ENGINEERING REPORT
FOR
CWM CHEMICAL SERVICES, LLC
MODEL CITY FACILITY, RESIDUALS MANAGEMENT UNIT 1
MODEL CITY, NIAGARA COUNTY, NEW YORK

February 1992

Revised November 1995

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Revised December 2003

Revised December 2004

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GENERAL SITE INFORMATION

Name of Facility:	CWM Chemical Services, LLC Residuals Management Unit No. 1 (RMU-1)
Address of Facility:	1550 Balmer Road Model City, NY 14107
Site Location:	1.9 miles east of NY State Route 18 along Balmer Road. Property aerial extent 710 acres.
Operator:	CWM Chemical Services, LLC
Landfill Capacity:	3,601,900 Cubic yards in RMU-1 (gross volume)
Total Acreage:	RMU-1 Outside Limit of Perimeter berm: 47.1 acres RMU-1 Limit of Waste: 39.4 acres
Current Zoning:	Heavy Industrial (M-3)
Current Land Use:	Waste treatment, storage and land disposal and recovery facility.
Contact Person:	Michael Mahar CWM District Manager 1550 Balmer Road Model City, NY 14107
Original Report and Design:	Earth Tech 412 Lincoln Highway Fairless Hills, PA 19030 (215) 269-2100
Original Project Manager:	Charles P. Ballod, P. E.
Original Project Engineers:	Kevin McKeon, P. E.

CHAPTER 1

INTRODUCTION

CWM Chemical Services, LLC, (CWM), a wholly owned subsidiary of Waste Management, Inc., owns and operates the Model City facility. The Model City facility is a state of the art hazardous waste treatment, storage, disposal, and recovery facility, which accepts industrial, hazardous waste and residues. Wastes may be accepted for pretreatment to meet land ban disposal criteria prior to land disposal, other wastes may be landfilled directly without pretreatment. Wastes which meet land disposal restrictions or other waste under variance could be disposed of in RMU-1. This pretreated waste will be disposed of in a residuals management unit which meets or exceeds design requirements for hazardous waste landfills under New York regulations and federal guidelines. CWM uses the Residuals Management Unit in conformance with the New York State Waste Management Hierarchy.

Residuals Management Unit No. 1 (RMU-1) is designed to provide an effective means of secure land disposal while safeguarding the environment with a double liner/leachate containment/collection system. This report addresses specific engineering criteria and provides pertinent background on the RMU-1 design.

Included are chapters on general site information, design requirements and approach, construction requirements and description of typical operations.

The design of RMU-1 is similar to past on-site double-lined facilities. The unit is contained by a perimeter berm to control run-off and run-on. The base grades slope at a minimum of two percent except for Cells 7/8, 9/10, 11/13 and 12/14 which are a minimum of one percent (post settlement) to the perimeter of the unit to leachate removal sumps. Final grades extend from the lined edge of the perimeter berm of the unit at 3H:1V slope to a maximum elevation of 412 feet above mean sea level (fmsl) and then at five percent to 420 fmsl. The total net volume available for waste placement is 3,482,400 cubic yards resulting from 3,601,900 cubic yards total airspace minus operational volumes such as select fill and grading layer above the final waste surface. Estimated site life is approximately 10.4 years, assuming gate receipts of 500,000 tons per year and/or in-place waste density of 1.5 tons per cubic yards.

Construction of RMU-1 will require regrading and relocating the existing southeast surface water drainage ditch along the abandoned railroad. The curved portion of the abandoned railroad along the southeast corner of RMU-1 will also be excavated and the track removed. Groundwater monitoring wells B-43, B-43A, and B-33A will be abandoned. Facultative Pond No. 9 will be removed from service under New York closure requirements to allow construction of the south half of RMU-1. New power distribution and control systems will be added to allow operation and monitoring of RMU-1.

A portion of the soils excavated from the proposed RMU-1 area will be suitable for use as clay liner, structural fill, or cover soil. These materials will be stockpiled separately on-site for later use. The use of these soil materials in construction and operations are discussed fully in this report.

ZONING AND UTILITIES

The landfill is currently zoned as heavy industrial use. The zoning is applicable for landfill operations. The RMU-1 area is completely within this zoned area, therefore, no additional modifications to current zoning requirements will be needed in this design.

Water lines exist between the "J" Street the ditch on the northern side and the northwest corner of proposed RMU-1. Above ground electrical and telephone lines are located just north of RMU-1 on the north side of the road. These water lines and power lines are not expected to be disturbed due to RMU-1 construction activities. The power lines east of RMU-1 will be removed to allow construction. This power line serves the Facultative Pond No. 8 pumps and the air monitoring station south of SLF-10. This line will be replaced with a new service.

The water line shown on the drawings is an abandoned service line. CWM will have the line removed to the limits of the RMU-1 construction. The sanitary sewer line shown on the drawings is an abandoned line from previous site operations. The line will be excavated to the limits of RMU-1 construction.

REQUIRED PERMITS AND APPROVALS

A number of Federal, State, and Local permits and approvals will be required to construct and operate the proposed unit. At the Federal level, the proposed unit is governed by regulations established pursuant to the Toxic Substances Control Act (TSCA) and the Resource Conservation and Recovery Act (RCRA), as amended by the Hazardous and Solid Waste Amendments of 1984 (HSWA). To comply with the TSCA regulations, CWM Chemical Services will submit to the U.S. Environmental Protection Agency (U.S. EPA) an "Initial Report" for RMU-1. In essence, the Initial Report constitutes a TSCA Disposal Approval Request for the disposal of Poly-Chlorinated Biphenyls (PCBs).

U.S. EPA has delegated the implementation of the RCRA regulations to the State of New York, except for certain provisions of HSWA. While U.S. EPA will issue a module addressing the HSWA requirements as part of the Hazardous Waste Management Facility (HWMF) permit issued by the New York State Department of Environmental Conservation (NYSDEC), a separate permit application to U.S. EPA is not required.

At the State level, the following permit applications and documents will be submitted to NYSDEC by CWM Chemical Services, Inc., for compliance with State permitting requirements established in Title 6 of the New York Codes, Rules and Regulations (6 NYCRR):

- o 6 NYCRR Part 373 Hazardous Waste Permit Application to Construct/Operate a HWMF.
- o 6 NYCRR Part 361 Application for a Certificate of Environmental Safety and Public Necessity.

- 6 NYCRR Part 201 Air Permit Application to Construct/Operate a HWMF.
- Supplemental Draft Environmental Impact Statement.

At the Local level, a permit for excavation will be obtained by CWM Chemical Services, Inc., from the Town of Porter.

RP/CWMNYORK/AA3

CHAPTER 2

GENERAL SITE INFORMATION

LOCATION AND DESCRIPTION

The proposed Residuals Management Unit 1 (RMU-1) is located within the property owned and operated by CWM Chemical Services, Inc., known as the Model City Facility. The facility encompasses approximately 710 acres, of which about 630 are permitted for hazardous waste management operations. RMU-1 outside perimeter berm limits is proposed to encompass about 47 acres. The RMU-1 location is accessible by existing roads and is convenient to utility connections. As part of the original military complex, the site has a local grid and elevation system to provide control for construction and documentation. This grid system is monumented at the site with numerous permanent monuments. For clarity, the RMU-1 specific site description is given in terms of this grid system shown on the drawings accompanying this report.

The limits of fill proposed for RMU-1 meet state and federal property setback criteria. The construction limits of RMU-1 which include the perimeter berm, extend from RMU-1 site grid station 12+10E to 27+55E and from station 82+50N to 101+30N. Waste limits will be from approximately stations 12+67E to 26+93E and 83+00N to 100+80N.

The area encompassed in the proposed RMU-1 is relatively flat and wooded. No evidence of past construction or operations were found over the northern half of proposed RMU-1 during the site investigation except for utilities. The southern half of proposed RMU-1 is currently occupied by Facultative Pond 9 (Fac Pond 9) has been removed from operation and is to be closed. The site is bounded on the west and north by Fac Pond 8, SLF-10, and existing site access roads. On the south side is a site access road. The east end is bounded by an abandoned railroad bed. The previously constructed access features control surface water flow. Presently, the majority of the surface water is routed to the west end of the RMU-1 area. Ditches currently convey the flow north along the western boundary to the existing north sedimentation basin. Site drainage will be modified to direct the majority of surface water from RMU-1 to the proposed eastern retention basin.

Construction of the landfill, including excavation, clay liner, geosynthetics, leachate collection system and final cover will be performed under the established CWM quality assurance programs.

GEOLOGY

Studies by Others and Preliminary Investigations

Numerous previous investigations have been conducted throughout the Model City Facility. Geologic and hydrogeologic investigation for the entire Model City facility was performed by Golder and Associates, and the results submitted to NYDEC and U.S. EPA in March 1985 and updated in February 1988. More than

Glaciolacustrine Clay unit typically overlies the Glaciolacustrine Silt/Sand units. The contrast between these two units is usually sharp. The glaciolacustrine clay is described as very soft to firm reddish brown to gray brown silty clay, occasional silt and fine sand partings and seams. The thickness of glaciolacustrine clay varies from 6 feet to 21 feet over the RMU-1 site.

Middle Silt Till is found between the upper and lower parts of the Glaciolacustrine Clay in the areas of Soil Borings B-4, B-7, and Monitoring Well G-3. This unit is described as red brown and gray coarse to fine sand and silt, trace of gravel, silt with occasional clay partings. The thickness of this unit varies from 3 feet to 8 feet over the RMU-1 site.

Upper Tills Three separate lithostratigraphic units have been grouped into the Upper Tills: the Upper Silt Till, the Upper Clay Till, and the Upper Alluvium.

The Upper Silt Till occurs discontinuously throughout the site. It directly overlies the Glaciolacustrine Clay unit and is described as brown to gray-brown silt and coarse to fine sand, some gravel. The thickness varies from 3 feet to 10 feet over the RMU-1 site.

The Upper Clay Till is continuous across the site. It either overlies the Upper Silt Till or directly overlies the Glaciolacustrine Clay unit. This unit is typically described as brown to orange-brown mottled clayey silt to silty clay, some coarse to fine sand, trace of gravel, faintly laminated, occasionally contains some organic material. The thickness of this unit varies from 2 feet to 18 feet.

The Upper Alluvium unit is discontinuous across the Model City site and was not encountered within the RMU-1 site boundary by the recent drilling activity. However, the boring logs of monitoring wells G-3 and B-34 recorded this deposit. Alluvial deposits which were encountered in these wells, consisting primarily of brown clayey silt with irregular laminations, or compact grey silt. The thickness of this deposit varies from 2 to 6 feet.

GENERAL HYDROGEOLOGY

Golder and Associates has performed a detailed hydrogeologic study of the Model City facility. Results of their study define the Glaciolacustrine Silt/Sand unit as the uppermost aquifer beneath the Model City facility. It is a confined aquifer. The overlying Glaciolacustrine Clay, Middle Silt Till and Upper Tills have much lower permeabilities and are aquitards. The Glaciolacustrine Clay unit is the major aquitard restricting vertical groundwater flow to the aquifer from the surface. Flow in the Glaciolacustrine Silt/Sand aquifer is essentially lateral to the northwest. (See the Glaciolacustrine Silt/Sand Potentiometric Contours Map, Golder and Associates, February 1988, contained in Appendix C.) Concentrations of total dissolved solids (TDS) indicate groundwater is considered saline by the NYSDEC water quality standards and is therefore not suitable for use as a potable water supply.

TABLE 1
SUMMARY OF GEOLOGIC FORMATION HYDRAULIC
CONDUCTIVITY DATA
(FROM GOLDER ASSOCIATES, 1988)

Formation	Geometric Mean Hydraulic Conductivity k (cm/s)(1)	Number of Data Entries	Type of Test
Upper Alluvium	$k_h = 3x10^{-6}$	4	Field Tests
	$k_v = 1x10^{-5}$	1	Lab Test
Upper Glacial Tills	$k_h = 2x10^{-6}$	19	Field Tests (2)
	$k_v = 2x10^{-8}$	6	Lab Tests (3)
	$k_h = 3x10^{-6}$	81	Field Tests (4)
Middle Silt Till	$k_h = 3x10^{-6}$	5	Field Tests
	$k_v = 1x10^{-7}$	2	Lab Tests
Glaciolacustrine Clay	$k_h = 5x10^{-8}$	5	Field & Lab Tests
	$k_v = 2x10^{-8}$	29	Lab Tests (5)
Glaciolacustrine Silt/Sand	$k_h = 3x10^{-5}$	20	Field Tests
	$k_h = 1x10^{-5}$	50	Field Tests (4)
Basal Red Till	$k_h = 4x10^{-8}$	2	Field Tests
	$k_v - 3x10^{-8}$	4	Lab Tests
Shallow Rock	$k = 1x10^{-5}$	11	Field Tests
Deep Rock	$k = 5x10^{-6}$	3	Field Tests

NOTES

(1) k = bulk hydraulic conductivity.
k_h = Hydraulic conductivity in the horizontal direction.
k_v = Hydraulic conductivity in the vertical direction.

(2) Data from SLF #11 area treated as one data entry.

(3) $k_v = 6x10^{-7}$ cm/s due to structural discontinuities. (See Text Sections 5.1 and 6.3.)

(4) Field tests performed in revised monitoring system well.

(5) Undisturbed boring samples.

CHAPTER 3

DESIGN

DESCRIPTION

This chapter provides a summary of the design considerations and calculations used in preparing the RMU-1 construction drawings.

The fundamental design of RMU-1 will remain consistent with the previous landfills at Model City with double composite liner systems.

LANDFILL BASE

The Federal law governing solid and hazardous waste management facilities enacted in 1984 established the requirements for double lined landfills. The principal design criteria used for the base of RMU-1 are as follows:

1. Comply with the new minimum technology requirements for double liner systems beneath hazardous waste landfills in accordance with the report entitled Minimum Technology Guidance on Double Liner Systems for Landfills and Surface Impoundments--Design, Construction, and Operation dated May 24, 1985, EPA/5300-SW-85-014 (referred to hereinafter as EPA Guidelines). In addition, the landfill design meets the new regulation published in the January 29, 1992, Federal Register concerning 40 CFR 264.

2. Maintain structural integrity of the prepared subgrade.

3. Minimal compression in the subsoils to protect the synthetic flexible membrane liners.

4. Mitigate potential earthquake impacts on the proposed landfill.

5. Meet requirements set forth by the NYSDEC.

The design philosophy behind the double composite liner system is to provide an additional measure of environmental protection against contaminant migration by providing leachate collection above and between the liners. The primary leachate collection system above the top liner is intended to minimize head on the liner system and to remove liquids. The secondary leachate collection system is intended to collect and remove liquids infiltrating into the space between the liners from the landfill or from the groundwater, as well as to provide for long-term minimization of head build-up within the closed unit and thus potential migration of hazardous waste constituents through the closed unit. The January 29, 1992, regulations require a composite of a geomembrane and a 3-foot compacted clay bottom liner. The design for RMU-1 has provided additional environmental safeguard by incorporating the composite liner approach for both the primary and secondary liner systems.

The landfill base will be constructed with the ascending order of layers listed below and shown on Figure 1:

Secondary Liner System

A. A varying thickness of in-situ glacial till will be left in place above the in-situ glaciolacustrine clay formation to withstand hydro-static pressures and provide a suitable surface for construction equipment. The thickness varies because of the irregularity of the surface of the glaciolacustrine clay. In conformance with requirements of 6NYCRR Subpart 373-2.14(b)(2), all waste will be placed at least 10 feet above bedrock or usable groundwater aquifer.

B. A minimum of three feet compacted glacial till or other suitable clay having a maximum permeability of $1.0x10^{-7}$ cm/sec.

C. An 80 mil high density polyethylene (HDPE) flexible membrane liner. (For Cells 7/8, 9/10, 11/13 and 12/14 an 80 mil Textured HDPE flexible membrane liner.)

Secondary Leachate Collection System

A. Drainage net (For Cells 7/8, 9/10, 11/13 and 12/14 - Geonet /Geotextile Composite).

B. A geotextile filter (Not included for Cells 7/8, 9/10, 11/13 and 12/14).

C. A nominal 1 foot of granular material. - (with 8" perforated pipe Cells 7/8, 9/10, 11/13 and 12/14).

D. A geotextile filter.

Primary Liner System

A. 1.5 feet nominal compacted clay over the base area. The upper foot shall be compacted to yield a maximum permeability of $1.0x10^{-7}$ cm/sec. (a geosynthetic clay liner has been added above the primary clay in the sump areas of Cells 5, 6, 7, 10, 13 and 14)

B. An 80 mil HDPE flexible membrane liner (For Cells 7/8, 9/10, 11/13 and 12/14 - 80 mil Textured HDPE flexible membrane liner).

Primary Leachate Collection System

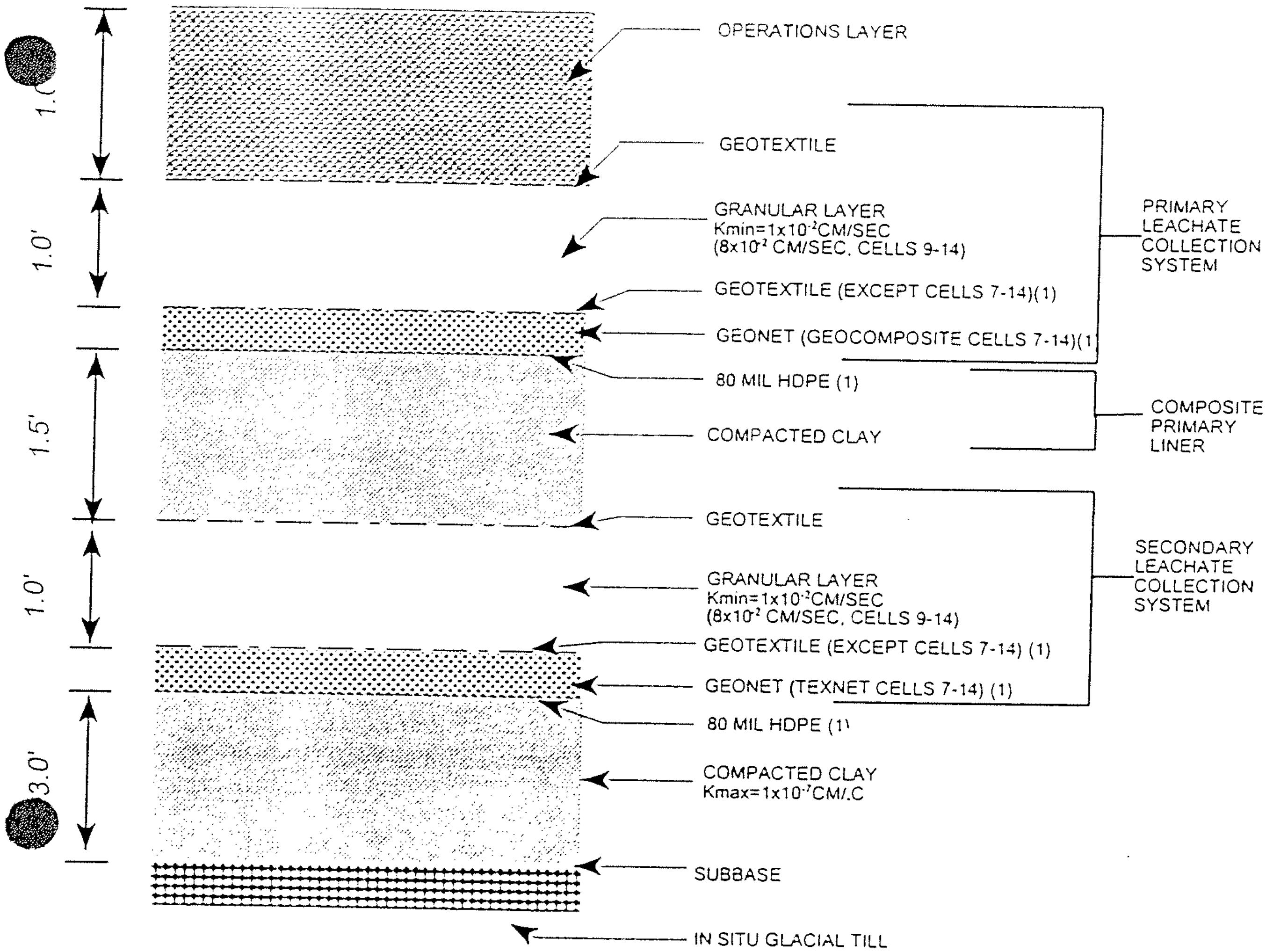
A. Drainage net (For Cells 7/8, 9/10, 11/13 and 12/14 - Geonet /Geotextile Composite).

B. A geotextile filter (Not included for Cells 7/8, 9/10, 11/13 and 12/14).

C. A minimum of 1 foot of granular drainage material (with 8" perforated pipe cells 7/8, 9/10, 11/13 and 12/14).

D. A geotextile separation layer.

E. A nominal 1 foot operational layer of granular material on the base (with 8" perforated pipe cells 7/8, 9/10, 11/13 and 12/14) and a minimum 1 foot operational layer on the sideslopes.



BASE LINER
NTS

Notes:

(1) Liner systems for Cells 7 through 14 to consist of 80 mil HDPE textured sheet and geocomposite for both primary and secondary liner systems. The geotextile above the geonet is also eliminated.

FIGURE 1
BASE COMPOSITE LINER

CWM CHEMICAL SERVICES, INC.
RESIDUAL MANAGEMENT UNIT NO. 1
Model CITY, NIAGARA COUNTY, NEW YORK

4|8|98
Revised: ~~Date Approved~~

Design details are illustrated on the detail sheets of the accompanying plans. The design for the primary and the secondary leachate collection system are discussed in detail in this report. The following subsections describe the remaining components and the evaluation criteria used to satisfy the principal criteria identified above.

The adoption of the new 40 CFR 264 regulations, published January 29, 1992, require several additional design items above and beyond the May 1985 minimum technology guidance. These items are:

1. 264.301 Design and Operating Requirements

   a. Top liner (primary) geomembrane.
   b. Bottom (secondary) liner, geocomposite, geomembrane and 3 feet of $1x10^{-7}$ cm/sec soil.
   c. Leachate collection and removal system which maintains less than 1-foot head on top liner.
   d. Leachate detection system must be at 1 percent slope, $1x10^{-2}$ cm/sec permeability, 12 inches thick or have a transmissivity of $3x10^{-5}$ m^2/sec.
   e. Leachate detection system constructed with sumps and liquid removal methods to prevent backing up of liquid and must be able to provide measuring and recording of removed liquids.

The design of RMU-1 meets these new design requirements as follows:

1. The primary liner for RMU is a 80-mil HDPE geomembrane (smooth Cells 1-6, textured Cells 7-14) on sideslopes and a composite of a 80-mil HDPE geomembrane and 18 inches of compacted clay on the base. This exceeds the requirements.

2. The secondary liner is a composite of 80-mil HDPE geomembrane (smooth Cells 1-6, textured Cells 7-14) and 3 feet of $1x10^{-7}$ cm/sec compacted clay on the base and sideslopes. This meets the requirements for a composite and the 80-mil exceeds the recommended guidance on geomembrane thickness.

3. The leachate collection and removal system is composed of redundant components including 1 foot of granular layer and a geonet in Cells 1-6 and a geonet/geotextile composite in Cells 7/8, 9/10, 11/13 and 12/14 . The granular layer in Cells 1 through 8 is 1 foot of $1x10^{-2}$ cm/s stone and in Cells 9 through 14 is 1 foot of $8x10^{-2}$ cm/s stone. A 8-inch perforated leachate collection pipe will be installed in Cells 7/8, 9/10, 11/13 and 12/14. The installation of two layers exceeds the requirements. Performance data to show leachate head is minimized are included in Appendix G of this report.

4. The secondary leachate collection and removal system is composed of redundant components including 1 foot of granular layer and a layer of geonet in Cells 1-6 and a geonet/geotextile composite in Cells 7-14. The granular layer in Cells 1 through 8 is 1 foot of $1x10^{-2}$ cm/s stone and in Cells 9 through 14 is foot of $8x10^{-2}$ cm/s stone. A leachate collection pipe (8-inch perforated) will be installed in Cells 7/8, 9/10, 11/13 and 12/14. This system provides rapid leak transmission and exceeds the requirements.

5. The secondary leachate collection and removal system is equipped with automated pumps which can be discharged to a tanker truck. CWM personnel will record pumping volumes.

DESIGN CONSIDERATIONS

Preceding sections of this report have described components of the primary and secondary liner systems and the manner in which each of the components meets or exceeds the minimum criteria established by the EPA. Preceding information addresses the first of the five design criteria identified previously in this report.

For the second design criteria item, maintaining structural integrity of the prepared subgrade, a limitation on the depth of excavation has been incorporated into the design to provide an adequate safety factor to overcome instability of the base due to hydrostatic uplift. Sump grades were checked and the average safety factor was 1.09 (see Appendix D-4). This is an acceptable safety factor due to the small area of sump and the short time the area will be exposed. Sumps will be backfilled with recompacted clay as soon as sump excavation documentation is completed, total time exposed is expected to be less than 24 hours.

Prior to construction, the safety factor of the sumps will be verified in the field by means of test pits and/or piezometric measurements in adjacent wells. If conditions other than those used in these calculations exist, the safety factor for excavation will be reevaluated. CWM Chemical Services, Inc. will retain Rust for design services during construction phases of the project. An independent certifying engineer will be retained by CWM to supervise subbase preparation activities. One week prior to sump excavation, piezometric measurements will be performed in the wells nearest to the proposed cell under construction. Rust will review this information and evaluate potential uplift during sump subbase excavation. The new piezometric surface information will be utilized to determine the factor of safety against potential heave. If the analysis indicates a factor of safety less 1.01, then the sump(s) excavation grade will be raised to allow for a minimum factor of safety 1.01. In addition, after determination of a satisfactory uplift condition, test pit(s) will be excavated at the sump to the proposed subbase. Test pit excavations will be performed by a small backhoe. The excavated dimensions of the test pit will not exceed 4 feet by 4 feet in plan. During test pit excavation, the certifying engineer will log the soils and note any potential groundwater hydrostatic conditions including cracking of subbase soils and groundwater seepage. If the observations suggest hydrostatic problems (i.e., by either tension cracking of the soils or excessive groundwater seepage), recompacted clay will be replaced immediately in the test pits. The sump subbase grade will be raised to a level where hydrostatic pressures are retained. If the test pit(s) show no influence by hydrostatic pressure, further excavation will be performed for the entire sump undercut dimensions. A nominal 3 feet of recompacted clay (i.e. secondary clay liner) will be placed within 24 hours. Compaction criteria of secondary clay liner is presented in the CQA Plan.

Subbase areas other than the sumps were evaluated for hydrostatic uplift and calculations show an average safety factor of 1.32. Hydrostatic uplift calculations are presented in Appendix D-4.

The third design criteria concerns the compression of the subsoils beneath the liner. Calculations were performed to check the magnitude of consolidation in the glaciolacustrine clay and to check the magnitude of excavation heave. One-dimensional consolidation analysis was checked at critical points on the landfill base. Magnitudes of consolidation averaged approximately 1.90 feet, ranging from approximately 0.97-feet to 2.59-feet (see Appendix D-1). The performance of the leachate collection systems will not be affected by slope changes due to consolidation. Excavation heave was calculated to be equal to or less than 2 inches. Calculations of the approximate range of soil movement are included in Appendix D-3.

For the fourth principal design criteria listed previously, slope stability of the landfill under the influence of seismic acceleration due to earthquake loads was evaluated. An earthquake induced acceleration equal to 0.10g (seismic coefficient equal to 0.055) was pseudostatically incorporated into the slope stability model for the critical slope condition at final cover. The analysis indicated that the most critical slope has a factor of safety of 1.23. For a static condition, where seismic event is not considered, the critical failure plane has a factor of safety of 1.52. This analysis assumes the following waste properties: Cohesion – 0 psf, Friction Angle – 24 degrees, and Unit Weight – 111.1 pcf. These calculations are presented in Appendix D-6. The slope stability model is discussed in more detail in later sections. In addition, the site subsoils were evaluated for potential liquefaction. This analysis determined that under a seismic event, liquefaction of the site subsoils will not occur. These calculations are presented in Appendix D-9.

The fifth design criteria, meeting the requirements of the NYSDEC has been met or exceeded with the design of RMU-1. In particular, this design exceeds Section 373-2.14(c). The clay portions of the liner will be constructed to maximum permeability of 1×10^{-7} cm/sec and the geotechnical calculations show the base capable of supporting the liner. The leachate collection system is designed to maintain leachate at a head of less than 1-foot above the primary liner. The leachate detection zone is designed to show response times of less than one day.

Slope stability of the perimeter berm, final buildout, and differential waste heights were evaluated using a complex program developed by Dr. Stephen G. Wright, University of Texas at Austin, entitled "SSTAB" and "UTEXAS2." Spencer's method of slices was utilized by the programs to determine minimum factors of safety. Also, "Geoslope" Slope Stability Analysis Computer Program employing the Bishop method applicable to circular shaped failure surfaces and the simplified Janbu method, applicable to sliding block failure surfaces was used to analyze the height of the final buildout to maximum elevation 398 ft. over Cells 1 through 8 and 420 ft. over Cells 9 through 14. The computer analyses were conducted to investigate a large number of potential failure surfaces for each of the analyzed conditions. An automatic search routine is employed in the program that searches circular shear surfaces until the lowest factor of safety is found. The computer outputs for perimeter berm, final buildout and differential waste heights are presented in Appendices D-5, D-6, and D-7, respectively.

Stability of the perimeter berm was checked using the SSTAB (Vax 11/780 computer developed by Dr. Stephen G. Wright, 1969) computer model. A safety factor of 1.84 was calculated for failure into the excavation in the area adjacent to SLF-10. This was assumed to be the most critical area of excavation.

Waste will be filled between cells starting at the inside edge of the cell separation berms. The following tabulation presents maximum differential waste height for varying waste slopes having a factor of safety near 1.5

	Differential Waste Height (ft)	Factor of Safety
3:1	57	1.55
2:1	45	1.51

The supporting calculations are presented in Appendix D-7.

Finally, an evaluation has been performed to assess the effect of the final cover modification (i.e., compacted clay cover system to GCL cover system) on landfill slope stability. This assessment concluded that the slope stability evaluations performed for the perimeter berm and differential waste height (Appendices D-5 and D-7, respectively) are unaffected by the final cover system because the analyses evaluate the landfill in an uncapped condition. The slope stability evaluation performed for the landfill under final buildout conditions (Appendix D-6) does consider the existence of the final cover. Because the final grading of the landfill is not affected by the final cover modification and the change in stress on the landfill due to the alternate final cover system is negligible (actually a slight reduction compared with the original compacted clay cover system), the final cover modification is not anticipated to negatively impact the global stability of the landfill and so Appendix D-6 is unaffected. The only stability analysis that is affected by the final cover modification is the final cover veneer stability analysis (Appendix D-8). As discussed later in this section, a veneer stability analysis specific to the GCL final cover system is contained in Appendix D-8a.

EXTERIOR BERMS

Exterior sideslopes will be 2:1, interior slopes will be 3:1. A 22.5-foot crest width will be maintained around the perimeter berm. RMU-1 perimeter berm height varies from site datum elevation 330.0 to 338.50 fmsl with additional soil placed atop the berm to provide a minimum 3 percent slope towards the inside face of the berm to collect surface water accumulated on the perimeter berm as shown on details in the accompanying drawings.

The accompanying set of drawings illustrates the typical detail of the perimeter berm for RMU-1. This detail illustrates the manner in which each component of the liner systems and leachate collection systems are to be extended along the perimeter berm. The 80 mil HDPE membrane (textured HDPE in Cells 7/8, 9/10, 11/13 and 12/14) is to be installed directly above the 3-foot thick secondary clay soil liner. The secondary leachate collection system along the side slope will be a geonet overlain with geotextile in Cells 1 through 6 and a geocomposite in Cells 7 through 14. The 80 mil HDPE FML component (textured HDPE in Cells 7 through 14) of the primary lining system will be extended along the perimeter slope and keyed into the anchor trench as detailed in the accompanying plan set. The primary leachate collection system on the sideslope will be a geonet and geotextile in Cells 1 through 6 and a geocomposite in Cells 7 through 14. Above the synthetic drainage net, a minimum of 1-foot of sideslope protection layer will be installed on the sideslopes to provide physical protection for the leachate collection and lining systems. Sideslope protection layer composed of granular cover will not be controlled to attain a specified minimum permeability.

LANDFILL CELLS

RMU-1 is designed with 14 cells, numbered 1 through 14. The 14 cells are separated by berms as illustrated in the accompanying plan set.

The construction of RMU-1 will be performed in phases to match the operational aspects of the facility based upon waste receipts.

New cells are to be separated in both the primary and secondary leachate collection systems. The systems will be separated by a compacted clay berm having a maximum permeability of $1.0x10^{-7}$ cm/sec and a nominal 8-foot top width. A 3-foot top width may be used as approved by the Engineer. The clay berm is overlain with both primary and secondary layers of HDPE liner. The purpose of the berms is for control of surface water. The berms will not be raised above the initial construction levels.

Temporary berms may be constructed in the cell area that clearly demarcates certified lined areas as current filling limits. The temporary berm consists of an HDPE flap installed over a mound of drainage stone material. The HDPE flap is carefully welded to the liner below the granular layer. The temporary berm segregates surface water outside the active filling area from water that has contacted the hazardous waste. This method of temporary segregation of surface water and leachate allows for progressive construction of all components of the liner system.

SECONDARY LINER SYSTEM

Excavation grades for RMU-1 are primarily above the glaciolacustrine clay unit. Due to the sensitive nature of these soils, disturbance to these soils will be reduced by not allowing excavation below the Upper Till unit. The design has attempted to maintain a slight buffer of till soils over the glaciolacustrine clay.

Drawing No. 4 of the accompanying plans illustrates the limit of excavation designed for RMU-1. The glaciolacustrine unit has been identified on the borings as generally level with a slight depression to the north and south. Past construction has shown the actual surface of the glaciolacustrine to undulate. Excavation grades for the northern four cells extend the deepest because the potentiometric surface of the glaciolacustrine silt sand unit is lower toward the north side and south end of RMU-1 with the mid portion elevated. All excavation grades are at a 1 percent minimum slope towards the sump areas in conformance with the EPA Technical Guidance.

After excavation grades are achieved a cutoff trench will be excavated at the top of the sideslope to the glaciolacustrine clay interface. Clay will be backfilled and compacted in lifts to achieve $1x10^{-7}$ cm/sec permeability. The purpose of the cutoff trench is to reduce groundwater seepage from the upper till units towards the landfill.

To comply with the new EPA Technical Guidance, a compacted clay liner of a minimum 3-foot thickness will be constructed after documentation of excavation grades. The clay will be compacted to achieve a maximum permeability of $1x10^{-7}$ cm/sec.

Drawing No. 6 of the accompanying plans illustrates the grades of the top of the clay component of the secondary liner system. As shown on Drawing No. 4, cell separation berms of compacted clay will be constructed in conjunction with the 3-foot secondary clay liner and side slope clay liner prior to placing a flexible membrane liner (FML). Cell separation berms and temporary cell separation berms will provide flow segregation to individual cells for the secondary and primary leachate systems. A detail of the cell separation berm is shown on the accompanying plans, Drawing Nos. 19, 19A, 19B, and 19C.

Immediately above the clay component of the secondary liner system is a 80 mil HDPE flexible membrane liner (smooth for Cells 1 through 6 and Textured on both sides for Cells 7 through 14). The composite secondary liner with a minimum of three feet of compacted clay and 80 mil HDPE synthetic liner exceeds the EPA Technical Guidance. Placing the HDPE directly on the smooth rolled surface of the clay liner complies with EPA Technical Guidance.

PRIMARY LINER SYSTEM

The primary liner system proposed for RMU-1 contains a voluntary compacted clay layer that is 1.5 feet thick across the base in a 12-inch initial layer and a 6-inch subsequent layer. EPA Guidelines do not require a composite primary liner, therefore the design of RMU-1 exceeds the minimum requirements. The first lift of clay will be placed 12 inches thick to minimize damage to the secondary system. Experience has shown that clay can be placed 12 inches thick directly above the secondary leachate collection system to densities adequate in the top 12 inches to achieve low permeability. The clay component of the primary liner system will parallel the secondary leachate collection system grades to the sump areas.

Primary and secondary sumps will be approximately 40 feet apart (from centerline to centerline). Primary and secondary sumps for cells 5, 6, 7, 10, 13 and 14 will be approximately 8.5 feet apart (from centerline to centerline). Sump locations are shown on Drawing Nos. 5 through 10 and detailed on the accompanying set of drawings.

The FML component of the primary liner system is to be 80 mil HDPE (smooth for Cells 1-6, textured for Cells 7-14). Selection of this material is consistent with past landfills at Model City and is expected to be compatible with RMU-1 leachate. The 80 mil thickness exceeds the minimum thickness for the FML component of the primary liner system of 45-mils specified in the EPA Guidelines, by 78 percent.

<u>SECONDARY LEACHATE COLLECTION SYSTEM</u>

The secondary leachate collection system proposed for RMU-1 has been designed to comply with EPA Guidelines, namely to provide an efficient collection system for prompt detection of inflow. The secondary leachate collection system will be the same as the primary with a 24-inch sideslope riser extending into the sump. Each cell will slope to its respective collection sump.

Details of the secondary sump are presented on the accompanying plans. Hydraulic calculations supporting the drainage net/geotextile and granular layer design are included in Appendix G. Number 2A stone as specified in Standard Specifications for Construction and Materials, State of New York Department of Transportation is proposed to be used in the secondary leachate collection system in addition to geonet and geotextile in Cells 1 through 6 and a geocomposite in Cells 7 through 14. Permeability testing data of the proposed stone in Cells 1 through 8 will be required to meet a minimum permeability of $1x10^{-2}$ cm/s according to EPA guidelines. Permeability testing data of the proposed stone in Cells 9 through 14 will be required to meet a minimum permeability of $8x10^{-2}$ cm/s. A perforated leachate collection pipe (8-inch) will be installed as a main collector in Cells 7/8, 9/10, 11/13 and 12/14. The pipe will provide additional hydraulic capacity to the secondary leachate collection system.

The secondary leachate collection system on the sideslopes will consist of a geonet in Cells 1 through 6, and a geocomposite in Cells 7 through 14, sandwiched between the primary and secondary HDPE liners. This drainage layer will provide effective transmission of inflow to the base of the cells.

To comply with the EPA Guidelines, a sump is provided within each cell to accommodate monitoring and pumping of the secondary leachate collection system. The sump is designed to be depressed about 2.5 feet. An HDPE sideslope riser pipe will be installed in each sump. This design allows access to the secondary leachate collection system without penetrating the primary liner within the cells. Flow into the riser will occur through 0.5 inch diameter holes drilled into the pipe. The sump is sandwiched between layers of geonet and geotextile to prevent migration of fines from the primary clay into the sump. The accompanying set of drawings illustrates the sump design. The use of a HDPE pipe is compatible with expected site leachate and waste.

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Hydraulic Design

Inflow to the secondary leachate collection system can come from several sources including:

1. Groundwater infiltration.

2. Leaks through the primary liner.

3. Precipitation entering the system prior to installation of the primary liner.

4. Moisture contained within the soil materials placed to construct the primary liner system.

The third and fourth sources of moisture identified above will be minimized by following the construction procedures discussed in Chapter 4 of this report. Inflow due to groundwater is estimated using the glaciolacustrine silt/sand ($K=3x10^{-5}$ cm/s, Table 1) which is equivalent to 0.0002 gpd/sf. This estimate is considered conservative because the 80 mil HDPE liner is ignored in the calculations and the glaciolacustrine permeability is the highest of the soil units.

Inflow from the primary leachate collection system is computed as if the final cover synthetic liner and the primary liner have both failed completely during the post-closure period. Therefore, the inflow rate to the secondary leachate system is equal to the inflow rate through the top of the landfill. Infiltration during operations (operations was taken as active conditions with 10 feet of waste over a cell) has been estimated using the EPA HELP model with a 25-year, 24 hour, SCS Type II storm added to the weather data input. The Peak daily infiltration rate through 10 feet of waste corresponding to this rainfall event is 0.1991 in. or 01.2 gal/sf, as calculated with the EPA's HELP model. The base was designed to handle a leachate inflow of $2.5x10^{-4}$ cfs/ft of width while inflow due to rainfall infiltration is $5.8x10^{-5}$ cfs/ft of width. The final cap over the landfill will significantly reduce potential infiltration during the closure period. Therefore, the secondary system is designed to handle a total failure of the primary system during operations as well as into the closure period. If a total failure of the liner occurs, peak maximum flow of approximately 7,200 to 14,400 gpd could be delivered to the sump depending on which cell is considered. This is about 5 to 10 gallons per minute which is well within the pumping capacities of the design.

PRIMARY LEACHATE COLLECTION SYSTEM

The primary leachate collection system proposed for RMU-1 is similar to the primary leachate collection system designed and constructed for previous double lined landfills at the site. The use of sideslope risers and multiple layers of geonet (Cells 1 through 6) or geocomposite/perforated pipes (Cells 7 through 14) for collection and transmission of leachate are utilized in this design.

The primary leachate collection system will drain to individual cell sumps. The sumps will be constructed with dual access provided by a 24-inch diameter HDPE vertical riser pipe and a 24-inch diameter HDPE sideslope riser pipe. The leachate pumping system, including controls, electrical cables and discharge pipe, will be installed inside the sideslope risers. Vertical risers provide contingency access to the sumps. The vertical risers are protected by concrete manhole sections as filling progresses during operations.

The primary leachate collection system will be constructed directly over the 80 mil HDPE primary liner component. The primary leachate system is a combination of drainage net/geotextile (Cells 1 through 6) or geocomposite/perforated pipe (Cells 7 through 14) and a granular layer which provides capacity to carry inflow to the sumps.

The drainage net/geotextile (Cells 1 through 6) or geocomposite/perforated pipe (Cells 7 through 14), and granular layer components have been designed to outlet the estimated infiltration with sufficient capacity to minimize leachate head buildup. Hydraulic computations for the drainage net/geotextile system for Cells 1 through 6 are included in Appendix G. Geocomposite transmissivity and pipe design calculations for Cells 7 through 14 are included in Appendix G. As the calculations show, one layer of drainage net or geocomposite in conjunction with the gravel layer and perforated pipe for geocomposite only is capable of carrying the peak daily infiltration through the waste. Appendix G contains hydraulic calculations pertaining to the performance of this layer in combination with drainage net/geotextile components.

<u>GEOTEXTILE DESIGN</u>

A geotextile is utilized to overlay the drainage net and granular layer in both primary and secondary leachate collection systems. It is intended to prevent fines from the waste or the clay liner from migrating into the drainage nets or granular layer and thereby reducing the hydraulic capacity. Trevira 1145 (or equal) was selected as the geotextile over the net because of its operating history in previous landfills at Model City and the calculations presented in Appendix F. It is expected that the geotextiles over the primary geonet on the sideslopes and over the granular layer on the base will be exposed to the environment for a longer period of time than either of the geotextile over the geonets on the base secondary or primary leachate collection systems. Heavier geotextiles such as Trevira 1145 (or equal) have higher initial strength characteristics which would result in greater survivability as compared to lighter geotextiles at the same exposure.

<u>LEACHATE PUMPING SYSTEM DESIGN</u>

The leachate pumping facilities consist of the primary leachate pumping system and the secondary leachate pumping system. Pumps will be installed in the sideslope risers in a manner similar to past designs.

The primary leachate system pumps will discharge to a force main at the perimeter of RMU-1. The force main consists of two lines, a west and an east transfer line. The west transfer line conveys leachate from six cells to the lift station at the midpoint along the western berm of the landfill. The east transfer line conveys leachate from eight cells to the same lift station. Both force mains are double encased HDPE pipe with gravity drainage to the lift station. A leak detection monitor for the carrier pipe will be installed at each vault location, junction manholes and at the lift station.

The secondary leachate system pumps will discharge to a forcemain dedicated to only the secondary system. It will parallel the primary leachate forcemain and pass through the vaults in the same manner as the primary forcemain. The secondary forcemain will be HDPE pipe and be installed within an HDPE containment pipe. The secondary containment pipe will be monitored for leakage in the secondary riser vaults and at the lift station. The pipe will be sealed in the containment pipe through the primary vault to reduce the risk of cross-contamination.

The lift station is a concrete structure encasing a 3,000-gallon steel tank. The concrete structure is designed as secondary containment in case of a failure of the steel tank. A containment area of 18 by 15 by 3.75 feet resulting in a volume of 5,780 gallons is available from floor elevation to door opening. A submersible pump is designed to empty the tank and discharge to the Model City leachate treatment facilities. Emergency shutoff valves, leak detection and an alarm system will be incorporated into tank operation. The lift station will be heated and insulated to prevent freezing of the leachate.

The secondary sumps will have an automated pump installed within them at the time of construction. Power will be provided at the equipment control panel and wired to the vault and pump. Controls will be installed which will allow automatic pumping to the forcemain or hand operation of the pump. Under hand operation the secondary sumps can be pumped into a tanker truck as a backup to the forcemain. The operator will record the tank level before pumping, pump the sump until the control system shuts it off, and record the final tank level. The difference in tank levels will be converted to gallons and recorded on the RMU-1 operating records.

FINAL COVER

The final cover will consist of one of two systems. The first final cover system consists of (from top to bottom) 36 inches of vegetative support cover soil, a geotextile or geocomposite drainage layer, a 40 mil textured HDPE liner, and 24 inches of compacted clay with a maximum permeability of $1x10^{-7}$ cm/sec. The stability of the final cover system was checked using the sliding work method. This method evaluates the required minimum liner interfacial friction by resolution of static equilibrium forces. For a slope of 3H:1V, a friction angle of at least 25 degrees will be required to provide a factor of safety greater than 1.5 under static conditions. Slope stability calculations for the first type of final cover system are included in Appendix D-8.

The second final cover system consists of (from top to bottom) 24 inches of vegetative support cover soil, a geocomposite drainage layer, a 40 mil textured HDPE geomembrane, a GCL layer, and 6 inches of general fill. Appendix D-8a contains slope stability calculations for the GCL final cover system. In order to provide a minimum factor of safety of 1.5 under short-term static conditions, a minimum peak friction angle of 26.0 degrees is required. In order to achieve a minimum factor of safety of 1.0 under short-term static conditions, a minimum residual friction angle of 17.8 degrees is required. In order to limit permanent seismic deformation to 12 inches for the design earthquake, a minimum residual friction angle of 22.4 degrees is required under rapid shearing (as opposed to the residual friction angle for static conditions, which is based on slower shearing rates). It is anticipated that, based on cover soil thickness and potential equipment loading, the GCL will be subjected to a normal load ranging from approximately 300 psf (with no equipment loading) to 1000 psf (with equipment loading). Therefore, the GCL specification requires that shear strength testing be performed at 200, 400, and 1000 psf to establish anticipated shear strength within the 0 to 1000 psf range.

Direct shear testing will be performed on the entire cross section for the GCL final cover system to identify the critical interface and verify that the shear strength along that interface meets or exceeds the minimum required values presented above. Because the GCL final cover design is based on a seismic event having a magnitude of M5.6, seismic events of equal or lesser magnitudes would likely not compromise the GCL final cover system. If a seismic event having a magnitude of greater than M5.6 occurs, a field inspection of the GCL final cover system will be performed to identify and evaluate any damage to the cover system. Evidence of damage to cover system will likely consist of fissures or surface sloughing. Although the exact approach used to repair damage to the cover system will depend on the nature and extent of the damage, repairs could range from simply replacing soil and revegetating the area to systematically deconstructing the final cover system across an area exhibiting damage. In the latter case, the cover soil would be removed and stockpiled nearby and the underlying geosynthetics cut and removed to inspect the various layers. The cover system would then be reconstructed in compliance with the RMU-1 Technical Specifications and provisions of the RMU-1 Quality Assurance Manual.

Appendix K presents a comparison of the hydraulic performance of the GCL in the second final cover system to the compacted clay layer in the first type of final cover system. A maximum allowable steady-state flux of 4.2×10^{-9} cfs/ft^2 was calculated for the GCL in order to be hydraulically equivalent to 2 feet of compacted clay. Under the hydraulic gradient specified in Appendix K, this steady-state flux is equivalent to a hydraulic conductivity of 1.2×10^{-7} cm/s. The final cover GCL specification requires laboratory testing of the GCL material to demonstrate that the actual steady-state flux through the material is less than or equal to the maximum allowable value.

The lateral drainage layers in both types of final cover systems were evaluated to demonstrate the capacity of the designs to manage the peak daily infiltration rate as predicted using the Hydrologic Performance of Landfill Performance (HELP) model. For these analyses, the HELP model climatic data was modified to include the 25-year, 24-hour design storm. The first calculation sheet in Appendix G contains hydraulic calculations that are applicable to final cover areas with compacted clay (i.e., the first type of final cover system). Appendix G-3 also contains hydraulic calculations that are applicable to final cover areas with GCL (i.e., the second type of final cover system). Appendix G-3 demonstrates that the collection pipe design that was originally developed for use in compacted clay final cover areas is also adequate for use in GCL final cover areas.

In addition to the stability and hydraulic considerations described above, the GCL design is technically equivalent, or exceeds, the compacted clay system in other areas. The report entitled *Technical Equivalency Report for Proposed Landfill Final Cover Modification* prepared by Emcon, dated June 2000, compares the performance and installation considerations for both the compacted clay and GCL final cover system. As stated in the Emcon report, the swelling and self-healing characteristics of the GCL enables it to withstand the effects of freeze/thaw and wet/dry cycling of landfill cover systems, unlike a compacted clay layer. Although GCL offers equivalent or better performance than the compacted clay layer in the first type of final cover system and is simpler to install, special consideration must be given to the installation of the GCL in order to maximize long-term performance. Consequently, several provisions, such as proof-rolling the subgrade beneath the final cover GCL and protecting the GCL from hydration prior to installation, have been incorporated into the RMU-1 Technical Specifications and Quality Assurance Manual to facilitate the successful installation and performance of the final cover GCL.

Waste settlement was calculated using the method explained in Yen and Scanlon's paper, "Sanitary Landfill Settlement Rates," Journal of the Geotechnical Engineering Division, ASCE, May 1975. Worst case assumptions show a maximum settlement of 5.6 feet during the life of the landfill. This should not affect the integrity of the final cover geomembrane, because it is expected to be predominantly even over the entire surface due to waste filling procedures. There is potential for differential settlement and the geomembrane has been designed to accommodate the minor movement. Result of waste settlement analysis is presented in Appendix D-2. Recognize this analysis assumes highly compressible municipal waste materials and as such calculated settlements will likely exceed actual settlements experience by RMU-1.

SURFACE WATER

To provide long-term protection against possible erosion of the cover slope, 15-foot wide benches, with surface water diversion ditches spaced at approximately 90-foot intervals collect a majority of the runoff surface water which is directed to the south and discharged through down flume piping to the east retention basin. Only surface water from below the first bench on the northern half of the unit and the northeast corner, above the first bench, will be directed to the north retention basin. Surface water calculations utilizing a 25-year 24-hour storm event are presented in Appendix I. Drawing No. 12 of the accompanying drawings shows the alignment of the surface water drainage system. The seeded topsoil slope will be maintained to prevent erosion. Sideslope diversion ditches will be constructed to minimize slope erosion. Appendix I contains erosion calculations for the final cover conditions.

Surface water during construction and operation of RMU-1 will be handled within the landfill cell. At completion of the final cover, some of the surface water will be allowed to drain to the north exiting retention basin, then off the site naturally. The majority of the surface water will drain to the east, through the new retention basin and then off-site in a channel. Jute mesh or other biodegradable mesh will be used to enhance the establishment of vegetation as soon as possible within the drainage channels. The channels may require sodding to reduce erosion rates if vegetation is not readily established.

ROADS

RMU-1 will be accessed via Balmer Road to the site's access roads. The truck entrance is located along Balmer Road at the northern section of the site where Balmer intersects the site's Marshall Street. Marshall Street provides access to perimeter access roads immediately adjacent to RMU-1. The road entering RMU-1 has been designed to enter over the perimeter berm at the cell separation berms and into the cells. The proposed filling sequence and waste types do not require a cell separation berm to be extended during operations (as in the past landfills). If CWM chooses to construct road support berms, the gravel removed during this construction within the landfill limits will remain in the landfill and be used as temporary road subgrade across the lift of waste.

During later stages of waste filling, the increasing elevations of the waste mass will prevent the use of traditional haul roads, which typically have encroached into the permitted waste envelop. Thus, a new landfill plateau access road (planned for construction in late 2012) will be constructed on top of existing final cover areas so that the landfill final buildout may proceed without further restrictions imposed by vehicle access needs. The new single-lane width gravel road will be constructed from the perimeter berm diagonally up the northern face of the landfill and onto the plateau. Other than topsoil removal within the road footprint, no other modifications should be needed to the existing final cover to accommodate the road. The majority of the road will be constructed of general fill and will be surfaced with an 18-inch-thick layer of crusher run, which will be underlain with a woven geotextile. A guiderail will be included along the outside edge. Once constructed, the landfill plateau access road will remain in place as a permanent feature. The accompanying drawings illustrate the planned access into RMU-1.

CHAPTER 4

LANDFILL CONSTRUCTION

GENERAL

RMU-1 will be constructed using clays, synthetic liners, drainage nets, geotextiles, and granular material. Each of the individual components of the design require individualized control during construction. This section of the report presents the special concerns for each component.

The clay and synthetic liners will be installed in accordance with the latest edition of the Chemical Waste Management, Inc., Quality Assurance (QA) Manual and Specifications. Material specifications for these and other materials are included in the technical specifications associated with RMU-1.

SITE PREPARATION

Site preparation for RMU-1 includes clearing existing vegetation and stripping topsoil. Existing utilities impacted during construction of RMU-1 will be relocated.

Perimeter drainage ditches will be constructed as a site preparation activity to allow control of surface water run-on and run-off throughout the construction period. Drainage culverts will be installed as shown in the accompanying drawings. Initial access roads around RMU-1 will be constructed during site preparation to prevent disruption of filling activities. In addition, the curved portion of the abandoned railroad will be removed. Testing of this area will be performed in accordance with Section 2100 of the technical specifications.

EXCAVATION

Based on a review of historical records, due to the location and configuration of the former TNT process areas, no TNT pipelines are expected to be found during construction of RMU-1. However, if unidentified pipelines are encountered during construction, the lines will be sampled, removed, and disposed of in accordance with results of the testing.

Excavation will proceed to the grades indicated on the accompanying drawing. Excavation will progress in a manner to allow control of surface water thus controlling erosion. Excavated soil types will be segregated. Suitable clay will be stockpiled as close as possible to the excavation area to reduce construction time. Care will be taken during excavation to segregate soils that may be unsuitable for compacted clay liner construction. This will be done by visual inspection and physical testing as needed in accordance with the Construction Quality Assurance (CQA) Plan. Laboratory testing will include grain size distribution, Atterberg Limits, and modified proctor tests. As noted in the soils section of this report, the Upper Clay Till has properties similar to clay liner requirements and will be stockpiled

Hydrostatic uplift concerns will require that the sump excavations be checked before full excavation. One week prior to sump excavation, piezometric measurements will be performed in the wells nearest to the proposed cell under construction. Rust will review this information and evaluate potential uplift during sump subbase excavation. The new piezometric surface information will be utilized to determine the factor of safety against potential heave. If the analysis indicates a factor of safety less 1.01, then the sump(s) excavation grade will be raised to allow for a minimum factor of safety 1.01. In addition, after determination of a satisfactory uplift condition, test pit(s) will be excavated at the sump to the proposed subbase. Test pit excavation will be performed in the present of Rust design engineer. The test pit excavations will be performed by a small backhoe. The excavated dimensions of the test pit will not exceed 4 feet by 4 feet in plan. During test pit excavation, the certifying engineer will log the soils and note any potential groundwater hydrostatic conditions including cracking of subbase soils and groundwater seepage. If the observations suggest hydrostatic problems (i.e., by either tension cracking of the soils or excessive groundwater seepage), recompacted clay will be replaced in the test pits. The sump subbase grade will be raised to level where hydrostatic pressures are retained. If the test pit(s) show no influence by hydrostatic pressure, further excavation will be performed for the entire sump undercut dimensions. A nominal 3 feet of recompacted clay (i.e., secondary clay liner) will be placed within 24 hours. Compaction criteria of secondary clay liner is presented in the CQA plan. Due to potential irregularities of the till, the bottom elevation will be verified before full excavation of the sump.

Upon attaining excavation grades, the surface shall be inspected by the CQA Engineer. Any weak glaciolacustrine clay incapable of supporting heavy equipment or any other undesirable material will be overexcavated, removed, and replaced with compacted clay. If any such visibly unsuitable areas are encountered, the recompacted surface of the excavation shall be proof-rolled to identify areas of insufficient consolidation to reduce the potential for differential base settlement.

The perimeter berm is to be constructed of suitable materials from either RMU-1 or other sources. The area upon which the berm is to be constructed shall be scarified and free of any rocks, debris, or topsoil that would interfere with the compaction effort. The perimeter berm is to be constructed by placing and compacting successive lifts of fill compacted to a nominal 90 percent of Modified Proctor Density. Glaciolacustrine clay will not be used as fill for the perimeter berm. The perimeter berm is not considered a portion of the RMU-1 liner system and as such structural fill may be utilized for its construction. For this application, low permeability characteristics after compaction are not required. Structural fill could include soil materials which are granular in nature; as such, an 18-inch lift for the first lift and 12-inch lifts thereafter compacted by vibratory rollers would provide acceptable compaction levels. If the selected berm soils are clayey in nature then 1-foot lifts compacted by a sheepsfoot roller will be employed.

When compacted clay is to be installed directly above a synthetic material (such as the initial lifts comprising the soil component of the primary liner system) compaction will be provided by equipment selected to minimize the risk of damaging the underlying geosynthetics. In such cases, the initial lift of clay will be permitted to be up to 12 inches thick to minimize the potential for damage. These initial lifts will be controlled for density and moisture consistent with the construction of the soil liners and embankment. No confirmatory testing for permeability will be conducted for the initial lift to avoid the possibility of damaging the underlying geosynthetics. As a result, which respect to the soil component of the primary liner system, the design provides a nominal 1.5-foot thick liner with the upper 1 foot of soil yielding a 1.0×10^{-7} cm/sec maximum permeability.

GEOSYNTHETIC CLAY LINER

The design of RMU-1 Cells 5 through 14 includes the installation of a geosynthetic clay liner (GCL) in the primary liner between the 18 inch thick compacted clay layer and the 80 mil HDPE geomembrane in the sump area only.

Construction and documentation will be in accordance with the CWM specifications entitled "Quality Assurance Manual for the Installation of Lining Systems CWM Model City Facility" revision dated November 22, 1995 Section 13.0.

TEMPORARY BERM INSTALLATION

The temporary Intercell berms installed between Cells 7 and 8, 9 and 10, 12 and 14, and 11 and 13(if cells are constructed at different times) have been designed to separate the cell's primary and secondary leachate collection systems and be removed at the appropriate phasing period. As depicted on Drawing Nos. 19B and 19C the berm will be constructed as follows:

1. The lower 80 mil HDPE flap will be extrusion welded to the primary 80 mil geomembrane.

2. The upper 80 mil HDPE flap will be extrusion welded to the secondary 80 mil geomembrane.

3. The lower and upper 80 mil flaps will be extrusion welded together at their termination.

4. At the perimeter berm and at the adjacent intercell berm the lower and upper 80 mil flaps will be extended into the perimeter berm anchor trench or over the intercell berm and anchored with 1' minimum operations layer stone.

5. The following is the construction sequencing for the future cell tie-in.

    a. Remove the protective stone and geotextile, at minimum, from the lower "secondary" portion of the berm.

    b. Complete the entire secondary clay liner and secondary geomembrane of the new cell and tie into the secondary clay and geomembrane lining system of the cell transition area.

    c. Remove the rest of protective stone and geotextile and remove the upper flap in its entirety. Extrusion weld from upper flap to secondary geomembrane remains intact.

Revised: ~~Date Approved~~ 5/18/99

d. Place the entire primary clay liner and geomembrane of the future cell and tie into the primary clay liner and geomembrane of the cell transition area.

e. Monitor secondary volumes for a period of two (2) weeks. The secondary leachate flow volumes must be below the Cell 6 response rate for Cell 6 and the combined Cell 7/8 response rate for Cell 7; combined Cell 9/10 response rate for Cell 10; combined Cell 11/13 response rate for Cell 13, and combined Cell 12/14 response rate for Cell 14 for two (2) consecutive weeks, prior to the removal of the lower flap.

f. Upon NYSDEC acceptance of the secondary monitoring data and the certifying engineer's interim certification through primary geomembrane, remove the entire lower flap. Extrusion weld from lower flap to primary geomembrane remains intact.

g. Complete the placement of the primary drainage stone, separator geotextile and operation stone in the new cell and the cell transition area.

6. All geomembrane deployment welding and testing will be performed in accordance with the permit specifications and the QA/QC manual in Attachment M and N of the permit.

7. Only low ground pressure equipment shall be used to construct this cell berm.

8. Sacrificial geotextile above and below the geomembrane(s) shall be Trevira 1155 or approved alternate.

4/8/98
Revised: ~~Date Approved~~

GEOMEMBRANE INSTALLATION

The 80-mil HDPE component of both the secondary liner system and primary liner system will be installed in conformance with the RMU-1 Technical Specifications and the site-specific CQA manual. The primary and secondary 80 mil HDPE liners will be smooth in Cells 1 through 6 and Textured in Cells 7 through 14. Specific detail with regard to the fabrication procedures and factory quality control assurance will be submitted to the NYSDEC with the certification report.

PRIMARY LEACHATE COLLECTION SYSTEM

Major components of the primary leachate collection system can be categorized into the following construction activities:

1. Installation of drainage net for Cells 1 through 6 and geocomposite for Cells 7 through 14.

2. Installation of granular layer.

3. Installation of perforated pipe for leachate collection in Cells 7/8, 9/10, 11/13 and 12/14.

4. Installation of geotextiles.

5. Construction of sumps and leachate withdrawal components.

6. Installation of leachate pumps.

Each of the above items are detailed in the following subsections.

Installation of Drainage Net or Geocomposite

Drainage nets or a geocomposite will be installed directly over the 80 mil HDPE liners and anchored in the trenches as shown on the drawings. All layers will be unrolled in the same direction to provide proper thickness (webbing can interlock if crossed). All sheets will be secured in-place by standard net ties to prevent movement during placement of overlying soil layers. Geotextile will be sewn at connecting seams. The drainage net will be covered as soon as practical by the specific geotextile to prevent fine airborne soil particles from entering.

Installation of Granular Layer and Perforated Pipe (if required)

The granular layer will be spread directly on the geotextile/net or geocomposite and HDPE liner components. A perforated leachate collection pipe will be installed in Cells 7/8, 9/10, 11/13 and 12/14 with the geocomposite to enhance the hydraulic performance of the system. The granular layer will be placed by spreading a 1-foot layer ahead of selected equipment to minimize the potential for damaging the underlying geosynthetics. Excessive turning and maneuvering of the equipment will not be allowed. No compaction other than that provided by the spreading equipment will be required on this layer.

Installation of Geotextile Component

Geotextiles will be installed in accordance with the technical specifications and the site-specific CQA manual. Quality control during placement will provide proper coverage and connection of sheets.

Construction of Sumps and Leachate Withdrawal Components

Primary sumps proposed for RMU-1 are consistent with past systems. Dual access is provided by HDPE sideslope risers and a 24-inch diameter HDPE vertical riser in each cell. Sideslope risers will be butt fused and anchored at the top of the slope as shown on the drawings. The sideslope riser will enclose the pumping system and a 2-inch discharge line. Typically, the sump will be excavated, the HDPE liner installed, the vertical riser sump assembly placed, and the sideslope riser installed prior to any backfilling of the sump. An initial 10-foot vertical section will be installed on the vertical sump assembly to provide a start for operations.

Installation of Leachate Pumps

Pumps will be installed in the primary leachate collection sumps via HDPE sideslope risers. The pumps will be modified to operate in the horizontal position and be installed in the cells by sliding them down sideslope risers into the primary leachate collection sump. Electrical and control wiring will be connected to an adjacent control panel located near the cell manholes. This will allow the primary pumps to operate in an automatic demand mode.

SECONDARY LEACHATE COLLECTION SYSTEM

The components and installation of the secondary leachate collection system will be similar to the primary collection system installation. The same level of control and documentation will be used on each system.

The secondary leachate collection sumps will have submersible pumps. As with the primary pumps, some modifications will be made to allow horizontal operation. Discharge will be through a flexible hose to the secondary forcemain. At completion of construction, the pumps will be wired into the controller system. A level controller similar to the primary system will be installed. This controller will be capable of indicating liquid level in the sump. When a pumpable quantity exists, the contractor will allow the secondary pump to run. The liquid will be discharged to the forcemain after being metered. The forcemain outlets to the off-station tank.

CELL SEPARATION BERMS

Cell separation berms over the geosynthetic layer will be constructed of satisfactory on-site materials compacted by normal construction vehicle traffic. They will be constructed in 1-foot loose lifts and graded to the dimensions shown on the plans.

FINAL COVER

The accompanying set of plans show top of vegetated cover grades of the landfill. These grades are the surface of the vegetative cover soil. There will be two types of final cover systems. One final cover system will consist of (from top to bottom) 3 feet of vegetative cover soil, a geocomposite (geonet with geotextile heat bonded to both sides) or a highly transmissive geotextile drainage layer, a 40 mil textured HDPE FML, and 2 feet of compacted clay. The compacted clay will be constructed in lifts and compacted to achieve permeabilities of 1×10^{-7} cm/sec or less. The 40 mil textured HDPE will be installed in accordance with the latest edition of CWM's Quality Assurance Plan. The vegetative cover layer will be composed of 2.5 feet of general fill and 6 inches of topsoil and will be placed over the drainage layer and graded to final elevations.

The other final cover system will consist of (from top to bottom) two feet of vegetative cover soil, a geocomposite (geonet with geotextile heat bonded to both sides) drainage layer, a 40 mil textured HDPE FML, a geosynthetic clay liner (GCL), and six inches of general fill. The GCL and 40 mil textured HDPE FML will be installed in accordance with the most current edition of CWM's Quality Assurance Plan. The vegetative cover soil layer will be composed of 1.5 feet of general fill and 6 inches of topsoil and will be placed over the drainage layer and graded to final elevations.

At closure, the landfill will be vegetated using a grass seed mixture. Soil testing may be performed to determine fertilizer and lime requirements. Mulching may be performed to reduce erosion potential during vegetative cover establishment. Periodic inspection will be performed to reseed and repair erosion areas. Critical sections of drainage ditches will be rip-rapped and underlain with geosynthetics to minimize erosion as detailed in the accompanying drawings.

GAS VENTING

The vertical leachate risers will provide outlets for the anticipated minimal flow of accumulated gases from the landfill. CWM has an ongoing air quality monitoring program used in monitoring SLF-11 which has demonstrated minimal concerns for gas generation in the disposal of similar waste types. Because biological activity is expected to be limited, gas generation is expected to be minimal.

CHAPTER 5

OPERATION

WASTE RECEIPT AND HANDLING

Procedures for receipt and handling of waste receipts are described in the Waste Analysis Plan (WAP), Section C of the Part 373 permit application. Waste may be directed to the landfill without pretreatment or some waste may be pretreated prior to landfill and placed in the appropriate cell as assigned on the individual treatment/disposal decisions (Section C-2d, Pre-acceptance Procedures). The disposal decisions are prepared and approved in accordance with the WAP.

The rate of vertical waste placement in any given location within RMU-1 will be no greater than 23 feet per month, while not exceeding 100 feet annually. These operational limits control landfill loading and allow the necessary shear strengths to develop in the Glaciolacustrine clay layer beneath the landfill.

WASTE VOLUME AND SITE LIFE

Total airspace available in RMU-1 is approximately 3,601,900 cubic yards between the top of the operations layer to the final waste grades. From this total airspace, volume for separation berms, daily cover and access roads will be deleted, leaving a waste capacity of about 3,482,400 cubic yards. Estimated site life is approximately 10.4 years for an estimate 500,000 tons per year gate receipts and 1.5 tons per cubic yard in place waste density.

EQUIPMENT

Equipment to be utilized for RMU-1 include forklifts with drum handling equipment, bulldozers, cranes, front-end loaders, water trucks, other trucks, compaction equipment, and backhoes. Aged equipment will be replaced as necessary.

COVER MATERIAL

Daily cover will be placed on waste at the end of each working day. Any soil used for this must have a minimum permeability of 1.0×10^{-4} cm/sec. A geosynthetic cover material and other types of approved cover materials may be used to satisfy daily cover requirements. Also, bulk waste that has been demonstrated to meet the permit requirements may be used for daily cover upon approval of NYSDEC.

At closure the landfill will be vegetated using a grass seed mixture. Soil testing may be performed to determine fertilizer and lime requirements. Mulching may be performed to reduce erosion potential during vegetative cover establishment. Periodic inspection will be performed to reseed and repair erosion areas. Critical sections of the drainage ditches will be rip-rapped and underlain with geosynthetics to minimize erosion as detailed in the accompanying Drawings.

MISCELLANEOUS OPERATIONS CONSIDERATIONS

Littering, vectors, and scavengers are not a problem because of the nature of the waste and the site security enforced by CWM. Soil over the FML on sideslopes is provided solely for physical protection of the double liner system and is not required to meet maximum permeability specifications. Therefore, procedures to prevent desiccation cracking are not required. However, this layer will receive periodic inspection and maintenance to repair erosion and provide that adequate thickness remains in place to protect the liner.

SAFETY AND FIRE CONTROL

RMU-1 373 permit application contains a detailed description of the safety and fire control procedures. Further detail regarding this aspect of the landfill's operation can be obtained from the Health and Safety Manual and the Standard Divisional Practice Manual.

LEACHATE COLLECTION SYSTEM

Leachate and liquids from the secondary systems will be extracted through sideslope risers, therefore filling operations will not be interrupted to pump leachate. This extension is shown on Drawing No. 20. The vertical concrete casing will be extended as the HDPE sections are needed.

Typically, when the waste height adjacent to the riser is near the riser top, the next segment of riser will be placed. Between construction segments, the HDPE pipe will be flanged except for pumping. This will limit the potential for debris in the riser.

Pumps and control systems will be inspected and maintained in accordance with site procedures and manufacturer's recommendations. Discharge lines are equipped with access points to allow flushing as needed.

The perimeter leachate force main header system for RMU-1 is an extension of the site's leachate handling system. Several access points for cleaning have been added for operational concerns. If operations indicate a buildup of solids in the header system, it can be flushed.

GROUND AND SURFACE WATER MONITORING

CWM Chemical Services, Inc., at the Model City Facility has ongoing programs for monitoring air and surface water quality at the site. Details of these monitoring programs are presented in revisions to Attachments I and K of the facility 6 NYCRR Part 373 Permit. Copies of these plans are on file with NYSDEC and are available at the Model City Facility. In addition, Golder Associates has prepared a new groundwater monitoring plan, for the RMU-1 area which is included in the Part 373 permit modification application. Future monitoring of RMU-1 will be in accordance with NYSDEC approvals.

RUNOFF CONTROL

Containment of surface water runoff within the embankments of RMU-1 can be accomplished for a 25-year, 24-hour storm by operating RMU-1 in accordance with NYSDEC approvals and methods stated in this report.

RP/CWMNYORK/AA7

APPENDIX A

BORING LOGS

General Note:

1. Residuals Management Unit No. 1, RMU-1 has replaced the proposed SLF-13 designation that was referred to during field investigation. All information contained in this appendix is applicable to the RMU-1 site location even if a SLF-13 reference is stated.

2. All work was performed for CWM Chemical Services, Inc. Other references should be considered outdated as a facility or Owner name.

RP/CWMNYORK/AC1

MEMORANDUM

DATE: November 6, 1989

TO: Files

CC: Mike Ruetten
Tony Pawloski

FROM: John Starke

SUBJECT: Subsurface Investigation
Model City Landfill - RMU-1 Project
Donohue Project No. 17365.020

During the week of October 30, 1989, five soil borings were performed at the CWM - Model City facility, located near the south and eastern perimeter of FAC. Pond No. 9. The borings were drilled by Empire Soil Testing. The purpose of the investigation was to further define the geologic units beneath the proposed RMU-1 facility and to obtain soil samples for laboratory testing.

With the exception of B4-89, the borings were extended through the surficial glacial till and terminated in the underlying glaciolacustrine clay unit. Boring B4-89 was extended through the subsoil units, including the glaciolacustrine clays until auger refusal, indicating possible bedrock.

Generally, the borings indicate the site is mantled by 8 to 11.5 feet of glacial till soils primarily consisting of brown lean clays having varying amounts of sand and gravel. Underlying the glacial till is the glaciolacustrine unit primarily consisting of gray lean clays having occasional sand and silt seams. At Boring B4-89 the glaciolacustrine unit was observed to be approximately 29 feet thick. Brown sands and sandy silts/silty sands were present below the glaciolacustrine clays at B4-89 which extended to the maximum depth investigated, approximately 41 feet.

Groundwater was encountered only in B4-89, approximately 11 feet below the ground surface after drilling.

The subsoil conditions observed in these borings generally correlated well with the "B" series borings performed by Golder Associates presented in their "Hydrogeologic Characterization Update Report" for Model City, dated February 1988. Some localized anomalies of the top of glaciolacustrine clay contours is present, however, the overall stratigraphic trends are consistent with Golder's presentation.

Soil samples were recovered from each boring by standard penetration test methods and shelby tubes. Testing of these samples will include: tri-axial strength testing for both drained and undrained conditions, unconfined compressive strength, direct shear testing, consolidation, Atterberg limits, natural moisture content and dry unit weight determinations, and particle size analysis.

Upon completion of drilling and water level measurements, each boring was grouted to the surface with a bentonite slurry. Approximately 1.5 to 2.0 pounds of granular bentonite per gallon of water was used in the slurry mix. Boring locations were staked for survey after completion of drilling.

JS/njr

TR/M/XD7

EMPIRE
SOILS INVESTIGATIONS INC.

SUBSURFACE INVESTIGATION REPORT
CHEM-WASTE SERVICES
RMU-1
MODEL CITY, NEW YORK

FOR

DONOHUE AND ASSOCIATES
4738 NORTH 40TH STREET
P.O. BOX 1067
SHEBOYGAN, WISCONSIN 53082

BD-89-134
NOVEMBER, 1989

SUBSURFACE INVESTIGATION REPORT
CHEM-WASTE SERVICES
RMU-1
MODEL CITY, NEW YORK

I. INTRODUCTION

The following report presents the results of our firm's subsurface investigation performed on October 31 through November 2, 1989 at the site of the proposed landfill (RMU-1) at the Chem-Waste Services Facility, Balmer Road in Model City, New York.

The test boring program was requested and authorized by Mr. Anthony Pawloski, P.E. of Donohue and Associates Inc., 4738 North 40th Street, P.O. Box 1067, Sheboygan, Wisconsin 53082. Test boreholes were located in the field by the client at locations as indicated on the Test Boring Location Plan which is attached as part of this report. Borehole coordinates and elevations were provided by Donohue and Associates. The site is presently the land surrounding Facultative Pond #9 at the Chem-Waste Facility.

II. METHOD OF INVESTIGATION

Standard drilling techniques were employed to advance the hollow stem augers through the overburden soils. Representative soil samples were obtained by driving a two (2) inch outside diameter split spoon sampler into the undisturbed soils beneath the augers, using a 140 pound drive hammer falling 30 inches. Data regarding compactness and consistency of the overburden soils are related to the penetration resistance of the standard split spoon, in accordance with the "Standard Penetration Test" (ASTM D-1586).

Three-inch (3") undisturbed samples (Shelby Tubes) were also obtained from various depths in each of the five (5) test boreholes.

All recovered samples were classified in the field by our drill foreman, and transported to our Hamburg, New York office where visual classification was performed by a geologist. Included with this report is our "General Information and Key to Subsurface Logs" as a supplement to explain the terms, symbols, and definitions which are utilized in our visual classification.

III. SUBSURFACE CONDITIONS

The general subsurface conditions at the site consist of occasional fills underlain by clayey silts, soft to hard silty clays and f-c sands. Depths at completion ranged from 17.0 feet to 41.1 feet below grade.

EMPIRE
SOILS INVESTIGATIONS INC.

Free standing water was encountered at 11.8 feet below grade in boring B-4-89 and at 14.5 feet below grade in boring B-6-89 at the completion of drilling. No free standing water was encountered in borings B-3-89, B-5-89 or B-7-89 at the time of completion.

The stratification lines shown on the boring logs are approximate, where in-situ the changes between strata may be more gradual. The subsurface information represented by the attached logs indicates conditions present only at the time and location of the investigation. Variations may be encountered in subsurface conditions that are not evident due to the location or depth of test boreholes.

A laboratory testing program consisting of grain size analysis, atterberg limits, natural moisture content, unit weight, unconfined compressive strength, consolidation permeability, direct shear and maximum density is currently in progress on the recovered samples. This testing program was set up under the direction of Donohue and Associates, Inc. The results will be made available as soon as the testing has been completed.

The following pages contain data recorded in the field by the drill foreman. This data, along with the recovered samples and their visual classification, constitutes the subsurface investigation report.

All recovered samples will be retained for a maximum of sixty (60) days, at which time the samples will be destroyed unless otherwise directed.

Empire Soils Investigations, Inc. is a full service organization which can supplement this report with additional services in the areas of foundation design, environmental assessments and construction quality control.

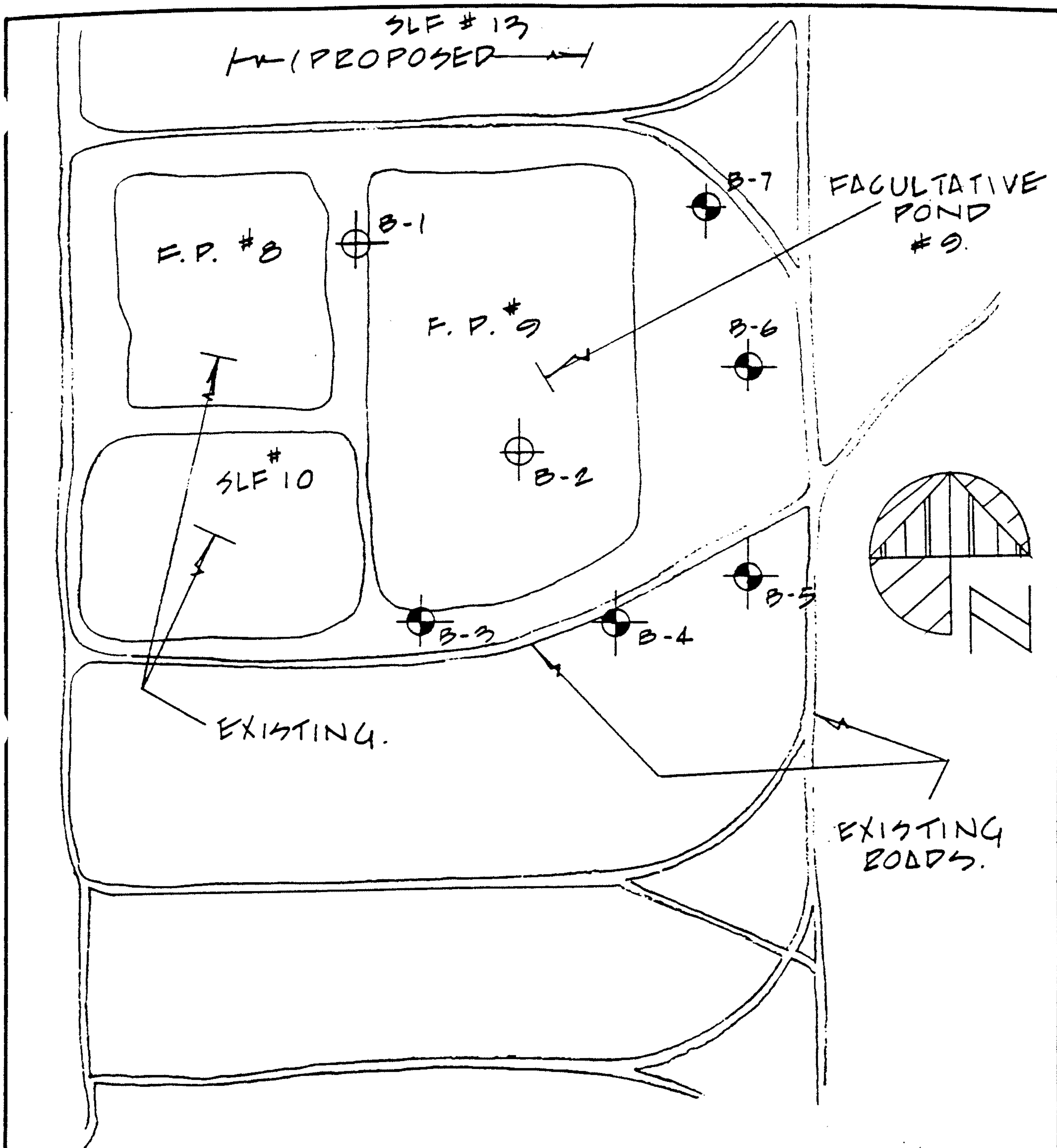
If you have any questions, please contact our office at any time.

EMPIRE SOILS INVESTIGATIONS, INC.

Frank R. Minnolera Jr

Frank R. Minnolera, Jr.
Geologist

FRM/clc
Enc.



LEGEND:

DRILLED TEST BORING LOCATIONS.

TEST BORINGS "NOT DRILLED."

EMPIRE SOILS INVESTIGATIONS INC	SUBSURFACE INVESTIGATION PLAN

BORING LOCATIONS - RMU-1
CHEM-WASTE SERVICES, MODEL CITY. NEW YORK.

DR.BY: D. LABELLE	SCALE: NONE	PROJ. NO. BD 89134
CK'D.BY: F.R.M.	DATE: NOV. 89'	DRWG.NO. 1

R/T FORM R-1

GENERAL INFORMATION & KEY TO SUBSURFACE LOGS

The Subsurface Logs attached to this report present the observations and mechanical data collected by the driller at the site, supplemented by classification of the material removed from the borings as determined through visual identification by technicians in the laboratory. It is cautioned that the materials removed from the borings represent only a fraction of the total volume of the deposits at the site and may not necessarily be representative of the subsurface conditions between adjacent borings or between the sampled intervals. The data presented on the Subsurface Logs together with the recovered samples will provide a basis for evaluating the character of the subsurface conditions relative to the project. The evaluation must consider all the recorded details and their significance relative to each other. Often analyses of standard boring data indicate the need for additional testing or sampling procedures to more accurately evaluate the subsurface conditions. Any evaluation of the contents of this report and the recovered samples must be performed by Professionals. The information presented in the following defines some of the procedures and terms used on the Subsurface Logs to describe the conditions encountered.

1. The figures in the Depth column defines the scale of the Subsurface Log.

2. The sample column shows, graphically, the depth range from which a sample was recovered. See Table 1 for a description of the symbols used to signify the various types of samples.

3. The Sample No. is used for identification on sample containers and/or Laboratory Test Reports.

4. Blows on Sampler — shows the results of the "Penetration Test", recording the number of blows required to drive a split spoon sampler into the soil. The number of blows required for each six inches of penetration is recorded. The first 6 inches of penetration is considered to be a seating drive. The number of blows required for the second and third 6 inches of penetration is termed the penetration resistance, N. The outside diameter of the sampler, the hammer weight and the length of drop are noted at the bottom of the Subsurface Log.

5. Blows on Casing — shows the number of blows required to advance the casing a distance of 12 inches. The casing size, the hammer weight and the length of drop are noted at the bottom of the Subsurface Log. If the casing is advanced by means other than driving, the method of advancement will be indicated in the Notes column or under the Method of Investigation at the bottom of the Subsurface Log.

6. All recovered soil samples are reviewed in the laboratory by an engineering technician, geologist or geotechnical engineer, unless note otherwise. The visual descriptions are made on the basis of a combination of the driller's field descriptions and observations and the sample as received in the laboratory. The method of visual classification is based primarily on the Unified Soil Classification (ASTM D 2487-83) with regard to the particle size and plasticity. (See Table No. II) Additionally, the relative portion, by weight, of two or more soil types is described for granular soils in accordance with "Suggested Methods of Test for Identification of Soils" by D. M. Burmister, ASTM Special Technical Publication 479, June 1970. (See Table No. III) The description of the relative soil density or consistency is based upon the penetration records as defined on Table No. IV. The description of the soil moisture is based upon the relative wetness of the soil as recovered and is described as dry, moist, wet and saturated. Water introduced in the boring either naturally or during drilling may have affected the moisture condition of the recovered sample. Special terms are used as required to describe materials in greater detail; several such terms are listed in Table V. When sampling gravelly soils with a standard two inch diameter split spoon, the true percentage of gravel is often not recovered due to the relatively small sampler diameter. The presence of boulders and large gravel is sometimes, but not necessarily, detected by an evaluation of the casing and samplers blows or through the "action" of the drill rig as reported by the driller.

7. The description of the rock shown is based on the recovered rock core and the driller's observations. The terms frequently used in the description are included in Table VI.

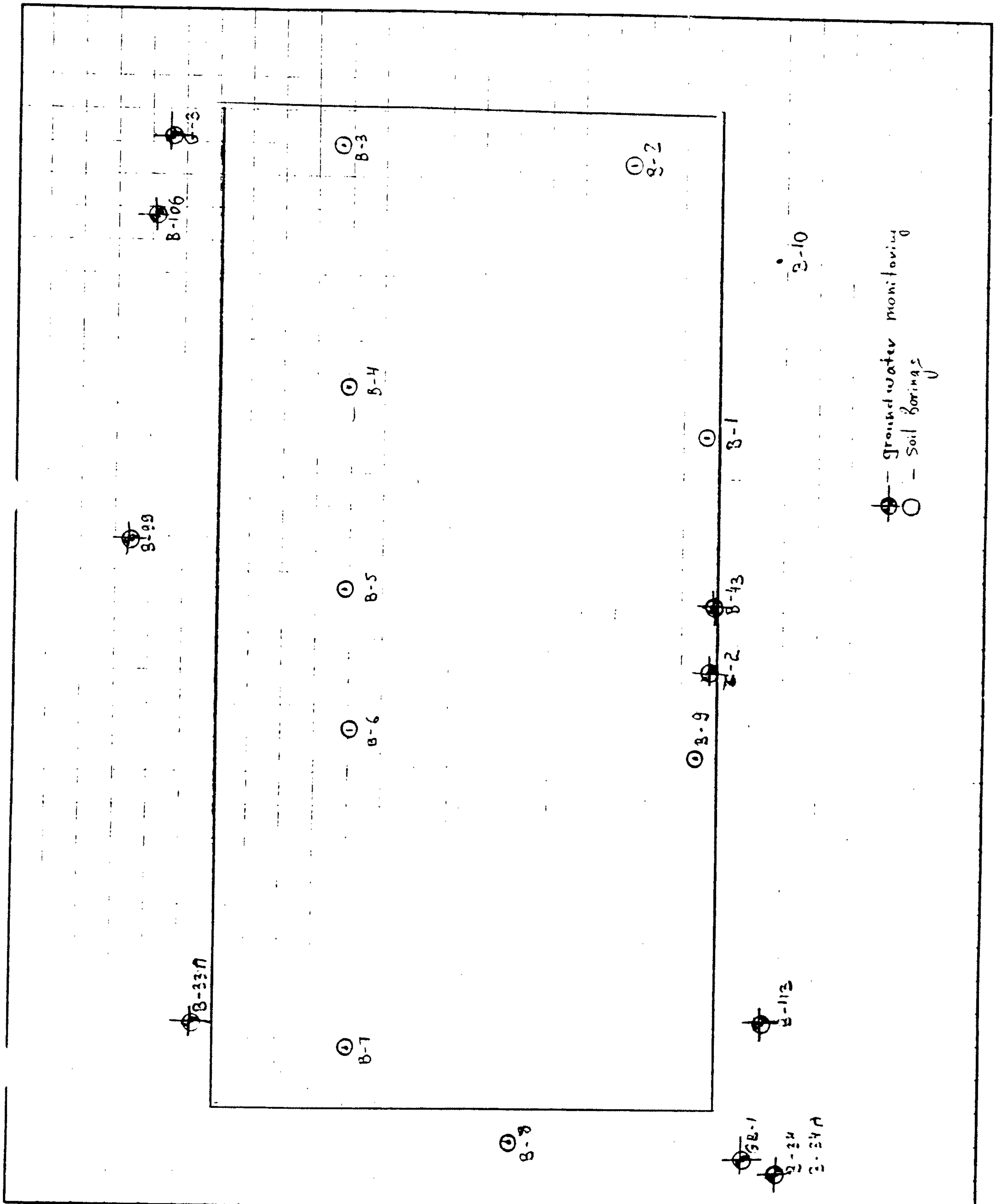
8. The stratification lines represent the approximate boundary between soil types and the transition may be gradual. Solid stratification lines are based on the driller's field observations.

9. Miscellaneous observations and procedures noted by the driller are shown in this column, including water level observations. It is important to realize the reliability of the water level observations depends upon the soil type (water does not readily stabilize in a hole through fine grained soils), and that drill water used to advance the boring may have influenced the observations. The ground water level typically will fluctuate seasonally. One or more perched or trapped water levels may exist in the ground seasonally. All the available readings should be evaluated. If definite conclusions cannot be made, it is often prudent to examine the conditions more thoroughly through test pit excavations or water observation wells.

10. The length of core run is defined as the length of penetration of the core barrel. Core recovery is the length of core recovered divided by the core run. The RQD (Rock Quality Designation) is the total pieces of NX core exceeding 4 inches in length divided by the core run. The size core barrel used is also noted.

DONOHUE & ASSOCIATES, INC.
CONSULTING ENGINEERS
SHEBOYGAN, WISCONSIN

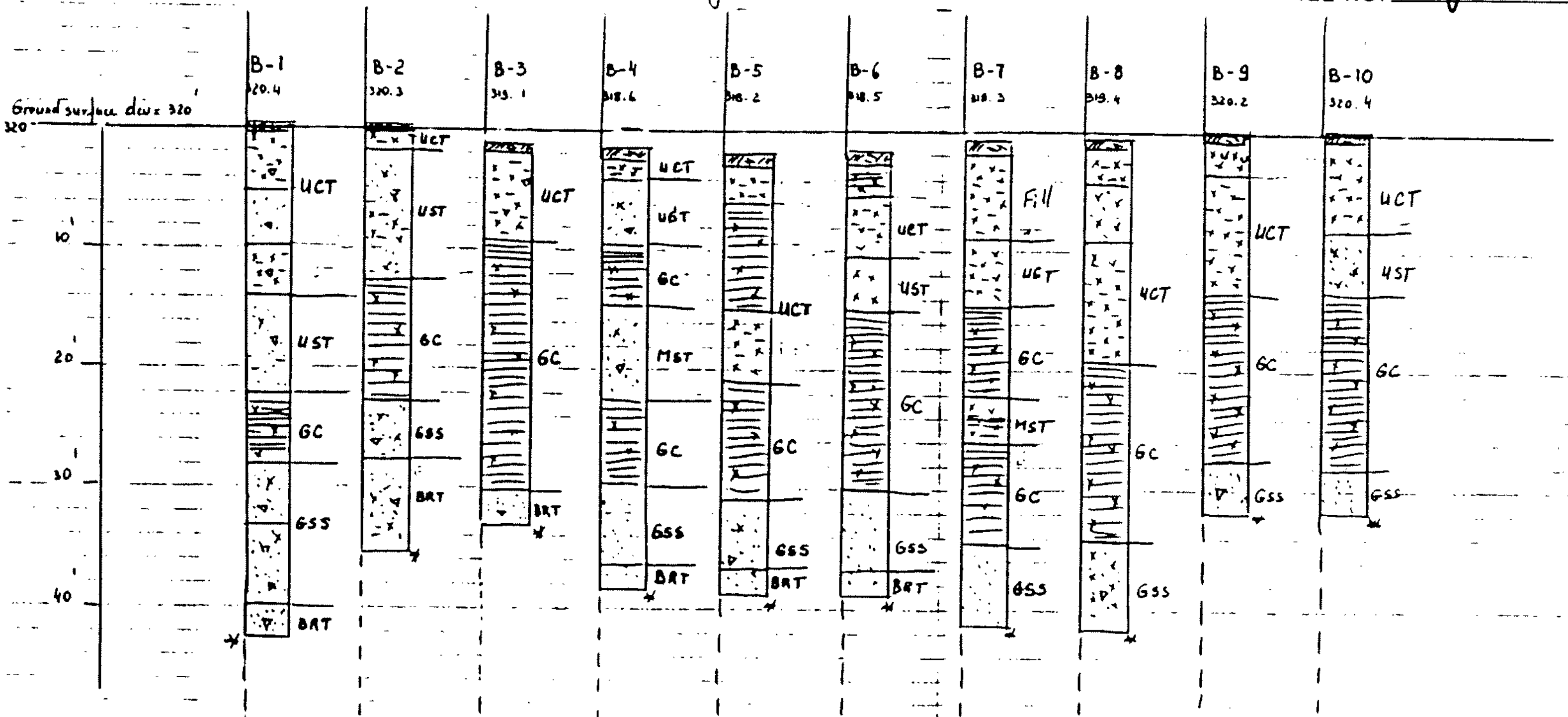
CLIENT ____________ DATE ____________
PROJECT ____________ BY ____________
PROJECT NO. ____________ PAGE NO. ____________



Donohue
Engineers & Architects

CLIENT ____________ PROJECT NO. 15718 BY L. Voskov

PROJECT Model City DATE 10/7/88 PAGE NO. 1 of 2



Thickness / Units	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10
UA	—	—	—	—	—	—	—	—	—	—
UCT	13.	2.	7.	2.0	18.0	8.0	~12.0	18.0	13.0	7.0
UST	8	10	—	5.0	—	4.0	—	—	—	5.0
MST	—	—	—	8.0	—	—	4.0	—	—	—
GC	6.	10.	21	7.0 + 5.0	10.0	15.0	8.0 + 8.0	15.0	14.0	15.0
GSS	12.	5.	—	7.0	6.0	7.0	7.0	7.0	4.0	4.0
BRT	~3.	~8.	~3.	~2.0	~2.0	~2.0	—	—	—	—

* Drilling until auger refusal

Legend:

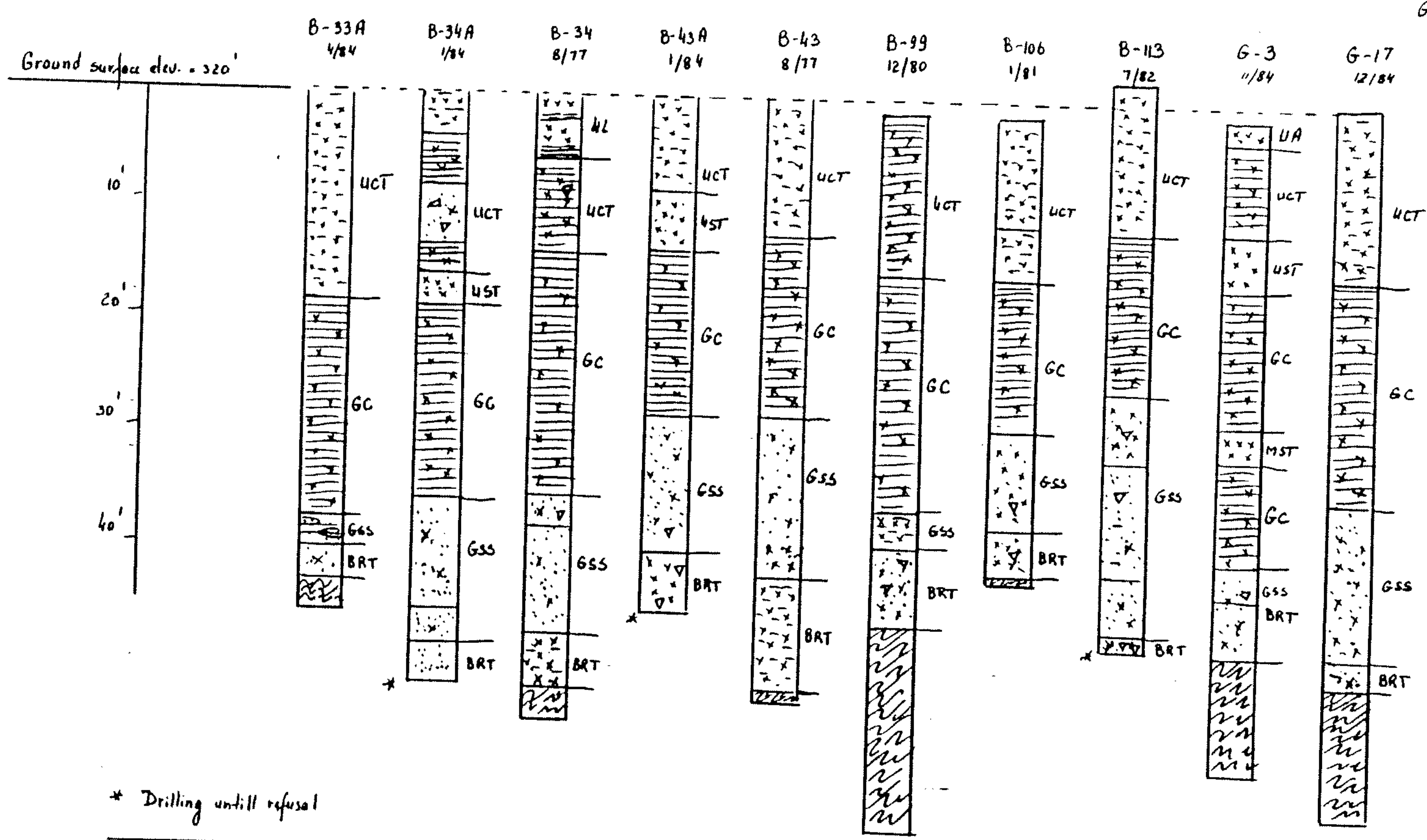
Lithology:
- sand
- silt
- clay
- gravel
- clayey silt
- clayey sand
- Topsoil

Stratigraphy:
- UA Upper alluvium
- UCT Upper clay Till
- UST Upper silt Till
- (Upper Tills)
- MST Middle Silt Till
- GC Glaciolacustrine clay
- GSS Glaciolacustrine Silt/Sand
- BRT Basal Red Till

Donohue
Engineers & Architects

CLIENT ____
PROJECT Model City
PROJECT NO. 15718.
DATE 11/1/88
BY L. Voskov
PAGE NO. 2 of 2

Groundwater monitoring wells data



* Drilling untill refusal

	B-33A	B-34A	B-34	B-43A	B-43	B-99	B-106	B-113	G-3	G-17
UA	–	–	6	–	–	–	–	–	–	–
UCT	18	16	8	8	12	14	14	13	2	–
UST	–	3	–	5	–	–	–	–	8	15
MST	–	–	–	–	–	–	–	–	5	–
GC	19	17	21	14	16	21	13	14	3	–
GSS	3	12	12	12	11	3	8	21	12 + 9	19
BRT	3	~3	5	~5	10	7	4	~2	3	13
									5	2.5

EMPIRE SOILS INVESTIGATIONS INC. SUBSURFACE LOG

DATE STARTED 4/11/88
FINISHED 4/12/88
SHEET 1 OF 2

HOLE NO. B-1
SURF. ELEV. N.A. 320.4
G. W. DEPTH See Note

PROJECT SCA-SLF-13
LOCATION SCA
Model City, New York

DEPTH FT.	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
0	1	1	3				TOPSOIL	
		7	9		10		Red-Brn. Clayey SILT, little f-c Sand, (moist, medium)	
	2	13	17				Contains tr. gravel, tr. fract. rock frags.(hard)	
		13	18		30			
5	3	10	17					
		31	26		48			No recovery Sample #3 due to stone lodged in shoe of spoon
	4	10	16				Red-brn. f-c SAND, some Silt, tr. gravel, tr. clay(moist, compact)	
		25	35		41			
	5	14	12					
10		14	16		26		Contains occ. Clay seams(firm)	
	6	10	19				Red-Brn. Clayey SILT, some f-c Sand, tr. gravel, tr. fract. rock frags. (moist, hard)	
		20	30		39			
	7	21	27					
		72	55		99		Contains "and" f-c Sand	
15	8	1	5				Brn.-gry. f-c SAND, some Silt, little-some f-m Gravel(moist-wet, firm)	
		7	8		12			
	9	20	16					
		12	14		28			
	10	21	10				Contains tr. clay	
20		17	21		27			
25	11	1	2				Red-brn. & gry. Silty CLAY, little f-c Sand, tr. gravel(moist, soft)	
		2	7		4			
30	12	17	30	100/0.4			Red-brn. f-m SAND, some Silt, little f-m Gravel(moist, v. compact)	
35	13	7	27				Red-brn. f-c SAND, little-some Silt, little-some f-c Gravel(moist, compact)	
		14	8		41			
40								

N = No. blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 " per blow
C = No. blows to drive ___ " casing ___ " with ___ lb. weight falling ___ " per blow

CLASSIFICATION Visual by Geologist

METHOD OF INVESTIGATION ASTM D-1586 Using Hollow Stem Augers

DATE STARTED 4/14/88 FINISHED 4/14/88 SHEET 1 OF 1	EMPIRE SOILS INVESTIGATIONS INC. SUBSURFACE LOG	HOLE NO. B-3 SURF. ELEV. N/A 319.1 G. W. DEPTH See Note

PROJECT SCA-SLF-13

LOCATION SCA
Model City, New York

DEPTH-FT	SAMPLES	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
0		1	1	2				TOPSOIL	
			5	7		7		Red-brn. Clayey SILT, little f-c Sand, tr. gravel(moist, medium)	
5		2	3	13				Contains some-and f-c Sand (hard)	
			22	27		35			
10		3	TUBE						3" Undisturbed sample (Shelby Tube) obtained from 10.0-12.0' 1.4' Recovery
		4	6	2				Grey-brn. Silty CLAY, tr. sand (moist, medium)	
			7	8		9			
15		5	TUBE						3" Undisturbed sample (Shelby Tube) obtained from 15.0-17.0' 1.9' recovery
20		6	2	1				(soft)	
			2	3		3			
25		7	1	1				Contains occ. Silt partings & seams (v. soft)	
			1	2		2			
30		8	18	62				Red-brn. f-c SAND, little f-m Gravel, little Silt(moist, v. compact)	
			75	100/0.4					
								Boring Complete with Sample Spoon Refusal at 32.0'	Free Standing Water recorded at 21.5' at Boring Completion Boring backfilled with bentonite grout at completion

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 " per blow

C = No blows to drive ____ " casing ____ " with ____ lb. weight falling ____ " per blow

CLASSIFICATION Visual by Geologist

METHOD OF INVESTIGATION ASTM D-1586 Using Hollow Stem Augers

DATE				
STARTED 4/14/88	**EMPIRE** SOILS INVESTIGATIONS INC.	SUBSURFACE LOG	HOLE NO.	B-4
FINISHED 4/14/88			SURF. ELEV.	N/A 318.6
SHEET 1 OF 1			G. W. DEPTH	See Note

PROJECT SCA-SLF-13

LOCATION SCA
Model City, New York

DEPTH FT	SAMPLES	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
0		1	1 5	3 8		8		TOPSOIL Red-brn. Clayey SILT and f-c Sand, tr. gravel(moist, medium)	
		2	7 12	12 10		24		Red-brn. f-c SAND, some Silt, tr. gravel, tr. clay(moist, firm)	
5		3	TUBE						Attempted to obtain 3" undisturbed sample (Shelby Tube) from 5.0-7.0' - no recovery
10		5	3 7	5 7		12		Red-brn. Silty CLAY, little-some f-c Sand(moist, medium)	
15		6	32 43	41 38		84		Red-brn. f-c SAND, some Silt, little f-c Gravel(moist, v. compact)	No recovery Sample #6 due to soil conditions
20		7	9 4	12 8		16		Grey-brn. Silty CLAY, tr. sand(moist)	Glacio lac
25		8	TUBE						Obtained 3" undisturbed sample(Shelby Tube) from 25.0'-27.0' 1.5' Recovery
30		9	5 15	7 33		22		Red-brn. f-c SAND, little Silt, tr. gravel(moist-wet, firm)	
35		10	5 75	30 31		105		(v. compact)	No free standing water enc. at boring completion Boring filled with bentonite grout at completion.
								Boring Complete at 37.0'	
40									

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 "per blow.

CLASSIFICATION Visual by Geologist

C = No blows to drive ____ " casing ____ " with ____ lb. weight falling ____ "per blow.

METHOD OF INVESTIGATION ASTM D-1586 Using Hollow Stem Augers

DATE STARTED 4/11/88	EMPIRE SOILS INVESTIGATIONS INC.	SUBSURFACE LOG	HOLE NO. B-1
FINISHED 4/11/88			SURF. ELEV. N.A.
SHEET 2 OF 2			G. W. DEPTH See Note

PROJECT SCA-SLF 13

LOCATION SCA
Model City, New York

DEPTH-FT	SAMPLES	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
40		14	11	37				Contains tr. silt, tr. gravel(moist, wet, v. compact)	
			51	50/0.1					
		15	77	100/0.0				Contains "and" Silt, tr. clay, tr. fract. rock frags.	
45								Boring Complete with Sample Spoon and Auger Refusal at 42.9'	Free Standing Water recorded at 19.5' at Boring Completion
50									

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 "per blow. CLASSIFICATION Visual by Geologist

C = No blows to drive ____ " casing ____ " with ____ lb. weight falling ____ "per blow.

METHOD OF INVESTIGATION ASTM D-1586 Using Hollow Stem Augers

DATE STARTED 4/14/88
FINISHED 4/14/88
SHEET 1 OF 1

EMPIRE SOILS INVESTIGATIONS INC.

SUBSURFACE LOG

HOLE NO. B-2
SURF. ELEV. N.A. 320.3
G. W. DEPTH See Note

PROJECT SCA-SLF-13

LOCATION SCA
Model City, New York

DEPTH FT.	SAMPLE NO.	BLOWS ON SAMPLER 0-6	6-12	12-18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
0	1	1	2				TOPSOIL	
		5	7		7		Tan-brn. Clayey SILT, little f-c Sand, tr. gravel, tr. roots(moist, medium)	
5	2	6	16				Red-brn. f-c SAND and Clayey Silt, tr. gravel(moist, compact)	
		23	27		39			Attempted to obtain 3" undisturbed sample (Shelby Tube) from 9.0'-11.0'- 0.7' recovery pushed stone
10	3	TUBE						
	4	51	27				Contains tr. fract. rock frags.(v. compact)	
		38	39		65			
15	5	11	3				Red-brn. & gry. varved Silty CLAY, tr. sand, occ. Silt seams(moist, medium)	3" undisturbed sample (Shelby Tube) obtained from 17.0'-19.0' 1.8' recovery
		4	3		7			
	6	TUBE						
20	7	4	5				Becomes brn.-gry, contains little f-c Sand	
		4	3		9			
25	8	2	5				Red-brn. fine SAND, little Silt, tr. gravel(wet, firm)	Driller reports enc. "running sands" at approximately 25.0'
		14	13		19			
30	9	10	27				Red-brn. f-c SAND, some f-c Gravel, little-some Silt(moist, v. compact)	
		52	72		79			
35	10	62	100/0.3				Boring Complete with Sample Spoon Refusal at 35.8'	Free Standing Water rec. at 8.0' at Boring Completion. Boring backfilled with bentonite grout at completion
40								

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 " per blow
C = No blows to drive ____ " casing ____ " with ____ lb. weight falling ____ " per blow.
CLASSIFICATION Visual by Geologist
METHOD OF INVESTIGATION ASTM D-1586 Using Hollow Stem Augers

DATE STARTED 5-1-86 FINISHED 5-1-86 HEET 1 OF 1	EMPIRE SOILS INVESTIGATIONS INC	SUBSURFACE LOG	HOLE NO. B-175 SURF. ELEV. 325.6 G. W. DEPTH See Note #1

Project ______________________ LOCATION ______________________

DEPTH-FT	SAMPLES	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
0		1	2	2	3	5	10	TOPSOIL 3"	NOTE #1 G.W. at 2.0' completion G.W. at 2.2' 24 hrs. after completion
							15	Brown SILT, some Sand, trace clay (Moist - Loose)	
							50/.5'		
								Gray SHALE, medium hard weathered, thin bedded some fractures	Run #1, 2.5' - 5.0' 95% Recovery 50% RQD
5									

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩

TABLE I

Split Spoon Sample	
Shelby Tube Sample	
Auger or Test Pit Sample	
Rock Core	

TABLE II

Identification of soil type is made on basis of an estimate of particle sizes, and in the case of fine grained soils also on basis of plasticity.

Soil Type	Soil Particle Size	
Boulder	> 12"	Coarse Grained (Granular)
Cobble	3" - 12"	
Gravel - Coarse	3" - ¾"	
- Fine	¾" - #4	
Sand - Coarse	#4 - #10	
- Medium	#10 - #40	
- Fine	#40 - #200	
Silt-Non Plastic (Granular) / Clay-Plastic (Cohesive)	<#200	Fine Grained

TABLE III

The following terms are used in classifying soils consisting of mixtures of two or more soil types. The estimate is based on weight of total sample.

Term	Percent of Total Sample
"and"	35 - 50
"some"	20 - 35
"little"	10 - 20
"trace"	less than 10

(When sampling gravelly soils with a standard split spoon, the true percentage of gravel is often not recovered due to the relatively small sampler diameter.)

TABLE IV

The relative compactness or consistency is described in accord with the following terms.

Granular Soils Term	Blows per Foot, N	Cohesive Soils Term	Blows per Foot, N
Loose	< 11	Very Soft	< 3
Firm	11 - 30	Soft	3 - 5
Compact	31 - 50	Medium	6 - 15
Very Compact	> 51	Stiff	16 - 25
		Hard	> 26

(Large particles in the soils will often significantly influence the blows per foot recorded during the Penetration Test.)

TABLE V

Varved	- Horizontal uniform layers or seams of soil(s).
Layer	- Soil deposit more than 6" thick.
Seam	- Soil deposit less than 6" thick.
Parting	- Soil deposit less than ⅛" thick.
Laminated	- Irregular, horizontal and angled seams and partings of soil(s).

TABLE VI

Rock Classification Terms

Term		Meaning
Hardness	Soft	Scratched by fingernail
	Medium Hard	Scratched easily by penknife
	Hard	Scratched with difficulty by penknife
	Very Hard	Cannot be scratched by penknife
Weathering	Very Weathered Weathered Sound	Judged from the relative amounts of disintegration iron staining, core recovery, clay seams, etc.
Bedding	Laminated	Natural breaks in Rock Layers (<1")
	Thin bedded	(1" - 4")
	Bedded	(4" - 12")
	Thick bedded	(12" - 36")
	Massive	(>36")

(Fracturing refers to natural breaks in the rock oriented at some angle to the rock layers.)

DATE			
STARTED 10/31/89	**EMPIRE** SOILS INVESTIGATIONS INC. SUBSURFACE LOG	HOLE NO.	B-3-89
FINISHED 10/31/89		SURF. ELEV.	320.2
SHEET 1 OF 1		G. W. DEPTH	see note

PROJECT RMU-1 Chem-Waste Services

LOCATION Balmer Road Model City, New York

DEPTH FT	SAMPLES	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	Q(U) T.S.F.	SOIL OR ROCK CLASSIFICATION	NOTES
0			AUGER					OVERBURDEN SOILS	Q(U) obtained using Forney "Geotester" Penetrometer
		1	8	8				Red-brn. Clayey SILT, little f-c Sand, tr. gravel (moist, stiff)	
			8	16		16			
5		2	7	8			4.1	Red-brn. laminated Silty CLAY, little f-c Sand (moist, stiff)	Q(T) obtained using Soiltest CL-600 Torvane Q(T)=1.7 T.S.F. in Sample #2
			13	11		21			
10		3	5	6				Contains little-some f-c Sand, (moist-wet, medium)	Poor recovery Sample #3
			7	6		13			
		4	TUBE						3" Undisturbed Sample (Shelby Tube) obtained from 13.0-15.0'
15									
		5	9	12				Red-brn. f-c SAND, some Silt, little f-c Gravel (moist, firm) Upper Till	Attempted to push tube at 18.0'. Refusal encountered
20			13	15		25			
								Glaciolacustrine (ARP 12-15-89) Clay	
		6	1	2			0.7	Gray Silty CLAY, tr. sand, tr. gravel (moist-wet, soft)	Q(T)=0.3 T.S.F. in Sample #6
25			2	3		4			
		7	TUBE						3" Undisturbed Sample (Shelby Tube) obtained from 25.0'-27.0'
								Boring Complete at 27.0'	No free standing water encountered at Boring Completion
30									Coordinates N-8226.6 E-1195.7

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 " per blow. CLASSIFICATION Visual by Geologist

C = No blows to drive ______ " casing ______ " with ______ lb. weight falling ______ " per blow.

METHOD OF INVESTIGATION ASTM D-1586 USING HOLLOW STEM AUGERS

DATE STARTED 10/30/89
FINISHED 10/30/89
SHEET 1 OF 2

EMPIRE SOILS INVESTIGATIONS INC.

SUBSURFACE LOG

HOLE NO. B-4-89
SURF. ELEV. 317.4
G. W. DEPTH see note

PROJECT RMU-1
Chem-Waste Services

LOCATION Balmer Road
Model City, New York

DEPTH FT	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	Q(U) T.S.F.	SOIL OR ROCK CLASSIFICATION
0	1	6	20				Red-brn. Clayey SILT, some-and f-c Sand, tr.gravel (moist, FILL)
		20	37		40		
	2	9	18			4.0	Red-brn. laminated Clayey SILT, little f-c Sand, tr. gravel (moist, hard)
		21	27		39		
5	3	4	7			2.8	Brn. Silty CLAY, little f-c Sand tr. gravel (moist, medium)
		8	11		15		
	4	9	17			1.5	Becomes brn.-gray contains tr. gravel (hard)
		17	16		34		
	5	1	1			0.4	(wet, soft)
		1	2		2		
10	6	TUBE					Glacio lacustrine clay @ 9'. ARP (12-15-89)
15	7	TUBE					
	8	1	1			0.3	
		3	6		4		
	9	2	2			0.4	
20		3	4		5		
	10	1	1			0.8	Contains little f-c Sand
		2	3		3		
	11	4	4			0.5	(medium)
		5	5		9		
25	12	1	3			0.5	
		3	4		6		
	13	1	3			0.2	Contains tr. sand
		5	6		8		
	14	1	2			0.5	
30		4	4		6		
	15	1	2			0.4	Becomes red-brn. (soft)
		2	3		4		
	16	3	3			0.3	(medium)
		3	3		6		
35	17	1	2			0.5	Becomes gray (soft)
		3	4		5		Red-brn. f-c SAND, some Silt, little f-c Gravel, tr. clay (moist-wet, firm)
	18	4	4				
		8	7		12		
	19	3	9				Red-brn. f-m SAND, tr. little silt (moist-wet, firm)
40		3	2		12		

NOTES

Q(U) obtained using Fourney "Geotester" Penetrometer
Q(T) obtained using Soiltest CL-600 Torvane
Q(T)=1.7 T.S.F. in Sample #2
Q(T)=1.3 T.S.F. in Sample #3
Q(T)=0.7 T.S.F. in Sample #4
Q(T)=0.15 T.S.F. in Sample #5
3" Undisturbed Sample (Shelby Tube)obtained from 10.0-12.0'
3" Undisturbed Sample (Shelby Tube)obtained from 14.0-16.0'
Q(T)=0.15 T.S.F. in Sample #8
Q(T)=0.2 T.S.F. in Sample #9
Q(T)=0.35 T.S.F. in Sample #10
Q(T)=0.3 T.S.F. in Sample #11
Q(T)=0.3 T.S.F. in Sample #12
Q(T)=0.15 T.S.F. in Sample #13
Q(T)=0.3 T.S.F. in Sample #14
Q(T)=0.2 T.S.F. in Sample #15
Q(T)=0.1 T.S.F. in Sample #16
Q(T)=0.25 T.S.F. in Sample #17

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 " per blow.
C = No blows to drive ____ " casing ____ " with ____ lb. weight falling ____ " per blow.
CLASSIFICATION Visual by Geologist
METHOD OF INVESTIGATION ASTM D-1586 USING HOLLOW STEM AUGERS

R/T Form H

DATE

STARTED 10/30/89

FINISHED 10/30/89

SHEET 2 OF 2

EMPIRE SOILS INVESTIGATIONS INC SUBSURFACE LOG

HOLE NO. B-4

SURF. ELEV. 317.4

G. W. DEPTH see note

PROJECT RMU-1

Chem-Waste Services

LOCATION Balmer Road

Model City, New York

DEPTH FT	SAMPLES	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	Q(U) T.S.F.	SOIL OR ROCK CLASSIFICATION	NOTES
40									
								Boring Complete with Auger refusal at 41.1'	Free standing water recorded at 11.8' at Boring Completion
45									

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 " per blow. CLASSIFICATION Visual by Geologist

C = No blows to drive ____ " casing ____ " with ____ lb. weight falling ____ " per blow.

METHOD OF INVESTIGATION ASTM D-1586 USING HOLLOW STEM AUGERS

EMPIRE SOILS INVESTIGATIONS INC.

SUBSURFACE LOG

DATE
STARTED 11/1/89
FINISHED 11/1/89
SHEET 1 OF 1

HOLE NO. B-5-89
SURF. ELEV. 319.8
G. W. DEPTH see note

PROJECT RMU-1
Chem-Waste Services

LOCATION Balmer Road
Model City, New York

DEPTH FEET	SAMPLES	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	Q(U) T.S.F.	SOIL OR ROCK CLASSIFICATION	NOTES
0		1	4	21				Brn. Clayey SILT, little f-c Sand (moist, FILL)	Q(U) obtained using Fourney "Geotester" Penetrometer
			30	46		51			Q(T) obtained using Soiltest CL-600 Torvane
5		2	10	12			3.3	Red-brn. Clayey SILT, little f-c Sand, tr. gravel (moist, hard)	Q(T)=1.5 T.S.F. in Sample #1
			33	26		45			
10		3	4	4			1.8	Brn. Silty CLAY, little f-c Sand tr. gravel (moist, medium)	Q(T)=0.8 T.S.F. in Sample #2
			6	7		10			
		4	2	2			0.4	Becomes red-brn. (wet, soft)	Q(T)=0.2 T.S.F. in Sample #4
15			3	6		5		Glaciolacustrine CLAY @ 12.0 Ft. 4RP (12-15-89).	Attempted to push Tube from 15.0 to 17-0' Refusal on boulder
		5	1/1.0				0.2	Becomes gray (very soft)	Q(T)=0.1 T.S.F. in Sample #5
20			1	1					
		6	TUBE						3" Undisturbed Sample (Shelby Tube) obtained from 20.0-22.0'
								Boring Complete at 22.0'	No free standing water encountered at Boring Completion
									Coordinates N-8506.2 E-12746.8

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 "per blow

C = No blows to drive ______ " casing ______ " with ______ lb. weight falling ______ "per blow

CLASSIFICATION Visual by Geologist

METHOD OF INVESTIGATION ASTM D-1586 USING HOLLOW STEM AUGERS

DATE

STARTED 11/1/89

FINISHED 11/1/89

SHEET 1 OF 1

EMPIRE SOILS INVESTIGATIONS INC

SUBSURFACE LOG

HOLE NO. B-6-89

SURF. ELEV. 318.3

G. W. DEPTH see note

PROJECT RMU-1
Chem-Waste Services

LOCATION Balmer Road
Model City, New York

DEPTH	SAMPLES	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	Q(U) T.S.F.	SOIL OR ROCK CLASSIFICATION	NOTES
0	/	1	1	2				Orange and brn. mottled Silty CLAY tr. sand, tr. roots (moist, soft)	Q(U) Obtained using Fourney "Geotester" Penetrometer Q(T) Obtained using Soiltest CL-600 Torvane
			3	6		5			
5	/	2	4	4			3.1	Becomes red-brn. contains little f-c Sand, tr. gravel (stiff)	Q(T)=1.5T.S.F. in Sample #2
			13	23		17			
10	/	3	11	17				Red-brn. f-c SAND, some Silt, tr. gravel, tr. clay (moist, compact)	
			17	10		34			
								Glaciolacustrine Clay. A.R.P. (12-15-89).	
		4	1/1.0'				0.3	Brn.-gray Silty CLAY, tr. sand (wet, very soft)	Q(T)=0.15 T.S.F. in Sample #4
			1	1					
15		5	TUBE						3" Undisturbed Sample (Shelby Tube) obtained from 15.0'-17.0'
20								Boring Complete at 17.0'	Free standing water recorded at 14.5' at Boring Completion
									Coordinates N-8863.6 E-12712.2

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 " per blow.

C = No blows to drive ___ " casing ___ " with ___ lb. weight falling ___ " per blow.

CLASSIFICATION Visual by Geologist

METHOD OF INVESTIGATION ASTM D.-1586 USING HOLLOW STEM AUGERS

DATE STARTED 11/2/89	**EMPIRE** SOILS INVESTIGATIONS INC. SUBSURFACE LOG
FINISHED 11/2/89	HOLE NO. B-7-89
SHEET 1 OF 1	SURF. ELEV. 318.1
	G. W. DEPTH see note

PROJECT RMU-1 Chem-Waste Services

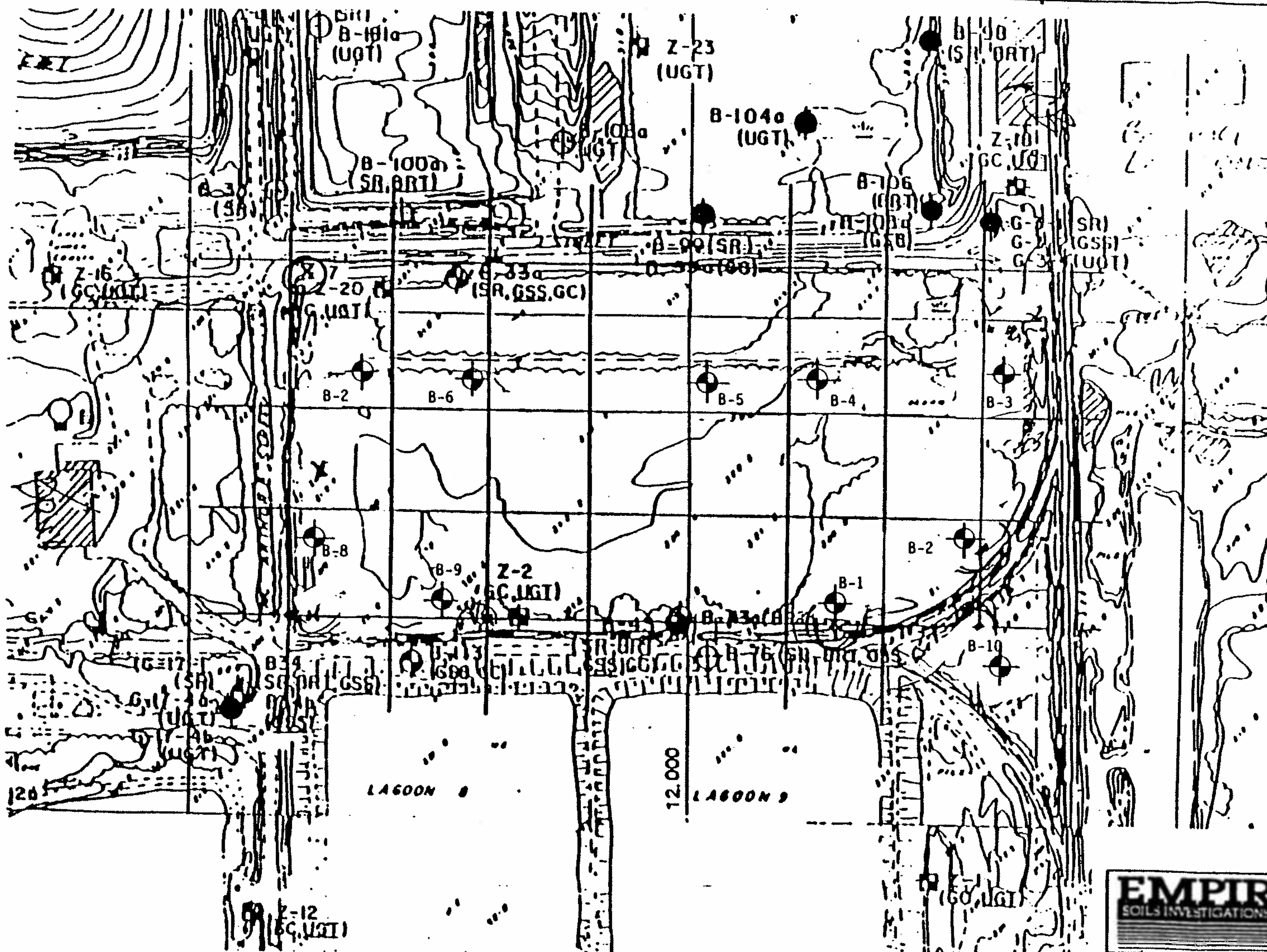
LOCATION Balmer Road Model City, New York

DEPTH FT	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	Q(U) T.S.F.	SOIL OR ROCK CLASSIFICATION	NOTES
0	1	1	4				Red-brn. and gray laminated Clayey SILT, tr. sand, tr. roots, tr. gravel (moist, medium)	Q(U) Obtained using Fourney "Geotester" Penetrometer Q(T) Obtained using Soiltest CL-600 Torvane
		10	23		14			
5	2	21	12			3.3	Contains "and f-c Sand (hard)	Q(T)=1.7 T.S.F in Sample #2
		19	38		31			
10	3	17	19				Red-brn. f-c SAND, some Silt, little f-c Gravel (moist-wet, compact)	
		22	20		41			
							Glaciolacustrine Clay. ARP (12-15-89	
	4	1	2			0.5	Gray Silty CLAY, tr. sand (wet, soft)	Q(T)=0.2 T.S.F. in Sample #4
15		2	3		4			
	5	TUBE						3" Undisturbed Sample (Shelby Tube) obtained from 15.0-17.0'
	6	1	2			0.5		
20		3	4		5			
	7	TUBE						3" Undisturbed Sample (Shelby Tube) obtained from 20.0-22.0'
							Boring Complete at 22.0'	No free standing water encountered at Boring Completion
								Coordinates N-9051.1 E-12698.4

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 " per blow. CLASSIFICATION Visual by Geologist

C = No blows to drive ____ " casing ____ " with ____ lb. weight falling ____ " per blow.

METHOD OF INVESTIGATION ASTM D-1586 USING HOLLOW STEM AUGERS



LEGEND

TEST BORING LOCATION

NOTE: This drawing was made from a reproduction of a plan provided by the client, and is intended for illustration purposes only.

EMPIRE SOILS INVESTIGATIONS INC

SUBSURFACE INVESTIGATION PLAN

Test Boring Location Plan
Proposed Secure Landfill
SCA - Model City Site

DR BY: -	SCALE: Enlarged	PROJ. NO. BD-88-52
CK'D BY: FRM	DATE: 6/30/88	DRWG NO. 1

E/T FORM R-2

DATE
STARTED 4/15/88
FINISHED 4/15/88
SHEET 1 OF 1

EMPIRE SOILS INVESTIGATIONS INC.

SUBSURFACE LOG

HOLE NO. B-5
SURF. ELEV. N/A 318.7
G. W. DEPTH See Note

PROJECT SCA-SLF-13
LOCATION SCA
Model City, New York

DEPTH FT	SAMPLES	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
0		1	1	1				TOPSOIL	
			2	5		3		Red-brn. Clayey SILT, little f-c Sand tr. roots(moist, soft)	3" undisturbed sample (Shelby Tube) obtained from 2.0-4.0' 1.2' recovery
		2	TUBE						
5		3	1	2				Orange-blk. & brn. mottled Silty CLAY, tr. sand, occ. Silt partings(moist, soft)	
			3	3		5			
		4	4	16					
10			27	18		43		Becomes brn.(hard)	
15		5	4	16				Red-brn. Clayey SILT, little-some f-c Sand(moist, stiff)	
			7	10		23			
20		6	TUBE						3"undisturbed sample (Shelby Tube) obtained from 20.0-23.0' 2.0' recovery
		7	2	3				Grey-brn. Silty CLAY, tr. sand(moist-wet, medium)	
			3	3		6			
25		8	1	2				Contains tr. gravel(soft)	
			1	2		3			
30		9	1	5				Red-brn. f-c SAND, little Silt, little f-c Gravel, tr. clay(wet, firm)	
			6	6		11			
35		10	1	18				Contains some Silt(moist, compact)	No free standing water enc. at boring completion. Boring backfilled with bentonite grout at completion
			22	43		40			
								Boring complete at 37.0'	
40									

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 "per blow.

CLASSIFICATION Visual by Geologist

C = No blows to drive ____ " casing ____ " with ____ lb. weight falling ____ "per blow.

METHOD OF INVESTIGATION ASTM D-1586 Using Hollow Stem Augers

DATE STARTED	4/15/88
FINISHED	4/15/88
SHEET	1 OF 1

EMPIRE SOILS INVESTIGATIONS INC.

SUBSURFACE LOG

HOLE NO. B-6
SURF. ELEV. N/A 318.5
G. W. DEPTH See Notes

PROJECT SCA-SLF-13

LOCATION SCA
Model City, New York

DEPTH FT	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
0	1	1	1				TOPSOIL Red-brn. Silty CLAY, tr. sand, tr. gravel, tr. roots(moist, soft)	
		3	5		4			
5	2	15	14				Red-brn. Clayey SILT, little f-c Sand, tr. gravel(moist, hard)	
		20	35		34			
10	3	26	43				Brn. SILT, tr. sand, tr. clay(miost, v. compact)	
		43	36		76			
15	4	TUBE						3" undisturbed sample (Shelby Tube)obtained from 15.0 - 17.0' 2.0' recovery
	5	2	4				Grey Silty CLAY, tr. sand(moist-wet, medium)	
		5	7		9			
20	6	2	2				(soft)	
		2	2		4			
25	7	TUBE						3" undisturbed sample (Shelby Tube) obtained from 25.0 - 27.0' 2.0' recovery
30	8	1	3				Brn.-gry. f-c SAND, little Silt, tr. clay(wet, loose)	
		3	5		6			
35	9	1	14				Becomes red-brn., contains some Silt, little f-c Gravel(moist-wet, firm)	Free Standing Water rec. at 30.5' at boring completion. Boring backfilled with bentonite grout at completion.
		24	90		38			
							Boring Complete at 37.0'	
40								

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 "per blow

C = No blows to drive ____ " casing ____ " with ____ lb. weight falling ____ "per blow

CLASSIFICATION Visual by Geologist

METHOD OF INVESTIGATION ASTM D-1586 Using Hollow Stem Augers

DATE
STARTED 4/18/88
FINISHED 4/18/88
SHEET 1 OF 2

EMPIRE SOILS INVESTIGATIONS INC.

SUBSURFACE LOG

HOLE NO. B-7
SURF. ELEV. N/A 319.3
G. W. DEPTH See Notes

PROJECT SCA-SLF-13
LOCATION SCA Model City, New York

DEPTH FT	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
0	1	1	2				TOPSOIL	
		8	10		10		Red-brn. Clayey SILT, little f-c Sand, tr. gravel(moist, FILL)	
	2	TUBE					C = 1300	3" undisturbed sample (Shelby Tube) obtained from 3.0'5.0' 1.1' recovery
5	3	3	8	68/0.1				Driller reports encountered abandoned steel water line. Boring moved 20.0'
10	4	3	7				Red-brn. Clayey SILT, little f-c Sand, tr. gravel(moist, stiff)	
		11	13		18			
15	5	2	5				Brn. Silty CLAY, some f-c Sand, tr. gravel(moist, medium)	
		6	7		11			
20	7	TUBE						3" undisturbed sample (Shelby Tube) obtained from 20.0-27.0' 1.2' recovery
	8	12	10				Red-brn. & gry. SILT, tr. sand, tr. clay, occ. clay partings(moist, firm)	
		9	14		19			
25	9	2	3				Grey-brn. Silty CLAY, tr. sand (moist, soft)	
		2	3		5			
30	10	1	3				(medium)	
		3	5		6			
35	11	WOH/1.0					Red-brn. f-c SAND, little Silt, little f-c Gravel, tr. clay(wet, loose)	WOH = Weight of hammer and rods
		2	7		9			
40								

N = No blows to drive 2" spoon 12" with 140 lb. pin wt. falling 30" per blow
C = No blows to drive ___" casing ___" with ___ lb. weight falling ___" per blow
CLASSIFICATION Visual by Geologist
METHOD OF INVESTIGATION ASTM D-1586 Using Hollow Stem Augers

DATE

STARTED

FINISHED 4/18/88

SHEET 2 OF 2

EMPIRE SOILS INVESTIGATIONS INC.

SUBSURFACE LOG

HOLE NO. B-7

SURF. ELEV. N/A

G. W. DEPTH See Note

PROJECT SCA-SLF-13

LOCATION SCA
Model City, New York

DEPTH FEET	SAMPLES	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
40		12	4	31	100/0.4			Contains some Silt(moist, v. compact)	
								Boring Complete with Sample Spoon Refusal at 41.4'	No free standing water encountered at boring completion Boring backfilled with bentonite grout at completion
45									

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 "per blow

C = No blows to drive ____ " casing ____ " with ____ lb. weight falling ____ "per blow

CLASSIFICATION Visual by Geologist

METHOD OF INVESTIGATION

DATE		
STARTED 4/18/88	**EMPIRE** SOILS INVESTIGATIONS INC. SUBSURFACE LOG	HOLE NO. B-8
FINISHED 4/18/88		SURF. ELEV. N/A 313.4
SHEET 1 OF 2		G. W. DEPTH See Note

PROJECT SCA-SLF-13

LOCATION SCA
Model City, New York

DEPTH-FT	SAMPLES	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
0		1	1 / 7	3 / 8		10		TOPSOIL Orange-brn. & blk. mottled Clayey SILT, tr. sand(moist, medium)	
5		2	16 / 32	24 / 30		56		Orange & gry.-brn.mottled SILT, tr. sand, tr. clay(moist, v. compact)	31
10		3	9 / 14	20 / 10		34		Orange-brn. Clayey SILT and f-c Sand (moist, hard)	
15		5	13 / 9	10 / 8		19		Becomes brn.-gry.(stiff)	
20		6	8 / 6	10 / 20		16		Gry-brn. Silty CLAY, tr. sand, occ. Silt partings(moist, stiff)	6
25		7	TUBE						3" undisturbed sample (Shelby Tube) obtained from 25.0-27.0' 0.9' Recovery
30		8	4 / 4	3 / 4		7		Contains occ. Silt seams(medium)	28
35		9	8 / 25	13 / 41		38		Grey f-c SAND and Silt, tr. clay, tr. gravel(moist, compact)	
40									

N = No. blows to drive 2" spoon 12" with 140 lb. pin wt. falling 30" per blow. CLASSIFICATION Visual by Geologist

C = No. blows to drive ____" casing ____" with ____ lb. weight falling ____" per blow.

METHOD OF INVESTIGATION ASTM D-1586 Using Hollow Stem Augers

DATE STARTED 4/18/88
FINISHED 4/18/88
SHEET 2 OF 2

EMPIRE SOILS INVESTIGATIONS INC

SUBSURFACE LOG

HOLE NO. B-8
SURF. ELEV. N/A
G. W. DEPTH See Note

PROJECT SCA-SLF-13
LOCATION SCA Model City, New York

DEPTH FEET	SAMPLES	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
40		10	44	100/0.5				Becomes red-brn., contains little f-c Gravel	2-3-4
								Boring Complete with Sample Spoon Refusal at 41.0'	No Free Standing Water encountered at Boring Completion Boring backfilled with bentonite grout at completion
45									

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 " per blow. CLASSIFICATION Visual by Geologist
C = No blows to drive ____ " casing ____ " with ____ lb. weight falling ____ " per blow.
METHOD OF INVESTIGATION ASTM D-1586 Using Hollow Stem Augers

EMPIRE SOILS INVESTIGATIONS INC. **SUBSURFACE LOG**

DATE STARTED 4/19/88
FINISHED 4/19/88
SHEET 1 OF 1

HOLE NO. B-9
SURF. ELEV. N/A 320.2
G. W. DEPTH See Note

PROJECT SCA-SLF-13
LOCATION SCA
Model City, New York

DEPTH-FT	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
0	1	2	2				TOPSOIL	
		2	8		4		Blk. organic SILT, little f-c Sand, tr. roots, tr. clay(moist, loose)	
5	2	9	15				Red-brn. Clayey SILT, little f-c Sand,	
		24	25		39		tr. gravel(moist, hard)	
10	3	10	14				Becomes laminated, brn.	
		20	21		34			
15	4	3	2				Grey-brn. Silty CLAY, tr. sand	
		2	2		4		(moist-wet, soft)	
20	5	TUBE						3" undisturbed sample (Shelby Tube) obtained from 20.0'-22.0' 2.0' recovery
25	6	2	2				Contains "and" f-c Sand	
		3	3		5			
30	7	4	24				Red-brn. f-c SAND, little Silt, little	
		34	30		58		f-c Gravel, tr. clay(wet, v. compact)	
							Boring Complete at 32.0'	Free Standing Water recorded at 31.0' at Boring Completion Boring backfilled with bentonite grout at completion.

N = No blows to drive 2" spoon 12" with 140 lb. pin wt. falling 30" per blow
C = No blows to drive ___" casing ___" with ___ lb. weight falling ___" per blow
CLASSIFICATION Visual by Geologist
METHOD OF INVESTIGATION ASTM D-1586 Using Hollow Stem Augers

DATE
STARTED 4/19/88
FINISHED 4/19/88
SHEET 1 OF 1

EMPIRE SOILS INVESTIGATIONS INC. SUBSURFACE LOG

HOLE NO. B-10
SURF. ELEV. N/A 320.4
G. W. DEPTH See Note

PROJECT SCA-SLF-13
LOCATION SCA
Model City, New York

DEPTH-FT	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
0	1	6	6				TOPSOIL	
		10	10		16		Brn. Clayey SILT, little f-c Sand, tr. gravel, tr. organics(moist, stiff)	
5	2	7	16				Becomes red-brn.(hard)	
		26	27		42			
10	3	18	21				Grey f-c SAND, some Silt, tr. clay (wet, firm)	Poor recovery sample #3
		9	11		30			
15	4	3	2				Grey Silty CLAY, tr. sand, occ. Silt partings & seams(moist-wet, soft)	
		3	2		5			
20	5	TUBE						3" undisturbed sample (Shelby Tube) obtained from 20.0'-22.0' 7.9" recovery
25	6	1	1					
		4	6		5			
30	7	4	30				Red-brn. f-c SAND, tr. silt, occ. fine Sand lenses(wet, v. compact)	
		40	36		70			
							Boring Complete at 32.0'	Free Standing Water recorded at 29.8' at Boring Completion. Boring backfilled with bentonite grout at completion.

N = No. blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 " per blow.
C = No. blows to drive ____ " casing ____ " with ____ lb. weight falling ____ " per blow.

CLASSIFICATION Visual by Geologist

METHOD OF INVESTIGATION ASTM D-1586 Using Hollow Stem Augers

DATE STARTED 4/26/84 FINISHED 4/26/84 SHEET 1 OF 2

EMPIRE SUBSURFACE LOG

HOLE NO. BH -33A
SURF. ELEV. 320
G.W. DEPTH See Notes

PROJECT SCA Monitoring Wells
LOCATION Model City, NY

DEPTH FT	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	RECOVERY	SOIL OR ROCK CLASSIFICATION	NOTES
0								Note: Water encountered at 40' ± while drilling. Recovery not noted.
5	S1	10	10	21	31		Red-Brown Clayey SILT, little f-c sand, little gravel (Moist - Hard)	
10	S2	7	8	13	21			Zone 1
15	S3	8	6	6	12		18.0 ±	
20	S4	1	2	2	4		Grey CLAY, trace f. gravel (Moist - Soft)	SCREENED IN CLAY, AL?? PWT, BR
25	S5	WOH	1	2	3		Similar w/silt lenses	Zone 2
							GC 18-37	
30	S6	1	2	2	4			
35	S7	1	1	2	3		Similar w/1.5" f. sand lenses 37.0±	Driller notes change at 37.0'
40							AL?	Zone 3

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 " per blow.
C = No blows to drive ___ " casing ___ " with ___ lb. weight falling ___ " per blow.

CLASSIFICATION Visual by Geologist

METHOD OF INVESTIGATION 3 3/4 Hollow Stem Auger Casing & Standard Penetration Test

DATE
STARTED 4/16/84
FINISHED 4/16/84
SHEET 2 OF 2

EMPIRE

SUBSURFACE LOG

HOLE NO. MW-33A
SURF. ELEV.
G. W. DEPTH See Not

PROJECT SCA Monitoring Wells
LOCATION Model City, NY

DEPTH	SAMPLES	SAMPLE NO.	BLOWS ON SAMPLER 0/6	6/12	12/18	N	RECOVERY	SOIL OR ROCK CLASSIFICATION	NOTES
40		S8	95	100/.5				Brown Fine SAND, some Silt (Wet - Very Compact)	
								PWT 43.5' ±	
								Damp Red Decomposed SHALE	
45		S9	100/.4						
								Boring Terminated at 45.5'	2" Stainless Steel well installed. See Drawing #2 for well construction details. All welds inspected by the geologist.

N = No blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 " per blow
C = No blows to drive ___ " casing ___ " with ___ lb. weight falling ___ " per blow
CLASSIFICATION Visual By Geologist
METHOD OF INVESTIGATION 3 3/4 Hollow Stem Auger Casing & Standard Penetration Test

DATE STARTED 1-12-84	EMPIRE SOILS INVESTIGATIONS INC	SUBSURFACE LOG	HOLE NO. B-34 A
FINISHED 1-16-84			SURF. ELEV. N.A.
SHEET 1 OF 2			G. W. DEPTH 6.12' 1-27-84

PROJECT Monitoring Wells SCA Model City Facility

LOCATION 1550 Balmer Road Lewiston, New York 220.4

DEPTH	SAMPLES	SAMPLE NO.	Blows on Sampler 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
0								0.2' TOPSOIL	
								Moist, tan-brown Clayey SILT, some fine Sand, some f-c Gravel	
5		1	9	16	21	37		Moist, hard, red-brown Silty CLAY with occasional tan & gray Silt and and fine Sand seams	
10		2	21	21	19	40		Wet, compact, brown fractured ROCK FRAGMENTS and f-c Sand, some Silt, trace clay	Driller notes cobbles/gravel between 9.0' to 13.0'
								Moist, stiff, gray-brown Silty CLAY, little fine-coarse Sand, trace clay	UGT 0.2 - 18.5
15		3	2	17	12	29		Moist-wet, hard, red-brown SILT, some fine-coarse Sand, trace clay	
20		4	2	7	7	14		Moist, medium, gray-brown Silty CLAY, trace-little fine Sand, occasional Silt partings	GC 18.5 - 35
25		5	1	1	1	2		Becomes moist-wet, very soft	
30		6	WOR	WOH	3	-		Contains little f-c Sand, with occasional Sand seams	
35		7	WOH	2	8	-		Wet, loose, brown & gray f-c SAND, little Silt, trace gravel	First free standing water recorded at approximately 36.0' GSS 35-48
40									

N = No. blows to drive 2 " spoon 12 " with 140 lb. pin wt. falling 30 " per blow. CLASSIFICATION Visual by Geologist

C = No. blows to drive ___ " casing ___ " with ___ lb. weight falling ___ " per blow.

METHOD OF INVESTIGATION ASTM D-15 86 Using 3 3/4" I.D. Hollow Stem Auger

DATE			
STARTED	1-12-84	HOLE NO.	B-34A cont.
FINISHED	1-16-84	SURF. ELEV.	N.A.
SHEET	2 OF 2	G. W. DEPTH	6.12' 1-27-84

EMPIRE SOILS INVESTIGATIONS INC

SUBSURFACE LOG

PROJECT: Monitoring Wells, SCA Model City Facility

LOCATION: 1550 Balmer Road, Lewiston, New York

DEPTH	SAMPLES	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
40		8	8	30		-		Becomes compact, contains little fine Gravel	Running sand between 36' and 45' Driller washed bore-hole from 40' to 45' prior to setting well point
45		9	37	63		-		Wet, very compact, brown fine SAND, some Silt, trace gravel	BRT 48-50'
								Wet, very compact, red-brown and gray f-c SAND, some fine Gravel, little Silt	
50		10	38	100/0.3'		-			
								Boring complete with Auger Refusal at 51.5 feet	Free standing water recorded at 12.2' on 1-13-84 with bottom of hole at 20.0 feet Welds on casing inspected on 1-13-84 Two-inch I.D. stainless steel well installed with bottom at 42.9', see Drawing 2 for well construction details.

N = No. blows to drive 2" spoon 12" with 140 lb. pin wt. falling 30" per blow.

C = No. blows to drive ___" casing ___" with ___ lb. weight falling ___" per blow.

CLASSIFICATION: Visual by Geologist

Method of advancing: ASTM D-1586. Using 3 3/4" I.D. Hollow Stem Auger

WEHRAN ENGINEERING

TEST BORING LOG

Project No. C-77213 Client SCA SERVICES, INC.

Project CHEM-TROL POLLUTION SERVICES, INC.

Location NIAGARA COUNTY, NEW YORK

Type of Rig CME AUGER Driller EMPIRE SOILS

Boring No. 34

Date Start 8/2/77

Date Finish 8/3/77

Inspector WSP

"O" Elev. = 319.9

Depth	Sample No.	Type	Spoon blows / 6" Penetr.		Average Blows/ft	Log	Classification	Remarks
							ALLUVIAL DEPOSIT:	
	1	SS	13	23	R=10"		Lt. brown SILT, trace fine Sand, trace fine Gravel	Very dense, dry
			17	17				
	2	SS	23	19	R=8"		Becoming @ 2':	
5	3	SS	10	14			Brown & green Clayey SILT to CLAY & SILT in irregular laminations	bec. slightly moist
			21					
			18"	REC.			5'-6"	
10							GLACIAL TILL:	
	4		10	9		UGT 5.5-14'	Red-brown CLAY & SILT little Sand, little Gravel	Very stiff, slightly moist
			10				Jointed, joints filled with grey silt and fine rocks	
			12"	REC.				bec. wet @ 10'-6"
15	5	SS	1	2			Becoming "mottled" with fine Sand, Clay @ 8' 14'-0"	
			1				GLACIOLACUSTRINE DEPOSIT:	
			14"	REC.			Occ. layer of Brn fine SAND and Silt @ 15'	Soft, wet
20	6	SS	8	11	R=18"			
			11					
	7	SS	W.H.	2			Grey Silty CLAY occ. laminations of Grey and Red-brown SILT	
			2					
25	8	US	Pres.	50 psi		GC 14-35'		
			24"	REC.				
30	9	SS	2	3			grading w/ occ. 1/8" layers of fine Sand & Silt, tr fine Gravel	Bec. Firm, wet
			3					
			18"	REC.				
35							TRANSITION 35'0"	
	10	SS	10	15		GSS 35-40'	GLACIOLACUSTRINE DEPOSIT:	V. dense, saturated
			30				Red-brown m-f SAND, some Silt, little m-f Gravel 38'-0"	
			18"	REC.			ALLUVIAL CHANNEL DEPOSITS:	

1 1/4" PVC CSG.

CEMENT GROUT

CLAYEY SOIL BACKFILL

BENTONITE PELLET SEAL

DATE STARTED 1-20-84
FINISHED 1-23-84
1 OF 2

EMPIRE SOILS INVESTIGATIONS INC

Applicable Borings

HOLE NO. B-43A
SURF. ELEV. N.A.
G. W. DEPTH 6.45' 1-27-84
r Road
lew York

PROJECT Monitoring Wells
SCA Model City Facility

31.0

DEPTH	SAMPLES	SAMPLE NO	0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
0								0.6' TOPSOIL	
5		1	6	11	13	24		Moist, stiff, brown Clayey SILT and fine-coarse Sand, trace gravel	
10		2	13	18	14	32		Moist-wet, hard, brown SILT, some fine-coarse Sand, some f-c Gravel, trace clay	UGT 0.6-12.5'
		4	2	2	2	4		Moist-wet, soft, brown and gray Silty CLAY with occasional Silt partings, trace gravel	GC 12.5-27'
20		5	WOH/1.0'		2	-		Becomes very soft	
25		6	2	2	3	5		Becomes soft, contains occasional fine-medium Sand and Silt seams	First free standing water recorded at 26'
30		7	9	15	16	31		Wet, compact, brown f-c SAND and Silt, little fine Gravel	Running sand between 27' and 41' Driller washed ahead from 26' to 41' prior to well installation
35		8	35	75	45	120		Becomes very compact	GSS 27-45'
40		9	16	50/0.5'					

N = No. blows to drive 2" spoon 12" with 140 lb. pin wt. falling 30" per blow. CLASSIFICATION Visual by Geologist
C = No. blows to drive ___" casing ___" with ___ lb. weight falling ___" per blow.
METHOD OF INVESTIGATION ASTM D-1586 Using 3 3/4" I.D. Hollow Stem Auger

WEHRAN ENGINEERING

TEST BORING LOG

Project No. C-77213 Client SCA SERVICES, INC. Boring No. 34

Project ______ Date Start ______

Location ______ Date Finish ______

Type of Rig ______ Driller ______ Inspector ______

Depth	Elevation	Casing Blows/ft	Sample No.	Sample Type	Spoon blows 6" Penetr.		Average Blows/ft	Log	Classification "O" Elev. = 319.9	Remarks
	1¼" WELLPOINT		11	SS	12	17		GSS 35-48'	Grey-brown mf SAND, trace Silt @41 becoming Red-brown fine SAND, ~~some~~ Silt	Sand ran 4' up into augers @40'
					29	—				
					13"	Rec.				
45	SAND		12	SS	30	60			Grading Brown mf SAND, w/ occ. layers Red-brown Silt to 1" thick 48.0'	Very dense, saturated
					12"	Rec.				
50			13	SS	120/5"			BRT 48-53'	PRE-WISCONSIN? GLACIAL TILL: Red-brown & grey Clayey SILT, w/ occ. weathered Shale frags. Occ. Cobbles & Boulders @ 49-50' 53.0'	Very dense, moist
					3"	Rec.				
55			14	SS	100/3"				Decomposed Red SHALE 55.7'	moist
					3"	Rec.				
0										
5										
0										
5										

DATE			
STARTED 1-20-84	**EMPIRE** SOILS INVESTIGATIONS INC	SUBSURFACE LOG	HOLE NO. B-43A Cont.
FINISHED 1-23-84			SURF. ELEV. N.A.
SHEET 2 OF 2			G. W. DEPTH 6.45' 1-27-84

PROJECT Monitoring Wells SCA Model City Facility

LOCATION 1550 Balmer Road Lewiston, New York

DEPTH	SAMPLES	SAMPLE NO.	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
40								Moist, very compact, red-brown SILT, some f-c Sand, trace fractured rock, trace clay	BRT 41-45'
45		10	42	100/0.3'				Contains "and" fractured Rock Fragments	
								Boring complete with REFUSAL at 45.3 feet	Welds inspected on casing on 1-23-84 Two-inch I.D. stainless steel well installed with bottom at 40.5', see Drawing 2 for well construction details.
50									

N = No. blows to drive 2" spoon 12" with 140 lb. pin wt. falling 30" per blow.
C = No. blows to drive ___" casing ___" with ___ lb. weight falling ___" per blow.

CLASSIFICATION Visual by Geologist

METHOD OF INVESTIGATION ASTM D-1586, Using 3 3/4" I.D. Hollow Stem Auger

WEHRAN ENGINEERING

TEST BORING LOG

Project No. C-77213 Client SCA SERVICES, INC. Boring No. 43

Project CHEM-TROL POLLUTION SERVICES, INC. Date Start 8/12/77

Location NIAGARA COUNTY, NEW YORK Date Finish 8/15/77

Type of Rig CME AUGER Driller EMPIRE SOILS Inspector RDM/GAJ

Depth	Elevation	Casing Blows/ft	Sample No.	Type	Spoon blows 6" Penetr.		Average Blows/ft	Log	Classification "O" Elev. = 320.7	Remarks
									GLACIAL TILL:	
			1	SS	7	8	R=4"			
					9	8			Brown CLAY & SILT, some Sand, some Gravel	Hard dry
			2	SS	10	13	R=5"			
5										
			3	SS	25	30		UGT 0-12'	Jointed to 8'±, filled with grey silt, clay & roots	
					33	—				
					12"	REC				
10									"Marbled" w/ Grey Silty CLAY; and Brn cf SAND, sc, & S @ Contact 12.0"	Hard, dry-moist
			4	SS	28	36				
					44	—				
					15"	REC			GLACIOLACUSTRINE DEPOSIT:	
15										
			5	SS	5	6				Soft-firm
					7	—			Grey laminated CLAY w/ laminations (1/8") of Red & Grey SILT @ 1 to 3" intervals; trace Sand, trace Gravel	
					10"	REC				
20								GC 12'-27'		
			6	SS	4	5	R=18"			
					6	—				
			7	SS	PRESS	500psi				
					24"	REC				
25										
			8	SS	6	6				Soft-firm
					7	—			27.0'	
									ALLUVIAL DEPOSIT:	Dense, saturated
30										
			9	SS	8	11			Brown cf SAND, little fine Gravel, little(-) Silt	
					15					
35								GSS 27-42'	Gravel: sub-rounded to well-rounded	
			10	SS	100/.5				Crudely stratified, w/ occ. v.f. beds of Red-brown SILT, some cf Sand	
40										

CEMENT SEAL

CLAYEY SOIL FILL

FILL

PELLET SEAL

CSG.

1 1/4" PVC

SAND PACK

1 1/4" WELL POINT

WEHRAN ENGINEERING

TEST BORING LOG

Project No. C-77213 Client SCA SERVICES, INC.

Project ______ Boring No. 43

Location ______ Date Start ______

Type of Rig ______ Date Finish ______

Driller ______ Inspector ______

Depth	Elevation	Casing Blows/ft	Sample No.	Type	Spoon blows 6" Penetr.		Average Blows/ft	Log	Classification "O" Elev. = 320.7	Remarks
	SAND PACK & NATURAL CAVED MATERIALS		11	SS	12	15			Grading @ 40' to: Alternating v. thin beds of Brown fine, some Silt; Brown m f SAND, some Silt 42'-0"	Saturated
					19	—				
45									PRE-WISCONSIN? GLACIAL TILL:	
			12	SS	28	45		BRT 42-52'	Red-brown Clayey SILT to SILT, and Sand, trace f/m Gravel	V. dense, dry
					70	—				
50			13	SS	100	—			grading to some Sand, some Gravel of Red SHALE fragments 52'-0"	
					—	—				
			14	SS	100/1"	—			Decomposed Red SHALE 53'-1"	
					—	—				
55										
0										
5										
0										
5										

WEHRAN ENGINEERING
CONSULTING ENGINEERS

TEST BORING LOG
BORING NO. B-99

PROJECT: SLF No. 11 - Model City, N.Y.
CLIENT: SCA Services, Inc.
BORING CONTRACTOR: Empire Soils

SHEET NO. 1 OF 2
JOB NO. 01360212
ELEVATION 318.57
DATE STARTED 12-9-80
DATE FINISHED 12-10-80
DRILLER Genovese
INSPECTOR RCM

GROUND WATER					CAS.	SAMP	CORE	TUBE
DATE	TIME	WATER EL.	SCREEN	TYPE	HSA	SS		ST
				DIA.	3 1/4"	2"		3"
				WT.		140 lb		
				FALL		30"		

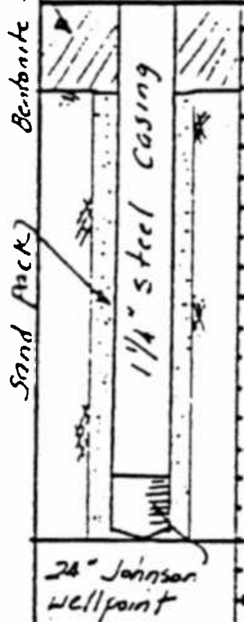
Top of Casing Elev = 320.40

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
Cement - bentonite grout; 1 1/4" steel casing	0	1	SS	4-5 / 10-18	TOPSOIL: clayey SILT, and SAND w/roots	* : used 300 lb hammer
		2	SS	12-16 / 20-24	Glacial Till (CL)	hard dry
	5	3	SS	35-50 / 60-25	Brown, orange-br., gray, white mottled CLAY & SILT little fine Sand, trace(+) fine Gravel	
		4	SS	25-35 / 30-30	@ 5', becoming reddish-brown	moist; UCT 0-14'
	10	5	SS	15-27 / 30-32	@ 9'-10', few SILT layers, and med-fine SAND partings	wet
		6	SS	10-11 / 12-14	~ irreg. vertical joints, w/ gray Silt-Clay filling noted to 10' depth	
		7	SS	8-12 / 27-16	14'0"	
	15	8	SS	3-4 / 5-6	Glaciolacustrine Dep. (CL-CH)	Stiff wet
		9	SS	6-6 / 5-4	Brown-gray Silty CLAY, trace fine Sand, trace(-) fine Gravel	
		10	SS	1-1 / 2-2	occ. gray & red silt partings, 17'-24'.	@18' Soft wet; GC 14-35'
	20	11U	ST	Press		
		12	SS	2-6 / 8-8	@ 22'-24', occ. 3" Silt layers - saturated.	
	25	13	SS	WH. WH. / 2-2	@ 24'-35', occ. 1/4' Silt layers	
		14	SS	2-2 / 4-4	occ. fine Sand or Silt partings.	
		15	SS	2-2 / 2-2		
	30	16U	ST	Press	35'0"	Very Soft
		17	SS	WH.-WH. / 1-1	Glaciolacustrine Dep (basal) (ML)	GSS 35-38'
	35	18	SS	1-1 / 5-7	Reddish-brown clayey SILT, little to some m-f Sand, little f.m. Gravel. 38'0"	med. dense Saturated
		19	SS	6-8 / 16-20	Pre-Wisconsin Glacial Till (SM-ML)	
	40	20	SS*	40-60 / 40-50	Red-br. med-fine SAND, little Silt, trace fine Gravel - @ 39'6"-40'6" grading fine SAND, trace Silt, w/8" layer c. Sand, some Gravel	Very dense moist to dry
		21	SS*	25-85	@ 40'6", grading SILT, little c-f Gravel, tr. f. Sand. w/ boulder frag. & weathered shale frag.	BRT 38-45'
		22	SS*	150/6"		
		23	SS*	120/6"	45'0"	
	45	24	SS*	126/4"	Decomposed Red SHALE	

WEHRAN ENGINEERING
CONSULTING ENGINEERS

PROJECT : SLF No. 11 - Model City, N.Y.	TEST BORING LOG
CLIENT : SCA Services, Inc.	BORING NO. B-99
	SHEET NO. 2 OF 2
	JOB NO. 01360212

WELL CONSTRUCTION



DEPTH FEET	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
45				Decomposed Red SHALE	
	25	SS A	94-100/2" 47'4"	grading decomposed, weathered & fractured rock to 52' ± w/ 12" fracture zone, 47-48'	
50	Run 1	Core	Rec 87% RQD=0%	@ 52', becomes slightly weathered, w/ 12" zone badly broken rock, 57-58'	
55			57'4"	@ 58'-4", 6" bed greenish-gray altered rock - then sound Red Shale w/ freq. horizontal breaks along bedding planes - Some w/ gypsum coating.	
60	Run 2	Core	Rec 100% RQD: 31%	Vertical jointing below 61'-6". Below 62'-4", zone greenish-gray altered rock, w/ occ. 1/4-1/2" voids. 63'-0"	
65				END OF BORING	
70					
75					
80					
85					
90					
95					

WEHRAN ENGINEERING
CONSULTING ENGINEERS

TEST BORING LOG
BORING NO. B-106

PROJECT:	SLF No. 11 - Model City, N.Y.
CLIENT:	SCA Services, Inc.
BORING CONTRACTOR:	Empire Soils
SHEET NO.	1 OF 1
JOB NO.	01360212
ELEVATION	318.06
DATE STARTED	1-14-81
DATE FINISHED	1-15-81
DRILLER	Legel
INSPECTOR	JLM

GROUND WATER

DATE	TIME	WATER EL.	SCREEN

	CAS.	SAMP.	CORE	TUBE
TYPE	HSA	SS	Denison	ST
DIA.	3 1/4"	2"	2"	3"
WT.		140 lb.		
FALL		30"		

SAMPLE

NO.	TYPE	BLOWS PER 6 INCHES	
1	SS	3	3
		3	3
2	SS	7	9
		9	10
3	SS	17	24
		30	33
4	SS	35	45
		50	40
5	SS	10	12
		11	30
6	SS	25	26
		22	29
7	SS	11	8
		8	8
8	SS	3	2
		4	2
9U	ST	Press	5
		Rec	10"
10U	ST	Press	5
		Rec	10"
11U	ST	Press	5
		Rec	10"
12	SS	3	3
		3	3
13	SS	0	2
		2	2
14	SS	3	4
		4	40
15	SS	7	7
		12	19
16D	Den.	Rec:	0"
17	SS	40	55
		30	34
18	SS*	18	26
		30	35
19	SS*	38	33
20D	Den.	Rec:	19"
21	SS*	100/3"	
22	SS*	100	

CLASSIFICATION

Glacial Till CL

Brown, orange-br., red-br. mottled SILT & CLAY, trace m-f Sand, trace m-f Gravel.

@ 4' grading red-brown CLAY & SILT, little c-f Sand, little c-f Gravel. 9'-6"

Brown Clayey SILT, little to some (+) Sand, trace med-fine Gravel. 14'-0"

Glaciolacustrine Dep. CL

Gray CLAY & SILT - laminated, w/ occ. red-brown Silt partings, below 26' 27'-6"

Glaciolacustrine Deposit (basal) ML-SM

Reddish-brown SILT, some med-fine Sand, trace fine Gravel. 36'-0"

Pre-Wisconsin Glacial Till ML

Red-br. SILT, little fine Sand, trace c-f Gravel. 40'-0"

Decomposed Red SHALE 40'-6"

END OF BORING

REMARKS

* Used 300 lb. hammer

moist, very stiff to hard.

@ 2-4', few black-stained joints.

UGT 0-14'

wet, medium

GC 14-27.5

Saturated medium to very dense

GSS 27.5-36'

Moist very dense

BRT 36-40

WELL CONSTRUCTION

1 1/4" PVC Casing

Cement Grout

Sand Pack

Bentonite Seal

Johnson 24" wellpoint

Bentonite Seal

DEPTH FEET: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45

DATE STARTED 7/15/82
FINISHED 7/15/82
SHEET 1 of 2

EMPIRE SOILS INVESTIGATIONS INC. SUBSURFACE LOG

HOLE NO B-113
SURF ELEV 322.4
G.W. DEPTH See Note

PROJECT SCA - Model City
LOCATION Balmer Road
Lewiston-Porter, New York

DEPTH	SAMPLES	SAMPLE NO.	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOWS ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
0								Moist firm red-brown Clayey SILT, little fine-coarse Gravel, trace sand	
5		1	5	8	12	20			UGT 0-13'
10		2	6	10	10	20		Contains trace gravel	
15		3	1	1	1	2		Moist very soft gray-brown Silty CLAY, trace gravel	GC 13'-28'
20		4	2	2	2	4		Becomes moist-wet, soft, contains occasional seams of Silt, trace sand	
25		5	WOH	2					
30		6	4	6	5	11		Wet firm brown SILT, some fine-coarse Sand, some fine-coarse Gravel	GSS 28-48'
35		7	9	12	15	27		Wet firm brown fine-coarse SAND, little fine-coarse Gravel, trace silt clay (Till)	
40									

N = No. blows to drive 2" spoon 12" with 140 lb pin wt falling 30" per blow
C = No. blows to drive ___" casing ___" with ___ lb weight falling ___" per blow

CLASSIFICATION Visual by Geologist

DATE STARTED 7/15/82
FINISHED 7/15/82
2 OF 2

EMPIRE SOILS INVESTIGATIONS INC

SUBSURFACE LOG

HOLE NO B-113
SURF ELEV
G. W. DEPTH See Note

PROJECT SCA - Model City
LOCATION Balmer Road
Lewiston-Porter, New York

DEPTH FT	SAMPLES	SAMPLE NO	BLOWS ON SAMPLER 0/6	6/12	12/18	N	BLOW ON CASING C	SOIL OR ROCK CLASSIFICATION	NOTES
40	/	8	12	14	14	28		Contains little Silt, trace gravel	GSS 28-48
45		9	Auger					Wet firm gray-brown fine-medium SAND, trace silt	1. Sample No. 9 was recovered from the auger flight due to soil nature.
	/	10	60	100/.5				Wet v.comp. red-br. f-c GRAVEL, little f-c Sand, trace silt	BRT 48-50
50								Boring Complete at 49.5 feet.	2. No free standing water encountered in hole at boring completion; wet samples recovered from 28.0-49.5 feet.
									3. Observation well installed at 48.0 feet:
									+4.0-1.0': 2"galvinized riser pipe w/ vented cap.
									1.0'-43.0: 2" stainless steel riser pipe.
									43.0-48.0: 2" stainless steel well screen.
									0.0'-25.0: Grout back fill.
									25.0-27.0: Bentonite seal.
									27.0-49.5: Sand filter

N = No. blows to drive 2" spoon 12" with 140 lb pin wt falling 30" per blow
C = No. blows to drive ___" casing ___" with ___ lb weight falling ___" per blow

CLASSIFICATION Visual by Geologist

BORING LOG G-3

LOCATION N 10201 E 12618 SHEET 1 OF 1

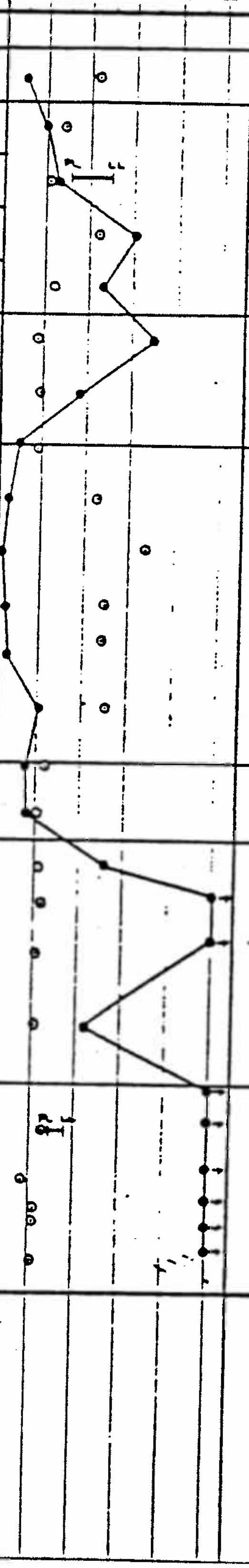
SURFACE ELEV 318.5 DATUM MSL PROJECT CWM / MODEL CITY / N.Y.

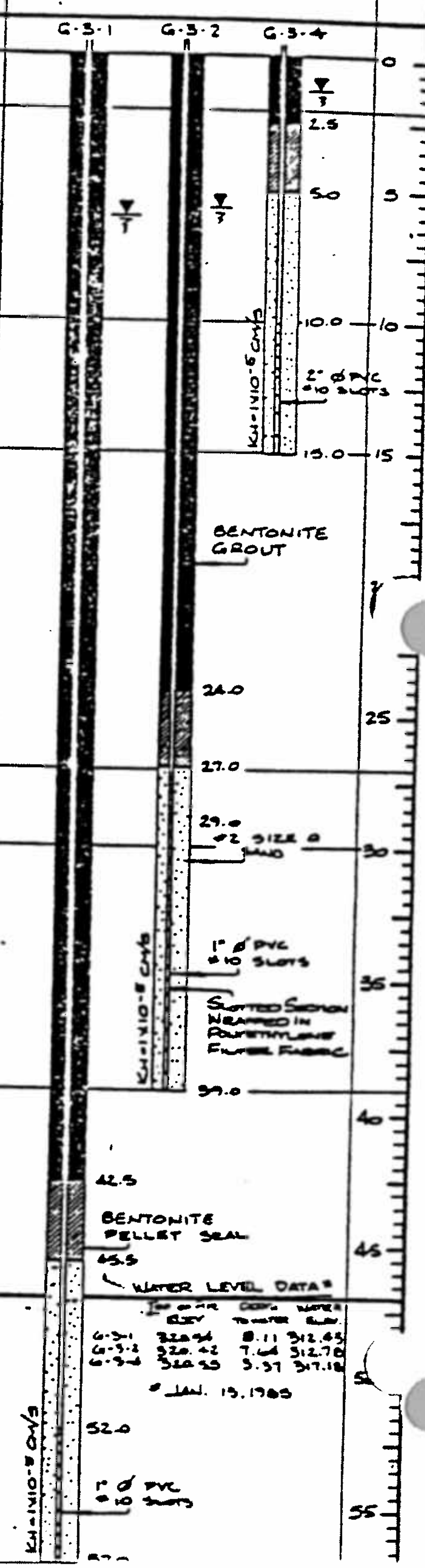
DRILLING COMPANY EMPIRE SOILS JOB No 853-3047

DATE STARTED NOV. 27 '84 DATE COMPLETED NOV. 30 '84 DRAWN C

DRILL RIG CME 45 DRILLING METHOD HOLLOW STEM AUGER, NX CORE CHECKED

DEPTH	DESCRIPTION	ELEV / DEPTH	SAMPLES NUMBER	REC/ATT	HAMMER BLOWS PER 6 IN.
0	GROUND SURFACE	318.5			
	ALLUVIUM Compact, Gray, SILT, Some Fine Sand (ML)	0.0	1	18/24	4-5 5-6
		316.5			
	UPPER CLAY TILL Stiff to Hard, Brown, CLAYEY SILT, Some C-F Sand (CL) Heterogeneous. Dry, Fine Sand and Silt Layer Between 6' and 8' Depth.	2.0	2	4/24	4-9 11-14
5			3*	14/24	6-11 15-19
			4	18/24	25-27 34-20
			5	24/24	6-9 38-24
10		308.5			
	UPPER SILT TILL Compact to Very Dense Brown SILT and C-F SAND, Little Fine Gravel (ML) Occasional Thin Oxidized Joints.	10.0	6	18/24	16-31 39-39
			7	22/24	17-19 18-17
15		303.5	8*	14/24	7-5 4-3
	GLACIOLACUSTRINE CLAY Soft to Firm, Gray SILTY CLAY, Trace to Some C-M Sand (CL) Occasional Gravel Sized Sub-angular Isolated Dropstones. Occasional Fine Sand and Silt Layers Between 16' and 18' Depth	15.0	9	20/24	WH-WH 4-3
			10	18/24	WR-WH 1-2
20			11	20/24	WH-2 2-1
			12	24/24	WH-2 3-5
25			13	24/24	WR-15 6-4
		291.5	14	20/24	WR-7 7-4
	MIDDLE SILT TILL Compact, Gray, SILT and C-F Sand, Little Fine Gravel (ML) Heterogeneous, Moist, Dilatant	27.0	15	20/24	2-7 8-12
30		288.5			
	GLACIOLACUSTRINE SILT/SAND Dense, Brown, SILT and C-F SAND, Little Fine Gravel (ML) Gap Graded with Gravel and Sand Isolated in Silt Matrix. Wet. Occasional Small Clean Fine Sand Pockets	30.0	16	22/24	19-19 33-51
			17	6/9	47-100/3"
35			18	4/6	80/6"
			19*	24/24	WH-20 24-36
		279.5			
40	BASAL RED TILL Very Dense, Red Brown, SILT and C-F SAND, Little Fine Gravel (ML) Indurated. Dry. Gravel as Angular Shale Fragments.	39.0	20	6/6	175/6"
			21	5/9	50-50/3"
			[illegible]	[illegible]	[illegible]
			23	6/6	144/6"
45			24	6/6	130/6"
			25	6/6	175/6"
		271.5			
	BEDROCK QUEENSTON FORMATION Red-Brown, Fissile, SHALE. Highly Weathered, Fragmented from 47' to 52.7' and 54' to 56.5' Moderately Weathered on Some Horizontal Fractures from 52.7' to 54'. Most Horizontal Fractures are Drilling Induced Broken Breaks.	47.0	1	48/80	NX CORE RQD-0%
55			2	39/39	NX CORE RQD-47%
	Boring Terminated to ...	261.5	5	10/12	NX CORE RQD-58%





WATER LEVEL DATA*

	TOP OF PVC ELEV	DEPTH TO WATER	WATER ELEV.
G-3-1	320.56	8.11	312.45
G-3-2	320.42	7.64	312.78
G-3-4	320.55	3.37	317.18

* JAN. 15, 1985

LOCATION N 9228 E 11076

BORING LOG G-17

SHEET 1 OF 2

SURFACE ELEV. 320.3 DATUM MSL PROJECT CWM / MODEL CITY / N.Y. JOB No. 853-3047

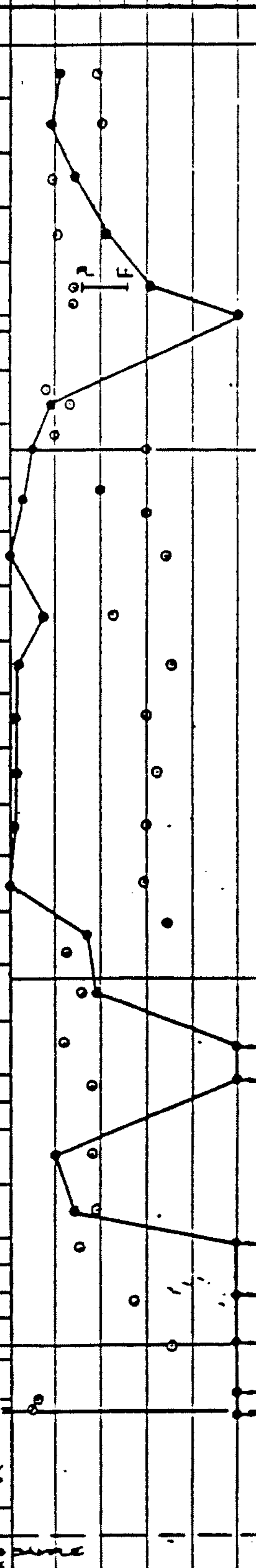
DRILLING COMPANY EMPIRE SOILS DATE STARTED DEC. 4 '84 DATE COMPLETED DEC 5 '84 DRAWN C.M.S.

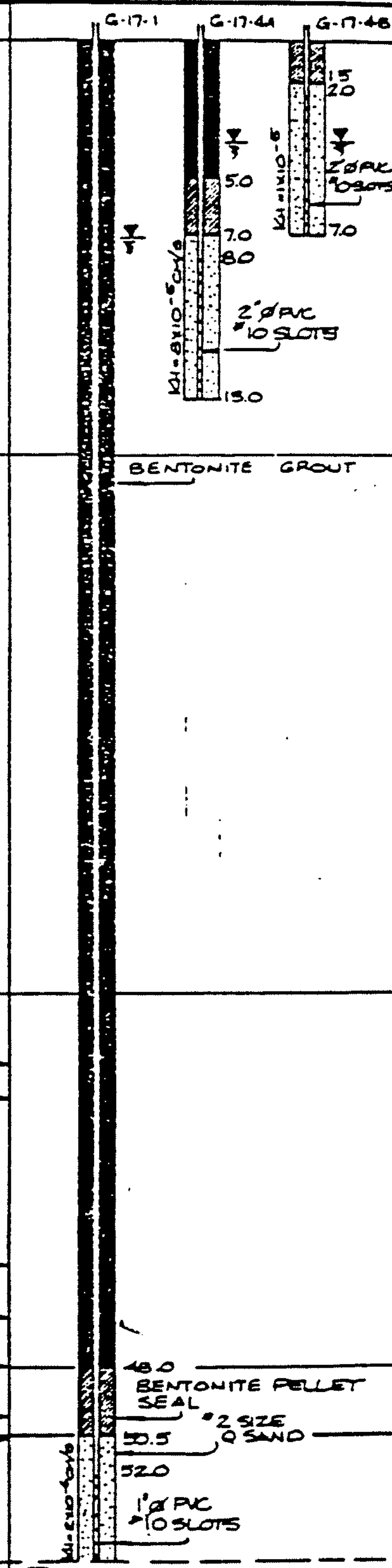
DRILL RIG CME 45 DRILLING METHOD HOLLOW STEM AUGER, NX CORE CHECKED MRD

DEPTH	DESCRIPTION	ELEV / DEPTH	SAMPLES NUMBER	REC/ATT	HAMMER BLOWS PER 6 IN
	GROUND SURFACE	320.3			
0	UPPER CLAY TILL Hard, Brown, CLAYEY SILT, Some c-f Sand, Some c-f Sand, Some Fine Gravel (CL)	0.0	1	14/24	5-10 11-11
			2	10/24	8-9 10-10
5			3*	8/24	10-12 17-17
	Layer from 2'-4' Depth. Wet Sand and Gravel Layer From 12'-13' Depth		4	5/24	14-24 18-19
			5*	9/24	19-27 34-36
10			6	6/6	100/6
			7	6/24	7-9 10-11
15		305.3	8	15/24	4-5 4-5
	GLACIOLACUSTRINE CLAY Firm to Soft, Gray-Brown To Gray, SILTY CLAY, Little To Some Fine Gravel (CL)	15.0	9	8/24	4-3 2-2
			10	24/24	WH-WH WH-2
20	Occasional Gravel Sized Sub-Angular Dropstones. Laminated With 1/16" to 1/8" Thick Brown Silt and/or Fine Sand Layers Spaced 0.2' to 6.0' Apart.		11	24/24	2-7 9-9
	Layer of Silt Till Between 32.5' and 34.0' Depth.		12	24/24	1-1 2-2
25			13	24/24	1-1 1-2
			14	24/24	1-2 1-2
			15	24/24	1-1 1-2
30			16	24/24	WR-WR WH-1
			17	24/24	7-14 20-24
35	GLACIOLACUSTRINE SILT/SAND Compact to Very Dense, Gray To Multicolored, m-f SAND, Little Silt (SP-SM)	285.8 34.5	18	18/24	24-17 22-26
			19	18/18	25-45 100
	Stratified Poorly Graded Wet. Well Graded Layer With More Silt (SM) Between 34.5' and 36.0' Depth.		20	12/12	46-110
40	Layer of Very Poorly Graded Brown SILT and Fine SAND (ML) Between 37.5' and 39.0' Depth		21	18/24	2-7 13-29
			22	2/24	10-12 16-50
			23	12/12	43-100
45			24	12/12	27-120
	BASAL RED TILL Very Dense, Red-Brown c-f SAND and CLAYEY SILT, Some c-f Gravel (SC)	272.3 48.0	25	6/6	126
50		269.8	26* 27*	[illegible]	100/5* 100/1*
	BEDROCK QUEENSTON FORMATION (Description on Sheet 2)	50.5	1	30/42	NX CORE RQD-0%
55			2	42/48	

CONTINUED ON SHEET 2 OF 2

* LAB TEST ON THIS SAMPLE OR IN THIS RANGE





BORING LOG G-17

LOCATION N 9228 E 11076 | SHEET 2 OF 2

SURFACE ELEV. 320.3 DATUM MSL PROJECT CWM / MODEL CITY / N.Y. JOB No. 853-5047

DRILLING COMPANY EMPIRE SOILS DATE STARTED DEC. 4 '84 DATE COMPLETED DEC. 5 '84 DRAWN CMS

DRILL RIG CME 45 DRILLING METHOD HOLLOW STEM AUGER, NX CORE CHECKED MO

DEPTH	DESCRIPTION	STRAT. PLOT	ELEV. / DEPTH	SAMPLES NUMBER	REC/ATT	HAMMER BLOWS PER 6 IN.	○ WATER CONTENT (%) 10 20 30 40 50 / ● N (BLOWS / FOOT) 20 40 60 80 100	PIEZOMETER INSTALLATIONS	DEPTH
	CONTINUED FROM SHEET 1 OF 2.								
55	BEDROCK CONT. QUEENSTON FORMATION Gray-Brown To Red-Brown, Fissile, SHALE.			2	42/48	NX CORE RQD=17%		#2 Size Q Sand	
60	Near Horizontal Bedding. Heavily Weathered, Fragmented, From 50.5' To 54', 56' To 58', And 61' To 62'.		258.3 / 62.0	3	41/48	NX CORE RQD=13%		1" Ø PVC #10 Slots; 62.0	
65	Moderately Weathered Elsewhere With Depth. Fractures Mostly Drilling Induced Bedding Breaks								
	Boring Terminated To Install G-17-1 Piezometer								

WATER LEVEL DATA*

	TOP OF PIPE ELEVATION	DEPTH TO WATER	WATER ELEV.
G-17-1	322.52	9.36	313.16
G-17-4A	322.25	5.78	316.47
G-17-4B	322.26	5.74	316.52

*JANUARY 13, 1985

APPENDIX B

LABORATORY SOIL TEST RESULTS

EMPIRE
SOILS INVESTIGATIONS INC.

January 5, 1990

Donohue & Associates, Inc.
4738 North 40th Street
P.O. Box 1067
Sheboygan, Wisconsin 53082-1067

Attention: Mr. Anthony R. Pawloski, P.E.

Reference: CWM-Chemical Services, Inc.
Testing Results
RMU-1 - Model City, New York

Gentlemen:

Enclosed are the results of the laboratory testing program on the recovered shelby tube samples obtained from RMU-1 in Model City, New York.

We appreciated the opportunity to perform this work for you. If you have any questions, or we can be of further assistance, please do not hesitate to contact us.

Sincerely,

EMPIRE SOILS INVESTIGATIONS, INC.

Frank R. Minnolera, Jr.
Geologist

FRM/clc

S-5167 SOUTH PARK AVENUE, P.O. BOX 0913, HAMBURG, NY 14075, 716-649-8110, TELEFAX 716-649-8051

EMPIRE
SOILS INVESTIGATIONS INC.

SUMMARY OF LABORATORY TEST RESULTS

SCA/RMU-1
MODEL CITY, NEW YORK

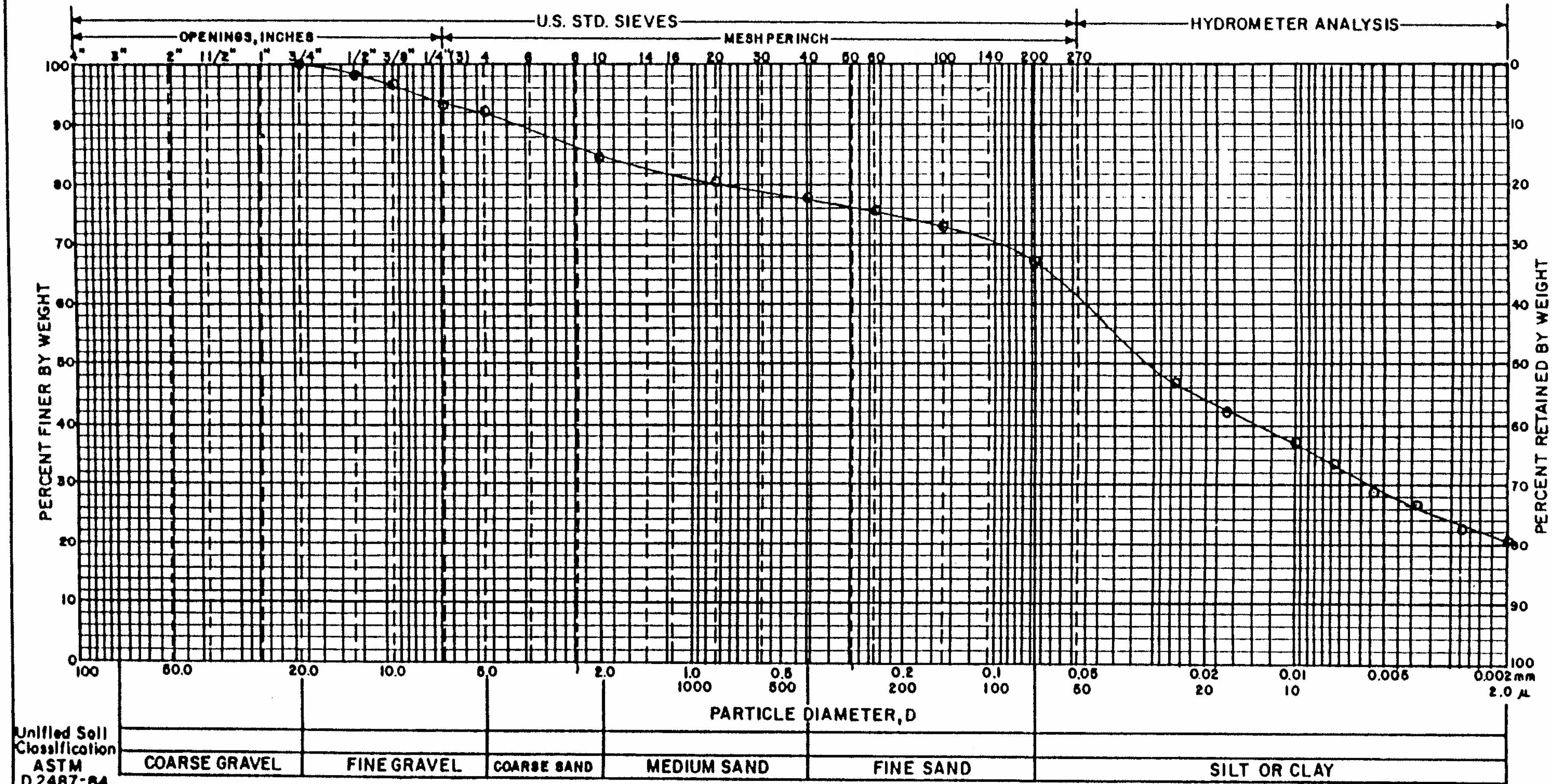
BORING NO.	SAMPLE NO.	SAMPLE DEPTH (FT)	NATURAL WATER CONTENT (%)	DRY UNIT WEIGHT (lbs/ft^3)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)
B-3-89	S-4	13.0-15.0	15.6	118.8	16.9	11.5	5.4
	S-7	25.0-27.0	22.7	106.9	--	--	--
B-4-89	S-6	10.0-12.0	39.6	81.8	--	--	--
	S-7	14.0-16.0	--	--	37.8	19.7	18.1
B-5-89	S-6	20.0-22.0	28.8	97.8	30.2	21.8	8.4
B-6-89	S-5	15.0-17.0	40.1	82.1	37.1	22.6	14.5
B-7-89	S-5	15.0-17.0	30.9	94.0	22.0	15.2	6.8
	S-7	20.0-22.0	31.3	92.4	--	--	--

BD-89-134

SCA-RMU.jfc

77.001

PARTICLE SIZE DISTRIBUTION CURVE



SAMPLE INFORMATION:

Boring No.	Sample No.	Sample Depth (ft.)
B-3-89	S-4	13.0-15.0

☐ Insufficient Sample Size per ASTM D 422

EMPIRE SOILS INVESTIGATIONS INC.

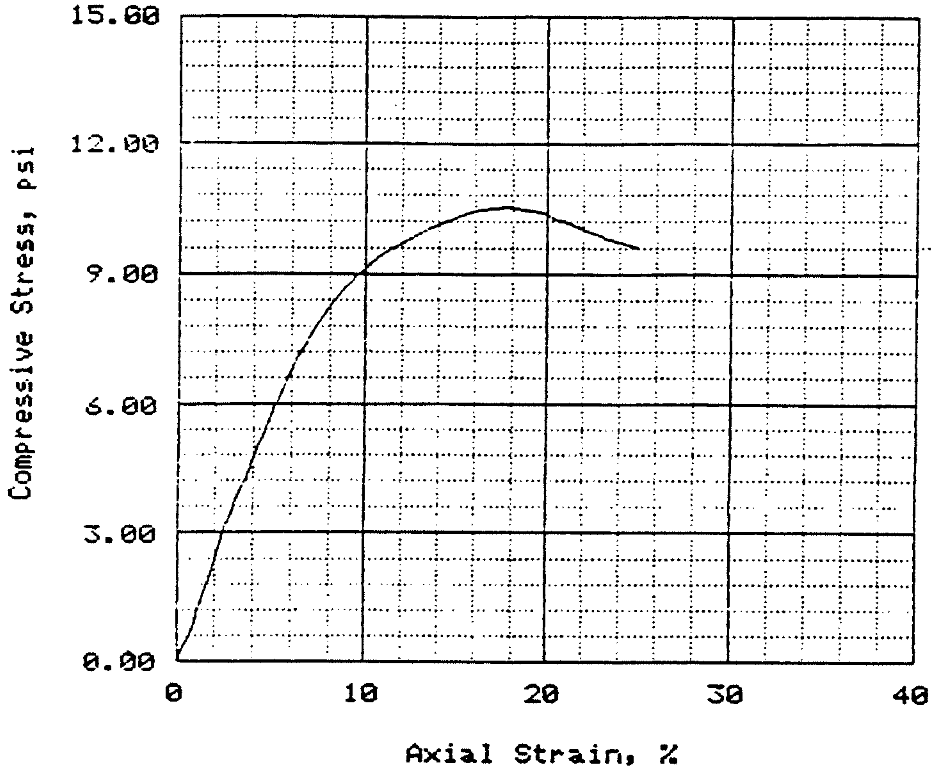
PARTICLE SIZE ANALYSIS

SCA/RMU-1
MODEL CITY, NEW YORK

DR. BY: JFC	CK'D. JFC	DATE: Dec. '89	PROJ. NO. BD-89-134

277.001

UNCONFINED COMPRESSION TEST



Sample number:	1			
Unconfined strength, psi	10.54			
Undrained shear strength, psi	5.27			
Rate of strain, %/min	0.799			
Water content, %	15.6			
Void ratio	0.6408			
Saturation, %	65.9			
Dry density, pcf	102.7			
Specimen diameter, in	2.88			
Specimen height, in	5.63			

Description: Brown CLAY & SILT, trace gravel

LL =	PL =	PI =	GS = 2.75	Type: 3" SHELBY TUBE

Project No.: BD-89-134
Date: 12-18-89
Remarks:

Client: DONOHUE & ASSOCIATES INC.

Project: SCA /RMU-1, MODEL CITY, NEW YORK

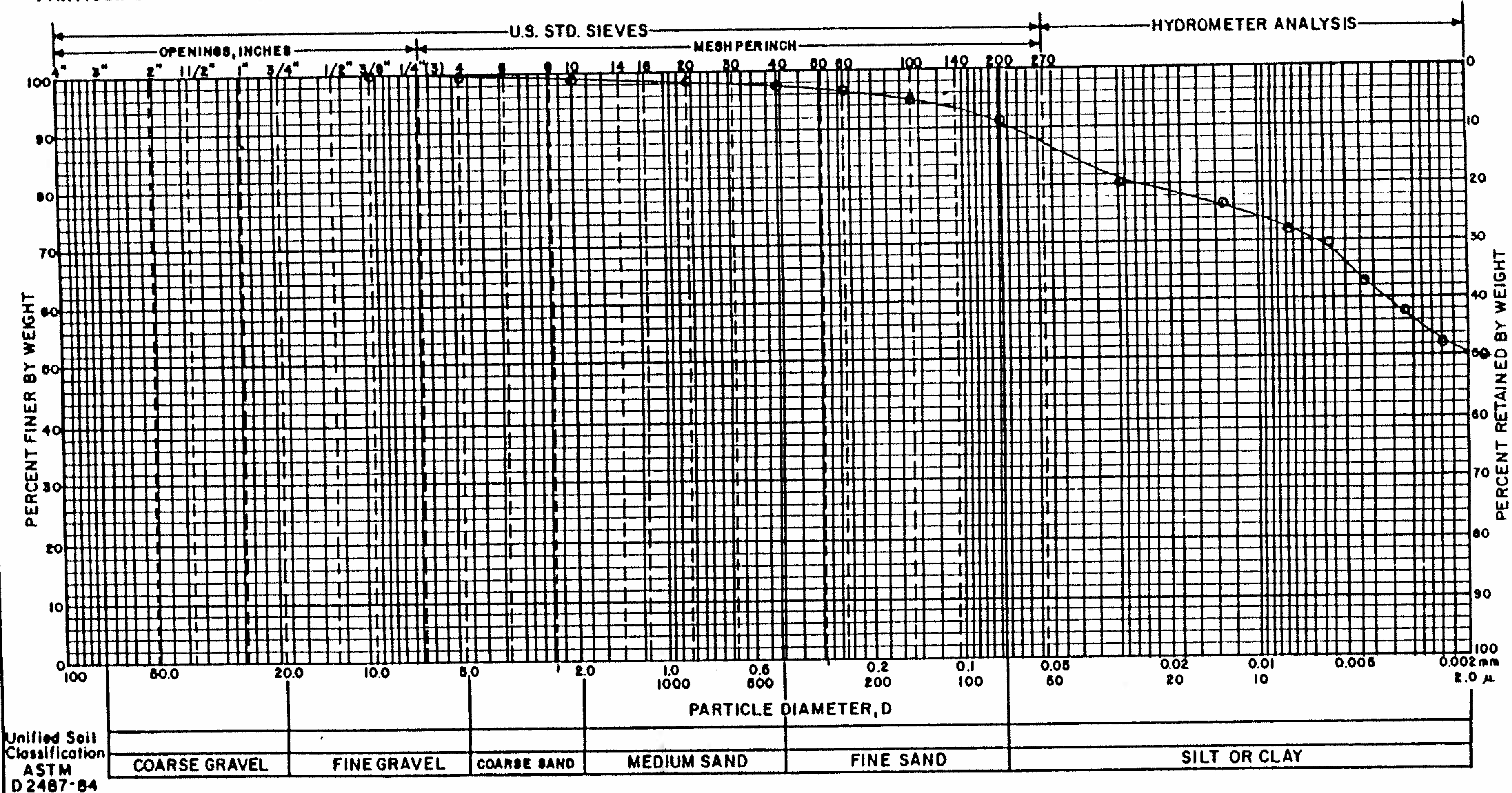
Location: BORING NO. B-3-89
S-4 13'-15'

UNCONFINED COMPRESSION TEST
Empire Soils Investigations, Inc.

Fig No.

77.003

PARTICLE SIZE DISTRIBUTION CURVE



SAMPLE INFORMATION:

Boring No.	Sample No.	Sample Depth (ft.)
B-4-89	S-7	14.0-16.0

☐ Insufficient Sample Size per ASTM D 422

EMPIRE SOILS INVESTIGATIONS INC

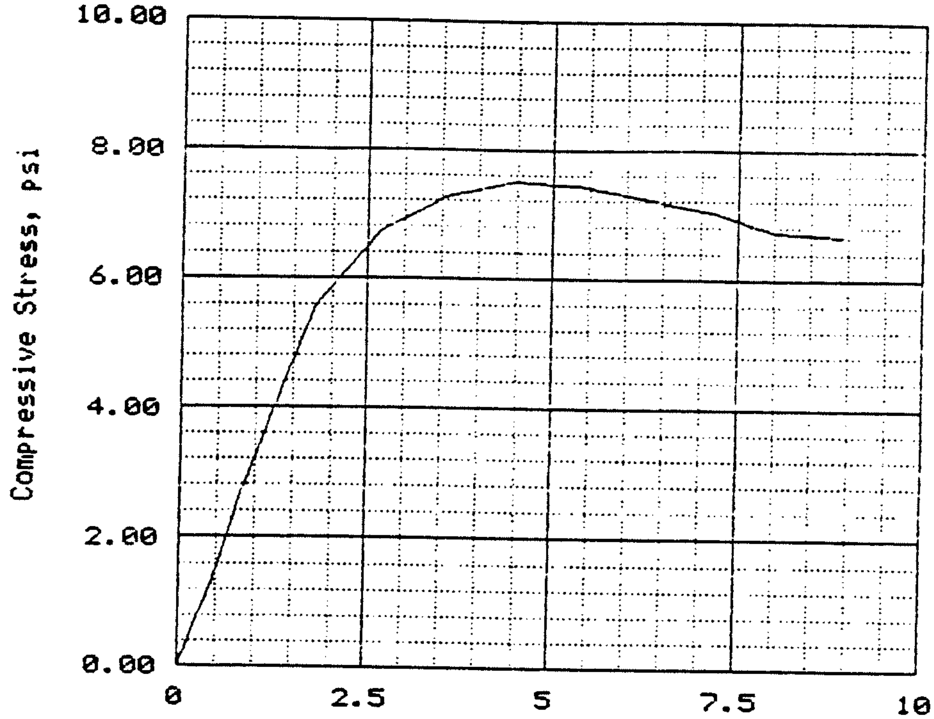
PARTICLE SIZE ANALYSIS

SCA/RMU-1
MODEL CITY, NEW YORK

DR. BY: JFC	CK'D. JFC	DATE: Dec. '89	PROJ. NO. BD-89-134

277.003

UNCONFINED COMPRESSION TEST



Sample number:	1			
Unconfined strength, psi	7.50			
Undrained shear strength, psi	3.75			
Rate of strain, %/min	0.801			
Water content, %	32.5			
Void ratio	0.8364			
Saturation, %	104.8			
Dry density, pcf	91.8			
Specimen diameter, in	2.81			
Specimen height, in	5.62			

Description: Brown CLAY & SILT, trace gravel & sand

LL =	PL =	PI =	GS = 2.75	Type: 3" SHELBY TUBE

Project No.: BD-89-134
Date: 12-18-89
Remarks:

Client: DONOHUE & ASSOCIATES INC.

Project: SCA / RMU-1, MODEL CITY, NEW YORK

Location: BORING NO. B-4-89
S-7 14'-16'

UNCONFINED COMPRESSION TEST
Empire Soils Investigations, Inc.

Fig No.

77.003

TEST DATA:

Specimen Height (cm):	11.32	
Specimen Diameter (cm):	6.99	
Dry Unit Weight (pcf):	89.7	
Moisture Content Before Test (%):	35.2	
Moisture Content After Test (%):	33.6	
Cell Confining Pressure (psi):	95.0	
Test Pressure (psi):	85.3	89.8
Back Pressure (psi):	80.0	79.8
Differential Head (psi):	5.3	10.0
Flow Rate ($\Delta V/t$)(cm^3/sec)	○ 4.67×10^{-5}	Δ 8.64×10^{-5}
Permeability (cm/sec):	○ 3.52×10^{-8}	Δ 3.55×10^{-8}

SAMPLE DATA:

Sample Identification: Boring B-4-89

Sample No. S-7, (14.0'-16.0')

Visual Description: Greyish-brown silt & clay.

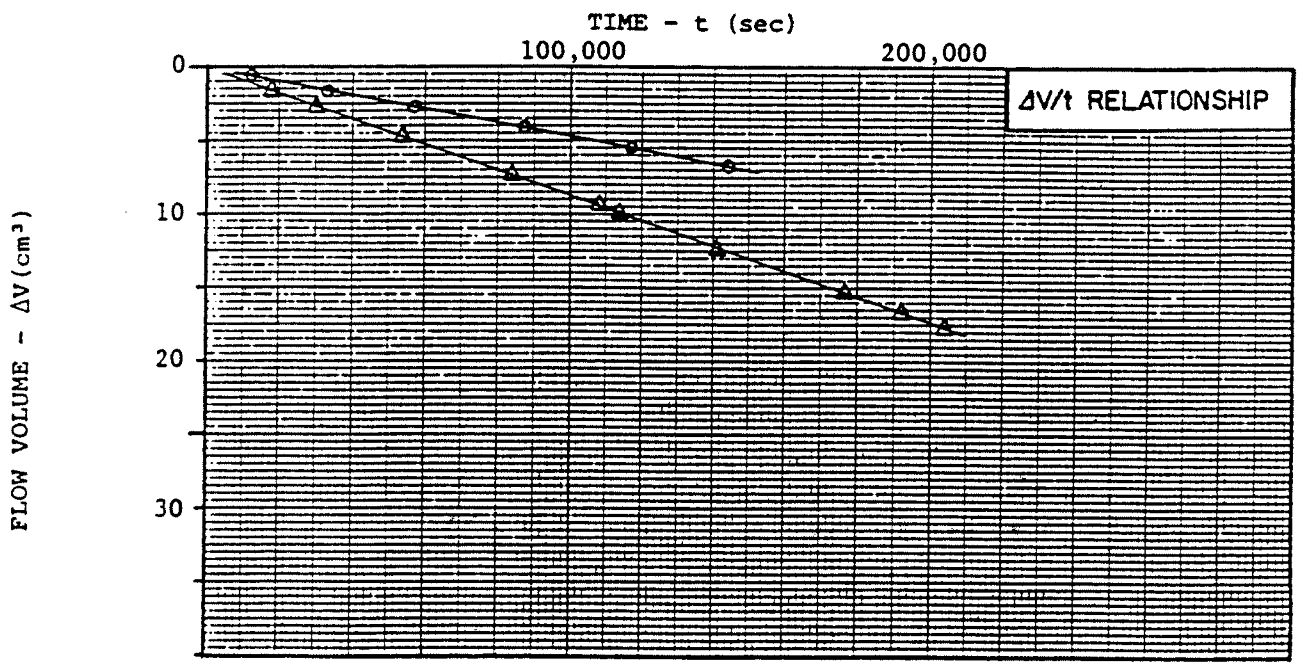
Remarks:

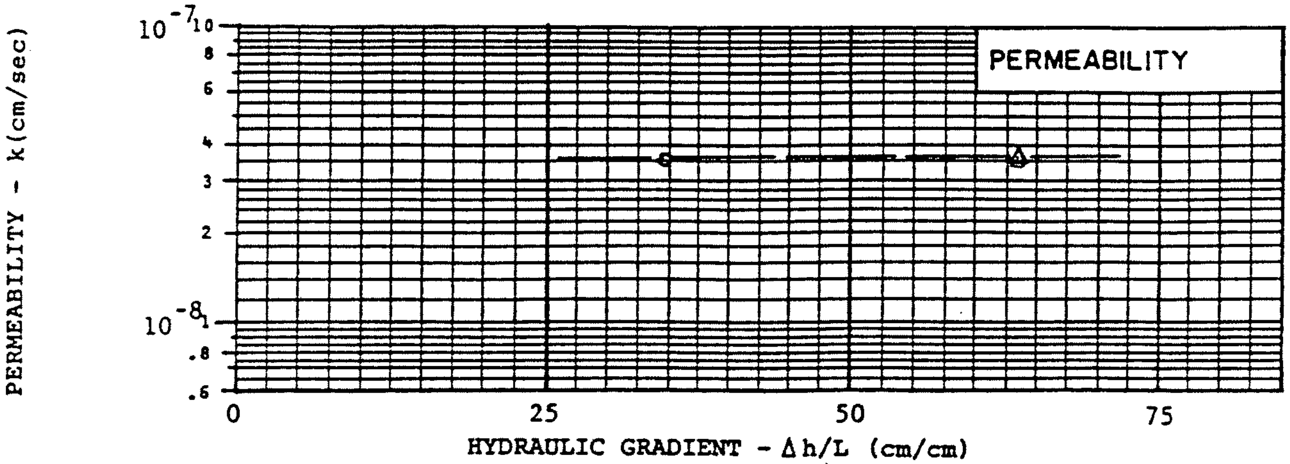
Maximum Dry Density (ASTM D _____) (pcf):

Optimum Moisture Content (%):

Percent Compaction:

Permeameter Type: Flexible wall.





