheets
SCALE As Noted
DRAWING No. 20

PROJECT NUMBER 02.[illegible]
AutoCAD FILE [illegible]



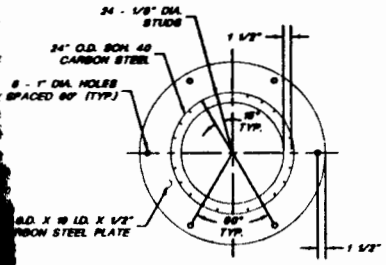
14 30|30 DETAIL
Vertical Riser Foundation

SCALE 0 0.5' 1' Feet



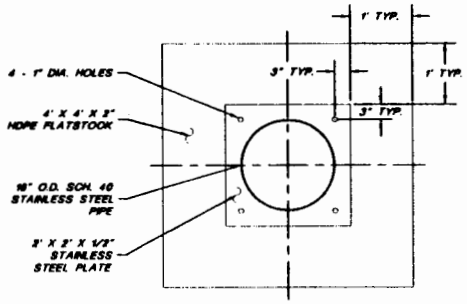
17 30|30 DETAIL
Vertical Riser Base

SCALE 0 0.5 1 Feet



15 30|30 DETAIL PLAN
Steel Plate

SCALE 0 1' 2' Feet



16 30|30 DETAIL PLAN
Stainless Steel Plate

SCALE 0 1' 2' Feet

NOTE:
FOR GEN[illegible] EGEND INFORMATION SEE DRAWING No. 2, "INDEX, LE[illegible] L NOTES".

PATRICK G. CORSER NEW MEXICO 12236 REGISTERED PROFESSIONAL ENGINEER

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Corser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Corser, NM P.E. 12236

Not For Construction

REV No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B REPORT	10/11/91	PGC/JRV/P	E Dawson	P Corser

TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE
VERTICAL RISER DETAILS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 2 Of 2 Sheets
SCALE As Noted
DRAWING No. 20

PROJECT NUMBER 192-8006
AutoCAD FILE 2-7_DRV_FLDR.DWG

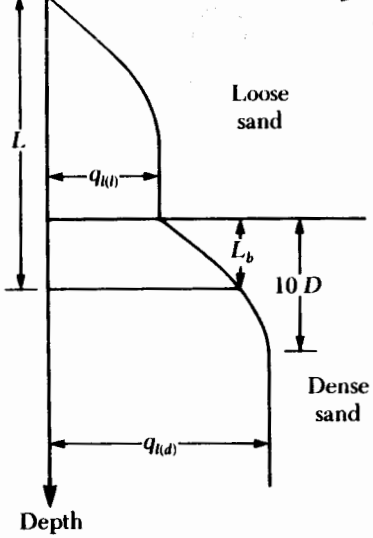


Figure 8.13 Variation of unit point resistance in layered soil

1. Obtain $(L_b/D)_{cr}$ for the given value of ϕ from Figure 8.12.
2. Calculate L_b/D.
3. If $L_b/D \geq (L_b/D)_{cr}/2$, take the maximum values of N_c^* and N_q^* from Figure 8.12.
4. If $L_b/D < (L_b/D)_{cr}/2$, then

$$N_c^* = N^*_{c(\text{at } L_b/D = 0)} + [N^*_{c(\max)} - N^*_{c(\text{at } L_b/D = 0)}] \left[\frac{\left(\frac{L_b}{D}\right)}{0.5\left(\frac{L_b}{D}\right)_{cr}}\right] \tag{8.17}$$

$$N_q^* = N^*_{q(\text{at } L_b/D = 0)} + [N^*_{q(\max)} - N^*_{q(\text{at } L_b/D = 0)}] \left[\frac{\left(\frac{L_b}{D}\right)}{0.5\left(\frac{L_b}{D}\right)_{cr}}\right] \tag{8.18}$$

Vesic's Method: Vesic (1977) proposed a method for estimating the pile point bearing capacity based on the theory of *expansion of cavities*. According to this theory, based on effective stress parameters,

$$Q_p = A_p q_p = A_p(cN_c^* + \sigma_o' N_\sigma^*) \tag{8.19}$$

where σ_o' = mean normal ground stress (effective) at the level of the pile point

$$= \left(\frac{1 + 2K_o}{3}\right) q' \tag{8.20}$$

N_c^*, N_σ^* = bearing capacity factors

Note that Eq. (8.19) is a modification of Eq. (8.11a) w

$$N_\sigma^* = \frac{3N_q^*}{(1 + 2K_o)} \tag{8.22}$$

The relation for N_c^* given in Eq. (8.19) can be expressed as

$$N_c^* = (N_q^* - 1) \cot \phi \tag{8.23}$$

According to the theory of Vesic

$$N_q^* = f(I_{rr}) \tag{8.24}$$

where I_{rr} = reduced rigidity index for the soil

However

$$I_{rr} = \frac{I_r}{1 + I_r \Delta} \tag{8.25}$$

where I_r = rigidity index $= \dfrac{E_s}{2(1 + \mu_s)(c + q' \tan \phi)} = \dfrac{G_s}{c + q' \tan \phi}$ (8.26)

E_s = Young's modulus of soil
μ_s = Poisson's ratio of soil
G_s = shear modulus of soil
Δ = average volumatic strain in the plastic zone below the pile point

For conditions of no volume change (that is, dense sand or saturated clay), $\Delta = 0$. So

$$I_r = I_{rr} \tag{8.27}$$

Table 8.8 gives the values of N_c^* and N_σ^* for various values of the soil friction angle (ϕ) and I_{rr}. For $\phi = 0$ (that is, undrained condition)

$$N_c^* = \frac{4}{3}(\ln I_{rr} + 1) + \frac{\pi}{2} + 1 \tag{8.28}$$

The values of I_r can be estimated from laboratory consolidation and triaxial tests corresponding to the proper stress levels. However, for preliminary use the following values are recommended:

Soil type	I_r
Sand	70–150
Silts and clays (drained condition)	50–100
Clays (undrained condition)	100–200

Ir value

Irrespective of the theoretical procedure adopted in calculating Q_p, it should be kept in mind that full value cannot be realized until the pile tip has

ϕ	I_{rr} 10	20	40	60	80	100	200	300	400	500
0	6.97	7.90	8.82	9.36	9.75	10.04	10.97	11.51	11.89	12.19
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1	7.34	8.37	9.42	10.04	10.49	10.83	11.92	12.57	13.03	13.39
	1.13	1.15	1.16	1.18	1.18	1.19	1.21	1.22	1.23	1.23
2	7.72	8.87	10.06	10.77	11.28	11.69	12.96	13.73	14.28	14.71
	1.27	1.31	1.35	1.38	1.39	1.41	1.45	1.48	1.50	1.51
3	8.12	9.40	10.74	11.55	12.14	12.61	14.10	15.00	15.66	16.18
	1.43	1.49	1.56	1.61	1.64	1.66	1.74	1.79	1.82	1.85
4	8.54	9.96	11.47	12.40	13.07	13.61	15.34	16.40	17.18	17.80
	1.60	1.70	1.80	1.87	1.91	1.95	2.07	2.15	2.20	2.24
5	8.99	10.56	12.25	13.30	14.07	14.69	16.69	17.94	18.86	19.59
	1.79	1.92	2.07	2.16	2.23	2.28	2.46	2.57	2.65	2.71
6	9.45	11.19	13.08	14.26	15.14	15.85	18.17	19.62	20.70	21.56
	1.99	2.18	2.37	2.50	2.59	2.67	2.91	3.06	3.18	3.27
7	9.94	11.85	13.96	15.30	16.30	17.10	19.77	12.46	22.71	23.73
	2.22	2.46	2.71	2.88	3.00	3.10	3.43	3.63	3.79	3.91
8	10.45	12.55	14.90	16.41	17.54	18.45	21.51	23.46	24.93	26.11
	2.47	2.76	3.09	3.31	3.46	3.59	4.02	4.30	4.50	4.67
9	10.99	13.29	15.91	17.59	18.87	19.90	23.39	25.64	27.35	28.73
	2.74	3.11	3.52	3.79	3.99	4.15	4.70	5.06	5.33	5.55
10	11.55	14.08	16.97	18.86	20.29	21.46	25.43	28.02	29.99	31.59
	3.04	3.48	3.99	4.32	4.58	4.78	5.48	5.94	6.29	6.57
11	12.14	14.90	18.10	20.20	21.81	23.13	27.64	30.61	32.87	34.73
	3.36	3.90	4.52	4.93	5.24	5.50	6.37	6.95	7.39	7.75
12	12.76	15.77	19.30	21.64	23.44	24.92	30.03	33.41	36.02	38.16
	3.71	4.35	5.10	5.60	5.98	6.30	7.38	8.10	8.66	9.11
13	13.41	16.69	20.57	23.17	25.18	26.84	32.60	36.46	39.44	41.89
	4.09	4.85	5.75	6.35	6.81	7.20	8.53	9.42	10.10	10.67
14	14.08	17.65	21.92	24.80	27.04	28.89	35.38	39.75	43.15	45.96
	4.51	5.40	6.47	7.18	7.74	8.20	9.82	10.91	11.76	12.46
15	14.79	18.66	23.35	26.53	29.02	31.08	38.37	43.32	47.18	50.39
	4.96	6.00	7.26	8.11	8.78	9.33	11.28	12.61	13.64	14.50
16	15.53	19.73	24.86	28.37	31.13	33.43	41.58	47.17	51.55	55.20
	5.45	6.66	8.13	9.14	9.93	10.58	12.92	14.53	15.78	16.83
17	16.30	20.85	26.46	30.33	33.37	35.92	45.04	51.32	56.27	60.42
	5.98	7.37	9.09	10.27	11.20	11.98	14.77	16.69	18.20	19.47
18	17.11	22.03	28.15	32.40	35.76	38.59	48.74	55.80	61.38	66.07
	6.56	8.16	10.15	11.53	12.62	13.54	16.84	19.13	20.94	22.47
19	17.95	23.26	29.93	34.59	38.30	41.42	52.71	60.61	66.89	72.18
	7.18	9.01	11.31	12.91	14.19	15.26	19.15	21.87	24.03	25.85
20	18.83	24.56	31.81	36.92	40.99	44.43	56.97	65.79	72.82	78.78
	7.85	9.94	12.58	14.44	15.92	17.17	21.73	24.94	27.51	29.67
21	19.75	25.92	33.80	39.38	43.85	47.64	61.51	71.34	79.22	85.90
	8.58	10.95	13.97	16.12	17.83	19.29	24.61	28.39	31.41	33.97
22	20.71	27.35	35.89	41.98	46.88	51.04	66.37	77.30	86.09	93.57
	9.37	12.05	15.50	17.96	19.94	21.62	27.82	32.23	35.78	38.81
23	21.71	28.84	38.09	44.73	50.08	54.66	71.56	83.68	93.47	101.83
	10.21	13.24	17.17	19.99	22.26	24.20	31.37	36.52	40.68	44.22
24	22.75	30.41	40.41	47.63	53.48	58.49	77.09	90.51	101.39	110.70
	11.13	14.54	18.99	22.21	24.81	27.04	35.32	41.30	46.14	50.29
25	23.84	32.05	42.85	50.69	57.07	62.54	82.98	97.81	109.88	120.23
	12.12	15.95	20.98	24.64	27.61	30.16	39.70	46.61	52.24	57.06

ϕ	I_{rr} 10	20	40	60	80	100	200	300	400	500
26	24.98	33.77	45.42	53.93	60.87	66.84	89.25	105.61	118.96	130.44
	13.18	17.47	23.15	27.30	30.69	33.60	44.53	52.51	59.02	64.62
27	26.16	35.57	48.13	57.34	64.88	71.39	95.02	113.92	128.67	141.39
	14.33	19.12	25.52	30.21	34.06	37.37	49.88	59.05	66.56	73.04
28	27.40	37.45	50.96	60.93	69.12	76.20	103.01	122.79	139.04	153.10
	15.57	20.91	28.10	33.40	37.75	41.51	55.77	66.29	74.93	82.40
29	28.69	39.42	53.95	64.71	73.58	81.28	110.54	132.23	150.11	165.61
	16.90	22.85	30.90	36.87	41.79	46.05	62.27	74.30	84.21	92.80
30	30.03	41.49	57.08	68.69	78.30	86.64	118.53	142.27	161.91	178.98
	18.24	24.95	33.95	40.66	46.21	51.02	69.43	83.14	94.48	104.33
31	31.43	43.64	60.37	72.88	83.27	92.31	126.99	152.95	174.49	193.23
	19.88	27.22	37.27	44.79	51.03	56.46	77.31	92.90	105.84	117.11
32	32.89	45.90	63.82	77.29	88.50	98.28	135.96	164.29	187.87	208.43
	21.55	29.68	40.88	49.30	56.30	62.41	85.96	103.66	118.39	131.24
33	34.41	48.26	67.44	81.92	94.01	104.58	145.46	176.33	202.09	224.62
	23.34	32.34	44.80	54.20	62.05	68.92	95.46	115.51	132.24	146.87
34	35.99	50.72	71.24	86.80	99.82	111.22	155.51	189.11	217.21	241.84
	25.28	35.21	49.05	59.54	68.33	76.02	105.90	128.55	147.51	164.12
35	37.65	53.30	75.22	91.91	105.92	118.22	166.14	202.64	233.27	260.15
	27.36	38.32	53.67	65.36	75.17	83.78	117.33	142.89	164.33	183.16
36	39.37	55.99	79.39	97.29	112.34	125.59	177.38	216.98	250.30	279.60
	29.60	41.68	58.68	71.69	82.62	92.24	129.87	158.65	182.85	204.14
37	41.17	58.81	83.77	102.94	119.10	133.34	189.25	232.17	268.36	300.26
	32.02	45.31	64.13	78.57	90.75	101.48	143.61	175.95	203.23	227.26
38	43.04	61.75	88.36	108.86	126.20	141.50	201.78	248.23	287.50	322.17
	34.63	49.24	70.03	86.05	99.60	111.56	158.65	194.94	225.62	252.71
39	44.99	64.83	93.17	115.09	133.66	150.09	215.01	265.23	307.78	345.41
	37.44	53.50	76.45	94.20	109.24	122.54	175.11	215.78	250.23	280.71
40	47.03	68.04	98.21	121.62	141.51	159.13	228.97	283.19	329.24	370.04
	40.47	58.10	83.40	103.05	119.74	134.52	193.13	238.62	277.26	311.50
41	49.16	71.41	103.49	128.48	149.75	168.63	243.69	302.17	351.95	396.12
	43.74	63.07	90.96	112.68	131.18	147.59	212.84	263.67	306.94	345.34
42	51.38	74.92	109.02	135.68	158.41	178.62	259.22	322.22	375.97	423.74
	47.27	68.46	99.16	123.16	143.64	161.83	234.40	291.13	339.52	382.53
43	53.70	78.60	114.82	143.23	167.51	189.13	275.59	343.40	401.36	452.96
	51.08	74.30	108.08	134.56	157.21	177.36	257.99	321.22	375.28	423.39
44	56.13	82.45	120.91	151.16	177.07	200.17	292.85	365.75	428.21	483.88
	55.20	80.62	117.76	146.97	172.00	194.31	283.80	354.20	414.51	468.28
45	58.66	86.48	127.28	159.48	187.12	211.79	311.04	389.35	456.57	516.58
	59.66	87.48	128.28	160.48	188.12	212.79	312.03	390.35	457.57	517.58
46	61.30	90.70	133.97	168.22	197.67	224.00	330.20	414.26	486.54	551.16
	64.48	94.92	139.73	175.20	205.70	232.96	342.94	429.98	504.82	571.74
47	64.07	95.12	140.99	177.40	208.77	236.85	350.41	440.54	518.20	587.72
	69.71	103.00	152.19	191.24	224.88	254.99	376.77	473.42	556.70	631.25
48	66.97	99.75	148.35	187.04	220.43	250.36	371.70	468.28	551.64	626.36
	75.38	111.78	165.76	208.73	245.81	279.06	413.82	521.08	613.65	696.64
49	70.01	104.60	156.09	197.17	232.70	264.58	394.15	497.56	586.96	667.21
	81.54	121.33	180.56	227.82	268.69	305.37	454.42	573.38	676.22	768.53
50	73.19	109.70	164.21	207.83	245.60	279.55	417.82	528.46	624.28	710.39
	88.23	131.73	196.70	248.68	293.70	334.15	498.94	630.80	744.99	847.61

From "Design of Pile Foundations," by A. S. Vesic, in NCHRB *Synthesis of Highway Practice 42*, Transportation Research Board, 1977. Reprinted by permission.

Note: Upper number N_c^*, lower number N_σ^*

6/6

6a-0220

13-Nov-97

E-31

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Tax

Project No. 602-0200

Calculation Title: LCRS Pumping Capacity

	Name	Date
Prepared By:	P. Pellicer	15-Nov-97
Checked By:	J. Pellicer	15-Nov-97
Reviewed By:	P. [illegible]	15 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of 5
Prepared By: P. Pelltier Date: 11-15-97
Checked By: J. Pellion Date: 15-Nov-97

LCRS Pumping Capacity

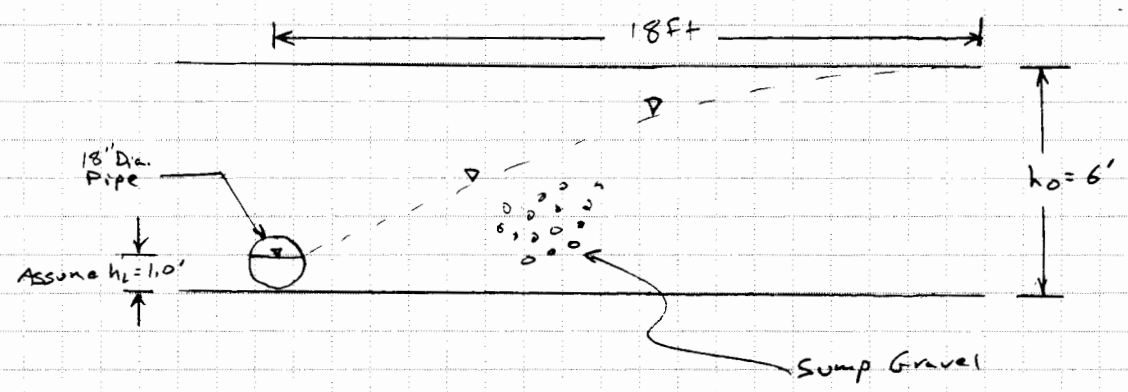
Objective: Check pumping capacity compared to the LCRS Flow Rate

Analysis: Check Capacity of sump for LCRS. See pg 3&4 for Layout and dimensions.

Use Method described in "Groundwater Hydrology and Hydraulics", 1977

Use Dupuit-Forcheimer Equation.

$$Q = \frac{k}{2L}\left(h_o^2 - h_L^2\right)$$



Q = Flow (Per foot of pipe)
L = 18 ft
h_o = 6 ft
h_L = 1 ft
k = Perm of Sump Gravel = 1 cm/sec = 1 cm/sec * $\frac{1\ ft}{30.48\ cm}$ = 0.0328 ft/sec ✓

$$Q = \frac{[0.0328\ ft/sec]}{2(18\ ft)}\left[6^2 - 1^2\right] = 0.0319\ ft^3/sec/ft$$ ✓

$$Q = 0.0319\ ft^3/sec/ft \times \frac{3600\ sec}{hr} = 114.84\ ft^3/hr/ft \times \frac{24\ hr}{day} \times \frac{7.48\ gal}{ft^3}$$

Q = 20616 gal/day/ft (pipe length = 30 ft see pg 4)

Q = 618,480 gal/day ✓

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602-0200 Sheet: 2 Of 5
Prepared By: P. Pellicer Date: 11-15-97
Checked By: J. Pellicer Date: 15-Nov-97

Determine flow rate into LCRS Sump from the Geocomposite

$Q_{in} = i \Theta w$

i = flow gradient = Maximum floor grade = 3.3% = 0.033

Θ = Transmisivity = 5×10^{-4} m²/sec (from ALR calc)

w = Maximum width of floor = 540 ft (see pg 5)

$Q_{in} = 0.033 \left(5 \times 10^{-4} \, m^2/sec * \frac{10.76391 \, ft^2}{m^2}\right)(540 \, ft) = 0.096 \, ft^3/sec$

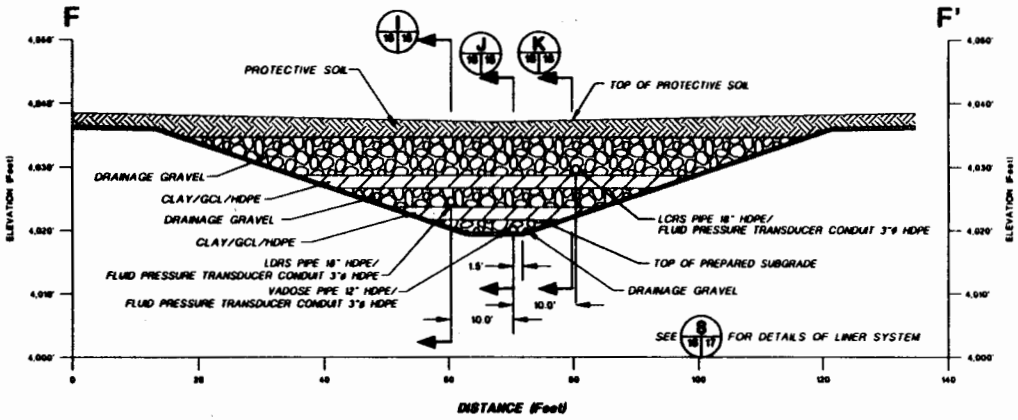
$Q_{in} = 0.096 \, ft^3/sec \left(\frac{7.48 \, gal}{ft^3}\right)\left(\frac{3600 \, sec}{hr}\right)\left(\frac{24 \, hr}{day}\right) = 62{,}042 \, gal/day$

$S.F. = \frac{Q_{out}}{Q_{in}} = \frac{618480 \, gpd}{62042 \, gpd} = \underline{\underline{9.9}}$

Conclusion: The LCRS sump has the capacity to pump out the flow Rate coming into the sump.

3 of 5
602-0200
15-NOV-97

E-31



F SUMP DETAIL -CROSS-SECTION A-A'

HORIZONTAL SCALE
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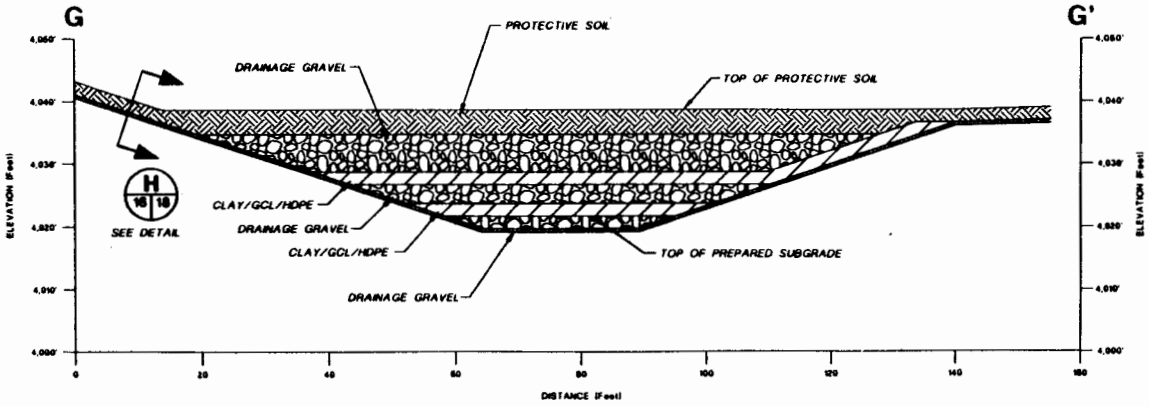
VERTICAL SCALE
0 10.0' 20.0'



G SUMP DETAIL -CROSS-SECTION B-B'

HORIZONTAL SCALE
0 10.0' 20.0'
VERTICAL SCALE
0 10.0' 20.0'

NOTE:
FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2, "GENERAL, LEGEND AND GENERAL NOTES".

K:/602/FINAL DWGS/LANDFILL
SUMPPLAN-XSEC.dwg
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PROFESSIONAL ENGINEER'S STATEMENT
I, Patrick G. Carver, state that this map was prepared under my supervision and all the information provided herein is true and correct to the best of my knowledge and information.

Date Patrick G. Carver, NM P.E. 10888

Not For Construction

REV. No.	REVISIONS	DATE	DRAWN BY	DESIGN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	12/10/97	PBC/JFP	E.Simonson	P.Carver

TRIASSIC PARK
WASTE DISPOSAL FACILITY

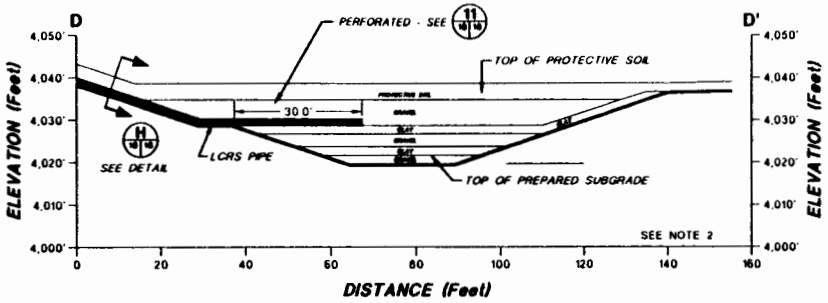
DRAWING TITLE:
SUMP CROSS-SECTIONS - PHASE 1A

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE:
DRAWING No. 10

4 of 5
602-0200
15-NOV-97
pmp

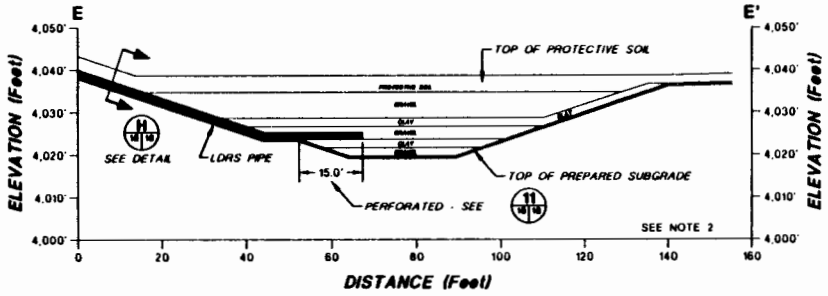
E-31



I 16/18 LCRS PIPE PLACEMENT IN SUMP

HORIZONTAL SCALE 0 15' 30'

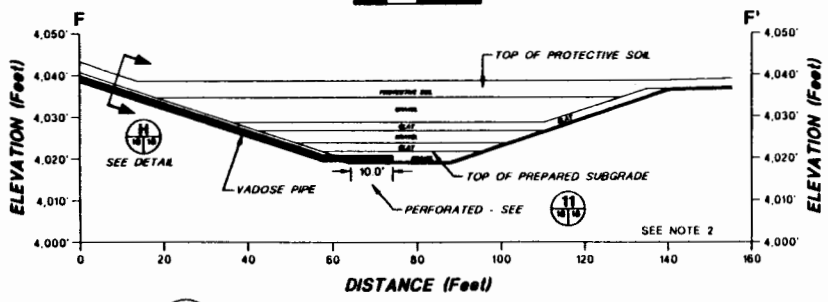
VERTICAL SCALE 0 15' 30'



J 16/18 LDRS PIPE PLACEMENT IN SUMP

HORIZONTAL SCALE 0 15' 30'

VERTICAL SCALE 0 15' 30'



K 16/18 VADOSE PIPE PLACEMENT IN SUMP

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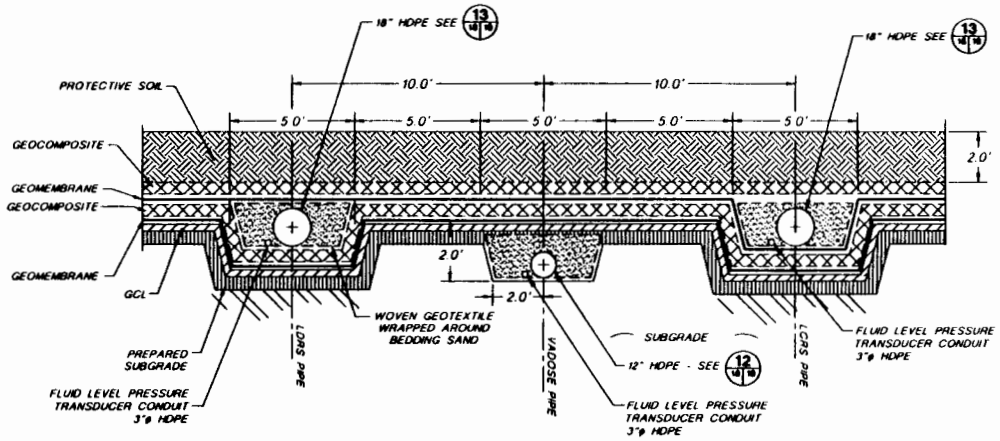
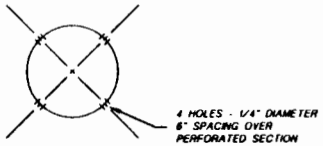
VERTICAL SCALE 0 15' 30'



H 16/18 H 18/18 LDRS, VADOSE AND LCRS PIPES SLOPE DETAIL

Not To Scale



11 18/18 PIPE PERFORATION DETAIL

Not To Scale

NOTE
1. FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2
2. INVERT ELEVATIONS AND GENERAL NOTES
3. SEE 1 18/18 FOR LINER DETAILS & SLOPE

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G Corser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Corser, NM P.E. 12238

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REV No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND SUBMITTED BY
0	PART B REPORT APPLICATION	6/16/97	PGC/JPP	K.Dorroh	P.Corser

TRIASSIC PARK

WASTE DISPOSAL FACILITY

DRAWING TITLE
VADOSE, LDRS, LCRS CROSS-SECTIONS AND DETAILS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE:
DRAWING No. 10

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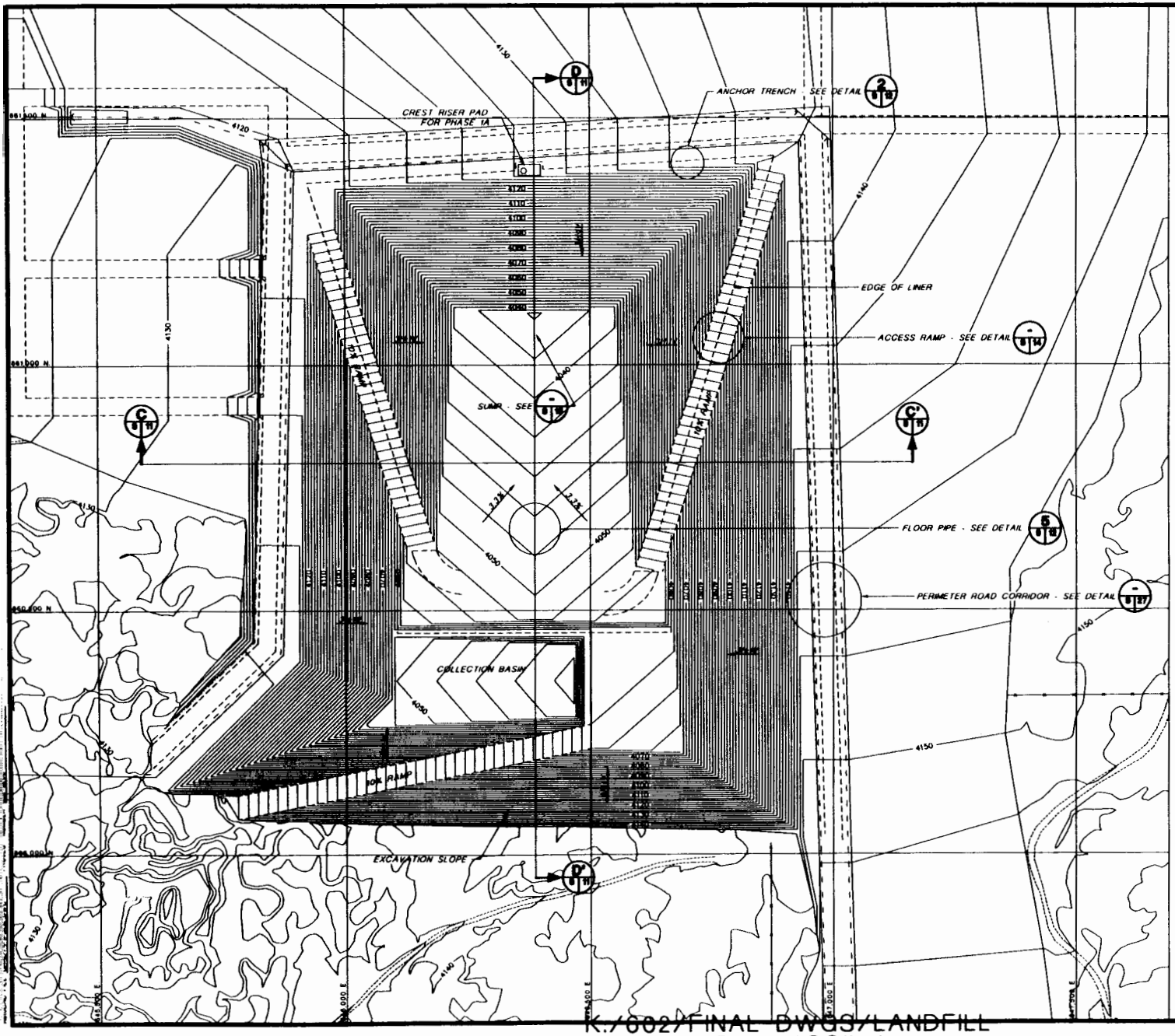
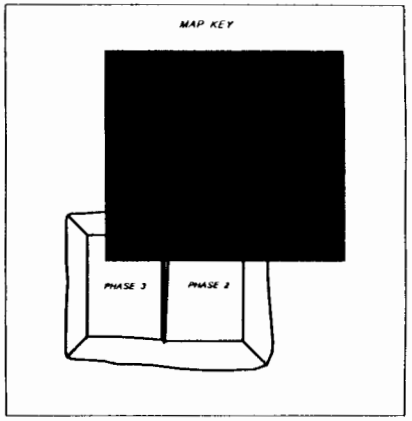
5 of 5
602-0200
15-NOV-97
pwp

E-31





NOTES
1 FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No 2, "INDEX, LEGEND AND GENERAL NOTES"

2 TOPOGRAPHY FROM AERIAL SURVEYS PERFORMED AUGUST 1997 BY KOOGLE AND POULS ENGINEERING

PATRICK G. CORSER NEW MEXICO 12236 REGISTERED PROFESSIONAL ENGINEER

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Corser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Corser, NM P.E. 12236

SCALE
100' 0 100' 200'
CONTOUR INTERVAL 5 FT.

Not For Construction

REV. No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND SIGNED BY
0	PART B PERMIT APPLICATION	10/15/97	PBC/JJP	T Smith	P Corser

TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE
TOP OF PROTECTIVE SOIL LAYER - PHASE 1A

TerraMatrix
MONTGOMERY WATSON
Joint Venture Group

Sheet 1 Of 1 Sheets
SCALE AS NOTED
DRAWING No 9

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12/09/97 12:03p

E-32

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Truck Roll Off LCRS Pumping Capacity

	Name	Date
Prepared By:	P. Pellicer	16-Nov-97
Checked By:	J. Pellicer	16-Nov-97
Reviewed By:	P. Copsel	16 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602-0200 Sheet: 1 Of 4
Prepared By: P. Pellicer Date: 16-Nov-97
Checked By: J. Pellicer Date: 16-Nov-97

TRUCK Roll off LCRS Pumping Capacity

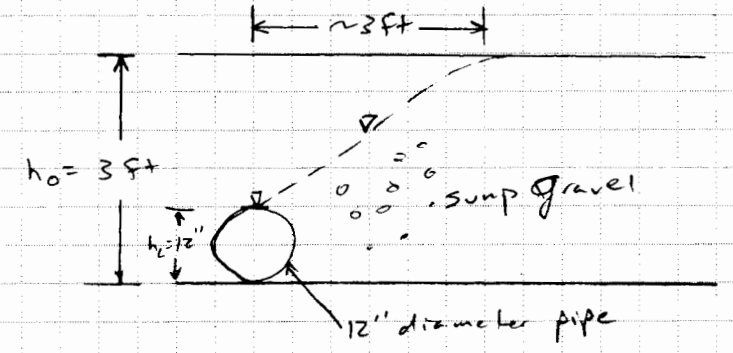
Objective: Check Pumping capacity compared to potential inflow due to the 25yr 24hr storm event.

Analysis: Check Capacity of Sump for LCRS. See page 3+4 for Layout and dimensions.

Use Method described in "Groundwater Hydrology and hydraulics", 1977

Use Dupuit-Forcheimer Equation.

$$Q = \frac{K}{2L}\left(h_o^2 - h_L^2\right)$$



Q: Flow (Per foot of pipe)
L = 3 ft
h_o = 3 ft
h_L = 1 ft
K = Perm of Sump Gravel = $1\ cm/sec \times \frac{1\ ft}{30.48\ cm} = 0.0328\ ft/sec$

$$Q = \frac{0.0328\ ft/sec}{2(3\ ft)} * \left[3ft^2 - 1ft^2\right] = 0.044\ ft^3/sec/ft$$

$$Q = 0.044\ ft^3/sec/ft * \frac{7.48\ gal}{ft^3} * \frac{3600\ sec}{hr} * \frac{24\ hr}{day} = 28{,}436\ gal/day\text{-}ft$$

Length of perf. pipe = 7 ft

$$Q = (28436\ gal/day\text{-}ft)(7\ ft) = \underline{\underline{199{,}000\ gal/day}}$$

TerraMatrix
Engineering & Environmental Services
P.O. Box 774018, 1475 Pine Grove Road
Steamboat Springs, Colorado 80477
Phone 970.879.6260 Fax 970.879.9048

Project Name: Triassic Park
Project Number: 602-0200 Sheet: 2 Of 4
Prepared By: P. Pellicer Date: 16-Nov-97
Checked By: J. Pellicer Date: 16-Nov-97

Determine amount of water required to be pumped per day
Based on 25yr 24hr storm event = 4.3 inches/day (from Surface water runoff calcs)

Area of liner = 59858 ft^2 (see pg 4)

4.3 in/day ~ 0.36 ft/day ✓

$\forall$/day = 59858 ft^2 * 0.36 ft/day = 21549 ft^3/day ✓

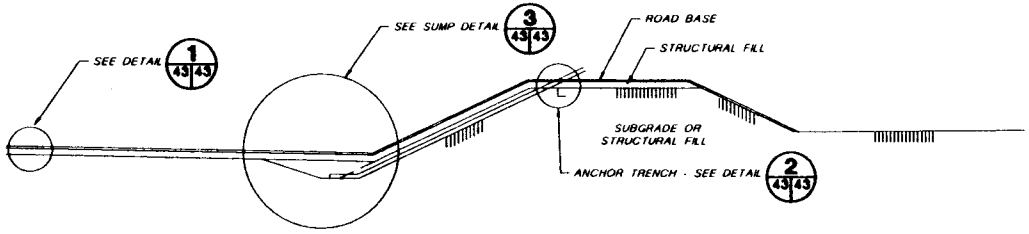
= 161,186 gal/day ✓

$$S.F. = \frac{199{,}000 \text{ gal/day}}{161{,}186 \text{ gal/day}} = \underline{\underline{1.2}}$$ ✓

Conclusions: Sump Capacity is <u>ok.</u>

3 of 4
602-0200
PWP
16-NOV-97

E-32



D 41/43 D 42/43 CROSS-SECTION D

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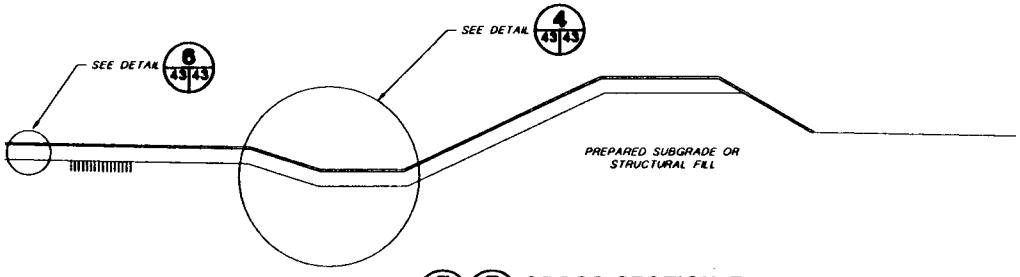
Feet



E 41/43 E 42/43 CROSS-SECTION E

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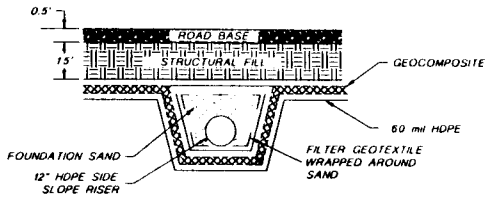
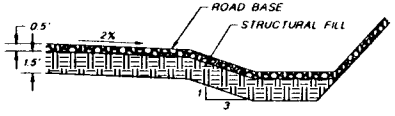
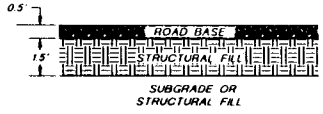


5 43/43 PIPE TRENCH DETAIL

NOT TO SCALE

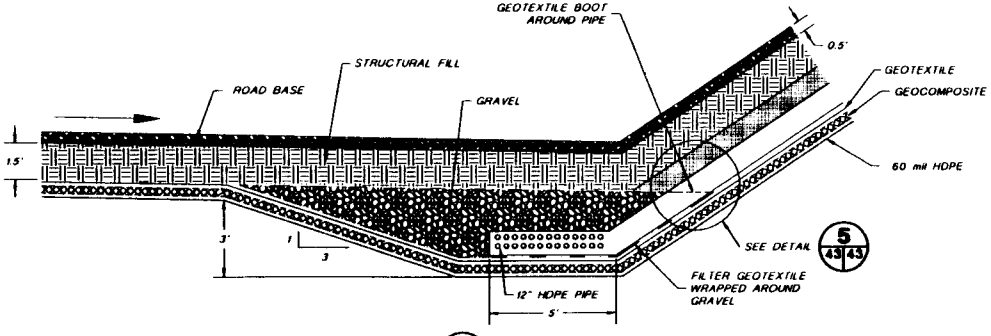


4 43/43 STABILIZED WASTE CELL SUMP



NON-STABILIZED WASTE CELL
6 43/43 LINER & DRAIN CROSS-SECTION

NOT TO SCALE



3 43/43 SUMP DETAIL

SCALE
0 2.5' 5'
Feet

NOTE:
FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No. 2, "INDEX, LEGEND AND GENERAL NOTES".