EMPIRE SOILS INVESTIGATIONS INC

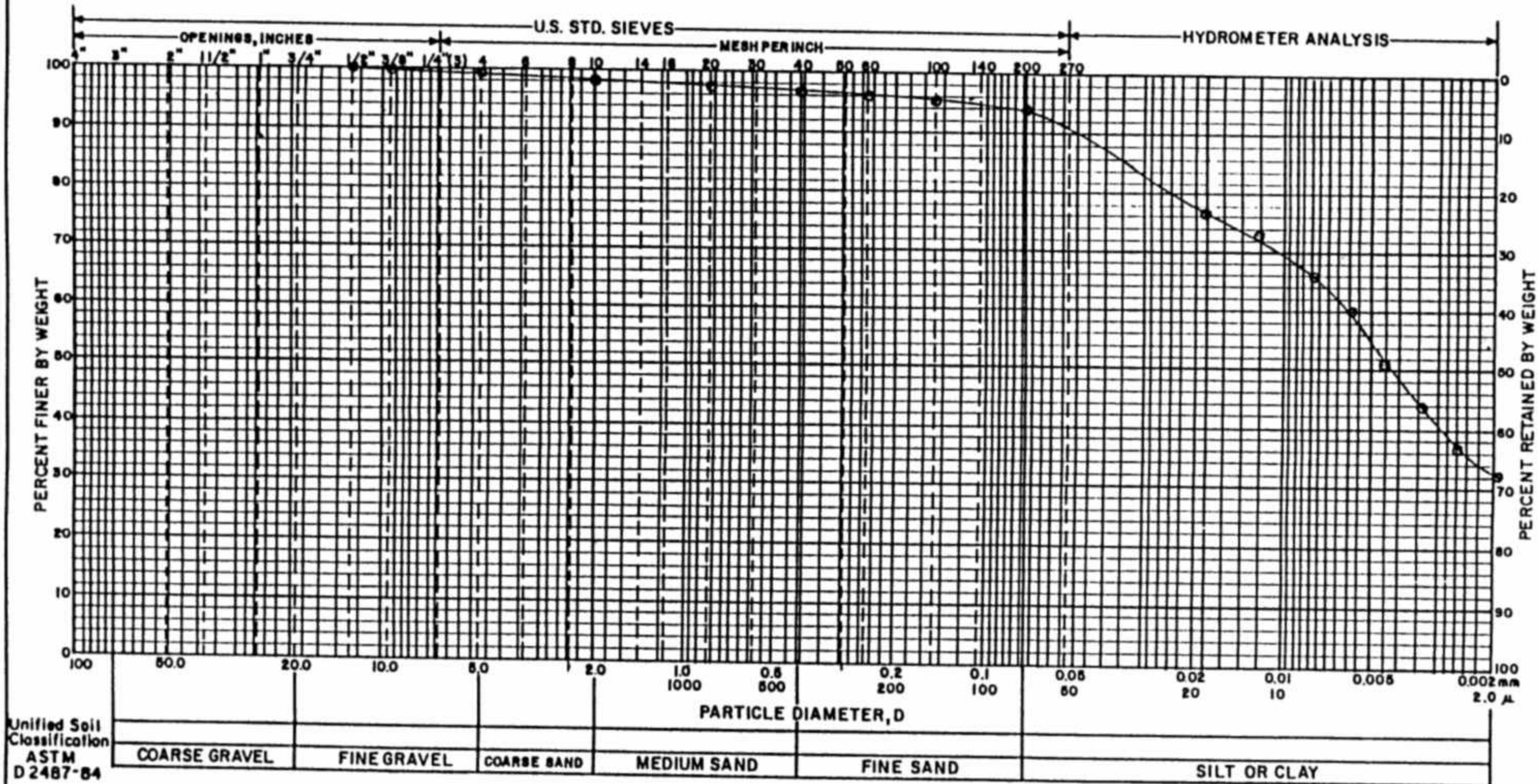
PERMEABILITY TEST REPORT

SCA/RMU-1
MODEL CITY, NEW YORK

DR BY:	CK'D.	DATE:	PROJ. NO.
JFC	JFC	Dec., 1989	BD-89-134

277.004

PARTICLE SIZE DISTRIBUTION CURVE



SAMPLE INFORMATION:

Boring No.	Sample No.	Sample Depth (ft.)
B-5-89	S-6	20.0-22.0

☐ In... t Sample Size per ASTM D 422

EMPIRE SOILS INVESTIGATIONS INC

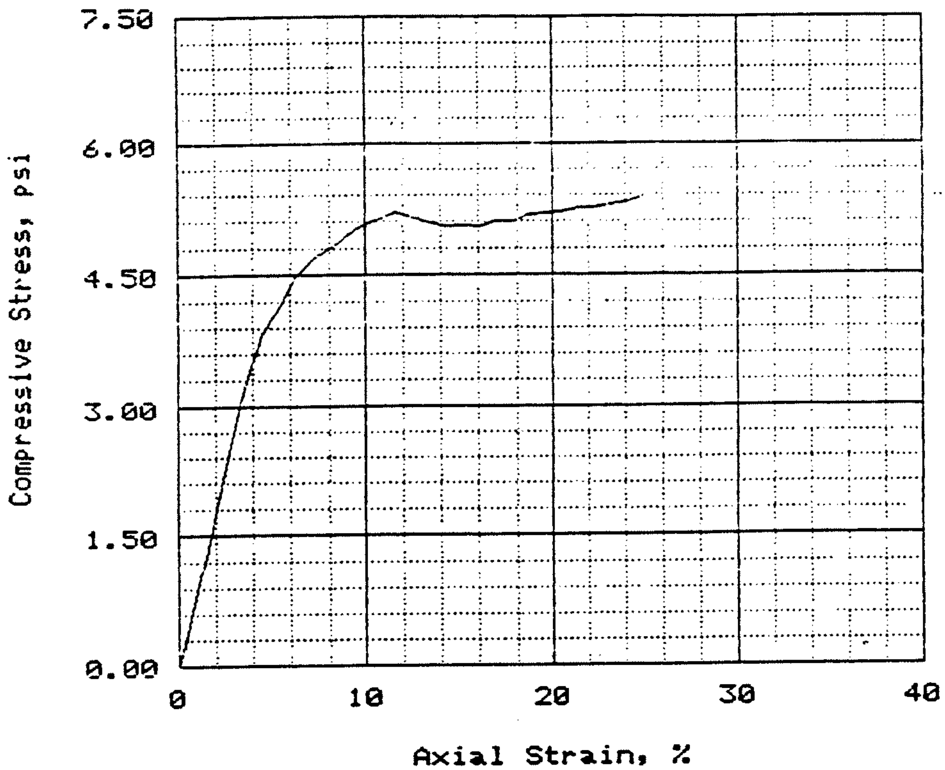
PARTICLE SIZE ANALYSIS

SCA/RMU-1
MODEL CITY, NEW YORK

DR. BY: JFC | CK'D. JFC | DATE: Dec '89 | PROJ. N... 89-13...

27

UNCONFINED COMPRESSION TEST



Sample number:	1			
Unconfined strength, psi	5.20			
Undrained shear strength, psi	2.60			
Rate of strain, %/min	0.800			
Water content, %	39.8			
Void ratio	1.0436			
Saturation, %	104.8			
Dry density, pcf	84.0			
Specimen diameter, in	2.83			
Specimen height, in	5.62			

Description: Brown CLAY & SILT

LL =	PL =	PI =	GS = 2.75	Type: 3" SHELBY TUBE

Project No.: BD-89-134
Date: 12-18-89
Remarks:

Fig No.

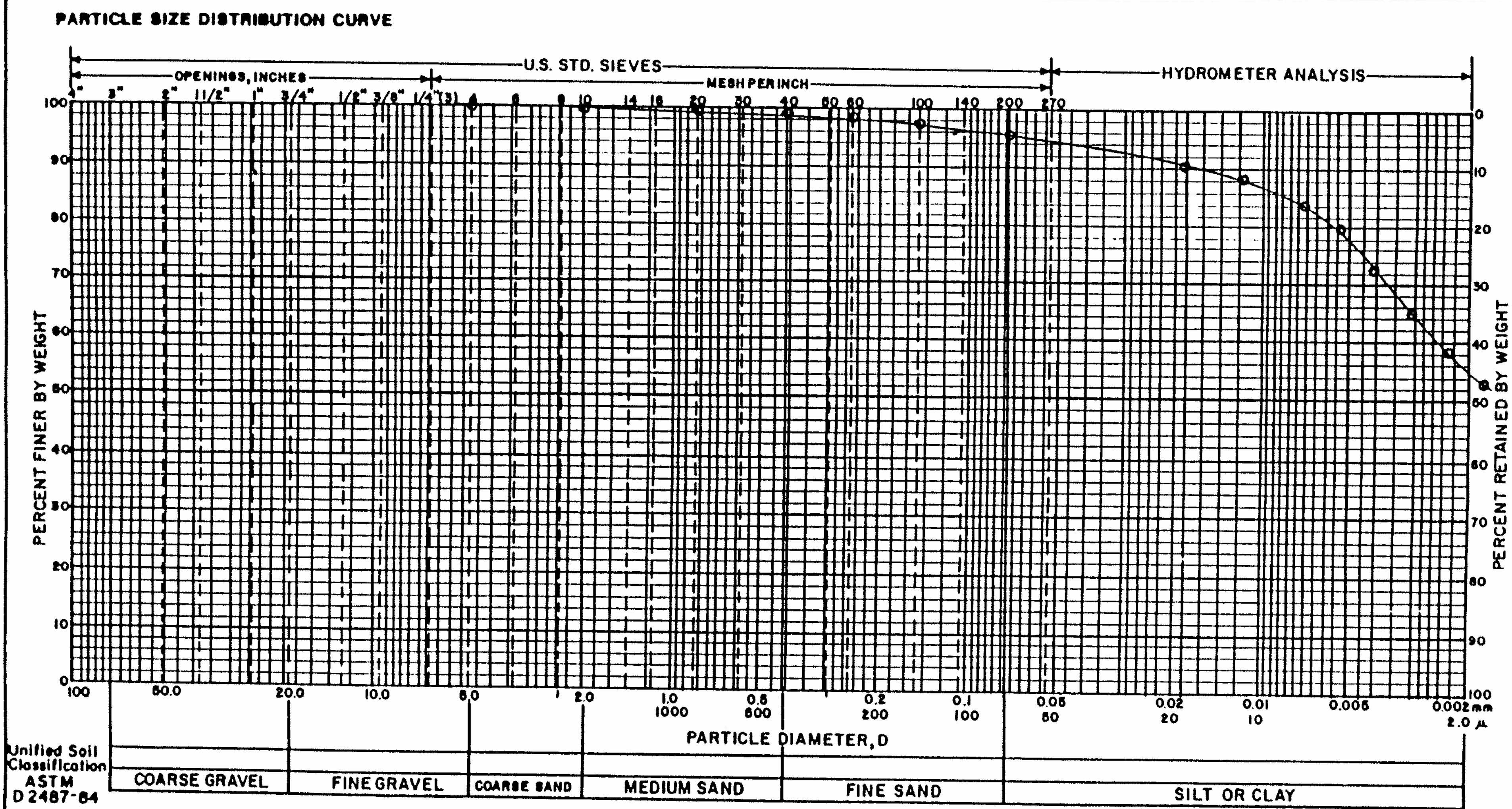
Client: DONOHUE & ASSOCIATES INC.

Project: SCA / RMU-1, MODEL CITY, NEW YORK

Location: BORING NO. B-5-89
S-6 20'-22'

UNCONFINED COMPRESSION TEST
Empire Soils Investigations, Inc.

277.005



SAMPLE INFORMATION:

Boring No.	Sample No.	Sample Depth (ft.)
B-6-89	S-5	15.0-17.0

☐ Insuffi... t Sample Size per ASTM D 422

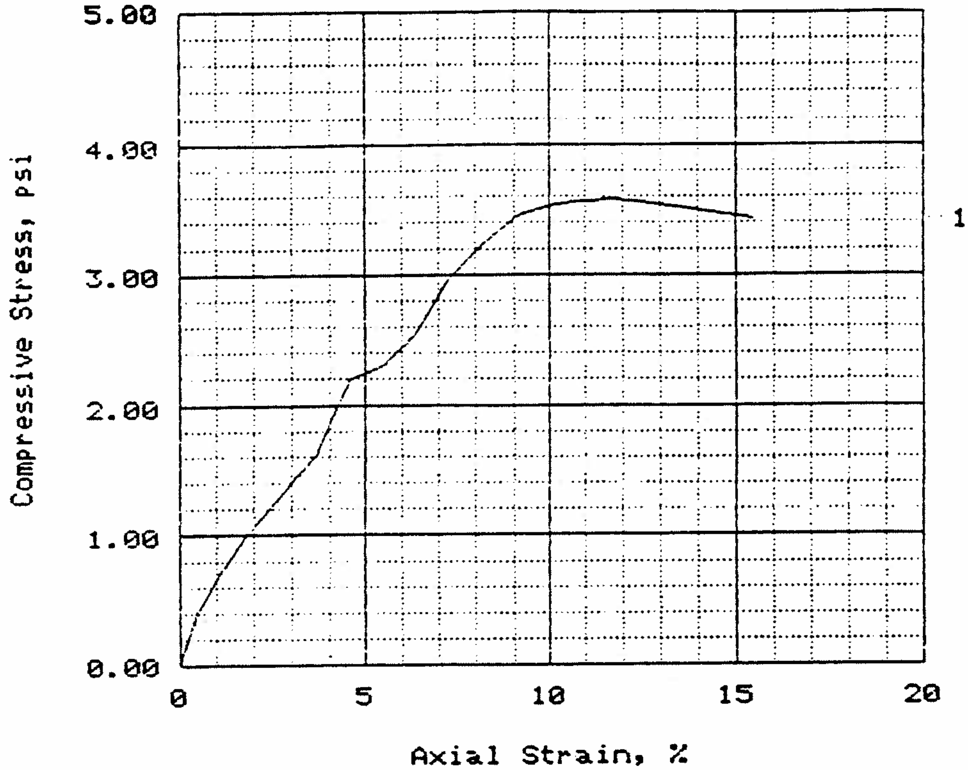
EMPIRE SOILS INVESTIGATIONS INC.

PARTICLE SIZE ANALYSIS

SCA/RMU-1
MODEL CITY, NEW YORK

DR. BY: JFC | CK'D. JFC | DATE: Dec. '89 | PROJ. N... 89-134

UNCONFINED COMPRESSION TEST



Sample number:	1			
Unconfined strength, psi	3.58			
Undrained shear strength, psi	1.79			
Rate of strain, %/min	0.818			
Water content, %	39.7			
Void ratio	1.0911			
Saturation, %	100.2			
Dry density, pcf	82.1			
Specimen diameter, in	2.81			
Specimen height, in	5.50			

Description: Brown CLAY & SILT

LL =	PL =	PI =	GS = 2.75	Type: 3" SHELBY TUBE

Project No.: BD-89-134
Date: 12-18-89
Remarks:

Fig No.

Client: DONOHUE & ASSOCIATES INC.

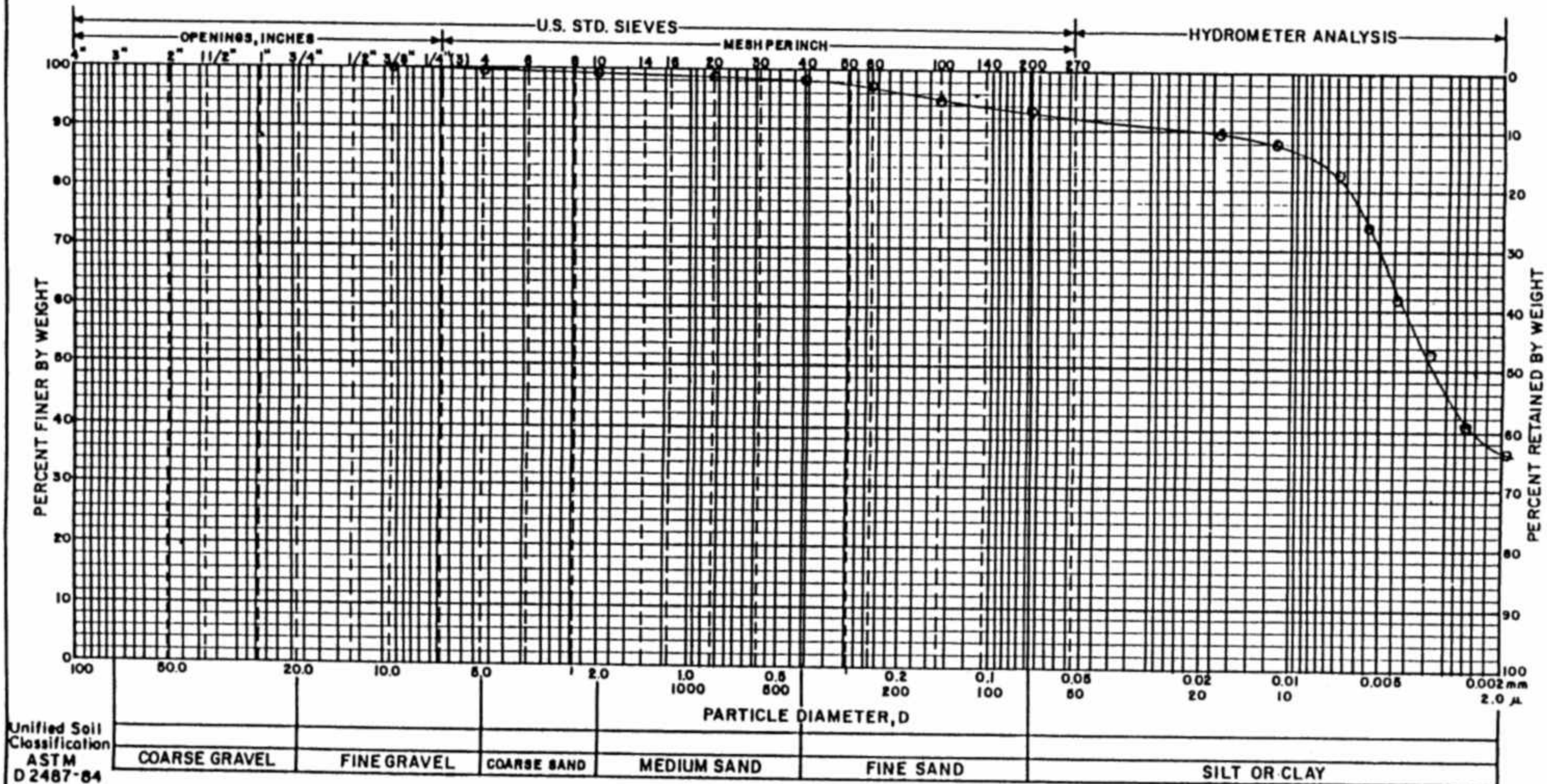
Project: SCA / RMU-1, MODEL CITY, NEW YOR

Location: BORING NO. B-6-89
S-5 15'-17'

UNCONFINED COMPRESSION TEST
Empire Soils Investigations, Inc.

277.007

PARTICLE SIZE DISTRIBUTION CURVE



SAMPLE INFORMATION:

Boring No.	Sample No.	Sample Depth (ft.)
B-7-89	S-5	15.0-17.0

☐ I[illegible] [illegible]nt Sample Size per ASTM D 422

EMPIRE SOILS INVESTIGATIONS INC

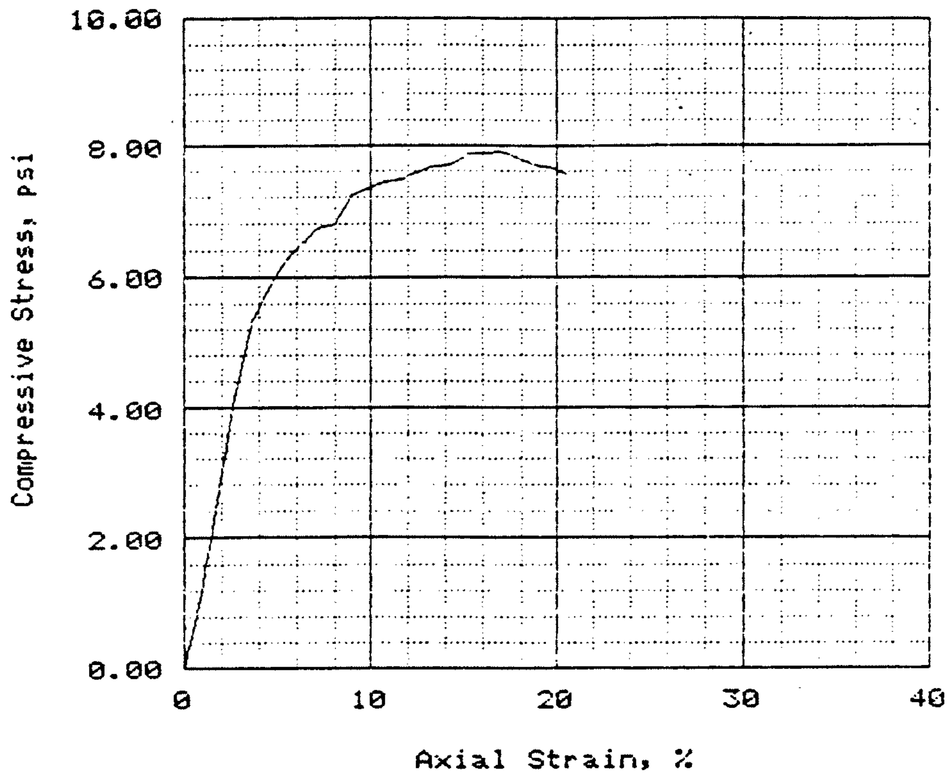
PARTICLE SIZE ANALYSIS

SCA/RMU-1
MODEL CITY, NEW YORK

DR. BY: [illegible] | CK'D. [illegible] | DATE: [illegible] | PROJ. N[illegible]

27..J07

UNCONFINED COMPRESSION TEST



Sample number:	1			
Unconfined strength, psi	7.90			
Undrained shear strength, psi	3.95			
Rate of strain, %/min	0.800			
Water content, %	31.0			
Void ratio	0.9543			
Saturation, %	89.3			
Dry density, pcf	87.8			
Specimen diameter, in	2.85			
Specimen height, in	5.62			

Description: Brown CLAY & SILT

LL =	PL =	PI =	GS = 2.75	Type: 3" SHELBY TUBE

Project No.: BD-89-134
Date: 12-18-89
Remarks:

Fig No.

Client: DONOHUE & ASSOCIATES INC.

Project: SCA / RMU-1, MODEL CITY, NEW YORK

Location: BORING NO. B-7-89
S-5 15'-17'

UNCONFINED COMPRESSION TEST
Empire Soils Investigations, Inc.

FINAL REPORT
SLUDGE STABILIZATION INVESTIGATION
UNCONSOLIDATED UNDRAINED
TRIAXIAL STRENGTH TESTING OF
STABILIZATION MIXES
MODEL CITY FACILITY

PER NO. 378-378-11

PERFORMED FOR:

CWM Chemical Services Inc.
P.O. Box 200
1550 Balmer Road
Model City, NY 14107

PERFORMED BY:

J&L Testing Company, Inc.
938 S. Central Avenue
Canonsburg, PA 15317

NOVEMBER, 1989

J & L TESTING COMPANY, INC.

GEOTECHNICAL, GEOMEMBRANE, GEOTEXTILE AND CONSTRUCTION MATERIALS TESTING AND RESEARCH

November 6, 1989

Project No. 89S466-01
PER No. 378-378-11

CWM Chemical Services, Inc.
P.O. Box 200
1550 Balmer Road
Model City, New York 14107

Attention: Mr. Joseph Pizzuto

RE: FINAL REPORT
SLUDGE STABILIZATION EVALUATION
UNCONSOLIDATED UNDRAINED TRIAXIAL
STRENGTH TESTING OF STABILIZATION MIXES
MODEL CITY FACILITY

Gentlemen:

In fulfillment with our proposal dated January 30, 1989 and subsequent revisions and clarifications made during the course of this testing program we are pleased to submit herein our final report of the sludge stabilization study.

Our work consisted of a comprehensive program of mixing six (6) designated sludges with stabilization materials, curing specimens for prescribed time periods and evaluating their engineering properties through a series of unconsolidated undrained triaxial tests. A description of the materials tested, preparation, curing and testing procedures are presented in the following sections.

MATERIALS OF INVESTIGATION

The materials supplied to our laboratory for this testing program were supplied in sealed five (5) gallon buckets obtained from CWM Chemical Services laboratory in Model City, New York. The samples were labeled as follows:

Material Description	I.D. Number
Allied - Amphenol Corp.	G71312-MDC
Eastman Kodak	M63483-MDC
General Electric	F62375-MDC
Harrison Radiator	H55059-MDC
Oneida Silversmith	F70531-MDC
Industrial Services Corp.	E57748-MDC

The stabilization material was Type I Cement derived from a local source and provided by CWM Chemical Services Inc.

MIX RATIOS

Stabilization mix ratios were prepared by CWM and supplied to our laboratory for this testing program. These mixes were as follows:

Sludge Material	Mix Ratio
Allied - Amphenol Corp.	1 lb. Sludge: 1/4 lb. cement
Eastman Kodak	1 lb. Sludge: 1/4 lb. cement
General Electric	1 lb. Sludge: 1/4 lb. cement
Harrison Radiator	1 lb. Sludge: 1/4 lb. cement
Oneida Silversmith	1 lb. Sludge: 1/4 lb. cement
Industrial Services Corp.	1 lb. Sludge: 1/4 lb. cement

PREPARATION AND TESTING PROCEDURES

Initially two (2) laboratory batches were prepared for each of the first five (5) waste streams using a ratio of one (1) pound of sludge to 1/4 pound of cement. The attached data Tables 1 and 2 labeled "Test 1" represents tests performed on batches cured at room temperature. Samples were extracted from the batches for strength testing (ASTM D-2850) at curing intervals of 1, 7 and 14 days.

The data labeled "Test 3" was performed to simulate the effect of placing and compacting the stabilized sludge within the landfill after the material is allowed to cure in the roll-off boxes at near room temperature for a maximum of three (3) days.

The "Test 3" laboratory batches were tested using the following general procedures:

1. The batches were allowed to cure at room temperature for one (1) day.
2. Samples were then extracted and trimmed for strength testing (ASTM D-2850).
3. The remaining material was remolded on the third day and allowed to cure four (4) days (the 7 day test) for the next test sequence.
4. The last set of tests were performed on the 14th day.

Additionally, an attempt was made to evaluate the effects of freezing on the strength of the first five (5) batches of stabilized sludge. The following presents our procedures and observations associated with this portion of the project known as Test Series 2.

1. The samples were mixed as prescribed.
2. The batch was bulk placed in a freezer at 25^{o}F to simulate exposure of the material in a roll-off box to subfreezing weather.
3. After 24 hours, three samples were extracted and trimmed for strength testing. The were then allowed to thaw to room temperature before performing unconsolidated undrained strength tests.
4. Upon testing, the ends of the samples crumbled and yielded little to no strength. However, the center of the sample was relatively strong compared to the ends which were exposed directly to the subfreezing temperatures. These test results are not presented due to their low strength.

To investigate the freezing problem further, we remixed batches and repeated the procedure. This time we extracted several samples, inspected the material under a 5X magnification and observed the following:

1. The end surfaces of the sample had frozen water crystals.
2. These crystals decreased in size and quantity the further they progressed into the sludge matrix.
3. In the center of the matrix, crystals were very few and small in size. (about 3 inches into the exposed surface).

From these observations we concluded that subfreezing conditions froze the water before it could react and hydrate with the cement. The first 3$\pm$ inches of penetration appeared to be the most critical after 24 hours of exposure to a 25^{o}F environment. Lower temperatures would most likely increase this depth of penetration.

By the direction of CWM we suspended the freezing portion of our testing program. Consequently, Test Series 2 is not presented.

The sixth batch, labeled E57748, was tested using the same procedures as Tests 1 and 3 for the first five (5) batches.

A more detailed outline of the preparation and test procedures is presented in Appendix G. Individual test results, raw data and test summaries are presented in Appendices A through F. As shown, testing consisted of

Unconsolidated Undrained Triaxial Tests per ASTM D-2850 generally using 1.85 inch diameter samples with a height to diameter ratio of of approximately 2.2.

DISCUSSION OF TEST RESULTS

It is obvious from the test results that the strength forming process of a sludge cement mixture is quite complex and highly dependent on the sludge components other than free water which reacts with the cement. The chemistry of this hydration process and the ancillary chemical reactions which either enhance or reduce strength were not addressed in this study. The focus of this work was to determine the total strength of the material at the end of 1, 7 and 14 days of curing to provide the engineer with appropriate strength data for stability evaluations.

A. General Observation

Our general observations are as follows:

1. Each sludge varies in strength with the same quantity of cement stabilizer. The rate of strength gain and ultimate strength over a 14 day period varies depending on the sludge components and the chemistry associated with the curing process.

2. In general, the higher the water content the lower the strength for the same sludge cement mixture.

3. Low temperatures (below freezing) tends to freeze the free water precluding it from hydrating with the cement. This was evidenced in the Series 2 tests which were discontinued.

4. Curing time is critical to fully develop strength of the mixture.

5. Sample disturbance after the first three days of curing tends to reduce the ultimate strength of the sludge probably due to the breaking of material bonds between the hydrated cement and the sludge.

6. All six streams of unstabilized sludge received in buckets were relatively firm when the material was left undisturbed. There was no apparent free water on the surface of the sample. Once the material was

removed from the buckets and placed in the grout mixer the strength decreased rapidly. The material became soft, developed free water and became a viscous liquid.

7. Adding cement to the grout mixer greatly reduced the material viscosity, eliminated free water and stiffened the material noticeably.

8. The hydration (strength gaining) process visually appeared to develop almost immediately once the material was compacted in the mold.

B. Series No. 1 Test Results

As shown by the test data on Tables 1 and 2, Series 1 tests were not subjected to remolding during the curing period and developed a considerable gain in strength with age. At 14 days of curing, the Eastman Kodak and Oneida Silversmith sludges became extremely hard and broke much like a concrete cylinder. It is pertinent to note that very little change in water content was noted over the 1, 7 and 14 day period indicating that initial hydration was substantially accomplished during the first 24 hours of curing. The remaining strength gain can be attributed mostly to the curing of the sludge and cement. Similar strength gains were also noted with the other materials but exhibited breaks more closely resembling soils with a cohesion and friction angle.

C. Series No. 3 Test Results

From Tables 1 and 2 it can be seen that the strength of the sample decreased after remolding. However, much of the strength was regained after a period of curing. On the 4th day after remolding (7 day age), the strength of some samples (Allied- Amphenol, Eastman Kodak, Harrison Radiator and General Electric) regained and exceeded or were close to that of the samples tested after one day of curing. Only the materials representing the Oneida Silversmith and Industrial Services sludges had strengths less than the one day strengths after 7 days of curing. Of all the samples tested with the prescribed mix ratio, the only material to have low strength gain after remolding and 14 days of curing was the Industrial Service Corporation sludge. This material also had the highest material water content. We could not perform 14 day tests on the Allied Amphenol or the Eastman Kodak sludges due to the lack of available materials. However, extrapolation of the 1 and 7 day tests leads to the conclusion that acceptable strength values would likely be achieved if 14 day tests could have been performed.

D. Comparison of Test 1 and Test 3 Data

Although there were slight differences in water contents between the buckets used for Tests 1 and 3 of the sludge samples, a number of comparisons can be made.

1. Since the 1 day (24 hours) tests were performed under the same non-remolded conditions for both test series, the only difference in strength data should be related to differences in moisture content and inherent variability of the materials. Table 2 can be used to make these comparisons.

2. After 7 days of curing, strength gains would continue to occur for Test Series 1 with a commensurate loss in strength for Test Series 3 due to remolding on the 3rd day of curing. This loss of strength due to remolding is clearly shown on Table 2 for Test Series 3. Obviously, material variability must be considered in this comparison.

3. After 14 days of curing, strength gains continued to occur for Test Series 1. (See Table 1 and 2) This is as expected because there was no remolding of the materials. For Test Series 3, strength gains generally increased but the data is less consistent probably due, in part, to remolding and variability of the materials and moisture content.

CONCLUSIONS

Based on the aforementioned discussion, the following conclusions can be drawn from this study.

1. If the material is subjected to freezing before it is placed in the landfill, substantial losses in strength are expected.

2. The addition of cement at a ratio of 1 lb. sludge to 1/4 lb cement realizes substantial gains in strength over a 14 day period of curing.

3. The strength of the sludge after 14 days is directly related to its ability to cure without disturbance or remolding.

4. Unnecessary disturbance of the sludge should be avoided to maximize the ability of the material to develop its full strength.

5. Available water for curing is critical in developing strength for the proposed design mixes. Based on this study, it appears that substantial increases in strength can be realized for the Industrial Services Corporation sludge if the delivered moisture content is lowered or the cement content is increased. From an economic view point, decreasing the moisture content would be preferrable if the stabilization process is fixed for all sludges (1 lb. sludge to 1/4 lb cement). Otherwise, the process may have to be adjusted when this stream arrives at the site for processing.

6. Based on the data developed in this study a conservative set of design strength values would be as follows:

   Cohesion = 800 psf
   Friction = 13.5 degrees

   See Figure 1 for a summary of strength characteristics.

   When using these properties consideration should be given to the placement of Industrial Service Corporation stabilized sludge into areas of the landfill outside the limits affected by slopes and the stability of the landfill. Alternately, the process can be adjusted to increase the strength of this material with additional cement provided the chemistry of the waste does not adversely affect the curing process. More research is necessary for this material.

The test results presented herein represent the strength characteristics of the delivered materials stabilized with Portland cement (Type 1) provided by CWM Chemical Services Inc. Care should be taken to monitor the streams of waste as they are delivered. Substantial deviations in water content or chemistry of the waste streams could yield different properties from these tested.

Sincerely,

J&L TESTING COMPANY, INC.

John Boschuk, Jr., PE, REP
President

JBJ/dlz
L-D#108
Enclosures

EMPIRE
SOILS INVESTIGATIONS INC.

SUBSURFACE INVESTIGATION REPORT
S.C.A. - SECURE LANDFILL #13
MODEL CITY, NEW YORK

for

DONAHUE AND ASSOCIATES
4738 NORTH 40TH STREET
SHEBOYGAN, WISCONSIN 53081

BD-88-52
June 1988

Check Kepson

S-5167 SOUTH PARK AVENUE, P.O. BOX 0913, HAMBURG, NY 14075, 716-649-8110

EMPIRE SOILS INVESTIGATIONS INC.

SUBSURFACE INVESTIGATION REPORT
SCA - SECURE LANDFILL #13
MODEL CITY, NEW YORK

I. INTRODUCTION

The following report presents the results of our firm's subsurface investigation performed on April 11 through April 19, 1988 at the site of the proposed S.C.A. Secure Landfill #13, S.C.A., Model City, New York. The program was divided into two phases. Phase I being the field investigation and Phase II the laboratory testing.

The test boring program was requested and authorized by Mr. Michael Reutten of Donahue and Associates, 4738 North 40th Street, Sheboygan, Wisconsin, 53081. Test boreholes were located in the field by Mr. Mark Powers of Donahue Associates at locations as indicated on the Test Boring Location Plan which is attached as part of this report. The site is presently an undeveloped parcel of land located within the S.C.A. facility.

II. METHOD OF INVESTIGATION

Standard drilling techniques were employed to advance the hollow stem augers through the overburden soils. Representative soil samples were obtained by driving a two (2) inch outside diameter split spoon sampler into the undisturbed soils beneath the augers, using a 140 pound drive hammer falling 30 inches. Data regarding compactness and consistency of the overburden soils are related to the penetration resistance of the standard split spoon, in accordance with the "Standard Penetration Test" (ASTM D-1586).

Standard sampling techniques were also employed to obtain 3" undisturbed samples (Shelby Tubes) from various depths. A total of fifteen attempts were made at obtaining undisturbed samples with a total of thirteen samples recovered. These recovered samples were waxed and sealed in the field by the driller, and returned to our office.

A total of ten bag samples were obtained by Mr. Powers from the borings. These bag samples consisted of auger returns from various depths in the upper soil strata.

All recovered samples were classified in the field by our drill foreman, and transported to our Hamburg, New York office where visual classification was performed by a geologist. Included with this report is our "General Information and Key to Subsurface Logs" as a supplement to explain the terms, symbols, and definitions which are utilized in our visual classification.

Included with this report are the results of the soils testing program performed by our laboratory as per Mr. Powers instructions. All testing was performed according to ASTM specifications. These results are tabulated in Appendices "A" through "D" of this report.

Please note that the triaxial test results will be provided as soon as the testing has been completed.

III. SUBSURFACE CONDITIONS

The general subsurface conditions encountered at the site consist of interbedded sands, silts, and clays. Depths of boring completion ranged from 32.0 feet below grade in borings B-3, B-9, and B-10 to 42.9 feet below grade in boring B-1.

Free standing water was encountered at depths ranging from 8.0 feet below grade in B-2 to 31.0 feet below grade in B-9 at time of completion. No free standing water was encountered in borings B-4, B-5, B-7, and B-8 at time of completion. It should be noted that all borings were backfilled with bentonite grout at time of completion.

The stratification lines shown on the boring logs are approximate, where in-situ the changes between strata may be more gradual. The subsurface information represented by the attached logs indicates conditions present only at the time and location of the investigation. Variations may be encountered in subsurface conditions that are not evident due to the location or depth of test boreholes.

The following pages contain data recorded in the field by the drill foreman and test data established within our laboratory. This data, along with the recovered samples and their visual classification , constitutes the subsurface investigation report.

All recovered samples will be retained for a maximum of sixty (60) days, at which time the samples will be destroyed unless otherwise directed.

EMPIRE
SOILS INVESTIGATIONS INC.

Empire Soils Investigations, Inc. is a full service organization which can supplement this report with additional services in the areas of foundation design, environmental assessments and construction quality control.

If you have any questions, please contact our office at any time.

EMPIRE SOILS INVESTIGATIONS, INC.

Frank R. Minnolera Jr.

Frank R. Minnolera, Jr.
Geologist

bjl
Enc.

APPENDIX A

LABORATORY TESTING RESULTS
SCA - SECURE LANDFILL #13

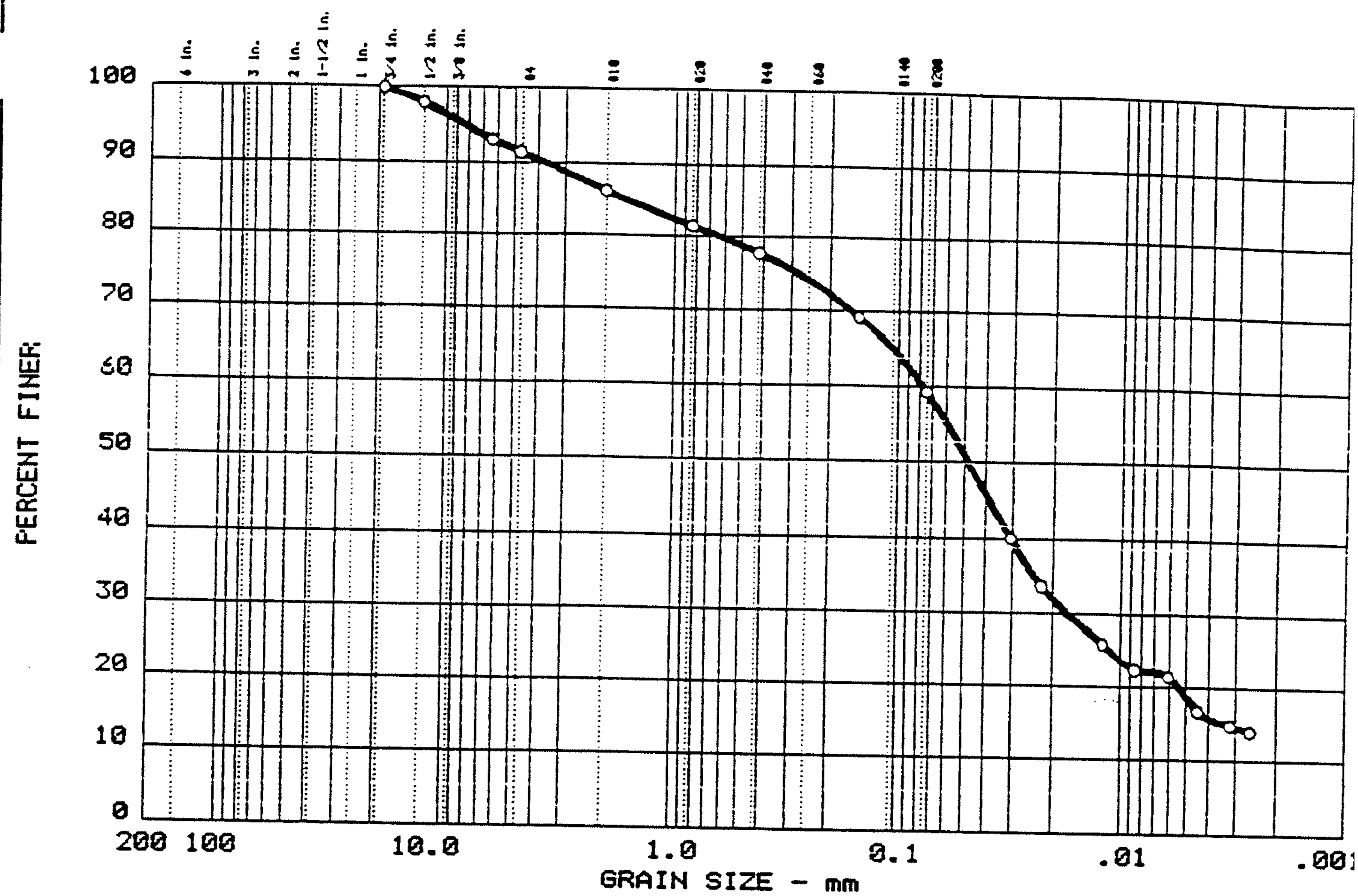
BAG SAMPLES

APPENDIX "A"

TABLE 1

SAMPLE	DEPTH	PHYSICAL COMPONENTS GRAVEL	SAND	FINES	ATTERBERG LIMITS LIQUID LIMITS	PLASTIC INDEX
B-4	2-3'	8.6%	32.2%	59.2%	17	1
B-4	3-10'	5.1%	27.2%	67.7%	18	3
B-5	2-5'	1.5%	17.1%	81.4%	31	11
B-6	3-7'	2.1%	13.0%	84.9%	25	9
B-7	2-7'	1.0%	15.9%	83.1%	26	8
B-8	5-8'	0.1%	5.3%	94.6%	19	0
B-9	4-8'	1.5%	14.2%	84.3%	29	12

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	2	0.0	8.6	32.2	40.7	18.5

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
O	17	1	1.58	0.08	0.05	0.017	0.0034			

MATERIAL DESCRIPTION	USCS	AASHTO
O SILT SOME SAND LITTLE CLAY TRACE GRAVEL	ML	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
O Location: BORING B-4, 2'-3'

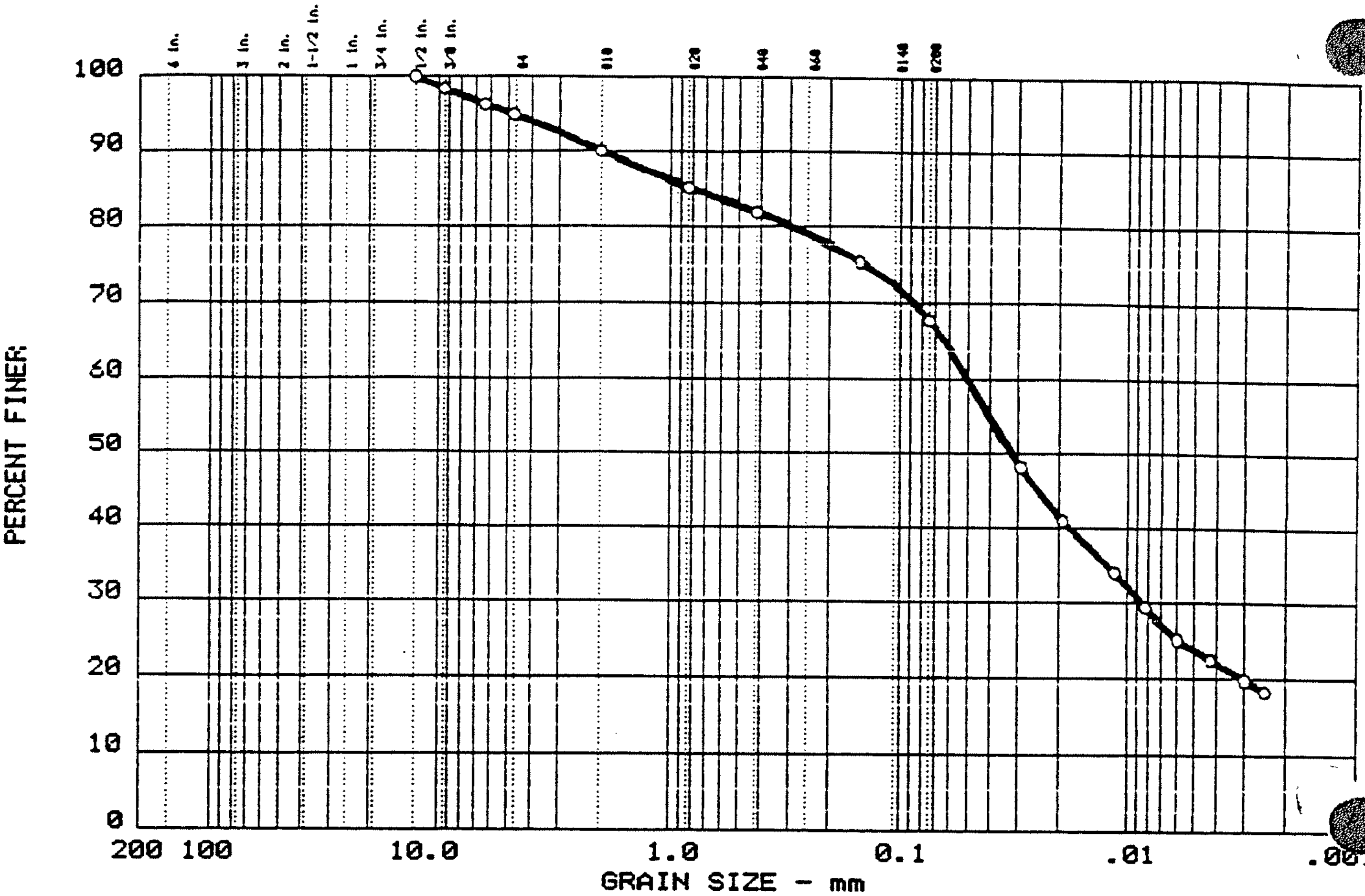
Date: 6-27-88

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Remarks:
BAG SAMPLE COLLLECTED
FROM AUGER CUTTINGS

Fig. No. 1

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
o	3	0.0	5.1	27.2	44.1	23.6

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
o	18	3	0.80		0.03	0.009				

MATERIAL DESCRIPTION	USCS	AASHTO
o SILT SOME SAND SOME CLAY TRACE GRAVEL	ML	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
o Location: BORING B-4, 3'-10'

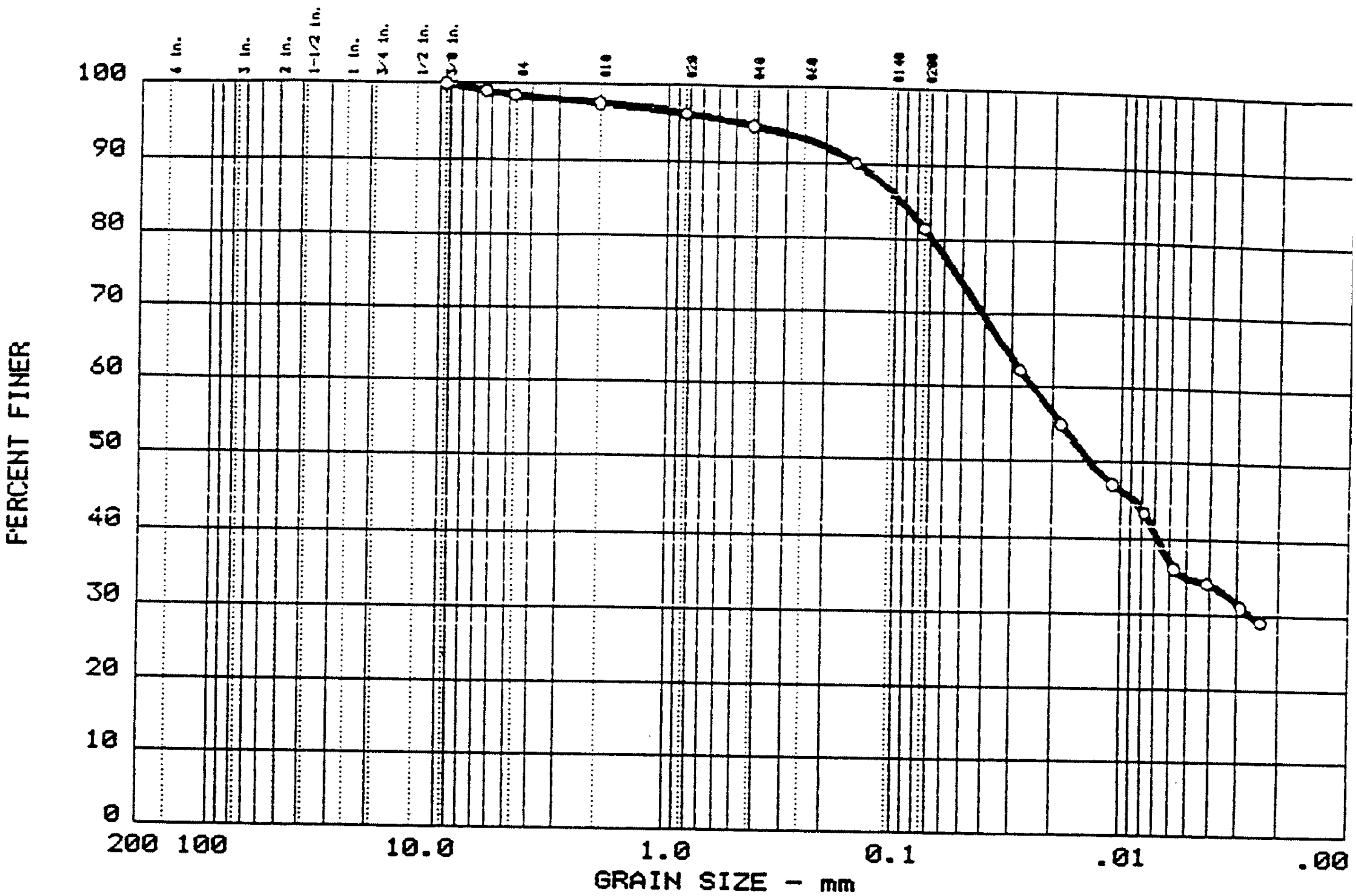
Date: 6-27-88

Remarks:
BAG SAMPLE COLLLECTED
FROM AUGER CUTTINGS

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Fig. No. 2

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
○	4	0.0	1.5	17.1	46.7	34.7

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	31	11	0.09		0.01	0.003				

MATERIAL DESCRIPTION	USCS	AASHTO
○ SILT SOME CLAY LITTLE SAND TRACE GRAVEL	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
○ Location: BORING B-5, 2'-5'

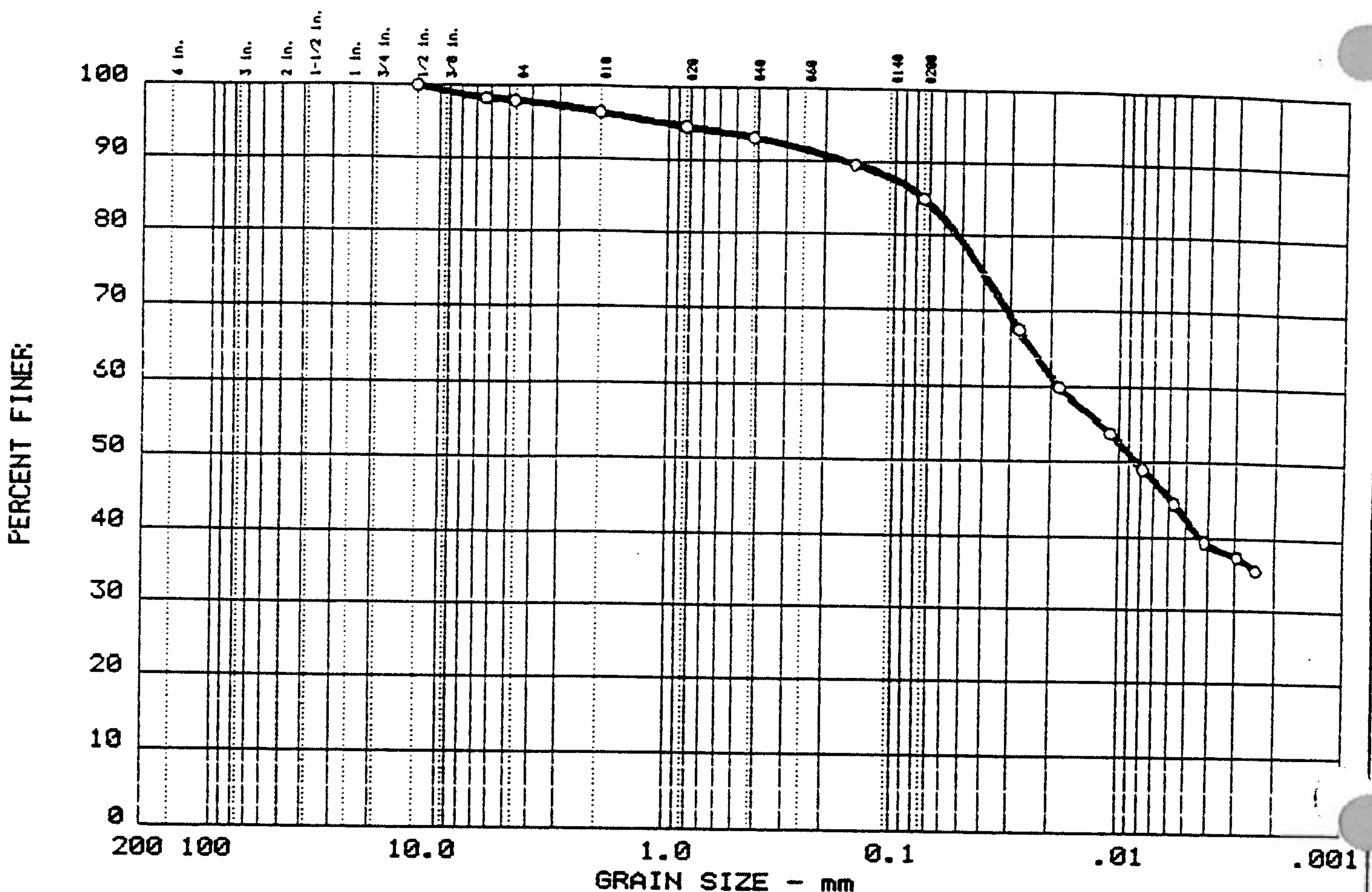
Date: 6-27-88

Remarks:
BAG SAMPLE COLLLECTED
FROM AUGER CUTTINGS

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Fig. No. 3

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
○	5	0.0	2.1	13.0	42.7	42.2

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	25	9	0.07		0.01					

MATERIAL DESCRIPTION	USCS	AASHTO
○ SILT AND CLAY LITTLE SAND TRACE GRAVEL	CL	
	–	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
○ Location: BORING B-6, 3'-7'

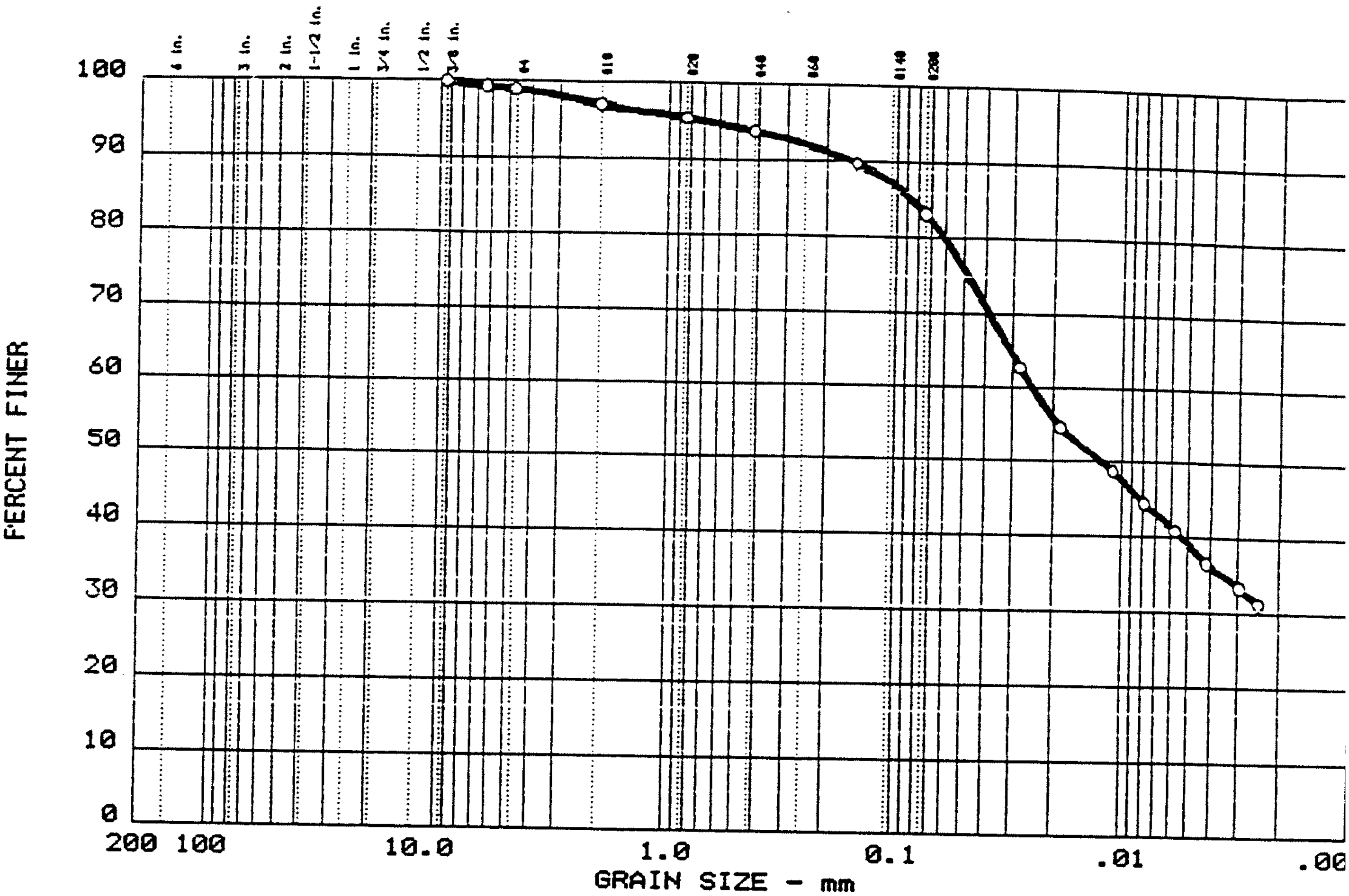
Date: 6-27-88

Remarks:
BAG SAMPLE COLLLECTED
FROM AUGER CUTTINGS

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Fig. No. 4

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	6	0.0	1.0	15.9	44.2	38.9

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
O	26	8	0.09		0.01					

MATERIAL DESCRIPTION	USCS	AASHTO
O SILT CLAY LITTLE SAND TRACE GRAVEL	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
O Location: BORING B-7, 2'-7'

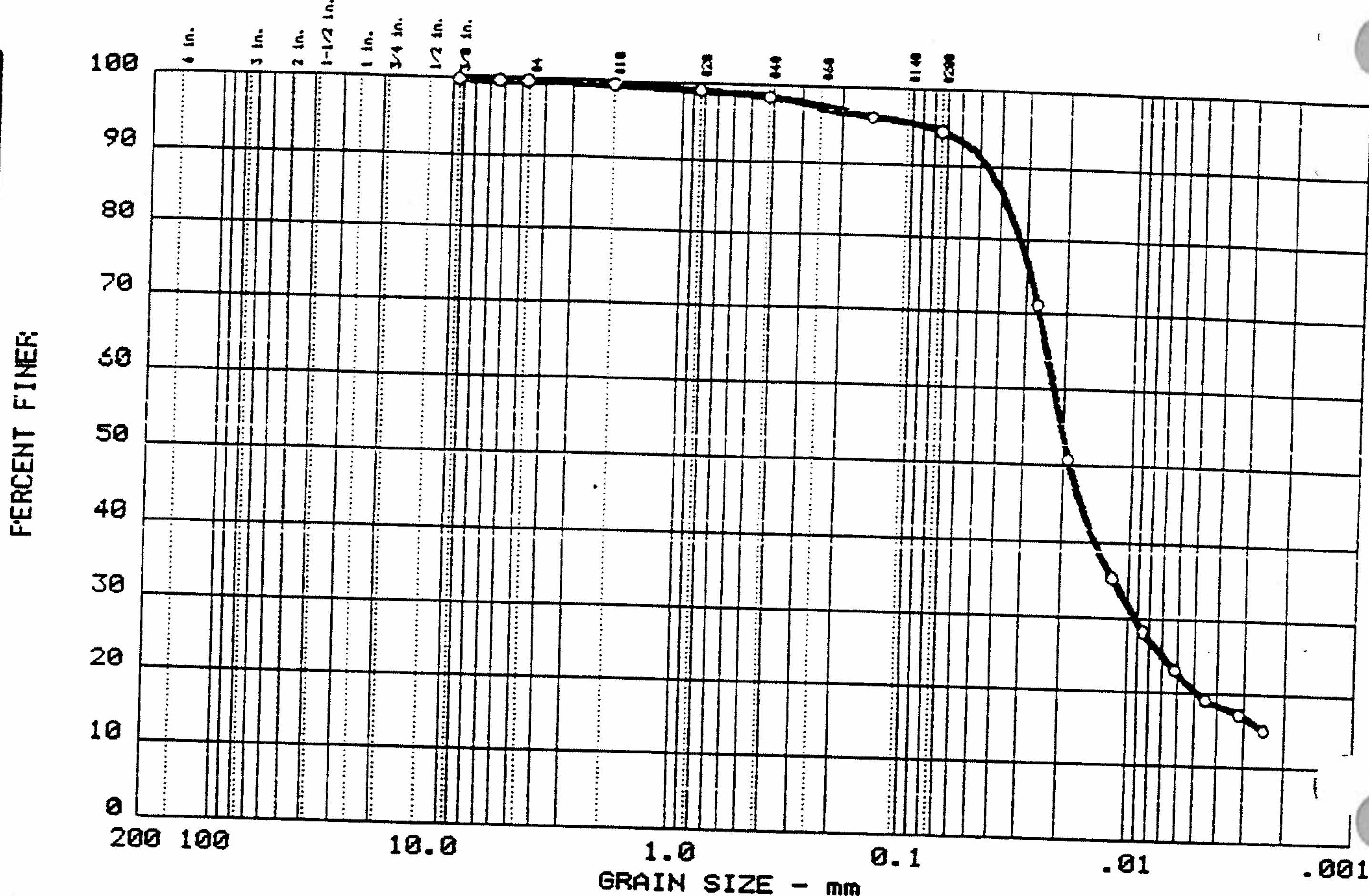
Date: 6-27-88

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Remarks:
BAG SAMPLE COLLLECTED
FROM AUGER CUTTINGS

Fig .No. 5

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
○	7	0.0	0.1	5.3	74.4	20.2

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	19				0.02	0.009				

MATERIAL DESCRIPTION	USCS	AASHTO
○ SILT SOME CLAY TRACE SAND	ML	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
○ Location: BORING B-8, 5'-8'

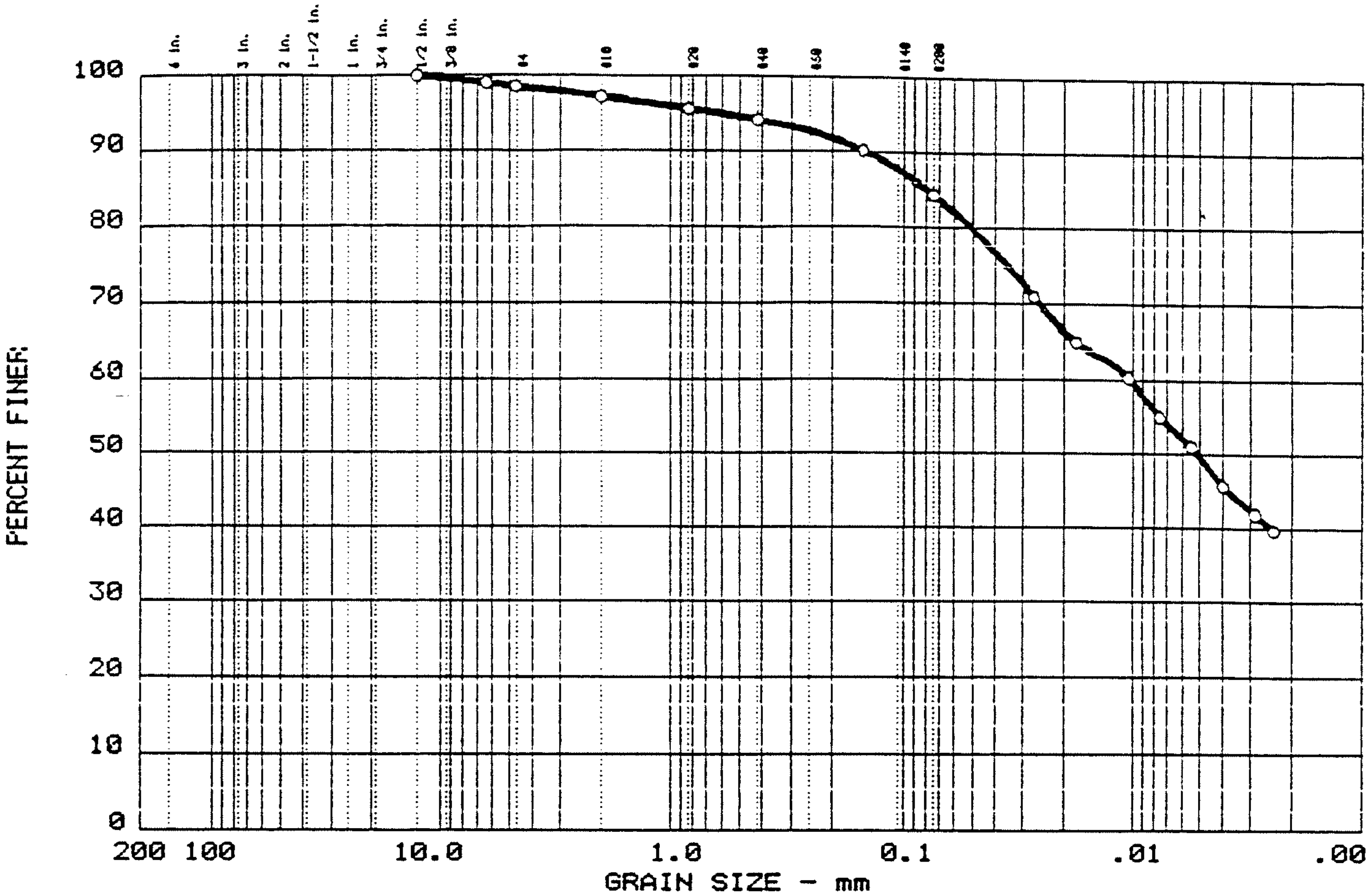
Date: 6-27-88

Remarks:
BAG SAMPLE COLLLECTED
FROM AUGER CUTTINGS

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Fig. No. 6

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	8	0.0	1.5	14.2	34.8	49.5

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
O	29	12	0.08		0.01					

MATERIAL DESCRIPTION	USCS	AASHTO
O CLAY SOME SILT LITTLE SAND TRACE GRAVEL	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
O Location: BORING B-9, 4'-8'

Date: 6-27-88

Remarks:
BAG SAMPLE COLLLECTED
FROM AUGER CUTTINGS

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Fig. No. 7

APPENDIX B

LABORATORY TESTING RESULTS
SCA - SECURE LANDFILL #13

SHELBY TUBES

APPENDIX "B"

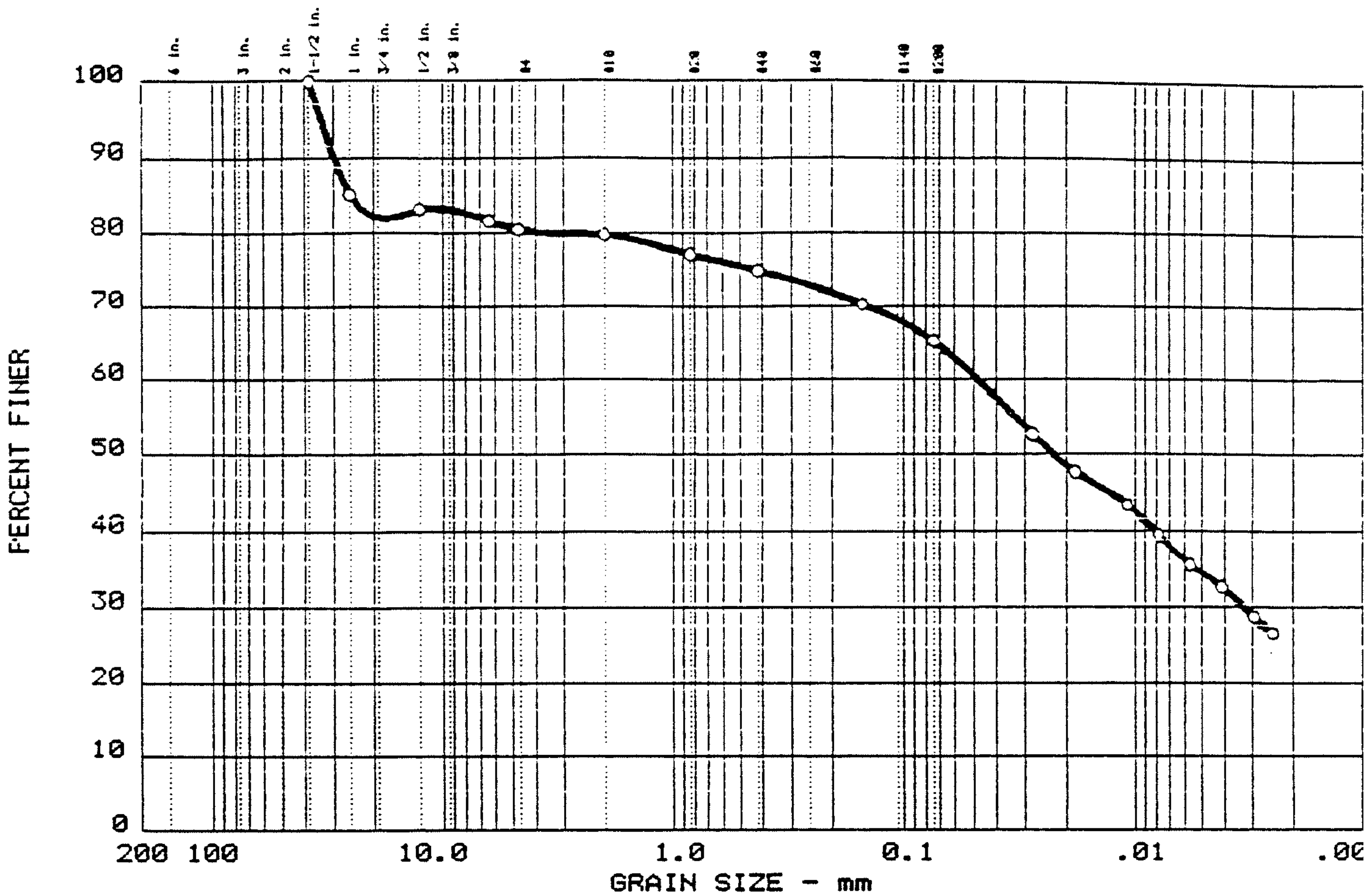
TABLE 2

Use wet weight for uplift

SAMPLE	DEPTH	PHYSICAL COMPONENTS GRAVEL	SAND	FINES	NATURAL MOISTURE(%)	ATTERBERG LIMITS LIQUID LIMITS	PLASTIC INDEX	DRY UNIT WEIGHT (P.C.F.)	WET DENS
B-2	9-10'	19.5%	15.3%	65.1%	19.3%	27	9	Not testable	
B-2	17-19'	0.8%	2.2%	97.0%	37.6%	37	15	81.2 pcf	111.7
B-3	15-17'	8.9%	11.8%	79.3%	33.9%	30	12	96.8 pcf	129.6
B-4	25-27'	1.3%	8.7%	90.0%	28.1%	26	9	96.7 pcf	123.9
B-5	2-4'	3.2%	16.9%	80.0%	17.2%	28	9	107.2 pcf	125.6 *
B-5	20-22'	12.0%	20.8%	67.2%	12.4%	26	9	Not testable	
B-6	15-17'	0.0%	15.4%	84.6%	19.9%	27	9	86.9 pcf	104.2
B-6	25-27'	4.9%	10.2%	84.9%	24.2%	35	15	Not testable	
B-7	3-5'	4.4%	20.4%	75.2%	19.8%	27	9	115.1 pcf	137.9 *
B-7	20-22'	18.4%	8.0%	73.6%	32.5%	23	4	Not testable	
B-8	25-27'	1.2%	8.3%	90.4%	30.3%	35	14	98.0 pcf	127.7
B-9	20-22'	1.4%	8.7%	89.9%	26.7%	30	11	Not testable	
B-10	20-22'	1.7%	16.1%	82.1%	24.9%	29	10	107.2 pcf	133.1

CLAY AVG 121.8 TILL AVG 131.8

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
○	9	0.0	19.5	15.3	30.7	34.4

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	27	9	25.12		0.02	0.003				

MATERIAL DESCRIPTION	USCS	AASHTO
○ CLAY SOME SILT LITTLE GRAVEL LITTLE SAND	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
○ Location: BORING B-2, 9'-10'

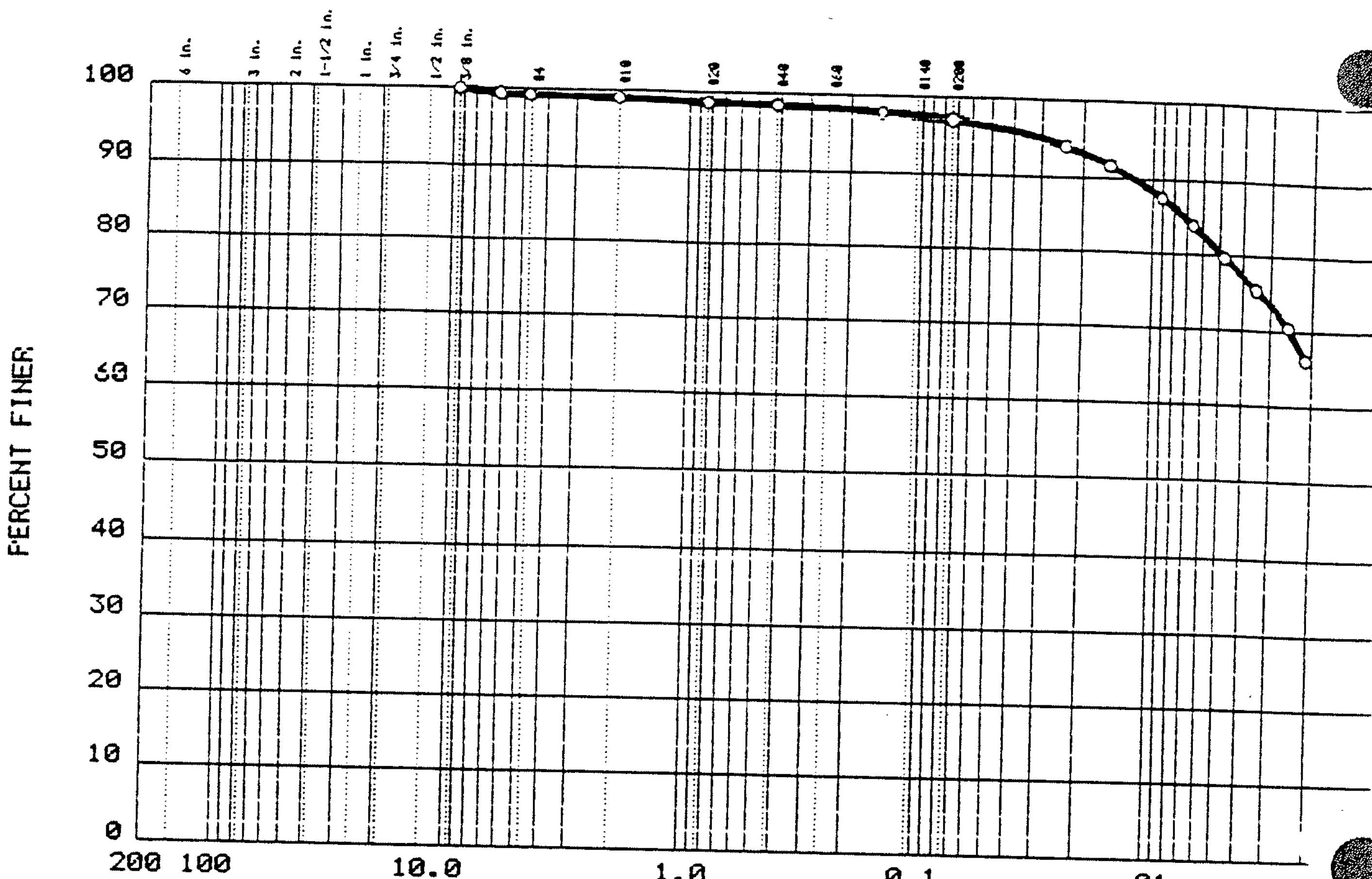
Date: 6-27-88

Remarks:
SHELBY TUBE SAMPLE
N.W.C. = 19.3 %
DRY UNIT WEIGHT
(NOT TESTABLE)

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Fig. No. 8

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	12	0.0	0.8	2.2	16.8	80.2

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
O	37	15								

MATERIAL DESCRIPTION	USCS	AASHTO
O CLAY LITTLE SILT TRACE SAND	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
O Location: BORING # B-2, 17' -19'

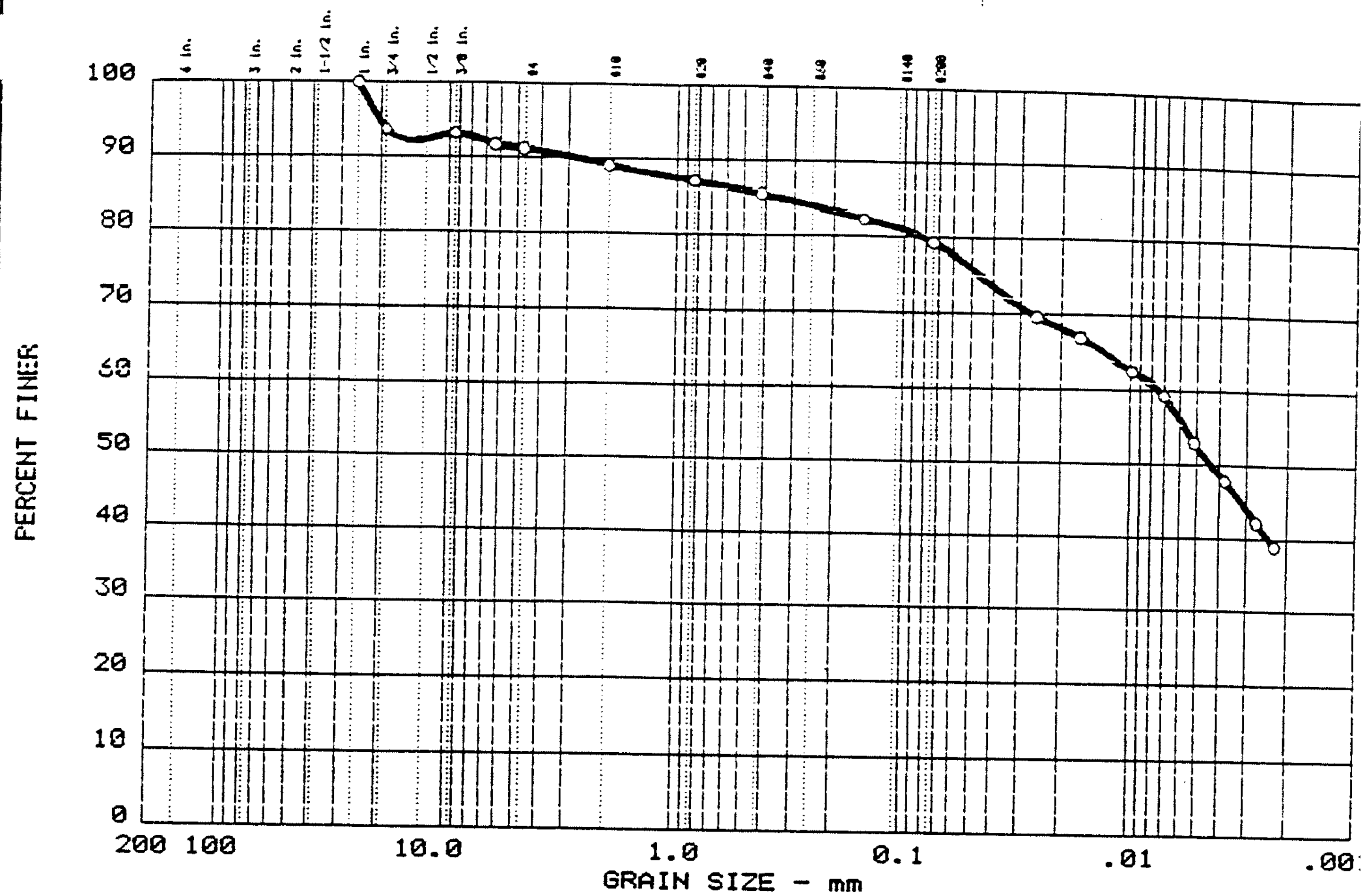
Date: 6-27-88

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Remarks:
SHELBY TUBE SAMPLE
N.W.C. = 37.6%
DRY UNIT WEIGHT
= 81.2 PCF

Fig. No. 9

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
○	13	0.0	8.9	11.8	27.0	52.3

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	30	12	0.36		0.00					

MATERIAL DESCRIPTION	USCS	AASHTO
○ CLAY SOME SILT LITTLE SAND TRACE GRAVEL	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
○ Location: BORING # B-3, 15'-17'

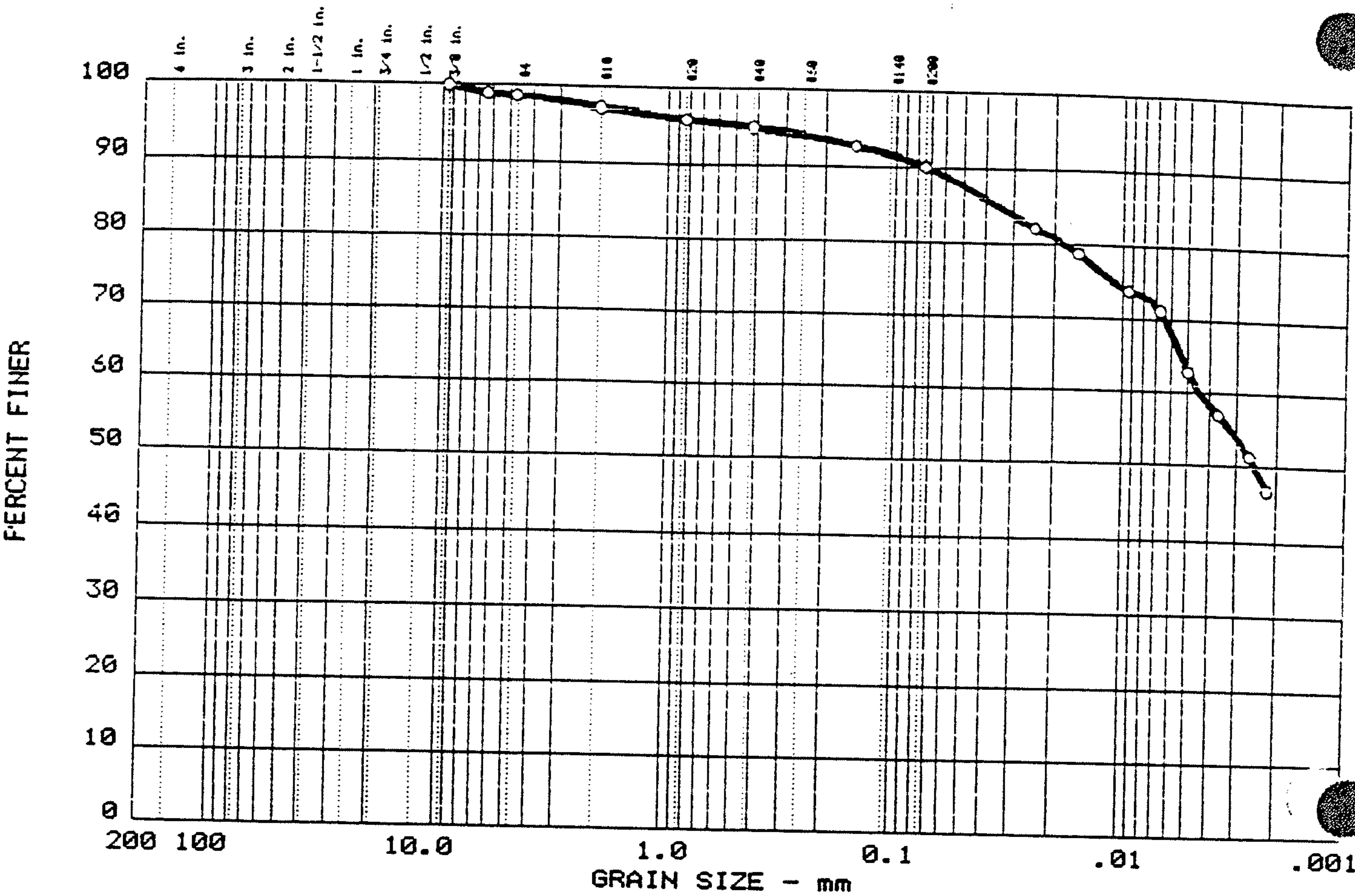
Date: 6-27-88

Remarks:
SHELBY TUBE SAMPLE
N.W.C. = 33.9%
DRY UNIT WEIGHT
= 96.8 PCF

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Fig. No. 10

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
○	14	0.0	1.3	8.7	27.3	62.7

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	26	9			0.00					

MATERIAL DESCRIPTION	USCS	AASHTO
○ CLAY SOME SILT TRACE SAND TRACE GRAVEL	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
○ Location: BORING # B-4, 25'-27'

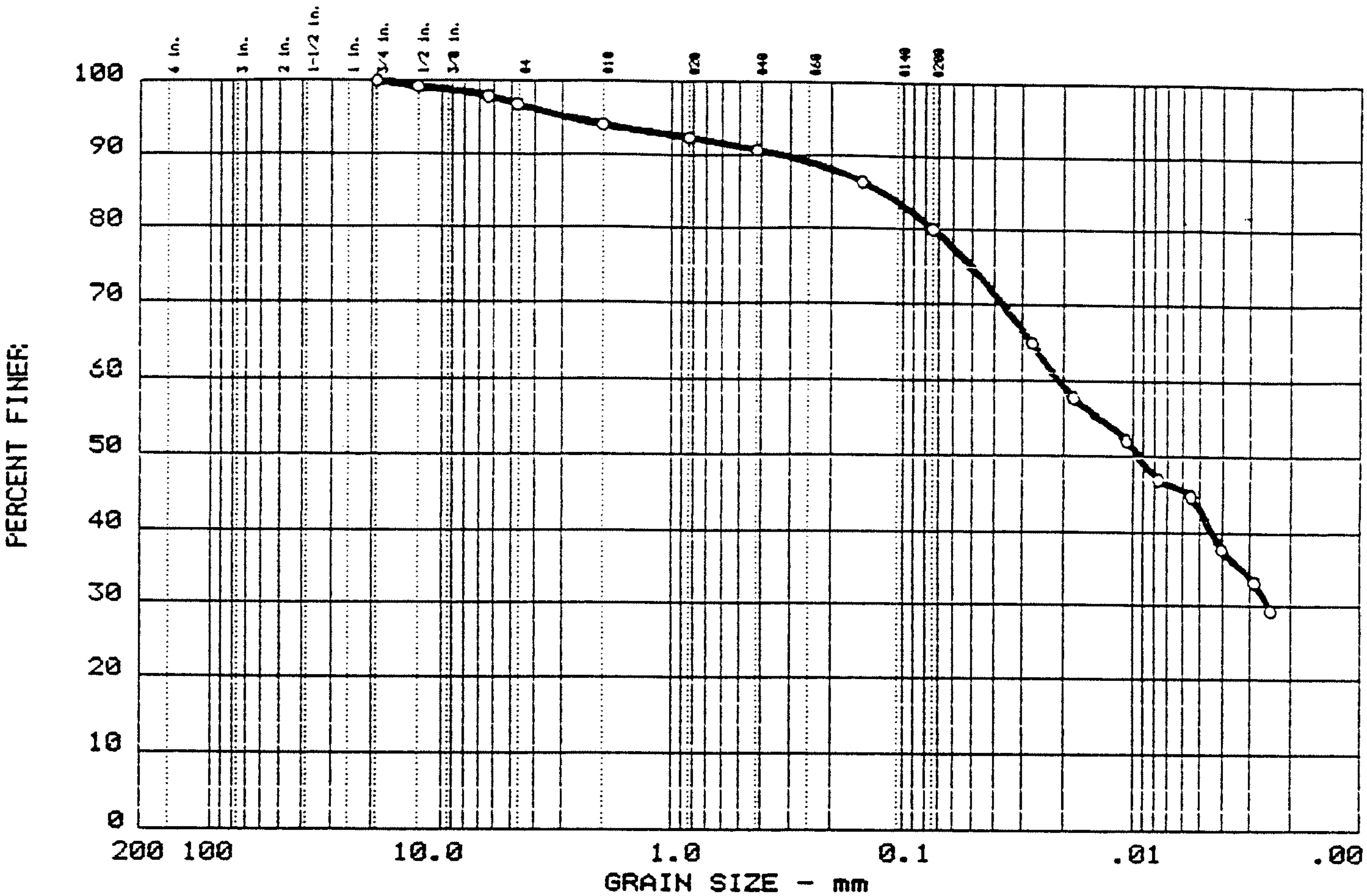
Date: 6-27-88

Remarks:
SHELBY TUBE SAMPLE
N.W.C. = 28.1%
DRY UNIT WEIGHT
= 96.7 PCF

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Fig. No. 11

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
○	10	0.0	3.2	16.9	37.1	42.9

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	28	9	0.12		0.01	0.003				

MATERIAL DESCRIPTION	USCS	AASHTO
○ CLAY AND SILT LITTLE SAND TRACE GRAVEL	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
○ Location: BORING B-5, 2'-4'

Date: 6-27-88

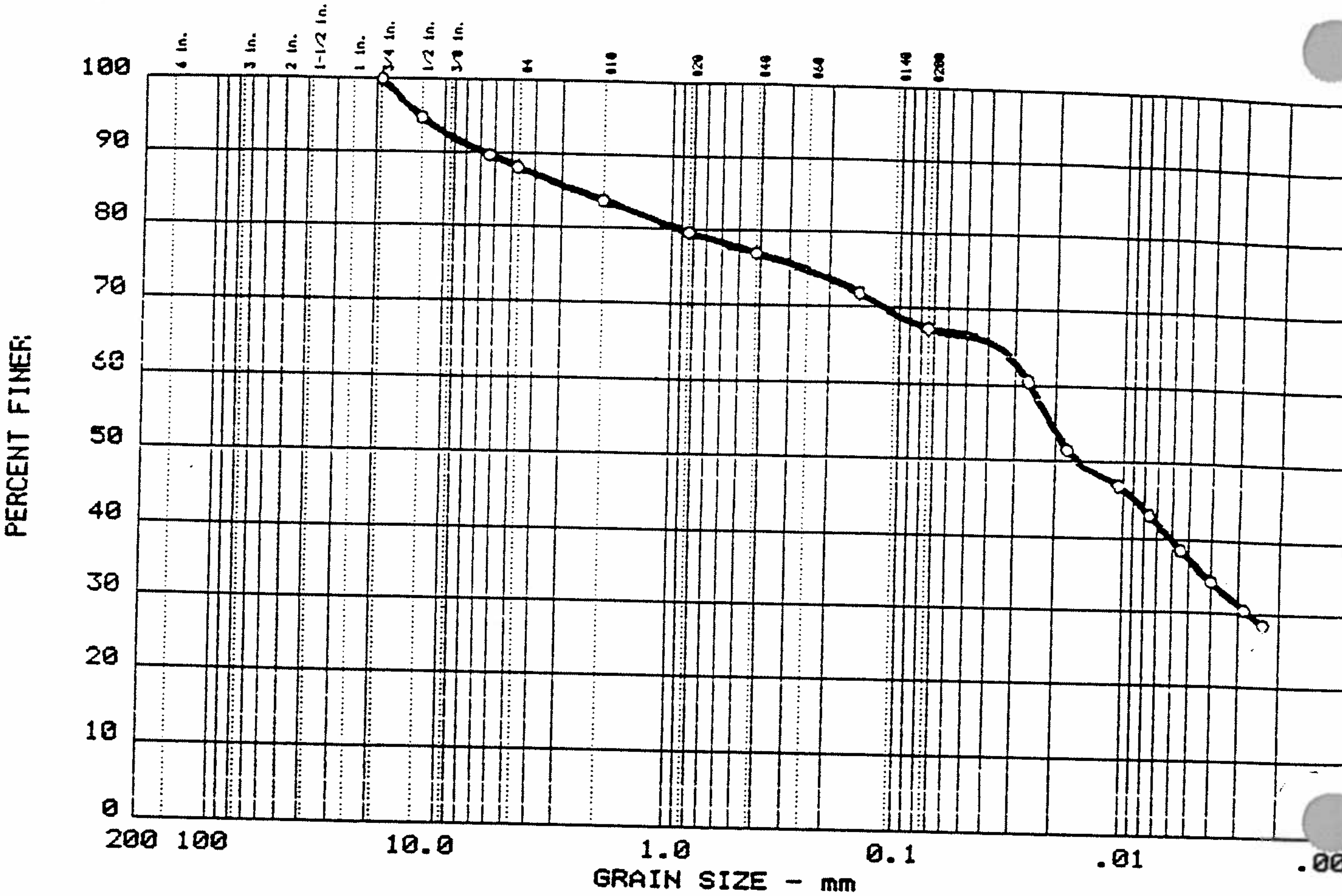
Remarks:
SHELBY TUBE SAMPLE
N.W.C. = 17.2 %
DRY UNIT WEIGHT
= 107.2 PCF

GRAIN SIZE DISTRIBUTION TEST REPORT

EMPIRE SOILS INVESTIGATIONS, INC.

Fig. No. 12

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	15	0.0	12.0	20.8	30.1	37.1

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
O	26	9	2.60		0.02	0.003				

MATERIAL DESCRIPTION	USCS	AASHTO
O CLAY SOME SILT SOME SAND LITTLE GRAVEL	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
O Location: BORING # B-5, 20'-22'

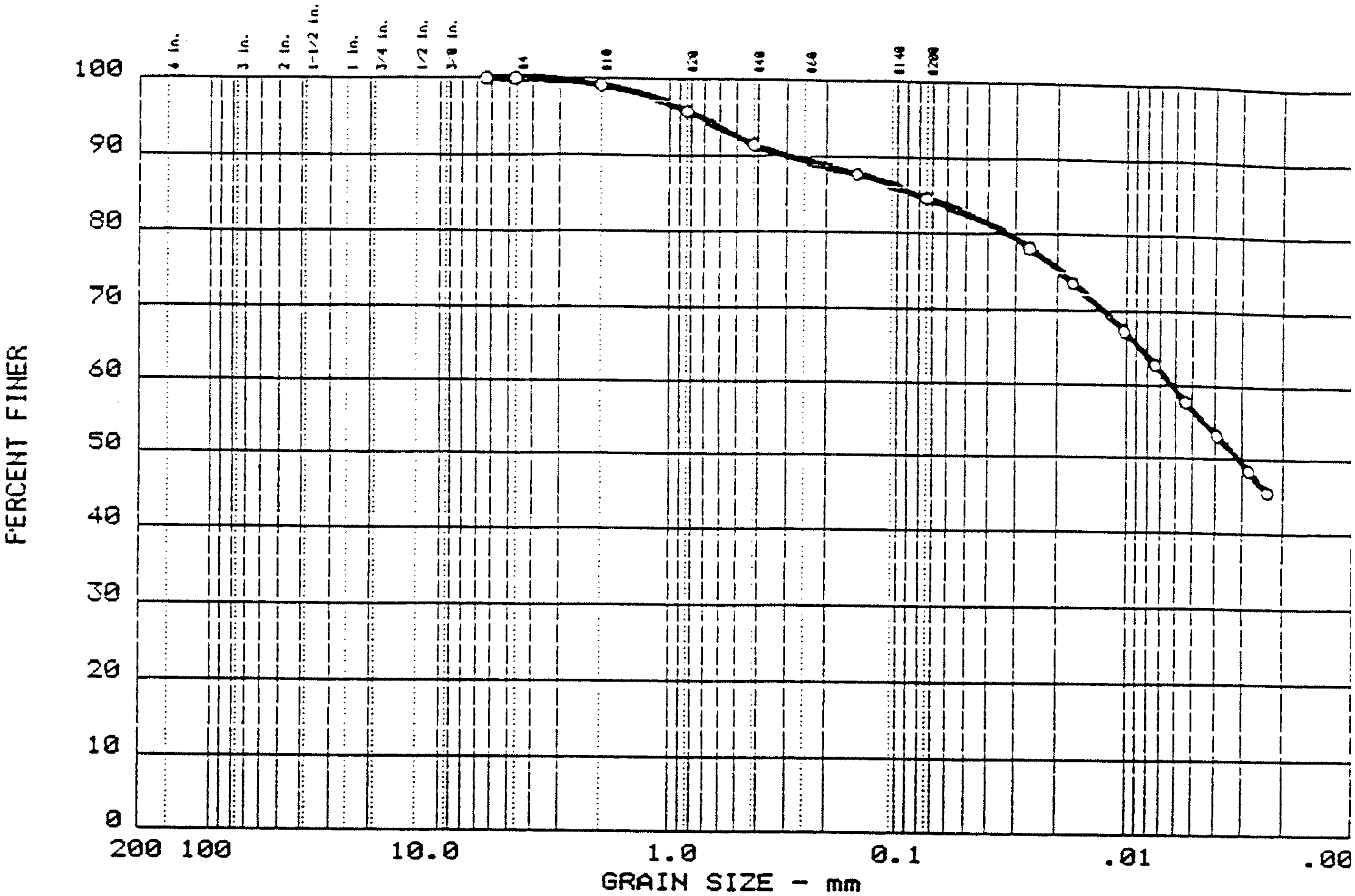
Date: 6-27-88

Remarks:
SHELBY TUBE SAMPLE
N.W.C. = 12.4 %
DRY UNIT WEIGHT
= PCF

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Fig. No. 13

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
○	16	0.0	0.0	15.4	28.0	56.6

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	27	9	0.09		0.00					

MATERIAL DESCRIPTION	USCS	AASHTO
○ CLAY SOME SILT LITTLE SAND	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
○ Location: BORING B-6, 15'-17'

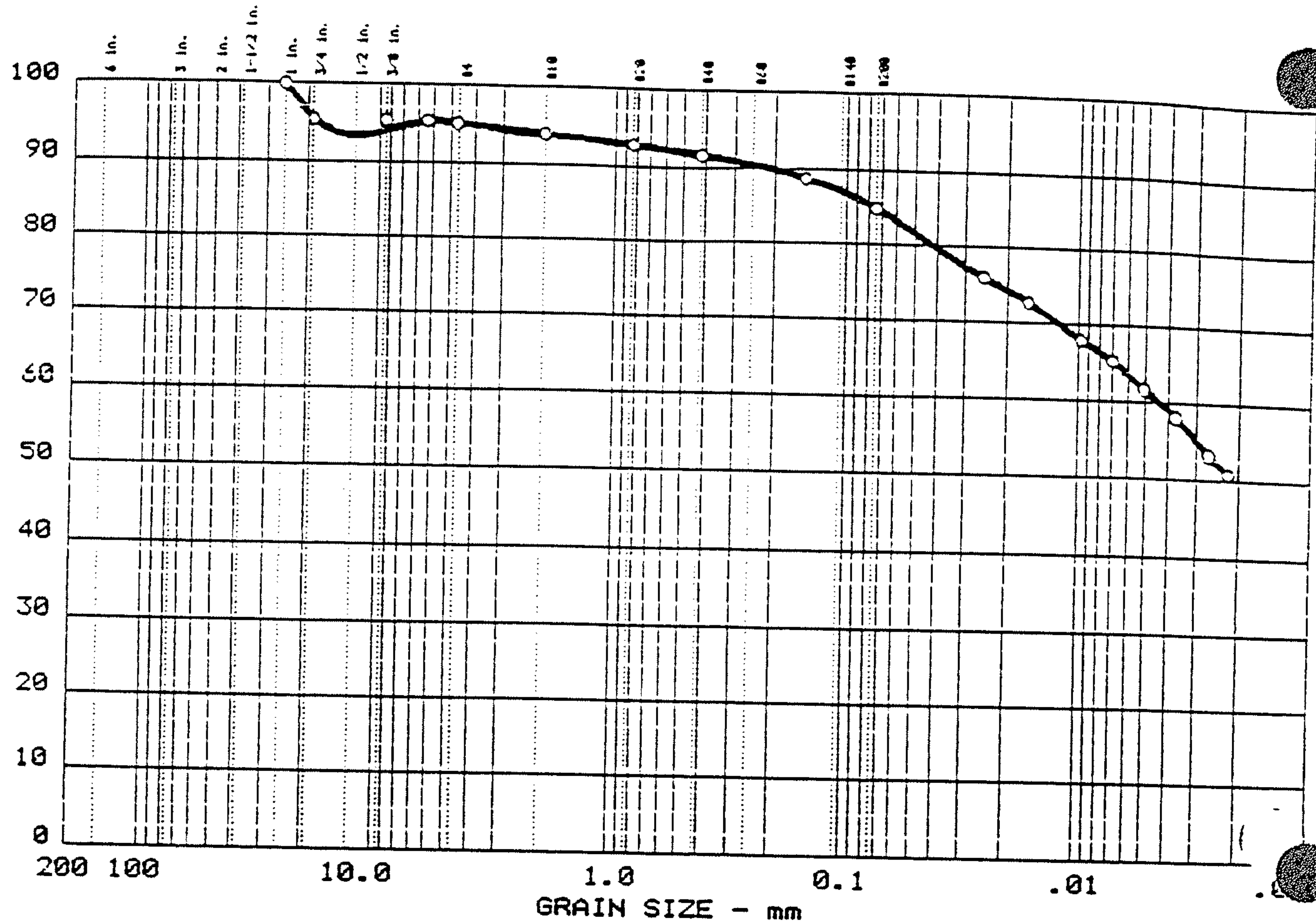
Date: 6-27-88

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Remarks:
SHELBY TUBE SAMPLE
N.W.C. = 19.9
DRY UNIT WEIGHT
= 86.9 PCF

Fig. No. 14

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	17	0.0	4.9	10.2	23.5	61.4

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
O	35	15	0.07							

MATERIAL DESCRIPTION	USCS	AASHTO
O CLAY SOME SILT LITTLE SAND TRACE GRAVEL	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
O Location: BORING B-6, 25'-27'

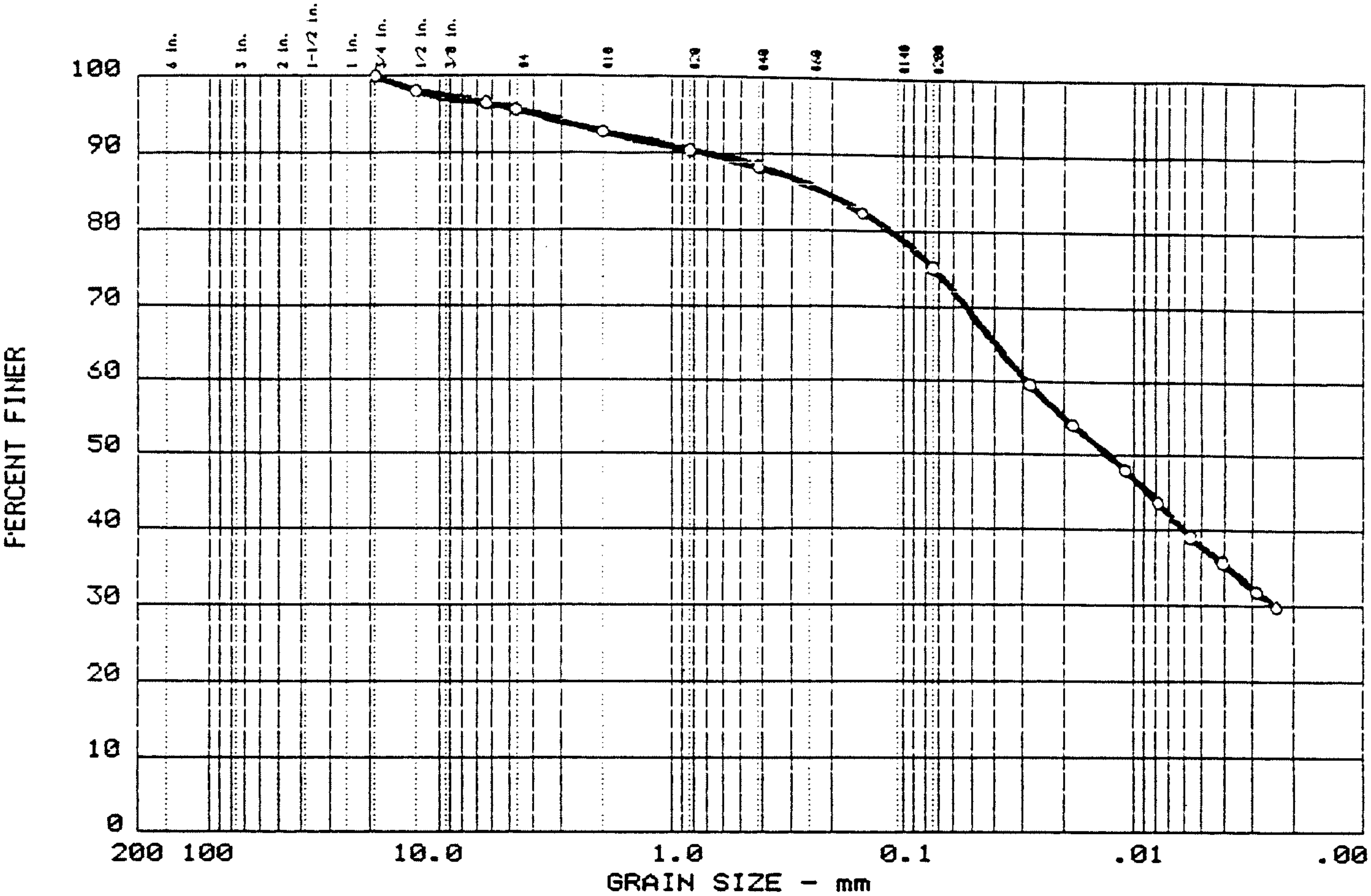
Date: 6-27-88

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Remarks:
SHELBY TUBE SAMPLE
N.W.C. = 24.2 %
DRY UNIT WEIGHT
= PCF

Fig. No. 15

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
○	11	0.0	4.4	20.4	37.6	37.6

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	27	9	0.22		0.01	0.002				

MATERIAL DESCRIPTION	USCS	AASHTO
○ CLAY AND SILT SOME SAND TRACE GRAVEL	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
○ Location: BORING B-7, 3'-5'

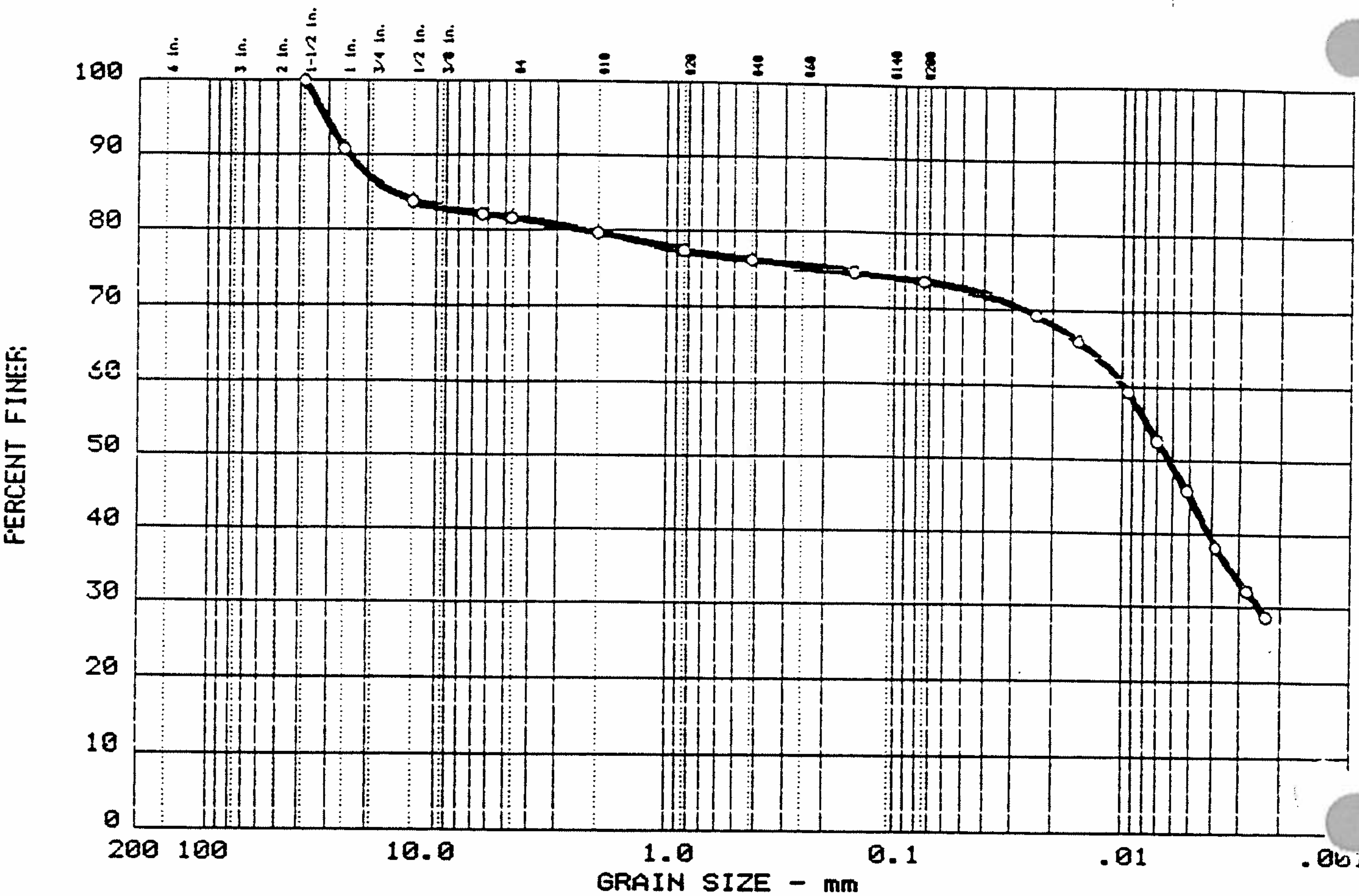
Date: 6-27-88

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Remarks:
SHELBY TUBE SAMPLE
N.W.C. = 19.8 %
DRY UNIT WEIGHT
= 115.1 PCF

Fig. No. 16

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
○	18	0.0	18.4	8.0	28.7	44.9

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	23	4	15.67		0.01	0.002				

MATERIAL DESCRIPTION	USCS	AASHTO
○ CLAY SOME SILT SOME GRAVEL TRACE SAND	CL-ML	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
○ Location: BORING B-7, 20'-22'

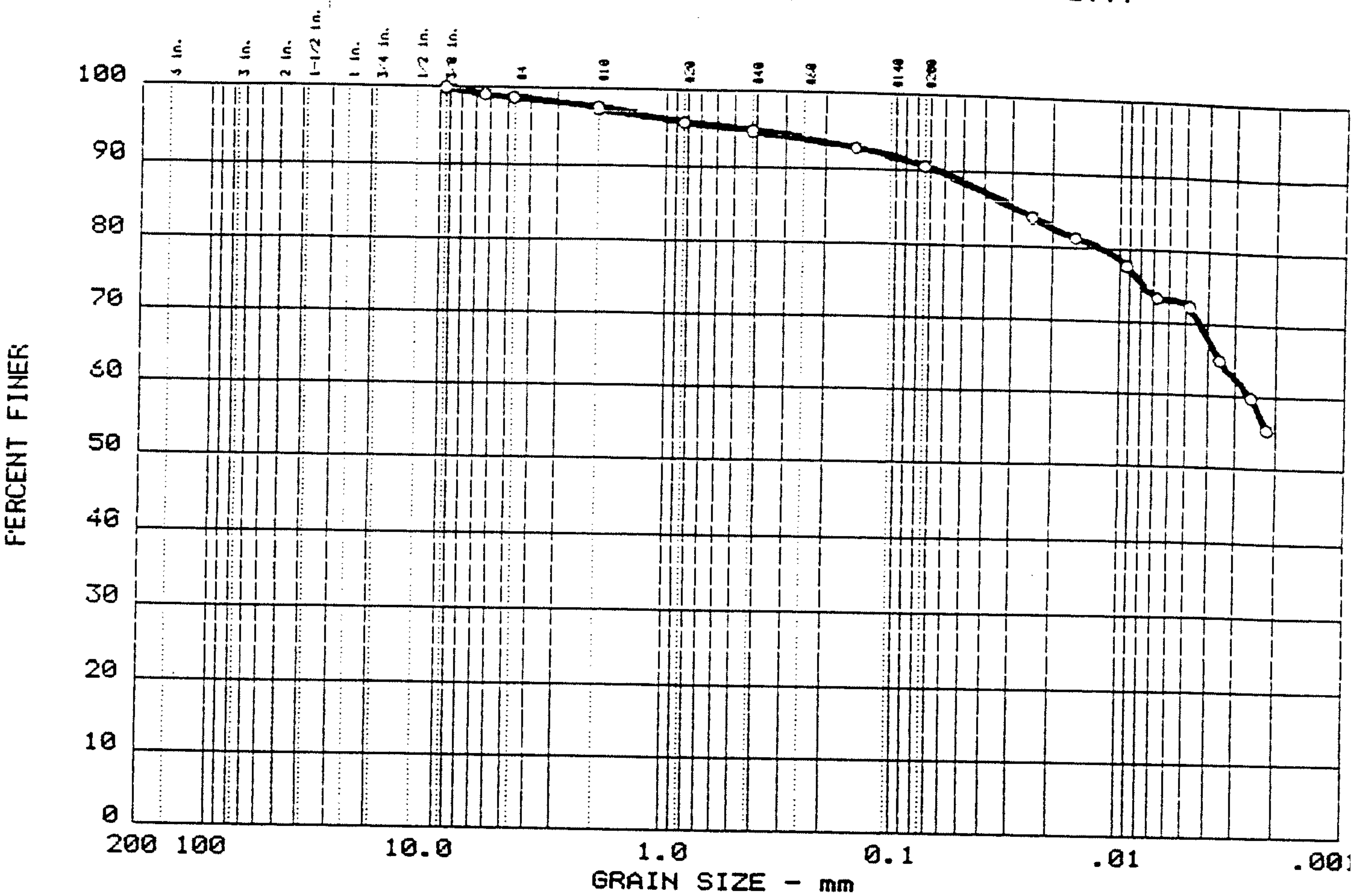
Date: 6-27-88

Remarks:
SHELBY TUBE SAMPLE
N.W.C. = 32.5 %
DRY UNIT WEIGHT
(NOT TESTABLE)

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Fig No. 17

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	19	0.0	1.2	8.3	17.7	72.7

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
O	35	14								

MATERIAL DESCRIPTION	USCS	AASHTO
O CLAY LITTLE SILT TRACE SAND TRACE GRAVEL	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
O Location: BORING B-8, 25'-27'

Date: 6-27-88

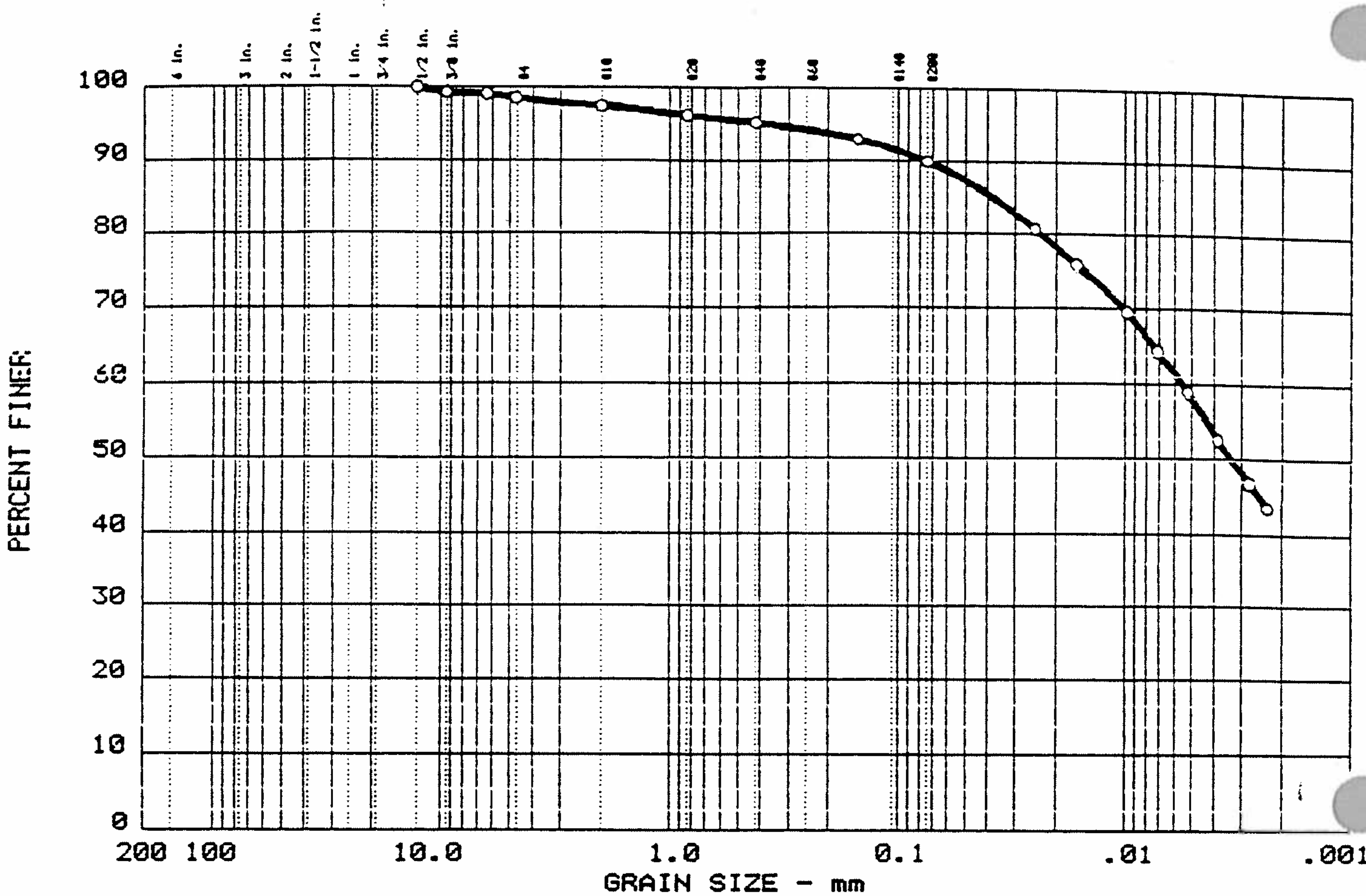
GRAIN SIZE DISTRIBUTION TEST REPORT

EMPIRE SOILS INVESTIGATIONS, INC.

Remarks:
SHELBY TUBE SAMPLE
N.W.C. = 30.3 %
DRY UNIT WEIGHT
= 98.0 PCF

Fig. No. 18

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
○	20	0.0	1.4	8.7	31.8	58.1

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	30	11			0.00					

MATERIAL DESCRIPTION	USCS	AASHTO
○ CLAY SOME SILT TRACE SAND TRACE GRAVEL	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
○ Location: BORING B-9, 20'-22'

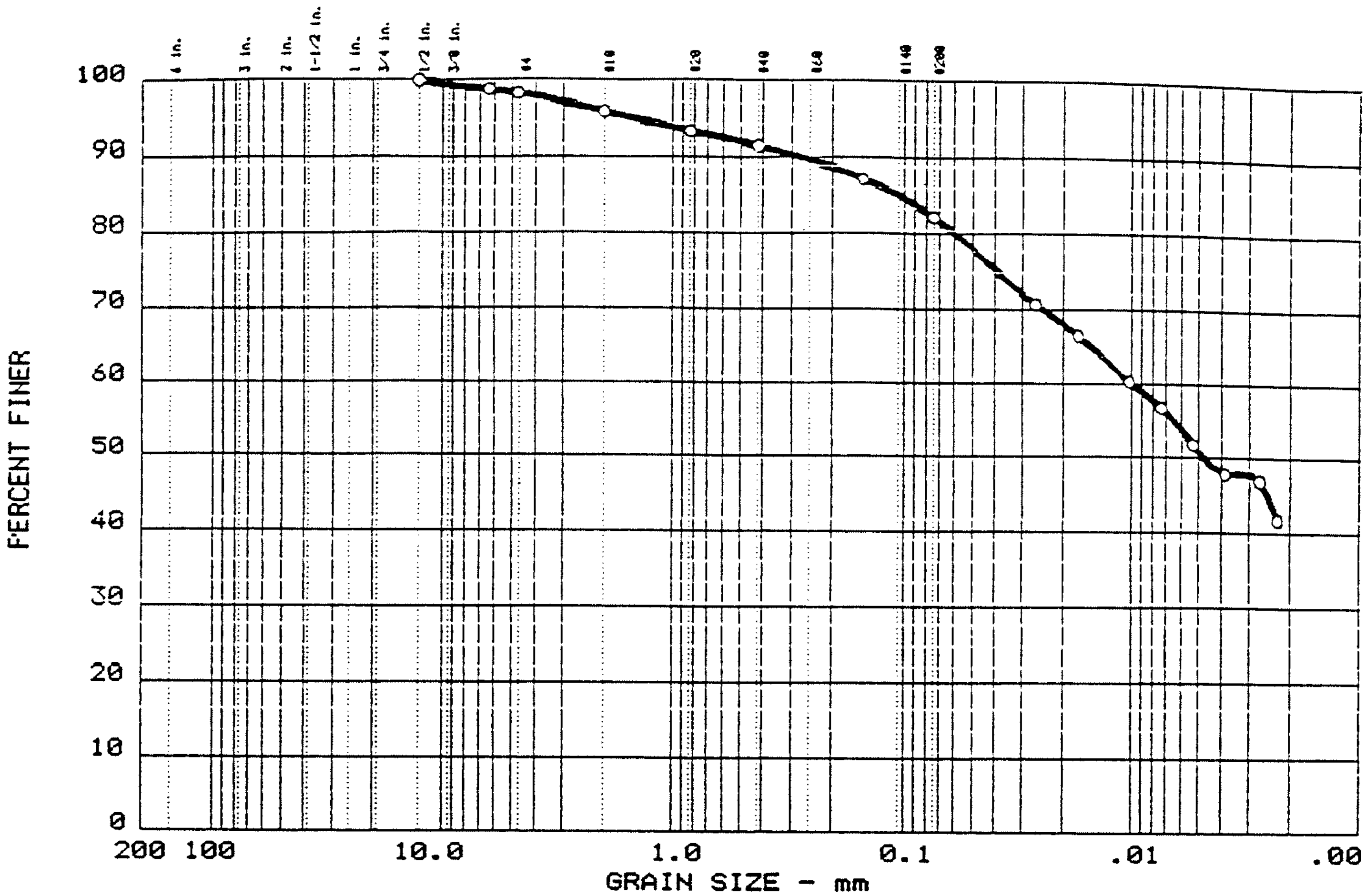
Date: 6-27-88

Remarks:
SHELBY TUBE SAMPLE
N.W.C. = 26.7 %
DRY UNIT WEIGHT
= PCF

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Fig. No. 19

GRAIN SIZE DISTRIBUTION TEST REPORT



	Test	%+3"	% GRAVEL	% SAND	% SILT	% CLAY
O	1	0.0	1.7	16.1	31.5	50.6

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
O	29	10	0.10		0.00					

MATERIAL DESCRIPTION	USCS	AASHTO
O CLAY SOME SILT LITTLE SAND TRACE GRAVEL	CL	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL # 13
O Location: BORING B-10, 20'-22'

Date: 6-27-88

Remarks:
SHELBY TUBE SAMPLE
N.W.C. = 24.9 %
DRY UNIT WEIGHT
= 107.2 PCF

GRAIN SIZE DISTRIBUTION TEST REPORT
EMPIRE SOILS INVESTIGATIONS, INC.

Fig. No. 20

APPENDIX C

LABORATORY TESTING RESULTS
SCA - SECURE LANDFILL #13

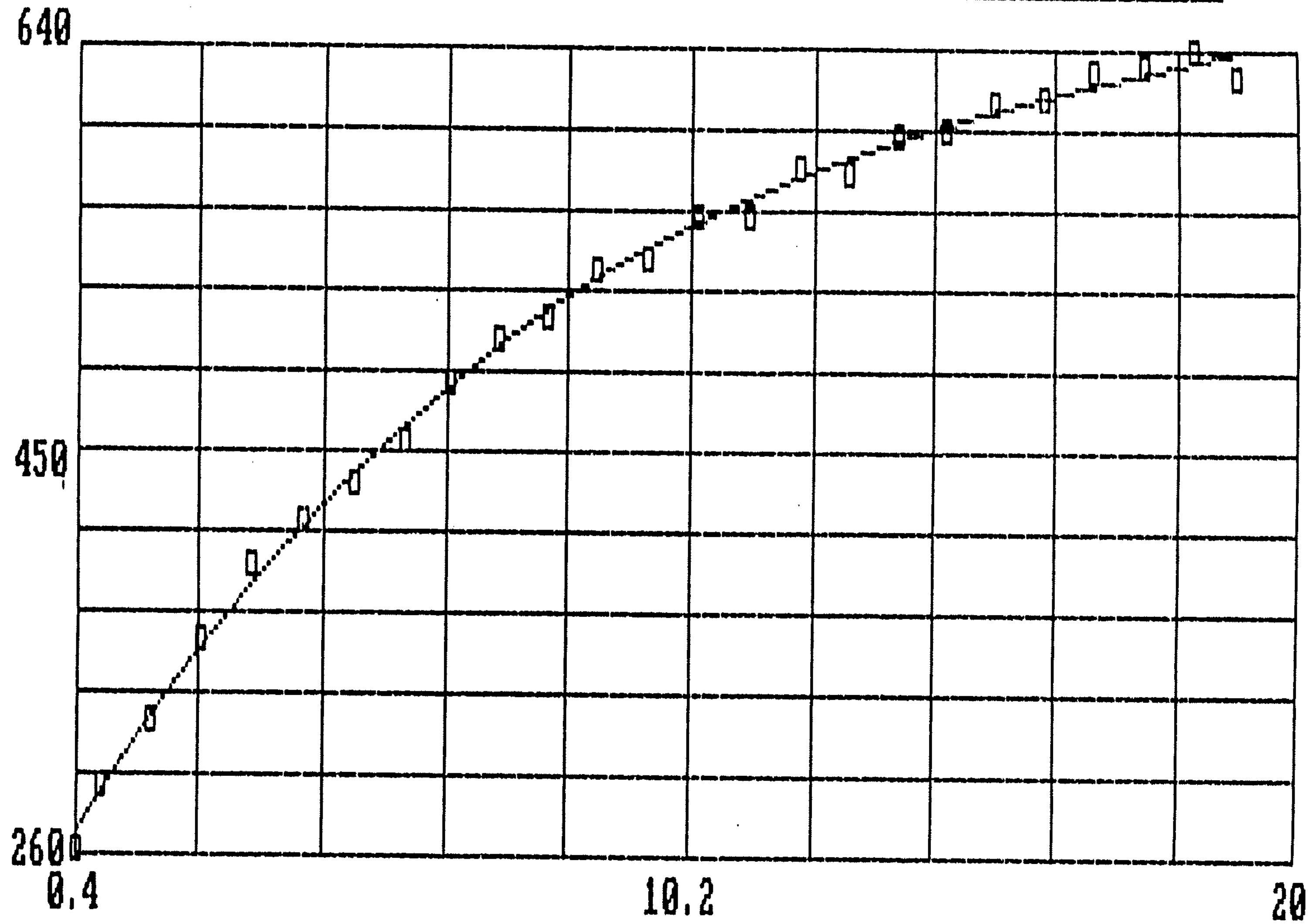
UNCONFINED COMPRESSIVE STRENGTHS

APPENDIX "C"

Table 3

Sample#	Depth	Dry Density	Natural Moisture	Maximum Stress	Peak Strain
B-4	25'-27'	96.7 pcf	28.1%	639 psf	18.3%
B-5	2'-4'	107.2 pcf	17.2%	1548 psf	12.5%
B-6	15'-17'	86.9 pcf	19.9%	1218 psf	6.8%
B-7	3'-5'	115.1 pcf	19.8%	2678 psf	10.9%

UNCONFINED COMPRESSI(SAMPLE # B-4, 25'-27'



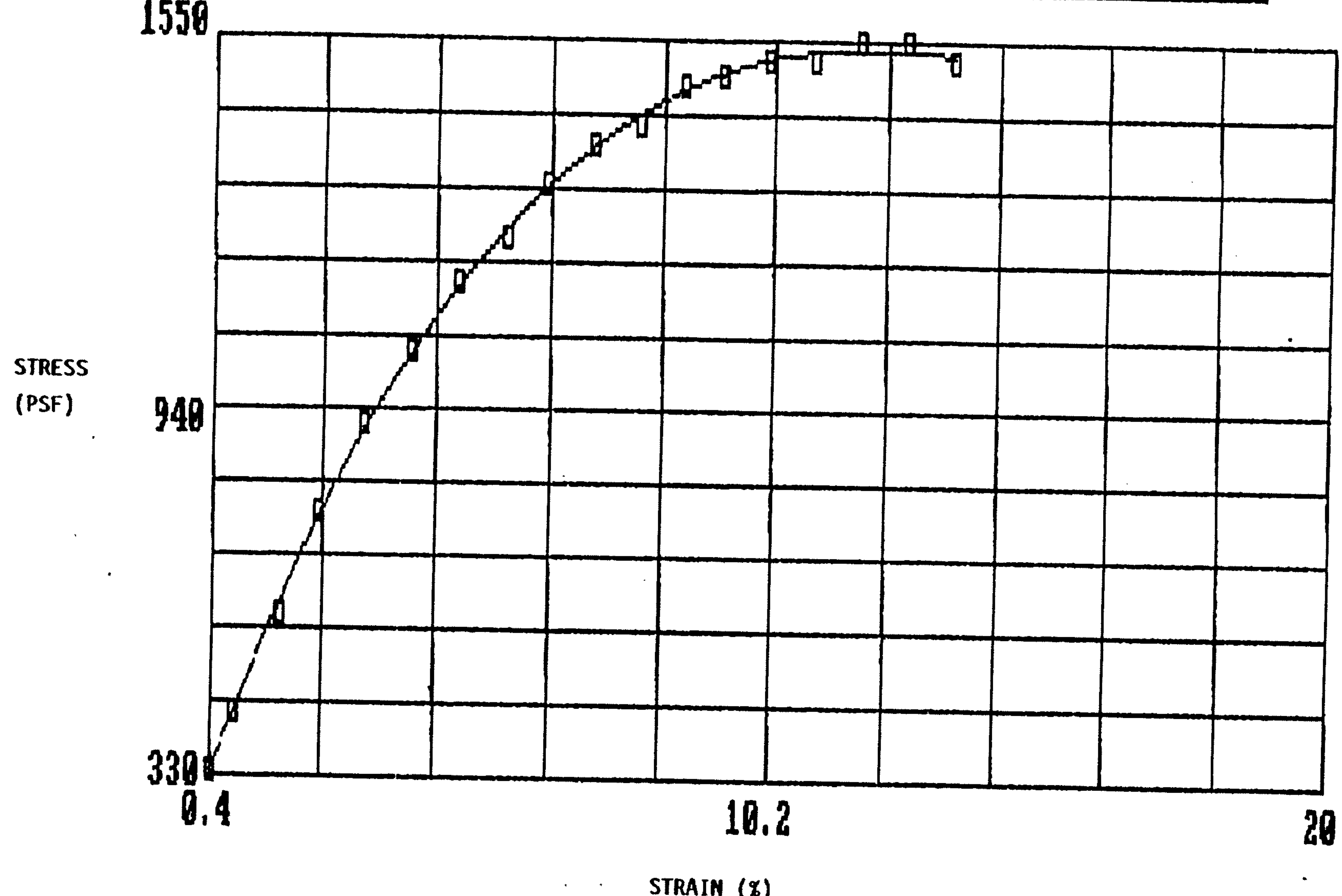
STRESS
(P.S.F.)

STRAIN (%)

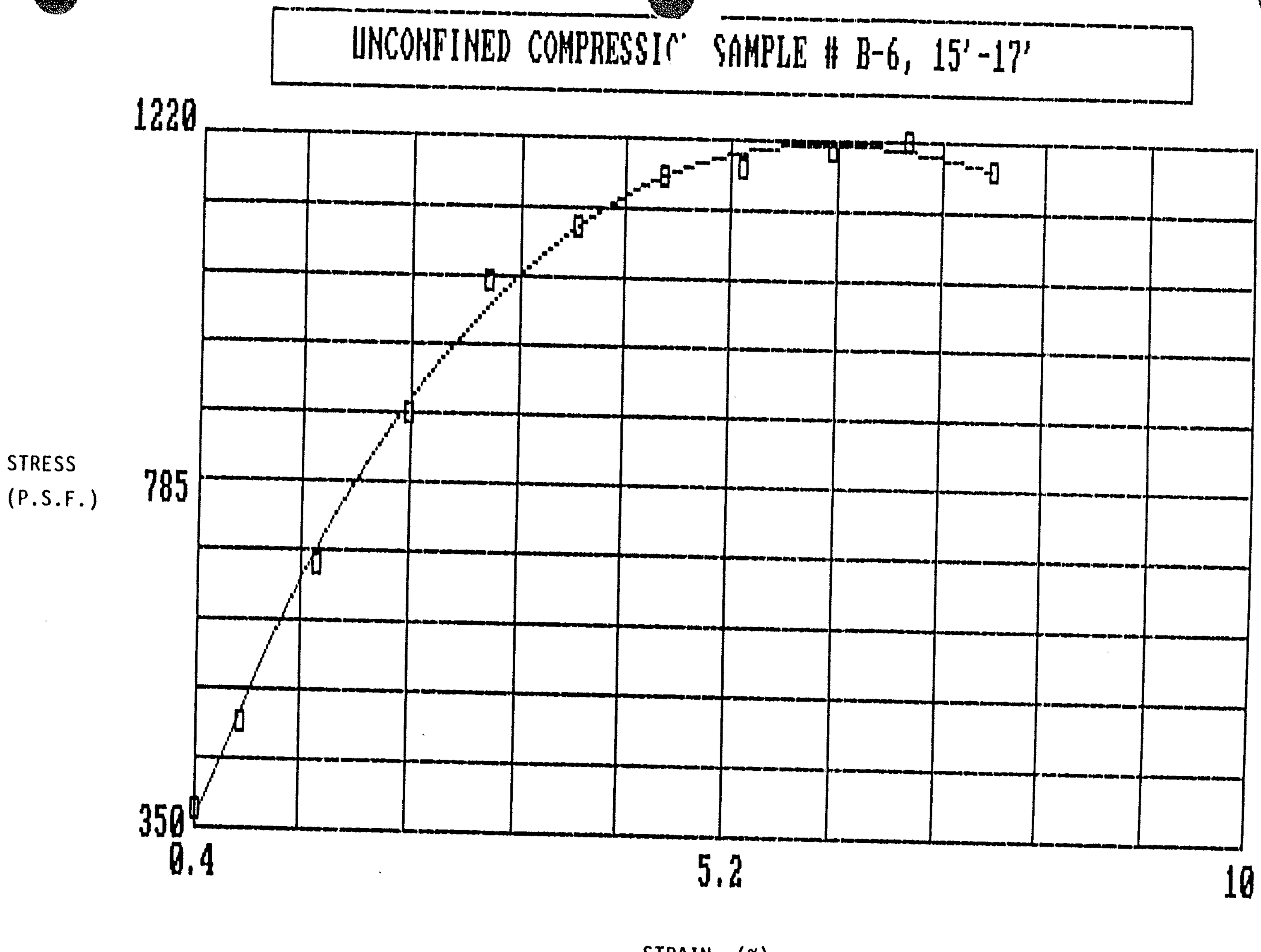
MAXIMUM STRESS 639 P.S.F.
PEAK STRAIN 18.3%

Table 21

UNCONFINED COMPRESSION SAMPLE # B-5, 2'-4'



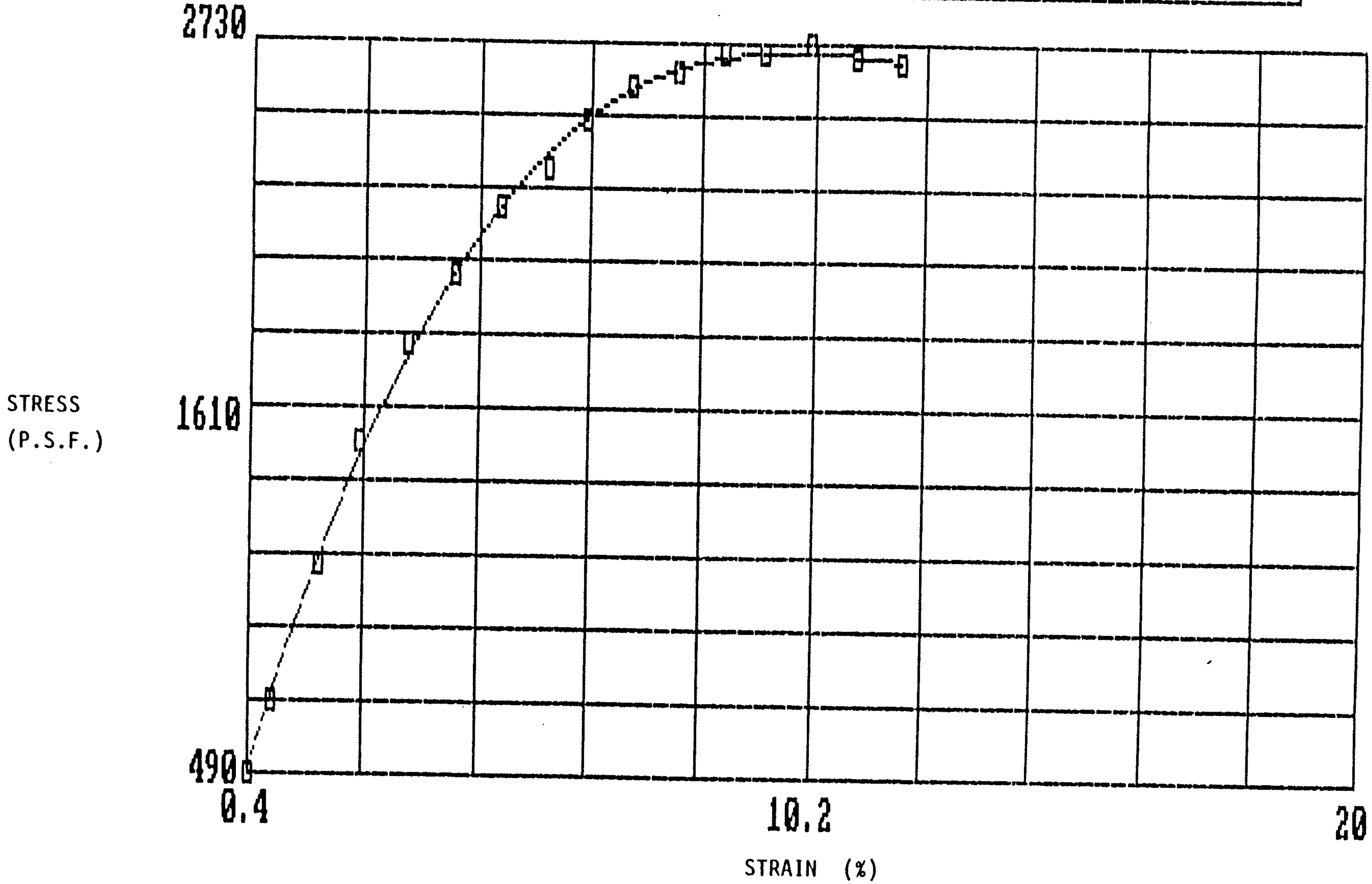
Maximum Stress = 1548 PSF
Peak Strain = 12.5%



MAXIMUM STRESS 1218 P.S.F.
PEAK STRAIN 6.8%

Table 22

UNCONFINED COMPRESSION SAMPLE # B-7, 3'-5'



MAXIMUM STRESS 2678 P.S.F.
PEAK STRAIN 10.9%

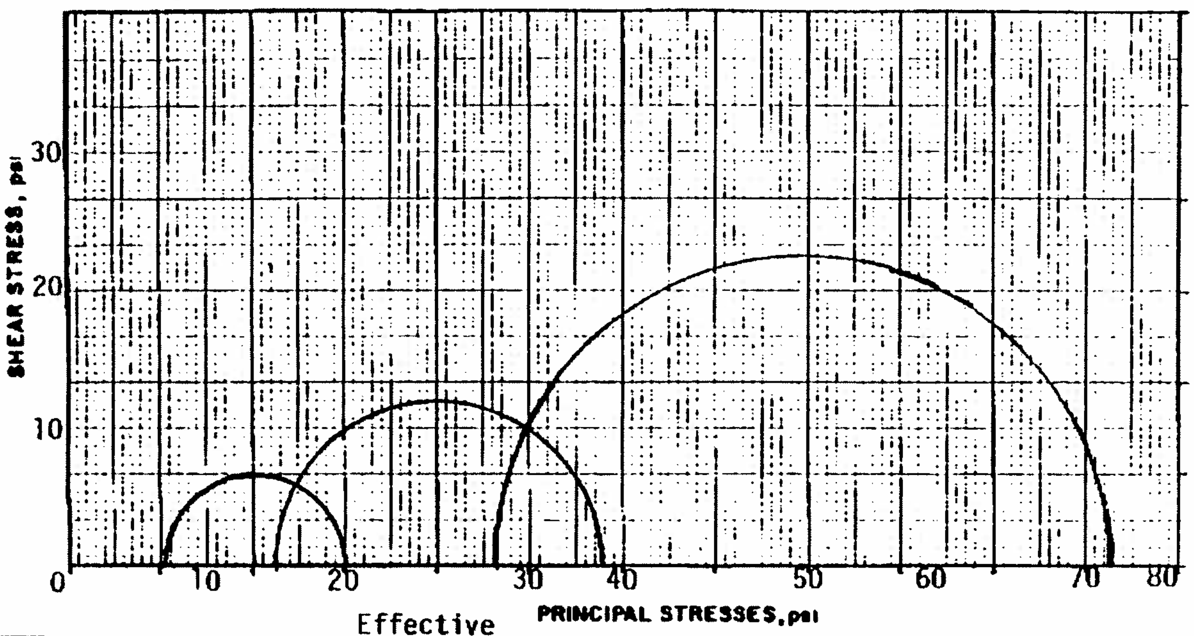
Table 23

APPENDIX D

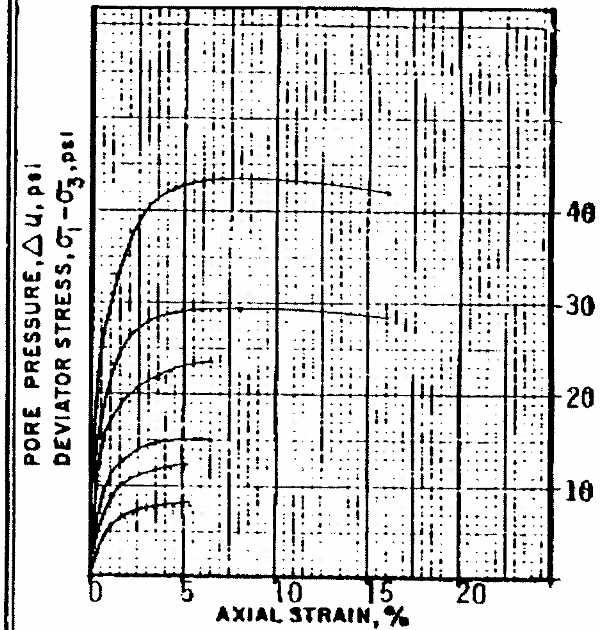
LABORATORY TESTING RESULTS
SCA - SECURE LANDFILL #13

PROCTOR VALUE FOR COMBINED
BAG SAMPLES AND SHELBY TUBE MATERIALS

MOHR STRESS CIRCLES



STRESS-STRAIN CURVES



TEST DATA:

TYPE OF TEST: Consolidated Undrained With Pore Pressure Measurement

BACK PRESSURE, PSI: 80 RATE OF STRAIN, INCH/MIN: 0.0006

SPECIMEN NUMBER	①	②	③	④	⑤
SPECIMEN HEIGHT, INCHES	5.742				
SPECIMEN DIAMETER, INCHES	2.856				
INITIAL WATER CONTENT, %	28.5				
INITIAL DRY DENSITY, pcf	97.6				
PORE PRESSURE RESPONSE, B, %	99.0				
NET CHAMBER PRESSURE, σ_3, psi	15	30	60		
DEVIATOR STRESS, $\sigma_1 - \sigma_3$, psi	12.7	23.4	43.4		
MAJOR PRINCIPAL STRESS, σ_1, psi (Effective)	19.7	38.4	74.4		
FAILURE SKETCH					

REMARKS:

FRICTION ANGLE ϕ DEGREES: 23°

COHESION INTERCEPT, c, psf: 190

SAMPLE DATA:

BORING NO. B-9 SURF. ELEV. ____

SAMPLE NO. ____ DEPTH, FT. 20'-22'

SAMPLE TYPE: 3" Diameter Shelby Tube Sample

VISUAL DESCRIPTION: Grey-Brown Clay and Silt, trace gravel

CLASSIFICATION TESTS:

SPECIFIC GRAVITY ____ ORGANIC CONTENT % ____

LIQUID LIMIT, % ____ PLASTIC LIMIT, % ____

EMPIRE SOILS INVESTIGATIONS INC

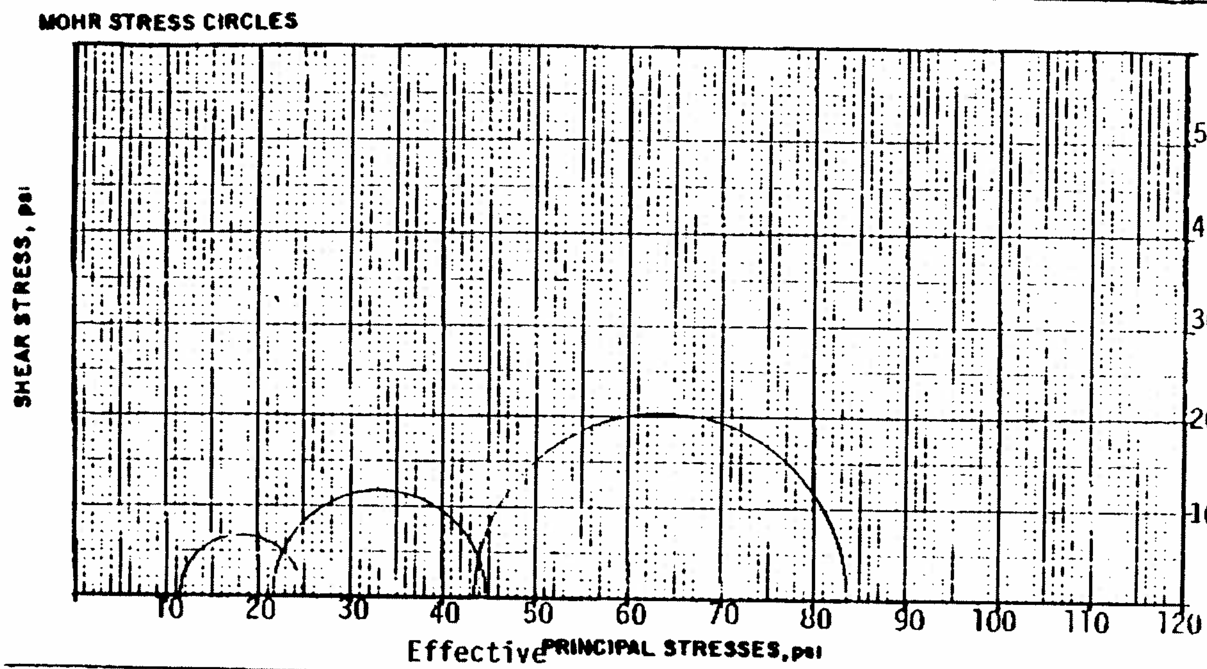
TRIAXIAL COMPRESSION TEST

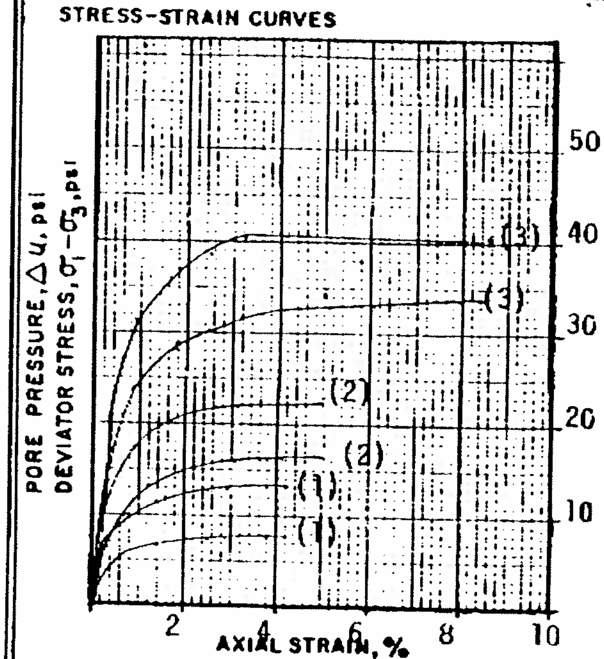
SCA - Model City REPORT NO: L-3 H

Donohue & Associates

DR BY: TH	CK'D: CK	DATE: 7/21/88	PROJ. NO. BD-88-52

FORM TCT-1





TEST DATA:

TYPE OF TEST: C.U. Triaxial Stage Test

BACK PRESSURE, PSI: 80 RATE OF STRAIN, INCH/MIN: 0.0012

SPECIMEN NUMBER	①	②	③	④	⑤
SPECIMEN HEIGHT, INCHES	5.738				
SPECIMEN DIAMETER, INCHES	2.860				
INITIAL WATER CONTENT, %	25.5				
INITIAL DRY DENSITY, pcf	127.9				
PORE PRESSURE RESPONSE, B, %	100				
NET CHAMBER PRESSURE, σ_3, psi	15	30	60		
DEVIATOR STRESS, $\sigma_1 - \sigma_3$, psi	13.4	22.4	40.5		
MAJOR PRINCIPAL STRESS, σ_1, psi (Effective)	20.6	36.0	67.0		
FAILURE SKETCH					

REMARKS:

FRICTION ANGLE Ø DEGREES: 24°

COHESION INTERCEPT, c, psf: 150

SAMPLE DATA:

BORING NO. B-6 SURF. ELEV. -

SAMPLE NO. - DEPTH, FT. 25'-27'

SAMPLE TYPE Shelby Tube

VISUAL DESCRIPTION: Grey Brown Clay and Silt, trace fine Gravel

CLASSIFICATION TESTS:

SPECIFIC GRAVITY ___ ORGANIC CONTENT % -

LIQUID LIMIT, % 35 PLASTIC LIMIT, % 20

EMPIRE SOILS INVESTIGATIONS INC

TRIAXIAL COMPRESSION TEST

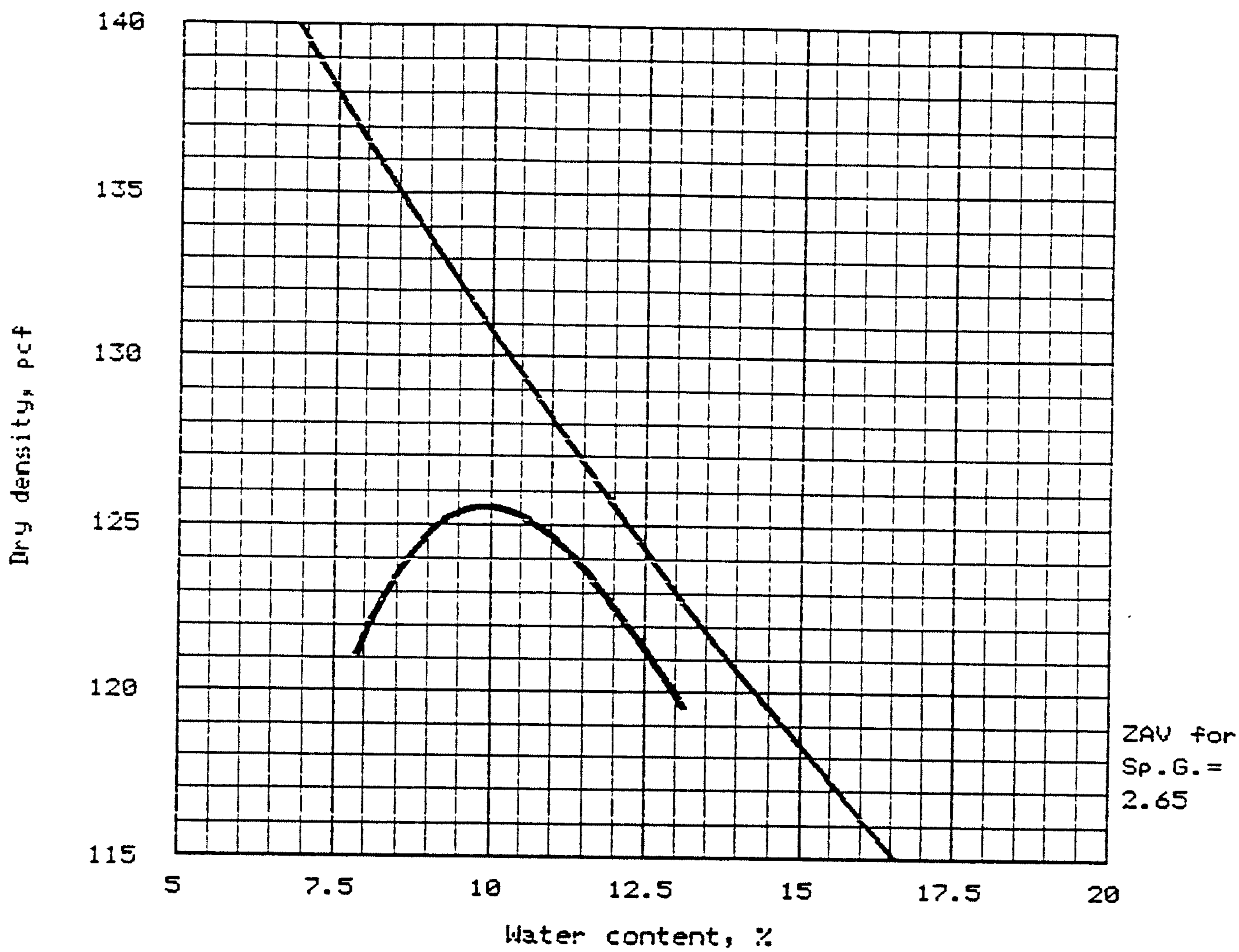
SCA - Model City
Donohue & Associates

REPORT NO: L-2

DR BY: TH	CK'D: CK	DATE 7/21/88	PROJ. -88-5

FORM TCT-

PROCTOR TEST REPORT



"Modified" Proctor, ASTM D 1557-78, Method A

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > No.4	% < No.200
	USCS	AASHTO						
				2.65			3.4 %	

TEST RESULTS	MATERIAL DESCRIPTION
Optimum moisture = 9.9 % Maximum dry density = 125.5 pcf	

Project No.: BD-88-52
Project: SCA SANITARY LANDFILL #13
ocation: COMBINATION OF BAG SAMPLES
AND SHELBY TUBE SAMPLES
Date: 6-27-1988

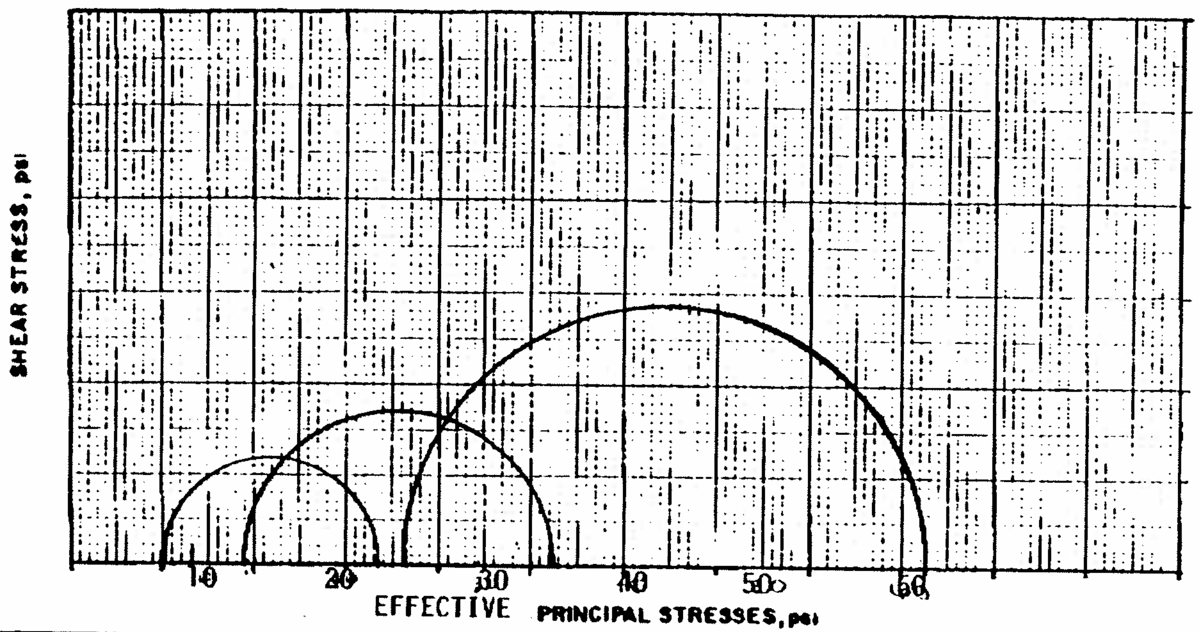
Remarks:

PROCTOR TEST REPORT

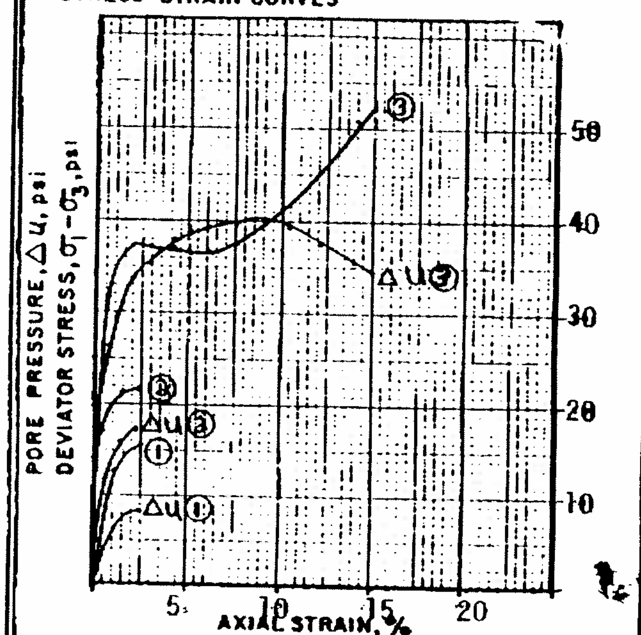
EMPIRE SOILS INVESTIGATIONS, INC.

Fig. No. 24

MOHR STRESS CIRCLES



STRESS-STRAIN CURVES



TEST DATA:

TYPE OF TEST: Consolidated undrained with Pore Pressure Measurement

BACK PRESSURE, PSI: 80 RATE OF STRAIN, INCH/MIN: 0:0018

SPECIMEN NUMBER	①	②	③	④	⑤
SPECIMEN HEIGHT, INCHES	5.515				
SPECIMEN DIAMETER, INCHES	2.926				
INITIAL WATER CONTENT, %	29.4				
INITIAL DRY DENSITY, pcf	94.8				
PORE PRESSURE RESPONSE, B, %	100				
NET CHAMBER PRESSURE, σ_3, psi	15.0	30.0	60.0		
DEVIATOR STRESS, $\sigma_1 - \sigma_3$, psi	15.4	21.9	37.2		
MAJOR PRINCIPAL STRESS, σ_1, psi (Effective)	22.1	34.6	61.4		
FAILURE SKETCH					

REMARKS: We note that in the third stage, two maximum points occured on the stress vs. strain curve. The first maximum point was utilized in our analysis.

FRICTION ANGLE ϕ DEGREES: 23°

COHESION INTERCEPT, c, psf: 316

SAMPLE DATA:
BORING NO. B-5 SURF. ELEV. ____
SAMPLE NO. ____ DEPTH, FT. 20-22'
SAMPLE TYPE 3" Diameter Shelby Tube Sampl

VISUAL DESCRIPTION: Red-Brown Silt and Clay

CLASSIFICATION TESTS:
SPECIFIC GRAVITY ____ ORGANIC CONTENT % ____
LIQUID LIMIT, % ____ PLASTIC LIMIT, % ____

EMPIRE SOILS INVESTIGATIONS INC

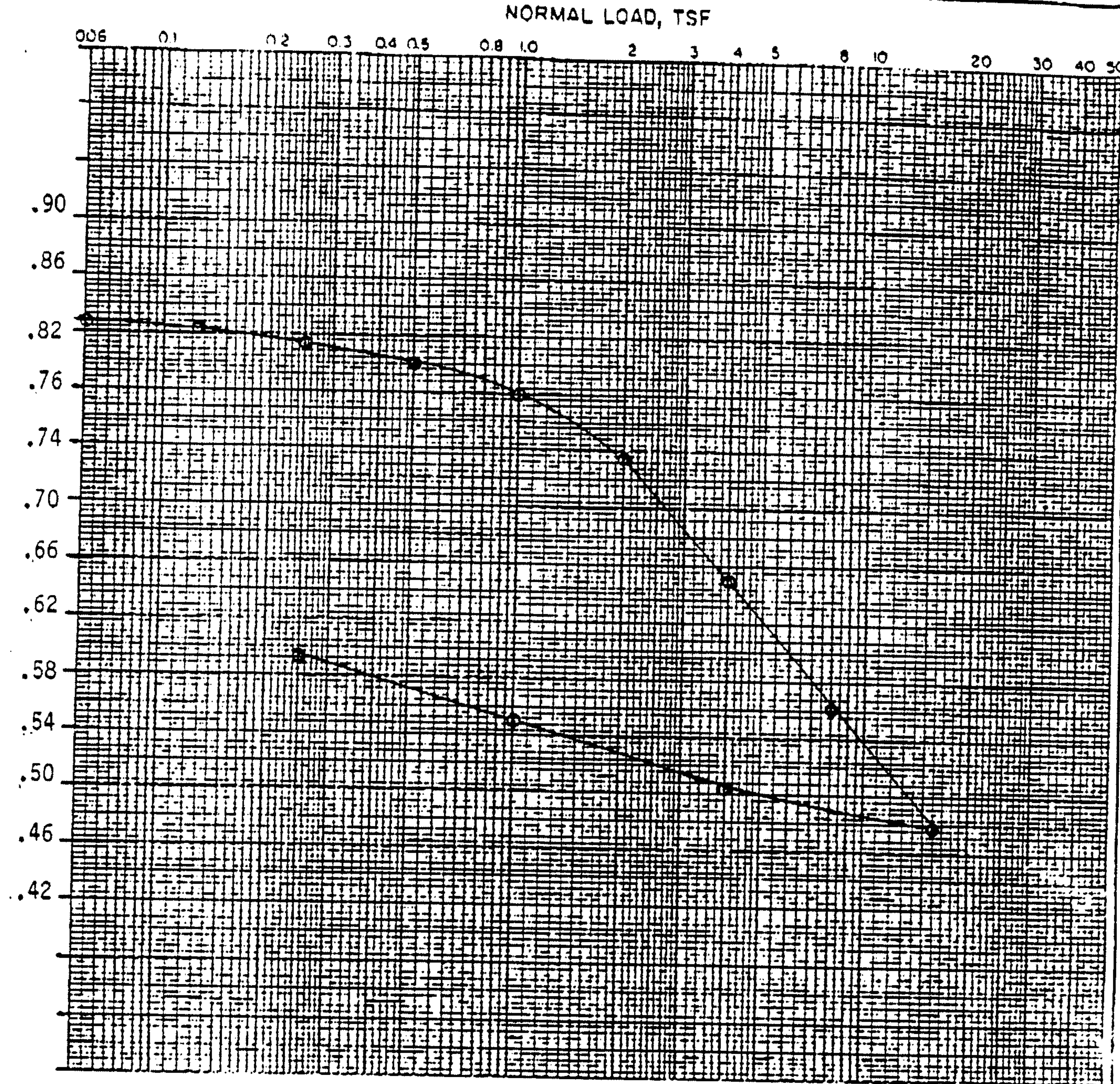
TRIAXIAL COMPRESSION TEST

SCA-Model City
SLF - 13
Donahue Associates

REPORT NO: 1-1

DR BY: TH | CK'D: CK | DATE: 7-21-88 | PROJ: ?D-88-5?

FORM TCT-1



SPECIMEN DATA	INITIAL	FINAL
MOISTURE CONTENT, %	31.8	27.4
VOID RATIO, e	.8260	.6592
DEGREE OF SATURATION, %	102.2	110.0
DRY DENSITY, pcf	90.6	——
HEIGHT, INCHES	1.000	0.909
DIAMETER, INCHES	2.50	——

TEST ANALYSIS:

EFFECTIVE IN-SITU PRESSURE, tsf -
PRECONSOLIDATION PRESS., tsf 1.6
NET PRECONSOLIDATION PRESS., tsf -
COMPRESSION INDEX, C_c .28
RECOMPRESSION INDEX, C_r .036

RELATED TESTS:

SPECIFIC GRAVITY 2.65
ORGANIC CONTENT, % -
LIQUID LIMIT, % -
PLASTIC LIMIT, % -
PLASTICITY INDEX -
LIQUIDITY INDEX -
PERCENT CLAY SIZE -
ACTIVITY -
UNDRAINED SHEAR STRENGTH, s_u, psf -

DRAWN BY: TH
CHECKED BY: CK

SAMPLE DATA:

BORING NO. B-6 SURF ELEV.
SAMPLE NO. DEPTH-FT. 25-27'

VISUAL DESCRIPTION: See Tube Log

EMPIRE SOILS INVESTIGATIONS, INC.

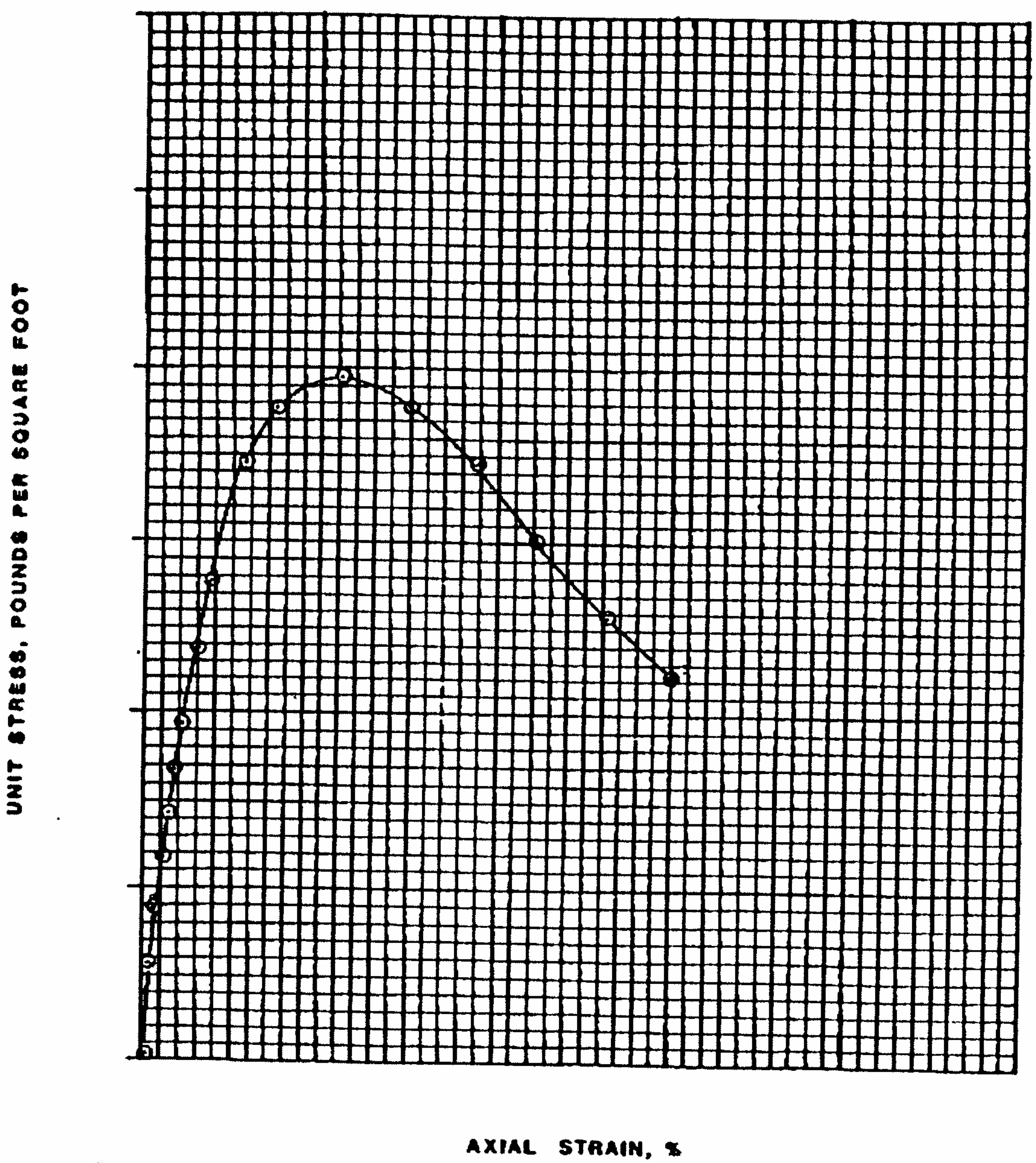
CONSOLIDATION TEST REPORT

SCA-Model
SLF - 13
Donahue Associates

REPORT NO: L-4

DATE: 7-21-88
PROJ. NO.: BD-88-52

Stress-Strain Curve



SAMPLE DATA:

Boring No. - Surf. Elev. -

Sample No. Depth, ft. -

Sample Type Composite Bag Samples&Tube Sample

VISUAL DESCRIPTION

CLASSIFICATION SYMBOL:

FAILURE SKETCH

SPECIMEN DATA:

Specimen Height, inches	5.40
Specimen Diameter, inches	2.81
Height to Diameter Ratio	1.92
Natural Water Content %	12.3
Dry Unit Weight, pcf	114.3
Rate of Strain %/min.	0.83
Peak Strain %	2.78
Unconfined Compressive Strength, Q, psf	3947
Shear Strength, $Q_u/2$, psf	1974

CLASSIFICATION TESTS:

Plastic Limit, % Liquid Limit, %

REMARKS:

Samples remolded to 91.1% of Proctor (125.4 lb/ft^3 @ 9.9%)

EMPIRE SOILS INVESTIGATIONS INC

UNCONFINED COMPRESSION TEST

SCA - Model City
SLF - 13
Donahue Associates

REPORT NO: L-5

DR.BY: TH	CK'D CK	DATE: 7-21-88	PROJ.NO. [illegible]-52

TEST DATA:

Specimen Height (cm): 14.06

Specimen Diameter (cm): 7.12

Dry Unit Weight (pcf): 111.3

Moisture Content Before Test (%): 12.4

Moisture Content After Test (%): 16.3

Cell Confining Pressure (psi): 95

	○	△
Test Pressure (psi):	85	90
Back Pressure (psi):	80	80
Differential Head (psi):	5	10
Flow Rate (ΔV/t)(cm³/sec)	○ 3.20×10^{-4}	△ 6.28×10^{-4}
Permeability (cm/sec):	○ 3.21×10^{-7}	△ 3.15×10^{-7}

SAMPLE DATA:

Sample Identification: Composite Sample

Visual Description: Red-brown Clay, some Silt

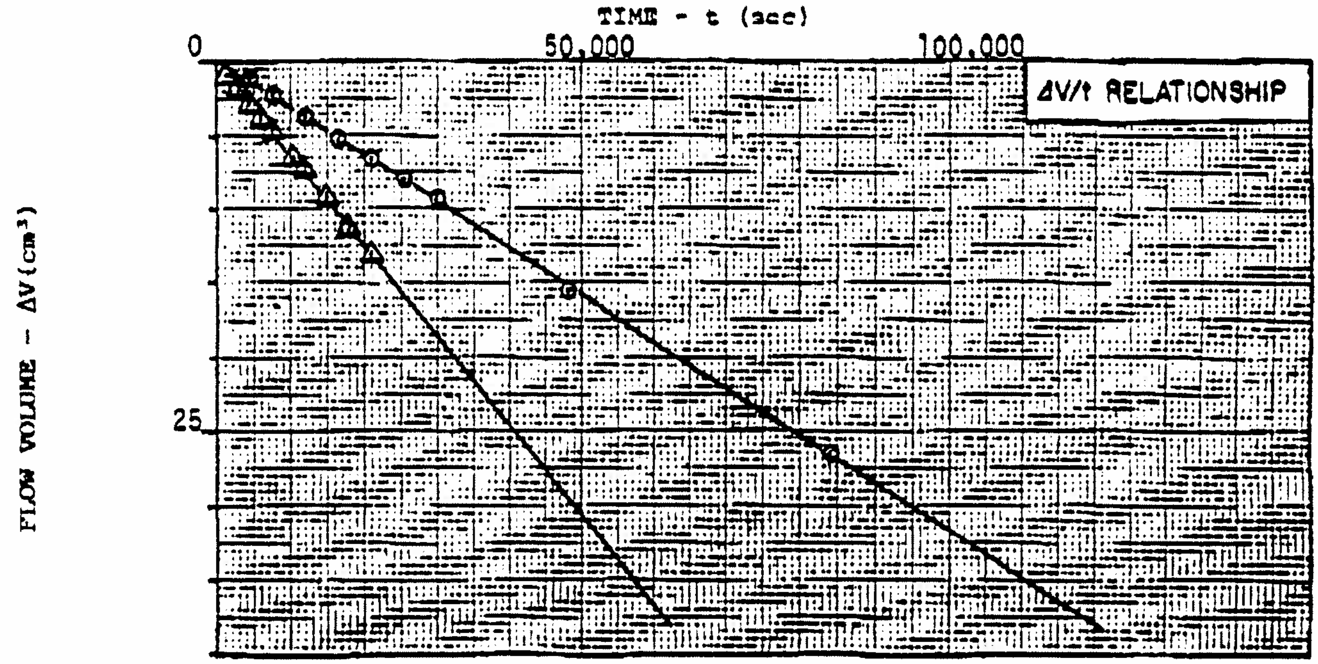
Remarks:

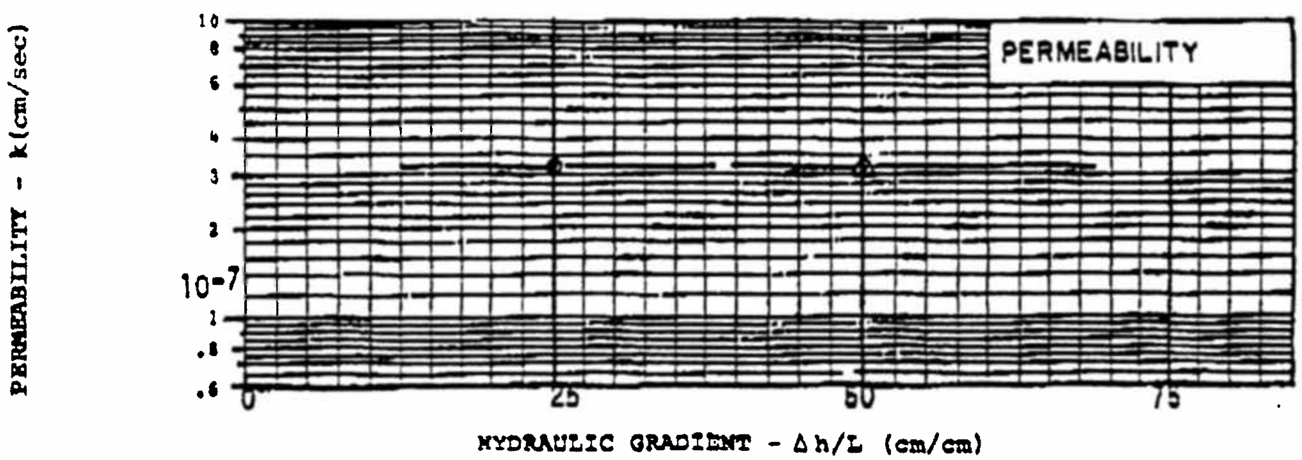
Maximum Dry Density (ASTM D 1557) (pcf): 125.4

Optimum Moisture Content (%): 9.9

Percent Compaction: 88.8

Permeameter Type: Constant Head Triaxial





EMPIRE

PERMEABILITY TEST REPORT

SCA - MODEL CITY
Donohue & Associates, Inc.

DRAWN: | CK'D: CK | DATE: 8/11/88 | PROJ. NO: 80-88-52

Donohue

April 28, 1988

Empire Soils Investigation, Inc.
South 1567 South Park Avenue
P.O. Box 0913
Hamburg, N.Y. 14075

Attn: Mr. Frank Minnolera

Re: Testing of Soil Samples from SCA-Model City Site
Model City, New York
Donohue Project No. 15718.102

Dear Mr. Minnolera:

This letter is a follow-up to our conversation on Thursday, April 21, 1988, regarding the proposed testing program for the soil samples recently collected at the SCA-Model City Site.

The purpose of the testing program is two-fold. First, to identify the permeability, optimum moisture, and strength characteristics of the upper red till for construction-related purposes. This material is to be used for the construction of a clay liner, berms, and sidewalls. Secondly, we would like to identify the strength, bearing, and load capacities of the lower soft, gray glacio-lacustrine clay. Due to the high in-place moisture content, and the putty-like nature of this clay, it may be difficult to run some of the proposed tests.

Enclosed with this letter are two tables showing a breakdown of the tests we would like run for the various samples. For your information, I am also enclosing copies of my boring logs, another copy of the original contract, and a site map showing the boring locations.

Donohue & Associates, Inc.
4738 North 40th Street
Sheboygan, Wisconsin 53083

Engineers & Architects
414-458-8711

Telex 910-264-3888
Telefax 414-458-0537

Donohue

If you have any questions or problems with this testing program, do not hesitate to call us. You may direct any inquiries to Michael Ruetten in Sheboygan, Wisconsin.

Sincerely,

DONOHUE & ASSOCIATES, INC.

Mark Powers

Mark A. Powers
Geologist

Michael G. Ruetten, P.E.
Project Manager

MAP/MGR/jkw

enc: As Noted

cc: Robert Isenberg - Donohue
Stanley Blas, Jr. - Empire/Thomson

TR/L/ZH4

TABLE 1

SAMPLE	BORING NUMBER	SAMPLING DEPTH	LITHOSTRATI GRAPHIC UNIT	PROPOSED TESTING COMMENTS
Shelby Tube	B-2	10'	Upper Till	GS,✓ ATT.✓, MC✓ U.WT.✓ C = 775
Shelby Tube	B-5	2'-4'	Upper Till	GS,✓ ATT.✓, MC✓ U.WT.✓, U.U or C.U
Shelby Tube	B-7	3'-5'	Upper Till	GS,✓ ATT.✓, MC✓ U.WT✓, U.U or C.U
				Total of 3 Tubes C = 1300
BAG Sample	B-4	2'-3'	Upper Till	GS, ATT. ✓
BAG Sample	B-4	3'-10'	Upper Till	GS, ATT. ✓
BAG Sample	B-5	2'-5'	Upper Till	GS, ATT. ✓
BAG Sample	B-6	3'-7'	Upper Till	GS, ATT. ✓
(2)BAG Sample	B-7	2'-7'	Upper Till	GS, ATT. ✓
(2)BAG Sample	B-8	5'-8'	Upper Till	GS, ATT. ✓
(2)BAG Sample	B-9	4'-8'	Upper Till	GS, ATT. ✓
				Total of 10 BAG Samples

COMMENTS:

1. On the Shelby Tubes, run each of the following test: Grain Size, Atterburgs, Moisture Content, and Unit Weight.

2. In addition, tubes from B-5 and B-7 run a C.U. test and U.U. test. One strength test per tube.

3. Combine all remaining (CL) material from the Shelby Tubes and BAG Samples. From this, run the following tests:

   One Proctor value, one remolded permeability run at 90% of modified proctor and several points above optimum moisture, one U.U. test, and one C.U. test on the remolded sample at 90% modified proctor, and several points above optimum moisture.

KEY

GS - Grain Size
MC - Moisture Content
ATT. - Atterburgs
Proc. - Proctor
R.P - Remolded Permeability
U.WT. - Unit Weights
C.U. - Consolidated Undrained at Perimeter
U.U - Unconsolidated Undrained

TR/L/ZH8

$\gamma_{max} = 125.5$

TABLE 2

SAMPLE	BORING NUMBER	SAMPLING DEPTH	LITHOSTRATIGRAPHIC UNIT	PROPOSED TESTING COMMENTS
Shelby Tube	B-2	17'-19'	Glaciolacustrine	GS, ATT., MC, U.WT.
Shelby Tube	B-3	15'-17'	Glaciolacustrine	GS, ATT., MC, U.WT.
Shelby Tube	B-4	25'-27'	Glaciolacustrine	GS, ATT., MC, U.WT. UU C = 320
Shelby Tube	B-5	20'-22'	Glaciolacustrine	GS, ATT., MC, U.WT. CU C = 316 ∅
Shelby Tube	B-6	15'-17'	Glaciolacustrine	GS, ATT., MC, U.WT. UU C = 610
Shelby Tube	B-6	25'-27'	Glaciolacustrine	GS, ATT., MC, U.WT. CU CON
Shelby Tube	B-7	20'-22'	Glaciolacustrine	GS, ATT., MC, U.WT. C=150 ∅ =
Shelby Tube	B-8	25'-27'	Glaciolacustrine	GS, ATT., MC, U.WT.
Shelby Tube	B-9	20'-22'	Glaciolacustrine	GS, ATT., MC, U.WT. CU C=190 ∅ =
Shelby Tube	B-10	20'-22'	Glaciolacustrine	GS, ATT., MC, U.WT.

COMMENTS:

1. Run the following tests on all 10 tubes: Grain Size, Atterburgs, Moisture Content, and Unit Weights (undisturbed).
2. Select five tubes and run two U.U. tests, and three C.U. three stage tests.
3. Run one consolidation test on the Shelby Tube with the softest glaciolacustraine material.

KEY

GS - Grain Size
MC - Moisture Content
ATT. - Atterburgs
Proc. - Proctor
R.P. - Remolded Permeability
U.WT. - Unit Weights
C.U. - Consolidated Undrained 3-Stage
U.U. - Unconsolidated Undrained
CON. - Consolidation

TR/L/ZH8

EMPIRE
SOILS INVESTIGATIONS INC.

TRANSMITTAL

DATE: 10-17-88

NAME: Donohue & Associates, Inc.

ADDRESS: 4738 North 40th. Street
Sheboygan, WI 53081

ATTENTION: Mike Pratter

RE: Model City JOB #: BD-88-52

WE ARE SENDING YOU: (x) Herewith ( ) Under Separate Cover

( ) Report ( ) Subsurface Logs ( ) Brochures

( ) Drawings ( ) Samples ( ) CT REPORTS

No. Copies	Title or Description
2	SCA-Model City

THESE ARE: (✓) For your information ( ) Per your request
( ) Other

REMARKS:

SENT BY:

( ) First Class Mail
( ) Certified Mail
( ) United Parcel Service
( ) Messenger
( ) Federal Express
( )

Very truly yours,

EMPIRE SOILS INVESTIGATIONS, INC

S-5167 SOUTH PARK AVENUE, P.O. BOX 0913, HAMBURG, NY 14075, 716-649-8110

EMPIRE
SOILS INVESTIGATIONS INC.

September 30, 1988

Donohue & Associates, Inc.
4738 North 40th. Street
Sheboygan, Wisconsin 53081

Attention: Mike Reutten

Reference: SCA - Model City

Gentlemen:

Enclosed please find laboratory test data for the above referenced project.

This data is in addition to that already reported by our subsurface investigation report dated June 1988.

The following test reports are included at this time.

1) Consolidation test Boring #6 at 25'-27'.
2) Consolidated undrained triaxial compression; composite sample.

This test data completes our work performed for this project.

If you have any further questions, please feel free to contact our office.

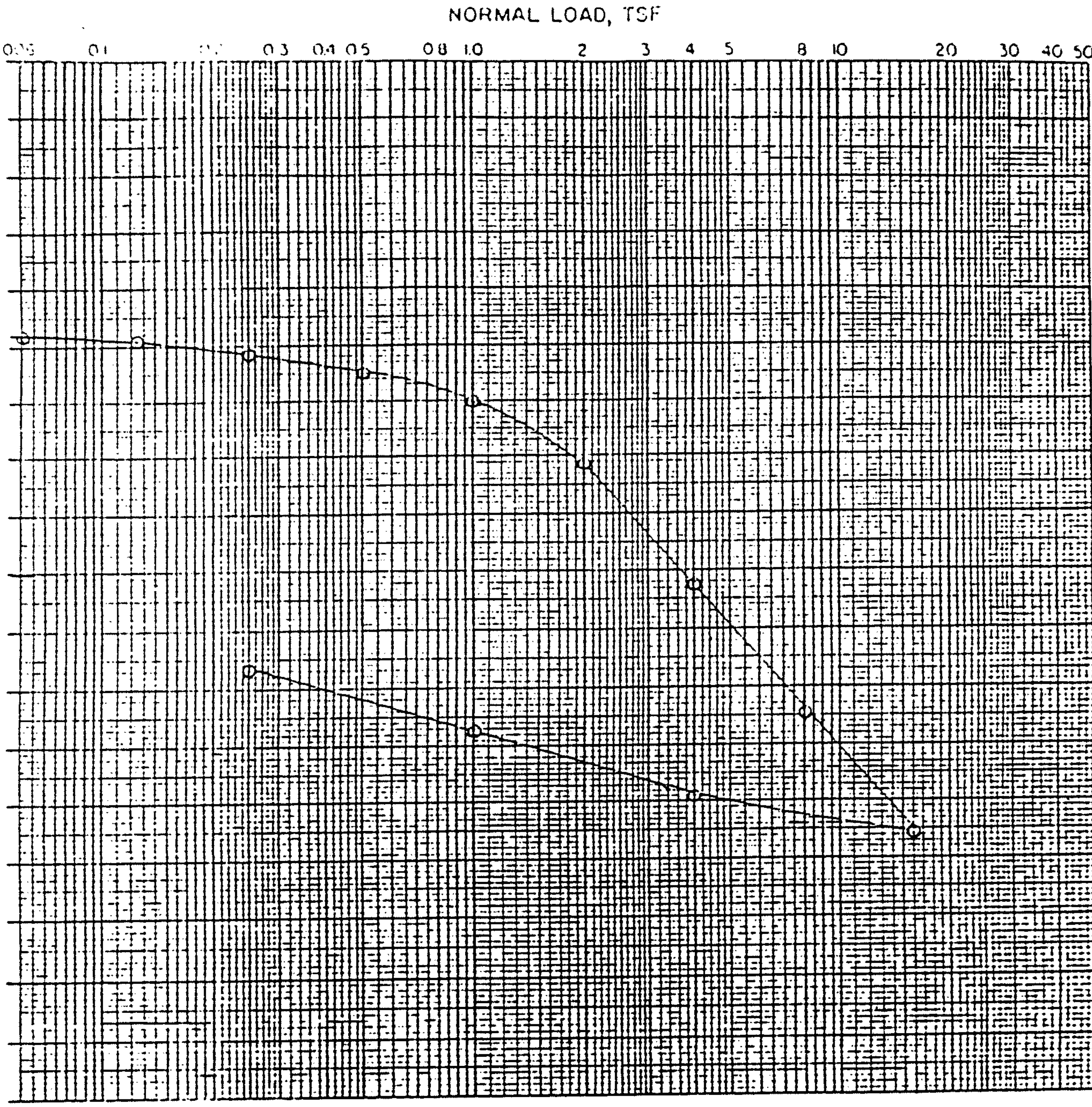
Respectfully submitted,

EMPIRE SOILS INVESTIGATIONS, INC.

Charles C. Keipper
Manager of Testing Services

Edward J. Barbiero
Civil/Materials Engineer

sll



SPECIMEN DATA	INITIAL	FINAL
MOISTURE CONTENT, %	31.8	27.4
VOID RATIO, e	.8260	.6592
DEGREE OF SATURATION, %	102.2	110.0
DRY DENSITY, pcf	90.6	—
HEIGHT, INCHES	1.000	0.909
DIAMETER, INCHES	2.50	—

TEST ANALYSIS:

EFFECTIVE IN-SITU PRESSURE, tsf -
CONSOLIDATION PRESS, tsf 1.6
NET PRECONSOLIDATION PRESS, tsf -
COMPRESSION INDEX, C_c .28
RECOMPRESSION INDEX, C_r .036

RELATED TESTS:

SPECIFIC GRAVITY 2.65
ORGANIC CONTENT, % -
LIQUID LIMIT, %
PLASTIC LIMIT, %
PLASTICITY INDEX
LIQUIDITY INDEX
PERCENT CLAY SIZE
ACTIVITY
UNDRAINED SHEAR STRENGTH, s_u, psf

DRAWN BY:
CHECKED BY

SAMPLE DATA:

BORING NO. B-6 SURF ELEV
SAMPLE NO DEPTH-FT 25-27'

VISUAL DESCRIPTION: See Tube Log

EMPIRE SOILS INVESTIGATIONS INC

CONSOLIDATION TEST REPORT

SCA - MODEL CITY
Donohue & Associates
REPORT NO: L-6

DATE: AUG. 1988 PROJ NO: BD-88-52

EMPIRE
SOILS INVESTIGATIONS INC

September 30, 1988

Donohue & Associates, Inc.
4738 North 40th. Street
Sheboygan, Wisconsin 53081

Attention: Mike Reutten

Reference: SCA - Model City

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This test data completes our work performed for this project.

If you have any further questions, please feel free to contact our office.

Respectfully submitted,

EMPIRE SOILS INVESTIGATIONS, INC.

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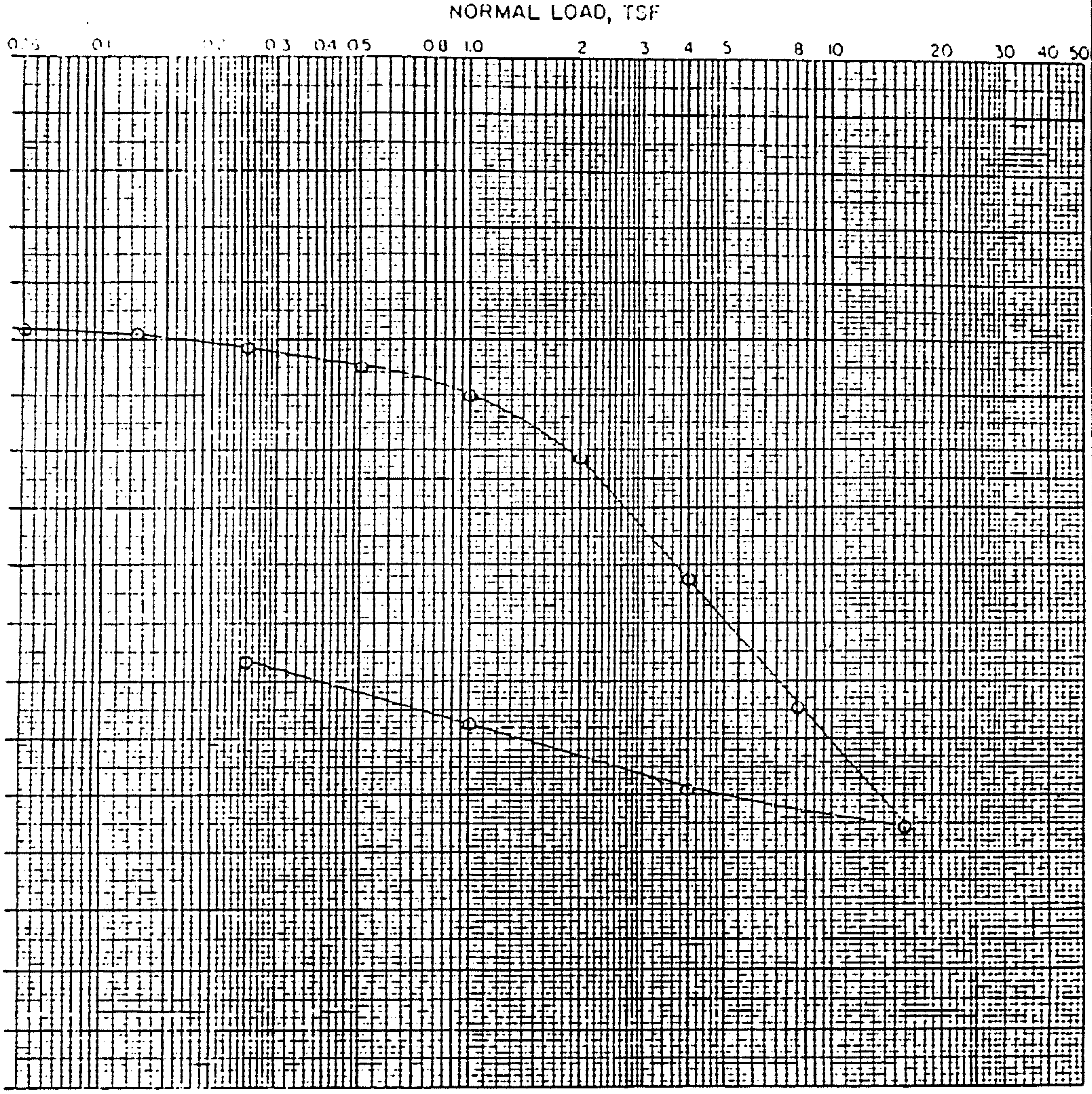
Civil/Materials Engineer

sll



SPECIMEN DATA	INITIAL	FINAL
MOISTURE CONTENT, %	31.8	27.4
VOID RATIO, e	.8260	.6592
DEGREE OF SATURATION, %	102.2	110.0
DRY DENSITY, pcf	90.6	——
HEIGHT, INCHES	1.000	0.909
DIAMETER, INCHES	2.50	——

TEST ANALYSIS:

TIVE IN-SITU PRESSURE, tsf –
NSOLIDATION PRESS., tsf 1.6
NET PRECONSOLIDATION PRESS., tsf –
COMPRESSION INDEX, C_c .28
RECOMPRESSION INDEX, C_r .036

RELATED TESTS:

SPECIFIC GRAVITY 2.65
ORGANIC CONTENT, % –
LIQUID LIMIT, %
PLASTIC LIMIT, %
PLASTICITY INDEX
LIQUIDITY INDEX
PERCENT CLAY SIZE
ACTIVITY
UNDRAINED SHEAR STRENGTH, s_u, psf

DRAWN BY
CHECKED BY

SAMPLE DATA:
BORING NO. B-6 SURF ELEV
SAMPLE NO DEPTH-FT 25-27'

VISUAL DESCRIPTION: See Tube Log

EMPIRE SOILS INVESTIGATIONS INC

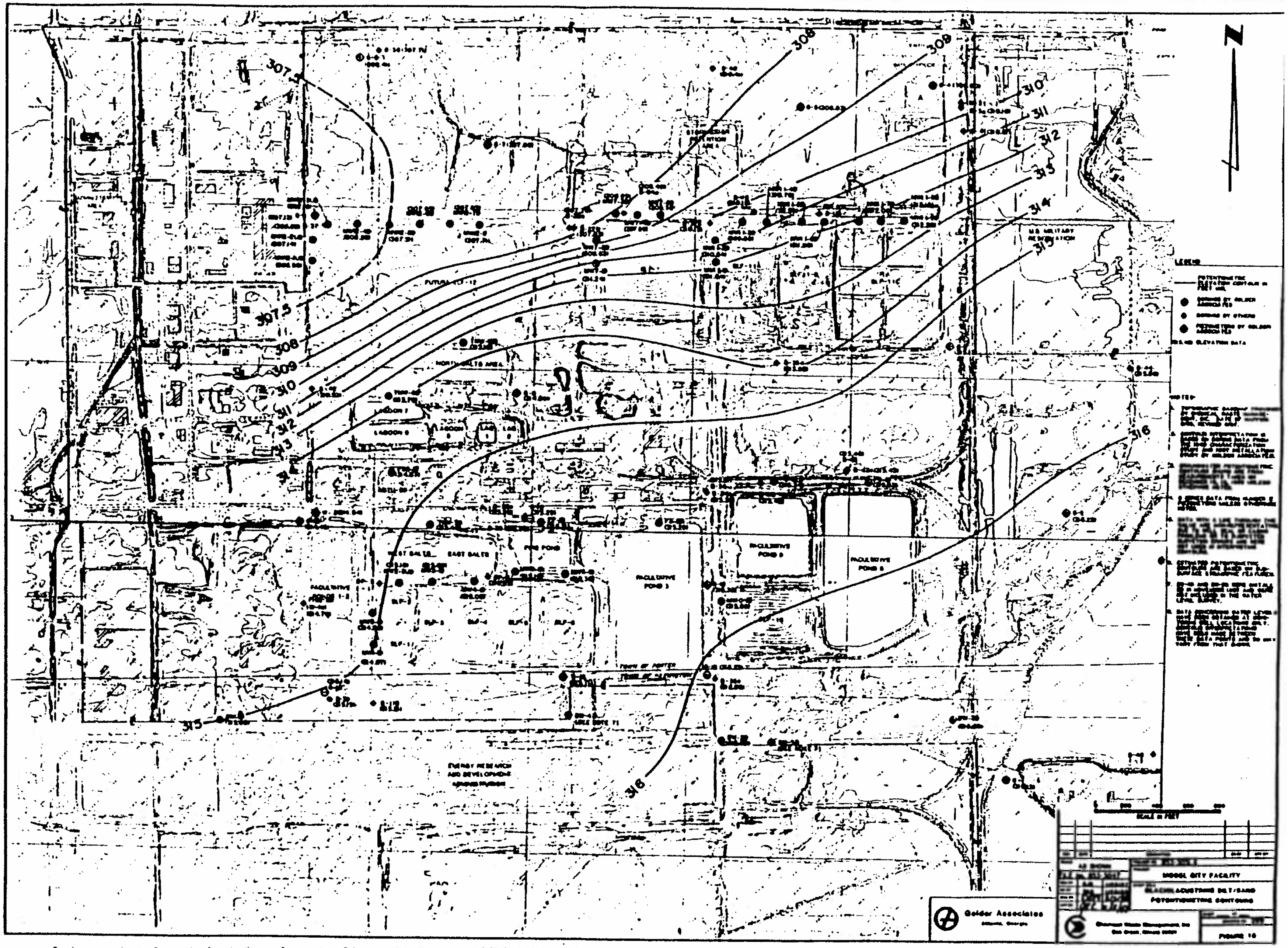
CONSOLIDATION TEST REPORT

SCA - MODEL CITY
Donohue & Associates
REPORT NO: L-6

DATE: AUG. 1988
PROJ NO: BD-88-52

APPENDIX C

GROUNDWATER POTENTIOMETRIC CONTOURS



N
LEGEND
NOTES:
SCALE IN FEET
AS SHOWN
MODEL CITY FACILITY
GLACIOLACUSTRINE SILT/SAND
POTENTIOMETRIC CONTOURS
Golder Associates
Atlanta, Georgia
FIGURE 10
FACULTATIVE POND 1
FACULTATIVE POND 2
FACULTATIVE POND 3
FIRE POND
EAST SALTS
NORTH SALTS AREA
U.S. MILITARY RESERVATION
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
307.5
308
309
310
311
312
313
314
315
316

APPENDIX D

GEOTECHNICAL CALCULATIONS

D-1 Consolidation of Glaciolacustrine Clay

D-2 Waste Settlement

D-3 Excavation Heave

D-4 Hydrostatic Uplift

D-5 Slope Stability of Perimeter Berm

D-6 Slope Stability at Final Buildout

D-7 Differential Waste Height Stability

D-8 Final Cover Stability

D-9 Liquefaction

D-10 Side Slope Gecomponents Tension Strength Analysis

D-1

CONSOLIDATION OF GLACIOLACUSTRINE CLAY

TASK:

To verify that the design centerline slope of 1.3% of the redesigned RMU - 1 Cells 9/10, 11/13, and 12/14 meets the 6 NYCRR Subpart 373-2.14 minimum post-settlement slope requirement of 1%.

REFERENCES:

1. Das, B. M.; "Principals of Geotechnical Engineering;" 3rd Edition; 1994.
2. Engineering Report for Model City Facility, Residual Management Unit 1, SEC Donohue, June 1992,
3. Drawing No. 4, "Excavation Grades," prepared by SEC Donohue, dated June 1992, revised by Rust Environment & Infrastructure, June 1997.
4. Drawing No. 10, "Top of Operations Layer Grades," prepared by Rust Environment & Infrastructure, dated April 1997.
5. Drawing No. 12, "Top of Vegetative Cover," prepared by SEC Donohue, dated June 1992, revised Augu
6. Isopach Map from "Hydrogeologic Characterization Update," prepared by Golder Associates, dated June
7. Figure - 4, "Subbase Grades Cells 9 through 14," prepared by Rust Environment & Infrastructure, dated April 1997.

ASSUMPTIONS:

1. Settlement will be evaluated for final landfill development permit grades.
2. The underlying glaciolacustrine clay layer is normally consolidated.
3. Primary consolidation settlement is assumed to account for the total settlement of the subgrade material. Secondary consolidation and immediate settlement are considered much smaller than the primary consolidation and of less practical significance.
4. The top of the glaciolacustrine clay layer is at elevation 305.

CALCULATIONS:

For normally consolidated soils (reference 1):

$$P_0 + \Delta P < P_C$$

$$S = \frac{C_C H}{1 + e_0} \log \frac{(P_0 + \Delta P)}{P_0}$$

where:

S = Settlement (ft)
C_C = Compression Index
e_0 = Initial Void Ratio
H = Thickness of Clay Layer (ft)
P_0 = Initial Pressure (psf)
ΔP = Stress Increase (psf)
P_C = Preconsolidation Stress (psf)

The following waste, soil, and liner properties have been determined from previous testing (reference 2):

$\gamma_{waste} = 111.1$ pcf
$\gamma_{liner} = 130$ pcf
$\gamma_{upper\ till} = 130$ pcf
$\gamma_{glaciolacustrine\ clay} = 125$ pcf
$C_C = 0.28$
$e_0 = 0.826$

Combined Cell 10/9

Settlement at Point A (at Cell 10 sump location)

Approximate Location	= 92+60 N, 19+21E	
Existing Elevation (reference 3)	= 311	ft
Top of Vegetative Cover (reference 5)	= 352	ft
Top of Operations Layer (reference 4)	= 315.5ft	
Top of Glaciolacustrine Clay Layer (reference 6)	= 305	ft
Thickness of Glaciolacustrine Clay Layer (reference 6)	= 15	ft
Liner System Thickness	= 7.5	ft
Final Cover System Thickness	= 5.0	ft

P_0 = initial pressure at midheight of clay layer

P_0 = [(311 ft - 305 ft) x 130 pcf] + [(15 ft/2) x 125 pcf] = 1,718 psf

ΔP = increase in pressure due to new landfill

ΔP = [(352 ft - 5 ft - 315.5 ft) x 111.1 pcf] + [(7.5 ft + 5.0 ft) x 130 pcf] = 5,125 psf

S = primary settlement

$$S = \frac{(0.28)\ (15\ ft)}{1\ +\ 0.826} \log \frac{(1{,}718\ psf\ +\ 5{,}125\ psf)}{1{,}718\ psf} = 1.38\ ft$$

Settlement at Point B (at mid-point of combined Cells 10/9)

Approximate Location	= 92+60 N, 22+63E	
Existing Elevation (reference 3)	= 315.5	ft
Top of Vegetative Cover (reference 5)	= 424	ft
Top of Operations Layer at 1.3% slope from sump (reference 4) 315.5 ft + 0.013 x 354 ft	= 320.0	ft
Top of Glaciolacustrine Clay Layer (reference 6)	= 305	ft
Thickness of Glaciolacustrine Clay Layer (reference 6)	= 15	ft
Liner System Thickness	= 7.5	ft
Final Cover System Thickness	= 5.0	ft

P_0 = initial pressure at midheight of clay layer

P_0 = [(315.5 ft - 305 ft) x 130 pcf] + [(15 ft/2) x 125 pcf] = 2,303 psf

ΔP = increase in pressure due to new landfill

ΔP = [(424 ft - 5 ft - 320.0 ft) x 111.1 pcf] + [(7.5 ft + 5.0 ft) x 130 pcf] = 12,624 psf

S = primary settlement

$$S = \frac{(0.28)\ (15\ \text{ft})}{1 + 0.826} \log \frac{(2{,}303\ \text{psf} + 12{,}624\ \text{psf})}{2{,}303\ \text{psf}} = 1.87\ \text{ft}$$

Settlement at Point C (at east side of Cell 9)

Approximate Location	= 92+60 N, 26+31E	
Existing Elevation (reference 4)	= 320	ft
Top of Vegetative Cover (reference 5)	= 352	ft
Top of Operations Layer (reference 3)	= 324.78	ft
Top of Glaciolacustrine Clay Layer (reference 6)	= 305	ft
Thickness of Glaciolacustrine Clay Layer (reference 6)	= 17	ft
Liner System Thickness	= 7.5	ft
Final Cover System Thickness	= 5.0	ft

P_0 = initial pressure at midheight of clay layer

P_0 = [(320 ft - 305 ft) x 130 pcf] + [(17 ft/2) x 125 pcf] = 3,013 psf

ΔP = increase in pressure due to new landfill

ΔP = [(352 ft - 5 ft - 324.78 ft) x 111.1 pcf] + [(7.5 ft + 5.0 ft) x 130 pcf] = 4,094 psf

S = primary settlement

$$S = \frac{(0.28)\ (17\ \text{ft})}{1 + 0.826} \log \frac{(3{,}013\ \text{psf} + 4{,}094\ \text{psf})}{3{,}013\ \text{psf}} = 0.97\ \text{ft}$$

Check Minimum Post - Settlement Slope Requirement of 1% (6 NYCRR Subpart 373-2.14)

Post-Settlement Slope Point A to Point B

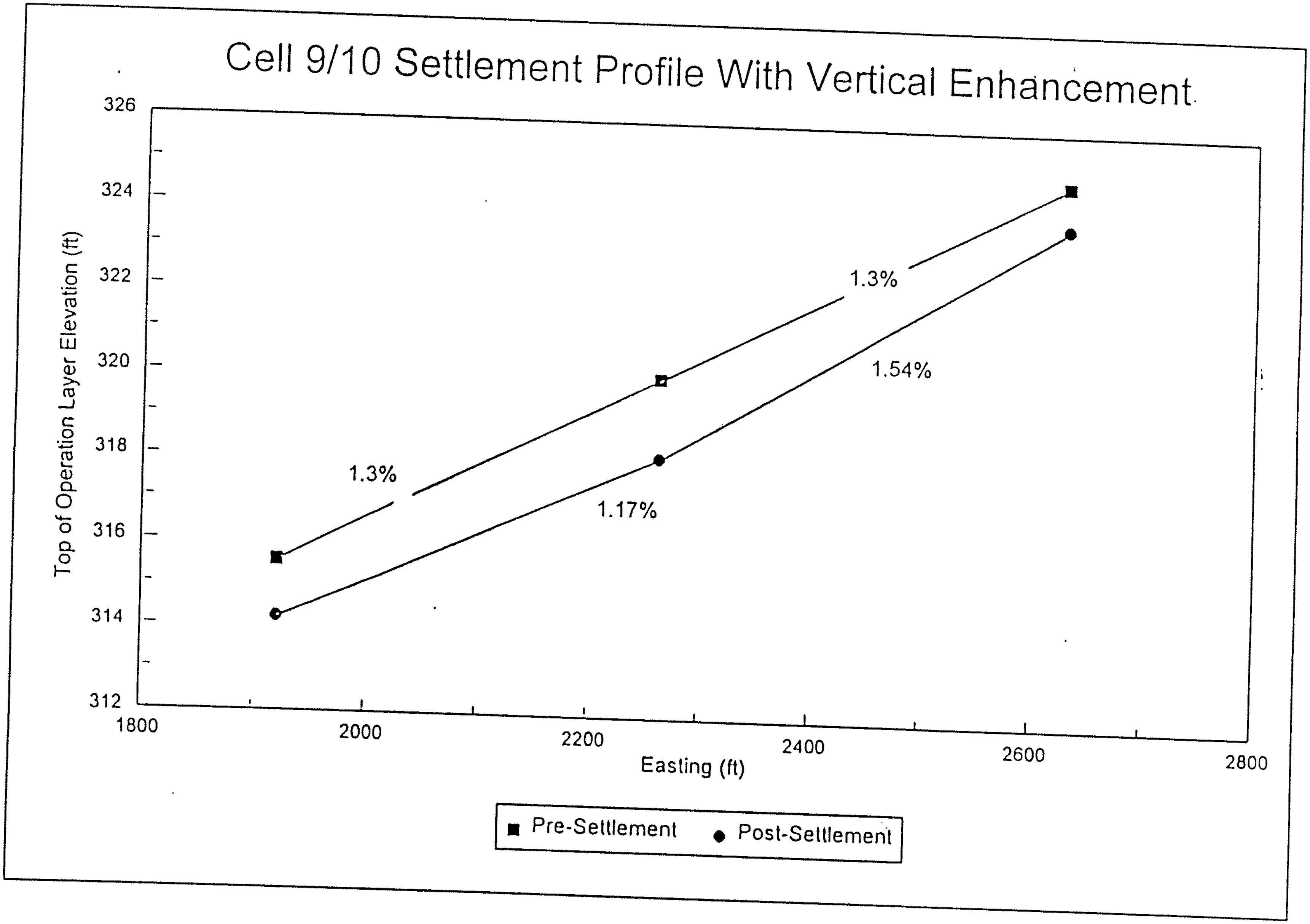
[(320.0 ft - 1.87 ft) - (315.5 ft - 1.38 ft)] / (2,263 ft - 1,921 ft) = 0.0117 ft/ft
= 1.17%

Post-Settlement Slope Point B to Point C

[(324.78 ft - 0.97 ft) - (320.0 ft - 1.87 ft)] / (2,631 ft - 2,263 ft) = 0.0154 ft/ft
= 1.54%

Conclusions

The post-settlement slope of 1.17% exceeds the required 1.0% post-settlement slope. Therefore, the centerline grade (pre-settlement) of 1.3% is sufficient for design.



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Combined Cell 11/13

Settlement at Point D (at Cell 13 Sump Location)

Approximate Location	= 85+37 N, 24+50 E	
Existing Elevation (reference 3)	= 306	ft
Top of Vegetative Cover (reference 5)	= 361	ft
Top of Operations Layer (reference 4)	= 312.16	ft
Top of Glaciolacustrine Clay Layer (reference 6)	= 305	ft
Thickness of Glaciolacustrine Clay Layer (reference 6)	= 20	ft
Liner System Thickness	= 7.5	ft
Final Cover System Thickness	= 5.0	ft

P_0 = initial pressure at midheight of clay layer

P_0 = [(306 ft - 305 ft) x 130 pcf] + [(20 ft/2) x 125 pcf] = 1,380 psf

ΔP = increase in pressure due to new landfill

ΔP = [(361 ft - 5 ft - 312.16 ft) x 111.1 pcf] + [(7.5 ft + 5.0 ft) x 130 pcf] = 6,496 psf

S = primary settlement

$$S = \frac{(0.28)\ (20\ \text{ft})}{1 + 0.826} \log \frac{(1{,}380\ \text{psf} + 6{,}496\ \text{psf})}{1{,}380\ \text{psf}} = 2.32\ \text{ft}$$

Settlement at Point E (at mid-point of combined Cells 11/13)

Approximate Location	= 87+55 N, 24+50 E	
Existing Elevation (reference 3)	= 307.5	ft
Top of Vegetative Cover (reference 5)	= 410	ft
Top of Operations Layer (reference 4)	= 315	ft
Top of Glaciolacustrine Clay Layer (reference 6)	= 301	ft
Thickness of Glaciolacustrine Clay Layer (reference 6)	= 21	ft
Liner System Thickness	= 7.5	ft
Final Cover System Thickness	= 5.0	ft

P_0 = initial pressure at midheight of clay layer

P_0 = [(307.5 ft - 301 ft) x 130 pcf] + [(21 ft/2) x 125 pcf] = 2,158 psf

ΔP = increase in pressure due to new landfill

ΔP = [(410 ft - 5 ft - 315 ft) x 111.1 pcf] + [(7.5 ft + 5.0 ft) x 130 pcf] = 11,624 psf

S = primary settlement

$$S = \frac{(0.28)\ (21\ ft)}{1 + 0.826} \log \frac{(2,158\ psf + 11,624\ psf)}{2,158\ psf} \qquad = 2.59 \quad ft$$

Settlement at Point F (at north side of Cell 11)

Approximate Location	= 90+02 N, 24+50 E	
Existing Elevation (reference 3)	= 311	ft
Top of Vegetative Cover (reference 5)	= 408	ft
Top of Operations Layer at 1.3% slope from sump (reference 4)	= 318.2	ft
Top of Glaciolacustrine Clay Layer (reference 6)	= 301	ft
Thickness of Glaciolacustrine Clay Layer (reference 6)	= 18	ft
Liner System Thickness	= 7.5	ft
Final Cover System Thickness	= 5.0	ft

P_0 = initial pressure at midheight of clay layer

P_0 = [(311 ft - 301 ft) x 130 pcf] + [(18 ft/2) x 125 pcf] = 2,425 psf

ΔP = increase in pressure due to new landfill

ΔP = [(408 ft - 5 ft - 318.2 ft) x 111.1 pcf] + [(7.5 ft + 5.0 ft) x 130 pcf] = 11,046 psf

S = primary settlement

$$S = \frac{(0.28)\ (18\ ft)}{1 + 0.826} \log \frac{(2,425\ psf + 11,046\ psf)}{2,425\ psf} \qquad = 2.06 \quad ft$$

Check Minimum Post - Settlement Slope Requirement of 1% (6 NYCRR Subpart 373-2.14)

Post-Settlement Slope Point D to Point E

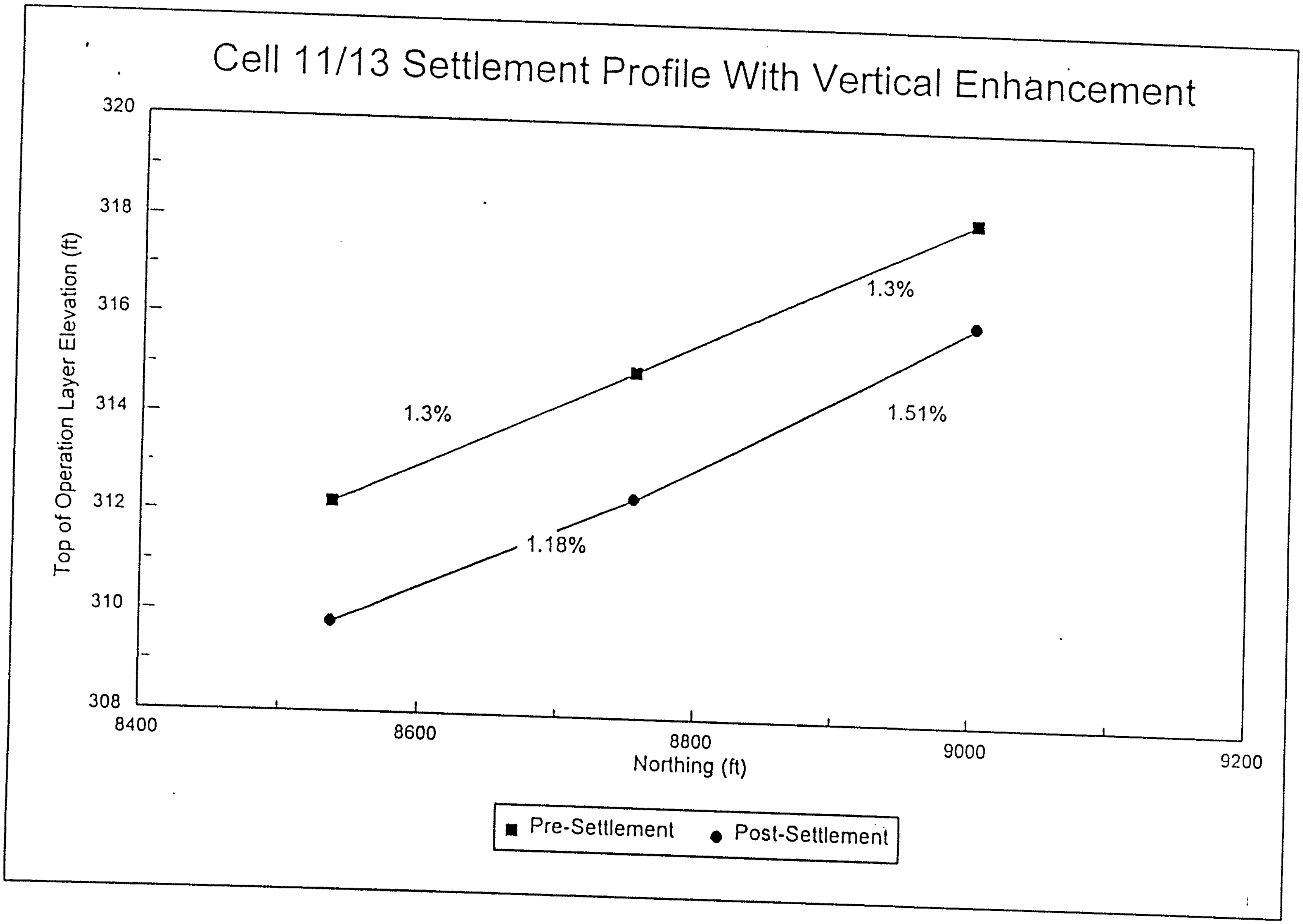
[(315.0 ft - 2.59 ft) - (312.16 ft - 2.32 ft)] / (8,755 ft - 8,537 ft) = 0.0118 ft/ft
= 1.18%

Post-Settlement Slope Point E to Point F

[(318.2 ft - 2.06 ft) - (315.0 ft - 2.59 ft)] / (9,002 ft - 8,755 ft) = 0.0151 ft/ft
= 1.51%

Conclusions

The post-settlement slope of 1.18% exceeds the required 1.0% post-settlement slope. Therefore, the centerline grade (pre-settlement) of 1.3% is sufficient for design.



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Cell 12/14

Settlement at Point G (at Cell 14 sump location)

Approximate Location	= 83+59 N, 20+88E	
Existing Elevation (reference 3)	= 306	ft
Top of Vegetative Cover (reference 5)	= 357	ft
Top of Operations Layer (reference 4)	= 312.41	ft
Top of Glaciolacustrine Clay Layer (reference 6)	= 303	ft
Thickness of Glaciolacustrine Clay Layer (reference 6)	= 18	ft
Excavation Grade (reference 7)	= 305.0ft	
Liner System Thickness	= 7.5	ft
Final Cover System Thickness	= 5.0	ft

P_0 = initial pressure at midheight of clay layer

P_0 = [(306 ft - 303 ft) x 130 pcf] + [(18 ft/2) x 125 pcf] = 1,515 psf

ΔP = increase in pressure due to new landfill

ΔP = [(357 ft - 5 ft - 312.41 ft) x 111.1 pcf] + [(7.5 ft + 5.0 ft) x 130 pcf] = 6,023 psf

S = primary settlement

$$S = \frac{(0.28)\ (18\ \text{ft})}{1 + 0.826} \log \frac{(1{,}515\ \text{psf} + 6{,}023\ \text{psf})}{1{,}515\ \text{psf}} = 1.92\ \text{ft}$$

Settlement at Point H (at mid-point of Combined Cells 12/14)

Approximate Location	= 87+12 N, 20+88E	
Existing Elevation (reference 3)	= 309	ft
Top of Vegetative Cover (reference 5)	= 400	ft
Top of Operations Layer (reference 4)	= 317	ft
Top of Glaciolacustrine Clay Layer (reference 6)	= 303	ft
Thickness of Glaciolacustrine Clay Layer (reference 6)	= 15	ft
Liner System Thickness	= 7.5	ft
Final Cover System Thickness	= 5.0	ft

P_0 = initial pressure at midheight of clay layer

P_0 = [(309 ft - 303 ft) x 130 pcf] + [(15 ft/2) x 125 pcf] = 1,718 psf

ΔP = increase in pressure due to new landfill

ΔP = [(400 ft - 5 ft - 317 ft) x 111.1 pcf] + [(7.5 ft + 5.0 ft) x 130 pcf] = 10,291 psf

S = primary settlement

$$S = \frac{(0.28)\ (15\ ft)}{1 + 0.826} \log \frac{(1{,}718\ psf + 108{,}291\ psf)}{1{,}718\ psf} \quad = 1.94\ ft$$

Settlement at Point I (at north limit of Cell 12)

Approximate Location	= 90+17 N, 20+88E	
Existing Elevation (reference 3)	= 309	ft
Top of Vegetative Cover (reference 5)	= 400	ft
Top of Operations Layer (reference 4)	= 320.96	ft
Top of Glaciolacustrine Clay Layer (reference 6)	= 305	ft
Thickness of Glaciolacustrine Clay Layer (reference 6)	= 15	ft
Liner System Thickness	= 7.5	ft
Final Cover System Thickness	= 5.0	ft

P_0 = initial pressure at midheight of clay layer

P_0 = [(309 ft - 305 ft) x 130 pcf] + [(15 ft/2) x 125 pcf] = 1,458 psf

ΔP = increase in pressure due to new landfill

ΔP = [(400 ft - 5 ft - 320.96 ft) x 111.1 pcf] + [(7.5 ft + 5.0 ft) x 130 pcf] = 9,851 psf

S = primary settlement

$$S = \frac{(0.28)\ (15\ ft)}{1 + 0.826} \log \frac{(1{,}458\ psf + 9{,}851\ psf)}{1{,}458\ psf} \quad = 2.05\ ft$$

Check Minimum Post - Settlement Slope Requirement of 1% (6 NYCRR Subpart 373-2.14)

Post-Settlement Slope Point G to Point H

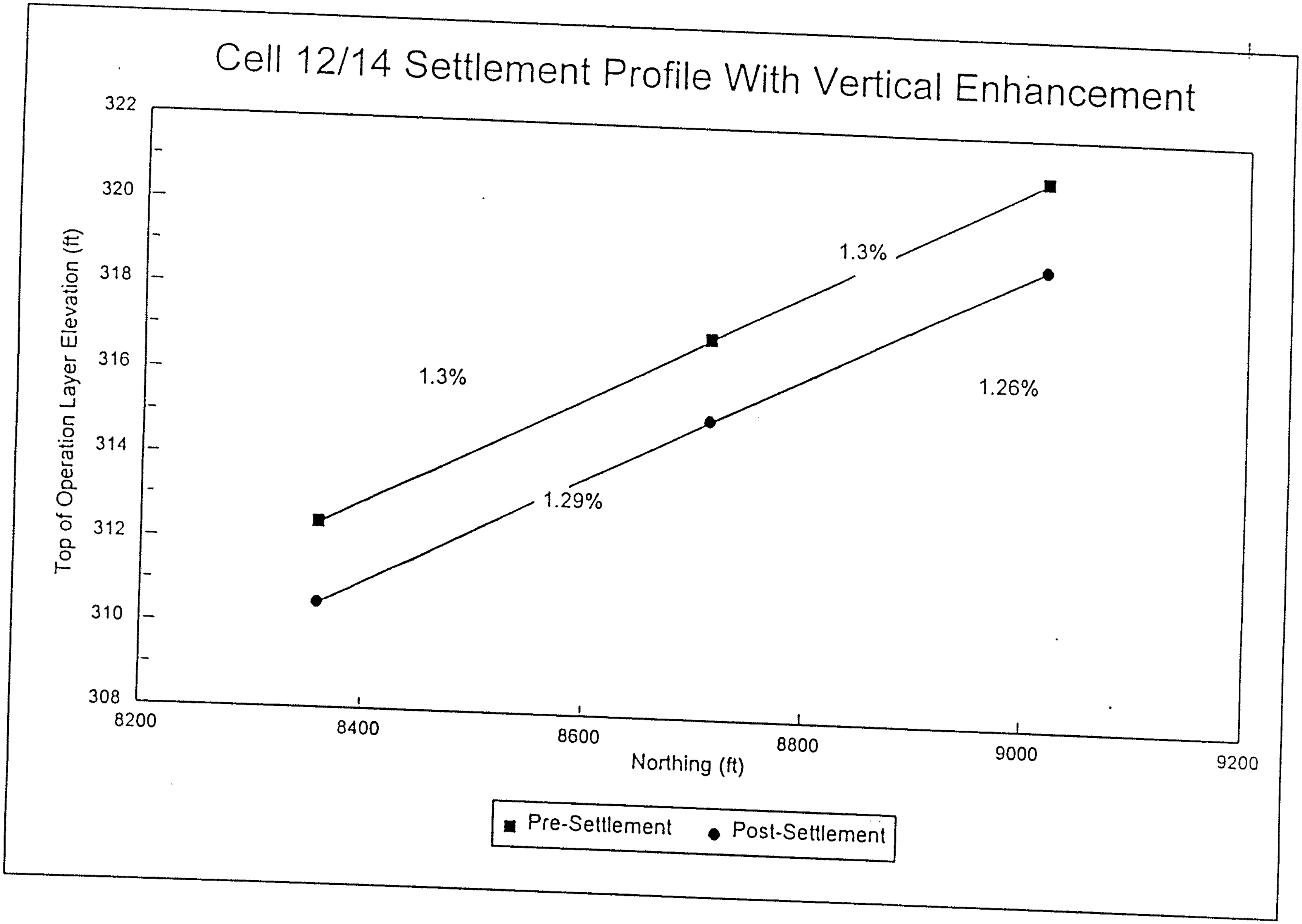
[(317.0 ft - 1.94 ft) - (312.41 ft - 1.92 ft)] / (8,712 ft - 8,359 ft) = 0.0129 ft/ft
= 1.29%

Post-Settlement Slope Point H to Point I

[(320.96 ft - 2.05 ft) -(317.0 ft - 1.94 ft)] / (9,017 ft - 8,712 ft) = 0.0126 ft/ft
= 1.26%

Conclusions

The post-settlement slope of 1.26% exceeds the required 1.0% post-settlement slope. Therefore, the centerline grade (pre-settlement) of 1.3% is sufficient for design.



SETCALC0.WK4

CWM CHEMICAL SERVICES, INC.
MODEL CITY FACILITY
VERTICAL ENHANCEMENT OF RMU-1

Consolidation Settlement of the Glaciolacustrine Clay Unit

Cell(s)	Location		Existing Elevation (ft)	Final Cover Elevation (ft)	Operations Layer Elev. (ft)	Top of Glac. Clay Elev. (ft)	Clay Thickness (ft)	Pressure at Midpoint of Clay (Po) (psf)	Increase due to new landfill Delta P (psf)	Settlement (ft)
	North	East								
9/10	92+60	19+21	311.00	352.00	315.55	305.00	15	1,718	5,125	1.38
	92+60	22+63	315.50	424.00	320.00	305.00	15	2,303	12,624	1.87
	92+60	26+31	320.00	352.00	324.78	305.00	17	3,013	4,094	0.97
11/13	85+37	24+50	306.00	361.00	312.16	305.00	20	1,380	6,496	2.32
	87+55	24+50	307.50	410.00	315.00	301.00	21	2,158	11,624	2.59
	90+02	24+50	311.00	408.00	318.20	301.00	18	2,425	11,046	2.06
12/14	83+59	20+88	306.00	357.00	312.41	303.00	18	1,515	6,023	1.92
	87+12	20+88	309.00	400.00	317.00	303.00	15	1,718	10,291	1.94
	90+17	20+88	309.00	400.00	320.96	305.00	15	1,458	9,851	2.05

Given:

1. Unit Weight of Waste = 111.1 pcf
2. Unit Weight of Liner and Cover Soils = 130 pcf
3. Unit Weight of Upper Till = 130 pcf
4. Unit Weight of Glaciolacustrine Clay = 125 pcf
5. Cc = 0.28; eo = 0.826
6. H = Thickness of Glaciolacustrine Clay = 15.0 ft (Cells 1 through 11); 16.0 ft (Cell 12); 17.0 ft (Cell 13); 18.0 (Cell 14)
7. Liner Soil Thickness = 7.5 ft; Cover Soil Thickness = 5.0 ft

Calculations:

Po = Pressure at midheight of clay layer = [(Existing Elevation - Top of Glac. Clay) x 130 pcf] + [(15.0 ft/2) x 125 pcf]
Delta P = Increase in pressure due to new landfill = [(Final Cover Elev. - 5.0 ft - Top of Operations Layer) x 111.1 pcf] + [(7.5 ft + 5.0 ft) x 130 pcf]

S = Settlement = (Cc/1+eo) x H x log [(Po + Delta P)/Po]

By : HKK
Date : 10/24/97
Chk : AMV
Date : 10/24/97

CWM Chemical Services, Inc.
Model City Facility
Vertical Enhancement of RMU-I

Post Settlement Slopes

Cell(s)	Slope of Centerline (ft/ ft)	Location North	Location East	Settlement (ft)	Length Between Points	Post-Settlement Slope (ft/ ft)
9/ 10	0.013	92+60	19+21	1.38		
					342	0.0117
		92+60	22+63	1.87		
					368	0.0154
		92+60	26+31	0.97		
11/ 13	0.013	85+37	24+50	2.32		
					218	0.0118
		87+55	24+50	2.59		
					247	0.0151
		90+02	24+50	2.06		
12/ 14	0.013	83+59	20+88	1.92		
					353	0.0129
		87+12	20+88	1.94		
					305	0.0126
		90+17	20+88	2.05		

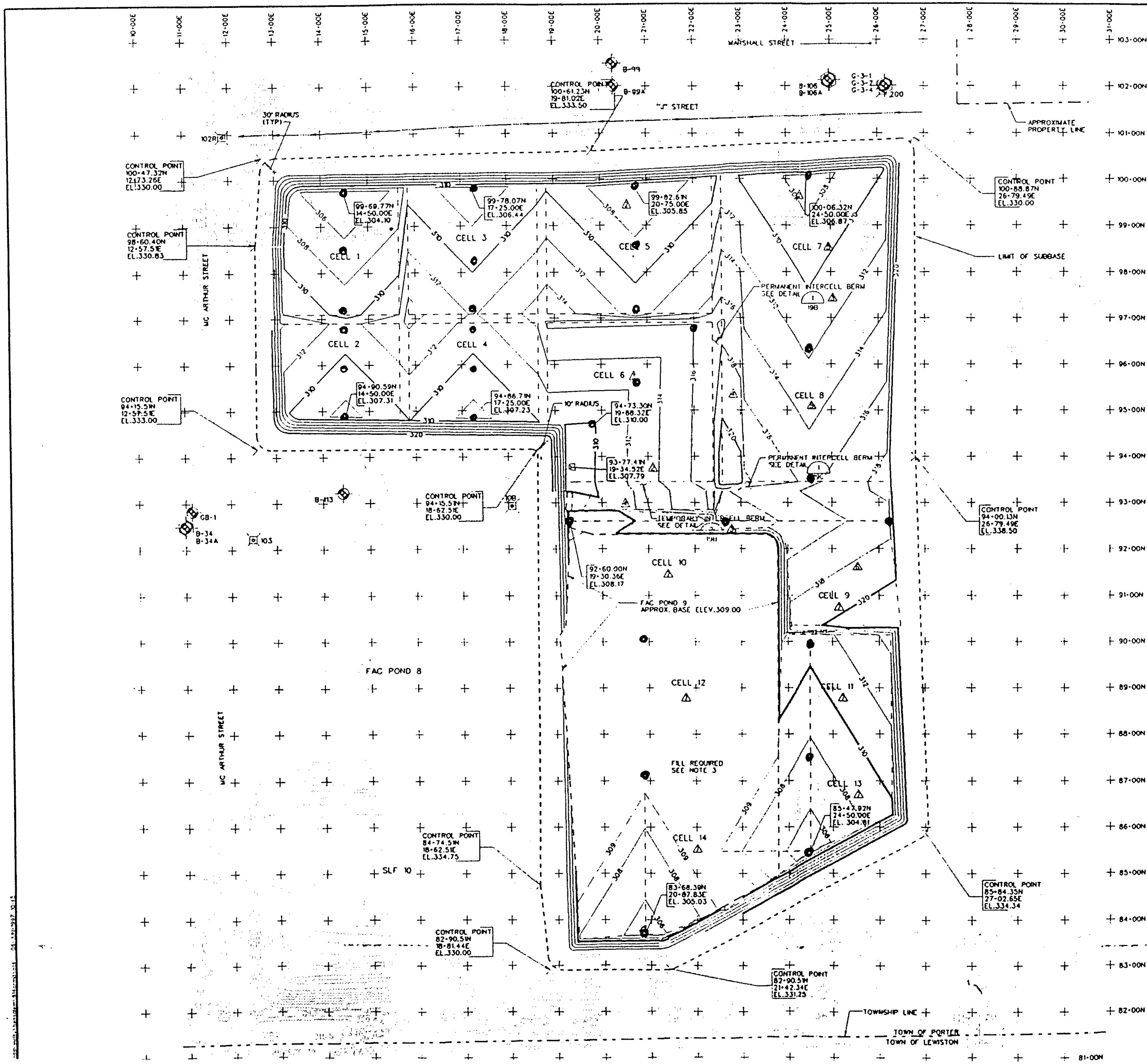
By: HKK
Date: 01/14/98
Chk: KDM
Date: 01/16/98

MODEL CITY RMU - 1
Cells 9 Through 14 Redesign Settlement Calculations Summary
With Vertical Enhancement

		Cell 10/9			Cell 11/13			Cell 12/14		
		A	B	C	D	E	F	G	H	I
Location N	ft	9,260	9,260	9,260	8,537	8,755	9,002	8,359	8,712	9,017
Location E	ft	1,921	2,263	2,631	2,450	2,450	2,450	2,088	2,088	2,088
Existing Elevation	ft	311	315.5	320	306	307.5	311	306	309	309
Top of Vegetative Cover	ft	352	424	352	361	410	408	357	400	400
Top of Operations Layer	ft	315.5	320.0	324.8	312.2	315.0	318.2	312.4	317.0	321.0
Top of Glaciolacustrine Clay Layer	ft	305	305	305	305	301	301	303	303	305
Glaciolacustrine Clay Layer Thickness	ft	15	15	17	20	21	18	18	15	15
Initial pressure at mid-height of clay layer	psf	1,718	2,303	3,013	1,380	2,158	2,425	1,515	1,718	1,458
Increase in pressure due to new landfill	psf	5,125	12,624	4,094	6,496	11,624	11,046	6,023	10,291	9,851
Primary Settlement	ft	1.38	1.87	0.97	2.32	2.59	2.06	1.92	1.94	2.05
Post Settlement Elevation	ft	314.1	318.1	323.8	309.8	312.4	316.1	310.5	315.1	318.9
Post Settlement Centerline Slope			1.17%	1.54%		1.18%	1.51%		1.29%	1.26%

BY: HKK
DATE: 10/23/97
CHK: KDM
DATE: 01/16/98

SETCALC0.WK4



LEGEND:

- EXISTING GRADE
- 320 PROPOSED GRADE
- LIMIT OF SUBBASE
- 3:1 SLOPE INDICATOR
- DRAINAGE DITCH
- ACCESS ROAD
- TOP OF BERM
- APPROXIMATE PROPERTY LINE
- TOWNSHIP LINE
- GROUNDWATER MONITORING WELL
- GROUNDWATER MONITORING WELL NEST
- SOIL BORING
- PERMANENT CONTROL MONUMENT
- CULVERT
- ABANDONED WELL

NOTES:

1. TOPOGRAPHIC BASE MAP WAS PROVIDED BY AERO-METRIC ENGINEERING, SHEBOYGAN, WISCONSIN, DATED DECEMBER 1986. GROUND CONTROL BY FRANK T. TRIPI AND ASSOC., P.C.
2. COORDINATES LABELED ON THESE PLANS ARE ACCORDING TO RMU-1 SITE GRID.REFER TO DRAWING NO. 2 FOR PLANT COORDINATES.
3. PROPOSED GRADES SHOWN ARE APPROXIMATE LIMITS OF EXCAVATION. FILL IS REQUIRED OVER A PORTION OF FAC POND 9 FOR SUBBASE GRADE. TOPSOIL WITHIN THE EXCAVATION AREA WILL BE STRIPPED AND STOCKPILED IN AREAS DESIGNATED BY THE OWNER.
4. SURFACE DRAINAGE SHALL BE DIRECTED AROUND EXCAVATION. SURFACE WATER SHALL BE PUMPED TO ADJACENT DRAINAGE DITCHES AND ROUTED TO EXISTING STORM WATER RETENTION BASINS DURING CONSTRUCTION.
5. SIDESLOPE AND ANCHOR TRENCH AREA SHALL BE OVERCUT AS SHOWN ON DETAILS.
6. WELLS TO BE ABANDONED ARE AS INDICATED. CONTRACTOR TO VERIFY SCHEDULE WITH OWNER.
7. RELOCATE OR ABANDON UTILITIES PER PROJECT SPECIFICATIONS AND WITH AUTHORIZATON OF OWNER.

● SETTLEMENT LOCATION

NOT FOR CONSTRUCTION
FOR REGULATORY REVIEW ONLY

REV	DATE	DESCRIPTION	DR BY	APP BY
7	6-97	MODIFY CELLS 9 THROUGH 14	FAS	CPB
6	4-97	MODIFY CELL 9	FAS	CPB
5	11-96	MODIFY CELLS 7 AND 8	FAS	CPB
4	6-96	MODIFY CELL 6 / 10 AND CELL 6 / 8 TRANSITIONS	FAS	CPB
3	4-96	MODIFY CELL 6 / CELL 10 TRANSITION GRADES	FAS	CPB
2	11-95	MODIFY SUMPS CELLS 5, 6 AND 7	FAS	CPB
1	6-92	NOTICE OF DEFICIENCY RESPONSES	FLD	GRM

RUST ENVIRONMENT & INFRASTRUCTURE

SIGNATURE

DATE

DES BY	BRJ/TJP
DRN BY	FLD
CHK BY	MGR
ERV BY	TJB
GRV BY	CFF
APP BY	GRM

PROJECT NO. 17365 DATE FEBRUARY 1991

PROJECT: RESIDUALS MANAGEMENT UNIT 1

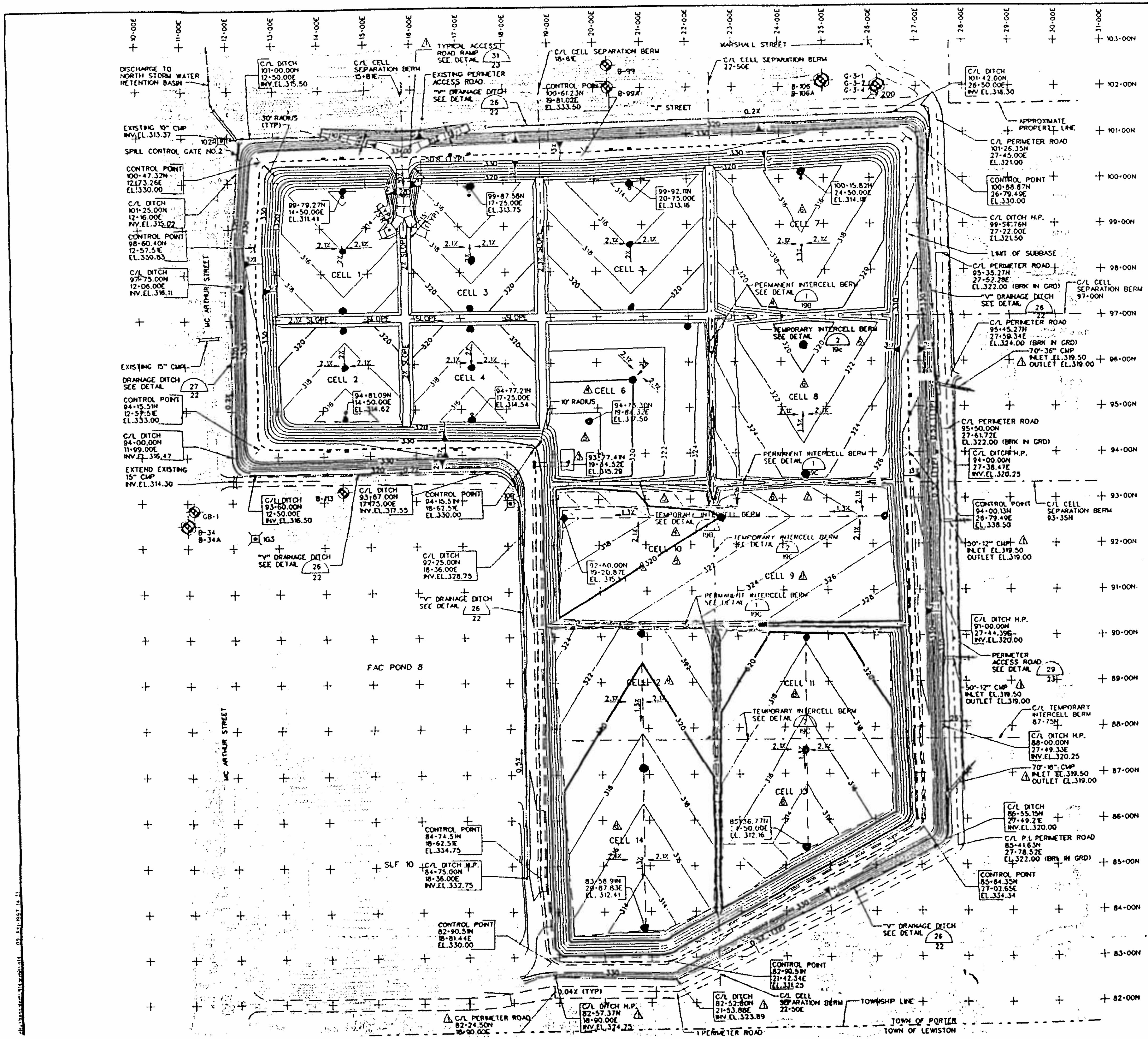
DRAWING TITLE:

EXCAVATION GRADES

CWM CHEMICAL SERVICES, INC.
MODEL CITY, NIAGARA COUNTY, NEW YORK

FILE NO. A-55296

DRAWING NO. 4



LEGEND:

	EXISTING GRADE
320	PROPOSED GRADE
	LIMIT OF SUBBASE
3:1	SLOPE INDICATOR
	DRAINAGE DITCH
	ACCESS ROAD
	TOP OF BERM
	APPROXIMATE PROPERTY LINE
	TOWNSHIP LINE
	GROUNDWATER MONITORING WELL
	GROUNDWATER MONITORING WELL NEST
	SOIL BORING
	PERMANENT CONTROL MONUMENT
	CULVERT
	VAULT

NOTES:

1. TOPOGRAPHIC BASE MAP WAS PROVIDED BY AERO-METRIC ENGINEERING, SHEBOYGAN, WISCONSIN, DATED DECEMBER 1986. GROUND CONTROL BY FRANK T. TRIPI AND ASSOC., P.C.
2. COORDINATES LABELED ON THESE PLANS ARE ACCORDING TO RMU-1 SITE GRID.REFER TO DRAWING NO. 2 FOR PLANT COORDINATES.
3. PROPOSED GRADES INDICATED ARE TOP OF OPERATIONS LAYER.
4. ACCESS ROADS TO BE CONSTRUCTED OVER PERIMETER BERMS AT CELL SEPARATION BERM LOCATIONS AS NEEDED.
5. ACCESS ROAD LOCATIONS SHOWN ARE FOR ILLUSTRATIVE PURPOSES. ACCESS ROADS MAY BE LOCATED AND MOVED AS NECESSARY FOR LANDFILL OPERATIONS.

● SETTLEMENT LOCATION

N

SCALE 0' 50' 100' 200'

NOT FOR CONSTRUCTION
FOR REGULATORY REVIEW ONLY

REV	DATE	DESCRIPTION	DR BY	APP BY
[illegible]	4-97	MODIFY CELLS 9 THROUGH 14	FAS	CPB
[illegible]	4-97	MODIFY CELL 9	FAS	CPB
[illegible]	11-96	MODIFY CELLS 7 AND 8	FAS	CPB
[illegible]	7-96	MODIFY CELL 6 / 10 AND CELL 6 / 8 TRANSITION	FAS	CPB
[illegible]	4-96	MODIFY CELL 6 / CELL 10 TRANSITION GRADES	FAS	CPB
[illegible]	11-95	MODIFY SUMPS CELLS 5, 6 AND 7	FAS	CPB
[illegible]	1-95	ADDED NOTE RE: ACCESS ROADS	JWH	DJA
[illegible]	8-92	NOTICE OF DEFICIENCY RESPONSES	FLD	GRM

RUST ENVIRONMENT & INFRASTRUCTURE

SIGNATURE

DATE

DES BY	BRJ/TJP
DRN BY	FLD
CHK BY	MCR
ERV BY	TJB
CRV BY	CFF
APP BY	GRM

PROJECT NO. 17365 DATE FEBRUARY 1991

PROJECT RESIDUALS MANAGEMENT UNIT 1

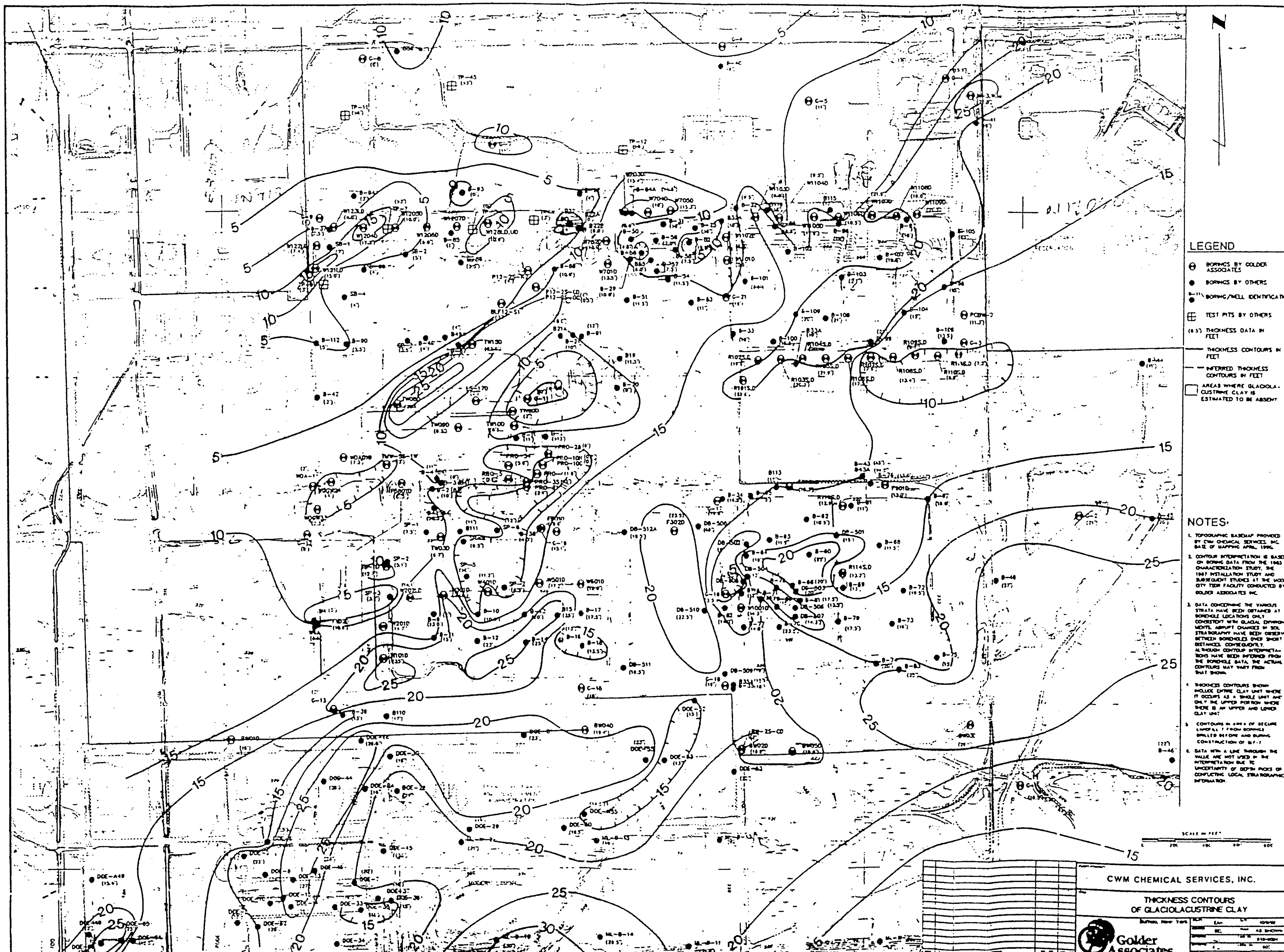
DRAWING TITLE

OPERATIONS LAYER GRADES

CWM CHEMICAL SERVICES, INC.
MODEL CITY, NIAGARA COUNTY, NEW YORK

FILE NO. A-55290

DRAWING NO. 10


N
LEGEND
BORINGS BY GOLDER ASSOCIATES
BORINGS BY OTHERS
BORING/WELL IDENTIFICATION
TEST PITS BY OTHERS
(8.5') THICKNESS DATA IN FEET
THICKNESS CONTOURS IN FEET
INFERRED THICKNESS CONTOURS IN FEET
AREAS WHERE GLACIOLACUSTRINE CLAY IS ESTIMATED TO BE ABSENT
NOTES:
1. TOPOGRAPHIC BASEMAP PROVIDED BY CWM CHEMICAL SERVICES, INC. DATE OF MAPPING APRIL, 1990.
2. CONTOUR INTERPRETATION IS BASED ON BORING DATA FROM THE 1985 CHARACTERIZATION STUDY, THE 1987 INSTALLATION STUDY AND SUBSEQUENT STUDIES AT THE MODEL CITY TSDR FACILITY CONDUCTED BY GOLDER ASSOCIATES INC.
3. DATA CONCERNING THE VARIOUS STRATA HAVE BEEN OBTAINED AT BOREHOLE LOCATIONS ONLY. CONSISTENT WITH GLACIAL ENVIRONMENTS, ABRUPT CHANGES IN SOIL STRATIGRAPHY HAVE BEEN OBSERVED BETWEEN BOREHOLES OVER SHORT DISTANCES. CONSEQUENTLY, ALTHOUGH CONTOUR INTERPRETATIONS HAVE BEEN INFERRED FROM THE BOREHOLE DATA, THE ACTUAL CONTOURS MAY VARY FROM THAT SHOWN.
4. THICKNESS CONTOURS SHOWN INCLUDE ENTIRE CLAY UNIT WHERE IT OCCURS AS A SINGLE UNIT AND ONLY THE UPPER PORTION WHERE THERE IS AN UPPER AND LOWER CLAY UNIT.
6. DATA WITH A LINE THROUGH THE VALUE ARE NOT USED IN THE INTERPRETATION DUE TO UNCERTAINTY OF DEPTH PICKS OR CONFLICTING LOCAL STRATIGRAPHIC INFORMATION.
SCALE IN FEET
CWM CHEMICAL SERVICES, INC.
THICKNESS CONTOURS OF GLACIOLACUSTRINE CLAY
Golder Associates
AS SHOWN
11

D-2

WASTE SETTLEMENT

5/19/99

Revised: ~~Date Approved~~

TASK: Estimate magnitude of total settlement of waste at final buildout configuration at the Model City Facility RMU-1.

REFERENCES:

1. "Settlement and Engineering Considerations in Landfill and Final Cover Design", Technical Paper by Morris and Woods from ASTM STP 1070 "Geotechnics of Waste Fills, Theory and Practice", 1990.
2. "Settlement of Waste Disposal Fills," George F. Sowers.
3. Engineering Report for Model City Facility, Residuals Management Unit 1, prepared by SEC Donohue, Revised June 24, 1992.
4. "Operation Layer Grades," Drawing No.10, prepared by SEC Donohue, February 1991, revised by Rust Environment & Infrastructure, June 1997.
5. "Top of Vegetative Cover Grades," Drawing No. 12, prepared by SEC Donohue, February 1991, revised by Rust Environment & Infrastructure, July 1997.
6. Friction Seal HD Geomembrane (40 mil) specification sheet from National Seal Company.

ASSUMPTIONS:

1. Settlement will be evaluated for final landfill development at the maximum height of waste.
2. Primary consolidation settlement of the waste is assumed to be completed by the time final cover is in place, therefore only secondary consolidation settlement (post-construction, long-term) will be evaluated.
3. Settlement of waste is due to the overburden stresses of the waste itself and cover soils along with biological decomposition of the waste. For this analysis, settlement from biological decomposition is assumed negligable due to the nature of the waste disposed of at this site.

CALCULATIONS:

Post-construction, long-term settlement of a landfill is similar to that of secondary consolidation of natural soils (Reference 1).

$$\Delta H = \frac{C_s H}{1 + e_0} \log (t_2/t_1)$$

Where,

ΔH = Total settlement, ft
C_s = Coefficient of secondary compression = 0.03 x e_0 = 0.06 (See Reference 1)
H = Maximum waste height, ft = 109 ft
e_0 = Initial void ratio = 2 (well-compacted waste, see Reference 2)
t_2 = Time at completion of settlement = 30 years (typical post-closure period)
t_1 = Time for completion of construction = 1 month

$$\Delta H = \frac{0.06\ (109\ ft)}{1+2} \log (360/1) = 5.6\ ft$$

Maximum percent settlement = $\Delta H/H$ = 5.6 ft/109 ft = 5.1 %

This is a typical value for waste landfills. Actual post-construction settlements are expected to be substantially less than this estimate as the amount of waste with the potential for long-term biological decomposition is expected to be minimal.

From Reference 6, the strain at yield for 40 mil textured geomembrane is 13.0%.

Maximum length of geomembrane for 5.6 ft of differential settlement at 13.0% yield:

T = stretched length of geomembrane = $[L^2 + (5.6)^2]^{1/2}$
L = maximum length of geomembrane

$(T - L)/L = 13.0\%$

$([L^2 + (5.6)^2]^{1/2} - L)/L = 13.0\%$

$L = 10.5$ ft

It is highly unlikely that differential settlement of 5.6 ft will occur in a distance of 10.5 ft. Therefore, the final cover will not be elongated to its yield point (13 percent).

Geotechnics of WASTE FILLS

Theory and Practice

Landva / Knowles, editors

ASTM

STP 1070

Initial Primary Compressions

(1) The initial primary mechanical compression due to changes in overburden pressure occurs rapidly with little or no pore pressure build-up. The initial and primary phases are complete in less than a month.

(2) The primary settlement occurring in an arbitrary waste layer due to construction of an additional layer can be expressed by the well-known equation:

$$S = H\frac{C_c}{1+e_o}\log\frac{P_o+dP}{P_o}$$

where,

S - primary compression occurring in the layer under consideration

H - initial (before-compression) thickness of the waste layer under consideration

C_c - primary compression index. C_c is assumed to be proportional to the initial void ratio of the layer (C_c = COEFF1*e_o, see Sample Results for typical COEFF1 values).

e_o - initial (before-compression) void ratio of the layer.

P_o - existing overburden pressure acting at the mid level of the layer.

dP - increment of overburden pressure at the mid level of the layer under consideration from the construction of an additional layer (100% of pressure increase at the top new layer is assumed to be transferred to the layer under consideration).

(3) The daily and final cover soils are not assumed to undergo compression due to overburden pressures. However, the thickness of a daily soil cover is assumed to reduce to one-fourth its original thickness after construction, due to the migration of soils into void spaces in waste layers. For very clayey soil cover, this value may be greater. This is an empirical assumption based on limited field observations, discussed previously in the section entitled "Analysis of Effect of Daily Cover".

(4) The above computation procedures are repeated for each waste layer and for each construction stage, and the contribution of that layer to the overall compression in a particular construction stage is determined. The sum of the contributions of each construction stage then constitutes the total compression achieved up to that construction stage under consideration.

Long-term Secondary Settlements

(1) Settlement of waste fills continues at substantial rates after construction. The settlement occurring in an arbitrary layer for a certain period of time after completion of the landfill can be expressed by the following equation:

$$SS = H\frac{C_a}{1+e_o}\log\frac{t_2}{t_1}$$

where,

SS - long-term secondary settlement occurring in the layer under consideration, between time periods t_1 and t_2.

H - initial (before settlement) thickness of the waste layer under consideration.

C_s - secondary compression index. C_s is assumed to be proportional to the initial void ratio of the layer (C_s = COEFF2*eo, see Sample Results for typical COEFF2 values).

e_o - initial (before settlement) void ratio of the layer.

t_1 - starting time of the time period for which long-term settlement of the layer is desired (t_1 = 1 month preset in the program).

t_2 - ending time of the time period for which long-term settlement of the layer is desired.

(2) The above computation procedure is repeated for each waste layer for the given time period. The sum of the contributions of each layer then constitutes the total long-term settlement achieved during that time period.

SAMPLE RESULTS

An example of such a computation is shown as follows. The following input data is required:

NPROB - number of problems to be analyzed, 1 in this case.

TITLE - self-explanatory, up to 60 characters for each problem.

NLAYER - number of waste layers (or lifts) placed, up to 40.

IFLAG - 0 if a compression index is to be computed from a COEFF1.
- 1 if a unit weight to be entered as GAMMAX.

HWASTE - original thickness of a waste layer (or lift), before compression.

HSOIL - original thickness of daily soil cover (assumed to be reduced to one-quarter of its original thickness after construction).

HCOVER - thickness of final soil cover (assumed to remain constant).

GAMMAW - initial compacted unit weight of waste, typically 3 to 6 kN/m^3 depending on composition and compaction techniques [2].

GAMMAS - initial unit weight of soil cover, typically 20 kN/m^3.

WC - initial water content of waste, as a decimal.

SG - specific gravity of waste, typically 1.5.

DUMMY - equal to COEFF1 if IFLAG = 0, typically 0.15 to 0.9 and increases with organic content in the waste [1].
- equal to GAMMAX if IFLAG = 1, expected unit weight of waste under full overburden at the site, if this is preferred to entering a value of COEFF1. See Fig. 4 for recommended values.

NTIME - number of time intervals for which a settlement calculation is desired (maximum of 20).

COEFF2 - secondary compression index divided by voids ratio, typically 0.03 to 0.09 and increases with conditions favorable to decomposition [1].

TIME(I) - time intervals after landfill completion for which a settlement calculation is desired (in months).

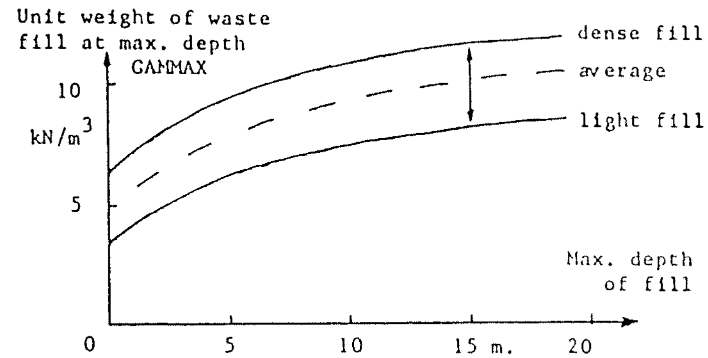


FIG. 4 - GAMMAX versus landfill depth

For a sample problem with 20 layers of waste fill placed initially 750 mm thick at a unit weight of 3.75 kN/m^3, water content of 0.15 and specific gravity 1.5, with 150 mm of soil cover of unit weight 19 kN/m^3 and a final 600 mm soil cover, the following results are obtained, if the primary compression of the waste can be described by COEFF1 = 0.8 and the secondary compression by COEFF2 = 0.06:

Initial as placed total thickness at site	-	18.6 m
Initial compression of site	-	7.3 m
Initial landfill thickness	-	11.3 m
Unit weight of waste at surface	-	3.8 kN/m^3
Unit weight of waste at bottom of landfill	-	8.7 kN/m^3
Long-term settlement, after 1 year	-	0.31 m
Long-term settlement, after 10 years	-	0.60 m
Long-term settlement, after 100 years	-	0.89 m

This program enables important settlement parameters to be calculated rapidly and to an accuracy impossible with hand-calculation, and the authors have found it to be a useful tool for analysis and design.

412 Lincoln Highway, Fairless Hills, Pennsylvania 19030

February 5, 1999

Mr. John Hino
Project Manager
CWM Chemical Services, LLC
1550 Balmer Road
PO Box 200
Model City, NY 14107

RE: CWM Chemical Services, LLC
Model City Facility
RMU-1 Airspace Enhancement
Response To NYSDEC Letter Dated January 19, 1999
Earth Tech Project No. 33047

Telephone
215.269.2100
Facsimile
215.269.2171

Dear John:

Earth Tech has reviewed the January 19, 1999 NYSDEC comment letter concerning the Model City RMU-1 Airspace Enhancement design and has provided responses included herein. For clarity the NYSDEC comments are repeated in bold type and are identified with the same numbers as those contained in the technical review letter. Our responses immediately follow each comment and are also similarly identified numerically. These are submitted for review and approval as follows:

ENCLOSURE No. 1 - NYSDEC comments on CWM's November 16, 1998 response to NYSDEC's September 30, 1998 Notice of Incomplete Application.

COMMENT NO. 1

CWM's Response to DEC Comments 1&2: **Attachment F - Closure Plan**
Attachment G - Post-Closure Plan

Before discussing CWM's responses, the Department must clarify matters regarding RMU-1 Closure and Post-Closure Plans & Estimates. Although the RMU-1 Closure and Post-Closure Plans submitted by CWM on September 16, 1998 are not formally part of the Permit at this time, and the corresponding Cost Estimates have not been formally approved at this time, the Department's December 3,1998 draft Permit modification signifies that they are tentatively acceptable pending receipt of comments from the public. As a result, the Department is willing to informally use them in consideration of the proposed RMU-1 vertical expansion.

Mr. John Hino
CWM Chemical Services, LLC
February 5, 1999
Page 2

For the most part the Department considers CWM's Responses 1 & 2 to be acceptable, however, some questions remain regarding the impact of the proposed vertical expansion on the RMU-1 Closure/Post-Closure Plans & Cost Estimates.

Question 1 - In Attachment No. 1 of a Department letter dated February 28, 1995, which constituted a Notice of Incomplete Application on CWM's September 19, 1994 RMU-1 Permit modification application, the Department issued a comment on CWM's proposed modification to the RMU-1 Closure Cost Estimate with regard to final capping costs. The comment (Comment #3) requested that CWM present the acreage used to determine capping costs, taking into account slope lengths. In response to this comment CWM submitted a revised RMU-1 Closure Plan which contained a table indicating the final cap areas of the RMU-1 cells along with a statement indicating that these areas (in acres) account for slope length. The values presented in this table of each cell's area adds up to 47.1 acres. This same table and statement appears on page 13 of CWM's September 1998 RMU-1 Closure Plan, which is part of the Department's December 3, 1998 draft Permit modification. CWM has now stated in its responses to the Department's September 30, 1998 comments on the proposed RMU-1 vertical expansion, that the acreage in is table represent the horizontal cap area for each RMU-1 cell, and do not account for slope length. However, this seems to conflict with the information presented in Appendix I, Section II. A of CWM's submittal, concerning the drainage areas of the RMU-1 final cover. Figure D-1 Section II. A divides the total RMU-1 final cover into 21 separate areas (A1-A21). Table I-1 in Section II. A presents the acreage value for each of these 21 areas, which adds up to 44.9 acres. The Department has assumed that the values presented in this table represent the horizontal cap area for the final cover since these values are used to determine the precipitation volume over the horizontal area of the landfill. The Department has also assumed that the cap area values presented on page 13 of the September 1998 RMU-1 Closure Plan do attempt to account for slope length, since their total value of 47.1 acres is 5% greater than the 44.9 acres which is assumed to be the landfill cover's true horizontal area based on Table I-1 in Section II A of Appendix I.

Therefore, if the Department's previous assumptions are accurate, page 13 of the RMU-1 Closure Plan, contained in CWM's November 16, 1998 submittal, should be revised to indicate the area values presented on this page are 5% greater than each cell's horizontal area to account for final cover slope lengths. If the Department's previous assumptions are not accurate, CWM must correct all landfill area and/or final cover area discrepancies.

N:\SW\PROJECTS\203593\WPDRAFT\9-30RESP\CWM

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<u>Question 2</u> - CWM has indicated in its responses to the Department's September 30, 1998 comments that 5% has been already added to the cap installation costs in the September 1998 RMU-1 Closure Cost Estimate to allow for the final cover slopes of the currently Permitted RMU-1 landfill. CWM has also indicated that the proposed vertical expansion will only increase the length of the final cover slopes by a maximum of 1.5%, and that this increase is already accounted for by the 5% and other additional allowances. Based on the Department's rough calculations it appears that the additional 5% should be adequate to account for the area of the final cover slopes, even with added slope area which would result from the proposed vertical expansion. However, CWM has not provided sufficient information to conclusively prove that the landfill area plus 5% would be adequate to account for the total final cover area of the expanded landfill (w/slopes). Therefore, CWM must submit an accurate estimate of the total final cover area of the expanded landfill (w/slopes), before the Department can agree that an increase in the RMU-1 Closure and Post-Closure cost estimates are not necessary with regard to the vertical expansion.

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Response No. 1

Earth Tech has performed a check on the final cap areas for the proposed November 16, 1998 design (maximum elevation of 430 feet msl) using the Intergraph computer software. The following areas were calculated:

Horizontal Area to Outside Toe of Slope of Perimeter Berm:	47.79 acres
Horizontal Area for Vertical Enhancement Top of Vegetative Cover to Toe of Slope of final cover:	41.25 acres
Slope Corrected Area for Vertical Enhancement Top of Vegetative Cover to Toe of Slope of final cover:	42.74 acres

The 44.9 acres contained in the surface water drainage calculations in Appendix I, Section II A, Table I-1, is a reasonable estimate considering that the "horizontal" final cover is 41.25 acres which did not account for the area of the perimeter berm roadway (3.6 acres). The 44.9 acres was estimated at the time of the original permit submission without using sophisticated computer techniques. Therefore, the 44.9 acres on Table I-1 is a "horizontal" area used for surface water calculations.

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The 47.1 acres listed in the RMU-1 Closure Plan is the horizontal area of the RMU-1 footprint to the outside toe of slope of the perimeter berm and is roughly equivalent to the 47.79 acres shown above. This acreage (47.1 ac.) was previously subdivided for each cell's area and used in the RMU-1 Closure Plan to prepare the closure cost estimate. The 47.1 acres exceeds the calculated "slope corrected" area of 42.74 acres and is considered a conservative estimate for preparing the closure cost estimate. The RMU-1 Closure Plan cell acreage is not revised in this response due to the conservative estimates made in previous submittals.

With this permit modification request, the maximum landfill height is being reduced from 430 feet msl to 420 feet msl (see response to Comment No. 2). For this lower height, the slope corrected area for the vertical enhancement top of vegetative cover to the toe of slope of the final cover is 42.68 acres. The horizontal areas listed above are unchanged. Therefore, the RMU-1 Closure Plan cell acreage is not affected. However, the drawing and drainage areas presented in Appendix I, Section II.A, have been revised to correspond to the modified design.

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COMMENT No. 2

<u>CWM's Response to DEC Comment 9</u>: **Attachment L, Appendix D-6 - Slope Stability of Landfill at Final Buildout**

a) <u>Geocomposite/Textured Geomembrane Interface</u> - In response to Comment 9, CWM has submitted 1997 site-specific frictional shear testing results for the geocomposite/textured geomembrane interface. The Department would like to clarify that its approval of these results, as mentioned in CWM's response, was granted based on the Department's judgement that they adequately demonstrated the achievement of the 15 degree friction angle assumed for the liner system in the stability analyses contained in Attachment L of the current RMU-1 Permit.

The 1997 tests resulted in values of $C = 930$psf, $\phi = 19.8°$ and $C = 533$ psf, $\phi = 22.0°$ for the textured geomembrane placed in the machine direction with respect to the geocomposite. CWM has also submitted an additional stability analysis of the landfill at final buildout using the $C = 930$psf, $\phi = 19.8°$ test results to represent the liner system. This analysis results in higher factors of safety than those which

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resulted from the use of C = 0psf, $\phi = 24°$ for the liner system in the same stability analysis.

The Department has significant concerns over assuming a "cohesion" value of 930psf for the geocomposite/textured geomembrane interface. While the Department acknowledges that some "cohesion" or "adhesion" force may exist between these two geosynthetics, there is no documented evidence to support the assumption that the "cohesion/adhesion" intercept value from the test result represents the actual magnitude of the geosynthetic adhesion force. In fact, the direct shear testing results on this geocomposite/textured geomembrane interface which appear in Appendix D-6 of the current permit's Attachment L contain notes which state that, "The reported value of adhesion *(from the test results)* may not be the true adhesion of the interface, and caution should be exercise in using this adhesion value for applications involving normal stresses outside the range of stresses covered by the test". In addition, the Department is concerned that the magnitude of the cohesion/adhesion force assumed in the stability analysis (930psf) may considerably overestimate the magnitude of the true adhesion force between these two geosynthetics in the landfill liner system. As a result of the above, the Department considers it appropriate to assume the adhesion force is 0psf for conservative design purposes. This conservative design approach is expressed in CWM's response to Comment 9, where the designer states that, "The friction angle of 24° and a cohesion of 0psf are conservative design parameters particularly because no cohesion was used in the stability analysis". While the Department does not agree that 24° is a conservative design parameter since this value is not supported by the 1997 site specific geosynthetic interface test results in the machine direction, it does agree with the remainder of the designer's statement.

Therefore, at present, the Department considers the values of C= 0psf, $\phi = 19.8°$ to be the appropriate assumption for the geocomposite/textured geomembrane interface.

b) <u>Textured Geomembrane/Clay Interface</u> - In response to Comment 9, CWM has indicated the following concerning the clay used to construct the liner system:

- The clay used to date has been relatively coarse with a low silt and sand content, which should result in higher clay shear strength; and
- Based on the 1997 Cell 7/8 Certification Report for the liner system, the clay moisture content ranged from 12 to 17.4%, which is not considered

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excessively wet that would cause a concern about the shear strength of the clay/textured HDPE liner interface.

Before addressing the issue of conducting site-specific friction testing on the clay/textured HDPE liner interface, the Department would like to respond to the two (2) items above which were mentioned in CWM's response:

- Based on the Department's review of the gradation results from the 1997 Cell 7/8 Certification Report for the liner system, the clay used in the secondary liner had a sand content ranging from 1.6 to 27.2 percent, with most of the data falling between 10 to 16 percent, and a silt content ranging from 28.4 to 40.0 percent. The Department does not consider that these percentages indicate a clay with a "low" sand/silt content, and therefore considers it possible that the actual sand/silt percentages could have a detrimental influence on the shear strength of the clay/textured HDPE liner interface; and

- Based on the Department's review of the moisture/density results from the 1997 Cell 7/8 Certification Report for the liner system, the moisture content range for the in-place secondary soil liner was actually 12 to 23 percent, with approximately 7% of the data exhibiting moisture contents above 17.4 percent indicated in CWM's response as the upper limit of the range. CWM has not presented any evidence to demonstrate that these moisture contents would not detrimentally influence the shear strength of the clay/textured HDPE liner interface, therefore, the Department cannot accept CWM's claim.

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CWM has stated that based on past industry testing and experience, the geotextile/textured HDPE liner interface has been recognized as the weakest shear interface rather than the clay/textured HDPE liner interface, and therefore additional friction testing of the clay/textured HDPE liner interface is not necessary. The Department has enclosed excerpts from the following publications which it considers support the need for site-specific testing of the textured geomembrane/clay interface:

1. "Landfill Closures - Geosynthetics, Interface Friction and New Developments", Edited by R. M. Koerner, 1991 Elsevier Applied Science publication.

Mr. John Hino
CWM Chemical Services, LLC
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2. "Seismic Analysis and Design of Lined Waste Fills: Current Practice", By Raymond B. Seed and Rudolph Bonaparte; From "Stability and Performance of Slopes and Embankments-II", Volume 2, Geotechnical Special Publication No. 31.

The enclosed excerpts from the above documents generally indicate that the textured geomembrane/clay interface has great potential to be the weakest interface in the liner system, depending on site specific conditions which can influence the shear strength of the clay at this interface. Some of these site specific conditions mentioned in the documents that would decrease the shear strength of the clay at this interface are as follows:

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- Compaction of the clay liner at "wet of optimum" moisture contents;
- Periodic application (spraying) of water onto the surface of the compacted clay to prevent drying and cracking, and periodic precipitation events; and
- Heating and cooling of the exposed geomembrane which covers the clay (prior to covering with subsequent layers) producing condensate on the underside of the geomembrane, which could result in a "wetting" of the interface.

The Department considers that each of the above site specific conditions are applicable to the way the RMU-1 liner system has been constructed to date. Therefore, the shear strength of the RMU-1 clay liner at this interface could be significantly reduced by these site specific conditions. Also, it is important to note that according to lined landfill failure case histories from Dr. Koerner which were presented by CWM in response to previous Comment 10, 2 out of the 5 slope failures occurred along the geomembrane/clay interface due to excessive wetness.

Based on discussions with staff from EPA's Center for Environmental Research Information and other experts in the field, as well as a review of the above publications on this topic, the Department cannot accept that the geotextile/textured HDPE liner interface is the weakest interface in the RMU-1 liner system without site-specific testing of the clay/textured HDPE liner interface. Therefore, the Department must reiterate its request for CWM to conduct a program of interface friction testing on the geomembrane/clay interface, before the Department will accept changing 15 degree value assumed for the liner system in the current RMU-1 Permit, Attachment L. As stated in Comment 9, to conduct this testing, the Department requests that the procedures specified by Module I, Condition B (8) be followed with regard to submission and prior Department approval of

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the conditions under which this testing will be conducted. Also, the number of tests to be run should be indicated and actual samples from each geosynthetic roll to be sampled for testing shall be supplied to Department staff.

Response No. 2

Attachment L, Appendix D-6 - Slope Stability of Landfill at Final Buildout has been revised to use the previously approved C = 0psf and $\phi = 15°$ for the geocomposite/textured geomembrane interface. As stated in the Department's comment, this design basis has been previously accepted and site specific clay/textured geomembrane interfaceshear testing will not be required at this time. To achieve adequate factors of safety in our slope stability analyses, the vertical enhancement top of vegetative cover contours have been lowered from a maximum elevation of 430ft to 420ft. The following sections of the vertical enhancement permit modification have been revised:

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- Attachment L, Appendix D-6 - Slope Stability at Final Buildout
- Attachment L, Appendix I - Surface Water Drainage and Erosion Calculations
- Attachment L, Appendix J - Site Volume Calculations
- Attachment O - Drawings for Residuals Management Unit 1
- Attachment S - Response Action Plan for Residuals Management Unit 1

The vertical enhancement permit modification, complete with revisions to the above Attachments, is enclosed with this response letter.

Earth Tech and CWM continue to assert that the previously submitted C=0psf and $\phi = 24°$ is an appropriate design basis for the textured liner system stability analysis. As noted by the Department, further discussions must be held before this can be accepted.

COMMENT No. 3

<u>CWM's Response to DEC Comment 10:</u> **Attachment L, Appendix D-6 - Slope Stability of Landfill at Final Buildout**

Although it was mentioned in the Department's previous comments, further review of the submitted slope stability analyses has identified an error in the cross sections which were analyzed. The Geoslope computer models used to analyze slope stability of the landfill at

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final build out evaluate the landfill's final grades, however do not model the landfill with final cover. This is of concern since the computer models in the current Permit's Attachment L model the final cover soils with a unit weight of 130 pcf which is heavier than the unit weight of the waste. Therefore, the computer models submitted with the RMU-1 vertical expansion request must be revised to include the landfill's final cover system, using the same assumptions for this system that are in the current Permit's Attachment L, Appendix D-6.

a) Critical Section - In response to Comment 10.a, CWM has indicated a couple of reasons why it does not consider it necessary to evaluate the stability of cross section 93+50N, as requested by the Department's comment. These reasons and the Department's reply to them are as follows:

- CWM has indicated that the 3-D equilibrium wedge forces at the concave corner of the landfill would contribute to the stability of nearby section 93+50N. CWM has presented the July 1992 3-D and 2-D stability analyses at this corner in support of this assertion. The results of the July 1992 analyses indicate that when the 3-D geometry of this corner is evaluated, the factors of safety are greater than that of the 2-D section at this same corner, and therefore serves to demonstrate that the concave geometry beneficially influences the slope stability. CWM claims that this concave geometry contributes to make section 93+50N less critical than section 17+10E where this geometry does not exist.

  First, the Department would like to point out that the July 1992 analyses only evaluated circular failure through the landfill subgrade and did not evaluate a block failure through the landfill's liner system, which may be more critical. However, the Department would agree that the effect of the concave geometry on slope stability would likely be similar. The Department would also agree that the effect of this waste mass geometry could beneficially influence section 93+50N, since this section is in close proximity to the concave corner.

- CWM has confirmed that the purpose of performing slope stability analyses on section 17+10E is to evaluate the impact of the landfill's vertical expansion over the smooth geomembrane of the Cell 1-6 liner system. Since section 93+50N is in close proximity to the textured

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geomembrane installed in Cell 9/10, this textured geomembrane would provide additional resistive forces that would apparently be difficult to accurately account for in a 2-D stability analysis. CWM claims that these additional resistive forces contribute to make section 93+50N less critical than section 17+10E which is not close to the textured liner system.

The Department cannot accept CWM's claim that resistive forces from the nearby textured geomembrane would influence the 93+50N slope section, without the presentation of supportive evidence. The Department considers the converse influence of a smooth geomembrane on a nearby textured geomembrane cross section to be just as valid. That is to say, it could be argued that the smooth geomembrane might lessen the stability of a nearby textured geomembrane cross section. Therefore, due to the uncertainty of the smooth next to textured geomembrane relationship, the Department cannot accept CWM's argument.

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Based on the July 1992 3-D and 2-D stability analyses near section 93+50N, and the possible beneficial influence of the concave waste mass geometry near section 93+50N, the Department agrees that an additional analysis of its stability is not necessary at this time. However, the Department still does not agree that section 17+10E which has been analyzed for stability by CWM, is representative of the most critical cross section over smooth geomembrane. A north-south cross section of the landfill's north slope taken at approximately 21+50E is located over smooth geomembrane. At this section, the landfill's final grade continues up at a 5% slope to a height which is several feet above the 398 foot elevation evaluated by CWM's stability analyses of section 17+10E. Like section 17+10E, section 21+50E is not located near the concave corner of RMU-1. Also, based on as-built documentation (i.e. Liner Construction Certification Reports), this section is approximately 120 feet west of any textured geomembrane, therefore the textured geomembrane is not a factor in the stability of this section.

Therefore, the Department requests that CWM include a series of stability analyses of section 21+50E in Appendix D-6, to provide verification of waste mass stability on the smooth geomembrane liner system.

b) <u>Three-Dimensional Stability</u> - The Department considers CWM's response to this portion of Comment 10 to be acceptable. However, as indicated in "a" above, the

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Department would like to clarify that the July 1992 analyses only evaluated circular failure through the landfill subgrade.

c) **<u>Figure Errors</u> - In response to Comment 10.c, CWM has stated that a diagonal section through elevation 430 feet is not the most critical cross section, and that adding 2 feet to the landfill height would not substantially change the slope stability results.**

The Department acknowledges that taking a diagonal section through the 430 feet landfill elevation which is not perpendicular to the slope, might serve to result in the analysis of a less than "worst-case" scenario. However, the Department does not see how taking an east-west cross section perpendicular to the slope at approximately 91+25N intersecting the 430 foot contour, would be less critical than CWM's section which intersects the 428 foot contour. These two sections are horizontally only about 50 feet apart, which should not make enough difference in operations layer grades to offset the 2 foot height difference. Also, the 2 foot height increase may make a difference in the overall outcome when it is considered in conjunction with the other stability analysis revisions (e.g. liner system frictional input values, final cover unit weight). In order to resolve this matter, the Department requests that CWM include a series of stability analyses of section 91+25N, intersecting the 430 foot contour, in Appendix D-6.

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Response No. 3

The slope stability cross sections taken at 91+25N and 21+50E to assess final buildout of the vertical enhancement top of vegetative cover grades are included in Attachment L, AppendixD-6 - Slope Stability at Final Buildout. The cross section profiles have been revised to include the final cover soils.

The peak bedrock acceleration of 0.1g used in the analysis results in a seismic coefficient of 0.055 with consideration of amplification based on the pseudo-static stability analysis prepared in November, 1997 and approved by the NYSDEC. Earth Tech agrees with the pseudo-static analysis previously approved for Model City which is based on the design methodology proposed by the USEPA and sponsored by the New York Association for Solid Waste Management. The seismic coefficient of 0.055 is the appropriate design parameter.

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As requested by the NYSDEC, a slope stability cross section was taken through the Cell 5 and 6 smooth liner system at 21+50E. The Slope Stability calculations for the cross section at 21+50E are included in revised Attachment L, Appendix D6 - Slope Stability at Final Buildout. The results of the Slope Stability analysis at 21+50E are:

Static Sliding Block	FS = 1.62
Seismic Sliding Block	FS = 1.29
Static Deep Circular	FS = 1.58
Seismic Deep Circular	FS = 1.28

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As requested by the Department, a Slope Stability cross section was taken through the Cell 9/10 textured liner system at 91+25N. As discussed in the Response No. 2, the interface friction parameters for the geocomposite/textured geomembrane have been revised to the previously approved C = 0psf and ϕ = 15°. The change in the interface parameters used in the Slope Stability analysis has resulted in the maximum top of vegetative cover contour elevation being lowered from EL.430ft to EL. 420ft. The results of the Slope Stability analysis at 91+25N are:

Static Sliding Block	FS = 1.52
Seismic Sliding Block	FS = 1.23
Static Deep Circular	FS = 1.57
Seismic Deep Circular	FS = 1.27

COMMENT No. 4

<u>**CWM's Response to DEC Comments 11-13:**</u> **Attachment L, Appendix D-7 - Differential Waste Height - Fill Progression Interim Waste Slopes**

In response to Comments 11-13, CWM has elected to withdraw the previous waste fill progression plans and their corresponding stability analyses from the Permit modification application. CWM has stated that these plans and analyses will be submitted in conjunction with the RMU-1 O&M Manual as each cell's construction is completed, as is the current practice.

The Department considers that this raises two separate questions:

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1. Should such waste fill progression plans and stability analyses be incorporated directly into the RMU-1 Permit?

2. Should such waste fill progression plans and stability analyses be submitted with the RMU-1 vertical expansion Permit modification application?

With regard to the first question, the Department is re-evaluating whether such plans and analyses should be in the Permit, in light of this modification application. However, atthis time, the Department has not made a decision on this matter.

With regard to the second question, the Department has determined such plans and analyses are technically necessary for the Department to evaluate CWM's Permit modification for the vertical expansion of RMU-1. This determination is based on the following factors:

- The Department considers the likelihood of interim slope failures to equal or exceed that of final slopes. According to published papers, numerous failures have occurred at other facilities during fill progression.

- The Department considers the interim fill progression slopes to be more susceptible to failure than the final slopes. This is because conditions are similar except for the fact that interim slopes are not buttressed by perimeter berms. Since the vertical expansion will undoubtedly also result in higher interim fill progression waste slopes, the Department considers it just as important to evaluate their stability, before the Permit modification is issued.

- Currently, Cell 1-8 are in operation, and construction is basically completed on Cell 9/10. Therefore, approved waste fill progression plans and stability analyses are already needed for Cells 1-10.

Therefore, the Department requests that CWM submit waste fill progression plans and stability analyses for each cell beyond and including Cell 9/10. A waste fill progression plan and stability analyses are also requested for Cells 1-8, if CWM intends to advance Cell 1-8 waste placement beyond <u>currently</u> Permitted grades, prior to waste placement in Cell 9/10. Also, Comment #2 above applies to each of the stability analyses, and the Comments in Enclosure No. 2 apply to the Cell 1-8 stability analyses.

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Response No. 4

The vertical enhancement waste fill progression plan for RMU-1 Cells 1 through 8 and the accompanying slope stability analyses will be submitted to the NYSDEC under separate cover. Subsequent fill progression plans and slope stability analyses for Cells 9/10 and beyond will be submitted for NYSDEC approval as part of the updates of the RMU-1 Operations Manual that will be submitted as those cells are constructed.

ENCLOSURE No. 2 - Cell 1-8 waste fill progression NYSDEC comments on CWM's October 21, 1998 submitted slope stability analysis.

COMMENT No. 1

CWM's Response to DEC Comment 1: **Calculation Sheet, Page 1 of 2, Methodology Section - Liner System Interface Friction**

In response to Comment 1 concerning the liner system assumptions used in the Cell 1-8 fill progression stability analyses, CWM has submitted much of the same information in support of the use of C=0psf, ϕ = 24° values as presented in response to Comment 9 on CWM's revised Permit modification application for vertical expansion of RMU-1 (November 16, 1998). However, in addition, CWM has referenced some past test results for a textured geomembrane/clay interface which indicate a result of 32° (Exhibit 1.3 in Appendix D-10 of the RMU-1 Permit's Attachment L), in an attempt to show that this liner system interface is not the most critical one.

With regard to the use of the C=0psf, ϕ = 24° values in the Cell 1-8 fill progression stability analyses, the Department's Comment #2 in Enclosure No. 1 applies here. In addition, the Department would like to make clear that it cannot accept the test result of 32° as conservatively representing the textured geomembrane/clay RMU-1 liner system interface for the following reasons:

- **The HDPE used in the test was not 80 mil and its type of texturing is unknown. Therefore, the specific HDPE material being used in the liner system was not tested.**

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- The source and characteristics of the clay used in the test are not known. Therefore, it is not known whether the clay used in the test was the specific clay(s) being used in the liner system.

- The orientation of the textured HDPE used in the test (machine verses cross) is not known for the 32° test result. The orientation of the textured HDPE may have influenced the test result.

- The moisture content of the clay surface is not known for the 32° test result. This may have played a critical role in the test result. In fact, in other test results presented here were the clay is described as "wet" or "moist", the test results ranged from 6° to 20°.

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Response No. 1

The Cell 1 through 8 Vertical Enhancement Fill Progression Plan and the Slope Stability analysis will be submitted to NYSDEC under separate cover. The previously approved geocomposite/textured geomembrane interface parameters of C = 0psf and ϕ = 15° will be used in the Slope Stability analysis.

COMMENT No. 2

<u>New DEC Comment:</u> **Attachment Nos. 6&7 - Slope Stability Calculations - Detention Basins C & D**

The upper most waste elevations used in the Detention Basin C Slope Stability Calculations in Attachment No. 6 (e.g.. 382' msl) are apparently based on the tope of waste grades in the <u>current</u> Permit. The upper most waste elevations used in the Detention Basin D Slope Stability Calculations in Attachment No. 7 (e.g.. 387' msl) are apparently also based on the top of waste grades in the <u>current</u> Permit. However, as indicated by Comment #4 in Enclosure No. 1, a Cell 1-8 fill progression plan and stability analyses reflective of the vertical expansion top of waste grades are also necessary if CWM intends to advance Cell 1-8 waste placement beyond <u>currently</u> Permitted grades, prior to waste placement in Cell 9/10. Therefore, in lieu of submitting two separate sets of fill progression plans and stability analyses for Cells 1-8, (one reflective of currently Permitted waste grades, and one reflective of the vertically expanded waste grades), CWM may submit a single Cell 1-8 fill progression plan and set of stability analyses in response to these comments, with upper

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end points which are based on top of waste grades in the Permit modification application for vertical expansion of RMU-1. If the Department determines this plan and set of analyses acceptable, it would be willing to approve them with the condition that waste placement may not advance beyond currently Permitted top of waste grades.

Response No. 2

The Cell 1 through 8 Vertical Enhancement Fill Progression Plan and Slope Stability analyses will be submitted to NYSDEC under separate cover.

COMMENT No. 3

New DEC Comment: **Attachment No. 7 - Slope Stability Calculations - Detention Basin D**

The Detention Basin D Slope Stability Calculations in Attachment No. 7 correctly indicate the bottom of the basin as 329' msl. However Figure 1 in Attachment #4 of the currently approved RMU-1 O&M Manual depicts Cross Section A-A (i.e. the cross section used to analyze Basin D slope stability) as terminating at approximately 332' msl. CWM should submit a revised Figure 1 to reflect the correct placement of Cross Section A-A.

Response No. 3

The Cell 1 through 8 Vertical Enhancement Fill Progression Plan and Slope Stability analyses will be submitted to NYSDEC under separate cover.

If you have any questions, please call us at (215) 269-2100.

Very truly yours,

Earth Tech, Inc.

Charles P. Ballod, P.E.
Division Manager

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D-3

EXCAVATION HEAVE

EXCAVATION HEAVE ANALYSIS

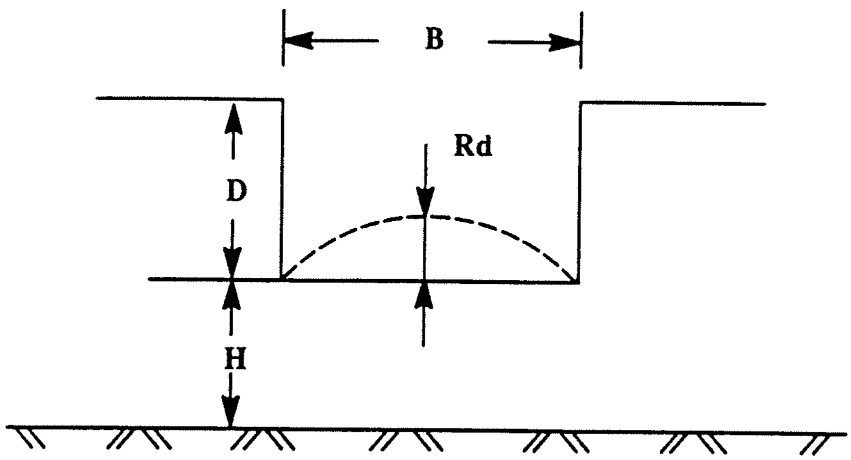
Objective: To evaluate the magnitude of heave resulting from the excavation of soils above the compressible glaciolacustrine clay unit.

Given: Size and shape of proposed RMU-1 excavation.

Assumptions: Maximum depth of excavation is to elevation +301.

Method: Winter Korn, H.F., and Fang, H.Y., Foundation Engineering Handbook, Van Nostrand Reinhold, 1975, pp. 152 and 153.

Summary:



The heave, Rd, is calculated from -

$$Rd = Cd'' \Delta s \frac{\gamma D^2}{E}$$

Where,

Rd = Maximum heave, ft.
Cd" = Shape factor.
Δs = Heave factor.
γ = Excavated soil unit weight, pcf.
D = Excavation depth, ft.
E = Elastic modulus of glaciolacustrine clay, psf.

For EW direction -

$$LEW/BEW = \frac{1400}{600} = 2.33$$

$$H/BEW = \frac{25}{600} = 0.04$$

For NS direction -

$$LNS/BNS = \frac{1700}{800} = 2.12$$

$$H/BNS = \frac{25}{800} = 0.03$$

From Charts Below

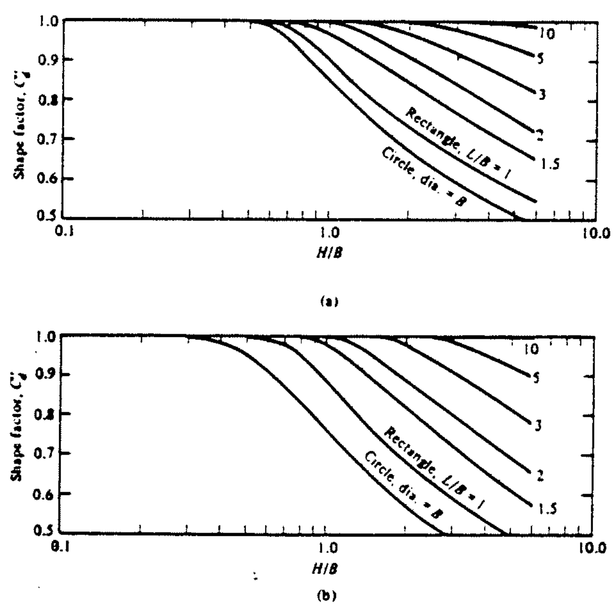
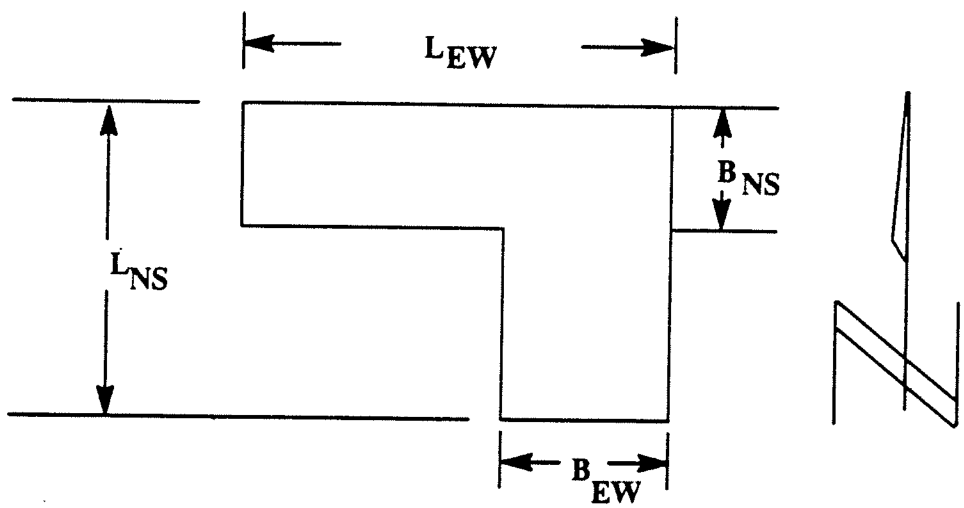


Fig. 4.7 Factors for correcting heave of strip excavation for shape of excavation. (a) Shape factor for heave at center; (b) shape factor for heave at midpoint of long side. *(Data from Egorov, 1958 as cited by Harr, 1966.)*



LEW = 1,400 ft
LNS = 1,700 ft
BEW = 600 ft
BNS = 800
H = 26 ft (depth to bedrock: EL. +301 -EL. +275)

Cd" = 1.0 (max) for either heave at center or midpoint longside EW or NS.

Soil Unit Weight of Excavated Soils, γ = 130 pcf

E (psf) = 500 Su (min) per Bowles, J.E., Foundation Analysis and Design, McGraw Hill, 4th Ed., 1988, pg. 266, Table 5-5.

Where,

Su is the underdrained shear strength of the glaciolacustrine clay.
$Su=C_{min}$ = 400 psf from previous triaxial UU testing.

E = 400 (500)
E = 2.0×10^5 psf

D = El. + 320 - El. +301 = 19 ft

For EW direction -

$BEW/D = \frac{600}{19} = 31.6$

For NS direction -

$BNS/D = \frac{800}{19} = 42.1$

From Charts Below

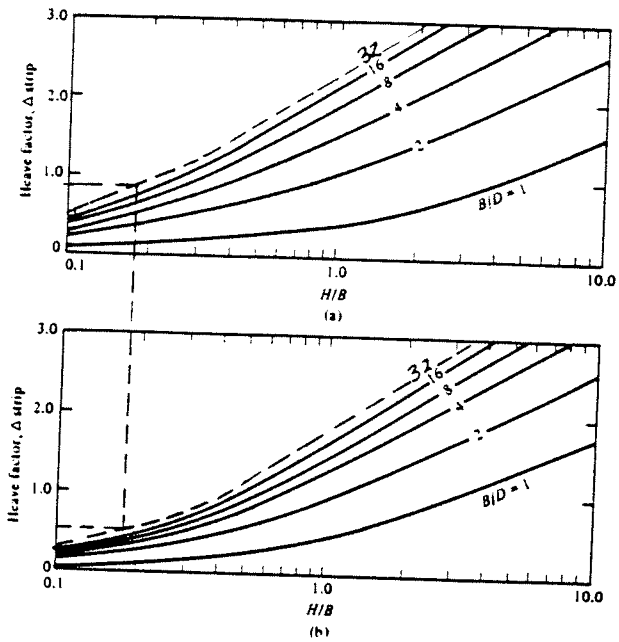


Fig. 4.6 Heave at base of strip excavation in linearly elastic medium of limited thickness. (a) Heave at center line; (b) heave at edge. (*Based on analysis of Baladi, 1968.*)

Δs(EW) = 0.6 at center
= 0.4 at edge

Δs(NS) = 0.7 at center
= 0.5 at center

For the E-W leg -

$$Rd = \frac{1.0(0.6)\ 130(19)^2}{200,000} = 0.14 \text{ ft} = \underline{\underline{1.7 \text{ in.}}} \text{ at center}$$

$$Rd = \frac{1.0(0.4)\ 130(19)^2}{200,000} = 0.09 \text{ ft} = \underline{\underline{1.1 \text{ in.}}} \text{ at edge}$$

For the N-S leg-

$$Rd = \frac{1.0(0.7)\ 130(19)^2}{200,000} = 0.16 \text{ ft} = \underline{\underline{2.0 \text{ in.}}} \text{ at center}$$

$$Rd = \frac{1.0(0.5)\ 130(19)^2}{200,000} = 0.12 \text{ ft} = \underline{\underline{1.4 \text{ in}}} \text{ at edge}$$

The magnitude of estimated heave for the base is relatively small compared to the depth/excavation and are not expected to have any significant impact on the structural integrity of the base.

D-4

HYDROSTATIC UPLIFT

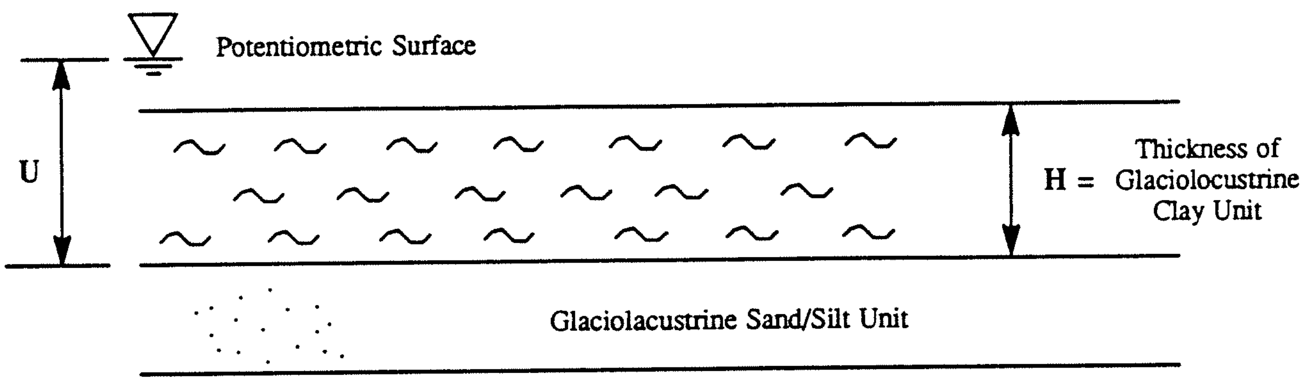
HYDROSTATIC UPLIFT CALCULATIONS

<u>Objective</u>: Estimate factor of safety against uplift for sump invert elevations and subbase low points.

<u>Given</u>: Sump invert and subbase low point elevations and locations.

<u>Assumptions</u>:
1. γ_g. clay = 125 pcf γ_w = 62.4.
2. Glaciolacustrine clay cohesion ignored (conservative approach).
3. Minimum adequate F.S. = 1.0 for sumps and 1.2 for subbase low point grades.

<u>Method</u>: Dept. of the Navy, <u>NAVFAC DM7.1</u>, "Soil Mechanics", May, 1982, Page 7.1 - 270, Figure 3.



$$F.S = \frac{H \times \gamma_{g.\ clay}}{U \times \gamma_w} = 2 \left(\frac{H}{u}\right)$$

U is estimated from site potentiometric contours as presented by Golden Associates, "Hydrogeologic Characterization Update, Model City, New York Facility," February, 1988, Figures 11, 12, and 18. This information is supplemented by borings completed by Donohue for SLF13 and submitted in the Engineering Report for SLF13 dated December, 1988, Appendix A.

H is estimated from the February, 1988, Golder Report from Figure 11 and proposed subbase and sump grades as shown on the following Figure 1.

<u>Summary</u>: Based on available potentiometric data, both the sump and subbase low point elevations, provide an adequate factor of safety against uplift failure.

Because of the relatively low factors of safety generated at the proposed sump invert elevations, consideration will be given to conducting test pit excavations at sump locations to evaluate if modifications to proposed subbase/base grades are necessary.

Factors of safety are presented on the following Tables 1 and 2.

Sump No.	Elev. T/Sand	Potent. Contour	U (Ft)	Inv. Sump Elev.	H (Ft)	F.S.
1A	284.0	314.2	30.2	301.16	17.16	1.14
1B	291.6	315.3	23.7	304.36	12.76	1.08
2A	290.3	314.5	24.2	303.50	13.2	1.09
2B	291.7	315.3	23.6	304.29	12.59	1.07
3A	288.8	314.9	26.1	302.91	14.11	1.08
3B	293.0	315.4	22.4	305.06	12.06	1.08
4A	290.6	315.1	24.5	303.93	13.33	1.09
4B	293.5	315.5	22.0	305.69	12.19	1.11
5A	295.9	316.0	20.1	306.15	10.25	1.02
5B	287.0	316.0	29.0	304.17	17.17	1.18
6A	290.1	314.5	24.4	302.46	12.36	1.01
6B	286.0	316.0	30.0	302.30	16.30	1.09
7A	285.5	316.0	30.5	302.09	16.59	1.09
7B	283.7	316.0	32.3	301.87	18.17	1.12
					Avg =	1.09

Table 1: Summary of factors of safety against uplift at sump invert elevations

Sump No.	Elev. T/Sand	Potent. Contour	U (Ft)	Inv. Sump Elev.	H (Ft)	F.S.
1A	284.0	314.2	30.2	304.10	20.16	1.33
1B	291.6	315.3	23.7	307.30	15.7	1.32
2A	290.3	314.5	24.2	306.44	16.14	1.33
2B	291.7	315.3	23.6	307.23	15.53	1.32
3A	288.8	314.9	26.1	305.85	17.05	1.31
3B	293.0	315.4	22.4	308.00	15.00	1.34
4A	290.6	315.1	24.5	306.87	16.27	1.33
4B	293.5	315.5	22.0	308.63	15.13	1.38
5A	295.9	316.0	20.1	309.09	13.19	1.31
5B	287.0	316.0	29.0	307.11	20.11	1.39
6A	290.1	314.5	24.4	305.40	15.30	1.25
6B	286.0	316.0	30.0	305.24	19.24	1.28
7A	285.5	316.0	30.5	305.03	19.53	1.28
7B	283.7	316.0	32.3	304.81	21.11	1.31
					Avg =	1.32

Table 2: Summary of factors of safety against uplift at subbase low points.

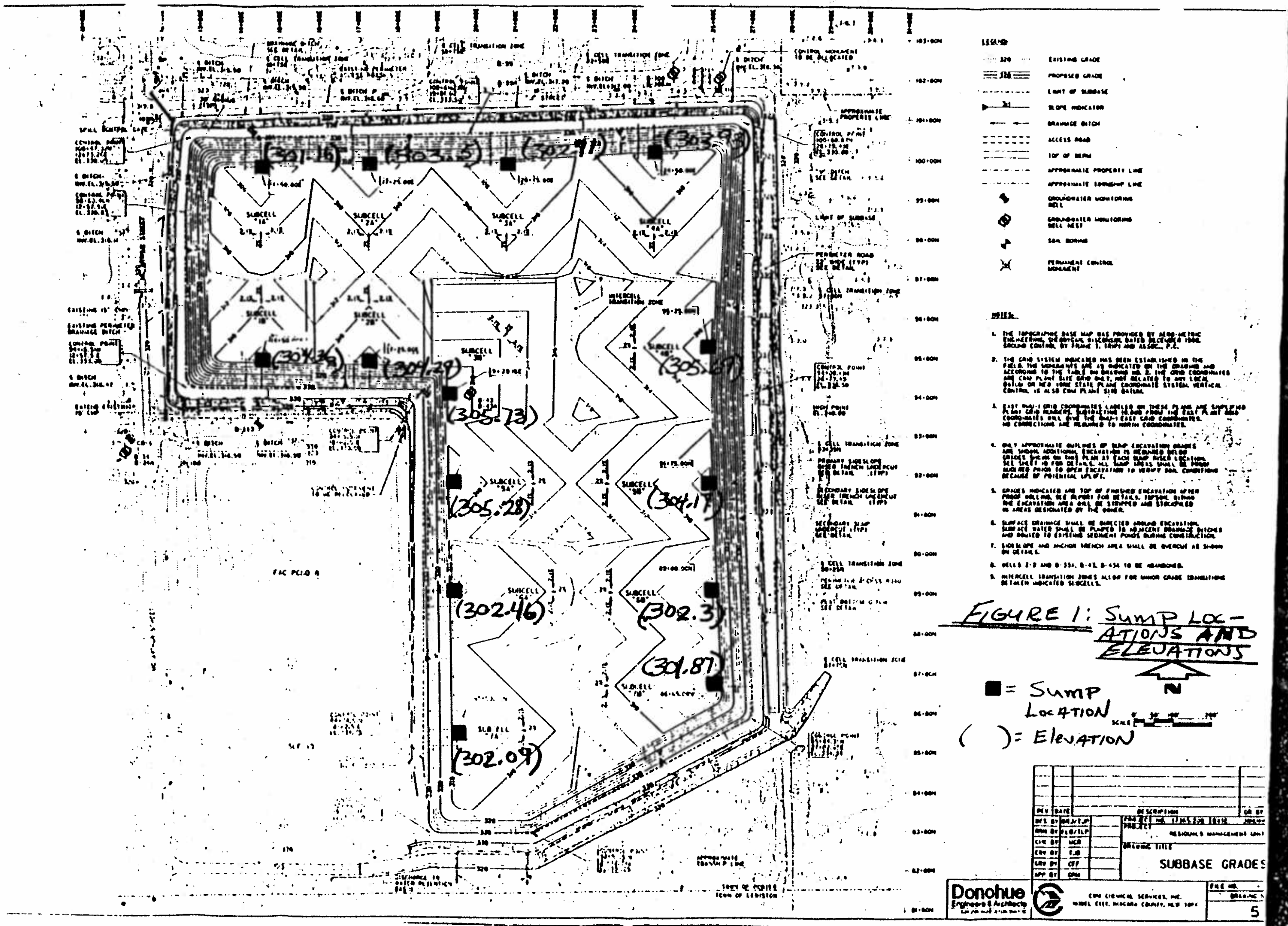


FIGURE 1: SUMP LOCATIONS AND ELEVATIONS
■ = SUMP LOCATION
( ) = ELEVATION
N
(301.16)
(303.5)
(302.91)
(303.93)
(304.39)
(304.29)
(305.73)
(305.67)
(305.28)
(304.17)
(302.46)
(302.3)
(301.87)
(302.09)
SUBCELL "1A"
SUBCELL "2A"
SUBCELL "3A"
SUBCELL "4A"
SUBCELL "1B"
SUBCELL "2B"
SUBCELL "3B"
SUBCELL "4B"
SUBCELL "5A"
SUBCELL "5B"
SUBCELL "6A"
SUBCELL "6B"
SUBCELL "7A"
SUBCELL "7B"
LEGEND
NOTES
SUBBASE GRADES
Donohue
5

UPLIFT ANALYSIS FOR CUTOFF TRENCH

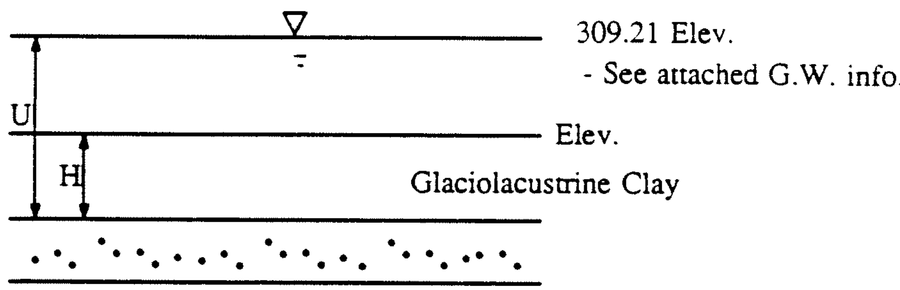
Uplift analysis was performed to determine minimum thickness of the glaciolacustrine clay needed for varying elevations with a given potentiometric surface to obtain a minimum factor of safety of 1.0. Use the following relationship:

$$FS = \frac{H q_{clay}}{U q_w} = 2\,\frac{H}{U}$$

q_{clay} = 125 pcf
q_w = 62.4 pcf

For Elev = 295

H	FS
5	0.52
10	0.83
15	1.03
20	1.17



For Elev = 300

H	FS
5	0.70
10	1.04
15	1.24
20	1.37

Note: U = H + (309.21 - Elev.)

For Elev = 305

H	FS
5	1.09
10	1.41
15	1.56
20	1.65

Based on data for Inv. Sump Elev. in Table 1, conditions at RMU-1 indicate a minimum Inv. Sump Elev. of 301.16 (at Cell 1). Analysis indicates that a clay thickness of 10 feet will provide adequate stability.

RMU-1 GROUNDWATER ELEVATIONS
March, 1992

Sample Point	Well Casing Elevation (ft MSL)	Depth to Groundwater (feet)	Groundwater Elevation (ft MSL)
R101S	321.65		317.16
R101D	321.98	13.48	308.5
R102S	320.66		316.52
R102D	319.69	11.26	308.45
R103S	321.25		317.13
R103D	319.30	11.34	308.16
R104S	320.37	5.61	314.89
R104D	320.50	12.50	308.0
R105S	320.82	3.66	317.16
R105D	320.27	12.36	307.91
R106S	320.83	4.00	316.83
R106D	321.79	13.72	308.07
R107S	320.71	4.03	316.68
R107D	320.50	12.39	308.11
R108S	321.77	3.57	318.20
R108D	321.66	12.60	309.06
R109S	320.18	2.32	317.86
R109D	320.88	11.67	309.21
R110S	322.16	4.53	317.63
R110D	321.35	12.45	308.88
R111S	321.14	2.34	318.6
R111D	321.95	13.17	308.78
R112S	337.61	26.07	311.54
R113S	325.61	DRY	*****
R114S	323.90	10.22	313.68
R114D	324.91	16.86	308.05
R115S	333.71	DRY	*****
R116S	322.24	7.66	314.58
R116D	322.60	14.48	308.12

RP/CWMNYORK/AD1

D-5

SLOPE STABILITY OF PERIMETER BERM

SLOPE STABILITY OF PERIMETER BERM

Objective: Analyze slope stability of perimeter berm for most critical case.

Given: Typical critical cross-section shown on the following Figure 1.

Assumptions: Most critical cross-section occurs adjacent to SLF-10.

Waste Properties (SLF-10):

γ = 100 pcf
C = 600 pcf
ϕ = 10°

Method: SSTAB

Summary: Critical Circle - X = 880
Y = 425
R = 145

Factor of Safety = 1.84

Perimeter berm stability appears adequate for the assumed critical case.

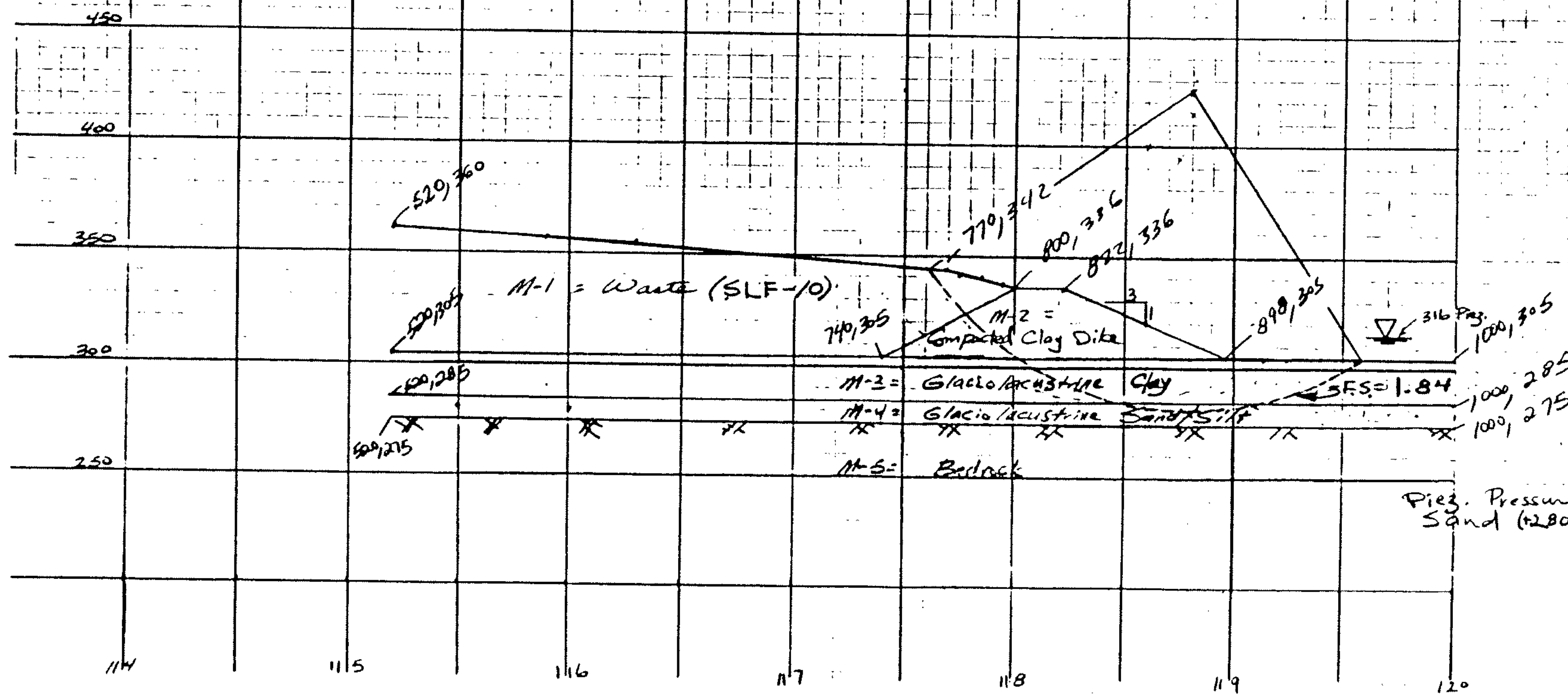
Donohue
Engineers & Architects

CLIENT: CWM PROJECT NO.: 17365.210 BY: AKP

PROJECT: Model City: RMU-1 DATE: 12-4-89 PAGE NO.: 2 of 14 Ck'd 12/10/89

FIGURE 1: SLOPE STABILITY OF PERIMETER BERM

M-TYPE	C (PSF)	ϕ (Deg)	γ (pcf)
M-1	600	10	100
M-2	2000	0	125
M-3	320	10	125
M-4	0	30	130
M-5	2000	40	140



Piez. Pressure @ Cent. 1
Sand (+280) = 36(62.4)
= 2246 psf

INPUT FILE

```
         1          0          0          1
MODEL CITY RMU-1 PERIMETER BERM STABILITY
         5          5
         3          1
       520        360
       770        342
       800        336
         4          2
       740        305
       800        336
       822        336
       898        305
         4          3
       520        305
       740        305
       898        305
      1000        305
         2          4
       520        285
      1000        285
         2          5
       520        275
      1000        275
       600                            10        100                 0
      2000                             0        125                 0
       320                            10        125                 0
         0                            30        130                 3
      2000                            40        140                 0
         6
       520        280       2246       4
       600        280       2246       4
       700        280       2246       4
       800        279       2246       4
       900        279       2246       4
      1000        279       2246       4
         1
MODEL CITY RMU-1 PERIMETER BERM STABILITY
         6
       520        360
       770        342
       800        336
       822        336
       898        305
      1000        305
         1
         3
       850        450        305                         275          5          0
         1                    10
         0          0          0          0        20
```

OUTPUT FILE

PROGRAM SSTAB1 - CODED BY S. G. WRIGHT

CODED NOVEMBER, 1970 - REVISED 6/ 4/74

NUMBER OF SOIL PROFILES ANALYZED = 1

MODEL CITY RMU-1 PERIMETER BERM STABILITY

ROFILE LINE NO. 1 MATERIAL TYPE 1

COORDINATES *****	X	Y
	520.00	360.00
	770.00	342.00
	800.00	336.00

PROFILE LINE NO. 2 MATERIAL TYPE 2

COORDINATES *****	X	Y
	740.00	305.00
	800.00	336.00
	822.00	336.00
	898.00	305.00

PROFILE LINE NO. 3 MATERIAL TYPE 3

COORDINATES *****	X	Y
	520.00	305.00
	740.00	305.00
	898.00	305.00
	1000.00	305.00

OFILE LINE NO. 4 MATERIAL TYPE 4

COORDINATES *****	X	Y
	520.00	285.00
	1000.00	285.00

PROFILE LINE NO. 5 MATERIAL TYPE 5

COORDINATES *****	X	Y
	520.00	275.00
	1000.00	275.00

MODEL CITY RMU-1 PERIMETER BERM STABILITY

M A T E R I A L   D A T A - T Y P E 1

COHESION (UNDRAINED STRENGTH) - ISOTROPIC

	C	C/Z	REF. HT.
0.	600.00	0.00	0.00

PHI - - - - - - - - - - - - - 10.00 DEGREES

UNIT WEIGHT - - - - - - - - - 100.00 PCF

PORE PRESSURE - - - - - - - - 0.00 PSF

M A T E R I A L   D A T A - T Y P E 2

COHESION (UNDRAINED STRENGTH) - ISOTROPIC

	C	C/Z	REF. HT.
0.	2000.00	0.00	0.00

PHI - - - - - - - - - - - - - 0.00 DEGREES

UNIT WEIGHT - - - - - - - - - 125.00 PCF

PORE PRESSURE - - - - - - - - 0.00 PSF

M A T E R I A L   D A T A - T Y P E 3

COHESION (UNDRAINED STRENGTH) - ISOTROPIC

	C	C/Z	REF. HT.
0.	320.00	0.00	0.00

PHI - - - - - - - - - - - - - 10.00 DEGREES

UNIT WEIGHT - - - - - - - - - 125.00 PCF

PORE PRESSURE - - - - - - - - 0.00 PSF

MODEL CITY RMU-1 PERIMETER BERM STABILITY

M A T E R I A L   D A T A   -   T Y P E 4

COHESION (UNDRAINED STRENGTH)   -   ISOTROPIC

	C	C/Z	REF. HT.
0.	0.00	0.00	0.00

PHI - - - - - - - - - - - - - -   30.00 DEGREES

UNIT WEIGHT - - - - - - - - - - 130.00 PCF

PORE PRESSURES INTERPOLATED FROM PORE PRESSURE DATA

M A T E R I A L   D A T A   -   T Y P E 5

COHESION (UNDRAINED STRENGTH)   -   ISOTROPIC

	C	C/Z	REF. HT.
0.	2000.00	0.00	0.00

PHI - - - - - - - - - - - - - -   40.00 DEGREES

UNIT WEIGHT - - - - - - - - - - 140.00 PCF

PORE PRESSURE - - - - - - - -   0.00 PSF

MODEL CITY RMU-1 PERIMETER BERM STABILITY

PORE PRESSURE INTERPOLATION DATA

	X	Y	U OR R(U)	MATERIAL TYPE
1	520.00	280.00	2246.00	4
2	600.00	280.00	2246.00	4
3	700.00	280.00	2246.00	4
4	800.00	279.00	2246.00	4
5	900.00	279.00	2246.00	4
6	1000.00	279.00	2246.00	4

1 SLOPE(S) ANALYZED FOR SOIL PROFILE TITLED -

MODEL CITY RMU-1 PERIMETER BERM STABILITY

KEEP1 = 0   KEEP2 = 0   KEEP3 = 0

SLOPE DESIGNATION -

MODEL CITY RMU-1 PERIMETER BERM STABILITY

SLOPE POINTS	X	Y
	520.00	360.00
	770.00	342.00
	800.00	336.00
	822.00	336.00
	898.00	305.00
	1000.00	305.00

1 SHEAR SURFACE(S) OR SEARCH(ES) CONSIDERED

MODEL CITY RMU-1 PERIMETER BERM STABILITY

*** INITIAL SEARCH INFORMATION ***

X COORDINATE FOR CENTER OF FIRST GRID - - - - - - - - - - - -	850.00 FT
Y COORDINATE FOR CENTER OF FIRST GRID - - - - - - - - - - - -	450.00 FT
ALL CIRCLES TANGENT TO A ROCKLINE AT ELEVATION, Y - - - -	305.00 FT
OVERALL CRITICAL CIRCLE LOCATED	
NO CIRCLE ALLOWED TO PASS BELOW ELEVATION, Y - - - - - - -	275.00 FT
REQUIRED ACCURACY IN CRITICAL CENTER LOCATION - - - - - -	5.00 FT
TIME LIMIT -	120.00 SECS.
CONSTANT ARC LENGTH SPECIFIED AS - - - - - - - - - - - - -	10.00 FT
ASSUMED DEPTH OF TENSION CRACK - - - - - - - - - - - - - -	0.00 FT
ASSUMED DEPTH OF WATER IN TENSION CRACK - - - - - - - - - -	0.00 FT
UNIT WEIGHT OF WATER - - - - - - - - - - - - - - - - - - -	62.40 PCF
INITIAL ASSUMED VALUE FOR FACTOR OF SAFETY - - - - - - - -	2.00
INITIAL ASSUMED VALUE FOR SIDE FORCE INCLINATION - - - -	0.00 DEGREES
ITERATION LIMIT - - - - -- - - - - - - - - - - - - - - - -,	20
ALLOWED FORCE INBALANCE SPECIFIED - - - - - - - - - - - - -	100.00 LBS.
ALLOWED MOMENT INBALANCE SPECIFIED - - - - - - - - - - - -,	100.00 FT-LBS.

MODEL CITY RMU-1 PERIMETER BERM STABILITY

***** CRITICAL CIRCLE INFORMATION *****

X COORDINATE OF CENTER - - - - - - - -	880.00
Y COORDINATE OF CENTER - - - - - - - -	425.00
RADIUS - - - - - - - - - - - - - - - - - -	145.00
FACTOR OF SAFETY - - - - - - - - - - - -	1.842
SIDE FORCE INCLINATION (DEGREES) - -	5.21
SECONDS REQUIRED TO LOCATE CIRCLE -	0.000

ITERATION INFORMATION

[illegible]	F	THETA (RADIANS	DEGREES)	DELF	DELT (RADIAN)	FORCE INBAL (LBS.)	MOMENT INBAL (FT.LBS.)
1	1.8416	0.09101	5.215	0.0000	0.00000	0.	1.

S O L U T I O N   I N F O R M A T I O N,

FACTOR OF SAFETY = 1.842 (1 ITERATIONS)

SIDE FORCE INCLINATION = 5.21 DEGREES

SLICE NO.	XAVG	NORMAL STRESS (PSF)	SHEAR STRESS (PSF)	LINE OF THRUST X	LINE OF THRUST YT(TOT)	LINE OF THRUST FRACTION	E-FORCE (LBS)
0				760.6	342.7	0.0000	0.
1	763.6	-24.	324.	766.6	338.4	0.4924	-2117.
2	768.3	484.	372.	770.0	341.0	0.9149	-1391.
3	773.1	919.	414.	776.2	318.6	0.0000	2288.
4	779.8	1076.	1086.	783.5	317.5	0.0288	1877.
5	787.3	1937.	1086.	791.1	314.4	0.1446	5916.
6	794.9	2705.	1086.	798.6	310.4	0.1717	12459.
7	799.3	3437.	503.	800.0	309.3	0.1631	14968.
8	804.3	3823.	540.	808.5	304.7	0.1585	30342.
9	813.0	4463.	601.	817.4	301.3	0.1697	45657.
10	819.7	4914.	644.	822.0	299.8	0.1748	53053.
11	826.6	5094.	662.	831.3	297.2	0.2001	65655.
12	836.1	5120.	664.	840.8	295.1	0.2263	74851.
13	841.5	5104.	663.	842.3	294.8	0.2302	75910.
14	847.1	5012.	867.	852.0	293.6	0.2639	78836.
15	856.9	4864.	821.	861.9	292.7	0.2997	78479.
16	866.8	4611.	742.	871.8	292.3	0.3402	75283.
17	875.9	4291.	641.	880.0	292.3	0.3788	71028.
18	885.0	3867.	508.	890.0	292.5	0.4351	64618.
19	894.0	3354.	347.	898.0	292.8	0.4890	59231.
20	902.9	3005.	238.	907.9	293.3	0.4762	52126.
21	912.7	2762.	162.	917.6	294.0	0.4524	44309.
22	917.7	2607.	113.	917.7	294.0	0.4519	44196.
23	922.5	2555.	418.	927.3	295.7	0.4535	32701.
24	932.0	2166.	381.	936.6	297.7	0.4619	21376.
25	941.2	1679.	335.	945.7	300.2	0.4867	11258.
26	950.1	1089.	278.	954.5	303.1	0.5714	3559.
27	957.9	462.	218.	961.4	789.2	0.0000	0.

SEARCH COMPLETED   F1 = 1.841558   THETA1 = 5.214550

D-6

SLOPE STABILITY OF LANDFILL AT FINAL BUILDOUT

5/18/99

SLOPE STABILITY OF LANDFILL AT FINAL BUILDOUT

This Appendix presents two (2) cases of landfill stability analyses. The first case (Section 21+50E) is the slope stability of the landfill at final buildout with a liner system consisting of:

- Prepared subgrade;
- Compacted secondary clay liner;
- 80 mil HDPE geomembrane secondary liner;
- Geonet secondary drainage layer;
- Geotextile;
- Granular secondary drainage layer;
- Geotextile;
- Compacted primary clay liner;
- 80 mil HDPE geomembrane primary liner;
- Geonet primary drainage layer;
- Geotextile;
- Granular primary drainage layer;
- Geotextile; and,
- Granular operations layer.

This applies to cells 1 through 6. The analysis attached is a circular stability analysis and sliding block stability analysis.

The second case (Section 91+25N) is the slope stability of the landfill at final buildout with a liner system consisting of:

- Prepared subgrade;
- Compacted secondary clay liner;
- Textured 80 mil HDPE geomembrane secondary liner;
- Geocomposite secondary drainage layer;
- Granular secondary drainage layer;
- Compacted primary clay liner;
- Textured 80 mil HDPE geomembrane primary liner;
- Geocomposite primary drainage layer;

3/18/99
Revised: ~~Date Approved~~

- Granular primary drainage layer;
- Geotextile; and,
- Granular operations layer.

This applies to cells 7/8, 9/10, 11/13 and 12/14. The analyses performed include circular stability analyses and sliding block stability analyses.

5/18/99
Revised: ~~Dated Approved~~

CLIENT	CWM CHEMICAL SERVICES, INC.	SUBJECT	SLOPE STABILITY ANALYSIS Sta 21 – 50	PROJECT NO [illegible]
PROJECT	MODEL CITY FACILITY MAJOR PERMIT MODIFICATION			BY BPS DATE 1 25 00
				CK KDM DATE 1 25 00
				Page 1 of 2

TASK: To verify the slope stability of the proposed RMU-1 Vertical Expansion Station 21 – 50 E through Cell 5 and Cell 6 in response to the NYSDEC Comment 3(a) in the Notice of Incomplete Application letter dated January 19, 1999.

REFERENCES:

1. Report of Interface Friction Testing 80 mil Smooth HDPE and HDPE Geonet NSC Products for RMU-1, ASTM D-5321-92 Test Protocols. J & L Testing Company, February 1, 1995.
2. "Final Report - Interface Direct Shear Testing - WMNA Friction Testing Program," prepared by GeoSyntec Consultants, November 16, 1992.
3. "Operations Layer Grades," Drawing No. 10, prepared by SEC Donohue, February 1991, revised by Rust Environment & Infrastructure, June 1997.
4. "Typical Liner Sections Cells 1 through 6," Drawing No. 17, prepared by SEC Donohue, February 1991, revised by Rust Environment & Infrastructure, April 1997.
5. "Typical Liner Sections Cells 7 through 14," Drawing No. 17A, prepared Rust Environment & Infrastructure, November 1996, revised April 1997.
6. "Top of Vegetative Cover Grades," Drawing No. 12, prepared by SEC Donohue, February 1991, revised by Earth Tech, Inc., February 1999.
7. Geoslope Computer Program, Version 5.10, by GEOCOMP Corp., 1992.
8. 6 NYCRR Part 373 Permit Application for Residuals Management Unit 1, SEC Donohue, June 1992.
9. NYSDEC Letter dated March 13, 1995 accepting geomembrane/geonet interface friction angle of 10.5°.
10. "Final Cover Details," Drawing No. 12, Prepared by Rust Environment & Infrastructure, revised October 1997.
11. Earth Tech February 5, 1999 letter in response to NYSDEC letter dated January 19,1999.

ASSUMPTIONS:

1. The primary and secondary geosynthetic layers will be modeled as 0.5' thick layers of soil with an internal friction angle equal to the lowest friction angle between any two liner system components.

2. The critical failure surface for the sliding block analysis will be within the geosynthetic secondary liner system. The critical interface is 10.5° between the smooth 80 mil HDPE and geonet (see Reference 1) for Cells 1 through 6.

3. The critical failure surface for the circular analysis will be through the underlying glaciolacustrene clay and/or sand/silt layers or through the waste mass.

CALCULATIONS:

1. A slope stability cross section is cut through Station 21+50E (Cells 5 and 6) using the final vertical enhancement top of vegetative cover grades shown on Drawing No. 12 (see Reference 6).

CLIENT CWM CHEMICAL SERVICES, INC.
PROJECT MODEL CITY FACILITY MAJOR PERMIT MODIFICATION
SUBJECT SLOPE STABILITY ANALYSIS Sta 21+50

PROJECT NO [illegible]
BY BPS DATE [illegible]
CK KDM DATE [illegible]

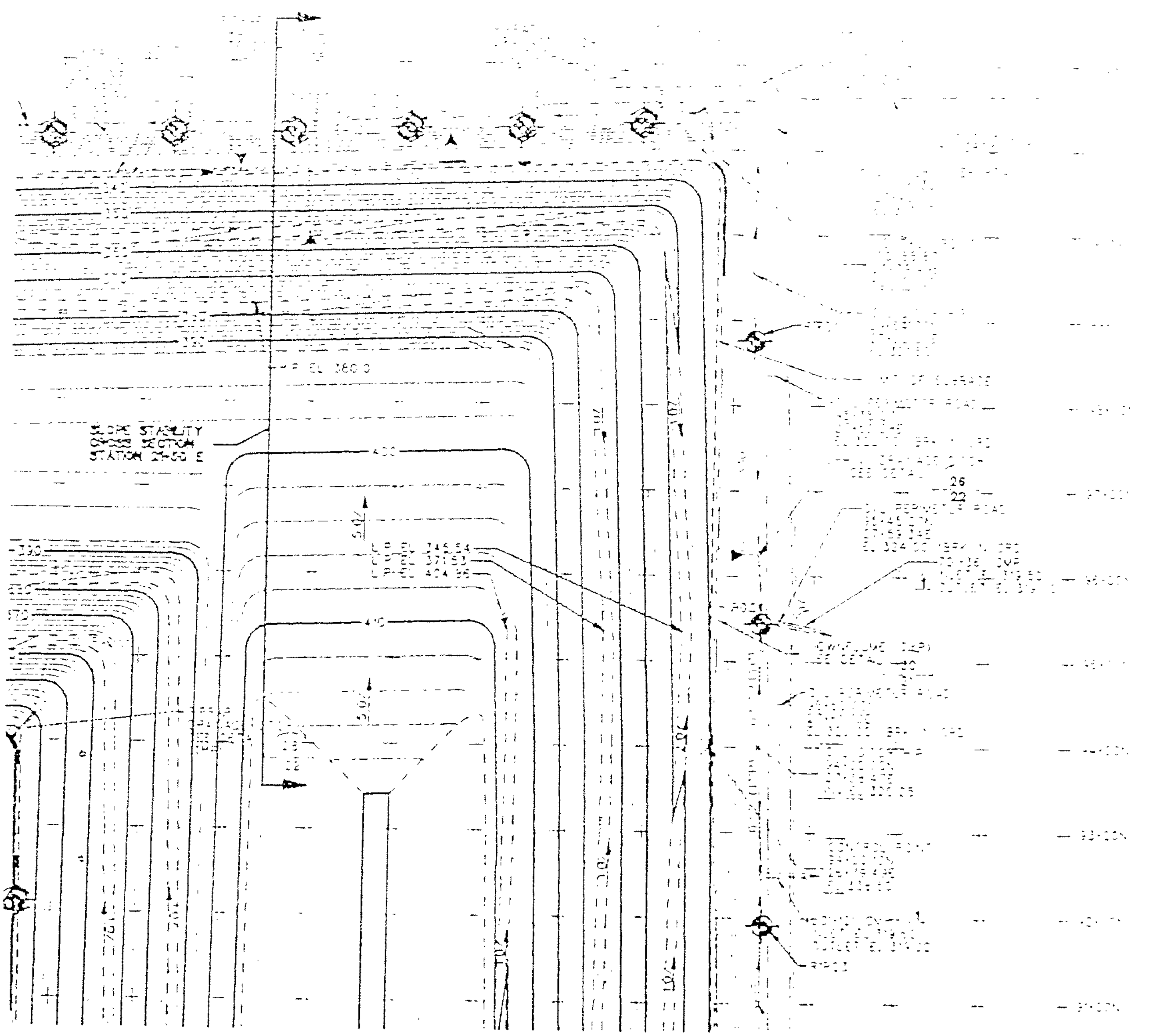
2. Input parameters:

Soil No.	Soil Type	Unit Wt., pcf	Cohesion, psf	Φ, degrees	Reference No.
1	Waste	111	0	24	8
2	Compacted Clay	130	1000	10	8
3	Granular/ Operations Layer	135	0	24	8
4	Textured Liner System	58.7	0	15	2
5	Upper Fill	130	800	10	8
6	Glacio Lacustrine Clay	125	320	10	8
7	Glacio/Lac. Sand/Silt	130	0	30	8
8	Bedrock	140	2000	40	8
9	Smooth Liner	58.7	0	10.5	1.9
10	Structural Fill	130	2000	0	-
11	Vegetative Cover	125	0	25	8

3. Seismic Coefficient: k = 0.055(References 8 and 11)

4. Results: (See attached GEOSLOPE output)

Section	Static Sliding Block F.S.	Seismic Sliding Block F.S.	Static Deep Circular F.S.	Seismic Deep Circular F.S.
21+50 E	1.617	1.292	1.584	1.277



LEGEND

320	EXISTING GRADE
	PROPOSED GRADE
	LIMIT OF SUBBASE
	SLOPE INDICATOR
	DRAINAGE DITCH
	ACCESS ROAD
	TOP OF BERM
	APPROXIMATE PROPERTY LINE
	TOWNSHIP LINE
	GROUNDWATER MONITORING WELL
	GROUNDWATER MONITORING WELL NEST
	SOIL BORING
	PERMANENT CONTROL MONUMENT
	CULVERT
	VAULT
	SLOPE STABILITY CROSS SECTION

E A R T H T E C H

CWM CHEMICAL SERVICES, INC.

RESIDUAL MANAGEMENT UNIT 1

SLOPE STABILITY CROSS SECTION
STATION- 21+50 EAST

FIGURE 1

FEB 1999

SECTION 21+50
TOP OF VEGETATIVE COVER GRADES

STATIC SLIDING BLOCK FAILURE ANALYSIS

```
*****************************************************************
*****                      GeoSlope                        *****
*****                    Version 5.10                      *****
*****                                                      *****
*****      (c)1992 by GEOCOMP Corp, Concord, MA            *****
*****               Licensed to RUST                       *****
*****************************************************************
```

Problem Title : "CWM Chemical Services, Inc. Model City RMU-1"
Description : "Vert Enhancement Section 21+50 East"
Remarks : "Static Sliding Block - Max El = 420 ft

```
*****************************************************************
*****                     INPUT DATA                       *****
*****************************************************************
```

Profile Boundaries

Number of Boundaries : 96
Number of Top Boundaries : 19

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	317.00	33.41	328.00	7
2	33.41	328.00	63.49	328.00	7
3	63.49	328.00	77.19	320.00	7
4	77.19	320.00	134.34	320.00	7
5	134.34	320.00	160.98	334.19	10
6	160.98	334.19	172.98	333.83	10
7	172.98	333.83	175.49	331.32	10
8	175.49	331.32	176.99	332.82	10
9	176.99	332.82	179.61	334.00	2
10	179.61	334.00	245.28	355.88	11
11	245.28	355.88	257.19	354.69	11
12	257.19	354.69	333.32	379.87	11
13	333.32	379.87	345.22	378.67	11
14	345.22	378.67	391.03	393.94	11
15	391.03	393.94	633.00	404.00	11
16	633.00	404.00	714.00	410.00	11
17	714.00	410.00	756.00	412.00	11
18	756.00	412.00	800.00	414.00	11
19	800.00	414.00	900.00	414.00	11
20	179.61	334.00	188.61	334.00	2
21	188.61	334.00	245.28	352.88	2
22	245.28	352.88	257.19	351.69	2
23	257.19	351.69	333.32	376.87	2
24	333.32	376.87	345.22	375.67	2
25	345.22	375.67	391.03	390.94	2
26	391.03	390.94	633.00	401.00	2
27	633.00	401.00	714.00	407.00	2
28	714.00	407.00	756.00	409.00	2
29	756.00	409.00	800.00	411.00	2
30	800.00	411.00	900.00	411.00	2
31	188.61	334.00	195.61	334.00	2
32	195.61	334.00	198.61	333.00	2

33	198.61	333.00	245.28	350.88	1
34	245.28	350.88	257.19	349.69	1
35	257.19	349.69	333.32	374.87	1
36	333.32	374.87	345.22	373.67	1
37	345.22	373.67	391.03	388.94	1
38	391.03	388.94	633.00	399.00	1
39	633.00	399.00	714.00	405.00	1
40	714.00	405.00	756.00	407.00	1
41	756.00	407.00	800.00	409.00	1
42	800.00	409.00	900.00	409.00	1
43	176.99	332.82	179.61	333.00	10
44	179.61	333.00	190.11	333.00	10
45	190.11	333.00	195.61	333.00	9
46	195.61	333.00	198.61	333.00	3
47	198.61	333.00	249.00	314.56	3
48	249.00	314.56	535.00	320.28	3
49	535.00	320.28	542.00	328.00	3
50	542.00	328.00	558.00	328.00	3
51	558.00	328.00	565.00	323.00	3
52	565.00	323.00	619.00	322.00	3
53	619.00	322.00	900.00	322.45	3
54	195.61	333.00	249.00	313.56	9
55	249.00	313.56	255.00	312.56	9
56	255.00	312.56	535.00	318.28	9
57	535.00	318.28	542.00	326.00	9
58	542.00	326.00	558.00	326.00	9
59	558.00	326.00	565.00	321.00	9
60	565.00	321.00	619.00	320.00	9
61	619.00	320.00	900.00	321.45	9
62	190.11	332.50	195.61	332.50	2
63	195.61	332.50	249.00	313.06	2
64	249.00	313.06	255.00	312.06	2
65	255.00	312.06	535.00	317.78	2
66	535.00	317.78	542.00	325.50	2
67	542.00	325.50	558.00	325.50	2
68	558.00	325.50	565.00	320.50	2
69	565.00	320.50	619.00	319.50	2
70	619.00	319.50	900.00	320.95	2
71	255.00	312.06	259.50	311.00	9
72	259.50	311.00	533.50	316.78	3
73	533.50	316.78	566.50	320.00	3
74	566.50	320.00	619.00	318.00	3
75	619.00	318.00	900.00	319.45	3
76	259.50	311.00	262.50	310.00	9
77	262.50	310.00	532.50	315.78	9
78	532.50	315.78	567.50	319.00	9
79	567.50	319.00	619.00	317.00	9
80	619.00	317.00	900.00	318.45	9
81	259.50	310.50	262.50	309.50	2
82	262.50	309.50	532.50	315.28	2
83	532.50	315.28	567.50	318.50	2
84	567.50	318.50	619.00	316.50	2
85	619.00	316.50	900.00	317.95	2
86	190.11	332.40	195.61	329.50	10
87	195.61	329.50	222.99	320.00	10
88	134.34	320.00	221.99	320.00	7
89	221.99	320.00	259.50	307.50	7
90	259.50	307.50	262.50	306.50	7
91	262.50	306.50	567.50	315.50	7
92	567.50	315.50	619.00	313.50	7
93	619.00	313.50	900.00	314.95	7
94	0.00	305.00	900.00	305.00	6

95	0.00	290.00	900.00	290.00	-
96	0.00	275.00	900.00	275.00	3

Soil Parameters

Number of Soil Types : 11

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	111.0	111.0	0.0	24.0	0.00	0.0	0
2	130.0	130.0	1000.0	10.0	0.00	0.0	0
3	135.0	135.0	0.0	24.0	0.00	0.0	0
4	58.7	58.7	0.0	15.0	0.00	0.0	0
5	130.0	130.0	800.0	10.0	0.00	0.0	0
6	125.0	125.0	320.0	10.0	0.00	0.0	0
7	130.0	130.0	0.0	30.0	0.00	0.0	0
8	140.0	140.0	2000.0	40.0	0.00	0.0	0
9	58.7	58.7	0.0	10.5	0.00	0.0	0
10	130.0	130.0	2000.0	0.0	0.00	0.0	0
11	125.0	125.0	0.0	25.0	0.00	0.0	0

****
*****   TRIAL SURFACE GENERATION   *****
****

Data for Generating Rankine Block Surfaces

Number of Trial Surfaces : 500
Number of Boxes : 5
Segment Length, ft : 1.00 ft

Box No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Height (ft)
1	195.61	332.75	255.00	313.31	0.00
2	255.00	312.31	255.00	312.31	0.00
3	259.50	310.75	259.50	310.75	0.00
4	262.50	309.75	262.50	309.75	0.00
5	262.50	309.75	532.50	315.53	0.00

****
*****   RESULTS   *****
****

The factor of safety for the trial failure surface defined by the coordinates listed below is MISLEADING.

Failure surface defined by 166 coordinate points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	208.37	343.75
2	209.43	343.39
3	210.27	342.85
4	211.11	342.32
5	211.96	341.78
6	212.66	341.19
7	213.42	340.55
8	214.19	339.91
9	214.96	339.26
10	215.13	339.15
11	215.97	338.60
12	216.81	338.06
13	217.65	337.51
14	218.49	336.97
15	219.33	336.42
16	220.17	335.88
17	221.01	335.33
18	221.84	334.79
19	222.68	334.24
20	223.52	333.70
21	224.36	333.16
22	225.20	332.61
23	226.04	332.07
24	226.88	331.52
25	227.71	330.98
26	228.55	330.43
27	229.39	329.89
28	230.23	329.34
29	231.07	328.80
30	231.91	328.25
31	232.75	327.71
32	233.59	327.16
33	234.42	326.62
34	235.26	326.07
35	236.10	325.53
36	236.94	324.99
37	237.78	324.44
38	238.62	323.90
39	239.46	323.35
40	240.29	322.81
41	241.13	322.26
42	241.97	321.72
43	242.81	321.17
44	243.65	320.63
45	244.49	320.08
46	245.33	319.54
47	246.17	318.99
48	247.00	318.45
49	247.84	317.91
50	248.68	317.36
51	249.52	316.32
52	250.36	316.27
53	251.20	315.73
54	252.04	315.18
55	252.87	314.64
56	253.16	314.45
57	254.00	313.91
58	254.84	313.36
59	255.00	312.31

60	259.50	310.75
61	262.50	309.75
62	380.74	312.23
63	380.95	312.54
64	381.50	313.37
65	381.63	313.58
66	382.27	314.34
67	382.54	314.67
68	382.97	315.17
69	383.51	316.01
70	384.05	316.85
71	384.32	317.27
72	384.87	318.11
73	385.41	318.94
74	385.96	319.78
75	386.50	320.62
76	387.05	321.46
77	387.59	322.30
78	388.14	323.14
79	388.68	323.98
80	389.23	324.81
81	389.77	325.65
82	390.32	326.49
83	390.86	327.33
84	391.40	328.17
85	391.95	329.01
86	392.49	329.85
87	393.04	330.69
88	393.58	331.52
89	394.13	332.36
90	394.67	333.20
91	395.22	334.04
92	395.76	334.88
93	396.31	335.72
94	396.85	336.56
95	397.40	337.39
96	397.94	338.23
97	398.49	339.07
98	399.03	339.91
99	399.57	340.75
100	400.12	341.59
101	400.66	342.43
102	401.21	343.27
103	401.75	344.10
104	402.30	344.94
105	402.84	345.78
106	403.39	346.62
107	403.93	347.46
108	404.48	348.30
109	405.02	349.14
110	405.57	349.97
111	406.11	350.81
112	406.65	351.65
113	407.20	352.49
114	407.74	353.33
115	408.29	354.17
116	408.83	355.01
117	409.38	355.85
118	409.92	356.68
119	410.47	357.52
120	411.01	358.36
121	411.56	359.20

122	412.10	360.04
123	412.65	360.88
124	413.19	361.72
125	413.73	362.55
126	414.28	363.39
127	414.82	364.23
128	415.37	365.07
129	415.91	365.91
130	416.46	366.75
131	417.00	367.59
132	417.55	368.43
133	418.09	369.26
134	418.64	370.10
135	419.18	370.94
136	419.73	371.78
137	420.27	372.62
138	420.82	373.46
139	421.36	374.30
140	421.90	375.13
141	422.45	375.97
142	422.99	376.81
143	423.54	377.65
144	424.08	378.49
145	424.63	379.33
146	425.17	380.17
147	425.72	381.01
148	426.26	381.84
149	426.81	382.68
150	427.35	383.52
151	427.90	384.36
152	428.44	385.20
153	428.98	386.04
154	429.53	386.88
155	430.07	387.71
156	430.62	388.55
157	431.16	389.39
158	431.71	390.23
159	431.98	390.64
160	432.62	391.41
161	433.26	392.17
162	433.71	392.71
163	434.25	393.56
164	434.79	394.40
165	435.33	395.24
166	435.68	395.80

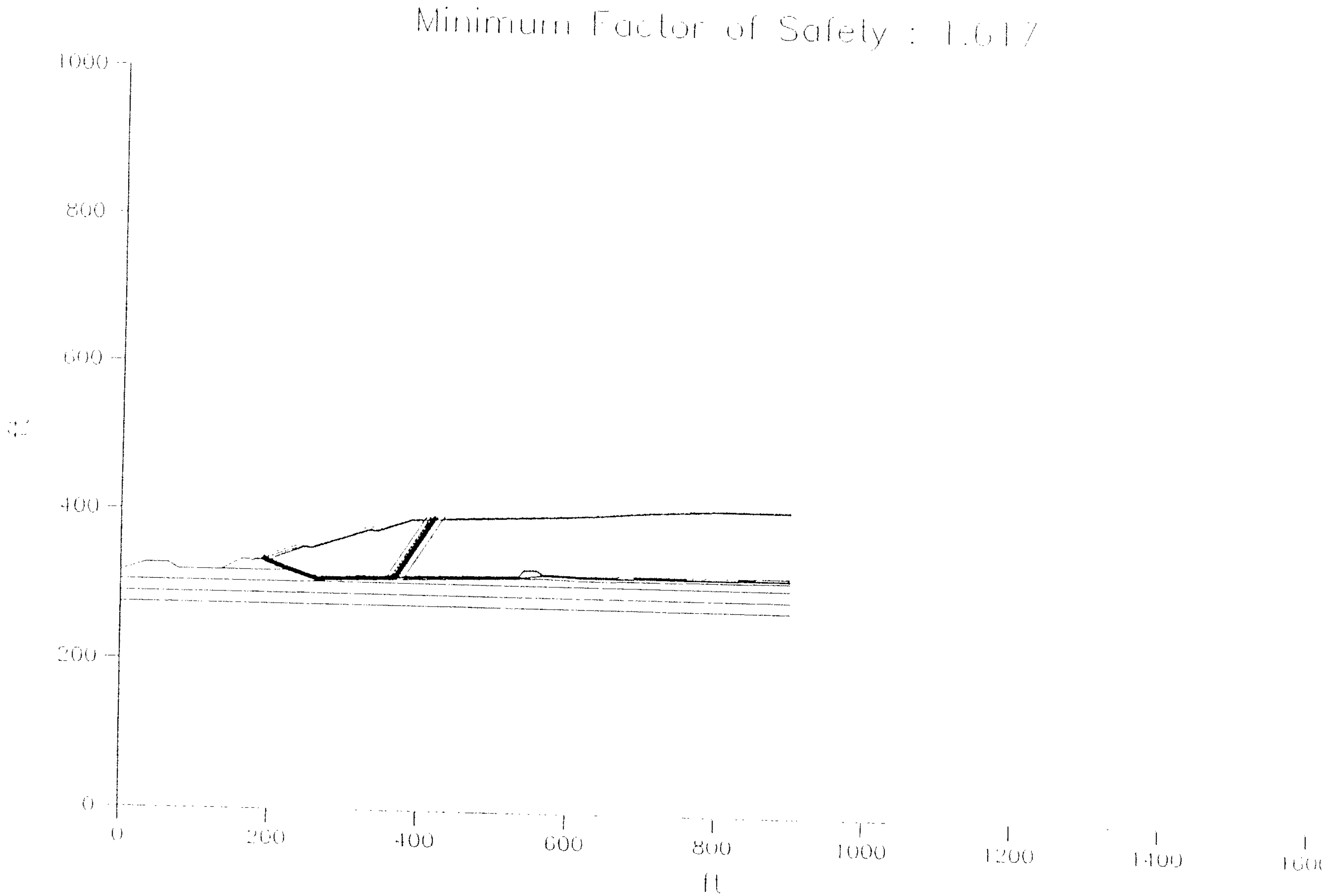
Factor of safety for the preceding specified surface = 1.699

Critical Surfaces

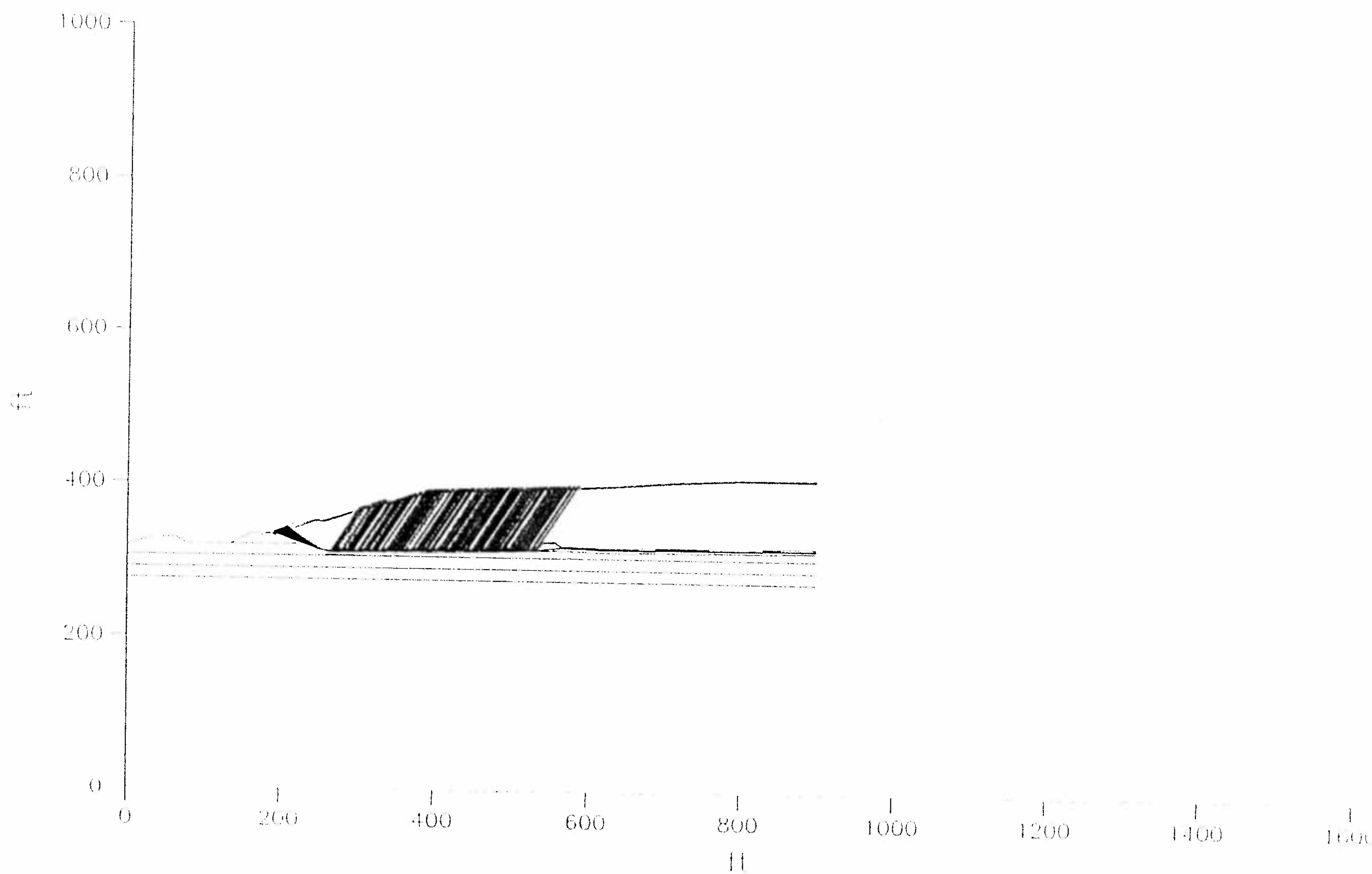
No.	Safety Factor
1	1.617
2	1.631
3	1.647
4	1.650

5	1.651
6	1.655
7	1.656
8	1.657
9	1.657
10	1.657

Rankine Block Surface – Most Critical Surfa…



Rankine Block Surfaces - Search for Critical Surfaces



SECTION 21+50
TOP OF VEGETATIVE COVER GRADES

STATIC DEEP CIRCULAR FAILURE ANALYSIS

```
*****************************************************************************
*****                              GeoSlope                             *****
*****                            Version 5.10                           *****
*****                                                                   *****
*****             (c) 1992 by GEOCOMP Corp, Concord, MA                 *****
*****                          Licensed to RUST                         *****
*****************************************************************************
```

Problem Title : "CWM Chemical Services, Inc. Model City RMU-1"
Description : "Vert Enhancement Section 21+50 East"
Remarks : "Static Circular Analysis - Max El = 420 ft"

```
*****************************************************************************
*****                             INPUT DATA                            *****
*****************************************************************************
```

Profile Boundaries

Number of Boundaries : 96
Number of Top Boundaries : 19

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	317.00	33.41	328.00	7
2	33.41	328.00	63.49	328.00	7
3	63.49	328.00	77.19	320.00	7
4	77.19	320.00	134.34	320.00	7
5	134.34	320.00	160.98	334.19	10
6	160.98	334.19	172.98	333.83	10
7	172.98	333.83	175.49	331.32	10
8	175.49	331.32	176.99	332.82	10
9	176.99	332.82	179.61	334.00	2
10	179.61	334.00	245.28	355.88	11
11	245.28	355.88	257.19	354.69	11
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14	345.22	378.67	391.03	393.94	11
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17	714.00	410.00	756.00	412.00	11
18	756.00	412.00	800.00	414.00	11
19	800.00	414.00	900.00	414.00	11
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31	188.61	334.00	195.61	334.00	2
32	195.61	334.00	198.61	333.00	2

33	198.61	333.00	245.28	350.88	1
34	245.28	350.88	257.19	349.69	1
35	257.19	349.69	333.30	374.87	1
36	333.30	374.67	345.22	373.67	1
37	345.22	373.67	391.03	388.94	1
38	391.03	388.94	633.00	399.00	1
39	633.00	399.00	714.00	405.00	1
40	714.00	405.00	756.00	407.00	1
41	756.00	407.00	800.00	409.00	1
42	800.00	409.00	900.00	409.00	1
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46	195.61	333.00	198.61	333.00	3
47	198.61	333.00	249.00	314.56	3
48	249.00	314.56	535.00	320.28	3
49	535.00	320.28	542.00	328.00	3
50	542.00	328.00	558.00	328.00	3
51	558.00	328.00	565.00	323.00	3
52	565.00	323.00	619.00	322.00	3
53	619.00	322.00	900.00	322.45	3
54	195.61	333.00	249.00	313.56	9
55	249.00	313.56	255.00	312.56	9
56	255.00	312.56	535.00	318.28	9
57	535.00	318.28	542.00	326.00	9
58	542.00	326.00	558.00	326.00	9
59	558.00	326.00	565.00	321.00	9
60	565.00	321.00	619.00	320.00	9
61	619.00	320.00	900.00	321.45	9
62	190.11	332.50	195.61	332.50	2
63	195.61	332.50	249.00	313.06	2
64	249.00	313.06	255.00	312.06	2
65	255.00	312.06	535.00	317.78	2
66	535.00	317.78	542.00	325.50	2
67	542.00	325.50	558.00	325.50	2
68	558.00	325.50	565.00	320.50	2
69	565.00	320.50	619.00	319.50	2
70	619.00	319.50	900.00	320.95	2
71	255.00	312.06	259.50	311.00	9
72	259.50	311.00	533.50	316.78	3
73	533.50	316.78	566.50	320.00	3
74	566.50	320.00	619.00	318.00	3
75	619.00	318.00	900.00	319.45	3
76	259.50	311.00	262.50	310.00	9
77	262.50	310.00	532.50	315.78	9
78	532.50	315.78	567.50	319.00	9
79	567.50	319.00	619.00	317.00	9
80	619.00	317.00	900.00	318.45	9
81	259.50	310.50	262.50	309.50	2
82	262.50	309.50	532.50	315.28	2
83	532.50	315.28	567.50	318.50	2
84	567.50	318.50	619.00	316.50	2
85	619.00	316.50	900.00	317.95	2
86	190.11	332.40	195.61	329.50	10
87	195.61	329.50	222.99	320.00	10
88	134.34	320.00	221.99	320.00	7
89	221.99	320.00	259.50	307.50	7
90	259.50	307.50	262.50	306.50	7
91	262.50	306.50	567.50	315.50	7
92	567.50	315.50	619.00	313.50	7
93	619.00	313.50	900.00	314.95	7
94	0.00	305.00	900.00	305.00	6

95	0.00	290.00	900.00	290.00	7
96	0.00	275.00	900.00	275.00	8

Soil Parameters

Number of Soil Types : 11

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	111.0	111.0	0.0	24.0	0.00	0.0	0
2	130.0	130.0	1000.0	10.0	0.00	0.0	0
3	135.0	135.0	0.0	24.0	0.00	0.0	0
4	58.7	58.7	0.0	15.0	0.00	0.0	0
5	130.0	130.0	300.0	10.0	0.00	0.0	0
6	125.0	125.0	320.0	10.0	0.00	0.0	0
7	130.0	130.0	0.0	30.0	0.00	0.0	0
8	140.0	140.0	2000.0	40.0	0.00	0.0	0
9	58.7	58.7	0.0	10.5	0.00	0.0	0
10	130.0	130.0	2000.0	0.0	0.00	0.0	0
11	125.0	125.0	0.0	25.0	0.00	0.0	0

****
***** TRIAL SURFACE GENERATION *****
****

Data for Generating Circular Surfaces

Number of Initiation Points : 10
Number of Surfaces From Each Point : 10
Left Initiation Point : 75.00 ft
Right Initiation Point : 175.49 ft
Left Termination Point : 350.00 ft
Right Termination Point : 450.00 ft
Minimum Elevation : 0.00 ft
Segment Length : 5.00 ft
Positive Angle Limit : 0.00 deg
Negative Angle Limit : 0.00 deg

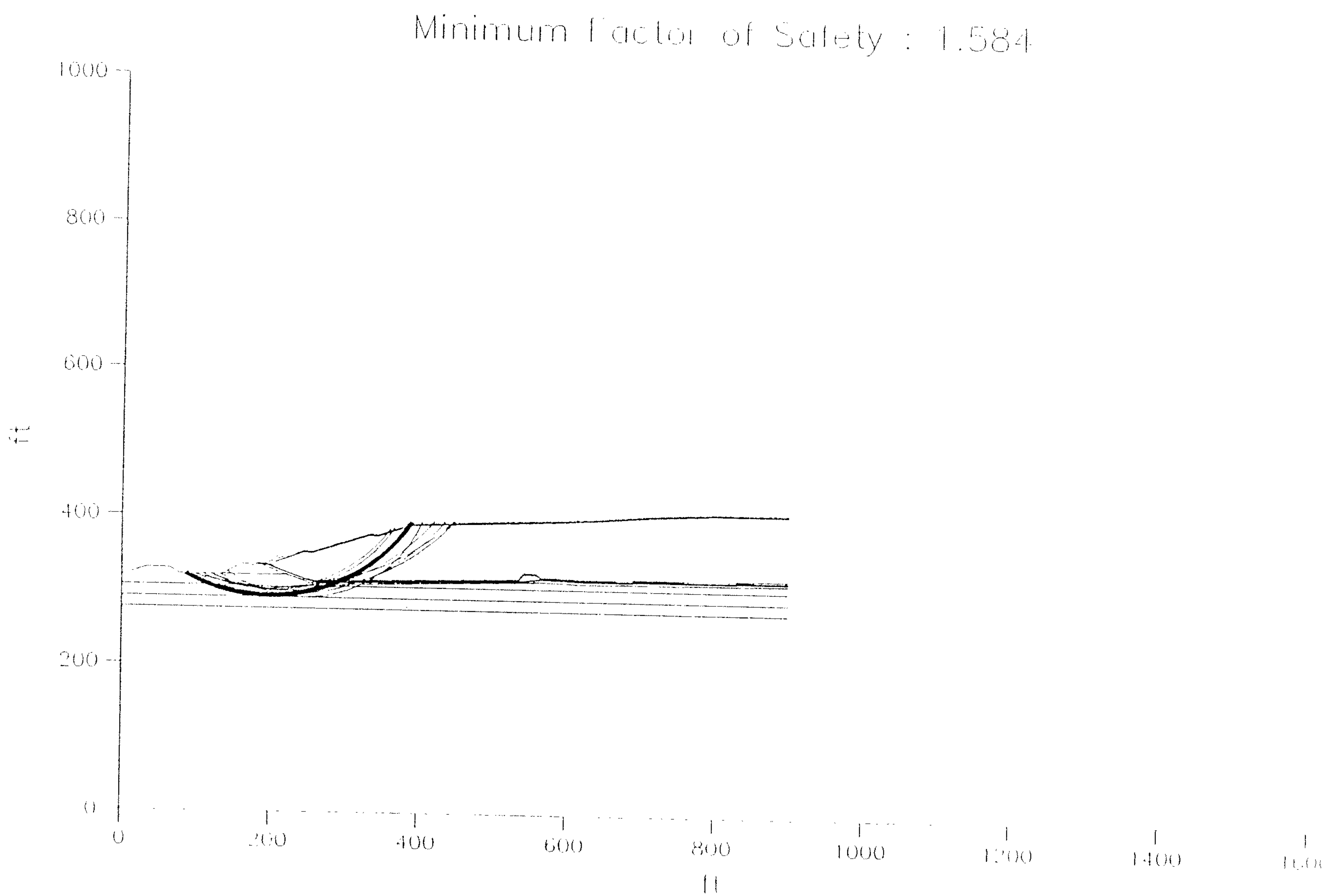
****
***** RESULTS *****
****

Critical Surfaces

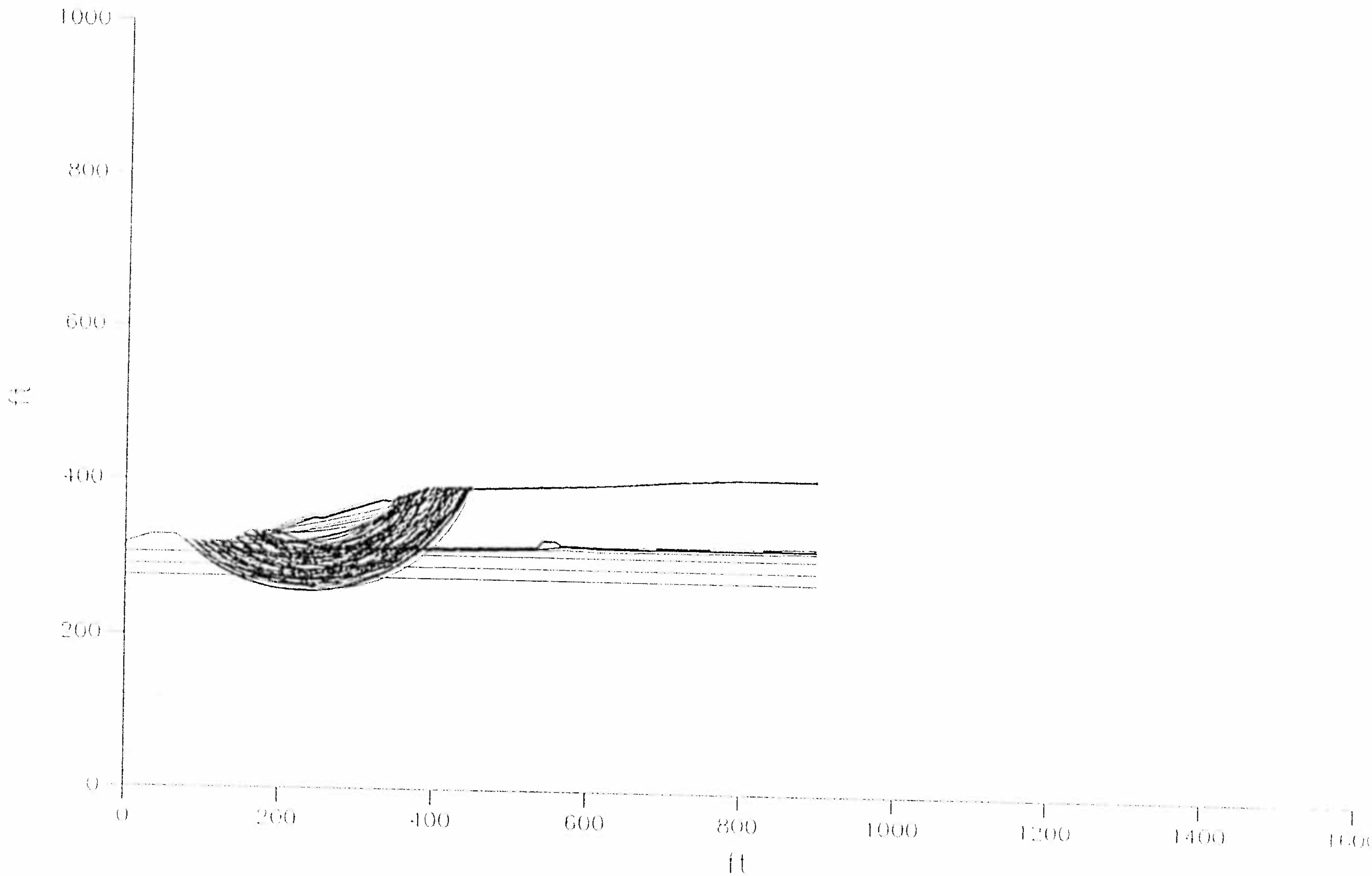
No.	Safety Factor	Center X (ft)	Center Y (ft)	Circle Radius (ft)
1	1.584	197.87	524.31	232.85

2	1.590	218.25	574.24	281.53
3	1.612	202.63	555.77	290.17
4	1.692	213.77	513.64	215.46
5	1.749	230.12	594.07	295.49
6	1.756	206.40	492.96	193.49
7	1.783	195.75	508.35	207.56
8	1.836	245.29	463.78	173.75
9	1.867	206.81	662.43	359.50
10	1.874	216.32	517.74	215.43

Bishop Circular Surface — Most Critical Surfaces



Bishop Circular Surfaces, Search for Critical Surfaces



SECTION 21+50
TOP OF VEGETATIVE COVER GRADES

SEISMIC SLIDING BLOCK FAILURE ANALYSIS

```
*****************************************************************
*****                       GeoSlope                        *****
*****                     Version 5.10                      *****
*****                                                       *****
*****         (c 1992 by GEOCOMP Corp, Concord, MA          *****
*****                  Licensed to RUST                     *****
*****************************************************************
```

Problem Title : "CWM Chemical Services, Inc. Model City RMU-1"
Description : "Vert Enhancement Section 21+50 East"
Remarks : "Seismic Sliding Block - Max El = 420 ft"

```
*****************************************************************
*****                      INPUT DATA                       *****
*****************************************************************
```

Profile Boundaries

Number of Boundaries : 96
Number of Top Boundaries : 19

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	317.00	33.41	328.00	7
2	33.41	328.00	63.49	328.00	7
3	63.49	328.00	77.19	320.00	7
4	77.19	320.00	134.34	320.00	7
5	134.34	320.00	160.98	334.19	10
6	160.98	334.19	172.98	333.83	10
7	172.98	333.83	175.49	331.32	10
8	175.49	331.32	176.99	332.82	10
9	176.99	332.82	179.61	334.00	2
10	179.61	334.00	245.28	355.88	11
11	245.28	355.88	257.19	354.69	11
12	257.19	354.69	333.32	379.87	11
13	333.32	379.87	345.22	378.67	11
14	345.22	378.67	391.03	393.94	11
15	391.03	393.94	633.00	404.00	11
16	633.00	404.00	714.00	410.00	11
17	714.00	410.00	756.00	412.00	11
18	756.00	412.00	800.00	414.00	11
19	800.00	414.00	900.00	414.00	11
20	179.61	334.00	188.61	334.00	2
21	188.61	334.00	245.28	352.88	2
22	245.28	352.88	257.19	351.69	2
23	257.19	351.69	333.32	376.87	2
24	333.32	376.87	345.22	375.67	2
25	345.22	375.67	391.03	390.94	2
26	391.03	390.94	633.00	401.00	2
27	633.00	401.00	714.00	407.00	2
28	714.00	407.00	756.00	409.00	2
29	756.00	409.00	800.00	411.00	2
30	800.00	411.00	900.00	411.00	2
31	188.61	334.00	195.61	334.00	2
32	195.61	334.00	198.61	333.00	2

33	198.61	333.00	245.23	350.88	1
34	245.23	350.88	257.19	349.69	1
35	257.19	349.69	333.32	374.87	1
36	333.32	374.87	345.22	373.67	1
37	345.22	373.67	391.03	388.94	1
38	391.03	388.94	633.00	399.00	1
39	633.00	399.00	714.00	405.00	1
40	714.00	405.00	756.00	407.00	1
41	756.00	407.00	800.00	409.00	1
42	800.00	409.00	900.00	409.00	1
43	176.99	332.82	179.61	333.00	10
44	179.61	333.00	190.11	333.00	10
45	190.11	333.00	195.61	333.00	9
46	195.61	333.00	198.61	333.00	3
47	198.61	333.00	249.00	314.56	3
48	249.00	314.56	535.00	320.28	3
49	535.00	320.28	542.00	328.00	3
50	542.00	328.00	558.00	328.00	3
51	558.00	328.00	565.00	323.00	3
52	565.00	323.00	619.00	322.00	3
53	619.00	322.00	900.00	322.45	3
54	195.61	333.00	249.00	313.56	9
55	249.00	313.56	255.00	312.56	9
56	255.00	312.56	535.00	318.28	9
57	535.00	318.28	542.00	326.00	9
58	542.00	326.00	558.00	326.00	9
59	558.00	326.00	565.00	321.00	9
60	565.00	321.00	619.00	320.00	9
61	619.00	320.00	900.00	321.45	9
62	190.11	332.50	195.61	332.50	2
63	195.61	332.50	249.00	313.06	2
64	249.00	313.06	255.00	312.06	2
65	255.00	312.06	535.00	317.78	2
66	535.00	317.78	542.00	325.50	2
67	542.00	325.50	558.00	325.50	2
68	558.00	325.50	565.00	320.50	2
69	565.00	320.50	619.00	319.50	2
70	619.00	319.50	900.00	320.95	2
71	255.00	312.06	259.50	311.00	9
72	259.50	311.00	533.50	316.78	3
73	533.50	316.78	566.50	320.00	3
74	566.50	320.00	619.00	318.00	3
75	619.00	318.00	900.00	319.45	3
76	259.50	311.00	262.50	310.00	9
77	262.50	310.00	532.50	315.78	9
78	532.50	315.78	567.50	319.00	9
79	567.50	319.00	619.00	317.00	9
80	619.00	317.00	900.00	318.45	9
81	259.50	310.50	262.50	309.50	2
82	262.50	309.50	532.50	315.28	2
83	532.50	315.28	567.50	318.50	2
84	567.50	318.50	619.00	316.50	2
85	619.00	316.50	900.00	317.95	2
86	190.11	332.40	195.61	329.50	10
87	195.61	329.50	222.99	320.00	10
88	134.34	320.00	221.99	320.00	7
89	221.99	320.00	259.50	307.50	7
90	259.50	307.50	262.50	306.50	7
91	262.50	306.50	567.50	315.50	7
92	567.50	315.50	619.00	313.50	7
93	619.00	313.50	900.00	314.95	7
94	0.00	305.00	900.00	305.00	6

95	0.00	290.00	900.00	290.00	7
96	0.00	275.00	900.00	275.00	8

Soil Parameters

Number of Soil Types : 11

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	111.0	111.0	0.0	24.0	0.00	0.0	0
2	130.0	130.0	1000.0	10.0	0.00	0.0	0
3	135.0	135.0	0.0	24.0	0.00	0.0	0
4	58.7	58.7	0.0	15.0	0.00	0.0	0
5	130.0	130.0	800.0	10.0	0.00	0.0	0
6	125.0	125.0	320.0	10.0	0.00	0.0	0
7	130.0	130.0	0.0	30.0	0.00	0.0	0
8	140.0	140.0	2000.0	40.0	0.00	0.0	0
9	58.7	58.7	0.0	10.5	0.00	0.0	0
10	130.0	130.0	2000.0	0.0	0.00	0.0	0
11	125.0	125.0	0.0	25.0	0.00	0.0	0

Earthquake Loading

Horizontal Acceleration Coefficient : 0.055
Vertical Acceleration Coefficient : 0.000

****
*****   TRIAL SURFACE GENERATION   *****
****

Data for Generating Rankine Block Surfaces

Number of Trial Surfaces : 500
Number of Boxes : 5
Segment Length, ft : 1.00 ft

Box No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Height (ft)
1	195.61	332.75	255.00	313.31	0.00
2	255.00	312.31	255.00	312.31	0.00
3	259.50	310.75	259.50	310.75	0.00
4	262.50	309.75	262.50	309.75	0.00
5	262.50	309.75	532.50	315.53	0.00

****
*****   RESULTS   *****
****

The factor of safety for the trial failure surface
defined by the coordinates listed below is MISLEADING.

Failure surface defined by 166 coordinate points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	208.87	343.75
2	209.43	343.39
3	210.27	342.85
4	211.11	342.32
5	211.96	341.78
6	212.66	341.19
7	213.42	340.55
8	214.19	339.91
9	214.96	339.26
10	215.13	339.15
11	215.97	338.60
12	216.81	338.06
13	217.65	337.51
14	218.49	336.97
15	219.33	336.42
16	220.17	335.88
17	221.01	335.33
18	221.84	334.79
19	222.68	334.24
20	223.52	333.70
21	224.36	333.16
22	225.20	332.61
23	226.04	332.07
24	226.88	331.52
25	227.71	330.98
26	228.55	330.43
27	229.39	329.89
28	230.23	329.34
29	231.07	328.80
30	231.91	328.25
31	232.75	327.71
32	233.59	327.16
33	234.42	326.62
34	235.26	326.07
35	236.10	325.53
36	236.94	324.99
37	237.78	324.44
38	238.62	323.90
39	239.46	323.35
40	240.29	322.81
41	241.13	322.26
42	241.97	321.72
43	242.81	321.17
44	243.65	320.63
45	244.49	320.08
46	245.33	319.54
47	246.17	318.99
48	247.00	318.45
49	247.84	317.91
50	248.68	317.36
51	249.52	316.82
52	250.36	316.27
53	251.20	315.73

54	252.34	315.13
55	252.37	314.64
56	253.16	314.45
57	254.00	313.91
58	254.54	313.36
59	255.00	312.31
60	259.50	310.75
61	262.50	309.75
62	380.74	312.28
63	380.95	312.54
64	381.50	313.37
65	381.63	313.58
66	382.27	314.34
67	382.54	314.67
68	382.97	315.17
69	383.51	316.01
70	384.05	316.85
71	384.32	317.27
72	384.87	318.11
73	385.41	318.94
74	385.96	319.78
75	386.50	320.62
76	387.05	321.46
77	387.59	322.30
78	388.14	323.14
79	388.68	323.98
80	389.23	324.81
81	389.77	325.65
82	390.32	326.49
83	390.86	327.33
84	391.40	328.17
85	391.95	329.01
86	392.49	329.85
87	393.04	330.69
88	393.58	331.52
89	394.13	332.36
90	394.67	333.20
91	395.22	334.04
92	395.76	334.88
93	396.31	335.72
94	396.85	336.56
95	397.40	337.39
96	397.94	338.23
97	398.49	339.07
98	399.03	339.91
99	399.57	340.75
100	400.12	341.59
101	400.66	342.43
102	401.21	343.27
103	401.75	344.10
104	402.30	344.94
105	402.84	345.78
106	403.39	346.62
107	403.93	347.46
108	404.48	348.30
109	405.02	349.14
110	405.57	349.97
111	406.11	350.81
112	406.65	351.65
113	407.20	352.49
114	407.74	353.33
115	408.29	354.17

116	408.83	355.01
117	409.38	355.85
118	409.92	356.68
119	410.47	357.52
120	411.01	358.36
121	411.56	359.20
122	412.10	360.04
123	412.65	360.88
124	413.19	361.72
125	413.73	362.55
126	414.28	363.39
127	414.82	364.23
128	415.37	365.07
129	415.91	365.91
130	416.46	366.75
131	417.00	367.59
132	417.55	368.43
133	418.09	369.26
134	418.64	370.10
135	419.18	370.94
136	419.73	371.78
137	420.27	372.62
138	420.82	373.46
139	421.36	374.30
140	421.90	375.13
141	422.45	375.97
142	422.99	376.81
143	423.54	377.65
144	424.08	378.49
145	424.63	379.33
146	425.17	380.17
147	425.72	381.01
148	426.26	381.84
149	426.81	382.68
150	427.35	383.52
151	427.90	384.36
152	428.44	385.20
153	428.98	386.04
154	429.53	386.88
155	430.07	387.71
156	430.62	388.55
157	431.16	389.39
158	431.71	390.23
159	431.98	390.64
160	432.62	391.41
161	433.26	392.17
162	433.71	392.71
163	434.25	393.56
164	434.79	394.40
165	435.33	395.24
166	435.68	395.80

Factor of safety for the preceding specified surface = 1.385

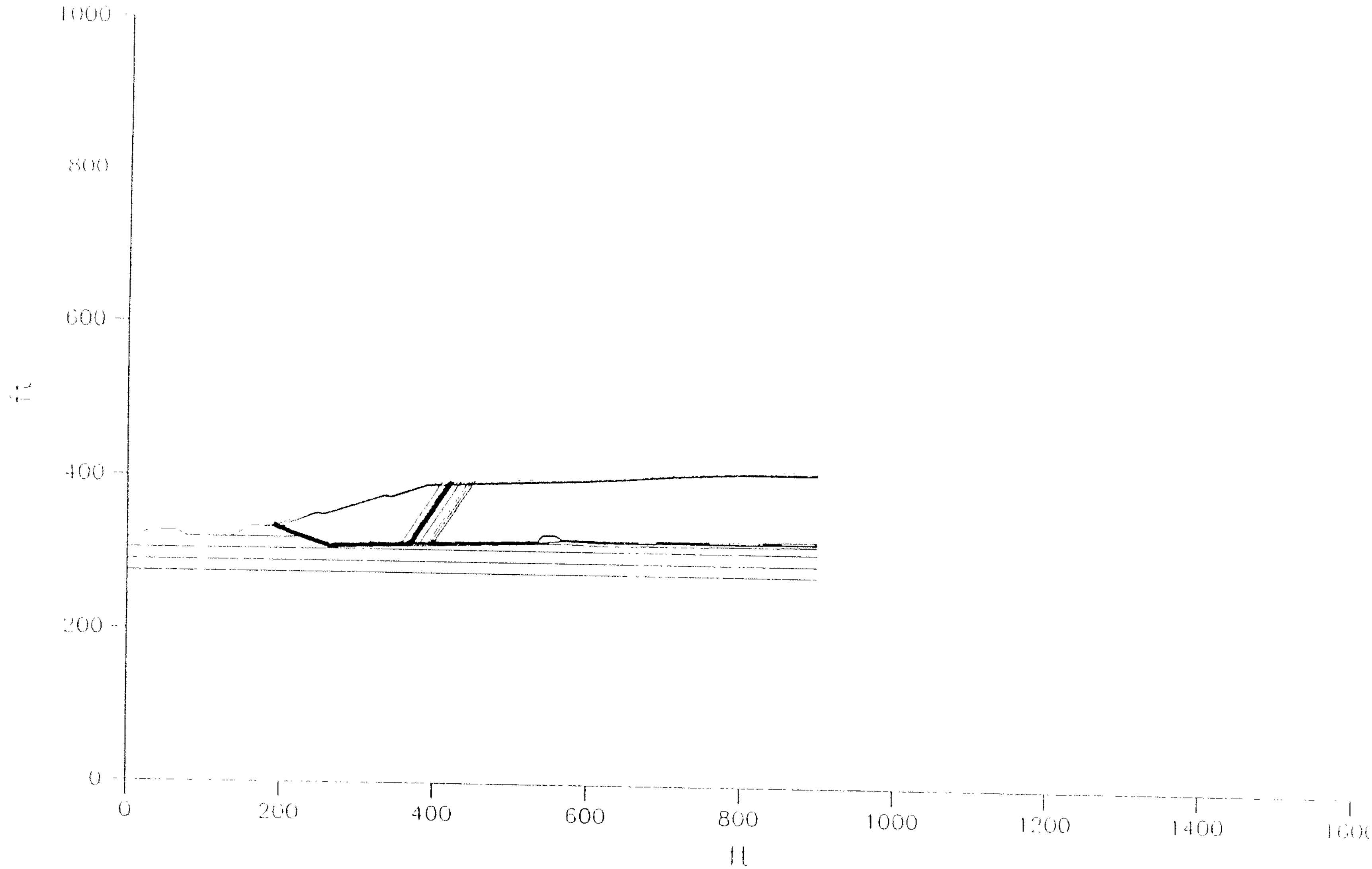
Critical Surfaces

Safety

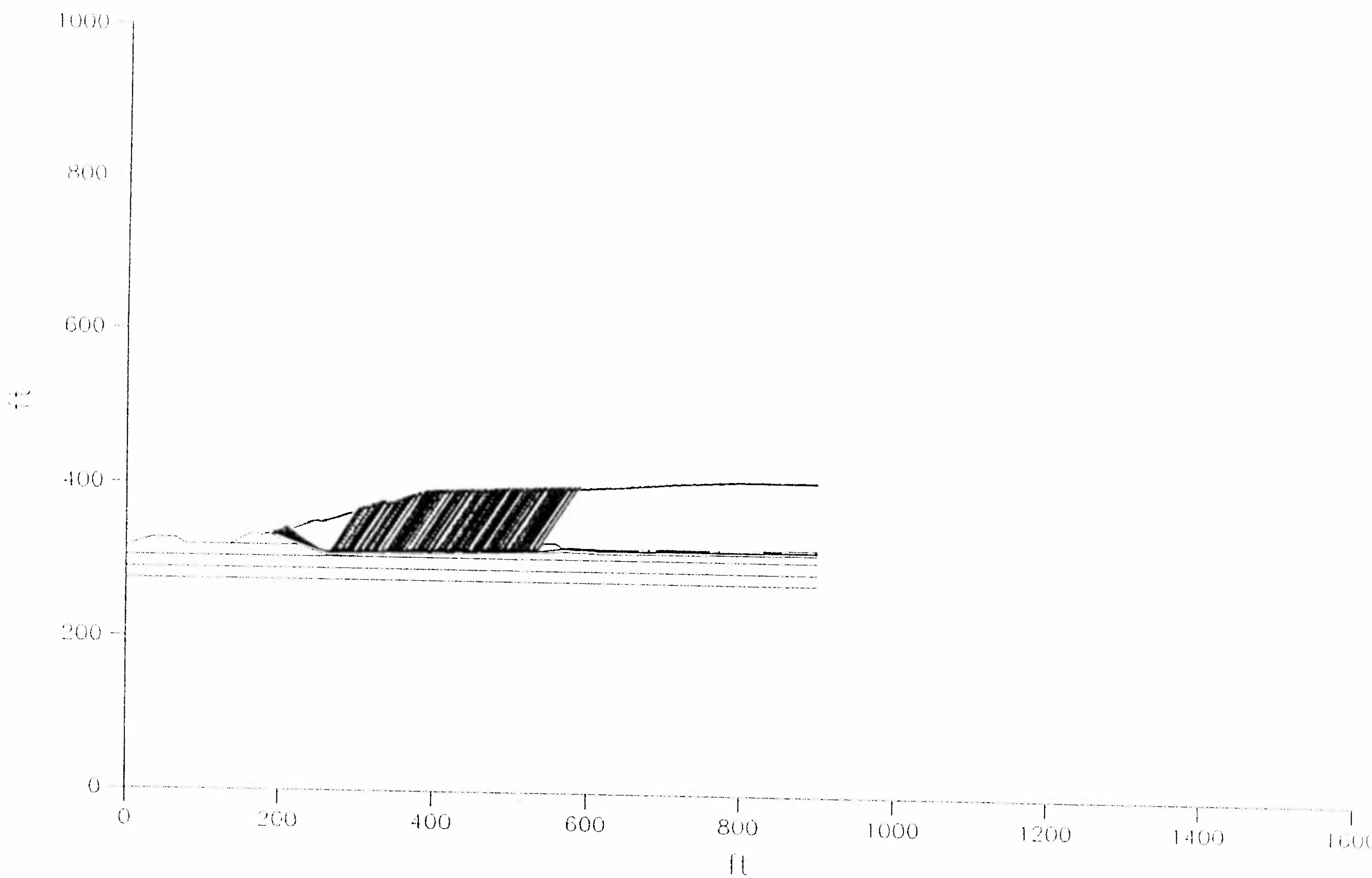
No.	Factor
1	1.292
2	1.306
3	1.310
4	1.312
5	1.316
6	1.317
7	1.319
8	1.324
9	1.325
10	1.326

Faultline Block Surface Most Critical Surfaces

Minimum Factor of Safety : 1.292



Rankine Block Surfaces - Search for Critical Surfaces



SECTION 21+50
TOP OF VEGETATIVE COVER GRADES

SEISMIC DEEP CIRCULAR FAILURE ANALYSIS

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*****                          GeoSlope                          *****
*****                        Version 5.10                        *****
*****                                                            *****
*****           (c)1992 by GEOCOMP Corp, Concord, MA             *****
*****                     Licensed to RUST                       *****
```

Problem Title : "CWM Chemical Services, Inc. Model City RMU-1"
Description : "Vert Enhancement Section 21+50 East"
Remarks : "Seismic Circular Analysis - Max El = 420 ft"

```
*****                        INPUT DATA                          *****
```

Profile Boundaries

Number of Boundaries : 96
Number of Top Boundaries : 19

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	317.00	33.41	328.00	7
2	33.41	328.00	63.49	328.00	7
3	63.49	328.00	77.19	320.00	7
4	77.19	320.00	134.34	320.00	7
5	134.34	320.00	160.98	334.19	10
6	160.98	334.19	172.98	333.83	10
7	172.98	333.83	175.49	331.32	10
8	175.49	331.32	176.99	332.82	10
9	176.99	332.82	179.61	334.00	2
10	179.61	334.00	245.28	355.88	11
11	245.28	355.88	257.19	354.69	11
12	257.19	354.69	333.32	379.87	11
13	333.32	379.87	345.22	378.67	11
14	345.22	378.67	391.03	393.94	11
15	391.03	393.94	633.00	404.00	11
16	633.00	404.00	714.00	410.00	11
17	714.00	410.00	756.00	412.00	11
18	756.00	412.00	800.00	414.00	11
19	800.00	414.00	900.00	414.00	11
20	179.61	334.00	188.61	334.00	2
21	188.61	334.00	245.28	352.88	2
22	245.28	352.88	257.19	351.69	2
23	257.19	351.69	333.32	376.87	2
24	333.32	376.87	345.22	375.67	2
25	345.22	375.67	391.03	390.94	2
26	391.03	390.94	633.00	401.00	2
27	633.00	401.00	714.00	407.00	2
28	714.00	407.00	756.00	409.00	2
29	756.00	409.00	800.00	411.00	2
30	800.00	411.00	900.00	411.00	2
31	188.61	334.00	195.61	334.00	2
32	195.61	334.00	198.61	333.00	2

33	198.61	333.00	245.28	350.88	1
34	245.28	350.88	257.19	349.69	1
35	257.19	349.69	333.32	374.87	1
36	333.32	374.87	345.22	373.67	1
37	345.22	373.67	391.03	388.94	1
38	391.03	388.94	633.00	399.00	1
39	633.00	399.00	714.00	405.00	1
40	714.00	405.00	756.00	407.00	1
41	756.00	407.00	800.00	409.00	1
42	800.00	409.00	900.00	409.00	1
43	176.99	332.82	179.61	333.00	10
44	179.61	333.00	190.11	333.00	10
45	190.11	333.00	195.61	333.00	9
46	195.61	333.00	198.61	333.00	3
47	198.61	333.00	249.00	314.56	3
48	249.00	314.56	535.00	320.28	3
49	535.00	320.28	542.00	328.00	3
50	542.00	328.00	558.00	328.00	3
51	558.00	328.00	565.00	323.00	3
52	565.00	323.00	619.00	322.00	3
53	619.00	322.00	900.00	322.45	3
54	195.61	333.00	249.00	313.56	9
55	249.00	313.56	255.00	312.56	9
56	255.00	312.56	535.00	318.28	9
57	535.00	318.28	542.00	326.00	9
58	542.00	326.00	558.00	326.00	9
59	558.00	326.00	565.00	321.00	9
60	565.00	321.00	619.00	320.00	9
61	619.00	320.00	900.00	321.45	9
62	190.11	332.50	195.61	332.50	2
63	195.61	332.50	249.00	313.06	2
64	249.00	313.06	255.00	312.06	2
65	255.00	312.06	535.00	317.78	2
66	535.00	317.78	542.00	325.50	2
67	542.00	325.50	558.00	325.50	2
68	558.00	325.50	565.00	320.50	2
69	565.00	320.50	619.00	319.50	2
70	619.00	319.50	900.00	320.95	2
71	255.00	312.06	259.50	311.00	9
72	259.50	311.00	533.50	316.78	3
73	533.50	316.78	566.50	320.00	3
74	566.50	320.00	619.00	318.00	3
75	619.00	318.00	900.00	319.45	3
76	259.50	311.00	262.50	310.00	9
77	262.50	310.00	532.50	315.78	9
78	532.50	315.78	567.50	319.00	9
79	567.50	319.00	619.00	317.00	9
80	619.00	317.00	900.00	318.45	9
81	259.50	310.50	262.50	309.50	2
82	262.50	309.50	532.50	315.28	2
83	532.50	315.28	567.50	318.50	2
84	567.50	318.50	619.00	316.50	2
85	619.00	316.50	900.00	317.95	2
86	190.11	332.40	195.61	329.50	10
87	195.61	329.50	222.99	320.00	10
88	134.34	320.00	221.99	320.00	7
89	221.99	320.00	259.50	307.50	7
90	259.50	307.50	262.50	306.50	7
91	262.50	306.50	567.50	315.50	7
92	567.50	315.50	619.00	313.50	7
93	619.00	313.50	900.00	314.95	7
94	0.00	305.00	900.00	305.00	6

95	0.00	290.00	900.00	290.00	7
96	0.00	275.00	900.00	275.00	8

Soil Parameters

Number of Soil Types : 11

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	111.0	111.0	0.0	24.0	0.00	0.0	0
2	130.0	130.0	1000.0	10.0	0.00	0.0	0
3	135.0	135.0	0.0	24.0	0.00	0.0	0
4	58.7	58.7	0.0	15.0	0.00	0.0	0
5	130.0	130.0	800.0	10.0	0.00	0.0	0
6	125.0	125.0	320.0	10.0	0.00	0.0	0
7	130.0	130.0	0.0	30.0	0.00	0.0	0
8	140.0	140.0	2000.0	40.0	0.00	0.0	0
9	58.7	58.7	0.0	10.5	0.00	0.0	0
10	130.0	130.0	2000.0	0.0	0.00	0.0	0
11	125.0	125.0	0.0	25.0	0.00	0.0	0

Earthquake Loading

Horizontal Acceleration Coefficient : 0.055
Vertical Acceleration Coefficient : 0.000

****
*****   TRIAL SURFACE GENERATION   *****
****

Data for Generating Circular Surfaces

Number of Initiation Points : 10
Number of Surfaces From Each Point : 10
Left Initiation Point : 75.00 ft
Right Initiation Point : 175.49 ft
Left Termination Point : 350.00 ft
Right Termination Point : 450.00 ft
Minimum Elevation : 0.00 ft
Segment Length : 5.00 ft
Positive Angle Limit : 0.00 deg
Negative Angle Limit : 0.00 deg

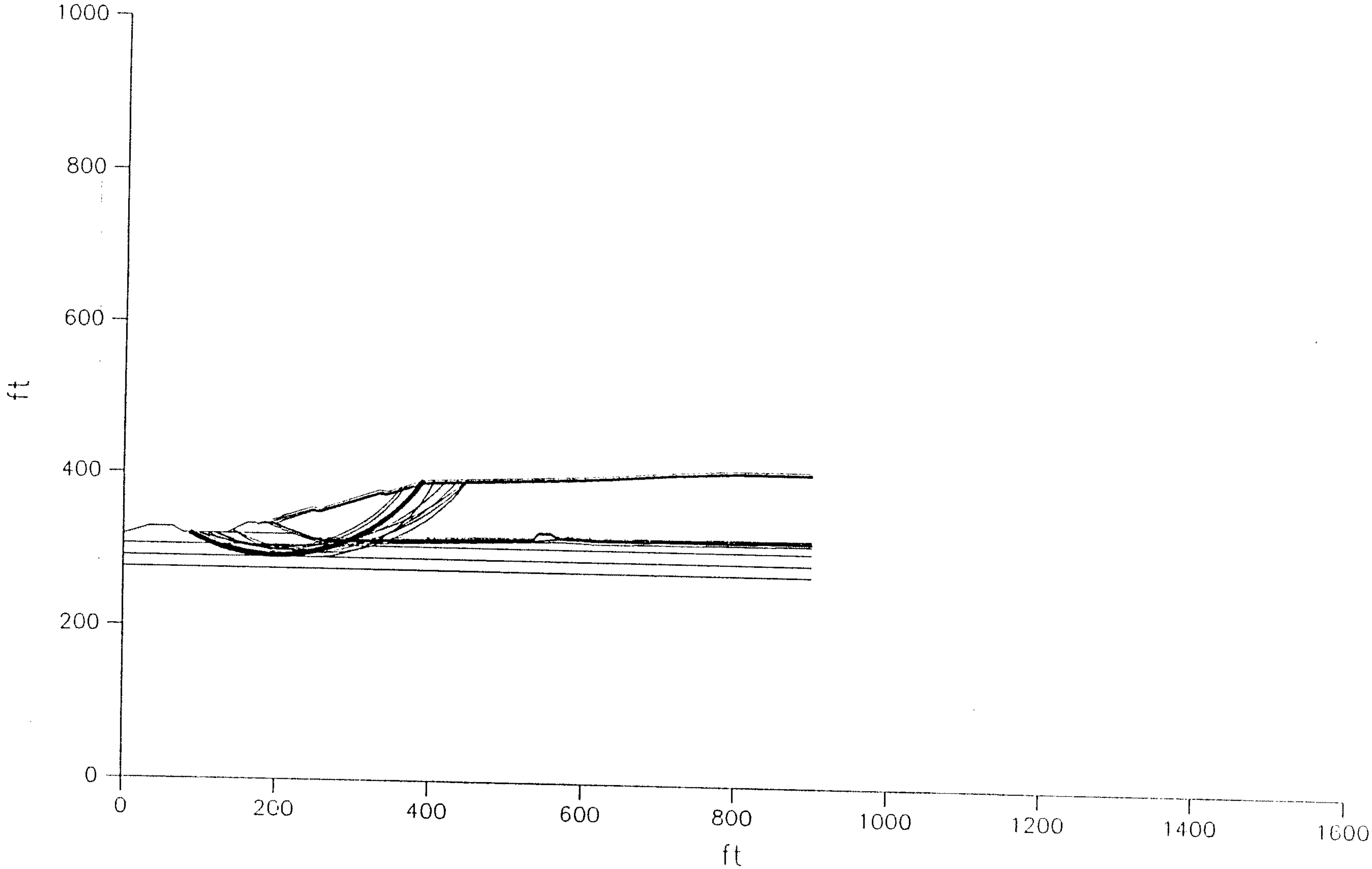
****
*****   RESULTS   *****
****

Critical Surfaces

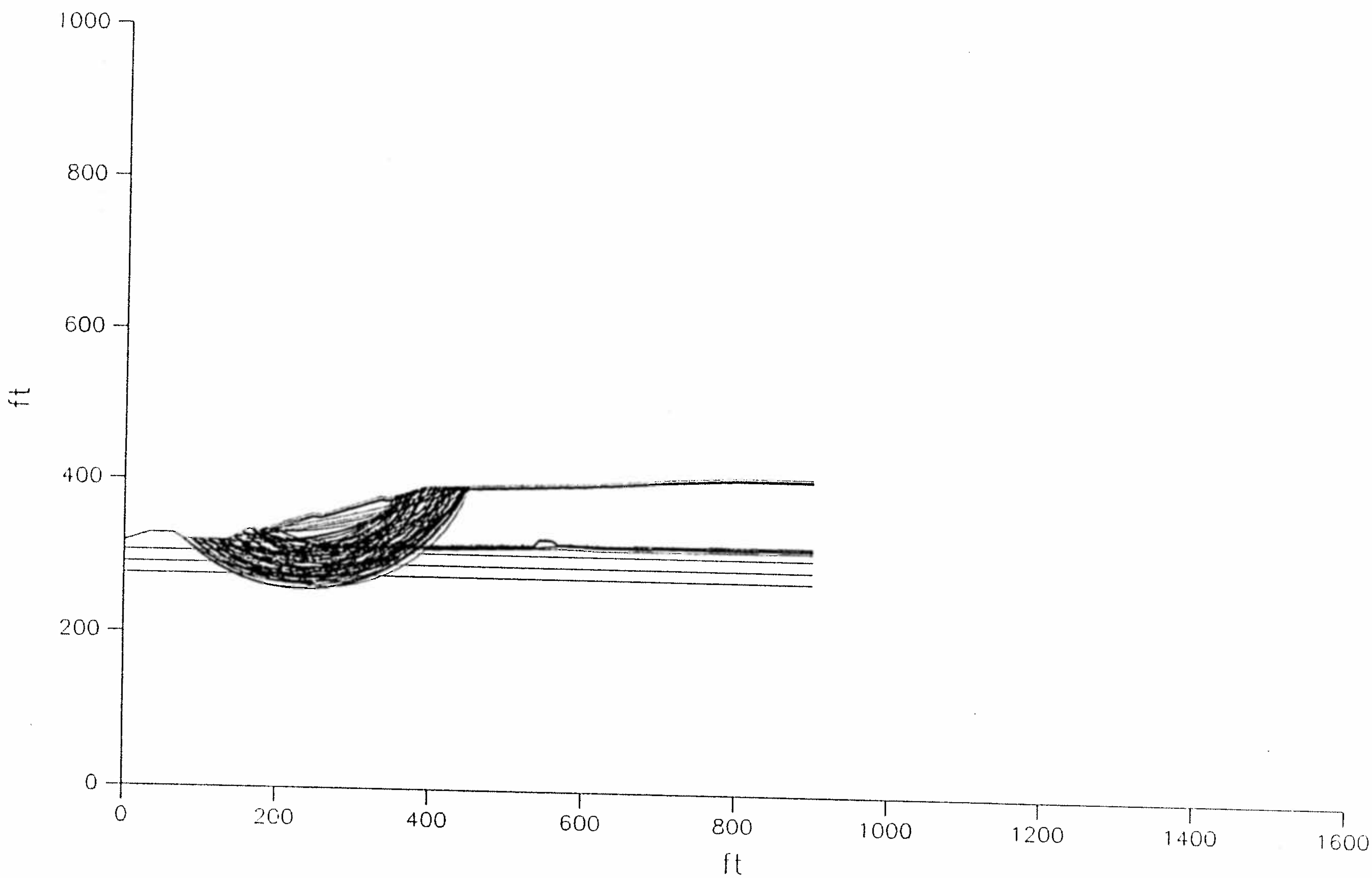
No.	Safety Factor	Center X (ft)	Center Y (ft)	Circle Radius (ft)
1	1.277	197.87	524.31	232.85
2	1.277	218.25	574.24	281.53
3	1.298	202.63	585.77	290.17
4	1.374	213.77	513.84	215.48
5	1.405	230.12	594.07	295.49
6	1.427	206.40	492.96	193.49
7	1.448	195.75	508.35	207.58
8	1.487	245.29	463.78	173.75
9	1.503	206.81	662.43	359.50
10	1.504	255.26	532.44	237.16

Bishop Circular Surface — Most Critical Surfaces

Minimum Factor of Safety : 1.277



Bishop Circular Surfaces - Search for Critical Surfaces



TASK: To verify the slope stability of the proposed RMU-1 Vertical Expansion Station 91+25 N through Cell 9/10 in response to the NYSDEC Comment 3(c) in the Notice of Incomplete Application letter dated January 19, 1999.

REFERENCES:

1. Report of Interface Friction Testing 80 mil Smooth HDPE and HDPE Geonet NSC Products for RMU-1, ASTM D-5321-92 Test Protocols, J & L Testing Company, February 1, 1995.
2. "Final Report - Interface Direct Shear Testing - WMNA Friction Testing Program," prepared by GeoSyntec Consultants, November 16, 1992.
3. "Operations Layer Grades," Drawing No. 10, prepared by SEC Donohue, February 1991, revised by Rust Environment & Infrastructure, June 1997.
4. "Typical Liner Sections Cells 1 through 6," Drawing No. 17, prepared by SEC Donohue, February 1991, revised by Rust Environment & Infrastructure, April 1997.
5. "Typical Liner Sections Cells 7 through 14," Drawing No. 17A, prepared Rust Environment & Infrastructure, November 1996, revised April 1997.
6. "Top of Vegetative Cover Grades," Drawing No. 12, prepared by SEC Donohue, February 1991, revised by Earth Tech, Inc., February 1999.
7. Geoslope Computer Program, Version 5.10, by GEOCOMP Corp., 1992.
8. 6 NYCRR Part 373 Permit Application for Residuals Management Unit 1, SEC Donohue, June 1992.
9. NYSDEC Letter dated March 13, 1995 accepting geomembrane/geonet interface friction angle of 10.5°.
10. "Final Cover Details," Drawing No. 12, Prepared by Rust Environment & Infrastructure, revised October 1997.
11. Earth Tech February 5, 1999 letter in response to NYSDEC letter dated January 19, 1999.

ASSUMPTIONS:

1. The primary and secondary geosynthetic layers will be modeled as 0.5' thick layers of soil with an internal friction angle equal to the lowest friction angle between any two liner system components.

2. The critical failure surface for the sliding block analysis will be within the geosynthetic secondary liner system. The critical interface is 15° between the textured 80 mil HDPE and nonwoven geotextile.

3. The critical failure surface for the circular analysis will be through the underlying glaciolacustrene clay and/or sand/silt layers or through the waste mass.

CALCULATIONS:

1. A slope stability cross section is cut through Station 91+25N (Cell 9/10) using the final vertical enhancement top of vegetative cover grades shown on Drawing No. 12 (see Reference 6).

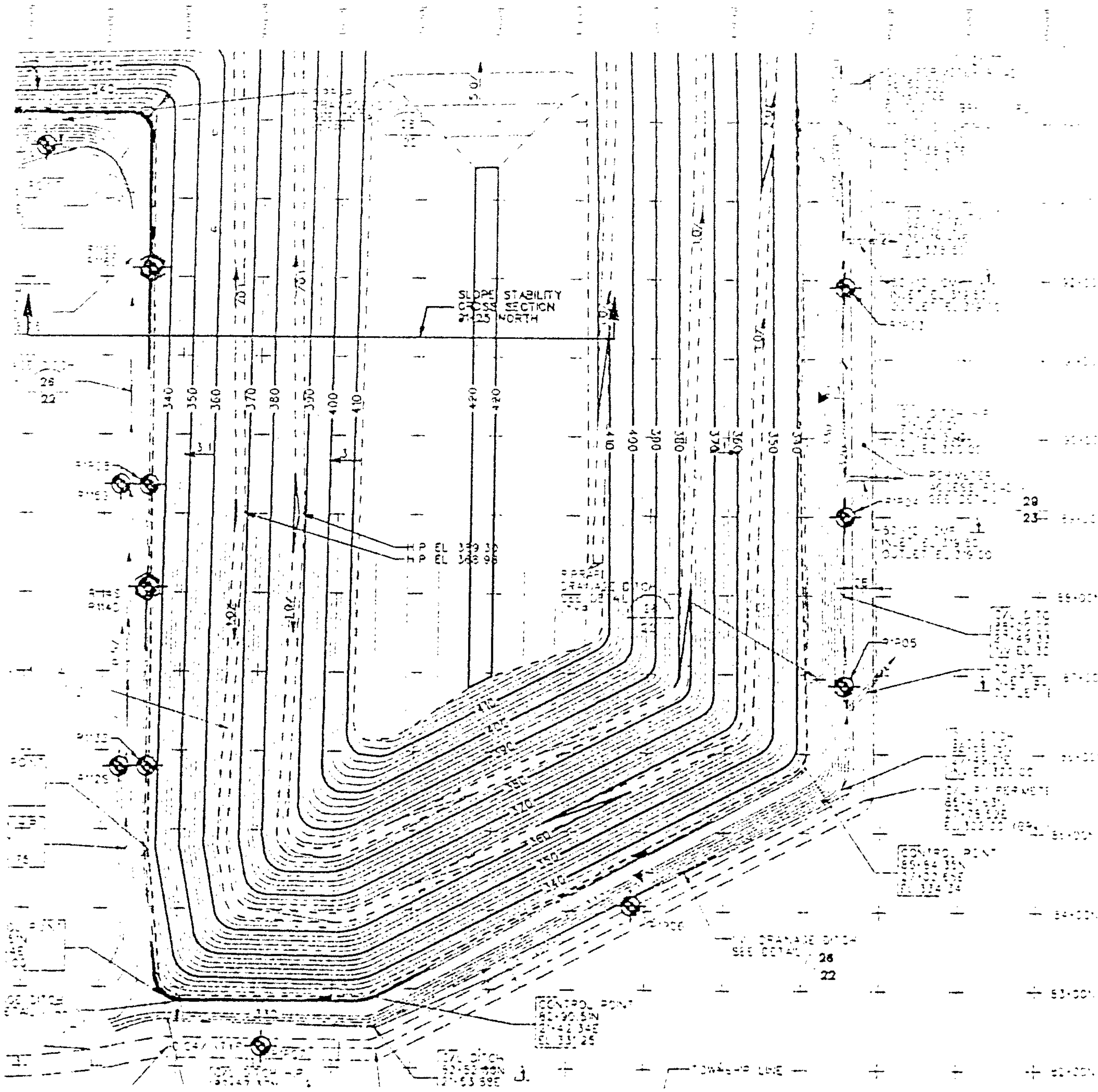
2. Input parameters:

Soil No.	Soil Type	Unit Wt., pcf	Cohesion, psf	Φ, degrees	Reference No.
1	Waste	111	0	24	8
2	Compacted Clay	130	1000	10	8
3	Granular/ Operations Layer	135	0	24	8
4	Textured Liner System	58.7	0	15	2
5	Upper Fill	130	800	10	8
6	Glacio Lacustrine Clay	125	320	10	8
7	Glacio/Lac. Sand/Silt	130	0	30	8
8	Bedrock	140	2000	40	8
9	Smooth Liner	58.7	0	10.5	1,9
10	Structural Fill	130	2000	0	8
11	Vegetative Cover	125	0	25	8

3. Seismic Coefficient: k = 0.055g(References 8 and 11)

4. Results: (See attached GEOSLOPE output)

Section	Static Sliding Block F.S.	Seismic Sliding Block F.S.	Static Deep Circular F.S.	Seismic Deep Circular F.S.
91+25 N	1.521	1.234	1.577	1.273



LEGEND

—— 320 ——	EXISTING GRADE
	PROPOSED GRADE
	LIMIT OF SUBBASE
3:1	SLOPE INDICATOR
	DRAINAGE DITCH
	ACCESS ROAD
	TOP OF BERM
	APPROXIMATE PROPERTY LINE
	TOWNSHIP LINE
	GROUNDWATER MONITORING WELL
	GROUNDWATER MONITORING WELL NEST
	SOIL BORING
	PERMANENT CONTROL MONUMENT
	CULVERT
	VAULT
	SLOPE STABILITY CROSS SECTION

NOTES

1. TOPOGRAPHIC BASE MAP WAS PROVIDED BY AERO-METRIC ENGINEERING, SHEBOYGAN, WISCONSIN, DATED DECEMBER 1988. GROUND CONTROL BY FRANK T. TRIP AND ASSOC., P.C.
2. COORDINATES LABELED ON THESE PLANS ARE ACCORDING TO RMU-1 SITE GRID. REFER TO DRAWING NO. 2 FOR PLANT COORDINATES.
3. PROPOSED GRADES INDICATED ARE TOP OF VEGETATIVE COVER SOIL.

EARTH TECH

CWM CHEMICAL SERVICES, INC.

RESIDUAL MANAGEMENT UNIT 1

SLOPE STABILITY CROSS SECTION

STATION- 91+25 NORTH

FIGURE 2

FEB 1999

SECTION 91+25
TOP OF VEGETATIVE COVER GRADES

STATIC SLIDING BLOCK FAILURE ANALYSIS