PROFESSIONAL ENGINEER'S STATEMENT
I, Patrick G. Carver, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Carver, NM P.E. 10236

Not For Construction

REV No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	9/30/97	PGC/PP	T Davis	P Carver

TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE
TRUCK ROLL-OFF AREA LINER DETAILS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 2 Of 2 Sheets
SCALE As Shown
DRAWING No 43

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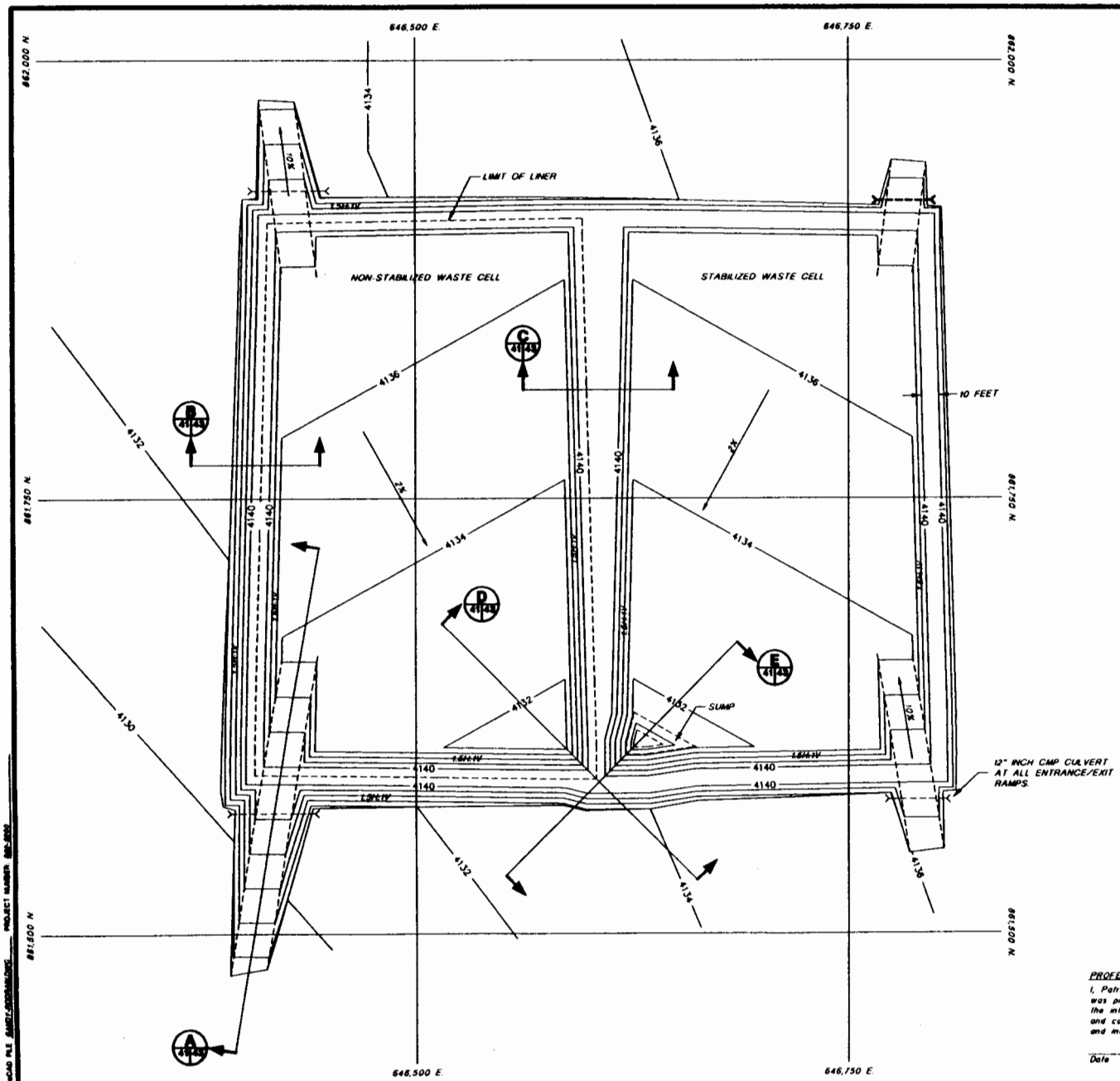
4 of 4
602-0200
pwp
16-NOV-97

E-32



NOTE.
FOR GENERAL NOTES AND LEGEND INFORMATION SEE DRAWING No 2, "INDEX, LEGEND AND GENERAL NOTES".

SCALE
30' 0 30' 60'
CONTOUR INTERVAL 2 FT.

Not For Construction

REV No	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND APPROVED BY
0	PART B PERMIT APPLICATION	10/16/97	PBC/JFF	T.SMITH	P.CORSER

PATRICK G. CORSER
NEW MEXICO
12236
REGISTERED PROFESSIONAL ENGINEER

PROFESSIONAL ENGINEER'S STATEMENT

I, Patrick G. Corser, state that this map was prepared under my supervision and all the information presented hereon is true and correct to the best of my knowledge and information.

Date Patrick G. Corser, NM P.E. 12236

TRIASSIC PARK
WASTE DISPOSAL FACILITY

DRAWING TITLE
TRUCK ROLL-OFF AREA
DRAINAGE SURFACE CONTOURS

TerraMatrix
MONTGOMERY WATSON
Mining Group

Sheet 1 Of 1 Sheets
SCALE AS NOTED
DRAWING No 41

AutoCAD FILE SANTY-RODRAINDWG PROJECT NUMBER 885-8200

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12/10/97 01:36p

E-33

FRED H. SCHOTT & ASSOCIATES
CIVIL AND STRUCTURAL ENGINEERING • LAND PLANNING AND BUILDING DESIGN

October 30, 1997

Mr. John Kendall
TerraMatrix Montgomery Watson
1475 Pine Grove Rd. Ste 109
PO Box 774018
Steamboat Springs, CO 80477

Subject: Proposed Hazardous Waste Mixing Bins at the Triassic Park Waste Disposal Facility.

Dear Mr. Kendall:

We are enclosing the following:

1. Plan & Sections of the Inner Plate Liner - Sheet S1.

2. Plan & Elevations of the Outer Plate/Support System - Sheet S2.

3. Longitudinal & Lateral Sections of the Bin Support System - Sheet S3.

4. Outline Specification for Proposed Hazardous Waste Mixing Bins at Triassic Park Waste Disposal Facility - 2 pages.

5. Overview of Preliminary Structural Analysis - 2 pages.

6. Photocopies of the general wire rope isolator page and the technical data sheet for the proposed wire rope isolator.

These documents give a good indication of the overall approach which was used to provide this preliminary design for the subject project. The actual calculations are not in a submittal form at this time, but we can provide you with any portions or all of the calculations you may wish to see. As noted in our telephone conversations there is no literature or computer programs available which address this type of problem. We have used basic engineering principles in conjunction with some finite plate element analyses to address the problem. Principles of impulse - momentum and conservation of energy were used to establish the mass, velocity and displacement relationships. Then plate stresses were approximated through the use of Sap 90. Finally force and displacement results were scaled up/down to limiting displacements (controlled by the wire rope isolators) and stresses (controlled by the grade of steel).

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We spent a significant amount of time researching the available energy absorbing devices. The wire rope isolators were an obvious choice, and we discussed the issues extensively with the Enidine people and obtained several technical papers on the product. We also felt that rubber shock absorbers might be applicable and pursued that option to a point where it appears that such devices are not readily available and that if custom manufactured the cost of such devices would be prohibitive. It should also be noted that the resistance to hostile environment of the wire rope isolators is far superior to the rubber absorbers.

We also spoke with a metallurgist and a Bethlehem Steel plant engineer to establish the desired steel properties and determine the properties and relative costs of the readily available steel. It appears that Bethlehem's Beth Star 80 (ASTM A656 Type 7 Grade 80) or Bethlehem's RQC 80, 90 or 100 (ASTM A678 Gr C 80, 90 or 100 ksi yield) would be appropriate and would only cost 30% (Beth Star 80) or 50% (RQC's) more than A36 steel(note that the maximum thickness of Beth Star 80 is 3/4" while the RQC's go to 1 1/4" or 1 1/2" thickness). All other applicable high strength steels would cost 140% to 160% more than A36 steel. It is possible but not likely that one of the more expensive steels would be a better buy due to substantially increased toughness, weldability, corrosion resistance or surface hardness. It is also possible that a cathodic protection might be warranted on the inner liner.

The final design of the mixing bins will entail far more detailed analysis than has been done in this preliminary study, but we feel that we have a good handle on the technical issues at this point and that the preliminary analysis has resulted in a structure which is reasonably close to that which will result from the final design process.

Sincerely,

Fred H Schott

Fred H. Schott

FHS:ms

(97571097.ltr)

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CIVIL AND STRUCTURAL ENGINEERING • LAND PLANNING AND BUILDING DESIGN

Outline Specification for
Proposed Hazardous Waste Mixing Bins at
Triassic Park Waste Disposal Facility

1. General

1.1 Mixing bins shall consist of an inner steel liner and outer reinforced steel plate support bin with energy absorbing devices attached to the inside face of the outer support system to provide cushioning of the inner liner when subjected to impact loading conditions.

1.2 The bins are generally to be shaped to enhance proper mixing of the hazardous waste material with stabilizing materials.

1.3 The bins are tapered from top to bottom to allow a smooth uniform support of the inner liner by the energy absorbing devices.

2. Inner Liner

2.1 Steel plate shaped & welded into a mixing bin having overall dimensions of approximately 10 feet wide, 12 feet deep and 26 feet long at the top.

2.2 Plate shall be selected on the basis of yield strength, surface hardness, toughness, resistance to corrosive chemicals and weldability. Preliminary analysis indicates the use of a metal such as Beth Star 80 which has a yield strength of 80 ksi, a tensile strength of 95 ksi, a hardness of 360 to 400 and a toughness of 10 to 15 ft lbs @-40 degrees F or Bethlehems RQC 80, 90 or 100 plate which has yield strengths of 80, 90 or 100 ksi and tensile strengths of 95, 100 & 110 ksi respectively would be appropriate for this application.

2.3 The thickness will be established after extensive finite element analyses for impact loadings at numerous selected critical locations. Preliminary analysis indicate that the thickness will be 1" +/-.

2.4 There will be a stiffener plate welded to the outer side of the inner liner all around the top edge to distribute loads laterally and minimize stress concentrations due to impact loads at or near the top of the bin.

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3. Outer Liner Plate/Support System

3.1 The outer support system consists of steel plate with 6 inch deep WT rib sections with webs welded to the plate. In some locations reinforcing cover plates are welded onto the outer flanges of the ribs. The open top of the bin is supported by a 12
inch channel with a cover plate at the outer edge.

3.2 The steel plate and structural sections will be fabricated from standard A36 material. Preliminary analyses indicates that the plate will be 1/2 inch thick and that the WT sections are generally WT 6 x 15 with some ribs supporting other ribs being WT 6 x 25. In some cases cover plates are added to the outer flange of the WT ribs.

4. Energy Absorbing Devices

4.1 The best selection for energy absorbing devices for this particular application appears to be wire rope isolators by Enidine. These isolators are fabricated from stainless steel wire rope wound into a tight elongated roll held in that shape by aluminum alloy retaining bars with a loadline protection.

4.2 The wire rope isolators best suited for this application appear to be WR28-200-D8 which have a fabricated height of 5.25 inches, a length of 14.5 inches and a maximum capacity of 9000 lbs at a deflection of 2 inches.

4.3 The isolators will be positively fastened to the outer liner/support system with no connection to the inner liner. The tapered shape of the bins (see item 1.3) will allow uniform support of the inner liner from all sides.

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Overview of Preliminary Structural Analysis

1. Initial calculations establish the structural capacity required to support the static loads from hazardous waste material plus the stabilizing materials. The worst case scenario for the static load case is 80 cubic yards of material weighing 110 #/cubic foot.

2. Preliminary dynamic analyses for vertical impact loads due to the material dropping into the bin indicate that this is not a significant problem. However impact from the bucket dropping freely due to a total & instantaneous hydraulic failure from a height of 15 feet would cause stresses in a 1 inch thick inner liner which would far exceed the yield stress of the steel & cause a permanent "dent" in the steel. It does not appear cost effective to design the inner liner for this possibility.

3. Preliminary dynamic analyses established a side to side impact load from the backhoe bucket with contributions from the stick & boom based upon their relative velocity & % of load transferred to the bucket when it impacts the sidewall of the mixing bin.

a. Static loads were applied to the wall of the inner liner to establish the relative deflections of points surrounding the point of impact. Then the effectiveness of the inner liner which would act to reduce the momentum of the bucket + was established and the conservation of momentum principle was used to determine the reduction in velocity immediately after impact.

b. After impact the moving bucket + plus the effective plate mass has a kinetic energy equal to one half of the total mass times the square of the velocity. That kinetic energy is "gradually" transferred into potential energy from force times displacement (or bending moment times angle change) in the inner liner, the energy absorbing springs and the outer plate support system. When the bucket + has been stopped all of the energy has been transferred from the kinetic state to the potential state. It appears that 80% to 90% of the energy absorption occurs in the springs.

c. Through a trial & error process, approximate relationships between initial velocity, displacements & stresses in the structural systems were established. It appears that the controlling factor in the system is the stress in the inner liner when subjected to impact loads.

d. The impact loads from the weight of the bucket plus contributions from the stick & boom totalling approximately 3290 lbs. result in a kinetic energy in excess of 800,000 # inches for the condition where a swing angle of 180 degrees can occur in 3 seconds (approximately 440 inches per second at the outer end of the bin).

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e. In order to limit the stresses in the high strength inner liner plate to an acceptable allowable value it will be necessary to reduce the side to side velocity of the bucket + to 15% of the present velocity with a 3/4 inch thick plate, 19% for a 7/8 inch plate and 23% for a 1 inch plate.

4. Preliminary analysis of the dominantly in and out impact loads caused by movement of the boom, stick & bucket were also made. Combinations of circular velocities of Boom + Stick + Bucket could easily result in velocities & resulting impact loads greater then the capacity of the inner plate to resist. Some of these velocities will probably need to be reduced to limit damage to the inner liner but this will require significantly more detailed calculations. Note that the effective mass at impact varies with each of these elements and the addition of these circular velocities & tributary masses in any particular direction and at any particular point is far from linear. The maximum reduction in velocity for any of these elements appears to be in the order of 50%.

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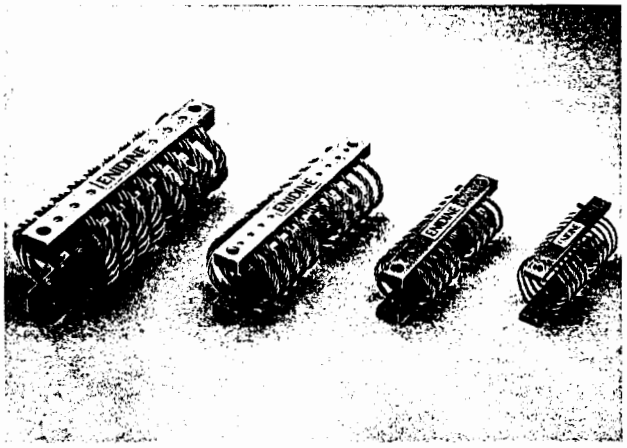
Introducing Wire Rope Isolators



Shock and vibration affect the performance of all types of mechanical and electronic equipment in industrial, defense and commercial aviation industries. If left uncontrolled, shock and vibration can cause premature equipment failure and costly downtime.

ENIDINE's Wire Rope Isolators protect valuable equipment by combating these harmful effects. The rugged all-metal design provides unsurpassed multi-axis isolation, requires no maintenance and is especially suitable for hostile environments. Performance of Wire Rope Isolators is unaffected by chemicals, oils, ozone, abrasives and temperature extremes. All products readily conform to numerous standards, including MIL-STD-167, MIL-S-901, MIL-E-5400, MIL-STD-810, STANAG-042, BV43-44 and DEF-STND 0755.

With a wide selection of Wire Rope Isolators, and load capacities ranging from 4 to 16 000 N (1 to 3,600 lbs.), most applications can be accommodated quickly with a product from our inventory. If your application is outside the standard product range, ENIDINE engineers will custom design a Wire Rope Isolator to your specifications.

For further technical assistance and pricing, please contact your local representative or contact ENIDINE directly. We look forward to working with you.

Typical Wire Rope Applications

- Shipping Cases, Skids & Containers
- Shipboard Electronics/Navigational Equipment
- Pump, Generator & Compressor Isolation
- Electronic Cabinets
- Chemical Processing Equipment
- Avionics
- Nuclear Power Plant Piping Suspension
- Transportable Shelters
- Sensitive Mobile Equipment
- Ordnance Equipment
- Over-The-Road Transport
- Seismic Isolation Applications
- Extreme Temperature Applications

Standard Materials & Finishes

Cable - Stainless Steel

Retaining Bars - Aluminum Alloy, Alodine Protected

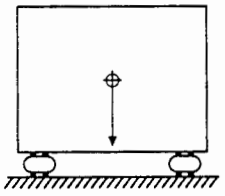
Attachment Screws - Alloy Steel, Zinc Plated (WR12 - WR40).

Consult ENIDINE if other materials/finishes are required.

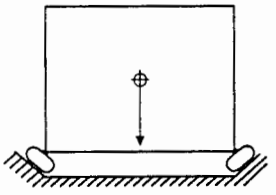
Operating Temperature Range

-100°C to 260°C (-150°F to 500°F)

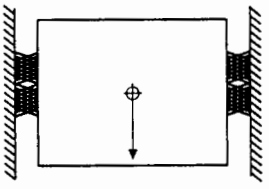
Mounting Methods - Load Axis



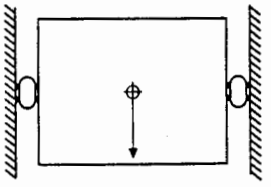
COMPRESSION



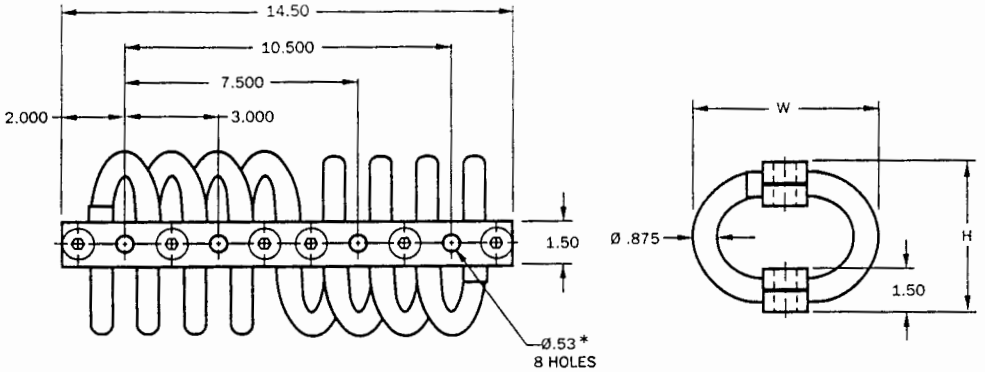
45°COMPRESSION/ROLL



SHEAR

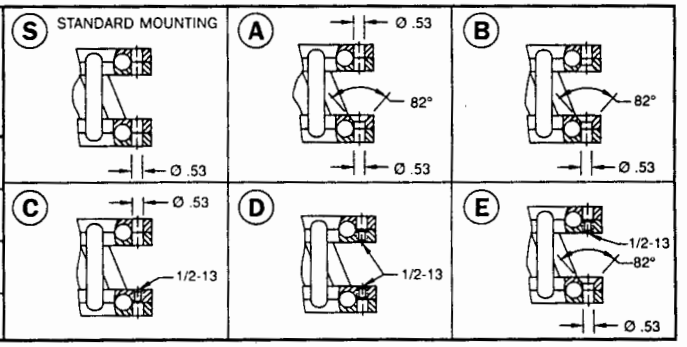


ROLL

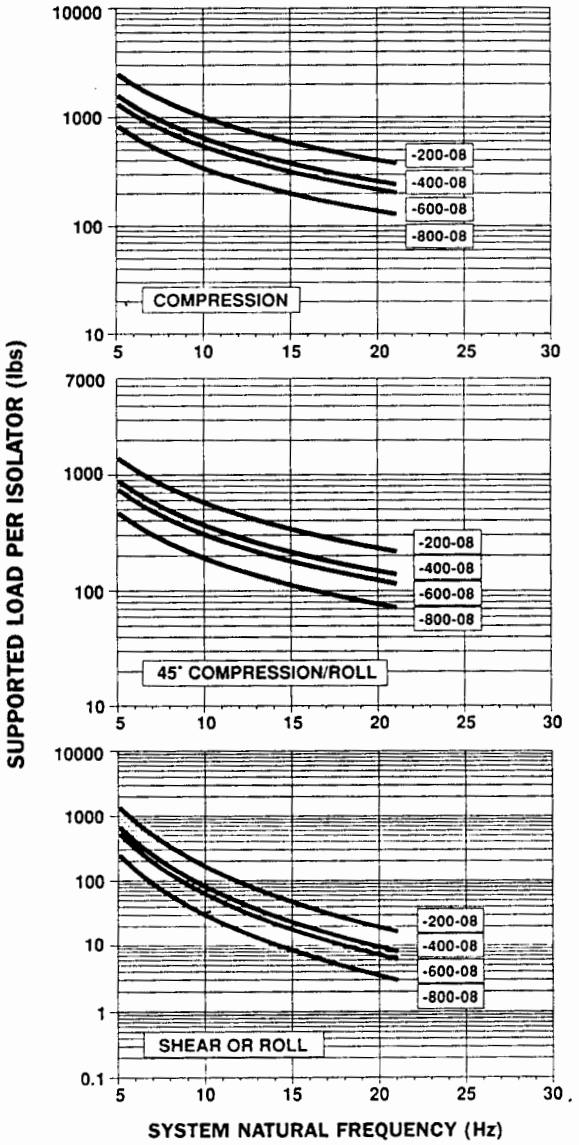


* Standard mounting configuration shown. See folder, page 3, for optional mounting configurations.

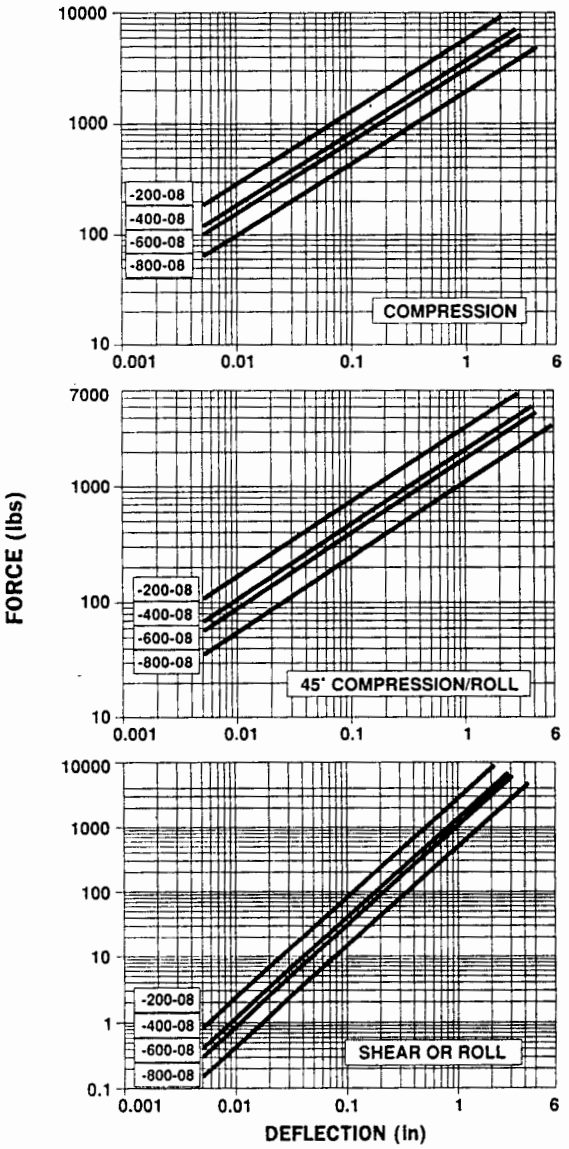
MODEL NO.	DIMENSIONS H (in)	DIMENSIONS W (in)	UNIT WEIGHT (lbs)
WR28-200-08	5.25	5.50	19
WR28-400-08	6.00	6.50	21
WR28-600-08	6.25	7.00	22
WR28-800-08	7.50	8.25	25



VIBRATION ISOLATION LOAD VS. SYSTEM NATURAL FREQUENCY



SHOCK ISOLATION FORCE VS. DEFLECTION



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LETTER OF TRANSMITTAL

DATE	November 12, 1997	JOB NO.	9757
ATTENTION	Mr. John Kendall		
RE:	TerraMatrix Bin Design		

TO TerraMatrix Montgomery Watson
Attn: John Kendall
1475 Pine Grove Rd., Ste 109
Steamboat Springs, CO 80477

WE ARE SENDING YOU ☒ Attached ☐ Under separate cover via _____ the following items:
☐ Shop drawings ☐ Prints ☐ Plans ☐ Samples ☐ Specifications
☐ Copy of letter ☐ Change order ☒ As Noted

COPIES	DATE	NO.	DESCRIPTION
		3	Impact loads from backhoe bucket calculations.
		7	Mathematical plate model calculations.
	10/08/97	22	Miscellaneous preliminary calculations.

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TELEPHONE 805/544-1216

IMPACT LOADS FROM BACKHOE BUCKET

MAX VELOCITY $= \frac{35' \times \pi}{3\ \text{sec}} = 36.7'/\text{sec} = 440''/\text{sec}$.

EFFECTIVE MASS: $\Sigma M_i V_i \cdot \frac{R_i}{R_3\ (\text{BUCKET})} = \Sigma M_i \cdot \frac{R_i}{R_3} \cdot V_3 \cdot \frac{R_i}{R_3} = \sum_0^3 M_i \cdot V_3 \left(\frac{R_i}{R_3}\right)$

		$\frac{R_i}{R_3}$	$M_i\left(\frac{R_i}{R_3}\right)^2$	EQUIVALENT W_i	
WT BUCKET =	1590#	1	1	1590/1 =	1590
BOOM	3450	.4	.16	3450	552
STICK	1774	.8	.64	1774	1136
					3277

ASSUMED $\frac{R_i}{R_3}$

$\frac{3277}{32.2} = 101.8$

@ 36.7'/sec INITIAL MOMENTUM = 101.8 × 36.7 = [illegible]

DETERMINE EQUIVALENT MASS OF INNER LINER REACTING INSTANTANEOUSLY AT IMPACT: ASSUME $V \sim \Delta$. 2.5' × 3' GRID.

AREA.	Δ	$A \cdot \Delta$
3.75	2.18	8.18
6.56 × 2	1.22	16.01
6.56 × 2	1.24	16.27
7.5 × 2	0.221	3.32
7.5 × 2	0.241	3.62
7.5 × 2	0.069	1.04
7.5 × 2	.371	5.56
	.388	5.82
	.073	1.09
	.017	.26
	.027	.40
		61.55

EQUIVALENT $M = \frac{61.55}{8.18} \times \frac{3.75\ \text{FT}^2 \times 30\#/\text{FT}^2}{32.2 \times 12}$ (3/4" PL.)

$= 26.3\ \#\text{sec}^2/\text{FT}$

$= 2.19\ \#\text{sec}^2/\text{in}$

$M_0 = \frac{3278}{32.2 \times 12} = 8.48\ \#\text{sec}^2/\text{in}$

INITIAL MOMENTUM $= M_0 V_0$

AFTER IMPACT $V_2 = V_0 \left(\frac{M_0}{M_0 + M_1}\right) = V_0 \cdot \frac{8.48}{8.48 + 2.19} = 0.795$

$M_0 V_0 + M_1 \cancel{V_0}^{0} = (M_0 + M_1) V_2$

1067

CONCLUSION: w/ 3/4" INNER LINER IMPACT VELOCITY WILL BE REDUCED 20.8% PER MOMENTUM PRINCIPLE

w/ 7/8" INNER LINER REDUCTION = 27.4%

w/ 1" = 33.6%

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IN ORDER TO QUANTIFY MAXIMUM DISPLACEMENTS USE CONSERVATION OF ENERGY PRINCIPLE WHERE INITIAL KINETIC ENERGY ($M_T \cdot V^2/2$) IS TRANSFERRED TO POTENTIAL ENERGY ($KX \cdot X/2$ OR $\int K(x)x$). WE HAVE ASSUMED THAT 85% OF ENERGY ABSORBED IS FROM SPRING WITH 15% COMING FROM FORCES/MOMENT ACTING THRU DISPLACEMENTS/ROTATIONS IN THE INNER PLATE + OUTER PLATE/SUPPORT SYSTEM.

(SEE PRINTOUTS OF GRID MODEL)

INITIALLY A STATIC FORCE IS APPLIED TO THE MATHEMATICAL MODEL OF A PLATE (6"×6" PLATE ELEMENTS) WITH WIRE ROPE ENERGY ABSORBER AT A 2'-6"×3'-0" GRID. FROM THE DISPLACEMENTS, CORRESPONDING ENERGY VALUES ARE OBTAINED FOR EACH OF THE WIRE ROPE ASSEMBLIES AND ADDED TOGETHER (THE ENERGY VALUES ARE TAKEN FROM THE SPRING FORCE VS. DEFLECTION GRAPH - FIG. 1). THE ENERGY ABSORBED IS SET EQUAL TO THE INITIAL KINETIC ENERGY TO DETERMINE THE AFTER IMPACT VELOCITY.

AT THIS POINT THE PLATE STRESSES ARE EXAMINED AND THE CORRESPONDING FORCE-DISPLACEMENT VALUES ARE SCALED DOWN TO A LEVEL WHICH CREATES A MAXIMUM BENDING STRESS OF 70 KSI. THE ENERGY ABSORBED

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AFTER REDUCTION IN IMPACT VELOCITY DUE TO MOMENTUM FURTHER REDUCTION IN VELOCITY RESULTS FROM RESISTING FORCES/MOMENTS DEVELOPED IN INNER LINER, WIRE ROPE SPRINGS & OUTER LINER/SUPPORT SYSTEM FROM DISPLACEMENTS.

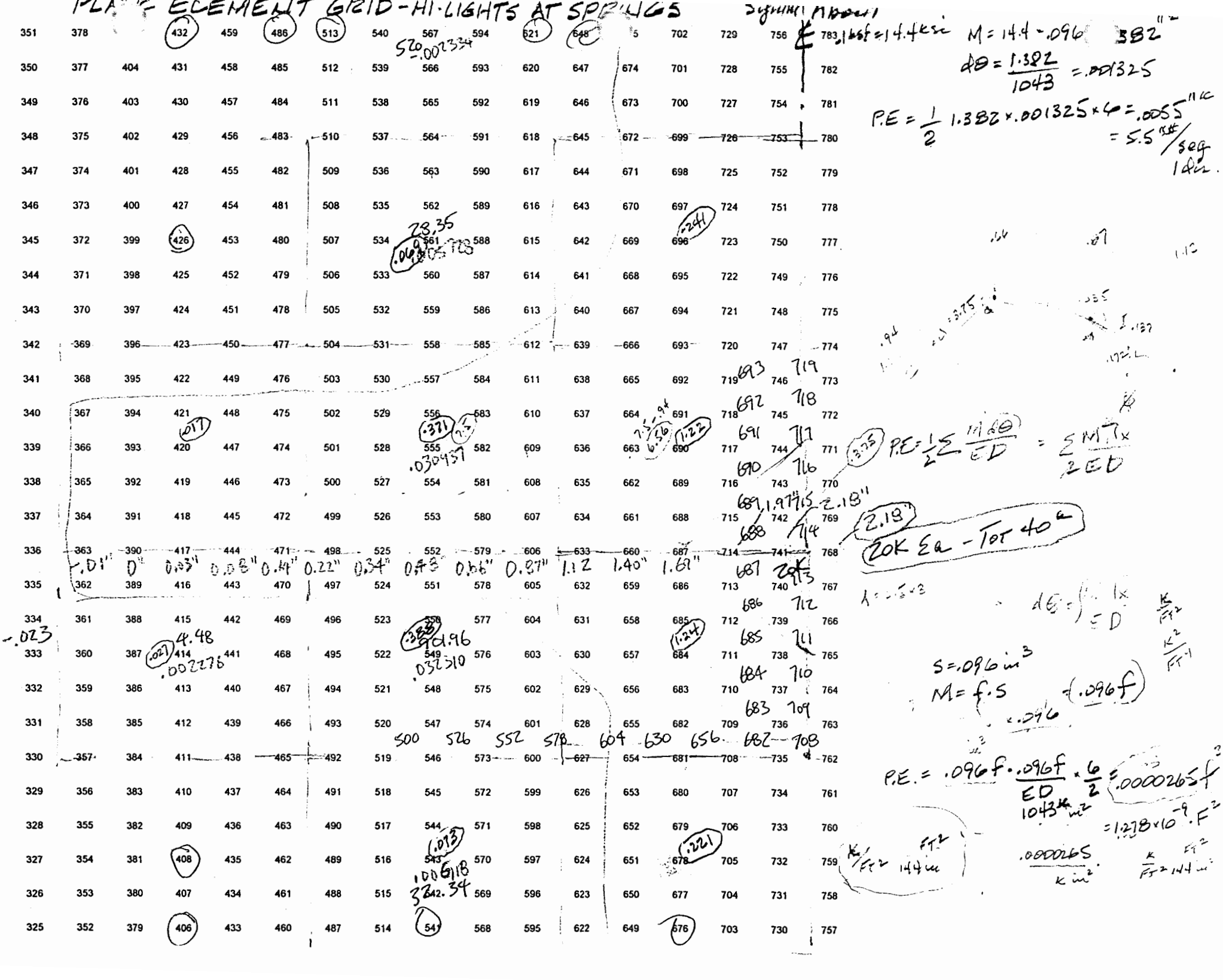
IS RECALCULATED AS ARE THE CORRESPONDING AFTER IMPACT VELOCITY & THE PRE-IMPACT VELOCITY. This was done for 3/4", 7/8" & 1" Thick plates (See DATA/CALCULATION SHEETS 3/4" PLATE, 7/8" PLATE & 1" PLATE)

NOTE THAT IN THESE PRELIMINARY CALCULATIONS THE DEFLECTIONS CALCULATED IN THE SAP 90 PROGRAM SIMULATE THE WIRE ROPE ASSEMBLY FORCE-DISPLACEMENT RELATIONSHIP AS LINEAR. AS A RESULT THE PLATE DEFLECTIONS ARE ONLY APPROXIMATE. CONSEQUENTLY, EVEN THOUGH THE ENERGY ABSORBED IS TAKEN FROM THE CORRECT NON LINEAR FORCE-DISPLACEMENT RELATIONSHIP THE RESULTING PLATE STRESSES, IMPACT LOADS & VELOCITIES CAN ONLY BE APPROXIMATE. FINAL ANALYSES WILL REQUIRE PROPER CONSIDERATION OF THE NON LINEAR PROPERTIES OF THE WIRE ROPE ASSEMBLIES AS WELL AS INVESTIGATION OF IMPACT LOADS AT FAR MORE LOCATIONS.

MATHEMATICAL PLATE MODEL
6"×6" PLATE ELEMENTS

27	54	81	108	135	162	189	216	243	270	297	324	351	378	405	432	459	486	513	540	567	594	621	648	675	702	729	756	783	810	837	864	891	918	945	972	999	1026	1053	1080	1107	1134	1161	1188	1215	1242	1269	1296	1323	1350	1377	1404	1431	1458	1485	1512
26	53	80	107	134	161	188	215	242	269	296	323	350	377	404	431	458	485	512	539	566	593	620	647	674	701	728	755	782	809	836	863	890	917	944	971	998	1025	1052	1079	1106	1133	1160	1187	1214	1241	1268	1295	1322	1349	1376	1403	1430	1457	1484	1511
25	52	79	106	133	160	187	214	241	268	295	322	349	376	403	430	457	484	511	538	565	592	619	646	673	700	727	754	781	808	835	862	889	916	943	970	997	1024	1051	1078	1105	1132	1159	1186	1213	1240	1267	1294	1321	1348	1375	1402	1429	1456	1483	1510
24	51	78	105	132	159	186	213	240	267	294	321	348	375	402	429	456	483	510	537	564	591	618	645	672	699	726	753	780	807	834	861	888	915	942	969	996	1023	1050	1077	1104	1131	1158	1185	1212	1239	1266	1293	1320	1347	1374	1401	1428	1455	1482	1509
23	50	77	104	131	158	185	212	239	266	293	320	347	374	401	428	455	482	509	536	563	590	617	644	671	698	725	752	779	806	833	860	887	914	941	968	995	1022	1049	1076	1103	1130	1157	1184	1211	1238	1265	1292	1319	1346	1373	1400	1427	1454	1481	1508
22	49	76	103	130	157	184	211	238	265	292	319	346	373	400	427	454	481	508	535	562	589	616	643	670	697	724	751	778	805	832	859	886	913	940	967	994	1021	1048	1075	1102	1129	1156	1183	1210	1237	1264	1291	1318	1345	1372	1399	1426	1453	1480	1507
21	48	75	102	129	156	183	210	237	264	291	318	345	372	399	426	453	480	507	534	561	588	615	642	669	696	723	750	777	804	831	858	885	912	939	966	993	1020	1047	1074	1101	1128	1155	1182	1209	1236	1263	1290	1317	1344	1371	1398	1425	1452	1479	1506
20	47	74	101	128	155	182	209	236	263	290	317	344	371	398	425	452	479	506	533	560	587	614	641	668	695	722	749	776	803	830	857	884	911	938	965	992	1019	1046	1073	1100	1127	1154	1181	1208	1235	1262	1289	1316	1343	1370	1397	1424	1451	1478	1505
19	46	73	100	127	154	181	208	235	262	289	316	343	370	397	424	451	478	505	532	559	586	613	640	667	694	721	748	775	802	829	856	883	910	937	964	991	1018	1045	1072	1099	1126	1153	1180	1207	1234	1261	1288	1315	1342	1369	1396	1423	1450	1477	1504
18	45	72	99	126	153	180	207	234	261	288	315	342	369	396	423	450	477	504	531	558	585	612	639	666	693	720	747	774	801	828	855	882	909	936	963	990	1017	1044	1071	1098	1125	1152	1179	1206	1233	1260	1287	1314	1341	1368	1395	1422	1449	1476	1503
17	44	71	98	125	152	179	206	233	260	287	314	341	368	395	422	449	476	503	530	557	584	611	638	665	692	719	746	773	800	827	854	881	908	935	962	989	1016	1043	1070	1097	1124	1151	1178	1205	1232	1259	1286	1313	1340	1367	1394	1421	1448	1475	1502
16	43	70	97	124	151	178	205	232	259	286	313	340	367	394	421	448	475	502	529	556	583	610	637	664	691	718	745	772	799	826	853	880	907	934	961	988	1015	1042	1069	1096	1123	1150	1177	1204	1231	1258	1285	1312	1339	1366	1393	1420	1447	1474	1501
15	42	69	96	123	150	177	204	231	258	285	312	339	366	393	420	447	474	501	528	555	582	609	636	663	690	717	744	771	798	825	852	879	906	933	960	987	1014	1041	1068	1095	1122	1149	1176	1203	1230	1257	1284	1311	1338	1365	1392	1419	1446	1473	1500
14	41	68	95	122	149	176	203	230	257	284	311	338	365	392	419	446	473	500	527	554	581	608	635	662	689	716	743	770	797	824	851	878	905	932	959	986	1013	1040	1067	1094	1121	1148	1175	1202	1229	1256	1283	1310	1337	1364	1391	1418	1445	1472	1499
13	40	67	94	121	148	175	202	229	256	283	310	337	364	391	418	445	472	499	526	553	580	607	634	661	688	715	742	769	796	823	850	877	904	931	958	985	1012	1039	1066	1093	1120	1147	1174	1201	1228	1255	1282	1309	1336	1363	1390	1417	1444	1471	1498
12	39	66	93	120	147	174	201	228	255	282	309	336	363	390	417	444	471	498	525	552	579	606	633	660	687	714	741	768	795	822	849	876	903	930	957	984	1011	1038	1065	1092	1119	1146	1173	1200	1227	1254	1281	1308	1335	1362	1389	1416	1443	1470	1497
11	38	65	92	119	146	173	200	227	254	281	308	335	362	389	416	443	470	497	524	551	578	605	632	659	686	713	740	767	794	821	848	875	902	929	956	983	1010	1037	1064	1091	1118	1145	1172	1199	1226	1253	1280	1307	1334	1361	1388	1415	1442	1469	1496
10	37	64	91	118	145	172	199	226	253	280	307	334	361	388	415	442	469	496	523	550	577	604	631	658	685	712	739	766	793	820	847	874	901	928	955	982	1009	1036	1063	1090	1117	1144	1171	1198	1225	1252	1279	1306	1333	1360	1387	1414	1441	1468	1495
9	36	63	90	117	144	171	198	225	252	279	306	333	360	387	414	441	468	495	522	549	576	603	630	657	684	711	738	765	792	819	846	873	900	927	954	981	1008	1035	1062	1089	1116	1143	1170	1197	1224	1251	1278	1305	1332	1359	1386	1413	1440	1467	1494
8	35	62	89	116	143	170	197	224	251	278	305	332	359	386	413	440	467	494	521	548	575	602	629	656	683	710	737	764	791	818	845	872	899	926	953	980	1007	1034	1061	1088	1115	1142	1169	1196	1223	1250	1277	1304	1331	1358	1385	1412	1439	1466	1493
7	34	61	88	115	142	169	196	223	250	277	304	331	358	385	412	439	466	493	520	547	574	601	628	655	682	709	736	763	790	817	844	871	898	925	952	979	1006	1033	1060	1087	1114	1141	1168	1195	1222	1249	1276	1303	1330	1357	1384	1411	1438	1465	1492
6	33	60	87	114	141	168	195	222	249	276	303	330	357	384	411	438	465	492	519	546	573	600	627	654	681	708	735	762	789	816	843	870	897	924	951	978	1005	1032	1059	1086	1113	1140	1167	1194	1221	1248	1275	1302	1329	1356	1383	1410	1437	1464	1491
5	32	59	86	113	140	167	194	221	248	275	302	329	356	383	410	437	464	491	518	545	572	599	626	653	680	707	734	761	788	815	842	869	896	923	950	977	1004	1031	1058	1085	1112	1139	1166	1193	1220	1247	1274	1301	1328	1355	1382	1409	1436	1463	1490
4	31	58	85	112	139	166	193	220	247	274	301	328	355	382	409	436	463	490	517	544	571	598	625	652	679	706	733	760	787	814	841	868	895	922	949	976	1003	1030	1057	1084	1111	1138	1165	1192	1219	1246	1273	1300	1327	1354	1381	1408	1435	1462	1489
3	30	57	84	111	138	165	192	219	246	273	300	327	354	381	408	435	462	489	516	543	570	597	624	651	678	705	732	759	786	813	840	867	894	921	948	975	1002	1029	1056	1083	1110	1137	1164	1191	1218	1245	1272	1299	1326	1353	1380	1407	1434	1461	1488
2	29	56	83	110	137	164	191	218	245	272	299	326	353	380	407	434	461	488	515	542	569	596	623	650	677	704	731	758	785	812	839	866	893	920	947	974	1001	1028	1055	1082	1109	1136	1163	1190	1217	1244	1271	1298	1325	1352	1379	1406	1433	1460	1487
1	28	55	82	109	136	163	190	217	244	271	298	325	352	379	406	433	460	487	514	541	568	595	622	649	676	703	730	757	784	811	838	865	892	919	946	973	1000	1027	1054	1081	1108	1135	1162	1189	1216	1243	1270	1297	1324	1351	1378	1405	1432	1459	1486