```
***********************************************************************
*****                         GeoSlope                           *****
*****                       Version 5.10                         *****
*****                                                            *****
*****          (c)1992 by GEOCOMP Corp, Concord, MA              *****
*****                    Licensed to RUST                        *****
***********************************************************************
```

Problem Title : "CWM Chemical Services, Inc. Model City RMU-1"
Description : "Vert Enhancement Section 91+25 North"
Remarks : "Static Sliding Block - Max El = 420 ft"

```
***********************************************************************
*****                        INPUT DATA                          *****
***********************************************************************
```

Profile Boundaries

Number of Boundaries : 69
Number of Top Boundaries : 17

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	310.00	54.00	312.00	10
2	54.00	312.00	105.00	333.55	10
3	105.00	333.55	153.50	332.00	10
4	153.50	332.00	156.00	329.50	10
5	156.00	329.50	157.50	331.00	10
6	157.50	331.00	158.50	332.00	2
7	158.50	332.00	265.34	367.91	11
8	265.34	367.91	277.23	366.72	11
9	277.23	366.72	341.76	388.23	11
10	341.76	388.23	353.65	387.05	11
11	353.65	387.05	431.76	413.00	11
12	431.76	413.00	570.00	420.00	11
13	570.00	420.00	600.00	420.00	11
14	600.00	420.00	718.00	414.10	11
15	718.00	414.10	735.13	408.96	11
16	735.13	408.96	743.77	410.14	11
17	743.77	410.14	750.00	408.00	11
18	158.50	332.00	167.50	332.00	2
19	167.50	332.00	265.34	364.91	2
20	265.34	364.91	277.23	363.72	2
21	277.23	363.72	341.76	385.23	2
22	341.76	385.23	353.65	384.05	2
23	353.65	384.05	431.76	410.00	2
24	431.76	410.00	570.00	417.00	2
25	570.00	417.00	600.00	417.00	2
26	600.00	417.00	718.00	411.10	2
27	718.00	411.10	735.13	405.96	2
28	735.13	405.96	743.77	407.14	2
29	743.77	407.14	750.00	405.00	2
30	167.50	332.00	174.50	332.00	2
31	174.50	332.00	265.34	362.91	1
32	265.34	362.91	277.23	361.72	1

33	277.23	361.72	341.76	383.23	1
34	341.76	383.23	353.65	382.05	1
35	353.65	382.05	431.76	408.00	1
36	431.76	408.00	570.00	415.00	1
37	570.00	415.00	600.00	415.00	1
38	600.00	415.00	718.00	409.10	1
39	718.00	409.10	735.13	403.96	1
40	735.13	403.96	743.77	405.14	1
41	743.77	405.14	750.00	403.00	1
42	174.50	332.00	214.65	318.30	3
43	214.65	318.30	750.00	325.26	3
44	157.50	331.00	166.50	331.00	2
45	166.50	331.00	174.50	331.00	4
46	174.50	331.00	214.65	317.30	4
47	214.65	317.30	217.65	316.30	4
48	217.65	316.30	750.00	323.26	4
49	218.50	316.06	750.00	322.76	2
50	217.65	316.30	222.15	314.80	4
51	222.15	314.80	750.00	321.26	3
52	222.15	314.80	225.15	313.80	4
53	225.15	313.80	750.00	320.26	4
54	166.50	330.50	174.50	330.50	2
55	174.50	330.50	214.65	316.80	2
56	214.65	316.80	217.65	315.80	2
57	217.65	315.80	222.15	314.30	2
58	222.15	314.30	225.15	313.30	2
59	225.15	313.30	750.00	320.01	2
60	166.50	324.50	174.50	324.50	5
61	174.50	324.50	184.75	324.50	5
62	184.75	324.50	214.65	313.80	5
63	214.65	313.80	217.65	312.80	5
64	217.65	312.80	222.15	311.30	5
65	222.15	311.30	225.15	310.30	5
66	225.15	310.30	750.00	317.01	5
67	0.00	305.00	750.00	305.00	6
68	0.00	290.00	750.00	290.00	7
69	0.00	275.00	750.00	275.00	8

Soil Parameters

Number of Soil Types : 11

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	111.0	111.0	0.0	24.0	0.00	0.0	0
2	130.0	130.0	1000.0	10.0	0.00	0.0	0
3	135.0	135.0	0.0	24.0	0.00	0.0	0
4	58.7	58.7	0.0	15.0	0.00	0.0	0
5	130.0	130.0	800.0	10.0	0.00	0.0	0
6	125.0	125.0	320.0	10.0	0.00	0.0	0
7	130.0	130.0	0.0	30.0	0.00	0.0	0
8	140.0	140.0	2000.0	40.0	0.00	0.0	0
9	58.7	58.7	0.0	10.5	0.00	0.0	0
10	130.0	130.0	2000.0	0.0	0.00	0.0	0
11	125.0	125.0	0.0	25.0	0.00	0.0	0

```
*************************************************************************
*****                  TRIAL SURFACE GENERATION                    *****
*************************************************************************
```

Data for Generating Rankine Block Surfaces

```
Number of Trial Surfaces : 500
        Number of Boxes : 6
    Segment Length, ft : 1.00 ft
```

Box No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Height (ft)
1	174.50	330.75	214.65	317.05	0.00
2	214.65	317.05	214.65	317.05	0.00
3	217.65	316.05	217.65	316.05	0.00
4	222.15	314.55	222.15	314.55	0.00
5	225.15	313.55	225.15	313.55	0.00
6	225.15	313.55	650.00	318.78	0.00

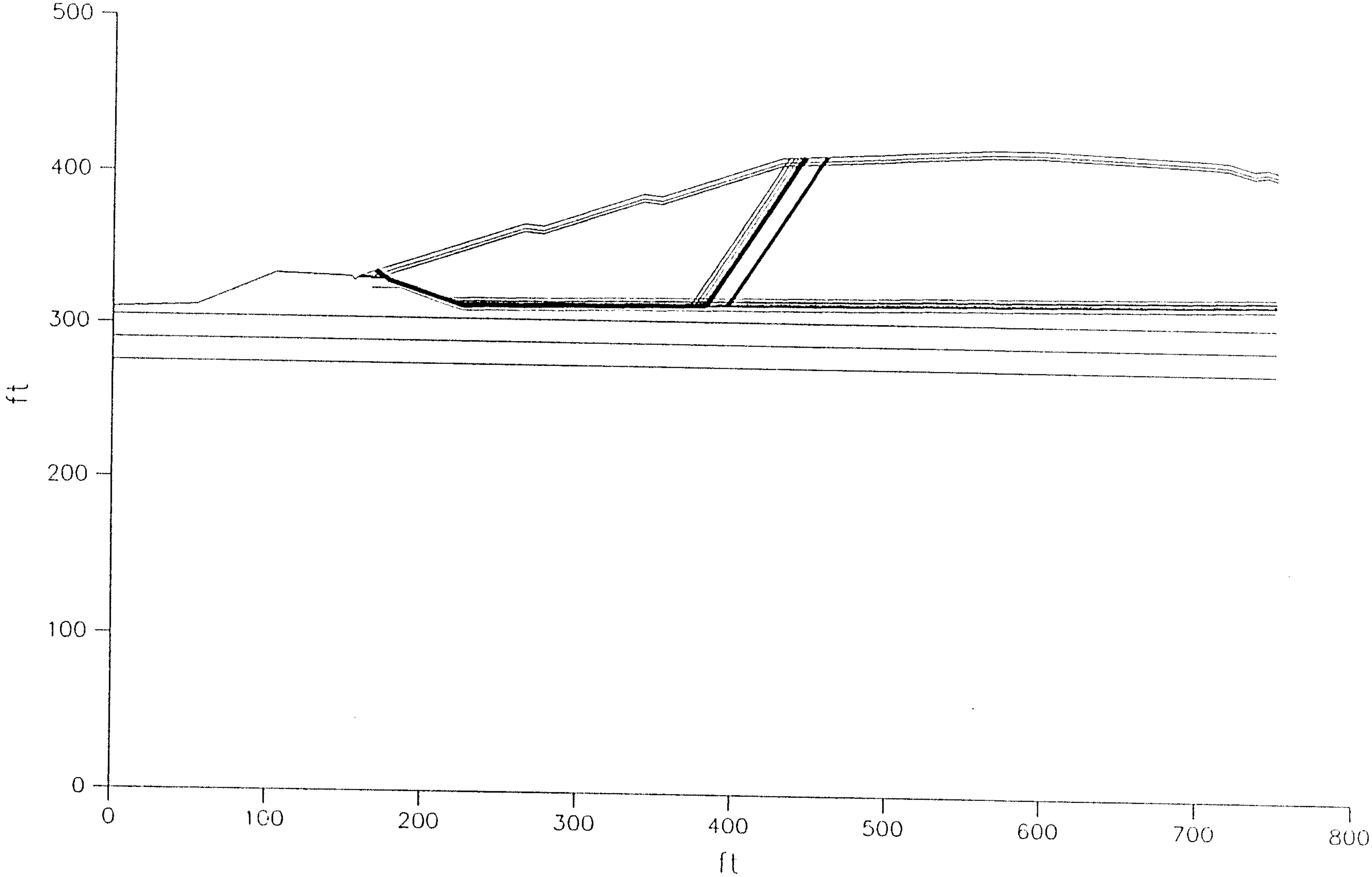
```
*************************************************************************
*****                          RESULTS                             *****
*************************************************************************
```

Critical Surfaces

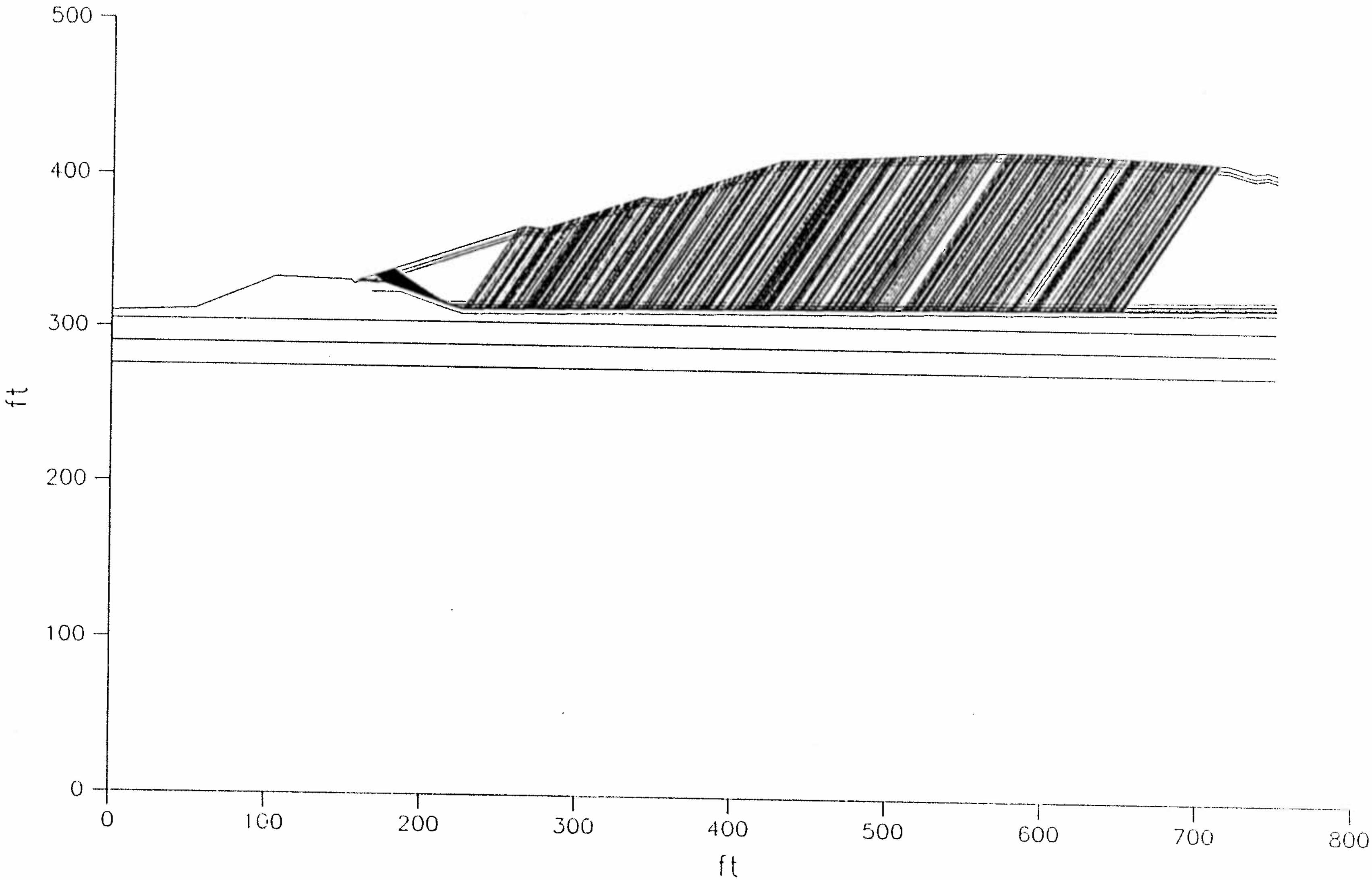
No.	Safety Factor
1	1.521
2	1.523
3	1.525
4	1.525
5	1.529
6	1.529
7	1.530
8	1.530
9	1.531
10	1.534

Rankine Block Surfaces - Most Critical Surfaces

Minimum Factor of Safety : 1.521



Rankine Block Surfaces – Search for Critical Surfaces



SECTION 91+25

TOP OF VEGETATIVE COVER GRADES

STATIC DEEP CIRCULAR FAILURE ANALYSIS

```
**************************************************************************
*****                          GeoSlope                              *****
*****                        Version 5.10                            *****
*****                                                                *****
*****           (c)1992 by GEOCOMP Corp, Concord, MA                 *****
*****                      Licensed to RUST                          *****
**************************************************************************
```

Problem Title : "CWM Chemical Services, Inc. Model City RMU-1"
Description : "Vert Enhancement Section 91+25 North"
Remarks : "Static Circular Analysis - Max El = 420 ft"

```
**************************************************************************
*****                         INPUT DATA                             *****
**************************************************************************
```

Profile Boundaries

Number of Boundaries : 69
Number of Top Boundaries : 17

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	310.00	54.00	312.00	10
2	54.00	312.00	105.00	333.55	10
3	105.00	333.55	153.50	332.00	10
4	153.50	332.00	156.00	329.50	10
5	156.00	329.50	157.50	331.00	10
6	157.50	331.00	158.50	332.00	2
7	158.50	332.00	265.34	367.91	11
8	265.34	367.91	277.23	366.72	11
9	277.23	366.72	341.76	388.23	11
10	341.76	388.23	353.65	387.05	11
11	353.65	387.05	431.76	413.00	11
12	431.76	413.00	570.00	420.00	11
13	570.00	420.00	600.00	420.00	11
14	600.00	420.00	718.00	414.10	11
15	718.00	414.10	735.13	408.96	11
16	735.13	408.96	743.77	410.14	11
17	743.77	410.14	750.00	408.00	11
18	158.50	332.00	167.50	332.00	2
19	167.50	332.00	265.34	364.91	2
20	265.34	364.91	277.23	363.72	2
21	277.23	363.72	341.76	385.23	2
22	341.76	385.23	353.65	384.05	2
23	353.65	384.05	431.76	410.00	2
24	431.76	410.00	570.00	417.00	2
25	570.00	417.00	600.00	417.00	2
26	600.00	417.00	718.00	411.10	2
27	718.00	411.10	735.13	405.96	2
28	735.13	405.96	743.77	407.14	2
29	743.77	407.14	750.00	405.00	2
30	167.50	332.00	174.50	332.00	2
31	174.50	332.00	265.34	362.91	1
32	265.34	362.91	277.23	361.72	1

33	277.23	361.72	341.76	383.23	1
34	341.76	383.23	353.65	382.05	1
35	353.65	382.05	431.76	408.00	1
36	431.76	408.00	570.00	415.00	1
37	570.00	415.00	600.00	415.00	1
38	600.00	415.00	718.00	409.10	1
39	718.00	409.10	735.13	403.96	1
40	735.13	403.96	743.77	405.14	1
41	743.77	405.14	750.00	403.00	1
42	174.50	332.00	214.65	318.30	3
43	214.65	318.30	750.00	325.26	3
44	157.50	331.00	166.50	331.00	2
45	166.50	331.00	174.50	331.00	4
46	174.50	331.00	214.65	317.30	4
47	214.65	317.30	217.65	316.30	4
48	217.65	316.30	750.00	323.26	4
49	218.50	316.06	750.00	322.76	2
50	217.65	316.30	222.15	314.80	4
51	222.15	314.80	750.00	321.26	3
52	222.15	314.80	225.15	313.80	4
53	225.15	313.80	750.00	320.26	4
54	166.50	330.50	174.50	330.50	2
55	174.50	330.50	214.65	316.80	2
56	214.65	316.80	217.65	315.80	2
57	217.65	315.80	222.15	314.30	2
58	222.15	314.30	225.15	313.30	2
59	225.15	313.30	750.00	320.01	2
60	166.50	324.50	174.50	324.50	5
61	174.50	324.50	184.75	324.50	5
62	184.75	324.50	214.65	313.80	5
63	214.65	313.80	217.65	312.80	5
64	217.65	312.80	222.15	311.30	5
65	222.15	311.30	225.15	310.30	5
66	225.15	310.30	750.00	317.01	5
67	0.00	305.00	750.00	305.00	6
68	0.00	290.00	750.00	290.00	7
69	0.00	275.00	750.00	275.00	8

Soil Parameters

Number of Soil Types : 11

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	111.0	111.0	0.0	24.0	0.00	0.0	0
2	130.0	130.0	1000.0	10.0	0.00	0.0	0
3	135.0	135.0	0.0	24.0	0.00	0.0	0
4	58.7	58.7	0.0	15.0	0.00	0.0	0
5	130.0	130.0	800.0	10.0	0.00	0.0	0
6	125.0	125.0	320.0	10.0	0.00	0.0	0
7	130.0	130.0	0.0	30.0	0.00	0.0	0
8	140.0	140.0	2000.0	40.0	0.00	0.0	0
9	58.7	58.7	0.0	10.5	0.00	0.0	0
10	130.0	130.0	2000.0	0.0	0.00	0.0	0
11	125.0	125.0	0.0	25.0	0.00	0.0	0

```
*****************************************************************************
*****                    TRIAL SURFACE GENERATION                      *****
*****************************************************************************
```

Data for Generating Circular Surfaces

```
          Number of Initiation Points : 25
   Number of Surfaces From Each Point : 25
               Left Initiation Point : 25.00 ft
              Right Initiation Point : 156.00 ft
              Left Termination Point : 300.00 ft
             Right Termination Point : 600.00 ft
                   Minimum Elevation : 0.00 ft
                      Segment Length : 5.00 ft
                Positive Angle Limit : 0.00 deg
                Negative Angle Limit : 0.00 deg
```

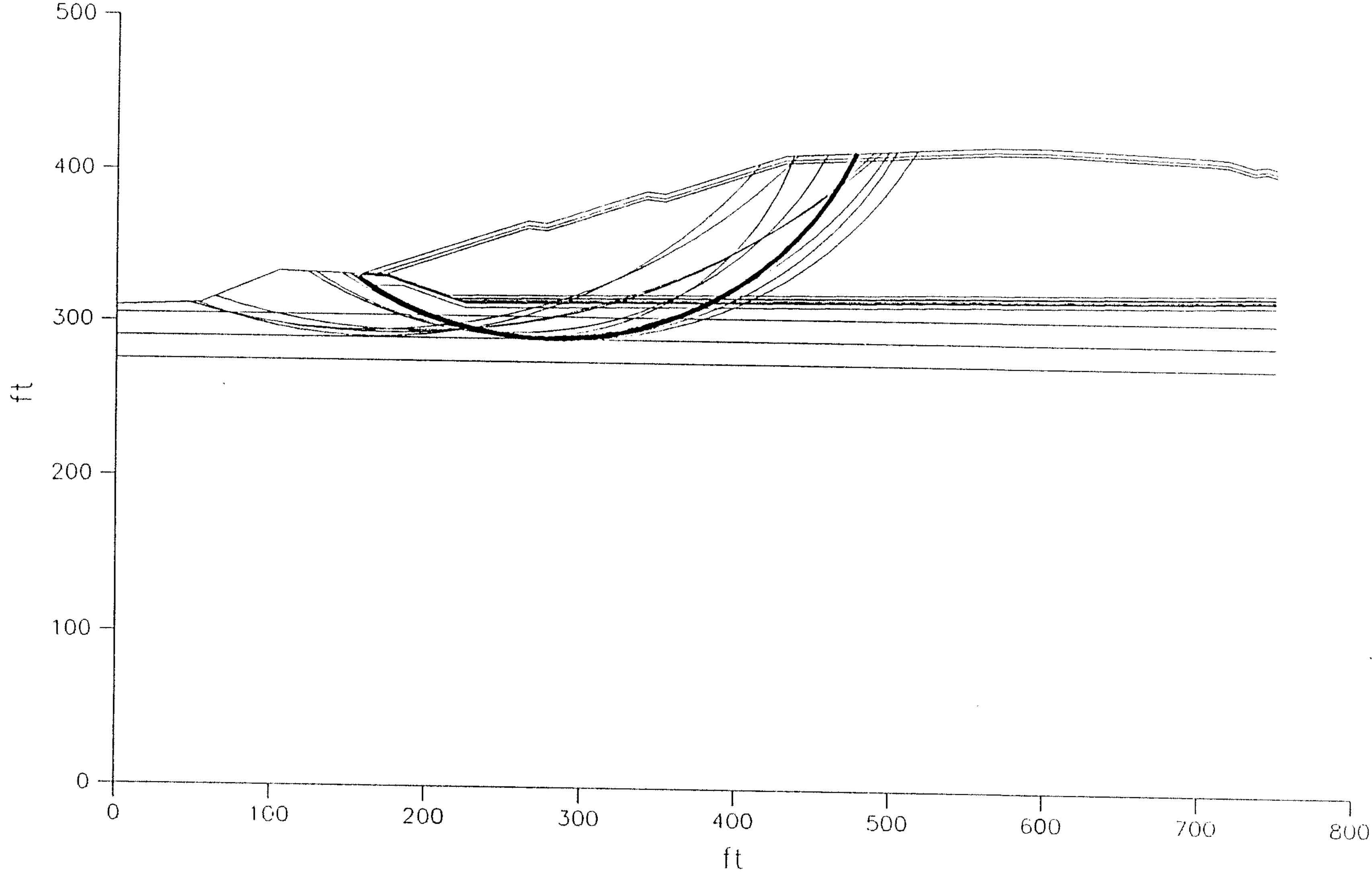
```
*****************************************************************************
*****                           RESULTS                                *****
*****************************************************************************
```

Critical Surfaces

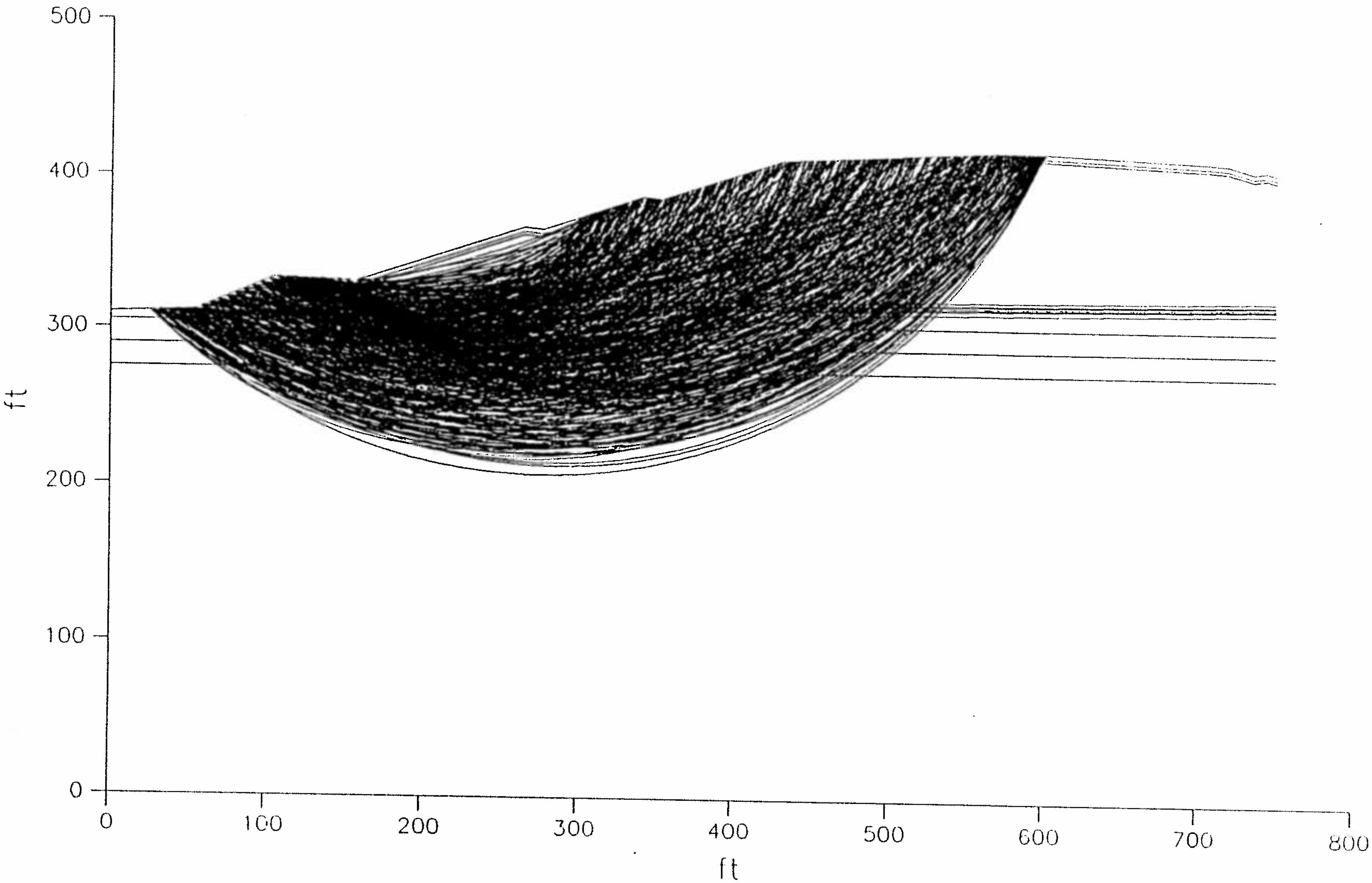
No.	Safety Factor	Center X (ft)	Center Y (ft)	Circle Radius (ft)
1	1.577	280.62	507.44	217.24
2	1.592	176.75	763.29	469.87
3	1.599	167.11	612.68	321.92
4	1.613	284.58	543.21	252.90
5	1.618	292.40	551.46	261.24
6	1.627	159.57	685.76	390.64
7	1.647	193.77	715.68	420.57
8	1.648	268.43	565.31	273.98
9	1.651	265.09	473.12	181.69
10	1.657	256.26	524.70	230.43

Bishop Circular Surface — Most Critical Surfaces

Minimum Factor of Safety : 1.577



Bishop Circular Surfaces -- Search for Critical Surfaces



SECTION 91+25
TOP OF VEGETATIVE COVER GRADES

SEISMIC SLIDING BLOCK FAILURE ANALYSIS

```
*************************************************************************
*****                          GeoSlope                             *****
*****                        Version 5.10                           *****
*****                                                               *****
*****           (c)1992 by GEOCOMP Corp, Concord, MA                *****
*****                     Licensed to RUST                          *****
*************************************************************************
```

Problem Title : "CWM Chemical Services, Inc. Model City RMU-1"
Description : "Vert Enhancement Section 91+25 North"
Remarks : "Seismic Sliding Block - Max El = 420 ft"

```
*************************************************************************
*****                         INPUT DATA                            *****
*************************************************************************
```

Profile Boundaries

Number of Boundaries : 69
Number of Top Boundaries : 17

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	310.00	54.00	312.00	10
2	54.00	312.00	105.00	333.55	10
3	105.00	333.55	153.50	332.00	10
4	153.50	332.00	156.00	329.50	10
5	156.00	329.50	157.50	331.00	10
6	157.50	331.00	158.50	332.00	2
7	158.50	332.00	265.34	367.91	11
8	265.34	367.91	277.23	366.72	11
9	277.23	366.72	341.76	388.23	11
10	341.76	388.23	353.65	387.05	11
11	353.65	387.05	431.76	413.00	11
12	431.76	413.00	570.00	420.00	11
13	570.00	420.00	600.00	420.00	11
14	600.00	420.00	718.00	414.10	11
15	718.00	414.10	735.13	408.96	11
16	735.13	408.96	743.77	410.14	11
17	743.77	410.14	750.00	408.00	11
18	158.50	332.00	167.50	332.00	2
19	167.50	332.00	265.34	364.91	2
20	265.34	364.91	277.23	363.72	2
21	277.23	363.72	341.76	385.23	2
22	341.76	385.23	353.65	384.05	2
23	353.65	384.05	431.76	410.00	2
24	431.76	410.00	570.00	417.00	2
25	570.00	417.00	600.00	417.00	2
26	600.00	417.00	718.00	411.10	2
27	718.00	411.10	735.13	405.96	2
28	735.13	405.96	743.77	407.14	2
29	743.77	407.14	750.00	405.00	2
30	167.50	332.00	174.50	332.00	2
31	174.50	332.00	265.34	362.91	1
32	265.34	362.91	277.23	361.72	1

33	277.23	361.72	341.76	383.23	1
34	341.76	383.23	353.65	382.05	1
35	353.65	382.05	431.76	408.00	1
36	431.76	408.00	570.00	415.00	1
37	570.00	415.00	600.00	415.00	1
38	600.00	415.00	718.00	409.10	1
39	718.00	409.10	735.13	403.96	1
40	735.13	403.96	743.77	405.14	1
41	743.77	405.14	750.00	403.00	1
42	174.50	332.00	214.65	318.30	3
43	214.65	318.30	750.00	325.26	3
44	157.50	331.00	166.50	331.00	2
45	166.50	331.00	174.50	331.00	4
46	174.50	331.00	214.65	317.30	4
47	214.65	317.30	217.65	316.30	4
48	217.65	316.30	750.00	323.26	4
49	218.50	316.06	750.00	322.76	2
50	217.65	316.30	222.15	314.80	4
51	222.15	314.80	750.00	321.26	3
52	222.15	314.80	225.15	313.80	4
53	225.15	313.80	750.00	320.26	4
54	166.50	330.50	174.50	330.50	2
55	174.50	330.50	214.65	316.80	2
56	214.65	316.80	217.65	315.80	2
57	217.65	315.80	222.15	314.30	2
58	222.15	314.30	225.15	313.30	2
59	225.15	313.30	750.00	320.01	2
60	166.50	324.50	174.50	324.50	5
61	174.50	324.50	184.75	324.50	5
62	184.75	324.50	214.65	313.80	5
63	214.65	313.80	217.65	312.80	5
64	217.65	312.80	222.15	311.30	5
65	222.15	311.30	225.15	310.30	5
66	225.15	310.30	750.00	317.01	5
67	0.00	305.00	750.00	305.00	6
68	0.00	290.00	750.00	290.00	7
69	0.00	275.00	750.00	275.00	8

Soil Parameters

Number of Soil Types : 11

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	111.0	111.0	0.0	24.0	0.00	0.0	0
2	130.0	130.0	1000.0	10.0	0.00	0.0	0
3	135.0	135.0	0.0	24.0	0.00	0.0	0
4	58.7	58.7	0.0	15.0	0.00	0.0	0
5	130.0	130.0	800.0	10.0	0.00	0.0	0
6	125.0	125.0	320.0	10.0	0.00	0.0	0
7	130.0	130.0	0.0	30.0	0.00	0.0	0
8	140.0	140.0	2000.0	40.0	0.00	0.0	0
9	58.7	58.7	0.0	10.5	0.00	0.0	0
10	130.0	130.0	2000.0	0.0	0.00	0.0	0
11	125.0	125.0	0.0	25.0	0.00	0.0	0

Earthquake Loading

Horizontal Acceleration Coefficient : 0.055
Vertical Acceleration Coefficient : 0.000

****
***** TRIAL SURFACE GENERATION *****
****

Data for Generating Rankine Block Surfaces

Number of Trial Surfaces : 500
Number of Boxes : 6
Segment Length, ft : 1.00 ft

Box No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Height (ft)
1	174.50	330.75	214.65	317.05	0.00
2	214.65	317.05	214.65	317.05	0.00
3	217.65	316.05	217.65	316.05	0.00
4	222.15	314.55	222.15	314.55	0.00
5	225.15	313.55	225.15	313.55	0.00
6	225.15	313.55	650.00	318.78	0.00

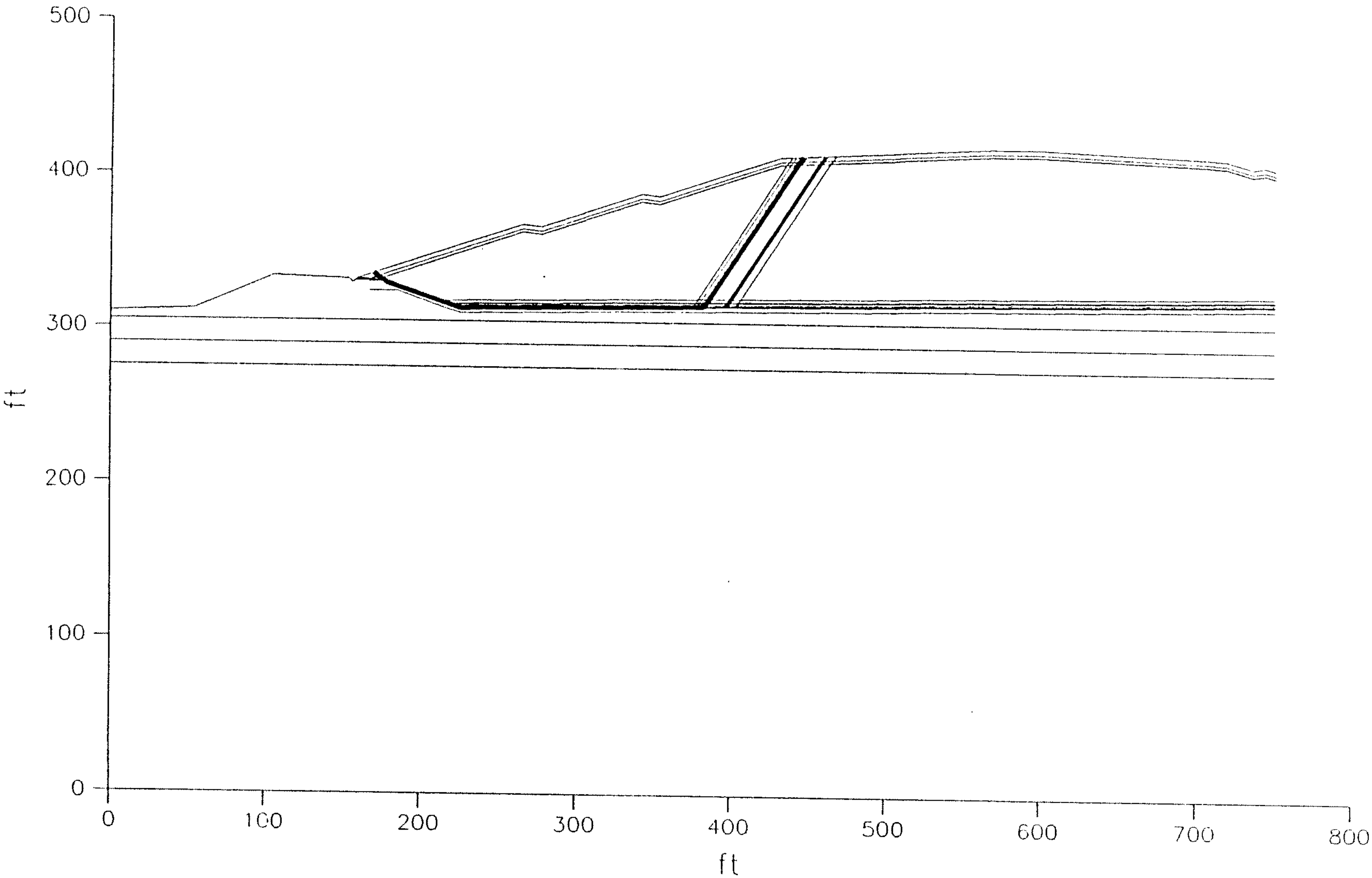
****
***** RESULTS *****
****

Critical Surfaces

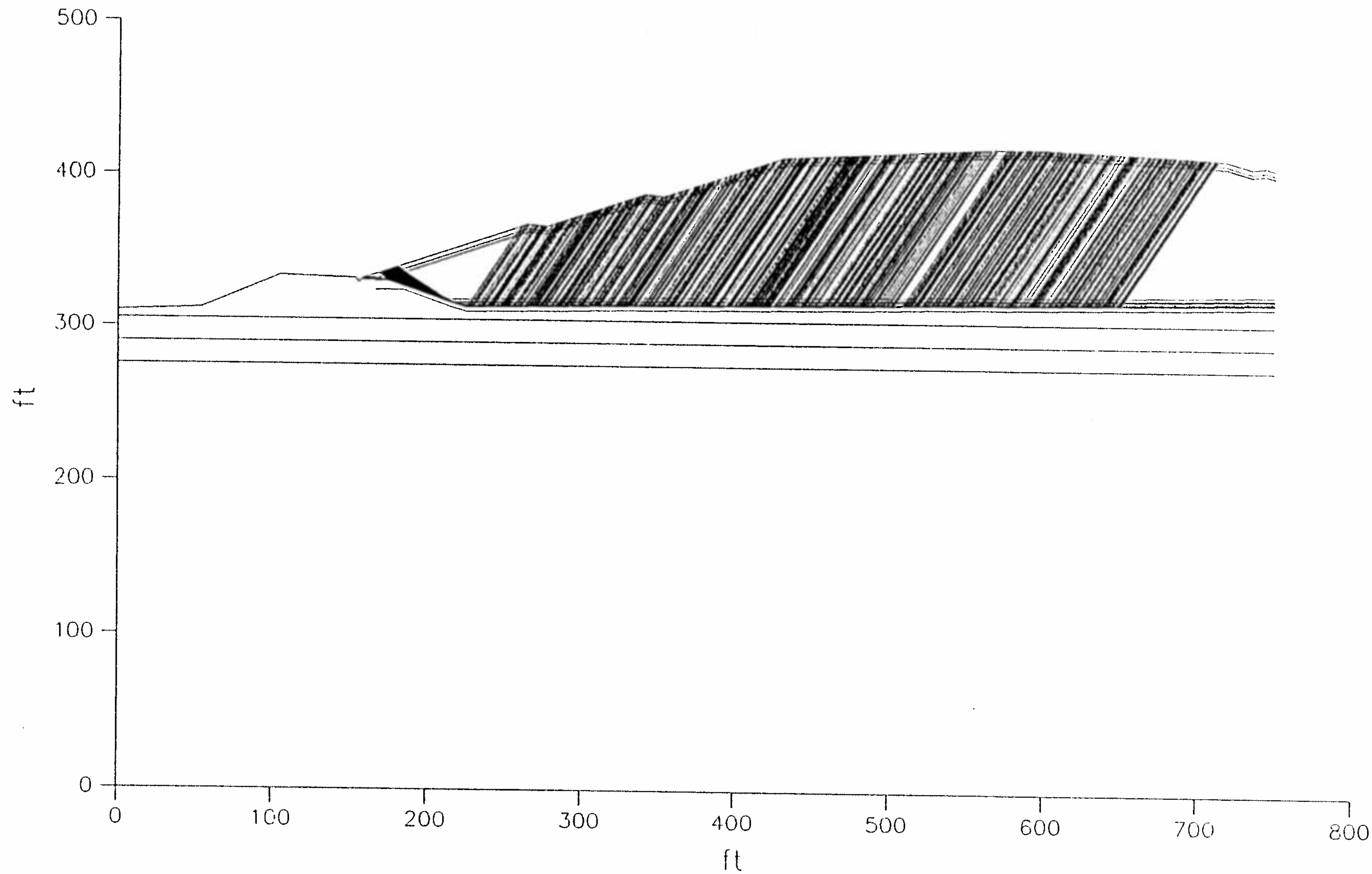
No.	Safety Factor
1	1.234
2	1.235
3	1.237
4	1.238
5	1.238
6	1.238
7	1.239
8	1.239
9	1.241
10	1.243

Rankine Block Surfaces – Most Critical Surfaces

Minimum Factor of Safety : 1.234



Rankine Block Surfaces — Search for Critical Surfaces



SECTION 91+25
TOP OF VEGETATIVE COVER GRADES

SEISMIC DEEP CIRCULAR FAILURE ANALYSIS

```
*****************************************************************************
*****                           GeoSlope                               *****
*****                         Version 5.10                             *****
*****                                                                  *****
*****              (c)1992 by GEOCOMP Corp, Concord, MA                *****
*****                       Licensed to RUST                           *****
*****************************************************************************
```

Problem Title : "CWM Chemical Services, Inc. Model City RMU-1"
Description : "Vert Enhancement Section 91+25 North"
Remarks : "Seismic Circular Analysis - Max El = 420 ft"

```
*****************************************************************************
*****                          INPUT DATA                              *****
*****************************************************************************
```

Profile Boundaries

Number of Boundaries : 69
Number of Top Boundaries : 17

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	310.00	54.00	312.00	10
2	54.00	312.00	105.00	333.55	10
3	105.00	333.55	153.50	332.00	10
4	153.50	332.00	156.00	329.50	10
5	156.00	329.50	157.50	331.00	10
6	157.50	331.00	158.50	332.00	2
7	158.50	332.00	265.34	367.91	11
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34	341.76	383.23	353.65	382.05	1
35	353.65	382.05	431.76	408.00	1
36	431.76	408.00	570.00	415.00	1
37	570.00	415.00	600.00	415.00	1
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62	184.75	324.50	214.65	313.80	5
63	214.65	313.80	217.65	312.80	5
64	217.65	312.80	222.15	311.30	5
65	222.15	311.30	225.15	310.30	5
66	225.15	310.30	750.00	317.01	5
67	0.00	305.00	750.00	305.00	6
68	0.00	290.00	750.00	290.00	7
69	0.00	275.00	750.00	275.00	8

Soil Parameters

Number of Soil Types : 11

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	111.0	111.0	0.0	24.0	0.00	0.0	0
2	130.0	130.0	1000.0	10.0	0.00	0.0	0
3	135.0	135.0	0.0	24.0	0.00	0.0	0
4	58.7	58.7	0.0	15.0	0.00	0.0	0
5	130.0	130.0	800.0	10.0	0.00	0.0	0
6	125.0	125.0	320.0	10.0	0.00	0.0	0
7	130.0	130.0	0.0	30.0	0.00	0.0	0
8	140.0	140.0	2000.0	40.0	0.00	0.0	0
9	58.7	58.7	0.0	10.5	0.00	0.0	0
10	130.0	130.0	2000.0	0.0	0.00	0.0	0
11	125.0	125.0	0.0	25.0	0.00	0.0	0

Earthquake Loading

Horizontal Acceleration Coefficient : 0.055
Vertical Acceleration Coefficient : 0.000

****
*****   TRIAL SURFACE GENERATION   *****
****

Data for Generating Circular Surfaces

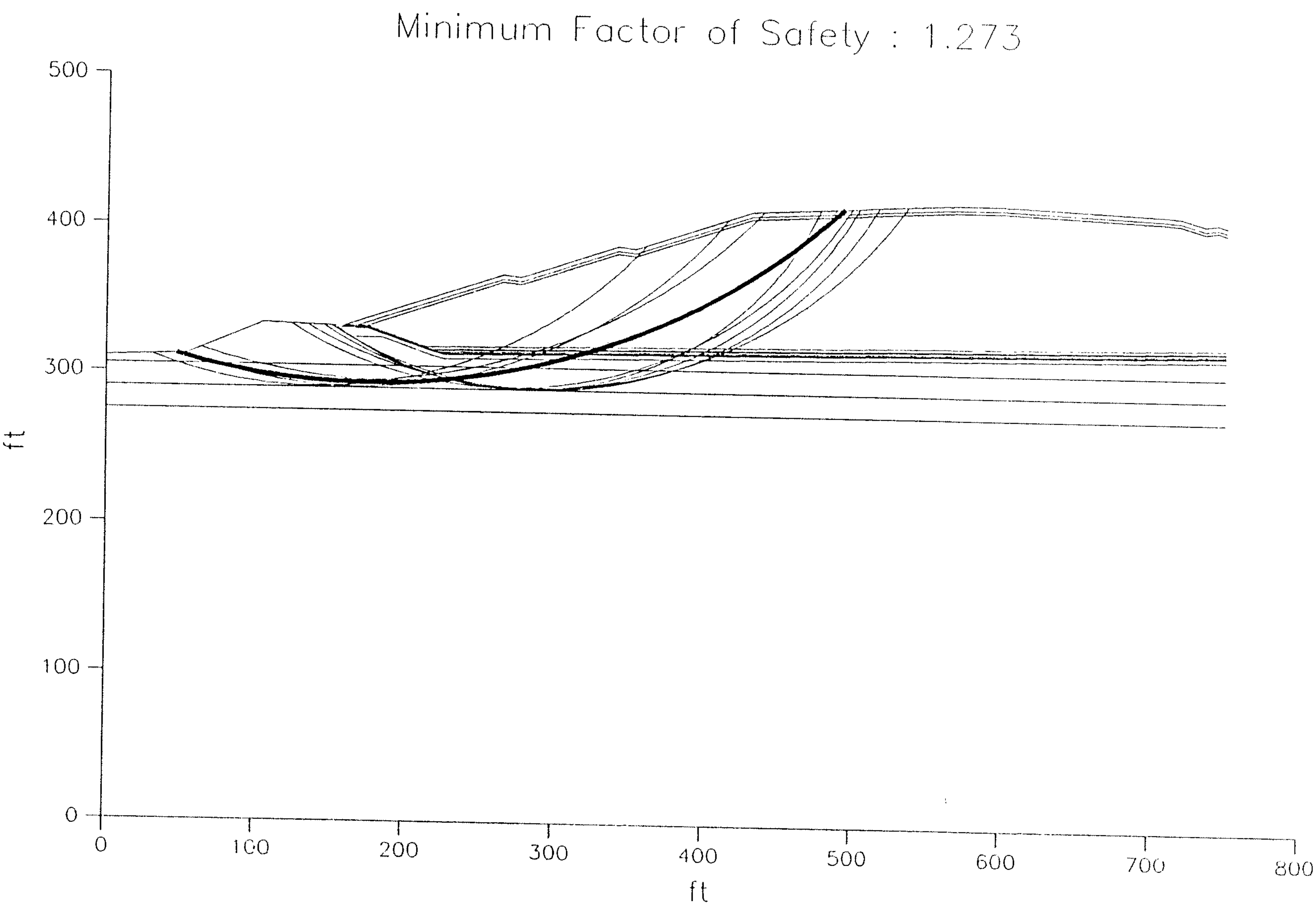
Number of Initiation Points : 25
Number of Surfaces From Each Point : 25
Left Initiation Point : 25.00 ft
Right Initiation Point : 156.00 ft
Left Termination Point : 300.00 ft
Right Termination Point : 600.00 ft
Minimum Elevation : 0.00 ft
Segment Length : 5.00 ft
Positive Angle Limit : 0.00 deg
Negative Angle Limit : 0.00 deg

****
*****   RESULTS   *****
****

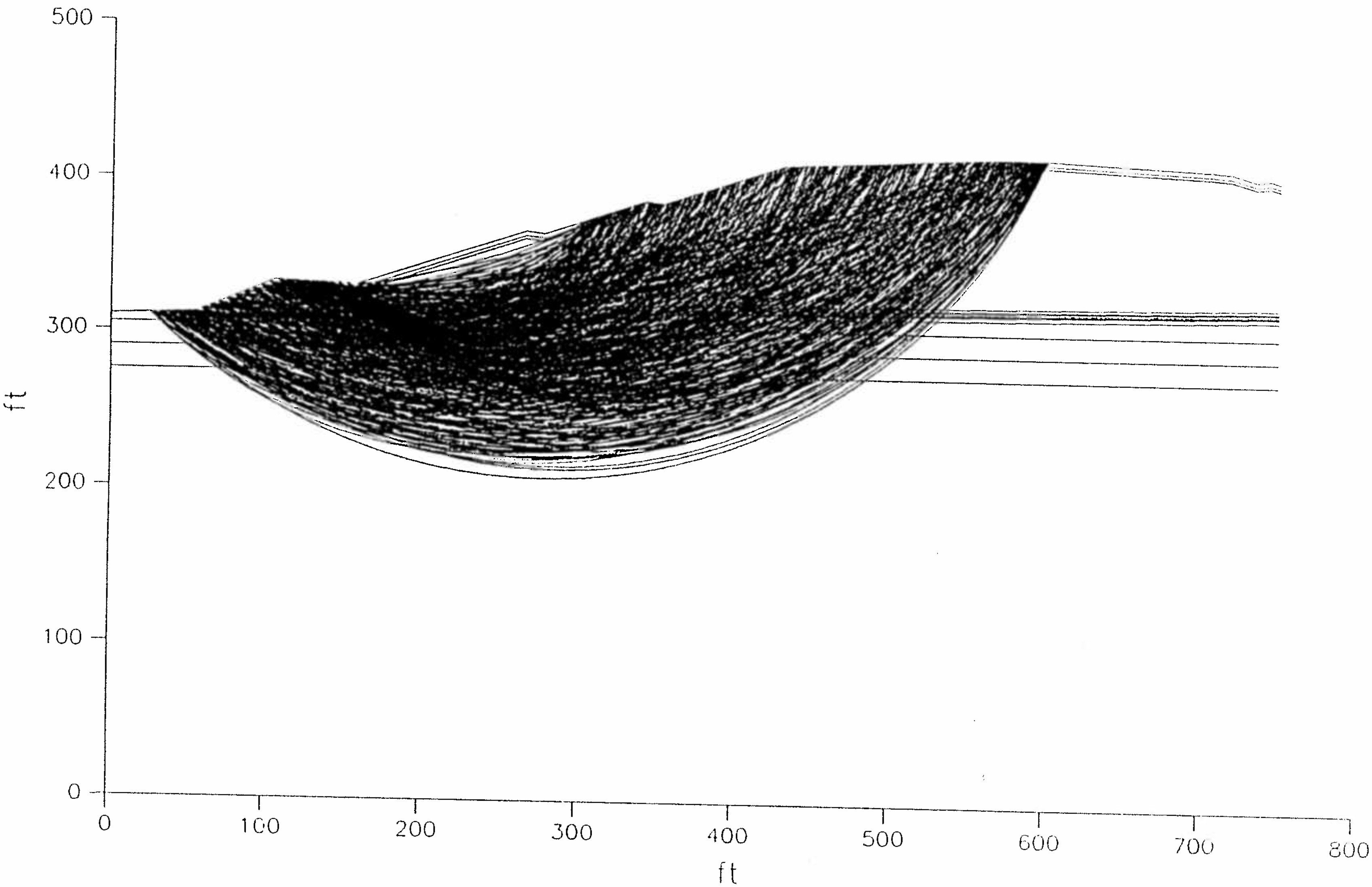
Critical Surfaces

No.	Safety Factor	Center X (ft)	Center Y (ft)	Circle Radius (ft)
1	1.273	176.75	763.29	469.87
2	1.277	167.11	612.68	321.92
3	1.281	280.62	507.44	217.24
4	1.300	292.40	551.46	261.24
5	1.301	284.58	543.21	252.90
6	1.307	159.57	685.76	390.64
7	1.318	193.77	715.68	420.57
8	1.328	288.00	597.19	306.04
9	1.329	138.76	590.02	299.18
10	1.330	268.43	565.31	273.98

Bishop Circular Surfaces – Most Critical Surfaces



Bishop Circular Surfaces Search for Critical Surfaces



D-7

DIFFERENTIAL WASTE HEIGHT STABILITY

DIFFERENTIAL WASTE HEIGHT STABILITY

Objective: Evaluate the waste slope stability during filling.

Method: UTEXAS 2 slope stability program developed by Professor Stephen G. Wright, University of Texas at Austin, 1987. Spencers Method was employed for the stability analysis.

Conditions:
- Waste side slopes are 3:1 and 2:1 (H:V) (Figure 1).
- Minimum acceptable factor of safety is 1.5.
- Waste backslope is horizontal.
- Material properties used in the analysis are presented in the table below:

Material Properties Used in the Analysis

Description	C (psf)	ϕ (Degrees)	γ (pcf)
Bedrock	2,000	40	140
Glaciolacustrine Sand	0	30	130
Glaciolacustrine Clay	320	10	125
Upper Till	800	10	130
Soil Liner	1,000	10	130
Synthetic Liner	0	10	130
Waste	800	13.5	111

Summary of Analysis:

Summary of the analysis is provided below.

Waste Slope	F.S.	H*	Max Elev.
3:1	1.49	62	380
	1.55	57	375
	1.61	52	370
2:1	1.39	52	370
	1.47	47	365
	1.51	45	363
	1.57	42	360

*Maximum differential waste height

Based upon this analysis, assuming a minimum factor of safety of 1.5, the maximum differential waste height should not exceed 57 feet for a waste slope of 3:1 and 45 feet for a waste slope of 2:1.

RP/CWMNYORK/AC5

Donohue
Engineers & Architects

CLIENT: CWM　　PROJECT NO. 17365.700　　BY: SYG & SB

PROJECT: RMU-1　　DATE: 5-16-92, 6-11-92　　PAGE NO.

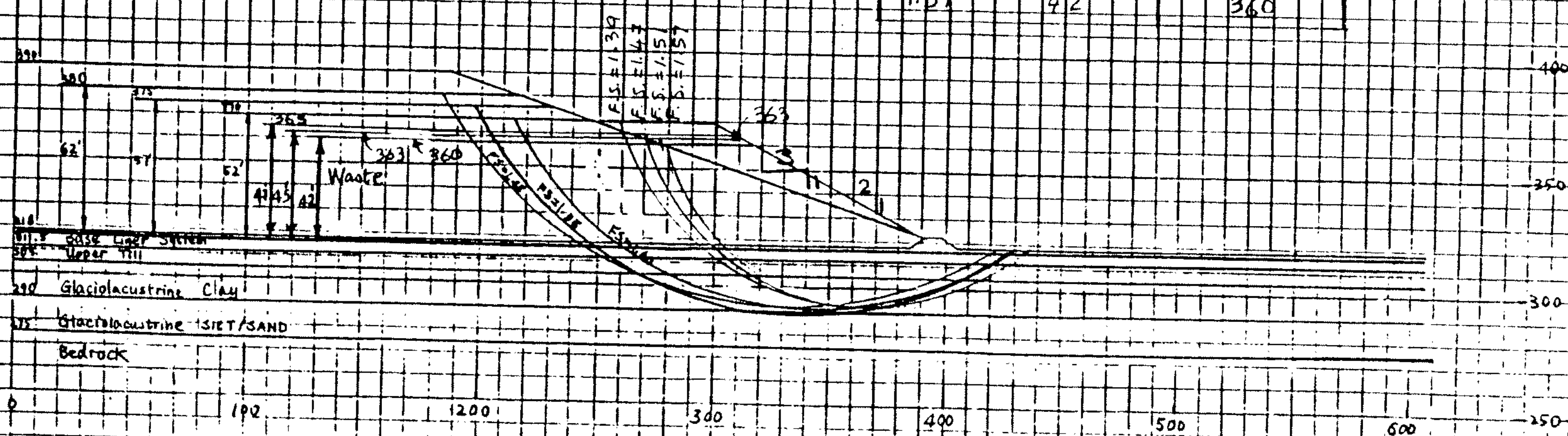
FIGURE 1 SLOPE STABILITY - WASTE FILLING SEQUENCE

SLOPE = 3:1

F.S.	H (feet)	Ele. of Waste
1.49	62'	380
1.55	57'	375
1.61	52'	370

SLOPE = 2:1

F.S.	H (feet)	Ele. of Waste
1.39	52'	370
1.47	47'	365
1.51	45'	363
1.57	42'	360



HEIGHT OF WASTE VS. FACTOR OF SAFETY

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

CASE 1. H = 52 FEET

SLOPE=3:1

TABLE NO. 1

```
*****************************************
* COMPUTER PROGRAM DESIGNATION - UTEXAS2 *
* ORIGINALLY CODED BY STEPHEN G. WRIGHT  *
* VERSION NO. 1.209                      *
* LAST REVISION DATE 11/23/87            *
* SERIAL NO. 00004                       *
* (C) COPYRIGHT 1985 STEPHEN G. WRIGHT   *
* ALL RIGHTS RESERVED                    *
*****************************************
```

```
**************************************************************
*                                                            *
*      RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
* PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
* HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL   *
* DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE   *
* ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER  *
* PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS      *
* PROGRAM BEFORE ATTEMPTING ITS USE.                         *
*                                                            *
*      NEITHER THE UNIVERSITY OF TEXAS NOR STEPHEN G. WRIGHT *
* MAKE OR ASSUME LIABILITY FOR ANY WARRANTIES, EXPRESSED OR  *
* IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS  *
* OR ADAPTABILITY OF THIS COMPUTER PROGRAM.                  *
*                                                            *
**************************************************************
```

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 2

```
************************
* NEW PROFILE LINE DATA *
************************
```

PROFILE LINE 1 - MATERIAL TYPE = 1
Bedrock

POINT	X	Y
1	-100.000	275.000
2	900.000	275.000

PROFILE LINE 2 - MATERIAL TYPE = 2
Glaciolacustrine Sand/Silt

POINT	X	Y
1	-100.000	290.000
2	900.000	290.000

PROFILE LINE 3 - MATERIAL TYPE = 3
LACUSTRINE CLAY

POINT	X	Y

1	-100.000	305.000
2	900.000	305.000

PROFILE LINE 4 - MATERIAL TYPE = 4
UPPER TILL

POINT	X	Y
1	-100.000	311.500
2	900.000	311.500

PROFILE LINE 5 - MATERIAL TYPE = 5
Lower Soil Liner

POINT	X	Y
1	-100.000	315.500
2	900.000	315.500

PROFILE LINE 6 - MATERIAL TYPE = 6
Synthetic Liner

POINT	X	Y
1	-100.000	316.000
2	900.000	316.000

PROFILE LINE 7 - MATERIAL TYPE = 5
Upper Soil Liner

POINT	X	Y
1	-100.000	318.000
2	383.000	318.000
3	391.000	322.000
4	399.000	322.000
5	407.000	318.000
6	900.000	318.000

PROFILE LINE 8 - MATERIAL TYPE = 7
Waste

POINT	X	Y
1	-100.000	370.000
2	247.000	370.000
3	403.000	318.000

ALL NEW PROFILE LINES DEFINED - NO OLD LINES RETAINED

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 3
****
* NEW MATERIAL PROPERTY DATA *
****

DATA FOR MATERIAL TYPE 1

```
BEDROCK

     UNIT WEIGHT OF MATERIAL =  140.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     COHESION - - - - - - - - -     2000.000
     FRICTION ANGLE - - - - -  40.000 DEGREES

     NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE  2
Glaciolacustrine Sand/Silt

     UNIT WEIGHT OF MATERIAL =  130.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     COHESION - - - - - - - - -         .000
     FRICTION ANGLE - - - - -  30.000 DEGREES

     NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE  3
Glaciolacustrine Clay

     UNIT WEIGHT OF MATERIAL =  125.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     COHESION - - - - - - - - -      320.000
     FRICTION ANGLE - - - - -  10.000 DEGREES

     NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE  4
UPPER TILL

     UNIT WEIGHT OF MATERIAL =  130.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     COHESION - - - - - - - - -      800.000
     FRICTION ANGLE - - - - -  10.000 DEGREES

     NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE  5
Soil Liner

     UNIT WEIGHT OF MATERIAL =  130.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     COHESION - - - - - - - - -     1000.000
     FRICTION ANGLE - - - - -  10.000 DEGREES

     NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE  6
Synthetic Liner

     UNIT WEIGHT OF MATERIAL =  130.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
```

COHESION - - - - - - - - .000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 7
Waste

UNIT WEIGHT OF MATERIAL = 111.100

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - 800.000
FRICTION ANGLE - - - - - 13.500 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

ALL NEW MATERIAL PROPERTIES DEFINED - NO OLD DATA RETAINED

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TABLE NO. 9
****
* NEW ANALYSIS/COMPUTATION DATA *
****

CIRCULAR SHEAR SURFACE(S)

AUTOMATIC SEARCH PERFORMED

STARTING CENTER COORDINATE FOR SEARCH AT -
X = 280.000
Y = 500.000

REQUIRED ACCURACY FOR CRITICAL CENTER (= MINIMUM
SPACING BETWEEN GRID POINTS) = 1.000

CRITICAL SHEAR SURFACE NOT ALLOWED TO PASS BELOW Y = 270.000

FOR THE INITIAL MODE OF SEARCH
ALL CIRCLES ARE TANGENT TO HORIZONTAL LINE AT -
Y = 290.000

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

INITIAL TRIAL ESTIMATE FOR THE FACTOR OF SAFETY = 3.000

INITIAL TRIAL ESTIMATE FOR SIDE FORCE INCLINATION = 15.000 DEGREES
(APPLICABLE TO SPENCER'S PROCEDURE ONLY)

MAXIMUM NUMBER OF ITERATIONS ALLOWED FOR
CALCULATING THE FACTOR OF SAFETY = 40

ALLOWED FORCE IMBALANCE FOR CONVERGENCE = 100.000

ALLOWED MOMENT IMBALANCE FOR CONVERGENCE = 100.000

INITIAL TRIAL VALUES FOR FACTOR OF SAFETY (AND SIDE FORCE INCLINATION

FOR SPENCER'S PROCEDURE) WILL BE KEPT CONSTANT DURING SEARCH

MAXIMUM SUBTENDED ANGLE TO BE USED FOR SUBDIVISION OF THE
CIRCLE INTO SLICES = 3.00 DEGREES

DEPTH OF CRACK = .000

SEARCH WILL BE CONTINUED TO LOCATE A MORE CRITICAL SHEAR
SURFACE (IF ONE EXISTS) AFTER THE INITIAL MODE IS COMPLETE

DEPTH OF WATER IN CRACK = .000

UNIT WEIGHT OF WATER IN CRACK = 62.400

SEISMIC COEFFICIENT = .000

PROCEDURE USED TO COMPUTE THE FACTOR OF SAFETY: SPENCER

TABLE NO. 10

****
* NEW SLOPE GEOMETRY DATA *
****

NOTE - NO DATA WERE INPUT, SLOPE GEOMETRY DATA
WERE GENERATED BY THE PROGRAM

SLOPE COORDINATES -

POINT	X	Y
1	-100.000	370.000
2	247.000	370.000
3	391.000	322.000
4	399.000	322.000
5	407.000	318.000
6	900.000	318.000

TABLE NO. 12

INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES ARE TANGENT
TO A HORIZONTAL LINE AT Y = 290.000

CENTER COORDINATES X	Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
250.00	470.00	180.00	2.919	-4.96	4
280.00	470.00	180.00	2.195	-5.98	5
310.00	470.00	180.00	1.791	-6.91	6
250.00	500.00	210.00	2.843	-5.06	4
280.00	500.00	210.00	2.196	-5.96	5

310.00	500.00	210.00	1.824	-6.73	5
250.00	530.00	240.00	2.803	-5.10	4
280.00	530.00	240.00	2.220	-5.86	5
310.00	530.00	240.00	1.870	-6.48	5
280.00	440.00	150.00	2.232	-5.84	4
310.00	440.00	150.00	1.795	-6.86	6
340.00	440.00	150.00	1.614	-7.68	6
340.00	470.00	180.00	1.639	-7.28	6
340.00	500.00	210.00	1.683	-6.88	6
310.00	410.00	120.00	1.828	-6.77	5
340.00	410.00	120.00	1.642	-7.88	7
370.00	410.00	120.00	1.853	-6.65	6
370.00	440.00	150.00	1.742	-7.44	6
370.00	470.00	180.00	1.713	-7.33	6
335.00	435.00	145.00	1.622	-7.69	6
340.00	435.00	145.00	1.614	-7.74	7
345.00	435.00	145.00	1.614	-7.77	8
335.00	440.00	150.00	1.622	-7.64	6
345.00	440.00	150.00	1.613	-7.71	8
335.00	445.00	155.00	1.625	-7.58	6
340.00	445.00	155.00	1.616	-7.62	6
345.00	445.00	155.00	1.615	-7.65	8
350.00	435.00	145.00	1.622	-7.78	8
350.00	440.00	150.00	1.620	-7.72	8
350.00	445.00	155.00	1.620	-7.66	8
342.00	437.00	147.00	1.613	-7.73	9
345.00	437.00	147.00	1.613	-7.75	8
348.00	437.00	147.00	1.617	-7.75	8
342.00	440.00	150.00	1.613	-7.70	9
348.00	440.00	150.00	1.617	-7.72	8
342.00	443.00	153.00	1.614	-7.66	7
345.00	443.00	153.00	1.614	-7.67	8
348.00	443.00	153.00	1.617	-7.68	8
339.00	434.00	144.00	1.615	-7.74	6
342.00	434.00	144.00	1.613	-7.77	9
345.00	434.00	144.00	1.614	-7.78	8
339.00	437.00	147.00	1.615	-7.71	6
339.00	440.00	150.00	1.615	-7.68	6
341.00	436.00	146.00	1.613	-7.74	9
342.00	436.00	146.00	1.613	-7.74	9
343.00	436.00	146.00	1.613	-7.75	8
341.00	437.00	147.00	1.613	-7.73	7
343.00	437.00	147.00	1.613	-7.74	8
341.00	438.00	148.00	1.613	-7.72	7
342.00	438.00	148.00	1.613	-7.72	9
343.00	438.00	148.00	1.613	-7.73	8
344.00	436.00	146.00	1.613	-7.76	8
344.00	437.00	147.00	1.613	-7.74	8
344.00	438.00	148.00	1.613	-7.73	8

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -

X-CENTER = 343.00 Y-CENTER = 437.00 RADIUS = 147.00
FACTOR OF SAFETY = 1.613 SIDE FORCE INCLINATION = -7.74
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TABLE NO. 13
INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES HAVE THE SAME RADIUS - RADIUS = 147.000

CENTER COORDINATES X	Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
313.00	407.00	147.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
343.00	407.00	147.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
373.00	407.00	147.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
313.00	437.00	147.00	1.765	-6.98	6
373.00	437.00	147.00	SEE MESSAGE ON NEXT LINE(S)		
LAST TRIAL VALUES =			1.832	9.33	5
VALUES SHOWN ABOVE ARE NOT CORRECT FINAL VALUES					
VALUE OF SIDE FORCE INCLINATION BECAME OUTSIDE RANGE OF FROM -80.00 TO 10.00 DEGREES					
313.00	467.00	147.00	2.529	-9.92	4
343.00	467.00	147.00	2.461	-12.63	5
373.00	467.00	147.00	3.374	-12.02	4
338.00	432.00	147.00	2.436	-10.13	4
343.00	432.00	147.00	2.417	-10.16	4
348.00	432.00	147.00	2.408	-10.17	4
338.00	437.00	147.00	1.616	-7.70	6
348.00	437.00	147.00	1.617	-7.75	8
338.00	442.00	147.00	1.650	-8.23	8
343.00	442.00	147.00	1.647	-8.30	7
348.00	442.00	147.00	1.652	-8.34	6
340.00	434.00	147.00	2.246	-10.00	5
343.00	434.00	147.00	2.238	-10.02	5
346.00	434.00	147.00	2.233	-10.03	5
340.00	437.00	147.00	1.614	-7.72	6
346.00	437.00	147.00	1.614	-7.75	8
340.00	440.00	147.00	1.630	-8.03	8
343.00	440.00	147.00	1.629	-8.06	7
346.00	440.00	147.00	1.631	-8.08	8
342.00	436.00	147.00	1.979	-9.46	5
343.00	436.00	147.00	1.978	-9.46	5
344.00	436.00	147.00	1.977	-9.47	5
342.00	437.00	147.00	1.613	-7.73	9
344.00	437.00	147.00	1.613	-7.74	8
342.00	438.00	147.00	1.617	-7.83	8
343.00	438.00	147.00	1.617	-7.84	8
344.00	438.00	147.00	1.617	-7.85	8

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL
CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER = 343.00 Y-CENTER = 437.00 RADIUS = 147.00
FACTOR OF SAFETY = 1.613 SIDE FORCE INCLINATION = -7.74

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TABLE NO. 15
***** FINAL CRITICAL CIRCLE INFORMATION *****
X COORDINATE OF CENTER - - - - - - - 343.000
Y COORDINATE OF CENTER - - - - - - - 437.000
RADIUS - - - - - - - - - - - - - - - 147.000
FACTOR OF SAFETY - - - - - - - - - - 1.613
SIDE FORCE INCLINATION - - - - - - - -7.74

NUMBER OF CIRCLES TRIED - - - - - - 86
NO. OF CIRCLES F CALC. FOR - - - - - 82

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TABLE NO. 20
****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	212.2	370.0					
1	214.0	366.6	1383.3	7	800.00	13.50	.0
	215.8	363.2					
2	217.9	360.0	4496.9	7	800.00	13.50	.0
	219.9	356.7					
3	222.1	353.5	8002.9	7	800.00	13.50	.0
	224.2	350.4					
4	226.6	347.3	11842.1	7	800.00	13.50	.0
	228.9	344.3					
5	231.5	341.3	15952.6	7	800.00	13.50	.0
	234.0	338.4					
6	236.6	335.6	20270.3	7	800.00	13.50	.0
	239.3	332.8					
7	242.1	330.2	24729.6	7	800.00	13.50	.0
	244.9	327.6					
8	245.9	326.6	10325.0	7	800.00	13.50	.0
	247.0	325.7					
9	250.0	323.2	30293.6	7	800.00	13.50	.0
	253.0	320.8					
10	254.8	319.4	19942.0	7	800.00	13.50	.0
	256.7	318.0					
11	258.1	317.0	15537.6	5	1000.00	10.00	.0
	259.5	316.0					
12	259.9	315.8	4079.4	6	.00	10.00	.0
	260.3	315.5					
13	263.4	313.5	35705.2	5	1000.00	10.00	.0
	266.5	311.5					

14	269.8	309.6	40220.3	4	800.00	10.00	.0
	273.1	307.7					
15	275.7	306.3	32259.6	4	800.00	10.00	.0
	278.3	305.0					
16	281.8	303.4	44630.3	3	320.00	10.00	.0
	285.3	301.8					
17	288.9	300.4	46464.6	3	320.00	10.00	.0
	292.5	299.0					
18	296.1	297.7	47824.2	3	320.00	10.00	.0
	299.8	296.5					
19	303.5	295.5	48680.1	3	320.00	10.00	.0
	307.2	294.4					
20	310.9	293.6	49010.5	3	320.00	10.00	.0
	314.7	292.8					
21	318.5	292.1	48801.6	3	320.00	10.00	.0
	322.3	291.5					
22	326.1	291.0	48048.0	3	320.00	10.00	.0
	329.9	290.6					

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TABLE NO. 20

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*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
```

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	329.9	290.6					
23	333.8	290.3	46751.4	3	320.00	10.00	.0
	337.6	290.1					
24	340.3	290.0	31812.7	3	320.00	10.00	.0
	343.0	290.0					
25	346.8	290.1	43328.8	3	320.00	10.00	.0
	350.7	290.2					
26	354.5	290.5	40641.0	3	320.00	10.00	.0
	358.4	290.8					
27	362.2	291.3	37488.9	3	320.00	10.00	.0
	366.0	291.8					
28	369.8	292.5	33911.4	3	320.00	10.00	.0
	373.6	293.2					
29	377.3	294.1	29954.1	3	320.00	10.00	.0
	381.0	295.0					
30	382.0	295.3	7193.3	3	320.00	10.00	.0
	383.0	295.5					
31	386.7	296.7	24749.0	3	320.00	10.00	.0
	390.3	297.8					
32	390.7	297.9	2020.9	3	320.00	10.00	.0
	391.0	298.1					
33	394.6	299.4	20307.7	3	320.00	10.00	.0
	398.2	300.8					
34	398.6	300.9	2107.7	3	320.00	10.00	.0
	399.0	301.1					
35	401.0	301.9	9646.7	3	320.00	10.00	.0
	403.0	302.8					
36	405.0	303.7	7913.6	3	320.00	10.00	.0

	407.0	304.7					
37	407.3	304.8	1183.3	3	320.00	10.00	.0
	407.7	305.0					
38	411.1	306.8	9944.3	4	800.00	10.00	.0
	414.5	308.6					
39	417.0	310.0	5210.7	4	800.00	10.00	.0
	419.5	311.5					
40	422.6	313.5	3628.5	5	1000.00	10.00	.0
	425.7	315.5					
41	426.1	315.8	213.4	6	.00	10.00	.0
	426.5	316.0					
42	427.9	317.0	367.5	5	1000.00	10.00	.0
	429.3	318.0					

TABLE NO. 21

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*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL  *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)                *
*******************************************************************
```

SLICE NO.	X	SEISMIC FORCE	Y FOR SEISMIC FORCE	FORCES DUE TO SURFACE PRESSURES NORMAL FORCE	SHEAR FORCE	X	Y
1	214.0	0.	368.3	0.	0.	.0	.0
2	217.9	0.	365.0	0.	0.	.0	.0
3	222.1	0.	361.8	0.	0.	.0	.0
4	226.6	0.	358.7	0.	0.	.0	.0
5	231.5	0.	355.7	0.	0.	.0	.0
6	236.6	0.	352.8	0.	0.	.0	.0
7	242.1	0.	350.1	0.	0.	.0	.0
8	245.9	0.	348.3	0.	0.	.0	.0
9	250.0	0.	346.1	0.	0.	.0	.0
10	254.8	0.	343.4	0.	0.	.0	.0
11	258.1	0.	341.6	0.	0.	.0	.0
12	259.9	0.	340.5	0.	0.	.0	.0
13	263.4	0.	338.7	0.	0.	.0	.0
14	269.8	0.	335.4	0.	0.	.0	.0
15	275.7	0.	332.6	0.	0.	.0	.0
16	281.8	0.	330.1	0.	0.	.0	.0
17	288.9	0.	327.3	0.	0.	.0	.0
18	296.1	0.	324.8	0.	0.	.0	.0
19	303.5	0.	322.4	0.	0.	.0	.0
20	310.9	0.	320.2	0.	0.	.0	.0
21	318.5	0.	318.3	0.	0.	.0	.0
22	326.1	0.	316.5	0.	0.	.0	.0
23	333.8	0.	314.9	0.	0.	.0	.0
24	340.3	0.	313.8	0.	0.	.0	.0
25	346.8	0.	312.7	0.	0.	.0	.0
26	354.5	0.	311.7	0.	0.	.0	.0
27	362.2	0.	310.9	0.	0.	.0	.0
28	369.8	0.	310.4	0.	0.	.0	.0
29	377.3	0.	310.0	0.	0.	.0	.0
30	382.0	0.	309.9	0.	0.	.0	.0
31	386.7	0.	309.9	0.	0.	.0	.0

32	390.7	0.	310.1	0.	0.	.0	.0
33	394.6	0.	310.5	0.	0.	.0	.0
34	398.6	0.	311.4	0.	0.	.0	.0
35	401.0	0.	311.4	0.	0.	.0	.0
36	405.0	0.	311.4	0.	0.	.0	.0
37	407.3	0.	311.4	0.	0.	.0	.0
38	411.1	0.	312.4	0.	0.	.0	.0
39	417.0	0.	314.0	0.	0.	.0	.0
40	422.6	0.	315.8	0.	0.	.0	.0
41	426.1	0.	316.9	0.	0.	.0	.0

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Chemical Waste Management

Slope Stability - Waste Filling Sequence

TABLE NO. 21

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*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*******************************************************************
```

						FORCES DUE TO SURFACE PRESSURES	
SLICE NO.	X	SEISMIC FORCE	Y FOR SEISMIC FORCE	NORMAL FORCE	SHEAR FORCE	X	Y
42	427.9	0.	317.5	0.	0.	.0	.0

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Chemical Waste Management

Slope Stability - Waste Filling Sequence

TABLE NO. 23

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*******************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY AND SIDE FORCE INCLINATION BY SPENCER'S PROCEDURE    *
*******************************************************************
```

ITER-ATION	TRIAL FACTOR OF SAFETY	TRIAL SIDE FORCE INCLINATION (DEGREES)	FORCE IMBALANCE (LBS.)	MOMENT IMBALANCE (FT.-LBS.)	DELTA-F	DELTA THETA (DEGREES)
1	3.00000	-15.0000	-.8775E+05	.3110E+08		
FIRST-ORDER CORRECTIONS TO F AND THETA					.274E+02	-.501E+03
VALUES FACTORED BY .172E-01 - DELTAS TOO LARGE					.470E+00	-.859E+01
2	3.46960	-23.5944	-.8333E+05	.2880E+08		
FIRST-ORDER CORRECTIONS TO F AND THETA					-.599E+01	.412E+02
VALUES FACTORED BY .835E-01 - DELTAS TOO LARGE					-.500E+00	.344E+01
3	2.96960	-20.1580	-.7375E+05	.2534E+08		
FIRST-ORDER CORRECTIONS TO F AND THETA					-.390E+01	.364E+02
VALUES FACTORED BY .128E+00 - DELTAS TOO LARGE					-.500E+00	.467E+01
4	2.46960	-15.4837	-.6004E+05	.2048E+08		
FIRST-ORDER CORRECTIONS TO F AND THETA					-.193E+01	.231E+02
VALUES FACTORED BY .259E+00 - DELTAS TOO LARGE					-.500E+00	.598E+01
5	1.96960	-9.5061	-.3684E+05	.1264E+08		

```
FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.482E+00  .362E+01
SECOND-ORDER CORRECTION - ITERATION   1 ........   -.403E+00  .362E+01
SECOND-ORDER CORRECTION - ITERATION   2 ........   -.401E+00  .362E+01
SECOND-ORDER CORRECTION - ITERATION   3 ........   -.401E+00  .362E+01

   6   1.56860    -5.8895   .1937E+04  -.9357E+05
FIRST-ORDER CORRECTIONS TO F AND THETA .........    .419E-01 -.181E+01
SECOND-ORDER CORRECTION - ITERATION   1 ........    .434E-01 -.181E+01
SECOND-ORDER CORRECTION - ITERATION   2 ........    .434E-01 -.181E+01

   7   1.61196    -7.7023  -.4531E+01   .1283E+05
FIRST-ORDER CORRECTIONS TO F AND THETA .........    .587E-03 -.362E-01
SECOND-ORDER CORRECTION - ITERATION   1 ........    .588E-03 -.362E-01

   8   1.61255    -7.7385   .8301E-02   .1349E+01
FIRST-ORDER CORRECTIONS TO F AND THETA .........    .294E-06 -.137E-04

FACTOR OF SAFETY - - - - - - - -      1.613
SIDE FORCE INCLINATION - - - - -      -7.74
NUMBER OF ITERATIONS - - - - - -      8
```

1
UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 24

```
********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
********************************************
```

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
FACTOR OF SAFETY = 1.613   SIDE FORCE INCLINATION = -7.74 DEGREES

-------- VALUES AT CENTER OF BASE OF SLICE--------

SLICE NO.	X-CENTER	Y-CENTER	TOTAL NORMAL STRESS	EFFECTIVE NORMAL STRESS	SHEAR STRESS
1	214.0	366.6	-310.7	-310.7	449.8
2	217.9	360.0	260.8	260.8	534.9
3	222.1	353.5	846.9	846.9	622.2
4	226.6	347.3	1441.1	1441.1	710.7
5	231.5	341.3	2037.7	2037.7	799.5
6	236.6	335.6	2631.7	2631.7	887.9
7	242.1	330.2	3218.7	3218.7	975.3
8	245.9	326.6	3618.0	3618.0	1034.8
9	250.0	323.2	3914.2	3914.2	1078.9
10	254.8	319.4	4212.7	4212.7	1123.3
11	258.1	317.0	4437.4	4437.4	1105.4
12	259.9	315.8	4849.3	4849.3	530.3
13	263.4	313.5	4758.9	4758.9	1140.5
14	269.8	309.6	5159.4	5159.4	1060.3
15	275.7	306.3	5436.6	5436.6	1090.6
16	281.8	303.4	5753.8	5753.8	827.6
17	288.9	300.4	5952.5	5952.5	849.3
18	296.1	297.7	6103.8	6103.8	865.9
19	303.5	295.5	6206.1	6206.1	877.1
20	310.9	293.6	6257.9	6257.9	882.7

21	318.5	292.1	6257.9	6257.9	882.7
22	326.1	291.0	6204.8	6204.8	876.9
23	333.8	290.3	6097.6	6097.6	865.2
24	340.3	290.0	5966.0	5966.0	850.8
25	346.8	290.1	5787.3	5787.3	831.3
26	354.5	290.5	5528.5	5528.5	803.0
27	362.2	291.3	5212.0	5212.0	768.4
28	369.8	292.5	4836.8	4836.8	727.3
29	377.3	294.1	4401.9	4401.9	679.8
30	382.0	295.3	4101.6	4101.6	646.9
31	386.7	296.7	3803.6	3803.6	614.4
32	390.7	297.9	3546.6	3546.6	586.3
33	394.6	299.4	3268.8	3268.8	555.9
34	398.6	300.9	3121.4	3121.4	539.8
35	401.0	301.9	2868.6	2868.6	512.1
36	405.0	303.7	2408.2	2408.2	461.8
37	407.3	304.8	2119.1	2119.1	430.2
38	411.1	306.8	2083.2	2083.2	723.9
39	417.0	310.0	1653.3	1653.3	676.9
40	422.6	313.5	1292.9	1292.9	761.5

1

-------- VALUES AT CENTER OF BASE OF SLICE---------

SLICE NO.	X-CENTER	Y-CENTER	TOTAL NORMAL STRESS	EFFECTIVE NORMAL STRESS	SHEAR STRESS
41	426.1	315.8	358.0	358.0	39.1
42	427.9	317.0	804.5	804.5	708.1

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = .02 (= .234E-01)
SHOULD NOT EXCEED .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = .07 (= .675E-01)
SHOULD NOT EXCEED .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN = -5.97 (= -.597E+01)
SHOULD NOT EXCEED .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = .00 (= .896E-02)
SHOULD NOT EXCEED .100E+03

***** CAUTION ***** EFFECTIVE OR TOTAL NORMAL STRESS ON SHEAR SURFACE IS NEGATIVE AT POINTS ALONG THE UPPER ONE-HALF OF THE SHEAR SURFACE - A TENSION CRACK MAY BE NEEDED.

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 25
****
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH) *
****

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
FACTOR OF SAFETY = 1.613 SIDE FORCE INCLINATION = -7.74 DEGREES

--------------- VALUES AT RIGHT SIDE OF SLICE ---------------

SLICE NO.	X-RIGHT	SIDE FORCE	Y-COORD. OF SIDE FORCE LOCATION	FRACTION OF HEIGHT	SIGMA AT TOP	SIGMA AT BOTTOM
1	215.8	-3792.	366.4	.463	-432.5	-679.8
2	219.9	-4245.	365.2	.637	-575.9	-56.2
3	224.2	-1577.	383.8	ABOVE	-652.9	493.9
4	228.9	3921.	332.5	BELOW	-717.4	1019.3
5	234.0	11892.	338.0	BELOW	-779.0	1525.3
6	239.3	21933.	336.3	.094	-840.3	2010.2
7	244.9	33600.	333.6	.142	-901.5	2470.5
8	247.0	38241.	332.5	.155	-926.2	2655.4
9	253.0	50998.	329.4	.183	-965.3	3106.1
10	256.7	58681.	327.7	.198	-968.2	3352.9
11	259.5	64484.	326.3	.207	-969.6	3534.4
12	260.3	66540.	325.9	.208	-991.9	3624.9
13	266.5	78612.	323.2	.225	-970.1	3965.3
14	273.1	91434.	320.5	.239	-959.3	4338.4
15	278.3	100363.	318.5	.248	-932.2	4577.4
16	285.3	113128.	315.9	.255	-950.4	4994.6
17	292.5	124021.	313.6	.263	-933.5	5331.4
18	299.8	132775.	311.6	.270	-887.2	5593.5
19	307.2	139184.	309.9	.279	-815.6	5784.7
20	314.7	143103.	308.4	.287	-721.5	5907.4
21	322.3	144456.	307.3	.296	-606.2	5963.0
22	329.9	143237.	306.4	.305	-470.4	5952.6
23	337.6	139512.	305.7	.315	-313.7	5876.3
24	343.0	135467.	305.5	.322	-190.4	5783.4
25	350.7	127836.	305.3	.334	5.8	5594.9
26	358.4	118250.	305.4	.347	230.3	5339.7
27	366.0	107049.	305.8	.363	489.9	5016.9
28	373.6	94649.	306.4	.382	795.7	4625.5
29	381.0	81534.	307.3	.406	1166.6	4164.6
30	383.0	78032.	307.6	.414	1279.4	4031.2
31	390.3	64696.	308.7	.447	1795.7	3462.5
32	391.0	63511.	308.8	.440	1636.7	3491.6
33	398.2	50553.	310.2	.443	1548.7	3168.1
34	399.0	49098.	310.3	.453	1708.4	3057.7
35	403.0	42058.	311.1	.485	2205.5	2641.0
36	407.0	35671.	311.9	.538	3225.8	2040.7
37	407.7	34651.	312.0	.538	3239.0	2043.4
38	414.5	22171.	313.7	.548	2996.5	1661.2
39	419.5	13839.	315.1	.550	2737.6	1481.8
40	425.7	3854.	317.2	.685	3221.3	-166.5

1

--------------- VALUES AT RIGHT SIDE OF SLICE ---------------

SLICE NO.	X-RIGHT	SIDE FORCE	Y-COORD. OF SIDE FORCE LOCATION	FRACTION OF HEIGHT	SIGMA AT TOP	SIGMA AT BOTTOM
41	426.5	3644.	317.2	.597	2857.1	753.9
42	429.3	1.	-414.1	BELOW	.0	.0

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = .02 (= .234E-01)

```
     SHOULD NOT EXCEED      .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION  =          .07  (=  .675E-01)
     SHOULD NOT EXCEED      .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN =        -5.97  (= -.597E+01)
     SHOULD NOT EXCEED      .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM   =          .00  (=  .896E-02)
     SHOULD NOT EXCEED      .100E+03


END-OF-FILE ENCOUNTERED WHILE READING COMMAND
WORDS - END OF PROBLEM(S) ASSUMED
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1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

CASE 2. H = 57 FEET

SLOPE=3:1

TABLE NO. 1

```
*******************************************
* COMPUTER PROGRAM DESIGNATION - UTEXAS2 *
* ORIGINALLY CODED BY STEPHEN G. WRIGHT  *
* VERSION NO. 1.209                      *
* LAST REVISION DATE 11/23/87            *
* SERIAL NO. 00004                       *
* (C) COPYRIGHT 1985 STEPHEN G. WRIGHT   *
* ALL RIGHTS RESERVED                    *
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***************************************************************
*                                                             *
*      RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
* PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
* HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL   *
* DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE   *
* ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER  *
* PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS      *
* PROGRAM BEFORE ATTEMPTING ITS USE.                         *
*                                                             *
*      NEITHER THE UNIVERSITY OF TEXAS NOR STEPHEN G. WRIGHT *
* MAKE OR ASSUME LIABILITY FOR ANY WARRANTIES, EXPRESSED OR  *
* IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS  *
* OR ADAPTABILITY OF THIS COMPUTER PROGRAM.                  *
*                                                             *
***************************************************************
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Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 2

```
*************************
* NEW PROFILE LINE DATA *
*************************
```

PROFILE LINE 1 - MATERIAL TYPE = 1
Bedrock

POINT	X	Y
1	-100.000	275.000
2	900.000	275.000

PROFILE LINE 2 - MATERIAL TYPE = 2
Glaciolacustrine Sand/Silt

POINT	X	Y
1	-100.000	290.000
2	900.000	290.000

PROFILE LINE 3 - MATERIAL TYPE = 3
LACUSTRINE CLAY

POINT X Y

1	-100.000	305.000
2	900.000	305.000

PROFILE LINE 4 - MATERIAL TYPE = 4
UPPER TILL

POINT	X	Y
1	-100.000	311.500
2	900.000	311.500

PROFILE LINE 5 - MATERIAL TYPE = 5
Lower Soil Liner

POINT	X	Y
1	-100.000	315.500
2	900.000	315.500

PROFILE LINE 6 - MATERIAL TYPE = 6
Synthetic Liner

POINT	X	Y
1	-100.000	316.000
2	900.000	316.000

PROFILE LINE 7 - MATERIAL TYPE = 5
Upper Soil Liner

POINT	X	Y
1	-100.000	318.000
2	383.000	318.000
3	391.000	322.000
4	399.000	322.000
5	407.000	318.000
6	900.000	318.000

PROFILE LINE 8 - MATERIAL TYPE = 7
Waste

POINT	X	Y
1	-100.000	375.000
2	232.000	375.000
3	391.000	322.000

ALL NEW PROFILE LINES DEFINED - NO OLD LINES RETAINED

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Model City Landfill
Chemical Waste Management
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TABLE NO. 3
****
* NEW MATERIAL PROPERTY DATA *
****

DATA FOR MATERIAL TYPE 1

BEDROCK

UNIT WEIGHT OF MATERIAL = 140.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 2000.000
FRICTION ANGLE - - - - - 40.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 2
Glaciolacustrine Sand/Silt

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - .000
FRICTION ANGLE - - - - - 30.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 3
Glaciolacustrine Clay

UNIT WEIGHT OF MATERIAL = 125.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 320.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 4
UPPER TILL

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 800.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 5
Soil Liner

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 1000.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 6
Synthetic Liner

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS

COHESION - - - - - - - - .000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 7
Waste

UNIT WEIGHT OF MATERIAL = 111.100

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - 800.000
FRICTION ANGLE - - - - - 13.500 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

ALL NEW MATERIAL PROPERTIES DEFINED - NO OLD DATA RETAINED
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TABLE NO. 9
****
* NEW ANALYSIS/COMPUTATION DATA *
****

CIRCULAR SHEAR SURFACE(S)

AUTOMATIC SEARCH PERFORMED

STARTING CENTER COORDINATE FOR SEARCH AT -
X = 280.000
Y = 500.000

REQUIRED ACCURACY FOR CRITICAL CENTER (= MINIMUM
SPACING BETWEEN GRID POINTS) = 1.000

CRITICAL SHEAR SURFACE NOT ALLOWED TO PASS BELOW Y = 270.000

FOR THE INITIAL MODE OF SEARCH
ALL CIRCLES ARE TANGENT TO HORIZONTAL LINE AT -
Y = 290.000

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

INITIAL TRIAL ESTIMATE FOR THE FACTOR OF SAFETY = 3.000

INITIAL TRIAL ESTIMATE FOR SIDE FORCE INCLINATION = 15.000 DEGREES
(APPLICABLE TO SPENCER'S PROCEDURE ONLY)

MAXIMUM NUMBER OF ITERATIONS ALLOWED FOR
CALCULATING THE FACTOR OF SAFETY = 40

ALLOWED FORCE IMBALANCE FOR CONVERGENCE = 100.000

ALLOWED MOMENT IMBALANCE FOR CONVERGENCE = 100.000

INITIAL TRIAL VALUES FOR FACTOR OF SAFETY (AND SIDE FORCE INCLINATION

FOR SPENCER'S PROCEDURE) WILL BE KEPT CONSTANT DURING SEARCH

MAXIMUM SUBTENDED ANGLE TO BE USED FOR SUBDIVISION OF THE CIRCLE INTO SLICES = 3.00 DEGREES

DEPTH OF CRACK = .000

SEARCH WILL BE CONTINUED TO LOCATE A MORE CRITICAL SHEAR SURFACE (IF ONE EXISTS) AFTER THE INITIAL MODE IS COMPLETE

DEPTH OF WATER IN CRACK = .000

UNIT WEIGHT OF WATER IN CRACK = 62.400

SEISMIC COEFFICIENT = .000

PROCEDURE USED TO COMPUTE THE FACTOR OF SAFETY: SPENCER

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Model City Landfill
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TABLE NO. 10

****
* NEW SLOPE GEOMETRY DATA *
****

NOTE - NO DATA WERE INPUT, SLOPE GEOMETRY DATA WERE GENERATED BY THE PROGRAM

SLOPE COORDINATES -

POINT	X	Y
1	-100.000	375.000
2	232.000	375.000
3	391.000	322.000
4	399.000	322.000
5	407.000	318.000
6	900.000	318.000

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TABLE NO. 12

INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES ARE TANGENT TO A HORIZONTAL LINE AT Y = 290.000

CENTER COORDINATES X	CENTER COORDINATES Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
250.00	470.00	180.00	2.514	-5.47	4
280.00	470.00	180.00	1.964	-6.51	5
310.00	470.00	180.00	1.655	-7.51	6
250.00	500.00	210.00	2.469	-5.56	4
280.00	500.00	210.00	1.970	-6.49	5

310.00	500.00	210.00	1.681	-7.30	6
250.00	530.00	240.00	2.450	-5.59	4
280.00	530.00	240.00	2.001	-6.33	5
310.00	530.00	240.00	1.722	-7.03	6
280.00	440.00	150.00	1.992	-6.38	5
310.00	440.00	150.00	1.669	-7.45	6
340.00	440.00	150.00	1.552	-8.35	8
340.00	470.00	180.00	1.555	-7.98	8
340.00	500.00	210.00	1.585	-7.55	7
310.00	410.00	120.00	1.710	-7.39	6
340.00	410.00	120.00	1.619	-8.19	9
370.00	410.00	120.00	1.857	-6.67	6
370.00	440.00	150.00	1.747	-7.29	6
370.00	470.00	180.00	1.675	-7.82	8
335.00	435.00	145.00	1.554	-8.36	9
340.00	435.00	145.00	1.556	-8.39	8
345.00	435.00	145.00	1.566	-8.37	7
335.00	440.00	150.00	1.551	-8.32	9
345.00	440.00	150.00	1.560	-8.35	7
335.00	445.00	155.00	1.549	-8.27	9
340.00	445.00	155.00	1.549	-8.30	8
345.00	445.00	155.00	1.556	-8.31	8
330.00	440.00	150.00	1.557	-8.25	7
330.00	445.00	155.00	1.556	-8.20	6
330.00	450.00	160.00	1.556	-8.15	6
335.00	450.00	160.00	1.549	-8.21	9
340.00	450.00	160.00	1.548	-8.24	8
345.00	450.00	160.00	1.554	-8.25	8
335.00	455.00	165.00	1.549	-8.15	9
340.00	455.00	165.00	1.548	-8.18	8
345.00	455.00	165.00	1.554	-8.20	8
337.00	447.00	157.00	1.548	-8.26	8
340.00	447.00	157.00	1.549	-8.28	8
343.00	447.00	157.00	1.552	-8.29	7
337.00	450.00	160.00	1.548	-8.23	8
343.00	450.00	160.00	1.551	-8.25	8
337.00	453.00	163.00	1.548	-8.19	8
340.00	453.00	163.00	1.548	-8.21	8
343.00	453.00	163.00	1.551	-8.22	8
334.00	447.00	157.00	1.549	-8.23	9
334.00	450.00	160.00	1.549	-8.20	9
334.00	453.00	163.00	1.550	-8.16	9
336.00	449.00	159.00	1.548	-8.23	8
337.00	449.00	159.00	1.548	-8.24	8
338.00	449.00	159.00	1.548	-8.25	8
336.00	450.00	160.00	1.548	-8.22	8
338.00	450.00	160.00	1.548	-8.23	8
336.00	451.00	161.00	1.548	-8.21	8
337.00	451.00	161.00	1.548	-8.22	8
338.00	451.00	161.00	1.548	-8.22	8
339.00	449.00	159.00	1.548	-8.25	8

339.00	450.00	160.00	1.548	-8.24	8
339.00	451.00	161.00	1.548	-8.22	8

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL
CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER = 338.00 Y-CENTER = 450.00 RADIUS = 160.00
FACTOR OF SAFETY = 1.548 SIDE FORCE INCLINATION = -8.23

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Model City Landfill
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Slope Stability - Waste Filling Sequence

TABLE NO. 13
INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES HAVE THE SAME RADIUS - RADIUS = 160.000

CENTER COORDINATES X	Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
308.00	420.00	160.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
338.00	420.00	160.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
368.00	420.00	160.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
308.00	450.00	160.00	1.679	-7.38	6
368.00	450.00	160.00	1.692	-7.72	7
308.00	480.00	160.00	2.364	-10.34	5
338.00	480.00	160.00	2.322	-12.81	5
368.00	480.00	160.00	2.988	-12.45	3
333.00	445.00	160.00	2.328	-10.59	4
338.00	445.00	160.00	2.311	-10.63	4
343.00	445.00	160.00	2.302	-10.64	4
333.00	450.00	160.00	1.551	-8.19	7
343.00	450.00	160.00	1.551	-8.25	8
333.00	455.00	160.00	1.585	-8.71	7
338.00	455.00	160.00	1.582	-8.78	6
343.00	455.00	160.00	1.586	-8.83	6
335.00	447.00	160.00	2.150	-10.46	5
338.00	447.00	160.00	2.143	-10.49	5
341.00	447.00	160.00	2.138	-10.50	5
335.00	450.00	160.00	1.549	-8.21	9
341.00	450.00	160.00	1.549	-8.25	8
335.00	453.00	160.00	1.566	-8.51	7
338.00	453.00	160.00	1.565	-8.54	8
341.00	453.00	160.00	1.566	-8.57	7
337.00	449.00	160.00	1.897	-9.93	5
338.00	449.00	160.00	1.896	-9.93	5
339.00	449.00	160.00	1.895	-9.94	5
337.00	450.00	160.00	1.548	-8.23	8
339.00	450.00	160.00	1.548	-8.24	8
337.00	451.00	160.00	1.552	-8.33	8
338.00	451.00	160.00	1.552	-8.33	8
339.00	451.00	160.00	1.552	-8.34	8

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL
CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER = 338.00 Y-CENTER = 450.00 RADIUS = 160.00
FACTOR OF SAFETY = 1.548 SIDE FORCE INCLINATION = -8.23

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 15

***** FINAL CRITICAL CIRCLE INFORMATION *****

X COORDINATE OF CENTER - - - - - - - -	338.000
Y COORDINATE OF CENTER - - - - - - - -	450.000
RADIUS - - - - - - - - - - - - - - - - -	160.000
FACTOR OF SAFETY - - - - - - - - - - -	1.548
SIDE FORCE INCLINATION - - - - - - - -	-8.23
NUMBER OF CIRCLES TRIED - - - - - - -	90
NO. OF CIRCLES F CALC. FOR - - - - - -	87

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Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 20

****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	196.7	375.0					
1	198.7	371.4	1668.9	7	800.00	13.50	.0
	200.8	367.7					
2	203.0	364.2	5407.5	7	800.00	13.50	.0
	205.3	360.6					
3	207.7	357.2	9594.6	7	800.00	13.50	.0
	210.1	353.8					
4	212.7	350.5	14159.5	7	800.00	13.50	.0
	215.3	347.3					
5	218.1	344.1	19028.0	7	800.00	13.50	.0
	220.9	341.0					
6	223.8	338.0	24123.8	7	800.00	13.50	.0
	226.8	335.0					
7	229.4	332.6	24696.3	7	800.00	13.50	.0
	232.0	330.2					
8	235.2	327.5	33135.0	7	800.00	13.50	.0
	238.4	324.8					
9	241.8	322.2	36794.3	7	800.00	13.50	.0
	245.1	319.7					
10	246.3	318.9	14094.9	7	800.00	13.50	.0
	247.6	318.0					
11	249.1	317.0	17440.2	5	1000.00	10.00	.0
	250.6	316.0					
12	251.0	315.8	4567.7	6	.00	10.00	.0
	251.3	315.5					
13	254.6	313.5	39812.7	5	1000.00	10.00	.0

	257.9	311.5					
14	261.6	309.5	46672.8	4	800.00	10.00	.0
	265.2	307.5					
15	267.8	306.2	33416.0	4	800.00	10.00	.0
	270.4	305.0					
16	274.2	303.3	51224.7	3	320.00	10.00	.0
	278.0	301.7					
17	282.0	300.2	53142.3	3	320.00	10.00	.0
	285.9	298.7					
18	289.9	297.5	54490.9	3	320.00	10.00	.0
	293.9	296.2					
19	297.9	295.2	55239.4	3	320.00	10.00	.0
	302.0	294.1					
20	306.1	293.3	55365.3	3	320.00	10.00	.0
	310.2	292.4					
21	314.3	291.8	54856.5	3	320.00	10.00	.0
	318.5	291.2					
22	322.6	290.8	53709.2	3	320.00	10.00	.0
	326.8	290.4					

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 20

```
*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL  *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)               *
*******************************************************************
```

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	326.8	290.4					
23	331.0	290.2	51930.0	3	320.00	10.00	.0
	335.2	290.0					
24	336.6	290.0	16949.2	3	320.00	10.00	.0
	338.0	290.0					
25	342.2	290.1	48596.3	3	320.00	10.00	.0
	346.4	290.2					
26	350.5	290.5	45419.5	3	320.00	10.00	.0
	354.7	290.9					
27	358.9	291.4	41700.2	3	320.00	10.00	.0
	363.0	292.0					
28	367.1	292.7	37484.4	3	320.00	10.00	.0
	371.3	293.5					
29	375.3	294.5	32826.1	3	320.00	10.00	.0
	379.4	295.5					
30	381.2	296.0	13019.8	3	320.00	10.00	.0
	383.0	296.5					
31	387.0	297.7	25740.5	3	320.00	10.00	.0
	391.0	299.0					
32	391.0	299.0	76.7	3	320.00	10.00	.0
	391.0	299.0					
33	394.9	300.5	21681.2	3	320.00	10.00	.0
	398.8	302.0					
34	398.9	302.0	442.6	3	320.00	10.00	.0
	399.0	302.1					
35	402.3	303.5	14449.0	3	320.00	10.00	.0
	405.6	305.0					

36	406.3	305.3	2303.9	4	800.00	10.00	.0
	407.0	305.6					
37	410.7	307.5	10137.7	4	800.00	10.00	.0
	414.5	309.5					
38	416.3	310.5	3570.5	4	800.00	10.00	.0
	418.1	311.5					
39	421.4	313.5	3830.5	5	1000.00	10.00	.0
	424.7	315.5					
40	425.0	315.8	225.6	6	.00	10.00	.0
	425.4	316.0					
41	426.9	317.0	388.9	5	1000.00	10.00	.0
	428.4	318.0					

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Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 21
****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

SLICE NO.	X	SEISMIC FORCE	Y FOR SEISMIC FORCE	FORCES DUE TO SURFACE PRESSURES NORMAL FORCE	SHEAR FORCE	X	Y
1	198.7	0.	373.2	0.	0.	.0	.0
2	203.0	0.	369.6	0.	0.	.0	.0
3	207.7	0.	366.1	0.	0.	.0	.0
4	212.7	0.	362.8	0.	0.	.0	.0
5	218.1	0.	359.6	0.	0.	.0	.0
6	223.8	0.	356.5	0.	0.	.0	.0
7	229.4	0.	353.8	0.	0.	.0	.0
8	235.2	0.	350.7	0.	0.	.0	.0
9	241.8	0.	347.0	0.	0.	.0	.0
10	246.3	0.	344.5	0.	0.	.0	.0
11	249.1	0.	343.1	0.	0.	.0	.0
12	251.0	0.	342.0	0.	0.	.0	.0
13	254.6	0.	340.1	0.	0.	.0	.0
14	261.6	0.	336.7	0.	0.	.0	.0
15	267.8	0.	333.9	0.	0.	.0	.0
16	274.2	0.	331.3	0.	0.	.0	.0
17	282.0	0.	328.4	0.	0.	.0	.0
18	289.9	0.	325.7	0.	0.	.0	.0
19	297.9	0.	323.2	0.	0.	.0	.0
20	306.1	0.	320.9	0.	0.	.0	.0
21	314.3	0.	318.8	0.	0.	.0	.0
22	322.6	0.	316.9	0.	0.	.0	.0
23	331.0	0.	315.3	0.	0.	.0	.0
24	336.6	0.	314.3	0.	0.	.0	.0
25	342.2	0.	313.5	0.	0.	.0	.0
26	350.5	0.	312.4	0.	0.	.0	.0
27	358.9	0.	311.5	0.	0.	.0	.0
28	367.1	0.	310.9	0.	0.	.0	.0
29	375.3	0.	310.5	0.	0.	.0	.0
30	381.2	0.	310.3	0.	0.	.0	.0
31	387.0	0.	310.4	0.	0.	.0	.0
32	391.0	0.	310.6	0.	0.	.0	.0

33	394.9	0.	311.3	0.	0.	.0	.0
34	398.9	0.	312.1	0.	0.	.0	.0
35	402.3	0.	312.0	0.	0.	.0	.0
36	406.3	0.	311.8	0.	0.	.0	.0
37	410.7	0.	312.8	0.	0.	.0	.0
38	416.3	0.	314.2	0.	0.	.0	.0
39	421.4	0.	315.8	0.	0.	.0	.0
40	425.0	0.	316.9	0.	0.	.0	.0
41	426.9	0.	317.5	0.	0.	.0	.0

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        Chemical Waste Management
        Slope Stability - Waste Filling Sequence

      TABLE NO. 23
      *****************************************************************
      * INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
      * OF SAFETY AND SIDE FORCE INCLINATION BY SPENCER'S PROCEDURE    *
      *****************************************************************

              TRIAL      TRIAL
             FACTOR    SIDE FORCE     FORCE      MOMENT                 DELTA
      ITER-    OF     INCLINATION   IMBALANCE   IMBALANCE    DELTA-F    THETA
      ATION  SAFETY    (DEGREES)     (LBS.)    (FT.-LBS.)             (DEGREES)

         1  3.00000   -15.0000   -.1076E+06   .3834E+08
      FIRST-ORDER CORRECTIONS TO F AND THETA .........   .652E+01 -.159E+03
      VALUES FACTORED BY  .541E-01 - DELTAS TOO LARGE    .353E+00 -.859E+01

         2  3.35285   -23.5944   -.1000E+06   .3478E+08
      FIRST-ORDER CORRECTIONS TO F AND THETA .........  -.559E+01  .402E+02
      VALUES FACTORED BY  .894E-01 - DELTAS TOO LARGE   -.500E+00  .359E+01

         3  2.85285   -20.0052   -.8795E+05   .3042E+08
      FIRST-ORDER CORRECTIONS TO F AND THETA .........  -.358E+01  .350E+02
      VALUES FACTORED BY  .140E+00 - DELTAS TOO LARGE   -.500E+00  .490E+01

         4  2.35285   -15.1095   -.7050E+05   .2424E+08
      FIRST-ORDER CORRECTIONS TO F AND THETA .........  -.170E+01  .206E+02
      VALUES FACTORED BY  .294E+00 - DELTAS TOO LARGE   -.500E+00  .605E+01

         5  1.85285    -9.0611   -.4012E+05   .1398E+08
      FIRST-ORDER CORRECTIONS TO F AND THETA .........  -.381E+00  .159E+01
      SECOND-ORDER CORRECTION - ITERATION   1 ........  -.326E+00  .159E+01
      SECOND-ORDER CORRECTION - ITERATION   2 ........  -.325E+00  .159E+01
      SECOND-ORDER CORRECTION - ITERATION   3 ........  -.325E+00  .159E+01

         6  1.52806    -7.4704    .1344E+04  -.1970E+06
      FIRST-ORDER CORRECTIONS TO F AND THETA .........   .190E-01 -.753E+00
      SECOND-ORDER CORRECTION - ITERATION   1 ........   .193E-01 -.753E+00
      SECOND-ORDER CORRECTION - ITERATION   2 ........   .193E-01 -.753E+00

         7  1.54739    -8.2236   -.5022E+00   .3572E+04
      FIRST-ORDER CORRECTIONS TO F AND THETA .........   .141E-03 -.949E-02
      SECOND-ORDER CORRECTION - ITERATION   1 ........   .142E-03 -.949E-02

         8  1.54753    -8.2331    .4639E-02  -.9646E+01
      FIRST-ORDER CORRECTIONS TO F AND THETA .........  -.313E-06  .224E-04

      FACTOR OF SAFETY - - - - - - - -      1.548
```

SIDE FORCE INCLINATION - - - - - -8.23
NUMBER OF ITERATIONS - - - - - - 8
1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 24
****
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH) *
****

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
FACTOR OF SAFETY = 1.548 SIDE FORCE INCLINATION = -8.23 DEGREES

-------- VALUES AT CENTER OF BASE OF SLICE---------

SLICE NO.	X-CENTER	Y-CENTER	TOTAL NORMAL STRESS	EFFECTIVE NORMAL STRESS	SHEAR STRESS
1	198.7	371.4	-288.7	-288.7	472.2
2	203.0	364.2	320.8	320.8	566.7
3	207.7	357.2	946.3	946.3	663.8
4	212.7	350.5	1580.6	1580.6	762.2
5	218.1	344.1	2217.8	2217.8	861.0
6	223.8	338.0	2852.4	2852.4	959.5
7	229.4	332.6	3434.7	3434.7	1049.8
8	235.2	327.5	3908.9	3908.9	1123.4
9	241.8	322.2	4308.3	4308.3	1185.3
10	246.3	318.9	4564.9	4564.9	1225.1
11	249.1	317.0	4748.9	4748.9	1187.3
12	251.0	315.8	5145.2	5145.2	586.3
13	254.6	313.5	5062.6	5062.6	1223.0
14	261.6	309.5	5458.5	5458.5	1138.9
15	267.8	306.2	5727.8	5727.8	1169.6
16	274.2	303.3	6029.7	6029.7	893.8
17	282.0	300.2	6226.3	6226.3	916.2
18	289.9	297.5	6371.0	6371.0	932.7
19	297.9	295.2	6462.1	6462.1	943.1
20	306.1	293.3	6497.9	6497.9	947.2
21	314.3	291.8	6476.8	6476.8	944.8
22	322.6	290.8	6397.4	6397.4	935.7
23	331.0	290.2	6258.5	6258.5	919.9
24	336.6	290.0	6138.1	6138.1	906.2
25	342.2	290.1	5977.8	5977.8	887.9
26	350.5	290.5	5694.9	5694.9	855.7
27	358.9	291.4	5348.6	5348.6	816.2
28	367.1	292.7	4937.4	4937.4	769.4
29	375.3	294.5	4460.2	4460.2	715.0
30	381.2	296.0	4078.8	4078.8	671.5
31	387.0	297.7	3692.6	3692.6	627.5
32	391.0	299.0	3426.4	3426.4	597.2
33	394.9	300.5	3252.1	3252.1	577.3
34	398.9	302.0	3071.5	3071.5	556.8
35	402.3	303.5	2640.7	2640.7	507.7
36	406.3	305.3	2335.0	2335.0	783.0
37	410.7	307.5	1993.7	1993.7	744.1
38	416.3	310.5	1601.9	1601.9	699.5

39	421.4	313.5	1300.1	1300.1	794.3
40	425.0	315.8	358.5	358.5	40.9

1

-------- VALUES AT CENTER OF BASE OF SLICE---------

SLICE NO.	X-CENTER	Y-CENTER	TOTAL NORMAL STRESS	EFFECTIVE NORMAL STRESS	SHEAR STRESS
41	426.9	317.0	808.7	808.7	738.3

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = .02 (= .239E-01)
SHOULD NOT EXCEED .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = .07 (= .708E-01)
SHOULD NOT EXCEED .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN = 9.61 (= .961E+01)
SHOULD NOT EXCEED .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = .00 (= .886E-02)
SHOULD NOT EXCEED .100E+03

***** CAUTION ***** EFFECTIVE OR TOTAL NORMAL STRESS ON SHEAR SURFACE IS NEGATIVE AT POINTS ALONG THE UPPER ONE-HALF OF THE SHEAR SURFACE - A TENSION CRACK MAY BE NEEDED.

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 25
****
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH) *
****

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
FACTOR OF SAFETY = 1.548 SIDE FORCE INCLINATION = -8.23 DEGREES

-------------- VALUES AT RIGHT SIDE OF SLICE ---------------

SLICE NO.	X-RIGHT	SIDE FORCE	Y-COORD. OF SIDE FORCE LOCATION	FRACTION OF HEIGHT	SIGMA AT TOP	SIGMA AT BOTTOM
1	200.8	-4093.	371.1	.459	-419.2	-691.4
2	205.3	-4375.	370.0	.651	-573.8	-29.1
3	210.1	-1110.	405.8	ABOVE	-659.2	555.6
4	215.3	5356.	338.8	BELOW	-731.8	1113.9
5	220.9	14600.	341.6	.019	-801.7	1651.0
6	226.8	26146.	339.3	.109	-871.4	2165.1
7	232.0	37408.	336.7	.147	-933.9	2604.7
8	238.4	51386.	333.4	.179	-981.4	3096.2
9	245.1	65313.	330.1	.204	-983.4	3523.0
10	247.6	70219.	329.0	.212	-975.0	3657.9
11	250.6	76227.	327.6	.220	-969.2	3826.3
12	251.3	78370.	327.2	.220	-990.0	3913.9
13	257.9	90739.	324.4	.236	-956.3	4229.6

14	265.2	104349.	321.5	.248	-934.7	4595.6
15	270.4	112757.	319.7	.256	-903.9	4804.9
16	278.0	126176.	316.9	.262	-919.2	5225.7
17	285.9	137375.	314.4	.269	-898.7	5561.8
18	293.9	146069.	312.3	.276	-848.2	5818.5
19	302.0	152043.	310.5	.284	-771.6	5999.6
20	310.2	155160.	308.9	.292	-671.7	6107.4
21	318.5	155361.	307.7	.301	-549.6	6143.1
22	326.8	152675.	306.8	.310	-405.8	6107.4
23	335.2	147215.	306.2	.319	-239.6	6000.6
24	338.0	144792.	306.0	.323	-178.4	5948.8
25	346.4	135955.	305.8	.335	21.2	5746.7
26	354.7	124953.	305.9	.348	250.6	5472.6
27	363.0	112195.	306.3	.364	517.2	5125.9
28	371.3	98177.	306.9	.383	833.0	4706.3
29	379.4	83480.	307.9	.408	1218.8	4214.7
30	383.0	76896.	308.3	.421	1422.9	3972.9
31	391.0	62268.	309.5	.458	1998.9	3363.5
32	391.0	62221.	309.5	.445	1748.2	3466.2
33	398.8	47860.	311.0	.447	1618.3	3121.7
34	399.0	47544.	311.0	.466	1967.3	2963.6
35	405.6	36360.	312.2	.524	3005.6	2255.1
36	407.0	33766.	312.5	.515	2740.6	2288.6
37	414.5	20484.	314.3	.563	3261.0	1482.1
38	418.1	14589.	315.2	.562	3050.8	1391.8
39	424.7	4079.	317.2	.700	3551.2	-321.8
40	425.4	3866.	317.2	.609	3162.1	663.9

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-------------- VALUES AT RIGHT SIDE OF SLICE ---------------

SLICE NO.	X-RIGHT	SIDE FORCE	Y-COORD. OF SIDE FORCE LOCATION	FRACTION OF HEIGHT	SIGMA AT TOP	SIGMA AT BOTTOM
41	428.4	9.	-201.9	BELOW	.0	.0

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION - .02 (= .239E-01)
SHOULD NOT EXCEED .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION - .07 (= .708E-01)
SHOULD NOT EXCEED .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN - 9.61 (= .961E+01)
SHOULD NOT EXCEED .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM - .00 (= .886E-02)
SHOULD NOT EXCEED .100E+03

END-OF-FILE ENCOUNTERED WHILE READING COMMAND
WORDS - END OF PROBLEM(S) ASSUMED

CASE 3. H = 62 FEET

SLOPE=3:1

TABLE NO. 1

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*******************************************
* COMPUTER PROGRAM DESIGNATION - UTEXAS2 *
* ORIGINALLY CODED BY STEPHEN G. WRIGHT  *
* VERSION NO. 1.209                      *
* LAST REVISION DATE 11/23/87            *
* SERIAL NO. 00004                       *
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*                                                             *
*      RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
* PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
* HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL   *
* DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE   *
* ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER  *
* PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS      *
* PROGRAM BEFORE ATTEMPTING ITS USE.                          *
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*                                                             *
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Model City Landfill
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TABLE NO. 2

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*************************
* NEW PROFILE LINE DATA *
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PROFILE LINE 1 - MATERIAL TYPE = 1
Bedrock

POINT	X	Y
1	-100.000	275.000
2	900.000	275.000

PROFILE LINE 2 - MATERIAL TYPE = 2
Glaciolacustrine Sand/Silt

POINT	X	Y
1	-100.000	290.000
2	900.000	290.000

PROFILE LINE 3 - MATERIAL TYPE = 3
LACUSTRINE CLAY

POINT	X	Y

1	-100.000	305.000
2	900.000	305.000

PROFILE LINE 4 - MATERIAL TYPE = 4
UPPER TILL

POINT	X	Y
1	-100.000	311.500
2	900.000	311.500

PROFILE LINE 5 - MATERIAL TYPE = 5
Lower Soil Liner

POINT	X	Y
1	-100.000	315.500
2	900.000	315.500

PROFILE LINE 6 - MATERIAL TYPE = 6
Synthetic Liner

POINT	X	Y
1	-100.000	316.000
2	900.000	316.000

PROFILE LINE 7 - MATERIAL TYPE = 5
Upper Soil Liner

POINT	X	Y
1	-100.000	318.000
2	383.000	318.000
3	391.000	322.000
4	399.000	322.000
5	407.000	318.000
6	900.000	318.000

PROFILE LINE 8 - MATERIAL TYPE = 7
Waste

POINT	X	Y
1	-100.000	380.000
2	217.000	380.000
3	391.000	322.000

ALL NEW PROFILE LINES DEFINED - NO OLD LINES RETAINED

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TABLE NO. 3
****
* NEW MATERIAL PROPERTY DATA *
****

DATA FOR MATERIAL TYPE 1

BEDROCK

UNIT WEIGHT OF MATERIAL = 140.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 2000.000
FRICTION ANGLE - - - - - 40.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 2
Glaciolacustrine Sand/Silt

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - .000
FRICTION ANGLE - - - - - 30.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 3
Glaciolacustrine Clay

UNIT WEIGHT OF MATERIAL = 125.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 320.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 4
UPPER TILL

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 800.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 5
Soil Liner

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 1000.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 6
Synthetic Liner

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS

COHESION - - - - - - - - .000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 7
Waste

UNIT WEIGHT OF MATERIAL = 111.100

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - 800.000
FRICTION ANGLE - - - - - 13.500 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

ALL NEW MATERIAL PROPERTIES DEFINED - NO OLD DATA RETAINED

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TABLE NO. 9
****
* NEW ANALYSIS/COMPUTATION DATA *
****

CIRCULAR SHEAR SURFACE(S)

AUTOMATIC SEARCH PERFORMED

STARTING CENTER COORDINATE FOR SEARCH AT -
X = 280.000
Y = 500.000

REQUIRED ACCURACY FOR CRITICAL CENTER (= MINIMUM
SPACING BETWEEN GRID POINTS) = 1.000

CRITICAL SHEAR SURFACE NOT ALLOWED TO PASS BELOW Y = 270.000

FOR THE INITIAL MODE OF SEARCH
ALL CIRCLES ARE TANGENT TO HORIZONTAL LINE AT -
Y = 290.000

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

INITIAL TRIAL ESTIMATE FOR THE FACTOR OF SAFETY = 3.000

INITIAL TRIAL ESTIMATE FOR SIDE FORCE INCLINATION = 15.000 DEGREES
(APPLICABLE TO SPENCER'S PROCEDURE ONLY)

MAXIMUM NUMBER OF ITERATIONS ALLOWED FOR
CALCULATING THE FACTOR OF SAFETY = 40

ALLOWED FORCE IMBALANCE FOR CONVERGENCE = 100.000

ALLOWED MOMENT IMBALANCE FOR CONVERGENCE = 100.000

INITIAL TRIAL VALUES FOR FACTOR OF SAFETY (AND SIDE FORCE INCLINATION

FOR SPENCER'S PROCEDURE) WILL BE KEPT CONSTANT DURING SEARCH

MAXIMUM SUBTENDED ANGLE TO BE USED FOR SUBDIVISION OF THE CIRCLE INTO SLICES = 3.00 DEGREES

DEPTH OF CRACK = .000

SEARCH WILL BE CONTINUED TO LOCATE A MORE CRITICAL SHEAR SURFACE (IF ONE EXISTS) AFTER THE INITIAL MODE IS COMPLETE

DEPTH OF WATER IN CRACK = .000

UNIT WEIGHT OF WATER IN CRACK = 62.400

SEISMIC COEFFICIENT = .000

PROCEDURE USED TO COMPUTE THE FACTOR OF SAFETY: SPENCER

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TABLE NO. 10

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**************************
* NEW SLOPE GEOMETRY DATA *
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NOTE - NO DATA WERE INPUT, SLOPE GEOMETRY DATA WERE GENERATED BY THE PROGRAM

SLOPE COORDINATES -

POINT	X	Y
1	-100.000	380.000
2	217.000	380.000
3	391.000	322.000
4	399.000	322.000
5	407.000	318.000
6	900.000	318.000

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TABLE NO. 12

INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES ARE TANGENT TO A HORIZONTAL LINE AT Y = 290.000

CENTER COORDINATES X	Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
250.00	470.00	180.00	2.218	-5.97	4
280.00	470.00	180.00	1.790	-7.07	6
310.00	470.00	180.00	1.550	-8.16	6
250.00	500.00	210.00	2.190	-6.05	5
280.00	500.00	210.00	1.796	-7.02	6

310.00	500.00	210.00	1.569	-7.92	6
250.00	530.00	240.00	2.183	-6.08	5
280.00	530.00	240.00	1.826	-6.84	5
310.00	530.00	240.00	1.603	-7.61	6
280.00	440.00	150.00	1.816	-6.94	5
310.00	440.00	150.00	1.574	-8.11	6
340.00	440.00	150.00	1.516	-8.84	7
340.00	470.00	180.00	1.495	-8.63	8
340.00	500.00	210.00	1.510	-8.22	8
370.00	440.00	150.00	1.747	-7.29	6
370.00	470.00	180.00	1.669	-7.86	8
370.00	500.00	210.00	1.624	-8.09	8
335.00	465.00	175.00	1.490	-8.68	8
340.00	465.00	175.00	1.495	-8.69	8
345.00	465.00	175.00	1.507	-8.67	8
335.00	470.00	180.00	1.491	-8.61	8
345.00	470.00	180.00	1.505	-8.62	8
335.00	475.00	185.00	1.493	-8.54	7
340.00	475.00	185.00	1.496	-8.57	8
345.00	475.00	185.00	1.505	-8.56	8
330.00	460.00	170.00	1.491	-8.70	8
335.00	460.00	170.00	1.491	-8.74	7
340.00	460.00	170.00	1.497	-8.74	8
330.00	465.00	175.00	1.491	-8.64	9
330.00	470.00	180.00	1.492	-8.57	9
332.00	462.00	172.00	1.490	-8.69	8
335.00	462.00	172.00	1.490	-8.71	8
338.00	462.00	172.00	1.493	-8.72	8
332.00	465.00	175.00	1.490	-8.66	8
338.00	465.00	175.00	1.493	-8.69	8
332.00	468.00	178.00	1.491	-8.62	8
335.00	468.00	178.00	1.491	-8.64	8
338.00	468.00	178.00	1.493	-8.65	8
329.00	459.00	169.00	1.492	-8.69	9
332.00	459.00	169.00	1.490	-8.73	8
335.00	459.00	169.00	1.491	-8.75	7
329.00	462.00	172.00	1.492	-8.66	9
329.00	465.00	175.00	1.492	-8.63	8
331.00	461.00	171.00	1.490	-8.70	8
332.00	461.00	171.00	1.490	-8.71	8
333.00	461.00	171.00	1.490	-8.71	8
331.00	462.00	172.00	1.490	-8.68	8
333.00	462.00	172.00	1.490	-8.70	8
331.00	463.00	173.00	1.491	-8.68	8
332.00	463.00	173.00	1.491	-8.69	8
333.00	463.00	173.00	1.491	-8.70	8
334.00	461.00	171.00	1.490	-8.72	8
334.00	462.00	172.00	1.490	-8.71	8
334.00	463.00	173.00	1.491	-8.70	8

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -

X-CENTER = 333.00 Y-CENTER = 462.00 RADIUS = 172.00
FACTOR OF SAFETY = 1.490 SIDE FORCE INCLINATION = -8.70

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TABLE NO. 13
INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES HAVE THE SAME RADIUS - RADIUS = 172.000

CENTER COORDINATES X	Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
303.00	432.00	172.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
333.00	432.00	172.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
363.00	432.00	172.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
303.00	462.00	172.00	1.603	-7.80	6
363.00	462.00	172.00	1.615	-8.15	8
303.00	492.00	172.00	2.229	-10.74	5
333.00	492.00	172.00	2.206	-12.98	5
363.00	492.00	172.00	2.723	-12.75	5
328.00	457.00	172.00	2.234	-11.03	5
333.00	457.00	172.00	2.219	-11.08	5
338.00	457.00	172.00	2.211	-11.09	5
328.00	462.00	172.00	1.493	-8.65	8
338.00	462.00	172.00	1.493	-8.72	8
328.00	467.00	172.00	1.527	-9.16	7
333.00	467.00	172.00	1.524	-9.24	6
338.00	467.00	172.00	1.528	-9.29	6
330.00	459.00	172.00	2.066	-10.90	5
333.00	459.00	172.00	2.059	-10.93	5
336.00	459.00	172.00	2.055	-10.95	5
330.00	462.00	172.00	1.491	-8.67	8
336.00	462.00	172.00	1.491	-8.72	8
330.00	465.00	172.00	1.508	-8.97	7
333.00	465.00	172.00	1.507	-9.01	7
336.00	465.00	172.00	1.508	-9.03	7
332.00	461.00	172.00	1.825	-10.38	6
333.00	461.00	172.00	1.824	-10.39	6
334.00	461.00	172.00	1.823	-10.39	6
332.00	462.00	172.00	1.490	-8.69	8
334.00	462.00	172.00	1.490	-8.71	8
332.00	463.00	172.00	1.495	-8.79	8
333.00	463.00	172.00	1.495	-8.80	8
334.00	463.00	172.00	1.495	-8.81	8

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER = 333.00 Y-CENTER = 462.00 RADIUS = 172.00
FACTOR OF SAFETY = 1.490 SIDE FORCE INCLINATION = -8.70

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TABLE NO. 15
***** FINAL CRITICAL CIRCLE INFORMATION *****

X COORDINATE OF CENTER - - - - - - - -	333.000
Y COORDINATE OF CENTER - - - - - - - -	462.000
RADIUS - - - - - - - - - - - - - - - - -	172.000
FACTOR OF SAFETY - - - - - - - - - - -	1.490
SIDE FORCE INCLINATION - - - - - - - -	-8.70

NUMBER OF CIRCLES TRIED - - - - - - -	86
NO. OF CIRCLES F CALC. FOR - - - - - -	83

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TABLE NO. 20
****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	181.8	380.0					
1	184.1	376.1	1949.4	7	800.00	13.50	.0
	186.3	372.2					
2	188.8	368.4	6303.9	7	800.00	13.50	.0
	191.2	364.6					
3	193.8	361.0	11164.9	7	800.00	13.50	.0
	196.5	357.4					
4	199.3	353.9	16450.0	7	800.00	13.50	.0
	202.2	350.4					
5	205.2	347.0	22073.3	7	800.00	13.50	.0
	208.2	343.7					
6	211.4	340.5	27946.4	7	800.00	13.50	.0
	214.5	337.3					
7	215.8	336.1	11964.6	7	800.00	13.50	.0
	217.0	335.0					
8	220.4	332.1	35392.5	7	800.00	13.50	.0
	223.8	329.1					
9	227.4	326.3	39630.0	7	800.00	13.50	.0
	230.9	323.6					
10	234.6	321.0	43593.1	7	800.00	13.50	.0
	238.3	318.4					
11	238.6	318.2	3890.0	7	800.00	13.50	.0
	238.9	318.0					
12	240.5	317.0	19274.9	5	1000.00	10.00	.0
	242.1	316.0					
13	242.5	315.8	5038.4	6	.00	10.00	.0
	242.9	315.5					
14	246.3	313.5	43767.7	5	1000.00	10.00	.0
	249.7	311.5					
15	253.7	309.4	53081.9	4	800.00	10.00	.0
	257.7	307.3					

16	260.2	306.2	34319.0	4	800.00	10.00	.0
	262.8	305.0					
17	266.9	303.3	57744.9	3	320.00	10.00	.0
	271.1	301.5					
18	275.3	300.0	59723.1	3	320.00	10.00	.0
	279.5	298.5					
19	283.9	297.2	61038.0	3	320.00	10.00	.0
	288.2	295.9					
20	292.6	294.9	61656.7	3	320.00	10.00	.0
	296.9	293.8					
21	301.4	293.0	61556.9	3	320.00	10.00	.0
	305.8	292.2					
22	310.2	291.6	60727.1	3	320.00	10.00	.0
	314.7	291.0					

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TABLE NO. 20
****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)   *
****

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	314.7	291.0					
23	319.2	290.6	59167.6	3	320.00	10.00	.0
	323.7	290.3					
24	328.2	290.1	56888.4	3	320.00	10.00	.0
	332.7	290.0					
25	332.8	290.0	1962.9	3	320.00	10.00	.0
	333.0	290.0					
26	337.5	290.1	53793.8	3	320.00	10.00	.0
	342.0	290.2					
27	346.5	290.6	50129.2	3	320.00	10.00	.0
	351.0	290.9					
28	355.4	291.5	45844.0	3	320.00	10.00	.0
	359.9	292.1					
29	364.3	292.9	40991.6	3	320.00	10.00	.0
	368.8	293.8					
30	373.1	294.8	35634.1	3	320.00	10.00	.0
	377.5	295.9					
31	380.3	296.6	19611.3	3	320.00	10.00	.0
	383.0	297.4					
32	387.0	298.8	24811.7	3	320.00	10.00	.0
	391.0	300.1					
33	395.0	301.6	21059.6	3	320.00	10.00	.0
	399.0	303.2					
34	401.1	304.1	9291.6	3	320.00	10.00	.0
	403.2	305.0					
35	405.1	305.9	6373.0	4	800.00	10.00	.0
	407.0	306.7					
36	411.0	308.8	9623.2	4	800.00	10.00	.0
	415.0	310.8					
37	415.6	311.2	1106.7	4	800.00	10.00	.0
	416.3	311.5					
38	419.7	313.5	4008.2	5	1000.00	10.00	.0

	423.1	315.5					
39	423.5	315.8	236.3	6	.00	10.00	.0
	423.9	316.0					
40	425.5	317.0	407.6	5	1000.00	10.00	.0
	427.1	318.0					

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TABLE NO. 21
****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

				FORCES DUE TO SURFACE PRESSURES			
SLICE NO.	X	SEISMIC FORCE	Y FOR SEISMIC FORCE	NORMAL FORCE	SHEAR FORCE	X	Y
1	184.1	0.	378.0	0.	0.	.0	.0
2	188.8	0.	374.2	0.	0.	.0	.0
3	193.8	0.	370.5	0.	0.	.0	.0
4	199.3	0.	366.9	0.	0.	.0	.0
5	205.2	0.	363.5	0.	0.	.0	.0
6	211.4	0.	360.2	0.	0.	.0	.0
7	215.8	0.	358.1	0.	0.	.0	.0
8	220.4	0.	355.5	0.	0.	.0	.0
9	227.4	0.	351.4	0.	0.	.0	.0
10	234.6	0.	347.6	0.	0.	.0	.0
11	238.6	0.	345.5	0.	0.	.0	.0
12	240.5	0.	344.5	0.	0.	.0	.0
13	242.5	0.	343.4	0.	0.	.0	.0
14	246.3	0.	341.5	0.	0.	.0	.0
15	253.7	0.	338.0	0.	0.	.0	.0
16	260.2	0.	335.1	0.	0.	.0	.0
17	266.9	0.	332.4	0.	0.	.0	.0
18	275.3	0.	329.4	0.	0.	.0	.0
19	283.9	0.	326.5	0.	0.	.0	.0
20	292.6	0.	323.9	0.	0.	.0	.0
21	301.4	0.	321.5	0.	0.	.0	.0
22	310.2	0.	319.3	0.	0.	.0	.0
23	319.2	0.	317.4	0.	0.	.0	.0
24	328.2	0.	315.7	0.	0.	.0	.0
25	332.8	0.	314.9	0.	0.	.0	.0
26	337.5	0.	314.2	0.	0.	.0	.0
27	346.5	0.	313.0	0.	0.	.0	.0
28	355.4	0.	312.1	0.	0.	.0	.0
29	364.3	0.	311.4	0.	0.	.0	.0
30	373.1	0.	311.0	0.	0.	.0	.0
31	380.3	0.	310.8	0.	0.	.0	.0
32	387.0	0.	310.9	0.	0.	.0	.0
33	395.0	0.	311.9	0.	0.	.0	.0
34	401.1	0.	312.5	0.	0.	.0	.0
35	405.1	0.	312.4	0.	0.	.0	.0
36	411.0	0.	313.4	0.	0.	.0	.0
37	415.6	0.	314.6	0.	0.	.0	.0
38	419.7	0.	315.8	0.	0.	.0	.0
39	423.5	0.	316.9	0.	0.	.0	.0

```
   40    425.5        0.        317.5        0.         0.         .0         .0
1  UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
     Model City Landfill
     Chemical Waste Management
     Slope Stability - Waste Filling Sequence

   TABLE NO. 23
   *******************************************************************
   * INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
   * OF SAFETY AND SIDE FORCE INCLINATION BY SPENCER'S PROCEDURE    *
   *******************************************************************

          TRIAL     TRIAL
          FACTOR   SIDE FORCE    FORCE     MOMENT                DELTA
   ITER-   OF     INCLINATION  IMBALANCE  IMBALANCE   DELTA-F    THETA
   ATION  SAFETY   (DEGREES)    (LBS.)    (FT.-LBS.)           (DEGREES)

     1   3.00000   -15.0000  -.1285E+06   .4597E+08
   FIRST-ORDER CORRECTIONS TO F AND THETA .........   .363E+01 -.116E+03
   VALUES FACTORED BY  .741E-01 - DELTAS TOO LARGE    .269E+00 -.859E+01

     2   3.26869   -23.5944  -.1180E+06   .4123E+08
   FIRST-ORDER CORRECTIONS TO F AND THETA .........  -.533E+01  .386E+02
   VALUES FACTORED BY  .938E-01 - DELTAS TOO LARGE   -.500E+00  .362E+01

     3   2.76869   -19.9694  -.1034E+06   .3594E+08
   FIRST-ORDER CORRECTIONS TO F AND THETA .........  -.336E+01  .333E+02
   VALUES FACTORED BY  .149E+00 - DELTAS TOO LARGE   -.500E+00  .494E+01

     4   2.26869   -15.0278  -.8195E+05   .2835E+08
   FIRST-ORDER CORRECTIONS TO F AND THETA .........  -.156E+01  .185E+02
   VALUES FACTORED BY  .320E+00 - DELTAS TOO LARGE   -.500E+00  .592E+01

     5   1.76869    -9.1040  -.4411E+05   .1552E+08
   FIRST-ORDER CORRECTIONS TO F AND THETA .........  -.336E+00  .738E+00
   SECOND-ORDER CORRECTION - ITERATION   1 ........  -.291E+00  .738E+00
   SECOND-ORDER CORRECTION - ITERATION   2 ........  -.290E+00  .738E+00
   SECOND-ORDER CORRECTION - ITERATION   3 ........  -.290E+00  .738E+00

     6   1.47904    -8.3664   .1215E+04  -.2920E+06
   FIRST-ORDER CORRECTIONS TO F AND THETA .........   .107E-01 -.332E+00
   SECOND-ORDER CORRECTION - ITERATION   1 ........   .108E-01 -.332E+00
   SECOND-ORDER CORRECTION - ITERATION   2 ........   .108E-01 -.332E+00

     7   1.48986    -8.6985  -.1028E+00   .1483E+04
   FIRST-ORDER CORRECTIONS TO F AND THETA .........   .484E-04 -.356E-02
   SECOND-ORDER CORRECTION - ITERATION   1 ........   .484E-04 -.356E-02

     8   1.48991    -8.7021  -.1807E-01   .5206E+01
   FIRST-ORDER CORRECTIONS TO F AND THETA .........  -.134E-06  .292E-05

   FACTOR OF SAFETY - - - - - - - - -       1.490
   SIDE FORCE INCLINATION - - - - -        -8.70
   NUMBER OF ITERATIONS - - - - - -        8
1  UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
     Model City Landfill
     Chemical Waste Management
     Slope Stability - Waste Filling Sequence

   TABLE NO. 24
```

```
*********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
*********************************************
```

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
FACTOR OF SAFETY = 1.490   SIDE FORCE INCLINATION = -8.70 DEGREES

-------- VALUES AT CENTER OF BASE OF SLICE---------

SLICE NO.	X-CENTER	Y-CENTER	TOTAL NORMAL STRESS	EFFECTIVE NORMAL STRESS	SHEAR STRESS
1	184.1	376.1	-273.3	-273.3	492.9
2	188.8	368.4	370.5	370.5	596.6
3	193.8	361.0	1031.9	1031.9	703.2
4	199.3	353.9	1703.4	1703.4	811.4
5	205.2	347.0	2378.5	2378.5	920.2
6	211.4	340.5	3051.4	3051.4	1028.6
7	215.8	336.1	3512.6	3512.6	1103.0
8	220.4	332.1	3861.5	3861.5	1159.2
9	227.4	326.3	4296.7	4296.7	1229.3
10	234.6	321.0	4696.8	4696.8	1293.8
11	238.6	318.2	4903.7	4903.7	1327.1
12	240.5	317.0	5040.9	5040.9	1267.8
13	242.5	315.8	5424.3	5424.3	641.9
14	246.3	313.5	5348.3	5348.3	1304.1
15	253.7	309.4	5740.6	5740.6	1216.3
16	260.2	306.2	6003.7	6003.7	1247.5
17	266.9	303.3	6292.6	6292.6	959.5
18	275.3	300.0	6487.2	6487.2	982.5
19	283.9	297.2	6625.9	6625.9	998.9
20	292.6	294.9	6706.6	6706.6	1008.5
21	301.4	293.0	6727.4	6727.4	1010.9
22	310.2	291.6	6686.7	6686.7	1006.1
23	319.2	290.6	6582.8	6582.8	993.8
24	328.2	290.1	6414.2	6414.2	973.9
25	332.8	290.0	6308.5	6308.5	961.4
26	337.5	290.1	6170.0	6170.0	945.0
27	346.5	290.6	5865.4	5865.4	908.9
28	355.4	291.5	5491.8	5491.8	864.7
29	364.3	292.9	5047.7	5047.7	812.2
30	373.1	294.8	4531.4	4531.4	751.1
31	380.3	296.6	4059.3	4059.3	695.2
32	387.0	298.8	3593.0	3593.0	640.0
33	395.0	301.6	3133.9	3133.9	585.7
34	401.1	304.1	2673.4	2673.4	531.2
35	405.1	305.9	2369.5	2369.5	817.4
36	411.0	308.8	1842.8	1842.8	755.0
37	415.6	311.2	1519.1	1519.1	716.7
38	419.7	313.5	1311.0	1311.0	826.3
39	423.5	315.8	359.4	359.4	42.5
40	425.5	317.0	817.2	817.2	767.9

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = .02 (= .244E-01)
SHOULD NOT EXCEED .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = .07 (= .670E-01)

```
     SHOULD NOT EXCEED      .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN =       -10.58  (= -.106E+02)
     SHOULD NOT EXCEED      .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM    =         .00  (=  .643E-02)
     SHOULD NOT EXCEED      .100E+03

***** CAUTION ***** EFFECTIVE OR TOTAL NORMAL STRESS ON SHEAR
                    SURFACE IS NEGATIVE AT POINTS ALONG THE
                    UPPER ONE-HALF OF THE SHEAR SURFACE - A
                    TENSION CRACK MAY BE NEEDED.
```

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 25

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**********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)               *
**********************************************
```

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
FACTOR OF SAFETY = 1.490   SIDE FORCE INCLINATION = -8.70 DEGREES

--------------- VALUES AT RIGHT SIDE OF SLICE ---------------

SLICE NO.	X-RIGHT	SIDE FORCE	Y-COORD. OF SIDE FORCE LOCATION	FRACTION OF HEIGHT	SIGMA AT TOP	SIGMA AT BOTTOM
1	186.3	-4400.	375.8	.456	-409.9	-705.3
2	191.2	-4527.	374.8	.662	-574.8	-8.1
3	196.5	-682.	449.6	ABOVE	-668.0	608.4
4	202.2	6733.	343.8	BELOW	-748.3	1197.3
5	208.2	17235.	345.1	.040	-826.1	1763.8
6	214.5	30277.	342.3	.118	-903.9	2305.4
7	217.0	35666.	341.1	.136	-937.8	2524.9
8	223.8	50721.	337.5	.173	-994.1	3056.4
9	230.9	65935.	334.0	.201	-1002.1	3519.1
10	238.3	80756.	330.6	.223	-971.9	3902.3
11	238.9	81983.	330.3	.224	-967.9	3931.6
12	242.1	88161.	328.9	.232	-956.7	4089.1
13	242.9	90380.	328.4	.232	-976.4	4174.4
14	249.7	102983.	325.6	.245	-933.9	4469.2
15	257.7	117262.	322.5	.257	-904.0	4828.1
16	262.8	125178.	320.7	.263	-871.5	5013.3
17	271.1	139144.	317.8	.268	-885.6	5436.9
18	279.5	150542.	315.2	.275	-863.4	5771.8
19	288.2	159072.	312.9	.281	-810.9	6023.4
20	296.9	164515.	311.0	.289	-731.8	6195.1
21	305.8	166743.	309.4	.296	-628.6	6288.8
22	314.7	165721.	308.2	.304	-502.6	6305.8
23	323.7	161512.	307.2	.313	-353.9	6246.6
24	332.7	154281.	306.6	.323	-181.5	6111.1
25	333.0	153974.	306.6	.323	-175.0	6104.9
26	342.0	143897.	306.3	.335	24.6	5890.1
27	351.0	131450.	306.4	.348	255.1	5598.1
28	359.9	117110.	306.8	.364	524.2	5228.4
29	368.8	101455.	307.4	.383	844.7	4780.8
30	377.5	85166.	308.4	.408	1238.7	4257.6

31	383.0	74874.	309.1	.428	1544.8	3889.5
32	391.0	60076.	310.3	.451	1853.1	3403.8
33	399.0	45531.	311.6	.461	1880.0	3038.2
34	403.2	38289.	312.3	.491	2412.4	2676.4
35	407.0	31035.	313.2	.525	2874.2	2126.0
36	415.0	17289.	315.0	.576	3463.9	1295.2
37	416.3	15338.	315.2	.575	3375.9	1289.3
38	423.1	4305.	317.3	.715	3896.2	-491.5
39	423.9	4089.	317.2	.621	3484.8	557.0
40	427.1	2.	2852.9	ABOVE	.0	.0

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = .02 (= .244E-01)
SHOULD NOT EXCEED .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = .07 (= .670E-01)
SHOULD NOT EXCEED .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN = -10.58 (= -.106E+02)
SHOULD NOT EXCEED .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = .00 (= .643E-02)
SHOULD NOT EXCEED .100E+03

END-OF-FILE ENCOUNTERED WHILE READING COMMAND
WORDS - END OF PROBLEM(S) ASSUMED

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

CASE 1. H=52 FEET

SLOPE=2:1

TABLE NO. 1

```
*******************************************
* COMPUTER PROGRAM DESIGNATION - UTEXAS2 *
* ORIGINALLY CODED BY STEPHEN G. WRIGHT  *
* VERSION NO. 1.209                      *
* LAST REVISION DATE 11/23/87            *
* SERIAL NO. 00004                       *
* (C) COPYRIGHT 1985 STEPHEN G. WRIGHT   *
* ALL RIGHTS RESERVED                    *
*******************************************

****************************************************************
*                                                              *
*      RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
* PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
* HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL   *
* DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE   *
* ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER  *
* PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS      *
* PROGRAM BEFORE ATTEMPTING ITS USE.                         *
*                                                              *
*      NEITHER THE UNIVERSITY OF TEXAS NOR STEPHEN G. WRIGHT *
* MAKE OR ASSUME LIABILITY FOR ANY WARRANTIES, EXPRESSED OR  *
* IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS  *
* OR ADAPTABILITY OF THIS COMPUTER PROGRAM.                  *
*                                                              *
****************************************************************
```

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Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 2

```
*************************
* NEW PROFILE LINE DATA *
*************************
```

PROFILE LINE 1 - MATERIAL TYPE = 1
Bedrock

POINT	X	Y
1	-100.000	275.000
2	900.000	275.000

PROFILE LINE 2 - MATERIAL TYPE = 2
Glaciolacustrine Sand/Silt

POINT	X	Y
1	-100.000	290.000
2	900.000	290.000

PROFILE LINE 3 - MATERIAL TYPE = 3
LACUSTRINE CLAY

POINT	X	Y

1	-100.000	305.000
2	900.000	305.000

PROFILE LINE 4 - MATERIAL TYPE = 4
UPPER TILL

POINT	X	Y
1	-100.000	311.500
2	900.000	311.500

PROFILE LINE 5 - MATERIAL TYPE = 5
Lower Soil Liner

POINT	X	Y
1	-100.000	315.500
2	900.000	315.500

PROFILE LINE 6 - MATERIAL TYPE = 6
Synthetic Liner

POINT	X	Y
1	-100.000	316.000
2	900.000	316.000

PROFILE LINE 7 - MATERIAL TYPE = 5
Upper Soil Liner

POINT	X	Y
1	-100.000	318.000
2	383.000	318.000
3	391.000	322.000
4	399.000	322.000
5	407.000	318.000
6	900.000	318.000

PROFILE LINE 8 - MATERIAL TYPE = 7
Waste

POINT	X	Y
1	-100.000	370.000
2	299.000	370.000
3	403.000	318.000

ALL NEW PROFILE LINES DEFINED - NO OLD LINES RETAINED

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 3
****
* NEW MATERIAL PROPERTY DATA *
****

DATA FOR MATERIAL TYPE 1

```
BEDROCK

     UNIT WEIGHT OF MATERIAL =  140.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     COHESION - - - - - - - - -      2000.000
     FRICTION ANGLE - - - - -   40.000 DEGREES

     NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE  2
Glaciolacustrine Sand/Silt

     UNIT WEIGHT OF MATERIAL =  130.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     COHESION - - - - - - - - -          .000
     FRICTION ANGLE - - - - -   30.000 DEGREES

     NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE  3
Glaciolacustrine Clay

     UNIT WEIGHT OF MATERIAL =  125.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     COHESION - - - - - - - - -       320.000
     FRICTION ANGLE - - - - -   10.000 DEGREES

     NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE  4
UPPER TILL

     UNIT WEIGHT OF MATERIAL =  130.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     COHESION - - - - - - - - -       800.000
     FRICTION ANGLE - - - - -   10.000 DEGREES

     NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE  5
Soil Liner

     UNIT WEIGHT OF MATERIAL =  130.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     COHESION - - - - - - - - -      1000.000
     FRICTION ANGLE - - - - -   10.000 DEGREES

     NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE  6
Synthetic Liner

     UNIT WEIGHT OF MATERIAL =  130.000

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
```

COHESION - - - - - - - - .000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 7
Waste

UNIT WEIGHT OF MATERIAL = 111.100

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - 800.000
FRICTION ANGLE - - - - - 13.500 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

ALL NEW MATERIAL PROPERTIES DEFINED - NO OLD DATA RETAINED
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Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 9
****
* NEW ANALYSIS/COMPUTATION DATA *
****

CIRCULAR SHEAR SURFACE(S)

AUTOMATIC SEARCH PERFORMED

STARTING CENTER COORDINATE FOR SEARCH AT -
X = 360.000
Y = 400.000

REQUIRED ACCURACY FOR CRITICAL CENTER (= MINIMUM
SPACING BETWEEN GRID POINTS) = 1.000

CRITICAL SHEAR SURFACE NOT ALLOWED TO PASS BELOW Y = 270.000

FOR THE INITIAL MODE OF SEARCH
ALL CIRCLES ARE TANGENT TO HORIZONTAL LINE AT -
Y = 290.000

DEPTH OF CRACK = 5.000

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

INITIAL TRIAL ESTIMATE FOR THE FACTOR OF SAFETY = 3.000

INITIAL TRIAL ESTIMATE FOR SIDE FORCE INCLINATION = 15.000 DEGREES
(APPLICABLE TO SPENCER'S PROCEDURE ONLY)

MAXIMUM NUMBER OF ITERATIONS ALLOWED FOR
CALCULATING THE FACTOR OF SAFETY = 40

ALLOWED FORCE IMBALANCE FOR CONVERGENCE = 100.000

ALLOWED MOMENT IMBALANCE FOR CONVERGENCE = 100.000

INITIAL TRIAL VALUES FOR FACTOR OF SAFETY (AND SIDE FORCE INCLINATION FOR SPENCER'S PROCEDURE) WILL BE KEPT CONSTANT DURING SEARCH

MAXIMUM SUBTENDED ANGLE TO BE USED FOR SUBDIVISION OF THE CIRCLE INTO SLICES = 3.00 DEGREES

SEARCH WILL BE CONTINUED TO LOCATE A MORE CRITICAL SHEAR SURFACE (IF ONE EXISTS) AFTER THE INITIAL MODE IS COMPLETE

DEPTH OF WATER IN CRACK = .000

UNIT WEIGHT OF WATER IN CRACK = 62.400

SEISMIC COEFFICIENT = .000

PROCEDURE USED TO COMPUTE THE FACTOR OF SAFETY: SPENCER

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Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 10

****
* NEW SLOPE GEOMETRY DATA *
****

NOTE - NO DATA WERE INPUT, SLOPE GEOMETRY DATA WERE GENERATED BY THE PROGRAM

SLOPE COORDINATES -

POINT	X	Y
1	-100.000	370.000
2	299.000	370.000
3	391.000	322.000
4	399.000	322.000
5	407.000	318.000
6	900.000	318.000

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Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 12

INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES ARE TANGENT TO A HORIZONTAL LINE AT Y = 290.000

CENTER COORDINATES X	Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
330.00	370.00	80.00	1.779	-5.69	6
360.00	370.00	80.00	1.460	-6.12	7
390.00	370.00	80.00	SEE MESSAGE ON NEXT LINE(S)		
	LAST TRIAL VALUES =		1.664	6.65	5

VALUES SHOWN ABOVE ARE NOT CORRECT FINAL VALUES

VALUE OF SIDE FORCE INCLINATION BECAME OUTSIDE RANGE OF FROM -80.00
TO 10.00 DEGREES

330.00	400.00	110.00	1.627	-7.69	6
360.00	400.00	110.00	1.393	-7.88	8
390.00	400.00	110.00	1.543	-8.25	6
330.00	430.00	140.00	1.609	-7.88	7
360.00	430.00	140.00	1.421	-7.69	8
390.00	430.00	140.00	1.493	-8.01	7

355.00 395.00 105.00 SEE MESSAGE ON NEXT LINE(S)
LAST TRIAL VALUES = 1.405 5.75 6
VALUES SHOWN ABOVE ARE NOT CORRECT FINAL VALUES
VALUE OF SIDE FORCE INCLINATION BECAME OUTSIDE RANGE OF FROM -80.00
TO 10.00 DEGREES

360.00	395.00	105.00	1.394	-7.85	9
365.00	395.00	105.00	1.392	-7.86	8
355.00	400.00	110.00	1.405	-7.90	9
365.00	400.00	110.00	1.390	-7.89	8
355.00	405.00	115.00	1.406	-7.91	10
360.00	405.00	115.00	1.394	-7.89	6
365.00	405.00	115.00	1.390	-7.89	8
370.00	395.00	105.00	1.400	-7.90	8
370.00	400.00	110.00	1.397	-7.93	8
370.00	405.00	115.00	1.395	-7.92	8
362.00	397.00	107.00	1.391	-7.87	8
365.00	397.00	107.00	1.391	-7.88	8
368.00	397.00	107.00	1.394	-7.90	8
362.00	400.00	110.00	1.390	-7.88	8
368.00	400.00	110.00	1.393	-7.91	8
362.00	403.00	113.00	1.391	-7.89	8
365.00	403.00	113.00	1.390	-7.89	8
368.00	403.00	113.00	1.392	-7.91	8
362.00	406.00	116.00	1.392	-7.88	8
365.00	406.00	116.00	1.390	-7.89	8
368.00	406.00	116.00	1.392	-7.90	8
364.00	402.00	112.00	1.390	-7.89	8
365.00	402.00	112.00	1.390	-7.89	8
366.00	402.00	112.00	1.390	-7.90	8
364.00	403.00	113.00	1.390	-7.89	8
366.00	403.00	113.00	1.390	-7.90	8
364.00	404.00	114.00	1.390	-7.89	8
365.00	404.00	114.00	1.390	-7.89	8
366.00	404.00	114.00	1.390	-7.90	8
363.00	401.00	111.00	1.390	-7.89	8
364.00	401.00	111.00	1.389	-7.89	8
365.00	401.00	111.00	1.390	-7.89	8
363.00	402.00	112.00	1.390	-7.89	8
363.00	403.00	113.00	1.390	-7.89	8
363.00	400.00	110.00	1.390	-7.88	8
364.00	400.00	110.00	1.390	-7.89	8

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL
CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER = 364.00 Y-CENTER = 401.00 RADIUS = 111.00

1

FACTOR OF SAFETY = 1.389 SIDE FORCE INCLINATION = -7.89
UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
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TABLE NO. 13
INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES HAVE THE SAME RADIUS - RADIUS = 111.000

CENTER COORDINATES X	Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
334.00	371.00	111.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
364.00	371.00	111.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
394.00	371.00	111.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
334.00	401.00	111.00	1.564	-7.89	8
394.00	401.00	111.00	1.599	-8.29	6
334.00	431.00	111.00	2.147	-11.64	5
364.00	431.00	111.00	1.805	-16.26	8
394.00	431.00	111.00	2.606	-19.23	5
359.00	396.00	111.00	2.145	-10.73	5
364.00	396.00	111.00	2.116	-10.70	5
369.00	396.00	111.00	2.100	-10.68	5
359.00	401.00	111.00	1.394	-7.89	7
369.00	401.00	111.00	1.394	-7.92	8
359.00	406.00	111.00	1.398	-8.71	7
364.00	406.00	111.00	1.393	-8.74	7
369.00	406.00	111.00	1.398	-8.79	7
361.00	398.00	111.00	1.960	-10.59	5
364.00	398.00	111.00	1.945	-10.57	5
367.00	398.00	111.00	1.935	-10.55	5
361.00	401.00	111.00	1.391	-7.89	8
367.00	401.00	111.00	1.391	-7.90	8
361.00	404.00	111.00	1.390	-8.36	7
364.00	404.00	111.00	1.388	-8.37	7
367.00	404.00	111.00	1.390	-8.39	7
361.00	407.00	111.00	1.399	-8.92	7
364.00	407.00	111.00	1.397	-8.95	7
367.00	407.00	111.00	1.399	-8.98	7
363.00	403.00	111.00	1.388	-8.20	7
364.00	403.00	111.00	1.388	-8.20	8
365.00	403.00	111.00	1.388	-8.21	8
363.00	404.00	111.00	1.389	-8.37	7
365.00	404.00	111.00	1.389	-8.38	7
363.00	405.00	111.00	1.390	-8.54	7
364.00	405.00	111.00	1.390	-8.55	7
365.00	405.00	111.00	1.390	-8.56	7
363.00	402.00	111.00	1.388	-8.04	9

364.00	402.00	111.00	1.388	-8.04	9
365.00	402.00	111.00	1.388	-8.05	9

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL
CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER = 364.00 Y-CENTER = 403.00 RADIUS = 111.00
FACTOR OF SAFETY = 1.388 SIDE FORCE INCLINATION = -8.20

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
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Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 12
INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES ARE TANGENT
TO A HORIZONTAL LINE AT Y = 292.000

CENTER COORDINATES X	Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
334.00	373.00	81.00	1.694	-6.29	6
364.00	373.00	81.00	1.450	-6.94	8
394.00	373.00	81.00	1.896	-6.70	7
334.00	403.00	111.00	1.572	-8.03	9
394.00	403.00	111.00	1.604	-8.60	7
334.00	433.00	141.00	1.575	-8.06	8
364.00	433.00	141.00	1.419	-7.91	9
394.00	433.00	141.00	1.533	-8.36	7
359.00	398.00	106.00	1.392	-8.18	8
364.00	398.00	106.00	1.388	-8.20	8
369.00	398.00	106.00	1.394	-8.24	8
359.00	403.00	111.00	1.393	-8.19	8
369.00	403.00	111.00	1.392	-8.24	8
359.00	408.00	116.00	1.395	-8.18	8
364.00	408.00	116.00	1.390	-8.18	7
369.00	408.00	116.00	1.393	-8.21	8
361.00	400.00	108.00	1.389	-8.19	8
364.00	400.00	108.00	1.388	-8.20	8
367.00	400.00	108.00	1.390	-8.22	8
361.00	403.00	111.00	1.390	-8.19	8
367.00	403.00	111.00	1.389	-8.22	8
361.00	406.00	114.00	1.391	-8.18	8
364.00	406.00	114.00	1.389	-8.19	8
367.00	406.00	114.00	1.390	-8.21	8
361.00	397.00	105.00	1.390	-8.18	8
364.00	397.00	105.00	1.389	-8.19	8
367.00	397.00	105.00	1.391	-8.21	8
363.00	399.00	107.00	1.388	-8.20	7
364.00	399.00	107.00	1.388	-8.20	8
365.00	399.00	107.00	1.388	-8.21	8
363.00	400.00	108.00	1.388	-8.20	7
365.00	400.00	108.00	1.388	-8.21	8
363.00	401.00	109.00	1.388	-8.20	7
364.00	401.00	109.00	1.388	-8.20	8

365.00	401.00	109.00	1.388	-8.21	8
363.00	402.00	110.00	1.388	-8.20	7
364.00	402.00	110.00	1.388	-8.20	8
365.00	402.00	110.00	1.388	-8.21	8

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL
CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER = 364.00 Y-CENTER = 401.00 RADIUS = 109.00
FACTOR OF SAFETY = 1.388 SIDE FORCE INCLINATION = -8.20

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
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Slope Stability - Waste Filling Sequence

TABLE NO. 15
***** FINAL CRITICAL CIRCLE INFORMATION *****
X COORDINATE OF CENTER - - - - - - - - 364.000
Y COORDINATE OF CENTER - - - - - - - - 401.000
RADIUS - - - - - - - - - - - - - - - - 109.000
FACTOR OF SAFETY - - - - - - - - - - - 1.388
SIDE FORCE INCLINATION - - - - - - - - -8.20

NUMBER OF CIRCLES TRIED - - - - - - - 122
NO. OF CIRCLES F CALC. FOR - - - - - - 117

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 20
****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	261.1	365.0					
1	262.1	362.3	1725.1	7	800.00	13.50	.0
	263.1	359.7					
2	264.3	357.1	3310.3	7	800.00	13.50	.0
	265.4	354.4					
3	266.7	351.9	5172.6	7	800.00	13.50	.0
	268.0	349.3					
4	269.4	346.9	7283.9	7	800.00	13.50	.0
	270.8	344.4					
5	272.4	342.0	9613.6	7	800.00	13.50	.0
	273.9	339.6					
6	275.6	337.3	12129.0	7	800.00	13.50	.0
	277.3	335.0					
7	279.1	332.7	14795.5	7	800.00	13.50	.0
	280.9	330.5					
8	282.8	328.4	17577.3	7	800.00	13.50	.0
	284.7	326.3					
9	286.7	324.2	20437.2	7	800.00	13.50	.0
	288.7	322.2					
10	290.8	320.3	23338.1	7	800.00	13.50	.0
	292.9	318.4					

11	293.1	318.2	2564.3	7	800.00	13.50	.0
	293.3	318.0					
12	294.6	317.0	14290.6	5	1000.00	10.00	.0
	295.8	316.0					
13	296.1	315.8	3809.1	6	.00	10.00	
	296.4	315.5					
14	297.7	314.5	16249.2	5	1000.00	10.00	.0
	299.0	313.5					
15	300.4	312.5	17853.4	5	1000.00	10.00	.0
	301.8	311.5					
16	304.2	309.9	31125.7	4	800.00	10.00	.0
	306.6	308.4					
17	309.0	306.9	32694.4	4	800.00	10.00	.0
	311.5	305.5					
18	311.9	305.2	5988.3	4	800.00	10.00	.0
	312.4	305.0					
19	314.9	303.7	34161.0	3	320.00	10.00	.0
	317.5	302.4					
20	320.1	301.3	35044.1	3	320.00	10.00	.0
	322.7	300.1					
21	325.4	299.1	35612.9	3	320.00	10.00	.0
	328.0	298.1					
22	330.7	297.2	35853.5	3	320.00	10.00	.0
	333.5	296.4					

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 20

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*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*******************************************************************
```

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	333.5	296.4					
23	336.2	295.6	35756.3	3	320.00	10.00	.0
	339.0	294.9					
24	341.8	294.3	35317.0	3	320.00	10.00	.0
	344.6	293.7					
25	347.4	293.3	34535.5	3	320.00	10.00	.0
	350.2	292.9					
26	353.0	292.6	33417.0	3	320.00	10.00	.0
	355.9	292.3					
27	358.7	292.2	31970.9	3	320.00	10.00	.0
	361.6	292.0					
28	362.8	292.0	13017.5	3	320.00	10.00	.0
	364.0	292.0					
29	366.9	292.1	29377.6	3	320.00	10.00	.0
	369.7	292.1					
30	372.5	292.4	27206.2	3	320.00	10.00	.0
	375.4	292.6					
31	378.2	293.0	24774.5	3	320.00	10.00	[illegible]
	381.1	293.3					
32	382.0	293.5	7972.7	3	320.00	10.00	.0
	383.0	293.7					
33	385.8	294.2	21289.0	3	320.00	10.00	.0

	388.6	294.8					
34	389.8	295.1	8443.8	3	320.00	10.00	.0
	391.0	295.4					
35	393.0	295.9	13365.5	3	320.00	10.00	.0
	395.0	296.5					
36	397.0	297.1	12393.7	3	320.00	10.00	.0
	399.0	297.8					
37	401.0	298.5	11346.2	3	320.00	10.00	.0
	403.0	299.2					
38	405.0	300.0	9766.0	3	320.00	10.00	.0
	407.0	300.8					
39	409.6	302.0	10681.0	3	320.00	10.00	.0
	412.2	303.2					
40	413.9	304.1	6195.7	3	320.00	10.00	.0
	415.6	305.0					
41	418.1	306.4	7459.1	4	800.00	10.00	.0
	420.6	307.8					
42	423.0	309.4	5378.6	4	800.00	10.00	.0
	425.4	310.9					
43	425.8	311.2	741.2	4	800.00	10.00	.0
	426.2	311.5					
44	428.5	313.2	2876.0	5	1000.00	10.00	.0
	430.8	314.9					

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 20

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*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
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SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	430.8	314.9					
45	431.2	315.2	289.8	5	1000.00	10.00	.0
	431.6	315.5					
46	431.9	315.8	183.6	6	.00	10.00	.0
	432.2	316.0					
47	433.4	317.0	314.5	5	1000.00	10.00	.0
	434.7	318.0					

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 21

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*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
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				FORCES DUE TO SURFACE PRESSURES			
SLICE NO.	X	SEISMIC FORCE	Y FOR SEISMIC FORCE	NORMAL FORCE	SHEAR FORCE	X	Y

1	262.1	0.	366.2	0.	0.	.0	.0
2	264.3	0.	363.5	0.	0.	.0	.0
3	266.7	0.	360.9	0.	0.	.0	.0
4	269.4	0.	358.4	0.	0.	.0	[illegible]
5	272.4	0.	356.0	0.	0.	.0	[illegible]
6	275.6	0.	353.6	0.	0.	.0	.0
7	279.1	0.	351.4	0.	0.	.0	.0
8	282.8	0.	349.2	0.	0.	.0	.0
9	286.7	0.	347.1	0.	0.	.0	.0
10	290.8	0.	345.1	0.	0.	.0	.0
11	293.1	0.	344.1	0.	0.	.0	.0
12	294.6	0.	343.4	0.	0.	.0	.0
13	296.1	0.	342.7	0.	0.	.0	.0
14	297.7	0.	342.0	0.	0.	.0	.0
15	300.4	0.	340.5	0.	0.	.0	.0
16	304.2	0.	338.0	0.	0.	.0	.0
17	309.0	0.	335.1	0.	0.	.0	.0
18	311.9	0.	333.4	0.	0.	.0	.0
19	314.9	0.	331.9	0.	0.	.0	.0
20	320.1	0.	329.2	0.	0.	.0	.0
21	325.4	0.	326.8	0.	0.	.0	.0
22	330.7	0.	324.4	0.	0.	.0	.0
23	336.2	0.	322.2	0.	0.	.0	.0
24	341.8	0.	320.1	0.	0.	.0	.0
25	347.4	0.	318.2	0.	0.	.0	.0
26	353.0	0.	316.4	0.	0.	.0	.0
27	358.7	0.	314.8	0.	0.	.0	.0
28	362.8	0.	313.7	0.	0.	.0	.0
29	366.9	0.	312.7	0.	0.	.0	.0
30	372.5	0.	311.5	0.	0.	.0	[illegible]
31	378.2	0.	310.4	0.	0.	.0	[illegible]
32	382.0	0.	309.8	0.	0.	.0	.0
33	385.8	0.	309.3	0.	0.	.0	.0
34	389.8	0.	308.9	0.	0.	.0	.0
35	393.0	0.	309.1	0.	0.	.0	.0
36	397.0	0.	309.4	0.	0.	.0	.0
37	401.0	0.	309.7	0.	0.	.0	.0
38	405.0	0.	309.6	0.	0.	.0	.0
39	409.6	0.	310.1	0.	0.	.0	.0
40	413.9	0.	311.1	0.	0.	.0	.0
41	418.1	0.	312.2	0.	0.	.0	.0

TABLE NO. 21

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********************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)               *
********************************************************************
```

				FORCES DUE TO SURFACE PRESSURES			
SLICE NO.	X	SEISMIC FORCE	Y FOR SEISMIC FORCE	NORMAL FORCE	SHEAR FORCE	X	Y
42	423.0	0.	313.7	0.	0.	.0	.0
43	425.8	0.	314.6	0.	0.	.0	.0
44	428.5	0.	315.6	0.	0.	.0	.0

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   45    431.2        0.       316.6       0.         0.        .0        .0
   46    431.9        0.       316.9       0.         0.        .0        .0
   47    433.4        0.       317.5       0.         0.        .0        .0
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   Chemical Waste Management
   Slope Stability - Waste Filling Sequence

  TABLE NO. 23
  *****************************************************************
  * INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
  * OF SAFETY AND SIDE FORCE INCLINATION BY SPENCER'S PROCEDURE    *
  *****************************************************************

           TRIAL      TRIAL
          FACTOR   SIDE FORCE    FORCE      MOMENT                 DELTA
  ITER-     OF     INCLINATION  IMBALANCE  IMBALANCE    DELTA-F     THETA
  ATION   SAFETY    (DEGREES)    (LBS.)    (FT.-LBS.)            (DEGREES)

     1   3.00000   -15.0000  -.1038E+06   .3876E+08
  FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.234E+01 -.835E+01
  VALUES FACTORED BY  .213E+00 - DELTAS TOO LARGE    -.500E+00 -.178E+01

     2   2.50000   -16.7813  -.7809E+05   .2889E+08
  FIRST-ORDER CORRECTIONS TO F AND THETA .........    .146E+00 -.326E+02
  VALUES FACTORED BY  .264E+00 - DELTAS TOO LARGE     .386E-01 -.859E+01

     3   2.53856   -25.3757  -.5556E+05   .1927E+08
  FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.323E+01  .351E+02
  VALUES FACTORED BY  .155E+00 - DELTAS TOO LARGE    -.500E+00  .543E+01

     4   2.03856   -19.9446  -.4043E+05   .1359E+08
  FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.143E+01  .241E+02
  VALUES FACTORED BY  .350E+00 - DELTAS TOO LARGE    -.500E+00  .842E+01

     5   1.53856   -11.5269  -.1335E+05   .4202E+07
  FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.189E+00  .438E+01
  SECOND-ORDER CORRECTION - ITERATION   1 ........   -.169E+00  .438E+01
  SECOND-ORDER CORRECTION - ITERATION   2 ........   -.169E+00  .438E+01
  SECOND-ORDER CORRECTION - ITERATION   3 ........   -.169E+00  .438E+01

     6   1.36956    -7.1476   .2899E+03   .1393E+06
  FIRST-ORDER CORRECTIONS TO F AND THETA .........    .177E-01 -.106E+01
  SECOND-ORDER CORRECTION - ITERATION   1 ........    .181E-01 -.106E+01
  SECOND-ORDER CORRECTION - ITERATION   2 ........    .181E-01 -.106E+01

     7   1.38766    -8.2043  -.2041E+00  -.1887E+03
  FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.192E-04  .114E-02
  SECOND-ORDER CORRECTION - ITERATION   1 ........   -.191E-04  .113E-02

     8   1.38764    -8.2032   .1953E-02  -.1831E+01
  FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.653E-07  .492E-05

  FACTOR OF SAFETY - - - - - - - -        1.388
  SIDE FORCE INCLINATION - - - - -        -8.20
  NUMBER OF ITERATIONS - - - - - -        8
1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
   Model City Landfill
   Chemical Waste Management
   Slope Stability - Waste Filling Sequence
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TABLE NO. 24

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*********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
*********************************************
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SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
FACTOR OF SAFETY = 1.388 SIDE FORCE INCLINATION = -8.20 DEGREES

-------- VALUES AT CENTER OF BASE OF SLICE---------

SLICE NO.	X-CENTER	Y-CENTER	TOTAL NORMAL STRESS	EFFECTIVE NORMAL STRESS	SHEAR STRESS
1	262.1	362.3	-322.5	-322.5	520.7
2	264.3	357.1	125.9	125.9	598.3
3	266.7	351.9	594.0	594.0	679.3
4	269.4	346.9	1076.0	1076.0	762.7
5	272.4	342.0	1566.7	1566.7	847.6
6	275.6	337.3	2062.2	2062.2	933.3
7	279.1	332.7	2558.7	2558.7	1019.2
8	282.8	328.4	3053.0	3053.0	1104.7
9	286.7	324.2	3542.5	3542.5	1189.4
10	290.8	320.3	4024.3	4024.3	1272.8
11	293.1	318.2	4288.4	4288.4	1318.5
12	294.6	317.0	4490.6	4490.6	1291.3
13	296.1	315.8	5067.5	5067.5	643.9
14	297.7	314.5	4861.9	4861.9	1338.4
15	300.4	312.5	5097.1	5097.1	1368.3
16	304.2	309.9	5371.7	5371.7	1259.1
17	309.0	306.9	5597.4	5597.4	1287.8
18	311.9	305.2	5717.2	5717.2	1303.0
19	314.9	303.7	5920.1	5920.1	982.9
20	320.1	301.3	6031.8	6031.8	997.1
21	325.4	299.1	6104.1	6104.1	1006.3
22	330.7	297.2	6136.0	6136.0	1010.3
23	336.2	295.6	6126.5	6126.5	1009.1
24	341.8	294.3	6074.9	6074.9	1002.5
25	347.4	293.3	5980.5	5980.5	990.5
26	353.0	292.6	5842.6	5842.6	973.0
27	358.7	292.2	5660.5	5660.5	949.9
28	362.8	292.0	5507.8	5507.8	930.5
29	366.9	292.1	5324.4	5324.4	907.2
30	372.5	292.4	5033.3	5033.3	870.2
31	378.2	293.0	4696.2	4696.2	827.4
32	382.0	293.5	4447.1	4447.1	795.7
33	385.8	294.2	4197.2	4197.2	763.9
34	389.8	295.1	3926.2	3926.2	729.5
35	393.0	295.9	3791.6	3791.6	712.4
36	397.0	297.1	3578.9	3578.9	685.4
37	401.0	298.5	3341.4	3341.4	655.2
38	405.0	300.0	2946.9	2946.9	605.1
39	409.6	302.0	2568.2	2568.2	556.9
40	413.9	304.1	2319.3	2319.3	525.3

1

-------- VALUES AT CENTER OF BASE OF SLICE---------

SLICE NO.	X-CENTER	Y-CENTER	TOTAL NORMAL STRESS	EFFECTIVE NORMAL STRESS	SHEAR STRESS
41	418.1	306.4	2321.4	2321.4	871.5
42	423.0	309.4	1951.6	1951.6	824.5
43	425.8	311.2	1713.7	1713.7	794.3
44	428.5	313.2	1608.8	1608.8	925.1
45	431.2	315.2	1343.8	1343.8	891.4
46	431.9	315.8	382.1	382.1	48.5
47	433.4	317.0	1095.3	1095.3	859.8

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = .02 (= .159E-01)
    SHOULD NOT EXCEED .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = .05 (= .523E-01)
    SHOULD NOT EXCEED .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN = .91 (= .911E+00)
    SHOULD NOT EXCEED .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = .00 (= .692E-02)
    SHOULD NOT EXCEED .100E+03

***** CAUTION ***** EFFECTIVE OR TOTAL NORMAL STRESS ON SHEAR SURFACE IS NEGATIVE AT POINTS ALONG THE UPPER ONE-HALF OF THE SHEAR SURFACE - A TENSION CRACK MAY BE NEEDED.

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 25
****
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH) *
****

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
FACTOR OF SAFETY = 1.388 SIDE FORCE INCLINATION = -8.20 DEGREES

--------------- VALUES AT RIGHT SIDE OF SLICE ---------------

SLICE NO.	X-RIGHT	SIDE FORCE	Y-COORD. OF SIDE FORCE LOCATION	FRACTION OF HEIGHT	SIGMA AT TOP	SIGMA AT BOTTOM
1	263.1	-2804.	362.2	.244	143.9	-680.9
2	265.4	-3531.	360.8	.411	-104.2	-345.0
3	268.0	-2238.	365.5	.783	-289.3	74.8
4	270.8	961.	303.7	BELOW	-428.4	502.7
5	273.9	5909.	335.5	BELOW	-539.8	924.6
6	277.3	12408.	336.1	.032	-634.1	1335.2
7	280.9	20226.	334.4	.098	-716.8	1731.0
8	284.7	29107.	332.1	.133	-791.3	2108.8
9	288.7	38772.	329.6	.155	-859.1	2465.3
10	292.9	48927.	327.1	.170	-920.9	2797.2
11	293.3	49986.	326.9	.171	-926.9	2829.8
12	295.8	55904.	325.5	.176	-966.3	3015.6
13	296.4	58056.	325.1	.175	-998.8	3107.5

14	299.0	64347.	323.7	.181	-1035.8	3304.9
15	301.8	70804.	322.3	.189	-1065.4	3522.3
16	306.6	81743.	320.0	.201	-1111.3	3916.1
17	311.5	91617.	317.9	.214	-1119.5	4246.[illegible]
18	312.4	93252.	317.5	.216	-1117.2	4298.[illegible]
19	317.5	103565.	315.5	.225	-1148.5	4687.2
20	322.7	112321.	313.6	.235	-1140.7	5007.0
21	328.0	119376.	312.0	.246	-1097.1	5261.3
22	333.5	124626.	310.6	.257	-1019.8	5452.5
23	339.0	128004.	309.5	.268	-909.7	5582.2
24	344.6	129489.	308.5	.281	-766.8	5651.2
25	350.2	129102.	307.7	.295	-589.7	5659.7
26	355.9	126906.	307.2	.309	-375.3	5607.0
27	361.6	123012.	306.8	.326	-118.5	5491.6
28	364.0	120892.	306.7	.334	4.8	5423.4
29	369.7	114860.	306.6	.354	337.4	5213.4
30	375.4	107581.	306.8	.377	742.3	4929.8
31	381.1	99318.	307.0	.405	1246.9	4561.4
32	383.0	96283.	307.2	.416	1452.9	4410.7
33	388.6	87127.	307.7	.453	2179.4	3883.5
34	391.0	83024.	308.0	.463	2364.9	3694.1
35	395.0	75915.	308.5	.470	2419.0	3474.5
36	399.0	68549.	309.1	.477	2473.0	3245.8
37	403.0	61027.	309.8	.509	3064.8	2747.6
38	407.0	53746.	310.5	.543	3752.9	2221.6
39	412.2	44634.	311.4	.554	3958.2	2023.0
40	415.6	38655.	312.0	.539	3628.6	2257.5

1

-------------- VALUES AT RIGHT SIDE OF SLICE --------------

SLICE NO.	X-RIGHT	SIDE FORCE	Y-COORD. OF SIDE FORCE LOCATION	FRACTION OF HEIGHT	SIGMA AT TOP	SIGMA AT BOTTOM
41	420.6	27649.	313.4	.545	3416.7	1966.8
42	425.4	17561.	314.8	.545	3114.7	1796.8
43	426.2	15887.	315.0	.542	3035.5	1802.6
44	430.8	6097.	316.8	.609	3199.9	666.6
45	431.6	4539.	317.2	.677	3704.2	-110.4
46	432.2	4315.	317.2	.587	3251.7	1019.1
47	434.7	2.	342.5	ABOVE	.0	.0

```
CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION      =        .02   (=  .159E-01)
     SHOULD NOT EXCEED     .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION    =        .05   (=  .523E-01)
     SHOULD NOT EXCEED     .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN   =        .91   (=  .911E+00)
     SHOULD NOT EXCEED     .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM     =        .00   (=  .692E-02)
     SHOULD NOT EXCEED     .100E+03
```

***** CAUTION ***** FORCES BETWEEN SLICES ARE NEGATIVE AT POINTS ALONG THE UPPER ONE-HALF OF THE SHEAR SURFACE - A TENSION CRACK MAY BE NEEDED.

***** CAUTION ***** SOME OF THE FORCES BETWEEN SLICES ACT AT POINTS ABOVE THE SURFACE OF THE SLOPE OR BELOW THE

SHEAR SURFACE - EITHER A TENSION CRACK MAY BE
NEEDED OR THE SOLUTION MAY NOT BE A VALID SOLUTION

END-OF-FILE ENCOUNTERED WHILE READING COMMAND
WORDS - END OF PROBLEM(S) ASSUMED

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

CASE 2. H=47 FEET

SLOPE=2:1

```
TABLE NO. 1
*****************************************
* COMPUTER PROGRAM DESIGNATION - UTEXAS2 *
* ORIGINALLY CODED BY STEPHEN G. WRIGHT  *
* VERSION NO. 1.209                      *
* LAST REVISION DATE 11/23/87            *
* SERIAL NO. 00004                       *
* (C) COPYRIGHT 1985 STEPHEN G. WRIGHT   *
* ALL RIGHTS RESERVED                    *
*****************************************

**************************************************************
*                                                            *
*      RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
* PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
* HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL   *
* DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE   *
* ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER  *
* PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS      *
* PROGRAM BEFORE ATTEMPTING ITS USE.                         *
*                                                            *
*      NEITHER THE UNIVERSITY OF TEXAS NOR STEPHEN G. WRIGHT *
* MAKE OR ASSUME LIABILITY FOR ANY WARRANTIES, EXPRESSED OR  *
* IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS  *
* OR ADAPTABILITY OF THIS COMPUTER PROGRAM.                  *
*                                                            *
**************************************************************
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Model City Landfill
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Slope Stability - Waste Filling Sequence

```
TABLE NO.  2
************************
* NEW PROFILE LINE DATA *
************************
```

PROFILE LINE 1 - MATERIAL TYPE = 1
Bedrock

POINT	X	Y
1	-100.000	275.000
2	900.000	275.000

PROFILE LINE 2 - MATERIAL TYPE = 2
Glaciolacustrine Sand/Silt

POINT	X	Y
1	-100.000	290.000
2	900.000	290.000

PROFILE LINE 3 - MATERIAL TYPE = 3
LACUSTRINE CLAY

POINT X Y

1	-100.000	305.000
2	900.000	305.000

PROFILE LINE 4 - MATERIAL TYPE = 4
UPPER TILL

POINT	X	Y
1	-100.000	311.500
2	900.000	311.500

PROFILE LINE 5 - MATERIAL TYPE = 5
Lower Soil Liner

POINT	X	Y
1	-100.000	315.500
2	900.000	315.500

PROFILE LINE 6 - MATERIAL TYPE = 6
Synthetic Liner

POINT	X	Y
1	-100.000	316.000
2	900.000	316.000

PROFILE LINE 7 - MATERIAL TYPE = 5
Upper Soil Liner

POINT	X	Y
1	-100.000	318.000
2	383.000	318.000
3	391.000	322.000
4	399.000	322.000
5	407.000	318.000
6	900.000	318.000

PROFILE LINE 8 - MATERIAL TYPE = 7
Waste

POINT	X	Y
1	-100.000	365.000
2	309.000	365.000
3	403.000	318.000

ALL NEW PROFILE LINES DEFINED - NO OLD LINES RETAINED

TABLE NO. 3

****
* NEW MATERIAL PROPERTY DATA *
****

DATA FOR MATERIAL TYPE 1

BEDROCK

UNIT WEIGHT OF MATERIAL = 140.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 2000.000
FRICTION ANGLE - - - - - 40.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 2
Glaciolacustrine Sand/Silt

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - .000
FRICTION ANGLE - - - - - 30.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 3
Glaciolacustrine Clay

UNIT WEIGHT OF MATERIAL = 125.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 320.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 4
UPPER TILL

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 800.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 5
Soil Liner

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 1000.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 6
Synthetic Liner

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS

```
     COHESION - - - - - - - - -           .000
     FRICTION ANGLE - - - - -  10.000 DEGREES

     NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE  7
Waste

     UNIT WEIGHT OF MATERIAL =  111.100

     CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
     COHESION - - - - - - - - -       800.000
     FRICTION ANGLE - - - - -  13.500 DEGREES

     NO (OR ZERO) PORE WATER PRESSURES

ALL NEW MATERIAL PROPERTIES DEFINED - NO OLD DATA RETAINED
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TABLE NO.  9
*********************************
* NEW ANALYSIS/COMPUTATION DATA *
*********************************

CIRCULAR SHEAR SURFACE(S)

AUTOMATIC SEARCH PERFORMED

STARTING CENTER COORDINATE FOR SEARCH AT -
                                              X =      360.000
                                              Y =      400.000

REQUIRED ACCURACY FOR CRITICAL CENTER (= MINIMUM
SPACING BETWEEN GRID POINTS) =       1.000

CRITICAL SHEAR SURFACE NOT ALLOWED TO PASS BELOW Y =      270.000

FOR THE INITIAL MODE OF SEARCH
ALL CIRCLES ARE TANGENT TO HORIZONTAL LINE AT -
                                              Y =      290.000

DEPTH OF CRACK =       5.000

------------------------------------------------------------------
THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

INITIAL TRIAL ESTIMATE FOR THE FACTOR OF SAFETY =   3.000

INITIAL TRIAL ESTIMATE FOR SIDE FORCE INCLINATION =  15.000 DEGREES
(APPLICABLE TO SPENCER'S PROCEDURE ONLY)

MAXIMUM NUMBER OF ITERATIONS ALLOWED FOR
CALCULATING THE FACTOR OF SAFETY =   40

ALLOWED FORCE IMBALANCE FOR CONVERGENCE =     100.000

ALLOWED MOMENT IMBALANCE FOR CONVERGENCE =     100.000
```

INITIAL TRIAL VALUES FOR FACTOR OF SAFETY (AND SIDE FORCE INCLINATION FOR SPENCER'S PROCEDURE) WILL BE KEPT CONSTANT DURING SEARCH

MAXIMUM SUBTENDED ANGLE TO BE USED FOR SUBDIVISION OF THE CIRCLE INTO SLICES = 3.00 DEGREES

SEARCH WILL BE CONTINUED TO LOCATE A MORE CRITICAL SHEAR SURFACE (IF ONE EXISTS) AFTER THE INITIAL MODE IS COMPLETE

DEPTH OF WATER IN CRACK = .000

UNIT WEIGHT OF WATER IN CRACK = 62.400

SEISMIC COEFFICIENT = .000

PROCEDURE USED TO COMPUTE THE FACTOR OF SAFETY: SPENCER

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Model City Landfill
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Slope Stability - Waste Filling Sequence

TABLE NO. 10
****
* NEW SLOPE GEOMETRY DATA *
****

NOTE - NO DATA WERE INPUT, SLOPE GEOMETRY DATA WERE GENERATED BY THE PROGRAM

SLOPE COORDINATES -

POINT	X	Y
1	-100.000	365.000
2	309.000	365.000
3	391.000	322.000
4	399.000	322.000
5	407.000	318.000
6	900.000	318.000

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Slope Stability - Waste Filling Sequence

TABLE NO. 12
INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES ARE TANGENT TO A HORIZONTAL LINE AT Y = 290.000

CENTER COORDINATES X	CENTER COORDINATES Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
330.00	370.00	80.00	1.970	-5.89	5
360.00	370.00	80.00	1.525	-6.29	8
390.00	370.00	80.00	1.800	-6.12	8
330.00	400.00	110.00	1.803	-7.22	6
360.00	400.00	110.00	1.489	-7.28	6

390.00	400.00	110.00	1.588	-7.64	7
330.00	430.00	140.00	1.780	-7.33	6
360.00	430.00	140.00	1.534	-7.04	7
390.00	430.00	140.00	1.575	-7.24	7
355.00	395.00	105.00	1.508	-7.31	7
360.00	395.00	105.00	1.487	-7.27	6
365.00	395.00	105.00	1.476	-7.25	6
355.00	400.00	110.00	1.511	-7.33	7
365.00	400.00	110.00	1.478	-7.25	6
355.00	405.00	115.00	1.515	-7.31	7
360.00	405.00	115.00	1.494	-7.26	6
365.00	405.00	115.00	1.482	-7.24	6
360.00	390.00	100.00	1.486	-7.23	6
365.00	390.00	100.00	1.476	-7.22	6
370.00	390.00	100.00	1.477	-7.23	6
370.00	395.00	105.00	1.476	-7.26	6
370.00	400.00	110.00	1.477	-7.26	6
375.00	390.00	100.00	1.491	-7.29	6
375.00	395.00	105.00	1.487	-7.32	6
375.00	400.00	110.00	1.486	-7.31	6
367.00	392.00	102.00	1.474	-7.24	6
370.00	392.00	102.00	1.476	-7.25	6
373.00	392.00	102.00	1.482	-7.28	6
367.00	395.00	105.00	1.474	-7.25	6
373.00	395.00	105.00	1.481	-7.29	6
367.00	398.00	108.00	1.475	-7.25	6
370.00	398.00	108.00	1.476	-7.27	6
373.00	398.00	108.00	1.481	-7.29	6
364.00	392.00	102.00	1.477	-7.23	6
364.00	395.00	105.00	1.477	-7.25	6
364.00	398.00	108.00	1.478	-7.26	6
366.00	394.00	104.00	1.475	-7.25	6
367.00	394.00	104.00	1.474	-7.25	6
368.00	394.00	104.00	1.474	-7.25	6
366.00	395.00	105.00	1.475	-7.25	6
368.00	395.00	105.00	1.474	-7.25	6
366.00	396.00	106.00	1.475	-7.25	6
367.00	396.00	106.00	1.475	-7.25	6
368.00	396.00	106.00	1.475	-7.26	6
367.00	393.00	103.00	1.474	-7.24	6
368.00	393.00	103.00	1.474	-7.24	6
369.00	393.00	103.00	1.475	-7.25	6
369.00	394.00	104.00	1.475	-7.25	6
369.00	395.00	105.00	1.475	-7.26	6

```
AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL
CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER =     368.00     Y-CENTER =     394.00     RADIUS =     104.00
FACTOR OF SAFETY =    1.474     SIDE FORCE INCLINATION =  -7.25
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TABLE NO. 13
INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES HAVE THE SAME RADIUS - RADIUS = 104.000

CENTER COORDINATES X	Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
338.00	364.00	104.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
368.00	364.00	104.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
398.00	364.00	104.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
338.00	394.00	104.00	1.673	-7.38	7
398.00	394.00	104.00	1.739	-7.80	8
338.00	424.00	104.00	2.340	-11.16	5
368.00	424.00	104.00	1.925	-16.12	6
398.00	424.00	104.00	3.097	-19.43	4
363.00	389.00	104.00	2.279	-10.02	5
368.00	389.00	104.00	2.249	-9.98	5
373.00	389.00	104.00	2.234	-9.95	5
363.00	394.00	104.00	1.479	-7.25	6
373.00	394.00	104.00	1.481	-7.29	6
363.00	399.00	104.00	1.480	-8.06	8
368.00	399.00	104.00	1.476	-8.08	8
373.00	399.00	104.00	1.483	-8.14	7
365.00	391.00	104.00	2.079	-9.88	5
368.00	391.00	104.00	2.064	-9.85	5
371.00	391.00	104.00	2.055	-9.83	5
365.00	394.00	104.00	1.476	-7.25	6
371.00	394.00	104.00	1.477	-7.27	6
365.00	397.00	104.00	1.473	-7.71	8
368.00	397.00	104.00	1.472	-7.72	8
371.00	397.00	104.00	1.474	-7.74	8
365.00	400.00	104.00	1.481	-8.26	7
368.00	400.00	104.00	1.480	-8.28	7
371.00	400.00	104.00	1.483	-8.31	7
367.00	396.00	104.00	1.471	-7.55	8
368.00	396.00	104.00	1.471	-7.55	7
369.00	396.00	104.00	1.472	-7.56	7
367.00	397.00	104.00	1.472	-7.71	8
369.00	397.00	104.00	1.472	-7.72	8
367.00	398.00	104.00	1.473	-7.89	8
368.00	398.00	104.00	1.473	-7.89	8
369.00	398.00	104.00	1.473	-7.90	8
366.00	395.00	104.00	1.473	-7.39	7
367.00	395.00	104.00	1.472	-7.39	7
368.00	395.00	104.00	1.472	-7.40	7
366.00	396.00	104.00	1.472	-7.55	8
366.00	397.00	104.00	1.472	-7.71	8

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL
CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER = 367.00 Y-CENTER = 396.00 RADIUS = 104.0^
FACTOR OF SAFETY = 1.471 SIDE FORCE INCLINATION = -7.55

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Model City Landfill
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TABLE NO. 12
INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES ARE TANGENT
TO A HORIZONTAL LINE AT Y = 292.000

CENTER COORDINATES X	CENTER COORDINATES Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
337.00	366.00	74.00	1.859	-5.49	5
367.00	366.00	74.00	1.543	-5.93	7
397.00	366.00	74.00	2.099	-6.14	5
337.00	396.00	104.00	1.695	-7.51	7
397.00	396.00	104.00	1.724	-8.10	8
337.00	426.00	134.00	1.694	-7.54	6
367.00	426.00	134.00	1.509	-7.29	7
397.00	426.00	134.00	1.641	-7.79	6
362.00	391.00	99.00	1.477	-7.53	8
367.00	391.00	99.00	1.471	-7.53	8
372.00	391.00	99.00	1.478	-7.57	7
362.00	396.00	104.00	1.478	-7.55	8
372.00	396.00	104.00	1.476	-7.58	7
362.00	401.00	109.00	1.481	-7.54	8
367.00	401.00	109.00	1.474	-7.54	8
372.00	401.00	109.00	1.477	-7.57	7
364.00	393.00	101.00	1.473	-7.54	10
367.00	393.00	101.00	1.471	-7.54	8
370.00	393.00	101.00	1.473	-7.56	7
364.00	396.00	104.00	1.474	-7.55	10
370.00	396.00	104.00	1.473	-7.57	7
364.00	399.00	107.00	1.476	-7.54	10
367.00	399.00	107.00	1.473	-7.54	8
370.00	399.00	107.00	1.473	-7.56	7

364.00 390.00 98.00 SEE MESSAGE ON NEXT LINE(S)
LAST TRIAL VALUES = 1.443 6.32 6
VALUES SHOWN ABOVE ARE NOT CORRECT FINAL VALUES
VALUE OF SIDE FORCE INCLINATION BECAME OUTSIDE RANGE OF FROM -80.00
TO 10.00 DEGREES

367.00	390.00	98.00	1.472	-7.52	8
370.00	390.00	98.00	1.474	-7.55	8
366.00	392.00	100.00	1.471	-7.53	8
367.00	392.00	100.00	1.471	-7.54	8
368.00	392.00	100.00	1.471	-7.54	8
366.00	393.00	101.00	1.471	-7.54	8
368.00	393.00	101.00	1.471	-7.55	7
366.00	394.00	102.00	1.471	-7.54	8

367.00	394.00	102.00	1.471	-7.55	8
368.00	394.00	102.00	1.471	-7.55	7
366.00	395.00	103.00	1.472	-7.54	8
367.00	395.00	103.00	1.471	-7.55	8
368.00	395.00	103.00	1.471	-7.55	7

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL
CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER = 367.00 Y-CENTER = 394.00 RADIUS = 102.00
FACTOR OF SAFETY = 1.471 SIDE FORCE INCLINATION = -7.55

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TABLE NO. 15
***** FINAL CRITICAL CIRCLE INFORMATION *****
X COORDINATE OF CENTER - - - - - - - - 367.000
Y COORDINATE OF CENTER - - - - - - - - 394.000
RADIUS - - - - - - - - - - - - - - - - - 102.000
FACTOR OF SAFETY - - - - - - - - - - - 1.471
SIDE FORCE INCLINATION - - - - - - - - -7.55

NUMBER OF CIRCLES TRIED - - - - - - - 127
NO. OF CIRCLES F CALC. FOR - - - - - - 123

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TABLE NO. 20
****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	270.8	360.0					
1	271.8	357.5	1591.1	7	800.00	13.50	.0
	272.7	355.0					
2	273.8	352.6	2995.2	7	800.00	13.50	.0
	274.9	350.1					
3	276.1	347.8	4640.4	7	800.00	13.50	.0
	277.3	345.4					
4	278.7	343.1	6502.1	7	800.00	13.50	.0
	280.0	340.7					
5	281.5	338.5	8553.4	7	800.00	13.50	.0
	282.9	336.3					
6	284.5	334.1	10765.4	7	800.00	13.50	.0
	286.0	331.9					
7	287.7	329.9	13107.8	7	800.00	13.50	.0
	289.4	327.8					
8	291.2	325.8	15549.1	7	800.00	13.50	.0
	293.0	323.8					
9	294.9	321.9	18056.9	7	800.00	13.50	.0
	296.8	320.0					
10	297.9	319.0	11339.1	7	800.00	13.50	.0

	299.0	318.0					
11	300.1	317.0	12323.4	5	1000.00	10.00	.0
	301.3	316.0					
12	301.6	315.8	3297.4	6	.00	10.00	
	301.9	315.5					
13	304.0	313.8	24183.7	5	1000.00	10.00	.0
	306.1	312.2					
14	306.5	311.8	5719.2	5	1000.00	10.00	.0
	307.0	311.5					
15	308.0	310.8	12200.6	4	800.00	10.00	.0
	309.0	310.1					
16	311.2	308.6	28205.4	4	800.00	10.00	.0
	313.5	307.2					
17	315.3	306.1	23684.9	4	800.00	10.00	.0
	317.2	305.0					
18	319.5	303.8	30500.0	3	320.00	10.00	.0
	321.9	302.5					
19	324.3	301.4	31376.0	3	320.00	10.00	.0
	326.7	300.3					
20	329.2	299.3	31978.5	3	320.00	10.00	.0
	331.7	298.3					
21	334.2	297.4	32294.2	3	320.00	10.00	.0
	336.8	296.6					
22	339.3	295.9	32313.6	3	320.00	10.00	.0
	341.9	295.1					

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TABLE NO. 20

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*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)               *
*******************************************************************
```

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	341.9	295.1					
23	344.5	294.5	32031.1	3	320.00	10.00	.0
	347.1	294.0					
24	349.7	293.5	31445.6	3	320.00	10.00	.0
	352.4	293.1					
25	355.0	292.7	30560.4	3	320.00	10.00	.0
	357.7	292.4					
26	360.3	292.3	29382.2	3	320.00	10.00	.0
	363.0	292.1					
27	365.0	292.0	21041.6	3	320.00	10.00	.0
	367.0	292.0					
28	369.7	292.1	26656.0	3	320.00	10.00	.0
	372.3	292.1					
29	375.0	292.3	24743.7	3	320.00	10.00	.0
	377.7	292.6					
30	380.3	292.9	22600.9	3	320.00	10.00	.
	383.0	293.3					
31	383.0	293.3	177.8	3	320.00	10.00	.
	383.0	293.3					
32	385.6	293.8	20363.3	3	320.00	10.00	.0
	388.3	294.2					

33	389.6	294.6	9853.0	3	320.00	10.00	.0
	391.0	294.9					
34	393.0	295.4	13644.5	3	320.00	10.00	.0
	395.0	295.9					
35	397.0	296.5	12695.0	3	320.00	10.00	.0
	399.0	297.1					
36	401.0	297.9	11664.8	3	320.00	10.00	.0
	403.0	298.6					
37	405.0	299.4	10096.4	3	320.00	10.00	.0
	407.0	300.2					
38	409.4	301.3	10463.5	3	320.00	10.00	.0
	411.9	302.4					
39	414.2	303.6	8809.7	3	320.00	10.00	.0
	416.6	304.9					
40	416.7	304.9	409.3	3	320.00	10.00	.0
	416.8	305.0					
41	419.1	306.4	6942.0	4	800.00	10.00	.0
	421.4	307.7					
42	423.6	309.2	5072.4	4	800.00	10.00	.0
	425.9	310.7					
43	426.4	311.1	1006.3	4	800.00	10.00	.0
	427.0	311.5					
44	429.1	313.1	2683.6	5	1000.00	10.00	.0
	431.2	314.8					

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
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TABLE NO. 20

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*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
```

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	431.2	314.8					
45	431.7	315.1	340.7	5	1000.00	10.00	.0
	432.1	315.5					
46	432.4	315.8	174.9	6	.00	10.00	.0
	432.7	316.0					
47	433.9	317.0	299.4	5	1000.00	10.00	.0
	435.0	318.0					

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TABLE NO. 21

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*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
```

SLICE NO.	X	SEISMIC FORCE	Y FOR SEISMIC FORCE	FORCES DUE TO SURFACE PRESSURES			
				NORMAL FORCE	SHEAR FORCE	X	Y

1	271.8	0.	361.3	0.	0.	.0	.0
2	273.8	0.	358.8	0.	0.	.0	.0
3	276.1	0.	356.4	0.	0.	.0	.0
4	278.7	0.	354.0	0.	0.	.0	
5	281.5	0.	351.8	0.	0.	.0	
6	284.5	0.	349.6	0.	0.	.0	.0
7	287.7	0.	347.4	0.	0.	.0	.0
8	291.2	0.	345.4	0.	0.	.0	.0
9	294.9	0.	343.5	0.	0.	.0	.0
10	297.9	0.	342.0	0.	0.	.0	.0
11	300.1	0.	340.9	0.	0.	.0	.0
12	301.6	0.	340.2	0.	0.	.0	.0
13	304.0	0.	339.1	0.	0.	.0	.0
14	306.5	0.	338.0	0.	0.	.0	.0
15	308.0	0.	337.4	0.	0.	.0	.0
16	311.2	0.	335.6	0.	0.	.0	.0
17	315.3	0.	333.1	0.	0.	.0	.0
18	319.5	0.	330.8	0.	0.	.0	.0
19	324.3	0.	328.3	0.	0.	.0	.0
20	329.2	0.	326.0	0.	0.	.0	.0
21	334.2	0.	323.7	0.	0.	.0	.0
22	339.3	0.	321.6	0.	0.	.0	.0
23	344.5	0.	319.6	0.	0.	.0	.0
24	349.7	0.	317.8	0.	0.	.0	.0
25	355.0	0.	316.0	0.	0.	.0	.0
26	360.3	0.	314.5	0.	0.	.0	.0
27	365.0	0.	313.2	0.	0.	.0	.0
28	369.7	0.	312.1	0.	0.	.0	.0
29	375.0	0.	310.9	0.	0.	.0	.0
30	380.3	0.	309.9	0.	0.	.0	
31	383.0	0.	309.4	0.	0.	.0	
32	385.6	0.	309.1	0.	0.	.0	.0
33	389.6	0.	308.7	0.	0.	.0	.0
34	393.0	0.	308.8	0.	0.	.0	.0
35	397.0	0.	309.1	0.	0.	.0	.0
36	401.0	0.	309.4	0.	0.	.0	.0
37	405.0	0.	309.3	0.	0.	.0	.0
38	409.4	0.	309.7	0.	0.	.0	.0
39	414.2	0.	310.8	0.	0.	.0	.0
40	416.7	0.	311.5	0.	0.	.0	.0
41	419.1	0.	312.2	0.	0.	.0	.0

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TABLE NO. 21

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*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
```

				FORCES DUE TO SURFACE PRESSURES			
SLICE NO.	X	SEISMIC FORCE	Y FOR SEISMIC FORCE	NORMAL FORCE	SHEAR FORCE	X	Y
42	423.6	0.	313.6	0.	0.	.0	.0
43	426.4	0.	314.5	0.	0.	.0	.0

44	429.1	0.	315.6	0.	0.	.0	.0
45	431.7	0.	316.6	0.	0.	.0	.0
46	432.4	0.	316.9	0.	0.	.0	.0
47	433.9	0.	317.5	0.	0.	.0	.0

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TABLE NO. 23

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*******************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY AND SIDE FORCE INCLINATION BY SPENCER'S PROCEDURE    *
*******************************************************************
```