PLATE - ELEMENT GRID - HI-LIGHTS AT SPRINGS



$M = 14.4 \times .096 = 1.382''^{k}$

$d\theta = \frac{1.382}{1043} = .001325$

$P.E = \frac{1}{2}\, 1.382 \times .001325 \times 4 = .0055''^{k}$

$= 5.5\ ''^{\#}/\text{seg}$

$P.E = \frac{1}{2}\sum \frac{M\,d\theta}{ED} = \frac{\sum M\,d\theta}{2ED}$

$S = .096\ in^3$

$M = f \cdot S$

$(.096f)$

$P.E. = .096f \cdot \frac{.096f}{ED} \times \frac{6}{2} = .0000265f^2$

$1043^{k}/in^2$

$= 1.278 \times 10^{-9} \cdot F^2$

$\frac{.0000265}{k\ in^2}$

$\frac{k}{FT^2}\ 144\ in^2$

$\frac{k}{FT^2} \cdot 144\ in^2$

$\int_0^{1in} kx^2$

A scaled down to give 70 ksi plate stress

Joint Number	Spring	Load	Deflection	Stresses	1/2*k*x^2
406	36		-0.033444		0.02013302
408	6		0.037788		0.004283799
414	6	.100 .122	0.206412	8.819444444	0.127817741
420	6	.092 .117	0.197688	8.75	0.117241636
426	6		0.056016		0.009413377
432	6		-0.057324		0.009858123
486	3		-0.060732		0.005532564
513	3		-0.060252		0.005445455
541	36		-0.022176		0.00885195
543	6	.102 .125	0.211452	10.34722222	0.134135845
549	6	1.064 .497	0.837708	17.22222222	2.10526408
555	6	1.057 .495	0.835584	17.63888889	2.094601863
561	6	.198 .183	0.30834	10.55555556	0.285220667
567	6		-0.054828	3.347222222	0.009018329
621	3		-0.045948		0.003166828
648	3		-0.040728		0.002488155
676	36		0.023808		0.010202776
678	6	.392 .271	0.456516	10.06944444	0.625220575
684	6	4.296 1.127	1.900176	17.84722222	10.83200649
690	6	4.309 1.129	1.904052	17.70833333	10.87624206
696	6	.665 .371	0.626064	15.34722222	1.175868396
702	6	12.275	23.8 0.031164	2.3125	0.002913585
741		40.16 ~~20K~~	2.829876	118.0555556	
768		40.16 ~~20K~~	23.8 2.829876	118.0555556	

symmetry

$\Sigma \int kx^2 = 12{,}275$ #in x 2

$\frac{MV^2}{2} = 12{,}275 \times 2$

after impact $V = \sqrt{\frac{12{,}275 \times 4}{12.55}} = 62.55$ "/sec

before impact $V = \frac{62.55 \times 12.55}{8.33} = 94.23$ "/sec 21% of 440

if 15% additional energy absorption by inner liner + outer system

after V = 67.08

before V = 101.1 in/sec = 23% of 440

if scaled down to 70 ksi (.593)

max drops to 1.13 in

& F drops to 23.81 k

Σkx^2 scaled down .536 (70 ksi mat)

Joint Number	Spring	Load	Deflection	Stresses	1/2*k*x^2
406	36		-0.026316		0.012465573
408	6		0.015552		0.000725594
414	6	.033 .062	0.122184	7.708333333	0.04478679
420	6	.024 .057	0.106524	7.638888889	0.034042088
426	6		0.004764		6.80871E-05
432	6		-0.042156		0.005331385
486	3		-0.049632		0.003695003
513	3		-0.051852		0.004032945
541	36		-0.027456		0.013568975
543	6	.057 .089	0.165324	9.722222222	0.081996075
549	6	.720 .389	0.72492	19.65277778	1.576527019
555	6	.690 .379	0.7071	19.09722222	1.49997123
561	6	.084 .111	0.206652	10.48611111	0.128115147
567	6		-0.052596	2.666666667	0.008299018
621	3		-0.050424		0.00381387
648	3		-0.04818		0.003481969
676	36		0.002364		0.000100593
678	6	.266 .217	0.403788	11.11111111	0.489134247
684	6	3.606 1.016	1.895496	23.26388889	10.77871526
690	6	3.552 1.007	1.877424	25.06944444	10.57416263
696	6	.390 .270	0.5031	16.59722222	0.75932883
702	6	9.422	-0.043044	19.23611111	0.005558358
741		~~20~~K 35 18.8"	3.014484	130.5555556	
768		~~20~~K 35 18.8"	3.014484	130.5555556	

$\Sigma \frac{1}{2}kx^2 = 9.422 \times 2$

$\frac{MV^2}{2} = 9422 \times 2$

after impact $V = \sqrt{\frac{9422 \times 4}{11.48}} = 57.30''/sec$

Springs only (ignored energy absorption by inner liner plate & outer plate support system)

If scaled down to 70 ksi (.536)

Δ_{max} drops to 1.02"

F drops to 18.77 k

before impact $V = 57.3 \times \frac{11.48}{8.33} = 78.96''/sec = 18\%$ of 440

.79% of 1"

If one assumes inner liner + outer support system will absorb 15% of energy absorbed by springs $V_{after} = 61.44$

$V_{before} = 84.7''/sec = 19.2\%$ of 440

10/22/97
11:23 AM

9757 - Terra Matrix
10.XLS
3/4" Plate

Energy Absorbed by springs w/Δ from 60.6"

Δ due to TOT 28.4

$\int kx^2$

Scaled down by .4667 (70 ksi max)

Joint Number	Spring	Load	Deflection	Stresses	1/2*k*x^2
406	36		-0.017604		0.005578215
408	6		-0.005448		8.90421E-05
414	6	0 .019	0.041508	6.041666667	0.005168742
420	6	0 .012	0.025764	5.868055556	0.001991351
426	6		-0.033564		0.003379626
432	6		-0.025116		0.00189244
486	3		-0.033996		0.001733592
513	3		-0.037692		0.00213103
541	36		-0.027276		0.013391643
543	6	.022 .052	0.1116	8.611111111	0.03736368
549	6	.403 .275	0.589344	21.59722222	1.041979051
555	6	.374 .263	0.564336	21.04166667	0.955425363
561	6	.021 .049	0.104484	8.680555556	0.032750719
567	6		-0.042576	1.854166667	0.005438147
621	3		-0.045732		0.003137124
648	3		-0.046032		0.003178418
676	36		-0.012888		0.00298981
678	6	.150 .157	0.336192	12.5	0.339075183
684	6	2.837 .883	1.8918	35.76388889	10.73672172
690	6	2.755 .868	1.860468	35.95138889	10.38402354
696	6	.176 .171	0.36564	17.22222222	0.401077829
702	6	6.738	-0.044724	15.41666667	0.006000709
741		30.4	14.2 3.320256	150	
768		30.4	14.2 3.320256	150	

$\Sigma \int kx^2 = 6.738 \times 2 = 13.476$ SYMMETRY

springs only

$MV^2/2 = 13,476$

after impact $V = \sqrt{\frac{13476 \times 2}{10.52}} = 50.62$"/sec

before impact $V = \frac{50.62 \times 10.52}{5.38} = 63.92$"/sec = 14.5% of 440

If scaled down to 70 ksi (.467)

Δ_{max} drops to .883'

& F drops to 14.19 k

60% of 1"

If one assumes energy absorbed by inner plate + outer support system = 15% of spring energy absorption

V after = 54.3

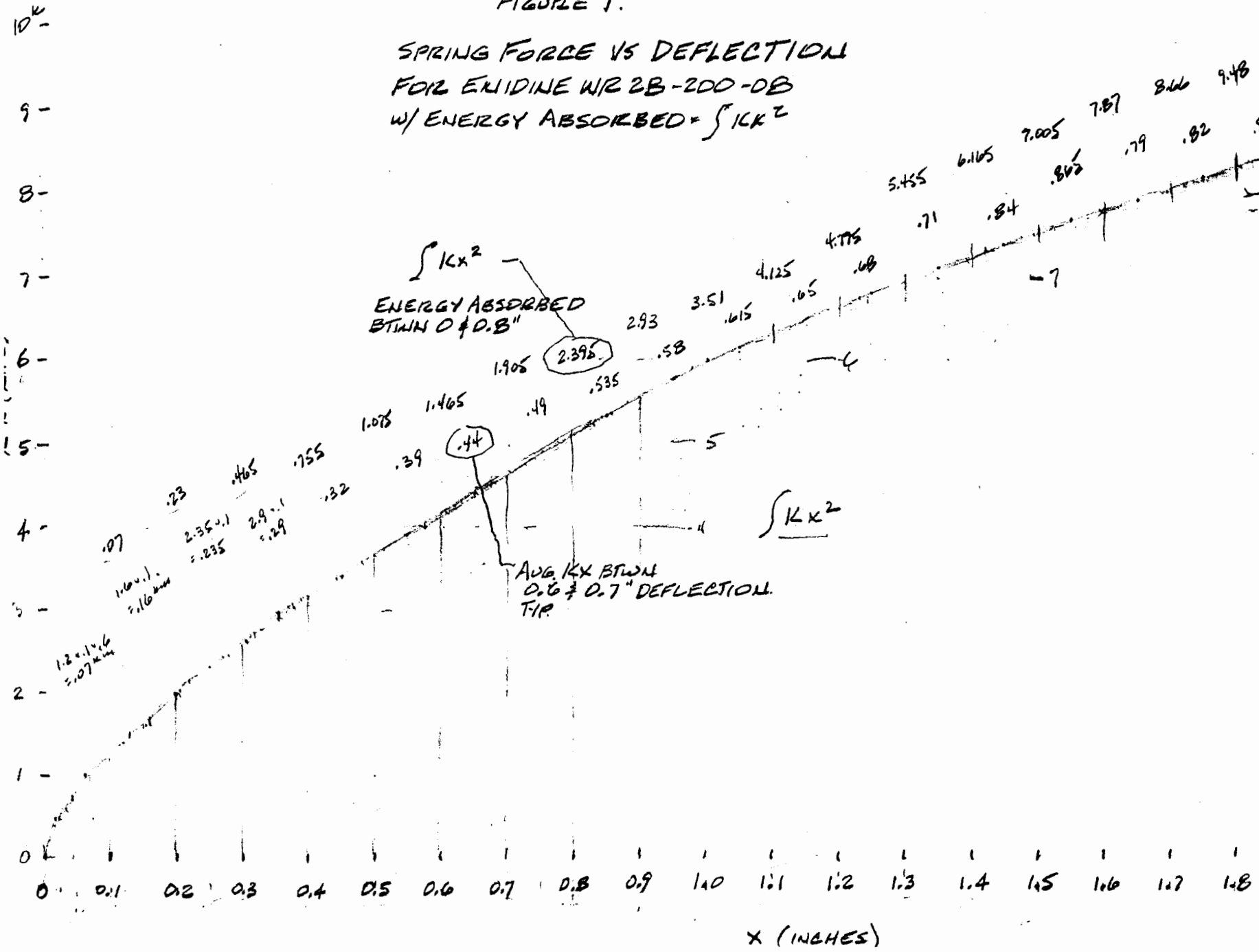
V before = 68.5 = 15.6% of 440

SAP 90 INPUT DATA

```
TOXIC TANK ANALYSIS-1" Thick Plate - 10/21/97
SYSTEM
L=1
JOINTS
1 X=0 Z=0
27 X=0 Z=13
1486 X=28 Z=0
1512 X=28 Z=13 Q=1,27,1486,1512,1,27

SPRINGS
1 1486 135 K=432,432,432
3 27 6 K=216,216,216
1488 1512 6 K=216,216,216
138 1353 135 K=72,72,72
144 1359 135 K=72,72,72
150 1365 135 K=72,72,72
156 1371 135 K=72,72,72
162 1377 135 K=72,72,72
81 1431 135 K=36,36,36
108 1458 135 K=36,36,36

SHELL
NM=1 O=1 X=1 Y=1 Z=1
1 E=4.176E6
1 JQ=1,2,28,29 ETYPE=2 M=1 TH=0.0833,0.0833 G=26,55

LOADS
741 741 1 L=1 F=0,40.16,0,0,0,0
768 768 1 L=1 F=0,40.16,0,0,0,0
```

FIGURE 1.

SPRING FORCE VS DEFLECTION
FOR ENIDINE W/R 2B-200-08
W/ ENERGY ABSORBED = $\int Kx^2$



PROJECT:
CLIENT:
Date:
By:
Sheet ____ of ____

FRED H. SCHOTT and ASSOCIATES
STRUCTURAL ENGINEER
200 SUBURBAN ROAD
SAN LUIS OBISPO, CALIF.
TELEPHONE 805/544-1216

Appendix F

F-1

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet _____ of _____

Project Title: GANDY TRIASSIC PARK LANDFILL

Project No. 602

Calculation Title: SEDIMENT DEMONSRATION

	Name	Date
Prepared By:	DAN GLEASON	11/15/97
Checked By::	TOM LEIDICH	11/15/97
Reviewed By:		
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

SOIL LOSS CALCULATIONS FOR TRIASSIC PARK LANDFILL COVER

1.0 EROSION CALCULATIONS

In order to evaluate the cover effectiveness for the Triassic Park Landfill an erosion analysis was performed. Calculated gross erosion effects on the existing surface slope were evaluated in comparison to State regulations. The equations and input parameters used to determine the gross annual sediment yield for the Triassic Park Landfill are presented in the following sections.

The Revised Universal Soil Loss Equation (RUSLE) was used to estimate the annual sediment yield (Barfield et al, 1981):

$$Y = R \bullet K \bullet L \bullet S \bullet C \bullet P$$

Where:

Y =	Sediment yield (tons per acre-year)
R =	Rainfall factor
K =	Soil erodibility factor
L =	Length factor
S =	Slope factor
C =	Control factor
P =	Practice factor

1.1 AVERAGE ANNUAL RAINFALL FACTOR, R_{annual}

The average annual rainfall factor was obtained for the following equation: $R = 27(P_{2,6})^{2.2}$ (Barfield et al, 1981). A value of 98 was used for the Triassic Park Landfill Cover Analysis.

1.2 SOIL ERODIBILITY FACTOR, K

The soil erodibility factor for the subject site was assumed based on site specific Soil Conservation data. The following soil erodibility factor was used for the Triassic Park Landfill analysis.

TABLE 1
SOIL ERODIBILITY FACTOR

Dominant Soil Type	Soil Texture	Soil Erodibility Factor (K)
Roswell - Faskin- Jalmer Association	Sand to sandy loam	0.30

1.3 LENGTH FACTOR, L

The length factor for the sediment yield equation was determined based on the following equation (Renard et al, 1996):

$$L = \left(\frac{\lambda}{72.6}\right)^m$$

Where:

λ =	Representative slope length (ft)
m =	Variable slope length exponent

The representative slope length was measured directly from topographic maps of the subject site. The slope length is defined as the distance from the point of origin of overland flow to the point where the slope decreases such that significant deposition occurs or the flow enters a defined channel.

The slope length exponent is related to the ratio β of rill erosion (caused by flow) to interill erosion (principally caused by raindrop impact) by the following equation (Renard et al, 1996):

$$m = \frac{\beta}{(1+\beta)}$$

$$\beta = \frac{\frac{\sin\theta}{0.0896}}{(3.0 \bullet (\sin\theta)^{0.8} + 0.56)}$$

Where: θ = Slope angle

1.4 SLOPE FACTOR, S

The slope factor is representative of the typical slope length found on the subject site and calculated as follows:

$S = 10.8 \bullet \sin(\theta) + 0.03$ for slopes < 9%

$S = 16.8 \bullet \sin(\theta) - 0.50$ for slopes ≥ 9%

Slope angles were determined from topographic maps or from design slope information.

1.5 CONTROL FACTOR, C

The control factor is used to account for vegetative or mulch cover. The following values were utilized:

TABLE 2
CONTROL FACTOR

Surface	Vegetation	Control Factor (C)
Vegetated Conditions	No appreciable canopy, 60 % herbaceous cover	0.042

1.6 PRACTICE FACTOR, P

The practice factor is used to account for soil surface conditions, such as contour furrow ditches. The following values were utilized:

TABLE 3
PRACTICE FACTOR

Surface	Practice	Practice Factor (P)
Vegetated Conditions	None	0.80

2.0 RESULTS

Based on the attached spreadsheet calculations a maximum slop length of 650 feet adequately meets the maximum allowable gross erosion rate of 2 tons per acre-year for 6 % slope and 30 feet.

3.0 REFERENCES

Barfield, Warner, and Haan, 1981. *Applied Hydrology and Sedimentology for Disturbed Areas.* Oklahoma Technical Press, Stillwater, Oklahoma

Renard, K.G., Foster, G.R. Weesies G.A., McCool D.K., Yoder D.C., coordinators, 1996. *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal soil Loss Equation (RUSLE).* Agriculture Handbook No. 703. U.S. Department of Agriculture

TRIASSIC PARK LANDFILL
CALCULATED SEDIMENTOLOGY DATA

FINAL COVER

SOIL ERODIBILITY FACTOR:

Soil Type	Soil Group	Erodibility Factor, K
Final Cover	B	0.3

SLOPE FACTOR:

Length (ft)	Elevation Change (ft)	Slope (%)	m	Slope Angle (deg)	LS Factor
30	7.5	25.0%	0.6	14.0	2.10

The LS Factor was calculated by:

LS = (Slope Length/72.6)^m(10.8*sin(slope angle) + 0.03) for Slopes < 9%*

LS = (Slope Length/72.6)^m(16.8*sin(slope angle) - 0.5) for Slopes > or = 9%*

Where:

Slope < or = 3%	*m = 0.3*
Slope = 4%	*m = 0.4*
5% > Slope < 10%	*m = 0.5*
Slope > 10%	*m = 0.6*

COVER AND PRACTICE FACTORS:

Cover Type	Cover (%)	Canopy (%)	Control Factor, C	Practice Factor, P
Final Cover	60%	0%	0.042	0.80

RAINFALL FACTOR:

R = 98

TRIASSIC PARK LANDFILL
CALCULATED SEDIMENT YIELD

The following spreadsheet calculates the predicted sediment yield for the project area. The gross sediment yield is determined according to the Revised Universal Soil Loss Equation.

PARAMETER DESCRIPTION	VALUE	
Annual Rainfall Factor	98.00	
Soil Erodibility Factor	0.30	
Length Slope Factor	2.10	
Control Factor	0.04	
Practice Factor	0.80	
Gross Annual Sediment Yield	2.08	tons/acre/year
Sediment Density	94.00	pcf
Gross Annual Sediment Yield	0.0010	acre-feet/acre/year
Sediment Delivery Ratio	90%	
Estimated Annual Sediment Yield	0.0009	acre-feet/acre/year
Watershed Area	0	acres
Watershed Annual Sediment Yield	0.0000	acre-feet/year
Number of years	1	years
Required Pond Sediment Storage	0.000	acre-feet

TRIASSIC PARK LANDFILL
CALCULATED SEDIMENTOLOGY DATA

FINAL COVER

SOIL ERODIBILITY FACTOR:

Soil Type	Soil Group	Erodibility Factor, K
Final Cover	B	0.3

SLOPE FACTOR:

Length (ft)	Elevation Change (ft)	Slope (%)	m	Slope Angle (deg)	LS Factor
650	39	6.0%	0.5	3.4	2.03

The LS Factor was calculated by:

LS = (Slope Length/72.6)^m(10.8*sin(slope angle) + 0.03) for Slopes < 9%*

LS = (Slope Length/72.6)^m(16.8*sin(slope angle) - 0.5) for Slopes > or = 9%*

Where:

Slope < or = 3%	*m = 0.3*
Slope = 4%	*m = 0.4*
5% > Slope < 10%	*m = 0.5*
Slope > 10%	*m = 0.6*

COVER AND PRACTICE FACTORS:

Cover Type	Cover (%)	Canopy (%)	Control Factor, C	Practice Factor, P
Final Cover	60%	0%	0.042	0.80

RAINFALL FACTOR: R = 98

TRIASSIC PARK LANDFILL
CALCULATED SEDIMENT YIELD

The following spreadsheet calculates the predicted sediment yield for the project area. The gross sediment yield is determined according to the Revised Universal Soil Loss Equation.

PARAMETER DESCRIPTION	VALUE	
Annual Rainfall Factor	98.00	
Soil Erodibility Factor	0.30	
Length Slope Factor	2.03	
Control Factor	0.04	
Practice Factor	0.80	
Gross Annual Sediment Yield	2.00	tons/acre/year
Sediment Density	94.00	pcf
Gross Annual Sediment Yield	0.0010	acre-feet/acre/year
Sediment Delivery Ratio	90%	
Estimated Annual Sediment Yield	0.0009	acre-feet/acre/year
Watershed Area	0	acres
Watershed Annual Sediment Yield	0.0000	acre-feet/year
Number of years	1	years
Required Pond Sediment Storage	0.000	acre-feet

F-2

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet _____ of _____

Project Title: GANDY TRIASSIC PARK LANDFILL

Project No. 602

Calculation Title: DRAINAGE CONTROL

	Name	Date
Prepared By:	DAN GLEASON	11/15/97
Checked By::	TOM LEIDICH	11/15/97
Reviewed By:		
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

SURFACE WATER CONTROL SYSTEM DESIGN

1.0 INTRODUTION

This appendix contains the methodology, assumptions , and calculation for the proposed channels, culverts and ponds.

METHODOLOGIES AND ASSUMPTIONS

2.0 HYDROLOGY

The hydrologic calculations used to evaluate the Triassic Park Landfill surface water control system were performed utilizing the SEDCAD+ computer model developed by Civil Software Design.

SEDCAD+ is a hydrologic, hydraulic, and sediment calculation model designed for use on computer systems. The SEDCAD+ hydrologic model calculates runoff volume, and peak flow via a numerical modeling technique based on user inputs of a design storm event, (i.e., precipitation frequency data, selection of rainfall distribution, and convolution increment). Hydrographs are developed on a subwatershed basis with the input of area, time of concentration, SCS curve number, and the selection of a hydrograph shape. Routing of hydrographs is accomplished by the Muskingum Method.

Inputs to the hydrology component of the SEDCAD+ computer model include:

- Precipitation Distribution
- Storm Duration
- Return Period/Precipitation
- Hydrograph Response Shape
- Drainage Basin Area
- Time of Concentration
- Muskingum Routing Parameters
- Curve Number

Input values used in this model, are shown on the SEDCAD+ printouts in Attachment 1, and are explained in the following text.

2.1 Precipitation Distribution

A precipitation distribution is input to model the runoff hydrograph. SEDCAD+ allows the user to choose between the SCS Type I and Type II Storms. The SCS Type II distribution was input as a geographical estimation of the area storms.

2.2 Storm Duration

A storm duration of 24 hours was used for the design and evaluation of the stormwater control system and represents the largest peak flow condition.

2.3 Return Period/Precipitation

A precipitation amount is required for the appropriate return period. As required by current regulations for the Triassic Park Landfill, the following precipitation amount was used for the design and evaluation of the stormwater control system (National Oceanic and Atmospheric Administration, 1973)

2-year, 24-hour event	2.1 inches
25-year, 24-hour event	4.3 inches
100-year, 24-hour event	5.3 inches

2.4 Hydrograph Response Shape

A unit hydrograph is chosen for each drainage area or sub-area model to predict the runoff response. The hydrograph responses available in the SEDCAD+ model are slow, medium, and fast. A slow response corresponds to a forested area or an area with a number of obstructions. A fast response corresponds to an unvegetated or poorly protected area. Medium hydrograph responses were chosen for disturbed and undisturbed areas.

The internal convolution increment is 0.05 hours and values are saved at the user specified interval of 0.1 hours or greater. A convolution increment of 0.1 was specified for the Triassic Park Landfill Area.

2.5 Drainage Basin Area

The drainage areas were determined by direct measurement from the U.S. Geological Survey, Mescalero Point quadrangle map, and a 1"=100' scale ariel survey topography map of the site. All basin areas are shown on the SEDCAD+ computer printouts in Attachment 1.

2.6 Time of Concentration, T_c

The time of concentration was calculated using the SCS upland method (a utility of SEDCAD+). All hydraulic lengths, drainage heights and slopes were measured directly from the above mentioned map and drawing. The calculated values for each structure are shown on the SEDCAD+ printouts in Attachment 1.

2.7 Muskingum Routing Parameters, K, X

The Muskingum Routing Parameters were also calculated using the SCS upland method. All hydraulic lengths, drainage heights and slopes were measured directly from the appropriate maps and drawings. The values calculated between each junction and/or subwatershed are shown on the SEDCAD+ printouts in Attachment 1.

2.8 Curve Number, CN

The run-off curve number is a factor relating the amount of rainfall to the amount of run-off for a given area. Curve numbers (CN) were evaluated based on vegetation and soil type for the given watershed. Vegetation was assumed based on anticipated cover vegetation. Indigenous surface soils types were obtained from the county Soil Conservation Service. The following curve numbers, presented in Table A-1, were assigned to area watersheds (U.S. Department of Commerce, 1986):

TABLE A-1
CURVE NUMBERS

AREA TYPE	HYDROLOGIC SOIL GROUP	VEGETATION	CURVE NUMBER
Final Cover	B	Herbaceous (Fair)	71
Facilities Disturbed	B	Newly Graded	86
Waste	C	Newly Graded	
Landfill Disturbed	D	Newly Graded	94
Undisturbed	B	Herbaceous (Fair)	71

3.0 CHANNEL DESIGNS

The surface water diversion dimensions were determined using Mannings Equation for open channel flow Channels with flow velocities less than 5 fps from a 25-year event will not require erosion protection. Channels with peak flow velocities greater than 5 fps from a 25-year event but less than 5 fps from and average storm (2-year event) will also not utilize erosion protection. During average storm events these channels should be stable, however, during major storm events the channels may show signs of erosion in some areas. These areas will be repaired as required following all major storm events. Channels with peak flow velocities greater than 5 fps from and average storm will be lined with gravel or riprap if required. To minimize sediment transport to receiving streams the East Channel and Final Cover Roadside Ditch will be lined with gravel.

Riprap sizes were determined using the SEDCAD+ subroutine for designing riprap lined channels, utilizing the PADER Method

All inputs and results are shown on the SEDCAD channel design computer printouts in Attachment 2.

A riprap apron will be constructed at the end of the East channel to dissipate the flow before entering the natural channel to help reduces erosion. The apron size and riprap requirement was designed using design curves relating culvert size, peak flow and taiwater conditions. The design calculations are shown in Attachment 3

All inputs and results are shown on the SEDCAD channel design computer printouts

4.0 CULVERT DESIGNS

The culverts were sized using the U.S. Bureau of Public Roads nomograph using a headwater/ diameter ratio of 1.5. The culvert design inputs and results are shown in Attachment 4 along with the nomographs.

5.0 PONDS

All three surface water detention basins are designed to contain the storm water discharge from the entire active site area given flows from a 25-year, 24-hour storm event. The total run-off for each basin was determined using SEDCAD+. All inputs and results are shown on the SEDCAD+ computer printouts in Attachment 1. The pond volumes were determine by determining the areas of the stages for every two

foot elevation and developing a stage storage table. The stage storage tables for each pond are shown in Attachment 5.

6.0 REFERENCES

Barfield, B.J., Warner, R.C., Haan, C.T., 1981, *Applied Hydrology and Sedimentology for Disturbed Areas.*

Warner, R.C., Schwab, P.J, 1992, *SEDCAD + Version 3.*

Urban Hydrology For Small Watersheds, TR-55, 1986, Soil Conservation Service, USDA

ATTACHMENT 1
SEDCAD+ COMPUTER PRINTOUTS

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

TRIASSIC PARK LANDFILL: FACILITIES DITCHES AND POND

by

Name: TEL

Company Name: ACZ, INC.
File Name: J:\602\SEDCAD\FACPOND

Date: 11-13-1997

Civil Software Design -- SEDCAD+ Version 3.1
Copyright (C) 1987-1992. Pamela J. Schwab. All rights reserved.

Company Name: ACZ, INC.
Filename: J:\602\SEDCAD\FACPOND User: TEL
Date: 11-13-1997 Time: 16:28:43
TRIASSIC PARK LANDFILL: FACILITIES DITCHES AND POND
Storm: 4.30 inches, 25 year-24 hour, SCS Type II
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	32.80	71	M	0.348	0.000	0.000	0.0	4.38	34.18
		Type: Null			Label: DITCH 1					
111	Structure	32.80							4.38	
111	Total IN/OUT	32.80							4.38	34.18
121	1	77.80	71	M	0.595	0.000	0.000	0.0	10.39	62.20
		Type: Null			Label: DITCH 2					
121	Structure	77.80							10.39	
121	Total IN/OUT	77.80							10.39	62.20
211	1	104.10	86	M	0.852	0.000	0.000	0.0	24.46	126.62
		Type: Null			Label: DITCH 3					
211	Structure	104.10							39.24	
211	Total IN/OUT	214.70							39.24	210.67
111 to 211 Routing						0.009	0.277			
221	1	4.40	86	M	0.563	0.000	0.000	0.0	1.03	6.78
		Type: Null			Label: DITCH 4					
221	Structure	4.40							1.03	
221	Total IN/OUT	4.40							1.03	6.78
311	1	4.50	86	M	0.099	0.000	0.000	0.0	1.06	12.35
		Type: Null			Label: DITCH 5					
311	Structure	4.50							41.33	
311	Total IN/OUT	223.60							41.33	217.26
211 to 311 Routing						0.078	0.277			
321	1	15.60	86	M	0.330	0.000	0.000	0.0	3.67	30.08
		Type: Null			Label: DITCH 6					
321	Structure	15.60							3.67	
321	Total IN/OUT	15.60							3.67	30.08

```
411  1                 8.30   86  M   0.166  0.000 0.000    0.0    1.95    19.65
411  2                 8.20   71  M   0.561  0.000 0.000    0.0    1.10     6.78
411  3                 9.80   98  F   0.001  0.000 0.000    0.0    3.32    32.12
                       Type: Null   Label: STORMWATER POND
411 Structure         26.30                                          51.36
 ---------------------------------------------------------------------------------
411 Total IN/OUT     265.50                                          51.36   254.54
=================================================================================
311 to 411 Routing                            0.000 0.486
=================================================================================
```

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

TRIASSIC PARK LANDFILL: FACILITIES DITCHES AND POND

by

Name: TEL

Company Name: ACZ, INC.
File Name: J:\602\SEDCAD\FACPOND

Date: 11-13-1997

Civil Software Design -- SEDCAD+ Version 3.1
Copyright (C) 1987-1992. Pamela J. Schwab. All rights reserved.

Company Name: ACZ, INC.
Filename: J:\602\SEDCAD\FACPOND User: TEL
Date: 11-13-1997 Time: 16:28:50
TRIASSIC PARK LANDFILL: FACILITIES DITCHES AND POND
Storm: 5.30 inches, 100 year-24 hour, SCS Type II
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	32.80	71	M	0.348	0.000	0.000	0.0	6.41	51.20
		Type: Null				Label: DITCH 1				
111	Structure	32.80							6.41	
111	Total IN/OUT	32.80							6.41	51.20
121	1	77.80	71	M	0.595	0.000	0.000	0.0	15.21	94.05
		Type: Null				Label: DITCH 2				
121	Structure	77.80							15.21	
121	Total IN/OUT	77.80							15.21	94.05
211	1	104.10	86	M	0.852	0.000	0.000	0.0	32.51	167.98
		Type: Null				Label: DITCH 3				
211	Structure	104.10							54.13	
211	Total IN/OUT	214.70							54.13	295.37
111 to 211 Routing						0.009	0.277			
221	1	4.40	86	M	0.563	0.000	0.000	0.0	1.37	8.98
		Type: Null				Label: DITCH 4				
221	Structure	4.40							1.37	
221	Total IN/OUT	4.40							1.37	8.98
311	1	4.50	86	M	0.099	0.000	0.000	0.0	1.41	15.99
		Type: Null				Label: DITCH 5				
311	Structure	4.50							56.91	
311	Total IN/OUT	223.60							56.91	302.93
211 to 311 Routing						0.078	0.277			
321	1	15.60	86	M	0.330	0.000	0.000	0.0	4.87	39.73
		Type: Null				Label: DITCH 6				
321	Structure	15.60							4.87	
321	Total IN/OUT	15.60							4.87	39.73

411	1	8.30	86	M	0.166	0.000	0.000	0.0	2.59	25.80
411	2	8.20	71	M	0.561	0.000	0.000	0.0	1.60	10.24
411	3	9.80	98	F	0.001	0.000	0.000	0.0	4.13	39.66
		Type: Null			Label: STORMWATER POND					
411 Structure		26.30							70.12	
411 Total IN/OUT		265.50							70.12	357.97
311 to 411 Routing						0.000	0.486			

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

TRIASSIC PARK LANDFILL: FACILITIES DITCHES AND POND

by

Name: TEL

Company Name: ACZ, INC.
File Name: J:\602\SEDCAD\FACPOND

Date: 11-14-1997

Civil Software Design -- SEDCAD+ Version 3.1
Copyright (C) 1987-1992. Pamela J. Schwab. All rights reserved.

Company Name: ACZ, INC.
Filename: J:\602\SEDCAD\FACPOND User: TEL
Date: 11-14-1997 Time: 09:55:46
TRIASSIC PARK LANDFILL: FACILITIES DITCHES AND POND
Storm: 2.10 inches, 2 year-24 hour, SCS Type II
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	32.80	71	M	0.348	0.000	0.000	0.0	0.84	4.77
		Type: Null			Label: DITCH 1					
111	Structure	32.80							0.84	
111	Total IN/OUT	32.80							0.84	4.77
121	1	77.80	71	M	0.595	0.000	0.000	0.0	1.99	8.34
		Type: Null			Label: DITCH 2					
121	Structure	77.80							1.99	
121	Total IN/OUT	77.80							1.99	8.34
211	1	104.10	86	M	0.852	0.000	0.000	0.0	8.03	40.04
		Type: Null			Label: DITCH 3					
211	Structure	104.10							10.85	
211	Total IN/OUT	214.70							10.85	51.23
111 to 211 Routing						0.009	0.277			
221	1	4.40	86	M	0.563	0.000	0.000	0.0	0.34	2.16
		Type: Null			Label: DITCH 4					
221	Structure	4.40							0.34	
221	Total IN/OUT	4.40							0.34	2.16
311	1	4.50	86	M	0.099	0.000	0.000	0.0	0.35	4.43
		Type: Null			Label: DITCH 5					
311	Structure	4.50							11.54	
311	Total IN/OUT	223.60							11.54	53.64
211 to 311 Routing						0.078	0.277			
321	1	15.60	86	M	0.330	0.000	0.000	0.0	1.20	9.80
		Type: Null			Label: DITCH 6					
321	Structure	15.60							1.20	
321	Total IN/OUT	15.60							1.20	9.80

411	1	8.30	86	M	0.166	0.000	0.000	0.0	0.64	6.61
411	2	8.20	71	M	0.561	0.000	0.000	0.0	0.21	0.91
411	3	9.80	98	F	0.001	0.000	0.000	0.0	1.53	15.47
		Type: Null			Label: STORMWATER POND					
411 Structure		26.30							15.12	
411 Total IN/OUT		265.50							15.12	64.78
311 to 411 Routing						0.000	0.486			

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

TRIASSIC PARK LANDFILL: RAMP DITCHES & CLAENWATER COLLECTION POND

by

Name: TEL

Company Name: ACZ, INC.
File Name: J:\602\SEDCAD\COLBASIN

Date: 11-14-1997

Civil Software Design -- SEDCAD+ Version 3.1
Copyright (C) 1987-1992. Pamela J. Schwab. All rights reserved.

Company Name: ACZ, INC.
Filename: J:\602\SEDCAD\COLBASIN User: TEL
Date: 11-14-1997 Time: 13:22:41
TRIASSIC PARK LANDFILL: RAMP DITCHES & CLAENWATER COLLECTION POND
Storm: 4.30 inches, 25 year-24 hour, SCS Type II
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	2.30	94	F	0.026	0.000	0.000	0.0	0.69	7.27
		Type: Null			Label: DITCH 7					
111	Structure	2.30							0.69	
111	Total IN/OUT	2.30							0.69	7.27
121	1	6.10	94	F	0.071	0.000	0.000	0.0	1.84	19.29
		Type: Null			Label: DITCH 8					
121	Structure	6.10							1.84	
121	Total IN/OUT	6.10							1.84	19.29
211	1	6.60	94	F	0.046	0.000	0.000	0.0	1.99	20.88
		Type: Null			Label: COLLECTION POND					
211	Structure	6.60							4.52	
211	Total IN/OUT	15.00							4.52	47.44
111 to 211 Routing						0.000	0.486			

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

GANDY TRIASSIC PARK LANDFILL : SITE PERIMETER DITCH

by

Name: DGG

Company Name: ACZ, INC.
File Name: J:\602\SEDCAD\OFFSITE

Date: 11-08-1997

Civil Software Design -- SEDCAD+ Version 3.1
Copyright (C) 1987-1992. Pamela J. Schwab. All rights reserved.

Company Name: ACZ, INC.
Filename: J:\602\SEDCAD\OFFSITE User: DGG
Date: 11-08-1997 Time: 13:07:58
GANDY TRIASSIC PARK LANDFILL : SITE PERIMETER DITCH
Storm: 4.30 inches, 25 year-24 hour, SCS Type II
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	377.80	71	M	0.709	0.000	0.000	0.0	50.47	272.76
		Type: Null			Label: EAST DITCH					
111	Structure	377.80							50.47	
111	Total IN/OUT	377.80							50.47	272.76

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

GANDY TRIASSIC PARK LANDFILL : FINAL COVER ROADSIDE DITCH

by

Name: DGG

Company Name: ACZ, INC.
File Name: J:\602\SEDCAD\ROADSIDE

Date: 11-07-1997

Civil Software Design -- SEDCAD+ Version 3.1
Copyright (C) 1987-1992. Pamela J. Schwab. All rights reserved.

Company Name: ACZ, INC.
Filename: J:\602\SEDCAD\ROADSIDE User: DGG
Date: 11-07-1997 Time: 15:14:00
GANDY TRIASSIC PARK LANDFILL : FINAL COVER ROADSIDE DITCH
Storm: 4.30 inches, 25 year-24 hour, SCS Type II
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	27.00	71	M	0.258	0.000	0.000	0.0	3.61	31.53
		Type: Null			Label: ROADSIDE DITCH					
111	Structure	27.00							3.61	
111	Total IN/OUT	27.00							3.61	31.53

CIVIL SOFTWARE DESIGN

SEDCAD+ Version 3

GANDY : LANDFILL PHASE 1 RUN-OFF

by

Name: TEL

Company Name: ACZ, INC.
File Name: J:\602\SEDCAD\LANDFILL

Date: 11-08-1997

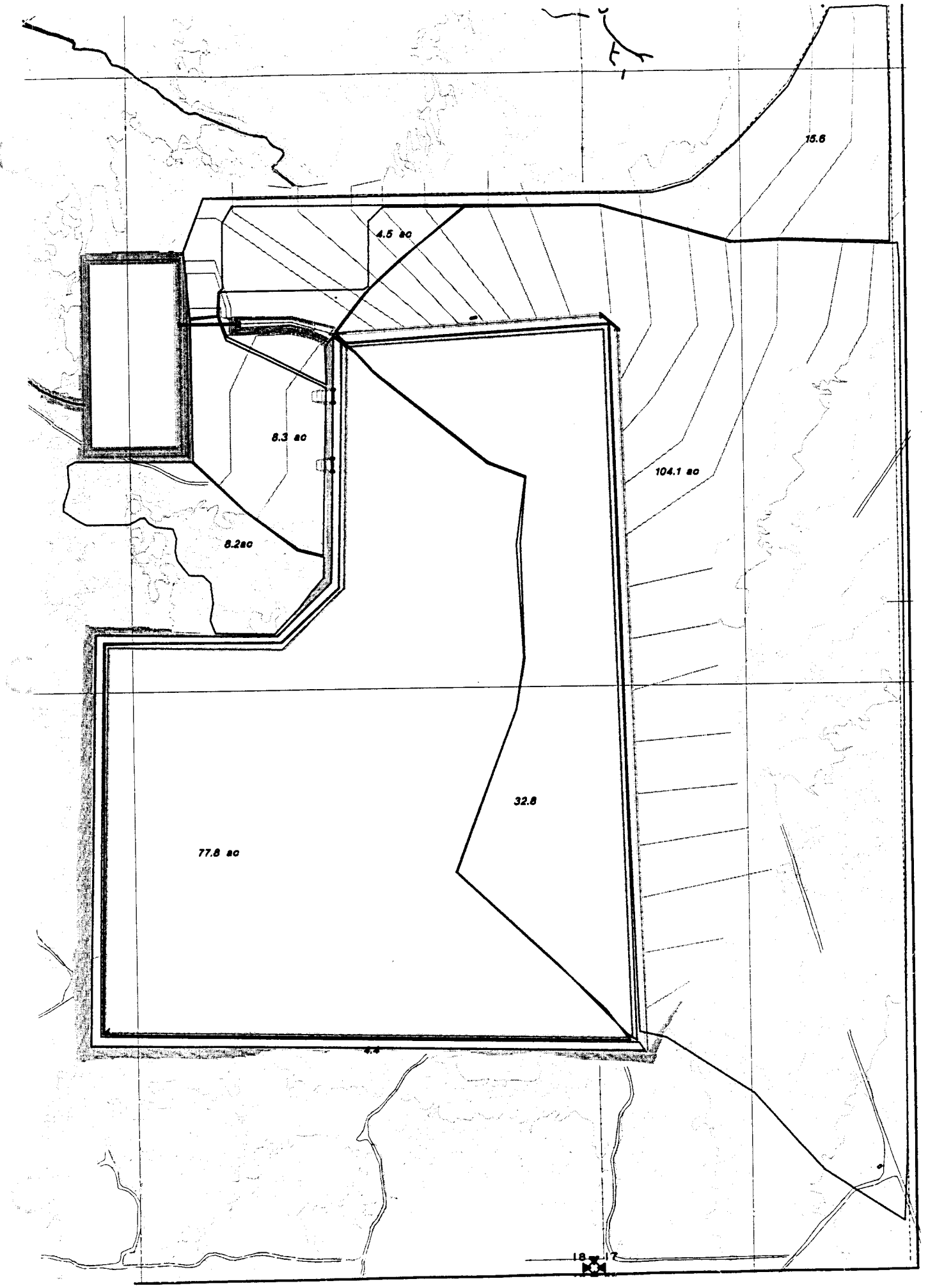
Civil Software Design -- SEDCAD+ Version 3.1
Copyright (C) 1987-1992. Pamela J. Schwab. All rights reserved.

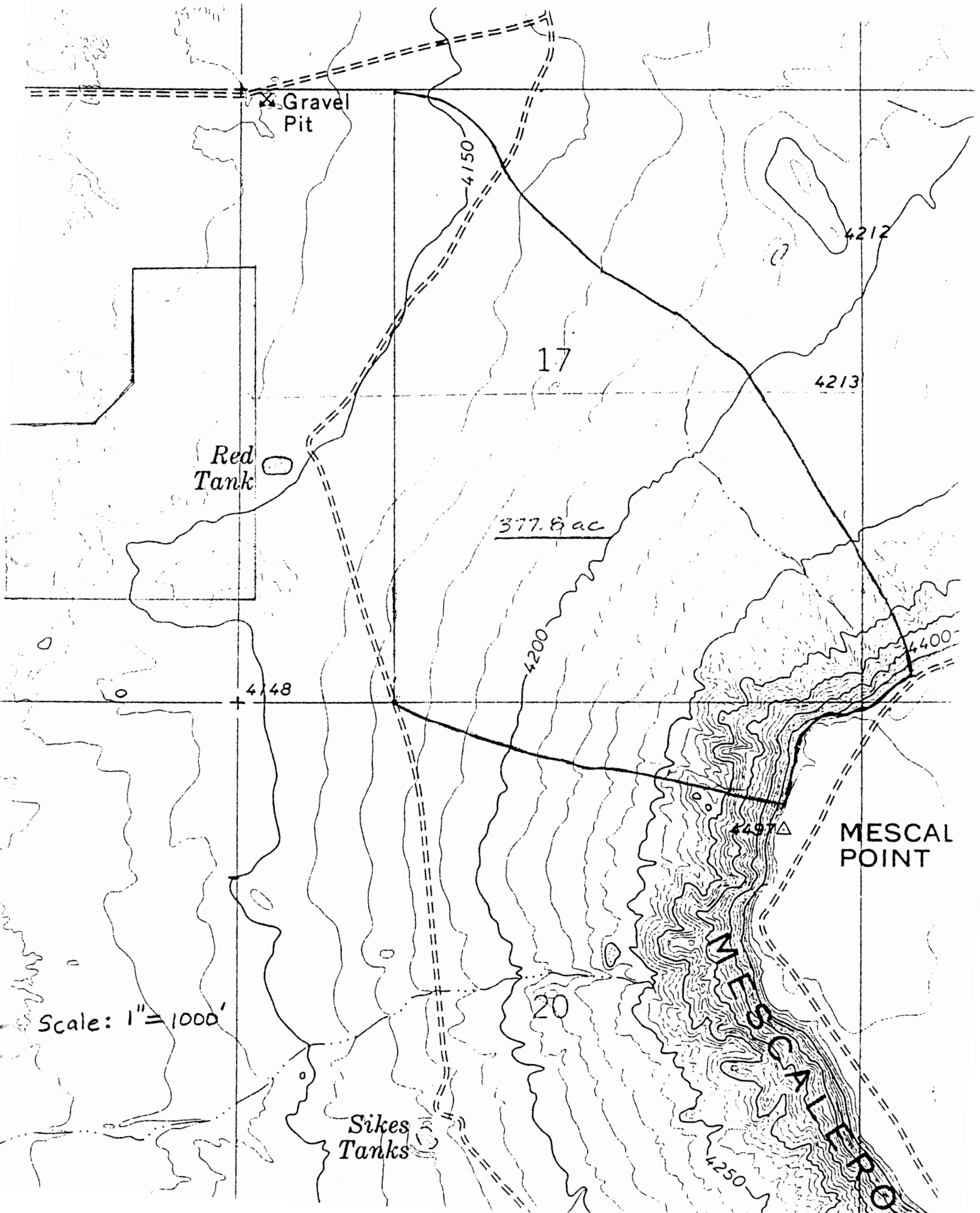
Company Name: ACZ, INC.
Filename: J:\602\SEDCAD\LANDFILL User: TEL
Date: 11-08-1997 Time: 16:23:38
GANDY : LANDFILL PHASE 1 RUN-OFF
Storm: 4.30 inches, 25 year-24 hour, SCS Type II
Hydrograph Convolution Interval: 0.1 hr

SUBWATERSHED/STRUCTURE INPUT/OUTPUT TABLE

-Hydrology-

JBS	SWS	Area (ac)	CN	UHS	Tc (hrs)	K (hrs)	X	Base-Flow (cfs)	Runoff Volume (ac-ft)	Peak Discharge (cfs)
111	1	15.60	91	M	0.070	0.000	0.000	0.0	4.30	47.23
		Type: Null			Label: PHASE 1 LANDFILL					
111	Structure	15.60							4.30	
111	Total IN/OUT	15.60							4.30	47.23


15.6
4.5 ac
8.3 ac
104.1 ac
8.2ac
32.8
77.8 ac
18
17


Gravel Pit
4150
4212
17
4213
Red Tank
377.8 ac
4200
4400
4148
4497
MESCAL POINT
MESCAL RO
Scale: 1" = 1000'
20
Sikes Tanks
4250

ATTACHMENT 2
CHANNEL DESIGNS

TRIASSIC PARK LANDFILL

CHANNEL DESIGNS

Ditch	25-yr,24-hr Flow Q (cfs)	Slope (%)	Bottom Width (ft)	Side Slope (H:1V)	Depth of Flow (ft)	Velocity (fps)	Freeboard (ft)	Minimum Total Depth (ft)	Erosion Protection	2 -yr,24-hr Flow Q (cfs)	Velocity (fps)
1	34.2	0.5-2.0	0	2	2.1	6.7	0.3	2.4	None	4.8	4.3
2	62.2	0.5-1.0	0	2	2.6	6.0	0.3	2.9	None	8.3	3.6
3	126.6	0.5-1	5	3	2.4	5.75	0.3	2.7	None	40	4.8
		1.1-2	5	3	2.1	6.6	0.3	2.3	Riprap D50=6"		
4	6.8	0.5-1.0	0	2	1.1	3.5	0.3	1.4	None		
5	217.3	0.5-1.0	10	2	2.3	7.3	0.3	2.6	None	53.6	5.0
6	30.1	0.5-1	0	2	2.0	5.0	0.3	2.3	None		
7 Lower	7.3	1	0	1.5	0.9	6.0	0.3	1.2	HDPE		
7 Upper	7.3	10	0	1.5	0.6	14.2	0.3	0.9	HDPE		
8 Lower	19.3	1	0	1.5	1.3	7.6	0.3	1.6	HDPE		
8 Upper	19.3	10	0	1.5	0.8	18	0.3	1.1	HDPE		
East	272.8	0.5-0.8	16	3	2.3	6.0	0.3	2.6	Gravel D50=3"		
Final Cover Road Side	31.5	0.5-2.4	0	3	1.8	5.7	0.3	2.1	Gravel D50=3"		
Spillway	358	0.5	20	3	2.4	5.4	1.0	3.4	Gravel D50=3"		

Notes:

(1) Maximum allowable velocity for channels without erosion protection 5 fps.

(2) Channels with velocities greater than 5 fps for the 25-year event and less than 5 fps for the 2 year storm will not be lined. These channels will be repaired after major storm events.

(3) Maximum allowable velocity for gravel lined channels is 6 fps

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 1

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	34.20 cfs	
Slope	0.50 %	
Sideslopes	2.00:1 (L)	2.00:1 (R)
Manning's n	0.025	
Material	STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	2.07 ft
with Freeboard	2.37 ft
Top Width	8.27 ft
with Freeboard	9.47 ft
Velocity	4.00 fps
Cross Sectional Area	8.55 sq ft
Hydraulic Radius	0.92 ft
Froude Number	0.69

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 1

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	34.20 cfs	
Slope	2.00 %	
Sideslopes	2.00:1 (L)	2.00:1 (R)
Manning's n	0.025	
Material	STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	1.59 ft
with Freeboard	1.89 ft
Top Width	6.38 ft
with Freeboard	7.58 ft
Velocity	6.73 fps
Cross Sectional Area	5.08 sq ft
Hydraulic Radius	0.71 ft
Froude Number	1.33

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 1

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	4.80 cfs	
Slope	2.00 %	
Sideslopes	2.00:1 (L)	2.00:1 (R)
Manning's n	0.025	
Material	STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	0.76 ft
with Freeboard	1.06 ft
Top Width	3.05 ft
with Freeboard	4.25 ft
Velocity	4.12 fps
Cross Sectional Area	1.17 sq ft
Hydraulic Radius	0.34 ft
Froude Number	1.17

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 2

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	62.20 cfs	
Slope	0.50 %	
Sideslopes	2.00:1 (L)	2.00:1 (R)
Manning's n	0.025	
Material	STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	2.59 ft
with Freeboard	2.89 ft
Top Width	10.35 ft
with Freeboard	11.55 ft
Velocity	4.65 fps
Cross Sectional Area	13.39 sq ft
Hydraulic Radius	1.16 ft
Froude Number	0.72

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 2

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	62.20 cfs	
Slope	1.00 %	
Sideslopes	2.00:1 (L)	2.00:1 (R)
Manning's n	0.025	
Material	STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	2.27 ft
with Freeboard	2.57 ft
Top Width	9.09 ft
with Freeboard	10.29 ft
Velocity	6.02 fps
Cross Sectional Area	10.33 sq ft
Hydraulic Radius	1.02 ft
Froude Number	1.00

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 2

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	8.30 cfs	
Slope	1.00 %	
Sideslopes	2.00:1 (L)	2.00:1 (R)
Manning's n	0.025	
Material	STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	1.07 ft
with Freeboard	1.37 ft
Top Width	4.27 ft
with Freeboard	5.47 ft
Velocity	3.64 fps
Cross Sectional Area	2.28 sq ft
Hydraulic Radius	0.48 ft
Froude Number	0.88

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 3

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	126.60 cfs	
Slope	0.50 %	
Sideslopes	3.00:1 (L)	3.00:1 (R)
Bottom Width	5.00 ft	
Manning's n	0.030	
Material	STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	2.36 ft
with Freeboard	2.66 ft
Top Width	19.13 ft
with Freeboard	20.93 ft
Velocity	4.45 fps
Cross Sectional Area	28.42 sq ft
Hydraulic Radius	1.43 ft
Froude Number	0.64

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 3

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	126.60 cfs	
Slope	1.00 %	
Sideslopes	3.00:1 (L)	3.00:1 (R)
Bottom Width	5.00 ft	
Manning's n	0.030	
Material	STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	2.00 ft
with Freeboard	2.30 ft
Top Width	17.00 ft
with Freeboard	18.80 ft
Velocity	5.75 fps
Cross Sectional Area	22.01 sq ft
Hydraulic Radius	1.25 ft
Froude Number	0.89

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 3

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	40.00 cfs	
Slope	1.00 %	
Sideslopes	3.00:1 (L)	3.00:1 (R)
Bottom Width	5.00 ft	
Manning's n	0.025	
Material	STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	1.03 ft
with Freeboard	1.33 ft
Top Width	11.18 ft
with Freeboard	12.98 ft
Velocity	4.80 fps
Cross Sectional Area	8.33 sq ft
Hydraulic Radius	0.72 ft
Froude Number	0.98

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 3

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	126.60 cfs	
Slope	1.10 %	
Sideslopes	3.00:1 (L)	3.00:1 (R)
Bottom Width	5.00 ft	
Manning's n	0.035	
Material	6" RIPRAP	
Freeboard	.3 ft	

RESULTS:

Depth	2.10 ft
with Freeboard	2.40 ft
Top Width	17.62 ft
with Freeboard	19.42 ft
Velocity	5.32 fps
Cross Sectional Area	23.80 sq ft
Hydraulic Radius	1.30 ft
Froude Number	0.81

SEDCAD+ RIPRAP CHANNEL DESIGN

DITCH 3

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	126.60 cfs	
Slope	2.00 %	
Sideslopes (L and R)	3.00:1	3.00:1
Bottom Width	5.00 feet	
Freeboard	.3 ft	

RESULTS:

Steep Slope Design - PADER Method

Depth	1.82 ft
with Freeboard	2.12 ft
Top Width	15.94 ft
with Freeboard	17.74 ft
Velocity	6.63 fps
Cross Sectional Area	19.10 sq ft
Hydraulic Radius	1.16 ft
Manning's n	0.035
Froude Number	1.07
Dmax	0.625 ft (7.50 in)
D50	0.500 ft (6.00 in)
D10	0.167 ft (2.00 in)

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 4

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	6.80 cfs	
Slope	0.50 %	
Sideslopes	2.00:1 (L)	2.00:1 (R)
Manning's n	0.025	
Material	STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	1.13 ft
with Freeboard	1.43 ft
Top Width	4.51 ft
with Freeboard	5.71 ft
Velocity	2.67 fps
Cross Sectional Area	2.55 sq ft
Hydraulic Radius	0.50 ft
Froude Number	0.63

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 4

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	6.80 cfs	
Slope	1.00 %	
Sideslopes	2.00:1 (L)	2.00:1 (R)
Manning's n	0.025	
Material	.STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	0.99 ft
with Freeboard	1.29 ft
Top Width	3.96 ft
with Freeboard	5.16 ft
Velocity	3.46 fps
Cross Sectional Area	1.96 sq ft
Hydraulic Radius	0.44 ft
Froude Number	0.87

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 5

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	217.30 cfs	
Slope	0.50 %	
Sideslopes	3.00:1 (L)	3.00:1 (R)
Bottom Width	10.00 ft	
Manning's n	0.025	
Material	.STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	2.27 ft
with Freeboard	2.57 ft
Top Width	23.63 ft
with Freeboard	25.43 ft
Velocity	5.69 fps
Cross Sectional Area	38.21 sq ft
Hydraulic Radius	1.57 ft
Froude Number	0.79

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 5

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	217.30 cfs	
Slope	1.00 %	
Sideslopes	3.00:1 (L)	3.00:1 (R)
Bottom Width	10.00 ft	
Manning's n	0.025	
Material	.STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	1.90 ft
with Freeboard	2.20 ft
Top Width	21.39 ft
with Freeboard	23.19 ft
Velocity	7.29 fps
Cross Sectional Area	29.79 sq ft
Hydraulic Radius	1.35 ft
Froude Number	1.09

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 5

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	53.60 cfs	
Slope	1.00 %	
Sideslopes	2.00:1 (L)	2.00:1 (R)
Bottom Width	10.00 ft	
Manning's n	0.025	
Material	STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	0.91 ft
with Freeboard	1.21 ft
Top Width	13.64 ft
with Freeboard	14.84 ft
Velocity	4.98 fps
Cross Sectional Area	10.76 sq ft
Hydraulic Radius	0.76 ft
Froude Number	0.99

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 6

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	30.10 cfs	
Slope	0.50 %	
Sideslopes	2.00:1 (L)	2.00:1 (R)
Manning's n	0.025	
Material	STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	1.97 ft
with Freeboard	2.27 ft
Top Width	7.88 ft
with Freeboard	9.08 ft
Velocity	3.87 fps
Cross Sectional Area	7.77 sq ft
Hydraulic Radius	0.88 ft
Froude Number	0.69

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 6

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	30.10 cfs	
Slope	1.00 %	
Sideslopes	2.00:1 (L)	2.00:1 (R)
Manning's n	0.025	
Material	STIFF CLAY	
Freeboard	.3 ft	

RESULTS:

Depth	1.73 ft
with Freeboard	2.03 ft
Top Width	6.92 ft
with Freeboard	8.12 ft
Velocity	5.02 fps
Cross Sectional Area	5.99 sq ft
Hydraulic Radius	0.77 ft
Froude Number	0.95

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 7 LOWER

INPUT VALUES:

Shape	TRIANGULAR		
Discharge	7.30 cfs		
Slope	1.00 %		
Sideslopes	1.50:1 (L)	1.50:1 (R)	
Manning's n	0.013		
Material	HDPE		
Freeboard	.3 ft		

RESULTS:

Depth	0.90 ft
with Freeboard	1.20 ft
Top Width	2.71 ft
with Freeboard	3.61 ft
Velocity	5.97 fps
Cross Sectional Area	1.22 sq ft
Hydraulic Radius	0.38 ft
Froude Number	1.57

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 7 UPPER

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	7.30 cfs	
Slope	10.00 %	
Sideslopes	1.50:1 (L)	1.50:1 (R)
Manning's n	0.013	
Material	HDPE	
Freeboard	.3 ft	

RESULTS:

Depth	0.59 ft
with Freeboard	0.89 ft
Top Width	1.76 ft
with Freeboard	2.66 ft
Velocity	14.15 fps
Cross Sectional Area	0.52 sq ft
Hydraulic Radius	0.24 ft
Froude Number	4.61

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 8 LOWER

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	19.30 cfs	
Slope	1.00 %	
Sideslopes	1.50:1 (L)	1.50:1 (R)
Manning's n	0.013	
Material	HDPE	
Freeboard	.3 ft	

RESULTS:

Depth	1.30 ft
with Freeboard	1.60 ft
Top Width	3.90 ft
with Freeboard	4.80 ft
Velocity	7.61 fps
Cross Sectional Area	2.54 sq ft
Hydraulic Radius	0.54 ft
Froude Number	1.66

SEDCAD+ NONERODIBLE CHANNEL DESIGN

DITCH 8 UPPER

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	19.30 cfs	
Slope	10.00 %	
Sideslopes	1.50:1 (L)	1.50:1 (R)
Manning's n	0.013	
Material	HDPE	
Freeboard	.3 ft	

RESULTS:

Depth	0.84 ft
with Freeboard	1.14 ft
Top Width	2.53 ft
with Freeboard	3.43 ft
Velocity	18.04 fps
Cross Sectional Area	1.07 sq ft
Hydraulic Radius	0.35 ft
Froude Number	4.89

SEDCAD+ NONERODIBLE CHANNEL DESIGN

EAST DITCH

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	272.80 cfs	
Slope	0.50 %	
Sideslopes	3.00:1 (L)	3.00:1 (R)
Bottom Width	16.00 ft	
Manning's n	0.030	
Material	GRAVEL	
Freeboard	.3 ft	

RESULTS:

Depth	2.33 ft
with Freeboard	2.63 ft
Top Width	29.99 ft
with Freeboard	31.79 ft
Velocity	5.09 fps
Cross Sectional Area	53.62 sq ft
Hydraulic Radius	1.74 ft
Froude Number	0.67

SEDCAD+ NONERODIBLE CHANNEL DESIGN

EAST DITCH

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	272.80 cfs	
Slope	0.80 %	
Sideslopes	3.00:1 (L)	3.00:1 (R)
Bottom Width	16.00 ft	
Manning's n	0.030	
Material	GRAVEL	
Freeboard	.3 ft	

RESULTS:

Depth	2.05 ft
with Freeboard	2.35 ft
Top Width	28.31 ft
with Freeboard	30.11 ft
Velocity	6.00 fps
Cross Sectional Area	45.48 sq ft
Hydraulic Radius	1.57 ft
Froude Number	0.83

SEDCAD+ NONERODIBLE CHANNEL DESIGN

FINAL COVER ROAD SIDE DITCH

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	31.50 cfs	
Slope	0.50 %	
Sideslopes	3.00:1 (L)	3.00:1 (R)
Manning's n	0.030	
Material	GRAVEL	
Freeboard	.3 ft	

RESULTS:

Depth	1.82 ft
with Freeboard	2.12 ft
Top Width	10.90 ft
with Freeboard	12.70 ft
Velocity	3.18 fps
Cross Sectional Area	9.90 sq ft
Hydraulic Radius	0.86 ft
Froude Number	0.59

SEDCAD+ NONERODIBLE CHANNEL DESIGN

FINAL COVER ROAD SIDE DITCH

INPUT VALUES:

Shape	TRIANGULAR	
Discharge	31.50 cfs	
Slope	2.40 %	
Sideslopes	3.00:1 (L)	3.00:1 (R)
Manning's n	0.030	
Material	GRAVEL	
Freeboard	.3 ft	

RESULTS:

Depth	1.35 ft
with Freeboard	1.65 ft
Top Width	8.12 ft
with Freeboard	9.92 ft
Velocity	5.73 fps
Cross Sectional Area	5.50 sq ft
Hydraulic Radius	0.64 ft
Froude Number	1.23

SEDCAD+ NONERODIBLE CHANNEL DESIGN

INPUT VALUES:

Shape	TRAPEZOIDAL	
Discharge	358.00 cfs	
Slope	0.50 %	
Sideslopes	3.00:1 (L)	3.00:1 (R)
Bottom Width	20.00 ft	
Manning's n	0.030	
Material	GRAVEL	
Freeboard	1 ft	

RESULTS:

Depth	2.44 ft
with Freeboard	3.44 ft
Top Width	34.67 ft
with Freeboard	40.67 ft
Velocity	5.36 fps
Cross Sectional Area	66.82 sq ft
Hydraulic Radius	1.88 ft
Froude Number	0.68

ATTACHMENT 3
APRON DESIGN

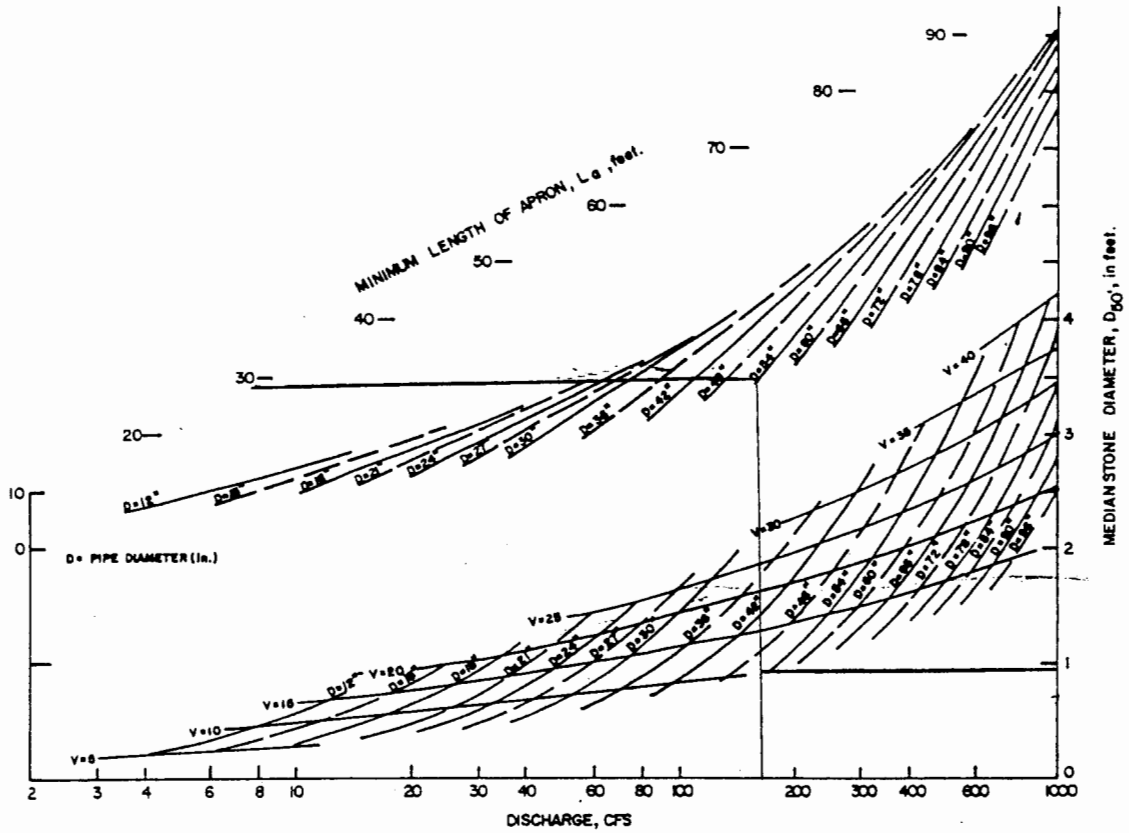


Figure 7.25. Design of outlet protection - minimum tailwater condition, $T_W < 0.5D$. (U.S. EPA, 1976)

Apron Calculation East Ditch

Flow 272 cfs (136 cfs per culvert)

Culverts 2 - 54 "ϕ

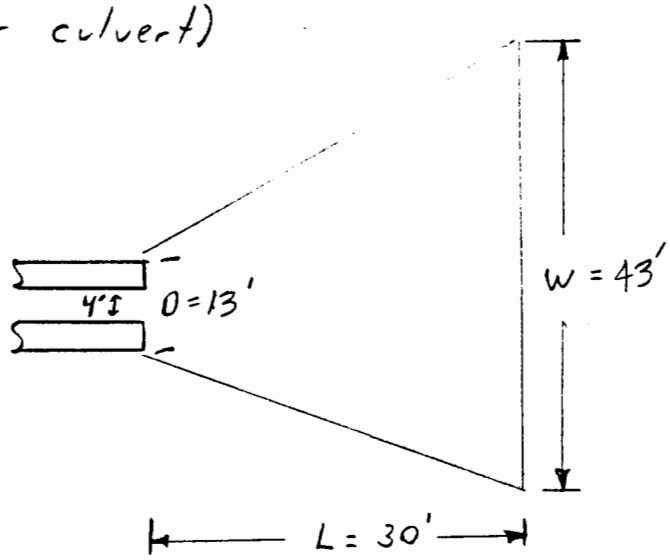
D_{50} = 1'

Apron Length L = 30'

Apron Width = W = D + L

= 13 + 30

= 43'



ATTACHMENT 4
CULVERT DESIGNS

CULVERT SUMMARY

Project: Triassic Park Landfill
Project Number: 602
Prepared by: D. Gleason

Channel	Flow Q (cfs)	Culvert Capacity (cfs)	No. of Culverts (1)	Culvert Dia. (in.)	Total Capacity (cfs)
East Ditch	272.8	155	2	54	310
Ditch 1 and 2	96.4	50	2	36	100
Ditch 3	126.6	50	3	36	150
Ditch 4	6.8	9	1	18	9
Ditch 5	217.3	135	2	54	270

Note:
(1) Represents the number of culverts needed at each road crossing.

Facilities Retention Basin

Elev.	Area	Area	Avg.Area	Depth	Volume	Cul. Vol.
4106	254327	5.8385				
4108	267492	6.1408	5.9897	2	11.9793	11.9793
4110	280944	6.4496	6.2952	2	12.5904	24.5697
4112	294685	6.7650	6.6073	2	13.2146	37.7843
4114	308713	7.0871	6.9261	2	13.8521	51.6364
4116	323030	7.4157	7.2514	2	14.5028	66.1392

Phase 1 Liner Basin

Elev.	Area	Area	Avg.Area	Depth	Volume	Cul. Vol.
4050	7000	0.1607				
4052	31400	0.7208	0.4408	2	0.8815	0.8815
4054	59500	1.3659	1.0434	2	2.0868	2.9683
4056	83300	1.9123	1.6391	2	3.2782	6.2466
4058	96096	2.2061	2.0592	2	4.1184	10.3649
4060	106300	2.4403	2.3232	2	4.6464	15.0113

Collection Basin

Elev.	Area	Area	Avg.Area	Depth	Volume	Cul. Vol.
4050	125	0.0029				
4052	13787	0.3165	0.1597	2	0.3194	0.3194
4054	27405	0.6291	0.4728	2	0.9456	1.2650
4056	42342	0.9720	0.8006	2	1.6012	2.8662
4058	58600	1.3453	1.1587	2	2.3173	5.1835
4060	69100	1.5863	1.4658	2	2.9316	8.1151

Appendix G

Prepared for:

TRIASSIC PARK WASTE DISPOSAL FACILITY
Post Office Box 827
1109 E. Broadway
Tatum, New Mexico 88267

ACTION LEAKAGE RATE AND RESPONSE ACTION PLAN FOR LANDFILL PHASE 1, 2, AND 3 AND EVAPORATION POND TRIASSIC PARK WASTE DISPOSAL FACILITY CHAVES COUNTY, NEW MEXICO

December 1997

Final

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B	Evaporation Pond ALR Calculation

1.0 INTRODUCTION

An Action Leakage Rate (ALR) and Response Action Plan (RAP) for the proposed Triassic Park Hazardous Waste Facility landfill and evaporation pond is required under 40 CFR Parts 264.302 and 304. A three phased landfill and a two phased evaporation pond have been proposed as part of a RCRA Part B Permit Application dated November 1997. This report presents proposed ALRs based on the landfill and evaporation pond specific designs and calculation methodologies recommended by EPA. The ALR, as defined in the final rule published in January 29, 1992, is the maximum design flow rate that the leak detection and removal system (LDRS) may remove without the fluid head on the bottom liner exceeding one foot. The RAP describes the steps to be taken in the event the ALR is exceeded in the landfill or the evaporation pond. The RAP specifies the initial notifications, steps to be taken in response to the leakage rate being exceeded, and follow-up reports.

2.0 PROPOSED LANDFILL DESIGN

This section briefly describes aspects of the landfill designs relevant to the ALR and the RAP. Engineering drawings and technical specifications are included in the Revised Part B Permit Application dated November 1997.

2.1 LINER DESIGN

The landfill liner system consists of a single and composite liner. The liner system which applies to the base and slopes of the landfill is described below (from top to bottom).

- A minimum 2-foot thick protective soil layer.
- A leachate collection system consisting of:
  - ◊ a double sided geocomposite (geonet with a layer of geotextile bonded to both sides, transmissivity $\geq 2 \times 10^{-4}$ m^2/sec).
- A primary liner consisting of:
  - ◊ 60-mil high density polyethylene (HDPE) geomembrane.
- A leak detection and removal system consisting of:
  - ◊ a double sided geocomposite (geonet with a layer of geotextile bonded to both sides, transmissivity $\geq 1.2 \times 10^{-4}$ m^2/sec) .
- A secondary composite liner consisting of :
  - ◊ 60-mil HDPE geomembrane
  - ◊ a geosynthetic clay liner (GCL) with $k \leq 5 \times 10^{-9}$ cm/sec (bentonite sandwiched between two layers of geotextile)
- Six inches of prepared subgrade.

The liner system in the sump area differs from the liner system in the landfill base and slope areas due to the inclusion of drainage gravel ($k \geq 1.0$ cm/sec) and compacted clay ($k \leq 1 \times 10^{-7}$ cm/sec) in the base area of the leachate collection and removal sump and the leak detection and removal sump. The liner system in the landfill sump area is illustrated on Drawing No. 16, sump cross sections, Drawing No. 18, vadose, LDRS, LCRS cross sections and details - phase 1A.

2.2 LEACHATE COLLECTION AND REMOVAL SYSTEM, LEAK DETECTION AND REMOVAL SYSTEMS, AND VADOSE MONITORING SYSTEM

The gecomposite leachate collection and removal system (LCRS) installed above the primary geomembrane will collect liquid above the geomembrane and transmit it to the LCRS collection sump.

•

The leak detection and removal system (LDRS) installed above the secondary geomembrane will detect and collect liquid above the geomembrane and transmit it to the LDRS sump. The vadose monitoring sump will detect and collect fluid leakage from the LDRS sump.

2.2.1 LEACHATE COLLECTION AND REMOVAL SYSTEM

Liquid entering the LCRS will come from rainfall which percolates through the waste thereby generating leachate. The function of the LCRS is to transport this liquid to the sump where it can be removed so that hydraulic head on the primary liner is minimized.

Components of this system, in addition to those described above, include a lateral 8-inch diameter drainage pipe located along the minimum grade line in the floor of the landfill, an 18-inch diameter HDPE sump collection and slope riser pipe, and a 24-inch diameter steel vertical riser pipe. The floor pipe and slope riser pipe will be surrounded by a gravel envelope, separated from the surrounding soil by an 8 oz. non-woven geotextile filter. The vertical riser pipe system, which will extend from the center of the LCRS sump vertically through the waste and cover system, provides a second access to the LCRS from which leachate can be removed. Accumulated liquids will be removed from the leachate collection sump by pumping either through the slope riser pipe or through the vertical riser pipe. A submersible pump will be used for leachate removal.

2.2.2 LEAK DETECTION AND REMOVAL SYSTEM

The potential sources of liquid entering the LDRS include primary liner leakage and consolidation water from the primary sump's clay liner. To meet the design requirements, the leak detection system must be able to collect and transmit liquid to the leak detection sump so that it can be removed.

The LDRS will be installed above the secondary composite liner on the landfill base and sideslopes. Should liquid enter the detection system, it will drain toward the collection sump via the LDRS drainage geocomposite and drainage pipe. Once in the sump, the liquid can be detected and removed via a riser pipe which extends up the slope of the landfill to the surface. The liquid will be pumped to the surface by a submersible pump.

2.2.3 VADOSE MONITORING SUMP

Sources of liquid entering the vadose sump include secondary liner leakage and consolidation water from the secondary sump's clay liner. The purpose of the vadose monitoring sump is to detect and remove leakage passing through both the primary and secondary liner systems. As with the LCRS sump and LDRS sump described above, liquid in the vadose sump will be pumped to the surface by a submersible pump.

3.0 PROPOSED EVAPORATION POND DESIGN

This section briefly describes aspects of the evaporation pond design relevant to the ALR and the RAP. Engineering drawings and technical specifications are included in the Revised Part B Permit dated November 1997.

3.1 LINER DESIGN

The evaporation pond liner system consists of a single and a composite liner. The liner system which applies to the base and slopes of the evaporation pond is described below (from top to bottom).

- A primary liner consisting of:
  - ◊ 60-mil HDPE geomembrane
- A leak detection system and removal system consisting of:
  - ◊ A geonet drainage layer (transmissivity $\geq 5 \times 10^{-3}$ m^2/sec) .
- A secondary composite liner consisting of :
  - ◊ A 60-mil HDPE geomembrane
  - ◊ A 3 foot thick compacted clay liner (CCL) with $k \leq 1 \times 10^{-7}$ cm/sec

The liner system in the sump area differs from the liner system elsewhere in the pond due to the inclusion of drainage gravel and geotextile cushion layers in the LDRS layer. Drawing No. 32, Evaporation Pond LDRS Plan and Details illustrates the liner sump liner system arrangement.

3.2 LEAK DETECTION AND REMOVAL SYSTEM AND VADOSE MONITORING SYSTEM

3.2.1 Leak Detection and Removal System

Liquid entering the LDRS will be the result of primary liner leakage. To meet design requirements, the LDRS must be able to collect and transmit liquid to the leak detection sump so that it can be removed.

The LDRS will be installed above the secondary composite liner on the evaporation pond floor and sideslopes. Should liquid enter the LDRS, it will drain toward the collection sump where it can be detected and removed via a slope riser pipe which extends up the side slope of the evaporation pond to the surface. The liquid will be pumped to the surface by a submersible pump.

3.2.2 Vadose Monitoring System

Sources of liquid entering the vadose sump include secondary liner leakage and consolidation water from the secondary clay liner. The purpose of the vadose monitoring sump is to detect

and remove leakage passing through the secondary liner systems. As with the LDRS sump described above, liquid in the vadose sump will be pumped to the surface by a submersible pump.

4.0 POTENTIAL SOURCES OF FLOW FROM THE LEAK DETECTION AND REMOVAL SYSTEM

Before ALRs and a RAP can be established for the potential sources of flow from the LDRS of the landfill and evaporation pond must be understood and the magnitudes of flow from the potential sources should be estimated. This understanding of the potential sources and magnitudes of flow is also useful in planning for the potential flow quantities and in identifying unusual flow conditions.

4.1 POTENTIAL SOURCES OF FLOW FROM THE LANDFILL LDRS

Potential source of flow from the landfill LDRS are:

- Precipitation that enters the leak detection layer during construction (hereafter referred to as construction water).
- Water expelled from consolidation of the clay components of the composite primary liner during landfill operations (hereafter referred to as consolidation water).
- Leakage through the primary liner.

These potential sources of liquid have been discussed in detail in the technical papers by Gross et al. (1990) and Bonaparte and Gross (1990). An evaluation of potential sources and magnitudes of flow from each of the sources discussed above is presented below:

Substantial flow rates of construction water are possible; however, since geocomposites do not exhibit significant capillarity, it is likely that the flow of construction water from the geocomposite and sump drainage gravel will be complete before waste placement begins.

The average consolidation water flow rate is dependent on the area, thickness, and degree of saturation of the primary clay component in the sump area; and rate of waste filling. Because the sump primary clay component is very small (limited to the sump area), consolidation water volumes are not expected to be significant.

The potential for leakage through the primary liner is the basis for the ALR and is discussed in Section 5.0.

4.2 POTENTIAL SOURCES OF FLOW FROM THE OF THE EVAPORATION POND LDRS

The source of flow from the evaporation pond LDRS is restricted to leakage through the primary geomembrane. Similar to the landfill, construction water will likely be removed from the LDRS prior to placement of waste liquids in the pond. Since there is no primary clay component in the pond liner system, consolidation water is not a potential source of liquids in the LDRS.

5.0 ACTION LEAKAGE RATE DETERMINATION

5.1 INTRODUCTION

As presented in Code of Federal Regulations, Title 40, Part 264, Rule '264.302 (40 CFR Rule 264.302):

> *The action leakage rate is the maximum design flow rate that the leak detection and removal system (LDRS) can remove without the fluid head on the bottom liner exceeding 1 foot. The action leakage rate must include an adequate safety margin to allow for uncertainties in the design (e.g., slope, hydraulic conductivity, thickness of drainage material), construction, operation, and location of the LDRS, waste and leachate characteristics, likelihood and amount of other sources of liquids in the LDRS and proposed response actions (e.g., the action leakage rate must consider decreases in the flow capacity of the system over time resulting from siltation and clogging, rib layover and creep of synthetic components of the system, overburden pressures, etc.).*

In other words, the ALR is the maximum design flow rate, including a safety factor, that the leak detection system can remove without the head on the bottom liner exceeding 1 ft.

5.2 DETERMINATION OF ACTION LEAKAGE RATE: LANDFILL

5.2.1 Equation for Geocomposite Flow Capacity

The leak detection drainage layer consists of a double sided geocomposite (geotextile/geocomposite/ geotextile). The maximum flow rate from a single hole in the primary HDPE liner that a geocomposite drainage layer can convey without the fluid head on the secondary liner exceeding a predetermined level is given by the following equation (USEPA 1992)

$$Q = k*D*(2h-D) \qquad \text{(Equation 1)}$$

where:

Q = the flow rate through a single hole in the primary liner;
k = the hydraulic conductivity of the leakage detection geocomposite drainage layer;
h = the head on the secondary liner; and
D = thickness of leak detection drain layer (geocomposite).

5.2.2 Design Parameters

<u>Hydraulic Conductivity</u>

The technical specifications require that over the base and side slopes of the landfill the geocomposite of the LDRS have a hydraulic transmissivity of at least 2.2×10^{-4} m^2/sec when subjected to testing conditions which include stress, hydraulic gradient, and boundary conditions similar to those anticipated in the field. The thickness of the geocomposite of the LDRS is 0.2 in. Using the specified hydraulic transmissivity of 2.2×10^{-4} m^2/sec (and adjusting the transmissivity by a total factor of safety of 3.3 to account for creep, chemical clogging, and sediment clogging) and geocomposite thickness of 0.2 in. results in a calculated hydraulic

conductivity of 1.3 cm/sec for the LDRS geocomposite drainage layer over the base of the landfill. Hydraulic transmissivity test results confirming that the specified geocomposite has this calculated hydraulic conductivity are required in the specifications and CQA Plan.

Head on Secondary Liner

The current Federal regulations require that the head on the liner should not exceed one foot. Therefore, one foot will be used for the calculated maximum head build-up on the secondary liner and the calculation of the ALR.

Geocomposite Thickness

A one foot head on the secondary liner does not mean that the flow thickness in the geocomposite is one foot (the geocomposite thickness is only 0.2 in.), it only means that the fluid pressure in the geocomposite directly beneath the hole in the primary liner could be equivalent to one foot of fluid head.

5.2.3 Discussion of Proposed Action Leakage Rates

The proposed ALR of 900 gpad is greater than the 100 gpad suggested by the USEPA (USEPA, 1992) for landfill units that are built to the minimum design specifications presented in 40 CFR Part 264 for the LDRS. This ALR (100 gpad) was developed by USEPA using calculations similar to those presented in this document. However, the proposed LDRS design for the Triassic Park landfill includes a geocomposite drainage layer with a hydraulic transmissivity at least two orders of magnitude greater than that required to meet the minimum design specifications (granular drainage layer) presented in CFR Part 264. With this greater hydraulic transmissivity, the geocomposite drainage layer is capable of conveying much greater flow rates without the fluid head on the secondary liner exceeding one foot. As a result, the proposed ALRs calculated using the equation given in USEPA (1992) are substantially greater than 100 gpad. However, consistent with 40 CFR Part 264, the proposed ALRs have been established to ensure that the maximum fluid head on the secondary liner is not in excess of one foot. This is demonstrated by the calculations presented in Appendix G-1. Therefore, the proposed ALRs are consistent with the requirements of 40 CFR Part 264, and the designs for the landfill are appropriate.