ITER-ATION	TRIAL FACTOR OF SAFETY	TRIAL SIDE FORCE INCLINATION (DEGREES)	FORCE IMBALANCE (LBS.)	MOMENT IMBALANCE (FT.-LBS.)	DELTA-F	DELTA THETA (DEGREES)
1	3.00000	-15.0000	-.8250E+05	.3057E+08		
FIRST-ORDER CORRECTIONS TO F AND THETA					-.169E+01	-.111E+02
VALUES FACTORED BY .295E+00 - DELTAS TOO LARGE					-.500E+00	-.327E+01
2	2.50000	-18.2736	-.5460E+05	.1970E+08		
FIRST-ORDER CORRECTIONS TO F AND THETA					-.116E+02	.190E+03
VALUES FACTORED BY .432E-01 - DELTAS TOO LARGE					-.500E+00	.820E+01
3	2.00000	-10.0765	-.4588E+05	.1630E+08		
FIRST-ORDER CORRECTIONS TO F AND THETA					.406E+00	-.309E+02
VALUES FACTORED BY .278E+00 - DELTAS TOO LARGE					.113E+00	-.859E+01
4	2.11301	-18.6708	-.3168E+05	.1039E+08		
FIRST-ORDER CORRECTIONS TO F AND THETA					-.138E+01	.219E+02
VALUES FACTORED BY .362E+00 - DELTAS TOO LARGE					-.500E+00	.794E+01
5	1.61301	-10.7294	-.9465E+04	.2840E+07		
FIRST-ORDER CORRECTIONS TO F AND THETA					-.174E+00	.398E+01
SECOND-ORDER CORRECTION - ITERATION 1					-.158E+00	.398E+01
SECOND-ORDER CORRECTION - ITERATION 2					-.157E+00	.398E+01
6	1.45565	-6.7495	.1758E+03	.9881E+05		
FIRST-ORDER CORRECTIONS TO F AND THETA					.152E-01	-.797E+00
SECOND-ORDER CORRECTION - ITERATION 1					.154E-01	-.797E+00
SECOND-ORDER CORRECTION - ITERATION 2					.154E-01	-.797E+00
7	1.47109	-7.5463	-.9082E-01	-.1336E+03		
FIRST-ORDER CORRECTIONS TO F AND THETA					-.154E-04	.818E-03
SECOND-ORDER CORRECTION - ITERATION 1					-.154E-04	.817E-03
8	1.47108	-7.5455	-.1001E-01	.3696E+01		
FIRST-ORDER CORRECTIONS TO F AND THETA					-.615E-07	-.771E-06

FACTOR OF SAFETY - - - - - - - - 1.471
SIDE FORCE INCLINATION - - - - - -7.55
NUMBER OF ITERATIONS - - - - - - 8

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TABLE NO. 24

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*******************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
*******************************************
```

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
FACTOR OF SAFETY = 1.471   SIDE FORCE INCLINATION = -7.55 DEGREES

-------- VALUES AT CENTER OF BASE OF SLICE---------

SLICE NO.	X-CENTER	Y-CENTER	TOTAL NORMAL STRESS	EFFECTIVE NORMAL STRESS	SHEAR STRESS
1	271.8	357.5	-293.9	-293.9	495.9
2	273.8	352.6	139.6	139.6	566.6
3	276.1	347.8	589.6	589.6	640.0
4	278.7	343.1	1050.5	1050.5	715.3
5	281.5	338.5	1517.9	1517.9	791.5
6	284.5	334.1	1988.0	1988.0	868.3
7	287.7	329.9	2457.5	2457.5	944.9
8	291.2	325.8	2923.7	2923.7	1021.0
9	294.9	321.9	3383.8	3383.8	1096.0
10	297.9	319.0	3739.8	3739.8	1154.1
11	300.1	317.0	4031.8	4031.8	1163.0
12	301.6	315.8	4614.0	4614.0	553.0
13	304.0	313.8	4496.0	4496.0	1218.7
14	306.5	311.8	4796.5	4796.5	1254.7
15	308.0	310.8	5025.3	5025.3	1146.2
16	311.2	308.6	5244.5	5244.5	1172.4
17	315.3	306.1	5434.6	5434.6	1195.2
18	319.5	303.8	5701.6	5701.6	900.9
19	324.3	301.4	5814.3	5814.3	914.4
20	329.2	299.3	5889.9	5889.9	923.5
21	334.2	297.4	5927.8	5927.8	928.0
22	339.3	295.9	5927.0	5927.0	927.9
23	344.5	294.5	5886.9	5886.9	923.1
24	349.7	293.5	5806.8	5806.8	913.5
25	355.0	292.7	5686.4	5686.4	899.1
26	360.3	292.3	5525.0	5525.0	879.8
27	365.0	292.0	5352.1	5352.1	859.0
28	369.7	292.1	5143.6	5143.6	834.0
29	375.0	292.3	4867.8	4867.8	801.0
30	380.3	292.9	4549.7	4549.7	762.9
31	383.0	293.3	4377.2	4377.2	742.2
32	385.6	293.8	4212.1	4212.1	722.4
33	389.6	294.6	3951.1	3951.1	691.1
34	393.0	295.4	3811.4	3811.4	674.4
35	397.0	296.5	3606.9	3606.9	649.9
36	401.0	297.9	3376.9	3376.9	622.3
37	405.0	299.4	2990.8	2990.8	576.0
38	409.4	301.3	2628.4	2628.4	532.6
39	414.2	303.6	2351.2	2351.2	499.3
40	416.7	304.9	2192.2	2192.2	480.3

-------- VALUES AT CENTER OF BASE OF SLICE---------

SLICE NO.	X-CENTER	Y-CENTER	TOTAL NORMAL STRESS	EFFECTIVE NORMAL STRESS	SHEAR STRESS
41	419.1	306.4	2287.7	2287.7	818.0
42	423.6	309.2	1934.4	1934.4	775.7
43	426.4	311.1	1691.9	1691.9	746.6
44	429.1	313.1	1576.0	1576.0	868.7
45	431.7	315.1	1313.6	1313.6	837.2
46	432.4	315.8	378.3	378.3	45.3
47	433.9	317.0	1059.5	1059.5	806.8

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = .01 (= .140E-01)
SHOULD NOT EXCEED .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = .05 (= .501E-01)
SHOULD NOT EXCEED .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN = .23 (= .230E+00)
SHOULD NOT EXCEED .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = .00 (= .564E-02)
SHOULD NOT EXCEED .100E+03

***** CAUTION ***** EFFECTIVE OR TOTAL NORMAL STRESS ON SHEAR SURFACE IS NEGATIVE AT POINTS ALONG THE UPPER ONE-HALF OF THE SHEAR SURFACE - A TENSION CRACK MAY BE NEEDED.

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Model City Landfill
Chemical Waste Management
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TABLE NO. 25
****
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH) *
****

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
FACTOR OF SAFETY = 1.471 SIDE FORCE INCLINATION = -7.55 DEGREES

--------------- VALUES AT RIGHT SIDE OF SLICE ---------------

SLICE NO.	X-RIGHT	SIDE FORCE	Y-COORD. OF SIDE FORCE LOCATION	FRACTION OF HEIGHT	SIGMA AT TOP	SIGMA AT BOTTOM
1	272.7	-2434.	357.4	.237	139.7	-623.0
2	274.9	-2987.	356.2	.410	-91.7	-306.7
3	277.3	-1720.	362.0	.849	-268.8	95.0
4	280.0	1257.	317.2	BELOW	-402.6	505.4
5	282.9	5796.	333.6	BELOW	-509.5	909.5
6	286.0	11716.	333.6	.049	-599.3	1302.1
7	289.4	18807.	331.8	.108	-677.5	1679.7
8	293.0	26838.	329.6	.141	-747.2	2039.5
9	296.8	35560.	327.3	.161	-810.0	2378.4
10	299.0	40698.	326.0	.170	-843.1	2559.9
11	301.3	46131.	324.6	.176	-880.4	2747.0
12	301.9	48124.	324.2	.175	-913.1	2840.7
13	306.1	57935.	321.9	.184	-973.3	3148.8

14	307.0	60115.	321.4	.186	-986.6	3214.4
15	309.0	64945.	320.4	.190	-1022.4	3393.0
16	313.5	75108.	318.2	.200	-1076.8	3760.[illegible]
17	317.2	82570.	316.7	.210	-1090.0	4028
18	321.9	92572.	314.7	.219	-1134.0	4427.[illegible]
19	326.7	101208.	312.9	.229	-1138.3	4759.4
20	331.7	108341.	311.4	.239	-1106.6	5026.9
21	336.8	113867.	310.1	.251	-1041.2	5233.1
22	341.9	117719.	308.9	.262	-943.4	5379.8
23	347.1	119864.	308.0	.275	-813.6	5468.3
24	352.4	120308.	307.3	.289	-650.9	5499.0
25	357.7	119095.	306.7	.303	-452.8	5471.8
26	363.0	116310.	306.3	.319	-215.4	5385.8
27	367.0	113271.	306.2	.333	-8.2	5281.9
28	372.3	108055.	306.1	.353	316.7	5087.1
29	377.7	101696.	306.3	.376	710.8	4823.1
30	383.0	94423.	306.6	.404	1199.9	4479.6
31	383.0	94360.	306.6	.404	1204.5	4476.4
32	388.3	86389.	307.0	.438	1837.6	4027.5
33	391.0	81979.	307.3	.450	2062.2	3814.0
34	395.0	75203.	307.8	.457	2122.9	3593.9
35	399.0	68101.	308.5	.465	2183.3	3361.7
36	403.0	60772.	309.2	.495	2729.9	2891.1
37	407.0	53602.	309.9	.529	3387.0	2377.4
38	411.9	45102.	310.9	.542	3587.4	2142.0
39	416.6	36852.	311.8	.526	3212.9	2350.0
40	416.8	36438.	311.8	.524	3186.4	2370.9

--------------- VALUES AT RIGHT SIDE OF SLICE --------------

SLICE NO.	X-RIGHT	SIDE FORCE	Y-COORD. OF SIDE FORCE LOCATION	FRACTION OF HEIGHT	SIGMA AT TOP	SIGMA AT BOTTOM
41	421.4	26351.	313.2	.531	3013.2	2074.0
42	425.9	17089.	314.6	.532	2769.2	1869.7
43	427.0	14872.	314.9	.530	2674.5	1862.0
44	431.2	5991.	316.7	.588	2795.4	861.8
45	432.1	4230.	317.2	.662	3311.4	42.9
46	432.7	4011.	317.2	.576	2889.8	1086.9
47	435.0	1.	-2527.9	BELOW	.0	.0

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = .01 (= .140E-01)
SHOULD NOT EXCEED .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = .05 (= .501E-01)
SHOULD NOT EXCEED .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN = .23 (= .230E+00)
SHOULD NOT EXCEED .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = .00 (= .564E-02)
SHOULD NOT EXCEED .100E+03

***** CAUTION ***** FORCES BETWEEN SLICES ARE NEGATIVE AT POINTS ALONG THE UPPER ONE-HALF OF THE SHEAR SURFACE - A TENSION CRACK MAY BE NEEDED.

***** CAUTION ***** SOME OF THE FORCES BETWEEN SLICES ACT AT POINTS ABOVE THE SURFACE OF THE SLOPE OR BELOW THE

SHEAR SURFACE - EITHER A TENSION CRACK MAY BE
NEEDED OR THE SOLUTION MAY NOT BE A VALID SOLUTION

END-OF-FILE ENCOUNTERED WHILE READING COMMAND
WORDS - END OF PROBLEM(S) ASSUMED

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

CASE 3. H=45 FEET

SLOPE=2:1

TABLE NO. 1

```
*****************************************
* COMPUTER PROGRAM DESIGNATION - UTEXAS2 *
* ORIGINALLY CODED BY STEPHEN G. WRIGHT  *
* VERSION NO. 1.209                      *
* LAST REVISION DATE 11/23/87            *
* SERIAL NO. 00004                       *
* (C) COPYRIGHT 1985 STEPHEN G. WRIGHT   *
* ALL RIGHTS RESERVED                    *
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*************************************************************
*                                                           *
*      RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
* PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
* HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL   *
* DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE   *
* ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER  *
* PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS      *
* PROGRAM BEFORE ATTEMPTING ITS USE.                         *
*                                                           *
*      NEITHER THE UNIVERSITY OF TEXAS NOR STEPHEN G. WRIGHT *
* MAKE OR ASSUME LIABILITY FOR ANY WARRANTIES, EXPRESSED OR  *
* IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS  *
* OR ADAPTABILITY OF THIS COMPUTER PROGRAM.                  *
*                                                           *
*************************************************************
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Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 2

```
************************
* NEW PROFILE LINE DATA *
************************
```

PROFILE LINE 1 - MATERIAL TYPE = 1
Bedrock

POINT	X	Y
1	-100.000	275.000
2	900.000	275.000

PROFILE LINE 2 - MATERIAL TYPE = 2
Glaciolacustrine Sand/Silt

POINT	X	Y
1	-100.000	290.000
2	900.000	290.000

PROFILE LINE 3 - MATERIAL TYPE = 3
LACUSTRINE CLAY

POINT	X	Y

1	-100.000	305.000
2	900.000	305.000

PROFILE LINE 4 - MATERIAL TYPE = 4
UPPER TILL

POINT	X	Y
1	-100.000	311.500
2	900.000	311.500

PROFILE LINE 5 - MATERIAL TYPE = 5
Lower Soil Liner

POINT	X	Y
1	-100.000	315.500
2	900.000	315.500

PROFILE LINE 6 - MATERIAL TYPE = 6
Synthetic Liner

POINT	X	Y
1	-100.000	316.000
2	900.000	316.000

PROFILE LINE 7 - MATERIAL TYPE = 5
Upper Soil Liner

POINT	X	Y
1	-100.000	318.000
2	383.000	318.000
3	391.000	322.000
4	399.000	322.000
5	407.000	318.000
6	900.000	318.000

PROFILE LINE 8 - MATERIAL TYPE = 7
Waste

POINT	X	Y
1	-100.000	363.000
2	313.000	363.000
3	403.000	318.000

ALL NEW PROFILE LINES DEFINED - NO OLD LINES RETAINED
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TABLE NO. 3
****
* NEW MATERIAL PROPERTY DATA *
****

DATA FOR MATERIAL TYPE 1

BEDROCK

UNIT WEIGHT OF MATERIAL = 140.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 2000.000
FRICTION ANGLE - - - - - 40.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 2
Glaciolacustrine Sand/Silt

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - .000
FRICTION ANGLE - - - - - 30.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 3
Glaciolacustrine Clay

UNIT WEIGHT OF MATERIAL = 125.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 320.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 4
UPPER TILL

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 800.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 5
Soil Liner

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 1000.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 6
Synthetic Liner

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS

COHESION - - - - - - - - .000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 7
Waste

UNIT WEIGHT OF MATERIAL = 111.100

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - 800.000
FRICTION ANGLE - - - - - 13.500 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

ALL NEW MATERIAL PROPERTIES DEFINED - NO OLD DATA RETAINED
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TABLE NO. 9
****
* NEW ANALYSIS/COMPUTATION DATA *
****

CIRCULAR SHEAR SURFACE(S)

AUTOMATIC SEARCH PERFORMED

STARTING CENTER COORDINATE FOR SEARCH AT -
X = 360.000
Y = 400.000

REQUIRED ACCURACY FOR CRITICAL CENTER (= MINIMUM
SPACING BETWEEN GRID POINTS) = 1.000

CRITICAL SHEAR SURFACE NOT ALLOWED TO PASS BELOW Y = 270.000

FOR THE INITIAL MODE OF SEARCH
ALL CIRCLES ARE TANGENT TO HORIZONTAL LINE AT -
Y = 290.000

DEPTH OF CRACK = 5.000

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

INITIAL TRIAL ESTIMATE FOR THE FACTOR OF SAFETY = 3.000

INITIAL TRIAL ESTIMATE FOR SIDE FORCE INCLINATION = 15.000 DEGREES
(APPLICABLE TO SPENCER'S PROCEDURE ONLY)

MAXIMUM NUMBER OF ITERATIONS ALLOWED FOR
CALCULATING THE FACTOR OF SAFETY = 40

ALLOWED FORCE IMBALANCE FOR CONVERGENCE = 100.000

ALLOWED MOMENT IMBALANCE FOR CONVERGENCE = 100.000

INITIAL TRIAL VALUES FOR FACTOR OF SAFETY (AND SIDE FORCE INCLINATION FOR SPENCER'S PROCEDURE) WILL BE KEPT CONSTANT DURING SEARCH

MAXIMUM SUBTENDED ANGLE TO BE USED FOR SUBDIVISION OF THE CIRCLE INTO SLICES = 3.00 DEGREES

SEARCH WILL BE CONTINUED TO LOCATE A MORE CRITICAL SHEAR SURFACE (IF ONE EXISTS) AFTER THE INITIAL MODE IS COMPLETE

DEPTH OF WATER IN CRACK = .000

UNIT WEIGHT OF WATER IN CRACK = 62.400

SEISMIC COEFFICIENT = .000

PROCEDURE USED TO COMPUTE THE FACTOR OF SAFETY: SPENCER

TABLE NO. 10

****
* NEW SLOPE GEOMETRY DATA *
****

NOTE - NO DATA WERE INPUT, SLOPE GEOMETRY DATA WERE GENERATED BY THE PROGRAM

SLOPE COORDINATES -

POINT	X	Y
1	-100.000	363.000
2	313.000	363.000
3	391.000	322.000
4	399.000	322.000
5	407.000	318.000
6	900.000	318.000

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TABLE NO. 12

INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES ARE TANGENT TO A HORIZONTAL LINE AT Y = 290.000

CENTER COORDINATES X	CENTER COORDINATES Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
330.00	370.00	80.00	2.067	-5.89	5
360.00	370.00	80.00	1.562	-6.26	8
390.00	370.00	80.00	1.794	-6.36	8
330.00	400.00	110.00	1.889	-7.02	5
360.00	400.00	110.00	1.537	-7.03	8

390.00	400.00	110.00	1.615	-7.35	7
330.00	430.00	140.00	1.863	-7.10	5
360.00	430.00	140.00	1.589	-6.79	7
390.00	430.00	140.00	1.615	-6.93	8
355.00	395.00	105.00	1.559	-7.09	7
360.00	395.00	105.00	1.533	-7.03	8
365.00	395.00	105.00	1.519	-7.00	7
355.00	400.00	110.00	1.563	-7.09	7
365.00	400.00	110.00	1.522	-6.99	7
355.00	405.00	115.00	1.568	-7.08	7
360.00	405.00	115.00	1.543	-7.01	8
365.00	405.00	115.00	1.528	-6.97	7
360.00	390.00	100.00	1.532	-7.01	8
365.00	390.00	100.00	1.517	-6.98	7
370.00	390.00	100.00	1.514	-6.98	6
370.00	395.00	105.00	1.515	-7.00	6
370.00	400.00	110.00	1.518	-6.99	6
365.00	385.00	95.00	1.518	-6.92	7
370.00	385.00	95.00	1.517	-6.93	6
375.00	385.00	95.00	1.528	-6.98	6
375.00	390.00	100.00	1.524	-7.03	6
375.00	395.00	105.00	1.522	-7.04	6
367.00	387.00	97.00	1.515	-6.94	7
370.00	387.00	97.00	1.515	-6.95	6
373.00	387.00	97.00	1.520	-6.98	6
367.00	390.00	100.00	1.514	-6.97	6
373.00	390.00	100.00	1.518	-7.00	6
367.00	393.00	103.00	1.515	-6.99	6
370.00	393.00	103.00	1.514	-6.99	6
373.00	393.00	103.00	1.518	-7.01	6
369.00	389.00	99.00	1.514	-6.97	6
370.00	389.00	99.00	1.514	-6.97	6
371.00	389.00	99.00	1.515	-6.98	6
369.00	390.00	100.00	1.514	-6.98	6
371.00	390.00	100.00	1.515	-6.99	6
369.00	391.00	101.00	1.514	-6.98	6
370.00	391.00	101.00	1.514	-6.99	6
371.00	391.00	101.00	1.515	-6.99	6
368.00	390.00	100.00	1.514	-6.97	6
368.00	391.00	101.00	1.514	-6.98	6
368.00	392.00	102.00	1.514	-6.98	6
369.00	392.00	102.00	1.514	-6.99	6
370.00	392.00	102.00	1.514	-6.99	6

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL
CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER = 369.00 Y-CENTER = 391.00 RADIUS = 101.00
FACTOR OF SAFETY = 1.514 SIDE FORCE INCLINATION = -6.98

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TABLE NO. 13

INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES HAVE THE SAME RADIUS - RADIUS = 101.000

CENTER COORDINATES X	Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
339.00	361.00	101.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
369.00	361.00	101.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
399.00	361.00	101.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
339.00	391.00	101.00	1.733	-7.16	6
399.00	391.00	101.00	1.794	-7.59	6
339.00	421.00	101.00	2.450	-10.87	7
369.00	421.00	101.00	1.982	-15.93	5
399.00	421.00	101.00	3.302	-19.45	4
364.00	386.00	101.00	2.347	-9.73	4
369.00	386.00	101.00	2.314	-9.68	4
374.00	386.00	101.00	2.298	-9.65	4
364.00	391.00	101.00	1.519	-6.99	7
374.00	391.00	101.00	1.520	-7.02	6
364.00	396.00	101.00	1.520	-7.78	9
369.00	396.00	101.00	1.514	-7.80	8
374.00	396.00	101.00	1.521	-7.86	8
366.00	388.00	101.00	2.138	-9.58	5
369.00	388.00	101.00	2.121	-9.56	5
372.00	388.00	101.00	2.112	-9.53	5
366.00	391.00	101.00	1.516	-6.98	7
372.00	391.00	101.00	1.516	-7.00	6
366.00	394.00	101.00	1.512	-7.44	8
369.00	394.00	101.00	1.510	-7.44	10
372.00	394.00	101.00	1.512	-7.47	8
366.00	397.00	101.00	1.520	-7.98	8
369.00	397.00	101.00	1.518	-8.00	8
372.00	397.00	101.00	1.521	-8.03	8
368.00	393.00	101.00	1.510	-7.28	7
369.00	393.00	101.00	1.510	-7.28	7
370.00	393.00	101.00	1.510	-7.29	7
368.00	394.00	101.00	SEE MESSAGE ON NEXT LINE(S)		
LAST TRIAL VALUES =			1.482	7.02	6
VALUES SHOWN ABOVE ARE NOT CORRECT FINAL VALUES					
VALUE OF SIDE FORCE INCLINATION BECAME OUTSIDE RANGE OF FROM -80.00 TO 10.00 DEGREES					
370.00	394.00	101.00	1.510	-7.45	8
368.00	395.00	101.00	1.511	-7.61	8
369.00	395.00	101.00	1.511	-7.62	8
370.00	395.00	101.00	1.511	-7.62	8

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER = 369.00 Y-CENTER = 394.00 RADIUS = 101.00
FACTOR OF SAFETY = 1.510 SIDE FORCE INCLINATION = -7.44

***** CAUTION ***** FACTOR OF SAFETY COULD NOT BE COMPUTED FOR SOME
OF GRID POINTS AROUND THE MINIMUM
***** RESULTS MAY BE ERRONEOUS *****

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TABLE NO. 12
INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES ARE TANGENT TO A HORIZONTAL LINE AT Y = 293.000

CENTER COORDINATES X	Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
339.00	364.00	71.00	1.919	-5.37	5
369.00	364.00	71.00	1.586	-5.82	7
399.00	364.00	71.00	2.238	-6.10	5
339.00	394.00	101.00	1.746	-7.39	7
399.00	394.00	101.00	1.806	-8.05	7
339.00	424.00	131.00	1.745	-7.42	6
369.00	424.00	131.00	1.552	-7.16	7
399.00	424.00	131.00	1.707	-7.73	6
364.00	389.00	96.00	1.514	-7.42	7
369.00	389.00	96.00	SEE MESSAGE ON NEXT LINE(S)		
LAST TRIAL VALUES =			1.464	6.67	6
VALUES SHOWN ABOVE ARE NOT CORRECT FINAL VALUES					
VALUE OF SIDE FORCE INCLINATION BECAME OUTSIDE RANGE OF FROM -80.00 TO 10.00 DEGREES					
374.00	389.00	96.00	SEE MESSAGE ON NEXT LINE(S)		
LAST TRIAL VALUES =			1.470	6.88	6
VALUES SHOWN ABOVE ARE NOT CORRECT FINAL VALUES					
VALUE OF SIDE FORCE INCLINATION BECAME OUTSIDE RANGE OF FROM -80.00 TO 10.00 DEGREES					
364.00	394.00	101.00	1.516	-7.44	7
374.00	394.00	101.00	1.517	-7.49	8
364.00	399.00	106.00	1.519	-7.43	7
369.00	399.00	106.00	SEE MESSAGE ON NEXT LINE(S)		
LAST TRIAL VALUES =			1.495	7.20	6
VALUES SHOWN ABOVE ARE NOT CORRECT FINAL VALUES					
VALUE OF SIDE FORCE INCLINATION BECAME OUTSIDE RANGE OF FROM -80.00 TO 10.00 DEGREES					
374.00	399.00	106.00	1.518	-7.47	8
366.00	391.00	98.00	1.511	-7.43	8
369.00	391.00	98.00	1.509	-7.44	10
372.00	391.00	98.00	1.513	-7.47	8
366.00	394.00	101.00	1.512	-7.44	8
372.00	394.00	101.00	1.512	-7.47	8
366.00	397.00	104.00	1.514	-7.43	8
369.00	397.00	104.00	1.511	-7.44	10
372.00	397.00	104.00	1.513	-7.46	8
366.00	388.00	95.00	1.511	-7.41	7

```
     369.00     388.00      95.00   1.510       -7.43          9
     372.00     388.00      95.00   1.514       -7.45         10

     368.00     390.00      97.00   1.509       -7.43          9
     369.00     390.00      97.00   1.509       -7.44         10
     370.00     390.00      97.00   1.510       -7.45          9
     368.00     391.00      98.00   1.509       -7.44          9
     370.00     391.00      98.00   1.510       -7.45          8
     368.00     392.00      99.00 SEE MESSAGE ON NEXT LINE(S)
            LAST TRIAL VALUES =   1.477        6.96          6
            VALUES SHOWN ABOVE ARE NOT CORRECT FINAL VALUES
 VALUE OF SIDE FORCE INCLINATION BECAME OUTSIDE RANGE OF FROM  -80.00
 TO   10.00 DEGREES
     369.00     392.00      99.00   1.509       -7.44         10
     370.00     392.00      99.00   1.510       -7.45          8

 AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL
 CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
 X-CENTER =     369.00     Y-CENTER =    391.00     RADIUS =     98.00
 FACTOR OF SAFETY =   1.509     SIDE FORCE INCLINATION =  -7.44


 ***** CAUTION ***** FACTOR OF SAFETY COULD NOT BE COMPUTED FOR SOME
                     OF GRID POINTS AROUND THE MINIMUM
 ***** RESULTS MAY BE ERRONEOUS *****
1UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
   Model City Landfill
   Chemical Waste Management
   Slope Stability - Waste Filling Sequence

 TABLE NO. 15
 ***** FINAL CRITICAL CIRCLE INFORMATION *****
 X COORDINATE OF CENTER - - - - - - - -   369.000
 Y COORDINATE OF CENTER - - - - - - - -   391.000
 RADIUS - - - - - - - - - - - - - - - -    98.000
 FACTOR OF SAFETY - - - - - - - - - - -     1.509
 SIDE FORCE INCLINATION - - - - - - - -     -7.44

 NUMBER OF CIRCLES TRIED  - - - - - - -  118
 NO. OF CIRCLES F CALC. FOR - - - - - -  110


 ***** CAUTION ***** FACTOR OF SAFETY COULD NOT BE COMPUTED FOR SOME
                     OF GRID POINTS AROUND THE MINIMUM
 ***** RESULTS MAY BE ERRONEOUS *****
1UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
   Model City Landfill
   Chemical Waste Management
   Slope Stability - Waste Filling Sequence

 TABLE NO. 20
 ******************************************************************
 * INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
 * SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
 ******************************************************************

 SLICE                         SLICE   MATL.             FRICTION    PORE
   NO.      X         Y        WEIGHT  TYPE   COHESION    ANGLE    PRESSURE

         276.7    358.0
```

1	277.7	355.6	1522.2	7	800.00	13.50	.0
	278.6	353.2					
2	279.6	350.9	2830.6	7	800.00	13.50	.0
	280.7	348.5					
3	281.8	346.3	4360.2	7	800.00	13.50	
	283.0	344.0					
4	284.3	341.8	6088.0	7	800.00	13.50	.0
	285.6	339.5					
5	287.0	337.4	7989.2	7	800.00	13.50	.0
	288.4	335.2					
6	289.9	333.2	10036.9	7	800.00	13.50	.0
	291.4	331.1					
7	293.1	329.1	12203.2	7	800.00	13.50	.0
	294.7	327.1					
8	296.4	325.2	14458.9	7	800.00	13.50	.0
	298.1	323.3					
9	299.9	321.5	16774.0	7	800.00	13.50	.0
	301.8	319.7					
10	302.7	318.9	9093.9	7	800.00	13.50	.0
	303.6	318.0					
11	304.8	317.0	11819.2	5	1000.00	10.00	.0
	305.9	316.0					
12	306.2	315.8	3171.7	6	.00	10.00	.0
	306.5	315.5					
13	308.5	313.9	22325.8	5	1000.00	10.00	.0
	310.6	312.3					
14	311.1	311.9	6595.0	5	1000.00	10.00	.0
	311.7	311.5					
15	312.3	311.0	7699.6	4	800.00	10.00	.0
	313.0	310.6					
16	315.1	309.2	25812.5	4	800.00	10.00	
	317.3	307.8					
17	319.5	306.5	27097.6	4	800.00	10.00	.0
	321.7	305.2					
18	321.9	305.1	1831.8	4	800.00	10.00	.0
	322.0	305.0					
19	324.3	303.8	28196.6	3	320.00	10.00	.0
	326.6	302.7					
20	328.9	301.6	28950.2	3	320.00	10.00	.0
	331.3	300.6					
21	333.7	299.6	29448.8	3	320.00	10.00	.0
	336.0	298.7					
22	338.5	297.9	29680.6	3	320.00	10.00	.0
	340.9	297.1					

UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 20

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*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
```

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSU
	340.9	297.1					
23	343.4	296.4	29637.9	3	320.00	10.00	.0

	345.9	295.8					
24	348.4	295.2	29316.3	3	320.00	10.00	.0
	350.9	294.7					
25	353.4	294.3	28715.7	3	320.00	10.00	.0
	356.0	293.9					
26	358.5	293.6	27839.6	3	320.00	10.00	.0
	361.1	293.3					
27	363.6	293.2	26695.5	3	320.00	10.00	.0
	366.2	293.0					
28	367.6	293.0	14120.5	3	320.00	10.00	.0
	369.0	293.0					
29	371.6	293.1	24419.0	3	320.00	10.00	.0
	374.1	293.1					
30	376.7	293.3	22650.4	3	320.00	10.00	.0
	379.2	293.5					
31	381.1	293.8	15456.4	3	320.00	10.00	.0
	383.0	294.0					
32	385.5	294.4	19207.3	3	320.00	10.00	.0
	388.1	294.9					
33	389.5	295.2	10325.9	3	320.00	10.00	.0
	391.0	295.5					
34	393.0	296.0	13336.7	3	320.00	10.00	.0
	395.0	296.5					
35	397.0	297.1	12407.8	3	320.00	10.00	.0
	399.0	297.7					
36	401.0	298.4	11395.3	3	320.00	10.00	.0
	403.0	299.1					
37	405.0	299.9	9841.4	3	320.00	10.00	.0
	407.0	300.7					
38	409.3	301.7	9816.6	3	320.00	10.00	.0
	411.7	302.8					
39	413.8	303.9	7888.9	3	320.00	10.00	.0
	416.0	305.0					
40	418.2	306.3	6754.5	4	800.00	10.00	.0
	420.4	307.6					
41	422.6	309.0	5037.0	4	800.00	10.00	.0
	424.7	310.4					
42	425.5	310.9	1452.3	4	800.00	10.00	.0
	426.3	311.5					
43	428.3	313.1	2624.8	5	1000.00	10.00	.0
	430.4	314.6					
44	430.9	315.1	418.9	5	1000.00	10.00	.0
	431.5	315.5					

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 20

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*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*******************************************************************
```

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	431.5	315.5					
45	431.8	315.8	175.3	6	.00	10.00	.0
	432.1	316.0					

46	433.2	317.0	299.5	5	1000.00	10.00	
	434.4	318.0					.0

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 21

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*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
```

SLICE NO.	X	SEISMIC FORCE	Y FOR SEISMIC FORCE	FORCES DUE TO SURFACE PRESSURES: NORMAL FORCE	SHEAR FORCE	X	Y
1	277.7	0.	359.3	0.	0.	.0	.0
2	279.6	0.	356.9	0.	0.	.0	.0
3	281.8	0.	354.6	0.	0.	.0	.0
4	284.3	0.	352.4	0.	0.	.0	.0
5	287.0	0.	350.2	0.	0.	.0	.0
6	289.9	0.	348.1	0.	0.	.0	.0
7	293.1	0.	346.1	0.	0.	.0	.0
8	296.4	0.	344.1	0.	0.	.0	.0
9	299.9	0.	342.3	0.	0.	.0	.0
10	302.7	0.	340.9	0.	0.	.0	.0
11	304.8	0.	339.9	0.	0.	.0	.0
12	306.2	0.	339.2	0.	0.	.0	.0
13	308.5	0.	338.1	0.	0.	.0	
14	311.1	0.	337.0	0.	0.	.0	[illegible]
15	312.3	0.	336.5	0.	0.	.0	.0
16	315.1	0.	334.9	0.	0.	.0	.0
17	319.5	0.	332.3	0.	0.	.0	.0
18	321.9	0.	330.9	0.	0.	.0	.0
19	324.3	0.	329.6	0.	0.	.0	.0
20	328.9	0.	327.3	0.	0.	.0	.0
21	333.7	0.	325.0	0.	0.	.0	.0
22	338.5	0.	322.9	0.	0.	.0	.0
23	343.4	0.	320.9	0.	0.	.0	.0
24	348.4	0.	319.0	0.	0.	.0	.0
25	353.4	0.	317.3	0.	0.	.0	.0
26	358.5	0.	315.6	0.	0.	.0	.0
27	363.6	0.	314.1	0.	0.	.0	.0
28	367.6	0.	313.1	0.	0.	.0	.0
29	371.6	0.	312.1	0.	0.	.0	.0
30	376.7	0.	311.0	0.	0.	.0	.0
31	381.1	0.	310.1	0.	0.	.0	.0
32	385.5	0.	309.4	0.	0.	.0	.0
33	389.5	0.	309.0	0.	0.	.0	.0
34	393.0	0.	309.1	0.	0.	.0	.0
35	397.0	0.	309.4	0.	0.	.0	.0
36	401.0	0.	309.6	0.	0.	.0	.0
37	405.0	0.	309.5	0.	0.	.0	.0
38	409.3	0.	309.9	0.	0.	.0	.0
39	413.8	0.	311.0	0.	0.	.0	
40	418.2	0.	312.1	0.	0.	.0	[illegible]
41	422.6	0.	313.5	0.	0.	.0	.0

UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 21

```
*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*******************************************************************
```

SLICE NO.	X	SEISMIC FORCE	Y FOR SEISMIC FORCE	FORCES DUE TO SURFACE PRESSURES NORMAL FORCE	SHEAR FORCE	X	Y
42	425.5	0.	314.5	0.	0.	.0	.0
43	428.3	0.	315.5	0.	0.	.0	.0
44	430.9	0.	316.5	0.	0.	.0	.0
45	431.8	0.	316.9	0.	0.	.0	.0
46	433.2	0.	317.5	0.	0.	.0	.0

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Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 23

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*******************************************************************
* INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
* OF SAFETY AND SIDE FORCE INCLINATION BY SPENCER'S PROCEDURE    *
*******************************************************************
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```
        TRIAL     TRIAL
        FACTOR   SIDE FORCE   FORCE      MOMENT                 DELTA
ITER-    OF     INCLINATION IMBALANCE  IMBALANCE    DELTA-F     THETA
ATION  SAFETY   (DEGREES)    (LBS.)   (FT.-LBS.)              (DEGREES)

  1   3.00000   -15.0000  -.7317E+05   .2717E+08
FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.158E+01 -.109E+02
VALUES FACTORED BY  .317E+00 - DELTAS TOO LARGE    -.500E+00 -.346E+01

  2   2.50000   -18.4578  -.4654E+05   .1675E+08
FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.744E+01  .118E+03
VALUES FACTORED BY  .672E-01 - DELTAS TOO LARGE    -.500E+00  .793E+01

  3   2.00000   -10.5294  -.3741E+05   .1326E+08
FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.123E+02  .355E+03
VALUES FACTORED BY  .242E-01 - DELTAS TOO LARGE    -.297E+00  .859E+01

  4   1.70329    -1.9350  -.3259E+05   .1151E+08
FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.160E+01  .545E+02
VALUES FACTORED BY  .158E+00 - DELTAS TOO LARGE    -.253E+00  .859E+01

  5   1.45069     6.6594  -.2272E+05   .8516E+07
FIRST-ORDER CORRECTIONS TO F AND THETA .........    .331E+01 -.216E+03
VALUES FACTORED BY  .398E-01 - DELTAS TOO LARGE     .132E+00 -.859E+01

  6   1.58251    -1.9350  -.2022E+05   .7498E+07
FIRST-ORDER CORRECTIONS TO F AND THETA .........    .170E+00 -.181E+02
VALUES FACTORED BY  .475E+00 - DELTAS TOO LARGE     .808E-01 -.859E+01
```

```
   7   1.66332    -10.5294   -.9725E+04    .3029E+07
FIRST-ORDER CORRECTIONS TO F AND THETA .........     -.193E+00   .407E+01
SECOND-ORDER CORRECTION - ITERATION   1 ........     -.174E+00   .407E+0
SECOND-ORDER CORRECTION - ITERATION   2 ........     -.173E+00   .407E
SECOND-ORDER CORRECTION - ITERATION   3 ........     -.173E+00   .407E

   8   1.48985     -6.4596    .2020E+03    .1042E+06
FIRST-ORDER CORRECTIONS TO F AND THETA .........
SECOND-ORDER CORRECTION - ITERATION   1 ........      .192E-01  -.982E+00
SECOND-ORDER CORRECTION - ITERATION   2 ........      .195E-01  -.982E+00
                                                      .195E-01  -.982E+00

   9   1.50938     -7.4418   -.1948E+00   -.5801E+02
FIRST-ORDER CORRECTIONS TO F AND THETA .........     -.148E-04   .709E-03
SECOND-ORDER CORRECTION - ITERATION   1 ........     -.148E-04   .708E-03

  10   1.50937     -7.4411    .2197E-02   -.2278E+01
FIRST-ORDER CORRECTIONS TO F AND THETA .........     -.137E-06   .838E-05

FACTOR OF SAFETY - - - - - - - -        1.509
SIDE FORCE INCLINATION - - - - -        -7.44
NUMBER OF ITERATIONS - - - - - -        10
1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
   Model City Landfill
   Chemical Waste Management
   Slope Stability - Waste Filling Sequence

TABLE NO. 24
*******************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
*******************************************

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
FACTOR OF SAFETY =  1.509     SIDE FORCE INCLINATION =  -7.44 DEGREES

     -------- VALUES AT CENTER OF BASE OF SLICE---------
```

SLICE NO.	X-CENTER	Y-CENTER	TOTAL NORMAL STRESS	EFFECTIVE NORMAL STRESS	SHEAR STRESS
1	277.7	355.6	-276.5	-276.5	486.0
2	279.6	350.9	145.1	145.1	553.1
3	281.8	346.3	581.5	581.5	622.5
4	284.3	341.8	1027.7	1027.7	693.5
5	287.0	337.4	1479.4	1479.4	765.3
6	289.9	333.2	1933.0	1933.0	837.5
7	293.1	329.1	2385.5	2385.5	909.5
8	296.4	325.2	2834.2	2834.2	980.8
9	299.9	321.5	3276.6	3276.6	1051.2
10	302.7	318.9	3602.6	3602.6	1103.1
11	304.8	317.0	3869.1	3869.1	1114.5
12	306.2	315.8	4442.7	4442.7	519.0
13	308.5	313.9	4324.0	4324.0	1167.7
14	311.1	311.9	4625.1	4625.1	1202.8
15	312.3	311.0	4825.9	4825.9	1093.8
16	315.1	309.2	5004.6	5004.6	1114.7
17	319.5	306.5	5204.5	5204.5	1138.0
18	321.9	305.1	5301.0	5301.0	1149.3
19	324.3	303.8	5483.1	5483.1	852.6

20	328.9	301.6	5582.3	5582.3	864.1
21	333.7	299.6	5645.7	5645.7	871.5
22	338.5	297.9	5672.5	5672.5	874.7
23	343.4	296.4	5661.9	5661.9	873.4
24	348.4	295.2	5613.5	5613.5	867.8
25	353.4	294.3	5526.6	5526.6	857.6
26	358.5	293.6	5400.8	5400.8	842.9
27	363.6	293.2	5235.6	5235.6	823.6
28	367.6	293.0	5083.2	5083.2	805.8
29	371.6	293.1	4900.8	4900.8	784.5
30	376.7	293.3	4633.7	4633.7	753.3
31	381.1	293.8	4370.5	4370.5	722.6
32	385.5	294.4	4098.1	4098.1	690.8
33	389.5	295.2	3844.3	3844.3	661.1
34	393.0	296.0	3703.4	3703.4	644.7
35	397.0	297.1	3505.0	3505.0	621.5
36	401.0	298.4	3280.3	3280.3	595.2
37	405.0	299.9	2899.5	2899.5	550.7
38	409.3	301.7	2546.6	2546.6	509.5
39	413.8	303.9	2292.5	2292.5	479.8
40	418.2	306.3	2258.7	2258.7	793.9

1

-------- VALUES AT CENTER OF BASE OF SLICE---------

SLICE NO.	X-CENTER	Y-CENTER	TOTAL NORMAL STRESS	EFFECTIVE NORMAL STRESS	SHEAR STRESS
41	422.6	309.0	1929.3	1929.3	755.4
42	425.5	310.9	1680.0	1680.0	726.3
43	428.3	313.1	1549.5	1549.5	843.5
44	430.9	315.1	1289.7	1289.7	813.2
45	431.8	315.8	375.8	375.8	43.9
46	433.2	317.0	1028.1	1028.1	782.6

CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION = .02 (= .153E-01)
SHOULD NOT EXCEED .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION = .05 (= .480E-01)
SHOULD NOT EXCEED .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN = 6.14 (= .614E+01)
SHOULD NOT EXCEED .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM = .00 (= .652E-02)
SHOULD NOT EXCEED .100E+03

***** CAUTION ***** EFFECTIVE OR TOTAL NORMAL STRESS ON SHEAR SURFACE IS NEGATIVE AT POINTS ALONG THE UPPER ONE-HALF OF THE SHEAR SURFACE - A TENSION CRACK MAY BE NEEDED.

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 25
****
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH) *

****

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
FACTOR OF SAFETY = 1.509   SIDE FORCE INCLINATION = -7.44 DEGRF

--------------- VALUES AT RIGHT SIDE OF SLICE ---------------

SLICE NO.	X-RIGHT	SIDE FORCE	Y-COORD. OF SIDE FORCE LOCATION	FRACTION OF HEIGHT	SIGMA AT TOP	SIGMA AT BOTTOM
1	278.6	-2243.	355.5	.232	138.0	-592.6
2	280.7	-2730.	354.4	.406	-82.1	-292.2
3	283.0	-1525.	360.4	.865	-253.6	94.7
4	285.6	1268.	319.3	BELOW	-384.2	491.4
5	288.4	5508.	333.0	BELOW	-488.7	882.2
6	291.4	11023.	332.8	.053	-576.3	1261.6
7	294.7	17619.	331.1	.110	-652.5	1626.4
8	298.1	25079.	328.9	.142	-720.2	1973.7
9	301.8	33172.	326.7	.162	-781.2	2300.6
10	303.6	37300.	325.6	.169	-809.1	2453.0
11	305.9	42514.	324.3	.176	-846.1	2640.0
12	306.5	44441.	323.8	.175	-879.2	2734.6
13	310.6	53495.	321.7	.184	-936.3	3030.2
14	311.7	56001.	321.1	.186	-952.0	3108.5
15	313.0	59059.	320.4	.189	-974.7	3233.1
16	317.3	68477.	318.3	.200	-1027.7	3590.4
17	321.7	77003.	316.5	.212	-1040.4	3907.8
18	322.0	77530.	316.4	.213	-1040.0	3926.6
19	326.6	86552.	314.5	.222	-1074.5	4300.[illegible]
20	331.3	94290.	312.8	.232	-1070.8	4609.
21	336.0	100625.	311.4	.243	-1032.2	4856.6
22	340.9	105469.	310.2	.255	-960.9	5044.8
23	345.9	108764.	309.1	.267	-857.7	5175.7
24	350.9	110488.	308.2	.280	-722.8	5250.3
25	356.0	110655.	307.6	.294	-554.8	5269.0
26	361.1	109313.	307.1	.309	-351.0	5231.4
27	366.2	106548.	306.7	.326	-106.5	5136.5
28	369.0	104461.	306.6	.336	48.0	5059.0
29	374.1	99739.	306.6	.357	372.4	4869.5
30	379.2	93972.	306.7	.381	767.4	4612.2
31	383.0	89171.	306.9	.401	1119.1	4372.8
32	388.1	82070.	307.3	.434	1714.6	3961.2
33	391.0	77663.	307.6	.448	1961.7	3737.5
34	395.0	71289.	308.1	.455	2020.0	3526.8
35	399.0	64565.	308.7	.462	2076.4	3304.7
36	403.0	57591.	309.4	.493	2610.7	2850.6
37	407.0	50749.	310.1	.527	3269.1	2348.1
38	411.7	42921.	311.0	.539	3446.4	2146.2
39	416.0	35701.	311.8	.523	3091.5	2354.6
40	420.4	26278.	313.1	.528	2924.5	2075.4

1

--------------- VALUES AT RIGHT SIDE OF SLICE ---------------

SLICE NO.	X-RIGHT	SIDE FORCE	Y-COORD. OF SIDE FORCE LOCATION	FRACTION OF HEIGHT	SIGMA AT TOP	SIGMA AT BOTTOM
41	424.7	17547.	314.4	.531	2704.3	1864.1

42	426.3	14495.	314.9	.528	2578.4	1844.0
43	430.4	6166.	316.6	.579	2653.0	951.7
44	431.5	4108.	317.2	.661	3200.7	58.3
45	432.1	3892.	317.1	.575	2793.0	1066.5
46	434.4	6.	1185.1	ABOVE	.0	.0

```
CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION     =          .02   (=  .153E-01)
     SHOULD NOT EXCEED     .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION   =          .05   (=  .480E-01)
     SHOULD NOT EXCEED     .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN =          6.14   (=  .614E+01)
     SHOULD NOT EXCEED     .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM    =          .00   (=  .652E-02)
     SHOULD NOT EXCEED     .100E+03
```

***** CAUTION ***** FORCES BETWEEN SLICES ARE NEGATIVE AT POINTS ALONG THE UPPER ONE-HALF OF THE SHEAR SURFACE - A TENSION CRACK MAY BE NEEDED.

***** CAUTION ***** SOME OF THE FORCES BETWEEN SLICES ACT AT POINTS ABOVE THE SURFACE OF THE SLOPE OR BELOW THE SHEAR SURFACE - EITHER A TENSION CRACK MAY BE NEEDED OR THE SOLUTION MAY NOT BE A VALID SOLUTION

END-OF-FILE ENCOUNTERED WHILE READING COMMAND WORDS - END OF PROBLEM(S) ASSUMED

```
1         UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

          TABLE NO. 1
          ******************************************
          * COMPUTER PROGRAM DESIGNATION - UTEXAS2 *
          * ORIGINALLY CODED BY STEPHEN G. WRIGHT  *
          * VERSION NO. 1.209                      *
          * LAST REVISION DATE 11/23/87            *
          * SERIAL NO. 00004                       *
          * (C) COPYRIGHT 1985 STEPHEN G. WRIGHT   *
          * ALL RIGHTS RESERVED                    *
          ******************************************
```

CASE 4. H=42 FEET

SLOPE=2:1

```
          **************************************************************
          *                                                            *
          *      RESULTS OF COMPUTATIONS PERFORMED USING THIS COMPUTER *
          * PROGRAM SHOULD NOT BE USED FOR DESIGN PURPOSES UNLESS THEY *
          * HAVE BEEN VERIFIED BY INDEPENDENT ANALYSES, EXPERIMENTAL   *
          * DATA OR FIELD EXPERIENCE. THE USER SHOULD UNDERSTAND THE   *
          * ALGORITHMS AND ANALYTICAL PROCEDURES USED IN THE COMPUTER  *
          * PROGRAM AND MUST HAVE READ ALL DOCUMENTATION FOR THIS      *
          * PROGRAM BEFORE ATTEMPTING ITS USE.                         *
          *                                                            *
          *      NEITHER THE UNIVERSITY OF TEXAS NOR STEPHEN G. WRIGHT *
          * MAKE OR ASSUME LIABILITY FOR ANY WARRANTIES, EXPRESSED OR  *
          * IMPLIED, CONCERNING THE ACCURACY, RELIABILITY, USEFULNESS  *
          * OR ADAPTABILITY OF THIS COMPUTER PROGRAM.                  *
          *                                                            *
          **************************************************************
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            Chemical Waste Management
            Slope Stability - Waste Filling Sequence

          TABLE NO.  2
          *************************
          * NEW PROFILE LINE DATA *
          *************************

          PROFILE LINE  1 - MATERIAL TYPE =  1
          Bedrock

               POINT       X              Y

                 1       -100.000        275.000
                 2        900.000        275.000

          PROFILE LINE  2 - MATERIAL TYPE =  2
          Glaciolacustrine Sand/Silt

               POINT       X              Y

                 1       -100.000        290.000
                 2        900.000        290.000

          PROFILE LINE  3 - MATERIAL TYPE =  3
          LACUSTRINE CLAY

               POINT       X              Y
```

1	-100.000	305.000
2	900.000	305.000

PROFILE LINE 4 - MATERIAL TYPE = 4
UPPER TILL

POINT	X	Y
1	-100.000	311.500
2	900.000	311.500

PROFILE LINE 5 - MATERIAL TYPE = 5
Lower Soil Liner

POINT	X	Y
1	-100.000	315.500
2	900.000	315.500

PROFILE LINE 6 - MATERIAL TYPE = 6
Synthetic Liner

POINT	X	Y
1	-100.000	316.000
2	900.000	316.000

PROFILE LINE 7 - MATERIAL TYPE = 5
Upper Soil Liner

POINT	X	Y
1	-100.000	318.000
2	383.000	318.000
3	391.000	322.000
4	399.000	322.000
5	407.000	318.000
6	900.000	318.000

PROFILE LINE 8 - MATERIAL TYPE = 7
Waste

POINT	X	Y
1	-100.000	360.000
2	319.000	360.000
3	403.000	318.000

ALL NEW PROFILE LINES DEFINED - NO OLD LINES RETAINED
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TABLE NO. 3
****
* NEW MATERIAL PROPERTY DATA *
****

DATA FOR MATERIAL TYPE 1

BEDROCK

UNIT WEIGHT OF MATERIAL = 140.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 2000.000
FRICTION ANGLE - - - - - 40.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 2
Glaciolacustrine Sand/Silt

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - .000
FRICTION ANGLE - - - - - 30.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 3
Glaciolacustrine Clay

UNIT WEIGHT OF MATERIAL = 125.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 320.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 4
UPPER TILL

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 800.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 5
Soil Liner

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 1000.000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 6
Synthetic Liner

UNIT WEIGHT OF MATERIAL = 130.000

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS

COHESION - - - - - - - - - .000
FRICTION ANGLE - - - - - 10.000 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

DATA FOR MATERIAL TYPE 7
Waste

UNIT WEIGHT OF MATERIAL = 111.100

CONVENTIONAL (ISOTROPIC) SHEAR STRENGTHS
COHESION - - - - - - - - - 800.000
FRICTION ANGLE - - - - - 13.500 DEGREES

NO (OR ZERO) PORE WATER PRESSURES

ALL NEW MATERIAL PROPERTIES DEFINED - NO OLD DATA RETAINED
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TABLE NO. 9
****
* NEW ANALYSIS/COMPUTATION DATA *
****

CIRCULAR SHEAR SURFACE(S)

AUTOMATIC SEARCH PERFORMED

STARTING CENTER COORDINATE FOR SEARCH AT -
X = 360.000
Y = 400.000

REQUIRED ACCURACY FOR CRITICAL CENTER (= MINIMUM
SPACING BETWEEN GRID POINTS) = 1.000

CRITICAL SHEAR SURFACE NOT ALLOWED TO PASS BELOW Y = 270.000

FOR THE INITIAL MODE OF SEARCH
ALL CIRCLES ARE TANGENT TO HORIZONTAL LINE AT -
Y = 290.000

DEPTH OF CRACK = 5.000

THE FOLLOWING REPRESENT EITHER DEFAULT OR PREVIOUSLY DEFINED VALUES:

INITIAL TRIAL ESTIMATE FOR THE FACTOR OF SAFETY = 3.000

INITIAL TRIAL ESTIMATE FOR SIDE FORCE INCLINATION = 15.000 DEGREES
(APPLICABLE TO SPENCER'S PROCEDURE ONLY)

MAXIMUM NUMBER OF ITERATIONS ALLOWED FOR
CALCULATING THE FACTOR OF SAFETY = 40

ALLOWED FORCE IMBALANCE FOR CONVERGENCE = 100.000

ALLOWED MOMENT IMBALANCE FOR CONVERGENCE = 100.000

INITIAL TRIAL VALUES FOR FACTOR OF SAFETY (AND SIDE FORCE INCLINATION FOR SPENCER'S PROCEDURE) WILL BE KEPT CONSTANT DURING SEARCH

MAXIMUM SUBTENDED ANGLE TO BE USED FOR SUBDIVISION OF THE CIRCLE INTO SLICES = 3.00 DEGREES

SEARCH WILL BE CONTINUED TO LOCATE A MORE CRITICAL SHEAR SURFACE (IF ONE EXISTS) AFTER THE INITIAL MODE IS COMPLETE

DEPTH OF WATER IN CRACK = .000

UNIT WEIGHT OF WATER IN CRACK = 62.400

SEISMIC COEFFICIENT = .000

PROCEDURE USED TO COMPUTE THE FACTOR OF SAFETY: SPENCER

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Slope Stability - Waste Filling Sequence

TABLE NO. 10

****
* NEW SLOPE GEOMETRY DATA *
****

NOTE - NO DATA WERE INPUT, SLOPE GEOMETRY DATA WERE GENERATED BY THE PROGRAM

SLOPE COORDINATES -

POINT	X	Y
1	-100.000	360.000
2	319.000	360.000
3	391.000	322.000
4	399.000	322.000
5	407.000	318.000
6	900.000	318.000

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Slope Stability - Waste Filling Sequence

TABLE NO. 12

INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES ARE TANGENT TO A HORIZONTAL LINE AT Y = 290.000

CENTER COORDINATES X	CENTER COORDINATES Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
330.00	370.00	80.00	2.241	-5.81	5
360.00	370.00	80.00	1.631	-6.13	9
390.00	370.00	80.00	1.795	-6.49	7
330.00	400.00	110.00	2.040	-6.70	5
360.00	400.00	110.00	1.621	-6.66	8

390.00	400.00	110.00	1.667	-6.88	8
330.00	430.00	140.00	2.005	-6.75	5
360.00	430.00	140.00	1.683	-6.40	8
390.00	430.00	140.00	1.687	-6.46	7
355.00	395.00	105.00	1.649	-6.75	9
360.00	395.00	105.00	1.616	-6.67	8
365.00	395.00	105.00	1.594	-6.62	7
355.00	400.00	110.00	1.654	-6.74	9
365.00	400.00	110.00	1.600	-6.60	7
355.00	405.00	115.00	1.660	-6.71	8
360.00	405.00	115.00	1.629	-6.64	8
365.00	405.00	115.00	1.608	-6.58	7
360.00	390.00	100.00	1.612	-6.66	8
365.00	390.00	100.00	1.590	-6.61	7
370.00	390.00	100.00	1.581	-6.59	7
370.00	395.00	105.00	1.585	-6.59	7
370.00	400.00	110.00	1.590	-6.58	7
365.00	385.00	95.00	1.589	-6.57	7
370.00	385.00	95.00	1.580	-6.56	7
375.00	385.00	95.00	1.585	-6.59	7
375.00	390.00	100.00	1.584	-6.61	7
375.00	395.00	105.00	1.587	-6.61	7
365.00	380.00	90.00	1.590	-6.49	8
370.00	380.00	90.00	1.583	-6.48	7
375.00	380.00	90.00	1.590	-6.52	7
367.00	382.00	92.00	1.584	-6.52	7
370.00	382.00	92.00	1.581	-6.52	7
373.00	382.00	92.00	1.583	-6.53	7
367.00	385.00	95.00	1.584	-6.56	7
373.00	385.00	95.00	1.582	-6.57	7
367.00	388.00	98.00	1.584	-6.59	7
370.00	388.00	98.00	1.580	-6.58	7
373.00	388.00	98.00	1.581	-6.59	7
369.00	384.00	94.00	1.581	-6.55	7
370.00	384.00	94.00	1.580	-6.55	7
371.00	384.00	94.00	1.580	-6.55	7
369.00	385.00	95.00	1.581	-6.56	7
371.00	385.00	95.00	1.580	-6.56	7
369.00	386.00	96.00	1.581	-6.57	7
370.00	386.00	96.00	1.580	-6.57	7
371.00	386.00	96.00	1.580	-6.57	7
372.00	385.00	95.00	1.581	-6.56	7
372.00	386.00	96.00	1.580	-6.57	7
370.00	387.00	97.00	1.580	-6.57	7
371.00	387.00	97.00	1.580	-6.58	7
372.00	387.00	97.00	1.580	-6.58	7

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL
CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER = 371.00 Y-CENTER = 386.00 RADIUS = 96.0[illegible]
FACTOR OF SAFETY = 1.580 SIDE FORCE INCLINATION = -6.57

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Slope Stability - Waste Filling Sequence

TABLE NO. 13
INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES HAVE THE SAME RADIUS - RADIUS = 96.000

CENTER COORDINATES X	Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
341.00	356.00	96.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
371.00	356.00	96.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
401.00	356.00	96.00	BOTTOM OF CIRCLE EXCEEDS ALLOWABLE DEPTH - CIRCLE REJECTED		
341.00	386.00	96.00	1.830	-6.82	5
401.00	386.00	96.00	1.902	-7.27	6
341.00	416.00	96.00	2.625	-10.49	4
371.00	416.00	96.00	2.077	-15.79	5
401.00	416.00	96.00	3.807	-19.45	5
366.00	381.00	96.00	2.457	-9.26	4
371.00	381.00	96.00	2.422	-9.21	4
376.00	381.00	96.00	2.405	-9.18	4
366.00	386.00	96.00	1.586	-6.58	7
376.00	386.00	96.00	1.587	-6.61	7
366.00	391.00	96.00	1.584	-7.37	7
371.00	391.00	96.00	1.578	-7.38	7
376.00	391.00	96.00	1.586	-7.44	8
366.00	396.00	96.00	1.629	-8.50	7
371.00	396.00	96.00	1.622	-8.57	7
376.00	396.00	96.00	1.633	-8.67	7
368.00	388.00	96.00	1.577	-6.86	6
371.00	388.00	96.00	1.575	-6.86	6
374.00	388.00	96.00	1.578	-6.89	7
368.00	391.00	96.00	1.580	-7.37	7
374.00	391.00	96.00	1.581	-7.41	8
368.00	394.00	96.00	1.599	-7.99	8
371.00	394.00	96.00	1.596	-8.02	8
374.00	394.00	96.00	1.600	-8.06	7
368.00	385.00	96.00	1.954	-8.52	6
371.00	385.00	96.00	1.942	-8.49	6
374.00	385.00	96.00	1.935	-8.47	6
370.00	387.00	96.00	1.577	-6.71	8
371.00	387.00	96.00	1.577	-6.71	8
372.00	387.00	96.00	1.577	-6.72	7
370.00	388.00	96.00	1.575	-6.86	6
372.00	388.00	96.00	1.575	-6.87	6
370.00	389.00	96.00	1.575	-7.02	6
371.00	389.00	96.00	1.574	-7.02	6
372.00	389.00	96.00	1.575	-7.03	6

370.00	390.00	96.00	1.575	-7.19	6
371.00	390.00	96.00	1.575	-7.20	6
372.00	390.00	96.00	1.576	-7.20	6

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL
CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER = 371.00 Y-CENTER = 389.00 RADIUS = 96.00
FACTOR OF SAFETY = 1.574 SIDE FORCE INCLINATION = -7.02

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TABLE NO. 12
INFORMATION FOR CURRENT MODE OF SEARCH - ALL CIRCLES ARE TANGENT
TO A HORIZONTAL LINE AT Y = 293.000

CENTER COORDINATES X	Y	RADIUS	FACTOR OF SAFETY	SIDE FORCE INCLINATION (DEGREES)	ITERATIONS
341.00	359.00	66.00	2.064	-4.65	6
371.00	359.00	66.00	1.668	-4.87	8
401.00	359.00	66.00	2.451	-5.67	5
341.00	389.00	96.00	1.843	-7.05	6
401.00	389.00	96.00	1.916	-7.72	7
341.00	419.00	126.00	1.835	-7.09	6
371.00	419.00	126.00	1.620	-6.77	6
401.00	419.00	126.00	1.797	-7.39	7
366.00	384.00	91.00	1.580	-6.99	7
371.00	384.00	91.00	1.574	-7.00	6
376.00	384.00	91.00	1.585	-7.06	6
366.00	389.00	96.00	1.581	-7.02	7
376.00	389.00	96.00	1.582	-7.07	6
366.00	394.00	101.00	1.585	-7.02	6
371.00	394.00	101.00	1.578	-7.02	6
376.00	394.00	101.00	1.583	-7.06	6
366.00	379.00	86.00	1.582	-6.91	7
371.00	379.00	86.00	1.578	-6.93	7
376.00	379.00	86.00	1.591	-6.99	7
368.00	381.00	88.00	1.577	-6.95	7
371.00	381.00	88.00	1.576	-6.96	6
374.00	381.00	88.00	1.581	-7.00	6
368.00	384.00	91.00	1.576	-6.99	6
374.00	384.00	91.00	1.579	-7.03	6
368.00	387.00	94.00	1.576	-7.01	6
371.00	387.00	94.00	1.574	-7.02	6
374.00	387.00	94.00	1.577	-7.04	6
368.00	390.00	97.00	1.577	-7.02	6
371.00	390.00	97.00	1.575	-7.03	6
374.00	390.00	97.00	1.578	-7.05	6
370.00	386.00	93.00	1.574	-7.01	6
371.00	386.00	93.00	1.574	-7.02	6

372.00	386.00	93.00	1.575	-7.02	6
370.00	387.00	94.00	1.574	-7.02	6
372.00	387.00	94.00	1.575	-7.03	6
370.00	388.00	95.00	1.574	-7.02	6
371.00	388.00	95.00	1.574	-7.02	6
372.00	388.00	95.00	1.575	-7.03	6
369.00	385.00	92.00	1.575	-7.00	6
370.00	385.00	92.00	1.574	-7.00	6
371.00	385.00	92.00	1.574	-7.01	6
369.00	386.00	93.00	1.575	-7.01	6
369.00	387.00	94.00	1.575	-7.01	6

AT THE END OF THE CURRENT MODE OF SEARCH THE MOST CRITICAL
CIRCLE WHICH WAS FOUND HAS THE FOLLOWING VALUES -
X-CENTER = 370.00 Y-CENTER = 386.00 RADIUS = 93.00
FACTOR OF SAFETY = 1.574 SIDE FORCE INCLINATION = -7.01

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TABLE NO. 15
***** FINAL CRITICAL CIRCLE INFORMATION *****
X COORDINATE OF CENTER - - - - - - - 370.000
Y COORDINATE OF CENTER - - - - - - - 386.000
RADIUS - - - - - - - - - - - - - - - 93.000
FACTOR OF SAFETY - - - - - - - - - - 1.574
SIDE FORCE INCLINATION - - - - - - - -7.01

NUMBER OF CIRCLES TRIED - - - - - - 135
NO. OF CIRCLES F CALC. FOR - - - - - 132

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
Chemical Waste Management
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TABLE NO. 20
****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	282.3	355.0					
1	283.2	352.7	1408.1	7	800.00	13.50	.0
	284.1	350.5					
2	285.1	348.2	2586.9	7	800.00	13.50	.0
	286.0	346.0					
3	287.1	343.8	3965.9	7	800.00	13.50	.0
	288.2	341.7					
4	289.5	339.6	5524.5	7	800.00	13.50	.0
	290.7	337.4					
5	292.0	335.4	7240.4	7	800.00	13.50	.0
	293.3	333.4					
6	294.8	331.4	9089.6	7	800.00	13.50	.0
	296.2	329.4					
7	297.7	327.5	11046.8	7	800.00	13.50	.0

	299.3	325.6					
8	300.9	323.8	13085.7	7	800.00	13.50	.0
	302.5	322.0					
9	304.2	320.3	15179.6	7	800.00	13.50	
	305.9	318.6					
10	306.3	318.3	2817.9	7	800.00	13.50	.0
	306.6	318.0					
11	307.7	317.0	10617.9	5	1000.00	10.00	.0
	308.8	316.0					
12	309.1	315.8	2858.0	6	.00	10.00	.0
	309.3	315.5					
13	311.2	314.0	19585.5	5	1000.00	10.00	.0
	313.1	312.4					
14	313.7	312.0	6615.1	5	1000.00	10.00	.0
	314.3	311.5					
15	316.3	310.1	22635.2	4	800.00	10.00	.0
	318.3	308.7					
16	318.7	308.5	4081.9	4	800.00	10.00	.0
	319.0	308.2					
17	319.0	308.2	6.3	4	800.00	10.00	.0
	319.0	308.2					
18	321.1	306.9	24763.1	4	800.00	10.00	.0
	323.1	305.7					
19	323.7	305.3	7027.2	4	800.00	10.00	.0
	324.3	305.0					
20	326.5	303.9	26075.7	3	320.00	10.00	.0
	328.6	302.7					
21	330.8	301.7	26830.5	3	320.00	10.00	.0
	333.0	300.7					
22	335.3	299.8	27356.3	3	320.00	10.00	
	337.5	298.8					

1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
Model City Landfill
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TABLE NO. 20

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*******************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)               *
*******************************************************************
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SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	337.5	298.8					
23	339.8	298.1	27641.5	3	320.00	10.00	.0
	342.1	297.3					
24	344.5	296.6	27678.1	3	320.00	10.00	.0
	346.8	295.9					
25	349.2	295.4	27461.3	3	320.00	10.00	.0
	351.6	294.8					
26	354.0	294.4	26990.1	3	320.00	10.00	.0
	356.4	294.0					
27	358.8	293.7	26266.9	3	320.00	10.00	.0
	361.2	293.4					
28	363.6	293.3	25297.6	3	320.00	10.00	[illegible]
	366.1	293.1					
29	368.0	293.0	19610.6	3	320.00	10.00	.0
	370.0	293.0					

30	372.4	293.1	22949.5	3	320.00	10.00	.0
	374.9	293.1					
31	377.3	293.3	21348.7	3	320.00	10.00	.0
	379.7	293.5					
32	381.4	293.7	13478.3	3	320.00	10.00	.0
	383.0	293.9					
33	385.4	294.3	18346.3	3	320.00	10.00	.0
	387.8	294.7					
34	389.4	295.1	11293.6	3	320.00	10.00	.0
	391.0	295.4					
35	393.0	295.9	13383.7	3	320.00	10.00	.0
	395.0	296.4					
36	397.0	297.0	12446.9	3	320.00	10.00	.0
	399.0	297.6					
37	401.0	298.3	11421.0	3	320.00	10.00	.0
	403.0	299.1					
38	405.0	299.9	9847.8	3	320.00	10.00	.0
	407.0	300.7					
39	409.2	301.7	9279.9	3	320.00	10.00	.0
	411.4	302.7					
40	413.6	303.9	7840.1	3	320.00	10.00	.0
	415.7	305.0					
41	417.8	306.3	6379.1	4	800.00	10.00	.0
	419.9	307.5					
42	421.9	308.9	4799.5	4	800.00	10.00	.0
	423.9	310.2					
43	424.8	310.9	1629.2	4	800.00	10.00	.0
	425.7	311.5					
44	427.6	313.0	2481.0	5	1000.00	10.00	.0
	429.5	314.5					

TABLE NO. 20

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*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
*****************************************************************
```

SLICE NO.	X	Y	SLICE WEIGHT	MATL. TYPE	COHESION	FRICTION ANGLE	PORE PRESSURE
	429.5	314.5					
45	430.1	315.0	452.6	5	1000.00	10.00	.0
	430.7	315.5					
46	430.9	315.8	168.6	6	.00	10.00	.0
	431.2	316.0					
47	432.3	317.0	287.8	5	1000.00	10.00	.0
	433.4	318.0					

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TABLE NO. 21

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*****************************************************************
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH)              *
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****

SLICE NO.	X	SEISMIC FORCE	Y FOR SEISMIC FORCE	FORCES DUE TO SURFACE PRESSURES			
				NORMAL FORCE	SHEAR FORCE	X	Y
1	283.2	0.	356.4	0.	0.	.0	.0
2	285.1	0.	354.1	0.	0.	.0	.0
3	287.1	0.	351.9	0.	0.	.0	.0
4	289.5	0.	349.8	0.	0.	.0	.0
5	292.0	0.	347.7	0.	0.	.0	.0
6	294.8	0.	345.7	0.	0.	.0	.0
7	297.7	0.	343.8	0.	0.	.0	.0
8	300.9	0.	341.9	0.	0.	.0	.0
9	304.2	0.	340.1	0.	0.	.0	.0
10	306.3	0.	339.1	0.	0.	.0	.0
11	307.7	0.	338.4	0.	0.	.0	.0
12	309.1	0.	337.7	0.	0.	.0	.0
13	311.2	0.	336.7	0.	0.	.0	.0
14	313.7	0.	335.5	0.	0.	.0	.0
15	316.3	0.	334.5	0.	0.	.0	.0
16	318.7	0.	333.6	0.	0.	.0	.0
17	319.0	0.	333.5	0.	0.	.0	.0
18	321.1	0.	332.2	0.	0.	.0	.0
19	323.7	0.	330.6	0.	0.	.0	.0
20	326.5	0.	329.1	0.	0.	.0	.0
21	330.8	0.	326.9	0.	0.	.0	.0
22	335.3	0.	324.7	0.	0.	.0	.0
23	339.8	0.	322.7	0.	0.	.0	.0
24	344.5	0.	320.7	0.	0.	.0	[illegible]
25	349.2	0.	318.9	0.	0.	.0	.0
26	354.0	0.	317.2	0.	0.	.0	.0
27	358.8	0.	315.6	0.	0.	.0	.0
28	363.6	0.	314.2	0.	0.	.0	.0
29	368.0	0.	313.0	0.	0.	.0	.0
30	372.4	0.	311.9	0.	0.	.0	.0
31	377.3	0.	310.8	0.	0.	.0	.0
32	381.4	0.	310.0	0.	0.	.0	.0
33	385.4	0.	309.4	0.	0.	.0	.0
34	389.4	0.	309.0	0.	0.	.0	.0
35	393.0	0.	309.1	0.	0.	.0	.0
36	397.0	0.	309.4	0.	0.	.0	.0
37	401.0	0.	309.6	0.	0.	.0	.0
38	405.0	0.	309.5	0.	0.	.0	.0
39	409.2	0.	309.9	0.	0.	.0	.0
40	413.6	0.	311.0	0.	0.	.0	.0
41	417.8	0.	312.1	0.	0.	.0	.0

TABLE NO. 21

****
* INFORMATION FOR INDIVIDUAL SLICES (INFORMATION IS FOR CRITICAL *
* SHEAR SURFACE IN THE CASE OF AN AUTOMATIC SEARCH) *
****

FORCES DUE TO SURFACE PRESSURES

SLICE NO.	X	SEISMIC FORCE	Y FOR SEISMIC FORCE	NORMAL FORCE	SHEAR FORCE	X	Y
42	421.9	0.	313.4	0.	0.	.0	.0
43	424.8	0.	314.4	0.	0.	.0	.0
44	427.6	0.	315.5	0.	0.	.0	.0
45	430.1	0.	316.5	0.	0.	.0	.0
46	430.9	0.	316.9	0.	0.	.0	.0
47	432.3	0.	317.5	0.	0.	.0	.0

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1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
   Model City Landfill
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   Slope Stability - Waste Filling Sequence

 TABLE NO. 23
 ****************************************************************
 * INFORMATION GENERATED DURING ITERATIVE SOLUTION FOR THE FACTOR *
 * OF SAFETY AND SIDE FORCE INCLINATION BY SPENCER'S PROCEDURE    *
 ****************************************************************

         TRIAL     TRIAL
        FACTOR   SIDE FORCE    FORCE       MOMENT                  DELTA
 ITER-    OF    INCLINATION  IMBALANCE    IMBALANCE     DELTA-F    THETA
 ATION  SAFETY   (DEGREES)     (LBS.)    (FT.-LBS.)             (DEGREES)

    1  3.00000   -15.0000  -.6135E+05   .2260E+08
 FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.100E+01 -.143E+02
 VALUES FACTORED BY  .498E+00 - DELTAS TOO LARGE    -.500E+00 -.712E+01

    2  2.50000   -22.1232  -.2615E+05   .8207E+07
 FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.213E+01  .250E+02
 VALUES FACTORED BY  .234E+00 - DELTAS TOO LARGE    -.500E+00  .585E+01

    3  2.00000   -16.2682  -.1419E+05   .4000E+07
 FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.689E+00  .129E+02
 VALUES FACTORED BY  .668E+00 - DELTAS TOO LARGE    -.460E+00  .859E+01

    4  1.53969    -7.6738   .5086E+04  -.1914E+07
 FIRST-ORDER CORRECTIONS TO F AND THETA .........    .353E-01  .569E+00
 SECOND-ORDER CORRECTION - ITERATION   1 ........    .362E-01  .569E+00
 SECOND-ORDER CORRECTION - ITERATION   2 ........    .362E-01  .569E+00

    5  1.57593    -7.1052  -.3049E+01  -.1455E+05
 FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.199E-02  .951E-01
 SECOND-ORDER CORRECTION - ITERATION   1 ........   -.199E-02  .951E-01

    6  1.57395    -7.0101  -.1538E-01  -.1237E+02
 FIRST-ORDER CORRECTIONS TO F AND THETA .........   -.237E-05  .108E-03

 FACTOR OF SAFETY - - - - - - - -      1.574
 SIDE FORCE INCLINATION - - - - -      -7.01
 NUMBER OF ITERATIONS - - - - - -      6
1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT
   Model City Landfill
   Chemical Waste Management
   Slope Stability - Waste Filling Sequence

 TABLE NO. 24
 ********************************************
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* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH) *
****

SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
FACTOR OF SAFETY = 1.574 SIDE FORCE INCLINATION = -7.01 DEGREES

-------- VALUES AT CENTER OF BASE OF SLICE---------

SLICE NO.	X-CENTER	Y-CENTER	TOTAL NORMAL STRESS	EFFECTIVE NORMAL STRESS	SHEAR STRESS
1	283.2	352.7	-268.0	-268.0	467.4
2	285.1	348.2	141.9	141.9	529.9
3	287.1	343.8	564.6	564.6	594.4
4	289.5	339.6	995.5	995.5	660.1
5	292.0	335.4	1430.7	1430.7	726.5
6	294.8	331.4	1866.9	1866.9	793.0
7	297.7	327.5	2301.1	2301.1	859.3
8	300.9	323.8	2731.0	2731.0	924.8
9	304.2	320.3	3154.3	3154.3	989.4
10	306.3	318.3	3400.3	3400.3	1026.9
11	307.7	317.0	3588.0	3588.0	1037.3
12	309.1	315.8	4166.7	4166.7	466.8
13	311.2	314.0	4033.4	4033.4	1087.2
14	313.7	312.0	4332.4	4332.4	1120.7
15	316.3	310.1	4683.2	4683.2	1032.9
16	318.7	308.5	4932.7	4932.7	1060.9
17	319.0	308.2	4966.2	4966.2	1064.6
18	321.1	306.9	5062.6	5062.6	1075.4
19	323.7	305.3	5179.8	5179.8	1088.6
20	326.5	303.9	5382.4	5382.4	806.3
21	330.8	301.7	5483.8	5483.8	817.7
22	335.3	299.8	5551.2	5551.2	825.2
23	339.8	298.1	5583.9	5583.9	828.9
24	344.5	296.6	5581.2	5581.2	828.6
25	349.2	295.4	5542.5	5542.5	824.2
26	354.0	294.4	5467.5	5467.5	815.8
27	358.8	293.7	5355.7	5355.7	803.3
28	363.6	293.3	5206.7	5206.7	786.6
29	368.0	293.0	5041.1	5041.1	768.1
30	372.4	293.1	4841.9	4841.9	745.7
31	377.3	293.3	4587.3	4587.3	717.2
32	381.4	293.7	4346.3	4346.3	690.2
33	385.4	294.3	4098.2	4098.2	662.4
34	389.4	295.1	3845.2	3845.2	634.1
35	393.0	295.9	3695.4	3695.4	617.3
36	397.0	297.0	3495.9	3495.9	594.9
37	401.0	298.3	3268.8	3268.8	569.5
38	405.0	299.9	2884.8	2884.8	526.5
39	409.2	301.7	2533.4	2533.4	487.1
40	413.6	303.9	2280.2	2280.2	458.8

-------- VALUES AT CENTER OF BASE OF SLICE---------

SLICE NO.	X-CENTER	Y-CENTER	TOTAL NORMAL STRESS	EFFECTIVE NORMAL STRESS	SHEAR STRESS

41	417.8	306.3	2240.7	2240.7	759.3
42	421.9	308.9	1922.9	1922.9	723.7
43	424.8	310.9	1670.6	1670.6	695.4
44	427.6	313.0	1533.7	1533.7	807.2
45	430.1	315.0	1276.0	1276.0	778.3
46	430.9	315.8	373.9	373.9	41.9
47	432.3	317.0	1010.6	1010.6	748.6

```
CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION     =          .01   (=  .113E-01)
     SHOULD NOT EXCEED      .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION   =          .05   (=  .516E-01)
     SHOULD NOT EXCEED      .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN =         9.98   (=  .998E+01)
     SHOULD NOT EXCEED      .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM    =          .00   (=  .505E-02)
     SHOULD NOT EXCEED      .100E+03

***** CAUTION ***** EFFECTIVE OR TOTAL NORMAL STRESS ON SHEAR
                    SURFACE IS NEGATIVE AT POINTS ALONG THE
                    UPPER ONE-HALF OF THE SHEAR SURFACE - A
                    TENSION CRACK MAY BE NEEDED.
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1 UTEXAS2 - VER. 1.209 - 11/23/87 - SN00004 - (C) 1985 S. G. WRIGHT

Model City Landfill
Chemical Waste Management
Slope Stability - Waste Filling Sequence

TABLE NO. 25

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*********************************************
* FINAL RESULTS FOR SHEAR SURFACE (CRITICAL *
* SURFACE IN CASE OF A SEARCH)              *
*********************************************
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SPENCER'S PROCEDURE USED TO COMPUTE FACTOR OF SAFETY
FACTOR OF SAFETY = 1.574   SIDE FORCE INCLINATION = -7.01 DEGREES

--------------- VALUES AT RIGHT SIDE OF SLICE ----------------

SLICE NO.	X-RIGHT	SIDE FORCE	Y-COORD. OF SIDE FORCE LOCATION	FRACTION OF HEIGHT	SIGMA AT TOP	SIGMA AT BOTTOM
1	284.1	-2048.	352.6	.227	136.0	-561.8
2	286.0	-2468.	351.6	.403	-73.5	-276.6
3	288.2	-1322.	358.0	.893	-240.2	97.1
4	290.7	1290.	320.6	BELOW	-367.7	481.3
5	293.3	5239.	331.6	BELOW	-469.6	860.0
6	296.2	10365.	331.2	.059	-554.7	1227.6
7	299.3	16491.	329.5	.114	-628.1	1580.7
8	302.5	23417.	327.5	.145	-693.1	1916.9
9	305.9	30934.	325.4	.164	-751.2	2233.4
10	306.6	32266.	325.0	.167	-760.6	2285.6
11	308.8	37182.	323.7	.175	-796.5	2473.9
12	309.3	39010.	323.3	.174	-829.7	2569.8
13	313.1	47385.	321.2	.184	-883.5	2860.4
14	314.3	50040.	320.6	.187	-900.4	2948.5
15	318.3	59168.	318.5	.191	-976.8	3265.8
16	319.0	60704.	318.2	.192	-988.9	3316.6

17	319.0	60706.	318.2	.192	-988.9	3316.7
18	323.1	69291.	316.3	.204	-1025.9	3663.6
19	324.3	71500.	315.8	.207	-1029.8	3748.7
20	328.6	80372.	314.0	.216	-1076.6	4132
21	333.0	88073.	312.4	.226	-1085.4	4452.
22	337.5	94488.	311.0	.237	-1059.7	4711.2
23	342.1	99527.	309.8	.248	-1001.8	4912.9
24	346.8	103133.	308.8	.260	-913.2	5059.0
25	351.6	105275.	307.9	.273	-794.2	5151.0
26	356.4	105958.	307.2	.286	-644.1	5189.5
27	361.2	105215.	306.7	.301	-461.1	5174.6
28	366.1	103116.	306.4	.317	-241.5	5105.8
29	370.0	100490.	306.3	.331	-33.1	5009.7
30	374.9	96211.	306.2	.351	269.7	4838.6
31	379.7	90938.	306.4	.374	635.8	4605.2
32	383.0	86891.	306.6	.391	931.0	4407.5
33	387.8	80355.	306.9	.422	1463.6	4042.7
34	391.0	75669.	307.3	.438	1732.5	3804.9
35	395.0	69379.	307.8	.444	1793.6	3590.9
36	399.0	62705.	308.4	.452	1852.1	3364.1
37	403.0	55751.	309.1	.482	2356.7	2926.3
38	407.0	48905.	309.9	.517	2996.7	2434.4
39	411.4	41497.	310.8	.528	3156.9	2237.8
40	415.7	34305.	311.7	.513	2825.9	2412.4

--------------- VALUES AT RIGHT SIDE OF SLICE ---------------

SLICE NO.	X-RIGHT	SIDE FORCE	Y-COORD. OF SIDE FORCE LOCATION	FRACTION OF HEIGHT	SIGMA AT TOP	SIGMA AT BOTTOM
41	419.9	25460.	313.0	.519	2682.2	2132.3
42	423.9	17249.	314.3	.522	2493.9	1907.3
43	425.7	13865.	314.9	.519	2363.6	1870.7
44	429.5	6097.	316.5	.566	2422.8	1050.4
45	430.7	3919.	317.1	.651	2962.5	149.0
46	431.2	3706.	317.1	.566	2572.3	1106.0
47	433.4	1.	10138.0	ABOVE	.0	.0

```
CHECK SUMS - (ALL SHOULD BE SMALL)
SUM OF FORCES IN VERTICAL DIRECTION       =       .01   (=  .113E-01)
     SHOULD NOT EXCEED       .100E+03
SUM OF FORCES IN HORIZONTAL DIRECTION     =       .05   (=  .516E-01)
     SHOULD NOT EXCEED       .100E+03
SUM OF MOMENTS ABOUT COORDINATE ORIGIN    =      9.98   (=  .998E+01)
     SHOULD NOT EXCEED       .100E+03
SHEAR STRENGTH/SHEAR FORCE CHECK-SUM      =       .00   (=  .505E-02)
     SHOULD NOT EXCEED       .100E+03

***** CAUTION ***** FORCES BETWEEN SLICES ARE NEGATIVE AT POINTS
                    ALONG THE UPPER ONE-HALF OF THE SHEAR SURFACE -
                    A TENSION CRACK MAY BE NEEDED.

***** CAUTION ***** SOME OF THE FORCES BETWEEN SLICES ACT AT POINTS
                    ABOVE THE SURFACE OF THE SLOPE OR BELOW THE
                    SHEAR SURFACE - EITHER A TENSION CRACK MAY BE
                    NEEDED OR THE SOLUTION MAY NOT BE A VALID SOLUTION
```

END-OF-FILE ENCOUNTERED WHILE READING COMMAND
WORDS - END OF PROBLEM(S) ASSUMED

D-8

FINAL COVER STABILITY ANALYSIS

Final Cover Stability Analysis

Objective: Analyze the stability of the final cover slope under the following conditions:

(1) Long-term Condition: Using long-term shear strength without construction equipment loadings.

(2) During Construction: With equipment loadings. The operation weight of construction equipment has been modeled as an equivalent line load applied on the cover slope and the dynamic breaking force has been approximated by 30 percent of the equipment weight applied at the cover surface and orientated paralleled to the slope suggested by Richardson & Koerner ("Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments," GRI, Drexel University, 1987).

(3) Seismic Effect: Horizontal seismic coefficient of 0.1 g for the dynamic analysis of the slope stability has been examined.

Methodology: The analysis assumes the cover slope to be infinite. Based upon this assumption, the failure mode of the cover liner system would occur through an interface of insufficient shear strength. In reality, slopes are not infinite. Therefore, modifications for the slope stability analysis have been made by considering soil buttressing effect as well as tensile strength of geosynthetics.

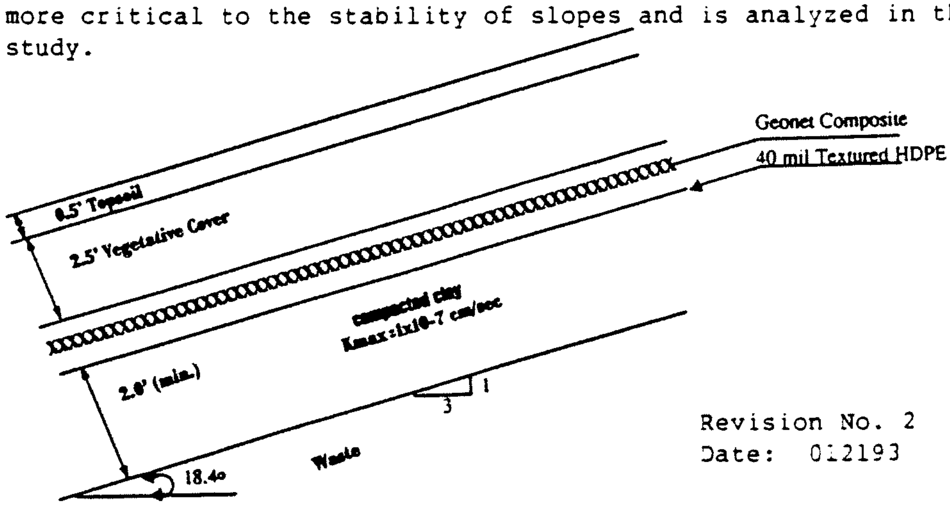
Design Criteria:

Minimum factors of safety have to be achieved:

F.S. = 1.5 for static conditions
F.S. = 1.0 for dynamic conditions

Components of Cover Slope:

The proposed final cover liner system is shown below. The slopes of the cover include 3:1 and 5%. The 3:1 slope is much more critical to the stability of slopes and is analyzed in this study.



Revision No. 2
Date: 012193

Calculations: The factor of safety is defined as:

$$F.S. = F_T/F_D$$

where F_T - resistant forces

here $F_T = F_R + F_G + F_B$

$F_R = \gamma hL \cos\beta\tan\phi_i$, the frictional resisting force at the sliding interface.

γ - unit weight of upper soil

h - height of upper soil

β - angle of the slope

ϕ_i - interface friction angle

F_G = allowable wide width tensile strength of the geosynthetics

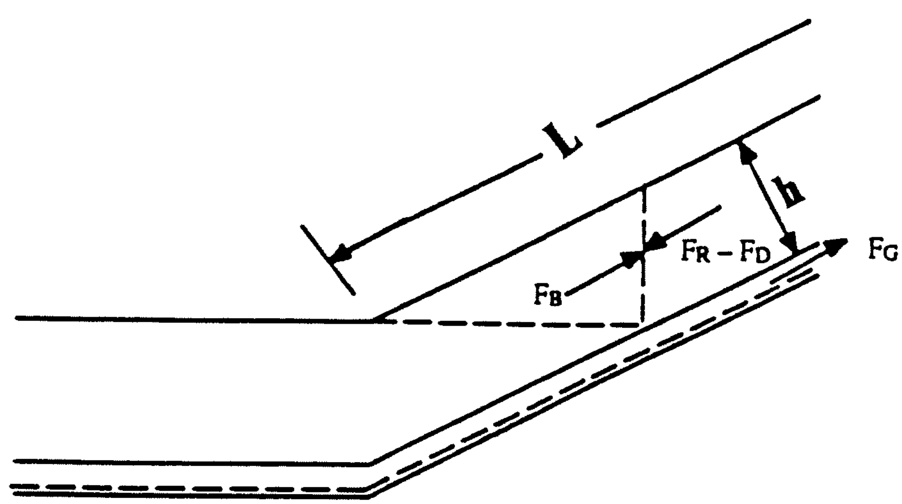
$$F_B = \frac{\cos\phi_s}{\cos(\phi_s+\beta)} [h/\cos\beta \times C_s + (\gamma h^2/\sin 2\beta)\tan\phi_s]$$

the buttress force of the cover soil.

C_s, ϕ_s - soil cohesion and friction angle.

$F_D = \gamma hL\sin\beta$, driving force

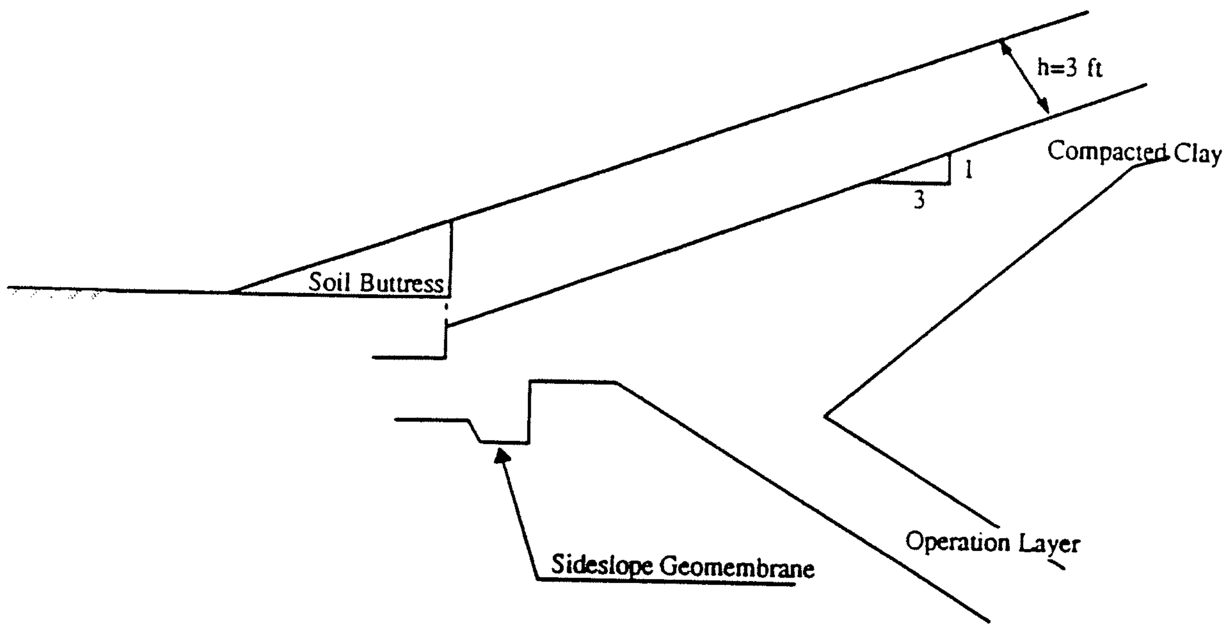
Reference: "Landfill Liner Side Slope Design to Minimize Geomembrane Tensile Stress," Geosynthetics 1991 Conference, Atlanta, Pages 113-123.



Revision No. 2
Date: 012193

CASE 1: Long-Term Condition

Assume: $\gamma = 130$ pcf
$C = 0$
$\phi_s = 28°$
$\beta = 18.4°$ for 3:1 slope



For final cover slope: $h = 3$ ft
$L = 100$ ft (terrace at 100-foot interval)

therefore:

$$F_R = \gamma h L \cos\beta \tan\phi_i$$

$$= 130 \text{ pcf} \times 3 \text{ ft} \times 100 \text{ ft} \times \cos 18.4° \times \tan\phi_i$$

$$= 34{,}160 \tan\phi_i \text{ lb/ft}$$

$$F_D = \gamma h L \sin\beta$$

$$= 130 \text{ pcf} \times 3 \text{ ft} \times 100 \text{ ft} \times \sin 18.4° = 11{,}363 \text{ lb/ft}$$

F_G = 0 neglected (conservative)

$$F_B = \frac{\cos 28^\circ}{\cos(28^\circ + 18.4^\circ)} [130 \text{ pcf} \times (3 \text{ ft})^2/\sin(2 \times 18.4^\circ)]\tan 28^\circ$$

$$= 1{,}227 \text{ lb/ft}$$

$$F.S. = \frac{F_R + F_G + F_B}{F_D}$$

$$= \frac{37{,}006 \tan\phi_i + 1{,}329}{12{,}310}$$

Summary of Safety Factors

ϕ_i	F.S.	F.S. = $\tan\phi_i/\tan\beta$
12.0°	0.747	0.639
14.0°	0.858	0.750
16.0°	0.970	0.862
18.0°	1.085	0.977
20.0°	1.202	1.094
22.0°	1.323	1.215
24.0°	1.447	1.338
25.0°	1.510	1.402
26.5°	1.607	1.500

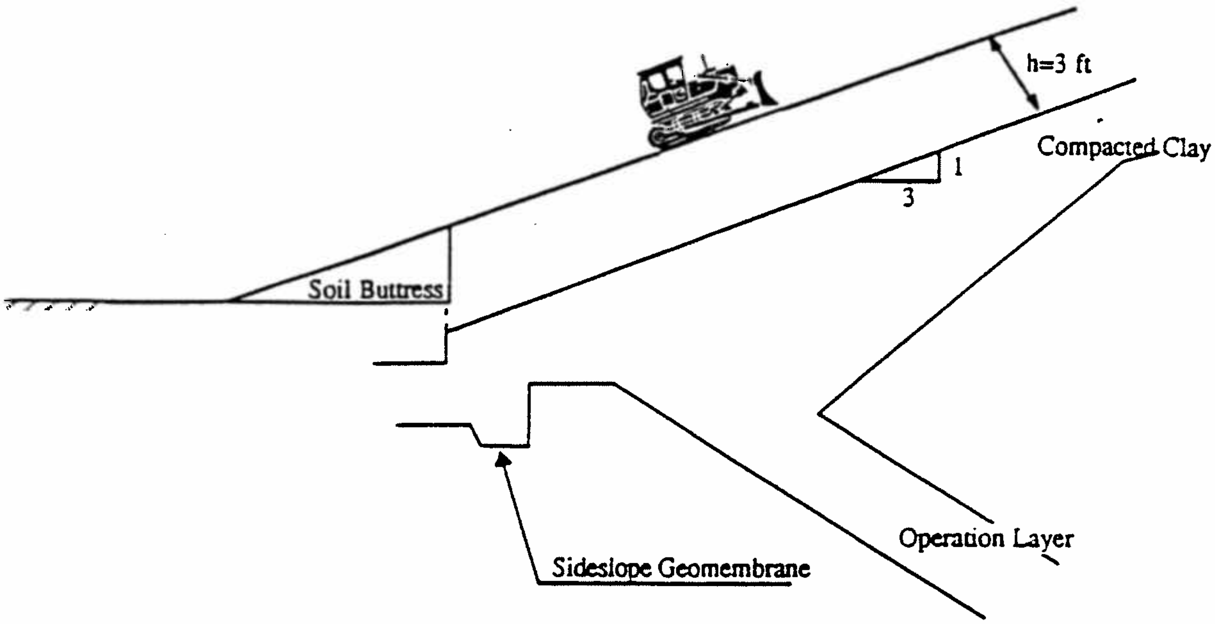
Summary: For a factor of safety of 1.5, the minimum requirement for the interface friction angle is 25 degrees under long-term condition at the final cover liner system.

CASE 2: Final Cover Slope Stability During Construction

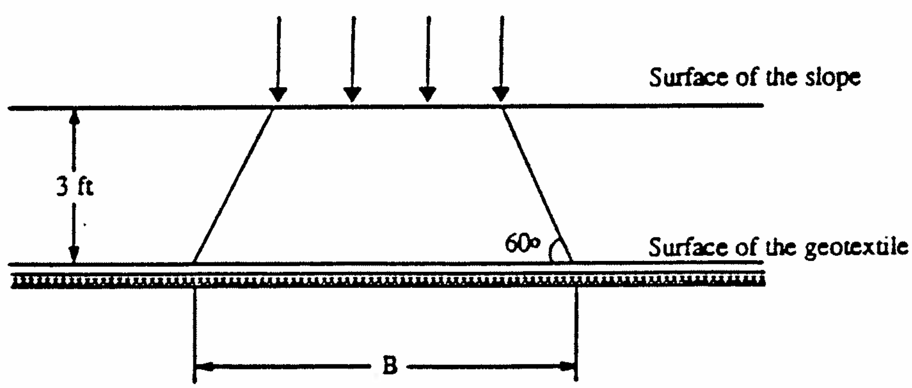
Assume: CAT D8K Track-Type Tractor

Operating weight = 71,700 lb

Width of standard track shoe = 22 in. = 1.83 ft



Calculate the projected imprint area onto geosynthetic liner surface:



Reference: Geotechnical Analysis, Dunn, 1980

$$B = (3\ \text{ft}/\tan 60^\circ) \times 2 + 1.83\ \text{ft} = 5.39\ \text{ft}$$

$$\text{Weight of equipment } W_p = \frac{71{,}700\ \text{lb}}{2 \times 5.39\ \text{ft}} = 6{,}651\ \text{lb/ft}$$

Factor of safety for this case is:

$$F.S. = \frac{(\gamma hL + W_p)\cos\beta\tan\phi + F_G + \dfrac{\cos\phi_5}{\cos(Q_5 + B)}\,(h/\cos\beta)\,C_5 + (\gamma h^2/\sin 2\beta)\tan\phi_S}{(\gamma hL + W_p)\sin\beta + 0.3\,W_p}$$

therefore:

$$F_D = (\gamma hL + W_p)\sin\beta + 0.3\,W_p$$

$$= (130\ \text{pcf} \times 3\ \text{ft} \times 100\ \text{ft} + 6{,}651\ \text{lb/ft}) \times \sin 18.4^\circ + 0.3 \times 6{,}651\ \text{lb/ft}$$

$$= 14{,}410\ \text{lb/ft} + 1{,}995\ \text{lb/ft} = 16{,}405\ \text{lb/ft}$$

$$F_R = (\gamma hL + W_p)\cos\beta\tan\phi_i$$

From Case 1, $\phi_i = 25^\circ$

$$F_R = (130\ \text{pcf} \times 3\ \text{ft} \times 100\ \text{ft} + 6{,}651\ \text{lb/ft}) \times \cos 18.4^\circ \times \tan 25^\circ$$

$$= 20{,}199\ \text{lb/ft}$$

F_G = 50% ultimate wide width strength per manufacturer's data

$$F.S. = \frac{F_R + F_G + F_B}{F_D} = \frac{20{,}199 + F_G + 1{,}329}{16{,}405}$$

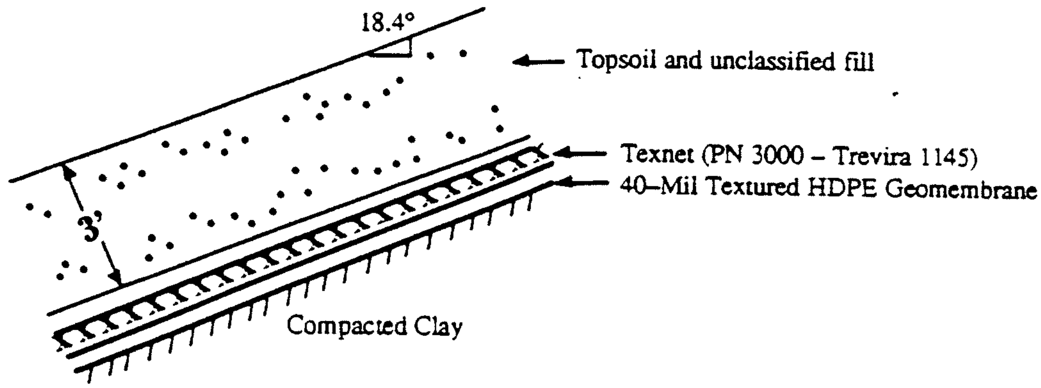
Summary of Safety Factor

F_G	Factor of Safety
0	1.312
500 (6 oz/yd2)	1.343
600 (7 oz/yd2)	1.349
900 (10 oz/yd2)	1.367

Summary: The factor of safety would be decreased from 1.51 to 1.31 when taking construction equipment load into consideration. However, after geosynthetics installed in anchor trench, tensile strength of geosynthetics can make a contribution to the stability of the slope. For example, if geonet composite TEX-NET 1001 is used, which has a form of geonet POLY-NET PN-3000 with geotextile Trevira 1120 heat bounded on both sides, tensile strength from geotextile Trevira 1120 which is immediately underlying the cover soil can be taken into account. The ultimate tensile strength of Trevira 1120 is 1171.2 lb/ft. Use 50% of the ultimate tensile strength which is 585.6 lb/ft. A factor of safety of approximately 1.35 can be achieved, which exceeds the design criterion of F.S. = 1.0 for dynamic conditions.

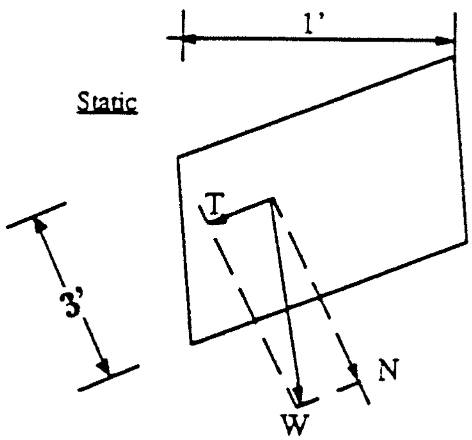
CASE 3: Seismic Effect

Final Cover Profile:



Utilizing Infinite Slope Analysis:

Static



Assume $\gamma_{soil} = 130\ lb/ft^3$

$$W = \frac{1}{\cos 18.4°} \times 3 \times 130 = 411\ lb/ft$$

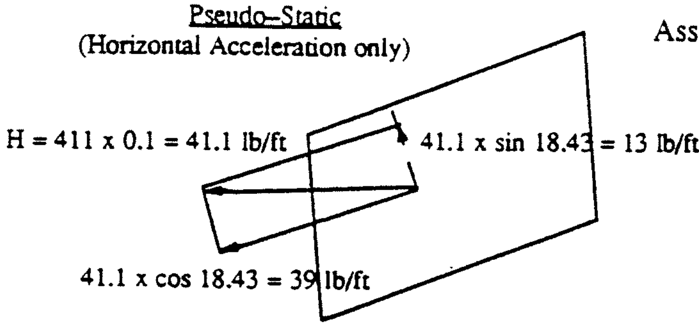
$T = W \sin d = 411 \times 0.316 = 130\ lb/ft$

$N = W \cos d = 411 \times 0.949 = 390\ lb/ft$

Pseudo–Static

(Horizontal Acceleration only)

Assume $a_h = 0.1\ g$



Revision No. 2

Date: 012193

Factor of Safety

$$F.S. = \frac{(390 - 13) \times \tan d}{130 + 39} = \frac{377}{169} \tan d = 2.23 \tan d$$

For F.S. = 1 $\tan d = 1/2.23 = 0.448$ $d = 24°$

Therefore, the angle of friction of the most critical interface should not be less than 24°. If adhesion component is also present, the total interface shear resistance should not be less than 169 lb/ft^2.

Summary:

The analysis results indicate that a minimum interface friction angle of 24 degrees is required when using a horizontal seismic coefficient of 0.1 g in the slope stability analysis with a minimum factor of safety of 1.0. The slope stability analysis result for Case 1 shows that a minimum interface friction angle of 25 degrees is required for a factor of safety of 1.5. Therefore, using 25 degrees for the minimum requirement of the interface friction strength for the final cover slope design should be adequate.

RP/CWMNYORK/ADO

PHASE III TO PHASE IV
FINAL CAP INTERCONNECTION

2H:1V SLOPE MODIFICATION

CLIENT: CWM Chemical Services, LLC
PROJECT: Model City RMU-1 Design Support

SUBJECT: Final Cover Soil Stability of the 2H:1V slope

Prepared By TW Date 08/15/01
Reviewed By JPD Date 08/15/01
Approved By ____ Date ____

TASK

Analyze the cover soil stability of the 2H:1V final cap slope above the Phase III and Phase IV final cap interconnection bench.

REFERENCES

1. Koerner, Robert M. and Soong, Te-Yang. "Analysis and Design of Veneer Cover Soils." Proc. 6th IGS Conf. St. Paul, MN: IFAI, 1998.
2. 6 NYCRR Part 361 Permit Application for Residuals Management Unit 1, prepared by SEC Donohue, Appendix D8, Revision 2, dated December 1, 1993.
3. Final Cap Interconnection Detail at Upper Limit of Phase III Cap, prepared by Earth Tech, August 2001.
4. Caterpillar Performance Handbook, 22nd edition.

METHOD

This analysis examines the cover soil stability of a 2H:1V slope with tapered cover soil thickness and tracked construction equipment forces. This analysis follows the method for veneer cover soil stability discussed in Reference 1. The force diagram on the attached calculation sheet does not show the force of the bulldozer. It must be included into the force summations.

Definition of Parameters

h_c = thickness of the cover soil at crest of the slope (measured perpendicular to the geosynthetic cap slope)
h = thickness of the cover soil at toe of the slope (measured perpendicular to the geosynthetic cap slope)
β = soil slope beneath the geosynthetic cap
ω = finished cover soil slope angle
L = length of slope measured along the geomembrane
$y1$ = $h_c / \cos\beta$
$y2$ = $(L - h/\sin\beta - h_c \tan\beta)(\sin\beta - \cos\beta \tan\omega)$
γ = unit weight of the cover soil
ϕ = friction angle of the cover soil
c = cohesion of the cover soil
δ = interface friction angle between cover soil and geocomposite
c_a = adhesion between cover soil and geocomposite
q = dozer ground pressure = $W_b / (2 \times w \times b)$
W_b = actual weight of the bulldozer
w = length of equipment trach
b = width of equipment track
I = influence factor of equipment at geosynthetic cap interface
a = acceleration/deceleration of the bulldozer
g = acceleration due to gravity

Active Wedge Force Summation

W_A = total weight of the active wedge
= $\gamma\,[\,(L - h/\sin\beta - h_c \tan\beta)((y_2 \cos\beta)/2 + h_c) + (h_c^2 \tan\beta)/2\,]$

N_A = effective force normal to the failure plane of the active wedge
= $W_A \cos\beta$

C_a = adhesive force between cover soil of the active wedge and the geosynthetic cap
= $c_a\,(L - h/\sin\beta)$

W_e = equivalent equipment force per unit width at the geosynthetic cap interface
= $q\,w\,I$

N_e = equivalent equipment force per unit width normal to the geosynthetic cap interface
= $W_e \cos\beta$

F_e = acceleration/deceleration force of the bulldozer
= $W_e\,(a/g)$

E_A = interwedge force acting on the active wedge from the passive wedge
FS = factor of safety against sliding of the cover soil

By balancing the forces in the vertical direction, the following summation results:

$$E_A \sin((\omega + \beta)/2) = W_A + W_e - (N_A + N_e)\cos\beta - [(N_A + N_e)\tan\delta + C_a + F_e](\sin\beta)/FS$$

The interwedge force acting on the active wedge is:

$$E_A = \frac{(FS)(W_A + W_e - (N_A + N_e)\cos\beta) - [(N_A + N_e)\tan\delta + C_a + F_e](\sin\beta)}{\sin((\omega + \beta)/2)\,(FS)}$$

Passive Wedge Force Summation

The passive wedge can be considered in a similar manner

W_P = total weight of the active wedge
= $(\gamma / 2\tan\omega)(y1 + y2)^2$

N_P = effective force normal to the failure plane of the passive wedge
= $W_P + E_P \sin((\omega + \beta)/2)$

C = cohesive force along the failure plane of the passive wedge
= $(c / \sin\omega)(y1 + y2)$

Ep = interwedge force acting on the passive wedge from the active wedge
FS = factor of safety against sliding of the cover soil

By balancing the force in the horizontal direction, the following summation results:

$$E_P \cos((\omega+\beta)/2) = (C + N_P \tan\phi) / FS$$

Substituting the equation for Np and solving for Ep yields:

$$E_P = \frac{C + W_P \tan\phi}{(\cos((\omega+\beta)/2)(FS) - (\sin((\omega+\beta)/2)(\tan\phi)}$$

Factor of Safety Formula

By setting $E_A = E_P$, a quadratic equation can be arranged in the form of $ax^2 + bx + c = 0$, which in this case is:

$$a(FS)^2 + b(FS) + c = 0$$

where,

$$a = (W_A + W_e - (N_A + N_e)\cos\beta)\cos((\omega+\beta)/2)$$

$$b = -[(W_A + W_e - (N_A + N_e)\cos\beta)\sin((\omega+\beta)/2)(\tan\phi) + ((N_A + N_e)\tan\delta + C_a + F_e)\sin\beta\cos((\omega+\beta)/2) + (C + W_P\tan\phi)\sin((\omega+\beta)/2)]$$

$$c = ((N_A + N_e)\tan\delta + C_a + F_e)\sin\beta\sin((\omega+\beta)/2)\tan\phi$$

The equation to solve for FS is:

$$FS = (-b + (b^2 - 4ac)^{1/2}) / (2a)$$

ASSUMPTIONS

1. The thickness of the cover soil at the crest of the slope is 3 ft and the thickness at the toe of the slope is 4.116 ft (determined using Reference 3).
2. The angle of the geosynthetic cap is 26.57° (2H:1V). The angle of the cover soil is 18.43° (3H:1V).
3. The maximum length of the 2H:1V slope is 13 ft (Reference 3).
4. The unit weight of the cover soil is 130 pcf (Reference 2).
5. The friction angle of the cover soil is 28° (Reference 2).
6. The cover soil has no cohesion and there is no adhesion between the cover soil and the geocomposite (Reference 2).
7. The interface friction angle between the cover soil and the geosynthetic cap is 25° (Reference 2).

8. The final cover soil will be placed with CAT D6H LGP Series II Track-Type Tractor. It has a weight of 44,131 lb (power shift differential steer), a track length (w) of 128.5 inches, and a track width (b) of 36 inches (Reference 4). The track width is standard size.
9. The acceleration of the dozer is 0.053g (assumed typical value).

CALCULATIONS

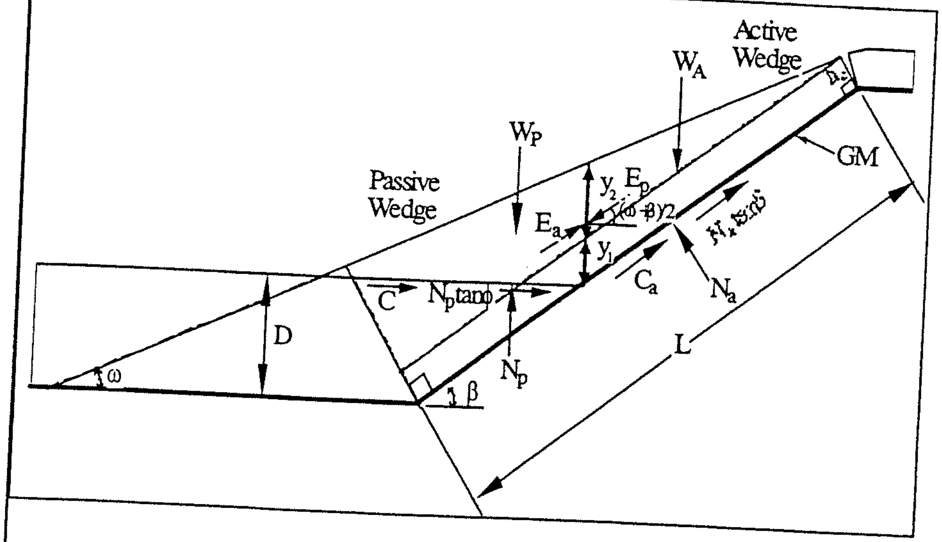
The calculations were performed using the attached spreadsheet. Units had to be converted from English to metric. The three conversions needed were:

1 ft = 0.3048 m
1 psf = 0.04788 kN/m^2
1 pcf = 0.1572 kN/m^3

The resulting factor of safety for the 2H:1V slope is **1.56**. The 2H:1V slope is safe against sliding of the cover soil under dozer loading.

Cover Soil Stability Analysis Worksheet

Tapered Cover Soil Thickness (with Dozer Weight Added In)



Calculation of FS

Active Wedge:

Wa= *18.02 kN*
Na= *16.12 kN*

Passive Wedge:

Wp= *38.91 kN*

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

a= *17.21*
b= *-29.41*
c= *3.90*

FS= 1.56

thickness of cover soil at top (crest) of the slope = hc =	0.914	m		
thickness of cover soil along the bottom of the site = h =	1.255	m		
soil slope angle beneath the geomembrane = β =	26.57	°	*= 0.464 (rad.)*	(2H:1V)
finished cover soil slope angle = ω =	18.43	°	*= 0.322 (rad.)*	(3H:1V)
length of slope measured along the geomembrane = L =	3.962	m		

y2= 0.1043 (m)
y1= 1.0223 (m)
(ω+β)/2= 0.393 (rad.)
(= 22.5 °)

unit weight of the cover soil = γ =	20.436	kN/m^3		
friction angle of the cover soil = φ =	28.0	°	*= 0.489 (rad.)*	
cohesion of the cover soil = c =	0.0	kN/m^2		*C= 0 kN*
interface friction angle between cover soil and geomembrane = δ =	25.0	°	*= 0.436 (rad.)*	
adhesion between cover soil and geomembrane = ca =	0.0	kN/m^2		*Ca= 0 kN*

thickness of cover soil = h =	0.914	m
equipment ground pressure (= wt. of equipment/(2wb)) = q =	32.887	kN/m^2
length of each equipment track = w =	3.264	m
width of each equipment track = b =	0.914	m
influence factor* at geomembrane interface = I =	0.70	
acceleration/deceleration of the bulldozer = a =	0.053	g

b/h= 1.0
We=q w I= 75.14
Ne=Wecosβ= 67.21
Fe=We (a/g)= 3.98

*Influence Factor Default Values

Cover Soil Thickness	Equipment Track Width		
	Very Wide	Wide	Standard
≤300 mm	1.00	0.97	0.94
300-1000 mm	0.97	0.92	0.70
≥1000 mm	0.95	0.75	0.30

Note: numbers in boxes are input values

numbers in Italics are calculated values

Model City 2H:1V final cap slope above interconnection bench

thickness of cover soil at top of 2H:1V slope =	3 ft	
thickness of cover soil at toe of 2H:1V slope =	4.116 ft	
length of 2H:1V slope =	13 ft	
unit weight of cover soil =	130 pcf	
dozer operating weight (W_b) =	44131 lb	(CAT D6H LGP Series II Track-Type Tractor)
equipment track length (w) =	128.5 in	
equipment track width (b) =	36 in	
equipment ground pressure [$q = W_b / (2wb)$] =	686.8638 psf	
braking force = 30% equip. weight		

Conversion factors

1 ft = 0.3048 m

1 pcf = 0.1572 kN/m^3

1 psf = 0.04788026 kN/m^2

L:\WORK\SW\PROJECTS\44347\wpdraft\Permit Mod Cap Interconnection\[tapered soil analysis_equipment.xls]Worksheet-1

CLIENT: CWM Chemical Services, LLC
PROJECT: Model City RMU-1
Design Support

SUBJECT: Anchor Trench Calculations

Prepared By TW Date 08/02/01
Reviewed By BPS Date 08/14/01
Approved By Date

TASK

Evaluate the anchorage of the 40 mil textured HDPE for the final cap interconnection at the upper limit of the Phase III cap.

REFERENCES

1. Koerner, Robert M. "Designing with Geosynthetics." 3rd ed. 1994.
2. Geotechnical Fabric Report: Specifier's Guide 2001, December 2000, Volume 18, Number 9.
3. 6 NYCRR Part 361 Permit Application for Residuals Management Unit 1, prepared by SEC Donohue, Appendix D8, Revision 2, dated December 1, 1993.
4. Final Cap Interconnection Detail at Upper Limit of Phase III Cap, prepared by Earth Tech, August 2001.
5. CWM-WMNA Friction Testing Database

METHOD

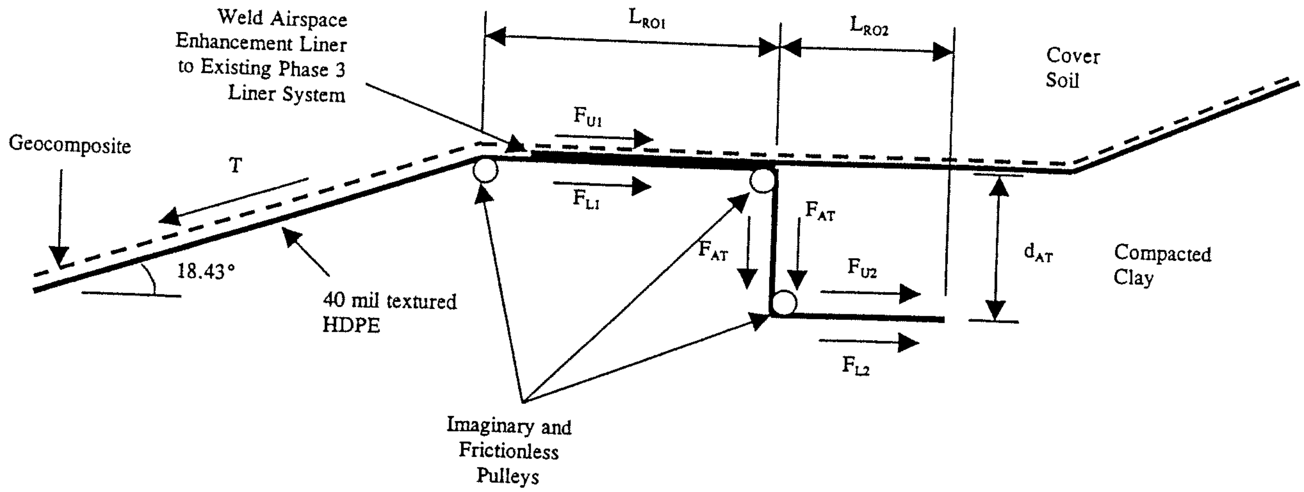
The anchor trench evaluation will follow the method discussed in Section 5.3.6 of Reference 1. The cross-section of the runout section and related stresses and forces involved is on Page 2. To establish static equilibrium, assume the geomembrane acts as a frictionless pulley, allowing it to be considered in its continuous form. The design equation is as follows:

$$T_{allow} = F_U + F_L + 2F_{AT}$$

Where,

T_{allow} = allowable force in the anchored geomembrane
F_U = friction force above final cap liner due to cover soil (assumed negligible because cover soil probably moves along the geocomposite as it deforms)
F_L = $q \tan \delta_L (L_{RO})$
q = surcharge pressure due to cover soil above liner
δ_L = friction angle between the geomembrane and the compacted clay below it
L_{RO} = length of runout
F_{AT} = $(\sigma_h)_{ave} \tan \delta (d_{AT})$
$(\sigma_h)_{ave}$ = average horizontal stress in anchor trench = $K_o \sigma_v$
σ_v = γH_{ave}
γ = unit weight of backfill soil
H_{ave} = average depth of anchor trench
K_o = $1 - \sin \phi$
ϕ = the angle of shearing resistance of backfill soil
d_{AT} = depth of the anchor trench

ANCHOR TRENCH – FREE BODY DIAGRAM



ASSUMPTIONS

1. The side slope angle is 18.43° (3H:1V).
2. The unit weight of the cover soil is 130 pcf (Reference 3).
3. The unit weight of the compacted clay in and below the anchor trench is conservatively assumed to equal 130 pcf.
4. The friction angle between the textured geomembrane and the compacted clay (δ_L) is 22° (typical value from Reference 5).
5. The angle of shearing resistance of the compacted clay is 27° (typical value).

CALCULATIONS

1. Allowable Force (T_{allow}) in the Anchored Geoemembrane

The runout lengths and the anchor trench depth are taken from Reference 4.

L_{RO1} = 1.91 ft
L_{RO2} = 0.5 ft
d_{AT} = 1.0 ft

The surcharge pressures above the first and second runout sections can be calculated. The thickness of the cover soil layer is 3 ft. The 1-ft deep anchor trench is filled with compacted clay.

q_1 = (3 ft of cover soil)(130 pcf)
= 390 psf

q_2 = (3 ft of cover soil)(130 pcf) + (1 ft of clay)(130 pcf)
= 520 psf

F_U = assumed negligible

$F_{L1} = q_1 \tan \delta_L (L_{RO1})$
= (390 psf)(tan 22°)(1.91 ft)
= 300.96 ppf

$F_{L2} = q_2 \tan \delta_L (L_{RO2})$
= (520 psf)(tan 22°)(0.5 ft)
= 105.05 ppf

$F_{AT} = (\sigma_h)_{ave} \tan \delta \, (d_{AT})$
$= K_o \, \sigma_v \, \tan \delta \, (d_{AT})$
$= (1 - \sin \phi)(\gamma H_{ave}) \tan \delta \, (d_{AT})$

where,

H_{ave} = 3.0 ft of cover soil + d_{AT} = 4.0 ft

F_{AT} = (1 – sin 27°)(130 pcf)(4 ft)(tan 22°)(1 ft)
= 114.71 ppf

$T_{allow} = F_U + F_{L1} + F_{L2} + 2F_{AT}$
= 0 + (300.96 ppf) + (105.05 ppf) + 2(114.71 ppf)
= 635.43 ppf
= 52.95 ppi

2. Yield Strength of Anchored Geomembrane

From Reference 2, Polyflex Coextruded Textured 40-mil HDPE has a yield tensile strength of 84 ppi.

3. Factor of Safety

FS = T_{act} / T_{allow}
= 84 ppi / 52.95 ppi
= 1.59

CONCLUSION

The factor of safety indicates that pullout of the geomembrane will occur before tensile failure. Since pullout is the preferable situation over geomembrane failure, the anchor trench is designed sufficiently.

CLIENT: CWM Chemical Services, LLC PROJECT: Model City, NY
TITLE: RMU-1 Final Cover Permit Modification
SUBJECT: Appendix D-8a: Final Cover Stability

Prepared By: APC Date: September 2007
Reviewed By: SRM Date: September 2007
Revised By: CRG Date: June 2008

PROJECT NO.: 05104.2008

OBJECTIVE:

Evaluate the stability of the final cover under the following conditions:

(1) Long-Term Stability – using peak and residual shear strengths without construction equipment loadings
(2) Short-Term Stability – using peak and residual shear strengths with construction equipment loadings
(3) Seismic Stability – using residual shear strength with a horizontal seismic coefficient calculated to simulate the design earthquake and limit permanent seismic deformation to 12 inches

As indicated above, analyses for peak and residual strengths are provided for long- and short-term analyses. Due to the allowance for larger deformations (up to 12 inches) during an earthquake, the residual strength is considered for the seismic case.

REFERENCES:

1. *Engineering Report for CWM Chemical Services, LLC Model City Facility, Residuals Management Unit-1*, Earth Tech (latest revised date May 18, 1999).

2. Koerner, Robert M. and T. Soong, "Analysis and Design of Veneer Cover Soils," *Sixth International Conference on Geosynthetics*, 1998.

3. *RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities*, USEPA, EPA/600/R-95/051, April, 1995.

4. RMU-1 Permit Drawing No. 12-a entitled *Top of Vegetative Cover Grades*, Blasland, Bouck & Lee, Inc., December 2003 (latest revision June 2008).

5. *Peak Acceleration with 2% Probability of Exceedance in 50 Years*, USGS Map, October 2002.

ASSUMPTIONS:

1. The minimum acceptable factors of safety for long-term and short-term static stability are 1.50 and 1.00 for peak and residual shear strength, respectively.

2. The minimum acceptable factor of safety for seismic stability is 1.00 for residual shear strength.

3. Although the slopes of the final cover include both 3 horizontal:1 vertical (3:1) and 5% slopes, only the critical slope (i.e., the 3:1 slope) is analyzed.

4. The final cover system consists of (from top to bottom) 24 inches of vegetative cover soil (composed of 6 inches of topsoil and 18 inches of general fill), a geocomposite drainage layer, a 40-mil textured high-density polyethylene geomembrane, and a geosynthetic clay liner (GCL). Six inches of general fill is also provided as a separation layer between the top of waste and the final cover GCL.

5. For the short-term cover stability analyses (peak and residual strength), the thickness of the cover soil under equipment loading is 18 inches. This represents the case of compaction equipment traveling over the initial lift of cover soil, which is the most critical scenario.

6. The seismic coefficient, C_s, used in the seismic stability analysis contained herein is the critical seismic coefficient that results in a factor of safety of 1.0 and is therefore equivalent to the yield acceleration, Ky, in Reference 3. Ky is obtained from graphs presented in Reference 3 and is based on limiting permanent seismic deformation to 12 inches

and using the assumption of soft soil for subsurface soils at the site and stiff soil for landfill waste. Although ARCADIS and others (Brierley Associates and Peter J. Carey & Associates, P.C.) have presented analyses demonstrating that subsurface soils at the site are considerably stiffer than those typically characterized as soft, the NYSDEC has requested the assumption of soft soil. The estimation of Ky is therefore conservative.

7. Seepage forces can be neglected in the final cover stability calculations since the final cover system has been designed with a geocomposite drain at the bottom of the cover soil to prevent horizontal seepage within the cover. Also, the New York State Department of Environmental Conservation considers it acceptable to neglect acceleration/deceleration forces in the analyses, provided soils are pushed up-slope during construction of the final cover.

8. The following parameters are used in the analysis:

Variable	Value
Thickness of cover soil, h (long term conditions)	2 ft
Thickness of cover soil, h (short term conditions)	1.5 ft
Assumed adhesion in cover system, C_a (both peak and residual)	0 psf
Unit weight of the cover soil, γ	130 pcf
Friction angle of the cover soil, ϕ	25°
Cohesion of the cover soil, C	0 psf
Equipment weight, W_b	38,400 lb
Equipment ground pressure, q	640 psf
Length of each equipment track, w	10 ft
Width of each equipment track, b	3 ft
Minimum acceptable factor of safety (peak strength, long and short term)	1.50
Minimum acceptable factor of safety (residual strength long and short term)	1.00
Minimum acceptable factor of safety (seismic)	1.00

METHODOLOGY:

A procedure developed by Koerner and Soong (Reference 2) was used for the long-term, short-term, and seismic stability calculations. This method is often referred to as the GRI-215 method.

CALCULATIONS:

A summary of the calculations used for the three analyses (i.e., long-term, short-term, and seismic) is provided below:

Long-Term Stability

This analysis is performed by evaluating the gravitational forces acting on a finite length of the cover system. As indicated in Reference 4, the maximum slope along the geomembrane, β, is 18.4°, and the maximum uninterrupted length measured along the geomembrane, L, is 112 feet. The other required values are defined in Assumption 8. A force diagram and calculations are provided in Attachment A and B, respectively, to supplement the summary provided below:

$$W_A = \gamma h^2 \left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right)$$

$$N_A = W_A \cos\beta$$

$$W_P = \frac{\gamma h^2}{\sin 2\beta}$$

$$E_A = \frac{(FS)(W_A - N_A\cos\beta) - (N_A \tan\delta + C_a)\sin\beta}{\sin\beta(FS)}$$

$$E_P = \frac{C + WP\tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi}$$

Where W_A is the total weight of the active wedge, N_A is the effective force normal to the failure plane of the active wedge, W_P is the weight of the passive wedge, E_A is the interwedge force acting on the active wedge form the passive wedge, E_P is the interwedge force acting on the passive wedge from the active wedge, and FS is the factor of safety. By setting E_A=E_P, the equation can be rearranged in the form of the quadratic equation as follows:

$$a(FS)^2 + b(FS) + c = 0$$

$$a = (W_A - N_A\cos\beta)\cos\beta$$

$$b = -[(W_A - N_A\cos\beta)\sin\beta\tan\phi + (N_A\tan\delta + C_a)\sin\beta\cos\beta + \sin\beta(C + W_P\tan\phi)]$$

$$c = (N_A\tan\delta + C_a)\sin^2\beta\tan\phi$$

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

Using the above equations (as shown in Attachment B), setting the factor of safety at 1.50 and 1.00, solving for the minimum acceptable peak and residual friction angle results in 25.7 and 17.4 degrees, respectively.

Short-Term Stability

The short-term stability calculation is performed in the same way as the long-term stability analysis, except an additional term is added to the total weight of the active wedge, W_A, and to the effective normal to the failure plane of the active wedge, N_A, to account for equipment. This calculation is performed as follows:

$$W_e = qwI$$

$$q = \frac{W_b}{2wb}$$

$$W_{A1} = W_e + W_A$$

$$N_e = W_e\cos\beta$$

$$N_{A1} = N_e + N_A$$

Where W_e is the equivalent equipment force per unit width at the geomembrane interface; N_e is the effective equipment force normal to the failure plane of the active wedge; I is the influence factor at the geomembrane interface (see Figure 7 from Reference 2 in Attachment A); q, W_b, w, and b are defined in Assumption 8; and W_{A1} and N_{A1} are the modified total weight of the active wedge and modified normal force, respectively. When W_{A1} and N_{A1} are used in place of W_A and N_A

in the calculations presented under Short-Term Stability, setting the factor of safety at 1.50 and 1.00, solving for the minimum acceptable peak and residual friction angle results in 26.0 and 17.8 degrees, respectively.

Seismic Stability

A pseudo-static stability analysis is performed to determine the stability of the final cover design under the anticipated maximum seismic event that may occur. The following is a summary of the pseudo-static analysis.

The pseudo-static analysis uses the same formulation as presented above, but adds a seismic force acting horizontally on the active wedge and the passive wedge. The force diagram depicting this configuration is provided in Attachment A. As presented below, both the interwedge active and passive forces are modified as compared to the previous analyses, resulting in new formulations for a, b, and c:

$$E_A = \frac{(FS)(C_S W_A + N_A \sin\beta)}{(FS)\cos\beta} - \frac{(N_A \tan\delta + C_a)\cos\beta}{(FS)\cos\beta}$$

$$E_P = \frac{C + W_P \tan\phi - C_S W_P (FS)}{(FS)\cos\beta - \sin\beta\tan\phi}$$

$$a = (C_S W_A + N_A \sin\beta)\cos\beta + C_S W_p \cos\beta$$

$$b = -[(C_S W_A + N_A \sin\beta)\sin\beta\tan\phi + (N_A \tan\delta + C_a)\cos^2\beta + (C + W_P \tan\phi)\cos\beta]$$

$$(N_A \tan\delta + C_a)\cos\beta\sin\beta\tan\phi$$

First, the site-specific free field acceleration is determined using a peak bedrock acceleration of 0.16 g (Reference 5). The free field peak acceleration, a_{max}, is dependent upon the average shear wave velocity in the upper 100 feet of material below the base of the landfill, which consists of approximately 50 feet of soft to stiff clays and tills and approximately 50 feet of bedrock. Using a procedure in the *2000 International Building Code* for classifying the soil conditions at a given site when distinctly different soil layers exist (such as beneath RMU-1), average conditions were found to be representative of "medium stiff" soil based on standard penetration test data for soil borings completed prior to RMU-1 construction. However, as discussed in Assumption 6, "soft" soil conditions are assumed for conservatism in this analysis at the request of the NYSDEC. For this soil classification, the free field peak ground acceleration is amplified to approximately 0.27g (obtained using Figure 4.5 in Reference 3). Further amplification through the landfill itself is not considered because operational practices specifically control the strength of the waste mass to ensure that a minimum shear strength is met and that compaction is maximized. Thus, the waste mass is considered equivalent to "stiff" soil and no further amplification occurs as the seismic energy is transmitted to the top of the landfill.

A pseudo-static stability analysis, including a Newmark deformation analysis, is performed according to Reference 5. This is accomplished using the following steps:

1. The Ky/Kmax ratio is calculated using a maximum seismic deformation of 12 inches and the upper limit of the M 6.5 earthquake range (Figure 6.5, Reference 3). Using this chart, a Ky/Kmax ratio of 0.32 is calculated.

2. Once the Ky/Kmax ratio is determined, the corresponding yield acceleration, Ky, can be determined. Using a Ky/Kmax = 0.32 and a Kmax of 0.27 (as determined from Figure 4.5, Reference 3), a yield acceleration of 0.086 is calculated.

3. Inserting the yield acceleration into the residual seismic analysis presented in Reference 2 and setting the safety factor to 1.0, a minimum interface friction angle of 22.4 degrees is required in the cover system to achieve the necessary cover stability.

c

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CALCULATION SHEET

CLIENT: CWM Chemical Services, LLC PROJECT: Model City, NY PROJECT NO.: 05104.2008
TITLE: RMU-1 Final Cover Permit Modification Prepared By: APC Date: September 2007
SUBJECT: Appendix D-8a: Final Cover Stability Reviewed By: SRM Date: September 2007
Revised By: CRG Date: June 2008

SUMMARY:

A summary of the minimum acceptable internal and interface friction angles for each scenario evaluated is presented below (bold values indicate governing conditions).

Analysis	Required Factor of Safety	Minimum Equivalent Friction Angle
Long-Term, Peak Strength	1.50	25.7°
Long-term, Residual Strength	1.00	17.4°
Short-Term, Peak Strength	1.50	**26.0°**
Short Term, Residual Strength	1.00	**17.8°**
Seismic, Residual Strength	1.00	**22.4°**

All geosynthetic materials and geosynthetic interfaces in the final cover system must achieve minimum internal and interface shear strengths equivalent to the following friction angles:

1. Peak Strength: 26.0° (slow strain rate)
2. Residual Strength: 17.8° (slow strain rate)
3. Residual Strength: 22.4° (rapid strain rate to simulate seismic conditions)

Testing will occur at confining pressures of 200, 400, and 1,000 pounds per square feet to measure shear strengths over the range of anticipated loadings (i.e., soil and equipment loadings). The minimum required shear strength at each confining pressure can be calculated by multiplying the confining pressure and the tangent of the minimum equivalent friction angle. Direct shear strength testing (American Society for Testing and Materials [ASTM] D6243 and ASTM D5321, as applicable) will be performed on the entire cover system to verify that the minimum required shear strength requirements are achieved.

ARCADIS

Excerpts from Reference 3

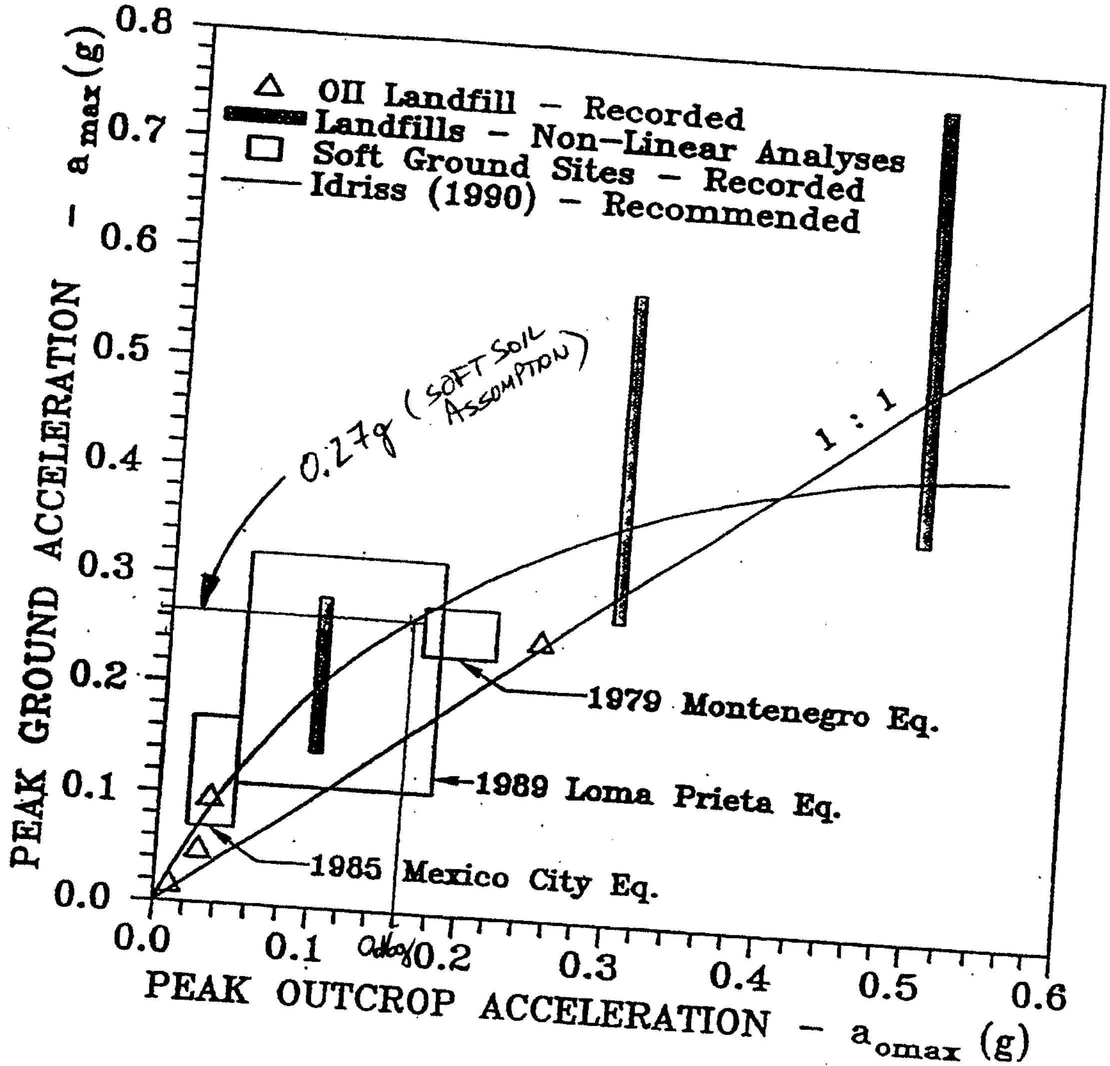
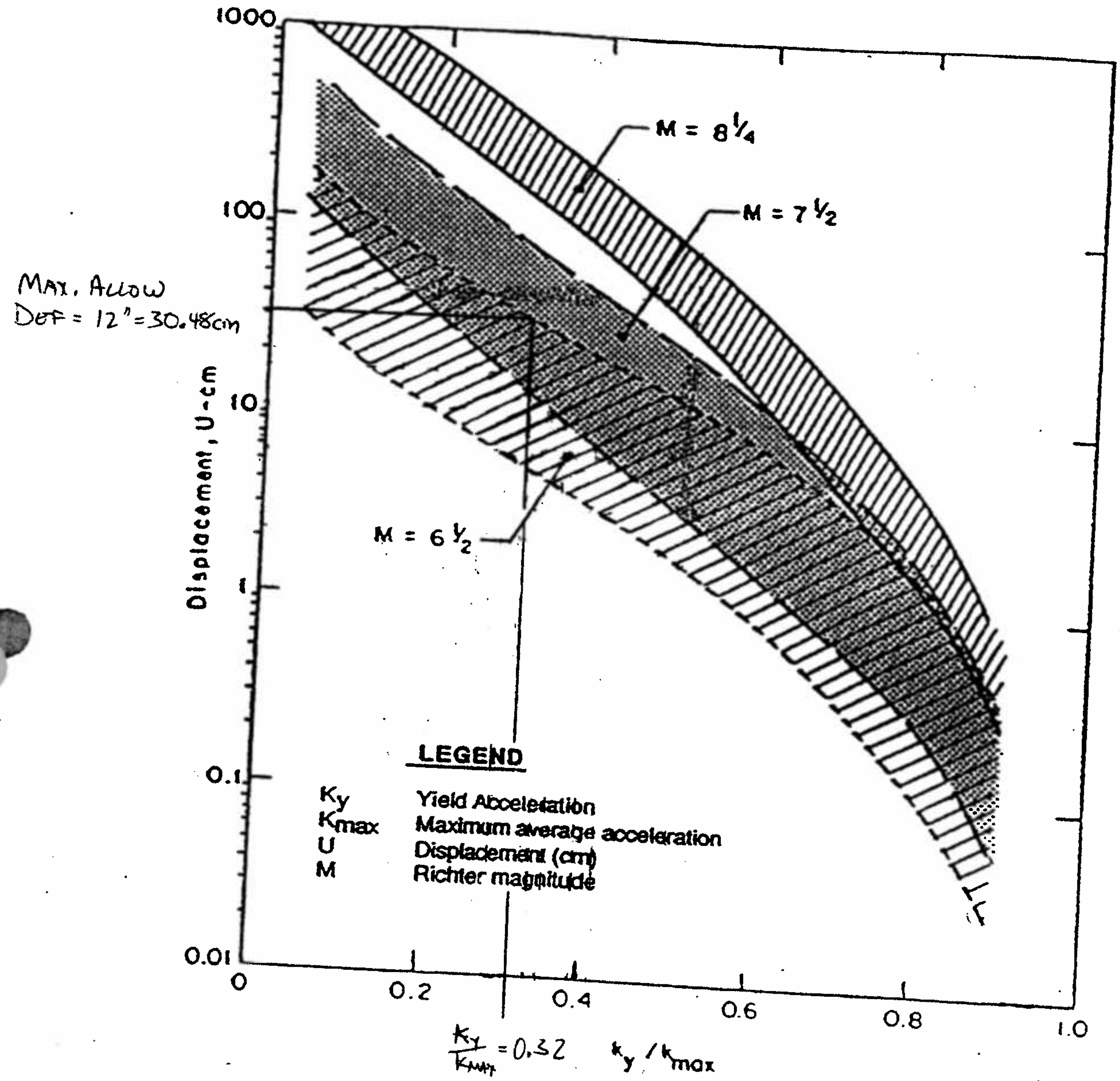


Figure 4.5 Observed Variations of Peak Horizontal Accelerations on Soft Soil and MSW Sites in Comparison to Rock Sites (Kavazanjian and Matasović, 1994).



$\therefore K_y = 0.32 K_{max} = (0.32)(0.27) = 0.086$

NOTE $K_y = C_s$

Figure 6.6 Makdisi and Seed Permanent Displacement Chart (Makdisi and Seed, 1978).

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Attachment A

Long-Term Stability

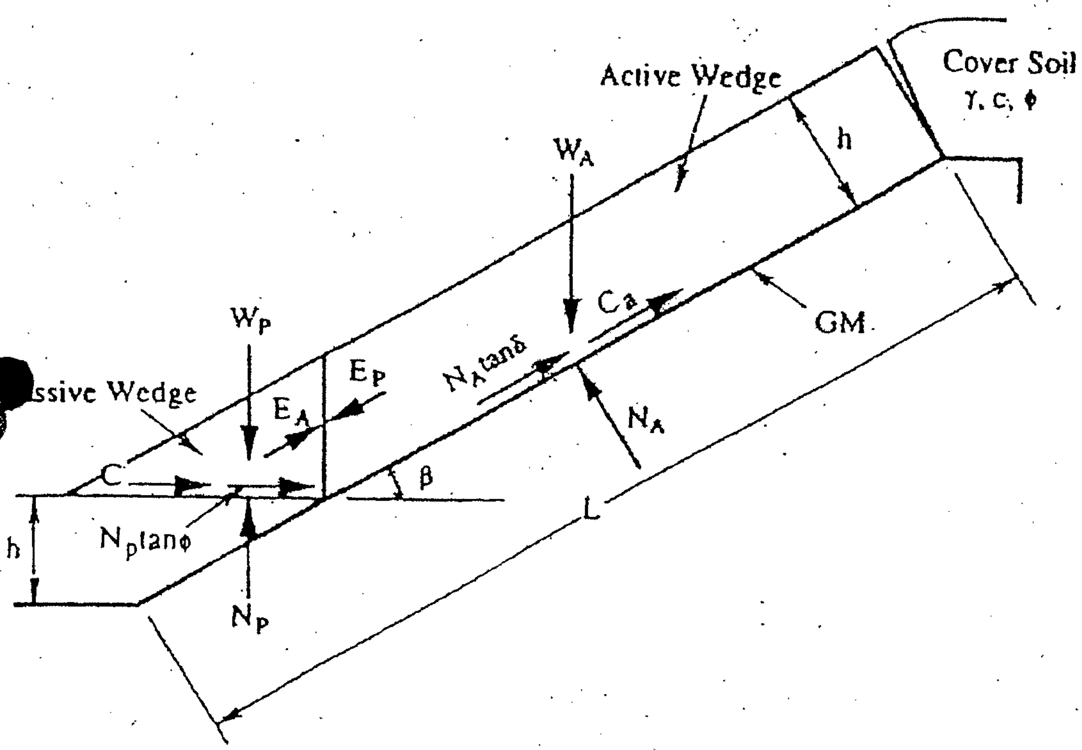

Figure 3 from "Analysis and Design of Veneer Cover Soils," in the Sixth International Conference on Geosynthetics '98, by Robert M. Koerner and Te-Yang Soong.

Equipment Loading

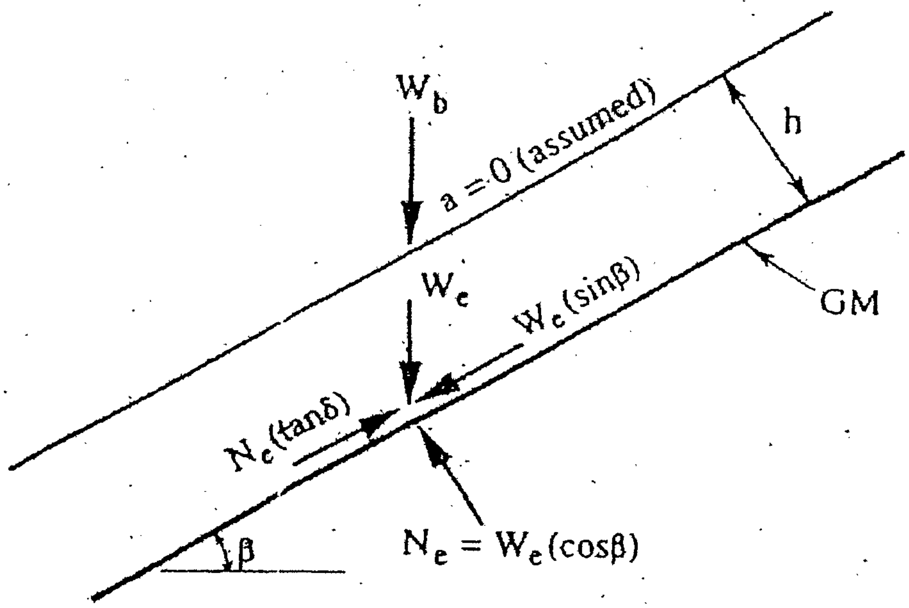

Figure 6a from "Analysis and Design of Veneer Cover Soils," in the Sixth International Conference on Geosynthetics '98, by Robert M. Koerner and Te-Yang Soong.

Pseudo-static Analysis Force Diagram

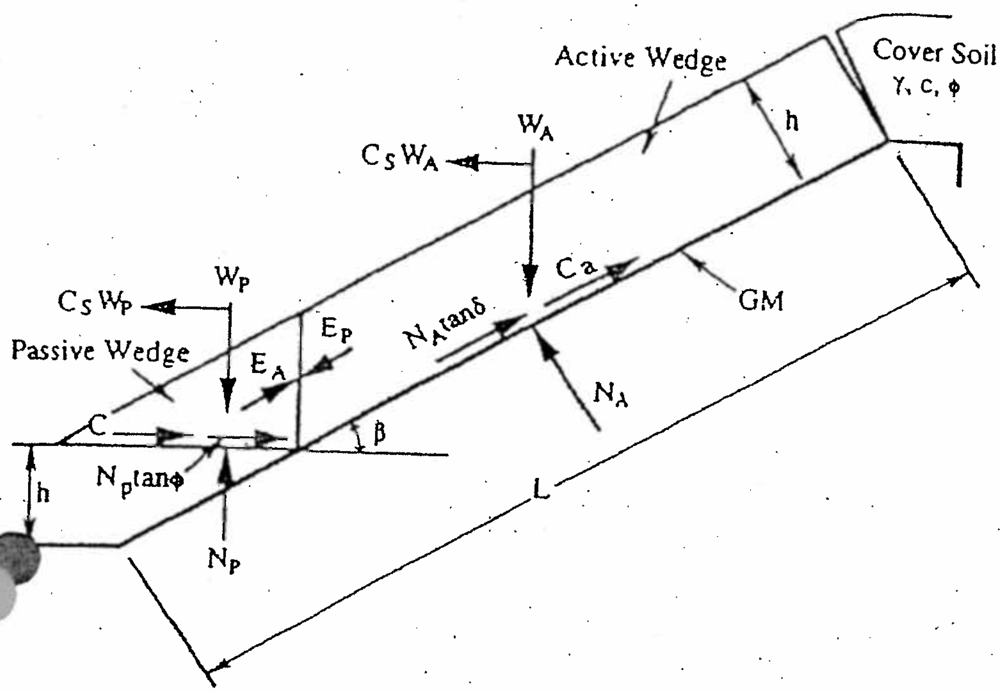

Figure 15 from "Analysis and Design of Veneer Cover Soils," in the Sixth International Conference on Geosynthetics '98, by Robert M. Koerner and Te-Yang Soong.

Influence Factor Values for Short-Term Analysis

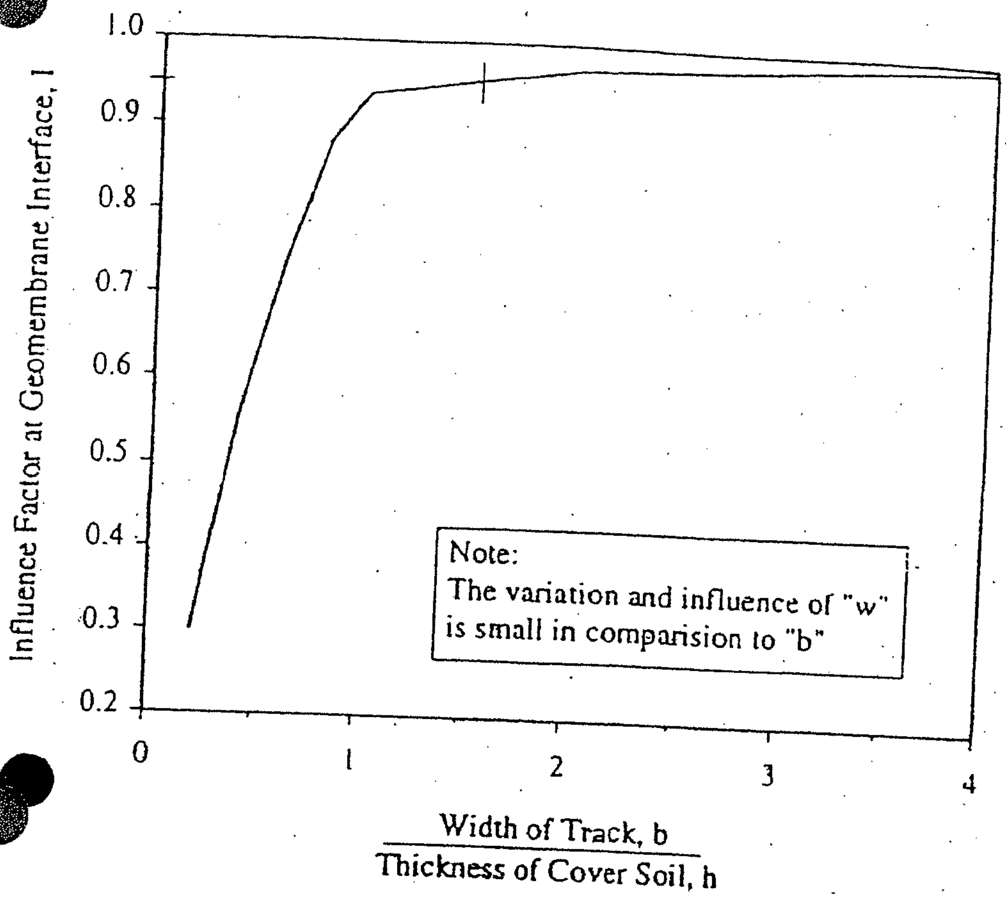

Figure 7 from "Analysis and Design of Veneer Cover Soils," in the Sixth International Conference on Geosynthetics '98, by Robert M. Koerner and Te-Yang Soong.

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Attachment B

CWM Chemical Services, LLC
Model City Facility
RMU-1 Airspace Enhancement Permit Modification

Appendix D-8a: Final Cover Stability Calculations

Peak Strength
Long-Term Static Veneer Cover Stability
Uniform Cover Soil Thickness

Thickness of cover soil, h	2	ft		
Soil slope angle beneath the geomembrane, beta	18.4	degrees	0.32	radians
Length of slope measured along the geomembrane, L	112	ft		
Unit weight of the cover soil, gamma	130	pcf		
Friction angle of the cover soil, theta	25	degrees	0.44	radians
Cohesion of the cover soil, c	0	psf		
Interface friction angle between cover soil and geomembrane, delta	25.7	degrees	0.45	radians
Adhesion between cover soil and geomembrane, c_a	0	psf		
Total weight of the active wedge, W_A	27,386	lb		
Total weight of the passive wedge, W_p	868	lb		
Effective force normal to the failure plane of the active wedge, N_A	25,986	lb		
a =	2,589			
b =	-4,271			
c =	580			
Factor of Safety =	1.5			

Notes:

(1) The above calculations are based on reference 3 "Analysis and Design of Veneer Cover Soils" by R.M. Koerner and Te-Yang Soong, published in Sixth International Conference on Geosynthetics (1998).
(2) The friction angle of the cover soil and the minimum interface friction angle in the cover system are assumed input parameters.

CWM Chemical Services, LLC
Model City Facility
RMU-1 Airspace Enhancement Permit Modification

Appendix D-8a: Final Cover Stability Calculations

Residual Strength
Long-Term Static Veneer Cover Stability
Uniform Cover Soil Thickness

Thickness of cover soil, h	2	ft		
Soil slope angle beneath the geomembrane, beta	18.4	degrees	0.32	radians
Length of slope measured along the geomembrane, L	112	ft		
Unit weight of the cover soil, gamma	130	pcf		
Friction angle of the cover soil, theta	25	degrees	0.44	radians
Cohesion of the cover soil, c	0	psf		
Interface friction angle between cover soil and geomembrane, delta	17.4	degrees	0.30	radians
Adhesion between cover soil and geomembrane, c_a	0	psf		
Total weight of the active wedge, W_A	27,386	lb		
Total weight of the passive wedge, W_p	868	lb		
Effective force normal to the failure plane of the active wedge, N_A	25,986	lb		
a =	2,589			
b =	-2,967			
c =	378			
Factor of Safety =	**1.0**			

Notes:

(1) The above calculations are based on reference 3 "Analysis and Design of Veneer Cover Soils" by R.M. Koerner and Te-Yang Soong, published in Sixth International Conference on Geosynthetics (1998).
(2) The friction angle of the cover soil and the minimum interface friction angle in the cover system are assumed input parameters.

Appendix D-8a: Final Cover Stability Calculations

Peak Strength
Short-Term Veneer Cover Stability
Uniform Cover Soil Thickness with Equipment Loads

Thickness of cover soil, h	1.5	ft		
Soil slope angle beneath the geomembrane, beta	18.4	degrees	0.32	radians
Length of slope measured along the geomembrane, L	112	ft		
Unit weight of the cover soil, gamma	130	pcf		
Friction angle of the cover soil, theta	25	degrees	0.44	radians
Cohesion of the cover soil, c	0	psf		
Minimum interface friction angle in the cover system, delta	26.0	degrees	0.45	radians
Adhesion between cover soil and geomembrane, c_a	0	psf		
Equipment weight, W_b	38,400	lb		
Equipment ground pressure (weight of equipment/(2wb)), q	640	psf		
Length of each equipment track, w	10	ft		
Width of each equipment track, b	3	ft		
Influence factor at geomembrane interface, I	0.95			
Acceleration/deceleration of the bulldozer, a	0	g		
b/h	2			
Equivalent equipment force per unit width at the geomembrane interface, W_e	6,080	lb		
Modified total weight of the active wedge, W_{A1}	26,945	lb		
Total weight of the passive wedge, W_p	488	lb		
Modified effective force normal to the failure plane of the active wedge, N_{A1}	25,567	lb		
a=	2,547			
b=	-4,208			
c=	580			
Factor of Safety =	**1.5**			

Notes:

(1) The above calculations are based on reference 3 "Analysis and Design of Veneer Cover Soils" by R.M. Koerner and Te-Yang Soong, published in Sixth International Conference on Geosynthetics (1998).
(2) The above calculation does not account for acceleration/deceleration of the bulldozer.
(3) The Influence Factor, I, is estimated from Figure 7 of reference 3.
(4) The friction angle of the cover soil, the minimum interface friction angle of the cover soil, and equipment weight are assumed input parameters.

CWM Chemical Services, LLC
Model City Facility
RMU-1 Airspace Enhancement Permit Modification

Appendix D-8a: Final Cover Stability Calculations

Residual Strength
Short-Term Veneer Cover Stability
Uniform Cover Soil Thickness with Equipment Loads

Thickness of cover soil, h	1.5	ft		
Soil slope angle beneath the geomembrane, beta	18.4	degrees	0.32	radians
Length of slope measured along the geomembrane, L	112	ft		
Unit weight of the cover soil, gamma	130	pcf		
Friction angle of the cover soil, theta	25	degrees	0.44	radians
Cohesion of the cover soil, c	0	psf		
Minimum interface friction angle in the cover system, delta	17.8	degrees	0.31	radians
Adhesion between cover soil and geomembrane, c_a	0	psf		
Equipment weight, W_b	38,400	lb		
Equipment ground pressure (weight of equipment/(2wb)), q	640	psf		
Length of each equipment track, w	10	ft		
Width of each equipment track, b	3	ft		
Influence factor at geomembrane interface, I	0.95			
Acceleration/deceleration of the bulldozer, a	0	g		
b/h	2			
Equivalent equipment force per unit width at the geomembrane interface, W_e	6,080	lb		
Modified total weight of the active wedge, W_{A1}	26,945	lb		
Total weight of the passive wedge, W_p	488	lb		
Modified effective force normal to the failure plane of the active wedge, N_{A1}	25,567	lb		
a=	2,547			
b=	-2,929			
c=	382			
Factor of Safety =	**1.0**			

Notes:

(1) The above calculations are based on reference 3 "Analysis and Design of Veneer Cover Soils" by R.M. Koerner and Te-Yang Soong, published in Sixth International Conference on Geosynthetics (1998).
(2) The above calculation does not account for acceleration/deceleration of the bulldozer.
(3) The Influence Factor, I, is estimated from Figure 7 of reference 3.
(4) The friction angle of the cover soil, the minimum interface friction angle of the cover soil, and equipment weight are assumed input parameters.

CWM Chemical Services, LLC
Model City Facility
RMU-2
Appendix C7: Final Cover Stability Calculations

Residual Strength
Seismic Veneer Cover Stability
Uniform Cover Soil Thickness with Seismic Forces

Thickness of cover soil, h	2	ft		
Soil slope angle beneath the geomembrane, beta	18.4	degrees	0.32	radians
Length of slope measured along the geomembrane, L	112	ft		
Unit weight of the cover soil, gamma	130	pcf		
Friction angle of the cover soil, theta	25	degrees	0.44	radians
Cohesion of the cover soil, c	0	psf		
Minimum interface friction angle in cover system, delta	22.4	degrees	0.39	radians
Adhesion between cover soil and geocomposite, c_a	0	psf		
Total weight of the active wedge, W_A	27,386	lb		
Total weight of the passive wedge, W_p	868	lb		
Effective force normal to the failure plane of the active wedge, N_A	25,986	lb		
Average seismic coefficient, C_s	0.0860			
a=	10,089			
b=	-11,582			
c=	1,496			
Factor of Safety =	**1.0**			

Notes:

(1) The above calculations are based on reference 3 "Analysis and Design of Veneer Cover Soils" by R.M. Koemer and Te-Yang Soong, published in Sixth International Conference on Geosynthetics (1998).
(2) The friction angle of the cover soil, the minimum required interface friction angle of the cover system, and the seismic coefficient are assumed input parameters.

D-9

LIQUEFACTION

5|18|99

Revised: ~~Dated Approved~~

TASK: To determine the potential of the underlying Glaciolacustrine silt/sand and Glaciolacustrine clay layers at the Model City Facility RMU-1 to liquefy during seismic activity under the final buildout.

REFERENCES:

1. "Seismic Analysis and Design Considerations For Municipal Solid Waste Landfills", NYSASWM, NYSDEC and USEPA, Saratoga Springs, NY, March 1994.
2. Engineering Report for Model City Facility, Residuals Management Unit 1, prepared by SEC Donohue. Revised June 24, 1992.
3. Seismic Hazard Evaluation, SLF#11, SCA-Model City, New York, prepared by Geoscience Services for Wehran Engineering, April 28, 1981.

CALCULATIONS:

1. Evaluate the likelihood for the underlying soil to liquefy.
   a. Geologic age and origin - The underlying Glaciolacustrine soils are from the upper Ordovician to Silurian period (see Geologic Section of Reference 2), which is a pre-pleistocene epoch. Based on Table 5.1 (Reference 1), the likelihood of liquefaction based on the age of the deposit is very low.
   b. Fines content and plasticity - Clayey soils having less than 15% (by weight) finer than 0.005 mm. a liquid limit below 35 percent and an in-situ water content less than 0.9 times the liquid limit generally do not liquefy. Also, if the clay content is greater that 20%, the soil will not liquefy unless it is extremely sensitive. The glaciolacustrine clay will not liquefy as its clay content ranges from 20 to 70 percent.
   c. Saturation - Full saturation is necessary for liquefaction to occur. The Glaciolacustrine silt/sand is a confined aquifer and is therefore saturated. The clay layer lies above the silt/sand layer and is not saturated.
   d. Depth below ground surface - Liquefaction does not generally occur past 50' below the ground surface. Both the silt/sand layer and clay layer occur above 50' below the ground surface.
   e. Soil penetration resistance - Liquefaction does not generally occur in deposits with Standard Penetration Test (SPT) blowcount, N, larger than 22. The silt/sand layer Standard Penetration Test blowcounts range from 9 to 58 based on borings (Reference 2) with the majority of the values greater than 38. Therefore, based on SPT blowcounts, the silt/sand layer is not likely to liquefy.

   If three or more of the above criteria indicate that liquefaction is not likely, the potential for liquefaction can be dismissed. Based on this criteria, the Glaciolacustrine clay layer will not liquefy. The potential for liquefaction for the silt/sand layer will be examined by comparing the critical stress ratio at which liquefaction is expected to occur during an earthquake to the critical stress ratio induced by the design earthquake.

2. Determine the standardized SPT blowcount, N_{60}. For the silt/sand layer, a typical blowcount of 30 will be used for the analysis.

3. Determine the total vertical stress, σ_0, and vertical effective stress, σ_0', in the soil at the time of sampling

and for design at the midpoint of the silt/sand layer. The design cross section is as follows:

- 5' of final cover soils;
- 109' (max.) of waste;
- 7.5' of base liner soils;
- 15' (average) of Glaciolacustrine clay; and,
- 15' (average) of Glaciolacustrine silt/sand.

σ_0 (design) = (5')(125 pcf) + (109')(111.1 pcf) + (7.5')(130) + (15')(130 pcf) + (7.5')(130 pcf) = 16,635 psf
= 8.32 tsf

σ_0' (sampling) = (15 ft) (130 pcf) + (7.5 ft) (130-62.4 pcf) = 2,457 psf = 1.23 tsf

σ_0' (design) =(5')(125 pcf) + (109')(111.1 pcf) + (7.5')(130) + (15')(130 pcf) + (7.5')(130-62.4) = 16,167 psf
= 8.08 tsf

4. Calculate the normalized standardized SPT blowcount, $(N_1)_{60}$. The normalized standardized blowcount normalizes N to an effective overburden pressure of 1 tsf to eliminate the influence of confining pressure.

$(N_1)_{60} = N_{60} \times C_N$

C_N = correction factor for effective overburden pressure = $(1/\sigma_0')^{1/2}$
σ_0' = vertical effective stress during sampling in tsf

$C_N = (1/1.23)^{1/2} = 0.90$
$(N_1)_{60} = (30)\ (0.90) = 27$

5. Determine the critical stress ratio, CSR, at which liquefaction is expected to occur during an earthquake of magnitude 7.5 based on the percent fines and $(N_1)_{60}$ using the chart on Figure 5.4 (See Reference 1). Assume the average percent fines is less than 5 percent based on the sandy nature of the material.

CSR = 0.35

6. Calculate the corrected critical stress ratio, CSR_L.

$CSR_L = CSR \times K_M \times K_\alpha$
K_M = correction factor for magnitudes other than 7.5 as shown on Figure 5.5
K_α = correction factor for non-level ground conditions = 1.0

Based on Reference 3, no significant earthquake magnitude has occured in the vicinity of the site. The design seismic event is an acceleration equal to 0.1g. This is less than the expected acceleration for a magnitude of 7.5. Therefore, use an upperbound value K_M = 1.6 from Figure 5.5 of Reference 1.

$CSR_L = (0.35)\ (1.6)\ (1.0) = 0.56$

7. Determine the stress reduction factor, r_d, defined as the ratio of the dynamic shear stress in the deformable soil column to that in a rigid body. For depths less than 40 ft, the average values from Figure 5.7 can be used. For a depth of 22.5 ft, $r_d = 0.95$.

8. Calculate the critical stress ratio induced by the design earthquake, CSR_{EQ}.

$$CSR_{EQ} = 0.65\ (a_{max}/g)\ (r_d)\ (\sigma_0 / \sigma_0')$$

$$CSR_{EQ} = 0.65\ (0.10)\ (0.95)\ (8.32/8.08) = 0.064$$

9. Calculate factor of safety against liquefaction, FS_{LIQ}.

$$FS_{LIQ} = CSR_L / CSR_{EQ} = 0.56 / 0.064 = 8.75$$

The factor of safety is greater than one, therefore, the sand/silt layer is not likely to liquefy and an evaluation of the liquefaction induced displacement is not necessary.

Table 5.1 Estimated Susceptibility of Sedimentary Deposits to Liquefaction During Strong Seismic Shaking (Youd and Perkins, 1978).

Type of deposit (1)	General distribution of cohesionless sediments in deposits (2)	Likelihood that Cohesionless Sediments, When Saturated, Would Be Susceptible to Liquefaction (by Age of Deposit)			
		<500 yr (3)	Holocene (4)	Pleistocene (5)	Pre-pleistocene (6)
(a) Continental Deposits					
River channel	Locally variable	Very high	High	Low	Very low
Flood plain	Locally variable	High	Moderate	Low	Very low
Alluvial fan and plain	Widespread	Moderate	Low	Low	Very low
Marine terraces and plains	Widespread	—	Low	Very low	Very low
Delta and fan-delta	Widespread	High	Moderate	Low	Very low
Lacustrine and playa	Variable	High	Moderate	Low	Very low
Colluvium	Variable	High	Moderate	Low	Very low
Talus	Widespread	Low	Low	Very low	Very low
Dunes	Widespread	High	Moderate	Low	Very low
Loess	Variable	High	High	High	Unknown
Glacial till	Variable	Low	Low	Very low	Very low
Tuff	Rare	Low	Low	Very low	Very low
Tephra	Widespread	High	High	?	?
Residual soils	Rare	Low	Low	Very low	Very low
Sebka	Locally variable	High	Moderate	Low	Very low
(b) Coastal Zone					
Delta	Widespread	Very high	High	Low	Very low
Esturine	Locally variable	High	Moderate	Low	Very low
Beach					
High wave energy	Widespread	Moderate	Low	Very low	Very low
Low wave energy	Widespread	High	Moderate	Low	Very low
Lagoonal	Locally variable	High	Moderate	Low	Very low
Fore shore	Locally variable	High	Moderate	Low	Very low
(c) Artificial					
Uncompacted fill	Variable	Very high	—	—	—
Compacted fill	Variable	Low	—	—	—

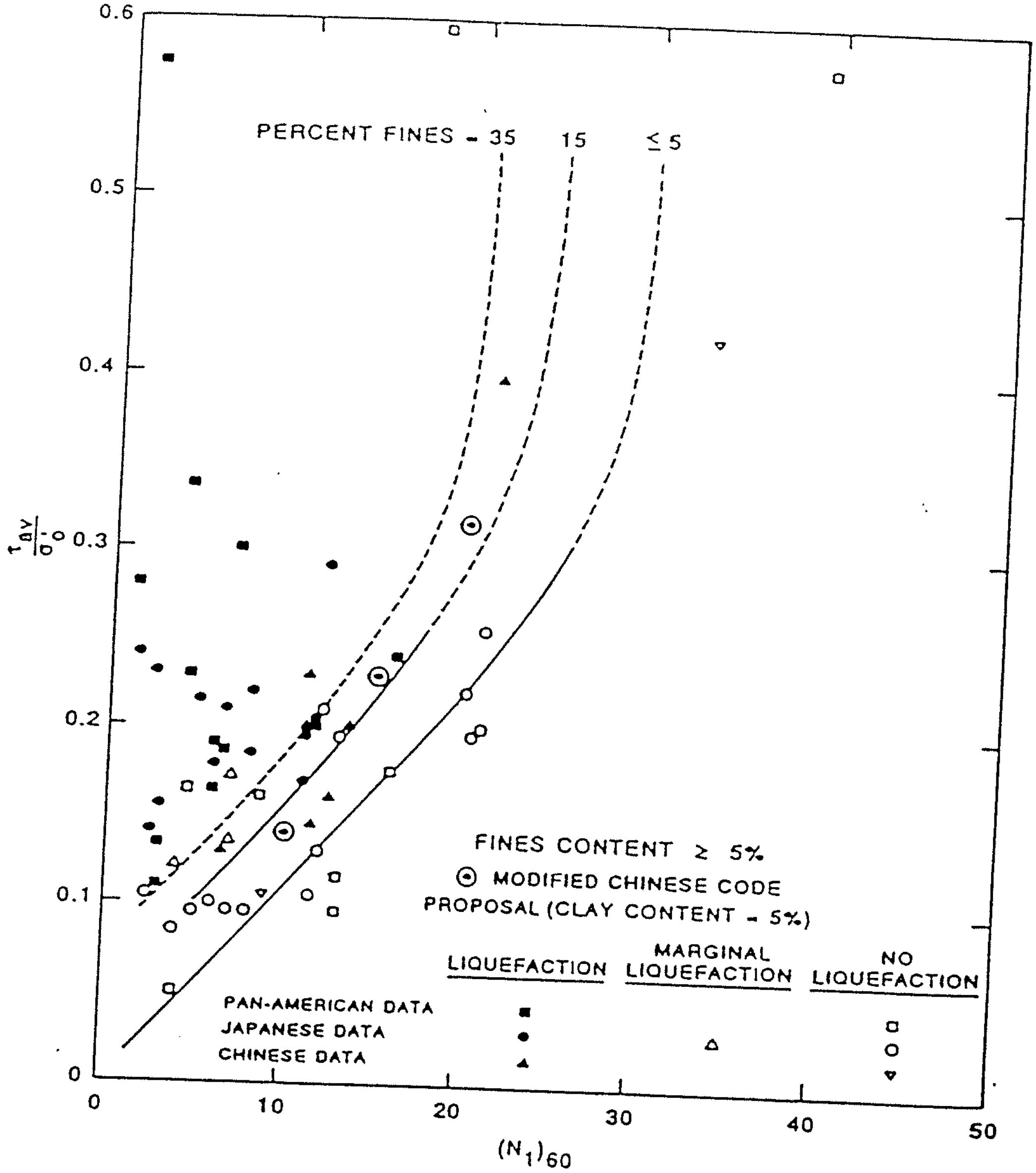


Figure 5.4 Relationships between stress ratio causing liquefaction and $(N_1)_{60}$ values for silty sands for M = 7.5 earthquakes (Seed et al., 1985).

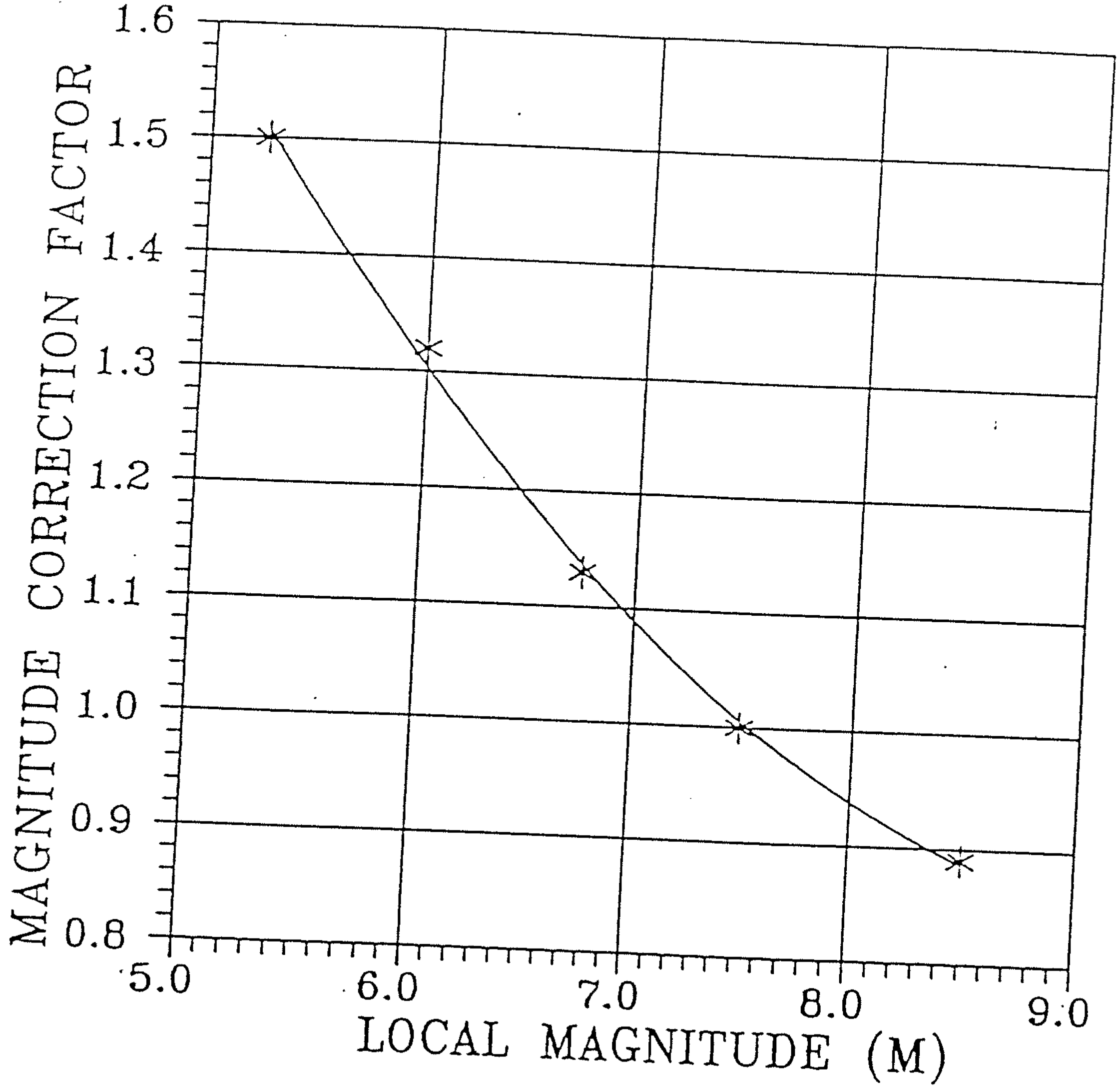


Figure 5.5 Curve for estimation of magnitude correction factor, K_M (after Seed et al., 1983).

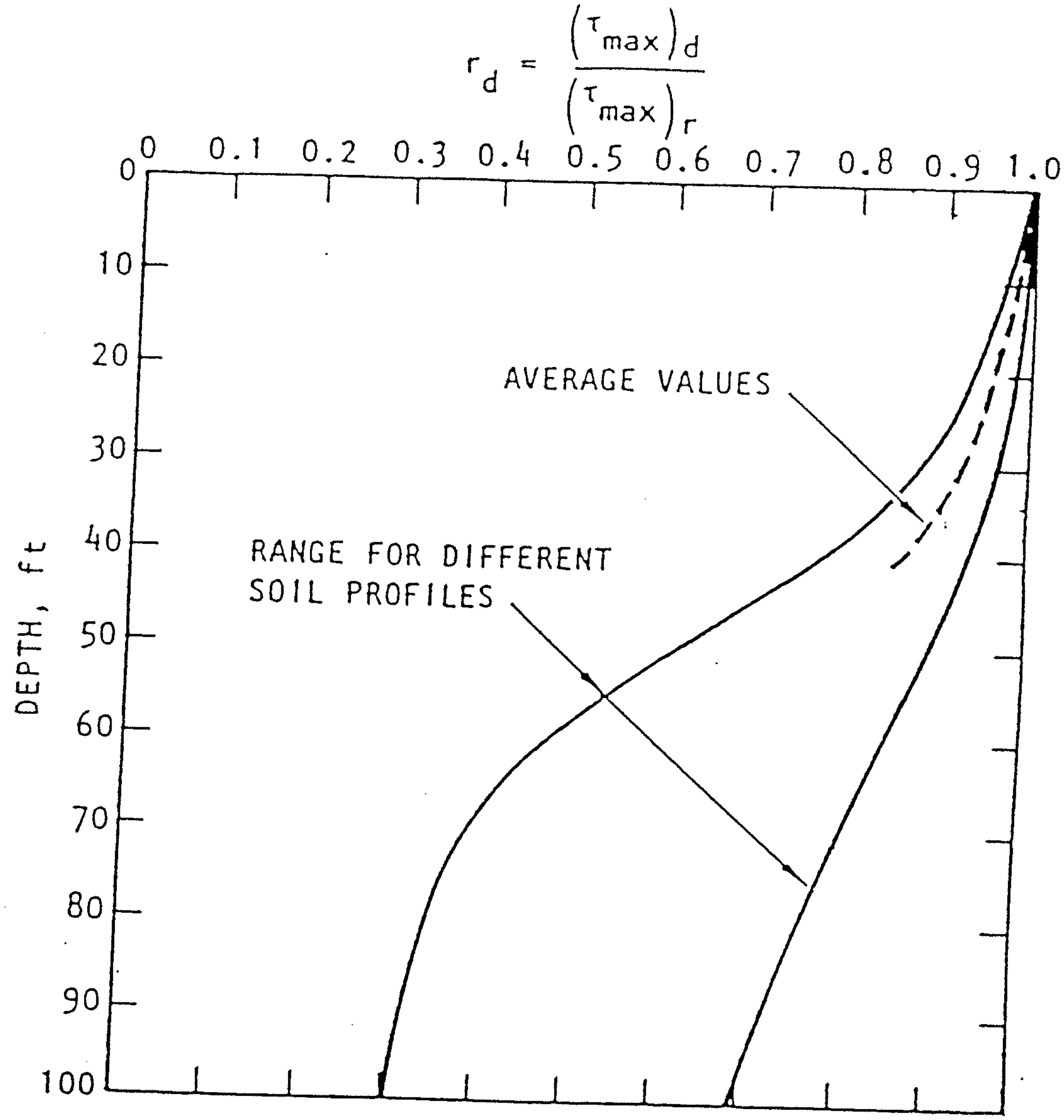


Figure 5.7 Curves for estimation of stress reduction factor r_d (Seed and Idriss, 1982).

D-10

TENSION STRESS ANALYSIS FOR
SIDE-SLOPE LINER SYSTEM

4/8/98
Revised: ~~Date Approved~~

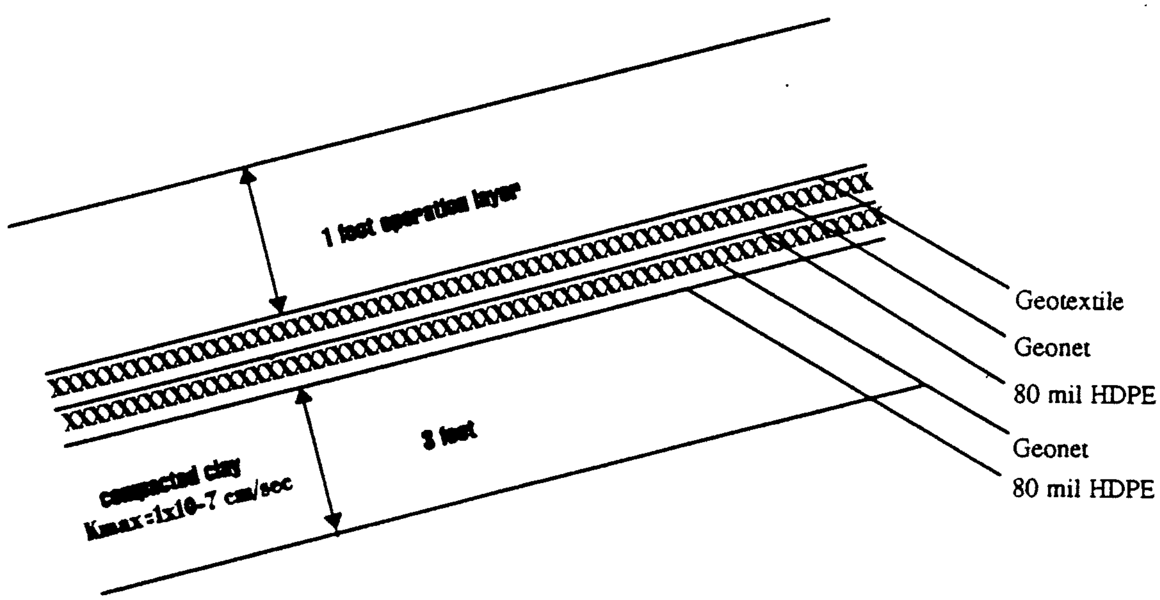
TENSION STRESS ANALYSIS FOR SIDE-SLOPE LINER SYSTEM

Objective: Due to placement of waste at the toe of the side-slope, the weight of waste mass could include shear stress through cover soil onto geosynthetic liners. The different interface frictional resistances between soil/geosynthetics and geosynthetics/geosynthetics would result in tensile stress on geosynthetic liners. The following calculation computes the tensile stress of each geosynthetics liner which is resulted from waste placement. A factor of safety is defined as the ratio of the allowable yield stress of the geosynthetics, which is given by manufacture test data sheet, to the required tensile stress.

Method: Refer to Dr. R.M. Koerner, "Designing with Geosynthetics," PP. 466-471.

Calculation:

The proposed side-slope liner system is shown below:



Revision No. 1
Date: 052992

Material Properties:

(1) Waste*: γ_w = 111.1 pcf, unit weight of waste
C_w = 800 pcf, cohesion of waste
ϕ_w = 13.5°, friction angle of waste
h_w = 10 ft, thickness of one lift of waste

*Data from CWM.

(2) Interface friction angle of side-slope liner system*:

operation layer/geotextile = 25°
geotextile/geonet = 14°
geonet/HDPE (smooth) = 10°
HDPE (smooth)/compacted clay = 15°

*Average values collected from published data (Exhibit 1).

(3) Geonet (POLYNET 3000)* :

thickness = 5.03 mm = 0.22 in.
tensile strength = 50± 10 lb/in.

*Manufacture data sheet from National Seal Co. (Exhibit 2).

(4) Geotextile (Trevira 1145)*

minimum thickness = 160 ml
wide width tensile strength = 183.5 lb/in.

*"Designing with Geosynthetics," 2nd, PP. 622-623.

(5) 80 mil HDPE*

thickness = 80 mil
stress at yield = 2200 psi

*Manufacture data sheet from National Seal Co. (Exhibit 3).

(6) Geonet*

geonet compressive strength = 15,000 lb/ft^2
geonet shear strength = 1,500 lb/in.

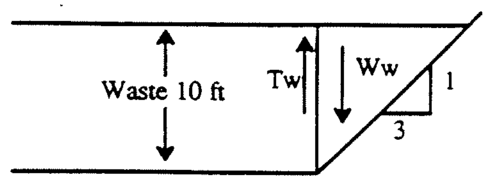
*Adopted from Page 468 of Dr. Koerner's "Designing with Geosynthetics."

- Weight of waste for a lift:

Ww = 1/2 x 10 ft x 30 ft x 111.1 pcf

= 16,665 lb/ft

- Friction force on edge of waste:



$$Tw = (\sigma_n \tan\phi_w + C_w) \times D$$

$$= (K_o\ \sigma_v \tan\phi_N + C_w) \times D$$

where σ_n - horizontal waste pressure

K_o - coefficient of at rest waste pressure

$K_o = (1-\sin\phi)$, experimental equation by Nooramy J. Seed

D - length of sliding surface

σ_v - vertical waste pressure

$K_o = 1 - \sin 13.5^\circ = 0.77$

$Tw = (0.77 \times 0.5 \times 10\ ft \times 111.1\ pcf \times \tan 13.5^\circ + 800\ pcf) \times 10\ ft$

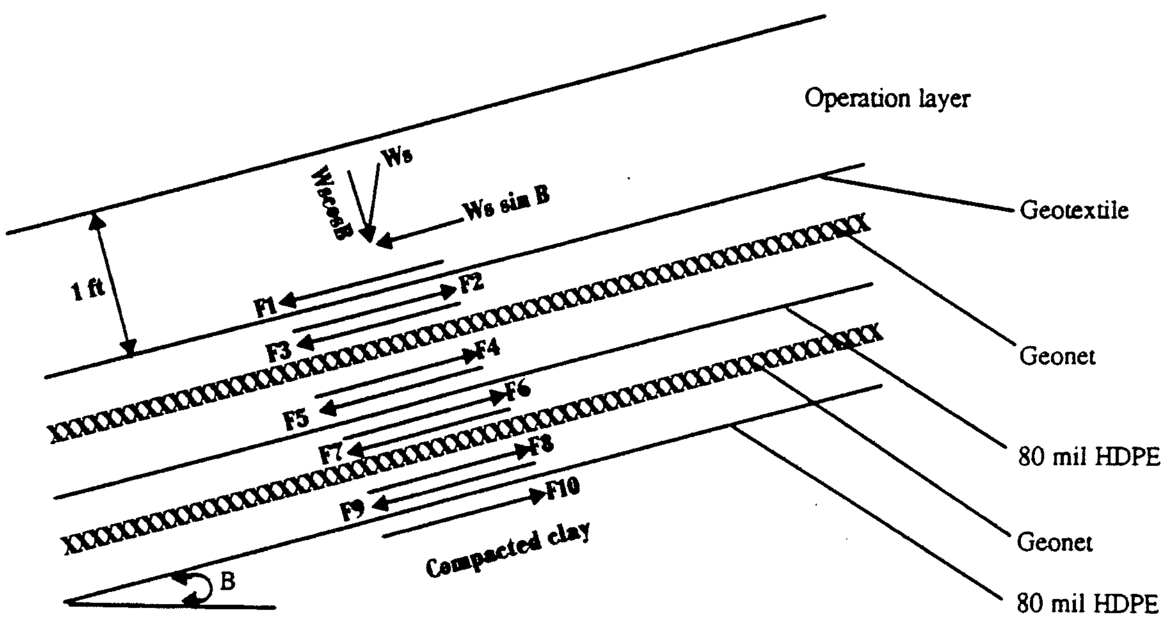
$= 9{,}027\ lb/ft$

$W_{net} = W = W_w - Tw$

$= 16{,}665\ lb/ft - 9{,}027\ lb/ft$

$= 7{,}638\ lb/ft$

- Resolution of shear stresses on side-slope liner system:



Revision No. 1
Date: 052992

- Calculate the shear forces above and below the geotextile induced by waste mass:

$F_1 = W \times \cos\beta \times \tan\delta_1$

$= 7{,}638 \text{ lb/ft} \times \cos 18.4^\circ \times \tan 25^\circ$

$= 3{,}380 \text{ lb/ft}$

$F_2 = W \times \cos\beta \times \tan\delta_2$

$= 7{,}638 \text{ lb/ft} \times \cos 18.4^\circ \times \tan 14^\circ$

$= 1{,}807 \text{ lb/ft}$

tension stress to be carried by the geotextile:

since $F_1 > F_2$, the geotextile will be in tension.

$$T_{act} = (F_1 - F_2)/12 = \frac{(3380 - 1807) \text{ lb/ft}}{12 \text{ in./ft}} = 131.08 \text{ lb/in.}$$

$T_{allowable} = 183.5$ lb/in.

$$F.S. = \frac{T_{allow}}{T_{act}} = \frac{183.5}{131.08} = 1.40$$

- Calculate the shear forces above and below the primary geonet:

$F_3 = F_2 = 1807$ lb/ft

$F_4 = W \times \cos\beta \times \tan 10^\circ$

$= 7{,}638 \text{ lb/ft} \times \cos 18.4^\circ \times \tan 10^\circ$

$= 1{,}278 \text{ lb/ft}$

Since $F_3 > F_4$, the primary geonet in tension

$$\sigma_{act} = F3-F4 = \frac{1807 - 1278 \text{ lb/ft}}{12 \text{ in./ft} \times 0.22 \text{ in.}} = 200 \text{ psi}$$

$\sigma_{allow} = 1{,}500$ psi

$$F.S. = \frac{\sigma_{allow}}{\sigma_{act}} = \frac{1{,}500}{200} = 7.5$$

- Calculate the shear forces above and below the primary geomembrane:

Since $F_5 = F_6 = F_4$, $\sigma_{act} = \dfrac{1278 \text{ lb/ft}}{12 \text{ in./ft} \times 0.08 \text{ in.}} = 1331.25$ psi

$$\sigma_{yield} = 2200 \text{ psi}$$

$$\text{F.S.} = \frac{\sigma_{yield}}{\sigma_{act}} = \frac{2200}{1331.25} = 1.65$$

- Calculate the shear forces above and below the secondary geonet:

Since $F_7 = F_8 = F_6 = 1278$ lb/ft

$$\sigma_{act} = \frac{1278 \text{ lb/ft}}{12 \text{ in./ft} \times 0.22 \text{ in.}} = 484 \text{ psi}$$

$$\sigma_{allowable} = 1500 \text{ psi}$$

$$\text{F.S.} = \frac{\sigma_{allow}}{\sigma_{act}} = \frac{1500}{484} = 3.10$$

- Calculate the shear forces above and below the secondary geomembrane:

$F_9 = F_8 = 1278$ lb/ft

$F_{10} = W \times \cos\beta \times \tan 15^\circ = 7638 \text{ lb/ft} \times \cos 18.4^\circ \times \tan 15^\circ$

$= 1942 \text{ lb/ft} > F_9$

Since $F_{10} > F_9$, there is no tension force in the secondary geomembrane.

Tabulation of Safety Factors

Shear Force	Liner Components	Interface Friction Angle	Factor of Safety
F_1	Operation layer/geotextile	25°	1.40
F_2	Geotextile/geonet	14°	
F_3	Geotextile/geonet	14°	7.5
F_4	Geonet/HDPE (smooth)	10°	
F_5	Geonet/HDPE (smooth)	10°	1.65
F_6	HDPE (smooth)/geonet	10°	
F_7	HDPE (smooth)/geonet	10°	3.10
F_8	Geonet/HDPE (smooth)	10°	
F_9	Geonet/HDPE (smooth)	10°	no tension
F_{10}	HDPE (smooth)/compacted clay	15°	

RP/CWMNYORK/AC8

Exhibit 1
Page 1/1

PRELIMINARY SLOPE STABILITY EVALUATION

A preliminary evaluation of slope stability was performed for the multi-layered liner system described above. The evaluation involved computing the factor of safety for each soil-to-geosynthetic and geosynthetic-to-geosynthetic interface based on an infinite slope analysis. Table 1 shows the various possible slope material interfaces for the specific side slope design interface friction angles, and resultant factors of safety. The factors of safety were computed using the equation below.

$$F.S. = \tan \phi_i / \tan \beta \quad (1)$$

Where: F.S. = the Factor of Safety
ϕ_i = the interface friction angle
β = the landfill side slope angle

TABLE 1

Factors of Safety for Selected Landfill Side Slope Interfaces
Based on a 3 Horizontal to 1 Vertical Slope Angle

Side Slope Interface	Interface Friction Angle	Factor of Safety
Compacted Soil/Geomembrane	15	0.80
Geomembrane/Geonet	10	0.53
Geonet/Geotextile	14	0.75
Geotextile/Geomembrane	9	0.48
Geotextile/Sand	>25	>1.40
Geomembrane/Sand	18	0.97

Review of Table 1 and the computed factors of safety shows that concerns for slope stability are warranted if slope stability is based entirely on interface friction and slope inclination. More importantly, however, this simple analysis identifies that a critical slope interface lies between the primary geomembrane and an underlying nonwoven geotextile. The side slope configured in this manner induces an unfavorable shear stress condition where shear stress below the liner (T_B) is lower than shear stress above the liner (T_A). This shear stress condition creates geomembrane tensile stress, and effectively forces the geomembrane to perform as a structural component of the liner system. Although a stable liner system could be designed under this shear stress condition, it would require the imposition of an unacceptable slope geometry. Therefore, an alternate design solution using additional geosynthetic materials was implemented.

NSC

Exhibit 2

Page 1/1

POLYNET® PN-3000

PRODUCT DESCRIPTION

PN-3000 is a profiled geonet manufactured by extruding two sets of polyethylene strands to form a diamond shape. The resulting net provides superior planar water flow, is inert to biological and naturally encountered chemicals, alkalies, and acids and is resistant to UV light exposure. Polynet PN-3000 conforms to the property values listed below.

PROPERTY	METHOD	UNITS	QUALIFIER	VALUE
Roll Length	-	ft	Normal	300
Roll Width	-	ft	Normal	7.54
Thickness	ASTM D1777	inches	Range	0.220±0.022
Area per Roll	-	ft^2	Normal	2262
Weight per Roll	-	lbs	Normal	407
Weight per Square Foot	ASTM D3776 (option C)	lbs/ft^2	Range	0.180±0.018
Carbon Black Content	ASTM D1603	percent	Range	2.5±0.5
Polymer Density	ASTM D1505	g/cm^3	Range	0.937±0.002
Melt Flow Index	ASTM D1238 (condition E)	g/10 min.	Maximum	1.0
Tensile Strength (Machine Direction)	ASTM D1682 (modified)	ppi	Range	50±10
Transmissivity[1] (gradient = 1.0 at 15,000 psf)	ASTM D4716	M^2/sec	Minimum	1×10^{-3}

1 Measured between two steel plates one hour after application of the confining pressure. Values may vary based on transmissivity specimen dimensions and specific laboratory.

9/27/88

Exhibit 3

Page 1/2

NSC

HDPE GEOMEMBRANE

National Seal Company's High Density Polyethylene (HDPE) geomembranes are extruded using virgin, first-quality, high molecular weight, polyethylene resin and are manufactured specifically for the purpose of containment in hydraulic structures. The HDPE compound used in NSC geomembranes has been formulated to be chemically resistant, free of leachable additives and resistant to ultraviolet degradation.

80 MIL (2mm) PHYSICAL PROPERTIES

ALL PROPERTIES MEET OR EXCEED NSF STANDARD 54 SPECIFICATIONS FOR HDPE

PROPERTY	MINIMUM AVERAGE ROLL VALUES (unless otherwise indicated)			
	ENGLISH		METRIC	
	UNITS	VALUE	UNITS	VALUE
THICKNESS, ASTM D 751, NSF Mod., Nominal	mils	80.0	mm	2.00
Minimum Average	mils	80.0	mm	2.03
Lowest Individual Reading	mils	76.0	mm	1.93
DENSITY, ASTM D 1505			g/cm^3	0.940
MELT FLOW INDEX, ASTM D 1238, Cond. E, Max.			g/10 min	1.0
CARBON BLACK CONTENT, ASTM D 1603	percent	2.0 to 3.0	percent	2.0 TO 3.0
CARBON BLACK DISPERSION, ASTM D 3015	rating	A1 or A2	rating	A1 or A2
MINIMUM TENSILE PROPERTIES, ASTM D 638				
Stress at Yield	psi	2200	MPa	15.2
	ppi	176	N/cm	308
Stress at Break	psi	3800	MPa	26.2
	ppi	304	N/cm	532
Strain at Yield nominal gage of 1.30" per NSF Mod.	percent	13	percent	13
Strain at Break nominal gage of 2.5" per NSF Mod.	percent	700	percent	700
	percent	560	percent	560
TEAR RESISTANCE, ASTM D1004	ppi	700	N/cm	1230
	lbs	56	N	249
PUNCTURE RESISTANCE, FTMS 101, 2065	ppi	1300	N/cm	2280
	lbs	104	N	463
ESCR, ASTM D 1693, NSF Mod., Pass	hours	1500	hours	1500
DIMENSIONAL STABILITY, ASTM D1204, NSF Mod, Max.	percent	2.0	percent	2.0

NATIONAL SEAL SEAMING PROPERTIES

(All NSC seams will demonstrate a Film Tearing Bond in Peel and Shear)

SHEAR STRENGTH, ASTM D 4437, NSF Mod.	psi	2000	MPa	13.8
	ppi	160	N/cm	280
PEEL ADHESION, ASTM D 4437, NSF Mod. (Hot wedge fusion weld)	psi	1500	MPa	10.3
	ppi	120	N/cm	210
PEEL ADHESION, ASTM D 4437, NSF Mod. (fillet extrusion weld)	psi	1300	MPa	8.97
	ppi	104	N/cm	182

HD-80-0391C

NSC

Exhibit 3

Page 2/2

HDPE GEOMEMBRANE

80 MIL (2mm) CHARACTERISTICS

PROPERTY	MINIMUM AVERAGE ROLL VALUES (unless otherwise indicated)			
	ENGLISH		METRIC	
	UNITS	VALUE	UNITS	VALUE
MODULUS OF ELASTICITY, ASTM D 882	psi	80,000	MPa	552
HYDROSTATIC RESISTANCE, ASTM D 751 A	psi	600	MPa	4.14
COEF. LINEAR THERMAL EXPANSION, Nominal	/°F	6.7×10^{-5}	/° C	1.2×10^{-4}
BRITTLENESS TEMP, ASTM D 746 B, Pass	°F	-103	°C	-75
SOIL BURIAL RESISTANCE, NSF 54, Max. Change	percent	10	percent	10
OIT, 200° C, 1 atm O_2 Al pan	minutes	100	sec	6,000
PUNCTURE RESISTANCE, ASTM D 4833	ppi	1800	N/cm	3150
	lbs	144	N	640
TENSILE IMPACT, ASTM D 1822	ft lbs/in²	238	kJ/m²	500
VOLATILE LOSS, ASTM D 1203A, Max.	percent	0.1	percent	0.1
OZONE RESISTANCE, ASTM D 1149, 168 hrs, 100 pphm		No Cracks		No Cracks
WATER ABSORPTION, ASTM D 570, 23° C	percent	0.1	percent	0.1
WATER VAPOR TRANSMISSION, ASTM E 96, Max.			g/hr m²	0.004
PERMEABILITY, WATER, ASTM E 96, Max.			cm/sec Pa	0.9×10^{-13}

STANDARD ROLL DIMENSIONS*	TYPICAL ROLL VALUE			
WEIGHT	lbs	5,000	kg	2,270
WIDTH	ft	15.0	m	4.57
LENGTH	ft	835	m	255
AREA	ft²	12,525	M²	1,164

*Values Are Approximate
Custom Roll Sizes And Half Size Rolls Are Available
Sheet is Rolled on 12" Diameter Cores

HD-80-0391C

NSC does not generally perform conformance testing for properties on this page.

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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TENSION STRESS ANALYSIS
SIDE-SLOPE LINER SYSTEM
CELLS 7 THROUGH 14

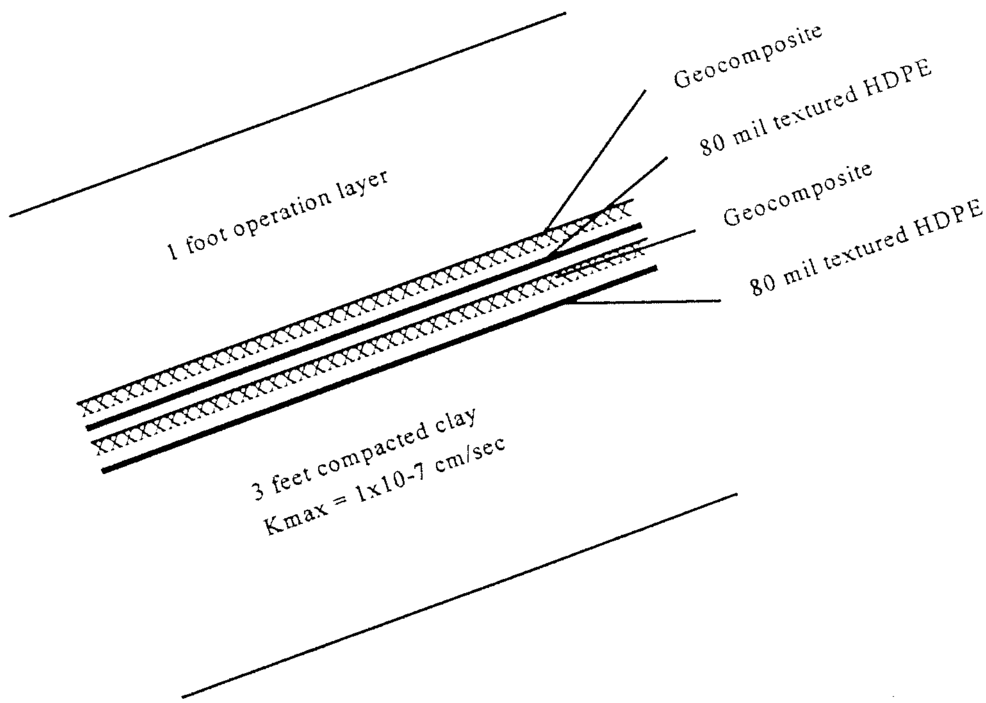
4/8/98
Revised: ~~Date Approved~~

TENSION STRESS ANALYSIS FOR SIDE-SLOPE LINER SYSTEM
CELLS 7 THROUGH 14 ONLY

Objective: Due to placement of waste at the toe of the side-slope, the weight of waste mass could include shear stress through cover soil onto geosynthetic liners. The different interface frictional resistances between soil/geosynthetics and geosynthetics / geosynthetics would result in tensile stress on geosynthetic liners. The following calculation computes the tensile stress of each geosynthetics liner which is resulted from waste placement. A factor of safety is defined as the ratio of the allowable yield stress of the geosynthetics, which is given by manufacture test data sheet, to the required tensile stress.

Method: Refer to Dr. R.M. Koerner, "Designing with Geosynthetics," pp. 466-471.

Calculation: The proposed side-slope liner system is shown below:



Material Properties:

(1) Waste*: Y_W = 111.1 pcf, unit weight of waste
C_W = 800 pcf, cohesion of waste
ϕ_W = 13.5°, friction angle of waste
h_W = 10 ft, thickness of one lift of waste

* Data from CWM.

(2) Interface friction angle of side-slope liner system:

Operation layer/composite = 25° (Exhibit 1.1, item 5) - analogous to geotextile/sand
geocomposite/HDPE (textured) =25° (Exhibit 1.2, item 17)-use 15° as conservative value*
HDPE (textured)/compacted clay = 32° (Exhibit 1.3, item 3)

* A friction angle of 15 degrees was used as a conservative value of the peak 25 degrees that is shown on item 17 of the testing report. The use of a peak friction angle is consistent with past practices at the site and is appropriate for the RMU-1 design.

(3) Geocomposite (TN3002-1620c)

thickness = 9 mm = 0.275 in.**
tensile strength for geotextile component = 180 lb/in.**

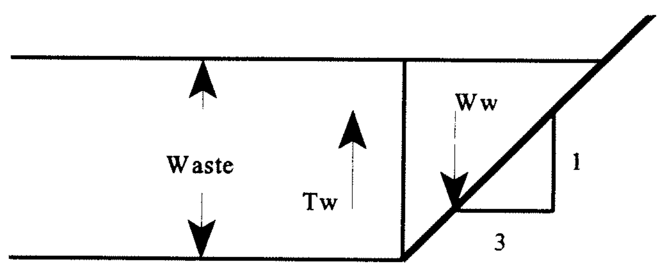
** Manufacture data sheet from NSC and Hoechst Celanese. (Exhibit 2.1 & 2.2).