5.3 DETERMINATION OF ACTION LEAKAGE RATE: EVAPORATION POND

5.3.1 Equation for Geocomposite Flow Capacity

The leak detection drainage layer consists of a geonet. The maximum flow rate from a single hole in the primary liner that a geonet drainage layer can convey without the fluid head on the secondary liner exceeding a predetermined level is given by the Equation 1 presented in Section 5.2.1.

5.3.2 Design Parameters

Hydraulic Conductivity

The technical specifications for the evaporation pond geonet require that over the base and the side slopes of the evaporation pond the geonet of the LDRS have a hydraulic transmissivity of at least 5 x 10^{-3} m^2/sec when subjected to testing conditions which include stresses, and

hydraulic gradient and boundary conditions similar to those anticipated in the field. Using the specified hydraulic transmissivity of 5 x 10^{-3} m^2/sec and (and adjusting the transmissivity by a total factor of safety of 5.1 to account for intrusion, chemical slogging, biological clogging, and sediment clogging) geonet thickness of 0.2 inches, the calculated hydraulic conductivity is 20 cm/sec. Hydraulic transmissivity test results confirming that the specified geonet has this calculated conductivity are required in the specifications and the CQA plan.

Head on Secondary Liner

Similar to the landfill LDRS regulations, the head on the evaporation pump liner should not exceed one foot. Therefore, one foot will be used for the calculated maximum head build-up on the secondary liner and the calculation of the ALR. Also, as with the landfill LDRS, one foot of head is interpreted to mean an equivalent fluid pressure of one foot rather than a one foot increase in fluid elevation.

5.3.3 Action Leakage Rate

Action Leakage Rate Calculation

Using Equation 1 and the design parameters listed above the maximum flow rate that the LDRS geocomposite drainage layer at the base of the evaporation pump can convey from a single hole in the primary layer is calculated to be approximately 13,000 gallons per acre per day (gpad). For the pond area this is approximately 9,000 gpd. The calculations are attached as Appendix G-1.

Design LDRS Sump Flow Capacity

The flow rate listed above is for the case of flow entering the drainage layer from a single hole in the primary liner. In order to determine if the LDRS sump has sufficient capacity to remove and therefore to detect the flow from a single hole in the primary liner, an analysis was carried out for the LDRS sump capacity.

The construction materials and layout for the LDRS sump are shown on Drawings 28 to 32. The calculations for the capacity of the LDRS sump presented in Appendix G-2 and indicate that the sumps can safely remove flows of approximately 75,600 gpd. This exceeds the expected flow capacity of LDRS geonet layer from a single hole in the primary liner; therefore, the sump could detect a leak of this magnitude.

5.3.4 Discussion of Proposed Action Leakage Rates

The proposed ALR of 1000 gpad is equivalent to the EPA recommended maximum and is substantially less then the calculated maximum. The ALR, as proposed by EPA, generally refers to values with units of gallons per acre per day (gpad). The calculated flow rates for the LDRS net layer for a single hole in the primary liner system are presented in units of gallons per day. However, if the value is divided by the pond area, the flows are reported in gallons per acre per day.

6.0 LEAK DETECTION AND REMOVAL SYSTEM MONITORING

The flow of liquid removed from each leak detection sump will be monitored either with a flow meter or using a container of known volume and a stop watch.

In accordance with 40 CFR 264.303 and 40 CFR 264.222, the volume of liquid removed from each leak detection system sump in the landfill and evaporation pond will be recorded at least once each week during the active life. Liquid volumes will also be recorded once each week for the landfill LDRS sumps during the closure period.

During the landfill post-closure care period, the volume of liquid removed from each leak detection system sump will be recorded at least monthly. If the liquid level in the sump stays below the pump operating level, i.e., one foot above the bottom liner, for two consecutive months, the level of liquid in the sump must be recorded at least quarterly. If the liquid level in the sump stays below the pump operating level for two consecutive quarters, the level of liquid in the sump will be recorded at least semi-annually. However, if at any time during the post-closure care period the pump operating level is exceeded for a sump on quarterly or semi-annual recording schedules, monthly recording of the volume of liquid removed from the sump will be reinstated. This will continue until such time that the liquid level in the sump again remains below the pump operating level for two consecutive months.

7.0 RESPONSE ACTIONS

In accordance with 40 CFR 264.304, if the ALR is exceeded for the landfill or evaporation pond LDRS sump, the Triassic Park facility will:

- Notify the NMED in writing of the exceedance within 7 days of the determination;
- Submit a preliminary written assessment to NMED within 14 days of the exceedance determination, as to the amounts of liquids, likely sources of liquids, possible location, size, and cause of any leaks, and short-term actions taken and planned.
- Determine, to the extent practicable, the location, size, and cause of any leak;
- Determine whether waste receipt should cease or be curtailed, whether any waste should be removed from the unit for inspection, repairs, or controls, and whether or not the unit should be closed;
- Determine any other short-term and long-term actions to be taken to mitigate or stop any leaks;
- Within 30 days after the notification that the action leakage rate has been exceeded, submit to NMED the results of the determinations described above, the results of the actions taken, a description of the actions planned;
- Monthly, as long as the action leakage rate continues to be exceeded, submit a report to NMED summarizing the results of any remedial actions taken and planned; and
- In making the determinations described in this section, either conduct the following investigation or document why such an investigation is not needed:
    - ◊ Assess the source and amount of liquid from each source collected in the sump.
    - ◊ Conduct a hazardous constituent analysis of the liquid collected in the sump and use the results to help identify the source(s) of the liquid and possible location of any leaks as well as the potential hazard associated with the liquid and its mobility.
    - ◊ Assess the seriousness of any leaks in terms of potential for escaping into the environment.

In accordance with 40 CFR 264.223, if the ALR is exceeded for the evaporation pond LDRS, the Triassic Park Facility will:

- Immediately remove the surface impoundment from service and remove any fluids contained in the surface impoundment by pumping to an adjacent approved pond

or other approved facility. The source of the leakage will then be determined and any necessary repairs will be made in accordance with the design specifications.

- Notify the NMED in writing of the exceedance within 7 days of the determination;
- Submit a preliminary written assessment to NMED within 14 days of the exceedance determination, as to the amounts of liquids, likely sources of liquids, possible location, size, and cause of any leaks, and short-term actions taken and planned.
- Determine, to the extent practicable, the location, size, and cause of any leak;
- Determine any other short-term and long-term actions to be taken to mitigate or stop any leaks;
- Within 30 days after the notification that the action leakage rate has been exceeded, submit to NMED the results of the determinations described above, the results of the actions taken, a description of the actions planned;
- Monthly, as long as the action leakage rate continues to be exceeded, submit a report to NMED summarizing the results of any remedial actions taken and planned; and
- In making the determinations described in this section, either conduct the following investigation or document why such an investigation is not needed:
    - ◊ Assess the source and amount of liquid from each source collected in the sump.
    - ◊ Conduct a hazardous constituent analysis of the liquid collected in the sump and use the results to help identify the source(s) of the liquid and possible location of any leaks as well as the potential hazard associated with the liquid and its mobility.
    - ◊ Assess the seriousness of any leaks in terms of potential for escaping into the environment.

8.0 REFERENCES

Bonaparte, R and Gross, B.A., "Field Behavior of Double-Liner Systems", *Waste Containment Systems* Construction, Regulation, and Performance, ASCE Geotechnical Special Publication No. 26, Nov 1990, pp. 52-83.

Giroud, J.P., Gross, B.A., and Darrasse, J., "Flow in Leachate Collection Layers" to be published, 1993.

Gross, B.A., Bonaparte, R., and Giroud, J.P., "Evaluation of Flow from Landfill Leakage Detection Layers", *Proceedings, Fourth International Conference on Geotextiles,* Vol. 2, The Hague, June 1990, pp. 481-486.

USEPA, "*Action Leakage Rates for Leak Detection Systems*", EPA/580-R-92004, Jan 1992, 69 p.

USEPA, Federal Register, Volume 57, No. 19, Wednesday, January 29, 1992 *Rules and Regulations,* pp 3462 - 3482

G-1

APPENDIX G-1

LANDFILL ALR CALCULATION

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Landfill Action Leakage Rate

	Name	Date
Prepared By:	J. Kendall	10/6/97
Checked By:	J. Pellicer	13-Nov-97
Reviewed By:	P. Gorsse	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

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Phone 970.879.6260 Fax 970.879.9048

TITLE: TRIASSIC PARK LANDFILL ACTION LEAKAGE RATE

OBJECTIVE: DETERMINE ACTION LEAKAGE RATE (ALR) FOR THE TRIASSIC PARK HAZARDOUS WASTE FACILITY LANDFILL

REFERENCES:

1. USEPA, FEDERAL REGISTER, VOL 57 NO 19, WEDNESDAY JANUARY 29, 1992, RULES AND REGULATIONS, pp 3462-3477
2. USEPA, "ACTION LEAKAGE RATES FOR LEAK DETECTION SYSTEMS", EPA/530-R-92004, JANUARY 1992.
3. CODE OF FEDERAL REGULATIONS, TITLE 40, PART 264.302
4. BEAR, JACOB, "HYDRAULICS OF GROUNDWATER", McGRAW-HILL, 1979. pp 74-89.
5. TERRAMATRIX/MONTGOMERY WATSON, TRIASSIC PARK HAZARDOUS WASTE FACILITY DRAWINGS AS FOLLOWS:

DRAWING NO.	DRAWING TITLE	DATE
6	CLIMATE LANDFILL EXCAVATION PLAN	NOV 97
12	LINER DETAILS	
15	SUMP PLAN VIEW	
16	SUMP CROSS-SECTIONS	
17	TYP. SUMP DETAILS	
18	CROSS-SECTION + DETAILS	

6. TERRAMATRIX/MONTGOMERY WATSON, TRIASSIC PARK HAZADOUS WASTE FACILITY SPECIFICATIONS AS FOLLOWS:

SPEC NO	SPEC TITLE	DATE
02224	DRAINAGE GRAVEL	NOV 97
02710	GEO COMPOSITE	NOV 97

7. MANUFACTURER'S PRODUCT SPECIFICATIONS AND TEST DATA AS FOLLOWS:

A. NSC, "TEX-NET TRANSMISSIVITY CHARTS", TEX-NET TN3002/1125 (PLATE/FRICTION SEAL/TN3002CN/1125/FRICTION SEAL/PLATE)

B. ADS, "TECHNICAL NOTE 2.109 RE: FLOW CAPACITY", 3/1/95.

8. MINIMUM EPA REQUIREMENTS FOR GEOSYNTHETIC DRAINAGE LAYERS IN LANDFILLS: 3×10^{-5} m²/SEC (REF 1. p 3468)

9. KOERNER, ROBERT M., "DESIGNING WITH GEOSYNTHETICS" 3rd ED., PRENTICE HALL, ENGLEWOOD CLIFFS, NJ, 1994.

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Project Name: TRASSIC PARK HW FACILITY - LF ALR
Project Number: 602-0200 Sheet: 2 Of 40
Prepared By: K Date: 10/6/97
Checked By: J. Pellch Date: 13-Nov-97

METHOD:

1. ALR IS DEFINED BY FEDERAL LAW AS:

REF 3.) 40 CFR PART 264, 302

§ 264.302 Action leakage rate.

(a) The Department shall approve an action leakage rate for landfill units subject to § 264.301(c) or (d). The action leakage rate is the maximum design flow rate that the leak detection system (LDS) can remove without the fluid head on the bottom liner exceeding 1 foot. The action leakage rate must include an adequate safety margin to allow for uncertainties in the design (e.g., slope, hydraulic conductivity, thickness of drainage material), construction, operation, and location of the LDS, waste and leachate characteristics, likelihood and amounts of other sources of liquids in the LDS, and proposed response actions (e.g., the action leakage rate must consider decreases in the flow capacity of the system over time resulting from siltation and clogging, rib layover and creep of synthetic components of the system, overburden pressures, etc.).

(b) To determine if the action leakage rate has been exceeded, the owner or operator must convert the weekly or monthly flow rate from the monitoring data obtained under § 264.303(c), to an average daily flow rate (gallons per acre per day) for each sump. Unless the Department approves a different calculation, the average daily flow rate for each sump must be calculated weekly during the active life and closure period, and monthly during the post-closure care period when monthly monitoring is required under § 264.303(c).

2. FLOW RATE INTO LEAK DETECTION SYSTEM CAN BE DETERMINED FROM THE FOLLOWING EQN CITED IN REF 1, p. 3474 AND DEVELOPED FOR GEONET DRAINAGE LAYERS CITED IN REF 2, p 12, (EQN 3).

$Q = K \cdot D(2h - D)$ WHERE

Q = FLOW RATE IN LEAK DETECTION SYSTEM RESULTING FROM 1 HOLE PER ACRE (GPAD)

K = HYDRAULIC CONDUCTIVITY OF DRAINAGE LAYER (FT/SEC)

FOR GEONET: $K = T/t$

WHERE T = TRANSMISSIVITY OF GEONET (FT^2/SEC)

t = THICKNESS (FT)

h = HEAD ON LINER (FT)

D = LEAK DETECTION LAYER THICKNESS (FT)

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METHOD (CONTINUED)

3. GEOCOMPOSITE TRANSMISSIVITY (OR FLOW RATE) CORRECTIONS FOR INTRUSION OF ADJACENT MATERIALS (REF 9, PP 402-423)

GEOCOMPOSITE MANUFACTURERS TYPICALLY REPORT TRANSMISSIVITY (OR FLOW RATE) DATA BASED ON ASTM 4716-87 TEST PROCEDURES CONDUCTED AT VARIOUS RANGES OF OVERBURDEN PRESSURES (NORMAL LOADS), HYDRAULIC GRADIENTS, AND MATERIAL LAYER ARRANGEMENTS. FOR THIS DATA TO BE APPLICABLE, THE TEST CONDITIONS MUST BE REPRESENTATIVE OF ACTUAL DESIGN AND OPERATING CONDITIONS. THEREFORE, APPROPRIATE FACTORS OF SAFETY MUST BE APPLIED TO MANUFACTURER'S DATA TO ACCOUNT FOR TEST PROCEDURE DIFFERENCES. FURTHER, HYDRAULIC TESTING OF THE SELECTED GEOCOMPOSITE SHOULD BE CONDUCTED UNDER ACTUAL DESIGN AND OPERATING CONDITIONS TO CONFIRM THAT THE FACTORS OF SAFETY APPLIED TO MANUFACTURER'S DATA ARE ADEQUATE.

4. CHECK LDRS PIPE FLOW CAPACITY VS LDRS INFLOW
CHECK LDRS SUMP FLOW CAPACITY VS LDRS INFLOW

NSC

National Seal Company

REF 7A

6v2-3203

R

10/6/92

4/40

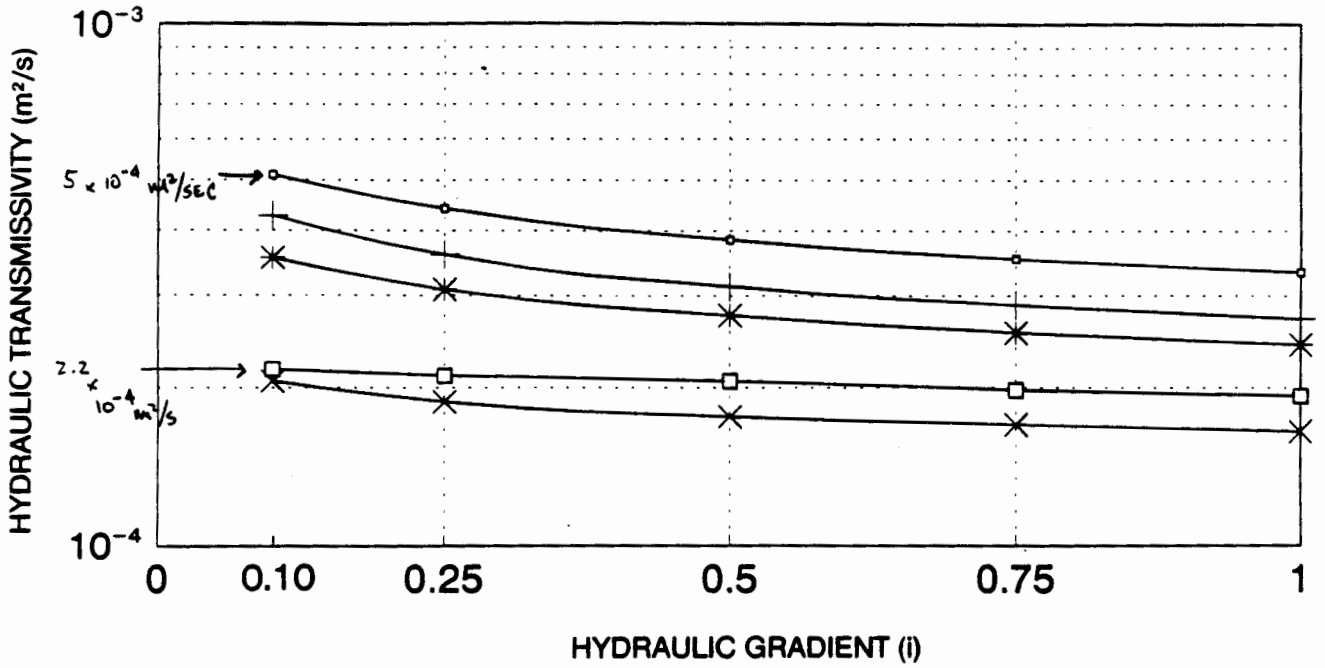
TEX-NET® TRANSMISSIVITY CHARTS

The results listed are nominal values based on limited testing. Minimum values and minimum average roll values may vary.

REF 7A
602.0200
10/6/97

TEX-NET TN3002/1125

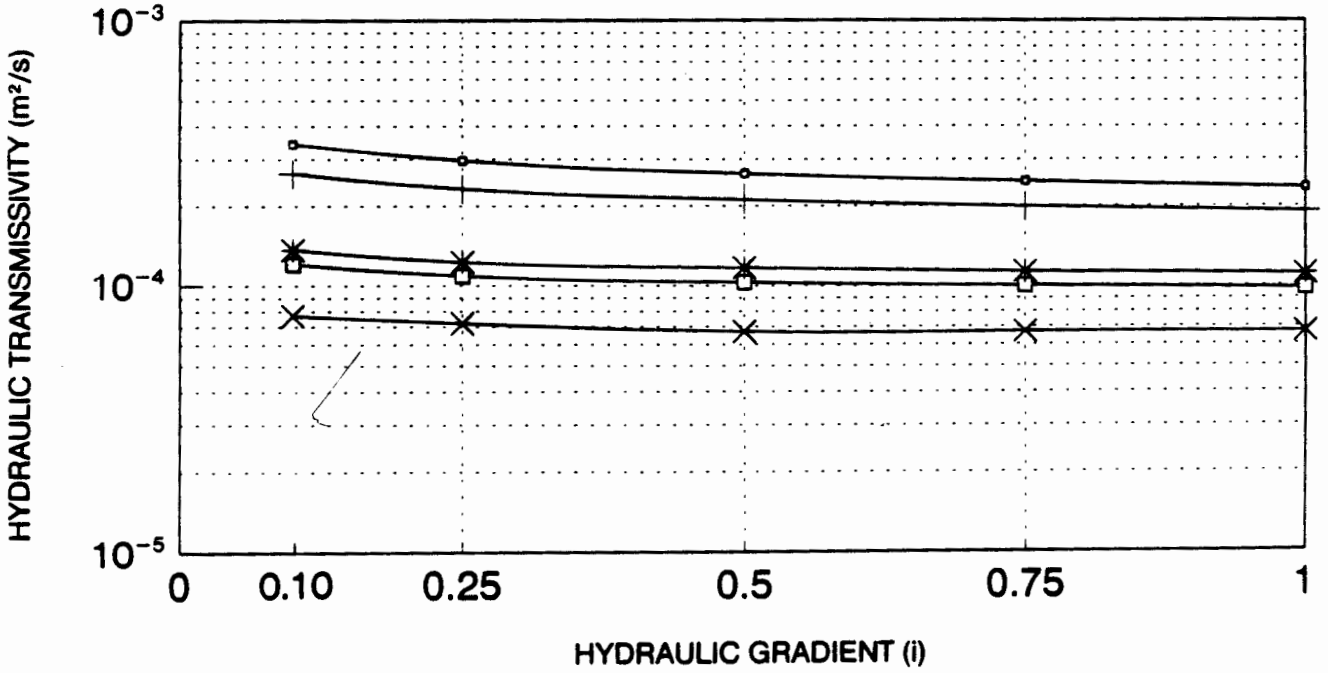
plate/FRICTION SEAL/TN3002/1125/FRICTION SEAL/plate



- 2000 psf
- 5000 psf
- 10000 psf
- 15000 psf
- 20000 psf

TEX-NET TN3002CN/1125

plate/FRICTION SEAL/TN3002CN/1125/FRICTION SEAL/plate



REF. 7A 6/40

602-0200 K 10/6/97

SPECIFICATION – Minimum Average Roll Values

Raw material	PN2000 polyethylene	PN3000 polyethylene	PN3000CN polyethylene
Weight (lbs/ft²) ASTM D5261	0.100	0.162	0.140
Thickness (inches) ASTM D5199	0.160	0.200	0.200
Density (g/cm³) ASTM D1505	0.940	0.940	0.940
Tensile strength (lb/in) ASTM D5035	30	45	32
Carbon black (%) ASTM D4218	2	2	2
Porosity (%), Nom.	83	80	76
Roll with (feet), Nom.	7.54 & 14.5	7.54 & 14.5	7.54 & 14.5
Standard roll length (feet), Nom.	300	300	300
Area per roll (ft²), Nom.	2262 & 4350	2262 & 4350	2262 & 4350

The transmissivity results listed on the preceding pages were determined in compliance with ASTM D4716-87 test procedure. The transmissivity was measured using water @ 20°C (68°F) with a seat time of one hour. Values may vary, based on dimensions of the transmissivity specimen and specific laboratory.

CONVERSION FACTORS FOR TRANSMISSIVITY UNITS

$1 m^2/s$ = 1 cubic meter/second/meter width/unit gradient
$1 m^2/s = 10^3$ liters/second/meter width/unit gradient
$1 m^2/s = 6 \times 10^4$ liters/minute/meter width/unit gradient
$1 m^2/s$ = 10.76 ft^2/second
$1 m^2/s$ = 646 ft^2/minute
$1 m^2/s$ = 4830 gallons/minute/foot width/unit gradient

1 ft^2/second = 1 cubic foot/second/foot width/unit gradient
1 ft^2/second = $9.3 \times 10^{-2} m^2/s$
1 ft^2/minute = 1 cubic foot/minute/foot width/unit gradient
1 ft^2/minute = $1.55 \times 10^{-3} m^2/s$
1 gpm/foot width/unit gradient = $2.07 \times 10^{-4} m^2/s$
1 liter/minute/meter width/unit gradient = $1.66 \times 10^{-5} m^2/s$
100 liters/minute/meter width/unit gradient = 1.07 ft^2/min.

The information contained herein has been compiled by National Seal Company and is, to the best of our knowledge, true and accurate. All suggestions and recommendations are offered without guarantee. Final determination of suitability for use based on any information provided, is the sole responsibility of the user. There is no implied or expressed warranty of merchantability or fitness of the product for the contemplated use.

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ASSUMPTIONS

1. GEOCOMPOSITE TRANSMISSIVITY

FROM REF 7A., CHART FOR TEX-NET TN 3002./1125. MINIMUM TRANSMISSIVITY REPORTED IS 2.2×10^{-4} / M^2/SEC @ NORMAL PRESSURE = 15,000 PSF AND HYDRAULIC GRADIENT OF 0.1, TEST SECTION WAS PLATE/FRICTION SEAL/TN 3002 CN/1125/FRICTION SEAL/PLATE.

ADJUST TRANSMISSIVITY CITED ABOVE FOR DIFFERENCES BETWEEN MANUFACTURER'S TEST CONDITIONS AND ACTUAL DESIGN CONDITIONS. APPLY FS IN A MANNER SIMILAR TO APPROACH SUGGEST BY KOERNER (REF. 9, PP 413-414)

$FS_{INTRUSION}$: SINCE TEST CONDITIONS ALLOW FOR INTRUSION OF GEOTEXTILE FROM ABOVE AND BELOW THE GEONET AND NORMAL PRESSURES ARE CONSISTENT WITH DESIGN (120 FT WASTE × 110 lb/CFT = 13,200 PSF), USE $FS_{IN} = 1$.

FS_{CREEP} : SINCE TEST CONDITIONS MAY REPRESENT SHORT DURATIONS, USE $FS_{CR} = 1.5$

$FS_{CHEMICAL\ CLOGGING}$: SINCE LEACHATE FROM WASTES OF A WIDE CHEMICAL VARIETY MAY BE PRESENT, USE $FS_{CC} = 1.5$.

$FS_{BIOLOGICAL\ CLOGGING}$: SINCE MUNICIPAL WASTES WILL NOT BE ACCEPTED IN THE LANDFILL, THE PERCENTAGE OF BIODEGRADEABLE MATERIAL PRESENT WILL BE SMALL, USE $FS_{BC} = 1$.

$FS_{SEDIMENT\ CLOGGING}$: SINCE FINE GRAINED SOILS MAY BE PRESENT IN THE PROTECTIVE COVER MATERIAL (SM CLASSIFICATION), USE $FS_{SC} = 1.5$

TOTAL FS = $FS_{IN} \times FS_{CR} \times FS_{CC} \times FS_{BC} \times FS_{SC} = 1 \times 1.5 \times 1.5 \times 1 \times 1.5$

$= 3.375$

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ASSUMPTIONS (CONTINUED)

1. GEOCOMPOSITE TRANSMISSIVITY (CONTINUED)

ALLOWABLE GEOCOMPOSITE FLOW RATE (q) = q (MANUF. TEST) x $\frac{1}{FS_{TOTAL}}$

$$q_{ALLOW} = \frac{2.2 \times 10^{-4}}{3.375} = 6.52 \times 10^{-5}\ m^2/SEC \quad \text{SAY } 6.5 \times 10^{-5}\ m^2/SEC$$

CHECK q_{ALLOW} VS EPA MINIMUM (REF 1, p 3468)

$6.5 \times 10^{-5} > 3.0 \times 10^{-5}$ ∴ OK

(NOTE: ALTHOUGH THE ASSUMPTIONS LEADING TO $q_{ALLOW} = 6.5 \times 10^{-5}\ m^2/SEC$ ARE CONSERVATIVE, CONFIRMATORY TESTING OF GEOCOMPOSITE TRANSMISSIVITY WILL BE REQUIRED. TESTING WILL BE CONDUCTED ON ACTUAL GEOCOMPOSITE SELECTED AT DESIGN CONDITIONS)

2. MAXIMUM HEAD ON LINER

USE 1.0 ft PER EPA 40 CFR 264.302

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Project Name: TRIASSIC PARK HW FACILITY - LF ALR
Project Number: 602-0200 Sheet: 9 Of 40
Prepared By: K Date: 10/6/97
Checked By: J. Pellicer Date: 13-Nov-97

CALCULATION

DETERMINE ALR

$ALR = Q_{ALLOWABLE} = KD(2h - D)$ (GPAD)

WHERE

$K_{GEOCOMPOSITE} = T/t$ T = TRANSMISSIVITY = 6.5×10^{-5} mm²/SEC
t = THICKNESS = 5 mm

$K_{GEOCOMPOSITE} = \frac{6.5 \times 10^{-5} \text{ mm}^2/\text{SEC}}{.005 \text{ mm}} = 0.013$ mm/SEC ✓
= 1.3 cm/SEC ✓
= 0.043 FT/SEC ✓

h = 1.0 ft

D = 5 mm = 0.0164 FT ✓

$ALR = Q_{ALLOWABLE} = 0.043 \frac{FT}{SEC} \times 0.0164 \text{ FT} \times (2 \times 1.0 \text{ FT} - 0.0164 \text{ FT})$
= 0.00140 CFT/Ac/SEC ✓
= 120.9 CFT/Ac/DAY ✓
= 904 GPAD ✓

RECOMMENDED ALR IS 900 GPAD

NOTE: THE RECOMMEND ALR VALUE OF 900 GPAD IS ABOVE THE EPA RECOMMENDED VALUE OF 100 GPAD (REF 1, p. 3474). THE PRIMARY REASON FOR THIS DIFFERENCE IS THE EPA VALUE IS BASED ON SAND PERMEABILITY (1×10^{-2} CM/SEC) COMPARED TO THE GEOCOMPOSITE PERMEABILITY ASSUMED ABOVE (1.3 CM/SEC).

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CALCULATION (CONTINUED)

CHECK LDRS FLOOR PIPE CAPACITY

USE FLOOR LAYOUT AND CROSS SECTIONS (REF.

USE ADS N-12 PIPE FLOW CAPACITY CHART FOR 8" DIAM. PIPE (REF. 7B)

FLOW = 2.07 CFT/SEC
= 929 GPM
= 1.337 MGPD

USE EPA FLOW RATE EQN TO DETERMINE FLOW INTO LDRS WITH $T = 5 \times 10^{-4}$ mm/SEC (REF. 7A) (most transmissiv value, conservative)

NOTE: TRANSMISSIVITY VALUE USED HERE IS GREATER THAN THAT USED FOR ALR CALC BECAUSE WE ARE CHECKING MAXIMUM FLOW CAPACITIES FOR THE LDRS PIPE AND SUMP GRAVEL. THE HIGH TRANSMISSIVITY VALUE HERE IS MORE REPRESENTATIVE OF A SCENARIO EARLY IN THE LIFE OF THE LANDFILL WHEN WASTE FILL HEIGHTS ARE RELATIVELY LOW.

$Q = K \cdot D(2h - D)$ (REF 2, P12, EQN 3)

$K = T/t = \frac{5 \times 10^{-4}\ mm^2/sec}{0.005\ mm} = 0.1\ mm/SEC$
$= 10\ CM/SEC$
$= 0.328\ FT/SEC$

$h = 1.0\ ft$
$D = 5\ mm = 0.0164\ FT$

$Q = 0.328 \times 0.0164 \times ((2 \times 1.0) - 0.0164)$
$= 0.0106\ CFT/AC/SEC$
$= 922\ CFT/AC/DAY$
$= 6898\ GAL/AC/DAY$ (GAPD)

FLOW INTO PHASE 1 LDRS = 6898 GAPD x 7Ac = 48,286 GPD

FLOW INTO PHASE 1 LDRS << PIPE FLOW CAPACITY
48,286 GPD << 1.34 MGPD So PIPE CAPACITY OK

10/6/97 K 602-0200 11/40

Technical Notes

Technical Note 2.109

Re: Flow Capacity
Date: March 1, 1995

It is the intent of this Technical Note to provide current hydraulic performance data for use by the engineering community. A bibliography is included for the engineer's use if further information or guidance is needed.

Manning's "n" values are offered for design purposes based on the best available data assembled from a variety of sources as indicated. Table 1 presents the Manning's "n" values recommended by the A.D.S. engineering staff for use in design.

REF 7B

Table 1
Manning's "n" Value For Design
(Storm & Sanitary Sewer and Culverts)

Pipe Type	"n"
A.D.S. Corrugated Polyethylene Pipe	
3" - 6" Diameter	0.015
8" Diameter	0.016
10" Diameter	0.017
12" - 15" Diameter	0.018
18" - 36" Diameter	0.020
A.D.S. N-12	0.012 ←
Concrete Pipe	0.013
Corrugated Metal Pipe (2 2/3" x 1/2" corrugation)	
Annular	
Plain	0.024
Paved Invert	0.020
Fully Paved (smooth lined)	0.013
Helical	
Plain 15" Diameter	0.013
Plain 18" Diameter	0.015
Plain 24" Diameter	0.018
Plain 36" Diameter	0.021
Spiral-Rib	0.012
Plastic Pipe (SDR, S&D, Etc.)	0.011
Vitrified Clay	0.013

REF. 7B

PIPE SLOPE = 2.5%

TABLE 4

CIRCULAR PIPE FLOW CAPACITY
Full Flow (cubic feet per second)

Mannings "n"= 0.012

Dia. (in.)	*Conv. Factor	% Slope (feet per 100 feet) 0.02	0.05	0.10	0.20	0.35	0.50	0.75	1.00	1.25	1.50	1.75	2.0	2.5	5.0	10.0	20.0
		(c.f.s.)															
3	0.957	0.014	0.021	0.030	0.043	0.057	0.068	0.083	0.096	0.107	0.12	0.13	0.14	0.15	0.21	0.30	0.43
4	2.062	0.029	0.046	0.065	0.092	0.122	0.146	0.179	0.206	0.231	0.25	0.27	0.29	0.33	0.46	0.65	0.92
5	3.738	0.053	0.084	0.118	0.167	0.221	0.264	0.324	0.374	0.418	0.46	0.49	0.53	0.59	0.84	1.18	1.67
6	6.079	0.086	0.136	0.192	0.272	0.360	0.430	0.526	0.608	0.680	0.74	0.80	0.86	0.96	1.36	1.92	2.72
8	13.091	0.185	0.293	0.414	0.585	0.774	0.926	1.134	1.309	1.464	1.60	1.73	1.85	2.07	2.93	4.14	5.85
10	23.74	0.34	0.53	0.75	1.06	1.40	1.68	2.06	2.37	2.65	2.91	3.14	3.36	3.75	5.31	7.51	10.61
12	38.60	0.55	0.86	1.22	1.73	2.28	2.73	3.34	3.86	4.32	4.73	5.11	5.46	6.10	8.63	12.21	17.26
15	69.98	0.99	1.56	2.21	3.13	4.14	4.95	6.06	7.00	7.82	8.57	9.26	9.90	11.06	15.65	22.13	31.30
18	113.80	1.61	2.54	3.60	5.09	6.73	8.05	9.86	11.38	12.72	13.94	15.05	16.09	17.99	25.45	35.99	50.89
21	171.65	2.43	3.84	5.43	7.68	10.16	12.14	14.87	17.17	19.19	21.02	22.71	24.28	27.14	38.38	54.28	76.77
24	245.08	3.47	5.48	7.75	10.96	14.50	17.33	21.22	24.51	27.40	30.02	32.42	34.66	38.75	54.80	77.50	109.60
27	335.51	4.74	7.50	10.61	15.00	19.85	23.72	29.06	33.55	37.51	41.09	44.38	47.45	53.05	75.0	106.1	150.0
30	444.35	6.28	9.94	14.05	19.87	26.29	31.42	38.48	44.44	49.68	54.42	58.78	62.84	70.26	99.4	140.5	198.7
36	722.57	10.22	16.16	22.85	32.31	42.75	51.09	62.58	72.26	80.79	88.50	95.59	102.19	114.25	161.6	228.5	323.1
42	1089.9	15.41	24.37	34.47	48.74	64.5	77.1	94.4	109.0	121.9	133.5	144.2	154.1	172.3	243.7	344.7	487.4
48	1556.1	22.01	34.80	49.21	69.59	92.1	110.0	134.8	155.6	174.0	190.6	205.9	220.1	246.0	348.0	492.1	695.9

* Conveyance Factor = (1.486 x R2/3 x A) / n

602-020

K
10/6/97

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CALCULATION (CONTINUED)

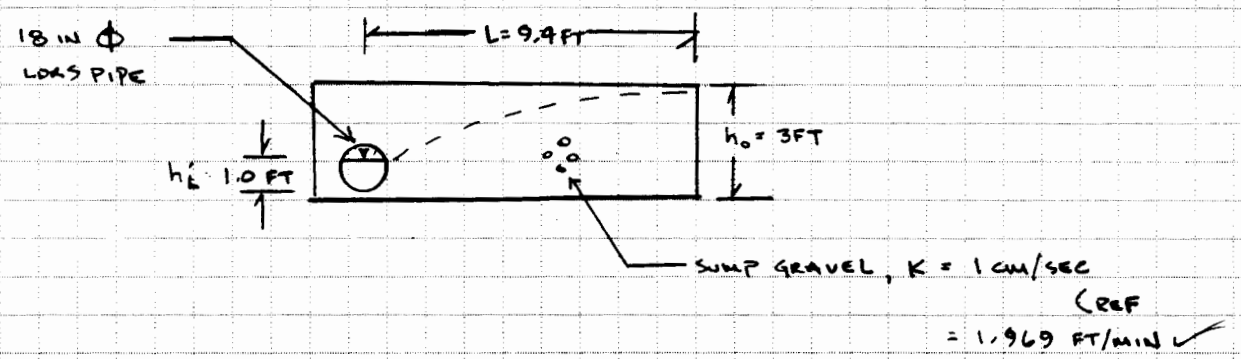
CHECK LDRS SUMP PUMPING CAPACITY

USE LDRS CROSS-SECTIONS (REF
USE METHOD DESCRIBED IN "HYDRAULICS OF GROUNDWATER" (REF 4)

USE DUPUIT-FORCHHEIMER EQN

$$Q = K/2L\left(h_o^2 - h_L^2\right)$$

WHERE: Q = FLOW RATE PER FT OF PIPE LENGTH
L = DISTANCE TO MAXIMUM FLUID ELEVATION
h_o = MAXIMUM FLUID ELEVATION
h_L = FLUID ELEVATION IN PIPE
K = PERMEABILITY OF LDRS SUMP GRAVEL



$$Q = \frac{1.969\ \text{FT/MIN}}{2 \times 9.4\ \text{FT}} \times \left(3^2\ \text{FT} - 1^2\ \text{FT}\right)$$

= 0.837 CFT/MIN/FT PIPE LENGTH

PIPE LENGTH = 15 FT (REF.

Q_{TOTAL} = 0.837 CFT/MIN/FT PIPE LENGTH × 15 FT = 12.57 CFT/MIN
= 135,403 GPD

FLOW INTO LDRS < FLOW CAPACITY OF SUMP

48,286 GPD < 135,403 GPD ∴ SUMP CAPACITY OK

10/6/97 JK 602-0200

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 260, 264, 265, 270, and 271

[FRL-4028-2]

RIN 2050-AA76

Liners and Leak Detection Systems for Hazardous Waste Land Disposal Units

AGENCY: Environmental Protection Agency.

ACTION: Notice of final rulemaking.

SUMMARY: The Environmental Protection Agency (EPA) is today amending its current regulations under the Resource Conservation and Recovery Act (RCRA) concerning liner and leachate collection and removal systems for hazardous waste surface impoundments, landfills, and waste piles. EPA is also adding new regulations requiring owners and operators of hazardous waste surface impoundments, waste piles, and landfills to install and operate leak detection systems at such time as these units are added, laterally expanded, or replaced. EPA is promulgating most of these regulations in response to the requirements of the 1984 Hazardous and Solid Waste Amendments (HSWA) to RCRA.

EFFECTIVE DATE: July 29, 1992.

ADDRESSES: The public docket (docket reference code F-92-LLDF-FFFFF) for this rule is in room M2427, US EPA, 401 M Street SW., Washington, DC 20460, and is open from 9 am to 4 pm, Monday through Friday, excluding holidays. Call 202-260-9327 for an appointment to review docket materials. Up to 100 pages may be copied free of charge from any one regulatory docket. Additional copies are $0.15 per page.

FOR FURTHER INFORMATION CONTACT: The RCRA/Superfund Hotline at 1-800-424-9346 (toll free), or 703-920-9810 in the Washington, DC area. For information on technical aspects of this rule, contact Ken Shuster, Office of Solid Waste (OS-340), U.S. Environmental Protection Agency, 401 M St SW., Washington, DC 20460, 202-260-2214.

SUPPLEMENTARY INFORMATION: Copies of the following documents are available for purchase through the National Technical Information Services (NTIS), U.S. Department of Commerce, Springfield, VA 22161, phone 1-800-553-7 or 703-487-4650: (1) U.S. EPA, "Compilation of Current Practices at Land Disposal Facilities", January 1992; (2) U.S. EPA, "Action Leakage Rates for Leak Detection Systems", January 1992.

Preamble Outline

I. Authority
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I. Authority

These regulations are being promulgated under authority of sections 3004, 3005, 3006, and 3015 of the Solid Waste Disposal Act, as amended by the Resource Conservation and Recovery Act, as amended, 42 U.S.C. 6924, 6925, 6926, and 6936.

II. Background

On November 8, 1984, Congress enacted the Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA), placing stringent new requirements on the land disposal of hazardous waste. Among other requirements, Congress amended section 3004 of RCRA and added section 3015 to impose specific design standards for land disposal units.

Section 3004(o)(1)(A) of RCRA, added by HSWA, requires each new landfill and surface impoundment, and each replacement and lateral expansion of a landfill and surface impoundment for which an application for a final permit determination is received after November 8, 1984, to install two or more liners (i.e., a double-liner system) and a leachate collection system above (for landfills) and between the liners. Section 3004(o)(5)(A) of RCRA requires EPA to promulgate regulations or issue technical guidance implementing the requirements of section 3004(o)(1)(A) by November 8, 1986. These HSWA requirements for double liner systems are intended to prevent the migration of hazardous constituents to ground water from land disposal units. Until the effective date of regulations promulgated under section 3004(o)(5)(A), Congress provided that an interim statutory double-liner standard in section 3004(o)(5)(B) could be used to meet the section 3004(o)(1)(A) double-liner system requirement.

Section 3004(o)(4) of RCRA requires EPA by May 8, 1987, to promulgate standards requiring new landfills, surface impoundments, waste piles, land treatment units, and underground hazardous waste tanks to use approved leak detection systems. The statute defines an "approved leak detection system" as a system or technology that EPA determines to be "capable of detecting leaks of hazardous constituents at the earliest practicable time." The term "new units" is defined as those units on which construction commences after the date of promulgation of the Agency's rule for leak detection systems. The impact of this language upon the applicability of this rule between today's promulgation and the effective date July 29, 1992 is discussed elsewhere in this preamble (See Section IV.A.).

Section 3015(a) of RCRA establishes standards for interim status waste piles. Any new waste pile, or replacement or lateral expansion of an existing waste pile at an interim status facility, must comply with requirements for liners and leachate collection systems or equivalent protection provided in regulations issued by EPA under section 3004 of RCRA before October 1, 1982, or revised under section 3004(o) of RCRA with respect to waste received beginning May 8, 1985.

Section 3015(b) of RCRA establishes standards for interim status surface impoundments and landfills. Any new unit, or replacement or lateral expansion of an existing unit at an interim status facility, is subject to the requirements promulgated under section 3004(o)(1) (relating to double-liners and leachate collection systems), with respect to waste received beginning on May 8, 1985.

The HSWA requirements described above either directly amended or directed the Agency to amend the existing RCRA liner standards for new hazardous waste landfills, surface impoundments, and waste piles issued by EPA on July 26, 1982 (47 FR 32262). On July 15, 1985, EPA issued a final rule (50 FR 28702) amending the existing liner standards by codifying the new liner standards of sections 3004(o)(1)(A), 3004(o)(5)(B), and 3015 (a) and (b) that

were to become effective immediately or shortly after the enactment of HSWA, as directed by the statute.

On March 28, 1986 (51 FR 10706), under section 3004(o)(5)(A) of RCRA, EPA proposed amendments to the statutory double-liner and leachate collection system standards for surface impoundments and landfills codified in EPA's regulations on July 15, 1985. The proposal set forth two types of designs for double-liner systems. One design consisted of a geomembrane (then referred to as a flexible membrane liner (FML)) as the top liner and a composite bottom liner consisting of a geomembrane underlain by compacted soil material to minimize flow through the geomembrane component should a breach occur, and having a hydraulic conductivity of no more than 1×10^{-7} cm/sec. The other proposed double-liner design consisted of a geomembrane top liner and a bottom liner constructed to prevent migration through the liner through the post-closure period and of at least 3 feet of compacted clay or other compacted soil material with a hydraulic conductivity of no more than 1×10^{-7} cm/sec. On April 17, 1987, EPA published a notice (52 FR 12566) requesting additional comments on certain aspects of the March 28, 1986 proposal. Specifically, EPA requested comments on data that demonstrated the advantages of a composite bottom liner versus a compacted soil material bottom liner. EPA also noticed the availability of two draft technical guidance documents for the design, construction, and operation of single- and double-liner systems and leachate collection systems. EPA solicited comments from the general public on the draft technical guidance documents.

On July 14, 1986 (51 FR 25422), EPA promulgated leak detection system requirements for underground hazardous waste tanks. In promulgating these regulations, EPA partially fulfilled its mandate under section 3004(o)(4) of RCRA to establish leak detection system requirements.

On May 29, 1987 (52 FR 20218), EPA proposed a rule establishing leak detection system requirements to fully implement section 3004(o)(4) of RCRA. The proposal specified design standards for leak detection systems for new and replacement landfills, surface impoundments, land treatment units, and waste piles, and for lateral expansions of these units at both permitted and interim status facilities. The proposal also expanded the double-liner requirements to waste piles. The proposal also included a requirement for a construction quality assurance program to be implemented by owners and operators to ensure the proper construction, installation, and closure of these units. Finally, the proposal included a requirement to develop a response action plan specifying actions that would be taken in reaction to liquid flow into the leak detection system above action leakage rates proposed by the owner or operator and approved by the Regional Administrator.

Today's rule finalizes EPA's proposed actions of March 28, 1986 and May 29, 1987, and completes the Agency's statutory rulemaking responsibilities imposed by RCRA sections 3004(o)(4) and 3004(o)(5)(A). EPA has not included additional leak detection standards for permitted land treatment units in today's rule because, as explained later in today's notice, existing unsaturated zone monitoring requirements in §§ 264.278 and 265.278 for such units are sufficient to ensure the detection of leaks at the earliest practicable time.

III. Summary of Today's Rule

A. Summary of Rule

Today's rule modifies the existing double-liner and leachate collection and removal system requirements for new and replacement surface impoundments and landfills and for lateral expansions of these units, including those units at interim status facilities. New surface impoundment and landfill units for which construction commences after January 29, 1992, and replacement units reused after and lateral expansions of existing units for which construction commences after July 29, 1992 must have a double liner consisting of a top liner designed to prevent the migration of hazardous constituents into the liner during the active life and post-closure period (e.g., a geomembrane) and a composite bottom liner consisting of a geomembrane underlain by at least 3 feet of compacted soil material having a hydraulic conductivity of no more than 1×10^{-7} cm/sec. EPA is also extending the revised landfill double-liner and leachate collection and removal system requirements to new waste pile units for which construction commences after January 29, 1992, and replacement units reused after and lateral expansions of waste pile units for which construction commences after July 29, 1992.

Today's rule also requires a leak detection system for each new surface impoundment, waste pile, and landfill for which construction commences after January 29, 1992, and each replacement surface impoundment, waste pile, and landfill reused after, and each lateral expansion of these units for which construction commences after July 29, 1992. The leachate collection and removal system drainage layer immediately above the bottom composite liner at these units must be used as the leak detection system. The drainage layer functioning as the leak detection system must meet minimum design criteria and ensure that leaks are detected at the earliest practicable time. Specifically, the drainage layer bottom slope must be one percent or more. If granular material is used in the drainage layer, it must have a minimum hydraulic conductivity of 1×10^{-2} cm/sec for waste piles and landfills and 1×10^{-1} cm/sec for surface impoundments and a minimum thickness of 1 foot. If synthetic drainage material is used in the drainage layer, the drainage material must have a minimum hydraulic transmissivity of 3×10^{-5} m^2/sec for waste piles and landfills and 3×10^{-4} m^2/sec for surface impoundments. These transmissivities are equivalent to the above hydraulic conductivities and thickness specifications for granular drainage layers. EPA is requiring that each unit have a leak detection sump to collect and remove liquids, sized to prevent liquids from backing up into the drainage layer. In lieu of meeting these requirements, the owner or operator may receive a variance for an alternative leak detection system that functions in an equivalent manner.

EPA is establishing a site-specific action leakage rate that specifies a liquid flow rate detected in the leak detection system sump that warrants followup actions by the owner or operator. Owners and operators are required to develop a response action plan specifying monitoring, inspection, and corrective measures to be implemented if the action leakage rate is exceeded.

The Agency is requiring owners and operators of units affected by today's rule to develop a construction quality assurance (CQA) program for various components of surface impoundments, waste piles, and landfills. The program will be implemented through a construction quality assurance plan that the owner or operator prepares to ensure that the constructed unit meets or exceeds all design criteria, plans, and specifications.

Owners or operators of facilities applying for a permit for new surface impoundments, waste piles, and landfills must submit information on liners and leak detection system designs, the action leakage rate, the response action plan, and CQA plans as part of the permit application. For new and replacement surface impoundment, waste pile, and landfill units, and lateral

16/4c

expansions of existing units at permitted facilities, owners and operators must submit this information as part of a permit modification request. For affected units at interim status facilities, the owner or operator must submit proposed action leakage rates, response action plans, and a certification that construction has been completed according to the design specifications in the CQA plan to the Agency in advance of the receipt of wastes. Liner and leak detection system designs and CQA plans need not be submitted to EPA, but must be maintained on site.

B. Achievement of EPA Program Goals

In developing today's rule, EPA paid careful attention to several principles that now guide its environmental programs: Pollution prevention, ground-water protection, cost-effective policies which provide protection of human health and the environment, flexibility in implementation, and fostering of an effective State-Federal partnership. Today's rule incorporates each of these principles.

The primary focus of today's rule is on pollution prevention and, more specifically, on ground-water protection. Effective liner and leak detection systems will minimize the potential for releases of hazardous constituents from hazardous waste land disposal units to underlying ground water. In this way, today's rule complements the Agency's waste minimization policies, which seek to reduce the quantities of waste produced, and the RCRA land disposal restrictions programs. Today's liner and leak detection standards contribute to pollution prevention by providing for the containment and isolation of hazardous waste after final disposal.

In today's rule, EPA has taken an important step in implementing its Ground-Water Principles, recently published in the Agency's "Protecting the Nation's Ground Water: EPA's Strategy for the 1990's (21Z-1020, July 1991). A central theme in EPA's ground-water policy, enunciated in the principles, is that prevention of ground-water contamination is often more cost effective and environmentally more desirable than remediation of ground-water after contamination. Experience in the RCRA and Superfund programs demonstrates that improperly designed landfills, surface impoundments, and waste piles can result in ground-water contamination. At the same time, remediation of contaminated ground-water has proved to be time-consuming, expensive, and in some cases technically infeasible. On the other hand, the release of hazardous constituents from landfills, surface impoundments, and waste piles can largely be eliminated through good design and construction.

Regarding costs, it should be noted that most of the standards incorporated into today's rule are already widely in use at hazardous waste facilities and are generally considered good engineering practices. Because HSWA required new landfills and surface impoundments, and lateral expansions and replacements of existing landfills and surface impoundments, for which an application for a permit is received after November 8, 1984, and those units in interim status receiving waste after May 8, 1985, to be designed with double-liner and leachate collection systems, most facilities already meet many of the design standards of today's rule. In addition, many facilities have designed units that are in compliance with today's final rule in anticipation of the promulgation of a final rule based on the March 28, 1986, and May 29, 1987 proposed rules. Thus, for a relatively small increase in cost (to those facilities that are not already meeting the standards of today's rule), the rule may save large corrective action costs. However, since all new units must comply with all the provisions of this rule and bear the corresponding costs, EPA has carefully chosen the minimum technical standards that adequately protect human health and the environment.

Although today's rule includes specific design standards, EPA has taken care to ensure that its requirements can be flexibly implemented. The presence of specific standards in the rules will simplify compliance by the regulated community, implementation by EPA and State permit writers, and enforcement by EPA and state officials. EPA, however, recognizes that national design standards may not be appropriate for every site and that technologies may improve. Therefore, today's rule allows EPA or an authorized State to approve alternative designs, as long as they achieve comparable or better levels of performance.

Similarly, today's rule requires construction quality assurance—a critical feature in land disposal unit construction—but it does so through general narrative performance standards. Thus, facility owners or operators can tailor the details of their construction quality assurance plans to the specifics of their facilities. These and similar provisions [illegible] ensure that the rule can be flexibly implemented, in a way that accommodates each regulated unit

Finally, in today's rule EPA has paid special attention to eliminating the frequent strains resulting from the joint implementation of RCRA by EPA and the States, in proposals for this rule, EPA laid out a complicated State authorization process, which would require EPA to implement some parts of the rule for selected land disposal units and the States to implement other parts for the same units, over different timeframes. After radically simplifying the proposal, EPA is now promulgating most of the rule under HSWA, which avoids much of the confusion of joint implementation at individual units. In this way, today's rule is consistent with the Agency's attempt to simplify and rationalize Federal and State implementation of RCRA. Today's rule also requires fewer reports and mandatory Agency reviews than the proposal while still providing opportunity for Agency reviews.

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IV. Detailed Discussion of the Final Rule

A. Scope of the Rule

The double liner and leak detection standards in today's final rule apply to new and replacement landfills, surface impoundments, and waste piles, and lateral expansions of these units. Today's rule applies, as it was proposed in May, 1987, to these units regardless of their permit status, including facilities that were issued permits prior to and after the enactment of HSWA and facilities that are still in interim status. In consideration of the explicit language of section 3004(o)(4) defining a new unit as a unit for which construction commences after the promulgation date of today's rule, the Agency maintains that the permit does not act as a shield with respect to the leak detection requirements under today's rule for new units. Because lateral expansions and replacement units are comparable in their environmental impact, the Agency has, as a policy matter, decided to similarly remove the permit as a shield for leak detection systems at replacement units and lateral expansions of existing units. EPA believes that the opportunity for constructing replacement units and lateral expansions of existing units to meet today's requirements is similar to that for new units. In addition, by requiring replacement units and lateral expansions at existing units to meet today's requirements, EPA is ensuring that these units meet the same minimum technological requirements and provide the same protection of human health and the environment. Therefore, the Agency is amending § 270.4 to require

owners or operators to apply for a permit modification to meet the standards of today's final rule. Owners and operators at permitted facilities may not begin construction of units subject to today's requirements, until the permitting Agency has approved the owner or operator's permit modification (see § 270.42).

Today's rule exempts certain replacements of permitted surface impoundment, waste pile, and landfill units from today's double-liner and leak detection system requirements. However, EPA has modified the scope of the exemption since the May 29, 1987 proposal. Sections 264.221(f), 264.251(f), 264.301(f), 265.221(c), 265.254(a), and 265.301(c) in today's rule exempt replacements of surface impoundments, waste piles, and landfills from the double-liner system and leak detection requirements if the replacements meet the following conditions: (1) The existing unit was constructed in compliance with the design standards for double-liner and leachate collection systems in sections 3004 (o)(1)(A)(i) and (o)(5) of RCRA; and (2) there is no reason to believe that the liner system is not functioning as designed. Of course, any replacement surface impoundment, waste pile, or landfill unit that otherwise qualified for a variance from the double-liner and leachate collection system requirements pursuant to sections 3004(o)(2), 3004(o)(3), or 3005(j) of RCRA remains exempt from today's double-liner and leak detection requirements.

In the May 29, 1987 proposed rule, EPA considered exempting replacements that were constructed in compliance with existing part 264 single-liner requirements for surface impoundments, waste piles, and landfills. EPA acknowledges that the arguments for this exemption in the proposed rule were erroneous and has decided not to exempt replacements of permitted single-lined surface impoundments, waste piles, and landfills in today's final rule, because owners or operators of these units have no early method of detecting whether the single liner is leaking. Owners or operators of such units would have to rely on ground-water monitoring to determine if the single liner was leaking. EPA agrees with the commenters that this is inconsistent with the statutory goal of leak detection at the earliest practicable time and of preventing leakage out of the unit.

The May 29, 1987 proposal indicated an effective date for most of the provisions, including the leak detection requirements, of six months after promulgation. The July 29, 1992 effective date of today's rule is consistent with that proposal and with section 3010(b) of RCRA. It is important to note that section 3004(o)(4)(B)(ii) defines "new units" as those units on which construction commences after date of promulgation (versus the effective date) of the Agency's rule for leak detection systems. Therefore, due to the clear language of the statute, construction of new landfills, new surface impoundments, and new waste piles is defined with respect to the promulgation date but today's final regulations become effective 6 months after promulgation. This interpretation is consistent with the Agency's definition of "new tank systems" discussed in the final hazardous waste tank requirements (51 FR 25446).

During the six month time period between promulgation and the effective date, owners and operators of new units have time to determine and then make any necessary adjustments to their designs, contract specifications, and other pre-construction plans so that the requirements of today's rule are satisfied by the effective date. This also allows adequate time, in the Agency's opinion, for preparation and submission to the Agency of documents and requests for approvals that are prerequisites to construction and operation. For permitted facilities, this includes permit modification requests. Similarly, any interim status facility that adds a new unit following the promulgation date is expected to comply with the requirements in today's rule to submit, along with their notification under §§ 265.221(b), 265.254(a), or 265.301(b), proposed action leakage rates and a response action plan, if the due date for that notification (i.e., at least 60 days prior to receipt of waste in the new unit) falls before the effective date.

Thus, the Agency anticipates that at the few facilities (both permitted and interim status) that plan to develop new units during this six month period, most of the effort will be the preparatory design and administrative work needed to comply by the effective date. If owners or operators at interim status facilities should commence construction of new units during this period, the construction would be subject to Agency review upon the effective date of today's requirements.

Replacement landfills, surface impoundment, or waste piles, or lateral expansions to those units are, in the absence of specific statutory direction, subject to this rule after July 29, 1992 (i.e., six months after promulgation as normally provided under section 3010(b) of RCRA).

It should be noted that EPA interprets the term "construction commences," as used in the "new unit" definition of section 3004(o)(4)(B)(ii) and in today's rule, according to its definition within the § 260.10 definitions of "existing hazardous waste management (HWM) facility" and "existing tank system." That is, a unit has commenced construction if (1) the owner or operator has obtained the Federal, State and local approvals or permits necessary to begin physical construction, and either (2)(i) a continuous on-site, physical construction program has begun; or (ii) the owner or operator has entered into a contractual obligation—which cannot be canceled or modified without substantial loss—for physical construction of the facility to be completed within a reasonable time. Therefore, any new unit that has commenced construction, according to this long-standing Agency definition of the term, prior to the promulgation date (i.e., today's **Federal Register** publication date) is outside the scope of today's rule. Similarly, any replacement unit that is reused (unlike new units and lateral expansions, construction is not a necessary step prior to reuse of a replacement unit) or lateral expansion on which construction commences prior to the effective date (i.e., six months after today's **Federal Register** publication date) of this rule is also beyond the scope of today's rule.

Today's rule includes a definition of "replacement unit" in § 260.10. EPA is today defining a replacement unit as a unit (1) from which all or substantially all of the waste is removed, and (2) that is subsequently reused after July 29, 1992 to treat, store, or dispose of hazardous waste. This definition, which is similar to the May 29, 1987, proposal, is consistent with the definition EPA has used in implementing the statutory liner requirements of section 3004(o)(5)(B) for replacement units.

In the 1987 proposal, EPA excluded from the definition of replacement units those units from which waste was removed and treated in preparation for closure and only the treated waste was replaced in the unit. EPA explained in the proposal that replacement units are units that remain in service for active waste management, not units that are permanently taken out of service through closure. EPA believed this approach not only reflected statutory intent, but also would encourage (or at least not discourage) environmentally beneficial activities during closure (e.g., waste treatment), because owners or

operators would not have to retrofit closing units from which waste was removed and replaced.

Today's definition of "replacement unit," like the proposal, exempts certain units undergoing closure. However, the exemption is slightly expanded in that today's definition of replacement unit would also exempt those closing units that receive compatible wastes from other closing units and/or corrective action areas at the facility, provided that such use of the closing unit is approved by EPA (or an authorized state) in the facility's closure plan or corrective action program. The Agency believes that the expanded exemption is a logical extension of the proposal since it is similarly necessary to encourage environmentally beneficial activities (e.g., treatment and consolidation of compatible wastes from on-site closing units into one unit, waste removal to inspect a liner, expeditious closure of other on-site units) that may not otherwise occur if the owner or operator had to retrofit the closing unit to meet today's liner and leak detection system requirements.

Thus, units and activities qualifying for exemption from the "replacement unit" definition are limited to the following conditions and safeguards: (1) The activity must be reviewed and approved by EPA or an authorized state as part of the closure plan or corrective action approval process, including a corrective action order; (2) only closing units that have notified EPA in accordance with § 264.113 or § 265.112 or notified an authorized State, may qualify; and (3) only compatible waste and debris that are from closing units or corrective action areas on-site may be deposited in these units. For a unit to qualify for this exemption, off-site waste, new waste generated on site, and waste from active units on site may not be disposed of in the unit.

The situations EPA envisions as qualifying for this exemption from the "replacement unit" definition include: (1) Waste is removed from a closing unit, treated (e.g., incinerated, dewatered, or solidified), and returned to the same unit; (2) waste is removed from a closing unit to inspect and/or repair the liner, and the waste is returned to the same unit; (3) scenario 1 or 2, plus waste from other closing units is disposed in the original unit; and (4) scenario 1 or 2, plus waste that is the result of corrective action at the same facility, is placed into the original unit.

Finally, EPA also proposed in the May 29, 1987, rule that the liner and leak detection system requirements apply to significant unused portions of existing units, where those portions did not have double liners and leachate collection systems meeting the minimum technological requirements. Today's rule has dropped this requirement. A number of commenters on the proposal pointed out the difficulty of defining "significant" unused portions of a unit, and EPA was unable to develop an unambiguous definition. Furthermore, after reviewing land disposal units constructed and permitted since 1984 (which is the universe most likely to have portions of units not yet covered by wastes), EPA noted that virtually all of these units were required in their permits to incorporate double liner and leak detection requirements into their respective designs. Therefore, EPA has concluded that it is no longer necessary to extend today's rule to significant unused portions of existing units. It should be noted, however, that lateral expansions of existing units remain subject to today's rule.

B. Standards for Liners and Leak Detection Systems

1. Technical Standards for Liner Systems

Today, EPA is promulgating regulations containing design standards for double liners in accordance with the requirements of section 3004(o)(1) and (c)(5)(A) of RCRA. These standards replace those contained in the interim statutory design provision of section 3004(o)(1)(B) of RCRA that were codified on July 15, 1985 (50 FR 28702).

Today's rule amends the double-liner requirements for surface impoundments and landfills in §§ 264.221(c), 264.301(c), 265.221(a), and 265.301(a). The major change from the existing rule is that the final rule requires owners or operators to install a composite bottom liner. Based on available data and public comments received by the Agency, the double liner system specified in today's rule, with the composite bottom liner, represents the best available technology with respect to: (1) Preventing hazardous constituent migration out of the unit during the active life and post-closure care period, (2) detecting leaks through the top liner at the earliest practicable time, and (3) maximizing the efficiency of the leachate collection and removal system.

Today's rule does not change the existing top liner performance standard for surface impoundment and landfill units. Owners or operators of affected units must still design the top liner to prevent the migration of hazardous constituents into the liner throughout the active life and post-closure period. EPA notes that for purposes of today's rule, the top liner is the liner directly above the leachate collection and removal system serving as the leak detection system (see Technical Standard for Leak Detection Systems in Section IV.B.2 of today's preamble).

The Agency, in the preambles to the July 26, 1982 rule (47 FR 32274) and the March 28, 1986 proposal (51 FR 10709), endorsed geomembranes as meeting the top liner performance standard. EPA was aware of a number of landfill unit designs that included a composite top liner consisting of a geomembrane upper component and a compacted soil or a soil/bentonite blanket lower component. Consequently, EPA raised several questions in the preamble to the May 29, 1987 proposal concerning the use of a composite liner as a top liner and the effect the compacted soil component would have on other components of the double liner system, principally the early detection of a leak through the upper geomembrane.

The Agency received several comments on this issue, all of which were in favor of allowing the use of a composite liner as a top liner. One comment on appropriate standards for a composite liner favored minimum thickness requirements for a compacted soil lower component. Most commenters, however, favored no restrictions on the use of top composite liners.

In response to these comments, EPA is not prohibiting the use of composite top liners in today's rule. A parenthetical reference to geomembranes has been included as an example to illustrate that the performance standard can be met through use of a geomembrane. EPA does not intend that this reference be interpreted to mean that the geomembrane is the only top liner design that will meet the performance standard. EPA does not want to discourage owners or operators from using top composite liners because such liners can provide additional environmental benefits by minimizing the flow rate through a leak in a geomembrane liner and potentially minimizing migration of hazardous constituents by attenuation. Although not specified in today's rule, EPA maintains that the soil component of the top liner, however, should generally not be more than three feet thick since a thickness of 2 to 3 feet adequately serves the purpose of minimizing the flow through the geomembrane component (a lesser thickness may be appropriate for soil/bentonite blankets). EPA finds that this depth balances the increased environmental protection afforded by top composite liners and the ability to detect leaks at the earliest

for granular materials used in surface impoundments; (3) a minimum hydraulic transmissivity of 3×10^{-5} m²/sec for synthetic materials used in drainage layers for waste piles and landfills and $\times 10^{-4}$ m²/sec for synthetic drainage aterials used in surface impoundments; and (4) sump design and operating requirements.

Location of leak detection systems. EPA proposed in the May 29, 1987 preamble (52 FR 20229) that the leachate collection and removal system adjacent to and below the top liner and above the bottom liner be designated as the leak detection system, but requested comments on the proper location of the leak detection system in a system with more than two liners. Commenters on this aspect of the rule stated that the leak detection system should be located immediately above the bottom liner. These comments claimed that specifying additional leachate collection and removal systems above the bottom liner as leak detection systems would create a regulatory disincentive for owners and operators to design systems with more than two liners by requiring these additional (intermediate) leachate collection and removal systems to meet the requirements for leak detection systems and to implement response actions in accordance with the unit's response action plan. As a result of these comments, EPA is today specifying that the leak detection system is the leachate collection and removal system drainage layer located immediately above the bottom composite liner. Under today's final rule, any additional leachate collection and removal systems located above the leak detection system are not required to meet the design and performance standards for leak detection systems.

Leak detection time. The design standards being promulgated today for leak detection systems will ensure that these systems meet the requirement in section 3004(o)(4) of RCRA for the detection of leaks of hazardous constituents at the "earliest practicable time". EPA has interpreted the term "earliest practicable time" to be the time lapse from the time a liquid has passed through a breach in the top liner to the time a technology-based leak detection system can detect the liquid, assuming saturated steady-state flow. Without these simplifying assumptions, modelling flow rates in the leak detection system is difficult given the complexity and uncertainty of fluid flow under unsaturated conditions. After careful consideration of public comments on the proposal, EPA has decided not to specify 1 day (i.e., 24 hours) as the earliest practicable time for the detection of a leak through the top liner.

Commenters on the proposed 1-day leak detection time requirement argued that it was unnecessary and overly restrictive. Another commenter stated that the detection time could not be verified by field measurements. EPA agrees with the commenters that the proposed 1-day leak detection time requirement is unnecessary given that the Agency is promulgating minimum design specifications for leak detection systems. In addition, the Agency acknowledges that field measurement of leak detection times is a problem. EPA has determined that a leak detection system meeting today's design requirements will be capable of detecting leaks "at the earliest practicable time" consistent with the statutory mandate. Therefore, EPA is simplifying the rule by deleting the 1-day performance standard.

Leak detection sensitivity. EPA is also not finalizing the proposed leak detection sensitivity value of 1 gallon per acre per day (gpad) that was proposed. When developing a leak detection sensitivity performance standard for the May 29, 1987 proposed rule, EPA conducted comparative studies between the performance of composite bottom liners versus compacted soil bottom liners (Background Document "Bottom Liner Performance in Double-Lined Landfills and Surface Impoundments", 1987). These studies showed that composite bottom liners have a much more sensitive leak detection capability than do compacted soil-only bottom liners. For example, a compacted soil liner with a hydraulic conductivity of 1×10^{-7} cm/sec will allow some liquid migration into the liner; as a result, a simple, one-dimensional theoretical model predicts that a leak will not be detected until the flowrate through the top liner is approximately 80 gpad. In contrast, simple, one-dimensional theoretical models predict that the leak detection sensitivities of landfills and surface impoundments with composite bottom liners similar to those required in today's rule range from 0.001 to 0.1 gpad. Because EPA is today stipulating the use of a composite bottom liner, the Agency is confident that lower leak detection sensitivities will be achieved for all units affected by today's rule. Consequently, a separate requirement for leak detection sensitivity is no longer necessary and EPA has dropped this requirement from the final rule.

Slope. EPA is today finalizing a minimum slope requirement for the leak detection system. After further consideration of the slope requirement, the Agency has determined that a minimum 1 percent slope will provide adequate drainage at land disposal units at which proper construction quality assurance is used to minimize settlement (§§ 264.221(c)(2)(i), 264.251(c)(3)(i), 264.301(c)(3)(i), 265.221(a), 265.254(a), and 265.301(a)). The purpose of the requirement is to promote good drainage in the leak detection systems of units affected by today's rule. This slope requirement applies to all planar components of the leak detection system.

In the May 29, 1987 proposed rule, EPA proposed a 2-percent minimum slope but requested comments on whether the minimum bottom slope should be increased to a value between 2 and 4 percent. One commenter preferred that a 3-percent bottom slope be used to account for settlement in the final slope value. However, most commenters argued that the minimum should not be above 2 percent, expressing opposition to raising the minimum slope value above 2 percent. Many of these commenters pointed out that other improvements included in the proposed rules, such as construction quality assurance and an increased transmissivity value for synthetic drainage materials, would obviate the need for a slope greater than two percent. One commenter argued that slopes of less than 2 percent should be allowed for certain circumstances provided that the leak detection system meets other minimum design criteria and performance goals and the owner or operator can demonstrate that post-construction settlement/consolidation will be minimized or eliminated. The Agency agrees that with good CQA a lesser slope can be adequate.

Based on these comments, EPA carefully evaluated the minimum bottom slope requirement for today's rule. EPA recognizes that slope is one of several factors that will affect the performance of the leak detection system. For example, the hydraulic conductivity of materials used in the drainage system is important. In addition, the appropriate minimum slope required will also depend on the spacing of leachate collection laterals in the leak detection system; closer spacing will allow for a flatter slope. All of these design factors should be considered in selecting the appropriate slope for the system.

EPA agrees with commenters that today's rule sets in place improvements that affect the minimum slope that is needed to construct an effective leak detection system. First, the new

requirement to install a composite bottom liner provides a smooth impermeable base on which to install the leak detection system. The decreased permeability of the composite bottom liner over that of a soil liner required under previous regulations allows for a reduced slope while at the same time continuing to promote good drainage. Second, today's enhanced construction quality assurance requirements enable owners or operators the flexibility to build a flatter slope by maintaining consistent drainage without significant ponding of liquids. In addition, some of the new, rapidly draining synthetic draining materials promote more rapid drainage on flatter slopes.

Because of these improvements, EPA believes that minimum bottom slopes of less than 2 percent should be allowed where the owner or operator uses proper construction quality assurance to minimize settlement and resultant ponding of any leachate, as required by §§ 264.19 and 265.19 of today's rule. Such construction quality assurance should include surveying and other inspection techniques to measure the horizontal and vertical alignment of the bottom slope to minimize ponding and ensure leachate flow to the sump. Some owners or operators may elect to design leak detection systems using bottom slopes of greater than 1 percent. EPA emphasizes that the requirements promulgated today are minimum technical standards; owners and operators can always adopt more stringent designs at their discretion.

Thickness of granular drainage layer. Today's rule also requires that a granular drainage layer be a minimum of 12 inches in thickness for use in leak detection systems of new and replacement landfills, surface impoundments, and waste piles, and for lateral expansions of these units (§§ 264.221(c)(2)(ii), 264.251(c)(3)(ii), 264.301(c)(3)(ii), 265.221(a), 265.254(a), and 265.301(a)). EPA received no comments on this requirement in the May 29, 1987 proposed rule, and therefore is finalizing the 12-inch thickness requirement as proposed. The purpose of this minimum thickness is to decrease the chance that the underlying geomembrane will be damaged by equipment during placement of the drainage material. Current equipment used to install granular layers can only place drainage material to an accuracy of a few inches. The Agency is concerned that if granular drainage layers are designed to less than 12 inches, this equipment could damage underlying liners in areas where the drainage material is thin.

Further, this requirement for granular layer thickness is consistent with current EPA policy. A 12-inch granular layer thickness is specified in current Agency guidance (Background Document "Draft Minimum Technology Guidance Document on Double Liner Systems", 1985). In addition, a recent EPA evaluation of existing hazardous waste land disposal units (Background Document "Compilation of Current Practices at Land Disposal Units", January 1992) showed that 24 out of 28 landfills, surface impoundments, and waste piles with granular drainage layers, had a specified thickness of 12 inches.

Hydraulic conductivity of granular drainage materials. EPA proposed to require that granular materials used in leak detection systems have a minimum hydraulic conductivity of 1 cm/sec. The Agency contended that greater permeability afforded by granular materials having 1 cm/sec hydraulic conductivity was necessary to minimize capillary tensions present in leak detection system granular materials and to satisfy the proposed leak detection time performance standard of 1 day.

EPA requested and received comments on the proposed hydraulic conductivity requirement. Commenters opposed the 1 cm/sec requirement for several reasons. Several commenters stated that the requirement would force them to use rounded gravels or other granular materials meeting the hydraulic conductivity value. These commenters maintained that such materials were either not available or only available at significantly higher costs in many areas of the country. One commenter suggested that EPA should provide a variance to owners or operators in areas where suitable granular drainage materials having the proposed hydraulic conductivity are unavailable. Another commenter stated that the Agency should continue to require granular materials to have minimum hydraulic conductivities of 1×10^{-2} cm/sec as currently specified in EPA guidance. This commenter asserted that sand, which is the most common granular material used in leak detection systems, generally has a hydraulic conductivity of 1×10^{-2} cm/sec. Other commenters argued that using granular materials with hydraulic conductivities on the order of 1 cm/sec would significantly increase the susceptibility of geomembranes (above and below the drainage layer) to puncture, because it would be difficult to remove angular materials from the materials used to construct the drainage layer. Another commenter argued that by requiring granular materials to have a 1 cm/sec hydraulic conductivity, EPA was forcing owners or operators to use synthetic drainage materials that are incompatible with many materials used for synthetic liners.

The Agency acknowledges that the availability of granular materials meeting the proposed hydraulic conductivity requirement may be limited. The Agency is also concerned with the greater potential for geomembranes to be damaged from the use of granular materials having hydraulic conductivities of 1 cm/sec. In response to the commenters concerns, the final rule (§§ 264.221(c)(2)(ii), 264.251(c)(3)(ii), 264.301(c)(3)(ii), 265.221(a), 265.254(a), and 265.301(a)) requires that granular materials used in leak detection systems at waste pile and landfill units subject to today's rule have a minimum hydraulic conductivity of 1×10^{-2} cm/sec consistent with current Agency guidance. However, the final rule specifies that granular materials used in leak detection systems at surface impoundments subject to today's rule must have a minimum hydraulic conductivity of 1×10^{-1} cm/sec.

The Agency has determined that granular materials used in leak detection systems at surface impoundments must have a higher hydraulic conductivity (one order of magnitude greater than what is currently specified by Agency guidance) to account for the potentially greater hydraulic heads imposed on the top liner in surface impoundments. Surface impoundments are typically used to manage liquids, therefore the hydraulic heads on the liner systems of these units are often much higher than those in waste piles and landfills, which are not allowed to manage wastes containing free liquids and must have a leachate collection system above the top liner. Consequently, if a leak occurs in the top liner of a surface impoundment, and is not rapidly drained to the detection sump, areas of the bottom-liner system will potentially be subjected to hydraulic heads in excess of one foot, increasing the probability of migration of hazardous constituents out of the unit. A greater permeability in the leak detection system will drain any leak more rapidly and thus reduce the head on the bottom liner system. Although granular materials having hydraulic conductivities of 1×10^{-1} cm/sec will typically be coarser sands and fine gravels, the Agency feels that two common construction techniques can be

practicable time. The Agency does not intend, however, to imply that multiple liner systems (including multiple composite liners) or that thicker soil components of bottom liners (e.g., 4 or 5 feet) should be precluded.

EPA notes that such general performance standards provide flexibility which is essential since liner and leak detection system technologies have advanced significantly over the past several years and are continuing to do so. Some examples include the use of geonets, the use of geotextile fabric filters, and better seaming and construction quality assurance. Recent EPA studies show soil/bentonite blankets may be effective and reliable complements to top liners, resulting in a new type of composite top liner. As technologies improve, today's performance standards will allow different materials and designs to be used and specified in permits as site-specific considerations.

Today's rule amends the requirements for bottom liners at surface impoundment and landfill units to require owners and operators of units subject to today's rule to use a composite bottom liner instead of a compacted-soil bottom liner allowed by the interim statutory design. The composite bottom liner required by today's rule specifies that the upper component of the bottom-liner must consist of a geomembrane, and the lower component of the bottom-liner must consist of a minimum of 3 feet of compacted soil with a hydraulic conductivity of no more than 1×10^{-7} cm/sec. The compacted soil component must be able to minimize hazardous constituent migration in the event of a breach in the geomembrane.

In the March 28, 1986 proposal, EPA offered two options for the bottom liner of the double-liner system. One option corresponded to a compacted soil liner with a maximum hydraulic conductivity of 1×10^{-7} cm/sec and sufficient thickness (minimum 3 feet) to prevent hazardous constituent migration through the liner during the active life and post-closure care period (51 FR 10710). The other proposed option was the composite liner specified in today's rule, consisting of a top component that would prevent hazardous constituent migration into the top component (a geomembrane) and a bottom compacted-soil component with a maximum hydraulic conductivity of 1×10^{-7} cm/sec and the preamble to the proposal recommended a minimum thickness of 3 feet (90 cm).

EPA received comments supporting both bottom liner options. Several commenters argued that the compacted soil bottom liner, coupled with the leachate collection and removal system between the top and bottom liners, would provide adequate protection of the environment. Some of these commenters also proposed the use of a composite top liner with a compacted soil bottom liner. Others supported the use of composite bottom liners as the design best able to enhance leachate detection, collection, and removal efficiency of the leachate collection and removal system between the liners. Several commenters favored the promulgation of performance standards in the rule and the specification of designs and materials in accompanying guidance documents.

After the proposal, EPA compiled information and data on performance of these two bottom liner systems with respect to maximizing leachate detection, collection, and removal, and preventing hazardous constituent migration out of the unit. The liners were evaluated based on leachate collection efficiency, leak detection capability, and leakage through the bottom liner. Results from computer simulations and engineering calculations showed that, on a comparative basis, the composite bottom liner will perform significantly better than the compacted soil liner with respect to the three criteria. The results were summarized in the April 17, 1987 Notice of Availability of Information (52 FR 12566–12575), with more detailed discussion of the calculations and analytical approach contained in the "Bottom Liner Performance in Double-Lined Landfills and Surface Impoundments" (EPA/530–SW–87–013). In the May 29, 1987 proposed rule on leak detection systems, the Agency indicated that it was likely to finalize a rule on double liners that would require a composite bottom liner as the generally applicable standard (52 FR 20251).

EPA also conducted a review of applications submitted for RCRA hazardous waste facility permits between November 8, 1984 and February 1987 to determine the type of bottom liner selected for installation at new landfills and surface impoundments. Of some 183 units for which permit applications were submitted as of February 1987, only seven units were to be constructed with compacted soil bottom liners. The vast majority of owners or operators selected the composite bottom liner rather than a compacted soil bottom-liner. More recent data available to EPA also confirms that the majority of owners and operators are using composite bottom-liners in their designs of hazardous waste surface impoundment and landfill units (Supporting Document #3 "Compilation of Current Practices of Land Disposal Facilities," 1992).

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In summary, today's rule requires composite bottom liners, based on: (1) Available information that composite bottom-liners perform significantly better than compacted soil liners in terms of maximizing leachate detection, collection, and removal, and preventing hazardous constituent migration out of the unit; and (2) evaluation of current hazardous waste industry practices.

Consistent with existing requirements for single liners at surface impoundments and landfills, today's rule in §§ 264.221(c)(1)(ii), 264.301(c)(1)(ii), 265.221(a), and 265.301(a) requires that each liner that is included in the unit's design must be chemically resistant to the waste, placed on a structurally stable foundation, and large enough to cover all areas likely to be exposed to the waste.

Double liner systems must be constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients (including status head and external hydrogeologic forces), physical contact with the waste or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation. The liners must be placed upon materials capable of providing support to the liners and resistance to pressure gradients above and below the liners to prevent failure of the liners due to settlement, compression, or uplift. They must also be installed to cover all surrounding earth likely to be in contact with the waste or leachate.

2. Technical Standards for Leak Detection Systems

EPA is today establishing design standards for the leak detection systems for new landfills, surface impoundments, and waste piles, and replacements and lateral expansions of these units (§§ 264.221(c)(2), 264.251(c)(3), 264.301(c)(3), 265.221(a), 265.254(a), and 265.301(a)). These leak detection standards are designed to detect a leak through the top liner at the earliest of practicable time. Today's final rule also establishes the following design criteria for leak detection system drainage layers for affected landfills, surface impoundments, and waste piles: (1) A minimum bottom slope of 1 percent; (2) a minimum thickness of 1 foot and a minimum hydraulic conductivity of 1×10^{-2} cm/sec for granular materials used for the drainage layer for waste piles and landfills and 1×10^{-1} cm/sec

used in combination to prevent any damage to geomembranes adjacent to the drainage materials. First, facilities may select rounded drainage materials; these materials are less likely to puncture or otherwise damage membranes. Second, owners or operators may use additional layers of synthetic materials (e.g., a needle-punched nonwoven geotextile) next to the liner to provide a cushion for the drainage materials and reduce the probability of puncturing. In addition, today's construction quality assurance requirements help to assure against such punctures.

The Agency's recent evaluation of current industrial practices (see "Compilation of Current Practices at Land Disposal Facilities", January 1992) revealed that many facilities are selecting synthetic drainage materials, such as geonets, for their leak detection systems. Synthetic drainage materials are often selected instead of granular materials because they typically require less space and are easier to install than granular materials. Also, as discussed below, virtually all synthetic drainage materials have permeabilities greater than 10^{-2} cm/sec.

Transmissivity of synthetic drainage materials. EPA proposed a minimum transmissivity value of 5×10^{-4} m²/sec for synthetic drainage materials that are used in lieu of granular drainage materials. This value was selected because it provides equivalent drainage capacity to that of a granular drainage layer meeting the requirements of the proposed rule; that is, 12 inches of a granular drainage layer with a hydraulic conductivity of 1 cm/sec. The minimum value of 5×10^{-4} m²/s for hydraulic transmissivity was based on numerical simulations of typical leak detection systems. In these simulations, EPA considered a range of synthetic drainage materials, including nets, mats, and waffles. From the results of these simulations ("Liner and Leak Detection Rule Background Document", 1987), EPA concluded that a hydraulic transmissivity value of 5×10^{-4} m²/sec would enable the leak detection system to collect and remove relatively large amounts of leakage while maintaining gravity flow conditions. This specification was to ensure that the liquids in the leak detection system would be rapidly collected while the hydraulic head on the bottom liner would be minimized.

One commenter objected to the transmissivity standard, claiming that a value of 5×10^{-4} m²/sec is not achievable with a single layer of currently available netting, and that performance may be worse when creep, loading, and rib layover come into effect. EPA disagrees. The Agency has data (Liner and Leak Detection Rule Background Document, 1987) showing transmissivities of single layers of synthetic drainage materials produced by four major manufacturers under the conditions of ASTM Test Method D 4716–87 (that is, a pressure of 100 kilopascals (kPa) and a hydraulic gradient between 0.1 and 0.25). At the time of the proposal, these transmissivities ranged from approximately 2×10^{-4} m²/sec to 4×10^{-4} m²/sec. Improvements in geonets since then have resulted in typical transmissivities of 2×10^{-3} to 4×10^{-3} m²/sec using the same ASTM test method. The Agency maintains that the conditions at which ASTM D 4716–87 is conducted are representative of the pressures and hydraulic gradients in many land disposal units, and as a result, a transmissivity value of 5×10^{-4} m²/sec can be obtained with typical commercially available synthetic drainage materials. However, the Agency recognizes that the requirements for synthetic drainage materials should be consistent with the requirements for granular drainage systems in leak detection systems. Thus, the Agency has revised the transmissivity requirements in today's rule (§§ 264.221(c)(2)(ii), 264.251(c)(3)(ii), 264.301(c)(3)(ii), 265.221(a), 265.254(a), and 265.301(a)) to require that synthetic drainage materials achieve equivalent flow rates to drainage layers utilizing granular materials.