(4) 80 mil HDPE (textured)

thickness = 80 mil
stress at yield = 2200 psi

- Weight of waste for a lift:

W_w = ½ x 10 ft x 30 ft x 111.1 pcf
= 16, 665 lb/ft



- Friction force on edge of waste:

$T_w = (\sigma_n \tan\phi_W + C_W) \times D$

$= (K_O\, \sigma_V \tan\phi_N + C_W) \times D$

where σ_n - horizontal waste pressure

K_O - coefficient of at rest waste pressure

$K_O = (1-\sin\phi)$, experimental equation by Nooramy J. Seed

D - length of sliding surface

σ_V - vertical waste pressure

$K_0 = 1 - \sin 13.5° = 0.77$

$T_W = (0.77 \times 0.5 \times 10 \text{ ft} \times 111.1 \text{ pcf} \times \tan 13.5° + 800 \text{ pcf}) \times 10 \text{ ft}$

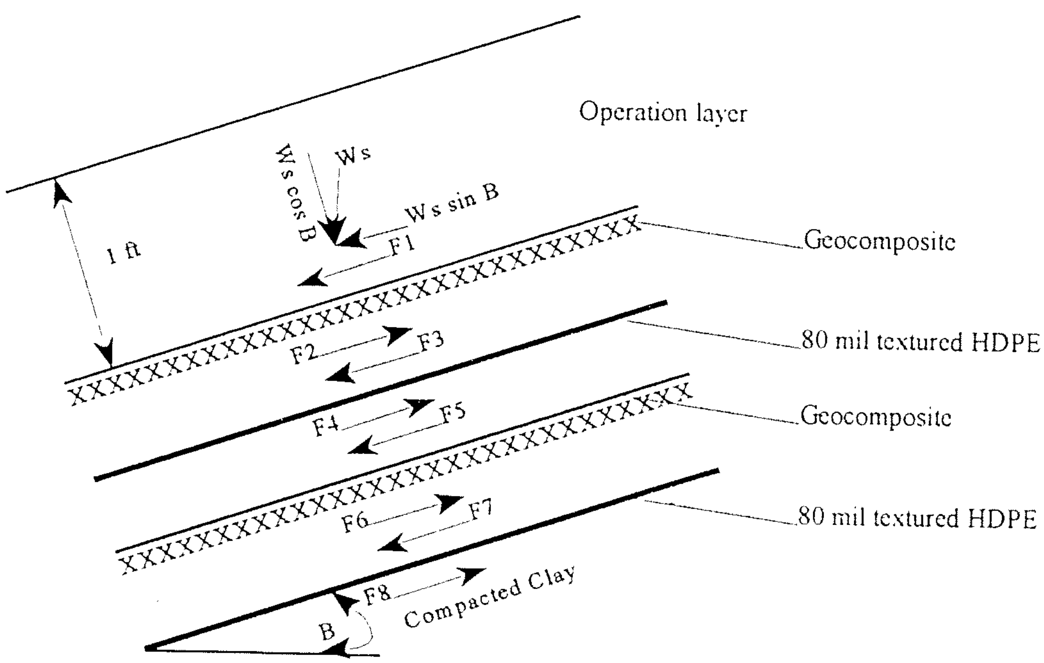
$= 9{,}027 \text{ lb/ft}$

$W_{net} = W = W_W - T_W$

$= 16{,}665 \text{ lb/ft} - 9{,}027 \text{ lb/ft}$

$= 7{,}638 \text{ lb/ft}$

- Resolution of shear stresses on side-slope liner system:



- Calculate the shear forces above and below the primary geocomposite induced by waste mass:

$$F_1 = W \times \cos\beta \times \tan\delta_1$$

$$= 7{,}638 \text{ lb/ft} \times \cos 18.4° \times \tan 25°$$

$$= 3{,}380 \text{ lb/ft}$$

$$F_2 = W \times \text{COS}\beta \times \tan\delta_2$$

$$= 7{,}638 \text{ lb/ft} \times \text{COS}18.4° \times \tan 15°$$

$$= 1{,}942$$

tension stress to be carried by the geocomposite

since $F_1 > F_2$, the geocomposite will be in tension.

$$T_{act} = (F_1 - F_2)/12 = \frac{(2280 - 1942)\ lb/ft}{12\ in./ft} = 119.83\ lb/in.$$

$T_{allowable}$ = 180 lb/in.

$$F.S. = \frac{T_{allow}}{T_{act}} = \frac{180}{119.83} = 1.50$$

- Calculate the shear forces above and below the primary geomembrane:

$$Since\ F_3 = F_4 = F_2 = 1942\ lb/ft.$$

$$\sigma_{act} = \frac{1942\ lb/ft.}{12\ in./ft \times 0.08\ in.} = 2023\ psi$$

$$\sigma_{allowable} = 2200\ psi$$

$$F.S. = \frac{\sigma_{allowable}}{\sigma_{act}} = \frac{2200\ psi}{2023\ psi} = 1.08$$

- Calculate the shear forces above and below the secondary geocomposite

$$Since\ F_5 = F_4 = F_6 = 1942\ lbs/ft$$

$$\sigma_{act} = \frac{1942\ lb/ft.}{12\ in./ft\ x\ 0.35\ in.} = 162\ ppi$$

$$\sigma_{allowable} = 180\ ppi$$

$$F.S. = \frac{\sigma_{all}}{\sigma_{act}} = \frac{180\ ppi}{162\ ppi} = 1.11$$

- Calculate the shear forces above the secondary GM.

$F_7 = F_6 = 1942$ lbs/ft

$F_8 = 7638$ lb/ft x cos(18.4) x tan(32°)
$= 4547$ lbs/ft.

Since $F_7 < F_8$ there is no tension in the secondary geomembrane.

Tabulation of Safety Factors			
Shear Force	Liner Component	Interface Friction Angle	Factor of Safety
F_1	Operation layer/geocomposite	25°	1.4
F_2	Geocomposite/ textured HDPE	15°	
F_3	Geocomposite/ textured HDPE	15°	1.08
F_4	Textured HDPE/geocomposite	15°	
F_5	Textured HDPE/geocomposite	15°	1.11
F_6	Geocomposite/ textured HDPE	15°	
F_7	Geocomposite/ textured HDPE	15°	no tension
F_8	Textured HDPE/compacted clay	32°	

Exhibit 1.1
Page 1/1

PRELIMINARY SLOPE STABILITY EVALUATION

A preliminary evaluation of slope stability was performed for the multi-layered liner system described above. The evaluation involved computing the factor of safety for each soil-to-geosynthetic and geosynthetic-to-geosynthetic interface based on an infinite slope analysis. Table 1 shows the various possible slope material interfaces for the specific side slope design interface friction angles, and resultant factors of safety. The factors of safety were computed using the equation below.

$$F.S. = \tan \phi_i / \tan \beta \qquad (1)$$

Where: F.S. = the Factor of Safety
ϕ_i = the interface friction angle
β = the landfill side slope angle

TABLE 1

Factors of Safety for Selected Landfill Side Slope Interfaces
Based on a 3 Horizontal to 1 Vertical Slope Angle

Side Slope Interface	Interface Friction Angle	Factor of Safety
Compacted Soil/Geomembrane	15	0.80
Geomembrane/Geonet	10	0.53
Geonet/Geotextile	14	0.75
Geotextile/Geomembrane	9	0.48
→ Geotextile/Sand	>25	>1.40
Geomembrane/Sand	18	0.97

Review of Table 1 and the computed factors of safety shows that concerns for slope stability are warranted if slope stability is based entirely on interface friction and slope inclination. More importantly, however, this simple analysis identifies that a critical slope interface lies between the primary geomembrane and an underlying nonwoven geotextile. The side slope configured in this manner induces an unfavorable shear stress condition where shear stress below the liner (T_B) is lower than shear stress above the liner (T_A). This shear stress condition creates geomembrane tensile stress, and effectively forces the geomembrane to perform as a structural component of the liner system. Although a stable liner system could be designed under this shear stress condition, it would require the imposition of an unacceptable slope geometry. Therefore, an alternate design solution using additional geosynthetic materials was implemented.

Exhibit 1.L
Page 1/1

TABLE 3 - (Continued)

INTERFACE DIRECT SHEAR TEST RESULTS
MEASURED TOTAL STRESS SHEAR STRENGTH PARAMETERS
SEC DONOHUE
WMNA FRICTION TESTING PROGRAM

15	Trevira 1145 Geotextile/60-mil NSC Smooth HDPE Geomembrane	250 to 3,000	14°	65	13°	40
16	Texnet TN3002-1125 Geocomposite/60-mil NSC Smooth HDPE Geomembrane	5,040 to 14,400	13°	0	12°	0
17	Texnet TN3002-1125 Geocomposite/60-mil NSC Textured HDPE Geomembrane	5,040 to 14,400	25°	1215	12°	775
18	Ottawa Sand/60-mil NSC Textured HDPE Geomembrane	5,040 to 14,400	27°	475	26°	300
19	Trevira 1145 Geotextile/60-mil NSC Textured HDPE Geomembrane	5,040 to 14,400	24°	1,015	17°	595
20	Texnet TN3001-1125 Geocomposite (Geonet Component Against Geomembrane)/60-mil NSC Smooth HDPE Geomembrane	5,040 to 14,400	13°	405	13°	405
21	Texnet TN3001-1125 Geocomposite (Geonet Component Against Geomembrane)/60-mil NSC Textured HDPE Geomembrane	5,040 to 14,400	23°	0	19°	0
22	Trevira 1145 Geotextile/Polynet PN-3000 Geonet	5,040 to 14,400	26°	0	16°	155

Notes: [1] Test specimens were sheared immediately after application of the normal stress.

[2] The reported value of adhesion may not be the "true adhesion" of the interface and caution should be exercised in using this adhesion value for applications involving normal stresses outside the range of stresses covered by the test.

Exhibit 1.3
PAGE 1/2

FINAL REPORT

INTERFACE DIRECT SHEAR TESTING
WMNA FRICTION TESTING PROGRAM

Prepared for

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Oak Brook Division
1240 East Diehl Road
Naperville, Illinois 60563

Prepared by

GeoSyntec Consultants
Geomechanics and Environmental Laboratory
5775 Peachtree Dunwoody Road, Suite 10D
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Project Number: GL3126

16 November 1992

Exhibit 1.3
Page 2/2

HDPE 60M TX GND	lean clay	22	68	NA	NA	dry	NA	GeoServices	432-1296	0.04	shear box	12 x 12	Aug-90	209	60
HDPE 60M TX GND	lean clay	23	66	NA	NA	dry	NA	GeoServices	432-1296	0.04	shear box	12 x 12	Aug-90	209	60
HDPE 60M TX GND	clay 10(-7) cm/sec	32	15	NA	NA	NA	NA	Golder Assoc	100-500	0.0394	shear box	17 x 12	June-90	301	50
HDPE 60M TX GND	clay CNTP-240	8	545	NA	NA	wet	machine	GeoSyntec	880-11520	0.04	shear box	12 x 12	Apr-91	210	63
HDPE 60M TX GND	clay CNTP-240	6	890	NA	NA	wet	machine	GeoSyntec	880-11520	0.04	shear box	12 x 12	Apr-91	210	63
HDPE 60M TX GND	clay CNTP-240	14	710	NA	NA	wet	machine	GeoSyntec	880-11520	0.04	shear box	12 x 12	Apr-91	210	63
HDPE 60M TX GND	clay CNTP-240	13	455	NA	NA	wet	machine	GeoSyntec	880-11520	0.04	shear box	12 x 12	Apr-91	210	63
HDPE 60M TX GND	clay CNTP-234	20	150	NA	NA	wet	machine	GeoSyntec	880-11520	0.04	shear box	12 x 12	Apr-91	210	64
HDPE 60M TX GND	clay CNTP-234	16	130	NA	NA	wet	machine	GeoSyntec	880-11520	0.04	shear box	12 x 12	Apr-91	210	64
HDPE 60M TX GND	Clay	18	580	NA	NA	moist	NA	Bing-Yen Assoc.	880-11520	NA	Triaxial	8 x 12	Jun-91	903	
HDPE 60M TX GND	Clay	14	1220	NA	NA	moist	NA	Bing-Yen Assoc.	880-11520	NA	Triaxial	8 x 12	Jun-91	903	

PVC GEOMEMBRANE - COHESIVE SOIL

PVC	Glacial Till	25	21	NA	NA	NA	NA	Georgia Tech	100-500	0.01	shear box	12 x 12	Conf '87	10005	10
PVC	Gulf Coast Clay	23	34	NA	NA	NA	NA	Georgia Tech	100-500	0.01	shear box	12 x 12	Conf '87	10005	9
PVC	Sand-10% Clay	19	14	NA	NA	NA	NA	Georgia Tech	100-500	0.01	shear box	12 x 12	'87 Conf	10005	7
PVC	Sand-5% Clay	19	16	NA	NA	NA	NA	Georgia Tech	100-500	0.01	shear box	12 x 12	'87 Conf	10005	6

CSPE GEOMEMBRANE - COHESIVE SOIL

CSPE	clay	10	115	NA	NA	sat.	machine	EPA	NA	NA	shear box	2 x 2	Nov-90	10010	31

SOIL TYPE UNKNOWN

HDPE TX GND	Soil	38.6	NA	NA	NA	dry	NA	J & L Testing	500-2000	NA	shear box	NA	Oct-88	510	51
HDPE TX GND	Soil	30	NA	NA	NA	dry	NA	J & L Testing	500-2000	NA	shear box	NA	Oct-88	510	51
HDPE TX GND	Soil	25.3	150	NA	NA	dry	NA	J & L Testing	500-2000	NA	shear box	NA	Oct-88	505	51
HDPE TX GND	Soil	33.5	180	NA	NA	dry	NA	J & L Testing	500-2000	NA	shear box	NA	Oct-88	505	51
HDPE	soil	18	NA	NA	NA	NA	NA	GRI	NA	NA	shear box	18 x 18	Oct-90('84)	407	
HDPE	soil	18	NA	NA	NA	NA	NA	GRI	NA	NA	shear box	4 x 4	Oct-90('84)	407	
HDPE	soil	26	NA	NA	NA	NA	NA	GRI	NA	NA	shear box	18 x 18	Oct-90('84)	407	
HDPE	soil	28	NA	NA	NA	NA	NA	GRI	NA	NA	shear box	18 x 18	Oct-90('84)	407	
HDPE 80M, mod SLT	typ cover soil	29.5	75	NA	NA	NA	NA	GeoServices	576-1008	0.04	shear box	12 x 12	Sept-89	206	62
HDPE 80M TX SLT	typ cover soil	33	153	NA	NA	NA	NA	GeoServices	576-1008	0.04	shear box	12 x 12	Sept-89	206	62
HDPE 80M TX SLT	typ cover soil	36.6	124	NA	NA	NA	NA	GeoServices	576-1008	0.04	shear box	12 x 12	Sept-89	206	62

NA-NOT AVAILABLE

EXHIBIT 2.2
PAGE 1/1

Hoechst Celanese

Trevira® Spunbond Type 016/200
Production Lot #200-4-380

Technical Fibers Group
Hoechst Celanese Corporation
Spunbond Business Unit
Post Office Box 5650
Spartanburg, SC 29304-5650
803 579 5007
Toll Free 1 800 845 7597
Fax 803 579 5930

Trevira® Spunbond Type 016/200 is a 100% continuous filament polyester nonwoven needlepunched heat bonded engineering fabric. The fabric is resistant to biological and naturally encountered chemicals, alkalies, acids, and ultraviolet light exposure. Trevira® Spunbond Type 016/200 from production lot #200-4-380 conforms to the property values listed in the following table (see attached actual test values for production lot #200-4-380):

FABRIC PROPERTY	UNIT	TEST METHOD	MINIMUM TEST VALUES[1]	MARV[2]
Fabric Weight	oz/yd^2	ASTM D-5261	5.7	5.7
Grab Strength (MD/CD)	lbs	ASTM D-4632	180	195
Grab Elongation (MD/CD)	%	ASTM D-4632	60	60
Trapezoid Tear Strength (MD/CD)	lbs	ASTM D-4533	70	70
Puncture Resistance	lbs	ASTM D-4833	80	85
Mullen Burst Strength	psi	ASTM D-3786	275	300
Water Flow Rate	gpm/ft^2	ASTM D-4491	25	30
Permittivity, Ψ	sec^{-1}	ASTM D-4491	.33	.40
AOS	Sieve Size mm	ASTM D-4751	140	170/200
Standard Roll Widths	ft	15.0		
Standard Roll Lengths	ft	300		

MD = Machine Direction CD = Cross Machine Direction

[1] These minimum values represent minimum test values as determined from Quality Control (QC) testing.
[2] MARV = Minimum Average Roll Values.

016200
January 26, 1995

Hoechst

EXIBIT 2.1 PAGE 1/1

TEX-NET® SPECIFICATIONS

GEOCOMPOSITE PROPERTIES

PROPERTY	TEST	UNITS	MINIMUM[2]	
			TN3002/1120	TN3002/1125
Thickness	ASTM D 5199	inch	0.275	0.305
Transmissivity[1] (15,000 psf)	ASTM D 4716	m^2/sec	5×10^{-5}	3×10^{-5}
Ply Adhesion	ASTM D 413 or F 904	lb/in	2.0	2.0
Tensile Strength (MD)	ASTM D 4632	lbs	535	580

COMPONENT PROPERTIES[3]

GEONET	TEST	UNITS	PN 3000
Polymer Density	ASTM D 1505	g/cm^3	0.94
Polymer Melt Index (Max)	ASTM D 1238	g/10 min	0.5
Carbon Black Content	ASTM D 4218	%	2.0
Thickness	ASTM D 5199	inches	0.200
Mass Per Unit Area	ASTM D 5261	lbs/ft^2	0.162
Transmissivity[1]	ASTM D 4716	m^2/sec	1×10^{-3} @ 15,000 psf
Tensile Strength	ASTM D 5035	lbs/in	45

GEOTEXTILE	TEST	UNITS	MINIMUM[2]	
			1120	1125
Fabric Weight	ASTM D 5261	oz/yd^2	5.7	7.1
Thickness	ASTM D 5199	mils	75	95
Grab Strength	ASTM D 4632	lbs	160	210
Water Flow Rate	ASTM D 4491	gpm/ft^2	130	110
AOS	ASTM D 4751	Sieve Size mm	70 0.210	70 0.210

1. Measured using water @ 20° C (68°F) with a gradient of one, between two steel plates, after one hour. Value may vary, based on dimensions of the transmissivity specimen and specific Laboratory.

2. These values represent minimum acceptable test values for a roll as tested according to NSC/FSI's Manufacturing Quality Control Manual. Individual test specimen values are not addressed in this specification.

3. Component properties are tested prior to the lamination process. They cannot be tested on the final product.

12/95

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FRICTION SEAL™ HD GEOMEMBRANE
QUALITY CONTROL SPECIFICATIONS

Exhibit 3
Page 1/2

80 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	0.41	0.42
Thickness[4]	ASTM D 751, NSF mod.			
Average		mils	80.0	81.5
Individual		mils	76.0	79.1
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	176	224
Stress at Break		psi	2200	3220
		ppi	176	262
Strain at Yield	1.3" gage length (NSF)	percent	13.0	19.3
Strain at Break	2.0" gage or extensometer	percent	200	545
	2.5" gage length (NSF)	percent	160	436
Dimensional Stability[2,4]	ASTM D 1204, NSF mod.	percent	1.0	0.4
Tear Resistance	ASTM D 1004	ppi	750	1000
		lbs	60	82
Puncture Resistance	ASTM D 4833	ppi	1800	2110
		lbs	144	172
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

Exhibit
Page 2/2

80 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	22.8
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	$°C^{-1}$	$1.5x10^{-4}$	$1.2x10^{-4}$
ESCR, Bent Strip	ASTM D 1693	hours	1500	>10,000
Hydrostatic Resistance	ASTM D 751	psi	600	780
Modulus of Elasticity	ASTM D 638	psi	80,000	137,000
Ozone Resistance[4]	ASTM D 1149, 168 hrs	P/F	P	P
Permeability[2,4]	ASTM E 96	cm/sec · Pa	$1.8x10^{-14}$	$6.8x10^{-15}$
Puncture Resistance	FTMS 101, method 2065	ppi	1300	1610
		lbs	104	131
Soil Burial Resistance[2]	ASTM D 3083, NSF mod.	% change	10	0
Tensile Impact	ASTM D 1822	ft lbs/in^2	130	170
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	0.018	0.007

SEAM PROPERTIES	METHOD	UNITS	MINIMUM[1]	TYPICAL
Shear Strength	ASTM D 4437, NSF mod.	psi	2000	2490
		ppi	160	203
Peel Strength (hot wedge fusion)	ASTM D 4437, NSF mod.	psi	1500	1880
		ppi	120	153
Peel Strength (fillet extrusion)	ASTM D 4437, NSF mod.	psi	1300	1660
		ppi	104	135

STANDARD ROLL DIMENSIONS

Length	650 feet	Area	9,750 ft^2
Width	15 feet	Weight	·4,000 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.

8FH-0893

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Appendix D-11

Landfill Plateau Access Road Stability

1 FINAL COVER STABILITY WITH ACCESS ROAD

1.1 INTRODUCTION

Evaluate the stability of the final cover under the following conditions:

(1) Long-Term Stability - using peak and residual shear strengths without construction equipment loadings;

(2) Short-Term Stability - using peak and residual shear strengths with trucks on the road surface.

As indicated above, analyses for peak and residual strengths are provided for long and short-term analyses. The proposed road traverses areas that have already been final covered. Therefore, the analyses have been performed using the results of interface shear tests that were performed at the time of construction in Phases I-III and Phase IV. In addition, the quality control testing also included a test of the cover soils above the cap fml/drainage geocomposite. This test result was utilized to represent the existing protective cover that will remain in place. Properties of the soils that comprise the proposed access road and the proposed geo-reinforcement are specified as minimum values that will be met or exceeded at the time of construction.

1.2 PROPERTY SELECTION

The access road traverses two phases of the final cover system that have already been constructed. The shear testing for the final cover interfaces and cover soils is presented in Figures 1, 2 and 3 for Phase I-III interfaces, Phase IV interfaces, and Protective cover, respectively. As can be seen in the aforementioned figures, the interface testing for the two phases had different values of both peak and residual (large displacement (LD)) shear strengths. Each figure also contains the best fit of the data to a Mohr-Coulomb envelope. The shear test results are summarized below.

RMU-1 Shear Test Results

Material	φ'_{peak}	c'_{peak}	φ'_{LD}	c'_{LD}
Phase I-III Interfaces	26.7°	162.6 psf	16.96°	153.6 psf
Phase IV Interfaces	25.91°	105.9 psf	12.07°	77.31 psf
Protective Cover Soil [1]	20.7 °	503.8 psf	NA	NA

1. For the protective cover the fully softened shear strength was chosen to represent the soil shear behavior in the test.

These tests were conducted with a normal stress range of 400 or 500 psf minimum to 1700 psf maximum for interface shear and up to 2269 psf for the protective soils.

Selected properties for Design are summarized below, including the materials not yet incorporated into the work.

RMU-1 Access Road Design Values

Material	**φ'_{peak}**	**c'_{peak}**	**φ'_{LD}**	**c'_{LD}**
Phase I-III Interfaces	26.7°	162.6 psf	16.96°	153.6 psf
Phase IV Interfaces	25.91°	105.9 psf	12.07°	77.31 psf
Protective Cover Soil [1]	20.7 °	503.8 psf	NA	NA
Added Compacted Fill	30°	0	NA	NA

RMU-1 Access Road Design Geo-Reinforcement Strengths

Reinforcing Layer	**Long Term Tension Capacity (TAL) (lbs/ft)**	**Short Term Tension Capacity (lbs/ft)**
Phase I-III	800	800/0.85 = 941
Phase IV	800	800/0.85 = 941

(Capacities refer to the direction normal to the slope of the landfill including reduction factors for placement, damage, and length of service)

1.3 ANALYSIS

Stability analyses were performed using the SlopeW module of GeoStudio 2012 geotechnical software version 8.0.7.1629, the latest version available at the time of this work. The analyses were performed using Spencer's Method.

The conditions with and without geo-reinforcement within the fills above the existing protective cover, with peak and large displacement shear strengths assigned to the interfaces were evaluated.

Simulation of a loaded waste delivery truck was performed using a 300 psf surcharge 10 feet wide centered on the berm or , where the berm widened, 14 feet wide.

Five sections were analyzed, representing the various locations of the proposed roadway berm relative to the existing benches, and also within the two closure phases. The locations are shown in Figure 4 The access road and final grading were provided by Arcadis. Each of the sections, named Sec R1 through R5, were used in the file name, which is called out in the Geostudio graphic output figures. Block and rotation failures were analyzed and optimization of all failure surfaces was allowed.

Graphical outputs of all the analyses are presented in Figures 5 through 34.

1.4 RESULTS

The analyses indicated that all critical failure surfaces were located within the proposed fill and or protective cover soils. Factors of safety of 1.5 or higher required the inclusion of typically 2 layers of geo-reinforcement with or without truck loading. Failures forced to FML interface level within the final cover system had higher factors of safety. This was true even when the geo-reinforcement was omitted from the analyses. In general geo-reinforcement layers located 4.3 and 6.8 feet below the proposed road surface and projecting back either 17 feet or 1 foot into the existing protective cover, whichever is less, were sufficient to provide the desired factor of safety. Where the road is located almost directly over the bench and fill is minimal, as reflected in Sec R-4, the lower geo-reinforcement layer was not necessary. Graphical outputs at this section show the reinforcement layer 2 to have a 0 strength.

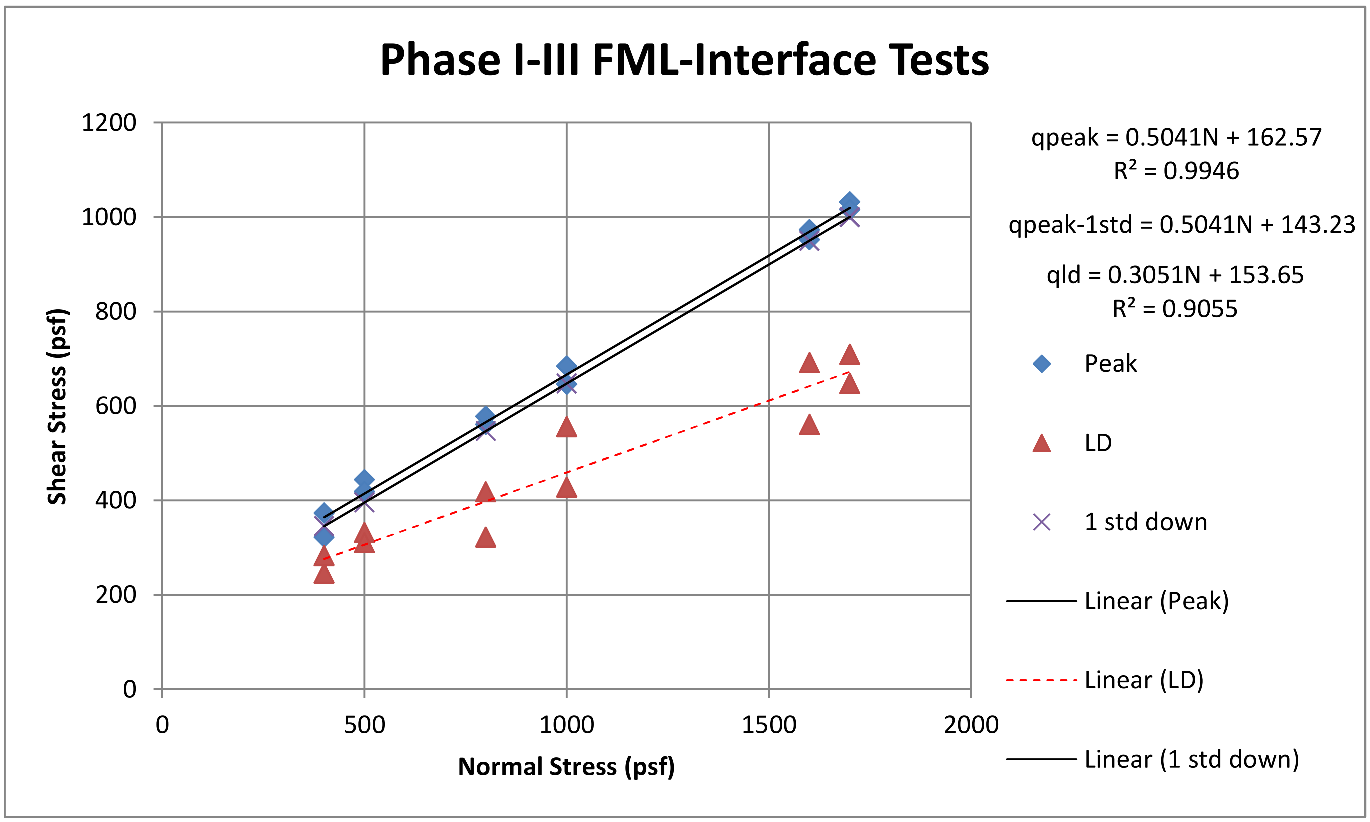
In addition, a factor of safety well in excess of 1 was obtained when residual strengths were assigned to the interfaces, even when the geo-reinforcement was omitted from the design

1.5 RECOMMENDATIONS

- Construct the access road as currently depicted with 2:1 out slopes
- Incorporate geo-reinforcement with a long term static tensile capacity of 800 pounds per lineal foot at depths of 4.3 and 6.8 feet below the road surface. The geo-reinforcement should be deployed with the machine direction perpendicular the to the protective cover slope unless biaxial geogrid is utilized. If biaxial grid is used it may be deployed with the machine direction along the road alignment provided the strength in the cross machine direction meets the above specified strengths.
- If deployed along the road alignment, overlap of geo-reinforcement shall be sufficient to fully develop the grid strength.
- Line the drainage ditch at the uphill side of the berm with an FML to prevent development of piezometric heads within the berm.
- Strip the vegetative layer and scarify the upper surface of the protective cover prior to construction of the access road fill

- Compact only the upper two feet of the fill added to form the road embankment. Below that depth track the materials with a dozer. Compaction of the lower portions of these soils will result in poor drainage over time and negatively impact stability.

- Geo-reinforcement should conform to the attached general specifications.



Phase I-III FML-Interface Tests
Shear Stress (psf)
Normal Stress (psf)
1200
1000
800
600
400
200
0
0
500
1000
1500
2000
qpeak = 0.5041N + 162.57
R² = 0.9946
qpeak-1std = 0.5041N + 143.23
qld = 0.3051N + 153.65
R² = 0.9055
Peak
LD
1 std down
Linear (Peak)
Linear (LD)
Linear (1 std down)

FIG - 1

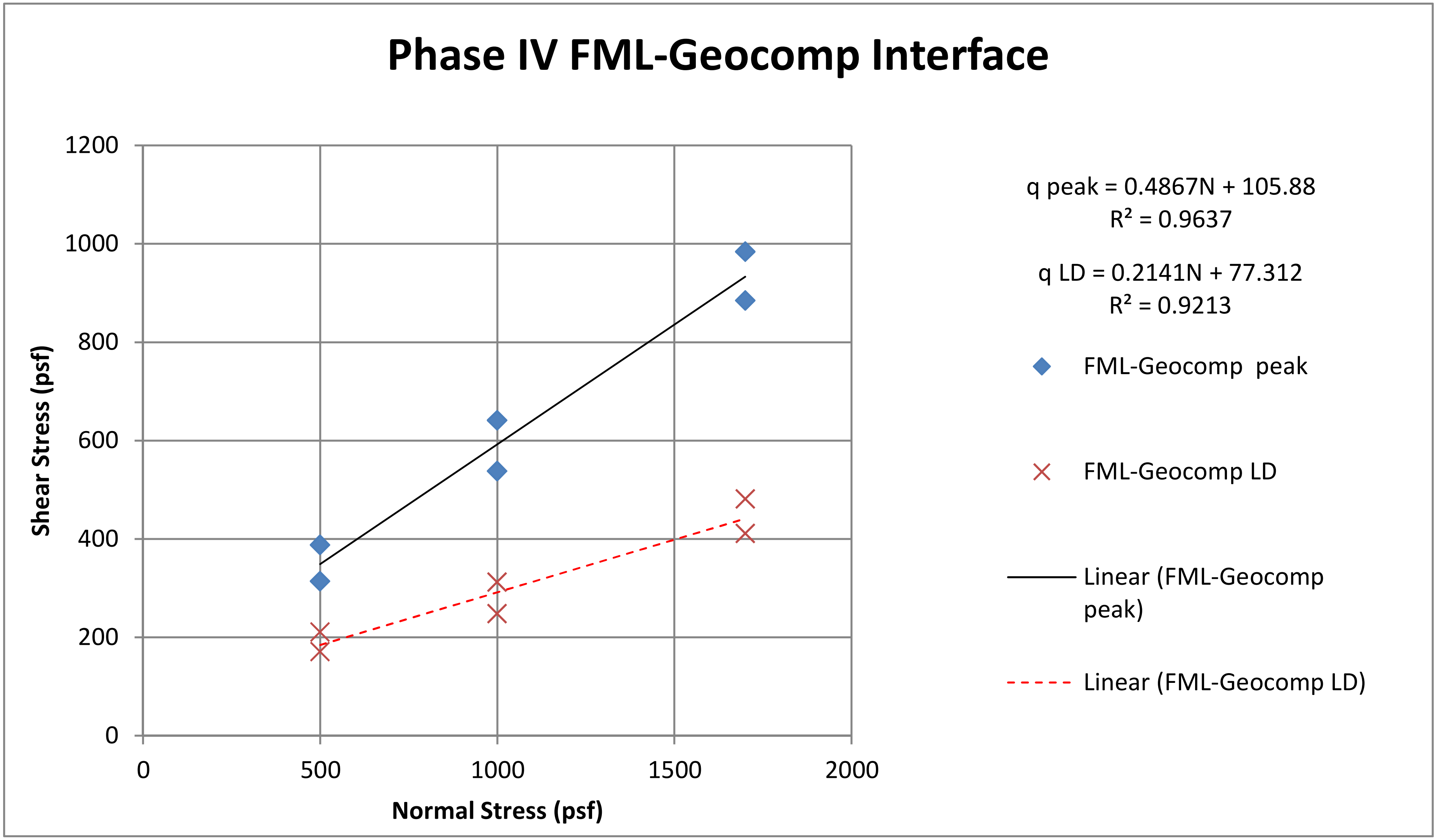

Phase IV FML-Geocomp Interface
Shear Stress (psf)
1200
1000
800
600
400
200
0
0
500
1000
1500
2000
Normal Stress (psf)
q peak = 0.4867N + 105.88
R² = 0.9637
q LD = 0.2141N + 77.312
R² = 0.9213
FML-Geocomp peak
FML-Geocomp LD
Linear (FML-Geocomp peak)
Linear (FML-Geocomp LD)

FIG - 2

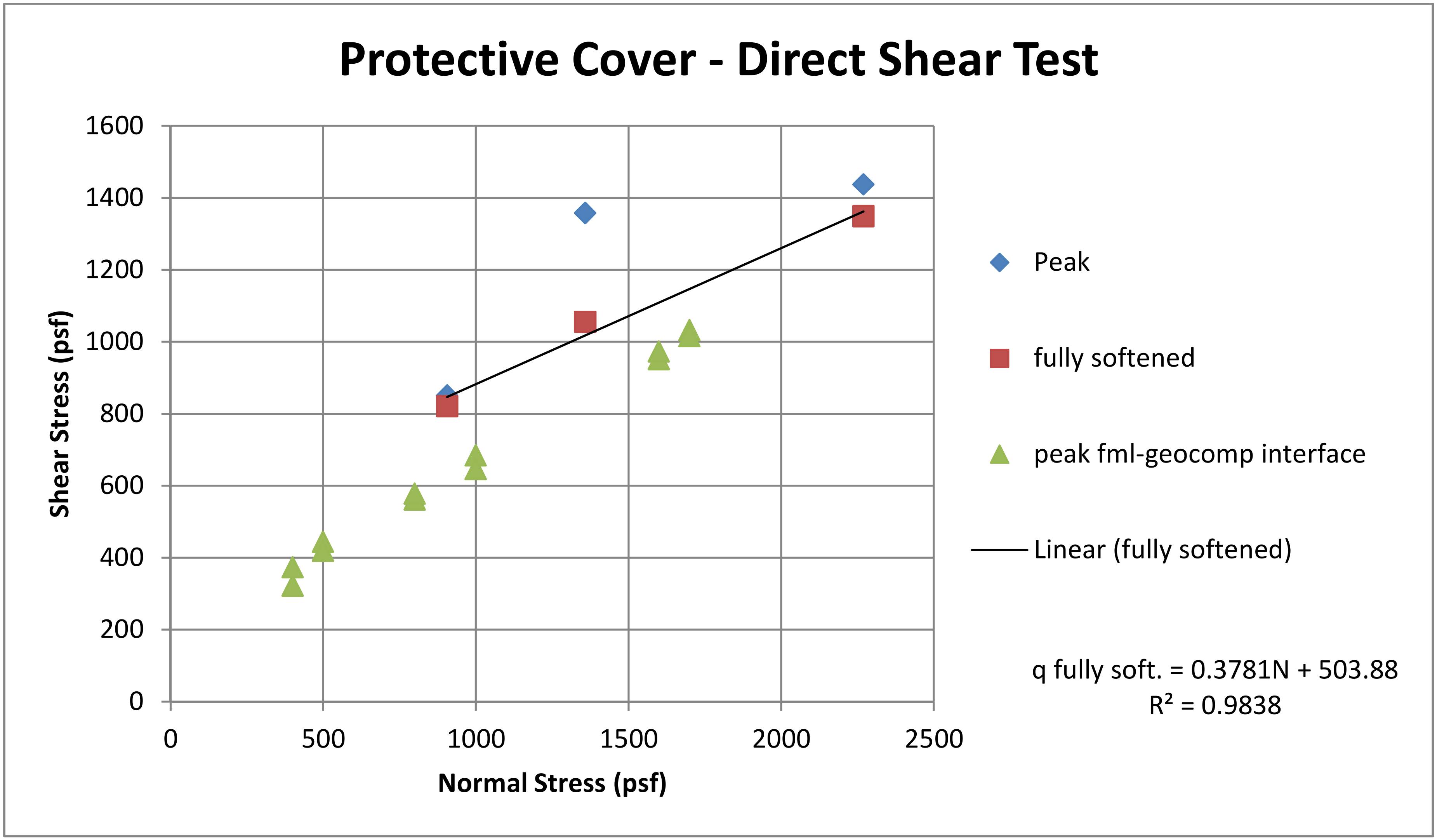
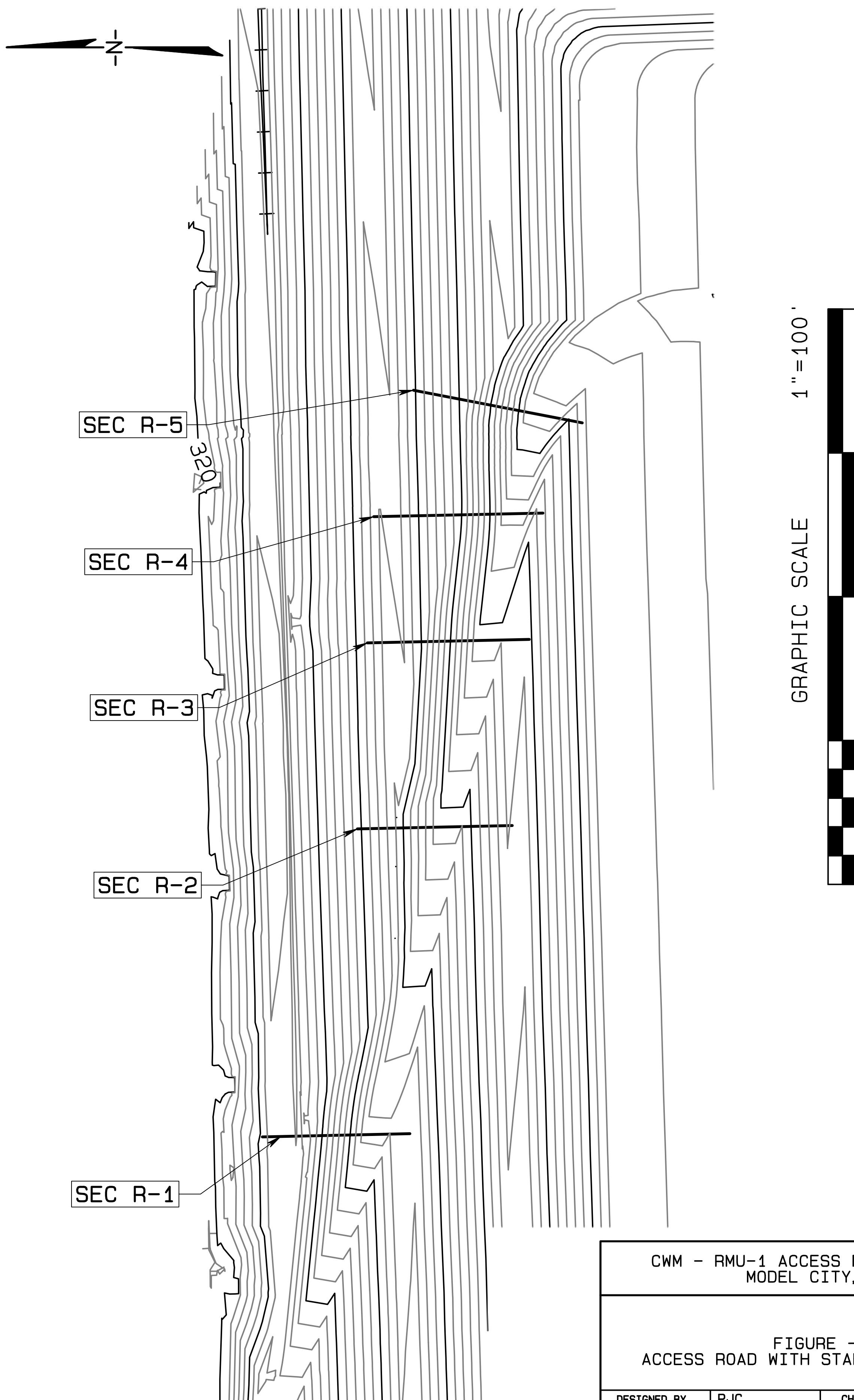

Protective Cover - Direct Shear Test
Shear Stress (psf)
1600
1400
1200
1000
800
600
400
200
0
0
500
1000
1500
2000
2500
Normal Stress (psf)
Peak
fully softened
peak fml-geocomp interface
Linear (fully softened)
q fully soft. = 0.3781N + 503.88
R^2 = 0.9838

FIG - 3

Project Desc.: Path: N:\Model_City\154.004_RMU1CapAccess\dwgs\RMU-1AccessRD.pro Plot Date/Time: Wed Aug 8, 2012 / 16:58:54



CWM - RMU-1 ACCESS ROAD ADDITION
MODEL CITY, NY

FIGURE -1
ACCESS ROAD WITH STABILTY SECTIONS

DESIGNED BY	PJC	CHECKED BY	
DRAWN BY	PJC	DATE	8/8/2012
SCALE: AS SHOWN		SHEET No. FIGURE 1	Revision No. 0

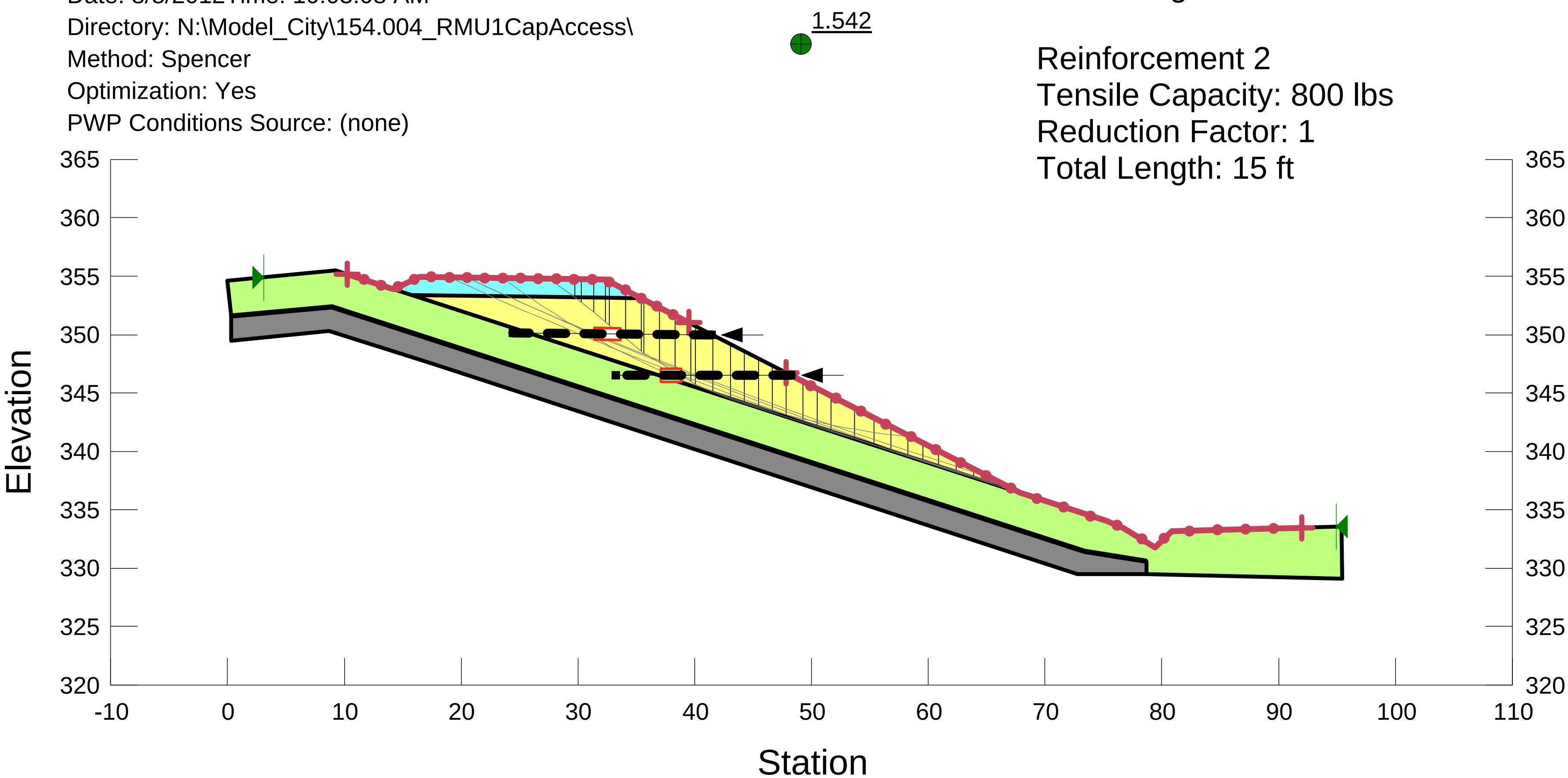
P. J. Carey & Associates, P.C.

FIG - 4

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Long Term no Loads
Description: Road Berm with no added loads
Name: SEC R-1.gsz
Date: 8/8/2012Time: 10:03:08 AM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 16.999997 ft

Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 15 ft

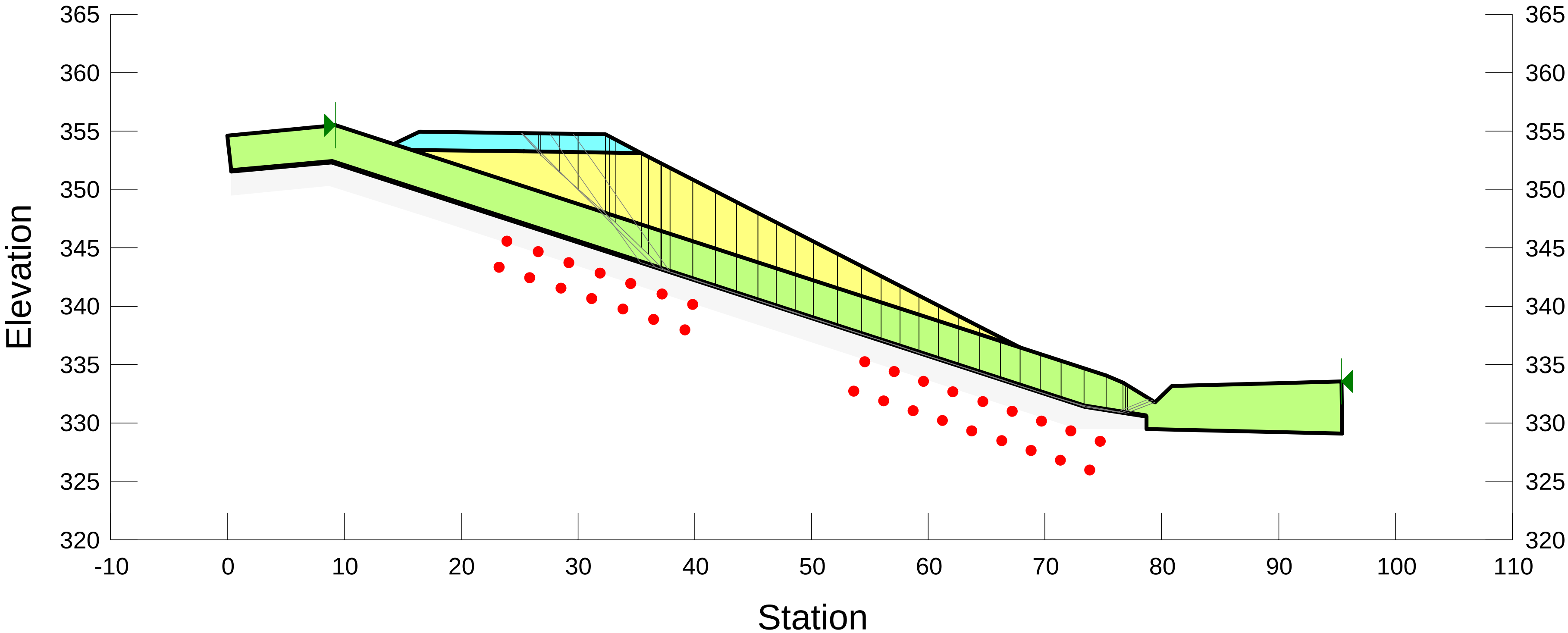


Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 5

2.018

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Long Term no Loads fml interface (2)
Description: block searches
Name: SEC R-1.gsz
Date: 8/8/2012Time: 10:03:08 AM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)



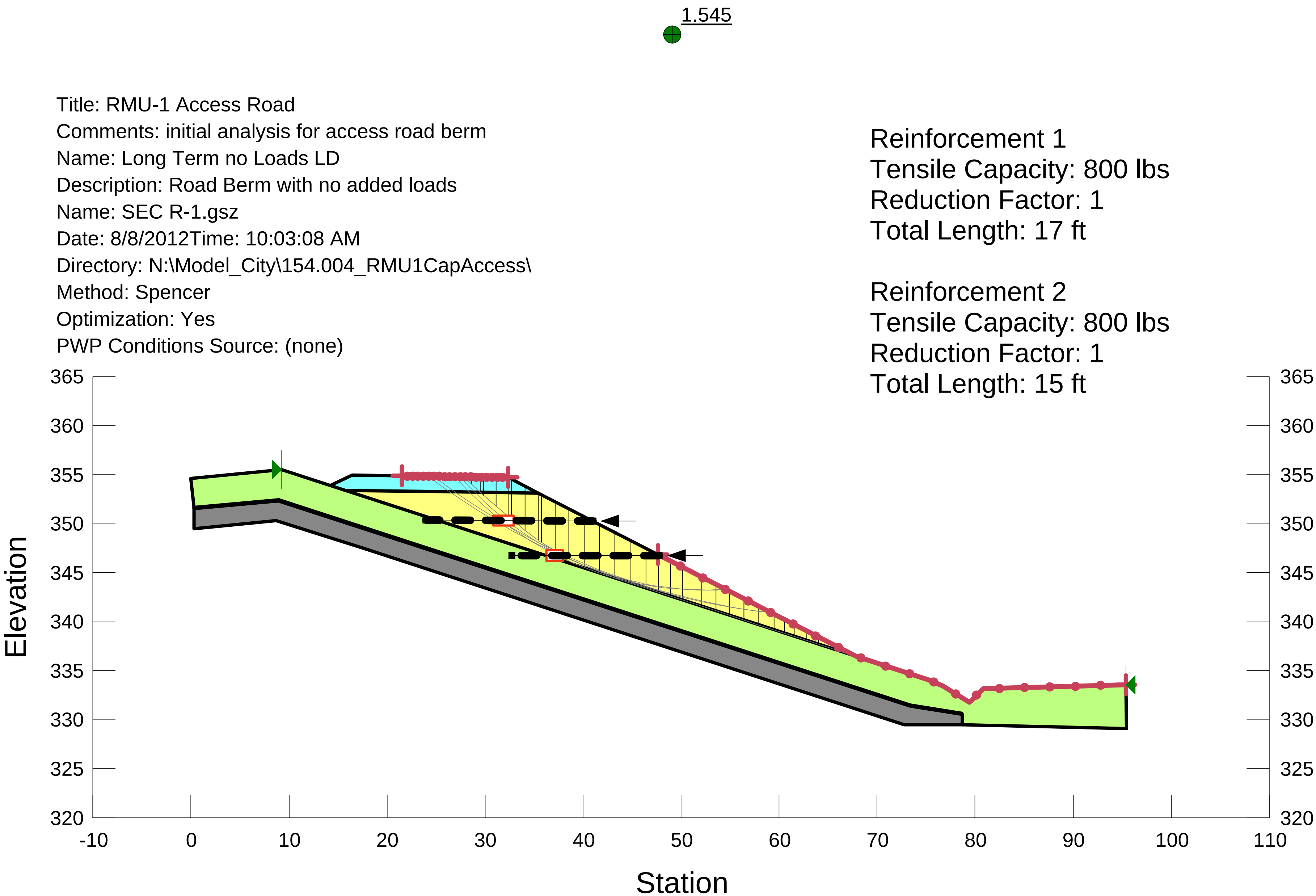
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 6

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Long Term no Loads LD
Description: Road Berm with no added loads
Name: SEC R-1.gsz
Date: 8/8/2012Time: 10:03:08 AM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 17 ft

Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 15 ft

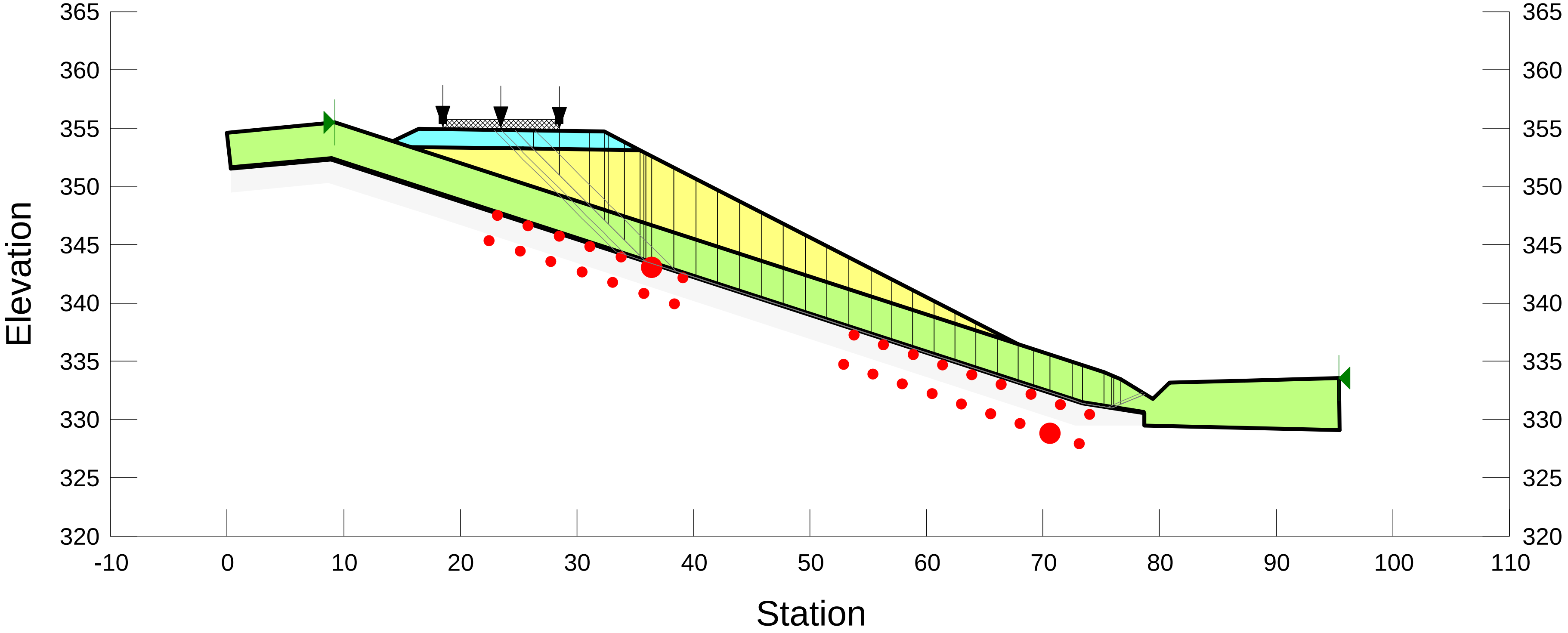


Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °
Name: FML-Interface LD Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 153 psf Phi': 16.96 °

FIG - 7

2.008

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Truck Loading
Description: block searches
Name: SEC R-1.gsz
Date: 8/8/2012Time: 10:03:08 AM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)



Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

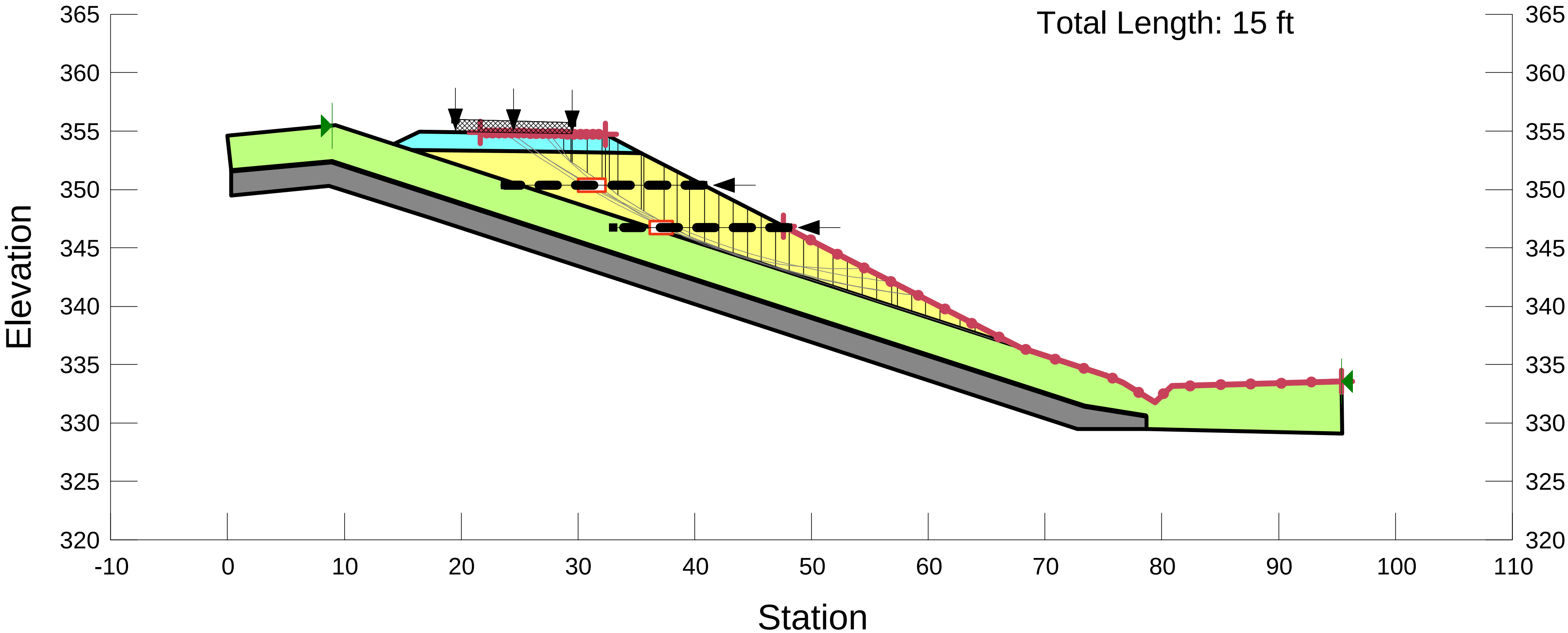
FIG - 8

1.544

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: with truck and 2 geotextiles
Description: Road Berm with truck loading
Name: SEC R-1.gsz
Date: 8/8/2012Time: 10:03:08 AM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 17 ft

Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 15 ft



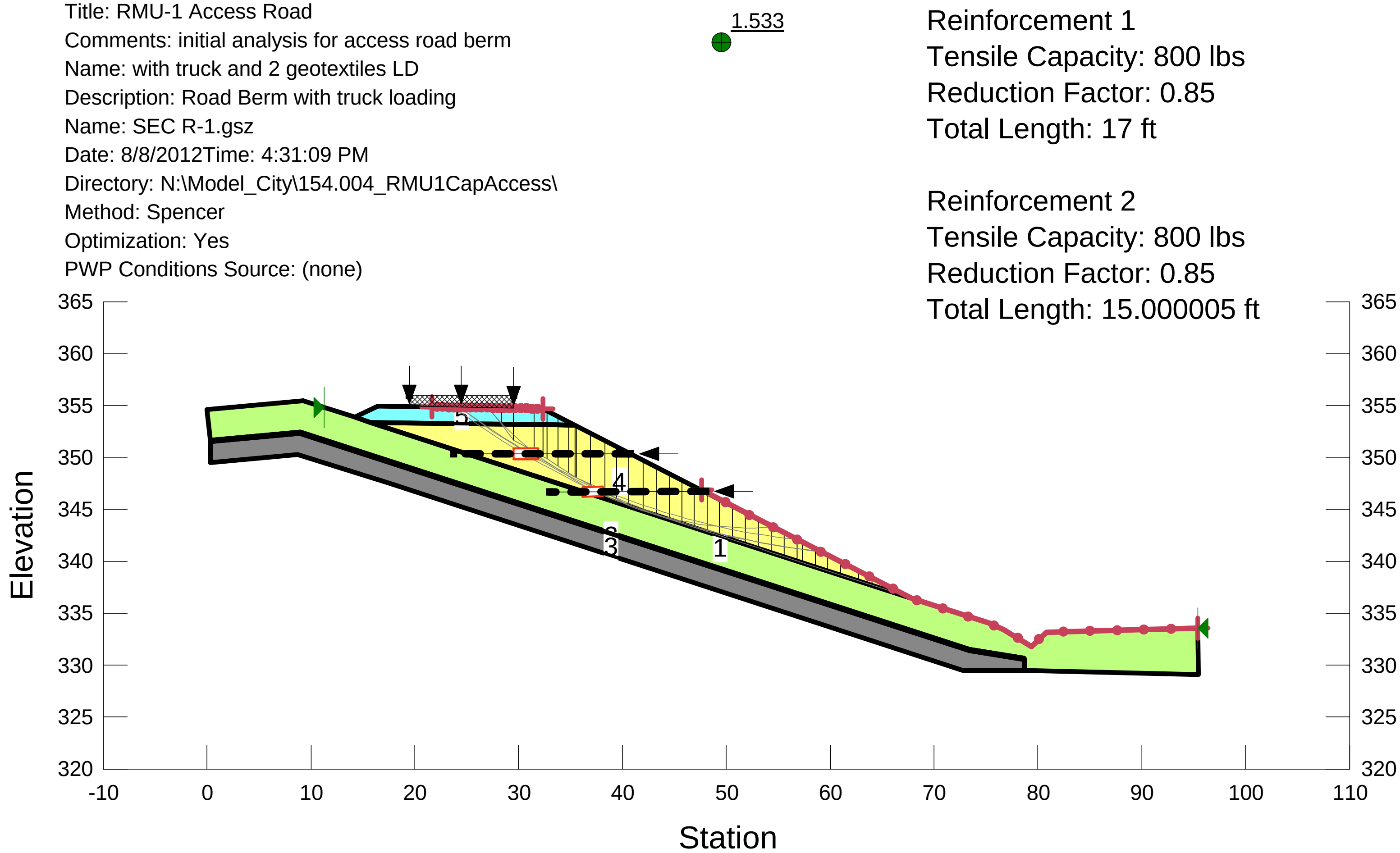
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 9

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: with truck and 2 geotextiles LD
Description: Road Berm with truck loading
Name: SEC R-1.gsz
Date: 8/8/2012Time: 4:31:09 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 17 ft

Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 15.000005 ft



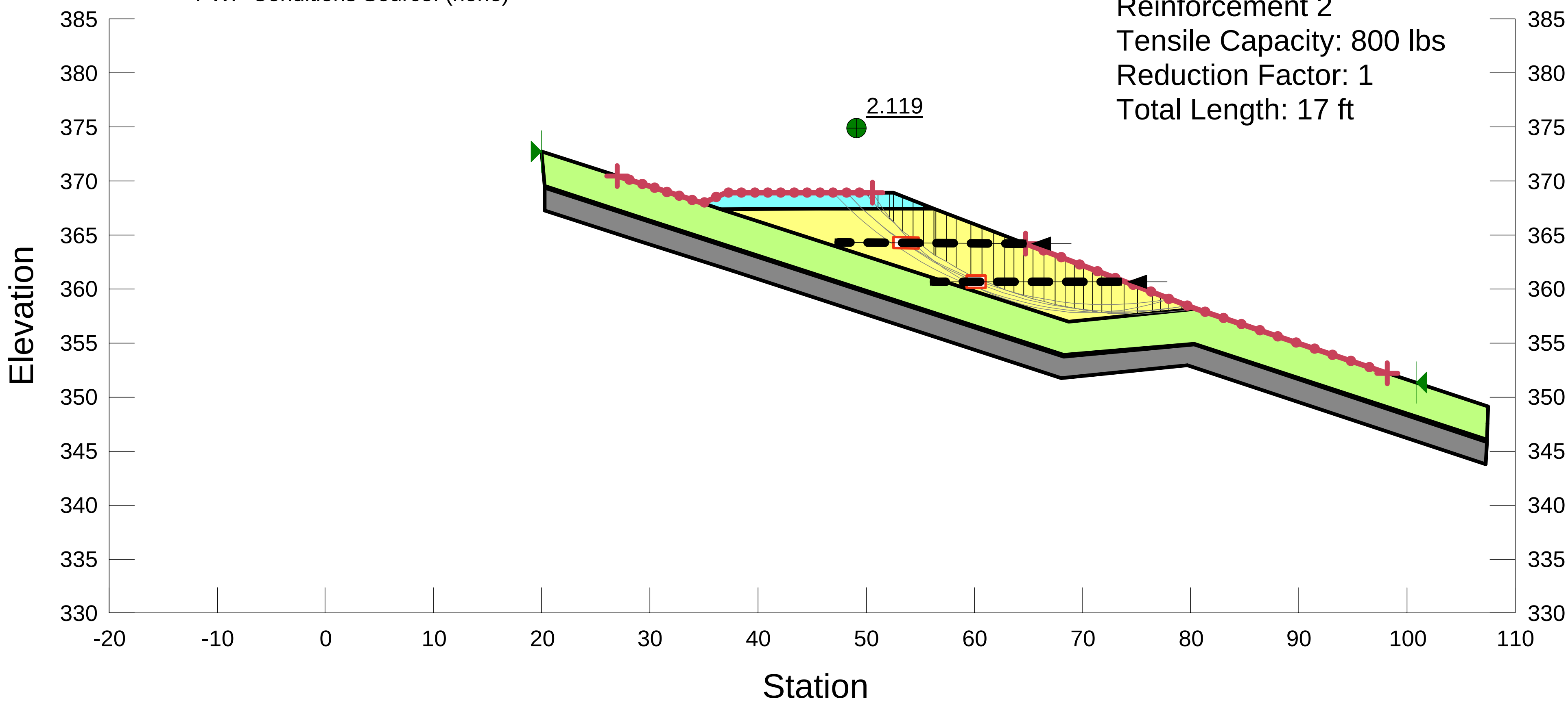
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °
Name: FML-Interface LD Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 153 psf Phi': 16.96 °

FIG - 10

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Long Term no Loads
Description: Road Berm with no added loads
Name: SEC R-2.gsz
Date: 8/8/2012Time: 11:36:45 AM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 16.999997 ft

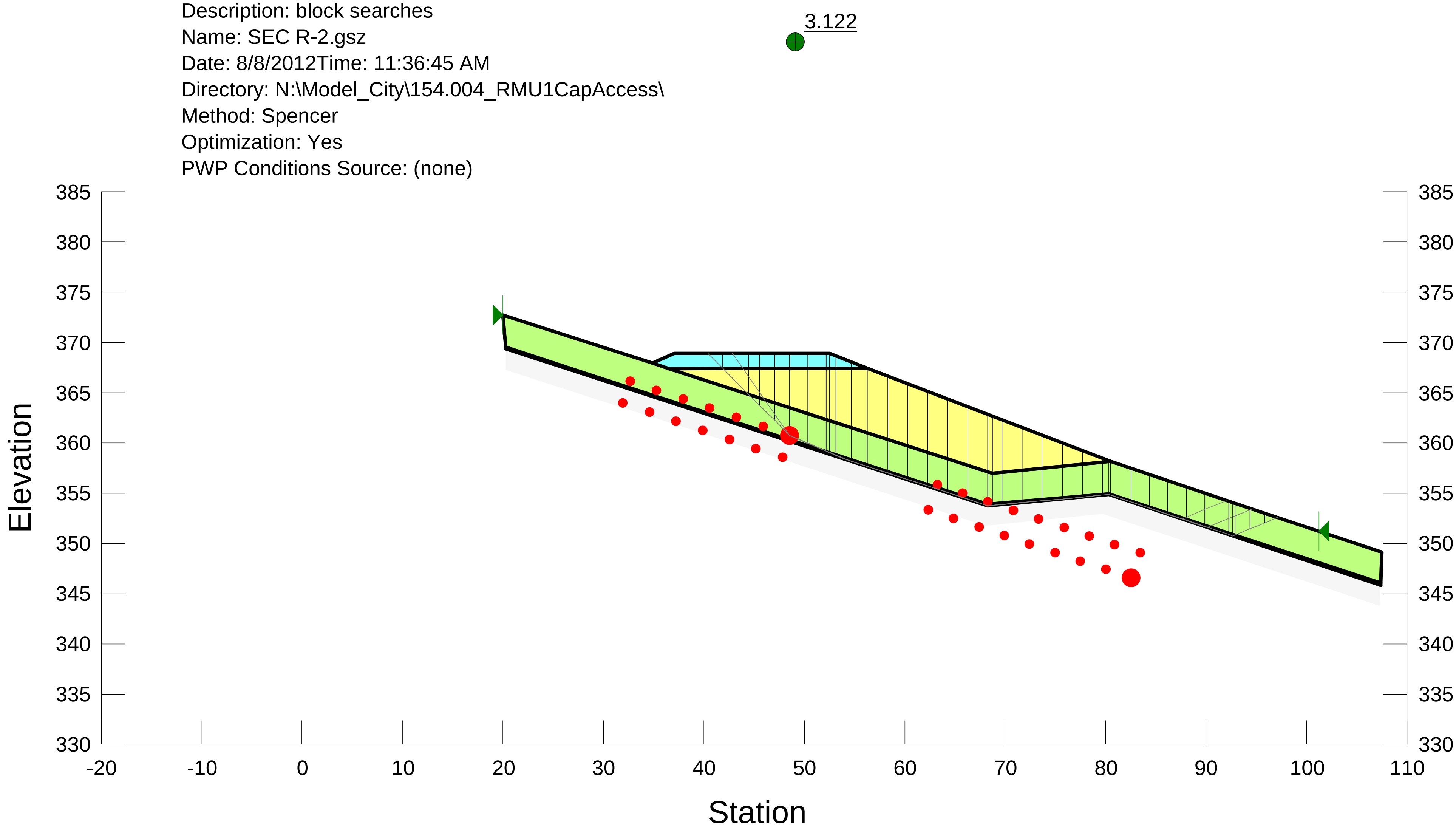
Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 17 ft



Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 11

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Long Term no Loads fml interface (2)
Description: block searches
Name: SEC R-2.gsz
Date: 8/8/2012Time: 11:36:45 AM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)



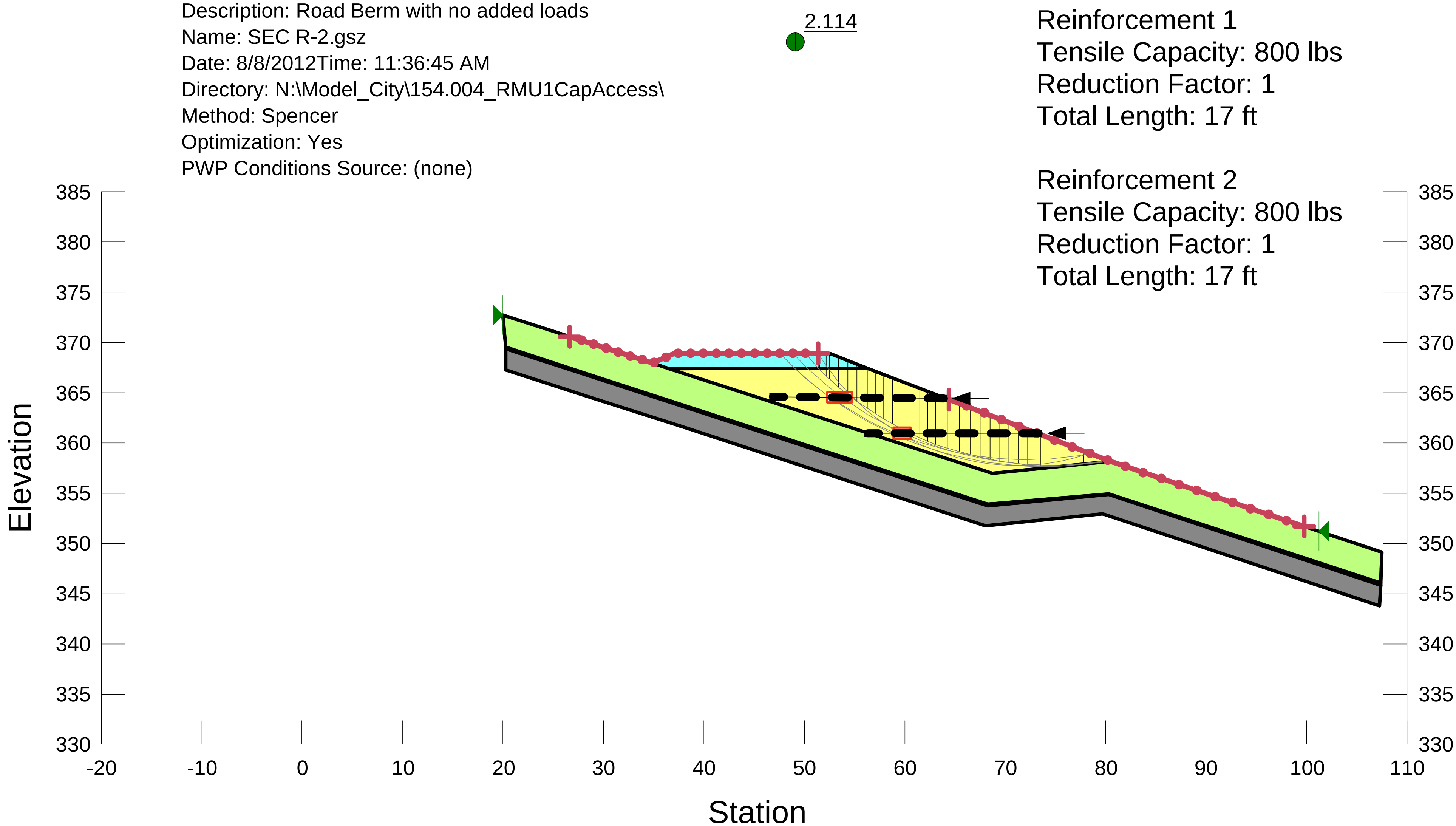
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 12

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Long Term no Loads LD
Description: Road Berm with no added loads
Name: SEC R-2.gsz
Date: 8/8/2012Time: 11:36:45 AM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 17 ft

Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 17 ft

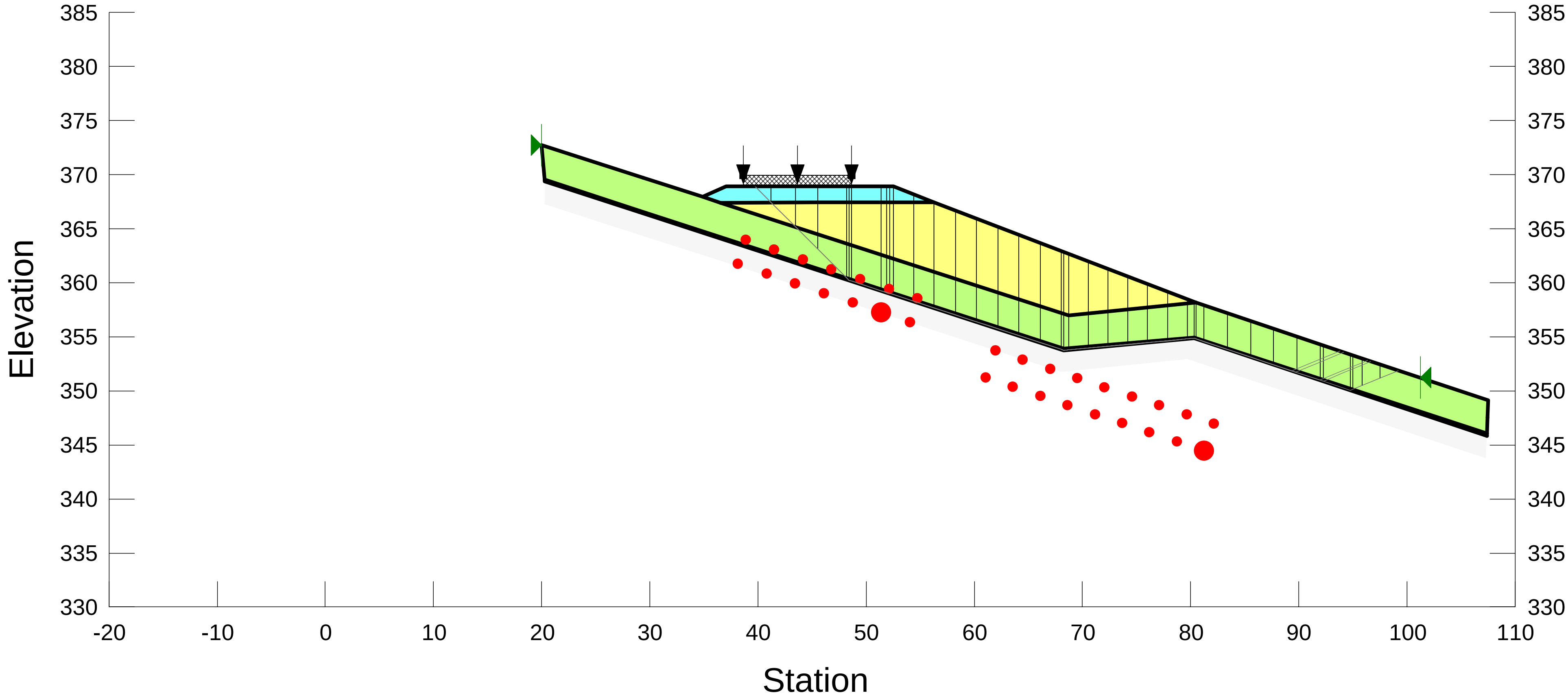


Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °
Name: FML-Interface LD Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 153 psf Phi': 16.96 °

FIG - 13

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Truck Loading
Description: block searches
Name: SEC R-2.gsz
Date: 8/8/2012Time: 11:36:45 AM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

2.746



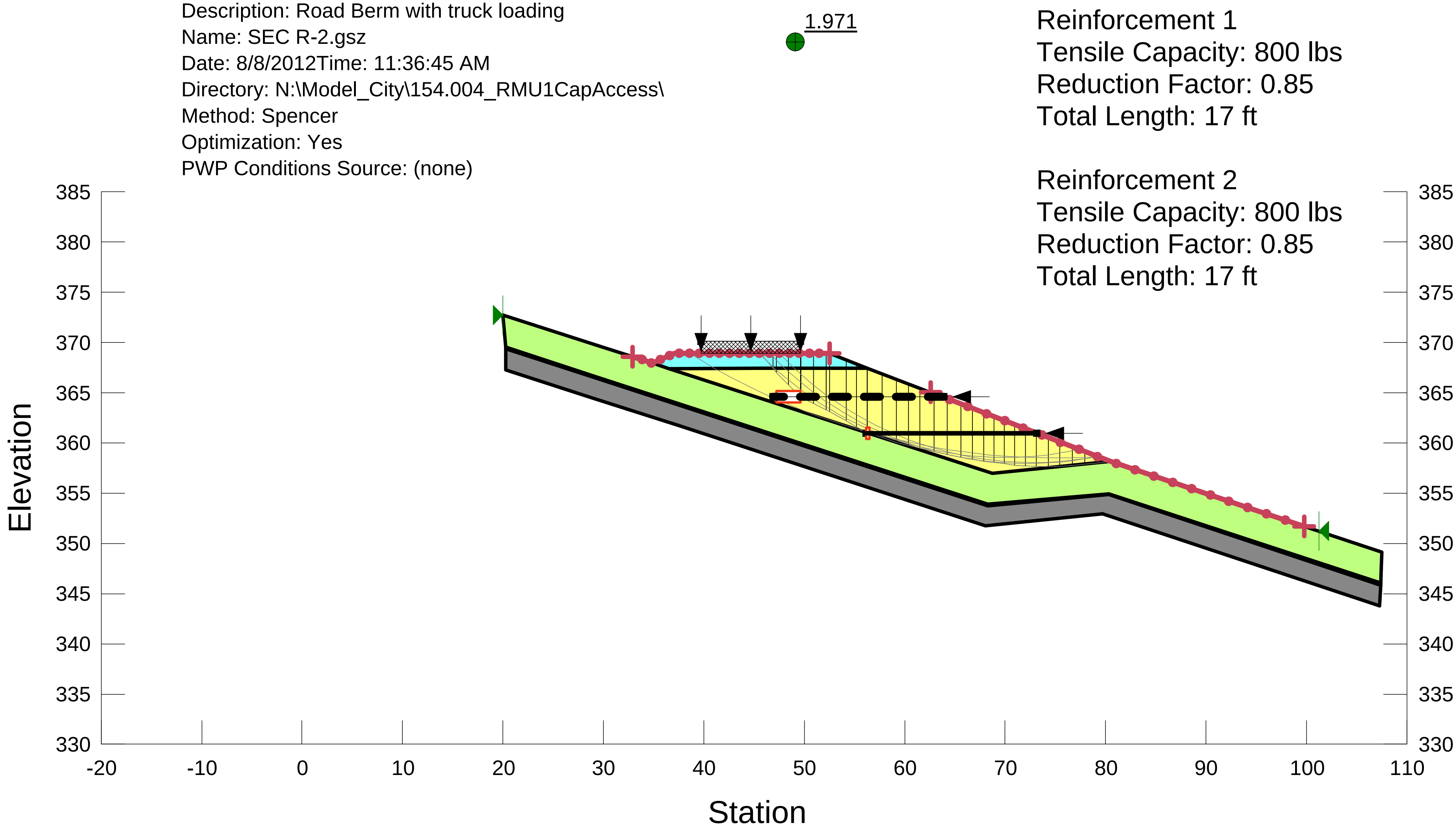
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 14

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: with truck and 2 geotextiles
Description: Road Berm with truck loading
Name: SEC R-2.gsz
Date: 8/8/2012Time: 11:36:45 AM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 17 ft

Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 17 ft



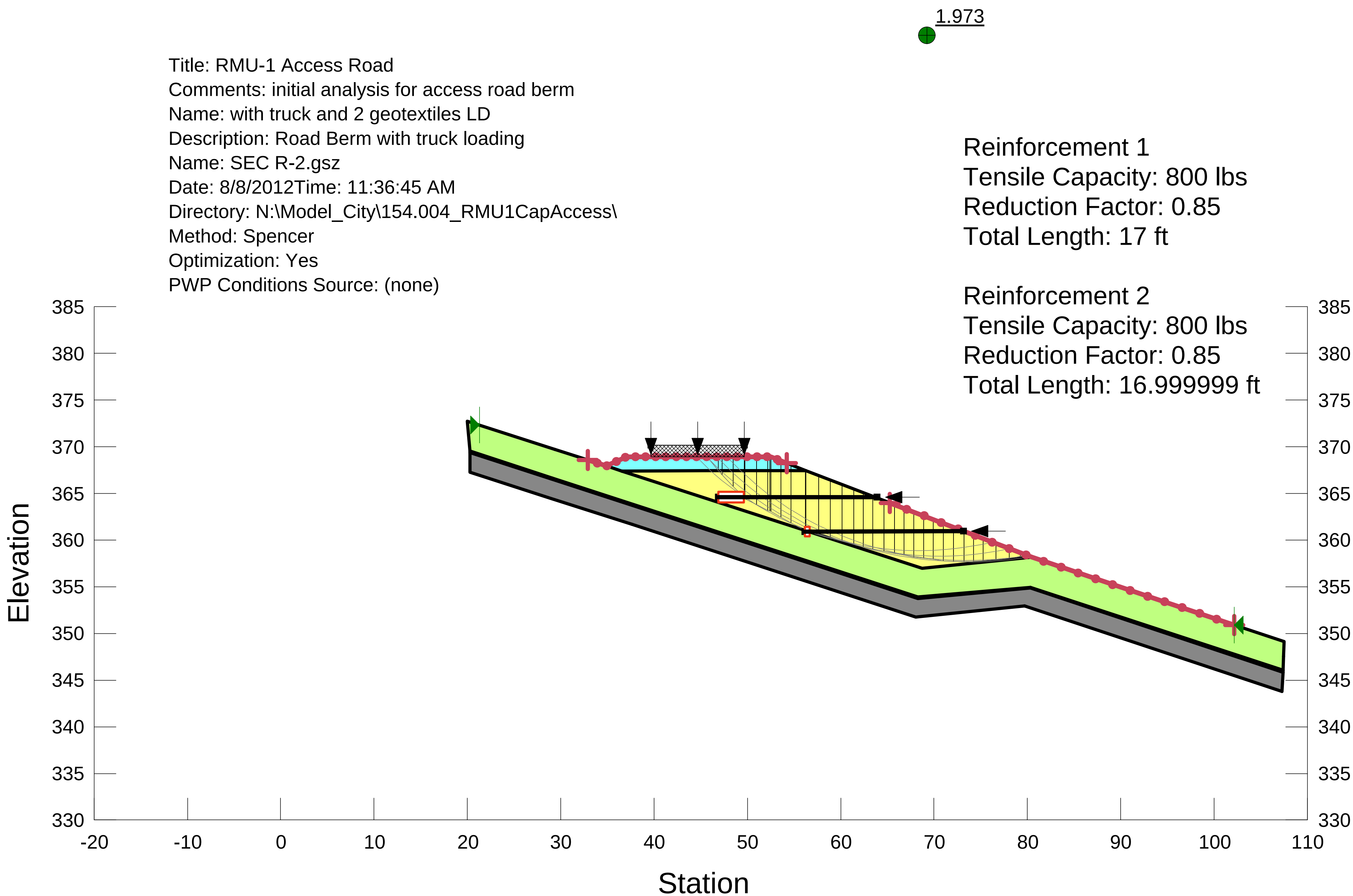
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 15

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: with truck and 2 geotextiles LD
Description: Road Berm with truck loading
Name: SEC R-2.gsz
Date: 8/8/2012Time: 11:36:45 AM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 17 ft

Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 16.999999 ft



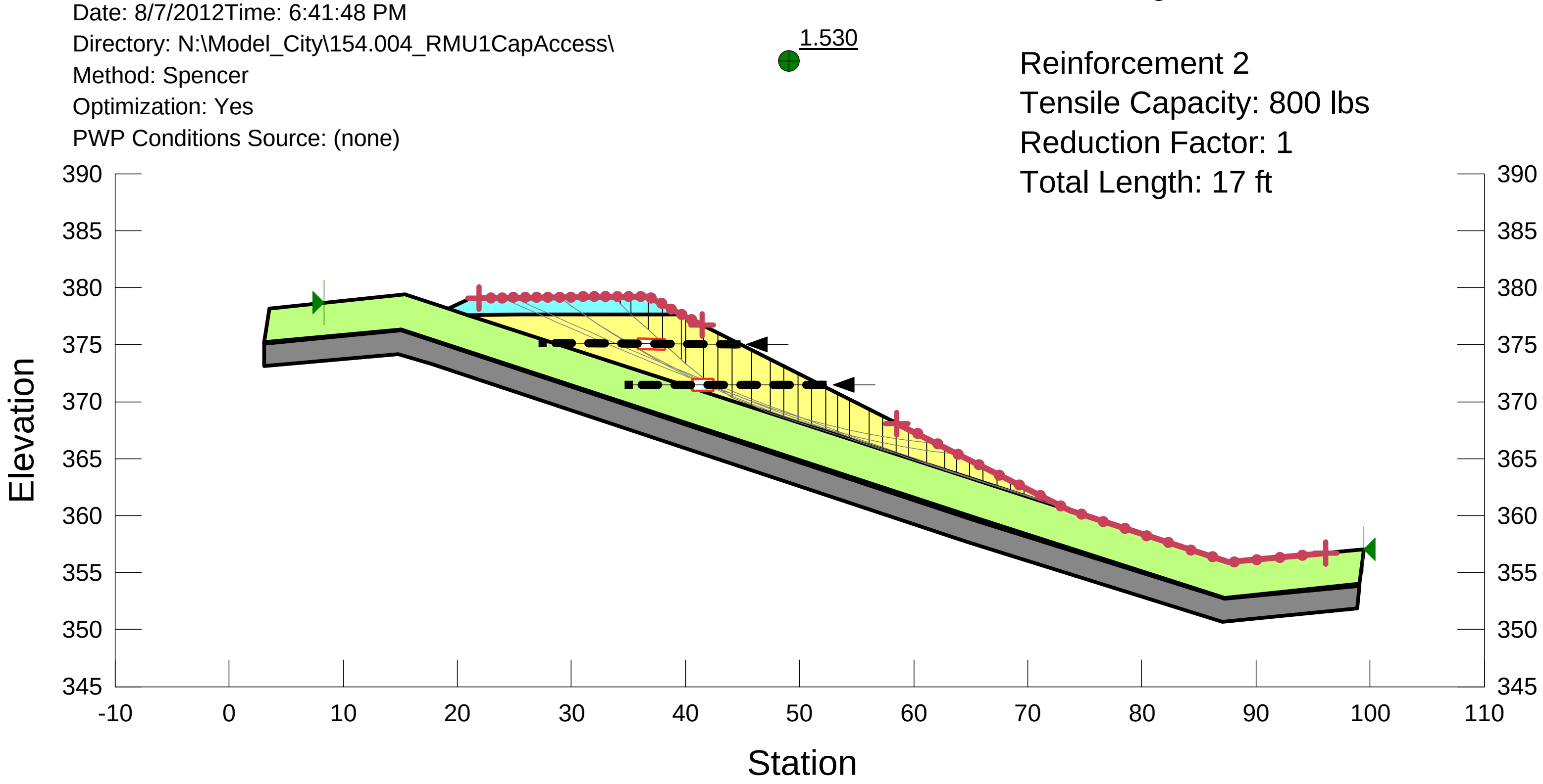
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °
Name: FML-Interface LD Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 153 psf Phi': 16.96 °

FIG - 16

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Long Term no Loads
Description: Road Berm with no added loads
Name: SEC R-3.gsz
Date: 8/7/2012Time: 6:41:48 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 16.999997 ft

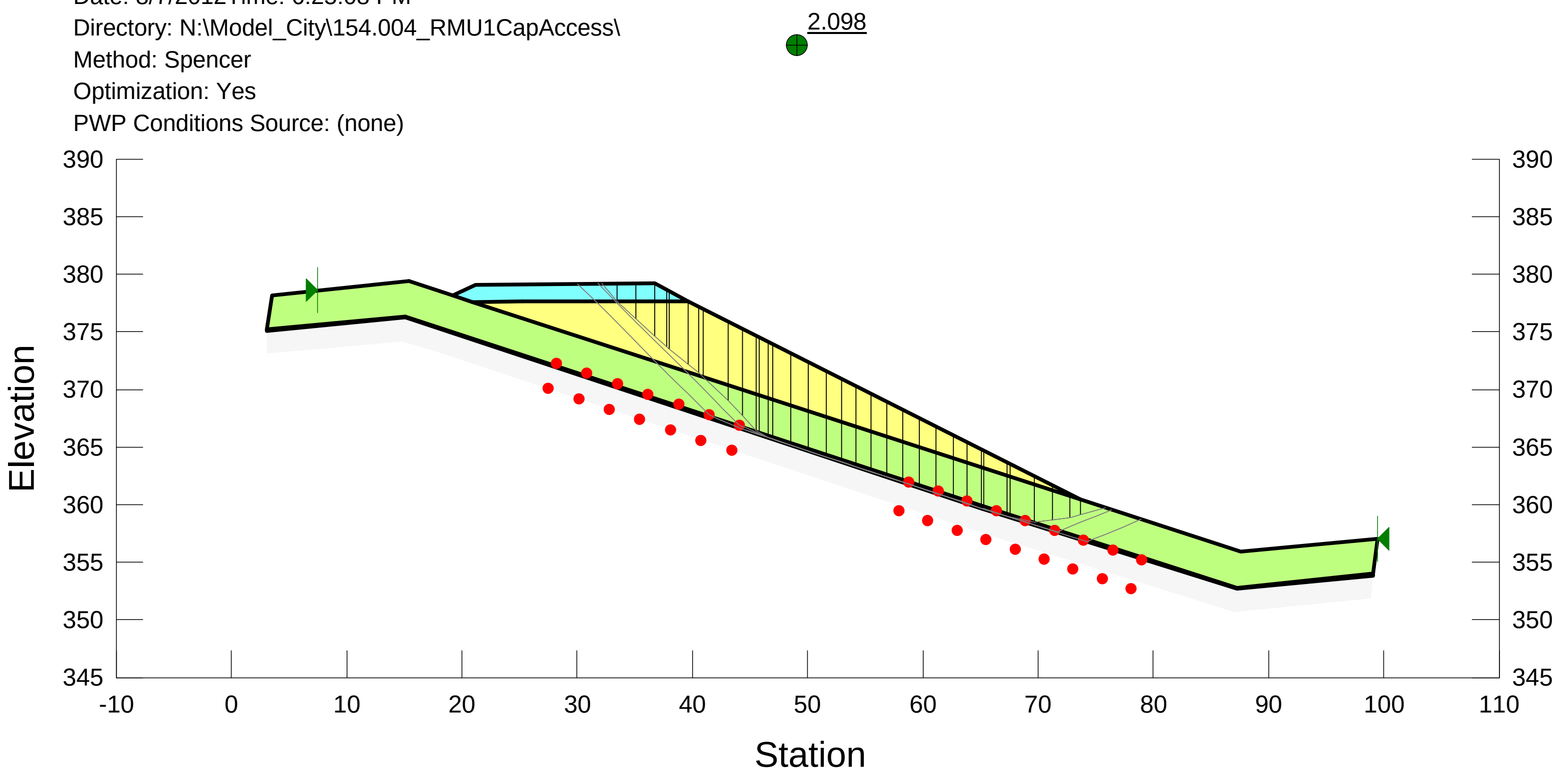
Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 17 ft



Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

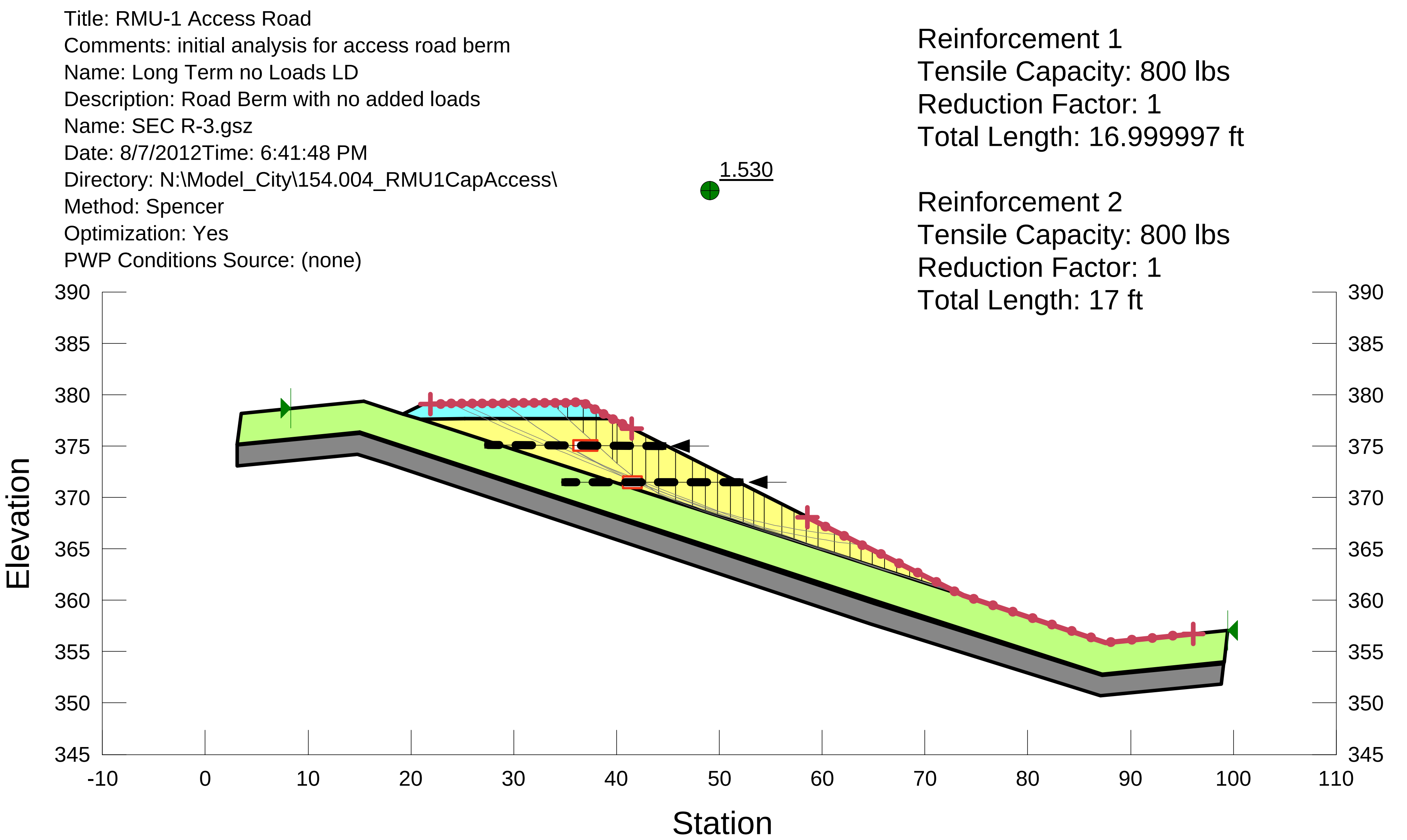
FIG - 17

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Long Term no Loads fml interface (2)
Description: block searches
Name: SEC R-3.gsz
Date: 8/7/2012Time: 6:25:08 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)



Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

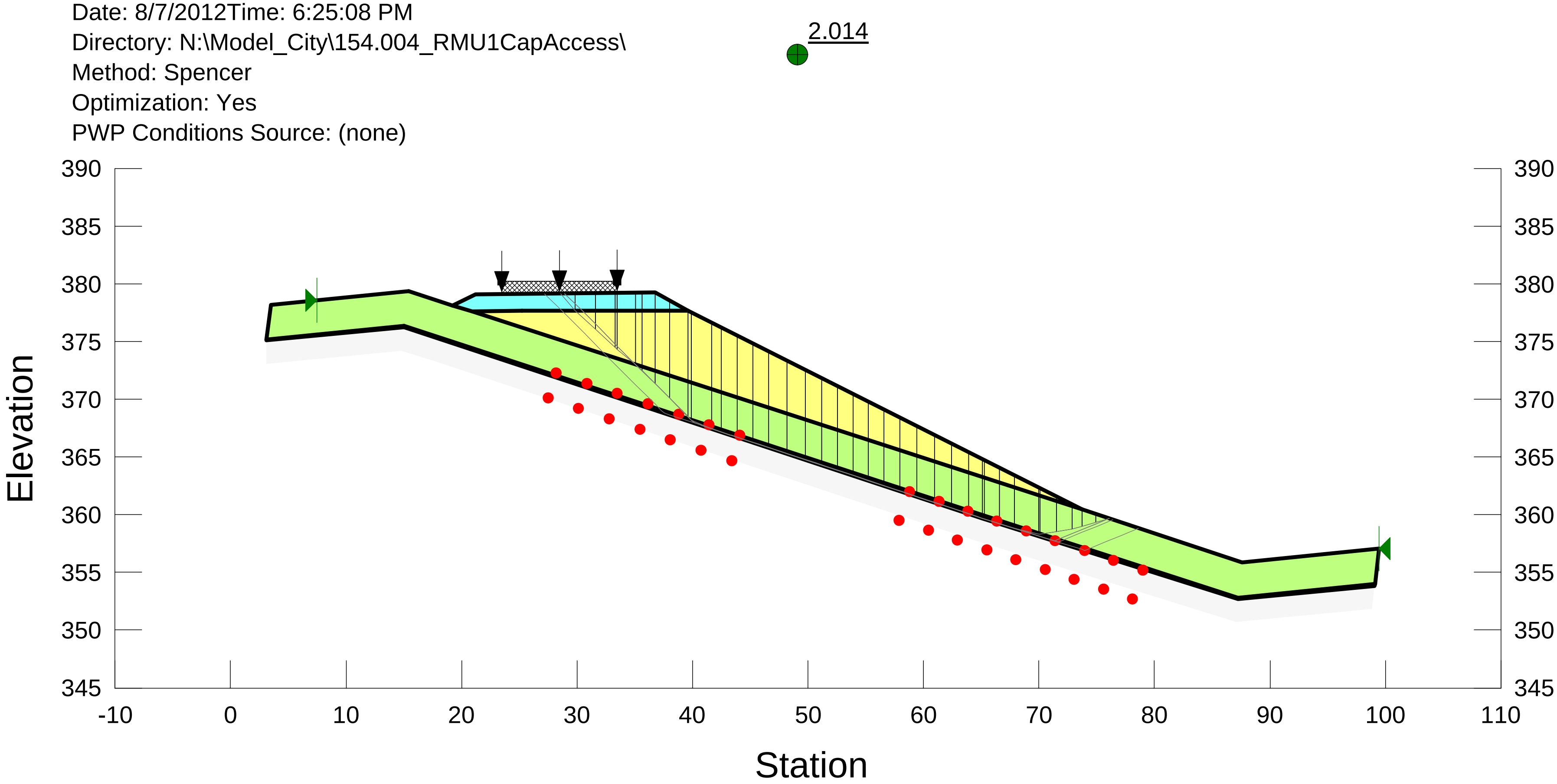
FIG - 18



Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °
Name: FML-Interface LD Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 153 psf Phi': 16.96 °

FIG - 19

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Truck Loading
Description: block searches
Name: SEC R-3.gsz
Date: 8/7/2012Time: 6:25:08 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)



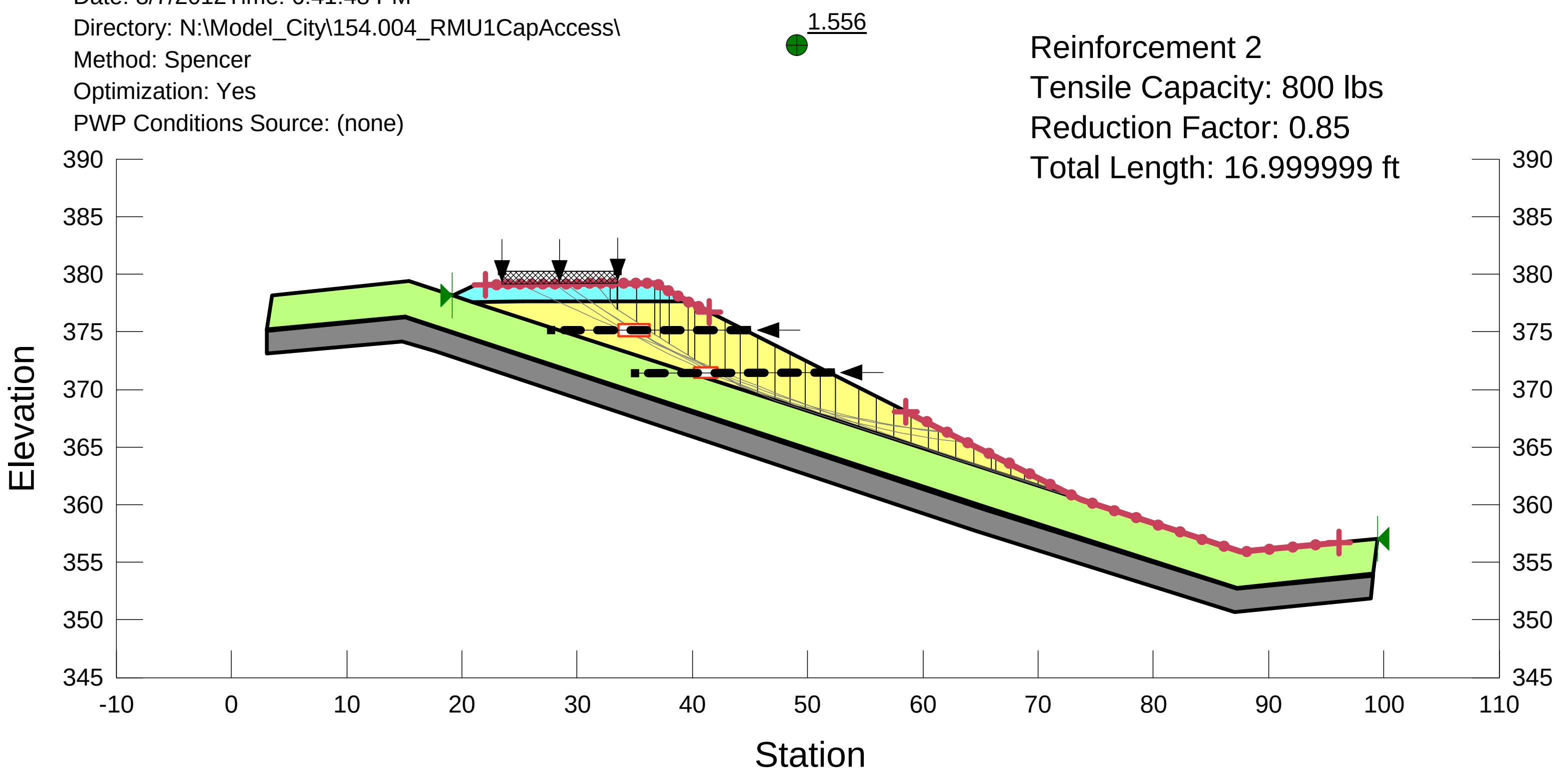
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 20

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: with truck and 2 geotextiles
Description: Road Berm with truck loading
Name: SEC R-3.gsz
Date: 8/7/2012Time: 6:41:48 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 17 ft

Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 16.999999 ft



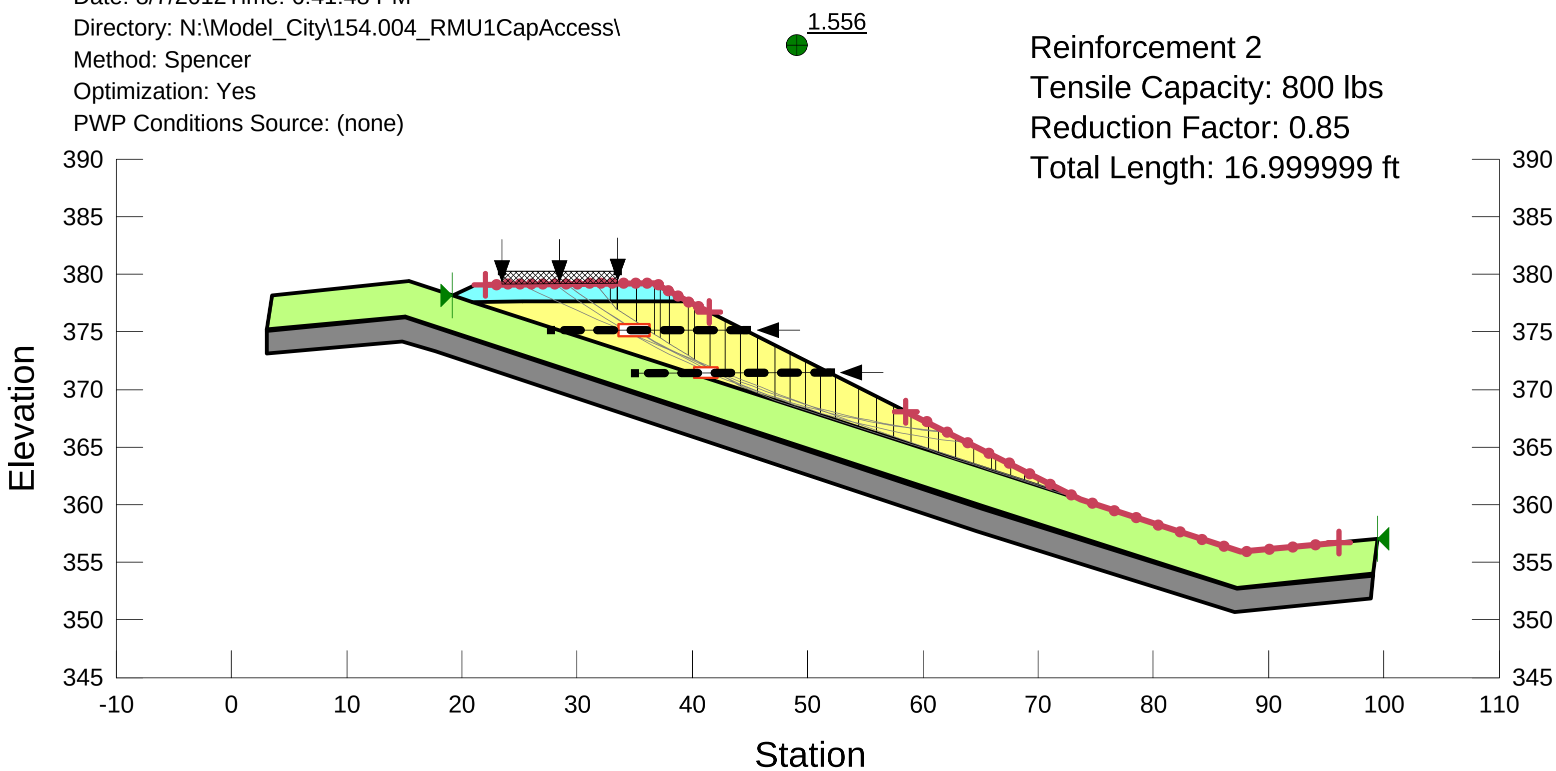
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 21

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: with truck and 2 geotextiles LD
Description: Road Berm with truck loading
Name: SEC R-3.gsz
Date: 8/7/2012Time: 6:41:48 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 17 ft

Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 16.999999 ft



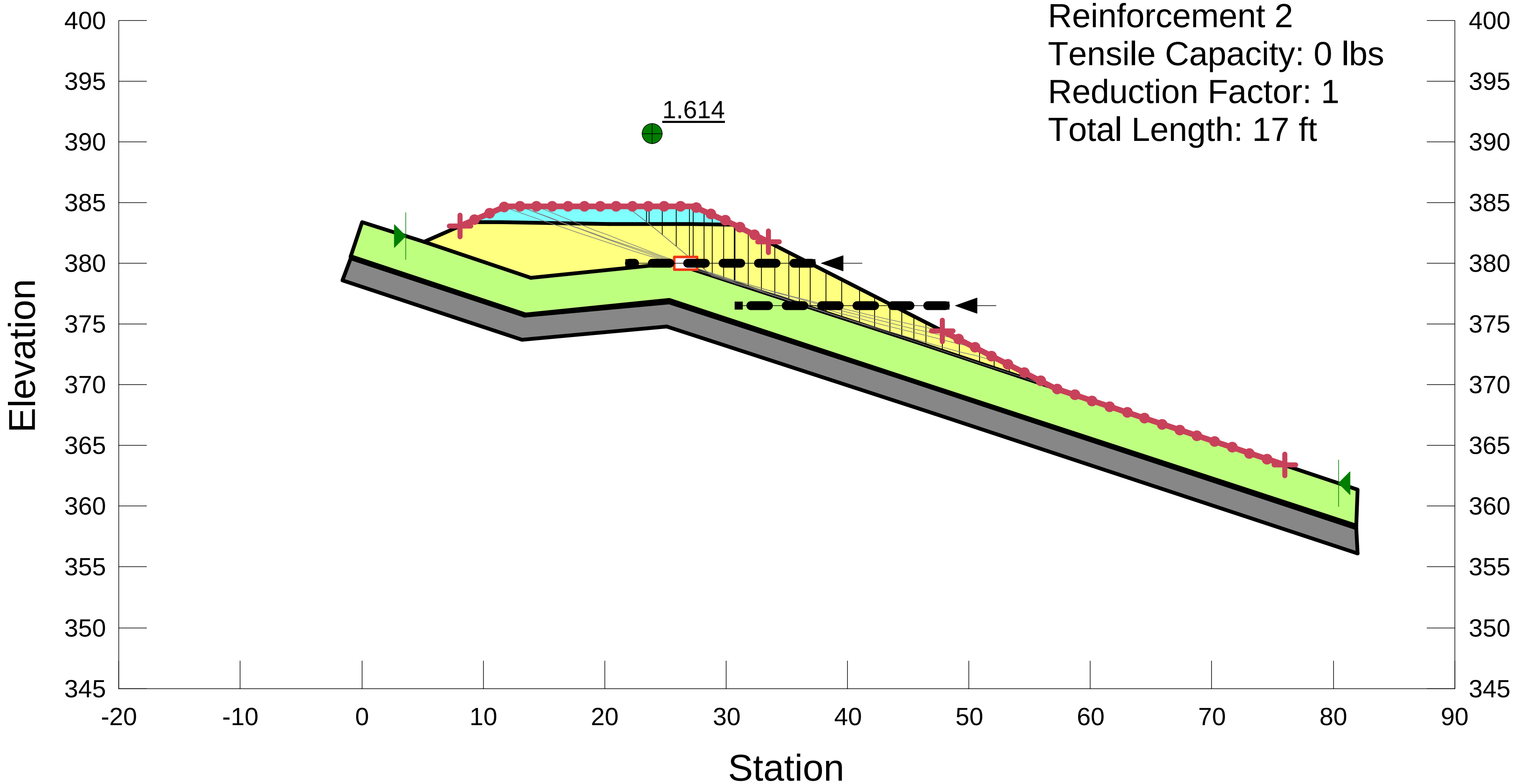
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °
Name: FML-Interface LD Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 153 psf Phi': 16.96 °

FIG - 22

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Long Term no Loads
Description: Road Berm with no added loads
Name: SEC R-4.gsz
Date: 8/8/2012Time: 2:08:45 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 15 ft

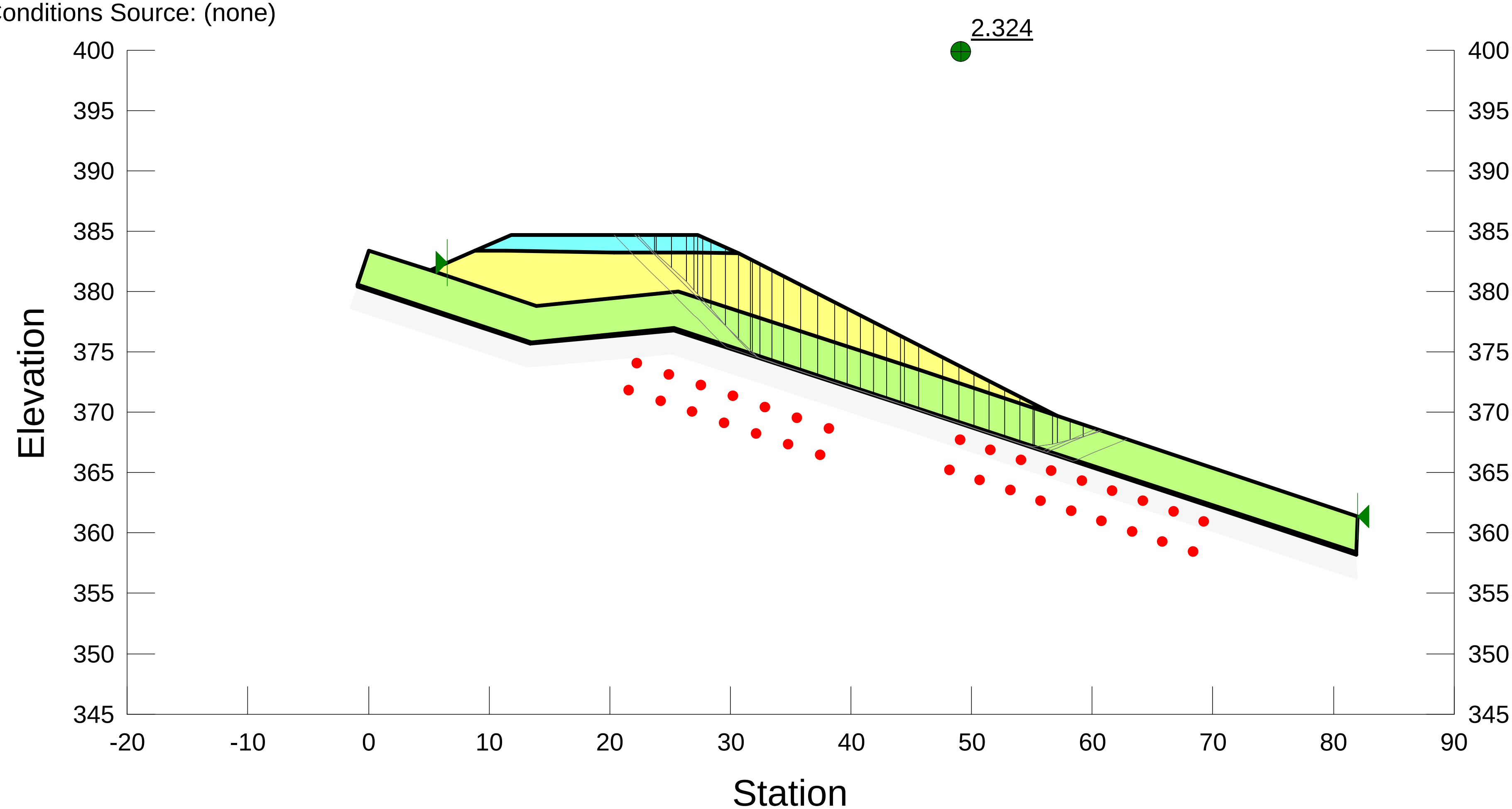
Reinforcement 2
Tensile Capacity: 0 lbs
Reduction Factor: 1
Total Length: 17 ft



Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 23

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Long Term no Loads fml interface (2)
Description: block searches
Name: SEC R-4.gsz
Date: 8/8/2012Time: 1:39:18 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)



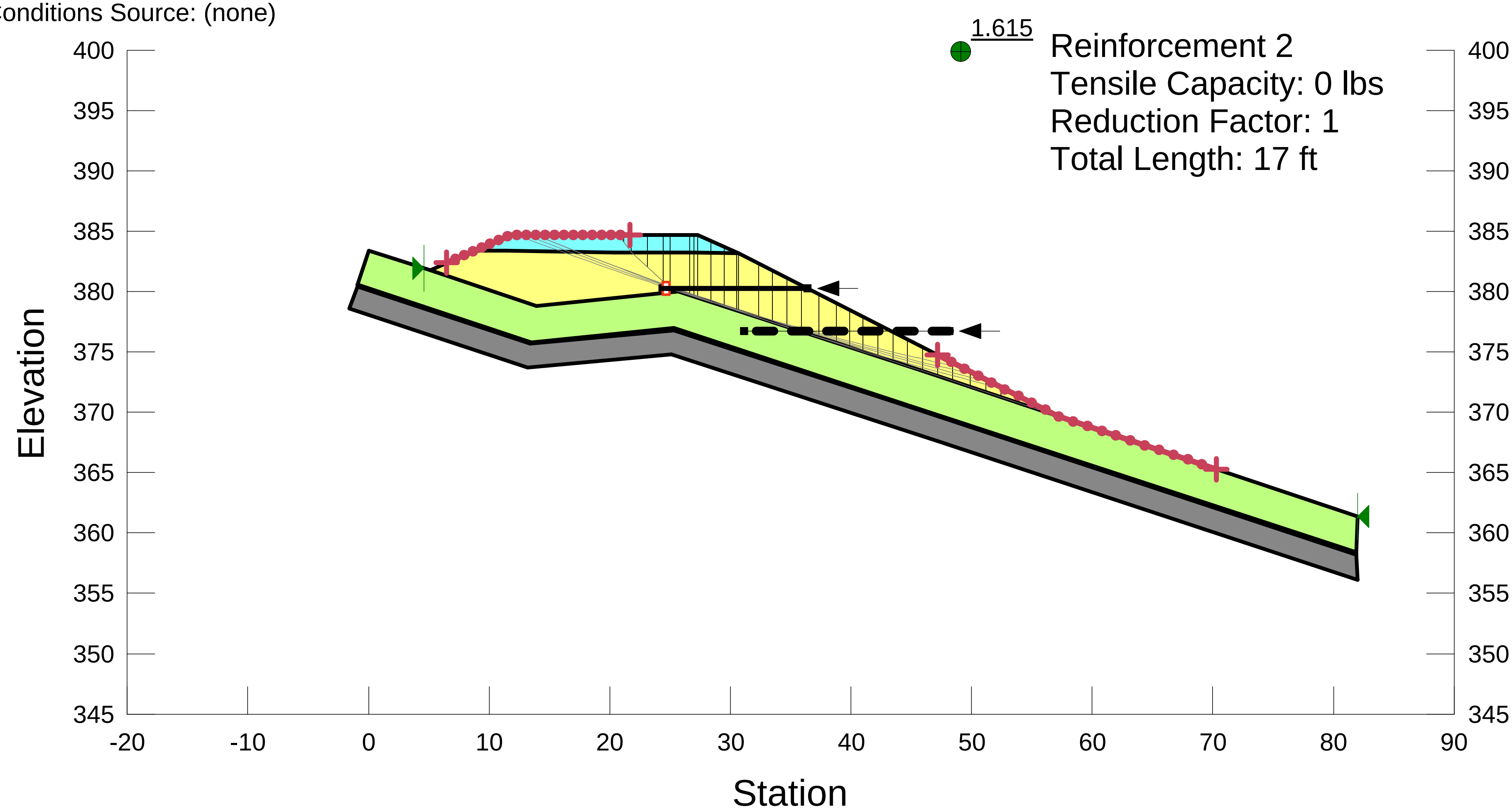
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 24

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Long Term no Loads LD
Description: Road Berm with no added loads
Name: SEC R-4.gsz
Date: 8/8/2012Time: 1:42:34 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 12 ft

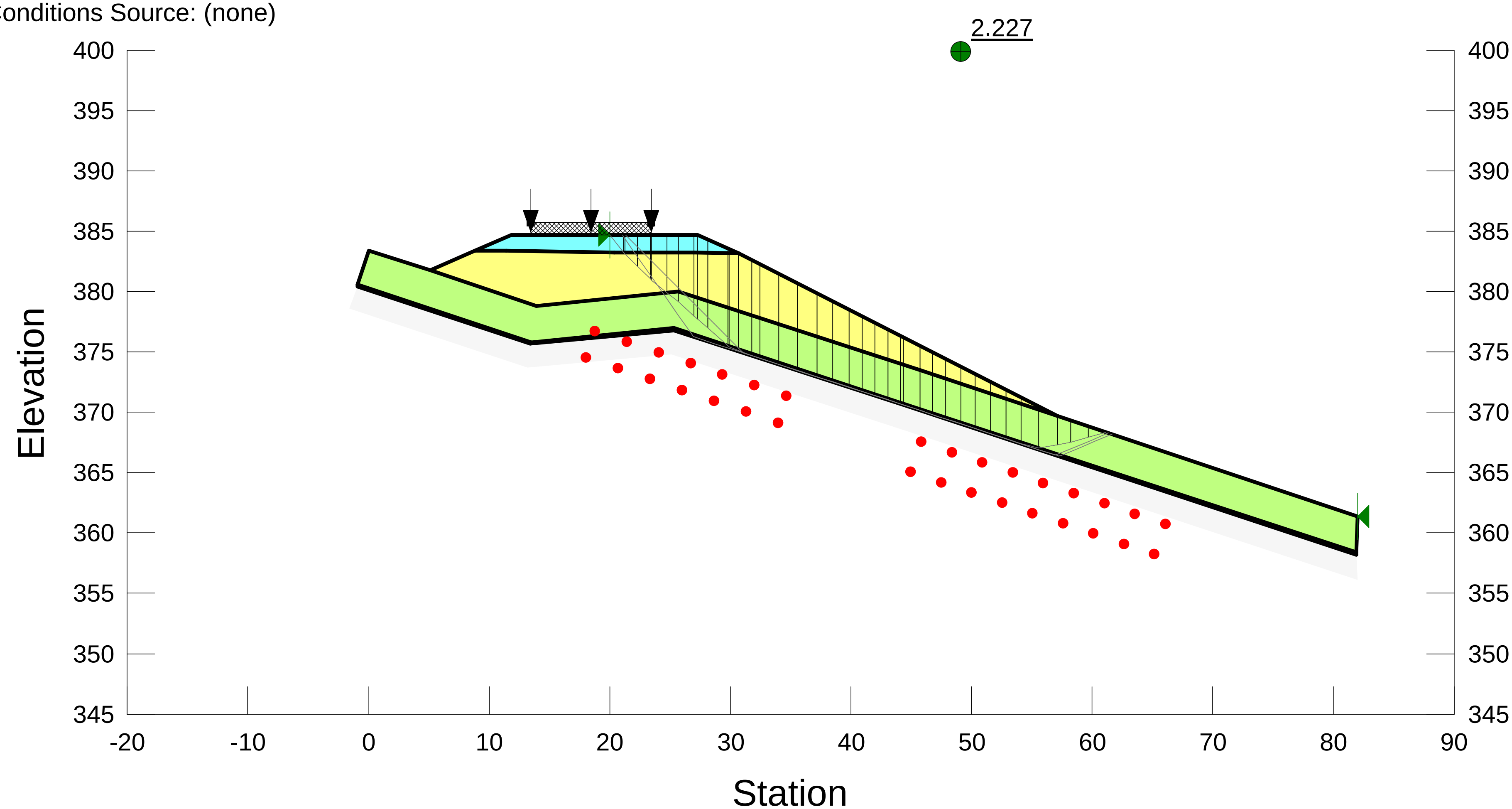
Reinforcement 2
Tensile Capacity: 0 lbs
Reduction Factor: 1
Total Length: 17 ft



Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °
Name: FML-Interface LD Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 153 psf Phi': 16.96 °

FIG - 25

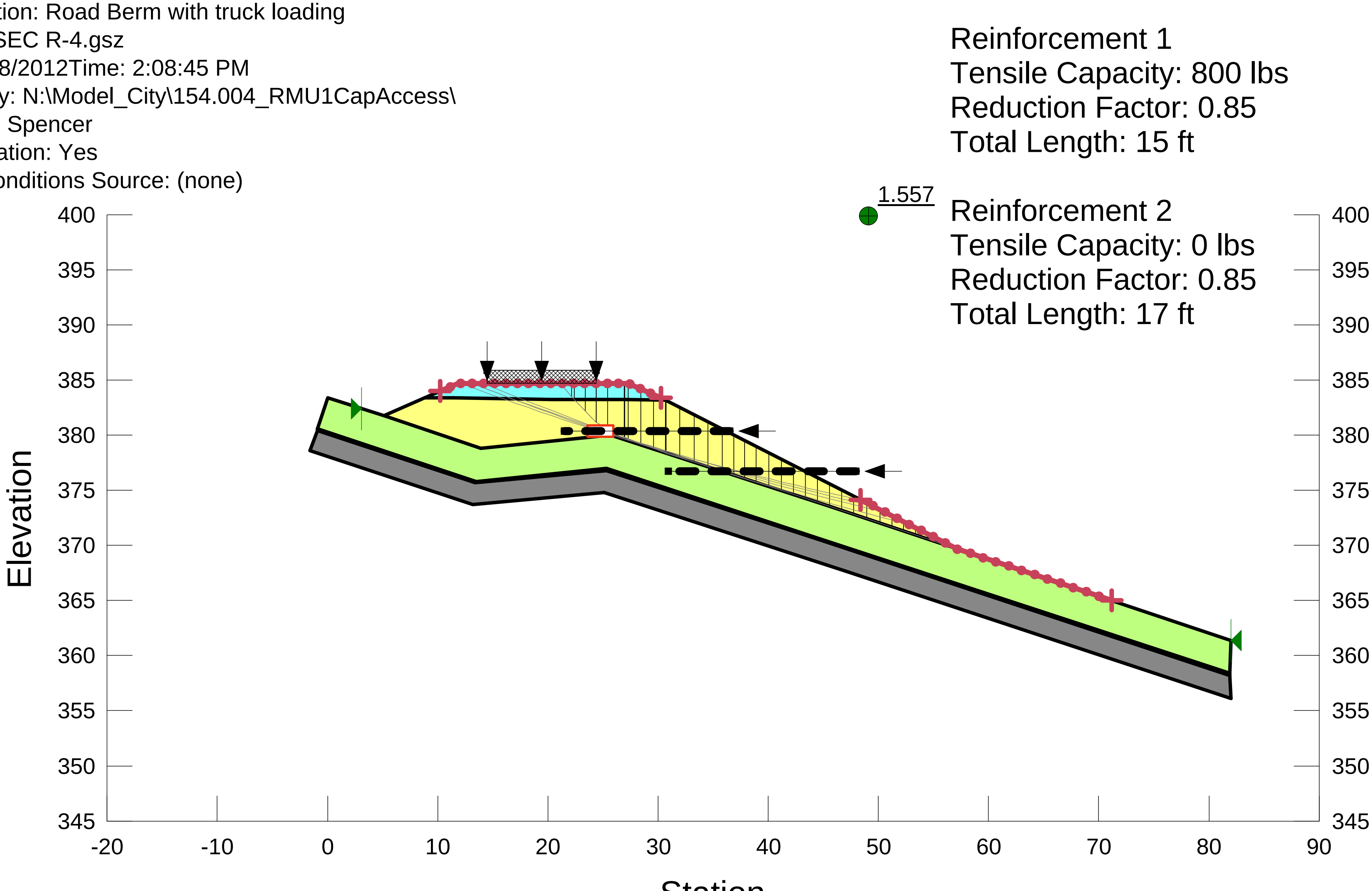
Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Truck Loading
Description: block searches
Name: SEC R-4.gsz
Date: 8/8/2012Time: 1:45:05 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)



Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 26

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: with truck and 2 geotextiles
Description: Road Berm with truck loading
Name: SEC R-4.gsz
Date: 8/8/2012Time: 2:08:45 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)



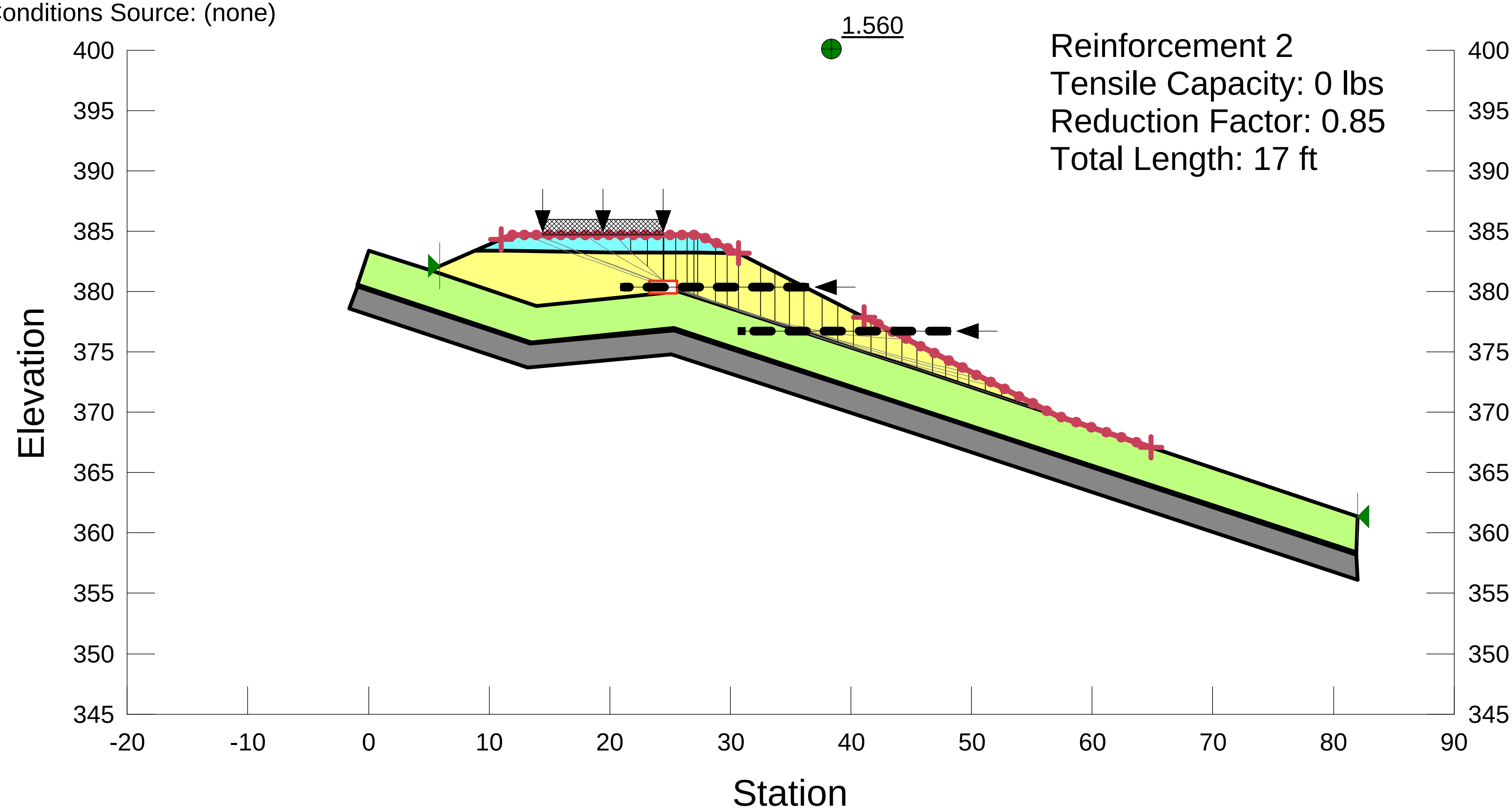
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 145 psf Phi': 26.75 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 27

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: with truck and 2 geotextiles LD
Description: Road Berm with truck loading
Name: SEC R-4.gsz
Date: 8/8/2012Time: 4:21:08 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 15 ft

Reinforcement 2
Tensile Capacity: 0 lbs
Reduction Factor: 0.85
Total Length: 17 ft



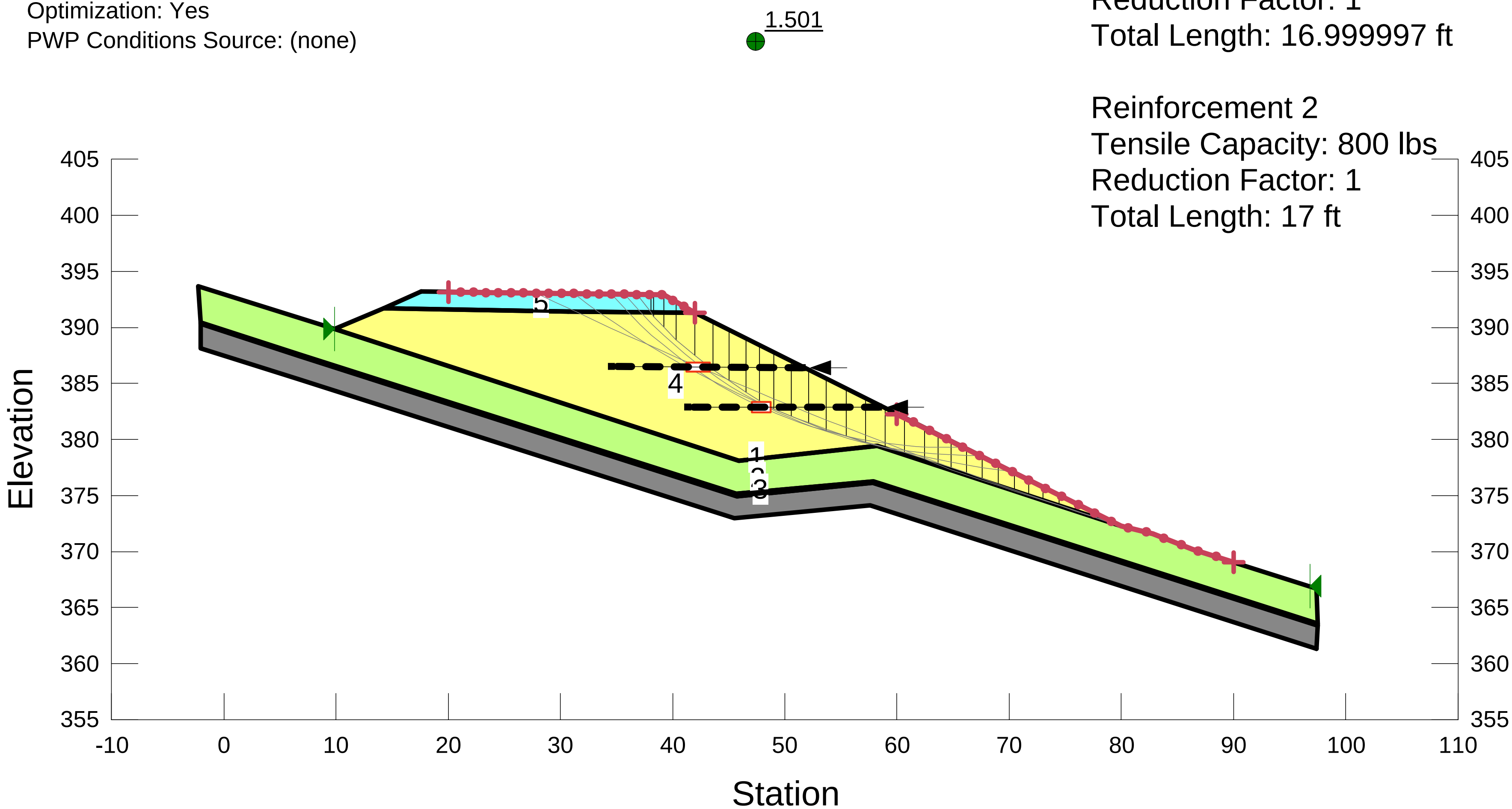
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °
Name: FML-Interface LD Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 153 psf Phi': 16.96 °

FIG - 28

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Long Term no Loads
Description: Road Berm with no added loads
Name: SEC R-5.gsz
Date: 8/8/2012Time: 3:24:54 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 16.999997 ft

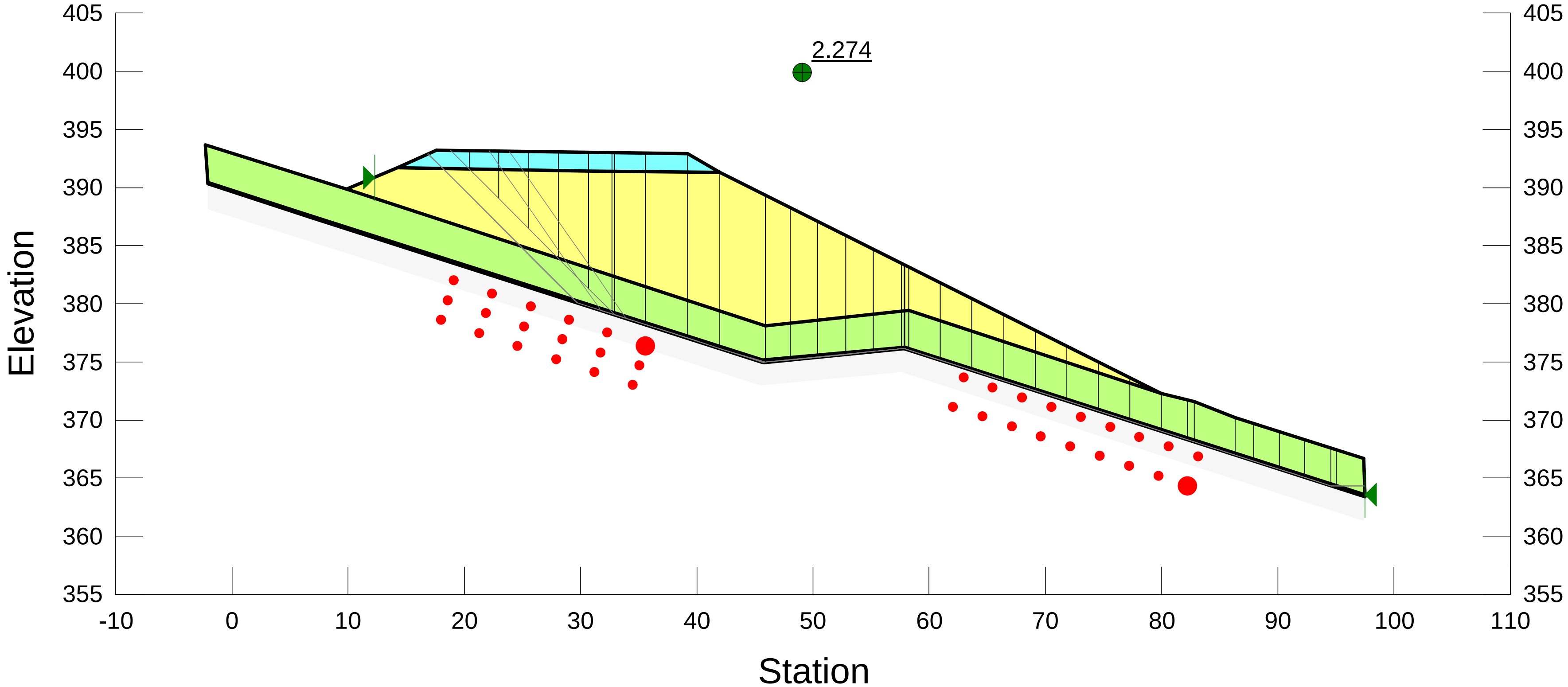
Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 17 ft



Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface phase IV Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 105.9 psf Phi': 25.91 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 29

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Long Term no Loads fml interface (2)
Description: block searches
Name: SEC R-5.gsz
Date: 8/8/2012Time: 3:24:54 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)



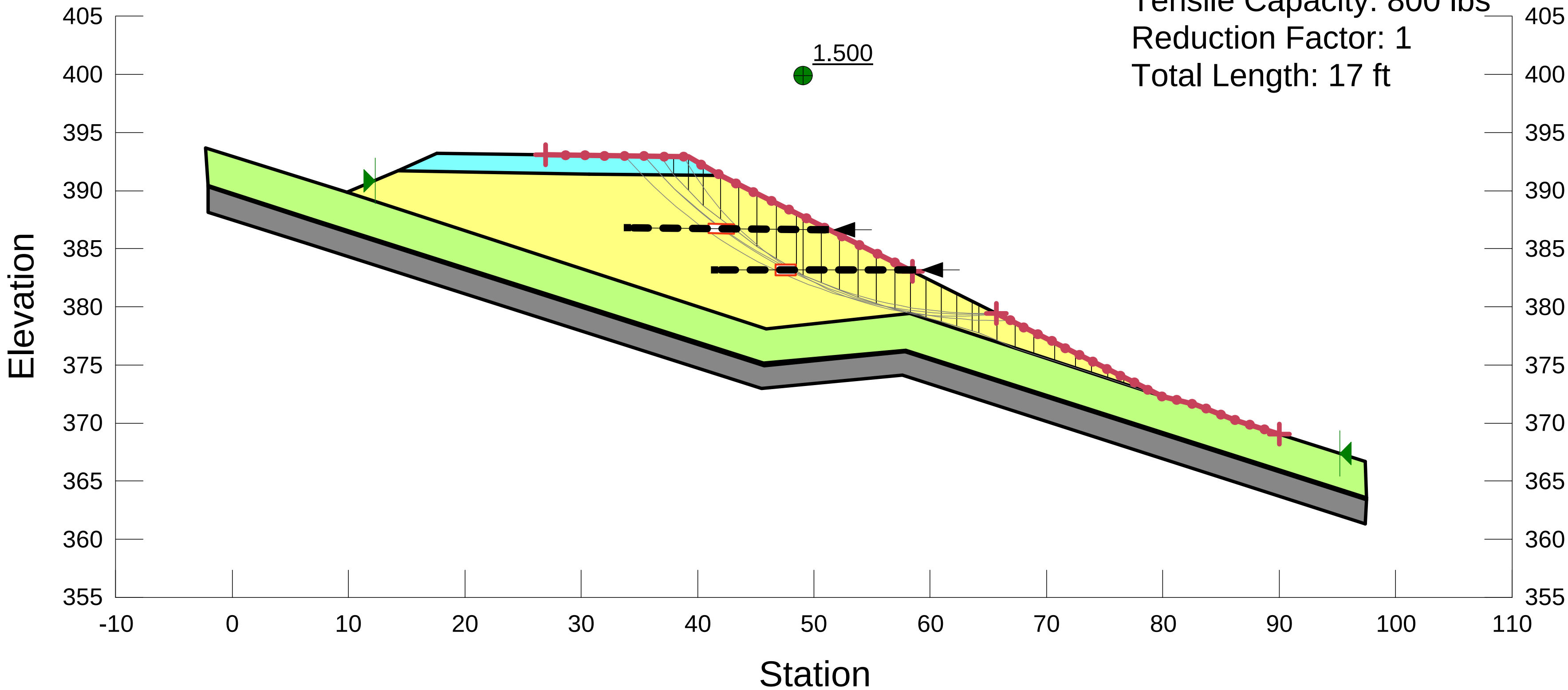
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface phase IV Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 105.9 psf Phi': 25.91 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 30

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Long Term no Loads LD
Description: Road Berm with no added loads
Name: SEC R-5.gsz
Date: 8/8/2012Time: 3:24:54 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 17 ft

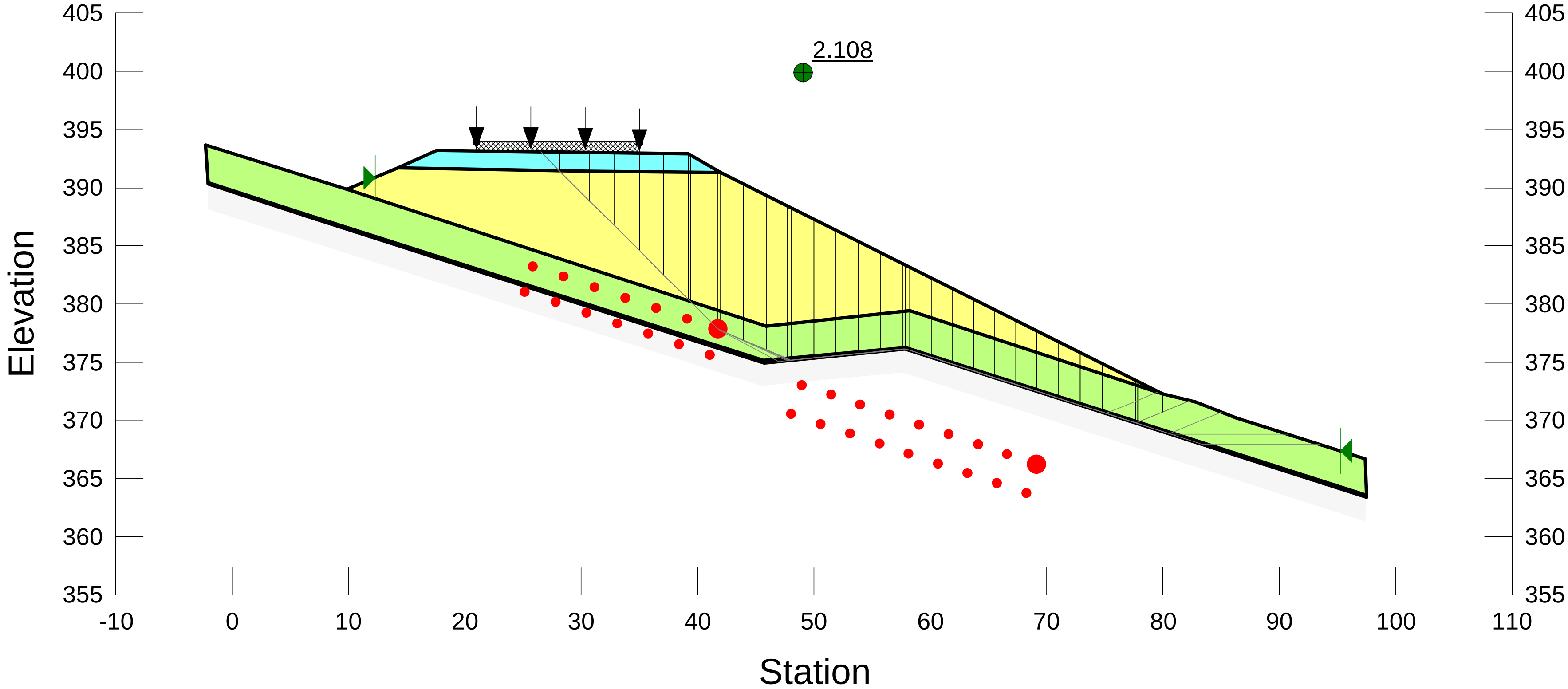
Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 1
Total Length: 17 ft



Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °
Name: FML-Interface LD phase IV Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 77.3 psf Phi': 12.7 °

FIG - 31

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: Truck Loading
Description: block searches
Name: SEC R-5.gsz
Date: 8/8/2012Time: 3:24:54 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)



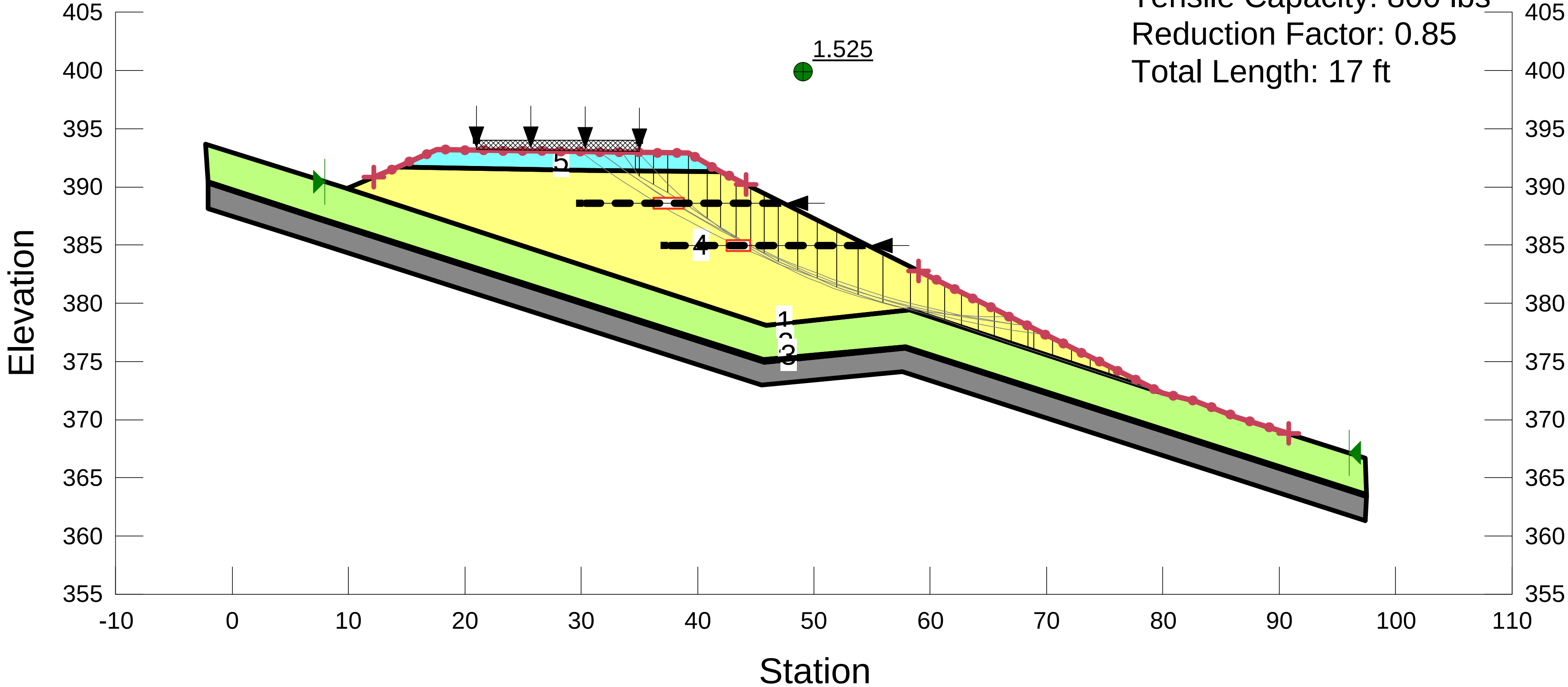
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface phase IV Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 105.9 psf Phi': 25.91 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 32

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: with truck and 2 geotextiles
Description: Road Berm with truck loading
Name: SEC R-5.gsz
Date: 8/8/2012Time: 3:24:54 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 17 ft

Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 17 ft



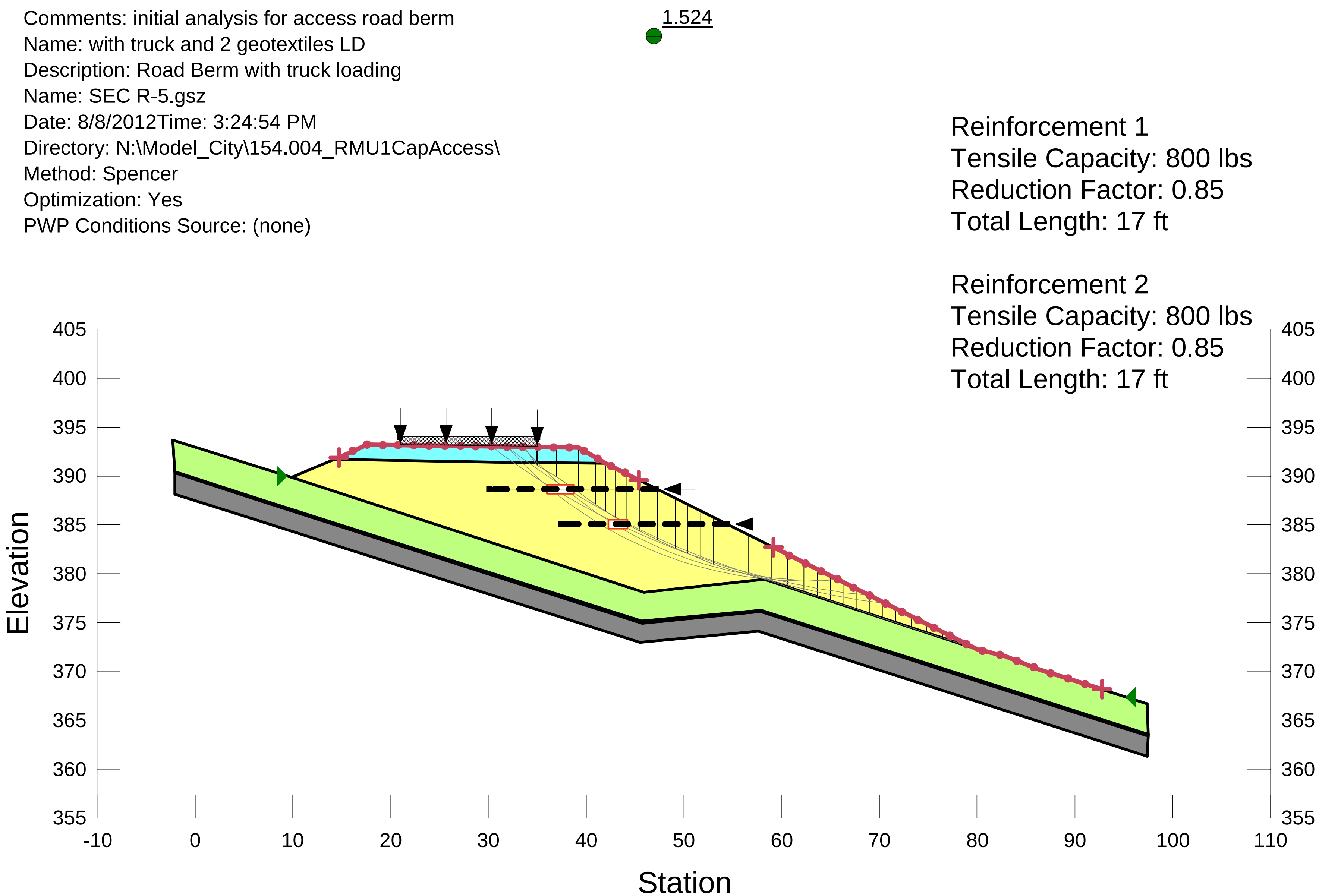
Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: FML-Interface phase IV Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion': 105.9 psf Phi': 25.91 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °

FIG - 33

Title: RMU-1 Access Road
Comments: initial analysis for access road berm
Name: with truck and 2 geotextiles LD
Description: Road Berm with truck loading
Name: SEC R-5.gsz
Date: 8/8/2012Time: 3:24:54 PM
Directory: N:\Model_City\154.004_RMU1CapAccess\
Method: Spencer
Optimization: Yes
PWP Conditions Source: (none)

Reinforcement 1
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 17 ft

Reinforcement 2
Tensile Capacity: 800 lbs
Reduction Factor: 0.85
Total Length: 17 ft



Name: Road Fill Model: Mohr-Coulomb Unit Weight: 130 pcf Cohesion': 0 psf Phi': 30 °
Name: Soil Cover Model: Mohr-Coulomb Unit Weight: 132 pcf Cohesion': 466 psf Phi': 23.2 °
Name: Compacted Soil Liner Model: Mohr-Coulomb Unit Weight: 133 pcf Cohesion': 500 psf Phi': 20.7 °
Name: Road Gravel Model: Mohr-Coulomb Unit Weight: 115 pcf Cohesion': 0 psf Phi': 40 °
Name: FML-Interface LD phase IV Model: Mohr-Coulomb Unit Weight: 120 pcf Cohesion': 77.3 psf Phi': 12.7 °

FIG - 34

SECTION 02600
GEOGRIDS

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Geogrids and Geotextiles used to reinforce and stabilize soil.

1.2 REFERENCES

A. Standard Test Methods for Mass Per Unit Area (Weight) of Fabric ASTM D 3776

B. Wide Width Tensile (geotextiles) ASTM D-4595

C. Specific Gravity (HDPE only) ASTM D-1505

D. Melt Flow index (PP & HDPE) ASTM D-1238

E. Intrinsic Viscosity (PET only) ASTM D-4603

F. Carboxyl End Group (PET only) ASTM D-2455

G. Single Rib Tensile (geogrids) GRI:GG1

H. FHWA Publication No FHWA-NH1-00-043

PART 2 PRODUCTS

2.1 MANUFACTURERS

A. Acceptable Manufacturers include Miragrid, Huesker, Stratagrid and Tensar . Requests for substitutions will be considered if supported with adequate documentation of equivalence.

2.2 GEOGRIDS

A. Primary and Secondary Reinforcement
   1. Open area: 60 percent minimum.
   2. Long-term allowable design load (T_{AL}) as shown on drawings
      a) T_{AL} to consider reductions for creep, chemical and biodegration, and installation damage.
      b) Service time to be 100 yr minimum
      c) Backfill will be structural fill (compacted silty clay/clayey silt)

B. Geotextile Reinforcement

1. Long-term allowable design load (T_{AL}) as shown on drawings
2. T_{AL} to consider reductions for creep, chemical and biodegration, and installation damage.
    a) Service time to be 100 yr minimum
    b) Backfill will be structural fill (compacted silty clay/clayey silt)

2.3 PRE APPROVAL SUBMITTALS

A. Contractor shall submit manufacturer's information for each type and strength of geosynthetic product to be used. Submittal shall contain quality control testing and manufacturer control procedures. At a minimum the following shall be submitted.

1. The primary resin used in manufacturing shall be identified as to its ASTM type, class, grade, and category.
    a) For HDPE resin type, class, grade and category in accordance with ASTM D-1248 shall be identified. For example type III, class A, grade E5, category 5.
    b) For PP resins, group, class and grade in accordance with ASTM D-4101 shall be identified. For example group 1, class 1, grade 4.
    c) For Polyester (PET) resins minimum production intrinsic viscosity (ASTM-4603) and maximum carboxyl end groups (ASTM D-2455) shall be identified.
    d) For all products the minimum UV resistance as measured by ASTM D-4355 shall be identified.
2. The adequacy of the data in support of allowable strength (T_a) for geosynthetic reinforcements including
    a) Laboratory test results documenting creep performance over a range of load levels for minimum duration of 10,000 hr. in accordance with ASTM D-5262.
    b) Laboratory test results and methodology for extrapolation of creep data for 75- and 100- year design life.
    c) Laboratory test results documenting ultimate strength in accordance with ASTM D-4595, or GRI-GG1 for geogrids. Tests to be conducted at a strain rate of 10 percent per minute.
    d) Laboratory test results and extrapolation techniques, documenting the hydrolysis resistance of PET, oxidative resistance of PP and HDPE, and stress cracking resistance of HDPE for all components of geosynthetic and values for partial factor of safety for aging degradation calculated for a 75- and 100-year design life. Recommended methods are outlined in FHWA RD 97-144.
    e) Field and laboratory test results along with literature review documenting values for partial factor of safety for installation damage as a function of backfill gradation
    f) Laboratory tests documenting pullout interaction coefficients for various soil types or site specific soils in accordance with GRI: GG5 and GT7.
    g) Laboratory tests documenting direct sliding coefficients for various soil types or project specific soils in accordance with ASTM D-5321

3. The adequacy of the QA/QC plan for the manufacture of geosynthetic reinforcements. Including at a minimum

   a) Manufacturing quality control program and data indicating minimum test requirements, test methods, test frequency, and lot size for each product. Further minimum conformance requirements as proscribed by the manufacturer shall be indicated. The following is a minimum list of conformance criteria required for approval:

Test	Test Procedure	Minimum Conformance Requirement
Wide Width Tensile (geotextiles)	ASTM D-4595	*To be provided*
Specific Gravity (HDPE only)	ASTM D-1505	*by material*
Melt Flow index (PP & HDPE)	ASTM D-1238	*supplier or*
Intrinsic Viscosity (PET only)	ASTM D-4603	*specialty company*
Carboxyl End Group (PET only)	ASTM D-2455	
Single Rib Tensile (geogrids)	GRI:GG1	

4. All determinations of T_{AL} values are to be based on MARV measurements

2.4 CONSTRUCTION SUBMITTALS

A. The Contractor shall submit a manufacturer's certification that the geosynthetics supplied meet the respective index criteria set when the geosynthetic was approved by the Owner, measured in full accordance with all test methods and standards specified. In case of dispute over validity of values, the Engineer can require the Contractor to supply test data from an agency approved laboratory to support the certified values submitted, the Contractor’s cost.

PART 3 EXECUTION

3.1 DELIVERY, STORAGE, AND HANDLING

A. Geosynthetics shall be unloaded, and inspected for damage prior to storing on level ground or pallets. The Contractor shall protect the work described in this Section before, during, and after installation, and shall protect the installed work covered by other Sections.

B. The Contractor shall, during all periods of shipment and storage, protect the geosynthetics from direct sunlight, ultraviolet rays, temperatures greater than 120°F, mud, dirt, dust, debris and other deleterious sources.

C. If the Engineer determines material is damaged the Contractor shall immediately make all repairs and replacements, at no additional cost to the Owner

3.2 INSTALLATION

A. The geosynthetic reinforcement shall be installed in accordance with the manufacturer's recommendations, unless otherwise modified by these specifications. The geosynthetic reinforcement shall be placed within the layers of the compacted soil as shown on the plans or as directed.

B. The geosynthetic reinforcement shall be placed in continuous longitudinal strips in the direction of main reinforcement. Joints in the design strength direction (perpendicular to the slope) shall not be permitted with geotextile or geogrid, except as indicated on the drawings.

C. Horizontal coverage of less than 100 percent shall not be allowed unless specifically detailed in the construction drawings. In the case of 100% coverage in plan view adjacent strips need not be overlapped.

D. Adjacent rolls of geosynthetic reinforcement shall be overlapped or mechanically connected where exposed in a wrap-around face system, as applicable.

E. Place only that amount of geosynthetic reinforcement required for immediately pending work to prevent undue damage. After a layer of geosynthetic reinforcement has been placed, the next succeeding layer of soil shall be placed and compacted as appropriate. After the specified soil layer has been placed, the next geosynthetic reinforcement layer shall be installed. The process shall be repeated for each subsequent layer of geosynthetic reinforcement and soil.

F. Geosynthetic reinforcement shall be placed to lay flat and pulled tight prior to backfilling. After a layer of geosynthetic reinforcement has been placed, suitable means, such as pins or small piles of soil, shall be used to hold the geosynthetic reinforcement in position until the subsequent soil layer can be placed. Under no circumstances shall a track-type vehicle be allowed on the geosynthetic reinforcement before at least 9 inch of soil has been placed. Sudden braking and sharp turning – sufficient to displace fill – shall be avoided.

G. During construction, the surface of the fill should be kept approximately horizontal. Geosynthetic reinforcement shall be placed directly on the compacted horizontal fill surface. Geosynthetic reinforcements are to be placed within 3 inches of the design elevations and extend the length as shown on the elevation view unless otherwise directed by the Owner's Engineer. Correct orientation of the geosynthetic reinforcement shall be verified by the Contractor.

3.3 FINAL SLOPE GEOMETRY VERIFICATION

A. Contractor shall confirm that as-built slope geometries conform to approximate geometries shown on construction drawings.

PART 4 FIELD QUALITY CONTROL

4.1 GENERAL FILL MATERIAL

A. Soil Testing

1. Perform soil testing accordance with the Section 02210 of the RMU-1 technical specifications, except in-place density testing, which shall be performed as indicated in this specification section and on Permit Drawing No. 23 A..

B. In-place Soil Moisture-Density Testing

1. Perform in-place density testing, ASTM 2922, on the upper 2 feet of general fill used in the landfill plateau access road at the frequency described in Section

02210 of the RMU-1 Technical Specifications. Deeper lifts (below the upper 2 ft of general fill) shall only be compacted by tracking over the material with a dozer, except for compaction and in-place density testing, which shall be performed as indicated on Permit Drawing No. 23A

4.2 GEOREINFORCEMENT

A. Inspect all rolls as deployed for damage.

B. Monitor placement of fill and geosynthetics.

C. Perform check for tolerance with design geometry by survey.

END OF SECTION

APPENDIX E

LANDFILL DESIGN CALCULATIONS

E-1. Pipe Strength Calculations for Base and Cover

E-2. Final Cover Drainage Pipe Flow Capacity

E-3. Cover Thickness for Corrugated Steel Pipe

E-4. Access Road Subgrade Evaluation

E-1

PIPE STRENGTH CALCULATIONS

PIPE STRENGTH CALCULATIONS

Objective: Evaluate the strength of pipes used at the proposed landfill by ensuring that pipe deflection is within the tolerance limits. The secondary riser at the cell bases represents the most critical section and so is used for this analysis.

Methodology: Iowa formula by Spangler & Watkins is used:

$$\Delta x = \frac{D\ell\ KWcr^3}{EI+.061\ E'r^3}$$

where

Δx = Horizontal deflection
$D\ell$ = Deflection lag factor
K = Bedding constant
Wc = Vertical load on pipe
r = Mean radius of pipe
I = Movement of inertia per unit Length of pipe wall cross-section
E' = Modulus of soil
E = Modulus of elasticity of pipe

Assumptions: (1) Secondary riser: 24" SDR-11 HDPE with 1/2-inch diameter perforations.

Assume using DRISCOPIPE 1000, from Exhibit 1, the manufacturing data sheet:

O.D. average = 24 inches
thickness t = 2.182 inches
I.D. = 19.636 inches

(2) Sketch of a typical secondary sidewall riser section (see following page)

(3) Material properties:

For final cover and base liner soils, use

γ_s = 130 pcf

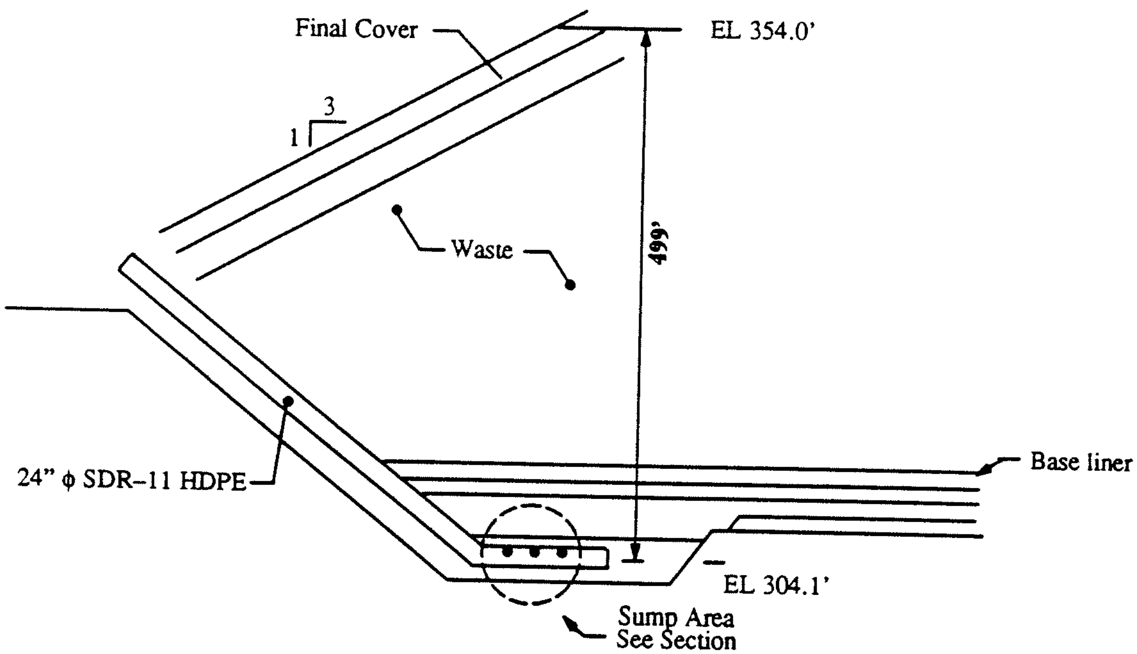
For waste materials, use

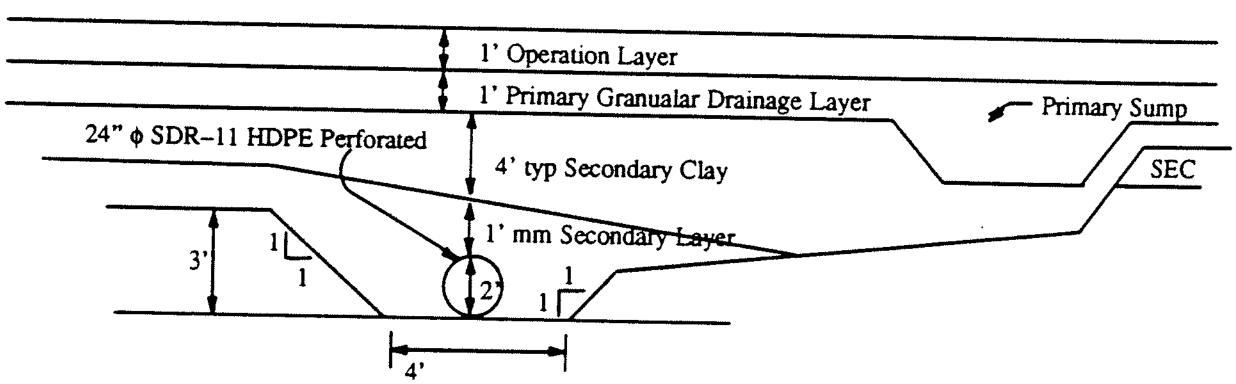
γ_w = 111.1 pcf

Pipe Strength Calculation

1. Calculate pipe deflection of sidewall riser pipe

<u>Sketch</u>: Secondary sidewall riser section





Secondary Sump Section

(4) Pipe properties:

K = 0.102 for end dumped gravel at relative density of 70 percent
E = 35,000 psi (conservative)
E' = 2,000 psi for coarse angular compacted gravel
$D\ell$ = 1.0

Calculate maximum overburden load Wc:

Thickness of Final Cover = 5'
Height of Waste = (354-304.1)' - 5' = 44.9'
Thickness of Base Liner at top of pipe = 1' + 1' + 4' + 1'(min) = 7'

Use γ_{soil} = 130 pcf for final cover and base liners

γ_{waste} = 111.1 pcf for waste mass

$$\text{weighted average } \gamma = \frac{130 \text{ pcf} \times (5+7) + 111.1 \text{ pcf} \times 44.9}{(5+7+44.9)} = 115 \text{ pcf}$$

In this study, a case of a flexible pipe conduit and side fills having the same degree of stiffness as the pipe is assumed, then

$Wc = Cd\ \gamma\ BcBd$*

where Wc = maximum load on the pipe
Cd = load coefficient for ditch conduits
Bc = outside width of the pipe
Bd = horizontal width of ditch at top of conduit
γ = unit weight of fill materials

*Reference: Merlin G. Spangler and Richard L. Handy, "Soil Engineering," 4th Edition, P 734.

The secondary riser at the cell base is in a ditch with 4-foot width at the bottom and 1:1 slope on both sides. According to the reference mentioned above, the width of the ditch at or slightly below the top of the conduit is the proper width to use for Bd in calculating the load. In this case, one side slope of the ditch transfers from 1:1 slope to 2 percent slope at the spring line of the pipe, a typical value of 16 feet for Bd is used.

$$H/Bd = \frac{5' + 44.9' + 7'}{16'} = 3.55$$

From Figure 26.7 on page 736 of the reference book, the curve for maximum Cd for sand and gravel is used, then

$Cd = 2.4$

$Wc = 2.4 \times 115 \text{ pcf} \times 2 \text{ feet} \times 16 \text{ feet} = 8{,}832 \text{ lbs/ft.ft}$

Since pipe is perforated, Wc is factioned to compensate for loss of strength due to perforations.

$$Wc = Wc \text{ (calculated load)} \times \frac{24}{24-P}$$

where P = cumulative inches

$$p = \frac{25 \text{ holes}}{12 \text{ in.}} \times \frac{12 \text{ in.}}{\text{ft}} \times 0.5 \text{ in. (dia. hole)}$$

$p = 12.5$ in./ft of pipe

$$Wc = wc \times \frac{24}{24 - 12.5}$$

$$= 8{,}832 \text{ lb/ft}^2 \times \frac{24}{(24-12.5)}$$

$$= 18{,}432 \text{ lb/ft}^2$$

Calculate Pipe Strength:

$$I = \frac{t3}{12} = \frac{(2.182)^3}{12} = 0.865 \text{ in.}^3$$

$\gamma = (24 \text{ in.} + 19.636 \text{ in.})/2 = 21.818 \text{ in.}$

Convert to lineal load per foot, wc

$$Wc = \frac{\text{external pipe pressure}}{\text{O.D.}} = \frac{18{,}432 \text{ lb/ft}^2}{(2 \text{ ft})} = 9{,}216 \text{ lb/ft}$$

$$\Delta x = \frac{D\ell\ K\ Wc\ \gamma^3}{EI + 0.061\ E'\ \gamma 3}$$

$$= \frac{1.0 \times 0.102 \times 9{,}216 \text{ lb/ft} \times \text{ft}/12 \text{ in.} \times (21.818 \text{ in.})^3}{(35{,}000 \text{ psi} \times 0.865 \text{ in.}^3) + 0.06 \times 2{,}000 \text{ psi} \times (21.818 \text{ in.})^3}$$

$$= 0.6373 \text{ in.}$$

$$\frac{0.6373 \text{ in.}}{24.0 \text{ in.}} \times 100 = 2.7\%$$

The deflection is less than the recommended pipe deflection value of 3.0 percent for SDR-11 HDPE pipe. Ref. Drisco pipe design manual.

RP/CWMNYORK/AC6

DRISCOPIPE 1000

Exhibit

Dimensions and Pressure Ratings

NOMINAL SIZE INCHES	AVERAGE OD INCHES	MINIMUM WALL, INCHES						
		SDR 32.5 50 PSI	SDR 26 65 PSI	SDR 21 80 PSI	SDR 15.5 110 PSI	SDR 11 160 PSI	SDR 9 200 PSI	SDR 7 265 PSI
3	3.500	.108	.135	.167	.226	.318	.389	.500
4	4.500	.138	.173	.214	.290	.409	.500	.643
5	5.563	.171	.214	.265	.359	.506	—	—
6	6.625	.240	.255	.315	.427	.602	.736	.946
7	7.125	.219	.274	.339	—	—	—	—
8	8.625	.265	.332	.411	.556	.784	.958	1.232
10	10.750	.331	.413	.512	.694	.977	1.194	1.536
12	12.750	.392	.490	.607	.823	1.159	1.417	1.821
13	13.386	.412	.515	.637	—	—	—	—
14	14.000	.431	.538	.667	.903	1.273	1.556	2.000
16	16.000	.492	.615	.762	1.032	1.455	1.778	—
18	18.000	.554	.692	.857	1.161	1.636	2.000	—
20	20.000	.615	.769	.952	1.290	1.818	2.222	—
21.5	21.500	.662	.827	1.024	1.387	1.955	—	—
24	24.000	.738	.923	1.143	1.548	2.182	—	—
28	28.000	.862	1.077	1.333	1.806	—	—	—
30	30.000	.923	1.154	1.429	1.935	—	—	—
800mm	31.496	.969	1.211	1.500	2.032	—	—	—
34	34.000	1.046	1.308	1.619	—	—	—	—
36	36.000	1.108	1.385	1.714	2.323	—	—	—
42	42.000	1.292	1.615	2.000	—	—	—	—
48	47.244	1.454	1.817	2.250	—	—	—	—

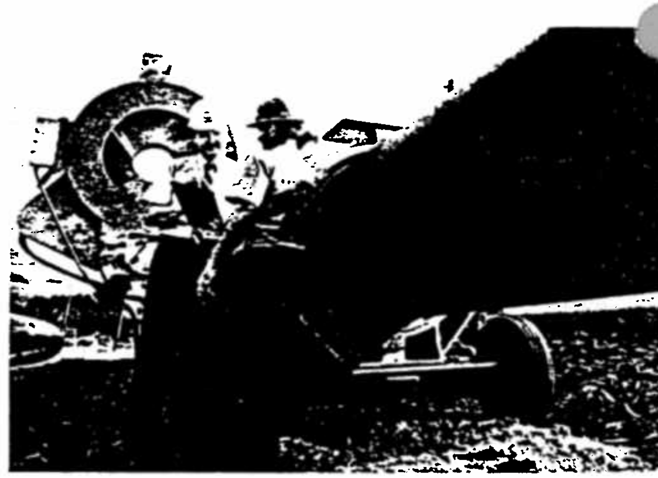
- Dimension and Pressure Ratings, where applicable, are in compliance with ASTM F714, "Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter".
- Short Term Surge Pressures to 2.5 times the pressure rating are allowed.
- Inquire for availability of other sizes, and presure ratings.

Temperature Range

Driscopipe 1000 may be used in pressure applications up to an operating temperature of 140° F. Short term and gravity flow applications operating at higher temperatures are considered. At lower temperatures tests have been conducted on Driscopipe 1000 showing that Driscopipe gains strength at sub-zero temperatures. Driscopipe 1000 maintains its flexibility and integrity to less than -180°F.

The pressure capabilities of polyethylene materials are rerated for operating temperatures other than 73.4° F. Driscopipe 1000 has been tested for thousands of hours at elevated temperatures without thermal degradation. These tests are used to obtain the pressure rerating factors.

Temperature degree F	Pressure Rerating Factor
50	1.14
73.4	1.00
100	0.79
140	0.50



Joining System

Driscopipe is joined by the butt fusion technique. This simple, visual procedure utilizes controlled temperatures and pressure to produce a fused, leak-free joint that is stronger than the pipe itself in both tension and hydrostatic loading. Pioneered and developed by Phillips, the butt fusion joint is recognized in the industry as a joining system of high integrity and reliability. Driscopipe may also be joined to itself, and transitioi to other materials with flanges, compression couplings and other mechanical means.

STRENGTH OF PIPES UNDER ROADS

Objective: Evaluate the strength of pipes used at the proposed landfill by ensuring that pipe deflection is within the tolerance limits. Check that pipes under roads are okay.

Methodology: Iowa formula by Spangler & Watkins is used:

$$\Delta x = \frac{D\ell\ KWcr^3}{EI + .061\ E'r^3}$$

where

Δx = Horizontal deflection
$D\ell$ = Deflection lag factor
K = Bedding constant
Wc = Vertical load on pipe
r = Mean radius of pipe
I = Movement of inertia per unit Length of pipe wall cross-section
E' = Modulus of soil
E = Modulus of elasticity of pipe

Assumptions: (1) Transfer pipe: 8" SDR-11 HDPE with 1/2-inch diameter perforations.

Assume using DRISCOPIPE 1000, from Exhibit 1, the manufacturing data sheet:

O.D. average = 8.625 inches
thickness t = 0.784 inches
I.D. = 7.057 inches

(2) Covered by 3 feet of soil over 2 feet of gravel. Assume unit weight of 120 pcf for all backfill material.

(3) Pipe properties:

K = 0.102 for end dumped gravel at relative density of 70 percent
E = 35,000 psi (conservative)
E' = 2,000 psi for coarse angular compacted gravel
$D\ell$ = 1.0

Revision No. 1
Date: 061892

Calculate maximum overburden load Wc:

Thickness of Cover = 5'

Use γ_{soil} = 120 pcf for material above pipe

In this study, a case of a flexible pipe conduit and side fills having the same degree of stiffness as the pipe is assumed, then

$$Wc = Cd \; \gamma \; BcBd^{*}$$

where Wc = maximum load on the pipe
Cd = load coefficient for ditch conduits
Bc = outside width of the pipe
Bd = horizontal width of ditch at top of conduit
γ = unit weight of fill materials

*Reference: Merlin G. Spangler and Richard L. Handy, "Soil Engineering," 4th Edition, P 734.

From Figure 26.7 on page 736 of the reference book, the curve for maximum Cd for sand and gravel is used, then

Cd = 2.4

$$Wc = 2.4 \times 120 \text{ pcf} \times 0.72 \text{ feet} \times 1 \text{ foot} = 207 \text{ lbs/ft}^2$$

Add pressure from loading from truck. Assume load = 2,000 lbs/ft^2 (approximately a loaded dump truck)

$$Wc = 207 \text{ lbs/ft}^2 + 2{,}000 \text{ lbs/ft}^2 = 2{,}207 \text{ lbs/ft}^2$$

Calculate Pipe Strength:

$$I = \frac{t3}{12} = \frac{(0.784)^3}{12} = 0.040 \text{ in.}^3$$

$$\gamma = (8.625 \text{ in.} + 7.057 \text{ in.})/2 = 7.841 \text{ in.}$$

Convert to lineal load per foot, wc

$$Wc = \frac{\text{external pipe pressure}}{\text{O.D.}} = \frac{2{,}207 \text{ lbs/ft}^2}{(0.72 \text{ ft})} = 3{,}065 \text{ lbs/ft}$$

$$\Delta x = \frac{D\ell \; K \; Wc \; \gamma^3}{EI + 0.061 \; E' \; \gamma 3}$$

$$= \frac{1.0 \times 0.102 \times 3{,}065 \text{ lbs/ft} \times \text{ft}/12 \text{ in.} \times (7.841 \text{ in.})^3}{(35{,}000 \text{ psi} \times 0.040 \text{ in.}^3) + 0.06 \times 2{,}000 \text{ psi} \times (7.841 \text{ in.})^3}$$

$$= 0.2120 \text{ in.}$$

$$\frac{0.2120 \text{ in.}}{8.625 \text{ in.}} \times 100 = 2.5\%$$

The deflection is less than the recommended pipe deflection value of 3.0 percent for SDR-11 HDPE pipe. Ref. Drisco pipe design manual.

RP/CWMNYORK/AC6

DRISCOPIPE 1000

Exhib...

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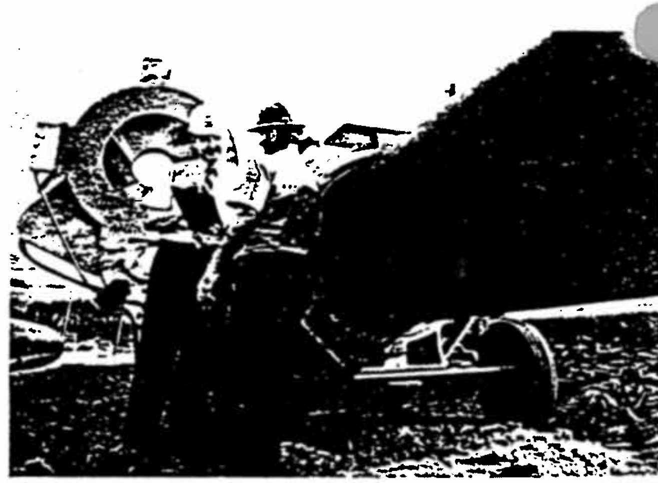

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PIPE LOADING CALCULATIONS
FOR 8" LEACHATE COLLECTION PIPE
CELLS 7 AND 8

5/6/97
Revised: ~~Date Approved~~

TASK: Determine the ability of an 8" diameter schedule 80 PVC pipe and an 8" diameter SDR 13.5 HDPE pipe to withstand the maximum loading due to overburden pressure from the refuse and final cover.

REFERENCES:

1. "Settlement Calculations for Cell 7/8", Prepared by Rust Environment & Infrastructure, September, 1996.
2. Driscopipe Systems Design guide
3. "General Properties of PVC Pipe", from Eslon Thermoplastics.
4. "Deflection - A Mark of Excellence", prepared by Unibell Plastic Pipe Association.

METHOD:

1. Determine the Ring Deflection by determining the soil strain and compare to the allowable ring deflection. To determine the soil strain, use:

$$\varepsilon = P_v / E'$$

where: ε = Granular fill's vertical elastic strain (dimensionless)
P_v = Vertical stress applied to the pipe (lb/ft^2)
E' = granular fill modulus (lb/ft^2)

2. Determine the Factor of Safety against Wall Crushing by finding the actual compressive stress and comparing it to the compressive yield strength of the pipe. Actual compressive stress is determined by:

$$S_A = \frac{(SDR-1)}{2} \times P_V$$

where: S_A = Actual compressive stress
SDR = Standard dimension ratio
= Outside diameter / wall thickness
P_v = Vertical stress applied to the pipe (lb/ft^2)

ASSUMPTIONS:

1. Vertical stress applied to the pipe = 12,159 lb/ft^2. (Reference 1)
2. The initial backfill embedment material will be a granular layer of New York State DOT 1A Stone which has a modulus (E') = 3000 psi. (Reference 2)

CALCULATIONS:

1. Ring Deflection:

$$\varepsilon = P_v / E'$$
$$= 12{,}159 \text{ lb/ft}^2 / 3000 \text{ lb/in}^2 / (144 \text{ in}^2/\text{ft}^2)$$
$$= 0.0281 = 2.81\%$$

For 8" Schedule 80 PVC pipe,allowable ring deflection is limited 7.5% (Reference 4). A deflection of 2.81% is in acceptable limits.

For 8" SDR 13.5 HDPE pipe, allowable ring deflection is limited at 3.4% (Reference 2). A deflection of 2.81% is in acceptable limits.

2. Wall Crushing:

8" Schedule 80 PVC pipe:

Dimensions: Outside diameter: 8.625 in
Thickness: 0.500 in
SDR = 8.625 in / 0.500 in = 17.25

$$S_A = \frac{(SDR-1)}{2} \times P_V$$
$$= \frac{(17.25 - 1)}{2} \times 12{,}159 \text{ lb/ft}^2$$
$$= 98{,}792 \text{ lb/ft}^2 = 686 \text{ lb/in}^2$$

The compressive strength of PVC pipe is 9,600 lb/in^2 (Reference 3). The resulting Factor of Safety against Wall Crushing is:

$$\text{F.S.} = \frac{9{,}600 \text{ lb/in}^2}{686 \text{ lb/in}^2} = \mathbf{14}$$

8" SDR 13.5 HDPE Pipe:

$$S_A = \frac{(SDR-1)}{2} \times P_V$$
$$= \frac{(13.5 - 1)}{2} \times 12{,}159 \text{ lb/ft}^2$$
$$= 75{,}994 \text{ lb/ft}^2 = 528 \text{ lb/in}^2$$

The compressive strength of Driscopipe is 1,500 lb/in^2 (Reference 2). The resulting Factor of Safety against Wall Crushing is:

$$\text{F.S.} = \frac{1{,}500 \text{ lb/in}^2}{528 \text{ lb/in}^2} = \mathbf{2.8}$$

CONCLUSION:

Both 8" Schedule 80 PVC pipe and 8" SDR 13.5 HDPE pipe will be adequate for the leachate collection system.

ESLON THERMOPLASTICS

General Properties Of PVC Pipe

(PVC TYPE I, GRADE 1, CELL CLASSIFICATION 12454-B)

Eslon Thermoplastics, Inc
Charlotte NC 28224

FIGURE 4

	PROPERTIES	VALUE	UNIT	REMARKS	ASTM TEST
MECHANICAL PARAMETERS	Specific Gravity	[illegible] ± 0.02	—	[illegible]	D-792
	Tensile Strength 73°F	7,000	PSI	Same as Circumferential Direction	D-638
	Modulus of Elasticity in Tension	[illegible]	PSI	[illegible]	D-638
	Compressive Strength 73°F	[illegible]	PSI	[illegible]	D-695
	Flexual Strength 73°F	[illegible]	PSI	[illegible]	D-790
	Izod Impact 73°F	[illegible]	ft-lbs/in Notched	[illegible]	D-256
	Hardness Durometer D / Rockwell R	[illegible]	—	[illegible]	D-2240 / D-785
THERMODYNAMICS	Coefficient of Thermal Linear Expansion per °F	[illegible]	in/in/°F	[illegible]	D-696
	Thermal Conductivity	[illegible]	cal/CM²/Sec/°C	[illegible]	C-177
	Specific Heat	[illegible]	cal/g/°C	[illegible]	—
	Maximum Operating Temperature	[illegible]	°F	[illegible]	—
	Heat Distortion Temperature at 264 PSI	[illegible]	°F	[illegible]	D-648
	Decomposition Point	[illegible]	°F	[illegible]	—
	Flammability	[illegible]	—	[illegible]	D-635
ELECTRICAL	Dielectric Strength	[illegible]	Volts/Mil	High [illegible]	D-149
	Dielectric Constant 60 CPS at 30°F	[illegible]	—	[illegible]	D-150
	Power Factor 60 CPS at 30°F	[illegible]	%	[illegible]	D-150
	Specific Volume Resistivity at 73°F	[illegible]	Ohm/CM	[illegible]	D-257
OTHER	Water Absorption	[illegible]	%	Weight gain in 24 hrs. at 73°F	D-570
	Poisson's Ratio	[illegible]	—	[illegible]	—

that time, the most commonly accepted flexible pipe was corrugated steel culvert. Through research and field investigation, it was determined that corrugated steel pipe would begin to reverse curvature at a deflection of about 20%. It was substantiated through testing and evaluation that inverse curvature could be considered the critical failure mode in deflection for that product. Manufacturers and engineers, at that time, selected a *4:1* safety factor and developed the recommended design deflection limit of 5% for that product. Today, this recommendation is readily accepted by most designers of flexible steel pipe systems. Some engineers have not been properly informed regarding the derivation of the 5% deflection limit and thus continue to apply that limit to all flexible pipe products. However, with increased knowledge of each flexible pipe material's critical failure mode, this misunderstanding is becoming less common.

When comparing one flexible pipe product with another, it is important to compare first the critical failure modes related to deflection. Various modes of failure in deflection that should be considered for various other pipe products in addition to inverse curvature collapse and compression wall buckling may include:

- tensile rupture of structural members or fibers
- compression buckling of structural webs
- interlaminar separation in pipe wall

Having then compared maximum deflection limits at which failure can be anticipated, comparison of the selected factors of safety used to develop a recommended design deflection limit should be made. Safety factors selected to insure the structural integrity of any buried pipe system – flexible or rigid – are important. Although PVC sewer pipe is offered with a recommended design deflection limit of 7½% providing a *4:1* factor of safety, flexible sewer pipe produced from other materials may be offered with a recommended design deflection limit of 5% providing factors of safety as low as *1½:1*. As with rigid pipe products, it remains important that the engineer, installer, operator, or owner knows his flexible pipe product – its advantages and limitations.

Having evaluated PVC sewer pipe, the theory behind the product's strength in deflection, the laboratory research and field investigation which supports that theory, and the performance limits which must be considered in selecting deflection limits and design recommendations, the need for deflection testing should be considered.

DEFLECTION TESTING

PVC sewer pipe, when installed in accordance with the Uni-Bell "Recommended Practice for the Installation of Polyvinyl Chloride (PVC) Sewer Pipe – UNI-B-5", will provide long-term performance

with ring deflection less than the recommended maximum limit of 7.5%.[14] Deflection testing of properly installed PVC sewer pipe is unnecessary.

Deflection of buried PVC sewer pipe is essential to the proper performance of the product. Deflection is necessary to transfer the overburden load to the side fill for support. Deflection testing of buried PVC sewer pipe does not measure product quality. It is one of several methods that can be used to verify proper installation practices.[3] When proper installation practices are assured by construction inspection, soils testing, photography or television inspection, deflecting testing is redundant.

With ring deflection of buried PVC sewer pipe maintained at or below the recommended 7.5% maximum limit, the design factor of safety provided to prevent structural failure of the buried pipe will exceed *4:1*. With this large margin of safety, deflection testing of PVC sewer pipe is generally considered unessential to assure proper installation procedures.

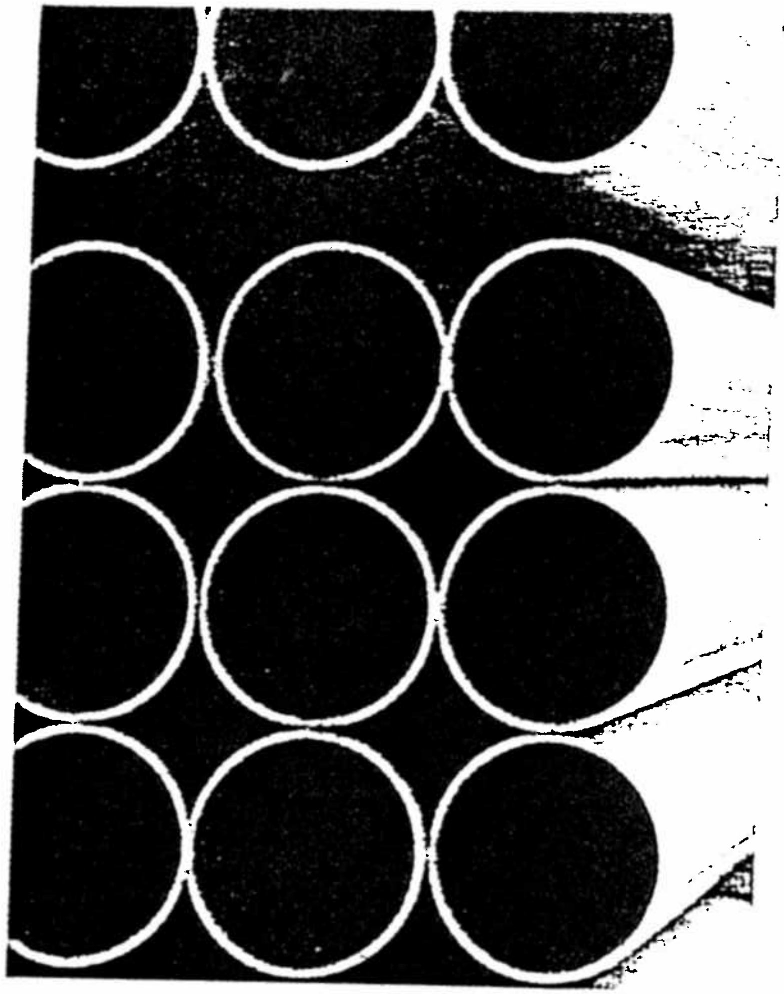
Deflection testing will not be necessary unless in isolated sections of a sewer line one or more of the following conditions are known to exist:

- Improper construction practices are evident
- Questionable embedment materials have been used
- Severe trench construction conditions were encountered
- Other inspection or testing methods have indicated unacceptable installation conditions

When measuring the deflection of buried PVC sewer pipe it is important to recognize that accepted test procedures measure the deflected vertical inside diameter of the pipe. ASTM D 3034, in specifying dimensions for PVC sewer pipe, only establishes average outside diameter, outside diameter tolerance, and *minimum* wall thickness dimensional requirements.[10] It does not specify maximum wall thickness or out-of-roundness tolerances; since such requirements not considered by ASTM to be essential to the proper performance of PVC sewer pipe.

Obviously, the selection of a proper base inside diameter for measurement of PVC sewer pipe deflection cannot be accomplished simply by subtracting two *minimum* wall thicknesses from the average outside diameter. In selection of a base inside diameter for deflection measurement it is important to include reasonable manufacturing tolerances, since the PVC sewer pipe standard does not specify a minimum inside diameter.

Table 9 is recommended by the Uni-Bell Plastic Pipe Association for selection of base inside diameters for deflection measurement of ASTM D 3034 DR 35 PVC sewer pipe.[3]



PVC Pressure Pipe Schedule 40/80

Nominal Size	Outside Diameter	Schedule 40 Wall Thickness	Schedule 40 Press Rating	Schedule 80 Wall Thickness	Schedule 80 Press Rating
4	4.500	0.237	220	0.337	320
6	6.625	0.280	180	0.432	280
8	8.625	0.322	160	0.500	250
10	10.750	0.365	140	0.593	230
12	12.750	0.406	130	0.687	230
14	14.000	0.438	130	—	—
16	16.000	0.500	130	—	—

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PE 3408 Industrial Piping System
Pipe Data and Pressure Ratings

PLEXCO® Chevron

(Pipe weights are calculated in accordance with PPI TR-7)

Pressure Ratings are for water at 73°F. For other fluids and service temperatures refer to Application Note No. 6 Chemical and Environmental Considerations.

PRESSURE RATING		255 psi SDR 7.3		200 psi SDR 9		160 psi SDR 11		130 psi SDR 13.5		110 psi SDR 15.5		100 psi SDR 17		80 psi SDR 21		65 psi SDR 26		50 psi SDR 32.5	
IPS* PIPE SIZE	O.D. SIZE (INCHES)	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT	MIN. WALL (INCHES)	WEIGHT LB/FT
1½″	1.900	—	—	—	—	.173	.41	—	—	—	—	—	—	—	—	—	—	—	—
2″	2.375	.325	.91	.264	.76	.216	.64	—	—	—	—	—	—	—	—	—	—	—	—
3″	3.500	.479	1.98	.389	1.65	.318	1.39	.259	1.15	.226	1.02	.206	.93	—	—	—	—	—	—
4″	4.500	.616	3.27	.500	2.74	.409	2.30	.333	1.90	.290	1.67	.265	1.54	.214	1.26	—	—	—	—
†5″	5.563	.762	5.00	.618	4.18	.506	3.50	.412	2.91	.359	2.57	.327	2.35	.265	1.93	.214	1.58	—	—
6″	6.625	.908	7.09	.736	5.93	.602	4.97	.491	4.13	.427	3.64	.390	3.34	.316	2.74	.255	2.23	.204	1.80
7″	7.125	—	—	—	—	—	—	—	—	—	—	.420	3.87	.340	3.17	.274	2.58	.220	2.09
8″	8.625	1.182	12.01	.958	10.05	.785	8.43	.639	7.00	.556	6.16	.508	5.66	.411	4.64	.332	3.79	.265	3.05
10″	10.750	1.473	18.66	1.194	15.62	.978	13.10	.797	10.89	.694	9.59	.633	8.80	.512	7.21	.413	5.87	.331	4.75
12″	12.750	1.747	26.25	1.417	21.97	1.160	18.43	.945	15.31	.823	13.47	.750	12.36	.608	10.14	.490	8.26	.392	6.67
14″	14.000	1.918	31.64	1.556	26.49	1.273	22.20	1.037	18.44	.903	16.24	.824	14.91	.667	12.22	.538	9.96	.431	8.05
16″	16.000	2.192	41.34	1.778	34.61	1.455	29.00	1.185	24.09	1.032	21.21	.941	19.46	.762	15.97	.615	13.02	.492	10.51
18″	18.000	2.466	52.31	2.000	43.79	1.636	36.69	1.333	30.48	1.161	26.85	1.059	24.65	.857	20.19	.692	16.48	.554	13.29
20″	20.000	2.740	64.57	2.222	54.05	1.818	45.30	1.481	37.64	1.290	33.13	1.176	30.42	.952	24.92	.769	20.34	.615	16.41
22″	22.000	—	—	2.444	65.41	2.000	54.82	1.630	45.56	1.419	40.09	1.294	36.81	1.048	30.19	.846	24.62	.677	19.87
24″	24.000	—	—	2.667	77.85	2.182	65.24	1.778	54.22	1.548	47.72	1.412	43.82	1.143	35.92	.923	29.29	.738	23.62
†26″	26.000	—	—	2.889	91.35	2.364	76.58	1.926	63.63	1.677	56.02	1.529	51.40	1.238	42.13	1.000	34.39	.800	27.74
†28″	28.000	—	—	—	—	2.545	88.79	2.074	73.76	1.806	64.94	1.647	59.62	1.333	48.86	1.077	39.89	.862	32.20
†30″	30.000	—	—	—	—	2.727	101.94	2.222	84.68	1.935	74.56	1.765	68.45	1.429	56.13	1.154	45.78	.923	36.92
†32″	32.000	—	—	—	—	2.909	115.99	2.370	96.35	2.065	84.88	1.882	77.86	1.524	63.83	1.231	52.10	.985	42.04
†34″	34.000	—	—	—	—	3.090	130.92	2.519	108.80	2.194	95.83	2.000	87.91	1.619	72.06	1.308	58.79	1.046	47.44
†36″	36.000	—	—	—	—	—	—	—	—	2.323	107.40	2.118	98.56	1.714	80.79	1.385	65.93	1.108	53.18

*Industrial PE (polyethylene) pipe sizes are identified by IPS (iron pipe size) diameters which designate the nominal diameter for 12″ IPS AND SMALLER PIPE, AND O.D. (outside diameter) for 14″ IPS and larger pipe.

Check with your PLEXCO sales office for availability of dimensions not listed.

† SUBJECT TO MINIMUM ORDER QUANTITIES, AND AVAILABILITY OF TOOLING.

Rev. 1/90

PIPE LOADING CALCULATIONS
FOR 8" LEACHATE COLLECTION PIPE
CELLS 9 THROUGH 14

4/8/98
Revised: ~~Date Approved~~

CLIENT CWM
PROJECT Model City Residual Management Unit No. 1

SUBJECT Pipe Loading Calculations For Proposed Cells 9 through 14

Prepared By JPD Date 05/05/97
Reviewed By KDM Date 05/05/97
Approved By ________ Date ________

TASK:

To determine the ability of 8 in. diameter Schedule 80 PVC pipe to withstand the maximum loading due to overburden pressure from the waste and final cover at the Model City, RMU-1 Facility. Present information from the PVC supplier to show that the perforated PVC pipe has capacity of withstanding the overburden pressure.