Other performance requirements. Today's final rule also includes several general performance standard requirements for leak detection systems that are simply restatements of what is already required in existing regulations for leachate collection and removal systems at surface impoundments, waste piles, and landfills subject to today's final rule. Under today's rule, leak detection systems for affected units must be constructed of materials that are chemically resistant to wastes and leachate in the unit, and be of sufficient strength to resist pressure gradients generated within the unit (§§ 264.221(c)(2)(iii), 264.251(c)(3)(iii), 264.301(c)(3)(iii), 265.221(a), 265.254(a), and 265.301(a)). These requirements are designed to ensure that leak detection systems are not damaged from chemical and physical stresses associated with the unit. Also, these requirements are simply an extension of the performance standards for liners.

Leak detection systems for units regulated under today's rule must also be designed and operated to minimize clogging during the [illegible] life and post-closure period (§§ 264.[illegible].c)([illegible] 264.251(c)(3)(iv), 264.[illegible] 265.221(a), 265.254(a), and 265.301(a)). This requirement is to ensure that drainage in leak detection systems is not impeded over time. EPA is concerned about the potential for drainage layers to become clogged as a result of physical, chemical, or biological mechanisms. EPA data indicate that the potential for clogging increases as the hydraulic conductivity of drainage material decreases. Examples of techniques to minimize clogging include: Using properly graded granular filter materials, filter fabrics (geotextiles), or other filter materials to reduce fines; using poorly graded (i.e., uniform) granular drainage material; increasing collection pipe slot numbers or size; reducing liquid residence time by increasing slope, decreasing pipe spacing, or increasing the size of granular drainage material; and cleaning collection system pipes and drainage media using hydraulic jetting, steam, or acidic solutions.

In addition, today's rule requires that leachate collection and removal systems immediately above the top liner (for landfill and waste pile units) be capable of ensuring that the leachate depth over the top liner does not exceed 1 foot (30 cm) as proposed in the March 28, 1986 proposed rule. EPA received no comments on these requirements and is therefore finalizing them as proposed.

EPA is today also promulgating several requirements for sumps that are part of a leak detection system. Owners or operators of new and replacement landfills, surface impoundments, waste piles, and lateral expansions of such units must use sumps of sufficient size to collect and remove liquids efficiently and prevent these liquids from accumulating on the drainage layer. In addition, the design of the sump and removal system must provide a method for measuring and recording the volume of liquids present in the sump and of liquids removed. EPA received no comments on these requirements and is therefore finalizing them as proposed (§§ 264.221(c)(2)(v), 264.251(c)(3)(v), 264.301(c)(3)(v), 265.221(a), 265.254(a), and 265.301(a)).

EPA is today promulgating a requirement for owners or operators of units affected by today's rule to collect and remove pumpable liquids in leak detection sumps to minimize the head on the bottom liner (§§ 264.221(c)(3), 264.251(c)(4), 264.301(c)(4), 265.221(a), 265.254(a), and 265.301(a)). The Agency had proposed, in the May 29, 1987

Federal Register, that the head in the sump for the leak detection sump be minimized; in the preamble, the Agency suggested that the average liquid levels in the sump should be below 12 inches. One commenter on the proposed rule stated that the 12-inch maximum was unachievable in many instances because of the size and geometry of most sumps and the pumps used to empty them. The commenter also mentioned that automated level control systems and minimum submergence requirements make the 12-inch maximum level an impossible performance standard. EPA agrees that the geometry of sumps may vary and that minimum pumping levels may be greater than 1 foot. Thus, the Agency is not setting a maximum level of liquids in the sump, but specifying only that the head on the bottom liner must be minimized by requiring owners and operators to remove pumpable liquids from the sump. "Pumpable liquids" means any amount of liquids that can be reasonably pumped out of the sump, based on sump dimensions, pump operating levels for automated pump systems, and the goals of minimizing head in the sump and backup of liquids (from the sump and drainage tile or pipes) into the drainage layer.

Today's rule also modifies the definition of the term "sump" in § 260.10 to redefine sumps used as part of leak detection systems for waste piles, surface impoundments, and landfills. The purpose of this modification is to make clear that the regulations for hazardous waste tanks that are otherwise applicable to certain sumps do not apply to those sumps used at land disposal units that function as part of the leak detection system. These sumps serve fundamentally different purposes than many other types of sumps. Sumps used at land disposal units are usually surrounded by one or more liners; therefore, many requirements, especially secondary containment, are not practicable for these units. The Agency maintains that subjecting these units to the requirements for hazardous waste tanks will not provide a substantial environmental benefit and has therefore modified the definition of the term sump to redefine sumps used as part of leachate collection and removal or leak detection systems for surface impoundments, waste piles, and landfills.

Finally, today's rule includes a requirement applicable only to those leak detection systems installed at new, replacement, or lateral expansions of landfills, surface impoundments, and waste piles that are not located above the seasonal high water table. EPA received no comments on this requirement and is finalizing it as proposed. The Agency is therefore requiring in today's rule that owners or operators of leak detection systems not located completely above the seasonal high water table demonstrate that the operation of the leak detection system will not be adversely affected by the presence of ground water (§§ 264.221(c)(4), 264.251(c)(5), 264.301(c)(5), 265.221(a), 265.254(a), and 265.301(a)).

3. Alternative Systems

Alternative designs. The existing rules (§§ 264.221(d), 264.251(b), 264.301(d), 265.221(c), and 265.301(c)) already provide for alternative designs to the liners and leachate collection and removal systems if an owner or operator can demonstrate that an alternative design will prevent the migration of any hazardous constituent into the ground water or surface water at least as effectively as the requirements in §§ 264.221(c), 264.251(a), and 264.301(c), as appropriate. Today's rule adds §§ 264.221(d), 264.251(d), 264.301(d), 265.221(a), 265.254(a), 261.301(a) to allow alternative designs for leak detection systems that are capable of detecting leaks of hazardous constituents at least as effectively as the new leak detection system requirements in §§ 264.221(c)(2), 264.251(c)(3), 264.301(c)(3), 265.221(a), 265.254(a), and 265.301(a). EPA feels that variance procedures allow owners or operators flexibility in designing their leak detection systems without discouraging the use of new leak detection systems.

In order to be granted a variance from the leak detection requirements of today's final rule, an owner or operator must demonstrate to the Regional Administrator that the proposed design detects leaks through the top liner at least as effectively as a leak detection system designed to meet today's minimum design standards. In deciding whether to allow a variance for an alternative leak detection system or technology, the Regional Administrator will consider: (1) The ability of the proposed system or technology to operate as effectively through the active life and post-closure period of the unit as a unit designed using the minimum design specifications; (2) the nature and quantity of the wastes to be managed in the unit; and (3) the ability of the system to detect leaks, and in combination with response actions to be taken upon discovery of leakage, prevent migration of hazardous constituents out of the unit during the active life and post-closure care period. For example, an alternative leak detection system that did not provide information about leakage until after the leakage migrated through the bottom liner would be deemed unacceptable, because such a system would trigger an owner or operator response after hazardous constituents migrated into the environment.

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Owners or operators may apply for a variance if they wish to propose a leak detection system design that deviates from today's design parameters. For example, if an owner or operator specified that the drainage layer of a surface impoundment would utilize granular materials having a hydraulic conductivity of 1×10^{-2} cm/sec (instead of the minimum required value of 1×10^{-1} cm/sec), the owner or operator would have to describe how other components of the system (e.g., depth of impoundment, bottom slope, flow path to a collection pipe or sump or pipe spacing) or the action leakage rate or response action plan would detect leaks at the earliest practicable time, minimize head on the bottom liner, and prevent migration of potentially hazardous constituents out of the unit as effectively as the design required in today's rule.

Temporary units. In the May 29, 1987 proposal EPA invited comment about whether double liners and leachate collection systems are necessary for all waste piles, or if alternative systems might provide adequate environmental protection at some units. In response to the Agency's request, a commenter questioned whether double liner and leachate collection systems are necessary for short-term waste piles created during corrective action. The same commenter also suggested that EPA should propose an overall policy in its upcoming corrective action rule as to what technological requirements will apply to units used for corrective action.

The Agency agrees with these comments. There are circumstances where the Agency believes it should allow temporary units constructed as a part of corrective action pursuant to a permit or 3008(h) enforcement order, or an approved closure plan, to be constructed without a double liner and a leachate collection system. Due to the limited time these units are in operation, in concert with alternative design, location and operating practices, there are situations which are equally effective as double lined units in preventing migration of constituents to ground water or surface water. Many waste piles (as well as some temporary storage surface impoundments) may thus qualify for the double liner waiver

found in §§ 264.221(d), 264.251(d), 265.221(a), and 265.254(a).

These provisions provide for a generic waiver of the double liner system, but do not specifically address temporary units. In response to the special needs raised by corrective action and facility closure (e.g., rapid cleanup and short-term operation) the Agency has published a proposed "Subpart S" rule (55 FR 30798) that, among other things, specifically addresses standards for temporary units. That proposal outlines Agency guidance on what factors to consider in determining what constitutes a temporary unit.

4. Applicability to Waste Piles

EPA is requiring that new and replacement waste piles, and lateral expansions of waste piles, install, operate, and maintain double liner and leak detection systems (§§ 264.251 and 265.254). The Agency is extending the double liner and leachate collection and removal system requirements to waste piles, as discussed in the preamble to the May 29, 1987 proposal (52 FR 20250), because the Agency maintains, for several reasons, that these units pose threats similar to or greater than landfills concerning leakage through the top liner and releases of hazardous constituents. First, waste piles are often exposed to precipitation for longer periods of time than landfills. Many owners or operators of landfills provide an intermediate cover to minimize leachate generation; this practice is not as common for waste piles. Second, waste piles have a higher potential for equipment-related damage than do landfills, because equipment is frequently used to add and remove waste from piles during these units' active lives. This increased equipment activity at waste piles increases the risk of damage to the primary liner and merits use of a secondary liner for these units. Finally, waste piles typically have much longer active lives than landfills: Waste piles are typically used for 20 years or more, whereas landfill units are more common used for periods of 3 months to 5 years before being closed.

Today's rule provides a waiver from the double liner and leachate collection and removal system requirements for certain waste piles that are monofills. In the May 29, 1987 proposal rule, EPA proposed a variance for monofills when (1) the monofill contains only hazardous wastes from foundry furnace emission controls or metal casting molding sand, such waste do not contain constituents which would render the wastes hazardous for reasons other than EP toxicity characteristic, (3) the monofill has at least one liner for which there is no evidence that such liner is leaking, (4) the monofill is located more than a quarter mile from an underground source of drinking water, and (5) the monofill is in compliance with generally applicable ground-water monitoring requirements for facilities with permits. The Agency proposed this waiver to codify the language in section 3004(o)(3) of RCRA and to be consistent with regulations for landfills and surface impoundments. Because EPA received no comments on this proposed waiver, it is being finalized as proposed in today's rule (§§ 264.251(e)(1) and 265.254(a)).

Today's rules do not affect the existing exemption in § 264.250(c) and now in § 265.254 for certain indoor waste piles. These units continue to be excluded from today's double-liner and leak detection requirements because they contain no free liquids and are protected from precipitation and surface water run-on and are therefore unlikely to have any leakage.

5. Applicability to Land Treatment Units

EPA proposed a number of leak detection requirements for land treatment units in the May 29, 1987 proposed rule. These requirements included (1) a 95-percent confidence level for detecting hazardous constituents in the treatment zone, (2) monitoring conducted above the seasonal high water table, (3) response action plans, and (4) inspection of unsaturated zone monitoring equipment. Today's rule does not include additional leak detection requirements for land treatment units. EPA has concluded that the current regulatory requirements for unsaturated zone monitoring at land treatment units are sufficient to ensure that leakage of hazardous constituents will be detected at the earliest practicable time. Therefore, EPA finds that additional regulations for such units are not needed to meet the statutory requirements of section 3004(o)(4) of RCRA for these units.

In the preamble to the 1987 proposal, EPA noted that unsaturated zone monitoring systems serve as effective leak detection systems for land treatment units. The Agency received no comments challenging this position or suggesting more effective alternatives. The existing regulations, however, already require unsaturated zone monitoring—i.e., leak detection systems—at all land treatment units, both new and existing. Specifically, §§ 264.278 and 265.278 contain detailed technical standards for soil and soil-pore liquid monitoring in the unsaturated zone below the land treatment unit to ensure detection of any hazardous constituents migrating out of the treatment zone. Furthermore, when releases are detected, the owner or operator of a permitted facility is required to modify operating procedures at the land treatment unit to prevent further release. EPA has implemented these requirements through two guidance documents: "Permit Guidance Manual on Hazardous Waste Land Treatment Demonstrations" and "Guidance Manual on Unsaturated Zone Monitoring for Hazardous Waste Land Treatment Units." After reviewing public comments and its experience in permitting land treatment units since the proposal, EPA concluded that the current regulatory requirements, coupled with existing guidance, are sufficient to ensure that leak detection systems in new land treatment units are capable of detecting releases at the earliest practicable time.

In the May, 1987 proposal, EPA did not propose to change the basic regulatory requirements for unsaturated zone monitoring, but added several relatively minor amendments. For example, the proposal would have added a requirement that constituents migrating out of the treatment zone be detected at a 95% confidence level and that the unsaturated zone monitoring take place above the seasonal high water table as well as below the treatment zone (as the current standards specify). EPA has concluded that these minor changes are unnecessary, either to meet the statutory standard or to protect human health and the environment. Available guidance documents already specify a 95% level of confidence for monitoring, and EPA and the States have successfully incorporated this standard into permits. Therefore, it is unnecessary to impose this requirement as a matter of regulation. Similarly, monitoring below the seasonal high water table is already prohibited by the existing regulations, because monitoring below the water table would not qualify as unsaturated zone monitoring. Therefore, the regulatory requirement that the monitoring be above the seasonal high water table is also unnecessary.

Today's final rule also does not finalize requirements for a response action plan describing remedial action if releases are detected in the unsaturated zone. EPA has concluded that a response action plan for permitted land treatment units is superfluous, because the current regulations (§ 264.278(g)) already require facility owners or operators to take specific responses in the case of hazardous constituents detected in the unsaturated zone monitoring system. EPA also notes that

migration found in the unsaturated zone monitoring system would constitute migration from the unit, and therefore could be addressed by the Agency, if necessary, under RCRA corrective action requirements. Finally, EPA notes that, because of the RCRA land disposal restrictions, most if not all hazardous waste land treatment units in the future will be able to operate only if wastes placed in them meet applicable treatment standards before placement in the unit or if they are granted a no-migration variance. A unit granted a no-migration variance that then releases hazardous constituents from the unit would have to cease receipt of prohibited wastes (§ 268.6(f)). In this case, a unit found to be releasing hazardous constituents to the unsaturated zone would be required to cease operating. For these reasons, EPA has concluded that a response action plan is not necessary for land treatment units.

A December 6, 1991 decision of the United States Court of Appeals, District of Columbia addressed the soil-pore water monitoring requirements for interim status land treatment facilities (*Shell Oil Company* v. *EPA*, No. 80-1532). As of the date of this rule, the Court's mandate was not yet issued and the regulation remains in place. The Agency is still considering what response to take to the Court's decision.

C. Response to Leaks

1. Action Leakage Rate

The final rule requires owners or operators to establish one action leakage rate (ALR) for each unit affected by today's rule (§§ 264.222, 264.252, 264.302, 265.222, 265.225, and 265.302). The action leakage rate is a leakage rate that requires implementation of a response action to prevent hazardous constituent migration out of the unit. The Agency has determined, the public comments support, the need for an ALR and response actions that the ALR triggers. EPA believes that the ultimate goal of the liner and leak detection system requirements is to prevent the release of hazardous constituents from the unit, thereby protecting the ground water and surface water. A system in place to detect leaks at the earliest practical time should be complemented by early follow-up actions to effectively minimize the chance for migration of hazardous constituents from the unit. Furthermore, it is often more effective to address leaks within the liners than to later address ground-water contamination through corrective action.

Today's final rule requires owners or operators to monitor the rate of leakage into the leak detection sump and to determine whether the measured rate of leakage over a specified period of time exceeds the action leakage rate (see Section IV.D. of the preamble for further discussion of today's monitoring requirements). If the owner or operator determines that the measured rate of leakage exceeds the ALR, the owner or operator must notify EPA and implement procedures contained in a response action plan that owners or operators must prepare for units affected by today's rule.

The proposed rule allowed the owner or operator a choice in establishing an action leakage rate. EPA proposed to specify an action leakage rate between 5–20 gallons/acre/day (gpad). Alternatively, the owner or operator could propose a site-specific action leakage rate for EPA approval. The proposed rule required owners and operators to develop and submit a plan for responding to the action leakage rate.

The proposed rule also required owners and operators to establish a value and a response action plan for a rapid and large leakage rate (RLL). The RLL was defined as the maximum design leakage rate (plus a safety factor) that the leak detection system can remove under gravity flow conditions (i.e., without the fluid head on the bottom liner exceeding one foot in granular leak detection systems and without the fluid head exceeding the thickness of synthetic lead detection systems). EPA also considered in the proposal the possibility of owners or operators developing responses to leakage rates between the action leakage rate and rapid and extremely large leakage rate (referred to as an intermediate leakage rate). In addition, the Agency considered requiring owners or operators to develop responses to "significant changes" in the flow rate (EPA suggested a 100 gpad or 25–50 percent increase, whichever was larger), leakage that exceeded health-based concentrations of hazardous constituents, and a leakage rate exceeding 50 gpad for any one-day period. In summary, EPA discussed six leakage rates in the proposal that could trigger various response actions by owners or operators.

Although no commenters objected to the establishment of an action leakage rate, EPA received many comments on the proposed action leakage rate value. Several commenters favored EPA setting an action leakage rate within the proposed range of 5–20 gpad. Some suggested that EPA should not finalize a specific value within the proposed range, but keep the range of 5–20 gpad and allow the permit writer to select a specific value within the range to apply to the unit. Some commenters suggested an action leakage rate of 50 or 100 gpad. Another commenter suggested that EPA set an action leakage rate at 75 percent of the proposed rapid and extremely large leakage rate. One commenter stated that the action leakage rate should be decreased over the life of the unit according to a formula, thus allowing a higher action leakage rate during initial operation of the unit to account for presence of liquids in the sump from sources other than leaks (e.g., construction water).

In general, most commenters stated that EPA had little or no field data to set an action leakage rate within the proposed range, and argued that the Agency should allow site-specific action leakage rates to be set by the permit writer, especially to account for other potential sources of liquids in the leak detection sump (e.g., soil liner construction water, precipitation during construction, and ground-water infiltration). Although the proposed rule would allow site-specific variances to the proposed action leakage rate, commenters expressed concern that EPA would not allow many site-specific action leakage rates. These commenters claimed that site-specific action leakage rates based on the design and operation of the unit should be common.

EPA also received many comments on other leakage rates that would require owners or operators to develop response actions. Commenters opposed using "significant changes" in the flow rate or health-based concentrations of hazardous constituents in liquids entering the detection sump to trigger a response by the owner or operator. Commenters felt that the proposed "significant change" concept was unclear and difficult to define. Commenters felt using leachate quality analysis at flow rates below the rapid and extremely large leakage rate to trigger a response was costly, time-consuming, and provided no additional environmental benefit. These commenters generally felt that liquid flow rates into the detection sump should be the sole trigger of an owner or operator's response. Many of these commenters also disagreed with the use of health-based levels (e.g., maximum contaminant levels) in the leachate to trigger a response. They argued that EPA's assumptions in proposing such levels were overly conservative and unrealistic because such liquid was still contained in the leak detection system and migration to the environment was

controlled by the bottom-liner and drainage system.

Many commenters maintained that EPA was proposing too many leakage rates without a clear distinction between them as to the differences in response associated with the leakage. These commenters claimed that some of the responses actions discussed by EPA in the preamble seemed to be redundant for different leakage rates, and that EPA's requirements were confusing, burdensome, and provided no additional benefit. As an example, the commenters cited that flow rates above the proposed action leakage rate (5–20 gpad) would trigger many of the same responses that exceedance of other leakage rates, such as the rapid and extremely large leakage rate (an example in the preamble showed a RLL of 3000 gpad) or significant change in leakage rate, would mandate. Some of these commenters stated that leakage rates less than the rapid and extremely large rate did not necessarily indicate a failure of the top liner, and that leakage would still be contained within the unit by the bottom liner. Therefore, they felt that the Agency should not stipulate excessive and redundant responses on the part of owners or operators for leakage rates that do not pose environmental concerns.

EPA requested and received field data on actual leakage rates from commenters on the proposed rule, and obtained additional data from more recent studies of leakage rates through top liners at land disposal units. However, these data are limited and furthermore, indicate that a portion of units (>25%) with CQA could exceed 20 gpad, the highest end of the proposed range for action leakage rates. Therefore, the Agency agrees with commenters that existing field data do not support establishment of an action leakage rate within the proposed range of 5–20 gpad for all units.

In response to EPA's request for comments on the appropriateness of the proposed range for surface impoundments, commenters argued that it was inappropriate for the Agency to set the same action leakage rate for landfills and surface impoundments and that the Agency should take into account the type, size, and operation of the unit when establishing an action leakage rate. EPA agrees with the commenters that the size, type, and operation of the unit should be accounted for in establishing a leakage rate that will trigger a response by the owner or operator, and that a standard leakage rate value for all units is not appropriate at this time.

In addition, EPA acknowledges commenters' concerns about the proposed number of leakage rates triggering a response by the owner or operator, and the lack of distinction among them for purposes of implementation. To simplify the final rule, EPA has chosen to establish one leakage rate that will trigger a response by the owner or operator, account for the site-specific design of the unit, and indicate significant evidence that there is problematic leakage through the top liner that mandates a response. EPA is requiring owners or operators to propose an action leakage rate for each unit subject to today's rule based on an approach that is similar to the proposed definition of the rapid and extremely large leakage rate. That is, owners or operators must calculate an action leakage rate based on the maximum design leakage rate that the leak detection system can remove without the fluid head on the bottom liner exceeding one foot. This leakage rate must account for an adequate margin of safety for uncertainties in design, construction, and operation of the leak detection system. The action leakage rate must not be greater than the flow capacity of the drainage layer in order to assure detection of leaks (e.g., if the ALR is 500 gpad and the flow capacity is 400 gpad then the ALR would never be exceeded no matter how large the leak). The action leakage rate should always be less than or equal to the pumping capacity of the leak detection sump since the pumping capacity is required to be greater than the maximum leak detection system flow rate under which gravity flow conditions prevail (i.e., to prevent liquids from backing up into the drainage layer). If the owner or operator determines that the action leakage rate is exceeded, the owner or operator must implement the procedures contained in the response action plan.

EPA believes that flow rates in excess of the action leakage rate indicate a major localized or general failure of the top liner, thus increasing the potential for a buildup of head on the bottom liner and increasing the potential for migration of hazardous constituents into the bottom liner. For this reason, it is necessary to maintain leak detection flow rates below the action leakage rate and for the owner or operator to take response actions for leaks greater than the action leakage rate.

Under today's rule, as in the May 29, 1987 proposal, the owner or operator must propose an action leakage rate based on calculations of the maximum flow capacity of the leak detection system design so as not to exceed one foot head on the bottom liner (called rapid and extremely large leak in the proposal). The proposal background document "Liner and Leak Detection Rule Background Document", (EPA/530-SW-87-015, May 1987) presented a number of mathematical models for making such a determination. All of these models are based on Darcy's Law for non-turbulent flow through saturated media. Of these models, the Agency finds that the following formula for flow originating through a hole in the liner is the most likely leak scenario for a geomembrane liner:

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$$Q = k.h.\tan\alpha.B$$

where

Q = flow rate in the leak detection system (drainage layer).
h = head on the bottom liner.
k = hydraulic conductivity of the drainage medium.
α = slope of the leak detection system.
B = width of the flow in the leak detection system, perpendicular to the flow.

Using this formula, the Agency calculated the maximum flow rates using the minimum specifications in today's rule: 1% slope, and 1×10^{-1} cm/sec hydraulic conductivity for surface impoundments and 1×10^{-2} cm/sec hydraulic conductivity for landfills and waste piles. Assuming that the head is 1 foot and the width of flow (B) is 100 feet, the results show maximum flow rates of 2,100 gpad for surface impoundments and 210 gpad for landfills and waste piles. Using a safety factor of two, as suggested in the proposed rule preamble, yields about 1,000 gpad for surface impoundments and 100 gpad for landfills and waste piles as the Agency recommended action leakage rates. Because this calculation used the minimum technical requirements and other design assumptions to maximize potential head on the bottom liner, the Agency believes that the units meeting the minimum technical requirements would not require action leakage rates below 100 gpad for landfills and waste piles and 1000 gpad for surface impoundments. The final background document on action leakage rates ("Action Leakage Rates for Leak Detection Systems," January 1992) provides further discussion and background on these recommended action leakage rates. As discussed earlier in the preamble, this document is available from the docket for this rule or from NTIS, U.S. Department of Commerce.

While EPA recommends the above action leakage rates for the minimum design specifications, the Agency recognizes that a number of site-specific

factors affect the maximum flow capacity of a leak detection system, and owners or operators may want to propose alternative action leakage rates. For example, the leak detection system design may be different than the minimums specified in today's rule. As indicated above and in the background document, hydraulic conductivity is a factor that significantly affects the flow capacity of the system. The Agency believes that leak detection systems with greater hydraulic conductivities would have higher action leakage rates. In additional, owners or operators may have information to justify a different width of flow in the above calculation. Owners or operators also may justify a higher action leakage rate by using a different formula or model. While the Agency recommends the use of the above model for defining the maximum flow capacity of the leak detection system and action leakage rate, EPA recognizes that there may be alternative models available now or in the future that may more accurately predict system flow capacity to justify higher action leakage rates. Therefore, owners or operators may propose to use an alternative model that they believe more accurately predicts the maximum flow capacity of the leak detection system. Further, owners or operators may want to do a flow (pump) test on the leak detection system to show actual flow capacity, which may justify a higher action leakage rate. Finally, the owner or operator may have flow rate data on similarly designed units to use to justify a different level. As more and more units are built, the Agency as well as owners or operators will develop a better data base that may be used to establish appropriate action leakage rates.

For facilities seeking a permit, the action leakage rate will be set after the Regional Administrator reviews the rate proposed by the owner or operator in either the facility's part B permit application or permit modification. for interim status facilities, the owner or operator must submit a proposed action leakage rate for the affected unit to the Regional Administrator 60 days prior to the receipt of waste in the unit. The Regional Administrator will either approve, modify, or deny the proposed leakage rate. The Regional Administrator may extend the review period to evaluate the owner or operator's proposed action leakage rate up to 30 more days. If none of these actions occur within 60 days (or if the review period is extended, within 90 days), the proposed rate can be considered approved.

Owners and operators of units affected by today's rule must monitor the leak detection sump and use the monitoring information to determine if the action leakage rate has been exceeded. The final rule sets forth the procedures owners or operators must use in determining whether the action leakage rate has been exceeded §§ 264.222(b), 264.252(b), 264.302(b), 265.222(c), 265.255(c), and 265.302(c)). To calculate the flow rate from the leak detection sump, owners, or operators must convert flow rate data into an average daily flow rate per acre (i.e., gpad) for each leak detection sump. This calculation must be performed weekly during the active life and closure period of the unit, unless the Regional Administrator approves otherwise. Upon closure (installation of the final cover for the unit), owners or operators will monitor the leak detection sump monthly, or in some cases quarterly or semi-annually (see Section IV.D. for further discussion). While on a monthly monitoring schedule, owners or operators will have to convert the monitoring data to an average daily flow rate to determine if the action leakage rate has been exceeded. If an owner or operator is monitoring quarterly or semi-annually no calculations are needed unless liquids are detected in the sump above the pump operating level, in which case the owner or operator must resume monitoring the sump on a monthly basis. Such an owner or operator would then have to convert monitoring data to an average daily flow rate per acre for the purpose of determining if the action leakage rate has been exceeded.

2. Response Action Plan

The final rule requires owners or operators of affected units to develop a response action plan for leaks exceeding the action leakage rate §§ 264.223, 264.253, 264.304, 265.223, 265.259, and 265.303). The response action plan is a site-specific plan that the owner or operator develops to address leakage through the top liner to assure that it does not migrate out of the unit. It is based on an assessment of the capability of the total design, construction, and operation of the unit rather than of individual components of the unit.

The majority of commenters on the proposed response action plan requirements stated that there were too many potential triggers (i.e., leakage rates) that the response action plan must potentially address in the proposed rule. These commenters argued that these trigger levels lacked distinction as to the responses they would necessitate. Other commenters felt that the response action plan requirements were confusing and inconsistent in certain cases. The commenters noted that many of the response actions for leaks above the proposed rapid and extremely large leakage rate were similar to actions for leaks above the proposed action leakage rate. In response to these comments, EPA has simplified and clarified the response action requirements in today's final rule.

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The final rule specifies minimum response actions that the owner or operator must take when the owner or operator determines that the action leakage rate has been exceeded. The minimum response actions are included in the response action plan that the owner or operator must prepare. Although minimum response actions are required to be in the response action plan, the content of a response action plan is determined by site-specific factors. The minimum responses required under today's rule are typical of response action plans EPA has identified at operating facilities and incorporate comments EPA received on the proposed response action plan requirements. Although today's rule only requires the owner or operator to initiate response actions upon exceedance of the action leakage rate, owners or operators may want to implement some types of response actions for leakage rates less than the action leakage rate, because these actions will lower the probability that leakage will exceed the action leakage rate and trigger today's final response action requirements.

An owner or operator's response action plan must include notifying EPA within 7 days that the action leakage rate has been exceeded. EPA received no comments on the proposed notification requirement and thus, is finalizing this requirement. The Agency is also requiring that the owner or operator submit a preliminary written assessment to the Regional Administrator within 14 days of the determination as to amount and source of the liquids in the detection sump, information on possible size, location, and cause of the leak, and any immediate and short term actions the owner or operator will take (e.g., additional pumping and removal of the leachate, changes in operating practices to reduce the leakage). As stated above, the Agency believes that exceedance of the action leakage rate is significant and indicates a major localized or general failure of the top liner, thus increasing the potential for a buildup of head on the bottom liner and increasing the potential for migration of hazardous

constituents into the bottom liner and out of the unit. For this reason, the Agency must be notified and given a preliminary assessment of the actions taken by the owner or operator.

The focus of the response action equirements for flow rates above the action leakage rate is the degree and schedule of what remediation, if any, is needed to reduce the leakage to the action leakage rate. The final rule requires that owners or operators identify the location, size, and cause of the leakage, and sample and analyze the leachate present in the detection sump. EPA believes that analyzing the leachate is necessary as part of determining the response needed to reduce the leakage to below the action leakage rate. For example, such information may be useful in locating a leak at sites where different wastes are disposed of in different cells. The owner or operators's's response action plan must discuss whether wastes should be removed to locate and repair the leak, whether repairs or controls will be used to minimize the leakage, and if so, whether operational changes, such as reduction or cessation of waste receipt, or partial or final closure of the unit, will be implemented, and if so, what types.

Today's rule clarifies when the owner or operator must submit a report documenting the response actions taken concerning leakage above the action leakage rate. The final rule requires that the owner or operator submit a report to the Regional Administrator describing how effective the response actions have been in reducing the leakage below the action leakage rate and preventing migration of hazardous constituents out of the unit within 30 days of exceeding the action leakage rate. The final rule also requires that the owner or operator continue to submit these reports monthly as long as the action leakage rate is exceeded.

EPA received several comments on the proposed response action submission and approval process. Several commenters expressed concern over possible delays associated with requiring a response action plan before receipt of waste. EPA received comments both supporting and objecting to submittal of the response action plan as part of the permit application process. One commenter suggested that the response action plan for both leakage rates above the rapid and extremely large leakage rate and leakage rates above the proposed action leakage rate but below the rapid and extremely large leakage rate should be submitted as part of the permit application. Another commenter argued against submittal as part of the permit application. The commenter stated that the bottom liner system can contain leakage rates in excess of the rapid and extremely large leakage rate until the response action plan is approved, and that such liquid would not migrate very far into the bottom liner before the response action plan was approved.

Unlike the proposed rule, the final rule requires owners or operators to submit only one response action plan for leakages exceeding the action leakage rate. Although EPA acknowledges that the bottom liner will provide initial containment of any leakage into the leak detection system, EPA still feels that leakage above the action leakage rate is an indication of a significant problem with the unit. The Agency believes that a response action plan is necessary before receipt of the waste into a unit to assure that there is both a commitment and an instrument in place to initiate responses upon exceedance of the action leakage rate, before leaks can potentially migrate out of the unit.

The final rule requires that new hazardous waste management facilities submit their response action plans and have them approved as part of the permit application process. Permitted facilities must submit the plan as part of a permit modification according to the procedures in § 270.42. Consistent with the minimum technology notification requirements of RCRA section 3015 for surface impoundments and landfills, owners and operators of units at interim status facilities subject to today's leak detection system rules are required to submit a response action plant in conjunction with the proposed action leakage rate 60 days prior to receiving waste into the unit.

D. Monitoring and Inspection Requirements

In today's final rule, EPA is promulgating several minor amendments to monitoring and inspection requirements for new and replacement landfills, surface impoundments, and waste piles, and lateral expansions of these units. These amendments add inspection requirements for leak detection systems (§§ 264.226, 264.254, 264.303, 265.226, 265.260, and 265.304). Specifically, today's rule requires facility owners and operators to monitor the sumps in leak detection systems for the presence of liquids in the sumps and record the amount of liquid removed from the sumps. Under §§ 264.222(b), 264.252(b), 264.302(b), 265.222(c), 265.255(c), and 265.302(c), owners or operators must calculate the average daily flow rate in gpad for each leak detection system sump on a weekly basis during the active life and monthly during the post-closure period, when monthly monitoring is required, to determine if the action leakage rate has been exceeded.

In the May 29, 1987, proposal, EPA proposed to require daily monitoring of the leak detection system sump during the active life of the units, and weekly monitoring during the post-closure period. EPA received several comments on the issue of the frequency of leak detection system sump monitoring requirements. Among those who commented, several objected to the requirement for leak detection system sump measurement on a daily basis during the active life because (1) not all facilities are operational on weekends and holidays, and (2) the payment of overtime rates to personnel for monitoring activities on weekends and holidays would be a significant financial burden. Other commenters stated that it would be difficult to monitor many sumps on a daily basis, especially large sumps or facilities with small leakage rates. One commenter suggested monthly monitoring of the leak detection sump. Most of these commenters suggested that monitoring the sump weekly during the active life was sufficient to determine exceedance of an action leakage rate.

EPA maintains that precipitation or other events may lead to large heads on the bottom liner over a period of a week, and that monthly monitoring of the sump during the active life is insufficient for observing changes in liquid levels in the sump that may necessitate action on the part of the owner or operator. However, EPA agrees with commenters that daily monitoring of the sumps is excessive given that the Agency has redefined the action leakage rate that triggers a response action. Thus, EPA has changed the requirement from daily monitoring of the leak detection system sump to require weekly monitoring during the active life and closure period. As discussed earlier, EPA has also changed the requirement from daily removal of accumulated liquids in the sump to a requirement to remove liquids from the sump as necessary to minimize head on the bottom liner (§§ 264.221(c)(3), 264.251(c)(4), 254.301(c)(4), 265.221(a), 265.254(a), and 265.301(a)).

Two commenters also objected to the requirement to monitor the leak detection system sump weekly during post-closure. These commenters stated that monthly monitoring would be sufficient because the elimination of liquids from incident precipitation and the reduction of drainage from wastes will result in insignificant leachate

generation in the years following closure. These commenters stated that monitoring should be conducted monthly or quarterly and more often only if the volumes of liquid in the sump increased.

EPA acknowledges that leachate generation should decrease in the years following closure of the unit, due to the effectiveness of the final cover. In response to comments received on this issue, EPA is allowing owners or operators to conduct monthly monitoring of the sump after the final cover is installed on the unit (§§ 264.226(d), 264.303(c), 265.226(c), and 265.304(a)). The Agency has also decided in the final rule to allow owners or operators to conduct quarterly monitoring of the sumps during post-closure, if the liquid levels in the sump stay below the pump operating level for two consecutive months, and/or semi-annual monitoring of the sumps if the liquid level in the sump stays below the pump operating level for two consecutive quarterly inspections. However, if pumping is required to remove liquids from the leak detection sump (i.e., liquids above the operating level of the sump) at any time during quarterly or semi-annual inspections, owners or operators must increase their monitoring to a monthly or quarterly basis, respectively. However, the Agency acknowledges that in some cases the levels may vary at facilities depending on the design and geometry of the sump and the type of pump used.

The "pump operating level" is a level proposed by the owner or operator and approved by the Regional Administrator based on sump dimensions, pump activation levels, and a level that avoids backup of liquids (from the sump and drainage tile or pipes) into the drainage layer.

Today's rule requires the owner or operator to monitor for and record the presence and level of liquids present in each leak detection sump, as well as the amount of liquids removed from the sump, to determine the leakage rate through the top liner. The leachate volume in the sump typically will be determined by measuring the liquid level in the sump. The leachate volume removed from the sump can be determined by collecting (in containers, tanks, etc.) and measuring the quantity of liquid pumped out of the sump or, alternatively, by installing flow-metering equipment to record the volumes. A third option is to install a device to measure inflow into the sump, for those units where the sump is located outside the unit; this may be a weir or pump at the sump inflow pipe. The leakage rate is to be calculated as the volume of liquid entering the sump over a period of time divided by the time and then also divided by the unit area served by the sump.

EPA is today requiring, as proposed, that the measured leakage rate in each sump in the leak detection system be used for determining whether the action leakage rate for the unit has been exceeded. EPA received several comments on this requirement. These commenters maintained that a variance from the action leakage rate should be available when it can be demonstrated that liquid in the leak detection system is from a source other than leakage through the top liner. EPA acknowledges that the actual leakage rate through the top liner may be different (larger or smaller) than the measured leakage rate at the sump depending on: (1) The collection efficiency of the system and (2) the presence of water in the leak detection system from construction, ground-water infiltration, consolidation of compacted soil liners, or additional sources of liquid other than leakage. However, owners and operators may consider these other sources of liquid when determining an action leakage rate that is appropriate for their unit and in developing their response action plan.

Today's final rule makes several technical amendments to the general inspection requirements and operating record requirements for units affected by today's rule. EPA today is amending § 264.15 by correcting an earlier oversight by adding requirements to inspect hazardous waste tanks as required by §§ 264.193 and 264.195 (today's amendments also remove two erroneous cross-references—§§ 264.194 and 264.253—from § 264.15). Section 265.15 is being amended by adding today's inspection requirements for units at interim status facilities under §§ 265.260, 265.278, and 265.304. EPA is also today making technical changes to the operating record requirements for units affected by today's rule at permitted and interim status facilities in §§ 264.73 and 265.73. These sections have been modified to reference recordkeeping requirements for permitted tank facilities (in §§ 264.191, 264.193, and 264.195) and interim status tank facilities (in §§ 265.191, 265.193, and 265.195).

E. Construction Quality Assurance

EPA today is promulgating construction quality assurance requirements (CQA) for all new landfills, surface impoundments, and waste piles, and replacements and lateral expansions of such units to the extent they are affected by the double-liner system and leak detection system requirements in today's rule. Today's CQA requirements also apply, to the extent they are relevant to units built under variances granted under §§ 264.221, 264.251, 264.301, 265.221, 265.254, and 265.301. The Agency has concluded that CQA is integral to ensure the proper construction, operation, and design of double-liner and leak detection systems and the closure of land disposal units. The CQA requirements being issued incorporate standard engineering practices and common hazardous waste management industry practices that have already been proven to ensure that the design and performance standards of today's final rule are met.

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EPA is today promulgating CQA requirements applicable to foundations, dikes, low-permeability soil liners, geomembranes, leachate collection and removal systems, leak detection systems, and final covers.

The Agency has conducted a number of studies that outline the need for CQA. In 1983, EPA conducted a study assessing existing technology for liner installation at hazardous waste land disposal facilities ("Liner and Leak Detection Rule Background Document", 1987). The data base used in the study consisted of information from the literature supplemented by data collected through 40 interviews with technical experts in industry, State regulatory agencies, trade and professional associations, research organizations, and waste management companies. This study's conclusions were: (1) Construction-related problems during liner system installation constituted one of the major causes of liner system failure and (2) a rigorous CQA program could have identified and corrected many of the problems that contributed to such failure. The study also concluded that construction techniques that were available at that time could be used to install geomembrane and clay liner systems that met the Agency's performance standards for liner systems. However, the study noted that a comprehensive monitoring and audit program during construction would be needed to attain the Agency's performance standards for liner systems.

In 1985, EPA conducted another study to supplement existing information on liner performance ("Liner and Leak Detection Rule Background Document", 1987). This study was designed to evaluate the factors that contributed to successes and failures at 27 landfills and surface impoundments selected for case studies. The results of this study showed

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tensors of the second, third, and fourth orders, respectively, which represent matrix properties only. At low *Re*, the last two terms on the right-hand side of (4-48) vanish. The last term describes the effect of matrix non-symmetry.

4-5 DUPUIT ASSUMPTIONS FOR A PHREATIC AQUIFER

A phreatic aquifer is defined in Sec. 2-3 as one in which a water table (phreatic surface) serves as its upper boundary. In Sec. 2-2, we have introduced the fact that actually above a phreatic surface, which is an imaginary surface, at all points of which the pressure is atmospheric, moisture does occupy at least part of the pore space (Fig. 2-3). The capillary fringe was introduced as an approximation of the actual distribution of moisture in the soil above a phreatic surface.

Figure 4-5a shows how the actual moisture distribution is approximated by a step distribution, assuming that no moisture is present in the soil above a certain level. This step defines the height, h_c, of the capillary fringe. Obviously, this approximation is justified only when the thickness of the capillary fringe thus defined is much smaller than the distance from the phreatic surface to the ground surface. Note also that the capillary fringe better approximates reality in the case of a poorly graded soil than in a well-graded soil (Fig. 4-5b). In the capillary fringe (as in the entire aerated zone above the phreatic surface), pressures are negative; therefore, they cannot be monitored by observation wells which serve as piezometers. A special device, called *tensiometer*, is needed in order to measure the negative pressures in the aerated zone (Fig. 6-6b and further details in Sec. 6-1). Water levels in observation wells that terminate below the phreatic surface give elevations of points on the phreatic surface. Using a sufficient number of such points, we can draw contours of this surface.

Thus, the capillary fringe approximation means that we assume a saturated zone up to an elevation h_c above the phreatic surface, and no moisture at all above it. In this case, the upper end of the capillary fringe may be taken as the *groundwater table*, as the soil is assumed saturated below it. However, when h_c is much smaller than the thickness of an aquifer below the phreatic surface, and this is indeed the situation encountered in most aquifers, the hydrologist often neglects the capillary fringe. He then assumes that the (phreatic) aquifer is bounded from above by a phreatic surface. This is also the assumption underlying the presentation in this book.