REFERENCES:

1. "General Properties of PVC Pipe," from Eslon Thermoplastics (Attachment B).
2. "Deflection - A Mark of Excellence," prepared by Unibell Plastic Pipe Association.
3. Appendix E-1 of Attachment L - Engineering Report for Residuals Management Unit 1 of "Part 373 Permit for Residuals Management Unit 1 (RMU-1)."
4. Buried Pipe Design, A.P. Moser (Attachment A).
5. Technical Information from Harvel Plastics, Inc. (Attachment C).

METHOD:

1. Determine the maximum loading due to overburden pressure by multiplying the maximum waste height by the unit weight of the waste, multiplying the unit weight of the cover soils by the cover soil thickness and summing the two.

2. Determine the vertical deflection of the pipe using the Modified Iowa equation developed by Spangler and Watkins (reference 2):

$$\Delta x = \frac{DI \times K \times W \times (R)^3}{E\ I + 0.061\ E' \times (R)^3}$$

Where:
- Δx = Vertical Deflection of Pipe (inches)
- DI = Deflection Lag Factor = 1.0 (reference 3)
- K = Bedding Constant = 0.10 (reference 2)
- W = Earth Loading on Pipe (pounds per linear inch)
- E = Modulus of Elasticity of Pipe (psi)
- I = Moment of Inertia (in^3) = $t^3/12$
  Where t = Pipe Wall Thickness (in)
- E′ = Soil Modulus (psi)
- R = Mean Radius of Pipe (in)

Determine the percent deflection from the following formula:

$$\%\ def = \frac{\Delta x}{D} \times 100$$

Where:
- Δx = Vertical Deflection of Pipe (inches)
- D = Nominal Pipe Outside Diameter (inches)

The maximum deflection limit for PVC pipe is 7.5% (reference 4). See attached letter from PVC supplier (reference 5).

3. Determine the Factor of Safety against Wall Crushing by finding the actual compressive stress and comparing it to the compressive yield strength of the pipe. Actual compressive stress is determined by:

$$S_A = \frac{(SDR-1)}{2} \times P_v$$

CLIENT CWM
PROJECT Model City Residual Management Unit No. 1

SUBJECT Pipe Loading Calculations For Proposed Cells 9 through 14

Prepared By JPD Date 05/05/97
Reviewed By KDM Date 05/05/97
Approved By ________ Date ________

Where: S_A = Actual Compressive Stress (psf)
SDR= Standard Dimension Ratio = Outside Diameter/Wall Thickness
P_V = Vertical Stress Applied to the Pipe (psf)

ASSUMPTIONS

1. The unit weight of the final cover soils is 130 pcf. The final cover thickness is 5 feet. The unit weight of the waste is 111 pcf. The unit weight of the base liner system materials is 130 pcf. The thickness of the base liner system is approximately 3.83 ft.

2. The initial backfill embedment material will be a granular layer of New York State DOT 1A Stone which has a modulus of E′=3,000 psi for crushed rock (reference 3).

3. A modulus of elasticity of 400,000 psi will be used for PVC pipe (reference 2).

CALCULATIONS:

1. Maximum Loading Due to Overburden Pressure

The waste height was determined at N92+60, E22+20 where the difference between the top of waste grades and top of secondary clay liner is the greatest based on site geometry.

418.5 ft (top of waste el.) - 315 ft (top of secondary clay el.) - 4.5 ft (thickness of liner system) = 99 ft.

This waste height provides an allowance for the possibility of a future waste height increase at RMU-1.

The maximum overburden pressure is calculated as follows:
(130 pcf x 3.83 ft) + (130 pcf x 5 ft) + (111 pcf x 99 ft) = 12,137 psf

The overburden pressure must be in pounds per linear inch of pipe (ppi) for input into the Spangler equation. To convert psf to psi multiply by 1 ft^2 / 144 in^2. To convert psi to pounds per linear inch multiply by the outside diameter of the pipe. The outside diameter of 8 in. PVC pipe is 8.625 in. (reference 1).

$$12{,}137 \text{ psf} \times 1 \text{ ft}^2 / 144 \text{ in}^2 \times 8.625 \text{ in} = 727 \text{ ppi}$$

2. Percent Deflection For 8 Inch Schedule 80 PVC Pipe:

$$\Delta x = \frac{DI \times K \times W \times (R)^3}{E\ I + 0.061\ E' \times (R)^3}$$

Δx = Vertical Deflection of Pipe (inches)
DI = Deflection Lag Factor = 1.0 (reference 3)
K = Bedding Constant = 0.10 (reference 2)
W = Earth Loading on Pipe (pounds per linear inch) = 727 ppi
E = Modulus of Tensile Elasticity of Pipe (psi) = 400,000 psi (reference 2)
E′ = Soil Modulus (psi) = 3,000 psi (reference 3)
I = Moment of Inertia (in^3) = t^3 /12
Where t = Pipe Wall Thickness (in) = 0.500 in. (reference 1)
R = Mean Radius of Pipe (in) = (8.625 in. + 7.625 in.) / 4 = 4.0625 in. (reference 1)

$$\Delta x = \frac{(1.0) \times (0.1) \times (727\ ppi) \times (4.0625\ inches)^3}{(400{,}000 lbs/sqin) \times \frac{0.5\ inches)^3}{12} + 0.061\ (3{,}000\ lbs/sqin) \times (4.0625\ inches)^3}$$

Δx = 0.30 in.

$$\%\ def = \frac{\Delta x}{D} \times 100$$

Δx = Vertical Deflection of Pipe (inches) = 0.30 in.

$$\%\ def = \frac{0.30}{8.625} \times 100$$

D = Nominal Pipe Outside Diameter (inches) = 8.625 in.
% def = 3.48%

For 8" Schedule 80 PVC pipe, allowable deflection is limited to 7.5% (reference 4). A deflection of 3.48% is within acceptable limits.

From the suppliers test information a perforated 8" Schedule 80 PVC pipe sample required 570 pounds of force to create a 7.5% deflection in the laboratory. Using ASTM D2412 (page 4) the Spangler equation can be used to determine pipe stiffness and deflection under earth loading as follows:

PS = $F/\Delta x$ = 570 lbs/.647 in. = 881 lbs/in

$$x = \frac{(1.0)\ (0.1)\ (727\ ppi)}{0.149\ (881\ ppi) + 0.061\ (3000\ psi)}$$

x = 0.23 in. deflection under earth loading which is less than the 7.5% allowable deflection.

2. Wall Crushing

$$S_A = \frac{(SDR-1)}{2} \times P_V$$

Dimensions:		
	Outside Diameter	= 8.625 in.
	Thickness	= 0.500 in.
	SDR = 8.625 in / 0.500 in	= 17.25

S_A = (17.25 - 1) x 12,137 psf/2
S_A = 98,613 psf = 685 psi

The Compressive Strength of PVC pipe is 9,600 psi (reference 1). The resulting Factor of Safety against wall crushing is:

F.S. = 9,600 psi / 685 psi = 14.0

CONCLUSIONS:

The 8" Schedule PVC pipe will be adequate for the leachate collection system for Cells 9 through 14.

ATTACHMENT A

Buried Pipe Design, Page 73

BURIED PIPE DESIGN

A.P. MOSER

inforcement is ...itted. However, the resulting radial strength may be adequate if deflections are controlled. Radial tension is given by

$$\sigma_r = \frac{T}{t(R + y)}$$

$$T = \int_{-c}^{y} \sigma \, da$$

where σ_r = radial tension stress
t = wall thickness
R = radius
y = distance from neutral axis to point in question
c = $t/2$
σ = stress in tangential direction as function of position in wall (My/I)
da = $(dy) \times$ (unit length)

A discussion of radial tension in curved members can be found in most advanced solid mechanics texts.

Delamination may also be caused by chemical action. A prime example is the corrosion of reinforcing steel. When corrosion takes place, corrosion products produce interlaminar pressure which can result in delamination. Reinforcement is usually protected and will not corrode except in case of product misapplication.

Safety factors

The need for selecting a design load that is less than the performance limit load arises mainly from uncertainties. These uncertainties are in service conditions, loads, uniformity in materials, and assumptions made in design. Thus, a reduction factor is needed and is usually referred to as a safety factor or factor of safety.

Rigid pipe. The safety factor for rigid pipe is usually based on the performance limit of injurious cracking.

W_f = load to cause failure (cracking)

W_w = safe working load

$$W_w = \frac{W_f}{SF}$$

SF = safety factor

The acceptable safety factor is

$$SF = 1.5$$

Thus, if a load of 2000 lb/ft will cause cracking, the safe design load should be 2000/1.5 = 1333 lb/ft.

Flexible pipe. Performance limits for flexible pipes are usually deflection related. Safety factors are then often based on deflection instead of being based on load. For example, if a cement-lined pipe has injurious cracking at 3 percent deflection, a design deflection of 2 percent would be based on a safety factor of 1.5. The design engineer has the responsibility to design the installation (pipe, bending, backfill, and so forth) so that the calculated design deflection does not exceed 2 percent.

Each product will exhibit different performance limits and the factor of safety is usually 1.5 or greater. For flexible products which exhibit only deflection as a performance limit, the design deflection is 7.5 percent and the factor of safety is 4 or greater.

The inexperienced design engineer should consider each possible performance limit, in succession, until the performance limit which occurs at the lowest load or deflection is arrived at. The factor of safety is then based on that performance limit. Literature published by the pipe manufacturer is very helpful in assessing the capabilities and limitations of pipe products.

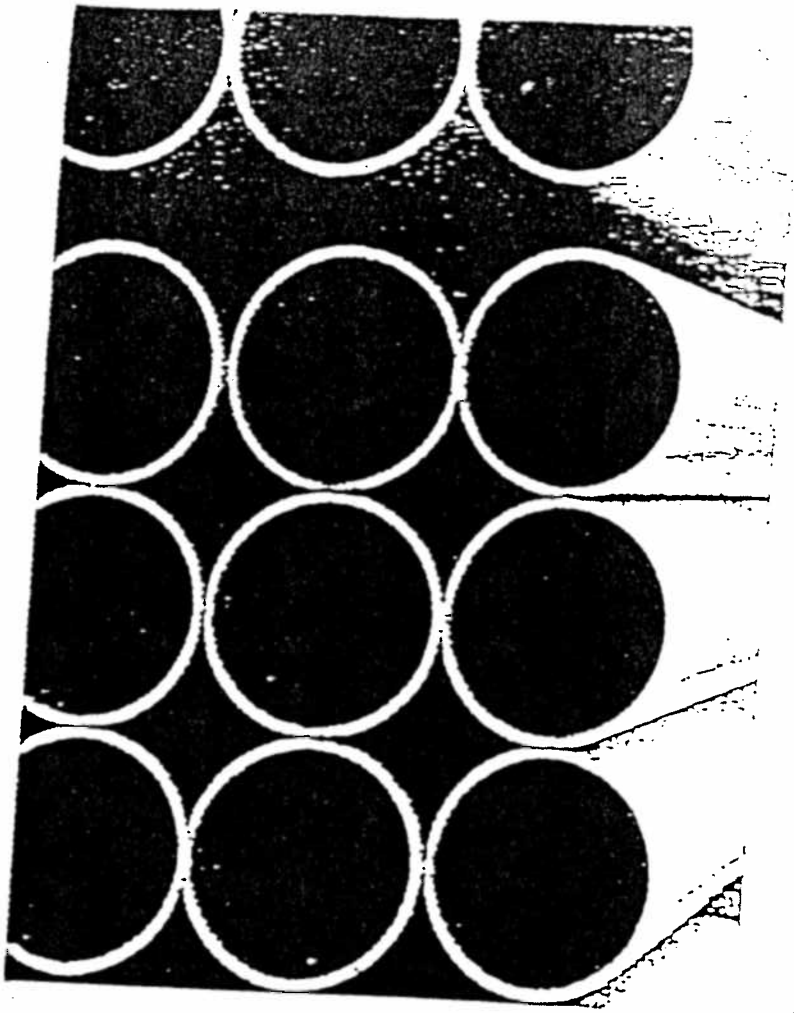
When a pipe deflects under load, bending strains are induced in the pipe wall. These strains vary linearly through the pipe wall. Somewhere within the wall section (usually about the center) these bending strains will be zero.

Profile-wall pipes are designed and manufactured to minimize the use of material by increasing the section modulus of the pipe wall. "Profile-wall" is a relatively new designation, but the concept is not new. Corrugated steel pipe is truly a profile-wall pipe. Some of the newer plastic products introduced in the last several years are of this type. That is, the plastic is placed primarily at the inside and outside walls or in ribs for higher pipe stiffness. Many of these products have been shown to perform with the profile section acting as a unit as designed. For adequate safety, for any such product, the design should include sufficient plastic between the inner and outer walls and/or between the ribs to carry shear and to ensure that the profile section indeed acts as a unit.

The placement of a rigid-like filler material between walls as a substitute, will impart a brittle-like behavior to the pipe and will interfere with the pipe's ability to deflect without cracking. Such pipes often deflect as a flexible pipe and have a brittle behavior and crack under deflection. Some pipes manufactured in this manner are sometimes referred to as semirigid. This is simply a misnomer. Many solid

ATTACHMENT B

"General Properties of PVC Pipe"



PVC Pressure Pipe Schedule 40/80

		Schedule 40		Schedule 80	
Nominal Size	Outside Diameter	Wall Thickness	Press Rating	Wall Thickness	Press Rating
4	4.500	0.237	220	0.337	320
6	6.625	0.280	180	0.432	280
8	8.625	0.322	160	0.500	250
10	10.750	0.365	140	0.593	230
12	12.750	0.406	130	0.687	230
14	14.000	0.438	130	—	—
16	16.000	0.500	130	—	—

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ESLON

General Properties Of PVC Pipe

(PVC TYPE I, GRADE 1, CELL CLASSIFICATION 12454-B)

Eslon Thermoplastics, Inc
Charlotte NC 28224

FIGURE 7

	PROPERTIES	VALUE	UNIT	REMARKS	ASTM TEST
MECHANICAL PARAMETERS	Specific Gravity	[illegible]	—	[illegible]	D-792
	Tensile Strength 73°F	[illegible]	PSI	[illegible]	D-638
	Modulus of Elasticity in Tension	[illegible]	PSI	[illegible]	D-638
	Compressive Strength 73°F 9,600	[illegible]	PSI	[illegible]	D-695
	Flexural Strength 73°F	[illegible]	PSI	[illegible]	D-790
	Izod Impact 73°F	[illegible]	ft-lb/in Notched	[illegible]	D-256
	Hardness: Durometer D Rockwell R	[illegible]	—	[illegible]	D-2240 D-785
THERMODYNAMICS	Coefficient of Thermal Linear Expansion per °F	[illegible]	in/in/°F	[illegible]	D-696
	Thermal Conductivity	[illegible]	[illegible]	[illegible]	C-177
	Specific Heat	[illegible]	[illegible]	[illegible]	—
	Maximum Operating Temperature	[illegible]	°F	[illegible]	—
	Heat Distortion Temperature at 264 PSI	[illegible]	°F	[illegible]	D-648
	Decomposition Point	[illegible]	°F	[illegible]	—
	Flammability	[illegible]	—	[illegible]	D-635
ELECTRICAL	Dielectric Strength	[illegible]	Volts/Mil	High [illegible]	D-149
	Dielectric Constant 60 CPS at 30°F	[illegible]	—	[illegible]	D-150
	Power Factor 60 CPS at 30°F	[illegible]	%	[illegible]	D-150
	Specific Volume Resistivity at 73°F	[illegible]	Ohm/Cm	[illegible]	D-257
OTHER	Water Absorption	[illegible]	%	[illegible]	D-570
	Poisson's Ratio	[illegible]	—	[illegible]	—

ATTACHMENT C

TECHNICAL INFORMATION
OBTAINED FROM HARVEL PLASTICS, INC.

HARVEL P.O. BOX 757 EASTON, PA. 18044-0757
PHONE: 610-252-7355 FAX: 610-253-4436

October 24, 1997

10 Pages Total

FAX TO: Mr. Kevin McKeon
Rust Environment & Infrastructure
(215) 269-2171

FROM: Bill Weaver
Technical Services

RE: 8" PVC Schedule 80 Pipe Deflection in Landfill Application

Dear Mr. McKeon:

The allowable ring deflection of 7.5% is well documented for rigid PVC piping. Per your request, we have performed testing on a sample of PVC 8" Schedule 80 pipe containing perforations (5/8" drilled holes; 120°pattern). This sample was subjected to parallel plate loading per ASTM D1785 (section 8.6 flattening). The results of this testing revealed that the perforated sample required 570 pounds of force to create a deflection of 7.5%; no signs of failure were evident at this deflection. (ASTM D2412 can be referenced using this information to calculate deflection under earth load using the modified Spangler equation as referenced in Appendix X1.1 of ASTM D2412.). It should be noted that the test sample was then further compressed to a 60% deflection (40% of pipe OD) with out any evidence of splitting, cracking, or breaking.

Please refer to the attached excerpt from ASTM D1785 pertaining to flattening resistance. This is a performance test method called out within this standard to quantify the pipe integrity when subjected to compressive load conditions. This test requires that the pipe be compressed between parallel plates using a uniform load within a specific time frame until 60% compression (deflection) is obtained. There shall be no signs of failure when subjected to this test. I have attached a copy of test results obtained from a recent production run of our 8"PVC Schedule 80 piping for reference. As the documented Quality Control Test results indicate, Harvel Plastics, Inc. PVC piping typically goes wall to wall (100% deflection) without evidence of failure. In addition to this information, this report also reveals the consistent integrity of our piping when subjected to the other performance test requirements called out within ASTM D1785. It should also be noted that as part of our Canadian Standards Association Listing, we are required to conduct impact testing at 32°F in addition to the other requirements of this Standard, as well as to the requirements of ASTM, and the National Sanitation Foundation (NSF). We feel that this additional testing routinely performed on our products is noteworthy. Please note that we consider the attached Q.C. results to be proprietary in nature, and that we are providing them directly to you toward addressing the issue at hand.

We are hopeful that the following information will prove beneficial. Please call with any questions you may have.

HARVEL PLASTICS, INC.

[illegible] Kuebler Rd., P.O. Box 757, Easton, Pa [illegible]
Tel [illegible] • Fax [illegible]
website [illegible] • e-mail [illegible]

CRITICAL COLLAPSE PRESSURE RATING OF HARVEL PVC AND CPVC PIPING IN PSI (and inches of water)

Based @ 73°F with no safety factor, appropriate temperature de-rating factors must be applied for the material selected when working at temperatures greater than 73°F

SIZE	DUCT	SDR 41	SDR 26	SDR 21	SCH 40	SCH 80	SCH 120
2"	N/A	▲	▲	▲	316 (8746)	939 (25989)	1309 (36230)
2 1/2"	N/A				451 (12483)	975 (26986)	1309 (36230)
3"	N/A				307 (8497)	722 (19983)	1128 (31221)
3 1/2"	N/A				217 (6006)	578 (15998)	N/A
4"	N/A				190 (5259)	451 (12482)	1128 (31221)
5"	N/A				117 (3238)	N/A	N/A
6"	N/A	*17 (470)*	*74 (2048)*	*126 (3487)*	90 (2491)	343 (9493)	722 (19983)
6" x 1/8"	5.2 (144)	N/A	N/A	N/A	N/A	N/A	N/A
6 x 3/16"	20.7 (426)	N/A	N/A	N/A	N/A	N/A	N/A
8"	10.0 (193)				58 (1605)	235 (6504)	N/A
10"	5.4 (100)				49 (1356)	217 (6006)	N/A
12"	3.0 (60)				42 (1162)	199 (5508)	N/A
14"	2.5 (45)				40 (1107)	194 (5369)	N/A
16"	1.6 (30)				40 (1107)	181 (5010)	N/A
18"	1.0 (25)				33 (913)	162 (4484)	N/A
20"	1.3 (28)				28 (775)	157 (4346)	N/A
24"	1.0 (20)	▼	▼	▼	25 (692)	150 (4152)	N/A

SDR Series Pipe maintains the same collapse ratings for all sizes due to the wall thickness/OD ratio.

Appropriate temperature de-rating factors must be applied at temperatures other than 73 °F based on the material selected.

CRITICAL COLLAPSE PRESSURE is the maximum allowable pressure that can be applied externally to pipe, and is directly related to the wall thickness of the pipe selected. Examples of external pressure conditions can occur: when buried pipe is subjected to soil loads; underwater applications; vacuum service; and pipe installed on pump suction lines. The actual external load being applied to the pipe is the difference between the external pressure and the internal pressure which counter act each other. As a

Physical Properties of Harvel Rigid PVC & CPVC Pipe

Properties	ASTM Test Method	PVC 1120 (Normal Impact)	PVC 2110 (Hi Impact)	Harvel CPVC 4120
Mechanical				
Specific Gravity, g/cm³	D792	1.40 ± .02	1.37 ± .02	1.55 ± .02
Tensile Strength at 73° F psi	D638	7,450	6,400	8,000
Modulus Elasticity In Tension, psi at 73° F	D638	420,000	385,000	360,000
Compressive Strength, psi at 73° F	D695	9,600	8,600	9,000
Flexural Strength at 73° F psi	D790	14,450	11,850	15,100
Izod Impact, ft. lb./in. notch at 73° F	D256	.75	10.9	1.5
Hardness Durometer D	D2240	82 ± 3	78 ± 3	—
Hardness Rockwell R	D785	110 - 120	—	119
Thermal				
Coefficient of Thermal Conductivity $\frac{(Cal.)(cm)}{(cm^2)(sec.)(°C)} \times 10^{-4}$	C177	3.5	4.5	0.95
Coefficient of Linear Expansion	D696			
$\times 10^{-5}$ cm/cm °C		5.2	9.9	6.2
$\times 10^{-5}$ in/in °F		2.9	5.5	3.4
Heat Distortion Temperature, °F at 264 psi	D648	170	146	217
Specific Heat, Cal./°C/gm	D2766	0.25	0.25	—
Upper Service Temp. Limit °F		140	140	200
Flammability				
Average Time of Burning (sec.)	D635	<5	<5	<5
Average Extent of Burning (mm)		<10	<15	<10
Flame Spread Index	E162	<10	—	<10
Flame Spread	E84	10-25	—	4-18
Flash Ignition		730°F	—	900°F
Smoke Developed*		600-1000	—	9-169
Flammability (.062")	UL-94	V-O	—	V-O, 5VB, 5VA
Softening Starts, approx. °F		250	—	295
Material Become Viscous, °F		350	—	395
Material Carbonizes, °F		425	—	450
Limiting Oxygen Index (LOI)			—	60
Electrical				
Dielectric Strength, volts/mil	D149	1,413	1,085	1,250
Dielectric Constant	D150			
60 cps at 30°C		3.70	3.90	—
1000 cps at 30°C		3.62	3.31	—
Power Factor %	D150			
60 cps at 30°C		1.25	2.85	—
1000 cps at 30°C		2.82	3.97	—
Volume Resistivity at 95°C, ohms/cm/10^{12}		1.2	2.4	—
Harvel Rigid Pipe is non-electrolytic.				
Other Properties				
Water Absorption, % increase— 24hrs. at 25°C	D570	0.05	0.10	0.03
Light Transmission	E308	Opaque	Opaque	—
Light Stability		Excellent	Excellent	—
Effect of Sunlight		Slight Darkening	Slight Darkening	—
Color (Standard)		Dark Grey	Light Grey	Medium Grey
Material Cell Classification				
ASTM D1784		12454-B	16334-D	23447-B
ASTM D3915		12452-4	14341-1	23444-4

ASTM D1784 and D3915 refer to similar compounds. The major difference is that the alphabetical sixth place designation refers to corrosion resistance under ASTM D1784, and the sixth place designation under D3915 refers to the hydrostatic design stress. In addition, D3915 also places upper limits for values in the second through the fifth place designations.

*Tests performed on pipe sizes 3/4" - 4" with a single pipe exposed each test. Some of the CPVC pipes were water filled and these resulted in the lower smoke development values.

NOTE: Harvel CPVC pipe is extruded from Corzan™ CPVC compounds manufactured by BF Goodrich Speciality Polymers and Chemicals Division.

E-2

FINAL COVER DRAINAGE PIPE FLOW
CAPACITY

FINAL COVER DRAINAGE PIPE FLOW CAPACITY CALCULATIONS

Purpose: Determine required size for drainage pipe located within final cover at drainage swales. Expected flow must be less than allowable flow in corrugated slotted pipe selected.

A. Expected flow to drainage pipe from geonet within final cover

Q_{EXP} = Expected flow

Q_{EXP} = (largest contributing area) x (infiltration rate to geonet)

Maximum contributing drainage area = 437,500 ft^2

Infiltration rate to geonet = .435 in./day from HELP model analysis

$$.435 \text{ in./day} \times \frac{1 \text{ ft}}{12 \text{ in.}} \times \frac{1 \text{ day}}{24 \text{ hr}} \times \frac{1 \text{ hr}}{3600 \text{ sec}} = 4.2 \times 10^{-7} \text{ ft/sec}$$

$Q_{EXP} = 437{,}500 \text{ ft}^2 \times 4.2 \times 10^{-7} \text{ ft/sec}$

$Q_{EXP} = 0.18 \text{ ft}^3/\text{sec}$

B. Determine Required Pipe Size

Mannings Equation

$$Q_{MAX} = \frac{1.49}{n} R^{2/3} S^{1/2} A$$

Q_{MAX} = Maximum flow allowable

n = Mannings roughness coefficient

n = 0.018 for corrugated polyethylene pipe from ADS, Advanced Drainage Systems, Inc., Form No. L-1061, 1986

$R = \text{Hydraulic radius} = \frac{\text{Diameter}}{4}$ - Pipe flowing full

$$6 \text{ in. pipe } R = \frac{.5}{4} = 0.125$$

$$4 \text{ in. pipe } R = \frac{.333}{4} = 0.083$$

S = Pipe slope = 0.01

A = Pipe area = πr^2

6 in. pipe = 0.196 ft^2

4 in. pipe = 0.087 ft^2

$$6 \text{ in. pipe } Q_{MAX} = \frac{1.49}{0.018} (0.125)^{2/3} (0.01)^{1/2} (0.196)$$

$$= \underline{\underline{4.06 \ ft^3/sec}}$$

$$4 \text{ in. pipe } Q_{MAX} = \frac{1.49}{0.018} (0.083)^{2/3} (.01)^{1/2} (0.087)$$

$$= \underline{\underline{0.14 \ ft^3/sec}}$$

Chose 6 in. pipe for final cover drainage swale.

$Q_{MAX} > Q_{EXP}$

E-3

COVER THICKNESS FOR CORRUGATED STEEL PIPE

CULVERT BACKFILL THICKNESS EVALUATION

Note: Table obtained from Armco Corrugated Steel Pipe - Technical Manual, Page 21

- This chart assumes backfill unit net of 120 pcf.

- Yield point of steel ≈ 33,000 psi.

Summary: Base on Table A 24-in. or 36-in. corrugated steel pipe needs nominal 12 in. of cover. It is assumed construction equipment, i.e., dozers and front end loaders, do no exceed E-80 loading.

Scope: Evaluate Overburden Thickness Over Culvert to Prevent Failure of Culverts

Table 16. Height–of–Cover Limits for Corrugated Steel Pipe 2 2/3" x 1/2" Corrugations

Diameter or Span in Inches	H 20 Live Load Min. Cover*	Maximum Cover in Feet H 20 or E 80 — Specified Thickness: 18 Ga.** 0.052 In.	16 Ga.** 0.064 In.	14 Ga.** 0.079 In.	12 Ga.** 0.109 In.	10 Ga.** 0.138 In.	8 Ga.** 0.168 In.	E80 Live Load Min. cover*	Diameter or Span in Inches
12	12 Inches	199	248	310				12 Inches	12
15	12 Inches	159	199	248				12 Inches	15
18	12 Inches	132	166	207				12 Inches	18
21	12 Inches	113	142	178	249			12 Inches	21
24	12 Inches	99	124	155	218			12 Inches	24
27	12 Inches		111	138	193			12 Inches	27
30	12 Inches		99	124	174			12 Inches	30
36	12 Inches		83	103	145	186		12 Inches	36
42	12 Inches		71	88	124	160	195	12 Inches	42
48	12 Inches		62	77	109	140	171	12 Inches	48
54	12 Inches			66	93	120	147	18 in.	54
60	12 Inches				79	102	125	18 in.	60
66	12 Inches				68	87	107	18 in.	66
72	12 Inches					73	89	18 in.	72
78	12 Inches						74	24 in.	78
84	12 Inches						61	24 in.	84
90	12 Inches						50	24 in.	90
96	12 Inches						41	24 in.	96

*From top of pipe to top of subgrade.

Table 17. Height–of–Cover Limits for Corrugated Steel Pipe 3" x 1" Corrugations

Diameter or Span in Inches	H 20 Live Load Min. Cover*	Maximum Cover in Feet H 20 or E 80 — Specified Thickness: 18 Ga.** 0.052 In.	16 Ga.** 0.064 In.	14 Ga.** 0.079 In.	12 Ga.** 0.109 In.	10 Ga.** 0.138 In.	8 Ga.** 0.168 In.	E80 Live Load Min. cover*	Diameter or Span in Inches
36	12 Inches	76	95	121	167	214	263	12 in.	36
42	12 Inches	65	81	102	143	185	225	12 in.	42
48	12 Inches	57	71	91	125	161	197	12 in.	48
54	12 Inches		63	80	111	143	175	18 in.	54
60	12 Inches		57	72	100	129	156	18 in.	60
66	12 Inches		52	66	91	117	143	18 in.	66
72	12 Inches		47	60	83	107	131	18 in.	72
78	12 Inches		44	55	76	99	121	24 in.	78
84	12 Inches		40	53	71	92	112	24 in.	84
90	12 Inches		38	48	66	85	105	24 in.	90
96	12 Inches		35	45	62	80	98	24 in.	96
102	18 in.		33	42	58	75	92	30 in.	102
108	18 in.			39	54	69	84	30 in.	108
114	18 in.			35	49	63	77	30 in.	114
120	18 in.				45	58	72	30 in.	120

*From top of pipe to top of subgrade.
***Gages shown for information purposes only.*

E-4

ACCESS ROAD SUBGRADE
EVALUATION

ACCESS ROAD SUBGRADE EVALUATION

Scope: Evaluate road subgrade for proposed vehicle activities to landfill.

Condition: Evaluate worst case condition where subgrade will consist of surficial clay till soils.

- Subgrade clay soils.
- C = 1,000 psf = 6.9 psi say 7.0 psi.
- Assume 108,000 lb. GVW truck.
- Tire pressure 80 psi.

* Use U.S. Forest Service Method where service level = CNc.

C = 1,000 psf
Nc = 2.8 for minimum amount rutting allowed
Rutting w/o fabric
Nc = 5.0 for minimum amount rutting w/fabric

A. W/o fabric

Service Level = CNc
= (7.0) (2.8) = 19.6
From attached figure require base course = 15.0"

B. W/fabric

Service Level = CNc

CNc = (7.0) (5.0) = 35.0
From attached figure required base course = 9.0" w/fabric

Note: Fabric will be Mirafi 600X or equal.

* "Guidelines for use of fabrics in construction and maintenance of low-volume roads." By Steward, Williamson, Mohoney.

RP/CWMNYORK/AB3

TANDEM WHEEL LOAD
ONE LAYER SYSTEM
TIRE PRESSURE = 80 PSI

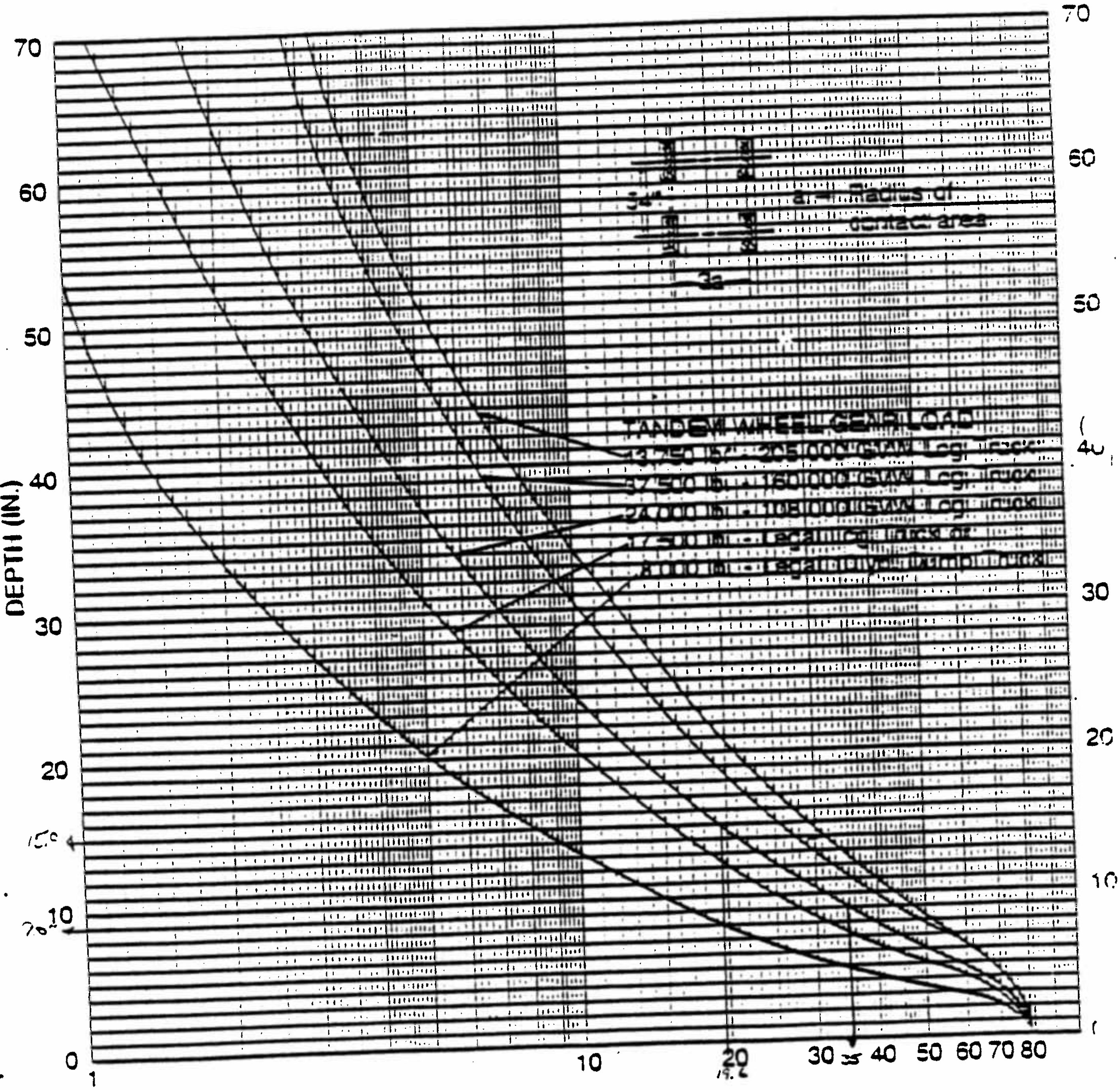


FIGURE 5.12 CN. PSI

*Total Wt. on 4 Tires Shown

APPENDIX F

GEOSYNTHETIC CALCULATIONS

5/18/99

GEOTEXTILE CALCULATIONS

DESIGN CONSIDERATIONS FOR GEOTEXTILES

1. Select geotextiles to prevent clogging from fine-grained materials.
2. Select geotextiles to meet physical requirements including strength and transmissivity.

USE OF GEOTEXTILES IN DESIGN

1. Trevira 1145 on base of secondary drainage layer: 1) overlaid with a granular layer, 2) overlaid with compacted clay.
2. Trevira 1145 on base of primary drainage layer, overlaid with granular layer.
3. Trevira 1145 place between operations layer and primary leachate granular layer.
4. Trevira 1145 on all sideslope applications overlaid with granular layer.
5. Trevira 1145 on final cover, overlaid with cover soil layer.

I. DESIGN CONSIDERATIONS OF TREVIRA 1145 ON SECONDARY BASE DRAINAGE SYSTEM

A. GRANULAR LAYER

1. FILTRATION (Piping Resistance)

Reference: "Geotextile Engineering Manual"
Federal Highway Administration (FWHA) 1982

Trevira 1145 overlaid with NYDOT No. 1A Stone

NYDOT No. 1A Stone Gradation

Percent Passing	Sieve Size
100 percent	½ inch
100-90 percent	¼ inch
0-15 percent	⅛ inch

For soils with $\leq$ 50 percent passing No. 200 sieve:

$AOS \leq B \times D_{85}$	D_{85} = 0.20 in. minimum
$C_u = D_{60}/D_{10}$	C_u = uniformity coefficient
If: $C_u \leq 2$ or ≥ 8	$B = 1$
If: $2 \leq C_u \leq 4$	$B = .5\,C_u$
If $4 \leq C_u < 8$	$B = 8/C_u$

Revision No. 2
Date: 060292

$\underline{\text{AOS Trevira 1145} = 0.149 \text{ mm} = 0.00587 \text{ in.}}$

AOS - Apparent opening size

$\underline{D_{60} = 0.185 \text{ in. } D_{10} = 0.125 \text{ in. } C_u = 1.48 \therefore \quad B = 1}$

AOS $\leq$ B x D_{85}

D_{85} = 0.20 in.

0.00587 in. < 0.20 in.

Trevira 1145 is adequate to resist piping

2. PERMEABILITY (FWHA)

Since the secondary leachate collection system is used in conjuction with both synthetic and granular, the permeability is moderate.

$\underline{K_{1145} = 0.48 \text{ cm/s}}$

$K_{soil} = 1 \times 10^{-2}$ cm/sec (minimum)

$\therefore K_{1145} \geq K_{soil}$

Trevira 1145 passes permeability criteria

3. CLOGGING

Due to lack of fines in the granular drainage blanket, clogging of the geotextile is not a significant problem.

4. STRENGTH

The main criteria for strength is the protection of the geomembrane from the overlying granular drainage layer. The geotextile and the geonet must provide adequate strength to prevent stone particles from puncturing the geomembrane.

Reference: "Designing with Geosynthetics"
Robert M. Koerner, 1986, pg. 70

$T_{reqd} = (3.142 d_i d_a)\, P' S'$

T_{reqd} = Total tensile force in fibers

d_i Initial average void diameter of geotextile

$\underline{d_i = AOS_{1145} = 0.00587 \text{ in.}}$

d_a Average diameter of the granular layer

d_a approximately $= D_{50} = 0.177$ in.

$P' =$ Pressure (maximum) = (maximum waste depth) x (unit weight of waste)

$\underline{P' = 109 \text{ feet} \times (111.1\ lb/ft^3)}$

$\underline{P' = 12{,}109.9\ lb/ft^2 = 84.10\ lb/in.^2}$

S' Shape Factor

$S' = 1-S$
$S =$ Sphericity
$= 0.4$ for crushed stone

$S' = 0.6$

$\therefore T_{reqd} = (3.142 \times 0.00587 \times 0.177 \times 84.10 \times 0.6)$
$= 0.16$ lbs

Puncture strength of <u>Trevira 1145 = 155 lbs</u>

<u>0.16 < <200 lbs OK</u>

5. ALTERNATE APPROACH (FWHA) STRENGTH

A. BURST STRENGTH

$$P_b = \frac{.4\ D_m\ P_v \times SF}{1.2}$$

P_b = Burst Strength

$D_m = D_{100} = 0.5$ in.

P_v = Vertical Pressure = $84.10\ lb/in.^2$

Hole Size = 30.5 mm or 1.2 in.

SF = Safety Factor = 3.0

$\therefore p_b = 42.1\ lb/in.^2$

<u>Trevira 1145 burst strength = 575 lb/in.²</u>

<u>575 > 42.1 OK</u>

6. PUNCTURE STRENGTH

$R = 3PD^2$

P = Vertical Pressure = 84.10 lb/in.^{2}

D = 0.5 in.

R = Puncture Strength

R = 63 lb

Trevira 1145 puncture strength = 155 lbs

155 > 63 OK

Strength Criteria	Specifications CWMI	AASHTO	Trevira 1145
Grab Strength	180 lb	180 lb	375 lb
Puncture	80 lb	75 lb	155 lb
Burst	290 lb/in^2	290 lb/in^2	575 lb
Trap Tear	50 lb	50 lb	140 lb

SUMMARY:

Under the assumed conditions and soil properties, Trevira 1145 will function as designed beneath the secondary granular drainage layer.

B. COMPACTED CLAY LINER

Trevira 1145 will be placed beneath the secondary granular layer and the primary compacted clay layer. Critical geotextile characteristics include: filtering.

1. FILTRATION FWHA Manual, Table 3-3, 1984

Trevira 1145 overlaid with compacted clay

Trevira 1145 AOS = 0.149 - 0.105 mm

If percent passing = 200 sieve > 50 percent, use a non-woven geotextile

$\therefore o \leq 1.8 D$

D = .10 mm (typical for clay)

(0.149 to 0.105 mm) $\leq$ 0.18 mm OK

2. PERMEABILITY FWHA Manual

Critical/Severe Application

$$K_{fabric} \geq 10 \times K_{soil}$$

K_{1145} = 0.48 cm/sec $K_{soil} = 1 \times 10^{-7}$ cm/sec minimum

$K_{1145} > 10 \times K_{soil}$ OK

3. CLOGGING

Due to the impervious intent of the clay liner, clogging of the underlying geotextile is not a significant problem.

4. STRENGTH CRITERIA

See secondary layer strength calculations for granular surface which remains the critical surface for this analysis.

II. DESIGN CONSIDERATIONS OF TREVIRA 1145 ON PRIMARY GRANULAR DRAINAGE SYSTEM

All assumed conditions and soil properties for the primary drainage layer will remain the same as the secondary granular drainage layer. Therefore, the secondary layer geotextile (Trevira 1145) calculations are applicable for the primary granular drainage layer.

III. DESIGN CONSIDERATIONS OF TREVIRA 1145 UNDERLYING OPERATIONS LAYER

1. Filtration (Piping Resistance)

Reference: FHWA Manual, 1984, Table 3-3

Trevira 1145 overlaid with select fill

If percent passing No. 200 sieve > 50 percent, use a non-woven geotextile.

AOS - $0_{95} < 1.8\ D_{85}$

Typical clayey silt grain size analysis*

D_{85} = 0.09 mm
D_{50} = 0.01 mm
D_{15} = 0.001 mm

*Assuming 80 percent passes use sieve No. 200

Trevira 1145 AOS = 0.149 to 0.105 mm

AOS < 1.8 D

0.149 < 1.8 x 0.09 mm

0.149 mm < 0.162 mm OK

This is based on an assumed soil grain size analysis. Select fill used for operations layer will be as coarse or coarser than the assumed soil.

2. PERMEABILITY FWHA Manual

Critical Condition

$K \geq 10\,K$

$K = 0.48$ cm/sec

Typical granular soil mix: $K = 1 \times 10^{-2}$ cm/s to 1×10^{-4} cm/s

$K > 10\,K$ Trevira 1145 OK

3. CLOGGING

Critical/Severe Application

Constant Gradient Ratio ≤ 3*

*ASTM D5101 with modified sample and conditions as directed by the DESIGNER.

4. STRENGTH CRITERIA

See secondary layer strength calculations. The granular drainage layer remains the critical surface for strength calculations.

	Specifications		
Strength Criteria	CWMI	AASHTO	Trevira 1145
Grab Strength	180 lb	180 lb	390 lb
Puncture	80 lb	75 lb	155 lb
Burst	290 lb	290 lb	640 lb
Trap Tear	50 lb	50 lb	130 lb

IV. DESIGN CONSIDERATIONS OF TREVIRA 1145 ON FINAL COVER DRAINAGE SYSTEM

A. COMPACTED CLAY LAYER

Trevira 1145 will be placed on both sides of a geonet forming a geocomposite. The final cover geocomposite will be between the clay layer above and textured HDPE below. The analysis and design considerations are exactly as presented in secondary drainage layer considerations for compacted clay layer. Therefore, the geotextile for the geocomposite selected is adequate.

RP/CWMNYORK/AB6

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, pondliners, retaining walls. And much more.

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.

TYPICAL PHYSICAL PROPERTIES OF TREVIRA® TYPE 11 PRODUCTS

Fabric Property	Unit	Test Method	1112	1114	1120	1125	1135	1145	1155
Fabric Weight	oz/yd²	ASTM D-3776	3.5	4.2	6.0	7.5	10.5	13.5	16.5
Thickness, t	mils	ASTM D-1777	60	70	90	110	140	170	210
Grab Strength (MD/CD)*	lbs	ASTM D-4632	120/95	150/115	230/180	300/235	420/350	540/450	650/570
Grab Elongation (MD/CD)*	%	ASTM D-4632	85/75	75/85	75/85	75/85	75/80	80/80	85/85
Trapezoid Tear Strength (MD/CD)*	lbs	ASTM D-4533	50/40	55/50	80/75	105/95	140/125	180/165	225/200
Puncture Resistance	lbs	ASTM D-4833	55	65	95	115	155	185	225
Mullen Burst Strength	psi	ASTM D-3786	195	225	320	400	560	700	855
Water Flow Rate	gpm/ft²	ASTM D-4491	195	190	170	150	120	100	80
Permittivity, Ψ	sec⁻¹	ASTM D-4491	2.61	2.54	2.27	2.01	1.60	1.34	1.07
Permeability, k = Ψt	cm/sec	ASTM D-4491	.40	.45	.52	.58	.57	.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	100-120 .149-.125	120-140 .125-.108	140-170 .108-.088
Standard Roll Widths**	ft		12.5 and 15.0						
Standard Roll Length**	ft		400	400	300	300	300	300	300

*MD = Machine Direction, CD = Cross Machine Direction.

**Other width and length rolls are available upon request

MINIMUM¹ PHYSICAL PROPERTIES OF TREVIRA® TYPE 11 PRODUCTS

Fabric Property	Unit	Test Method	1112	1114	1120	1125	1135	1145	1155
Fabric Weight	oz/yd²	ASTM D-3776	3.3	4.0	5.7	7.1	10.0	13.0	16.0
Thickness, t	mils	ASTM D-1777	50	55	75	95	125	150	185
Grab Strength	lbs	ASTM D-4632	80	100	160	210	305	390	500
Grab Elongation	%	ASTM D-4632	60	60	60	60	60	65	70
Trapezoid Tear Strength	lbs	ASTM D-4533	30	40	60	75	100	130	150
Puncture Resistance	lbs	ASTM D-4833	40	50	80	95	130	155	195
Mullen Burst Strength	psi	ASTM D-3786	170	180	275	360	510	640	780
Water Flow Rate	gpm/ft²	ASTM D-4491	155	150	130	110	80	60	40
Permittivity, Ψ	sec⁻¹	ASTM D-4491	2.07	2.01	1.74	1.47	1.07	0.80	0.51
Permeability, k = Ψt	cm/sec	ASTM D-4491	.26	.28	.33	.35	.34	.31	.25
AOS	Sieve Size mm	ASTM D-4751	50 .300	50 .300	70 .210	70 .210	70 .210	100 .149	100 .149

¹These minimum values represent minimum test values determined from Q.C. testing on all lots produced in 1989. Certified "Minimum Average Roll Values" representing the industry standard of a 95 percent confidence level (i.e. mean less two standard deviations) may be higher than these values and are determined for each production lot. Please contact your Trevira® Distributor or Hoechst Celanese Corporation for additional information.

TABLE 3-3

SUMMARY OF GEOTEXTILE DESIGN AND SELECTION CRITERIA FOR DRAINAGE, FILTRATION, AND EROSION CONTROL APPLICATIONS

I. SOIL RETENTION (PIPING RESISTANCE CRITERIA)[1]

Soils	Steady State Flow	Dynamic, Pulsating, and Cyclic Flow
≤ 50% Passing[2] U.S. No. 200 sieve	AOS $O_{95} \leq B\, D_{85}$	$O_{95} \leq D_{15}$
	$C_u \leq 2$ or ≥ 8: $B = 1$	or
	$2 \leq C_u \leq 4$: $B = 0.5\, C_u$	$O_{50} \leq 0.5\, D_{85}$
	$4 < C_u < 8$: $B = \frac{8}{C_u}$	
≥ 50% Passing U.S. No. 200 sieve	Woven: $O_{95} \leq D_{85}$	$O_{50} \leq 0.5\, D_{85}$
	Nonwoven: $O_{95} \leq 1.8\, D_{85}$	
	AOS No. (fabric) ≥ No. 50 sieve	

1. When the protected soil contains particles from 1 inch size to those passing the U.S. No. 200 sieve, use only the gradation of soil passing the U.S. No. 4 sieve in selecting the fabric.
2. Select fabric on the basis of largest opening value required (smallest AOS)

II. PERMEABILITY CRITERIA[1]

A. Critical/Severe Applications

k (fabric) ≥ 10 k (soil)

B. Less Critical/Less Severe and (with Clean Medium to Coarse Sands and Gravels)

k (fabric) ≥ k (soil)

C. Additional Qualifier (Optional): $O_{95} > 2\, D_{15}$

1. Permeability should be based on the actual fabric open area available for flow. For example, if 50% of fabric area is to be covered by flat concrete blocks, the effective flow area is reduced by 50%.

III. CLOGGING CRITERIA

A. Critical/Severe Applications[1]

Select fabrics meeting I, II, IIIB, and perform soil/fabric filtration tests before specification, prequalifying the fabric, or after selection before bid closing. Alternative: use approved list specification for filtration applications. Suggested performance test method: Gradient Ratio ≤ 3

B. Less Critical/Non-Severe Applications

1. Whenever possible, fabric with maximum opening size possible (lowest AOS No.) from retention criteria should be specified.
2. Effective Open Area Qualifiers[2]

Woven fabrics: Percent Open Area ≥ 4%

Nonwoven fabrics: Porosity[2] ≥ 30%

Note:
1. Filtration tests are performance tests and cannot be performed by the manufacturer as they depend on specific soil and design conditions. Tests to be performed by specifying agency or his representative. Note: experience required to obtain reproducible results in gradient ratio test.
2. Qualifiers in potential clogging condition situations (e.g. gap-graded soils and silty type soils) where filtration is of concern.
3. Porosity requirement based on graded granular filter porosity.

IV. CHEMICAL COMPOSITION REQUIREMENT/CONSIDERATIONS

See Tables 3-4 and 3-5

Exceptions: Non-stabilized or low susceptible geotextiles should not be exposed to UV radiation for more than five days.

V. CONSTRUCTABILITY AND SURVIVABILITY REQUIREMENTS

See Tables 3-4 and 3-5

Exceptions: In abrasive environments such as many erosion control applications, abrasion resistance must be considered. It is recommended that either soil/fabric abrasion evaluation tests be performed by the agency or his representatives or a standard abrasion test specified and the tested specimens visually examined to identify holes or other characteristics such as significant strength loss that may influence the performance of the fabric in these applications (i.e., run Taber Abrasion and submit tested specimens to Agency).

The listed criteria were developed on the basis of the state-of-the-art at this time. As many of the criteria are empirical and may not have historical justification, they provide the suggested minimum guidelines. Final selection must be based on good engineering evaluation of the specific design requirements as subsequently discussed in this manual.

RECOMMENDED MINIMUM ENGINEERING FABRIC SELECTION CRITERIA
IN DRAINAGE AND FILTRATION APPLICATIONS

TABLE 3-4

I. PIPING RESISTANCE (soil retention - all applications)

A. Soils with 50% or less particles by weight passing U. S. No. 200 Sieve:

EOS No. (fabric) $\geq$ 30 sieve

B. Soils with more than 50% particles by weight passing U. S. No. 200 Sieve:

EOS No. (fabric) $\geq$ 50 sieve

Note:

1. Whenever possible, fabric with the lowest possible EOS No. should be specified.

2. When the protected soil contains particles from 1 inch size to those passing the U. S. No. 200 Sieve, use only the gradation of soil passing the U. S. No. 4 Sieve in selecting the fabric.

II. PERMEABILITY

Critical/Severe Applications*

k (fabric) $\geq$ 10 k (soil)

Normal Applications

k (fabric) $\geq$ k (soil)

*Woven monofilament fabrics only: percent open area $\geq$ 4.0 and EOS No. $\leq$ 100 sieve.

III. CHEMICAL COMPOSITION REQUIREMENTS/CONSIDERATIONS

A. Fibers used in the manufacture of civil engineering fabrics shall consist of long chain synthetic polymers, composed of at least 85% by weight of polyolefins, polyesters, or polyamides. These fabrics shall resist deterioration from ultraviolet exposure.

B. The engineering fabric shall be exposed to ultraviolet radiation (sunlight) for no more than 30 days total in the period of time following manufacture until the fabric is covered with soil, rock, concrete, etc.

IV. PHYSICAL PROPERTY REQUIREMENTS (all fabrics)

	Fabric Unprotected	Fabric Protected[4]
Grab Strength (ASTM D-1682) (Minimum in either principal direction)	180 lbs.	80 lbs.
Puncture Strength (ASTM D-751-68)[2]	80 lbs.	25 lbs.
Burst Strength (ASTM D-751-68)[3]	290 psi	130 psi
Trapezoid Tear (ASTM D-1117) (Any direction)	50 lbs.	25 lbs.

[1] All numerical values represent minimum average roll values (i.e., any roll in a lot should meet or exceed the minimum values in the table) Note: these values are normally 20% less than manufacturers typically reported values.

[2] Tension Testing Machine with Ring Clamp, steel ball replaced with a 5/16 inch diameter solid steel cylinder with hemispherical tip centered within the ring clamp

[3] Diaphragm Test Method

[4] Fabric is said to be protected when used in drainage trenches or beneath/behind concrete (Portland or asphalt cement) slabs. All other conditions are said to be unprotected.

Examples of each condition are:

Protected: highway edge drains, blanket drains, smooth stable trenches < 10 feet in depth. In trenches, in which the aggregate is extra sharp additional puncture resistance may be necessary.

Unprotected: stabilization trenches, interceptor drains on cut slopes, rocky or caving trenches or smooth stable trenches > 10 feet in depth.

RECOMMENDED MINIMUM[1] ENGINEERING FABRIC SELECTION CRITERIA IN EROSION CONTROL APPLICATIONS

TABLE 3-5

I. PIPING RESISTANCE (soil retention - all applications)

A. Soils with 50% or less particles by weight passing U. S. No. 200 Sieve:

EOS No. (fabric) ≥ 30 sieve

B. Soils with more than 50% particles by weight passing U. S. No. 200 Sieve:

EOS No. (fabric) ≥ 50 sieve

Note:

1. Whenever possible, fabric with the lowest possible EOS No. should be specified.

2. When the protected soil contains particles from 1 inch size to those passing the U. S. No. 200 Sieve, use only the gradation of soil passing the U. S. No. 4 Sieve in selecting the fabric.

II. PERMEABILITY

Critical/Severe Applications*

k (fabric) ≥ 10 k (soil) [2]

Normal Applications

k (fabric ≥ k (soil) [2]

*Woven monofilament fabrics only: percent open area ≥ 4.0 and EOS No. ≤ 100 sieve.

III. CHEMICAL COMPOSITION REQUIREMENTS/CONSIDERATIONS

A. Fibers used in the manufacture of civil engineering fabrics shall consist of long chain synthetic polymers, composed of at least 85% by weight of polyolefins, polyesters, or polyamides. These fabrics shall resist deterioration from ultraviolet exposure.

B. The engineering fabric shall be exposed to ultraviolet radiation (sunlight) for no more than 30 days total in the period of time following manufacture until the fabric is covered with soil, rock, concrete, etc.

IV. PHYSICAL PROPERTY REQUIREMENTS (all fabrics)

	Fabric Unprotected	Fabric Protected[5]
Grab Strength (ASTM D-1682) (Minimum in either principal direction)	200 lbs.	90 lbs.
Puncture Strength (ASTM D-751-68)[3]	80 lbs.	40 lbs.
Burst Strength (ASTM D-751-68)[4]	320 psi	145 psi
Trapezoid Tear (ASTM D-1117) (Any direction)	50 lbs.	30 lbs.
Elongation at Failure (ASTM D-1682) (Any direction)	[illegible]	[illegible]

[1] All numerical values represent minimum average roll values (i.e., any roll in a lot should meet or exceed the minimum values in the table) Note: these values are nominally 20% less than manufacturers typically reporte values.

[2] Permeability should be based on the actual fabric open area available for flow. For example, if 50% of the fabric area is to be covered by flat concrete blocks, the effective flow area is reduced by 50%.

[3] Tension Testing Machine with Ring Clamp, steel ball replaced with a 5/16 inch diameter solid steel cylinder with hemispherical tip centered within the ring clamp.

[4] Diaphragm Test Method

[5] Fabric is said to be protected when cushioned from rock placement by a layer of sand or by zero height placement. All other conditions are said to be unprotected.

6. Note: abrasion resistance excluded because of controversy over test method and appropriate quantitative value.

Page 7-8

In TABLE 702-5 ASPHALT EMULSIONS under MATERIAL DESIGNATION 702-3102, Demulsibility, 35 ml. 0.02N $CaCl_2$, percent, *delete* "10 Min. 80 Max." and *replace* with "60 Min.".

Page 52 of Addendum No. 1

Under Page 7-16, in each instance where "(4)" is listed, *change* "(4)" to "(3)".

Page 7-16

In Table 703-3, Physical Requirements (Deleterious Materials), under Material Designation, *delete* the 7th through 11th lines including footnote (3) beginning with "Material Passing..." and ending with "...No. 2 size".

Also under "Maximum percent by weight in any primary size", *delete* the last two lines that list 1.0 and 0.7 in four columns.

Page 7-17

Delete TABLE 703-4, SIZES OF STONE, GRAVEL AND SLAG and *replace* with the following:

TABLE 703-4 (1)
SIZES OF STONE, GRAVEL AND SLAG

Size Designation	Screen Sizes										
	4"	3"	2 1/2"	2"	1 1/2"	1"	1/2"	1/4"	1/8"	No. 80 Sieve	No. 200 (3) Sieve
Screenings (2)	—	—	—	—	—	—	100	90-100	—	—	0-1.0
1B	—	—	—	—	—	—	—	100	90-100	0-15	0-1.0
1A	—	—	—	—	—	—	100	90-100	0-15	—	0-1.0
1ST	—	—	—	—	—	—	100	0-15	—	—	0-1.0
1	—	—	—	—	—	100	90-100	0-15	—	—	0-1.0
2	—	—	—	—	100	90-100	0-15	—	—	—	0-1.0
3A	—	—	—	100	90-100	0-15	—	—	—	—	0-0.7
3	—	—	100	90-100	35-70	0-15	—	—	—	—	0-0.7
4A	—	100	90-100	—	0-20	—	—	—	—	—	0-0.7
4	100	90-100	—	0-15	—	—	—	—	—	—	0-0.7
5	90-100	0-15	—	—	—	—	—	—	—	—	0-0.7

(1) Percentage by weight passing the following square openings.

(2) Screenings shall include all of the fine material passing a 1/4" screen.

(3) The minus 200 material requirements apply only to aggregate for use in portland cement concrete, surface treatments and cold mix bituminous pavements. The test (NYSDOT TEST METHOD 703-2P) will be performed on the entire sample of the designated size aggregate. Primary size does not apply in the determination of the minus 200 material.

All crushing plants shall be fitted with tailing chutes so that no aggregate will reach the bins other than that which passes through the proper screens.

CLIENT CWM Chemical Services, Inc.
PROJECT RMU-1, Cell 6

SUBJECT Supplemental Geotextile Calculations

Prepared By DMH Date 11-20-96
Reviewed By BPB Date 11-21-96
Approved By ________ Date ________

APPENDIX F: SUPPLEMENTAL GEOTEXTILE CALCULATIONS

DESIGN CONSIDERATIONS FOR GEOTEXTILES

1. Select geotextiles to prevent clogging from fine-grained materials.

2. Select geotextiles to meet physical requirements including strength and transmissivity.

USE OF GEOTEXTILES IN DESIGN

1. Trevira 1155 on base of secondary drainage layer overlaid with a granular layer.

CLIENT CWM Chemical Services, Inc.
PROJECT RMU-1 Cell 6

SUBJECT Supplemental Geotextile Calculations

Prepared By DMH Date 11-20-96
Reviewed By BPB Date 11-21-96
Approved By ______ Date ______

TASK: Complete geotextile calculations for Model City secondary base drainage system design using Trevira 1155 for the material.

METHOD: Use design methods from "Designing with Geosynthetics, 3rd Edition" by Robert M. Koerner, Prentice-Hall, Inc. 1994

REFERENCE:
1) "Designing with Geosynthetics" Koerner, R. M., Prentice-Hall, Inc. 1994
2) Typical Physical Properties of Trevira Type 11 products Data Sheet From Hoechst Celanese.
3) Geotextile Calculations Appendix F.

CALCULATIONS:

1. Design considerations of Trevira 1155 on secondary base drainage system.

A. Granular Layer

1. Filtration (Soil Retention)
(Reference 1, p251-252)

Use Giroud's Method

$$O_{95RQD} < \frac{18 d_{50}}{cu}$$

For NYDOT 1A Stone

$d_{60} = 0.185$ in.
$d_{10} = 0.125$ in.
$cu = 1.48$
$d_{50} = 0.177$ (est.)

$$O_{95rqd} \le \frac{18(0.177)}{1.48}$$

$$< 2.15 \text{ in.} = 54.7 \text{ mm}$$

AOS for 1155 = 0.106 mm to 0.088 mm

$AOS_{1155} < O_{95req}$ Therefore Trevira 1155 is adequate for soil retention

2. PERMEABILITY (Reference 1, pp250 - 251)

a) Estimate maximum flow to the geotextile from active case HELP Model for Cell 6 Tributary Area

I = 0.1991 in/day = 1.92×10^{-2} ft/s
A = 141,671 ft^2 contributing area Cell 6
Q = $1.92 \times 10^{-7} \times 141{,}671\ ft^2 = 2.72 \times 10^{-2}\ ft^3/s$

b) Calculate required permittivity
(add 10 gpd [1.55×10^{-5} ft³/s] factor of safety)

$$q = kiA$$
$$= k \frac{\Delta h}{t} A$$
$$\frac{k}{t} = \frac{q}{\Delta h A}$$
$$= \frac{(2.72 \times 10^{-2}\ ft^3/s + 1.55 \times 10^{-5}\ ft^3/s)}{1\ ft\ (1\ ft \times 60\ ft)}$$
$$\psi_{req} = 4.54 \times 10^{-4}\ sec^{-1}$$

c) Check required permittivity against allowable permittivity of the geotextile

$$\psi_{ult} = 1.07\ sec^{-1}$$

d) Find allowable permittivity for geotextile through partial factor of safety

$$\psi_{all} = \psi_{ult}\ [F.S._{SCB} \times F.S._{IIN} \times F.S._{CR} \times F.S._{CC} \times F.S._{BC}]^{-1}$$

where
$F.S._{SCB}$ = Factor of Safety against soil clogging and blinding = 5.0 - 10.0
$F.S._{IN}$ = Factor of Safety against intrusion into voids = 1.0 - 1.2
$F.S._{CR}$ = Factor of Safety against creep reduction of voids = 1.5 - 2.0
$F.S._{CC}$ = Factor of Safety against chemical clogging = 1.2 - 1.5
$F.S._{BC}$ = Factor of Safety against biological clogging = 2.0 - 50

$$\psi_{all} = 1.07[5 \times 1.1 \times 1.75 \times 1.4 \times 25]^{-1}$$
$$= 3.18 \times 10^{-3}$$

e) Determine global factor of safety for Cell 6

$$F.S._{g} = \psi_{all}/\psi_{reg}$$
$$= 3.18 \times 10^{-3}/4.54 \times 10^{-4}$$
$$= 7.0\ \text{Acceptable}$$

f) Repeat above permeability calculations for Cell 12 and 14 combined (worst case). Add an anticipated 20 gpd (3.09×10^{-5} ft³/sec) factor of safety

- Maximum flow to geotextile from active case HELP Model for tributary area of Cells 12 and 14

$$Q = 1.92 \times 10^{-7} \text{ ft/sec} \times 278{,}432 \text{ ft}^2$$
$$= 5.35 \times 10^{-2} \text{ ft}^3\text{/sec}$$

- Required permittivity. Add 20 gpd (3.09×10^{-5} ft³/sec) factor of safety

$$\psi_{req} = \frac{q}{\Delta h A}$$

$$= \frac{(5.35 \times 10^{-2} \text{ ft}^3\text{/sec} + 3.09 \times 10^{-5} \text{ ft}^3\text{/sec})}{1 \text{ ft} (1 \text{ ft} \times 60 \text{ ft})}$$

$$\psi_{req} = 8.91 \times 10^{-4} \text{ sec}^{-1}$$

- Ultimate geotextile permittivity

$$\psi_{ULT} = 1.07 \text{ sec}^{-1}$$

- Allowable geotextile permittivity

$$\psi_{ALL} = 3.18 \times 10^{-3} \text{ sec}^{-1}$$

- Global Factor of Safety for Cell 12 and 14 combined

$$F.S._G = \psi_{all} \times \psi_{reg}$$
$$= 3.18 \times 10^{-3}/8.91 \times 10^{-4}$$
$$= 3.6 \text{ Acceptable}$$

3. CLOGGING

The drainage blanket consists of NYDOT 1A washed stone, which has neglibible fines. Clogging of the geotextile is not a significant problem. As per Reference 1, partial factors of safety of 5.0 for soil clogging and blinding, 1.4 for chemical clogging and 25 for biological clogging have been included in the permeability calculations. See attached grain size distribution reports. Additionally, clogging will not occur as any additional fines will be of a low potential due to additional geotextiles in the secondary system.

4. STRENGTH

a) Tensile Strength (Reference 1 pp162-164)

$T_{reqd} = p^{'}(d_v)^2\,[f\varepsilon]$

T_{reqd} = required grab tensile force
$p^{'}$ = the applied pressure
d_v = maximum void diameter = $0.33\ d_a$
d_a = the average stone diameter = d_{50}

$f[\varepsilon]$ = the strain function of the deformed geotextile
= $1/4[(2y/b) + (b/2y)]$

b = width of opening or void strain
y = deformation into opening or void strain

$p^{'}$ = maximum pressure = maximum waste depth x unit weight of waste
= 109 ft x 111.1 lb/ft^3
= 12,109.9 lb/ft^2
= 84.10 lb/in^2

d_v = $0.33\ d_{50}$
= $0.33 \bullet 0.177$
= 5.84×10^{-2}

$f[\varepsilon]$ = $1/4[2(0.85)/0.85 + 0.85/2(0.85)]$
= 0.625

Note: assume y = b = grab elongation = 85% = 0.85

T_{reqd} = 84.10 lb/in^2 $(5.84 \times 10^{-2})^2 \times 0.625$
= 0.179 lbs

$$F.S. = \frac{T_{all}}{T_{req}} = \frac{650}{0.179} = 3626 \text{ Acceptable}$$

b) Burst Strength (Reference 1, pp160 - 162)

$$F.S._g = \frac{2.4\ P_{TEST}}{p' d_a} \qquad \text{[Equ 2.28]}$$

where $F.S._g$ = global factor of safety against burst

P_{test} = the burst test pressure
= 855 lb/in^2 for Trevira 1155
p' = stress at the geotextile surface
= 100 psi, assuming the geotextile is most vulnerable to burst when traffic is crossing over the 12-inch layer of 1A stone during stone placement. 100 psi represents the maximum allowable tire pressure.
d_a = average stone diameter ≈ d_{50}
= 0.177 in

$$F.S._g = \frac{2.4\ (855)}{100\ (0.177)}$$

$F.S._g$ = 116 Acceptable

c) Puncture Resistance (Reference 1, pp165 - 167)

$$F_{req} = p' d_a^2\ S_1\ S_2\ S_3$$

where:

F_{req} = the required vertical force to resisted
p' = the pressure exerted on the textile or 100% of tire pressure for small stone thickness
= 100 psi for maximum tire pressure
d_a = average stone diameter or d_{50}
= 0.177 in
S_1 = protrusion factor = h_h/d_a where $h_h \leq d_a$
= 1
S_2 = scale factor to adjust ASTM D4833 test value using 5/16" diameter puncture probe to actual puncture object
= $0.31/d_a$
= 0.31/0.177
= 1.75
S_3 = shape factor to adjust flat puncture probe of ASTM D4333 to actual shape of puncture object
= $1 - A_p/A_c$
A_p/A_c = 0.7 for run of bank gravel
= 1-0.7
= 0.3

$$F_{req} = 100 \text{ psi } (0.177)^2 (1)(1.75)(0.3)$$
$$= 1.646$$

$$F.S. = \frac{F_{ult}}{F_{req}}$$

$$F.S. = 137 \text{ Acceptable}$$

5. GEOTEXTILE SEPARATOR REMOVAL

Removal of the existing geotextile separation in the secondary system may cause unseen damage to both geotextiles, geomembranes, geosynthetic caly liner and other soil and clay components of the secondary system.

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 PRODUCTS

Fabric Property	Unit	Test Method	011/120	011/140	011/200	011/250	011/280	011/350	011/420	011/450	011/550
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)[a]	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)[a]	%	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)[a]	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 = Ψt	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[b]	ft		12.5 and 15.0								
Standard Roll Lengths[b]	ft		400	400	300	300	300	300	300	300	300

[a] MD = Machine Direction, CD = Cross Machine Direction

[b] Other width and length rolls are available upon request.

MINIMUM[1] PHYSICAL PROPERTIES OF TREVIRA® TYPE 11 PRODUCTS

Fabric Property	Unit	Test Method	011/120	011/140	011/200	011/250	011/280	011/350	011/420	011/450	011/550
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	700
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 = Ψt	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

[1] These minimum values represent minimum test values as determined from Quality Control (Q.C.) testing.

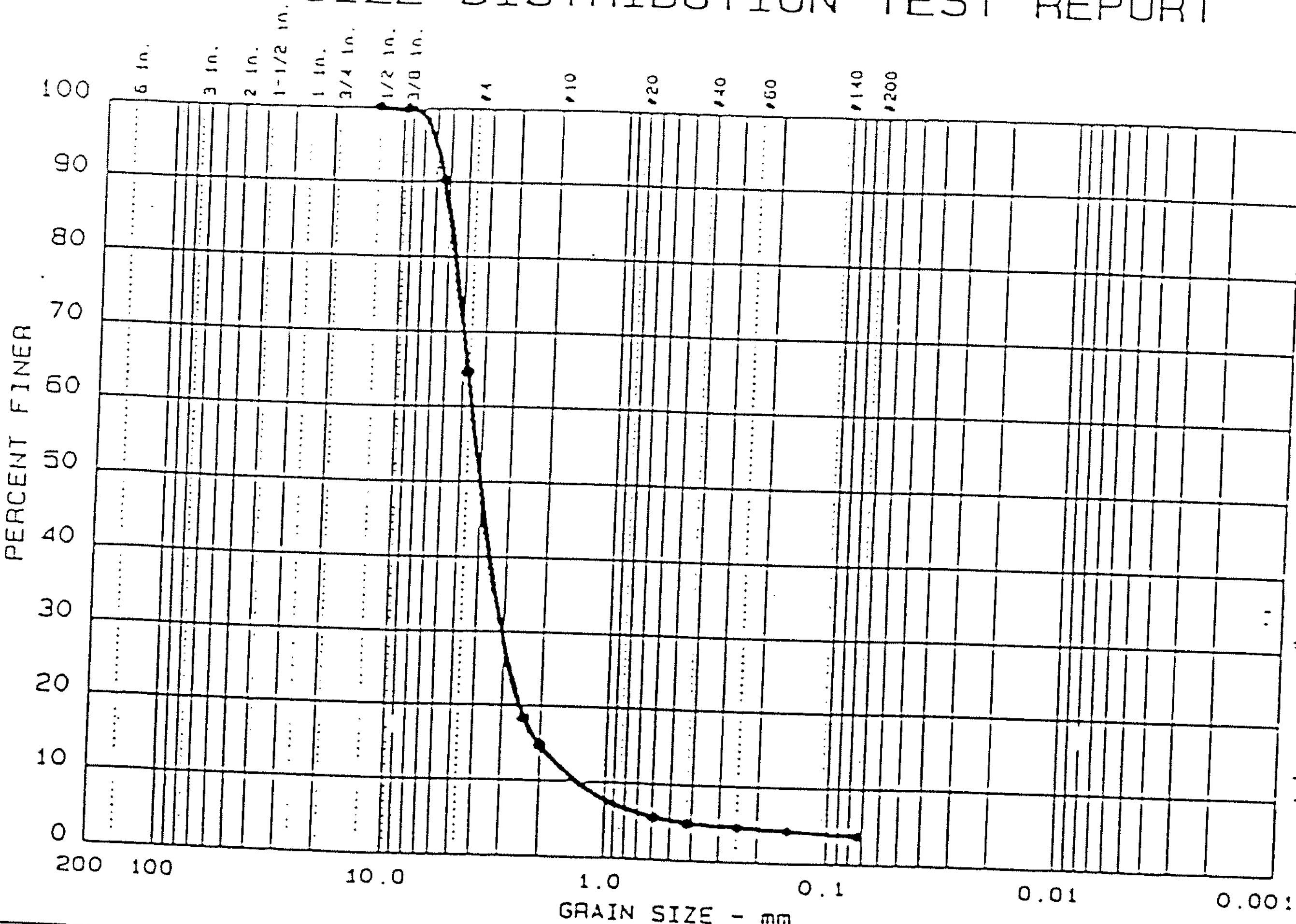
TABLE MM-1
CWM CHEMICAL SERVICES, INC.
RMU-1 CELL 6 CQA SERVICES
SECONDARY GRANULAR LAYER CONSTRUCTION TESTING
LABORATORY RESULTS SUMMARY
TYPE 1A STONE

LAB SAMPLE NO.	SAMPLE LOCATION	DATE COLLECTED	NATURAL MOISTURE (%)	GRAIN SIZE DISRIBUTION % FINER 1/2-INCH	% FINER 1/4-INCH	% FINER NO. 8	% FINER NO. 200	PERMEABILITY TESTING UNIT WEIGHT WET (pcf)	UNIT WEIGHT DRY (pcf)	PERM. (cm/sec.)	COMMENTS	SOURCE
REQUIREMENTS				100.0	40-100	0-15	<5%			1.00E-02		
GAIP-1	9625N/2175E	7/18/96	1.9	100.0	90.2	18.3*	3.7	—	—	3.53E-01	Construction QA/Secondary	Redlands
GAIP-2	9575N/1975E	7/18/96	1.8	100.0	90.0	10.9	3.4	—	—	6.62E-01	Construction QA/Secondary	Redlands
GAIP-3	9475N/2175E	7/18/96	1.8	100.0	88.4	13.5	4.1	—	—	5.37E-01	Construction QA/Secondary	Redlands
GAIP-4	9425N/2275E	7/23/96	3.0	100.0	85.9	8.9	1.6	—	—	1.04E+00	Construction QA/Secondary	Redlands
GAIP-5	9375N/2075E	7/29/96	1.6	99.8	88.3	17.3*	3.2	—	—	1.21E+00	Construction QA/Secondary	Redlands
GAIP-6	9425N/1975E	7/29/96	1.1	100.0	88.1	13.2	3.7	—	—	1.24E+00	Construction QA/Secondary	Redlands

* Results are slightly above the upper limit of the required percent finer, however, the results are acceptable as per the designer as documented in Specification Clarification No.89 (SC-89).

Secondary Granular Drainage Layer
Particle Size Distribution
Laboratory Test Results

GRAIN SIZE DISTRIBUTION TEST REPORT



S. #	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
● 1	0.0	35.4	60.9	3.7	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			5.92	4.53	4.06	3.087	2.0160	1.3474	1.56	3.4

MATERIAL DESCRIPTION	ASTM	BURMISTER	AASHTO
● GRAY GRAVEL & CRUSHED STONE			

Project No.: 85803003 Date: 7-23-96
Project: AMU-1 CELL 6 CONSTRUCTION
Client: CWM CHEM. SERV. MODEL CITY, N.Y. FACILITY
● Sample: GAIP-1 Sample No.: 1

Performed by: H.K.
Entered by: D.L.
Checked by: R.S.A.
Remarks:
MOISTURE CONTENT- 1.9%

EMCON

Figure No.

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 12

)ate: 7-23-96 Project No.: 85803003
ect: RMU-1 CELL 6 CONSTRUCTION
: CWM CHEM. SERV. MODEL CITY, N.Y. FACILITY

Sample Data

aterial Des. 1: GRAY GRAVEL & CRUSHED STONE
aterial Des. 2:
ample: GAIP-1
ample No.: 1
STM Class:
URMISTER Class: AASHTO Class:
iquid limit: Plasticity index:

Notes

emarks: MOISTURE CONTENT= 1.9%
ig. No.:

Mechanical Analysis Data

	Initial	After wash
ry sample and tare=	1989.80	1920.00
are =	15.50	15.50
ry sample weight =	1974.30	1904.50

inus #200 from wash= 3.5 %
are for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	% retained	% finer
(inches	0.00	0.0	100.0
375 inches	2.60	0.1	99.9
0.25 inches	192.80	9.8	90.2
# 4	699.40	35.4	64.6
# 8	1613.30	81.7	18.3
# 10	1683.00	85.2	14.8
# 30	1864.40	94.4	5.6
# 40	1877.60	95.1	4.9
# 60	1885.10	95.5	4.5
# 100	1891.20	95.8	4.2
# 200	1901.50	96.3	3.7

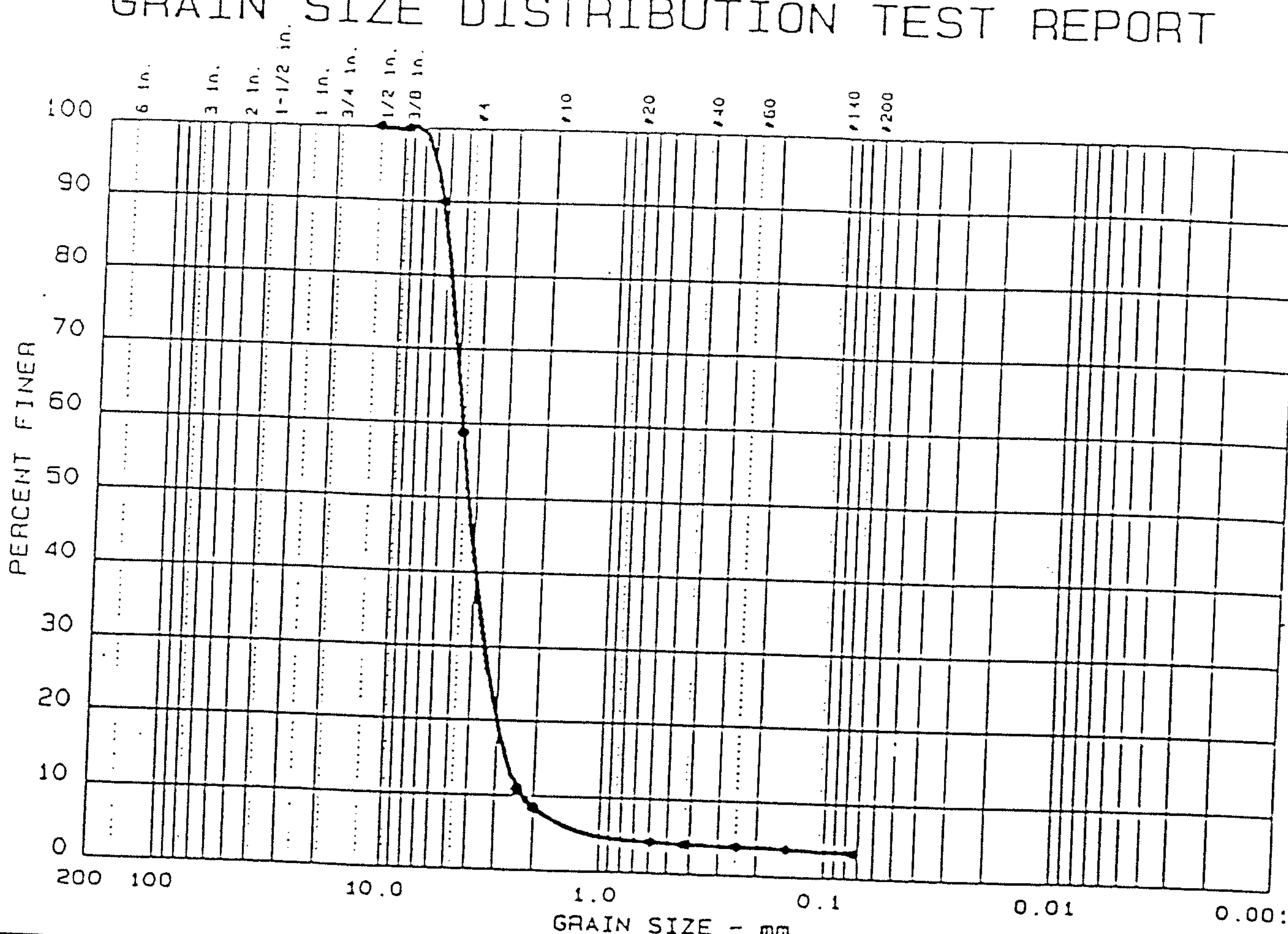
Fractional Components

+ 75mm. = 0.0 % GRAVEL = 35.4 % SAND = 60.9
FINES = 3.7

85= 5.92 D60= 4.534 D50= 4.055
30= 3.0867 D15= 2.01604 D10= 1.34741
c = 1.5596 Cu = 3.3651

Performed by: M.K.
Entered by: D.L.
Checked by: R.S.A.

GRAIN SIZE DISTRIBUTION TEST REPORT



S. #	% +75 mm	% GRAVEL	% SAND	% SILT	% CLAY
• 2	0.0	41.3	55.4	3.3	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
•			6.00	4.81	4.39	3.512	2.6946	2.2673	1.13	2.1

MATERIAL DESCRIPTION	ASTM	BURMISTER	AASHTO
• GRAY GRAVEL & CRUSHED STONE			

Project No.: 85803003 Date: 7-23-95

Project: AMU-1 CELL 6 CONSTRUCTION

Client: CWM CHEM. SERV. MODEL CITY, N.Y. FACILITY

• Sample: GAIP-2 Sample No.: 2

Performed by: M.K.

Entered by: D.L.

Checked by: R.S.A.

Remarks:

MOISTURE CONTENT- 1.8%

EMCON

Figure No.

GRAIN SIZE DISTRIBUTION TEST DATA

Test No.: 13

Date: 7-23-96 Project No.: 85803003

Project: RMU-1 CELL 6 CONSTRUCTION

Location: CWM CHEM. SERV. MODEL CITY, N.Y. FACILITY

Sample Data

Material Des. 1: GRAY GRAVEL & CRUSHED STONE
Material Des. 2:
Sample: GAIP-2
Sample No.: 2
ASTM Class:
BURMISTER Class:
AASHTO Class:
Liquid limit:
Plasticity index:

Notes

Remarks: MOISTURE CONTENT= 1.8%
Fig. No.:

Mechanical Analysis Data

	Initial	After wash
Dry sample and tare=	1889.70	1832.40
Tare =	15.50	15.50
Dry sample weight =	1874.20	1816.90
Minus #200 from wash=	3.1 %	

Tare for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	% retained	% finer
(inches	0.00	0.0	100.0
.375 inches	1.60	0.1	99.9
0.25 inches	188.20	10.0	90.0
# 4	773.50	41.3	58.7
# 8	1669.10	89.1	10.9
# 10	1715.70	91.5	8.5
# 30	1795.90	95.8	4.2
# 40	1799.50	96.0	4.0
# 60	1802.10	96.2	3.8
# 100	1804.80	96.3	3.7
# 200	1811.40	96.6	3.4

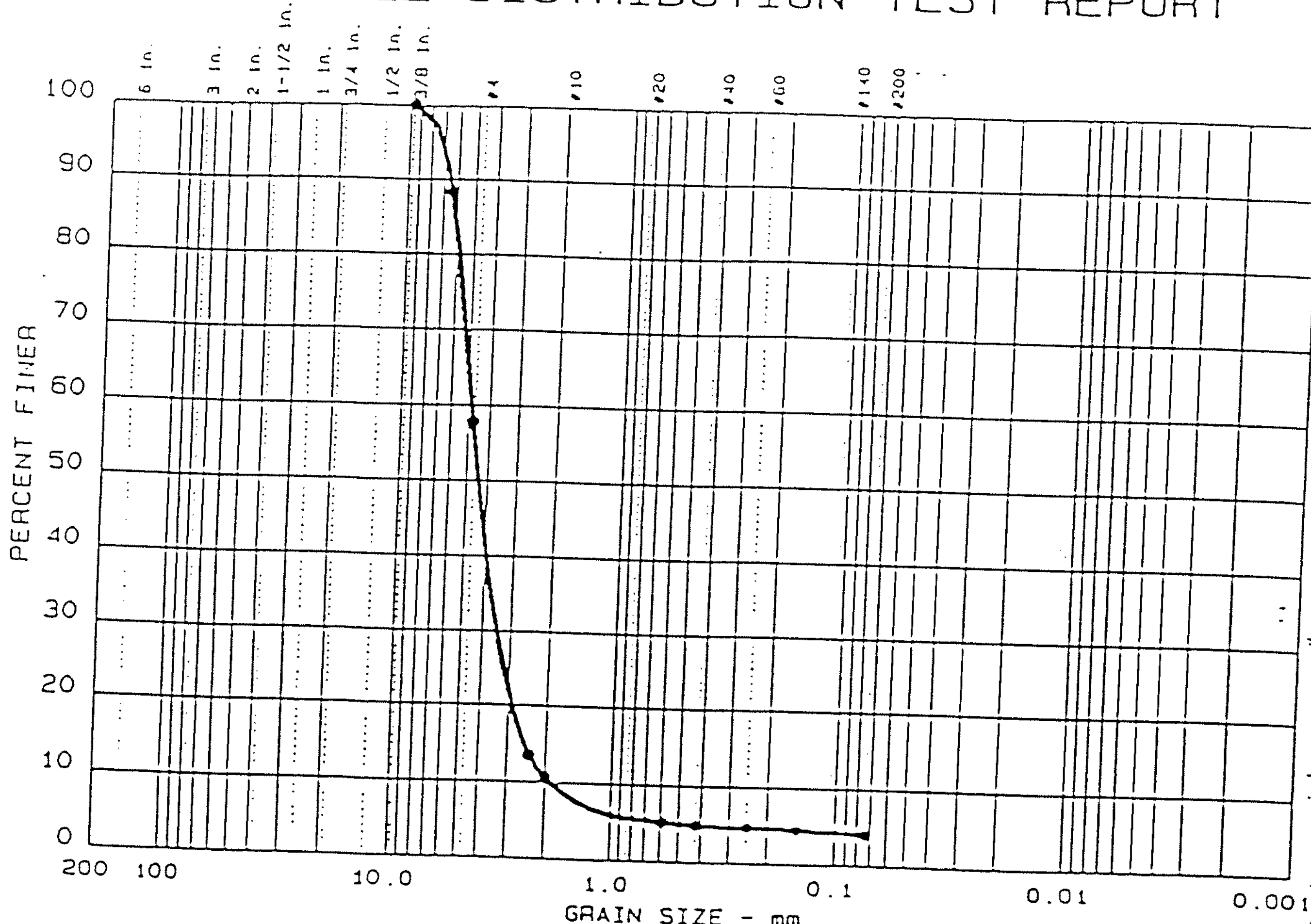
Fractional Components

% + 75mm. = 0.0 % GRAVEL = 41.3 % SAND = 55.4
% FINES = 3.3

D85= 6.00 D60= 4.808 D50= 4.390
D30= 3.5116 D15= 2.69464 D10= 2.26725
Cc = 1.1311 Cu = 2.1208

Performed by: M.K.
Entered by: D.L.
Checked by: R.S.A.

GRAIN SIZE DISTRIBUTION TEST REPORT



	S. #	% +75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	3	0.0	42.2	53.7	4.1	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			6.10	4.85	4.42	3.463	2.5090	1.8815	1.31	2.6

MATERIAL DESCRIPTION	ASTM	BURMISTER	AASHTO
● GRAY GRAVEL & CRUSHED STONE			

Project No.: 85803003 Date: 7-23-96
Project: AMU-1 CELL 6 CONSTRUCTION
Client: CWM CHEM. SERV. MODEL CITY, N.Y. FACILITY
● Sample: GAIP-3 Sample No.: 3

Performed by: M.K.
Entered by: D.L.
Checked by: R.S.A.
Remarks:
MOISTURE CONTENT= 1.8%

EMCON

Figure No.

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 14

ate: 7-23-96 Project No.: 85803003
--t: RMU-1 CELL 6 CONSTRUCTION
: CWM CHEM. SERV. MODEL CITY,N.Y. FACILITY

Sample Data

aterial Des. 1: GRAY GRAVEL & CRUSHED STONE
aterial Des. 2:
ample: GAIP-3
ample No.: 3
STM Class:
URMISTER Class: AASHTO Class:
iquid limit: Plasticity index:

Notes

emarks: MOISTURE CONTENT= 1.8%
ig. No.:

Mechanical Analysis Data

		Initial	After wash
ry sample and tare	=	1862.40	1796.70
are	=	15.50	15.50
ry sample weight	=	1846.90	1781.20

inus #200 from wash= 3.6 %
are for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	% retained	% finer
(5 inches	0.00	0.0	100.0
:5 inches	214.00	11.6	88.4
# 4	778.90	42.2	57.8
# 8	1597.80	86.5	13.5
# 10	1650.20	89.3	10.7
# 30	1751.00	94.8	5.2
# 40	1757.20	95.1	4.9
# 60	1760.80	95.3	4.7
# 100	1764.10	95.5	4.5
# 200	1771.40	95.9	4.1

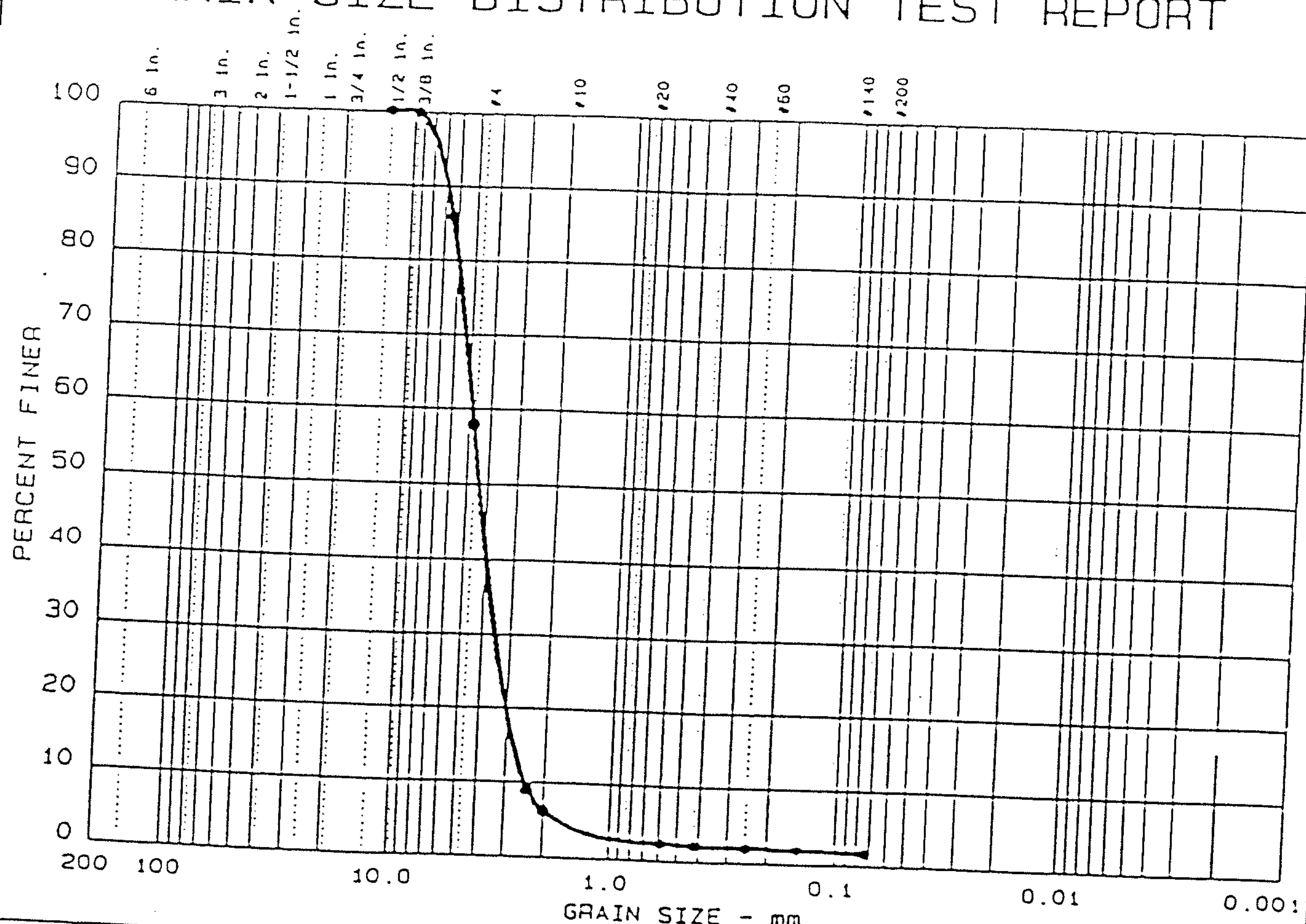
Fractional Components

+ 75mm. = 0.0 % GRAVEL = 42.2 % SAND = 53.7
FINES = 4.1

35= 6.10 D60= 4.853 D50= 4.416
30= 3.4634 D15= 2.50900 D10= 1.88148
: = 1.3137 Cu = 2.5793

Performed by: M.K.
Entered by: D.L.
Checked by: R.S.A.

GRAIN SIZE DISTRIBUTION TEST REPORT



	S. #	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	4	0.0	42.1	56.3	1.6	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			6.27	4.85	4.40	3.516	2.7893	2.4575	1.04	2.0

MATERIAL DESCRIPTION	ASTM	BURMISTER	AASHTO
● GRAY GRAVEL & CRUSHED STONE			

Project No.: 85803000

Project: RMU-1 CELL 6 CONSTRUCTION

Date: 7-26-96

Client: CWM CHEM. SERV. MODEL CITY, N.Y. FACILITY

● Sample: GAIP-4

Sample No.: 4

Performed by: M.K.

Entered by: D.L.

Checked by: R.S.A.

Remarks:

MOISTURE CONTENT- 3.0%

EMCON

Figure No.

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 1

te: 7-26-96 Project No.: 85803000
oject: RMU-1 CELL 6 CONSTRUCTION
CWM CHEM. SERV. MODEL CITY, N.Y. FACILITY

Sample Data

terial Des. 1: GRAY GRAVEL & CRUSHED STONE
terial Des. 2:
mple: GAIP-4
mple No.: 4
TM Class:
RMISTER Class: AASHTO Class:
quid limit: Plasticity index:

Notes

marks: MOISTURE CONTENT= 3.0%
g. No.:

Mechanical Analysis Data

	Initial	After wash
/ sample and tare=	1621.70	1598.10
re =	15.40	15.40
/ sample weight =	1606.30	1582.70

nus #200 from wash= 1.5 %
re for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	% retained	% finer
0.5 inches	0.00	0.0	100.0
(inches	1.60	0.1	99.9
. inches	226.10	14.1	85.9
# 4	676.40	42.1	57.9
# 8	1463.00	91.1	8.9
# 10	1506.50	93.8	6.2
# 30	1569.40	97.7	2.3
# 40	1572.40	97.9	2.1
# 60	1574.80	98.0	2.0
# 100	1576.50	98.1	1.9
# 200	1580.30	98.4	1.6

Fractional Components

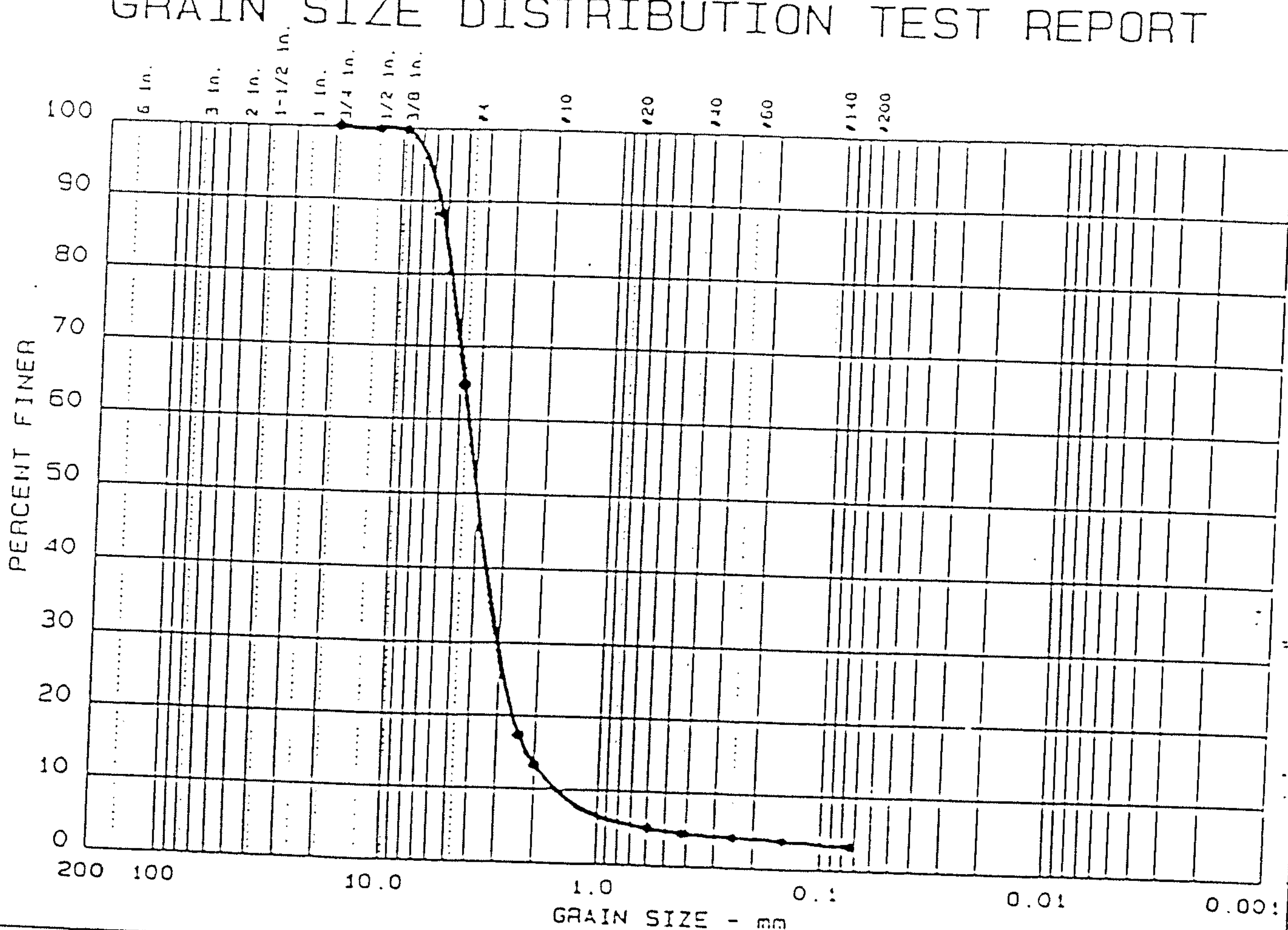
+ 75mm. = 0.0 % GRAVEL = 42.1 % SAND = 56.3
FINES = 1.6

5= 6.27 D60= 4.853 D50= 4.400
0= 3.5156 D15= 2.78933 D10= 2.45754
= 1.0363 Cu = 1.9747

Performed by: M.K.
Entered by: D.L.
Checked by: R.S.A.

EMCON

GRAIN SIZE DISTRIBUTION TEST REPORT



	S. #	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	5	0.0	35.3	61.5	3.2	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			6.05	4.51	4.02	3.083	2.1802	1.5794	1.33	2.9

MATERIAL DESCRIPTION	ASTM	BURMISTER	AASHTO
● GRAY GRAVEL & CRUSHED STONE			

Project No.: 85803000
Project: AMU-1 CELL 6 CONSTRUCTION
Date: 8-1-96
Client: CWM CHEM. SERV. MODEL CITY, N.Y. FACILITY
● Sample: GAIP-5
Sample No.: 5

Performed by: M.K.
Entered by: D.L.
Checked by: A.S.A.
Remarks:
MOISTURE CONTENT- 1.5%

EMCON

Figure No.

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 3

)te: 8-1-96 Project No.: 85803000
t: RMU-1 CELL 6 CONSTRUCTION
: CWM CHEM. SERV. MODEL CITY,N.Y. FACILITY

Sample Data

iterial Des. 1: GRAY GRAVEL & CRUSHED STONE
iterial Des. 2:
imple: GAIP-5
imple No.: 5
STM Class:
JRMISTER Class:
.quid limit: AASHTO Class:
Plasticity index:

Notes

:marks: MOISTURE CONTENT= 1.6%
.g. No.:

Mechanical Analysis Data

	Initial	After wash
'Y sample and tare=	1907.00	1859.60
ire =	15.40	15.40
'Y sample weight =	1891.60	1844.20

.nus #200 from wash= 2.5 %
ire for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	% retained	% finer
inches	0.00	0.0	100.0
inches	4.60	0.2	99.8
0.375 inches	6.20	0.3	99.7
0.25 inches	222.00	11.7	88.3
# 4	668.00	35.3	64.7
# 8	1564.20	82.7	17.3
# 10	1639.50	86.7	13.3
# 30	1796.80	95.0	5.0
# 40	1807.70	95.6	4.4
# 60	1814.40	95.9	4.1
# 100	1820.30	96.2	3.8
# 200	1830.80	96.8	3.2

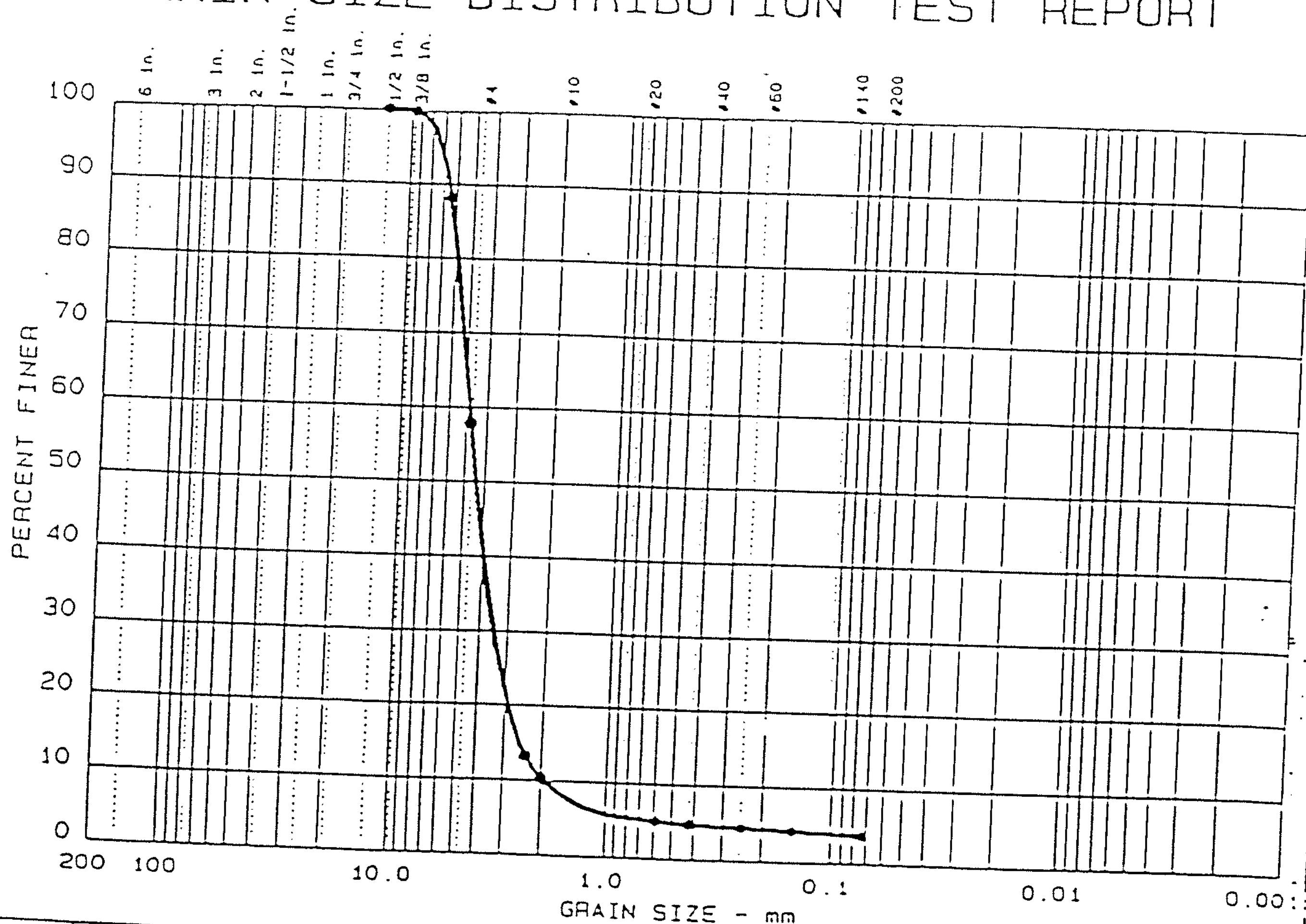
Fractional Components

+ 75mm. = 0.0 % GRAVEL = 35.3 % SAND = 61.5
FINES = 3.2

5= 6.05 D60= 4.513 D50= 4.023
0= 3.0832 D15= 2.18022 D10= 1.57943
= 1.3335 Cu = 2.8576

Performed by: M.K.
Entered by: D.L.
Checked by: R.S.A.

GRAIN SIZE DISTRIBUTION TEST REPORT



	S. #	% +75 mm	% GRAVEL	% SAND	% SILT	% CLAY
●	6	0.0	42.1	54.2	3.7	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			6.12	4.85	4.41	3.459	2.5351	1.9231	1.28	2.5

MATERIAL DESCRIPTION	ASTM	BURMISTER	AASHTO
● GRAY GRAVEL & CRUSHED STONE			

Project No.: 85803000 Date: 8-1-96
Project: AMU-1 CELL 6 CONSTRUCTION
Client: CWM CHEM. SERV. MODEL CITY, N.Y. FACILITY
◆ Sample: GAIP-6 Sample No.: 6

Performed by: M.K.
Entered by: D.L.
Checked by: R.S.A.
Remarks:
MOISTURE CONTENT- 0.6%

EMCON

Figure No.

GRAIN SIZE DISTRIBUTION TEST DATA Test No.: 4

ate:	8-1-96	Project No.:	85803000
(t:	RMU-1 CELL 6 CONSTRUCTION		
.c:	CWM CHEM. SERV. MODEL CITY,N.Y. FACILITY		

Sample Data

aterial Des. 1: GRAY GRAVEL & CRUSHED STONE
aterial Des. 2:
ample: GAIP-6
ample No.: 6
STM Class:
URMISTER Class: AASHTO Class:
iquid limit: Plasticity index:

Notes

emarks: MOISTURE CONTENT= 0.6%
ig. No.:

Mechanical Analysis Data

	Initial	After wash
ry sample and tare=	1811.10	1753.90
are =	15.30	15.30
ry sample weight =	1795.80	1738.60
inus #200 from wash=	3.2 %	

are for cumulative weight retained= 0

Sieve	Cumul. Wt. retained	% retained	% finer
inches	0.00	0.0	100.0
375 inches	3.50	0.2	99.8
0.25 inches	213.10	11.9	88.1
# 4	756.40	42.1	57.9
# 8	1558.90	86.8	13.2
# 10	1610.30	89.7	10.3
# 30	1704.50	94.9	5.1
# 40	1711.50	95.3	4.7
# 60	1716.60	95.6	4.4
# 100	1721.00	95.8	4.2
# 200	1729.60	96.3	3.7

Fractional Components

+ 75mm. = 0.0 % GRAVEL = 42.1 % SAND = 54.2
FINES = 3.7

85= 6.12 D60= 4.847 D50= 4.411
30= 3.4594 D15= 2.53513 D10= 1.92309
c = 1.2838 Cu = 2.5206

Performed by: M.K.
Entered by: D.L.
Checked by: R.S.A.

Secondary Granular Drainage Layer Permeability Laboratory Test Results

EMCON

PERMEABILITY TEST BY CONSTANT HEAD METHOD

ASTM D2434

Project: RMU-1 CELL 6 CONSTRUCTION — Proj. #: 85603.000.002

Client: CWM CHEMICAL SERVICES, INC. — Date: 7-24-96

Sample ID: GAIP-1
Description: TYPE 1A DRAINAGE STONE

Unit Weight Determination:

Diameter,D	11.35 cm	Height of Mold	8.25 in.
Area, A	101.18 cm2	Height from top of Mold	1.05 in.
Length, L	11.43 cm	Height of Sample, H, in.	7.20 in.

	Initial (lbs.)	Final (lbs.)	Dry (lbs.)
Soil & Tare	7.01	7.43	7.00
Tare	0.00	0.14	0.14
Soil	7.01	7.29	6.86

Moisture Content

Initial: 2.2 %
Final: 6.3 %

Density Dry, W: 104.98 pcf

Test #	Manometers h1	Manometers h2	Head,h cm	Q ml	t sec.	Q/At	h/L	Temp C	k cm/s
1	50.6	49.1	1.5	450	90	0.0494	0.13	0.931	3.506E-01
2	50.6	49.1	1.5	450	90	0.0494	0.13	0.931	3.506E-01
3	50.6	49.1	1.5	460	90	0.0505	0.13	0.931	3.584E-01

Remarks: RECOMPACTED SAMPLE.
TESTED WITH TAP WATER.

EMCON

PERMEABILITY TEST BY CONSTANT HEAD METHOD

ASTM D2434

Project: RMU-1 CELL 6 CONSTRUCTION — Proj. #: 35503.000.002

Client: CWM CHEMICAL SERVICES, INC. — Date: 7-24-96

Sample ID: GAIP-2
Description: TYPE 1A DRAINAGE STONE

Unit Weight Determination:

Diameter,D	11.35 cm
Area, A	101.18 cm2
Length, L	11.43 cm
Height of Mold	8.25 in.
Height from top of Mold	1.02 in.
Height of Sample, H, in.	7.23 in.

	Initial (lbs.)	Final (lbs.)	Dry (lbs.)
Soil & Tare	7.00	7.41	7.00
Tare	0.00	0.14	0.14
Soil	7.00	7.27	6.86

Moisture Content

Initial: 2.0 %
Final: 6.0 %

Density Dry, W: 104.55 pcf

Test #	Manometers h1	h2	Head,h cm	Q ml	t sec.	Q/At	h/L	Temp C	k cm/s
1	19.8	18.8	1.0	560	90	0.0615	0.09	0.931	6.544E-01
2	19.8	18.8	1.0	570	90	0.0626	0.09	0.931	6.661E-01
3	19.8	18.8	1.0	570	90	0.0626	0.09	0.931	6.661E-01

Remarks: RECOMPACTED SAMPLE
TESTED WITH TAP WATER.

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EMCON

PERMEABILITY TEST BY CONSTANT HEAD METHOD

ASTM D2434

Project: RMU-1 CELL 6 CONSTRUCTION   Proj. #: 35505.000.002

Client: CWM CHEMICAL SERVICES, INC.   Date: 7-24-96

Sample ID: GAIP-3
Description: TYPE 1A DRAINAGE STONE

Unit Weight Determination:

Diameter,D	11.35 cm	Height of Mold	8.25 in.
Area, A	101.18 cm2	Height from top of Mold	0.95 in.
Length, L	11.43 cm	Height of Sample, H, in.	7.30 in.

	Initial (lbs.)	Final (lbs.)	Dry (lbs.)
Soil & Tare	7.04	7.40	7.03
Tare	0.00	0.14	0.14
Soil	7.04	7.26	6.89

Moisture Content

Initial: 2.2 %
Final: 5.4 %

Density Dry, W 104.00 pcf

Test #	Manometers h1	Manometers h2	Head,h cm	Q ml	t sec.	Q/At	h/L	Temp C	k cm/s
1	51.1	50.1	1.0	460	90	0.0505	0.09	0.931	5.375E-01
2	51.1	50.1	1.0	460	90	0.0505	0.09	0.931	5.375E-01
3	51.1	50.1	1.0	460	90	0.0505	0.09	0.931	5.375E-01

Remarks: RECOMPACTED SAMPLE
TESTED WITH TAP WATER.

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EMCON

PERMEABILITY TEST BY CONSTANT HEAD METHOD

ASTM D2434

Project: RMU-1 CELL 6 CONSTRUCTION

Proj. #: 85803.000.002

Client: CWM CHEMICAL SERVICES, INC.

Date: 7-30-96

Sample ID: GAIP-4

Description: TYPE IA DRAINAGE STONE

Unit Weight Determination:

Diameter, D	11.35 cm
Area, A	101.18 cm2
Length, L	11.43 cm

Height of Mold	8.25 in.
Height from top of Mold	0.98 in.
Height of Sample, H, in.	7.27 in.

	Initial (lbs.)	Final (lbs.)	Dry (lbs.)
Soil & Tare	6.81	7.14	6.80
Tare	0.00	0.14	0.14
Soil	6.81	7.00	6.66

Moisture Content

Initial: 2.3 %

Final: 5.1 %

Density Dry, W: 100.34 pcf

Test #	Manometers h1	h2	Head, h cm	Q ml	t sec.	Q/At	h/L	Temp C	k cm/s
1	3.8	2.3	1.5	890	60	0.1466	0.13	0.931	1.040E+00
2	3.8	2.3	1.5	890	60	0.1466	0.13	0.931	1.040E+00
3	3.8	2.3	1.5	890	60	0.1466	0.13	0.931	1.040E+00

Remarks: RECOMPACTED SAMPLE
TESTED WITH TAP WATER.

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EMCON

PERMEABILITY TEST BY CONSTANT HEAD METHOD

ASTM D2434

Project: RMU-1 CELL 6 CONSTRUCTION — Proj. #: 85803.000.002

Client: CWM CHEMICAL SERVICES, INC. — Date: 7-31-96

Sample ID: GAIP-5

Description: TYPE 1A DRAINAGE STONE

Unit Weight Determination:

Diameter, D	11.35 cm
Area, A	101.18 cm2
Length, L	11.43 cm

Height of Mold	8.25 in.
Height from top of Mold	1.14 in.
Height of Sample, H, in.	7.11 in.

	Initial (lbs.)	Final (lbs.)	Dry (lbs.)
Soil & Tare	7.10	7.56	7.12
Tare	0.00	0.14	0.14
Soil	7.10	7.42	6.98

Moisture Content

Initial: 1.7 %

Final: 6.3 %

Density Dry, W: 108.17 pcf

Test #	Manometers h1	h2	Head, h cm	Q ml	t sec.	Q/At	h/L	Temp C	k cm/s
1	23.5	22.5	1.0	660	60	0.1087	0.09	0.976	1.213E+00
2	23.5	22.5	1.0	660	60	0.1087	0.09	0.976	1.213E+00
3	23.5	22.5	1.0	660	60	0.1087	0.09	0.976	1.213E+00

Remarks: RECOMPACTED SAMPLE
TESTED WITH TAP WATER.

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EMCON

PERMEABILITY TEST BY CONSTANT HEAD METHOD

ASTM D2434

Project: RMU-1 CELL 6 CONSTRUCTION — Proj. #: 85803.000.002

Client: CWM CHEMICAL SERVICES, INC — Date: 8-1-96

Sample ID: GAIP-6
Description: TYPE 1A DRAINAGE STONE

Unit Weight Determination:

Diameter, D — 11.35 cm
Area, A — 101.18 cm2
Length, L — 11.43 cm

Height of Mold — 8.25 in.
Height from top of Mold — 0.94 in.
Height of Sample, H, in. — 7.31 in.

	Initial (lbs.)	Final (lbs.)	Dry (lbs.)
Soil & Tare	7.29	7.74	7.35
Tare	0.00	0.14	0.14
Soil	7.29	7.60	7.21

Moisture Content

Initial: 1.1 %
Final: 5.4 %

Density Dry, W — 108.68 pcf

Test #	Manometers h1	h2	Head,h cm	Q ml	t sec.	Q/At	h/L	Temp C	k cm/s
1	18.8	17.8	1.0	680	60	0.1120	0.09	0.976	1.250E+00
2	18.8	17.8	1.0	670	60	0.1104	0.09	0.976	1.231E+00
3	18.8	17.8	1.0	680	60	0.1120	0.09	0.976	1.250E+00

Remarks: RECOMPACTED SAMPLE
TESTED WITH TAP WATER.

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APPENDIX G

HYDRAULIC CALCULATIONS FOR COLLECTION SYSTEMS

APPENDIX G

PURPOSE

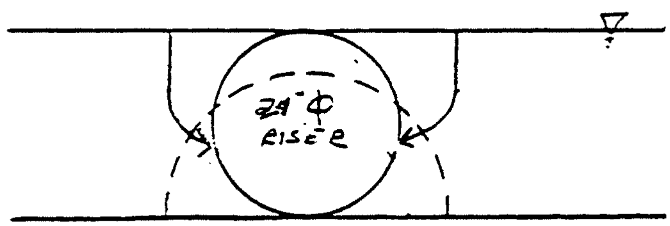
Determine flow capacity of various sump components to determine the action leakage rate (ALR).

Components

- Flow to pipe.
- Pipe perforations.
- Capacity through secondary leachate collection system at entrance to sump.

1. Flow to pipe through drainage layer

   The flow to the pipe can be estimated by drawing a flow net.



   $N_f = 3$
   $N_d = 2$

   Darcy's Law is applicable and flow net is similar to net used in the generic RAP.

   Pipe is perforated HDPE with 1/2-inch holes spaced 6 inches each way. Refer to Figure 6.

Assumptions:

- Pipe and pump capacity are greater than flow that will reach the pipe through the drainage material.

- Darcy's Law is valid and flow quantity can be estimated using a flow net.

- Conditions within the drain remain saturated.

Revision No. 2
Date: 061292

- The maximum head is equal to the drain thickness; the average head on all sumps is assumed to be 2.5 feet.

- Length of section of pipe with perforations is 4 feet.

Method:

- Draw approximate flow net (see above).

- Determine Q_{est} using Darcy's Law for flow nets.

$$Q_{estimated} = Kh_L\left(\frac{N_f}{N_d}\right)L$$

L = Length of pipe

Calculation:

$K = 2.0 \times 10^{-2}$ cm/sec (56.7 ft/day)

$$Q_{estimated} = (56.7 \text{ ft/day})(2.5 \text{ ft})(3/2)(4 \text{ ft})\left(\frac{7.48 \text{ gal}}{1 \text{ ft}^3}\right)$$

$Q_{estimated}$ = 6,361.7 GPD

$$Q_{act}{}^{1} = \frac{722.8 \text{ cu ft}}{\text{day}} \times \frac{7.48 \text{ gal}}{\text{cu ft}} = 5406 \text{ GPD}$$

[1] 722.8 cu ft daily is peak daily lateral drainage during active landfilling

∴ $Q_{estimated}$ is greater than Q_{act} (peak daily flow from HELP analysis).

2. Pipe Perforations

The flow through the pipe perforations can be estimated using the Bernoulli orifice equation.

Assumptions:

- Free flows occur through the holes.

- The head is constant and equal to the depth of drain at the sump; the average head for all sumps is assumed to be 1 foot.

- The perforations have sharp edges; C=0.61.

- There are no holes in the side slope riser APE.

Calculations:

Area of 1/2-inch diameter hole

$$A = \frac{\pi d^2}{4} = 0.00136 \text{ ft}^2$$

22 holes per foot

$Q = CA\sqrt{2gh}$

$= (0.61)(0.00136)\sqrt{2(32.2\ ft/sec^2)1\ ft}\quad (22)$

$= 0.146\ ft^3/sec$

$= 94{,}656$ GPD/ft

For a 4-foot section of pipe

4 ft(94,656 GPD/ft) = 378,625 GPD

3. Capacity through secondary leachate collection system at entrance to sump.

Method:

- Determine the quantity of flow per lineal foot of sump perimeter using Darcy's equation Q = Kia.
- Apply a factor of safety.

Assumptions:

- i = Slope of liner system.
- h is less than or equal to thickness of drainage layer.
- Assume uniform 2% slope to edge of sump.
- Transmissivity for two layers of geonet (polynet PN3000) at the specified load = $3.88 \times 10^{-2}\ ft^2/sec$.

Calculation:

Q = Kia   K = hydraulic conductivity of drainage layer
          i = hydraulic gradient = 2%
          a = area

Transmissivity (in plane permeability) = K(thickness)

$$Q = \frac{T}{t}ia = \frac{T}{t}i(t)(w)$$

Q = Tiw

$$Q = 3.88 \times 10^{-2}\ ft^2/sec \times 60\ sec/1\ min \times 60\ min/hr \times 24\ hr/1\ day\ (.02)w$$

$$Q = \frac{67.04\ ft^2\ /day}{\text{Lineal ft of perimeter}}$$

Sump Perimeters:

Length = 60 ft (Figures 7 and 8)
Width = 40 ft (Figures 7 and 8)

Total Perimeter = 2(60 ft) + 2(40 ft) = 200 ft

Cell Ultimate Capacity:

$$Q_{ult} = (200\ ft)(67.04\ ft^2/day/LF)(7.48\ GPD/ft^3) = 100{,}292\ GPD$$

A factor of safety of 2.0 has been suggested in the preamble of the January 29, 1991, Final Rule. This will allow for uncertainties in the design (e.g., slope, hydraulic conductivity, thickness of drainage material), construction, operation, and location of the SLCS, waste and leachate characteristics, likelihood and amounts of other sources of liquids in the SLCs, and proposed response actions (e.g., the ALR must consider decreases in the flow capacity of the system over the time resulting from siltation and clogging, rib layover and creep of synthetic components of the system, overburden pressure, etc.).

$$\begin{aligned} Q_{allowable} &= (1/F.S.)(Q_{ult}) \\ &= (1/2)(100{,}292\ GPD) \\ &= 50{,}146\ GPD \end{aligned}$$

RP/CWMNYORK/AD4

Drainage System Analysis

The Drainage System calculations were done in five sections:

1. Sideslope drainage system design.
2. Base drainage system design.
3. Base channel design.
4. Final cover design.
5. Geonet transmissivity conversion to hydraulic conductivity calculations.

The calculations were performed using the EPA's Geosynthetic Design Guidance Document as a reference.

Applicable Equation:

$$T = Q/Wi$$

T = transmissivity
Q = flow
W = Geonet width
i = Gradient
(For all cases, i was assumed equal to the slope. This models a saturated condition.)

The flow designed for was produced by a 3.6-inch, 24-hour rainfall event. This rainfall represents an event with a reoccurrence interval of 25 years for the Buffalo area. The base and channel flows were analyzed with the aid of the EPA HELP Model Version II. The model simulated an active cell with a 10-foot layer of waste in place. This represents a realistic conservative approach for determining the infiltration through the waste mass.

1. Sideslope Drainage System Calculations

EPA Help Model II Input: See this Appendix.

Climatic Data: Syracuse, New York.

Soil Data: According to design.

HELP Model Results: See this Appendix.

Design Considerations:

1. The head on the liner must not exceed 1 foot.
2. $K > 1 \times 10^{-2}$ cm/sec (Drainage Aggregate).
3. Transmissivity of geonet (PN-3000) $T = 7.5 \times 10^{-4}$ m^2/sec, which is interpolated from J&L transmissivity testing curve as shown on Figure 2A in this appendix.
4. Q net > Q inflow from contributing area.

5. Response time (A leak in the primary system must be detected within 24 hours in the secondary system).

References: Properties of plastic nets for liquid and gas drainage associated with Geomembranes, William N. Giroud, J.P. Bonaparte R. Published in Geotextiles and Geomembranes 3rd Ed.

*Geosynthetic Design Guidance Document EPA Office of Research and Development, Richardson G., Koerner R.

Purpose: To determine the effectiveness of using one layer of geonet (Polynet PN-3000) with a transmissivity of 7.5×10^{-4} m^2/s (Normal Load = 11,111 psf) to transmit the infiltration due to a 25-year, 24-hour rainfall event (3.6 in./day). The gravel layer is omitted from the sideslope analysis.

Applicable Equations:

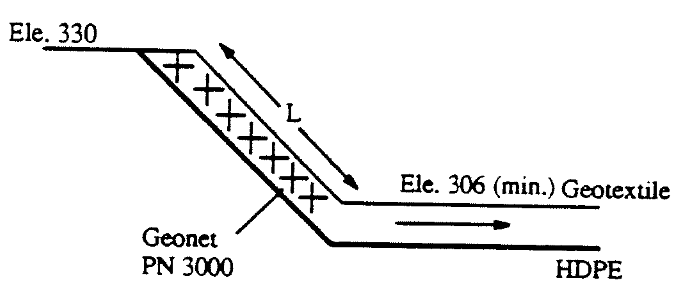
Transmissivity = T = Q/Wi

Q = flow rate
W = width of geonet
i = gradient

Calculations:

Q = LWI; Set W=1 ft (i.e.: Calculate the flow per unit width of geonet.)

L = horizontal length of flow, the maximum flow length of the sideslope
L = 76 ft



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I = intensity = 3.6 in./day = 3.47×10^{-6} ft/s

$Q = 76 \text{ ft} \times 1 \text{ ft} \times 3.47 \times 10^{-6} \text{ ft/s} = 2.6 \times 10^{-4} \text{ ft}^3\text{/s}$

The required sideslope transmissivity is:

$$T_{req} = \frac{Q_{req}}{Wi} = \frac{2.6 \times 10^{-4} \text{ ft}^3\text{/s}}{1 \text{ ft} \times 0.33} = 8 \times 10^{-4} \text{ ft}^2\text{/s}$$

The actual geonet transmissivity is taken from manufacturer's graphs for normal load = 11,111 psf, i = 0.33:

$$T_{act} = 7.5 \times 10^{-4} \text{ m}^2\text{/s} = 8.07 \times 10^{-3} \text{ ft}^2\text{/s}$$

The EPA (Geosynthetic Design Guidance 1986) recommends a Design Ratio (DR) of three. This reflects the high probability of the design event not occurring during the short operational period when the sideslope is exposed.

$$T_{act}/T_{req} = 8.07 \times 10^{-4}/8.0 \times 10^{-3} = 10$$

One layer is sufficient according to EPA's guidance document for the sideslope primary leachate collection system and secondary leachate collection system.

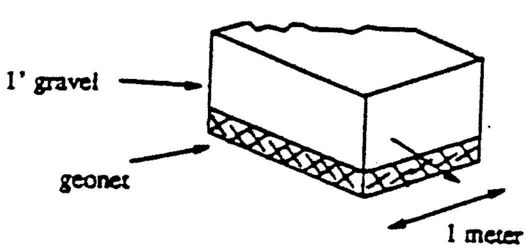
2. Base Drainage System Calculations

The base drainage system transmits leachate that infiltrates through the waste layer as well as run-off caused by rainfall on the exposed sideslope. The amount of infiltration was computed with the aid of the EPA's HELP model. The model simulated an active landfill with 10 feet of refuse on the base. The results of the HELP analysis follow.

To calculate the required transmissivity of the base drainage system, a 1-meter wide flow path along the direction of farthest travel length was used. The flow comes from infiltrating leachate and sideslope run-off. The HELP model analysis showed that the infiltrating leachate peak lags the sideslope run-off by 3 days. Since the sideslope calculations showed the drainage system can handle the sideslope run-on, the following calculations will check the drainage system capacity for infiltrating leachate.

The same "driving equations" are used for the base calculations as were used for the sideslope calculations. The transmissivity of the drainage system must be large enough to transmit the flow through the ends of the "Design Unit". (The system will be assumed at steady state conditions.)

For one single layer of geonet PN-3000, the transmissivity in the order of 8.0×10^{-4} m²/sec is interpolated from J&L transmissivity testing curve for normal load of 11,111 psf and gradient of 2.9 percent as shown on Figure 2A.



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Base Drainage System Calculations

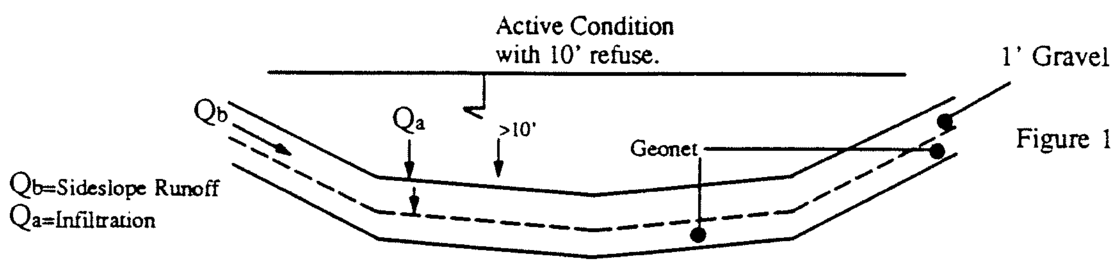
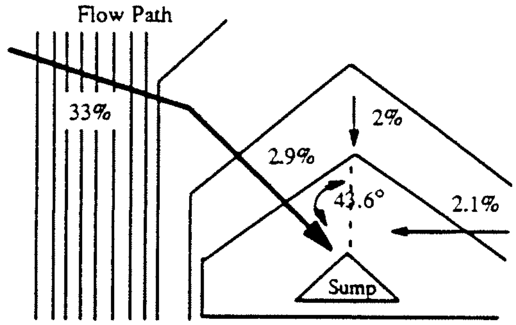


Figure 1



Slope in direction of flow.

$$\tan^{-1}\left(\frac{.02}{.021}\right) = 43.6°$$

$$\cos 43.6° * 100 = 72.4'$$

$$\sin 43.6° * 100 = 68.97'$$

$$\frac{2.0}{100} * 68.97 = 1.3794'$$

$$\frac{2.1}{100} * 72.4 = 1.5204'$$

$$\text{Slope} = \frac{1.3794 + 1.5204}{100} = 0.029 = 2.9\%$$

Applicable Equation $T = \frac{Q}{Wi}$

T = transmissivity (ft^2/s), T = K x t, t - the thickness of drainage layer
Q = flow (ft^3/s)
W = width of flow (ft): W = 1; unit width of flow
i = gradient   i = 2.9% = .029

Flow capacity/ft width of granular layer on base:

$Q = T \times W \times i$
$T = K \times t$
$K = 1 \times 10^{-2}$ cm/s $= 3.28 \times 10^{-4}$ ft/s, t = 1 ft
$Q_{granular} = 3.28 \times 10^{-4}$ ft/s x 1 ft x 1 ft x 0.029
$= 9.51 \times 10^{-6}\ ft^3/s$

Flow capacity/ft width of geonet:

$T = 8.0 \times 10^{-4}\ m^2/s = 8.61 \times 10^{-3}\ ft^2/s$
$Q_{geonet} = 8.61 \times 10^{-3}\ ft^2/s \times 1\ ft \times 0.029$
$= 2.5 \times 10^{-4}\ ft^3/s$

Collection system total capacity Q total:

$Q_{total} = Q_{granular} + Q_{geonet} = 9.51 \times 10^{-6} + 2.5 \times 10^{-4} = 2.6 \times 10^{-4}\ ft^3/s$

Actual flow from HELP analysis results for landfill active condition:

Peak daily infiltration $I = 0.1991$ in./day $= 1.92 \times 10^{-7}$ ft/s
$L = 300$ ft
$W = 1$ ft

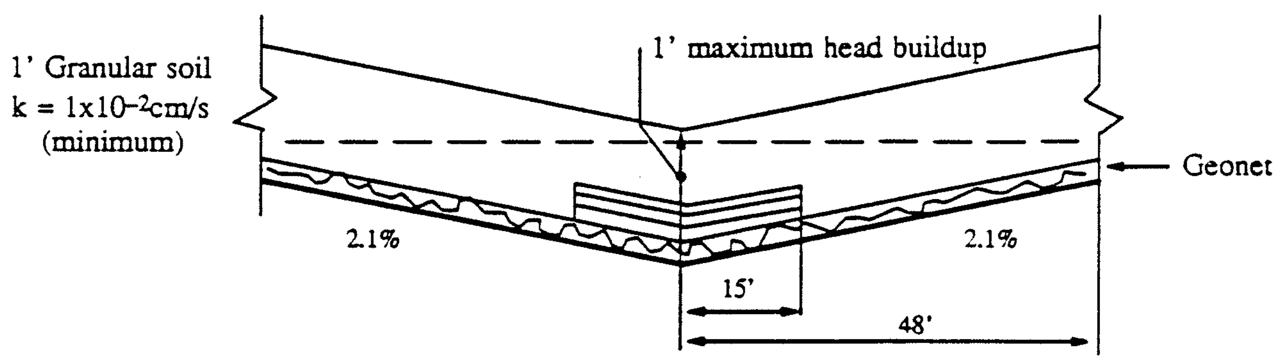
$Q_{req} = 1.92 \times 10^{-7}$ ft/s $\times$ 300 ft $\times$ 1 ft $= 5.76 \times 10^{-5}$ ft^3/s
$Q_{total} = 2.6 \times 10^{-4}$ ft^3/s $> Q_{req} = 5.76 \times 10^{-5}$ ft^3/s

Since the peak daily value of the flow is the most critical condition at the site, the design of the primary leachate collection system at landfill base is adequate.

3. Channel Geonet Calculations

Layers of geonet will be used to replace the pipes that are normally used to collect leachate from the low points in the landfill. The required capacity is the flow from the contributing area shown in Figure 3.

The worst case is represented by Cell 3B. The calculations follow:



Granular Soil Capacity:

$K = 1 \times 10^{-2}$ cm/s $= 3.28 \times 10^{-4}$ ft/s
$T = K \times t$

$Q_g = T \times W \times i = (3.28 \times 10^{-4}$ ft/s $\times$ 1 ft) $\times$ 48' $\times .021 = 3.3 \times 10^{-4}$ ft^3/s

Geonet Capacity (2 layers of double geonet):

$T = 1.8 \times 10^{-3}$ m^2/sec obtained from J&L transmissivity testing curve
$= 1.94 \times 10^{-2}$ ft^2/s for normal load of 11,111 psf and gradient of 2.1 percent as shown on Figure 1A.

$Q_{geonet} = 1.94 \times 10^{-2} \times 2 \times 30' \times .021 = 2.44 \times 10^{-2}$ ft^3/s

$Q_{Total} = 2.47 \times 10^{-2}$ ft^3/s

Peak daily infiltration from active case HELP for contributing area on Figure 1

$I = 0.1991$ in/day $= 1.92 \times 10^{-7}$ ft/s

$A = 93{,}000\ ft^2$, contributing area

$Q = 1.92 \times 10^{-7}$ ft/s $\times$ $93{,}000\ ft^2$

$= 1.79 \times 10^{-2}\ ft^3/s$

$Q_{actual} = 1.79 \times 10^{-2}\ ft^3/s$

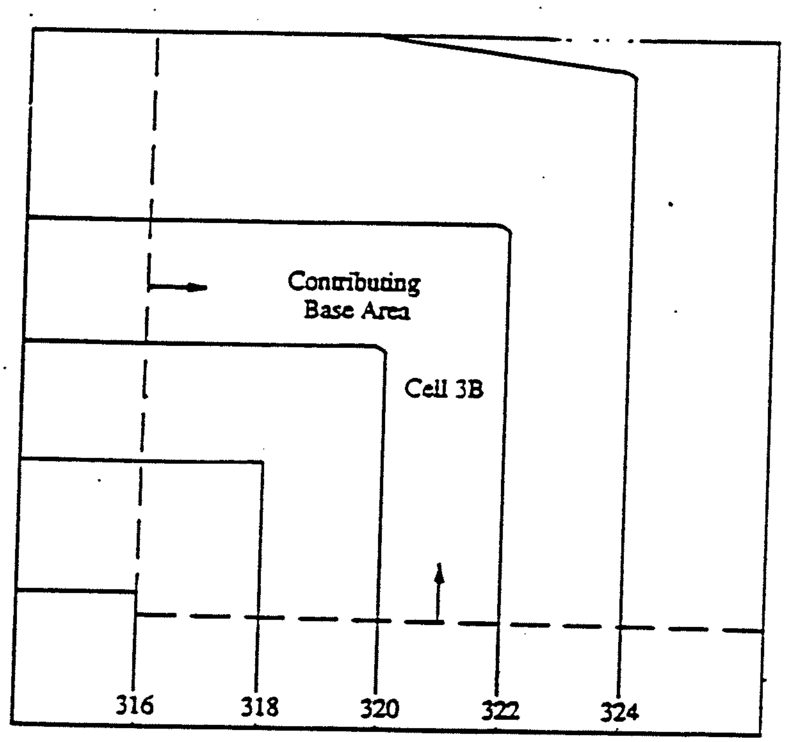
$Q_{actual} < Q_{system} = 1.79 \times 10^{-2}\ ft^3/s < 2.44 \times 10^{-2}\ ft^3/s$ okay

The low point will handle the peak daily 10' refuse infiltration as determined by the HELP model with a Design ratio of:

$\frac{2.44 \times 10^{-2}}{1.79 \times 10^{-2}} = 1.37$, with 2 layers of geonet 25 ft wide and gravel; liquid not greater than 1-foot deep

Although the design ratio is only slightly greater than unit, it should be noted that a factor of safety of 10 has been taken into account when the transmissivity of geonet is selected.

Figure 3



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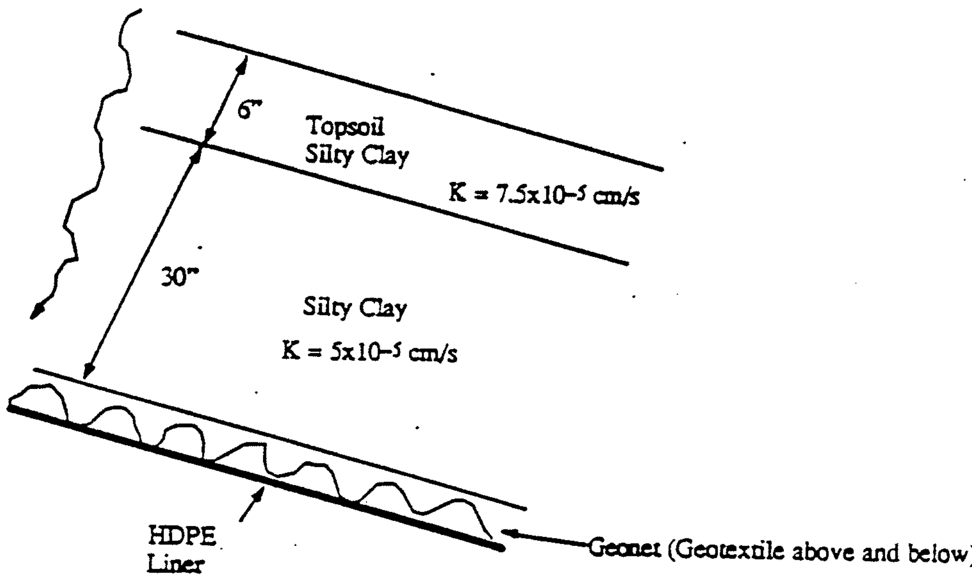
4. Final Cover Geonet Calculations



Applicable Equation:

Transmissivity $T = \frac{Q}{Wi}$

Q = IWL, Flow rate

where: W = unit width of flow
I = 0.4216 in./day = 4.06×10^{-7} ft/s, infiltration from HELP closed conditions

i = 0.33, gradient (assume saturation)
L = 100 ft, flow length

$Q = 4.06 \times 10^{-7}$ ft/s x 1 ft x 100 ft = 4.06×10^{-5} ft/s

$T = 4.06 \times 10^{-5}/(1 \times 0.33) = 1.22 \times 10^{-4}$ ft^2/s

T_{actual} from test data (following)

$= 1 \times 10^{-4}$ m^2/s = 1.08×10^{-3} ft/s

$T_{actual} > T_{req} = 1.08 \times 10^{-3}$ ft^2/s > 1.22×10^{-4} ft^2/s, OK

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Use 1 layer of geonet between geotextile in cap.

It is also allowable to use natural or geosynthetic material with a transmissivity greater than 1.0×10^{-4} m^2/s.

5. Geonet Transmissivity Conversion to Hydraulic Conductivity Calculations

(Material ---> Polynet PN-3000)

This calculation shows drainage layers exceed 1×10^{-2} cm/sec

HELP MODEL ACTIVE CASE (Condition 1)

Base Geonet — Use J&L test data attached with a safety factor of 10 incorporated into load from 10 ft of waste.

$$\text{Over Burden} = \frac{1.5 \text{ ton/cyd} \times 2{,}000 \text{ lb}}{27 \text{ ft}^3\text{/cyd}} \times 10 \text{ ft} \times 10 \approx 11{,}111 \text{ lbs/ft}^2$$

From test data $T = 8.0 \times 10^{-4}$ m^2/s (See Figure 2A from J&L Testing Lab)

$K = T/b$

Where T = transmissivity
b = thickness
k = permeability

Thus $K = \frac{T}{b} = \frac{8.0 \text{ cm}^2\text{/s}}{0.5 \text{ cm}} = 16$ cm/s   Geonet thickness, b = 0.5 cm

HELP MODEL CLOSED CASE (Condition 2)

Cap Geonet

Use Fluid Systems test data for PN-3000 with Trevira 1120 on both sides. Safety factor of greater than 10 is incorporated into lead from final cover.

From Test Data $T = 1 \times 10^{-4}$ m^2/s

Thus $K = \frac{T}{b} = \frac{1 \text{ cm}^2\text{/s}}{0.5 \text{ cm}} = 2$ cm/s

Base Geonet

Use J&L test data with σ = maximum 12,500 lbs

From Test Data, $T = 5.5 \times 10^{-4}$ m^2/s (see Figure 2A from J&L Testing Lab)

$K = \frac{T}{b} = \frac{5.5 \text{ cm}^2\text{/s}}{0.5 \text{ cm}} = 11$ cm/s

Permeability of Waste

$K_{waste} = 5.7 \times 10^{-4}$ cm/sec

which is adopted from the report of Wehran-New York, Inc., "In-Place Waste Permeability Testing for Secure Landfill No. 12 (SLF-12)" dated May 22, 1992.

RP/CWMNYORK/AB7

UNDERDRAIN CAPACITY ANALYSIS

Find: Q mac

Given: S = 0.5%

d_1 = 6"

d_2 = 4"

Material is perforated plastic pipe, n = 0.012

Manning

$$Q = \frac{1.49}{n} \quad A \quad R \quad 2/3 \quad S \quad 1/2$$

$$Q = \frac{1.49}{n} \quad (\pi r^2) \quad \left(\frac{\pi r^2}{2\pi r}\right)^{2/3} \quad S \quad 1/2$$

$$Q = \frac{1.49}{n} \quad (\pi r^2) \quad \left(\frac{r}{2}\right)^{2/3} \quad S \quad 1/2$$

$$= \frac{1.49}{0.012} \quad (\pi\ .167^2) \quad \left(\frac{.167}{2}\right)^{2/3} \quad .005$$

$Q_{max4"}$

= 0.147 cfs = 65.9 gal/min

$$= \frac{1.49}{0.012} \quad (\pi\ .25^2) \quad \left(\frac{25}{2}\right)^{2/3} \quad .005$$

$Q_{max6"}$

= 0.431 cfs = 193.4 gal/min

Use 4" pipe with outlets every 300 feet.

Assume Q = KiA = (16 cm/sec) (.33) (0.5 cm) (1 cm)

= 2.64 cm^3/sec/L

= 0.006 ft^3/min/ft

= 0.042 gal/min/ft

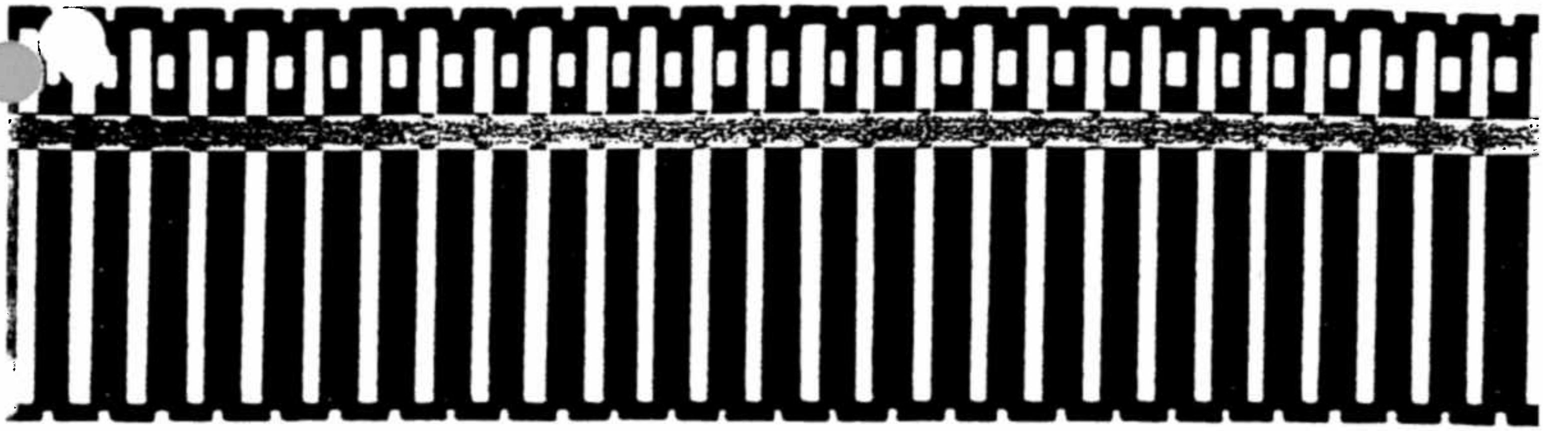
At 300',

(0.042 gal/min/ft) (300 ft)

= 12.6 gal/min   300-ft spacing is ok

RP/CWMNYORK/AB7

PAUL WINTHEISER



- N-12 Storm Sewer Pipe — 4″-36″
- P.E. Manholes — Storm/Sanitary
- AdvanEdge Panel Drain
- Culvert Pipe
- Drainage Pipe
- SB2 Gravel-less leach bed Pipe
- P.E. End Sections
- Geotextile Fabrics
- Accessory Products

ADVANCED DRAINAGE SYSTEMS INC

PAUL MEYER
TERRITORIAL MANAGER

RES: 2208 ASTER ROAD
WAUSAU, WI 54401
(715) 359-8790

733-5477
ADS PLANT:
HARVARD, IL (800) ~~[illegible]~~
ADS REGIONAL OFFICE:
MONTICELLO, IL (217) 762-9448
800-733-9449

ADVANCED DRAINAGE SYSTEMS, INC.

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
		18" Diameter	0.015
		24" Diameter	0.018
		36" Diameter	0.021
Spiral-Rib			0.012
Plastic Pipe (SDR, S&D, Etc.)			0.011
Vitrified Clay			0.013

Within the pipe industry, there are a wide range of "n" values for various pipe types. A couple of items should be considered prior to selecting a lower "n" value for design on any gravity flow system:

1. "n" values developed for any given pipe are velocity dependent; as the velocity increases, the "n" value decreases within the range of velocities normally used for storm sewer or culvert design. For A.D.S. N-12, A.D.S. chose to use the Manning's "n" value of 0.012 indicated at approximately 2.5 F.P.S. rather than the "n" value of 0.010 indicated at 7.5 F.P.S. Figure 1 shows the test curve for N-12 pipe.

2. There is a wide variation of actual pipe inside diameters depending on pipe type. A.D.S. pipe, both N-12 and corrugated, is manufactured so that the actual inside diameter equals or exceeds the nominal diameter. Design flow rates should be based on actual inside diameters. Table 2 shows typical pipe inside diameters for a number of pipe types.

TABLE 2

Actual Pipe Inside Diameters
(inches)

Nominal Diameter	A.D.S.	PVC	CSP	RCP
12	12.1	11.78	11.5	12
15	15.15	14.42	14.5	15
18	18.2	17.65	17.5	18
24	24.2	23.5	23.5	24
30	30.1	29.5	29.5	30
36	36.1	35.5	35.5	36

TABLE 4

CIRCULAR PIPE FLOW CAPACITY
Full Flow (cubic feet per second)

Mannings "n"= 0.012

Dia. (in.)	*Conv. Factor	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
		% Slope (feet per 100 feet) (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	0.16	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	0.66	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	25.46	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	109.00
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

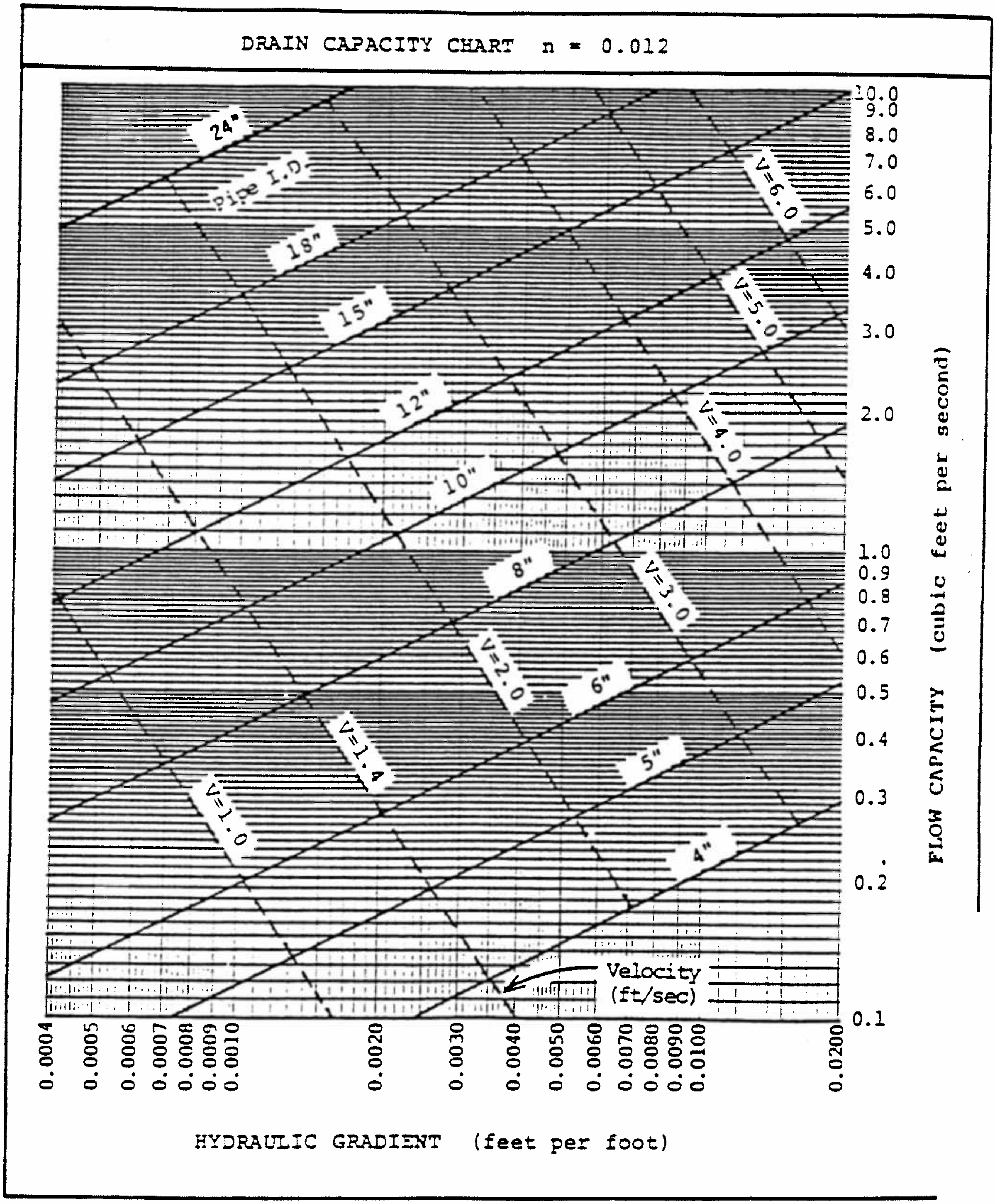

DRAIN CAPACITY CHART n = 0.012
24"
Pipe I.D.
18"
15"
12"
10"
8"
6"
5"
4"
V=6.0
V=5.0
V=4.0
V=3.0
V=2.0
V=1.4
V=1.0
Velocity (ft/sec)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
FLOW CAPACITY (cubic feet per second)
0.0004
0.0005
0.0006
0.0007
0.0008
0.0009
0.0010
0.0020
0.0030
0.0040
0.0050
0.0060
0.0070
0.0080
0.0090
0.0100
0.0200
HYDRAULIC GRADIENT (feet per foot)

Figure 2

LABORATORY TEST RESULTS
DETERMINATION OF FLOW CHARACTERISTICS
PRIMARY AND SECONDARY COLLECTION SYSTEMS
SLF-12, MODEL CITY FACILITY
P.O. NO.: 55440

PERFORMED FOR:

CWM Chemical Services, Inc.
Administrative Entrance
1355 Balmer Road
Model City, New York 14107

PERFORMED BY:

J&L Testing Company, Inc.
938 South Central Avenue
Canonsburg, Pennsylvania 15317

OCTOBER 13, 1989

J & L TESTING COMPANY, INC.

GEOTECHNICAL, GEOMEMBRANE, GEOTEXTILE AND CONSTRUCTION
MATERIALS TESTING AND RESEARCH

October 13, 1989

Job No. 89R634-01
P.O. No.: 55440

CWM Chemical Services, Inc.
Administrative Entrance
1355 Balmer Road
Model City, New York 14107

Attention: Mr. Joseph S. Pizzuto, P.E.
Special Projects Manager

RE: **LABORATORY TEST RESULTS**
DETERMINATION OF FLOW CHARACTERISTICS
PRIMARY AND SECONDARY COLLECTION SYSTEMS
SLF-12, MODEL CITY FACILITY

ear Mr. Pizzuto:

Presented herewith are the results of our test program to determine the flow characteristics of the primary and secondary leachate collection systems within SLF-12. This test program was developed subsequent to USEPA comments regarding the performance of the primary and secondary collection systems. The data presented within includes determinations of permittivity, permeability and transmissivity of the components of the primary and secondary systems using realistic boundary conditions in an attempt to verify the design values used in the initial design of the facility with the materials which were delivered to the site.

The following figures Numbered 1A & 1B and 2A & 2B present the transmissivity of each collection system. Permeability of the primary collection system is presented on the data sheets titled "Coefficient of Permeability" followed by a plot depicting permeability versus load (Figure 3) and a schematic which illustrates our test apparatus (Figure 4). Table PER-1 includes permittivity of the Trevira 1145 and Figure 5 presents an evaluation of the creep potential of the geonet double layer.

H CENTRAL AVENUE
CANONSBURG, PENNSYLVANIA 15317

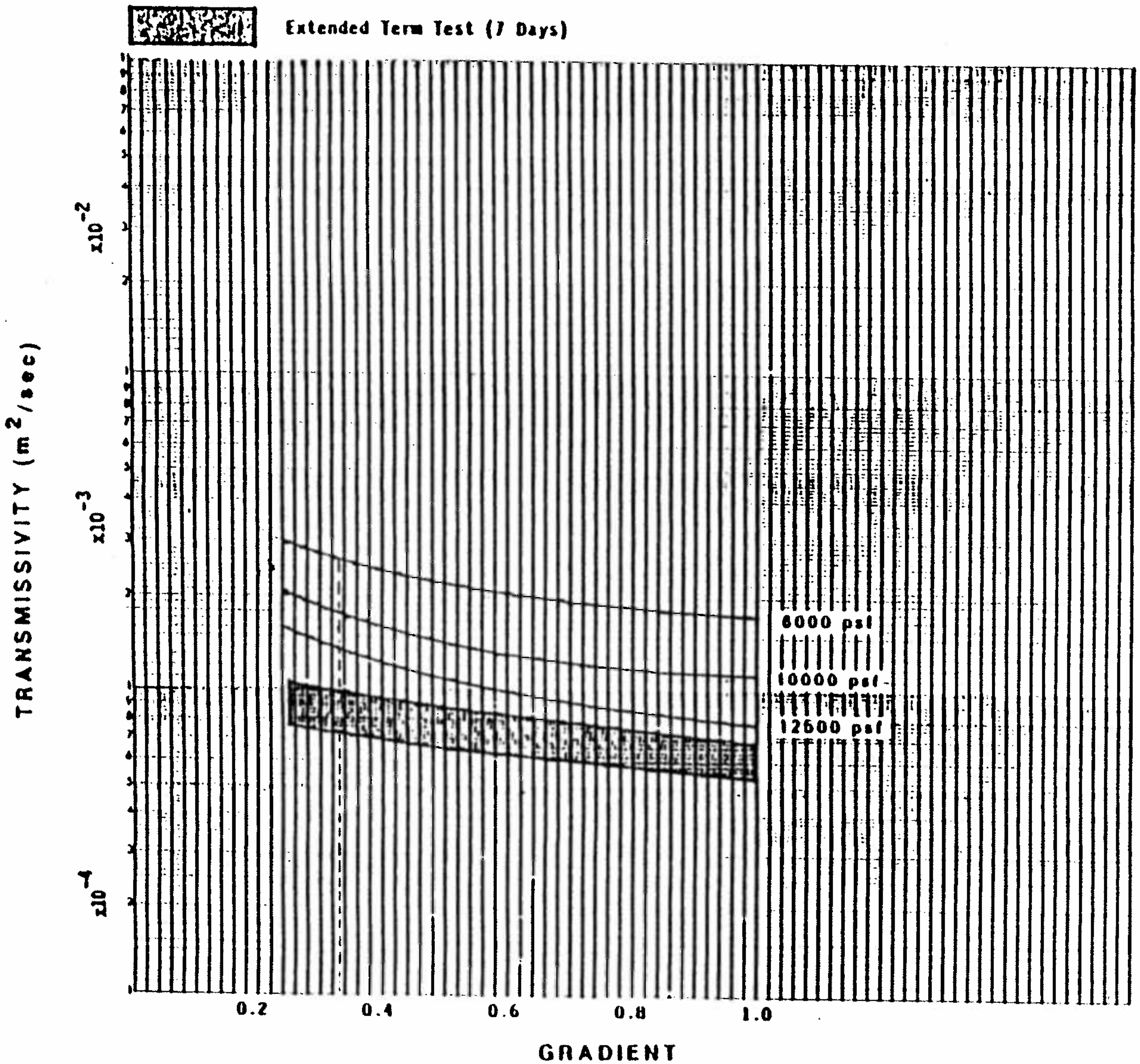
We hope the enclosed data fulfills your needs. If you have any questions or require additional information, please call.

Sincerely,

J&L TESTING COMPANY, INC.

Dean E. Ferry, P.E.
Manager - Geotechnical Testing

DEF/sjs
L-S#92



J & L TESTING COMPANY, INC.
Geotechnical Geomembrane and Geotextile Testing

MATERIALS:

Clay - Site Stockpiled Material
Trevira 1145 Non-Woven Geotextile
PN-3000 Geonet
Gundle 80 Mil HDPE
Trevira 1155 Non-Woven Geotextile

FLUID: Water

UNIT NO.: 3 TEMPERATURE: 70°F

SECTION:

UPPER LOAD PLATE
CLAY
TREVIRA 1145
PN-3000
PN-3000
HDPE
TREVIRA 1155
CLAY
LOWER LOAD PLATE

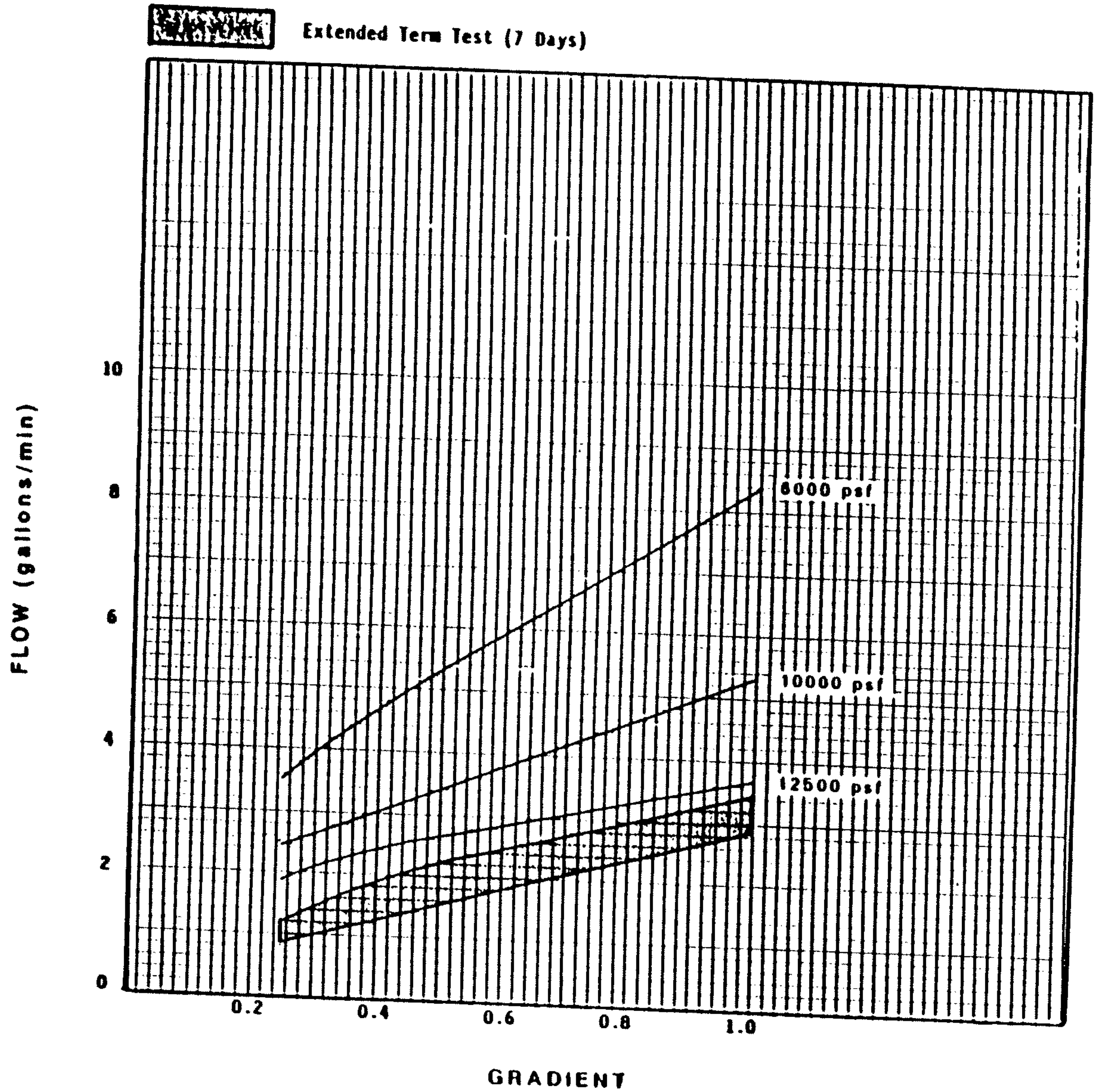
TRANSMISSIVITY TEST RESULTS

CHEMICAL WASTE MANAGEMENT, INC.
SLF-12
MODEL CITY FACILITY
SECONDARY COLLECTION SYSTEM

PROJECT NO: 89R634-01

DATE: 10-2-89

FIGURE 1A



J & L TESTING COMPANY, INC.
Geotechnical Geomembrane and Geotextile Testing

MATERIALS:

Clay - Site Stockpiled Material
Trevira 1145 Non-Woven Geotextile
Pn-3000 Geonet
Gundle 80 Mil HDPE
Trevira 1155 Non-Woven Geotextile

FLUID: Water

UNIT NO.: 3 TEMPERATURE: 70°F

SECTION:

UPPER LOAD PLATE
CLAY
TREVIRA 1145
PN-3000
PN-3000
HDPE
TREVIRA 1155
CLAY
LOWER LOAD PLATE

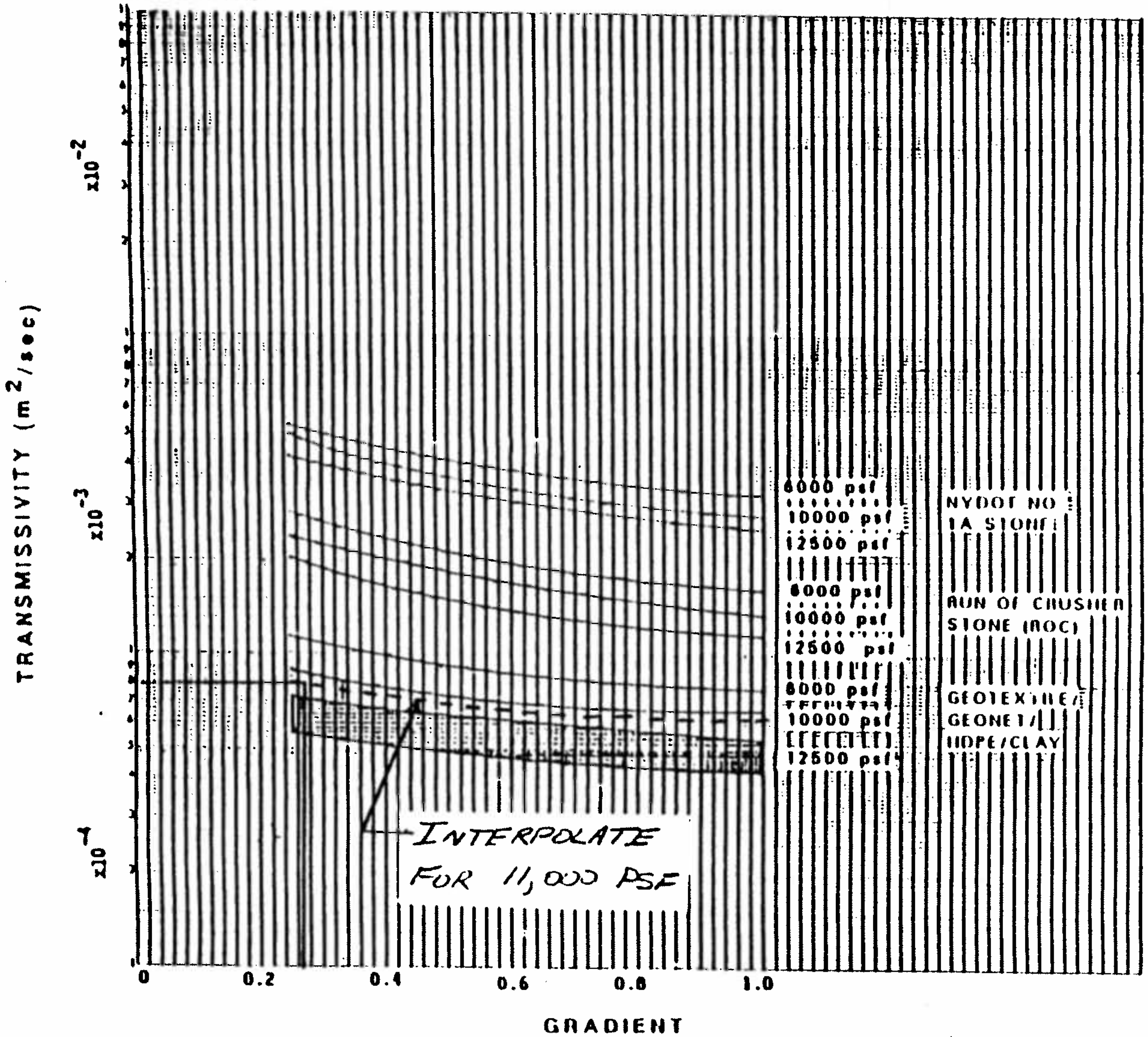
TRANSMISSIVITY TEST RESULTS

CHEMICAL WASTE MANAGEMENT, INC.
SLF-12
MODEL CITY FACILITY
SECONDARY COLLECTION SYSTEM

PROJECT NO: 89R634-01

DATE: 10-2-89 FIGURE 18

Extended Term Test (7 Days)



J & L TESTING COMPANY, INC.

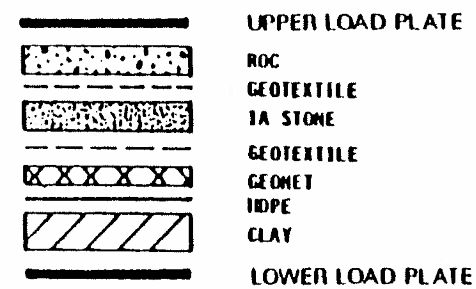
MATERIALS:

Run of Crusher Stone (ROC)
Trevira 1145 Non-Woven Geotextile
NYDOT No.: 1A Stone
PN-3000 Geonet
Gundle 80 Mil HDPE
Clay (Site Stockpiled Material)

FLUID: Water

UNIT NO.: 3 TEMPERATURE: 70°F

SECTION:

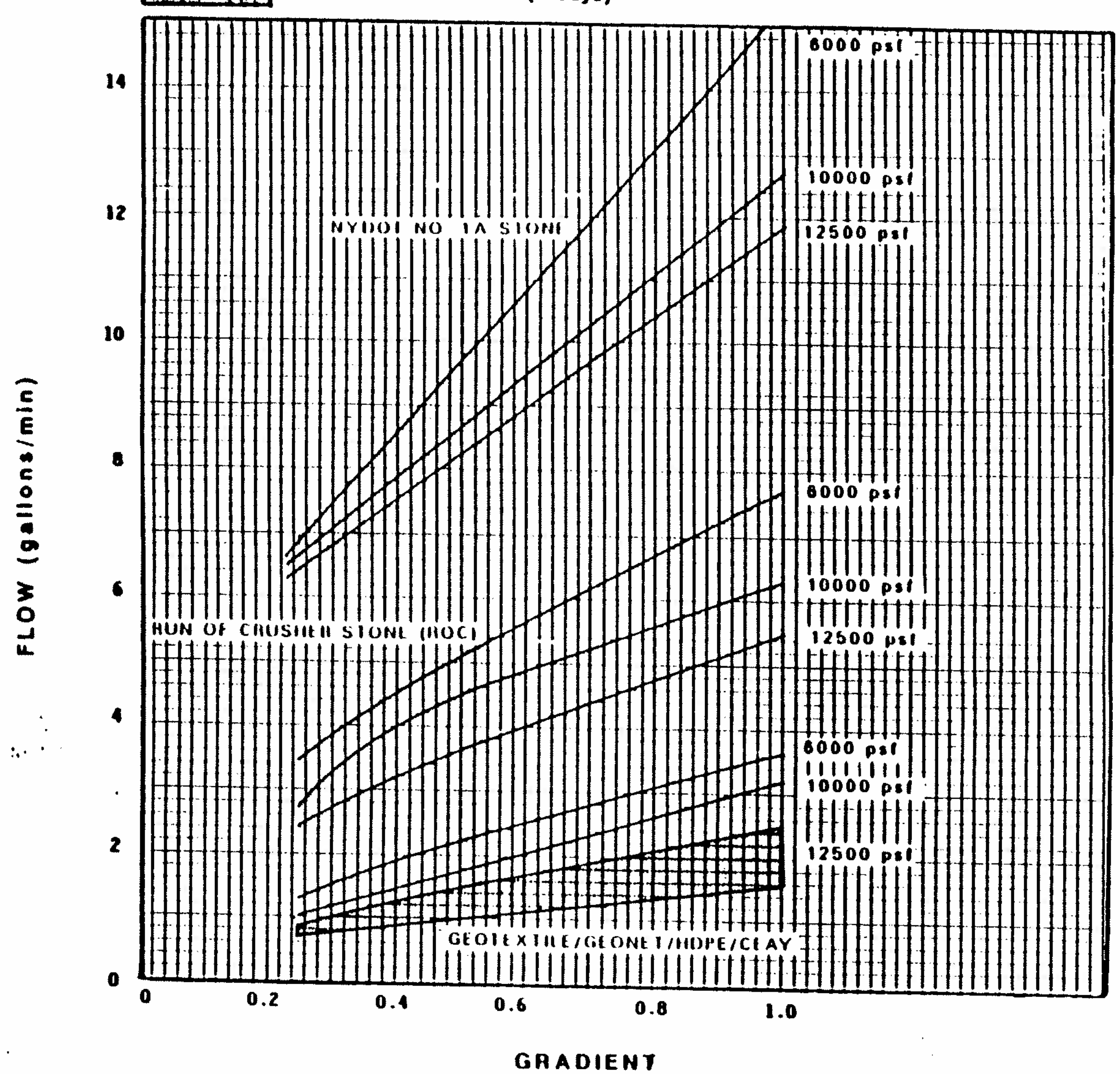


TRANSMISSIVITY TEST RESULTS

CHEMICAL WASTE MANAGEMENT, INC.
SLF-12
MODEL CITY FACILITY
PRIMARY COLLECTION SYSTEM

PROJECT NO: 89R634-01

DATE: 10-13-89 FIGURE 2A



J & L TESTING COMPA. . ., INC.

Geotechnical Geomembrane and Geotextile Testing

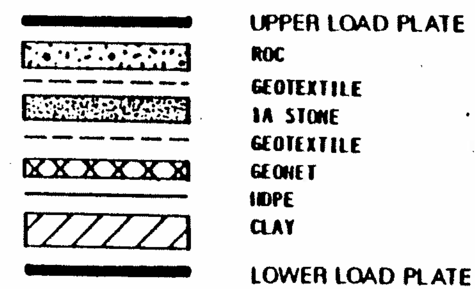
MATERIALS:

Run of Crusher Stone (ROC)
Trevira 1145 Non-Woven Geotextile
NYDOT No. 1A Stone
PN-3000 Geonet
Gundle 80 Mil HDPE
Clay (Site Stockpiled Material)

FLUID: Water

UNIT NO.: 3 TEMPERATURE: 70°F

SECTION:



TRANSMISSIVITY TEST RESULTS

CHEMICAL WASTE MANAGEMENT, INC.
SLF-12
MODEL CITY FACILITY
PRIMARY COLLECTION SYSTEM

PROJECT NO.: 89R634-01

DATE: 10-13-89

FIGURE 28

COEFFICIENT OF PERMEABILITY (Constant Head, Falling Head)

Project CMM - SLF-12 Job No. 89R634-01

Location of Project Model City

Description of Soil See Figure

Tested by DEF Date of Testing 9-26-89

Constant Head

Mold dimensions: Diam. 33.0 cm ; Ht. 30.5 cm ; Area 856 cm² ; Vol. --- cu ft

Wt. of mold + gasket + base = ---

Wt. of mold + gasket + base + soil = --- Unit wt. --- pcf

Wt. of soil = ---

h = 41.3 cm inches Normal Stress = 6,000 psf

Test data / *Test data used*

Test No.	t, sec	Q, cu cm	T, °C	Test No	t, sec	Q, cu cm	T, °C
1	228	17,300	21				
2	230	17,300	21				
3	210	17,300	21				
4							
				Average[a]		17,300	21

$k_T = QL/Aht = \dfrac{17{,}300 \times 30.5 \text{ cm}}{(856 \text{ cm}^2 \times 41.3 \text{ cm})\ 223 \text{ sec.}}$ $\eta_T/\eta_{20} =$ 0.9761

$= 6.7 \times 10^{-2}$ cm/sec $k_{20} = k_T\eta_T/\eta_{20} = 6.5 \times 10^{-2}$ cm/sec

Falling Head

Standpipe = [burette, other (specify)] ________

Area of standpipe, a = ________ sq cm

Test data[b] / *Test data used*

Test no	h_1, cm	h_2, cm	t sec	Q_{in}, cu cm	Q_{out}, cu cm	T °C	Test no	h_1, cm	h_2, cm	t, sec	T °C
1											
2											
3											
4											
							Average				

$\eta_T/\eta_{20} =$ ________

$k_T = \dfrac{2.3aL}{At}\text{Log } h_1/h_2 =$ ________ = ________ cm/sec

$k_{20} = k_T\eta_T/\eta_{20} =$ ________ = ________ cm/sec

[a]Use averaged values only if there is a small difference in test temperature, say, 1–2°C.
[b]This test can be considerably simplified by using the same values of h_1 and h_2 each time; otherwise, you cannot average these values regardless of T.

J & L TESTING COMPANY
Geotechnical Testing

COEFFICIENT OF PERMEABILITY (Constant Head, Falling Head)

Project CMM - SLF-12 Job No. 89R634-01

Location of Project Model City

Description of Soil See Figure

Tested by DEF Date of Testing 9-26-89

Constant Head

Mold dimensions: Diam. 33.0 cm ; Ht 30.5 cm ; Area 856 cm² ; Vol. --- cu ft

Wt. of mold + gasket + base = ---

Wt. of mold + gasket + base + soil = --- Unit wt. --- pcf

Wt. of soil = ---

h = 41.3 cm inches

Normal Stress = 10,000 psf

Test data / *Test data used*

Test No.	t, sec	Q, cu cm	T, °C	Test No.	t, sec	Q, cu cm	T, °C
1	283	17,300	21				
2	262	17,300	21				
3	271	17,300	21				
4							
				Average[a]	272	17,300	21

$k_T = QL/Aht = \dfrac{17{,}300 \times 30.5\ \text{cm}}{(856\ \text{cm}^2 \times 41.3\ \text{cm})\ 272\ \text{sec.}}$

$= 5.5 \times 10^{-2}$ cm/sec

$\eta_T/\eta_{20} = 0.9761$

$k_{20} = k_T\eta_T/\eta_{20} = 5.4 \times 10^{-2}$ cm/sec

Falling Head

Standpipe = [burette, other (specify)] ________

Area of standpipe, a = ________ sq cm

Test data[b] / *Test data used*

Test no	h_1, cm	h_2, cm	t sec	Q_{in}, cu cm	Q_{out}, cu cm	T, °C	Test no	h_1, cm	h_2, cm	t, sec	T °C
1											
2											
3											
4											
							Average				

η_T/η_{20} = ________

$k_T = \dfrac{2.3aL}{At}\text{Log}\, h_1/h_2$ = ________ = ________ cm/sec

$k_{20} = k_T\eta_T/\eta_{20}$ = ________ = ________ cm/sec

[a]Use averaged values only if there is a small difference in test temperature, say, 1–2°C.

[b]This test can be considerably simplified by using the same values of h_1 and h_2 each time, otherwise, you cannot average these values regardless of T.

COEFFICIENT OF PERMEABILITY (Constant Head, Falling Head)

Project CMM - SLF-12 Job No. 89R634-01

Location of Project Model City

Description of Soil See Figure

Tested by DEF Date of Testing 9-26-89

Constant Head

Mold dimensions: Diam. 33.0 cm ; Ht. 30.5 cm ; Area 856 cm² ; Vol. --- cu ft

Wt. of mold + gasket + base = ---

Wt. of mold + gasket + base + soil = ---

Wt. of soil = ---

Unit wt. --- pcf

h = 41.3 cm inches

Normal Stress = 12,500 psf

Test data

Test No.	t, sec	Q, cu cm	T, °C
1	308	17,300	21
2	294	17,300	21
3	298	17,300	21
4			

Test data used

Test No.	t, sec	Q, cu cm	T, °C
Average [a]	300	17,300	21

$k_T = QL/Aht = \dfrac{17{,}300 \times 30.5 \text{ cm}}{(856 \text{ cm}^2 \times 41.3 \text{ cm})\ 300 \text{ sec.}}$

$= 5.0 \times 10^{-2}$ cm/sec

$\eta_T/\eta_{20} =$ 0.9761

$k_{20} = k_T\eta_T/\eta_{20} =$ 4.9×10^{-2} cm/sec

Falling Head

Standpipe = [burette, other (specify)] ______

Area of standpipe, a = ______ sq cm

Test data [b]

Test no.	h_1, cm	h_2, cm	t sec	Q_{in}, cu cm	Q_{out}, cu cm	T, °C
1						
2						
3						
4						

Test data used

Test no.	h_1, cm	h_2, cm	t, sec	T °C
Average				

$\eta_T/\eta_{20} =$ ______

$k_T = \dfrac{2.3aL}{At} \text{Log } h_1/h_2 =$ ______ = ______ cm/sec

$k_{20} = k_T\eta_T/\eta_{20} =$ ______ = ______ cm/sec

[a]Use averaged values only if there is a small difference in test temperature, say, 1–2°C.

[b]This test can be considerably simplified by using the same values of h_1 and h_2 each time, otherwise, you cannot average these values regardless of T.

J & L TESTING COMPANY
Geotechnical Testing

PERMEABILITY VERSUS LOAD

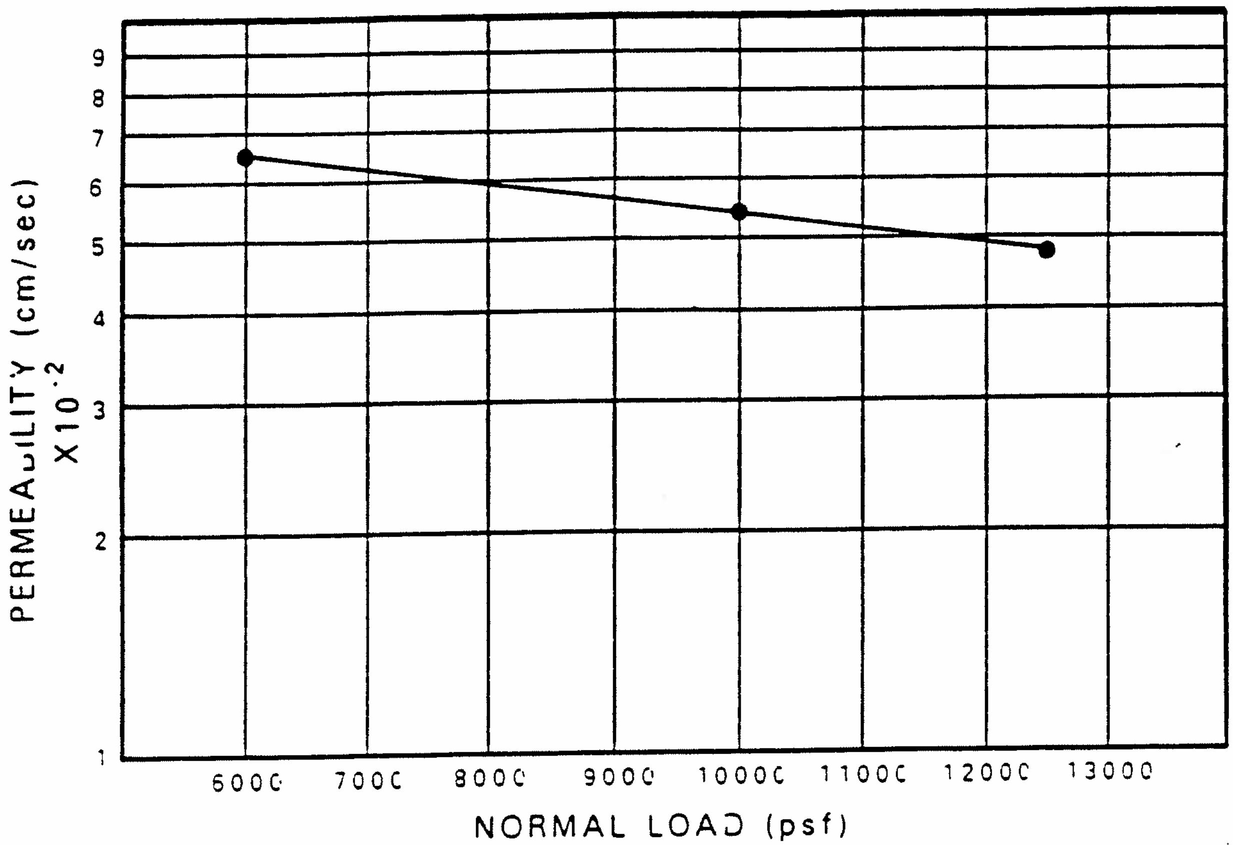


FIGURE 3

PERMEAMETER

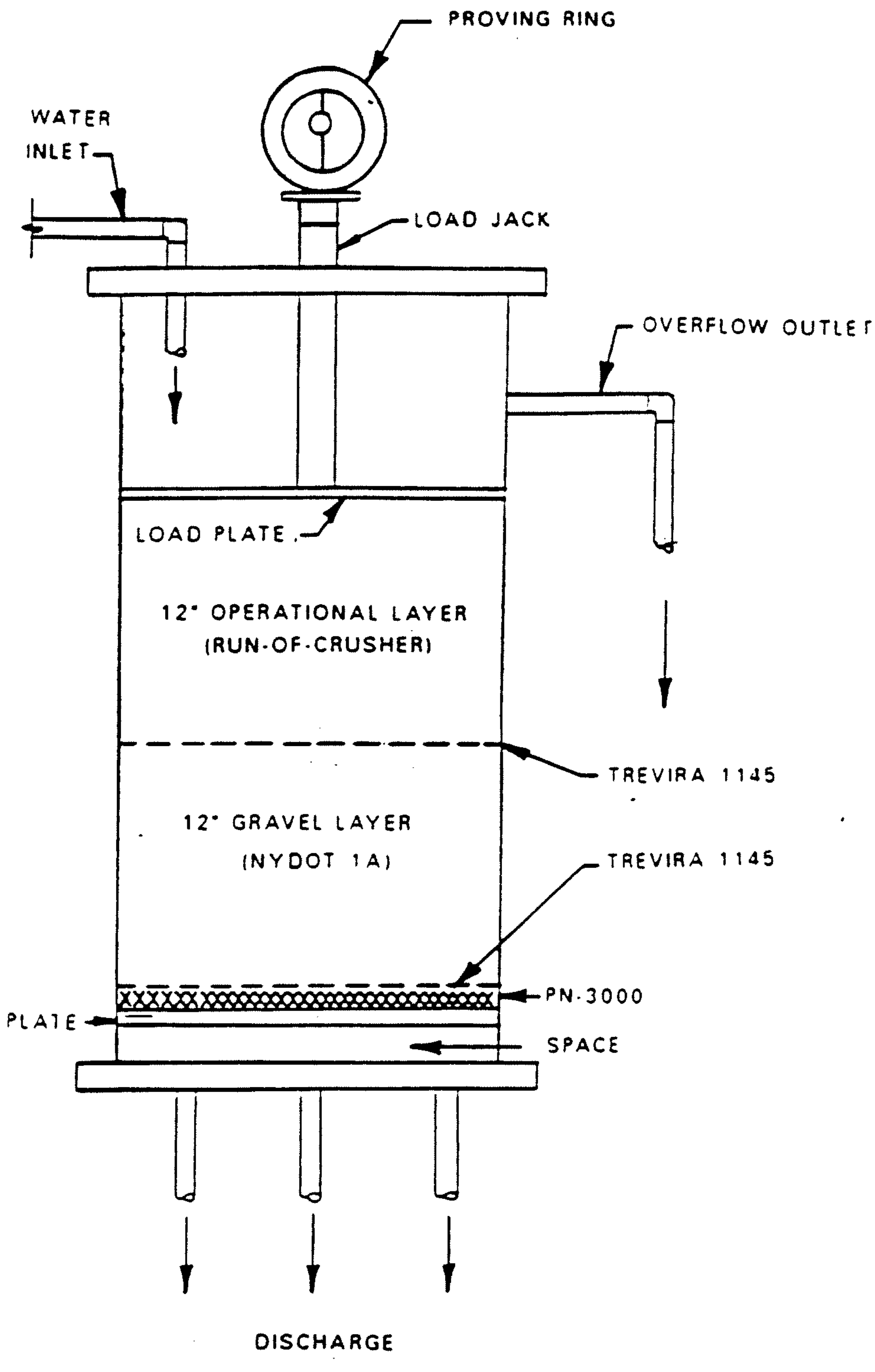


FIGURE 4

TABLE PER-1

PERMITTIVITY TEST RESULTS
TREVIRA 1145 GEOTEXTILE
FOR
CWM CHEMICAL SERVICES,INC.
MODEL CITY LANDFILL

ASTM D-4491
(CONSTANT HEAD METHOD)

REPLICATE NO.	PERMITTIVITY (sec-1)
1	0.82
2	0.79
3	0.78
4	0.91
AVERAGE	0.83
PERMEABILITY(cm/sec)	0.37

NOTES:
1. Values corrected for water temperature of 20 deg. C.
2. Sample diameter = 5.40 cm.
3. Constant head = 5.0 cm.

CREEP POTENTIAL EVALUATION

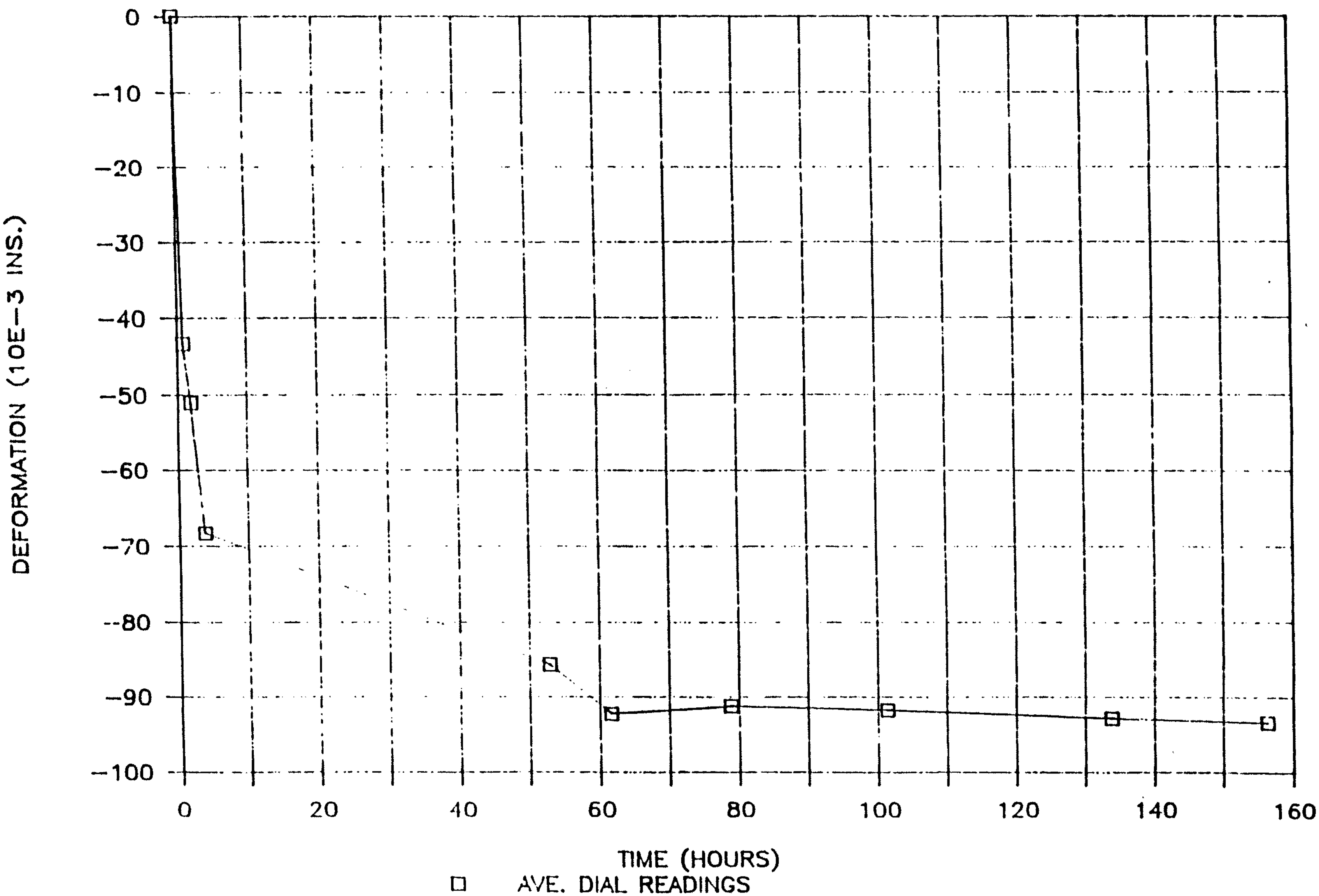


FIGURE 5

FOR CHANNEL CALCULATION

Passed, BB.

PLATE / SOIL / TN3000 DOUBLE / SOIL / PLATE

ASTM D 4716 HYDRAULIC TRANSMISSIVITY

Received 10-11-89

TN3000

SAMPLE: ~~[illegible]~~ - 1120 - DOUBLE

JOB 89146

SPECIMEN: 1 **Confining Pressure:** 6000psf **Gradient:** .45

	Seconds	Liters	Temp	Fv	Transmissivity x 10^{-4}
Run #1	60.1	.76	18.3°	1.043	1.0
Run #2	60.3	.75			.90
Run #3	60.1	.74			.90
				Avg:	.933
				SD:	.0577

SPECIMEN: 2 **Confining Pressure:** 6K **Gradient:** .45

	Seconds	Liters	Temp	Fv	Transmissivity x 10^{-4}
Run #1	60.39	.95	19.5°	1.012	1.2
Run #2	60.03	.92			1.1
Run #3	60.07	.88			1.1
				Avg:	1.133
				SD:	.057

SPECIMEN: 3 **Confining Pressure:** 6K **Gradient:** .45

	Seconds	Liters	Temp	Fv	Transmissivity x 10^{-4}
Run #1	60.21	1.22	20.7°	.9831	1.0
Run #2	61.15	1.27			1.0
Run #3	59.94	1.19			1.0
				Avg:	1.0
				SD:	-0-

SPECIMEN: 4 **Confining Pressure:** 6K **Gradient:** .45

	Seconds	Liters	Temp	Fv	Transmissivity x 10^{-4}
Run #1	60.5	.83	21.5°	.9644	1.0
Run #2	60.13	.81			.90
Run #3	59.81	.81			1.0
				Avg:	.967
				SD:	.0577

AVG = 1.00833×10^{-4} m²/sec

SD = $.0903 \times 10^{-4}$ m²/sec

FOR FINAL COVER CALCULATION

Westinghouse Environmental and Geotechnical Services
Geosynthetics Laboratory
ASTM D4716 Hydraulic Transmissivity Test Result Summary

Cincinnati Branch
Cincinnati, Ohio 45241
(513) 733-9374
Fax No. (513) 733-8213

Date Tested: 02 AUG 89

Date of Summary: 07 AUG 89

-------- Project Identification --------

Client: Fluid Systems, Inc.
Project: BFI Facility Zion, IL
Specimen Description: Polynet 4000 Geocomposite
Specimen Orientation: Machine Direction
Westinghouse Project Number: 4147-89-412

-------- Laboratory Parameters --------

Specimen Width: 12 inches
Bearing Medium: Compacted On-Site Soil @ 90% top and bottom
Water Temp. (C): 23 Temperature Correction: 0.931
Lab Technician: KAB
Gauge Pressure: 6000 psf

-------- R E S U L T S --------

Specimen Number	Elapsed Time (hr)	Hydraul. Gradient	Volume Recorded (gal)	Avg. Time Recorded (sec)	Flow Rate (gpm)	Hydraulic Transmis. (gpm/ft)
1	0.00	0.45	2.0	119.8	1.00	2.1
	0.25	0.45	2.0	132.6	0.90	1.9
	0.50	0.45	2.0	143.2	0.84	1.7
	1.00	0.45	2.0	158.1	0.76	1.6

* Note: Only the hydraulic transmissivity values have been adjusted for temperature.

Filename : HT89412A
Source : Q17

```
*************************************************************************
*************************************************************************

 MODEL CITY, RMU-1
 EPA HELP ANALYSIS
 ACTIVE CONDITIOIN, 6-11-92

*************************************************************************
*************************************************************************


                              BARE GROUND


                               LAYER  1
                               --------

                      VERTICAL PERCOLATION LAYER
  THICKNESS                               =    120.00 INCHES
  POROSITY                                =      0.5200 VOL/VOL
  FIELD CAPACITY                          =      0.2942 VOL/VOL
  WILTING POINT                           =      0.1400 VOL/VOL
  INITIAL SOIL WATER CONTENT              =      0.2819 VOL/VOL
  SATURATED HYDRAULIC CONDUCTIVITY        =      0.000570000033 CM/SEC


                               LAYER  2
                               --------

                      VERTICAL PERCOLATION LAYER
  THICKNESS                               =     24.00 INCHES
  POROSITY                                =      0.4170 VOL/VOL
  FIELD CAPACITY                          =      0.0454 VOL/VOL
  WILTING POINT                           =      0.0200 VOL/VOL
  INITIAL SOIL WATER CONTENT              =      0.1007 VOL/VOL
  SATURATED HYDRAULIC CONDUCTIVITY        =      0.010000000708 CM/SEC


                               LAYER  3
                               --------

                        LATERAL DRAINAGE LAYER
  THICKNESS                               =       0.20 INCHES
  POROSITY                                =       0.8300 VOL/VOL
  FIELD CAPACITY                          =       0.0454 VOL/VOL
  WILTING POINT                           =       0.0200 VOL/VOL
  INITIAL SOIL WATER CONTENT              =       0.0962 VOL/VOL
  SATURATED HYDRAULIC CONDUCTIVITY        =     16.000000000000 CM/SEC
  SLOPE                                   =       2.90 PERCENT
  DRAINAGE LENGTH                         =     100.0 FEET
```

LAYER 4

BARRIER SOIL LINER WITH FLEXIBLE MEMBRANE LINER

THICKNESS	=	18.00 INCHES
POROSITY	=	0.4300 VOL/VOL
FIELD CAPACITY	=	0.3663 VOL/VOL
WILTING POINT	=	0.2802 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4300 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.000000100000 CM/SEC
LINER LEAKAGE FRACTION	=	0.01000000

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	89.04
TOTAL AREA OF COVER	=	43560. SQ FT
EVAPORATIVE ZONE DEPTH	=	8.00 INCHES
POTENTIAL RUNOFF FRACTION	=	0.000000
UPPER LIMIT VEG. STORAGE	=	4.1600 INCHES
INITIAL VEG. STORAGE	=	2.2552 INCHES

SOIL WATER CONTENT INITIALIZED BY USER.

CLIMATOLOGICAL DATA

DEFAULT RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND
SOLAR RADIATION FOR SYRACUSE NEW YORK

MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	133
END OF GROWING SEASON (JULIAN DATE)	=	282

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
22.80	24.00	33.30	46.10	57.00	66.30
70.90	69.30	62.10	51.30	40.60	28.30

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 74 THROUGH 78

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.01	1.98	3.59	3.67	3.71	4.61
	6.32	4.98	5.35	3.91	3.29	3.54
STD. DEVIATIONS	1.57	0.90	0.85	2.56	2.79	1.66
	2.98	1.25	2.22	1.95	1.85	1.07
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	0.440	0.832	1.690	2.883	3.073	3.787
	3.498	3.730	3.030	1.823	1.215	0.543
STD. DEVIATIONS	0.083	0.239	0.114	0.854	2.190	0.662
	1.409	1.090	0.864	0.508	0.194	0.130
LATERAL DRAINAGE FROM LAYER 3						
TOTALS	1.9566	1.8206	1.8127	1.8864	1.6844	1.2861
	1.3363	1.5129	1.5549	2.0829	1.7797	1.9614
STD. DEVIATIONS	0.9333	1.2856	0.8755	0.8610	1.0536	0.8104
	0.6211	0.7323	0.8094	1.3199	0.8197	0.9798
PERCOLATION FROM LAYER 4						
TOTALS	0.0003	0.0002	0.0003	0.0002	0.0003	0.0002
	0.0003	0.0003	0.0002	0.0003	0.0002	0.0003
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

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 74 THROUGH 78

	(INCHES)		(CU. FT.)	PERCENT
PRECIPITATION	47.97	(8.723)	174131.	100.00
RUNOFF	0.000	(0.000)	0.	0.00
EVAPOTRANSPIRATION	26.545	(5.110)	96358.	55.34
LATERAL DRAINAGE FROM LAYER 3	20.6749	(5.8340)	75050.	43.10
PERCOLATION FROM LAYER 4	0.0030	(0.0000)	11.	0.01
CHANGE IN WATER STORAGE	0.747	(3.707)	2713.	1.56

****

****

PEAK DAILY VALUES FOR YEARS 74 THROUGH 78

	(INCHES)	(CU. FT.)
PRECIPITATION	3.90	14157.0
RUNOFF	0.000	0.0
LATERAL DRAINAGE FROM LAYER 3	0.1991	722.8
PERCOLATION FROM LAYER 4	0.0000	0.0
HEAD ON LAYER 4	0.0	
SNOW WATER	3.46	12551.4

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4486

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1359

****

****

FINAL WATER STORAGE AT END OF YEAR 78

LAYER	(INCHES)	(VOL/VOL)
1	37.88	0.3157
2	2.10	0.0877
3	0.01	0.0651
4	7.74	0.4300
SNOW WATER	0.00	

****
****

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************************************************************************
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 MODEL CITY, RUM-1
 EPA HELP ANALYSIS
 FINAL CLOSURE CONDITION, 6-11-92

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FAIR GRASS

LAYER 1

VERTICAL PERCOLATION LAYER

THICKNESS	=	6.00 INCHES
POROSITY	=	0.5010 VOL/VOL
FIELD CAPACITY	=	0.2827 VOL/VOL
WILTING POINT	=	0.1353 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3231 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.000075000004 CM/SEC

LAYER 2

VERTICAL PERCOLATION LAYER

THICKNESS	=	30.00 INCHES
POROSITY	=	0.4300 VOL/VOL
FIELD CAPACITY	=	0.3210 VOL/VOL
WILTING POINT	=	0.2208 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3610 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.000049999999 CM/SEC

LAYER 3

LATERAL DRAINAGE LAYER

THICKNESS	=	0.20 INCHES
POROSITY	=	0.4170 VOL/VOL
FIELD CAPACITY	=	0.0454 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0760 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	2.000000000000 CM/SEC
SLOPE	=	33.00 PERCENT
DRAINAGE LENGTH	=	100.0 FEET

LAYER 4

BARRIER SOIL LINER WITH FLEXIBLE MEMBRANE LINER

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4300 VOL/VOL
FIELD CAPACITY	=	0.3663 VOL/VOL
WILTING POINT	=	0.2802 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4300 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.000000100000 CM/SEC
LINER LEAKAGE FRACTION	=	0.01000000

LAYER 5

VERTICAL PERCOLATION LAYER

THICKNESS	=	120.00 INCHES
POROSITY	=	0.5200 VOL/VOL
FIELD CAPACITY	=	0.2942 VOL/VOL
WILTING POINT	=	0.1400 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1624 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.000570000033 CM/SEC

LAYER 6

VERTICAL PERCOLATION LAYER

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4170 VOL/VOL
FIELD CAPACITY	=	0.0454 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0454 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.000999999931 CM/SEC

LAYER 7

LATERAL DRAINAGE LAYER

THICKNESS	=	0.20 INCHES
POROSITY	=	0.4170 VOL/VOL
FIELD CAPACITY	=	0.0454 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0454 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	11.000000000000 CM/SEC
SLOPE	=	2.90 PERCENT
DRAINAGE LENGTH	=	100.0 FEET

LAYER 8

BARRIER SOIL LINER WITH FLEXIBLE MEMBRANE LINER

THICKNESS	=	18.00 INCHES
POROSITY	=	0.4300 VOL/VOL
FIELD CAPACITY	=	0.3663 VOL/VOL
WILTING POINT	=	0.2802 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4300 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.000000100000 CM/SEC
LINER LEAKAGE FRACTION	=	0.01000000

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	81.48
TOTAL AREA OF COVER	=	43560. SQ FT
EVAPORATIVE ZONE DEPTH	=	20.00 INCHES
UPPER LIMIT VEG. STORAGE	=	9.0260 INCHES
INITIAL VEG. STORAGE	=	6.9926 INCHES

SOIL WATER CONTENT INITIALIZED BY USER.