An estimate of h_c can be obtained, for example, from (Mavis and Tsui, 1939)

$$h_c = \frac{2.2}{d_H}\left(\frac{1-n}{n}\right)^{3/2} \tag{4-49}$$

where h_c is in inches, and d_H is the mean grain diameter, also in inches and n is porosity. Another expression is (Polubarinova-Kochina, 1952, 1962)

$$h_c = \frac{0.45}{d_{10}}\,\frac{1-n}{n} \tag{4-50}$$

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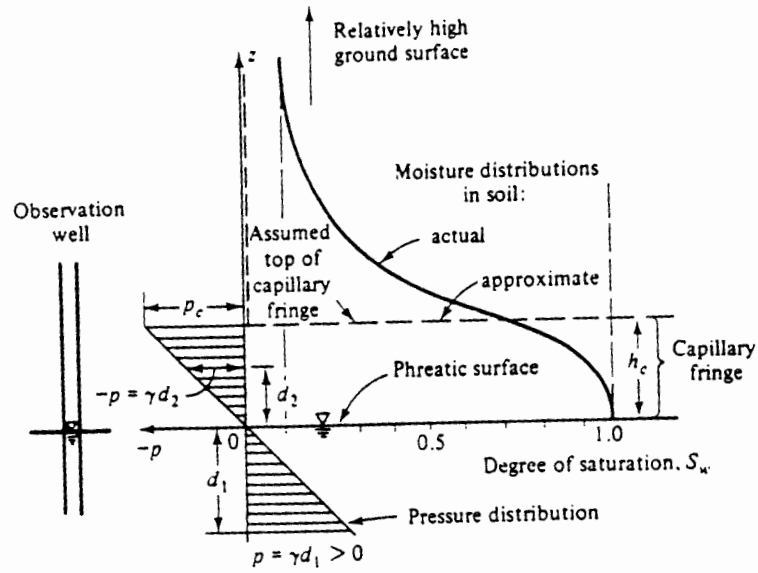
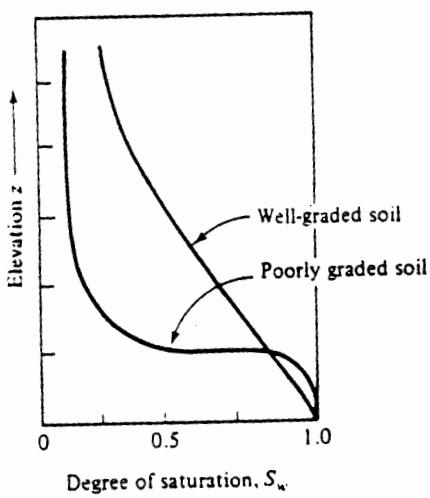


(a)



(b)

Figure 4-5 (a) Approximation of phreatic surface and capillary fringe. (b) Retention curves in soil.

where both h_c and the effective particle diameter are in centimeters. Silin Bekchurin (1958) suggested a capillary rise of 2–5 cm in coarse sand, 12–35 cm in sand, 35–70 cm in fine sand, 70–150 cm in silt, and 2–4 m and more in clay. Equations (4-49) and (4-50) can be compared with the rise of water in a capillary tube of radius r: $h_c = 2\sigma/r$, where σ is the surface tension of the water.

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Both ϕ and $\mathbf{q}$ vary from point to point within a phreatic aquifer. In order to obtain the specific discharge $\mathbf{q} = \mathbf{q}(x, y, z, t)$ at every point, we have to know the piezometric head $\phi = \phi(x, y, z, t)$. In Sec. 5-5 below, we shall show how to derive $\phi = \phi(x, y, t)$ by solving certain partial differential equations. However, because the phreatic surface is never horizontal (except for special cases like water at rest), even in the case of an aquifer with a horizontal impervious bottom, equipotentials are never vertical (Fig. 4-6a) and we have to derive $\phi = (x, y, z, t)$ by solving a partial differential equation in the three-dimensional xyz space. Adding also the fact that on the phreatic surface we have to specify a non-linear boundary condition, and that the location of this surface is unknown before the problem is solved, we immediately realize that this is not a practical way of solving common problems of flow in phreatic aquifers.

The Dupuit assumptions discussed below are probably the most powerful tool for treating unconfined flows. In fact, it is the only simple tool available to most engineers and hydrologists for solving such problems.

Dupuit (1863) based his assumptions on the observation that in most groundwater flows, the slope of the phreatic surface is very small. Slopes of 1/1000 and 10/1000 are commonly encountered. In steady flow without accretion in the vertical two-dimensional xz plane (Fig. 4-6a), the phreatic surface is a streamline. At every point P along this streamline, the specific discharge is in a direction tangent to the streamline and is given by Darcy's law

$$q_s = -K d\phi/ds = -K\, dz/ds = -K \sin\theta \tag{4-51}$$

since along the phreatic surface $p = 0$ and $\phi = z$. As θ is very small, Dupuit suggested that $\sin\theta$ be replaced by the slope $\tan\theta = dh/dx$. The assumption of small θ is *equivalent* to assuming that equipotential surfaces are vertical (that is, $\phi = \phi(x)$ rather than $\phi = \phi(x, z)$) and the flow is essentially horizontal. Thus, the Dupuit assumptions lead to the specific discharge expressed by

$$q_x = -K dh/dx, \qquad h = h(x) \tag{4-52}$$

In general, $h = h(x, y)$ and we have

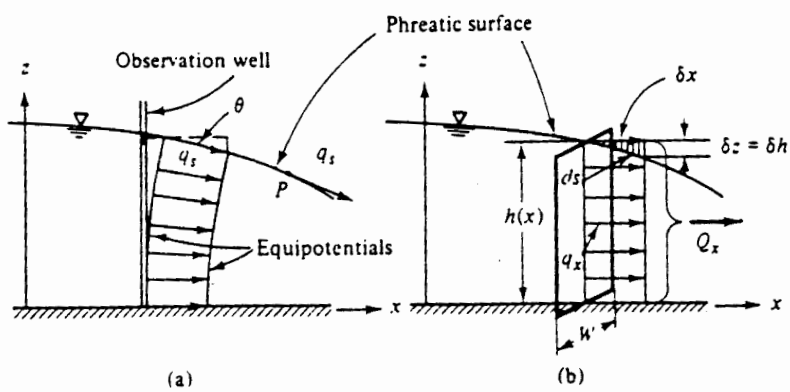

Figure 4-6 The Dupuit assumptions.

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$$q_x = -K\partial h/\partial x, \qquad q_y = -K\partial h/\partial y; \qquad h = h(x, y) \tag{4-53}$$

or

$$\mathbf{q} = -K\nabla' h; \qquad \nabla'(\quad) \equiv \{\partial(\quad)/\partial x\}\,\mathbf{1x} + \{\partial(\quad)/\partial y\}\,\mathbf{1y} \tag{4-54}$$

Since $\mathbf{q}$ is thus independent of elevation, the corresponding total discharge through a vertical surface of width W (normal to the direction of flow; Fig. 4-6b) is

$$Q_x = -KWh\partial h/\partial x, \quad Q_y = -KWh\partial h/\partial y; \qquad h = h(x, y) \tag{4-55}$$

or, in the compact vector form

$$\mathbf{Q} = -KWh\nabla' h = -KW\nabla'(h^2/2) \tag{4-56}$$

Per unit width, we obtain

$$\mathbf{Q}' \equiv \mathbf{Q}/W = -Kh\nabla' h = -K\nabla'(h^2/2) \tag{4-57}$$

In (4-55) through (4-57), the aquifer's bottom is horizontal. It should be emphasized that the Dupuit assumptions may be considered as a good approximation in regions where θ is indeed small and/or the flow is essentially horizontal.

The important advantage gained by employing the Dupuit assumptions is that $\phi = \phi(x, y, z)$ has been replaced by $h = h(x, y)$, that is, z does not appear as an independent variable. Also, since at a point on the free surface, $p = 0$ and $\phi = h$, we assume that the vertical line through the point is also an equipotential line on which $\phi = h = \text{const}$. In general h varies also with time so that $h = h(x, y, t)$.

In order to obtain a better understanding of what is involved in the Dupuit assumptions, let us attempt to determine the exact expression for flow in a phreatic aquifer where $\phi = \phi(x, y, z, t)$ and $h = h(x, y, t)$. We obtain it by integrating along the vertical from the bottom of the aquifer, $\eta = \eta(x, y)$, which need not be horizontal, to the phreatic surface at elevation $h = h(x, y, t)$. For flow in the $+x$ direction, assuming $K = \text{const}$. or $K = K(x, y)$, we obtain

$$\begin{aligned} Q'_x &= \int_{\eta(x,y)}^{h(x,y,t)} q_x\,dz = -K\int_{\eta(x,y)}^{h(x,y,t)} (\partial\phi/\partial x)\,dz \\ &= -K\left\{\frac{\partial}{\partial x}\int_\eta^h \phi\,dz - \phi\Big|_h \frac{\partial h}{\partial x} + \phi\Big|_\eta \frac{\partial \eta}{\partial x}\right\} \\ &= -K\left\{\frac{\partial}{\partial x}[(h-\eta)\bar{\phi}] - \phi\Big|_h \frac{\partial h}{\partial x} + \phi\Big|_\eta \frac{\partial \eta}{\partial x}\right\} \end{aligned} \tag{4-58}$$

where the average head is

$$\bar{\phi} = \frac{1}{h-\eta}\int_\eta^h \phi\,dz$$

and $\phi|_h \equiv h$ on the phreatic surface.

Equation (4-58) involves no approximation. If we now *assume* a vertical equipotential, i.e.

$$\phi\Big|_h (= h) \cong \phi\Big|_\eta \cong \bar{\phi},$$

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(4-58) reduces to

$$Q'_x = -K(h-\eta)\frac{\partial h}{\partial x}, \qquad \text{or } \mathbf{Q}' = -K(h-\eta)\nabla' h \tag{4-59}$$

which is the same as (4-57), written for a non-horizontal bottom.

For a horizontal bottom, $\eta = 0$, (4-58) can be written as

$$Q'_x = -K\frac{\partial}{\partial x}(h\tilde{\phi} - h^2/2), \qquad \text{or } \mathbf{Q}' = -K\nabla'(h\tilde{\phi} - h^2/2) \tag{4-60}$$

By comparing (4-60) with (4-57), we see that we have replaced $h\tilde{\phi} - h^2/2$ by $h^2/2$ in the Dupuit assumptions. The error reduces to zero as $\tilde{\phi} \to h$. Bear (1972, p. 363) gives an estimate of the error involved in replacing $\phi'' \equiv h\tilde{\phi} - h^2/2$ by $h^2/2$ in (4-57)

$$0 < \frac{h^2/2 - \phi''}{h^2/2} < \frac{i^2}{1+i^2}; \qquad i \equiv dh/dx \tag{4-61}$$

so that the error is small as long as $i^2 \ll 1$, where i is the slope of the phreatic surface. When the medium is anisotropic, with $K_x \neq K_z$ (x, z principal directions), i^2 in (4-61) should be replaced by $(K_x/K_z)i^2$.

Dupuit–Forchheimer Discharge Formula

As a simple example of the application of (4-52), consider the case of steady unconfined flow through a homogeneous formation between two reservoirs with vertical faces (Fig. 4-7). Following the Dupuit assumptions, the total discharge in the x direction per unit width, through a vertical cross section of height $h(x)$ is given by (4-57)

$$Q'_x \equiv Q' = qh(x) = -Kh(x)\,dh/dx = \text{const.}; \qquad Q'\,dx = -Kh(x)\,dh \tag{4-62}$$

By integrating this expression between the boundary at $x = 0$, where $h = h_0$, and any distance x, where $h = h(x)$, we obtain

$$Q'\int_{x^*=0}^{x} dx^* = -K\int_{h^*=h_0}^{h(x)} h^*(x^*)\,dh^*; \qquad Q'x = K\frac{h_0^2 - h^2(x)}{2} \tag{4-63}$$

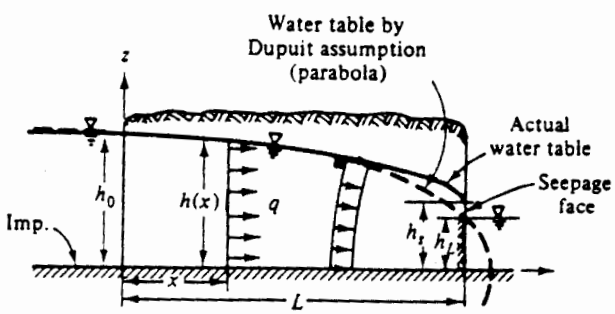

Figure 4-7 Steady unconfined flow between two reservoirs.

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Equation (4-63) describes a water table, $h = h(x)$, which has the shape of a parabola passing through $x = 0$, $h = h_0$. If we know $h(x)$ at some distance x, we can use (4-63) to derive Q' (obviously, if K is known). The boundary condition at the other end, $x = L$, however, is somewhat more complicated.

Whenever a phreatic surface approaches the downstream external boundary of a flow domain, it always terminates on it at a point that is above the water table of the body of open water present outside the flow domain. Points A in Figs. 4-8a, b, and c are such points. The segment AB of the boundary above the water table and below the phreatic surface is called the *seepage face*. Along the seepage face, water emerges from the porous medium into the external space, trickling down along the seepage face. In Figs. 4-8c and b, the phreatic surface at A is tangent to the external boundary; in Fig. 4-8a, it is tangent to a vertical line at A.

Back to our problem, because of the presence of a seepage face which terminates at a point on the (*unknown*) phreatic surface, h_s in Fig. 4-7 is unknown. Instead, when the Dupuit assumptions are employed, we approximate the situation by overlooking the presence of the seepage face and assuming that the water table at $x = L$ passes through $h = h_L$. Using this as the downstream boundary condition, we obtain from (4-63)

$$Q' = K\frac{h_0^2 - h_L^2}{2L} \tag{4-64}$$

known as the *Dupuit–Forchheimer discharge formula*.

The parabolic water table is shown in broken line in Fig. 4-7. A discrepancy exists mainly at the boundaries at $x = 0$, where the water table should be tangent to the horizontal line, whereas the parabola has a slope of

$$dh/dx\Big|_{x=0} = -Q'/Kh_0$$

and at $x = L$, where the seepage face is neglected. Otherwise, the discrepancy between the curves derived by the exact theory of the phreatic surface boundary, and by the Dupuit approximation is negligible. A simple rule is that at distances

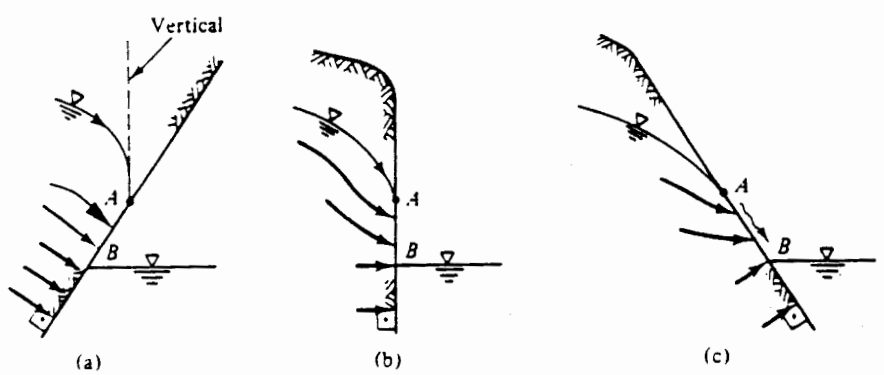

Figure 4-8 The seepage face (AB).

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from the downstream end, larger than 1.5–2 times the height of the flow domain, the solution based on the Dupuit assumption is sufficiently accurate for all practical purposes.

Moreover, it can be shown (Bear, 1972; p. 367) that (4-64) *is accurate* as far as the rate of discharge is concerned, although (4-63) does not give the accurate water table elevations $h = h(x)$.

Flow Through a Stratified Phreatic Aquifer

As a second example, consider the case of phreatic flow through the stratified aquifer shown in Fig. 4-9. The flow is made up of two parts, each corresponding to one of the layers. Using the Dupuit assumption of vertical equipotentials, we obtain for the total discharge, Q', per unit width through the system

$$Q' = -K'a\,dh/dx - K''(h - a)\,dh/dx = \text{const.} \tag{4-65}$$

Upon integration from $x = 0$, $h = h_0$ to $x = L$, $h = h_L$ (i.e., neglecting the presence of a seepage face), we obtain

$$Q' = \frac{K''}{2L}(h_0 - h_L)\left[h_0 + h_L - 2a + 2a(K'/K'')\right] \tag{4-66}$$

We could obtain the approximate shape of the phreatic surface by integrating from $x = 0$ to any x. Bear (1972, p. 370) shows that (4-66) is again an accurate expression for Q', although we have made use of the Dupuit assumptions and neglected the seepage face.

Equation (4-66) may be rewritten as

$$Q' = K'a\frac{h_0 - h_L}{L} + \frac{K''}{2L}\left[(h_0 - a)^2 - (h_L - a)^2\right] \tag{4-67}$$

which shows that when the Dupuit assumptions are employed, the total flow may be obtained as the sum of a confined-type flow in the lower layer, and a phreatic-type flow in the upper one.

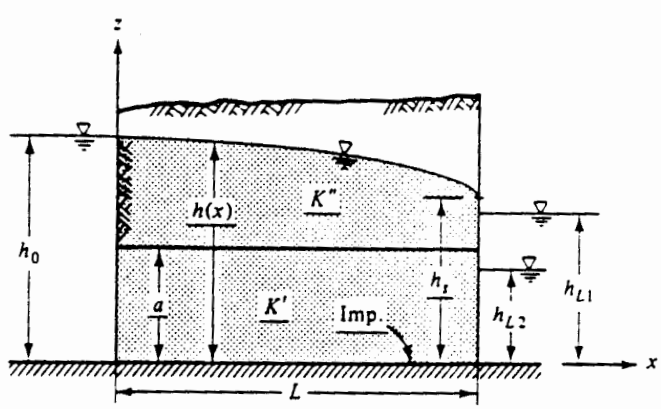

Figure 4-9 Unconfined flow in a horizontally stratified aquifer.

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Finally consider the case of unconfined flow in an aquifer with vertical strata shown in Fig. 4-10. Using the Dupuit assumptions, we obtain from (4-62) and (4-63) for the region $0 \le x \le L'$

$$h^2 = h_0^2 - 2Q'x/K'; \qquad h_{L'}^2 = h_0^2 - 2Q'L'/K' \tag{4-68}$$

Similarly, we obtain for the region $L' \le x \le L$

$$h^2 = h_{L'}^2 - 2Q'(x - L')/K''; \qquad h_{L'}^2 = h_L^2 + 2Q'(L - L')/K'' \tag{4-69}$$

Hence

$$Q' = \frac{h_0^2 - h_L^2}{2[L''/K'' + L'/K']} \tag{4-70}$$

$$h^2 = h_0^2 - \frac{h_0^2 - h_L^2}{K'[L''/K'' + L'/K']}x, \qquad 0 \le x \le L'$$

$$h^2 = h_L^2 + \frac{h_0^2 - h_L^2}{K''[L''/K'' + L'/K']}(L - x), \qquad L' \le x \le L \tag{4-71}$$

Again, the expression for Q' in (4-70) can be shown to be an accurate one (Bear, 1972, p. 373). Equation (4-70) can easily be extended to N strata

$$Q' = (h_0^2 - h_L^2)/2 \sum_{i=1}^{N} (L_i/K_i) \tag{4-72}$$

The Dupuit assumptions cannot be applied in regions where the vertical flow component is not negligible. Such flow conditions occur as a seepage face is approached (Fig. 4-11a) or at a crest (*water divide*) in a phreatic aquifer with accretion (Fig. 4-11b). Another example is the region close to the impervious vertical boundary of Fig. 4-11a. It is obvious that the assumption of vertical equipotentials fails at, and in the vicinity of such a boundary. Only at distances $x > \sim 2h_0$ have we equipotentials that may be approximated as vertical lines or surfaces. It is important to note here that in cases with accretion, a horizontal (or almost so) water table is not sufficient to justify the application of the Dupuit assumptions. One must verify that vertical flow components may indeed be

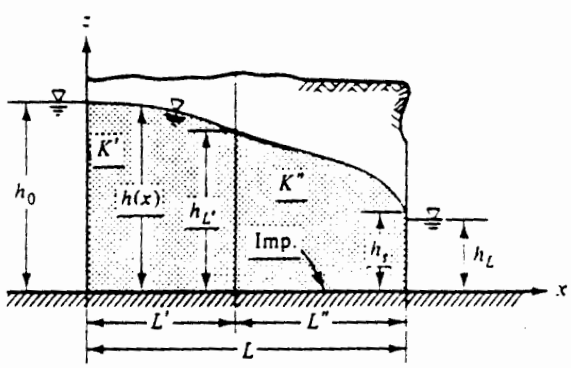

Figure 4-10 Unconfined flow through a vertically stratified aquifer.

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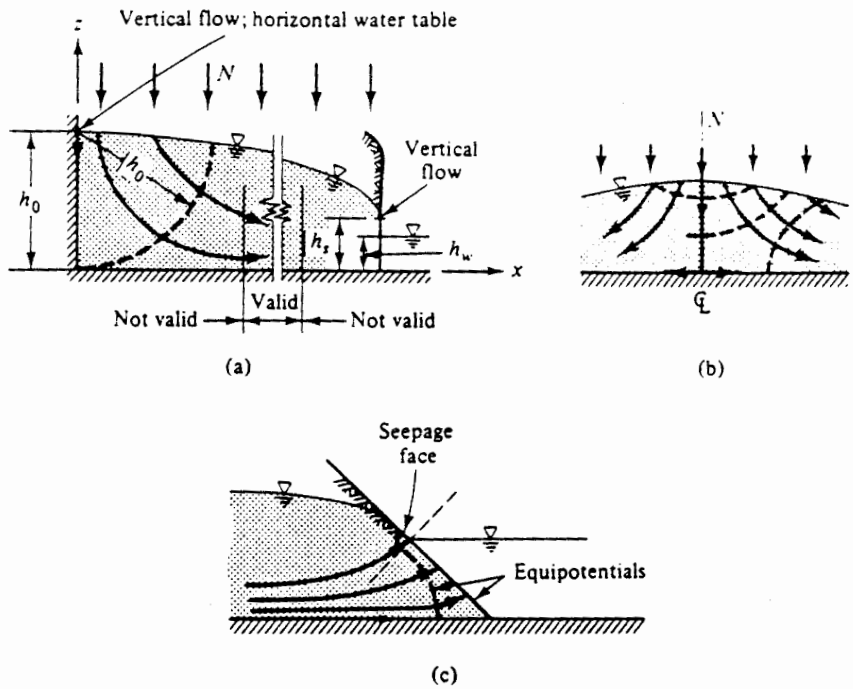

Figure 4-11 Regions where Dupuit assumptions are not valid.

neglected, before applying the Dupuit assumptions. Another case to which the Dupuit assumptions should be applied with care is that of unsteady flow in a decaying phreatic surface mound. Although no accretion takes place, yet at, and in the vicinity of, the crest the flow is vertically downward. At a distance of say $1.5 \div 2$ times the thickness of the flow, the approximation of vertical equipotentials is again valid.

In spite of what was said above, in regional studies, the Dupuit assumptions, because of their simplicity and the relatively small error involved, are usually applied also to those (relatively small) parts of an investigated region where they are not strictly applicable. One should, however, be careful in making use of results (say, water levels) derived for these parts of an investigated region.

G-2

APPENDIX G-2

EVAPORATION POND ALR CALCULATION

TERRAMATRIX INC.

Calculation Cover Sheet

Sheet 1 of 1

Project Title: Triassic Park

Project No. 602-0200

Calculation Title: Evaporation Pond Action Leakage Rate

	Name	Date
Prepared By:	J. Kendall	10/7/97
Checked By:	J. Pellicer	14-Nov-97
Reviewed By:	P. Lorser	14 Nov 97
QA Review:		

Revisions	Date	By	Checked By	Reviewed By	QA Review

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Project Name: TRIASSIC PARK HW FACILITY - EVAP POND ALR
Project Number: 602-0200 Sheet: 1 Of 11
Prepared By: K Date: 10/7/97
Checked By: J. Pullich Date: 14-NOV-97

TITLE: TRIASSIC PARK EVAPORATION POND ACTION LEAKAGE RATE

OBJECTIVE: DETERMINE ACTION LEAKAGE RATE (ALR) FOR THE TRIASSIC PARK HAZARDOUS WASTE FACILITY EVAPORATION POND

REFERENCES:
1. USEPA, FEDERAL REGISTER, VOL 57 NO. 19, WEDNESDAY JANUARY 29, 1992, RULES AND REGULATIONS, PP. 3462-3477
2. USEPA, "ACTION LEAKAGE RATES FOR LEAK DETECTION SYSTEMS", EPA/530-R-92004, JANUARY 1992.
3. CODE OF FEDERAL REGULATIONS, TITLE 40, PART 264.222.
4. BEAR, JACOB, "HYDRAULICS OF GROUNDWATER", McGRAW-HILL, 1979. PP 74-89
5. TERRAMATRIX/MONTGOMERY WATSON, TRIASSIC PARK HAZARDOUS WASTE FACILITY DRAWINGS AS FOLLOWS:

DRAWINING NO.	DRAWING TITLE	DATE
29	EVAP. POND CAP LINER CONTOURS	NOV 97
32	EVAP POND LDRS PLAN AND DETAILS	NOV 97
		NOV 97
		NOV 97
		NOV 97
		NOV 97

6. TERRAMATRIX/MONTGOMERY WATSON, TRIASSIC PARK HAZARDOUS WASTE FACILITY SPECIFICATIONS AS FOLLOWS:

SPEC NO.	SPEC TITLE	DATE
02224	DRAINAGE GRAVEL	NOV 97
02710	GEOCOMPOSITE	NOV 97

7. MANUFACTURER'S PRODUCT SPECIFICATIONS AND TEST DATA AS FOLLOWS

A. NSC, "POLY-NET® TRANSMISSIVITY CHARTS, PN 3000, HDPE/POLY-NET/HDPE @ 2,000 PSF AND i = 1.

8. MINIMUM EPA REQUIREMENTS FOR GEOSYNTHETIC DRAINAGE LAYERS IN SURFACE IMPOUNDMENTS: 5×10^{-4} m²/sec (REF 1 p. 3468)

9. KOERNER, ROBERT M, "DESIGNING WITH GEOSYNTHETICS" 3RD ED, PRENTICE HALL, ENGLEWOOD CLIFFS, NJ, 1994.

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Project Name: TRIASSIC PARK HW FACILITY - EVAP POND ALR
Project Number: 602-0200 Sheet: 2 Of 11
Prepared By: JK Date: 10/7/97
Checked By: J. Pullen Date: 14-Nov-97

METHOD:

1. ALR IS DEFINED BY FEDERAL LAW AS

^U264.222 Action leakage rate.

(a) The Regional Administrator shall approve an action leakage rate for surface impoundment units subject to ^U264.221(c) or (d). The action leakage rate is the maximum design flow rate that the leak detection system (LDS) can remove without the fluid head on the bottom liner exceeding 1 foot. The action leakage rate must include an adequate safety margin to allow for uncertainties in the design (e.g., slope, hydraulic conductivity, thickness of drainage material), construction, operation, and location of the LDS, waste and leachate characteristics, likelihood and amounts of other sources of liquids in the LDS, and proposed response actions (e.g., the action leakage rate must consider decreases in the flow capacity of the system over time resulting from siltation and clogging, rib layover and creep of synthetic components of the system, overburden pressures, etc.).

(b) To determine if the action leakage rate has been exceeded, the owner or operator must convert the weekly or monthly flow rate from the monitoring data obtained under ^U264.226(d) to an average daily flow rate (gallons per acre per day) for each sump. Unless the Regional Administrator approves a different calculation, the average daily flow rate for each sump must be calculated weekly during the active life and closure period, and if the unit is closed in accordance with ^U264.228(b), monthly during the post-closure care period when monthly monitoring is required under ^U264.226(d). [^U264.222 added at 57 FR 3486, Jan. 29, 1992]

2. FLOW RATE INTO LEAK DETECTION SYSTEM CAN BE DETERMINED FROM THE FOLLOWING EQUATION CITED IN REF 1, p 3474 AND DEVELOPED FOR GEONET DRAINAGE LAYERS CITED IN REF. 2, p.2, (EQN 3)

$Q = K \cdot D(2h - D)$ WHERE

Q = FLOW RATE IN LEAK DETECTION SYSTEM RESULTING FROM 1 HOLE PER ACRE (GAPD)

K = HYDRAULIC CONDUCTIVITY OF DRAINAGE LAYER (FT/SEC)

FOR GEONET: $K = T/t$

WHERE T = TRANSMISSIVITY OF GEONET (FT/SEC)

t = THICKNESS (FT)

h = HEAD ON LINER (FT)

D = LEAK DETECTION LAYER THICKNESS

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Project Name: TRIASSIC PARK HW FACILITY - EVAP POND ALR
Project Number: 602-0200 Sheet: 3 Of 11
Prepared By: JK Date: 10/7/97
Checked By: J. Pallister Date: 14-Nov-97

METHOD (CONTINUED)

3. GEONET TRANSMISSIVITY CORRECTIONS FOR INTRUSION OF ADJACENT MATERIALS (REF 9.pp 402-423)

GEONET MANUFACTURERS TYPICALLY REPORT TRANSMISSIVITY (OR FLOW RATE) DATA BASED ON ASTM 4716-87 TEST PROCEDURES CONDUCTED AT VARIOUS RANGES OF OVERBURDEN PRESSURES (NORMAL LOADS), HYDRAULIC GRADIENTS, AND MATERIAL LAYER ARRANGEMENTS. FOR THIS DATA TO BE APPLICABLE, THE TEST CONDITIONS MUST BE REPRESENTATIVE OF ACTUAL DESIGN AND OPERATING CONDITIONS. FURTHER, HYDRAULIC TESTING OF THE SELECTED GEOCOMPOSITE SHOULD BE CONDUCTED UNDER ACTUAL DESIGN AND OPERATING CONDITIONS TO CONFIRM THAT THE FACTORS OF SAFETY APPLIED TO THE MANUFACTURER'S DATA ARE ADEQUATE.

4. CHECK LDRS SUMP FLOW CAPACITY VS LDRS INFLOW

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ASSUMPTIONS

1. GEONET TRANSMISSIVITY

FROM REF 7a. HDPE/POLY-NET/HDPE (PN 3000) (ASTM 4716-87) MINIMUM GEONET TRANSMISSIVITY IS 5.0×10^{-3} m^2/sec @ NORMAL LOAD OF 2000 PSF AND HYDRAULIC GRADIENT OF 1. TEST RAN FOR 1 HOUR. (15 ft H_2O x 62.4 lb/cft = 936 PSF)

ADJUST TRANSMISSIVITY VALUE CITED ABOVE FOR DIFFERENCES BETWEEN MANUFACTURER'S TEST CONDITIONS AND ACTUAL DESIGN CONDITIONS. APPLY FS IN A MANNER SIMILAR TO THE APPROACH SUGGESTED BY KOERNER (REF 9, pp 413-414)

$FS_{INTRUSION}$: FACTOR OF SAFETY FOR ELASTIC DEFORMATION, OR INTRUSION, OF ADJACENT MATERIALS INTO GEONET CORE. SINCE TESTS WERE RUN WITH STEEL PLATES ABOVE AND BELOW THE HDPE WITHOUT SOIL INFLUENCES, USE, $FS_{IN} = 1.5$.

FS_{CREEP}: FACTOR OF SAFETY FOR CREEP DEFORMATION OF GEONET, SINCE NORMAL LOADS IN THE TEST ARE HIGHER THAN EXPECTED LOADS IN THE POND DESIGN (20 ft x 62.4#/cft = 1250 PSF VS 2000 PSF), USE $FS_{CR} = 1$

$FS_{CHEMICAL\ CLOGGING}$: FACTOR OF SAFETY FOR CHEMICAL CLOGGING AND OR PRECIPITATION OF CHEMICALS IN THE GEONET CORE. SINCE CHEMICAL WASTES OF A WIDE VARIETY MAY BE PRESENT, USE $FS_{CC} = 1.5$

$FS_{BIOLOGICAL\ CLOGGING}$: FACTOR OF SAFETY FOR BIOLOGICAL CLOGGING IN THE GEONET CORE. HIGH CONCENTRATIONS OF BIODEGRADEABLE FLUIDS ARE NOT EXPECTED IN THE POND, HOWEVER, SINCE THIS IS AN AQUEOUS SOLUTION, USE $FS_{BC} = 1.5$.

$FS_{SEDIMENT\ CLOGGING}$: FACTOR OF SAFETY FOR CLOGGING DUE TO FINE GRAINED SEDIMENT BUILD UP IN THE GEONET. USE $FS_{SC} = 1.5$.

TOTAL FS = $FS_{IN} \times FS_{CR} \times FS_{CC} \times FS_{BC} \times FS_{SC} = 1.5 \times 1 \times 1.5 \times 1.5 \times 1.5 = 5.1$

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ASSUMPTIONS (CONTINUED)

1. GEONET TRANSMISSIVITY (CONTINUED)

ALLOWABLE GEONET FLOW RATE (q) = $q_{(MANUF. TEST)} \times \frac{1}{FS_{TOTAL}}$

$$q_{ALLOW} = \frac{5.0 \times 10^{-3}\ m^2/SEC}{5.1} = 9.8 \times 10^{-4}\ m^2/SEC$$

CHECK q_{ALLOW} VS. EPA MINIMUM (REF 1, p 3468)

$9.8 \times 10^{-4}\ m^2/SEC > 3 \times 10^{-4}\ m^2/SEC$ so OK

(NOTE: ALTHOUGH THE ASSUMPTIONS LEADING TO $q_{ALLOW} = 9.8 \times 10^{-4}\ m^2/SEC$ ARE CONSERVATIVE, CONFIRMATORY TESTING OF GEONET TRANSMISSIVITY WILL BE REQUIRED. TESTING WILL BE CONDUCTED ON THE ACTUAL GEOCOMPOSITE SELECTED AT DESIGN CONDITIONS)

2. MAXIMUM HEAD ON LINER

USE 1.0 ft PER EPA 40 CFR 264.222

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Project Name: TRIASSIC PARK HW FACILITY - EVAP POND ALR
Project Number: 602-0280 Sheet: 6 Of 11
Prepared By: JK Date: 10/7/97
Checked By: J. Pellicer Date: 14-Nov-96

CALCULATION

$$ALR = Q_{ALLOWABLE} = KD(2h - D) \quad (GAPD)$$

WHERE

$K_{GEONET} = T/t$ T = TRANSMISSIVITY = 9.8×10^{-4} m²/SEC
t = THICKNESS = 5mm

$$K_{GEONET} = \frac{9.8 \times 10^{-4} m^2/SEC}{.005 \ mm} = 0.1961 \ mm/SEC$$
$$= 19.61 \ cm/SEC$$
$$= 0.64 \ FT/SEC$$

h = 1.0 ft

D = 5mm = 0.0164 ft

$$ALR = Q_{ALLOWABLE} = 0.64 \frac{ft}{SEC} \times 0.0164 ft \times (2 \times 1.0 ft - 0.0164 ft)$$
$$= 0.0208 \ CFT/AC/SEC$$
$$= 1{,}798 \ CFT/AC/DAY$$
$$= 13{,}456 \ GAL/AC/DAY$$

NOTE: THE ALR CALCULATED ABOVE IS MANY TIMES GREATER THAN THE MAXIMUM ALR VALUE OF 1000 GPAD RECOMMENDED BY EPA (REF 1, p3474). THE PRIMARY REASON FOR THIS IS THE EPA VALUE IS BASED ON SAND PERMEABILITY (1×10^{-2} cm/SEC) COMPARED TO THE GEONET PERMEABILITY ASSUMED ABOVE (19.61 cm/SEC).

ALTHOUGH, BASED ON THIS APPROACH, AN ALR VALUE FOR THE EVAPORATION POND MUCH LARGER THAN THE EPA MAXIMUM VALUE OF 1000 GPAD COULD BE RECOMMENDED, HOWEVER, WE RECOMMEND THE MAXIMUM ALR VALUE OF 1000 GPAD BE ADOPTED. GIVEN THE RELATIVE SMALL SIZE OF THE EVAPORATION POND, A LEAKAGE RATE OF 1000 GPAD WOULD ADEQUATELY REPRESENT A LARGE AND RAPID LEAK.

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POLY-NET® TRANSMISSIVITY CHARTS

The results listed are nominal values based on limited testing.
Minimum values and minimum average roll values may vary.

HDPE/POLY-NET/HDPE

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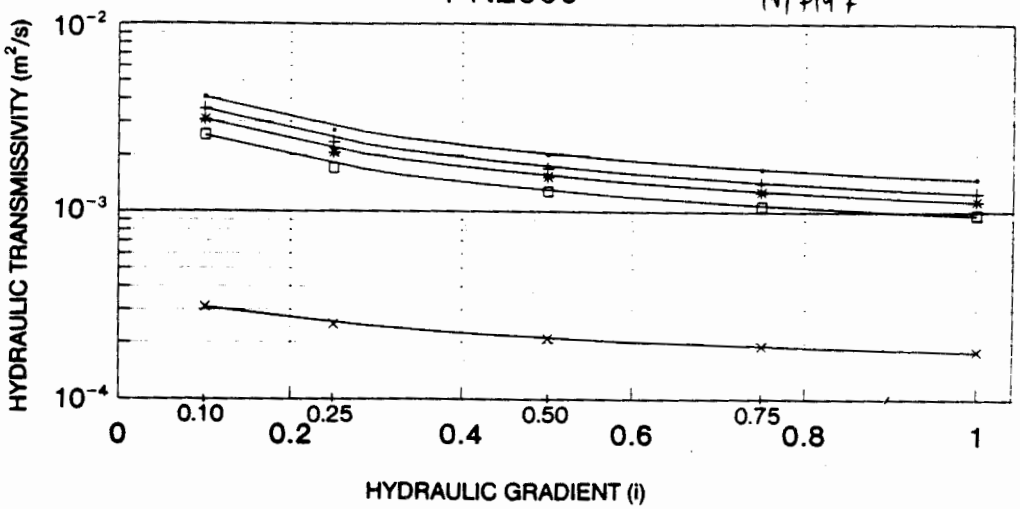
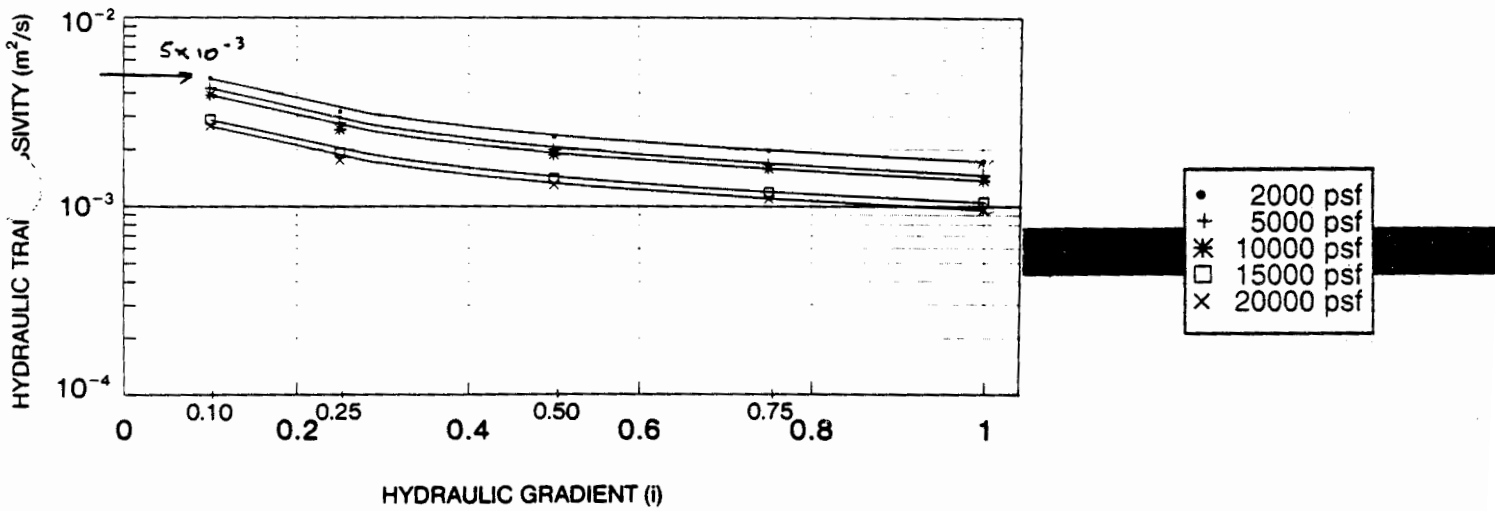
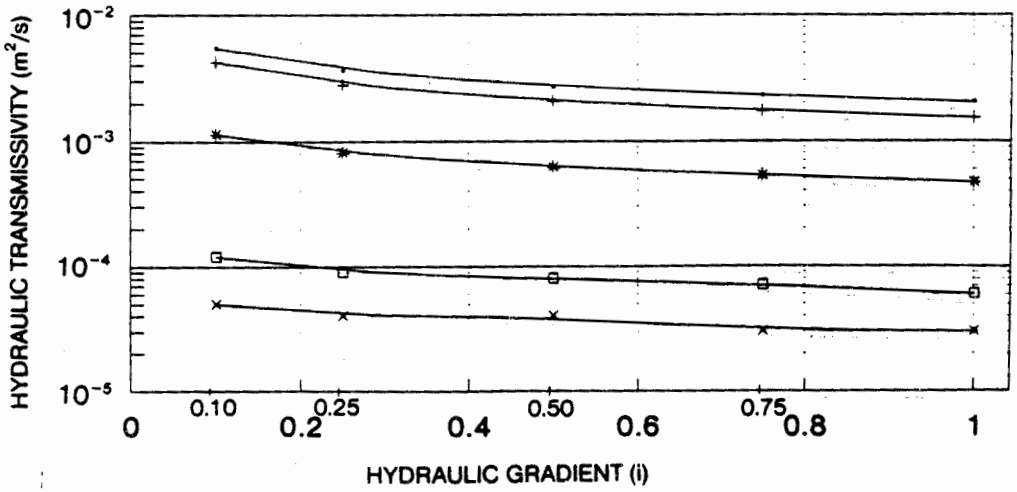
PN2000



PN3000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