CLIMATOLOGICAL DATA

DEFAULT RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND
SOLAR RADIATION FOR SYRACUSE NEW YORK

MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	133
END OF GROWING SEASON (JULIAN DATE)	=	282

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
22.80	24.00	33.30	46.10	57.00	66.30
70.90	69.30	62.10	51.30	40.60	28.30

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 74 THROUGH 78

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.01	1.98	3.59	3.67	3.71	4.61
	6.32	4.98	5.35	3.91	3.29	3.54
STD. DEVIATIONS	1.57	0.90	0.85	2.56	2.79	1.66
	2.98	1.25	2.22	1.95	1.85	1.07
RUNOFF						
TOTALS	0.071	0.019	0.076	0.152	0.172	0.050
	0.674	0.233	0.611	0.114	0.027	0.163
STD. DEVIATIONS	0.150	0.021	0.080	0.310	0.377	0.059
	0.748	0.187	1.012	0.129	0.047	0.264
EVAPOTRANSPIRATION						
TOTALS	0.418	0.801	1.689	3.309	3.383	4.488
	4.932	4.977	3.346	1.910	1.152	0.523
STD. DEVIATIONS	0.075	0.225	0.175	0.708	2.131	0.605
	1.865	1.056	0.873	0.286	0.213	0.118
LATERAL DRAINAGE FROM LAYER 3						
TOTALS	1.6721	1.8476	2.1830	1.7344	0.9546	0.3775
	0.3579	0.1962	0.3229	1.4045	1.2247	2.2154
STD. DEVIATIONS	0.9318	1.0961	1.3561	0.8658	1.1673	0.3130
	0.2967	0.1913	0.4732	1.6813	0.9471	1.4450
PERCOLATION FROM LAYER 4						
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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LATERAL DRAINAGE FROM LAYER 7						
TOTALS	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
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

PERCOLATION FROM LAYER 8

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	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 74 THROUGH 78

	(INCHES)		(CU. FT.)	PERCENT
PRECIPITATION	47.97	(8.723)	174131.	100.00
RUNOFF	2.363	(1.236)	8577.	4.93
EVAPOTRANSPIRATION	30.928	(5.995)	112269.	64.47
LATERAL DRAINAGE FROM LAYER 3	14.4909	(4.3574)	52602.	30.21
PERCOLATION FROM LAYER 4	0.0011	(0.0000)	4.	0.00
LATERAL DRAINAGE FROM LAYER 7	0.0050	(0.0004)	18.	0.01
PERCOLATION FROM LAYER 8	0.0016	(0.0000)	6.	0.00
CHANGE IN WATER STORAGE	0.182	(1.440)	659.	0.38

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PEAK DAILY VALUES FOR YEARS 74 THROUGH 78

	(INCHES)	(CU. FT.)
PRECIPITATION	3.90	14157.0
RUNOFF	1.649	5987.5
LATERAL DRAINAGE FROM LAYER 3	0.4210	1528.2
PERCOLATION FROM LAYER 4	0.0000	0.0
HEAD ON LAYER 4	6.8	
LATERAL DRAINAGE FROM LAYER 7	0.0000	0.1
PERCOLATION FROM LAYER 8	0.0000	0.0
HEAD ON LAYER 8	0.0	
SNOW WATER	3.46	12568.8

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4338
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1951

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FINAL WATER STORAGE AT END OF YEAR 78

LAYER	(INCHES)	(VOL/VOL)
1	2.14	0.3569
2	11.55	0.3849
3	0.03	0.1540
4	10.32	0.4300
5	19.48	0.1624
6	1.07	0.0444
7	0.01	0.0454
8	7.74	0.4300
SNOW WATER	0.00	

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APPENDIX G-1

HYDRAULIC CALCULATIONS FOR CELLS 7 AND 8 COLLECTION SYSTEM

Hydraulic Calculations for Cells 7 and 8

Drainage System Analysis For Combined Cells 7 and 8

The Drainage System calculations were done in six sections:

1. **SIDESLOPE DRAINAGE SYSTEM DESIGN.**
2. **BASE DRAINAGE SYSTEM DESIGN.**
3. **BASE CHANNEL DESIGN.**
4. **LEACHATE COLLECTION PIPE DESIGN.**
5. **GEOCOMPOSITE TRANSMISSIVITY CONVERSION TO HYDRAULIC CONDUCTIVITY CALCULATIONS.**

The calculations were performed using the EPA's Geosynthetic Design Guidance Document as a reference.

Applicable Equation:

$$T = Q/Wi$$

T = Transmissivity
Q = flow
W = Geocomposite width
i = Gradient
(For all cases, i was assumed equal to the slope. This models a saturated condition.)

The design flow, produced by a 25 year storm, is a 3.9-inch, 24-hour rainfall event. This rainfall represents an event with a reoccurrence interval of 25 years for the Buffalo area. The base and channel flows were analyzed using this worst case flow.

1. SIDESLOPE DRAINAGE SYSTEM CALCULATIONS

EPA Help Model II Input: See Appendix G.

Climatic Data: Syracuse, New York.

Soil Data: According to design.

HELP Model Results: See Appendix G

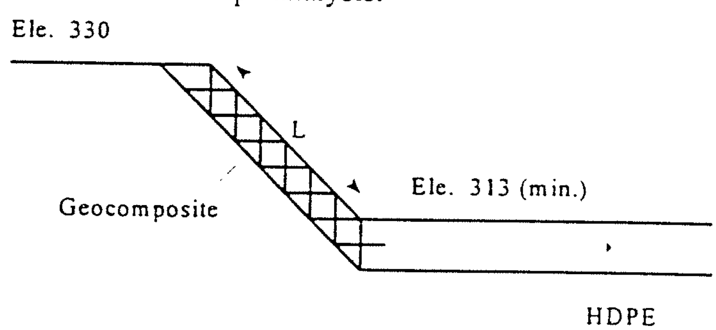
Design Considerations:

1. The head on the liner must not exceed 1 foot.
2. $K > 1 \times 10^{-2}$ cm/sec (Drainage Aggregate).
3. Transmissivity of geocomposite (TN3002-1620C) $T = 1.58 \times 10^{-4}$ m^2/s, which is interpolated from J&L transmissivity testing report attached to these calculations.
4. Q net > Q inflow from contributing area.
5. Response time (A leak in the primary system must be detected within 24 hours in the secondary system).

References: Properties of plastic nets for liquid and gas drainage associated with Geomembranes, William N. Giroud, J.P. Bonaparte R. Published in Geotextiles and Geomembranes 3rd Ed.

Geosynthetic Design Guidance Document EPA Office of Research and Development, Richardson G., Koerner R.

Purpose: To determine the effectiveness of using one layer of geocomposite (TN3002-1620C) with a transmissivity of 1.58×10^{-4} m^2/s (Normal Load = 12,000 psf) to transmit the infiltration due to a 25-year, 24-hour rainfall event (3.9 in./day). The gravel layer is omitted from the sideslope analysis.



Applicable Equations:

Transmissivity = T = Q/Wi

Q = flow rate
W = width of geocomposite
i = gradient

P 40157.WPDRAFT.FEB97REV\DRAINAGE REV

Calculations:

Q = LWI; Set W=1 ft (i.e.: Calculate the flow per unit width of geocomposite.)
L = horizontal length of flow, the maximum flow length of the sideslope
L = 21 ft in Cell 7 (length of sideslope minus 10 ft initial waste lift)
I = intensity = 3.9 in./day = 3.76×10^{-6} ft/s

Q = 21 ft x 1 ft x 3.76×10^{-6} ft/s = 7.90×10^{-5} ft³/s (flow off 21 ft. exposed sideslope)

Calculations were prepared to evaluate runoff (2.9 inches/day) from a 20 foot waste slope and 3.9 inches/day on a 6 ft. exposed sideslope. The flow per unit width was calculated at 7.86×10^{-5} ft³/s which is less than the 7.90×10^{-5} ft³/s unit flow from the 21 ft exposed sideslope. The unit flow of 7.9×10^{-5} ft³/s was used to evaluate the other components of the leachate collection system in Cells 7 and 8.

The required sideslope transmissivity is:

$$T_{req} = \frac{Q_{reg}}{Wi} = \frac{7.90 \times 10^{-5}\ ft^3/s}{1\ ft \times 0.33} = 2.39 \times 10^{-4}\ ft^2/s$$

The actual geocomposite transmissivity is taken from manufacturer's data for normal load = 12,000 psf, i = 0.33:

$T_{act} = 1.58 \times 10^{-4}\ m^2/s = 1.70 \times 10^{-3}\ ft^2/s$

The EPA (Geosynthetic Design Guidance 1986) recommends a Design Ratio (DR) of three. This reflects the high probability of the design event not occurring during the short operational period when the sideslope is exposed.

$T_{act}/T_{req} = 1.70 \times 10^{-3} / 2.39 \times 10^{-4} = 7.1$

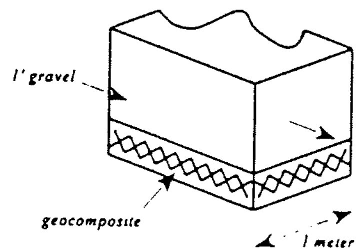
One layer is sufficient according to EPA's guidance document for the sideslope primary leachate collection system and secondary leachate collection system.

2. BASE DRAINAGE SYSTEM CALCULATIONS

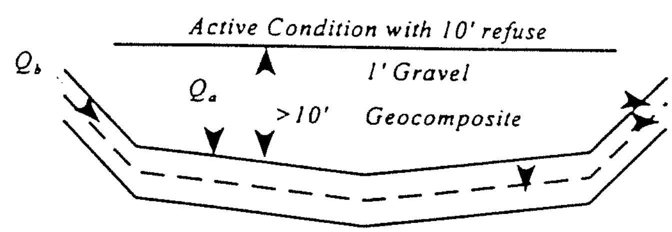
To calculate the required transmissivity of the base drainage system, a 1-foot wide flow path along the direction of farthest travel length was used. The flow comes from sideslope run-off. Since the sideslope calculations showed the drainage system can handle the sideslope run-on, the following calculations will check the base drainage system capacity for the exposed 21 ft. sideslope flow.

The same "driving equations" are used for the base calculations as were used for the sideslope calculations. The transmissivity of the drainage system must be large enough to transmit the flow through the ends of the "Design Unit." (The system will be assumed at steady state conditions.)

For one single layer of geocomposite TN3002 1620C, the transmissivity in the order of 2.73×10^{-4} m^2/sec is taken from J&L transmissivity testing data for normal load of 12,000 psf and gradient 2.0 percent as shown in the attached report.

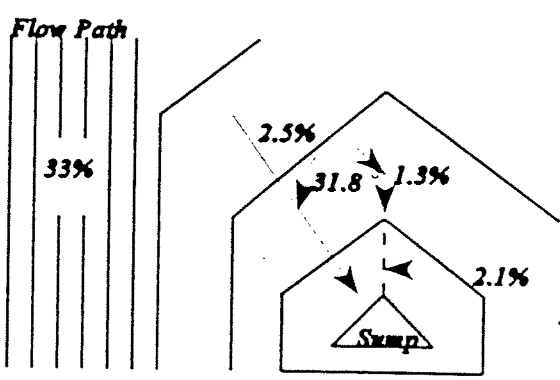


Base Drainage System Calculations



Q_b = *Sideslope Runoff*

Q_a = *Infiltration*



Slope in direction of flow.

$\tan^{-1}(.013/.021) = 31.8°$

$\cos(31.8°) \times 100 = 85.0'$
$\sin(31.8°) \times 100 = 52.7'$

$1.3/100 \times 52.7 = 0.685$
$2.1/100 \times 85.0 = 1.785$

Slope $= (0.685 + 1.785)/100 = 0.025 = 2.5\%$

FIGUR

E 1

Applicable Equation $T = \frac{Q}{Wi}$

T = transmissivity (ft^2/s), $T = K \times t$, t - the thickness of drainage layer
Q = flow (ft^3/s)
W = width of flow (ft): $W = 1$; unit width of flow
i = gradient $i = 2.5\% = .025$

Flow capacity/ft width of granular layer on base:

$Q = T \times W \times i$
$T = K \times t$

$K = 1 \times 10^{-2}$ cm/s $= 3.28 \times 10^{-4}$ ft/s, t = 1 ft
$Q_{granular} = 3.28 \times 10^{-4}$ ft/s x 1 ft x 1 ft x 0.025
$= 8.20 \times 10^{-6}$ ft^3/s

Flow capacity/ft width of geocomposite:

$T = 2.73 \times 10^{-4}$ $m^2/s = 2.94 \times 10^{-3}$ ft^2/s
$Q_{geocomposite} = 2.94 \times 10^{-3}$ ft^2/s x 1 ft x 0.025
$= 7.35 \times 10^{-5}$

Collection system total capacity Q total:

$Q_{total} = Q_{granular} + Q_{geocomposite} = 8.20 \times 10^{-6} + 7.35 \times 10^{-5} = 8.2 \times 10^{-5}$

Evaluating required flow from HELP model results for landfill active conditions:

Peak daily infiltration $I = 0.1991$ in/day $= 1.92 \times 10^{-7}$ ft/s
$L = 347$ ft
$W = 1$ ft

$Q_{req} = 1.92 \times 10^{-7}$ ft/s x 347 ft x 1 ft $= 6.66 \times 10^{-5}$ ft^3/s
$Q_{Total} = 8.2 \times 10^{-5}$ $ft^3/s > Q_{req} = 6.66 \times 10^{-5}$ ft^3/s

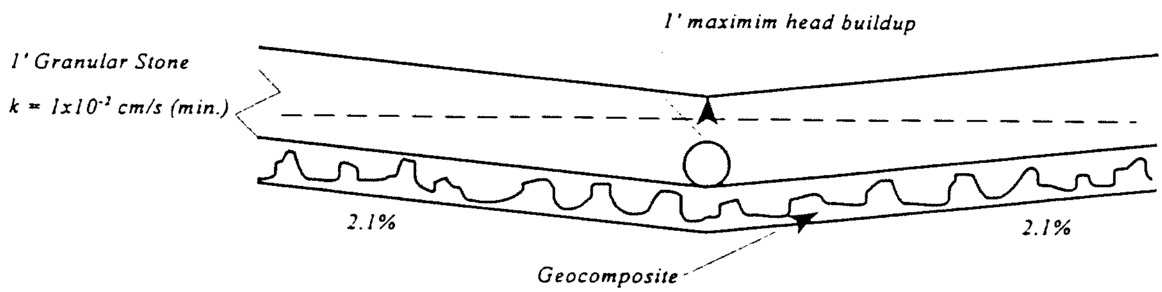
Evaluating flow from exposed sideslope:

$Q_{req} = 7.90 \times 10^{-5}$ ft^3/s (flow from 21 ft exposed sideslope)
$Q_{total} = 8.2 \times 10^{-5}$ $ft^3/s > Q_{req} = 7.90 \times 10^{-5}$ ft^3/s

Since the peak daily value of the flow from the exposed sideslope is the most critical condition at the site, the design of the primary leachate collection system of the landfill base is adequate.

3. CHANNEL GEOCOMPOSITE CALCULATIONS

Layers of geocomposite will be used to replace the pipes that are normally used to collect leachate from the low points in the landfill. The required capacity is the flow from the contributing area



shown in Figure 3.

FIGURE 2

Granular Stone Capacity:

$K = 1 \times 10^{-2}$ cm/s $= 3.28 \times 10^{-4}$ ft/s
$T = K \times t$

$Q_g = T \times W \times i = (3.28 \times 10^{-4}$ ft/s x 1 ft) x 48' x .021 $= 3.3 \times 10^{-4}$ ft^3/s

Geocomposite Capacity:

$T = 2.73 \times 10^{-4}$ m^2/sec $= 2.94 \times 10^{-3}$ ft^2/s	obtained from J&L transmissivity testing data for normal load of 12,000 psf and gradient of 2.0 percent as shown in the attached data.

$Q_{geocomposite} = 2.94 \times 10^{-3} \times 2 \times 15' \times .021 = 1.85 \times 10^{-3}$ ft^3/s

$Q_g + Q_{geocomposite} = Q_{total} = 2.18 \times 10^{-3}$ ft^3/s

Peak daily infiltration from HELP model for contributing area on Figure 1:
$I = 0.1991$ in/day $= 1.92 \times 10^{-7}$ ft/s
$A = 314{,}000$ ft^2, contributing area
$Q = 1.92 \times 10^{-7}$ ft/s x 314,000 ft^2
$= 6.03 \times 10^{-2}$ ft^3/s

$Q_{actual} = 6.03 \times 10^{-2}$ ft^3/s

$Q_{actual} > Q_{system}$ 6.03×10^{-2} $ft^3/s > 2.18 \times 10^{-3}$ ft^3/s is not okay, need a leachate collection pipe in the channel. See Item 4, Leachate Collection Pipe Design.

Flow from the 21 ft. exposed sideslope into the leachate collection system from the perimeter of the Cells 7 and 8:

Length of perimeter channel:

Cell 7: 580 ft.
Cell 8: 220 ft.
800 ft.

Total flow per ft. width along the perimeter is 7.90×10^{-5} ft^3/sec.
Total flow into base collection system:

$$Q_{act} = 7.90 \times 10^{-5} \text{ ft}^3/\text{sec} \times 800 = 6.32 \times 10^{-2} \text{ ft}^3/\text{sec}$$

$Q_{actual} > Q_{system}$ 6.32×10^{-2} $ft^3/s > 2.18 \times 10^{-3}$ ft^3/s is not okay, need a leachate collection pipe in the channel. See Item 4 - Leachate Collection Pipe Design.

4. LEACHATE COLLECTION PIPE DESIGN

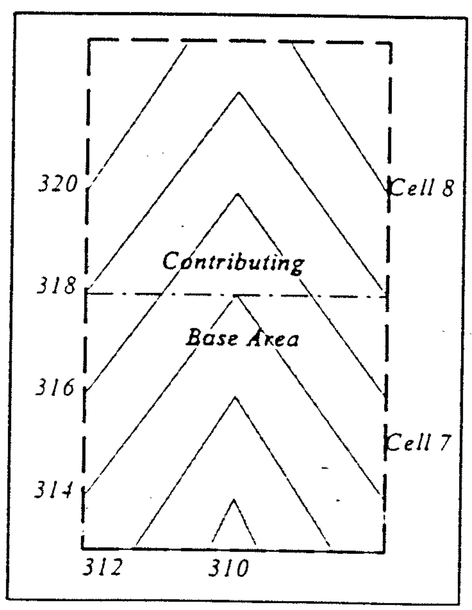


FIGURE 3

An 8" perforated leachate collection pipe will be placed in the center line to handle the actual flow.

The capacity of the 8" perforated leachate collection pipe can be determined by the Manning formula.

$$Q = \frac{1.49}{n} A \, R^{2/3} \, S^{1/2}$$

Where: Q = flow rate (cfs)
n = Manning's roughness coefficient = 0.012 for plastic pipe

$$A = Pipe\ AREA = \frac{1}{4} \pi \, d^2$$

For $8''$ *(SDR 13.6) inner diameter* = 7.347 *in*

$$A = \frac{1}{4} \pi \left(\frac{7.347}{12} \right)^2$$

$$= 0.294 \ ft^2$$

$$R = Hydraulic Radius = \frac{Diameter}{4} \ for \ full \ flowing \ pipes$$

$$R = \frac{7.347}{4} \ x \ \frac{1 \ ft}{12 \ in} = 0.15 \ ft.$$

$$s = Pipe\ Slope = 1.3\% = .013 \ ft/ft$$

$$Q_{pipe} = \frac{1.49}{.012} (0.294 \ ft^2) \ (0.15)^{2/3} \ (0.013)^{1/2} = 1.18 \ ft^3/s$$

$$Q_{actual} < Q_{pipe} = 6.32 \ x \ 10^{-2} \ ft^3/s < 1.18 \ ft^3/s \ okay$$

The channel with a perforated pipe will handle the actual flow with a design ratio of:

$$\frac{1.18}{6.32 \ x \ 10^{-2}} = 19 \ with \ a \ perforated \ pipe \ in \ the \ centerline.$$

Pipe Perforation Design.

The flow through the pipe perforations can be estimated using the Bernoulli Orfice equation.

Assumptions:

- Free flow occurs through the holes;
- The head is constant and equal to the thickness of the drainage layer (12 inches) less 2 inches to account for the position of the holes (60° from vertical) on the 8 inch pipe. The head is equal to 10 inches;
- The perforations have sharp edges, C = 0.61; and,
- Factor of safety for perforation design = 2.
- Calculations

Area of ½-inch diameter hole

$$A = \frac{\pi d^2}{4} = 1.36 \times 10^{-3} ft^2$$

$$Q_{actual} = 6.32 \times 10^{-2} ft^3/s$$

$$Q_{design} = F.S. \times Q_{actual}$$

$$= 2 \times 6.32 \times 10^{-2}$$

$$= 1.26 \times 10^{-1} ft^3/s$$

Flow per Hole.

$$Q_{hole} = CA \sqrt{Z g h}$$

$$= (0.61)\ (1.36 \times 10^{-3} ft^2) \sqrt{(2)(32.2\ ft/\sec^2) \times \frac{10}{12} ft.}$$

$$= 6.07 \times 10^{-3} ft^3/s$$

Determine number of holes needed (N).

$$N = \frac{Q_{design}}{Q_{hole}} = \frac{1.26 \times 10^{-1} ft^3/s}{6.07 \times 10^{-3} ft^3/s}$$

$$= 21 \ holes$$

Determine Spacing of holes (S):

$$S = \frac{Length\ of\ Pipe}{N} = \frac{697}{21}$$

$$= 33.19\ ft.$$

Final Design:

For the design, an 8 in. leachate collection pipe with ½" holes spaced 30 ft apart alternating 60° from the bottom of the pipe is adequate. For construction, perforations will be 5/8" holes, spaced at 3 inches in an alternating 120° pattern. Holes will be on the bottom of the pipe.

6. GEOCOMPOSITE TRANSMISSIVITY CONVERSION TO HYDRAULIC CONDUCTIVITY CALCULATIONS

This calculation shows drainage layers exceed 1×10^{-2} cm/sec.

Base Geocomposite   Use J&L test data for the load of 12,000 lbs/ft^2

From Test Data $T = 2.73 \times 10^{-4}$ m^2/s

$$K = \frac{T}{b}$$

where: T = transmissivity
b = thickness; b = 0.5 cm
K = Permeability

$$Thus: K = \frac{T}{b} = \frac{2.73\ cm^2/s}{0.5\ cm} = 5.5\ cm/s.$$

CLIENT	CWM CHEMICAL SERVICES, INC.	SUBJECT	TRAVEL TIME CALCULATIONS FOR PROPOSED CELL 7/8
PROJECT	MODEL CITY FACILITY RMU - 1		

PROJECT NO. 36730
BY DMH DATE 2/3/97
CH BPB DATE 2/4/97

TASK: Determine if the travel time from the farthest point hydraulically in the cell to the sump in the secondary leachate collection system is less than the 24 hour requirement.

REFERENCES:

1. Appendix G: Hydraulic Calculations for Cells 7 and 8
2. "Secondary Clay Liner Grade", Dwg. No. 6, Prepared by Rust Environment & Infrastructure, February, 1991, Revised October, 1996.

ASSUMPTIONS:

1. Leachate will take the path of least resistance through the secondary leachate collection system; therefore, the highest velocity component of the section will be used to evaluate the travel time.

CALCULATIONS:

Section 1, Perimeter Berm

Length = 41 ft
Transmissivity of the Geocomposite = 1.70×10^{-3} ft^2/sec
Geocomposite thickness = 0.35 inches

Travel Time = 41 ft / (1.70×10^{-3} ft^2/sec) x 0.35 in x 1ft/12 in = 669 sec

Section 2, Cell Floor

Length = 225 ft
Transmissivity of the Geocomposite = 2.94×10^{-3} ft^2/sec
Geocomposite thickness = 0.35 inches

Travel Time = 225 ft / (2.94×10^{-3} ft^2/sec) x 0.35 in x 1ft/12 in = 2232 sec

Section 3, Cell Centerline (leachate collection pipe)

Length = 540 ft
Flow rate of pipe = 3.7 ft^3/sec
Cross-sectional area of SDR 13.6 pipe = 0.294 ft^2

Travel Time = 540 ft / (3.7 ft^3/sec) x 0.294 ft^2 = 43 sec

CONCLUSION:

Total Travel Time = (669 sec + 2232 sec + 43 sec) / 3600 sec/hr = 0.8 hr

0.8 hr < 24 hr The secondary leachate collection system is adequate!

NSC

National Seal Company

THE LINER STORE
309/342-9037
FAX 309/342-2524

TECHNICAL CENTER
309/342-1936
FAX 309/342-2524

MANUFACTURING DIVISION
1255 Monmouth Blvd.
P.O. Box 1443
Galesburg, IL 61402-1443
309/343-3418
FAX 309/343-1536

May 16, 1995

Mr. Anthony W. Eith, P.E.
RUST Environment & Infrastructure
3220 Tillman Avenue
Bensalem, PA 19020

Dear Mr. Eith,

Attached are the results of a series of long-term transmissivity tests with our TN3002-1620C geocomposite. The report has been reviewed and the results deemed reasonable based upon past experience. If you have any questions in relation to this data, please don't hesitate to contact me at the above number for the Technical Center.

Sincerely,

John R. Siebken
Technical Services Supervisor
National Seal Company

NSC

May 9, 1995

Long Term Transmissivity Test on TN3002-1620C Geocomposite
NSC Job # 95036P

The purpose of this test was to study how the transmissivity of TN3002-1620C geocomposite would change over time when it was left under load over the span of a week. Each of the tests were run under the following conditions.

Top Plate
Foam } MORE CONSERVATIVE THAN STONE AS FOAM PILLOWS & FORMS SHAPE OF NET WHERE STONE HAS BRIDGING ACTION
Geocomposite
40 mil HDPE Friction Geomembrane
Bottom plate

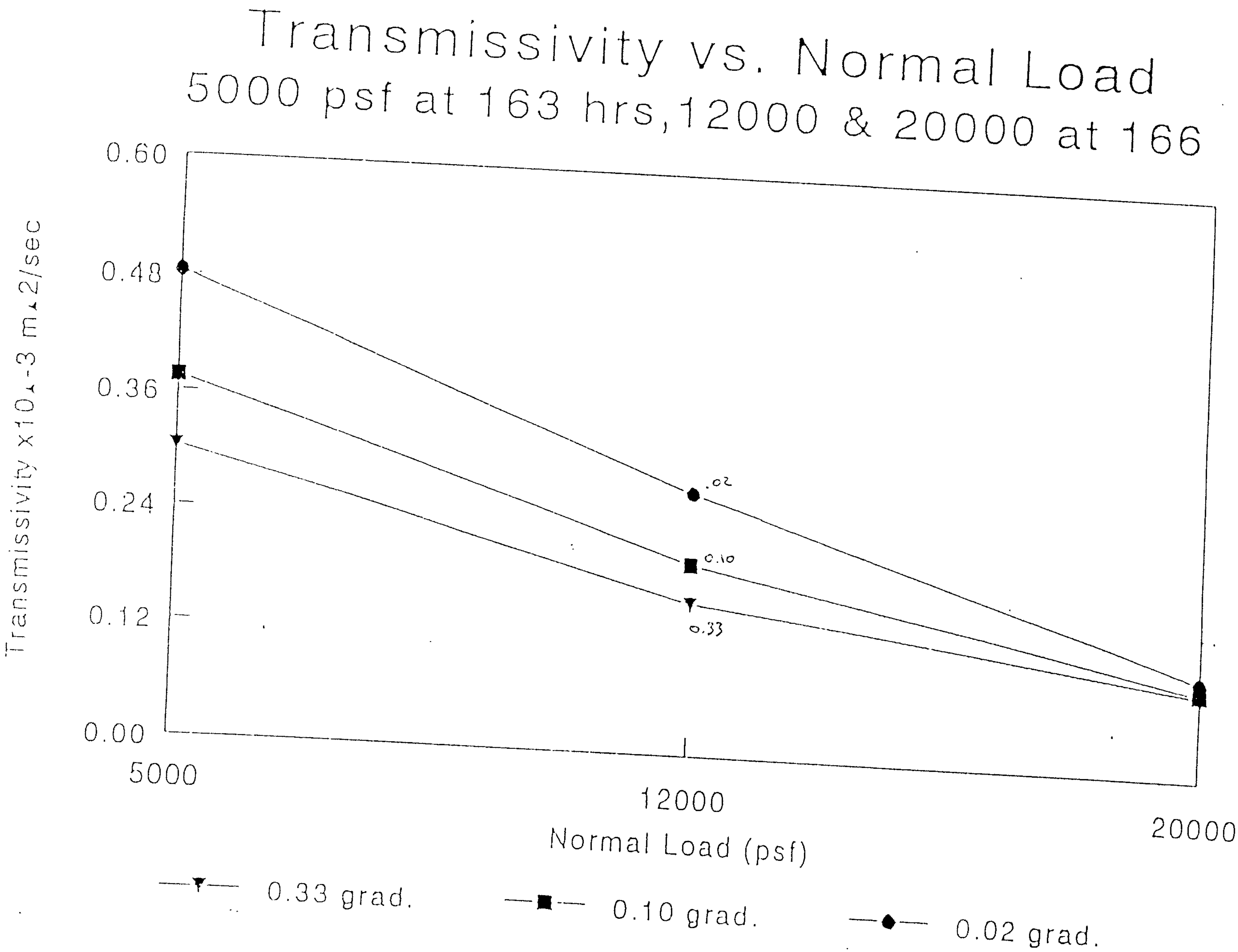
GB 10/30/9_

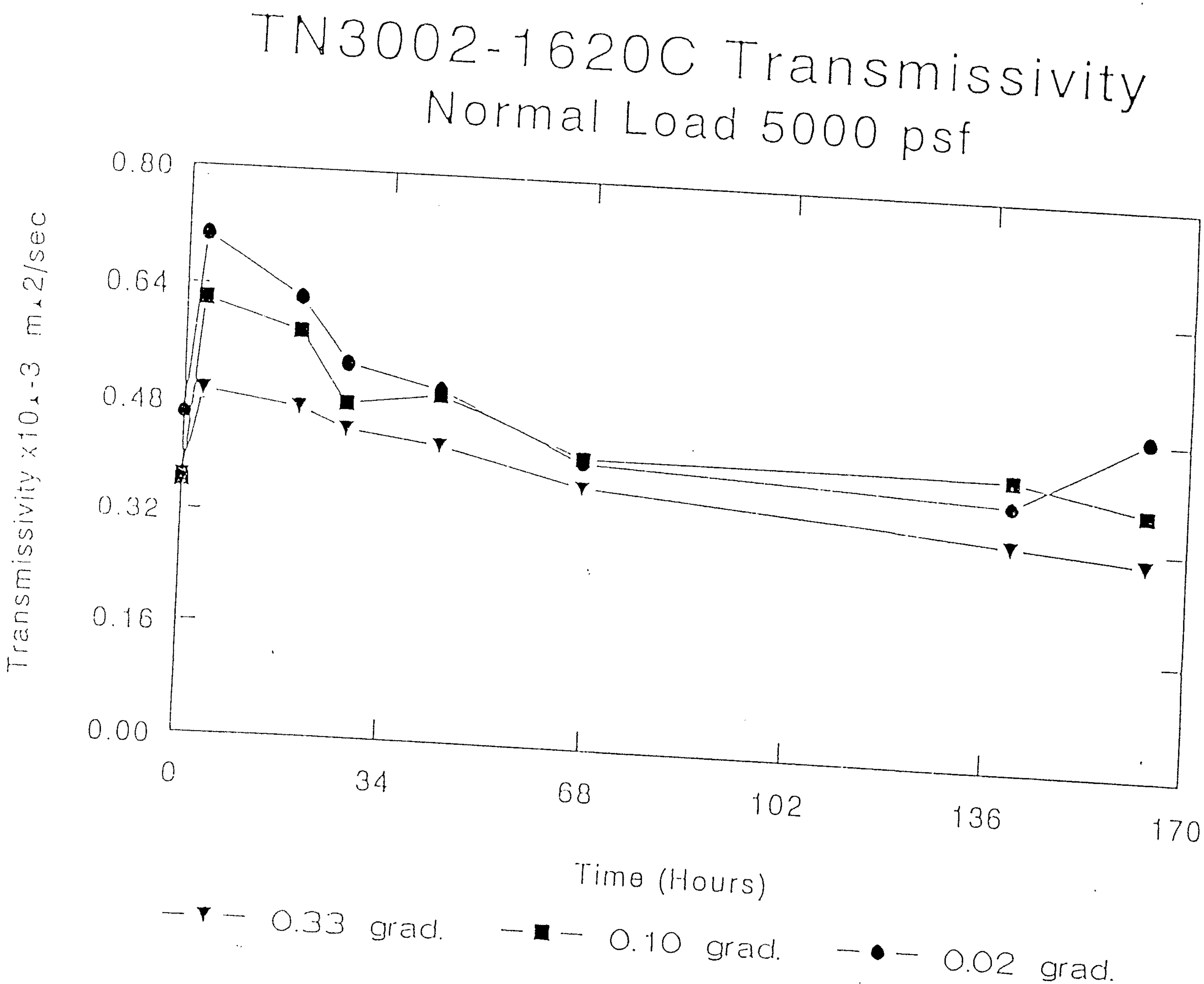
The foam used was 2 layers of 1/2" thick closed cell foam, and the friction coated geomembrane was positioned so that its machine direction was parallel to the axis flow. A total of three tests were performed at 5,000, 12,000 and 20,000 psf normal pressures. The pressures were maintained on the test configuration for seven days. Transmissivity readings were taken periodically at each of three different gradients, 0.33, 0.10 and 0.02. For each transmissivity reading at a given gradient three repetitions were performed.

Don Cunningham
Reasearch Technician
National Seal Company
Don Cunningham

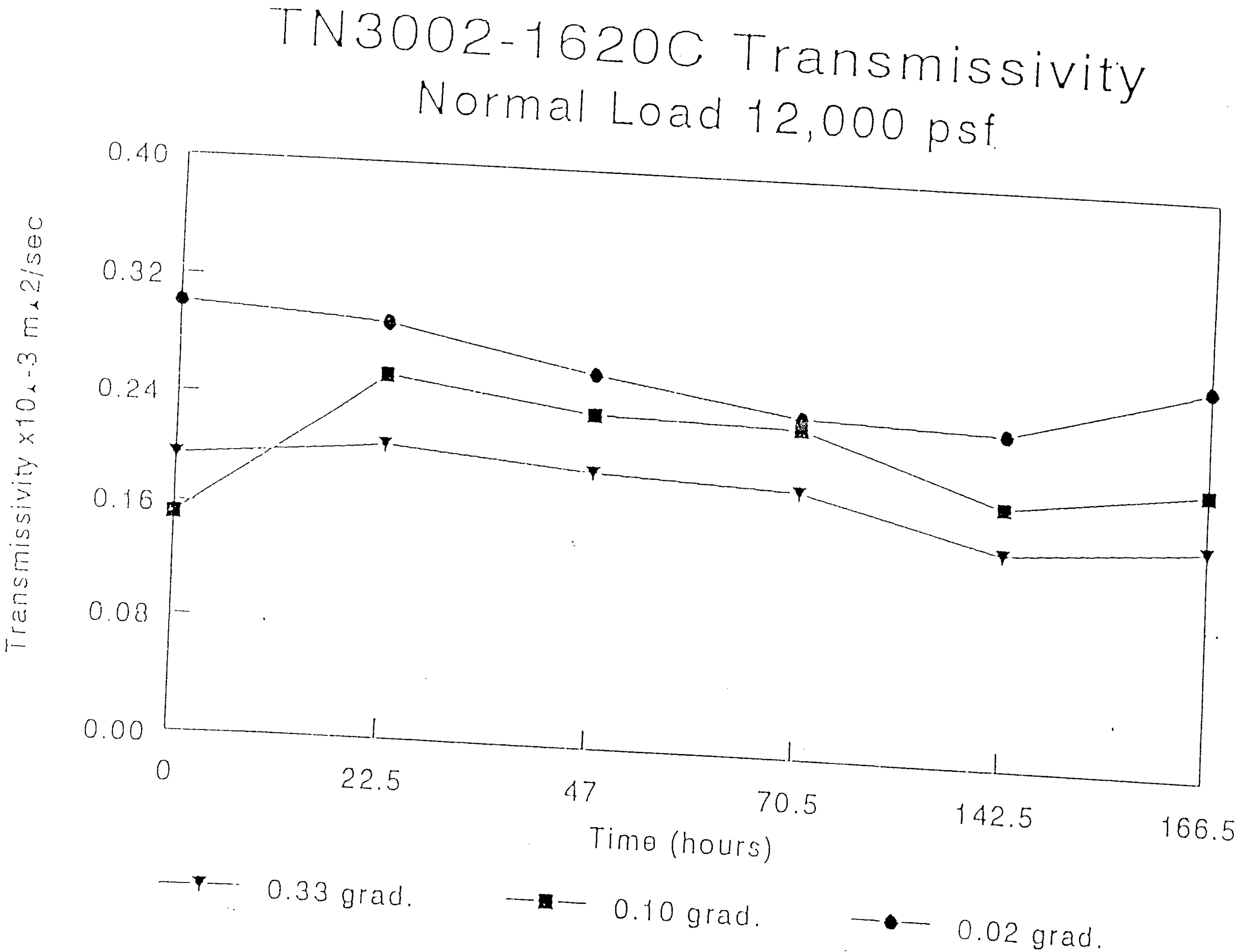
NSC

Long Term Transmissivity Result Summary NSC Job# 95036P			
Normal Stress (psf)	Elapsed Time (hours)	Planar Flow Rate (gal/min-ft)	Transmissivity (x 10^{-3} m^2/sec)
Gradient (i) = 0.33			
5000	163	0.472	0.303
12,000	166.5	0.255	0.158
20,000	166.5	0.139	0.086
Gradient (i) = 0.1			
5000	163	0.178	0.376
12,000	166.5	0.099	0.199
20,000	166.5	0.044	0.089
Gradient (i) = 0.02			
5000	163	0.046	0.484
12,000	166.5	0.027	0.273
20,000	166.5	0.010	0.101


Transmissivity vs. Normal Load
5000 psf at 163 hrs, 12000 & 20000 at 166
0.60
0.48
0.36
0.24
0.12
0.00
5000
12000
20000
Normal Load (psf)
Transmissivity x10^-3 m^2/sec
.02
0.10
0.33
0.33 grad.
0.10 grad.
0.02 grad.

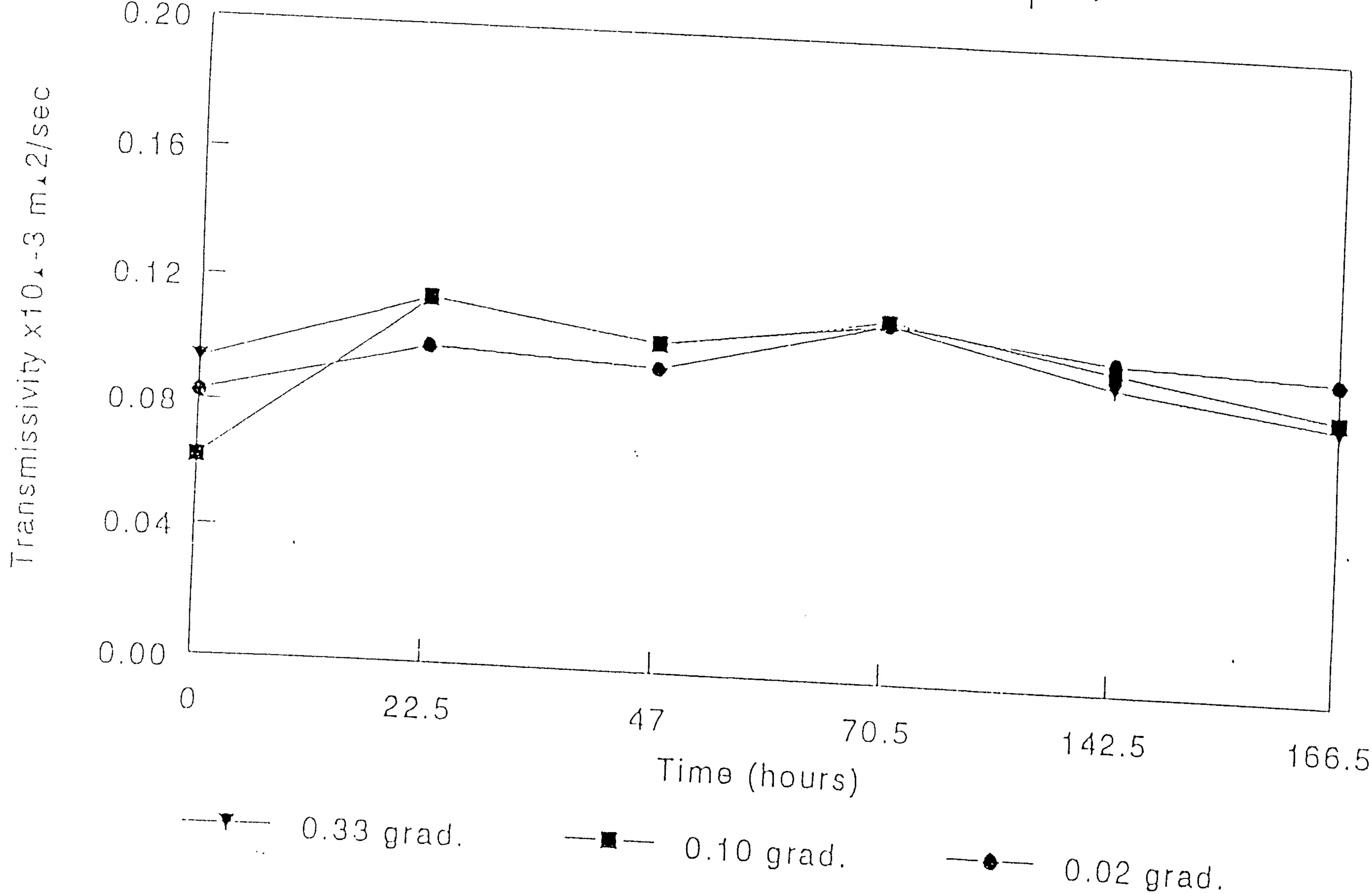


TN3002-1620C Transmissivity
Normal Load 5000 psf
Transmissivity x10^-3 m^2/sec
0.80
0.64
0.48
0.32
0.16
0.00
0
34
68
102
136
170
Time (Hours)
0.33 grad.
0.10 grad.
0.02 grad.



TN3002-1620C Transmissivity
Normal Load 12,000 psf
Transmissivity x10^-3 m^2/sec
0.40
0.32
0.24
0.16
0.08
0.00
0
22.5
47
70.5
142.5
166.5
Time (hours)
0.33 grad.
0.10 grad.
0.02 grad.

TN3002-1620C Transmissivity
Normal Load 20,000 psf



Transmissivity Test Data for Normal Load of 5000 psf at 0 hours

	Gradient=0.33, 19.3C	Gradient=0.10, 19.3C	Gradient=0.02, 19.3C
lbs. water 1st run	8.50	7.50	4.22
time (sec.) 1st run	99	267	620
lbs. water 2nd run	8.42	7.11	3.61
time (sec.) 2nd run	106	300	600
lbs. water 3rd run	7.82	6.55	3.30
time (sec.) 3rd run	102	330	607
Avg.Flow Rate gpm	0.58	.172	.044
Avg. Transmissivity	.370 E-3	.363 E-3	.461 E-3

Transmissivity Test Data for Normal Load of 5000 psf at 3 hours

	Gradient=0.33, 21.1C	Gradient=0.10, 21.1C	Gradient=0.02, 21.1C
lbs. water 1st run	9.275	7.94	4.89
time (sec.) 1st run	73	195	480
lbs. water 2nd run	8.215	8.28	4.765
time (sec.) 2nd run	73	195	488
lbs. water 3rd run	8.435	8.535	4.48
time (sec.) 3rd run	76	206	481
Avg.Flow Rate gpm	0.810	0.308	0.070
Avg. Transmissivity	0.495 E-3	0.620E-3	0.707 E-3

Transmissivity Test Data for Normal Load of 5000 psf at 19 hours

	Gradient=0.33, 18.8C	Gradient=0.10, 18.9C	Gradient=0.02, 19.0C
lbs. water 1st run	8.62	8.015	4.105
time (sec.) 1st run	83	206	482
lbs. water 2nd run	8.36	8.03	2.46
time (sec.) 2nd run	82	213	301
lbs. water 3rd run	8.845	7.99	2.4
time (sec.) 3rd run	88	218	304
Avg.Flow Rate gpm	0.734	.0272	0.059
Avg. Transmissivity	0.474 E-3	0.578E-3	0.625 E-3

Transmissivity Test Data for Normal Load of 5000 psf at 27 hours

	Gradient=0.33,19.5C	Gradient=0.10, 19.5C	Gradient=0.02, 19.5C
lbs. water 1st run	8.675	8.265	2.99
time (sec.) 1st run	87	240	405
lbs. water 2nd run	8.635	7.88	2.75
time (sec.) 2nd run	89	238	386
lbs. water 3rd run	8.81	7.86	4.335
time (sec.) 3rd run	92	246	634
Avg.Flow Rate gpm	0.701	0.230	0.051
Avg. Transmissivity	0.455 E-3	0.482 E-3	0.536 E-3

Transmissivity Test Data for Normal Load of 5000 psf at 43 hours

	Gradient=0.33,18.0C	Gradient=0.10,18.0 C	Gradient=0.02,18.0 C
lbs. water 1st run	8.25	8.15	2.44
time (sec.) 1st run	89	245	368
lbs. water 2nd run	9.175	8.235	2.44
time (sec.) 2nd run	102	259	368
lbs. water 3rd run	8.89	7.775	2.42
time (sec.) 3rd run	101	252	373
Avg.Flow Rate gpm	0.649	0.23	0.47
Avg. Transmissivity	0.427 E-3	0.499E-3	0.507 E-3

Transmissivity Test Data for Normal Load of 5000 psf at 67 hours

	Gradient=0.33, 17.5C	Gradient=0.10, 17.8C	Gradient=0.02, 18.3C
lbs. water 1st run	8.815	7.97	2.63
time (sec.) 1st run	111	291	481
lbs. water 2nd run	9.2	8.04	3.415
time (sec.) 2nd run	118	304	647
lbs. water 3rd run	8.37	7.855	3.38
time (sec.) 3rd run	109	303	656
Avg.Flow Rate gpm	0.561	0.191	0.038
Avg. Transmissivity	0.375 E-3	0.413 E-3	0.411 E-3

Transmissivity Test Data for Normal Load of 5000 psf at 140 hours

	Gradient=0.33,17.2C	Gradient=0.10, 17.9C	Gradient=0.02, 18.4C
lbs. water 1st run	8.295	8.59	6.045
time (sec.) 1st run	121	311	1187
lbs. water 2nd run	8.45	8.61	6.75
time (sec.) 2nd run	128	326	1381
lbs. water 3rd run	8.575	8.195	6.06
time (sec.) 3rd run	134	318	1285
Avg.Flow Rate gpm	0.476	0.191	0.35
Avg. Transmissivity	0.320 E-3	0.417 E-3	0.379 E-3

Transmissivity Test Data for Normal Load of 5000 psf at 163 hours

	Gradient=0.33,19.0C	Gradient=0.10, 19.3C	Gradient=0.02, 19.7C
lbs. water 1st run	8.28	7.555	4.885
time (sec.) 1st run	125	301	749
lbs. water 2nd run	8.41	7.755	4.885
time (sec.) 2nd run	128	313	758
lbs. water 3rd run	8.12	7.735	4.735
time (sec.) 3rd run	125	315	738
Avg.Flow Rate gpm	0.472	0.178	0.046
Avg. Transmissivity	0.303 E-3	0.376 E-3	0.484 E-3

Transmissivity Test Data for Normal Load of 12,000 psf at 0 hours

	Gradient=0.33,20.5C	Gradient=0.10, 20.8C	Gradient=0.02, 20.8C
lbs. water 1st run	7.85	6.77	3.345
time (sec.) 1st run	158	506	801
lbs. water 2nd run	7.55	6.44	3.78
time (sec.) 2nd run	181	629	901
lbs. water 3rd run	8.81	5.96	3.80
time (sec.) 3rd run	226	777	952
Avg.Flow Rate gpm	0.312	0.075	0.03
Avg. Transmissivity	0.194 E-3	0.152 E-3	0.301 E-3

Transmissivity Test Data for Normal Load of 12,000 psf at 22.5 hours

	Gradient=0.33,19.1C	Gradient=0.10, 19.6C	Gradient=0.02, 20.0C
lbs. water 1st run	8.25	7.55	5.825
time (sec.) 1st run	183	433	1325
lbs water 2nd run	8.47	8.315	4.72
time (sec.) 2nd run	190	489	1202
lbs. water 3rd run	8.76	8.475	5.2
time (sec.) 3rd run	198	512	1526
Avg.Flow Rate gpm	0.0321	0.0122	0.028
Avg. Transmissivity	0.206 E-3	0.256 E-3	0.291 E-3

Transmissivity Test Data for Normal Load of 12,000 psf at 47 hours

	Gradient=0.33,18.0C	Gradient=0.10, 19.1C	Gradient=0.02, 19.5C
lbs. water 1st run	7.73	8.145	3.305
time (sec.) 1st run	184	520	909
lbs. water 2nd run	8.34	7.765	3.40
time (sec.) 2nd run	200	502	971
lbs. water 3rd run	8.405	7.45	4.52
time (sec.) 3rd run	203	483	1355
Avg.Flow Rate gpm	0.300	0.111	0.025
Avg. Transmissivity	0.193 E-3	0.235 E-3	0.263 E-3

Transmissivity Test Data for Normal Load of12,000 psf at 70.5 hours

	Gradient=0.33,18.1C	Gradient=0.10, 18.3C	Gradient=0.02, 19.3C
lbs. water 1st run	8.13	7.73	4.2
time (sec.) 1st run	206	529	1290
lbs. water 2nd run	8.07	8.105	4.225
time (sec.) 2nd run	205	535	1492
lbs. water 3rd run	7.67	8.315	5.13
time (sec.) 3rd run	196	553	1676
Avg.Flow Rate gpm	0.283	0.107	0.023
Avg. Transmissivity	0.186 E-3	0.232 E-3	0.240 E-3

Transmissivity Test Data for Normal Load of 12,000 psf at 142.5 hours

	Gradient=0.33,20.5C	Gradient=0.10, 21.0C	Gradient=0.02, 21.3C
lbs. water 1st run	8.92	7.485	3.845
time (sec.) 1st run	267	606	1203
lbs. water 2nd run	7.855	7.715	4.02
time (sec.) 2nd run	240	628	1254
lbs. water 3rd run	8.195	7.5	3.915
time (sec.) 3rd run	251	613	1232
Avg.Flow Rate gpm	0.237	0.088	0.023
Avg. Transmissivity	0.149 E-3	0.182 E-3	0.235 E-3

Transmissivity Test Data for Normal Load of 12,000 psf at 166.5 hours

	Gradient=0.33,20.5C	Gradient=0.10, 21.0C	Gradient=0.02, 21.3C
lbs. water 1st run	8.2	7.190	3.015
time (sec.) 1st run	230	546	796
lbs. water 2nd run	8.19	5.875	3.415
time (sec.) 2nd run	230	422	902
lbs. water 3rd run	7.725	6.375	3.975
time (sec.) 3rd run	219	454	1049
Avg.Flow Rate gpm	0.255	0.099	0.027
Avg. Transmissivity	0.158 E-3	0.199 E-3	0.273 E-3

Transmissivity Test Data for Normal Load of 20,000 psf at 0 hours

	Gradient=0.33,20.2C	Gradient=0.10, 20.8C	Gradient=0.02, 20.8C
lbs. water 1st run	6.895	3.685	2.82
time (sec.) 1st run	302	748	2208
lbs. water 2nd run	6.575	2.65	2.15
time (sec.) 2nd run	334	652	2216
lbs. water 3rd run	7.17	2.975	1.93
time (sec.) 3rd run	354	780	1651
Avg.Flow Rate gpm	0.151	0.030	0.008
Avg. Transmissivity	0.094 E-3	0.062 E-3	0.083 E-3

Transmissivity Test Data for Normal Load of 20,000 psf at 22.5 hours

	Gradient=0.33,19.0C	Gradient=0.10, 19.4C	Gradient=0.02, 19.8C
lbs. water 1st run	7.69	4.805	2.74
time (sec.) 1st run	301	601	1872
lbs. water 2nd run	8.235	5.14	1.925
time (sec.) 2nd run	332	677	1451
lbs. water 3rd run	8.83	5.065	1.835
time (sec.) 3rd run	364	706	1513
Avg.Flow Rate gpm	0.179	0.055	0.010
Avg. Transmissivity	0.115 E-3	0.115 E-3	0.100 E-3

Transmissivity Test Data for Normal Load of 20,000 psf at 47 hours

	Gradient=0.33,19.0C	Gradient=0.10, 19.0C	Gradient=0.02, 19.5C
lbs. water 1st run	8.045	5.62	1.71
time (sec.) 1st run	352	795	1202
lbs. water 2nd run	7.825	4.065	1.795
time (sec.) 2nd run	347	603	1301
lbs. water 3rd run	8.05	3.74	1.69
time (sec.) 3rd run	362	571	1203
Avg.Flow Rate gpm	0.162	0.049	0.009
Avg. Transmissivity	0.104 E-3	0.104 E-3	0.096 E-3

Transmissivity Test Data for Normal Load of 20,000 psf at 70.5 hours

	Gradient=0.33, 18.1C	Gradient=0.10, 18.3C	Gradient=0.02, 19.0C
lbs. water 1st run	8.24	6.995	2.61
time (sec.) 1st run	341	927	1683
lbs. water 2nd run	7.875	7.095	1.79
time (sec.) 2nd run	328	964	1219
lbs. water 3rd run	9.075	6.62	2.185
time (sec.) 3rd run	381	921	1535
Avg.Flow Rate gpm	0.173	0.53	0.011
Avg. Transmissivity	0.113 E-3	0.114 E-3	0.113 E-3

Transmissivity Test Data for Normal Load of 20,000 psf at 142.5 hours

	Gradient=0.33, 20.0C	Gradient=0.10, 20.2C	Gradient=0.02, 20.5C
lbs. water 1st run	7.94	6.285	1.955
time (sec.) 1st run	369	912	1364
lbs. water 2nd run	8.43	5.385	1.76
time (sec.) 2nd run	394	788	1239
lbs. water 3rd run	8.08	5.605	1.69
time (sec.) 3rd run	378	825	1207
Avg.Flow Rate gpm	0.154	0.049	0.010
Avg. Transmissivity	0.096 E-3	0.101 E-3	0.104 E-3

Transmissivity Test Data for Normal Load 20,000 psf at 166.5 hours

	Gradient=0.33, 20.7C	Gradient=0.10, 21.0C	Gradient=0.02, 21.3C
lbs. water 1st run	7.485	5.155	1.695
time (sec.) 1st run	388	841	1203
lbs. water 2nd run	7.085	3.795	1.83
time (sec.) 2nd run	367	621	1313
lbs. water 3rd run	6.98	4.64	1.815
time (sec.) 3rd run	363	756	1307
Avg.Flow Rate gpm	0.139	0.044	0.010
Avg. Transmissivity	0.086 E	0.089E-3	0.101 E-3

APPENDIX G-2

HYDRAULIC CALCULATIONS FOR CELLS 9 THROUGH 14 COLLECTION SYSTEM

Hydraulic Calculations for Cells 9 and 10, Cells 11 and 13 and Cells 12 and 14

Drainage System Analysis For Combined Cells 9 and 10, Cells 11 and 13, Cells 12 and 14

The Drainage System calculations were done in sections:

1. SIDESLOPE DRAINAGE SYSTEM DESIGN.
2. BASE DRAINAGE SYSTEM DESIGN.
3. BASE CHANNEL DESIGN.
4. LEACHATE COLLECTION PIPE DESIGN.
5. GEOCOMPOSITE TRANSMISSIVITY CONVERSION TO HYDRAULIC CONDUCTIVITY CALCULATIONS.

The calculations were performed using the EPA's Geosynthetic Design Guidance Document as a reference.

Applicable Equation:

$$T = Q/Wi$$

T = Transmissivity
Q = flow
W = Geocomposite width
i = Gradient
(For all cases, i was assumed equal to the slope. This models a saturated condition.)

The design flow, produced by a 25 year storm, is a 3.9-inch, 24-hour rainfall event. This rainfall represents an event with a reoccurrence interval of 25 years for the Buffalo area. The base and channel flows were analyzed using this worst case flow.

References:

EPA Help Model II Input: See Appendix G.

Climatic Data: Syracuse, New York.

Soil Data: According to design.

HELP Model Results: See Appendix G

1. SIDESLOPE DRAINAGE SYSTEM CALCULATIONS

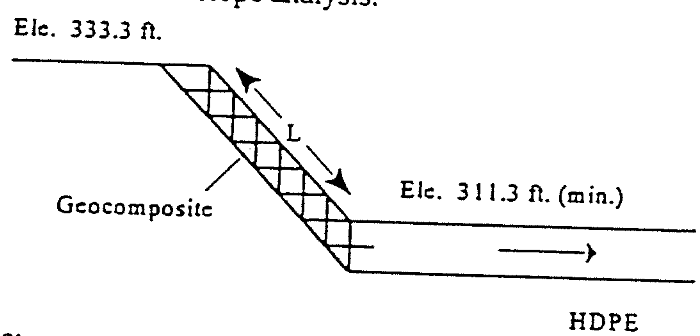
Design Considerations:

1. The head on the liner must not exceed 1 foot.
2. K >8 x 10^{-2}cm/sec (Drainage Aggregate).
3. Transmissivity of geocomposite (TN3002-1620C) T = 1.58 x 10^{-4} m^2/s, which is interpolated from J&L transmissivity testing report attached to these calculations.
4. Q net > Q inflow from contributing area.
5. Response time (A leak in the primary system must be detected within 24 hours in the secondary system).

References: Properties of plastic nets for liquid and gas drainage associated with Geomembranes, William N. Giroud, J.P. Bonaparte R. Published in Geotextiles and Geomembranes 3rd Ed.

Geosynthetic Design Guidance Document EPA Office of Research and Development, Richardson G., Koerner R.

Purpose: To determine the effectiveness of using one layer of geocomposite (TN3002-1620C) with a transmissivity of 1.58 x 10^{-4} m^2/s (Normal Load = 12,000 psf) to transmit the infiltration due to a 25-year, 24-hour rainfall event (3.9 in./day). The gravel layer is omitted from the sideslope analysis.



Applicable Equations:

Transmissivity = T = Q/Wi

Q = flow rate
W = width of geocomposite
i = gradient

Calculations:

> Q = LWI; Set W=1 ft (i.e.: Calculate the flow per unit width of geocomposite.)
> L = horizontal length of flow, the maximum flow length of the sideslope
> L = 36 ft in Cell 13 (length of sideslope minus 10 ft initial waste lift - This is the worst case length of exposed sideslope for Cells 9 through 14)
> I = intensity = 3.9 in./day = 3.76×10^{-6} ft/s

> Q = 36 ft x 1 ft x 3.76×10^{-6} ft/s = 1.35×10^{-4} ft^3/s (flow off 36 ft. exposed sideslope)

Calculations were prepared to evaluate runoff (2.9 inches/day) from an average 20 foot waste slope and 3.9 inches/day on a 6 ft. exposed sideslope. The flow per unit width was calculated at 7.86×10^{-5} ft^3/s which is less than the 1.35×10^{-4} ft^3/s unit flow from the 36 ft exposed sideslope. The unit flow of 1.35×10^{-4} ft^3/s was used to evaluate the other components of the leachate collection system in Cells 9 through 14.

The required sideslope transmissivity is:

$$T_{req} = \frac{Q_{reg}}{Wi} = \frac{1.35 \times 10^{-4}\ ft^3/s}{1\ ft \times 0.33} = 4.1 \times 10^{-4}\ ft^2/s$$

The actual geocomposite transmissivity is taken from manufacturer's data for normal load = 12,000 psf, i = 0.33:

$$T_{act} = 1.58 \times 10^{-4}\ m^2/s = 1.70 \times 10^{-3}\ ft^2/s$$

The EPA (Geosynthetic Design Guidance 1986) recommends a Design Ratio (DR) of three. This reflects the high probability of the design event not occurring during the short operational period when the sideslope is exposed.

$$T_{act}/T_{req} = 1.70 \times 10^{-3} / 4.1 \times 10^{-4} = 4.1$$

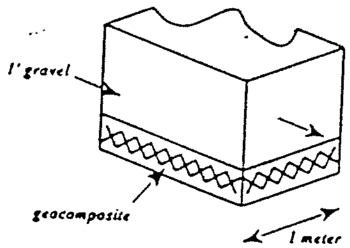
One layer is sufficient according to EPA's guidance document for the sideslope primary leachate collection system and secondary leachate collection system.

2. BASE DRAINAGE SYSTEM CALCULATIONS

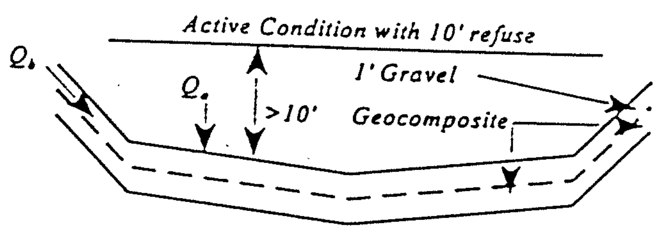
To calculate the required transmissivity of the base drainage system, a 1-foot wide flow path along the direction of farthest travel length was used. The flow comes from sideslope run-off. Since the sideslope calculations showed the drainage system can handle the sideslope run-on, the following calculations will check the base drainage system capacity for the exposed 36 ft. sideslope flow.

The same "driving equations" are used for the base calculations as were used for the sideslope calculations. The transmissivity of the drainage system must be large enough to transmit the flow through the ends of the "Design Unit." (The system will be assumed at steady state conditions.)

For one single layer of geocomposite TN3002 1620C, the transmissivity in the order of 2.73×10^{-4} m^2/sec is taken from NSC transmissivity testing data for normal load of 12,000 psf and gradient 2.0 percent as shown in the attached report.

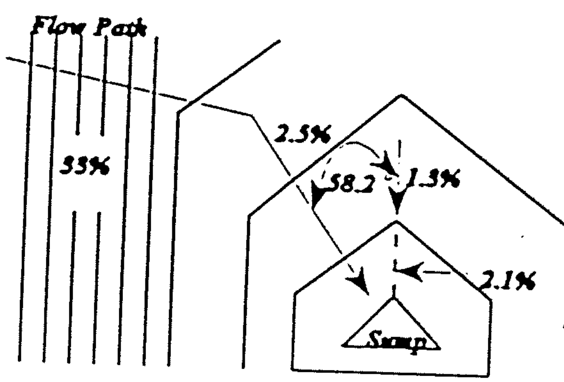


Base Drainage System Calculations



Q_s = Sideslope Runoff

Q_a = Infiltration



Slope in direction of flow.

$\tan^{-1}(0.021/0.013) = 58.2°$

$\cos(58.2°) \times 100 = 52.7'$
$\sin(58.2°) \times 100 = 85.0'$

$1.3/100 \times 52.7 = 0.685$
$2.1/100 \times 85.0 = 1.785$

Slope $= (0.685+1.785)/100 = 0.025 = 2.5\%$

FIGURE 1

Applicable Equation $T = \dfrac{Q}{Wi}$

T = transmissivity (ft^2/s), $T = K \times t$, t - the thickness of drainage layer
Q = flow (ft^3/s)
W = width of flow (ft): $W = 1$; unit width of flow
i = gradient $i = 2.5\% = .025$

Flow capacity/ft width of granular layer on base:

$Q = T \times W \times i$
$T = K \times t$

$K = 8 \times 10^{-2}$ cm/s $= 2.62 \times 10^{-3}$ ft/s (permeability for leachate collection stone), $t = 1$ ft
$Q_{granular} = 2.62 \times 10^{-3}\ ft^3/s$ ft/s x 1 ft x 1 ft x 0.025
$= 6.55 \times 10^{-5}\ ft^3/s$

Flow capacity/ft width of geocomposite:

$T = 2.73 \times 10^{-4}\ m^2/s = 2.94 \times 10^{-3}\ ft^2/s$
$Q_{geocomposite} = 2.94 \times 10^{-3}\ ft^2/s \times 1\ ft \times 0.025$
$= 7.35 \times 10^{-5}\ ft^3/s$

Collection system total capacity Q total:

$Q_{total} = Q_{granular} + Q_{geocomposite} = 6.55 \times 10^{-5}\ ft^3/s \div 7.35 \times 10^{-5} = 1.39 \times 10^{-4}\ ft^3/s$

Evaluate 2 flow cases:

1. Evaluating required flow from HELP model results for landfill active conditions:

Peak daily infiltration $I = 0.1991$ in/day $= 1.92 \times 10^{-7}$ ft/s
$L = 347$ ft
$W = 1$ ft

$Q_{req} = 1.92 \times 10^{-7}$ ft/s x 347 ft x 1 ft $= 6.66 \times 10^{-5}\ ft^3/s$
$Q_{total} = 1.39 \times 10^{-4}$ ft3/s $> Q_{req} = 6.66 \times 10^{-5}\ ft^3/s$

2. Evaluating flow from exposed sideslope:

$Q_{req} = 1.35 \times 10^{-4}\ ft^3/s$ (flow from 36ft exposed sideslope)
$Q_{total} = 1.39 \times 10^{-4}\ ft^3/s > Q_{req} = 1.35 \times 10^{-4}$ ft3/s

Since the peak daily value of the flow from the exposed sideslope is the most critical condition at the site, the design of the primary leachate collection system of the landfill base is adequate.

3. CHANNEL GEOCOMPOSITE CALCULATIONS

A layer of geocomposite will be used to replace the pipes that are normally used to collect leachate from the low points in the landfill. The capacity of the geocomposite and granular stone is compared with the calculated flow from the contributing drainage area to determine if a pipe is required. Figure 2 (below) shows the pipe in relation to the geocomposite.

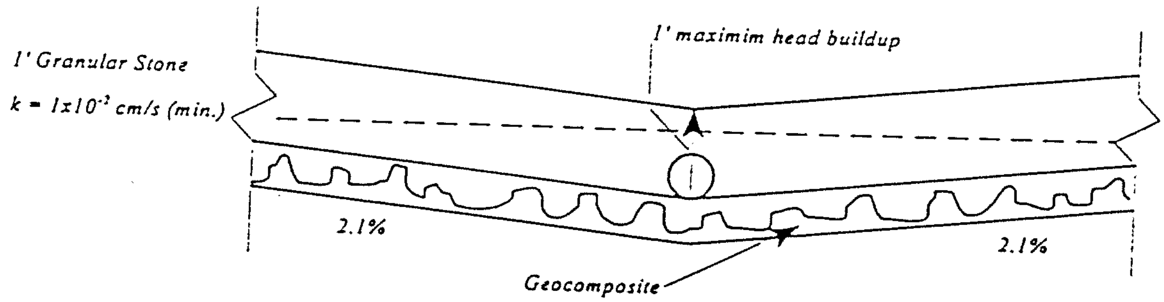


FIGURE 2

Primary Leachate Collection Granular Stone Capacity:

$K = 8 \times 10^{-2}$ cm/s $= 2.62 \times 10^{-3}$ ft/s
$T = K \times t$

$Q_g = T \times W \times i = (2.62 \times 10^{-3}$ ft/s $\times$ 1 ft) $\times$ 48' $\times$ .021 $= 2.64 \times 10^{-3}$ ft³/s

Geocomposite Capacity:

$T = 2.73 \times 10^{-4}$ m²/sec $= 2.94 \times 10^{-3}$ ft²/s	obtained from NSC transmissivity testing data for normal load of 12,000 psf and gradient of 2.0 percent as shown in the attached data.

$Q_{geocomposite} = 2.94 \times 10^{-3} \times 2 \times 15' \times .021 = 1.85 \times 10^{-3}$ ft³/s

$Q_g + Q_{geocomposite} = Q_{total} = 4.49 \times 10^{-3}$ ft³/s

Peak daily infiltration from HELP model for contributing area on Figure 1:

$I = 0.1991$ in/day $= 1.92 \times 10^{-7}$ ft/s
$A = 273{,}000$ ft², contributing area
$Q = 1.92 \times 10^{-7}$ ft/s $\times$ 273,000 ft² (Combined Cells 12 and 14)
$= 5.24 \times 10^{-2}$ ft³/s

$Q_{actual} = 5.24 \times 10^{-2}$ ft³/s

$Q_{actual} > Q_{system}$ 5.24×10^{-2} ft³/s > 4.49×10^{-3} ft³/s is not okay, need a leachate collection pipe in the channel. See Item 4, Leachate Collection Pipe Design.

Flow from the 36 ft. exposed sideslope into the leachate collection system from the perimeter of the combined Cells 11/13 or 12/14.

Length of perimeter channel:

Combined Cell 11/13 - 1000 ft.
Combined Cell 12/14 - 1300 ft (worst case)

Total flow per ft. width along the perimeter is 1.35×10^{-4} ft³/sec/ft.
Total flow into base collection system:

$Q_{act} = 1.35 \times 10^{-4}$ ft³/sec x 1300= 1.76×10^{-1} ft³/sec

$Q_{actual} > Q_{system}$ 1.76×10^{-1} ft³/s > 4.49×10^{-3} ft³/s is not okay, need a leachate collection pipe in the channel. See Item 4 - Leachate Collection Pipe Design.

4. LEACHATE COLLECTION PIPE DESIGN

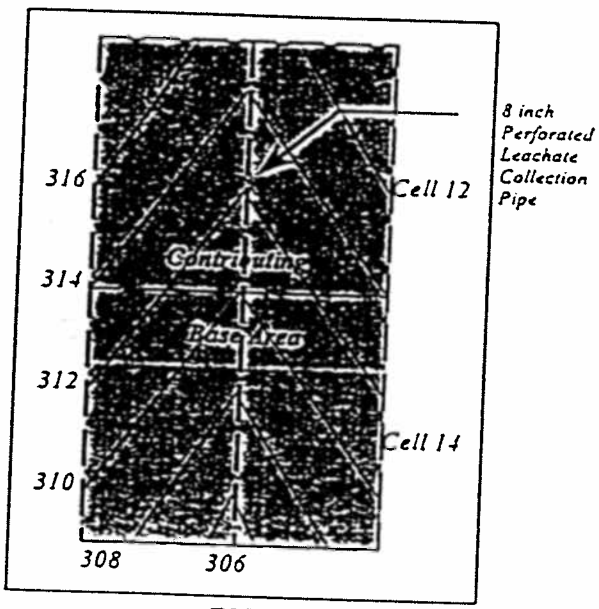


FIGURE 3

An 8" perforated leachate collection pipe (Figure 3) will be placed in the center line to handle the actual flow.

The capacity of the 8" perforated leachate collection pipe can be determined by the Manning formula.

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$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

Where:
- Q = flow rate (cfs)
- n = Manning's roughness coefficient = 0.012 for plastic pipe

$$A = Pipe\ AREA = \frac{1}{4} \pi d^2$$

$For\ 8''\ (SCH\ 80\ PVC)\ inner\ diameter = 7.625\ in$

$$A = \frac{1}{4} \pi \left(\frac{7.625}{12} \right)^2$$
$$= 0.317\ ft^2$$

$$R = Hydraulic Radius = \frac{Diameter}{4}\ for\ full\ flowing\ pipes$$

$$R = \frac{7.625}{4} x \frac{1\ ft}{12\ in} = 0.16\ ft.$$

$$s = Pipe\ Slope = 1.3\% = .013\ ft/ft$$

$$Q_{pipe} = \frac{1.49}{.012} (0.317\ ft^2)\ (0.16)^{2/3}\ (0.013)^{1/2} = 1.32\ ft^3/s$$

$$Q_{actual} < Q_{pipe}\ 1.76\ x\ 10^{-1}\ ft^3/s < 1.32\ ft^3\ okay$$

The channel with a perforated pipe will handle the actual flow with a design ratio of:
Pipe Perforation Design.

$$\frac{1.32}{1.76\ x\ 10^{-1}} = 8\ with\ a\ perforated\ pipe\ in\ the\ centerline.$$

The flow through the pipe perforations can be estimated using the Bernoulli Orifice equation.

Assumptions:

- Free flow occurs through the holes;
- The head is constant and equal to the thickness of the drainage layer (12 inches) less 2 inches to account for the position of the holes (60° from vertical) on the 8 inch pipe. The head is equal to 10 inches;
- The perforations have sharp edges, C = 0.61; and,
- Factor of safety for perforation design = 2.
- Calculations

Area of ½-inch diameter hole

$$A = \frac{\pi d^2}{4} = 1.36 \times 10^{-3}\ ft^2$$

$$Q_{actual} = 1.76 \times 10^{-1}\ ft^3/s$$

$$Q_{design} = F.S. \times Q_{actual}$$

$$= 2 \times 1.76 \times 10^{-1}$$

$$= 3.52 \times 10^{-1}\ ft^3/s$$

Flow per Hole.

$$Q_{hole} = CA\sqrt{Z\ g\ h}$$

$$= (0.61)\ (1.36 \times 10^{-3}\ ft^2)\sqrt{(2)(32.2\ ft/\sec^2) \times \frac{10}{12}ft.}$$

$$= 6.07 \times 10^{-3}\ ft^3/s$$

Determine number of holes needed (N).

$$N = \frac{Q_{design}}{Q_{hole}} = \frac{3.52 \times 10^{-1}\ ft^3/s}{6.07 \times 10^{-3}\ ft^3/s}$$

$$= 58\ holes$$

Determine Spacing of holes (S):

$$S = \frac{Length\ of\ Pipe}{N} = \frac{697}{58}$$

$$= 12.01\ ft.$$

Final Design:

For the design, an 8 in. leachate collection pipe with ½" holes spaced 12 ft apart alternating 60° from the bottom of the pipe is adequate. For construction, perforations will be 5/8" holes, spaced at 3 inches in an alternating 120° pattern. Holes will be on the bottom of the pipe.

5. GEOCOMPOSITE TRANSMISSIVITY CONVERSION TO HYDRAULIC CONDUCTIVITY CALCULATIONS

This calculation shows drainage layers exceed 8×10^{-2} cm/sec.

Base Geocomposite Use NSC test data for the load of 12,000 lbs/ft^2

From Test Data $T = 2.73 \times 10^{-4}\ m^2/s$

$$K = \frac{T}{b}$$

where: T = transmissivity
b = thickness; b = 0.5 cm
K = Permeability

$$Thus:\ K = \frac{T}{b} = \frac{2.73\ cm^2/s}{0.5\ cm} = 5.5\ cm/s.$$

TASK:

Determine if the travel time for the farthest point hydraulically in the cell to the sump in the secondary leachate collection system of Cells 10/9, 11/13, and 12/14 is less than the 24 hour requirement.

REFERENCES:

1. Appendix G - Hydraulic Calculations For Collection Systems of the "Engineering Report for RMU - 1."
2. "General Properties of PVC Pipe," from Eslon Termoplastics.
3. Drawing 5, "Subbase Grades", Rev. 5/97 Rust Environment & Infrastructure.

METHOD:

1. Determine the maximum capacity of the 8 inch SCH 80 PVC perforated pipe to be used in the centerline of Cells 10/9, 11/13, 12/14 using Manning's Formula:

$$Q = \frac{1.49}{n} A\, R^{2/3}\, S^{1/2}$$

Where: Q = Flow Rate (cfs)
n = Manning's Roughness Coefficient
A = Pipe Area = $(0.25)\pi\, d^2$ (sf)
R = Hydraulic Radius = d / 4 for full flowing pipe (ft)
S = Pipe Slope (ft/ft)

2. Determine the travel time through the following liner components:

- Geocomposite on Perimeter Berm
- Geocomposite on Cell Floor
- Leachate Collection Pipe (Cell Centerline)

The travel time through the geocomposite is calculated as follows:

$$\text{Travel Time} = \frac{\text{Flow Length} \times \text{Geocomposite Thickness}}{\text{Geocomposite Transmissivity}}$$

The travel time through the pipe is determined by dividing the flow length by the flow velocity.

ASSUMPTIONS

1. Leachate will take the path of least resistance through the secondary leachate collection system; therefore, the highest velocity component of the section will be used to evaluate the travel time.

CALCULATIONS:

1. Flow Capacity of 8 Inch Sch 80 PVC Perforated Pipe

$$Q = \frac{1.49}{n} A\ R^{2/3}\ S^{1/2}$$

The Nominal Inside Diameter of 8" SCH 80 PVC Pipe is 7.625 inches (reference 2).
The required flow capacity from the HELP Model is 6.03×10^{-2} ft^3 / s (reference 1).

n = 0.012 for plastic pipe
A = (0.25) (3.14) (7.625 inches)^2 = 45.6 inches
A = 0.317 ft^2
R = (7.625 inches) / 4 = 1.906 inches
R = 0.159 ft
S = 1.3% = 0.013 ft/ft

$$Q_{Pipe} = \frac{1.49}{(0.012)} (0.317\ ft^2)\ (0.159\ ft)^{2/3}\ (0.013)^{1/2}$$

$Q_{pipe} = 1.3\ ft^3 / sec$

$Q_{pipe} > Q_{required} = 1.3\ ft^3 / sec > 6.03 \times 10^{-2}\ ft^3 / s$

8 inch SCH 80 PVC pipe is adequate to handle the required flow rate.

2. Travel Time

A. Cell 10/9

Section 1: Perimeter Berm (Point A to Point B)

Length	=	30 ft
Transmissivity of Geocomposite	=	1.70×10^{-3} ft^2 / s (reference 1)
Geocomposite Thickness	=	0.35 inches

Travel Time = (30 ft) x (0.35 inches) x (1 ft / 12 inches) / 1.70×10^{-3} ft^2 / s = 515 sec

Section 2: Cell Floor (Point B to Point C)

Length	=	262 ft
Transmissivity of Geocomposite	=	2.94×10^{-3} ft^2 / s (reference 1)

Geocomposite Thickness = 0.35 inches

Travel Time = (262 ft) x (0.35 inches) x (1 ft / 12 inches) / 2.94 x 10^{-3} ft^2 / s = 2,599 sec

Section 3: Cell Center Line - Leachate Collection Pipe (Point C to Point D)

Length = 578 ft
Flow Rate of Pipe = 1.3 ft^3 / s
Cross Section Area of 8 inch SCH 80 PVC pipe = 0.317 ft^2

Travel Time = (578 ft) / (1.3 ft^3 / s) x (0.317 ft^2) = 141 sec

Cell 10/9 Total Travel Time
(515 sec + 2,599 sec + 141 sec) / 3,600 sec / hr = **0.9 hr**

B. Cell 11/13

Section 1: Perimeter Berm (Point E to Point F)

Length = 51 ft
Transmissivity of Geocomposite = 1.70 x 10^{-3} ft^2 / s (reference 1)
Geocomposite Thickness = 0.35 inches

Travel Time = (51 ft) x (0.35 inches) x (1 ft / 12 inches) / 1.70 x 10^{-3} ft^2 / s = 875 sec

Section 2: Cell Floor (Point F to Point G)

Length = 206 ft
Transmissivity of Geocomposite = 2.94 x 10^{-3} ft^2 / s (reference 1)
Geocomposite Thickness = 0.35 inches

Travel Time = (206 ft) x (0.35 inches) x (1 ft / 12 inches) / 2.94 x 10^{-3} ft^2 / s = 2,044sec

Section 3: Cell Center Line - Leachate Collection Pipe (Point G to Point H)

Length = 366 ft
Flow Rate of Pipe = 1.3 ft^3 / s
Cross Section Area of 8 inch SCH 80 PVC pipe = 0.317 ft^2

Travel Time = (366 ft) / (1.3 ft^3 / s) x (0.317 ft^2) = 89 sec

Cell 11/13 Total Travel Time
(875 sec + 2,044 sec + 89 sec) / 3,600 sec / hr = **0.8 hr**

C. Cell 12/14

Section 1: Perimeter Berm (Point I to Point J)

Length	=	32 ft
Transmissivity of Geocomposite	=	1.70×10^{-3} ft^2 / s (reference 1)
Geocomposite Thickness	=	0.35 inches

Travel Time = (32 ft) x (0.35 inches) x (1 ft / 12 inches) / 1.70×10^{-3} ft^2 / s = 549 sec

Section 2: Cell Floor (Point J to Point K)

Length	=	540 ft
Transmissivity of Geocomposite	=	2.94×10^{-3} ft^2 / s (reference 1)
Geocomposite Thickness	=	0.35 inches

Travel Time = (216 ft) x (0.35 inches) x (1 ft / 12 inches) / 2.94×10^{-3} ft^2 / s= 2,143sec

Section 3: Cell Center Line - Leachate Collection Pipe (Point C to Point D)

Length	=	540 ft
Flow Rate of Pipe	=	1.3 ft^3 / s
Cross Section Area of 8 inch SCH 80 PVC pipe	=	0.317 ft^2

Travel Time = (540 ft) / (1.3 ft^3 / s) x (0.317 ft^2) = 132 sec

Cell 12/14 Total Travel Time

(549 sec + 2,143 sec + 132 sec) / 3,600 sec / hr = **0.8 hr**

CONCLUSIONS:

The Secondary Leachate Systems for Cells 10/9, 11/13, and 12/14 are adequate.

CLIENT: CWM Chemical Services, LLC PROJECT: Model City, NY
TITLE: RMU-1 Final Cover Modification Application
SUBJECT: Appendix G-3: Hydraulic Calculations for Collection System in GCL Final Cover Areas

Prepared By: BMS Date: December 2003
Reviewed By: PHB Date: December 2003
Revised By: RLP Date: March 2008

OBJECTIVES:

Determine the required transmissivity for the final cover geocomposite in geosynthetic clay liner (GCL) final cover areas. Evaluate the final cover collection piping configuration for use in GCL final cover areas.

REFERENCES:

1. Residuals Management Unit 1 (RMU-1) Permit Drawing No. 12-a entitled "Top of Vegetative Cover Grades," Blasland, Bouck & Lee, Inc. (BBL), December 2003 (last revised March 2008).
2. Visual HELP v2.2.0.1 (Windows-based implementation of HELP model v. 3), Waterloo Hydrogeologic, Inc.
3. Advanced Geotech Systems website entitled "landfilldesign.com."
4. "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers Comprising Two Different Slopes," Giroud, J.P., Zornberg, J.G., and Beech, J.F., technical paper presented in Geosynthetics International - Special Issue on Liquid Collection Systems, 2000.
5. Engineering Report for Residuals Management Unit 1, Appendix G entitled "Hydraulic Calculation for Collection Systems," June 1992.
6. Engineering Report for Residuals Management Unit 1, Appendix E-2 entitled "Final Cover Drainage Pipe Flow Capacity," undated.
7. RMU-1 Permit Drawing No. 21B entitled "Site Details," BBL, December 2003.
8. Engineering Report for Residuals Management Unit 1, Appendix I entitled, "Surface Water Drainage and Erosion Calculations," BBL, December 2003.

ASSUMPTIONS:

1. The required transmissivity for the final cover geocomposite is governed by the longest undrained lengths and flattest slopes of the final cover. Based on Reference 1, three representative slope conditions are evaluated – one on the plateau area, one composite slope on the plateau area and extending onto the sideslope, and one completely on the sideslope. The first two slope conditions are used to represent portions of the final cover that are upgradient of the uppermost surface-water diversion berm. The third slope condition is used to represent all other final cover areas.

2. The first slope ("slope 1") consists of approximately 396 feet of final cover sloped at 5%. This slope begins at the high point of RMU-1 and extends towards the north to a collection pipe at the interface of the compacted clay final cover and GCL final cover.

3. The second slope ("slope 2") is located in Cell 10 and begins at the high point of RMU-1 and extends westerly to the invert of the uppermost surface-water diversion berm. This composite slope consists of approximately 150 feet of final cover sloped at 5% and 83 feet at 33% (approximately 233 feet total).

4. The third slope ("slope 3") is located in Cell 10 and begins at the outboard crest of the lowermost surface-water diversion berm and extends to the toe drain in the anchor trench of the final cover system. This slope consists of approximately 111 feet of final cover sloped at 33%.

5. The required transmissivity for the final cover geocomposite is based on Giroud's equation (presented in Reference 3) and the following parameters:

- Maximum allowable head in the geocomposite is limited to the thickness of the drainage layer (i.e., the thickness of the geonet core).

- Impingement rate (i.e., rate at which liquid infiltrates to geonet core) is calculated using Reference 2 and the following parameters, which are generally consistent with Reference 5:

  - 25-year, 24-hour rainfall of 4.0 inches (HELP model climatic data was modified to include the design storm)
  - Maximum leaf area index = 2.0 (fair stand of grass)
  - Evaporative zone depth = 12 inches (approximately the middle of the range of guidance values for silty soils presented in the User's Guide for HELP model v.3)
  - Maximum hydraulic conductivities for the topsoil and general soil fill in the final cover are $7.5x10^{-5}$ centimeters per second (cm/s) and $5x10^{-5}$ cm/s, respectively

  Separate impingement rates are calculated for 5% and 33% slopes.

6. Typical factors of safety for required transmissivity are from Reference 3 (see attached calculations for specific values).

7. The final cover system consists of (from top to bottom) 24 inches of vegetative support cover soil, a geocomposite drainage layer, a 40 mil textured high-density polyethylene (HDPE) geomembrane, a GCL layer, and 6 inches of general fill. Geocomposite material to be used in GCL final cover areas will be subject to laboratory testing to verify that the material's transmissivity meets or exceeds the minimum values determined in this calculation. The laboratory testing will be performed under conditions that are representative of those likely to be experienced in the final cover. Such conditions include bounding the geocomposite sample with geomembrane (below the sample) and soil (above the sample), establishing representative hydraulic gradients (0.10 for the plateau areas and 0.33 for the sideslope areas), using a minimum seat time of 24 hours (with 100 hours preferred), and using an applied load of 2,500 pounds per square foot (psf). This load is approximately twice the anticipated load that the geocomposite will experience in the final cover. The anticipated load is approximately 1,260 psf due to the final cover soil weight (2 feet x 130 pcf = 260 psf) and the operation of low ground pressure construction equipment (approximately 7 psi = 1,000 psf).

8. The hydraulic capacity of the final cover collection piping must equal or exceed the rate at which infiltrating water is expected to reach the piping.

9. The rate at which water is expected to reach the final cover collection piping is calculated based on impingement rates, as predicted using Reference 2, and the acreages of final cover draining to the piping.

10. The hydraulic capacity of the final cover collection pipes is based on the diameter of the pipes (6 inches), the Manning "n" of the pipes (assumed to be 0.018 for 6-inch-diameter corrugated HDPE pipe [from Reference 6]), and the slope of the pipes. The slopes of pipes installed in the surface-water diversion berms are equal to the longitudinal slopes of the berms themselves (obtained from Reference 1). The slopes of pipes installed in the final cover system anchor trench and at the interface of the compacted clay and GCL final cover systems are sloped at 0.5%.

CALCULATIONS:

1. Required Transmissivity for Slope 1

The required transmissivity for Slope 1 is based on Giroud's equation:

$$\Theta = \frac{TSF q_h L}{\sin\beta + \frac{t_{TCL}/L}{TSF}\cos^2\beta}$$

where,

Θ = required transmissivity
TSF = total serviceability factor (a combination of reduction and overall design safety factors)
= 4.72 (see attached calculations for individual factors of safety)
q_h = impingement rate (rate at which water infiltrates through the cover soils into the geocomposite)
= 0.68 inches/day = 1.99×10^{-5} cm/s (calculated using Reference 2 based on Assumption 5)
L = maximum drainage length = 396 feet = 120.7 m
β = slope angle of drainage layer = 2.9° (5%)
t_{LCL} = thickness of geonet core in geocomposite = 0.50 cm (based on 200-mil geonet core)

$\therefore \Theta = 2.27 \times 10^{-3}\ m^2/s = 22.7\ cm^2/s$ = Required Transmissivity for Slope 1

2. Required Transmissivity for Slope 2

Because Slope 2 is a composite slope consisting of two distinct slope lengths and gradients, separate required transmissivities are determined for the 5% and 33% slope segments (per Reference 4).

The required transmissivity for the 5% slope segment is based on the following parameters:

TSF = 4.72 (see attached calculations for individual factors of safety)
q_h = 0.63 inches/day = 1.87×10^{-5} cm/s (calculated using Reference 2 based on Assumption 5)
L = 150 feet = 45.6 m
β = 2.9° (5%)
t_{LCL} = 0.50 cm (based on 200-mil geonet core)

$\therefore \Theta = 8.05 \times 10^{-4}\ m^2/s = 8.05\ cm^2/s$ = Minimum Required Transmissivity for the 5% Component of Slope 2

The required transmissivity for the 33% slope segment is based on the following parameters:

TSF = 4.72 (from above)
q_h = 0.63 inches/day = 1.87×10^{-5} cm/s (from the 5% segment of slope 2 above)
L = 150 feet + 83 feet = 233 feet = 71.0 m (to account for flow through geocomposite from the upgradient 5% slope segment per Reference 4)
β = 18.4° (33%)
t_{LCL} = 0.50 cm (based on 200-mil geonet core)

$\therefore \Theta = 2.00 \times 10^{-4}\ m^2/s = 2.00\ cm^2/s$ = Minimum Required Transmissivity for the 33% Component of Slope 2

CLIENT: CWM Chemical Services, LLC PROJECT: Model City, NY
TITLE: RMU-1 Final Cover Modification Application
SUBJECT: Appendix G-3: Hydraulic Calculations for Collection System in GCL Final Cover Areas

Prepared By: BMS Date: December 2003
Reviewed By: PHB Date: December 2003
Revised By: RLP Date: March 2008

3. Required Transmissivity for Slope 3

Using Giroud's equation (presented above) with the following parameters for Slope 3:

TSF = 4.72 (see attached calculations for individual factors of safety)
q_h = 0.42 inches/day = 1.23×10^{-5} cm/s = (calculated using Reference 2 based on Assumption 5)
L = 111 feet = 33.8 m
$\beta = 18.4^\circ$ (33%)
t_{LCL} = 0.50 cm (based on 200-mil geonet core)

$\therefore \Theta = 6.3 \times 10^{-5}\ m^2/s = 0.63\ cm^2/s$ = Required Transmissivity for Slope 3

4. Evaluation of Final Cover Collection Piping

The final cover collection piping configuration includes 6-inch perforated corrugated HDPE pipes installed along the inverts of the surface-water diversion berms, in the anchor trench of the final cover system, and at the interface of the compacted clay and GCL final cover systems. The adequacy of the collection piping is evaluated below.

Currently Permitted Collection Piping in the Surface-Water Diversion Berms

The perforated pipes installed in the surface-water diversion berms are required to convey water from the high points of the surface-water diversion berms to the low points (which occur at the downchutes). In order to evaluate the adequacy of the currently permitted final cover collection pipe design, the critical drainage area is identified and evaluated. Based on Reference 1, the final cover collection pipe in the second surface-water diversion berm (from the toe of slope), beginning in Cell 12 and extending to Cell 1, collects runoff from the largest drainage area. At its downstream end, this collection pipe collects water from approximately 6.45 acres of final cover (drainage area A10, as depicted on Reference 8). Approximately 3.42 acres of this drainage area consists of GCL final cover and the remainder is compacted clay final cover. Because the impingement rates for each type of final cover are expected to be similar (based on a comparison of the HELP model output for Reference 5 and for the evaluation of slope 3 above), the flow rate from the two final cover types for this drainage area are not significantly different.

The flowrate that this pipe is required to convey is calculated based on the impingement rate (4.1×10^{-7} feet per second [ft/s] from either Reference 5 or the evaluation of Slope 3 above) and the drainage area. The required flowrate is:

$$Q_{req} = (4.1 \times 10^{-7}\ ft/s)(43{,}560\ ft^2/acre)(6.45\ acres)$$
$$= 0.12\ cfs$$

Based on Reference 1, the slope of the surface-water diversion berm varies along its length. At the downstream end, the slope is approximately 0.8%. The capacity of a 6-inch-diameter corrugated HDPE pipe installed at a slope of 0.8% can be calculated using the Manning equation and the parameters discussed in Assumption 10:

$$Q_{pipe} = \frac{1.49}{n} AR^{2/3}S^{1/2}$$

where,

Q_{pipe} = pipe-full flowrate
A = cross sectional area of pipe flowing full = $\pi D^2/4$ = 0.196 ft^2
n = Manning "n" for corrugated HDPE pipe = 0.018
R = hydraulic radius of pipe flowing full= A/P = 0.125 ft
P = wetted perimeter of pipe flowing full = πD = 1.57 ft
S = longitudinal slope of pipe = 0.008

$\therefore$ Q_{pipe} = 0.36 cfs

The currently permitted pipe configuration provides a factor of safety of approximately 3.0 with respect to the required flowrate (0.36 cubic feet per second [cfs]/0.12 cfs = 3.0).

Currently Permitted Collection Piping in the Final Cover System Anchor Trench

Based on Reference 7, the final cover collection pipe at the toe of the RMU-1 sideslope is a 6-inch-diameter corrugated HDPE with outlets spaced every 300 feet along the pipe. The flowrate that this pipe is required to convey is calculated d on the maximum sideslope length from the lowermost surface-water diversion berm to the toe of the 33% slope roximately 111 feet per Assumption 4), an outlet spacing every 300 feet, and the predicted impingement rate from ference 2 (4.1×10^{-7} ft/s from the evaluation of slope 3 above). The required flowrate is:

Q_{req} = (4.1×10^{-7} ft/s)(111 feet)(300 feet)
= 0.013 cfs

The capacity of a 6-inch-diameter corrugated HDPE pipe installed at a slope of 0.5% can be calculated using the Manning equation and the parameters discussed in Assumption 10:

$$Q_{pipe} = \frac{1.49}{n} AR^{2/3}S^{1/2}$$

where,

Q_{pipe} = pipe-full flowrate
A = cross sectional area of pipe flowing full = $\pi D^2/4$ = 0.196 ft^2
n = Manning "n" for corrugated HDPE pipe = 0.018
R = hydraulic radius of pipe flowing full= A/P = 0.125 ft
P = wetted perimeter of pipe flowing full = πD = 1.57 ft
S = longitudinal slope of pipe = 0.005

$\therefore$ Q_{pipe} = 0.29 cfs

urrently permitted pipe configuration provides a factor of safety of approximately 22.3 with respect to the required ate (0.29 cfs/0.013 cfs = 22.3).

Proposed Collection Piping at the Interface of the Compacted Clay and GCL Final Cover Systems

The collection piping at the interface of the compacted clay and GCL final cover systems is a 6-inch diameter corrugated HDPE sloped at a minimum 0.5%. At its downstream end, this collection pipe collects water from approximately 2.00 acres of final cover. The flowrate that this pipe is required to convey is calculated based on this acreage and the predicted impingement rate from Reference 2 (4.1×10^{-7} ft/s from the evaluation of slope 1 above). The required flowrate is:

$$Q_{req} = (4.1 \times 10^{-7} \text{ ft/s})(43{,}560 \text{ ft}^2/\text{acre})(2.00 \text{ acres}) = 0.036 \text{ cfs}$$

The capacity of a 6-inch-diameter corrugated HDPE pipe installed at a slope of 0.5% is calculated above as 0.29 cfs.

The proposed pipe configuration provides a factor of safety of approximately 8.1 with respect to the required flowrate (0.29 cfs/0.036 cfs = 8.1).

SUMMARY:

For areas upgradient of the uppermost surface-water diversion berm, the required geocomposite transmissivities are:

$\Theta = 22.7$ cm^2/s (with a hydraulic gradient of 0.05, representative of 5% slope areas)
$\Theta = 2.00$ cm^2/s (with a hydraulic gradient of 0.33, representative of 33% slope areas)

r all other areas, the required geocomposite transmissivity is:

$\Theta = 0.63$ cm^2/s (with a hydraulic gradient of 0.33, representative of 33% slope areas)

The geocomposite must have a minimum transmissivity of 22.7 cm^2/s at a hydraulic gradient of 0.05 and a minimum transmissivity of 2.00 cm^2/s at a hydraulic gradient of 0.33 to satisfy all three slope conditions. All geocomposite material will be subjected to laboratory transmissivity testing with appropriate boundary conditions prior to use in the final cover.

Based on this evaluation, the final cover collection piping configuration (both currently permitted and proposed) is adequate for use with GCL final cover areas.

HELP Model Output Data

Slope 1 – 396 feet at 5%

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**                                                                          **
**             HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                **
**             HELP MODEL VERSION 3.07  (1 November 1997)                   **
**             DEVELOPED BY ENVIRONMENTAL LABORATORY                        **
**             USAE WATERWAYS EXPERIMENT STATION                            **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:      C:\WHI\UNSAT22\data\P260.VHP\_weather1.dat
TEMPERATURE DATA FILE:        C:\WHI\UNSAT22\data\P260.VHP\_weather2.dat
SOLAR RADIATION DATA FILE:    C:\WHI\UNSAT22\data\P260.VHP\_weather3.dat
EVAPOTRANSPIRATION DATA:      C:\WHI\UNSAT22\data\P260.VHP\_weather4.dat
SOIL AND DESIGN DATA FILE:    C:\WHI\UNSAT22\data\P260.VHP\I_385375.inp
OUTPUT DATA FILE:             C:\WHI\UNSAT22\data\P260.VHP\O_385375.prt


TIME:  17:17      DATE:   3/19/2008


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      TITLE:  EPA profile1

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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   8
          THICKNESS                   =      15.24   CM
          POROSITY                    =       0.5010 VOL/VOL
          FIELD CAPACITY              =       0.2827 VOL/VOL
          WILTING POINT               =       0.1353 VOL/VOL
          INITIAL SOIL WATER CONTENT  =       0.3231 VOL/VOL
          EFFECTIVE SAT. HYD. COND.   =  0.750000000000E-04 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
               FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 9

THICKNESS	=	45.72	CM
POROSITY	=	0.4300	VOL/VOL
FIELD CAPACITY	=	0.3210	VOL/VOL
WILTING POINT	=	0.2208	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3610	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.500000000000E-04	CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.50	CM
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.	=	46.0000000000	CM/SEC
SLOPE	=	5.00	PERCENT
DRAINAGE LENGTH	=	120.7	METERS

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.10	CM
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.	=	0.200000000000E-12	CM/SEC
FML PINHOLE DENSITY	=	2.00	HOLES/HECTARE
FML INSTALLATION DEFECTS	=	2.00	HOLES/HECTARE
FML PLACEMENT QUALITY	=	4 - POOR	

Slope 1 – 396 feet at 5%

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 121. METERS.

SCS RUNOFF CURVE NUMBER	=	72.59	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	0.4047	HECTARES
EVAPORATIVE ZONE DEPTH	=	30.5	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	10.426	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	14.188	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	5.427	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	21.434	CM
TOTAL INITIAL WATER	=	21.434	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM Buffalo NY

STATION LATITUDE	=	42.89	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	126	
END OF GROWING SEASON (JULIAN DATE)	=	285	
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	12.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	76.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	68.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	72.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	76.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Buffalo NY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.02	2.40	2.97	3.06	2.89	2.72
2.96	4.16	3.37	2.93	3.62	3.42

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Buffalo NY

Slope 1 – 396 feet at 5%

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
23.50	24.50	33.00	45.40	56.10	66.00
70.70	68.90	62.10	51.50	40.30	28.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Buffalo NY
AND STATION LATITUDE = 42.90 DEGREES

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5 and their dates (DDDYYYY)

		(INCHES)	(CU. FT.)	
10001	PRECIPITATION	4.00	14519.68352	
760002	RUNOFF	2.778	10084.05841	
3150004	**DRAINAGE COLLECTED FROM LAYER 3**	**0.67579**	2453.06642	
3150004	PERCOLATION/LEAKAGE THROUGH LAYER 4	0.003758	13.64072	
	AVERAGE HEAD ON TOP OF LAYER 4	0.021		
	MAXIMUM HEAD ON TOP OF LAYER 4	0.041		
	LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET		
	SNOW WATER	7.94	28816.9056	680003
	MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.4641	
	MINIMUM VEG. SOIL WATER (VOL/VOL)		0.1780	

*** 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	2.1106	0.3518
2	6.2426	0.3468
3	0.0028	0.0145
4	0.0000	0.0000
SNOW WATER	0.088	

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5% Segment of Slope 2 – 150 feet at 5%

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE              **
**                HELP MODEL VERSION 3.07 (1 November 1997)                **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                   USAE WATERWAYS EXPERIMENT STATION                     **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY            **
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PRECIPITATION DATA FILE:      C:\WHI\UNSAT22\data\P260.VHP\_weather1.dat
TEMPERATURE DATA FILE:        C:\WHI\UNSAT22\data\P260.VHP\_weather2.dat
SOLAR RADIATION DATA FILE:    C:\WHI\UNSAT22\data\P260.VHP\_weather3.dat
EVAPOTRANSPIRATION DATA:      C:\WHI\UNSAT22\data\P260.VHP\_weather4.dat
SOIL AND DESIGN DATA FILE:    C:\WHI\UNSAT22\data\P260.VHP\I_385502.inp
OUTPUT DATA FILE:             C:\WHI\UNSAT22\data\P260.VHP\O_385502.prt


TIME:  17:24      DATE:   3/19/2008


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     TITLE:  EPA profile 2

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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   8
          THICKNESS                     =     15.24   CM
          POROSITY                      =      0.5010 VOL/VOL
          FIELD CAPACITY                =      0.2827 VOL/VOL
          WILTING POINT                 =      0.1353 VOL/VOL
          INITIAL SOIL WATER CONTENT    =      0.3231 VOL/VOL
          EFFECTIVE SAT. HYD. COND.     =  0.750000000000E-04 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
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5% Segment of Slope 2 – 150 feet at 5%

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                    LAYER  2
                    --------

         TYPE 1 - VERTICAL PERCOLATION LAYER
            MATERIAL TEXTURE NUMBER   9
THICKNESS                     =      45.72   CM
POROSITY                      =       0.4300 VOL/VOL
FIELD CAPACITY                =       0.3210 VOL/VOL
WILTING POINT                 =       0.2208 VOL/VOL
INITIAL SOIL WATER CONTENT    =       0.3610 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =   0.500000000000E-04 CM/SEC


                    LAYER  3
                    --------

         TYPE 2 - LATERAL DRAINAGE LAYER
            MATERIAL TEXTURE NUMBER  20
THICKNESS                     =       0.50   CM
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.     =   46.0000000000      CM/SEC
SLOPE                         =       5.00    PERCENT
DRAINAGE LENGTH               =      45.7     METERS


                    LAYER  4
                    --------

         TYPE 4 - FLEXIBLE MEMBRANE LINER
            MATERIAL TEXTURE NUMBER  35
THICKNESS                     =       0.10   CM
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.     =   0.200000000000E-12 CM/SEC
FML PINHOLE DENSITY           =       2.00    HOLES/HECTARE
FML INSTALLATION DEFECTS      =       2.00    HOLES/HECTARE
FML PLACEMENT QUALITY         =   4 - POOR
```

5% Segment of Slope 2 – 150 feet at 5%

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 46. METERS.

SCS RUNOFF CURVE NUMBER	=	74.21	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	0.4047	HECTARES
EVAPORATIVE ZONE DEPTH	=	30.5	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	10.426	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	14.188	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	5.427	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	21.434	CM
TOTAL INITIAL WATER	=	21.434	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM Buffalo NY

STATION LATITUDE	=	42.89	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	126	
END OF GROWING SEASON (JULIAN DATE)	=	285	
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	12.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	76.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	68.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	72.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	76.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Buffalo NY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.02	2.40	2.97	3.06	2.89	2.72
2.96	4.16	3.37	2.93	3.62	3.42

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR Buffalo NY

5% Segment of Slope 2 – 150 feet at 5%

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
23.50	24.50	33.00	45.40	56.10	66.00
70.70	68.90	62.10	51.50	40.30	28.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Buffalo NY
AND STATION LATITUDE = 42.90 DEGREES

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 5 and their dates (DDDYYYY)

	(INCHES)	(CU. FT.)	
PRECIPITATION	4.00	14519.68352	10001
RUNOFF	2.778	10084.08134	760002
DRAINAGE COLLECTED FROM LAYER 3	**0.63472**	2303.97564	3150004
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.001468	5.32835	3150004
AVERAGE HEAD ON TOP OF LAYER 4	0.009		
MAXIMUM HEAD ON TOP OF LAYER 4	0.015		
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET		
SNOW WATER	7.94	28816.9056	680003

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4641

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1780

*** 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             2.1106           0.3518

           2             6.2429           0.3468

           3             0.0028           0.0143

           4             0.0000           0.0000

        SNOW WATER       0.088

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Slope 3 - 111 feet at 33%

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**                                                                        **
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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE             **
**                HELP MODEL VERSION 3.07 (1 November 1997)               **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                  **
**                   USAE WATERWAYS EXPERIMENT STATION                    **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY           **
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PRECIPITATION DATA FILE:      C:\WHI\UNSAT22\data\P318.VHP\_weather1.dat
TEMPERATURE DATA FILE:        C:\WHI\UNSAT22\data\P318.VHP\_weather2.dat
SOLAR RADIATION DATA FILE:    C:\WHI\UNSAT22\data\P318.VHP\_weather3.dat
EVAPOTRANSPIRATION DATA:      C:\WHI\UNSAT22\data\P318.VHP\_weather4.dat
SOIL AND DESIGN DATA FILE:    C:\WHI\UNSAT22\data\P318.VHP\I_385718.inp
OUTPUT DATA FILE:             C:\WHI\UNSAT22\data\P318.VHP\O_385718.prt

TIME:  14:39     DATE:  10/ 1/2003

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  TITLE:  EPA profile1

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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   8
          THICKNESS                  =     15.24    CM
          POROSITY                   =      0.5010 VOL/VOL
          FIELD CAPACITY             =      0.2827 VOL/VOL
          WILTING POINT              =      0.1353 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.3231 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.750000000000E-04 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 9

THICKNESS	=	45.72	CM
POROSITY	=	0.4300	VOL/VOL
FIELD CAPACITY	=	0.3210	VOL/VOL
WILTING POINT	=	0.2208	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3610	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.500000000000E-04	CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.50	CM.
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	=	33.8	METERS

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.10	CM
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.	=	0.200000000000E-12	CM/SEC
FML PINHOLE DENSITY	=	2.00	HOLES/HECTARE
FML INSTALLATION DEFECTS	=	2.00	HOLES/HECTARE
FML PLACEMENT QUALITY	=	4 - POOR	

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 33.% AND A SLOPE LENGTH OF 34. METERS.

SCS RUNOFF CURVE NUMBER = 81.91

FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	0.4047	HECTARES
EVAPORATIVE ZONE DEPTH	=	30.5	CM
INITIAL WATER IN EVAPORATIVE ZONE	=	10.426	CM
UPPER LIMIT OF EVAPORATIVE STORAGE	=	14.188	CM
LOWER LIMIT OF EVAPORATIVE STORAGE	=	5.427	CM
INITIAL SNOW WATER	=	0.000	CM
INITIAL WATER IN LAYER MATERIALS	=	21.434	CM
TOTAL INITIAL WATER	=	21.434	CM
TOTAL SUBSURFACE INFLOW	=	0.00	MM/YR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Buffalo NY

STATION LATITUDE	=	42.89	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	126	
END OF GROWING SEASON (JULIAN DATE)	=	285	
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	12.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	76.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	68.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	72.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	76.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Buffalo NY

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.02	2.40	2.97	3.06	2.89	2.72
2.96	4.16	3.37	2.93	3.62	3.42

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Buffalo NY

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
23.50	24.50	33.00	45.40	56.10	66.00
70.70	68.90	62.10	51.50	40.30	28.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR Buffalo NY
AND STATION LATITUDE = 42.90 DEGREES

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 5 and their dates (DDDYYYY)

	(INCHES)	(CU. FT.)	
PRECIPITATION	4.00	14519.68352	910001
RUNOFF	3.984	14462.46338	910001
DRAINAGE COLLECTED FROM LAYER 3	0.42040	1526.00460	3200004
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000757	2.74962	3330001
AVERAGE HEAD ON TOP OF LAYER 4	0.006		
MAXIMUM HEAD ON TOP OF LAYER 4	0.006		
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET		
SNOW WATER	7.65	27777.7330	640003
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.4554	
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.1780	

*** 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.

****

****

FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	2.0956	0.3493
2	6.2429	0.3468
3	0.0028	0.0143
4	0.0000	0.0000
SNOW WATER	0.088	

****

****

Transmissivity Calculations

Giroud's Equation (1985) for Minimum Required Transmissivity

Input

Drainage Length [m]:	120.7
Drainage Layer Thickness [cm]:	0.50
Slope of Drainage Layer:	0.05
Impingement Rate, q_h, [cm/s]:	1.99E-05

Factor of Safety

		Typical Range for Factor of Safety		
		Surface Water	Leachate Collection	Leachate Detection
Intrusion Reduction Factor, RF_{in}	1.1	1.0-1.2	1.0-1.2	1.0-1.2
Creep Reduction Factor, RF_{cr}:	1.2	1.1-1.4	1.4-2.0	1.4-2.0
Chemical Clogging Reduction Factor, RF_{cc}:	1.1	1.0-1.2	1.5-2.0	1.5-2.0
Biological Clogging Reduction Factor, RF_{bc}:	1.3	1.2-1.5	1.5-2.0	1.5-2.0
Overall FS for Drainage, FS_d:	2.5	2.0-3.0	2.0-3.0	2.0-3.0

Output

Total Serviceability Factor	4.72
Required Transmissivity [cm^2/s]:	**22.7**

Giroud's Equation (1985) for Minimum Required Transmissivity

Input

Drainage Length [m]:	45.6
Drainage Layer Thickness [cm]:	0.50
Slope of Drainage Layer:	0.05
Impingement Rate, q_h, [cm/s]:	1.87E-05

Factor of Safety

		Typical Range for Factor of Safety		
		Surface Water	Leachate Collection	Leachate Detection
Intrusion Reduction Factor, RF_{in}	1.1	1.0-1.2	1.0-1.2	1.0-1.2
Creep Reduction Factor, RF_{cr}:	1.2	1.1-1.4	1.4-2.0	1.4-2.0
Chemical Clogging Reduction Factor, RF_{cc}:	1.1	1.0-1.2	1.5-2.0	1.5-2.0
Biological Clogging Reduction Factor, RF_{bc}:	1.3	1.2-1.5	1.5-2.0	1.5-2.0
Overall FS for Drainage, FS_d:	2.5	2.0-3.0	2.0-3.0	2.0-3.0

Output

Total Serviceability Factor	4.72
Required Transmissivity [cm^2/s]:	**8.05**

Giroud's Equation (1985) for Minimum Required Transmissivity

Input

Drainage Length [m]:	71
Drainage Layer Thickness [cm]:	0.50
Slope of Drainage Layer:	0.33
Impingement Rate, q_h, [cm/s]:	1.87E-05

Factor of Safety		Typical Range for Factor of Safety		
		Surface Water	Leachate Collection	Leachate Detection
Intrusion Reduction Factor, RF_{in}	1.1	1.0-1.2	1.0-1.2	1.0-1.2
Creep Reduction Factor, RF_{cr}:	1.2	1.1-1.4	1.4-2.0	1.4-2.0
Chemical Clogging Reduction Factor, RF_{cc}:	1.1	1.0-1.2	1.5-2.0	1.5-2.0
Biological Clogging Reduction Factor, RF_{bc}:	1.3	1.2-1.5	1.5-2.0	1.5-2.0
Overall FS for Drainage, FS_d:	2.5	2.0-3.0	2.0-3.0	2.0-3.0

Output

Total Serviceability Factor	4.72
Required Transmissivity [cm^2/s]:	**2.00**

Giroud's Equation (1985) ...mum Required Transmissivity

Input

Drainage Length [m]:	33.8
Drainage Layer Thickness [cm]:	0.50
Slope of Drainage Layer:	0.33
Impingement Rate, q_h, [cm/s]:	1.23E-05

Factor of Safety

		Typical Range for Factor of Safety		
		Surface Water	Leachate Collection	Leachate Detection
Intrusion Reduction Factor, RF_{in}	1.1	1.0-1.2	1.0-1.2	1.0-1.2
Creep Reduction Factor, RF_{cr}:	1.2	1.1-1.4	1.4-2.0	1.4-2.0
Chemical Clogging Reduction Factor, RF_{cc}:	1.1	1.0-1.2	1.5-2.0	1.5-2.0
Biological Clogging Reduction Factor, RF_{bc}:	1.3	1.2-1.5	1.5-2.0	1.5-2.0
Overall FS for Drainage, FS_d:	2.5	2.0-3.0	2.0-3.0	2.0-3.0

Output

Total Serviceability Factor	4.72
Required Transmissivity [cm^2/s]:	**0.63**

APPENDIX H

HYDROLOGY, TIME OF EXCEEDANCE AND LIFT STATION DESIGN CALCULATIONS

APPENDIX H

HYDROLOGY, TIME OF EXCEEDANCE AND
LIFT STATION DESIGN CALCULATIONS

INTRODUCTION

Design calculations were prepared for the Leachate Level Compliance Plan (LLCP) to size the pumps and piping for all cells and the RMU-1 Lift Station. The calculations were based on the fill progression plan for Cells 1 through 8 (attached Figure 1). The calculation summaries included herein are:

- Hydrology calculations to determine leachate inflows into Cells 3, 5, 6 and 7/8 for the 25Year-24Hour design storm;

- Leachate outflows from the sumps in Cells 3, 5, 6 and 7/8 and time of exceedance over 1.0 foot of head on the liner system; and,

- Hydraulic model and calculations for the RMU-1 lift station.

METHODOLOGY

Based on the fill progression plan for Cells 1 through 8 a portion of the run-off from the waste and perimeter berm side slopes can not physically be collected and diverted to the proposed detention basins. These areas are located along the perimeter berm in Cells 3, 5, 6 and 7, and along the cell separation berms on the south sides of Cells 6 and 8. These perimeter infiltration areas are shown on Figure 1. Calculated areas of run-off are as follows:

CELL	DRAINAGE AREA (ACRES)
3	0.37
5	0.52
6	0.56
7	0.93
8	0.34

Run-off from these areas is collected in the perimeter channels between the waste toe of slope and berms, and infiltrates through the exposed operations layer stone on the berms and into the primary leachate collection system. This is the primary component of inflow into the primary leachate collection system now that portions of Cells 1, 2 and 4 will be capped, there will be no infiltration basins, and Detention Basins C and D will be lined to prevent direct inflow of collected run-off.

Run-off is calculated using the TR-55 Method from the Soils Conservation Service. The run-off hydrograph determined by the TR-55 Method is based on a CN of 90, T_c of 0.1 hours, and 4.0 inch rainfall in 24 hours, i.e. 25-year storm event. A rating curve (stage/discharge) was developed for each perimeter channel to model outflow from the channel to the primary leachate collection system. The rate curve is developed using the geometry of the channel to determine the wetted area as well as the permeability of the material lining the channel (in this case the operations layer stone). The staged flow through the operations layer (Q) is then calculated using Darcy's equation.

The inflow hydrograph from the TR-55 run is then routed through the perimeter channel using the rating curves and utilizing the POND2 computer program. This analysis determines a peak outflow discharge as well as an outflow hydrograph to the leachate collection system. The outflow hydrograph is then used as the basis of leachate flow to the primary leachate collection system. A summary of the calculation results is attached.

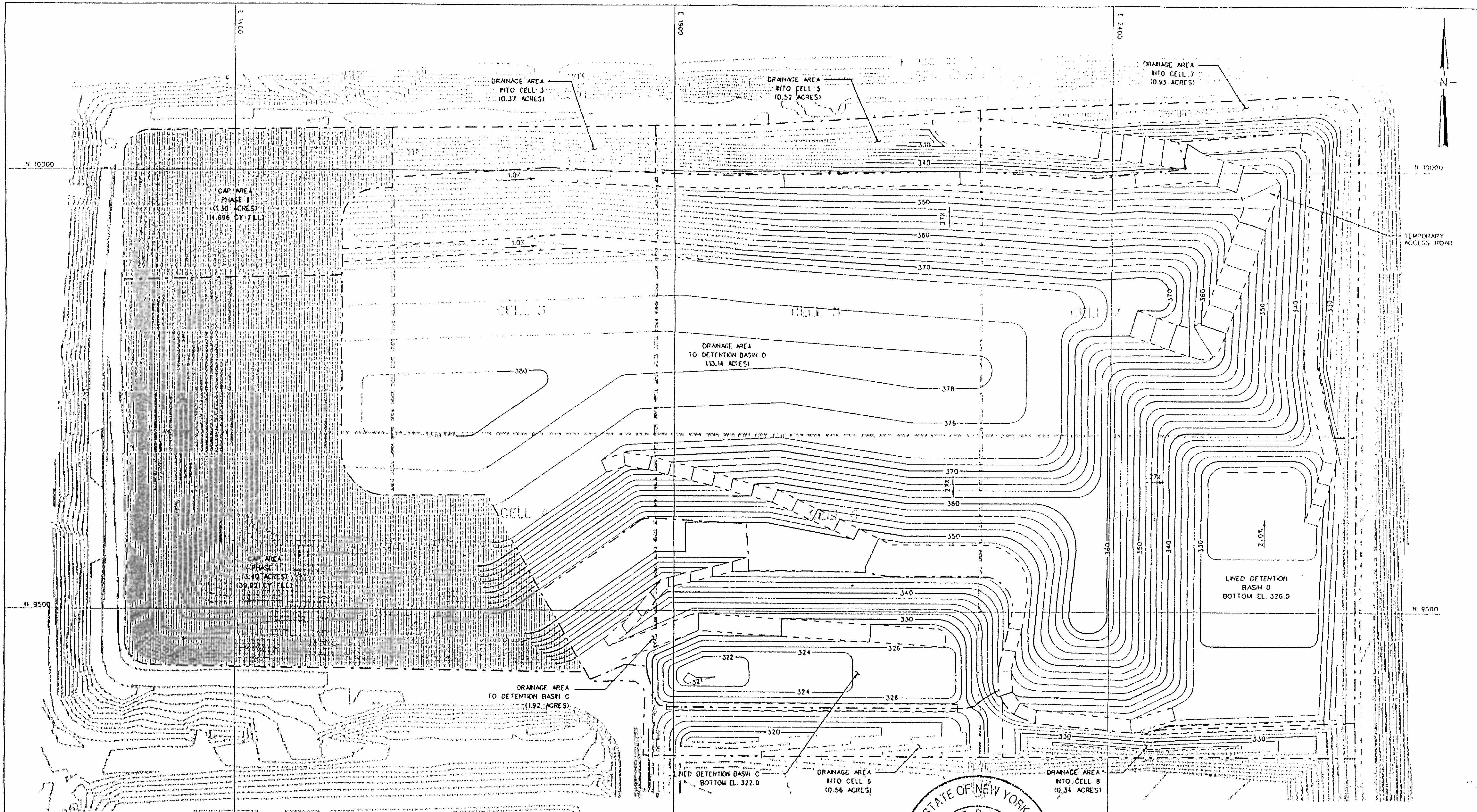
The peak outflow hydrograph from the channel to the leachate sump was used in the POND2 computer program to flood route the hydrograph through the sump and determine the time of exceedance over 1.0 foot of head on the liner.

LEACHATE OUTFLOWS AND TIME OF EXCEEDANCE

Calculations were performed to determine leachate levels and potential time of exceedance of the one foot maximum allowable leachate head. Apart from base flow (infiltration through the waste), which was shown to be relatively small, the main component of inflow to the primary leachate collection system during storm events is from the perimeter channels in Cells 3, 5, 6, 7, and 8. The peak outflows from the perimeter channels into the primary leachate collection system were used to determine leachate level in the affected cells. The lower area of Cells 3, 5, 6 and 7 (assuming Cells 7 and 8 are combined with flow directed to a single sump at the north end of Cell 7) was evaluated to determine storage volume per foot of elevation above the top of the primary sump. The sump storage area was assumed to be negligible and the porosities of the leachate collection system granular layer, operations layer, and waste, were assumed to be 0.42, 0.33, and 0.35, respectively. The selected pumps with estimated pumping capacities were used for a pump outflow. Flood routing calculations using the POND2 computer program were prepared to determine the maximum leachate head in Cells 3, 5, 6 and 7, and the time that the leachate exceeded the one foot maximum allowable value. The leachate inflow hydrographs for 2-year, 5-year, 10-year, and 25-year, 24-hour storms were routed through each cell with a constant outflow from each sump based on the selected pumps, to determine the maximum leachate head (depth) and time of exceedance of the maximum allowable one foot value. The results of this analysis are summarized in the attached calculations. Since there will be no exposed perimeter channels in Cells 1, 2 and 4 after completion of Phase I and II final cover, the minimal base flow to the primary leachate sumps of these cells will be adequately managed by the specified 60 gpm nomimal capacity pumps.

RMU-1 LIFT STATION DESIGN

In the LLCP it was proposed that the ABS Jumbo 200HH, or equal, pump be installed inside Tank T-160, alongside the existing Goulds 3888D pump. Both pumps will be connected to the existing 6-inch diameter force main which runs to the SLF 12 Oil/Water Separator facility through a manifold connection in the RMU-1 Lift Station building outside of Tank T-160. The PLC will be programmed to allow the Goulds pump to function under normal low flow conditions. Higher flows will be handled by the ABS pump by setting a higher pump on level for this pump in the PLC. Calculations are attached with the system shown on Permit Drawing 26 - Lift Station and Junction Manholes.



LEGEND

340	EXISTING MAJOR CONTOURS
	EXISTING MINOR CONTOURS
340	PROPOSED CONCEPTUAL CONTOURS (TOP OF WASTE)
	GRADE BREAK
	LIMIT OF DRAINAGE AREA
	LIMIT OF CELL
	PROPOSED FINAL CAP AREA FOR 1997

NOTES:

1. CONCEPTUAL TOP OF WASTE CONTOURS HAVE BEEN DEVELOPED FOR THE FILL PROGRESSION FOR CELLS 1 THROUGH 8. THE CONCEPTUAL CONTOURS AND DRAINAGE AREAS ARE DELINEATED FOR THE PURPOSES OF DESIGNING LINED DETENTION BASINS C AND D AND DETERMINING LEACHATE INFLOWS INTO CELLS 3, 5, 6, 7 AND 8. THIS DRAWING HAS BEEN PREPARED FOR THE LEACHATE LEVEL COMPLIANCE PLAN.

STATE OF NEW YORK
CHARLES P. BALLOD
59683-1
LICENSED PROFESSIONAL ENGINEER

JUN 25 1997

50 0 50 100
SCALE: 1" = 50'

CADD PRODUCED DRAWING

RUST ENVIRONMENT & INFRASTRUCTURE

SIGNATURE

DATE

REV.	DATE	DESCRIPTION	DRN BY	APP BY

DATE: FEBRUARY 1997

DES BY	WJR
DRN BY	WJR
CHK BY	KDM
REV BY	CPB
APP BY	AWE

PROJECT NO. 40309 SCALE: AS SHOWN

PROJECT: CWM CHEMICAL SERVICES, INC. MODEL CITY FACILITY LEACHATE LEVEL COMPLIANCE PLAN

SHEET TITLE: FILL PROGRESSION WITH DETENTION BASINS RMU-1, CELLS 1 THROUGH 8

CWM CHEMICAL SERVICES, INC.

SHEET 1 OF 1

DRAWING NO.

FIGURE 1

HYDROLOGY CALCULATIONS TO DETERMINE
LEACHATE INFLOWS INTO CELLS 3, 5, 6 AND 7/8
FOR THE 25YEAR-24HOUR DESIGN STORM

RUST ENVIRONMENT & INFRASTRUCTURE	Project: Model City - Leachate Compliance Report	Proj#: 40309.200
		By: WJR
Client: CWM Chemical Services	Subject: Infiltration From Perimeter Channels Into Cells 3, 5,6,7 and 8.	Date: 02/03/97
		Ck'd: KDM
		Date: 07/07/97

TASK:

Calculate the leachate inflows into Cells 3, 5, 6, 7 and 8 from perimeter drainage areas. Use the Soil Conservation Service TR-55 method to determine inflow hydrographs and POND2 to flood route the inflow hydrographs through the perimeter ditch.

REFERENCES:

1. Golder Associates. Void Ratio for Granular Drainage and Operations Layer Materials, Cell 5 of RMU-1, Chemical Services, Inc., Model City TSD Facility, Model City, New York. Memo to Charles P. Ballod P.E., Rust Environment and Infrastructure, November 11, 1996.

2. Haestad Methods Engineering Software. Basin Routing Program, "POND2".

3. Soil Conservation Service, Technical Release - 55, Urban Hydrology for Small Watersheds, January, 1987.

4. Soil Conservation Service, "Quick TR-55" Computer Program, Haestad Methods Engineering Software.

5. New York Urban Soil Erosion and Sediment Control Committee. Guidelines for Urban Erosion and Sediment Control, No. 3, October, 1991.

6. Rust Environment & Infrastructure. Project Manual for Model City Facility RMU-1, 1995 Construction. March, 1995.

7. Golder Associates, Leachate Level Compliance Plan For Residuals Management Unit One, February, 1997.

METHODOLOGY:

1. The TR-55 site runoff parameters are determined including:
   - runoff curve number (CN) from the determined hydrologic soil group (assumed to be 90 for waste);
   - rainfall (4" for the 25 year, 24 hour design storm);
   - area of each drainage subarea (calculated from and delineated on attached Figure 1); and
   - the time of concentration (Tc) for each subarea (0.1 hours).

2. The stormwater hydrograph is developed for each watershed subarea using the TR-55 computer program (Reference 4) to determine a peak discharge to the receiving perimeter channel.

3. Develop a rating curve (stage/discharge) for each section of the perimeter channels.

4. Route the previously corrected inflow hydrographs through the perimeter channels utilizing the POND2 computer program (Reference 2).

CALCULATIONS:

1. TR55 INPUT PARAMETERS

The following table shows the TR55 input parameters for each drainage area.

DRAINAGE AREA	AREA (ACRES)	CURVE NUMBER (CN)	TIME OF CONCENTRATION (TC)	25 YR, 24 HR PRECIPITATION (IN)
3	0.37	90	0.1	4"
5	0.52	90	0.1	4"
6	0.56	90	0.1	4"
7	0.93	90	0.1	4"
8	0.34	90	0.1	4"

2. STORMWATER HYDROGRAPHS (TR55 OUTPUT)

The above input parameters are entered into TR55 to calculate peak flows into the perimeter channels and hydrographs from each drainage area. Drainage areas were multiplied by a factor of 100 in order to get more accurate TR-55 output. The hydrographs calculated with these modified drainage areas were then corrected in the POND2 program by multiplying by a factor of 0.01 (this is an option in the POND2 program). The stormwater hydrograph output files are included in the Leachate LevelCompliance Plan For Residuals Management Unit One, Dated February 1997(Reference 7). The peak flows are:

DRAINAGE AREA	25 YR, 24 HR STORM PEAK FLOWS (CFS)
3	1.71
5	2.40
6	2.72
7	4.29
8	1.57

3. Rating Curve (Stage/discharge)

Rating curves were developed for each section of perimeter channel. Figure 2 (page 5) presents the typical cross section for the perimeter channels in Cells 3, 5, 7 and 8 and Figure 3 (page 6) presents the typical cross section for the intermediate berm channel in Cell 6. Based on the geometry of each channel, cross sectional areas and areas of side slope (Operational Layer) as functions of channel depth (b) were calculated per unit length of channel. Refer to pages 5 and 6 for calculation of these parameters.

Rating curves (stage/discharge curves) were developed for each channel. The outflows from the channels are a function of:

- Permeability of the channel lining material (Operations Layer),
- Area of Operations Layer exposed at each stage (elevation) in the channel,
- Volume of channel segment at each stage (which is the cross sectional area per unit length multiplied by the length of each channel segment), and
- Hydraulic gradient in the Operations Layer at each stage.

The infiltration rate in each channel are calculated as follows:

$Q = KiA$, where:

Q = infiltration rate (cfs),
K = permeability of Operations Layer (6.8×10^{-2} cm/sec),
i = hydraulic gradient (dh/dL), where dh is the average head at a given stage and dL is the thickness of the Operations Layer (1.0 ft), and
A = area of Operations Layer exposed at each stage

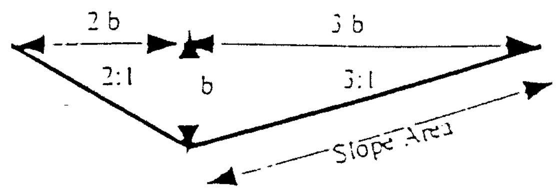
The rating curves are included in the Leachate Level Compliance Plan (Referance 7).

4. Flood Routing

The previously developed inflow hydrographs were routed through the perimeter channels using the rating tables for stage vs discharge. The POND-2 output files are included in the Leachate Level Compliance Plan. The results of the channel routings follow:

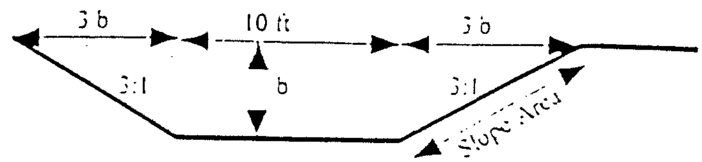
Drainage Area	Area (Acres)	25 Yr, 24 Hr Peak Flow Into Channel (CFS)	25 Yr, 24 Hr Peak Outflow From Channel (CFS)	Peak Depth (FT)	Available Freeboard (FT)
3	0.37	1.71	1.08	1.01	0.99
5	0.52	2.40	1.52	1.06	0.94
6	0.56	2.72	1.56	0.37	1.63
7	0.93	4.29	2.72	1.13	0.87
8	0.34	1.57	0.99	1.11	0.89

Perimeter Channel Design
Left Sideslope: 3:1
Right Sideslope: 2:1
Depth: Varies



Stage (b) (ft)	Cross Sectional Area 1/2 (2b)(b) +1/2 (3b)(b) (sf)	Operations Layer Area [(b^2) + (3b^2)]^1/2 (sf)
0.00	0.00	0.00
0.50	0.63	1.58
1.00	2.50	3.16
1.50	5.63	4.74
2.00	10.00	6.32
2.50	15.63	7.91
3.00	22.50	9.49
5.00	62.50	15.81
6.00	90.00	18.97
7.00	122.50	22.14
8.00	160.00	25.30
9.00	202.50	28.46
10.00	250.00	31.62
11.00	302.50	34.79
12.00	360.00	37.95
13.00	422.50	41.11
14.00	490.00	44.27
15.00	562.50	47.43
16.00	640.00	50.60
17.00	722.50	53.76
18.00	810.00	56.92
19.00	902.50	60.08
20.00	1000.00	63.25

Intermediate Channel Design
Left Sideslope: 3:1
Right Sideslope: 3:1
Bottom Length: 10 ft
Depth: Varies



Stage (b) (ft)	Cross Sectional Area 1/2 (2b)(b) + 1/2 (3b)(b) + (10 b) (sf)	Operations Layer Area (b^2) + (3b^2)]^1/2 + (10) (sf)
0.00	0.00	10.00
0.50	5.63	11.58
1.00	12.50	13.16
1.50	20.63	14.74
2.00	30.00	16.32
2.50	40.63	17.91
3.00	52.50	19.49
5.00	112.50	25.81
6.00	150.00	28.97
7.00	192.50	32.14
8.00	240.00	35.30
9.00	292.50	38.46
10.00	350.00	41.62
11.00	412.50	44.79
12.00	480.00	47.95
13.00	552.50	51.11
14.00	630.00	54.27
15.00	712.50	57.43
16.00	800.00	60.60
17.00	892.50	63.76
18.00	990.00	66.92
19.00	1092.50	70.08
20.00	1200.00	73.25

LEACHATE OUTFLOWS FROM THE SUMPS IN
CELLS 3, 5, 6 AND 7/8 AND
TIME OF EXCEEDANCE OVER 1.0 FOOT OF
HEAD ON THE LINER SYSTEM

RUST ENVIRONMENT & INFRASTRUCTURE

Client: CWM-Model City

Project: RMU-1 Leachate Management Evaluation
Subject: Leachate Head and Time of Exceedence Calculations Cells 3, 5, 6 and 7

Proj#: 40309.200
By: WJR
Date: 02/13/97
Ck'd: KDM
Date: 07/07/97

TASK:

Determine the maximum leachate elevations in RMU-1, Cells 3, 5, 6 and 7 for the 25 year, 24 hour design storm. Also determine the amount of time it will take to pump down to a maximum of 1 foot of leachate head on the liner system.

REFERENCES:

1. Soil Conservation Service, Technical Release - 55, Urban Hydrology for Small Watersheds, January, 1987.

2. Quick TR-55 computer program by Haestad Methods.

3. POND-2 computer program by Haestad Methods.

4. Rust Environment and Infrastructure. "RMU-1 Redesign Drawing Set." Rev. October, 1996.

5. SEC Donohue, "Permit Application, CWM Chemical Services, Inc, Model City, RMU-1." Rev. June, 1992.

6. Golder Associates, Leachate Level Compliance Plan For Residuals Management Unit One, Dated February, 1997.

ASSUMPTIONS:

1. The 25 year, 24 hour design storm will be analyzed.

2. The porosity of Granular Drainage Layer is 0.42, for the Operations Layer is 0.33, and for waste is 0.35.
3. The sump storage volume was assumed to be negligible.

4. The top of sump elevations and maximum allowable leachate elevations follow:

	Top of Sump Elevation (ft)	Max Allowable Leachate Elevation (ft)
Cell 3	312.17	313.17
Cell 5	311.28	312.28
Cell 6	313.90	314.90
Cell 7/8	313.18	314.18

5. Pump flow rates for each cell are shown on the attached pump curves:

   - Cell 3 - 68.4 gpm (0.15 cfs) discharge,
   - Cell 5 - 66.6 gpm (0.15 cfs) discharge,
   - Cell 6 - 169.6 gpm (0.38 cfs) discharge, and
   - Cell 7/8 - 162.8 gpm (0.37 cfs) discharge.

METHODOLOGY:

1. The sump area of the cells were planimetered to determine the areas of each contour. Top of primary liner was planimetered. Each contour area was corrected to account for the porosity of the granular drainage layer stone, operational layer stone and refuse within the storage area. The corrected areas were used to develop a stage-storage curve for the cells.

2. Outflow hydrographs for the perimeter channels into the cells for the 25 year, 24 hour design storm were previously developed.

3. Using POND-2 (Reference 3), the inflow hydrograph, and constant discharges based on the pumping configurations, routing calculations were performed to determine the peak liquid surface elevation, and the time that the 1 foot of leachate head is exceeded.

CALCULATIONS:

1. The planimetered areas were multiplied by the porosity of the granular drainage layer stone, operational layer stone and refuse to account for the actual liquid storage potential of the cells. These areas and the outflow (pump) rates were used to develop the adjusted stage storage table..

2. Outflow hydrographs for the perimeter channels into the cells for the 25 year, 24 hour design storm were previously developed:

DRAINAGE AREA	25 YR, 24 HR PEAK OUTFLOW FROM CHANNEL (CFS)
3	1.08
5	1.52
6	1.56
7/8	3.71

3. The hydrographs developed above were used as the inflow hydrographs for the POND2 routing

analysis. These inflow hydrographs were routed in POND2 using the rating tables calculated above. POND2 calculated the peak leachate elevation in each cell. The time of exceedence was calculated by taking the time (in hours) that the allowable leachate elevation was exceeded and subtracting it from the time when the leachate level dropped back below this limit. Refer to the Leachate Level Compliance Plan (Reference 6) for POND2 output.

CONCLUSIONS:

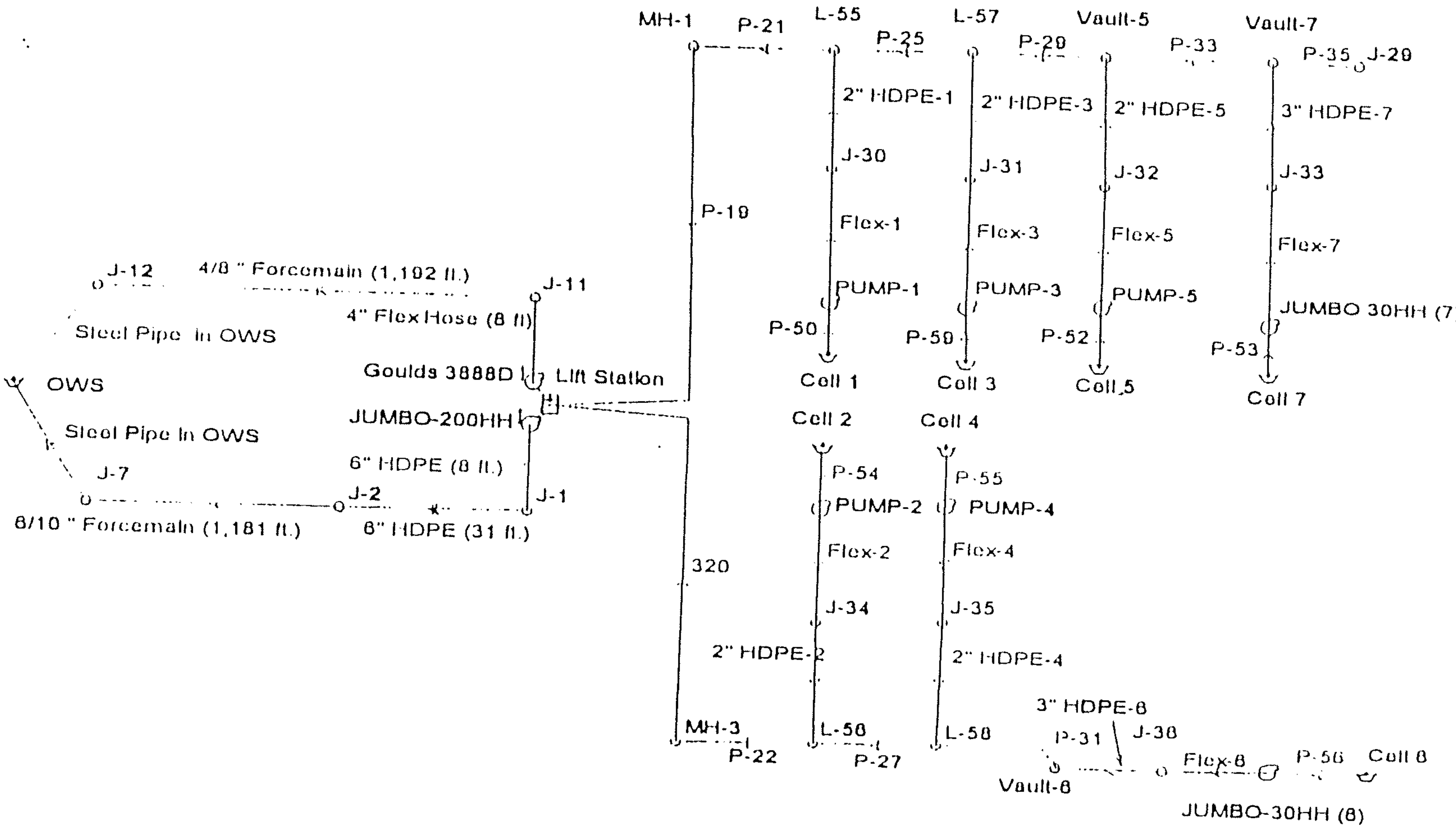
From the POND 2 output, the following was determined:

Cell	Allowable Leachate Elevation (ft)	Peak Leachate Elevation (ft)	Time Exceeding 1 Ft Depth (hrs)
Cell 3	313.17	314.11	4.3
Cell 5	312.28	313.47	5.9
Cell 6	314.90	316.02	2.0
Cell 7/8	314.18	315.12	7.5

HYDRAULIC MODEL AND CALCULATIONS
FOR RMU-1 CELLS 1 THROUGH 8 AND RMU-1 LIFT STATION

Steady Sta nalysis

HYDRAULIC MODEL SCHEMATIC·
RMU-1 LANDFILL CELL PRIMARY SUMP PUMPS
THROUGH RMU-1 LIFT STATION TO TANKS 152/153
IN OWS BUILDING



HYDRAULIC STATUS:

Hydraulic status for steady-state conditons

Balanced	Trials = 5, Accuracy = 0.000002
Flow Supplied	706.03 gpm
Flow Demanded	0.00 gpm
Flow Stored	706.03 gpm
Lift Station	Tank: Emptying
Cell 1	Reservoir: Emptying
Cell 3	Reservoir: Emptying
Cell 5	Reservoir: Emptying
Cell 7	Reservoir: Emptying
Cell 2	Reservoir: Emptying
Cell 4	Reservoir: Emptying
Cell 6	Reservoir: Emptying
OWS	Reservoir: Filling
6" HDPE (31 ft.	Check Valve: Open
4/8 " Forcemain	Check Valve: Open
JUMBO-200HH	Pump: On
Goulds 3888D	Pump: Off
JUMBO 30HH (7)	Pump: On
PUMP-5	Pump: On
PUMP-3	Pump: On
JUMBO-30HH (6)	Pump: On
PUMP-4	Pump: On
PUMP-2	Pump: On
PUMP-1	Pump: On

Analysis Results
Steady State Analysis

Project Title: CWM: RMU-1 Leachate System Evaluation
Project Engineer: EMCON
Project Date: 01/30/97
Comments: RMU-1 landfill cell primary pumps through RMU-1 lift station to discharge into Tanks 152/153 in OWS building. Landfill cells modeled as constant-head reservoirs. Tanks 152/153 modeled as contant head reservoir.

Hydraulic Analysis Summary

Analysis	Steady State	Demand Scenario	Default-Average Daily
Friction Method	Hazen-Williams Formula	Accuracy	0.001000
Trials	40		

Liquid Characteristics

Liquid	Water at 20C(68F)	Specific Gravity	1.00
Kinematic Viscosity	0.108e-4 ft²/s		

Network Inventory

Number of Pipes	40	Number of Reservoirs	8
Number of Junctions	22	Number of Tanks	1
Number of Pumps	9	Number of Valves	0
- Constant Power:	0	- FCV's:	0
- One Point (Design Point):	0	- PBV's:	0
- Standard (3 Point):	9	- PRV's:	0
- Standard Extended:	0	- PSV's:	0
- Custom Extended:	0	- TCV's:	0

Analysis Results
Steady State Analysis

Pipes @ 0.00 hr

Label	Status	Constituent (mg/l)	Flow (gpm)	Velocity (ft/s)	From Grade (ft)	To Grade (ft)	Friction Loss (ft)	Minor Loss (ft)	Total Headloss (ft)	Headloss Gradient (ft/1000ft)
2" HDPE-1	Open	0.0	-67.65	7.34	326.34	336.60	1.80	8.46	10.26	512.96
2" HDPE-3	Open	0.0	68.36	7.42	338.23	329.02	1.83	7.37	9.21	460.38
2" HDPE-2	Open	0.0	69.70	7.56	335.83	324.95	1.90	8.98	10.88	544.07
2" HDPE-4	Open	0.0	69.68	7.64	337.85	326.73	1.95	9.17	11.11	555.64
2" HDPE-5	Open	0.0	66.55	7.22	340.12	331.04	1.74	7.33	9.07	453.66
3" HDPE-6	Open	0.0	169.55	8.47	339.15	327.29	1.78	10.07	11.85	493.91
3" HDPE-7	Open	0.0	162.80	8.13	342.89	332.23	1.38	9.29	10.66	533.13
6" HDPE (8 ft.)	Open	0.0	706.03	9.82	406.37	404.80	0.37	1.20	1.57	196.09
6" HDPE (31 ft.)	Open	0.0	706.03	9.82	404.80	395.45	1.43	7.92	9.36	301.81
6/10 " Forcemain (1,181 ft.)	Open	0.0	706.03	9.82	395.45	338.32	54.84	2.29	57.13	48.37
320	Open	0.0	308.93	4.30	322.47	318.50	3.22	0.75	3.97	12.40
Flex-1	Open	0.0	67.65	6.91	348.03	336.60	11.37	0.06	11.43	125.58
Flex-2	Open	0.0	69.70	7.12	347.91	335.83	12.01	0.06	12.08	132.71
Flex-3	Open	0.0	68.36	6.98	349.88	338.23	11.59	0.06	11.65	128.03
Flex-4	Open	0.0	69.68	7.12	348.73	337.85	10.82	0.06	10.88	132.74
Flex-5	Open	0.0	66.55	6.80	351.81	340.12	11.63	0.06	11.69	121.79
Flex-6	Open	0.0	169.55	7.70	346.17	339.15	7.02	0.00	7.02	94.91
Flex-7	Open	0.0	162.80	7.39	350.20	342.89	7.31	0.00	7.31	88.05
P-19	Open	0.0	365.35	5.08	323.66	318.50	4.12	1.05	5.16	17.21
P-21	Open	0.0	365.35	5.08	326.34	323.66	2.68	0.00	2.68	13.73
P-22	Open	0.0	308.93	4.30	324.95	322.47	2.11	0.37	2.48	11.81
P-25	Open	0.0	297.71	4.14	329.02	326.34	2.58	0.09	2.68	9.74
P-27	Open	0.0	239.23	3.33	326.73	324.95	1.72	0.06	1.78	6.49
P-29	Open	0.0	229.35	3.19	331.04	329.02	1.97	0.06	2.03	5.96
P-31	Open	0.0	169.55	2.36	327.29	326.73	0.53	0.03	0.56	3.51
P-33	Open	0.0	162.80	2.26	332.23	331.04	1.15	0.03	1.18	3.15
P-35	Open	0.0	0.00	0.00	332.23	332.23	0.00	0.00	0.00	0.00
Steel Pipe in OWS	Open	0.0	706.03	8.01	338.32	326.23	5.72	6.36	12.09	134.31

Pumps @ 0.00 hr

Label	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Pump Power (Hp)
Goulds 3888D	Off	0.0	318.50	326.23	0.00	0.00	0.00	0.00
JUMBO 30HH (	On	0.0	313.95	350.20	162.80	36.25	1.00	1.49
JUMBO-30HH (	On	0.0	314.50	346.17	169.55	31.67	1.00	1.36
JUMBO-200HH	On	0.0	318.50	406.37	706.03	87.87	1.00	15.66
PUMP-1	On	0.0	309.99	348.03	67.65	38.04	1.00	0.65
PUMP-2	On	0.0	313.20	347.91	69.70	34.71	1.00	0.51
PUMP-3	On	0.0	312.99	349.88	68.36	36.89	1.00	0.64
PUMP-4	On	0.0	314.00	348.73	69.68	34.73	1.00	0.61
PUMP-5	On	0.0	311.99	351.81	66.55	39.82	1.00	0.67

Detailed Report for Pump: PUMP-1

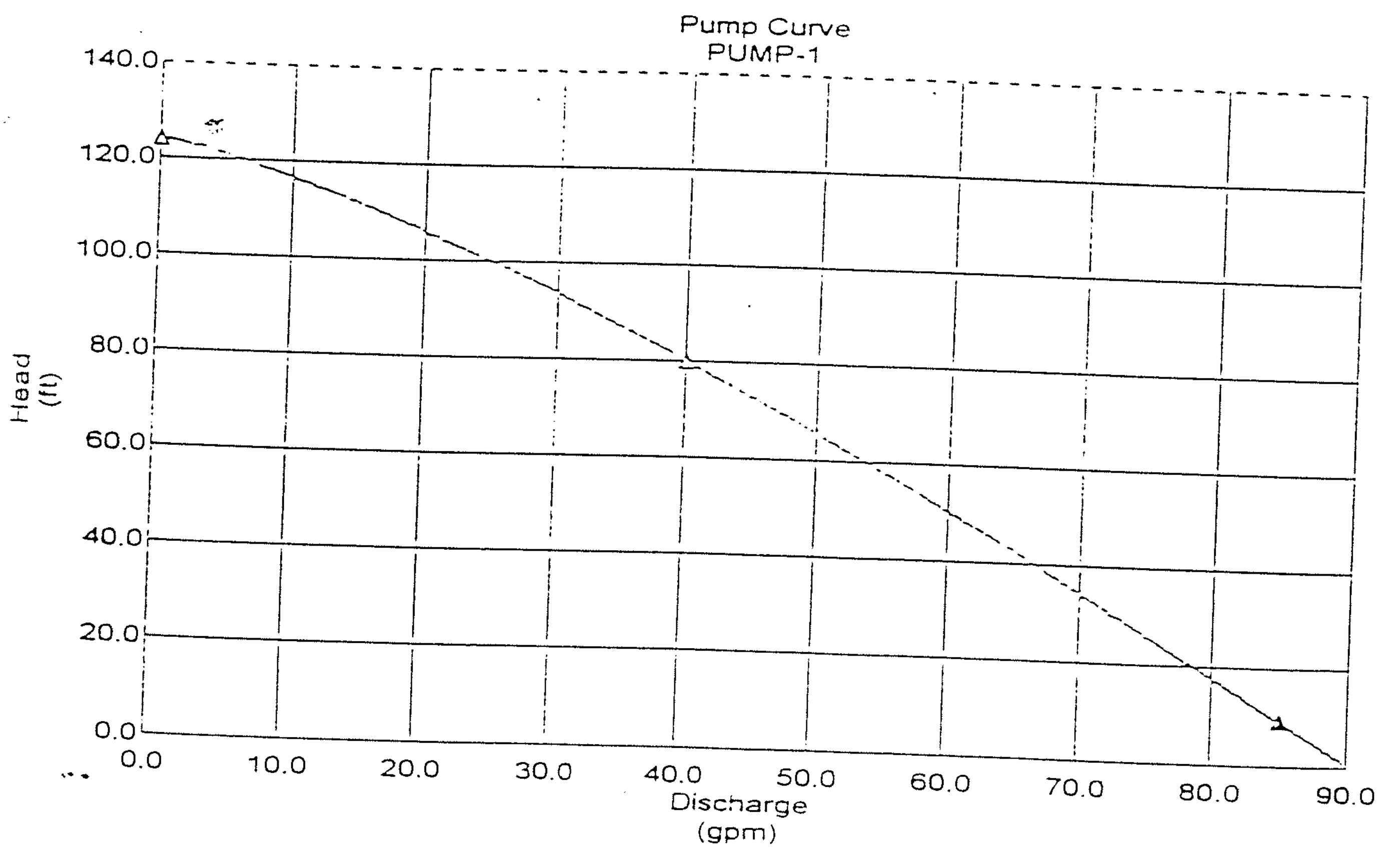
Loading Summary			
Demand Scenario	Default-Average Daily		

Calibration Summary			
Demand	<none> 0.0	Roughness	<none> 0.0

Geometric Summary			
Northing	10,150.71 ft	From Pipe	P-50
Easting	12,315.02 ft	To Pipe	Flex-1
Elevation	308.00 ft		

Initial Condition Summary			
Status	On	Relative Speed Factor	1.00

Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	124.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	40.00 gpm
Maximum Operating Head	9.00 ft	Maximum Operating Discharge	85.00 gpm

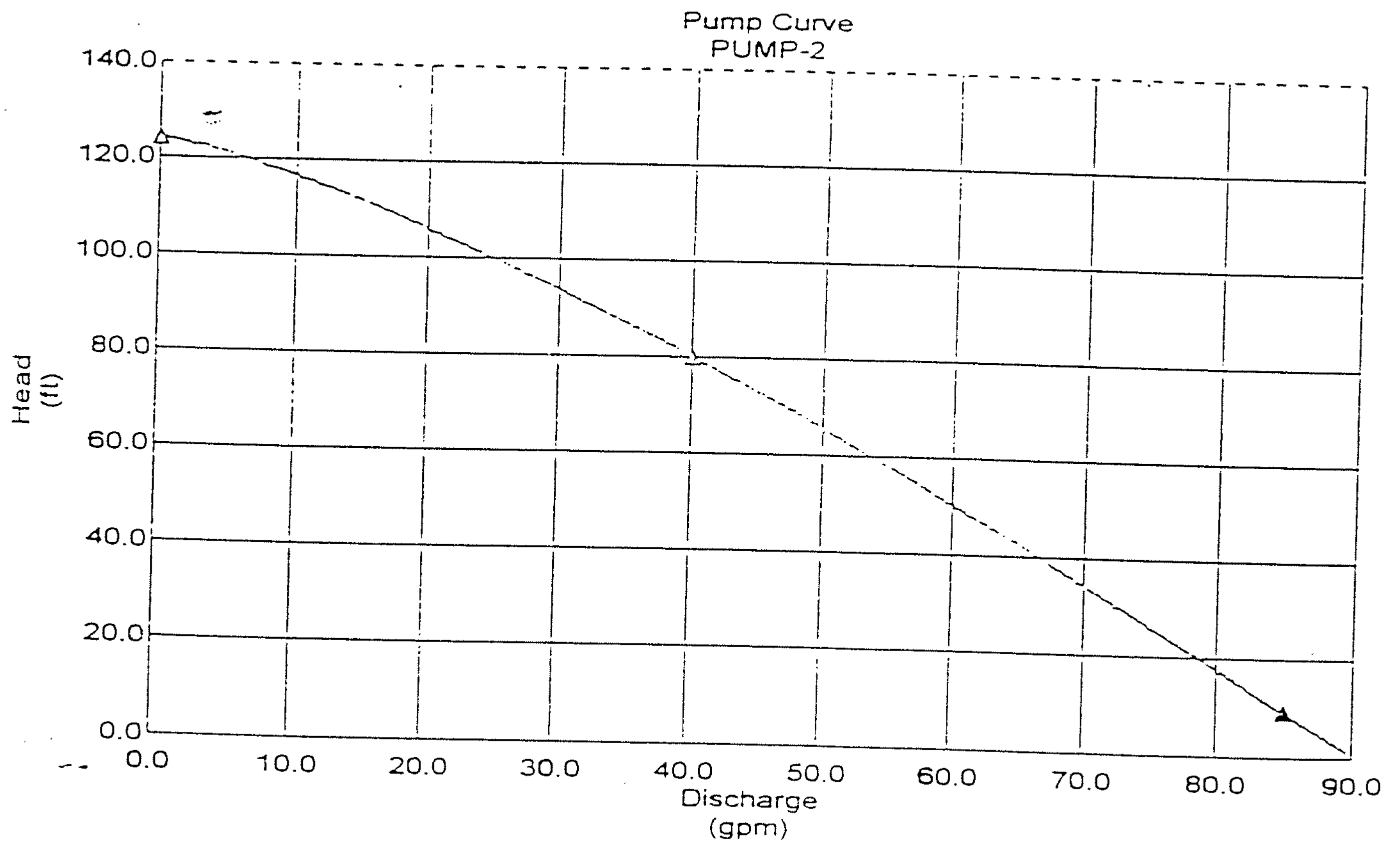


Detailed Report for Pump: PUMP-1

Calculated Results Summary								
Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Pump Power (Hp)
0.00 hr	On	0.0	309.99	348.03	67.65	38.04	1.00	0.65

Detailed Report for Pump: PUMP-2

Loading Summary			
Demand Scenario	Default-Average Daily		
Calibration Summary			
Demand	<none> 0.0	Roughness	<none> 0.0
Geometric Summary			
Northing	9,570.47 ft	From Pipe	P-54
Easting	12,305.40 ft	To Pipe	Flex-2
Elevation	311.00 ft		
Initial Condition Summary			
Status	On	Relative Speed Factor	1.00
Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	124.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	40.00 gpm
Maximum Operating Head	9.00 ft	Maximum Operating Discharge	85.00 gpm



Detailed Report for Pump: PUMP-2

Calculated Results Summary								
Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Pump Power (Hp)
0.00 hr	On	0.0	313.20	347.91	69.70	34.71	1.00	0.61

Detailed Report for Pump: PUMP-3

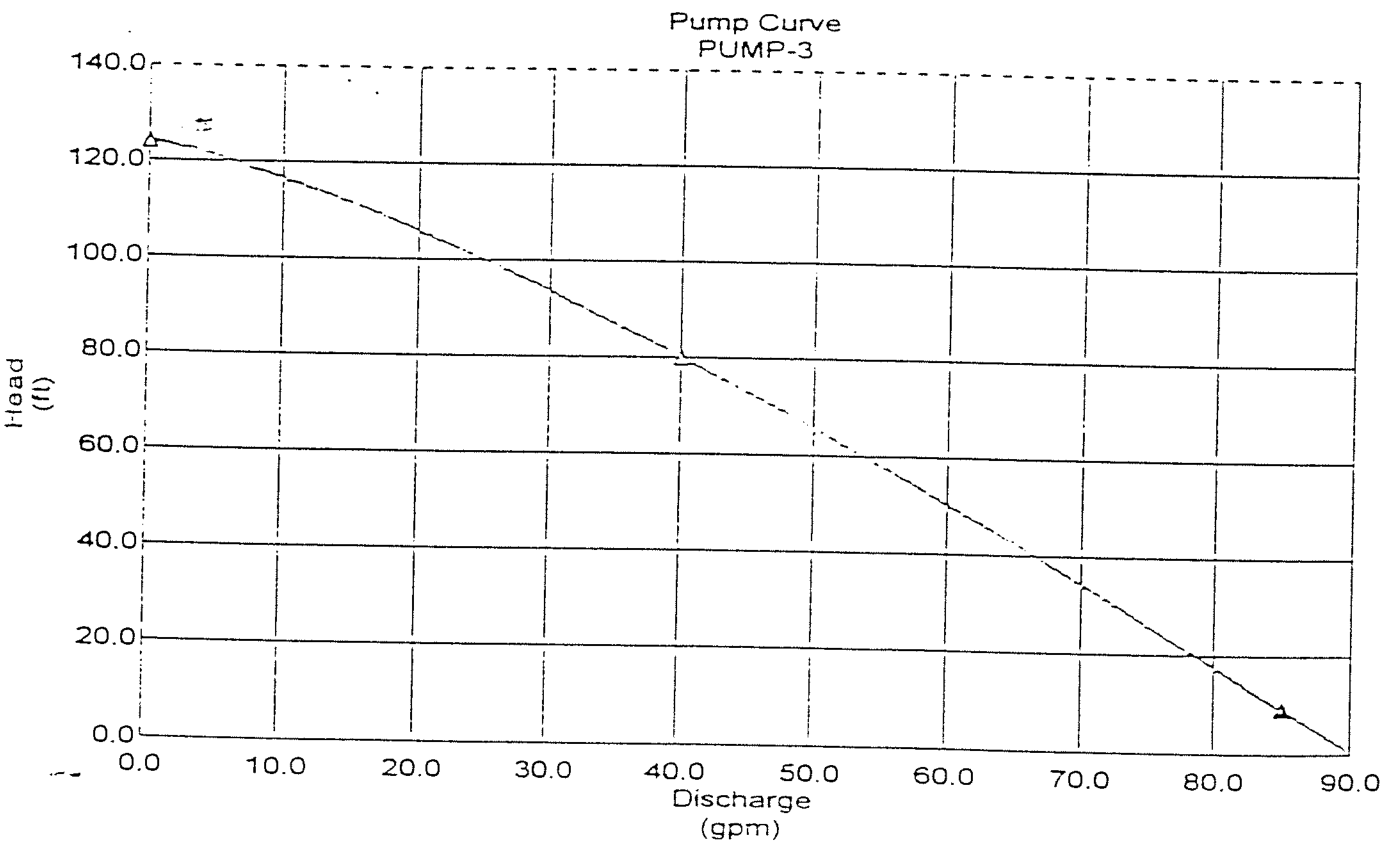
Loading Summary			
Demand Scenario	Default-Average Daily		

Calibration Summary			
Demand	<none> 0.0	Roughness	<none> 0.0

Geometric Summary			
Northing	10,144.86 ft	From Pipe	P-59
Easting	12,698.18 ft	To Pipe	Flex-3
Elevation	311.00 ft		

Initial Condition Summary			
Status	On	Relative Speed Factor	1.00

Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	124.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	40.00 gpm
Maximum Operating Head	9.00 ft	Maximum Operating Discharge	85.00 gpm



Detailed Report for Pump: PUMP-3

Calculated Results Summary								
Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Pump Power (Hp)
0.00 hr	On	0.0	312.99	349.88	68.36	36.89	1.00	0.64

Detailed Report for Pump: PUMP-4

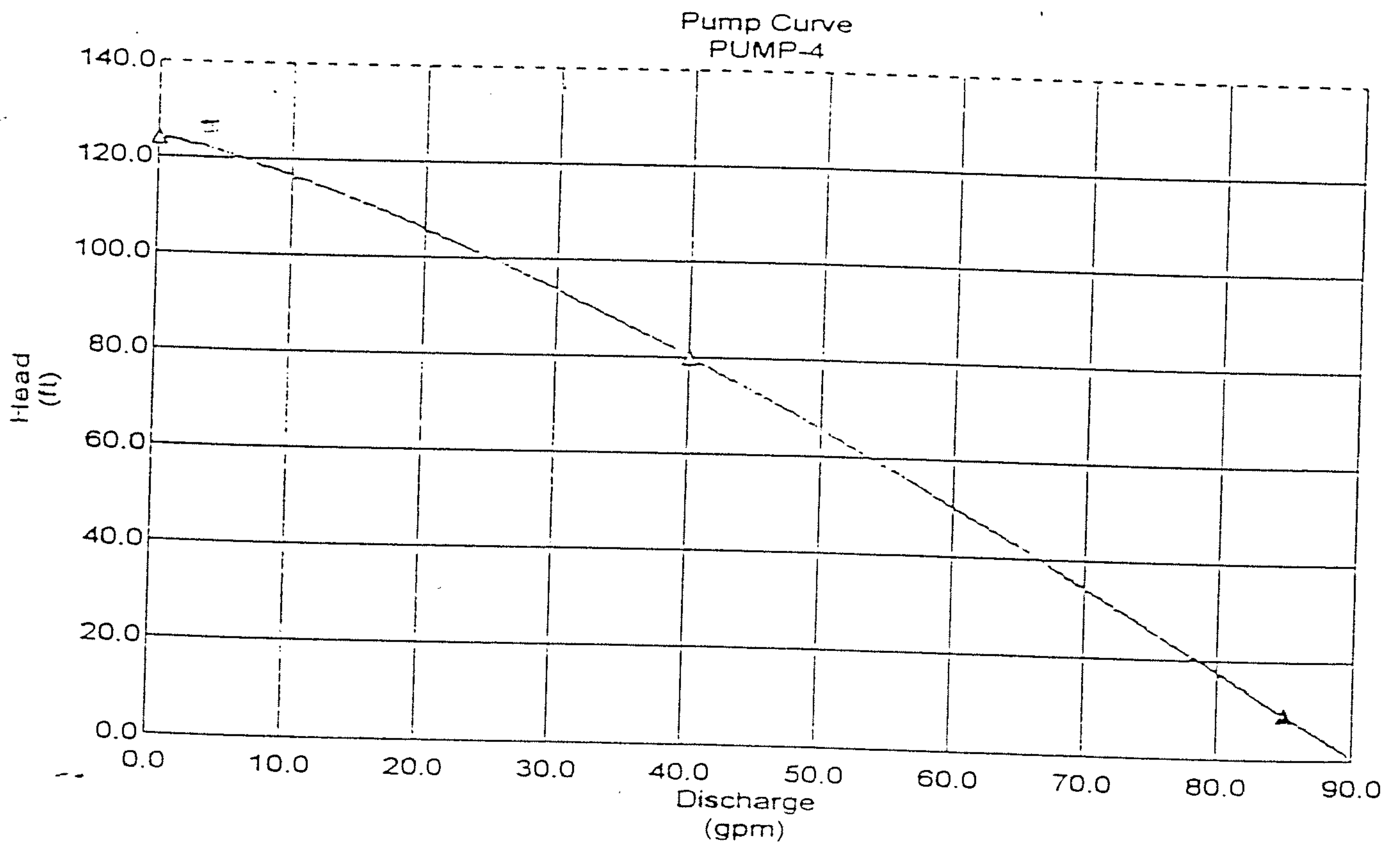
Loading Summary			
Demand Scenario	Default-Average Daily		

Calibration Summary			
Demand	<none> 0.0	Roughness	<none> 0.0

Geometric Summary			
Northing	9,585.90 ft	From Pipe	P-55
Easting	12,655.50 ft	To Pipe	Flex-4
Elevation	312.00 ft		

Initial Condition Summary			
Status	On	Relative Speed Factor	1.00

Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	124.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	40.00 gpm
Maximum Operating Head	9.00 ft	Maximum Operating Discharge	85.00 gpm



Detailed Report for Pump: PUMP-4

Calculated Results Summary

Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Pump Power (Hp)
0.00 hr	On	0.0	314.00	348.73	69.68	34.73	1.00	0.61

Detailed Report for Pump: PUMP-5

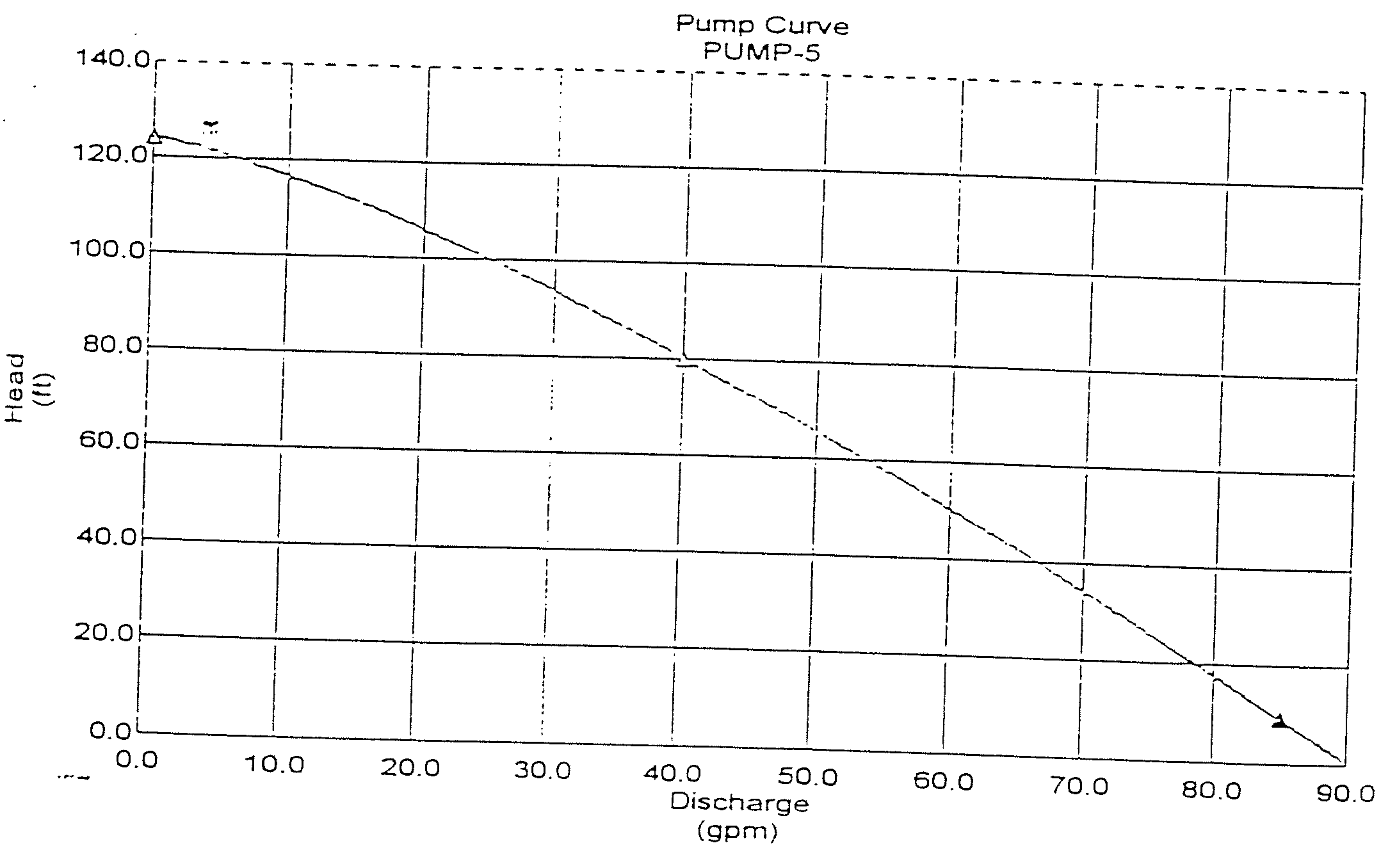
Loading Summary			
Demand Scenario	Default-Average Daily		

Calibration Summary			
Demand	<none> 0.0	Roughness	<none> 0.0

Geometric Summary			
Northing	10,158.03 ft	From Pipe	P-52
Easting	13,077.21 ft	To Pipe	Flex-5
Elevation	311.00 ft		

Initial Condition Summary			
Status	On	Relative Speed Factor	1.00

Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	124.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	40.00 gpm
Maximum Operating Head	9.00 ft	Maximum Operating Discharge	85.00 gpm

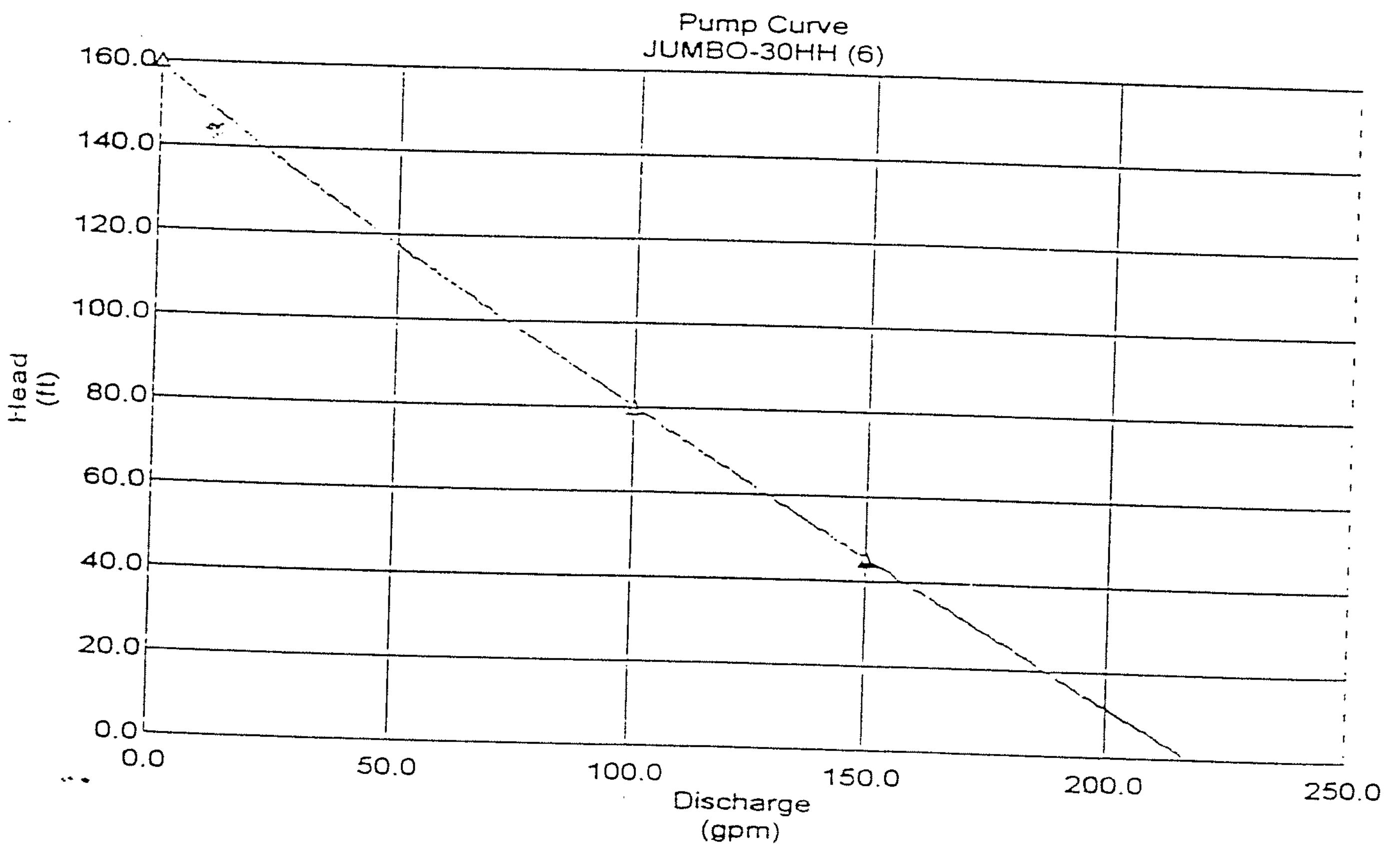


Detailed Report for Pump: PUMP-5

Calculated Results Summary								
Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Pump Power (Hp)
0.00 hr	On	0.0	311.99	351.81	66.55	39.82	1.00	0.67

Detailed Report for Pump: JUMBO-30HH (6)

Loading Summary			
Demand Scenario	Default-Average Daily		
Calibration Summary			
Demand	<none> 0.0	Roughness	<none> 0.0
Geometric Summary			
Northing	8,860.85 ft	From Pipe	P-56
Easting	13,586.94 ft	To Pipe	Flex-6
Elevation	312.25 ft		
Initial Condition Summary			
Status	On	Relative Speed Factor	1.00
Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	160.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	100.00 gpm
Maximum Operating Head	45.00 ft	Maximum Operating Discharge	150.00 gpm



Detailed Report for Pump: JUMBO-30HH (6)

Calculated Results Summary								
Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Pump Power (Hp)
0.00 hr	On	0.0	314.50	346.17	169.55	31.67	1.00	1.36

Detailed Report for Pump: JUMBO 30HH (7)

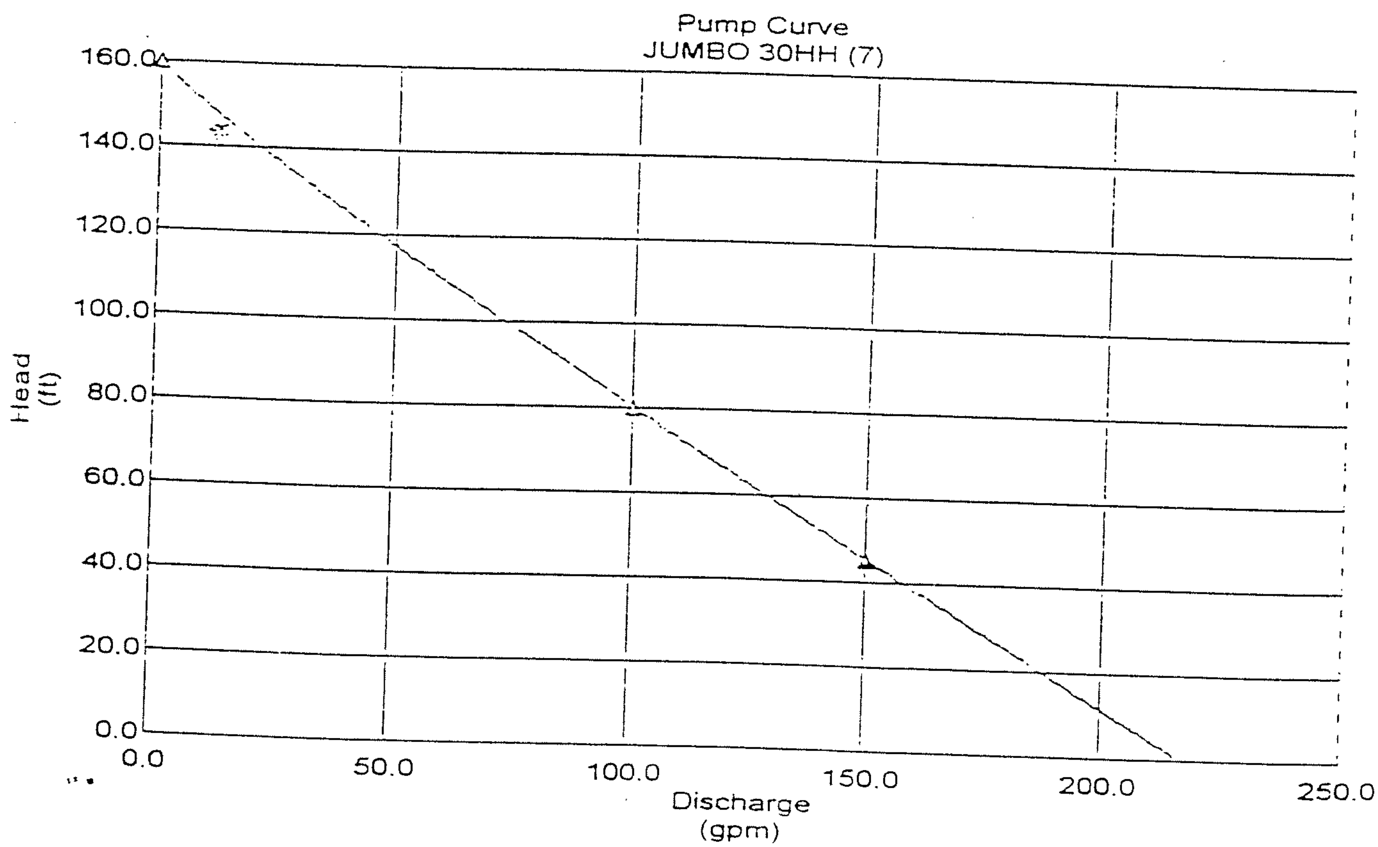
Loading Summary			
Demand Scenario	Default-Average Daily		

Calibration Summary			
Demand	<none> 0.0	Roughness	<none> 0.0

Geometric Summary			
Northing	10,115.70 ft	From Pipe	P-53
Easting	13,550.28 ft	To Pipe	Flex-7
Elevation	311.00 ft		

Initial Condition Summary			
Status	On	Relative Speed Factor	1.00

Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	160.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	100.00 gpm
Maximum Operating Head	45.00 ft	Maximum Operating Discharge	150.00 gpm



Detailed Report for Pump: JUMBO 30HH (7)

Calculated Results Summary								
Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Pump Power (Hp)
0.00 hr	On	0.0	313.95	350.20	162.80	36.25	1.00	1.49

Detailed Report for Pump: JUMBO-200HH

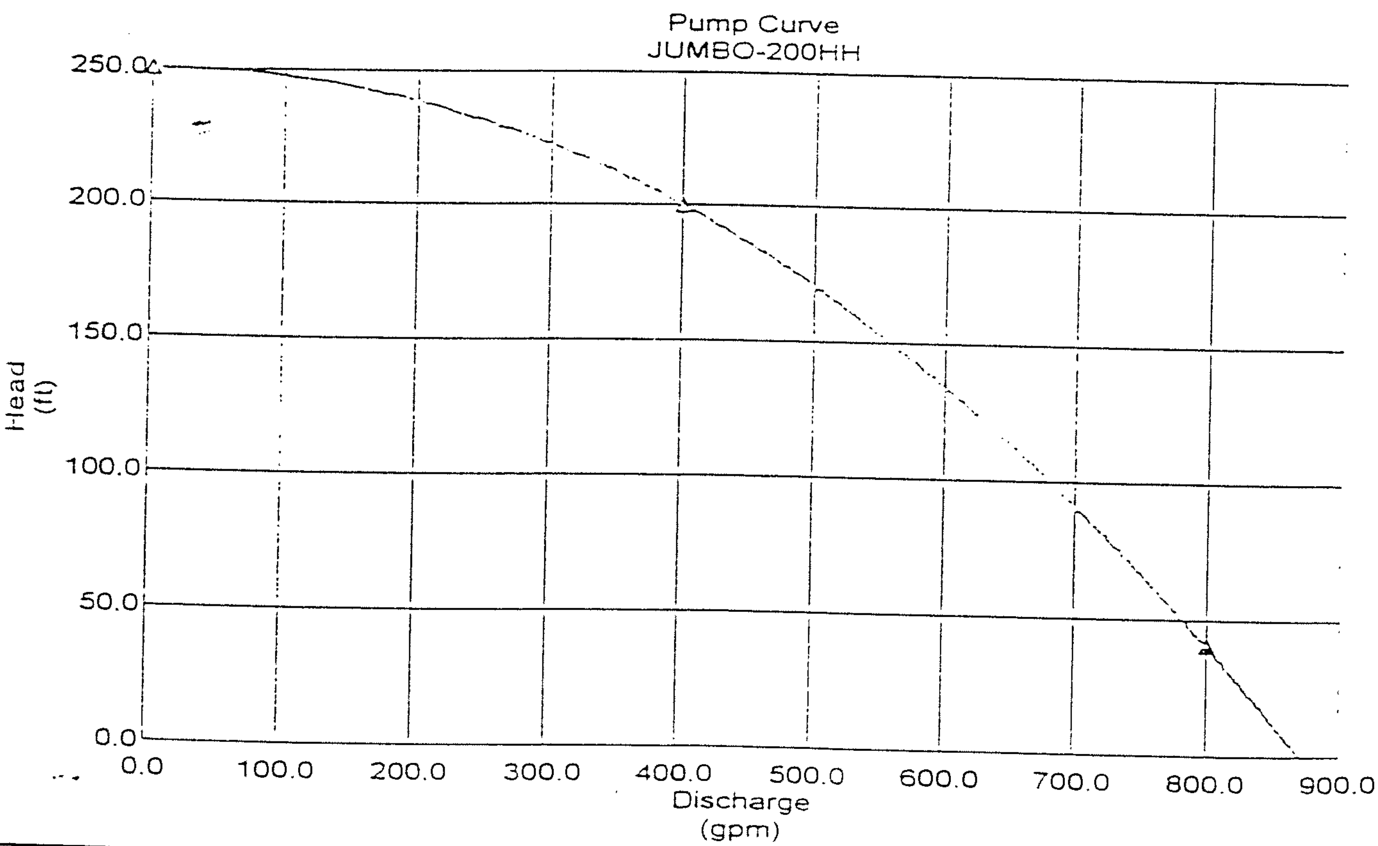
Loading Summary			
Demand Scenario	Default-Average Daily		

Calibration Summary			
Demand	<none> 0.0	Roughness	<none> 0.0

Geometric Summary			
Northing	9,782.30 ft	From Pipe	
Easting	11,490.60 ft	To Pipe	6" HDPE (8 ft.)
Elevation	317.00 ft		

Initial Condition Summary			
Status	On	Relative Speed Factor	1.00

Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	250.00 ft	Shutoff Discharge	0.00 gpm
Design Head	200.00 ft	Design Discharge	400.00 gpm
Maximum Operating Head	40.00 ft	Maximum Operating Discharge	800.00 gpm



Operating Controls Summary
Controls
On if node Lift Station above 322.50 ft

Detailed Report for Pump: JUMBO-200HH

Operating Controls Summary
Controls
Off if node Lift Station below 318.50 ft

existing Goulds 3196 MT submersible pump

Calculated Results Summary

Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Pump Power (Hp)
0.00 hr	On	0.0	318.50	406.37	706.03	87.87	1.00	15.66

Detailed Report for Pump: Goulds 3888D

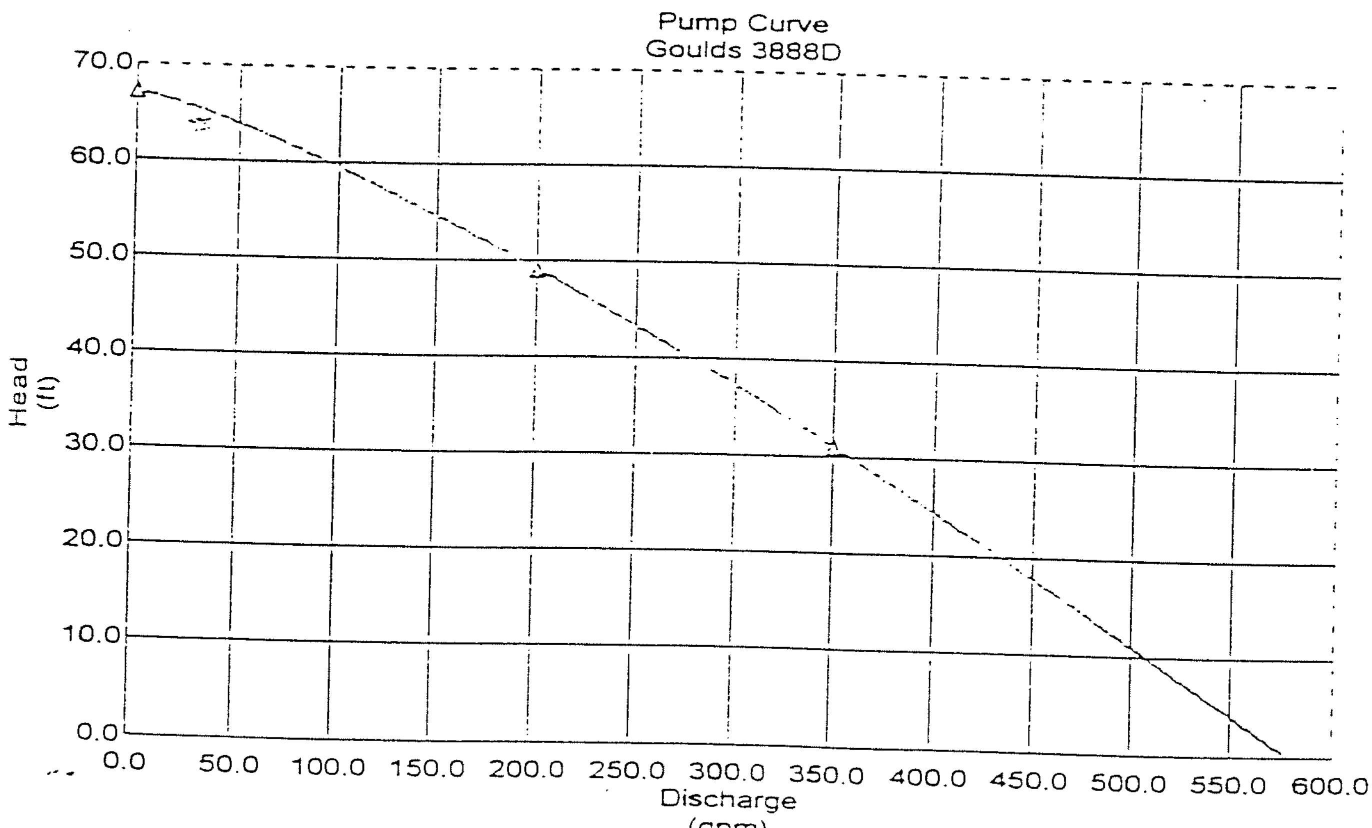
Loading Summary			
Demand Scenario	Default-Average Daily		

Calibration Summary			
Demand	<none> 0.0	Roughness	<none> 0.0

Geometric Summary			
Northing	9,900.65 ft	From Pipe	
Easting	11,493.91 ft	To Pipe	4" Flex Hose (8 ft)
Elevation	316.75 ft		

Initial Condition Summary			
Status	Off	Relative Speed Factor	1.00

Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	67.00 ft	Shutoff Discharge	0.00 gpm
Design Head	49.00 ft	Design Discharge	200.00 gpm
Maximum Operating Head	31.00 ft	Maximum Operating Discharge	350.00 gpm



Operating Controls Summary
Controls
On if node Lift Station above 322.00 ft

Detailed Report for Pump: Goulds 3888D

Operating Controls Summary
Controls
Off if node Lift Station below 319.00 ft

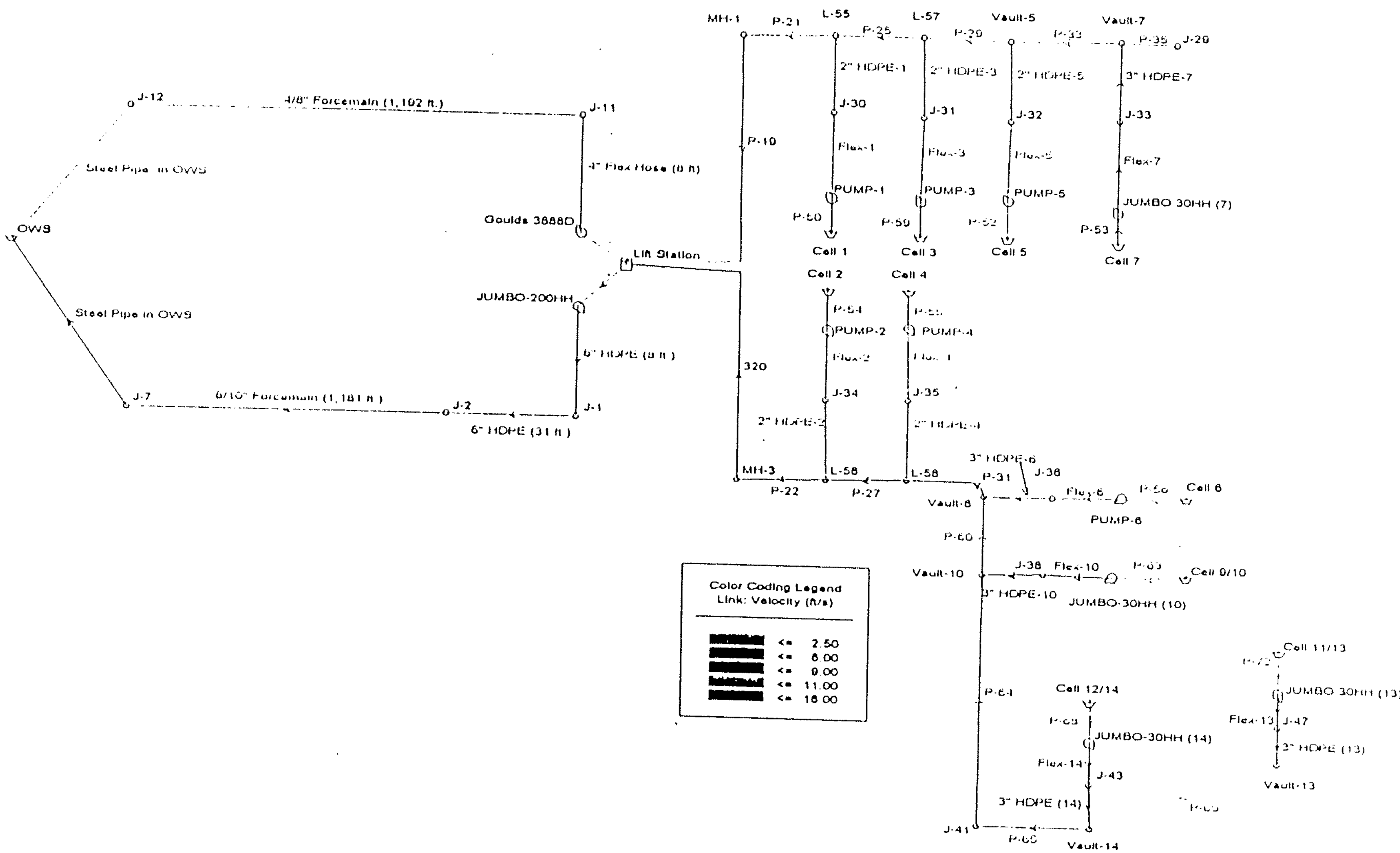
Calculated Results Summary

Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Pump Power (Hp)
0.00 hr	Off	0.0	318.50	326.23	0.00	0.00	0.00	0.00

HYDRAULIC MODEL AND CALCULATIONS
FOR RMU-1 CELLS 9 THROUGH 14 AND RMU-1 LIFT STATION

Steady State Analysis

HYDRAULIC MODEL SCHEMATIC
RMU-1 LANDFILL CELL PRIMARY SUMP PUMPS
THROUGH RMU-1 LIFT STATION TO TANKS 152/153
IN OWS BUILDING



Title: CWM: RMU-1 Leachate System Evaluation
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Project Engineer: EMCON
WaterCAD v3.0 [051]

HYDRAULIC STATUS:

Hydraulic status for steady-state conditons

Balanced	Trials = 5, Accuracy = 0.000002
Flow Supplied	658.61 gpm
Flow Demanded	0.00 gpm
Flow Stored	658.60 gpm
Lift Station	Tank: Emptying
Cell 1	Reservoir: Closed Or Stagnant
Cell 3	Reservoir: Closed Or Stagnant
Cell 5	Reservoir: Closed Or Stagnant
Cell 7	Reservoir: Emptying
Cell 2	Reservoir: Closed Or Stagnant
Cell 4	Reservoir: Closed Or Stagnant
Cell 6	Reservoir: Emptying
Cell 9/10	Reservoir: Emptying
Cell 12/14	Reservoir: Emptying
Cell 11/13	Reservoir: Emptying
OWS	Reservoir: Filling
JUMBO 30HH (7)	Pump: On
PUMP-5	Pump: Off
PUMP-3	Pump: Off
PUMP-6	Pump: On
PUMP-4	Pump: Off
PUMP-2	Pump: Off
PUMP-1	Pump: Off
JUMBO-30HH (10)	Pump: On
JUMBO-30HH (14)	Pump: On
JUMBO 30HH (13)	Pump: On
Goulds 3888D	Pump: Off
JUMBO-200HH	Pump: On

Analysis Results
Steady State Analysis

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

Title:	CWM: RMU-1 Leachate System Evaluation
Project Engineer:	EMCON
Project Date:	11/13/97
Comments:	RMU-1 landfill cell primary pumps through RMU-1 lift station to discharge into Tanks 152/153 in OWS building. Landfill cells modeled as constant-head reservoirs. Tanks 152/153 modeled as contant head reservoir.

Liquid Characteristics

Liquid	Water at 20C(68F)	Specific Gravity	1.00
Kinematic Viscosity	0.108e-4 ft²/s		

Network Inventory

Number of Pipes	53	Number of Tanks	1
Number of Reservoirs	11	- Constant Area:	1
Number of Junctions	29	- Variable Area:	0
Number of Pumps	12	Number of Valves	0
- Constant Power:	0	- FCV's:	0
- One Point (Design Point):	0	- PBV's:	0
- Standard (3 Point):	12	- PRV's:	0
- Standard Extended:	0	- PSV's:	0
- Custom Extended:	0	- TCV's:	0
- Multiple Point:	0		

Pipe Inventory

Total Length	8,067.00 ft		
1.94 in	100.00 ft	4.00 in	8.00 ft
2.00 in	451.00 ft	5.42 in	5,646.00 ft
2.86 in	116.00 ft	6.00 in	186.00 ft
3.00 in	383.00 ft	48.00 in	2.00 ft
3.68 in	1,175.00 ft		

Junctions @ 0.00 hr

Label	Constituent (mg/l)	Hydraulic Grade (ft)	Pressure (psi)	Demand (gpm)	Pressure Head (ft)
J-1	N/A	404.80	34.62	0.00	80.05
J-2	N/A	395.45	36.99	0.00	85.54
J-7	N/A	338.32	8.78	0.00	20.30
J-11	N/A	326.23	0.64	0.00	1.48
J-12	N/A	326.23	3.55	0.00	8.21
J-29	N/A	323.85	140.04	0.00	323.85
J-30	N/A	320.42	138.56	0.00	320.42
J-31	N/A	321.39	138.98	0.00	321.39
J-32	N/A	322.54	-5.39	0.00	-12.46
J-33	N/A	335.76	145.19	0.00	335.76
J-34	N/A	333.62	144.27	0.00	333.62
J-35	N/A	340.28	147.15	0.00	340.28
J-36	N/A	346.35	149.78	0.00	346.35
J-38	N/A	356.03	153.96	0.00	356.03
J-41	N/A	354.11	153.13	0.00	354.11

Analysis Results
Steady State Analysis

Junctions @ 0.00 hr

Label	Constituent (mg/l)	Hydraulic Grade (ft)	Pressure (psi)	Demand (gpm)	Pressure Head (ft)
J-1	N/A	404.80	34.62	0.00	80.05
J-2	N/A	395.45	36.99	0.00	85.54
J-7	N/A	338.32	8.78	0.00	20.30
J-11	N/A	326.23	0.64	0.00	1.48
J-12	N/A	326.23	3.55	0.00	8.21
J-29	N/A	323.85	140.04	0.00	323.85
J-30	N/A	320.42	138.56	0.00	320.42
J-31	N/A	321.39	138.98	0.00	321.39
J-32	N/A	322.54	-5.39	0.00	-12.46
J-33	N/A	335.76	145.19	0.00	335.76
J-34	N/A	333.62	144.27	0.00	333.62
J-35	N/A	340.28	147.15	0.00	340.28
J-36	N/A	346.35	149.78	0.00	346.35
J-38	N/A	356.03	153.96	0.00	356.03
J-41	N/A	354.11	153.13	0.00	354.11
J-43	N/A	363.61	157.24	0.00	363.61
J-47	N/A	364.42	157.59	0.00	364.42
L-55	N/A	320.42	138.56	0.00	320.42
L-56	N/A	333.62	144.27	0.00	333.62
L-57	N/A	321.39	-2.86	0.00	-6.61
L-58	N/A	340.28	147.15	0.00	340.28
MH-1	N/A	319.76	138.27	0.00	319.76
MH-3	N/A	327.81	141.76	0.00	327.81
Vault-5	N/A	322.54	-2.36	0.00	-5.46
Vault-6	N/A	344.26	148.87	0.00	344.26
Vault-7	N/A	323.85	-1.79	0.00	-4.15
Vault-10	N/A	346.37	149.78	0.00	346.37
Vault-13	N/A	356.66	154.23	0.00	356.66
Vault-14	N/A	355.68	153.81	0.00	355.68

Tanks @ 0.00 hr

Label	Constituent (mg/l)	Hydraulic Grade (ft)	Tank Level (ft)	Pressure (psi)	Percent Full (%)	Current Storage Volume (ft^3)	Tank Inflow (gpm)	Tank Outflow (gpm)	Status
Lift Station	N/A	318.50	1.50	0.65	0.0	0.00	N/A	47.42	Draining

Reservoirs @ 0.00 hr

Label	Constituent (mg/l)	Hydraulic Grade (ft)	Reservoir Inflow (gpm)	Reservoir Outflow (gpm)
Cell 1	N/A	310.00	0.00	0.00
Cell 2	N/A	313.20	N/A	0.88e-3
Cell 3	N/A	313.00	0.00	0.00
Cell 4	N/A	314.00	0.00	0.00
Cell 5	N/A	312.00	0.00	0.00
Cell 6	N/A	314.50	N/A	70.59
Cell 7	N/A	314.00	N/A	172.14
Cell 9/10	N/A	315.50	N/A	148.50

Analysis Results
Steady State Analysis

Reservoirs @ 0.00 hr				
Label	Constituent (mg/l)	Hydraulic Grade (ft)	Reservoir Inflow (gpm)	Reservoir Outflow (gpm)
Cell 11/13	N/A	312.16	N/A	132.99
Cell 12/14	N/A	312.41	N/A	134.39
OWS	N/A	326.23	706.03	N/A

Pipes @ 0.00 hr											
Label	Status	Constituent (mg/l)	Flow (gpm)	Velocity (ft/s)	From Grade (ft)	To Grade (ft)	Friction Loss (ft)	Minor Loss (ft)	Total Headloss (ft)	Headloss Gradient (ft/1000ft)
	Open	N/A	706.03	0.13	318.50	318.50	0.00	0.00	0.00	0.00
	Open	N/A	0.00	0.00	318.50	318.50	0.00	0.00	0.00	0.00
2" HDPE-1	Open	N/A	0.00	0.00	320.42	320.42	0.00	0.00	0.00	0.00
2" HDPE-2	Open	N/A	0.00	0.00	333.62	333.62	0.00	0.00	0.00	0.00
2" HDPE-3	Open	N/A	0.00	0.00	321.39	321.39	0.00	0.00	0.00	0.00
2" HDPE-4	Open	N/A	0.00	0.00	340.28	340.28	0.00	0.00	0.00	0.00
2" HDPE-5	Open	N/A	0.00	0.00	322.54	322.54	0.00	0.00	0.00	0.00
3" HDPE-10	Open	N/A	148.50	7.42	356.03	346.37	1.39	8.27	9.66	402.45
3" HDPE-6	Open	N/A	70.59	3.53	346.35	344.26	0.35	1.75	2.10	87.43
3" HDPE-7	Open	N/A	172.14	8.60	335.76	323.85	1.52	10.38	11.91	595.35
3" HDPE (13)	Open	N/A	132.99	6.64	364.42	356.66	1.14	6.63	7.76	323.54
3" HDPE (14)	Open	N/A	134.39	6.71	363.61	355.68	1.16	6.77	7.93	330.34
4" Flex Hose (8 ft)	Open	N/A	0.00	0.00	326.23	326.23	0.00	0.00	0.00	0.00
4/8" Forcemain (1,192 ft.)	Open	N/A	0.00	0.00	326.23	326.23	0.00	0.00	0.00	0.00
6" HDPE (31 ft.)	Open	N/A	706.03	9.82	404.80	395.45	1.43	7.92	9.36	301.81
6" HDPE (8 ft.)	Open	N/A	706.03	9.82	406.37	404.80	0.37	1.20	1.57	196.09
6/10" Forcemain (1,181 ft.)	Open	N/A	706.03	9.82	395.45	338.32	54.84	2.29	57.13	48.37
320	Open	N/A	486.47	6.76	327.81	318.50	7.46	1.86	9.31	29.11
Flex-1	Open	N/A	0.00	0.00	320.42	320.42	0.00	0.00	0.00	0.00
Flex-2	Open	N/A	0.00	0.00	333.62	333.62	0.00	0.00	0.00	0.00
Flex-3	Open	N/A	0.00	0.00	321.39	321.39	0.00	0.00	0.00	0.00
Flex-4	Open	N/A	0.00	0.00	340.28	340.28	0.00	0.00	0.00	0.00
Flex-5	Open	N/A	0.00	0.00	322.54	322.54	0.00	0.00	0.00	0.00
Flex-6	Open	N/A	70.59	3.20	347.74	346.35	1.39	0.00	1.39	18.76
Flex-7	Open	N/A	172.14	7.81	343.86	335.76	8.10	0.00	8.10	97.61
Flex-10	Open	N/A	148.50	6.74	361.53	356.03	5.50	0.00	5.50	74.27
Flex-13	Open	N/A	132.99	6.04	368.91	364.42	4.48	0.00	4.48	60.56
Flex-14	Open	N/A	134.39	6.10	368.18	363.61	4.57	0.00	4.57	61.75
P-19	Open	N/A	172.13	2.39	319.76	318.50	1.02	0.23	1.26	4.18
P-21	Open	N/A	172.13	2.39	320.42	319.76	0.67	0.00	0.67	3.41
P-22	Open	N/A	486.47	6.76	333.62	327.81	4.89	0.91	5.80	27.64
P-25	Open	N/A	172.13	2.39	321.39	320.42	0.94	0.03	0.97	3.52
P-27	Open	N/A	486.47	6.76	340.28	333.62	6.41	0.25	6.66	24.22
P-29	Open	N/A	172.13	2.39	322.54	321.39	1.12	0.03	1.15	3.51
P-31	Open	N/A	486.47	6.76	344.26	340.28	3.73	0.25	3.98	24.87
P-33	Open	N/A	172.13	2.39	323.85	322.54	1.28	0.03	1.31	3.49
P-35	Open	N/A	0.00	0.00	323.85	323.85	0.00	0.00	0.00	0.00
P-50	Open	N/A	0.00	0.00	310.00	310.00	0.00	0.00	0.00	0.00
P-52	Open	N/A	0.00	0.00	312.00	312.00	0.00	0.00	0.00	0.00
P-53	Open	N/A	172.14	7.81	314.00	313.94	0.06	0.00	0.06	60.79
P-54	Open	N/A	0.88e-3	1.0e-5	313.20	313.20	0.00	0.00	0.00	0.00

Analysis Results
Steady State Analysis

Pipes @ 0.00 hr

Label	Status	Constituent (mg/l)	Flow (gpm)	Velocity (ft/s)	From Grade (ft)	To Grade (ft)	Friction Loss (ft)	Minor Loss (ft)	Total Headloss (ft)	Headloss Gradient (ft/1000ft)
P-55	Open	N/A	0.00	0.00	314.00	314.00	0.00	0.00	0.00	0.00
P-56	Open	N/A	70.59	0.80	314.50	314.50	0.43e-3	0.00	0.43e-3	0.43
P-59	Open	N/A	0.00	0.00	313.00	313.00	0.00	0.00	0.00	0.00
P-60	Open	N/A	415.88	5.78	346.37	344.26	1.94	0.18	2.12	19.08
P-63	Open	N/A	148.50	1.69	315.50	315.50	0.17e-2	0.00	0.17e-2	1.68
P-64	Open	N/A	267.38	3.72	354.11	346.37	7.66	0.08	7.74	7.78
P-65	Open	N/A	267.38	3.72	355.68	354.11	1.49	0.08	1.57	8.09
P-68	Open	N/A	134.39	1.52	312.41	312.41	0.14e-2	0.00	0.14e-2	1.40
P-69	Open	N/A	132.99	1.85	356.66	355.68	0.94	0.04	0.98	2.19
P-72	Open	N/A	132.99	1.51	312.16	312.16	0.14e-2	0.00	0.14e-2	1.37
Steel Pipe in OWS	Open	N/A	0.00	0.00	326.23	326.23	0.00	0.00	0.00	0.00
Steel Pipe in OWS	Open	N/A	706.03	8.01	338.32	326.23	5.72	6.36	12.09	134.31

Pumps @ 0.00 hr

Label	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Useful Power (Hp)
Goulds 3888D	Off	N/A	318.50	326.23	0.00	0.00	0.00	0.00
JUMBO-30HH (	On (10)	N/A	315.50	361.53	148.50	46.03	1.00	1.73
JUMBO-30HH (	On (14)	N/A	312.41	368.18	134.39	55.77	1.00	1.89
JUMBO-200HH	On	N/A	318.50	406.37	706.03	87.87	1.00	15.66
JUMBO 30HH (	On (13)	N/A	312.16	368.91	132.99	56.75	1.00	1.91
JUMBO 30HH (	On (7)	N/A	313.94	343.86	172.14	29.92	1.00	1.30
PUMP-1	Off	N/A	310.00	320.42	0.00	0.00	0.00	0.00
PUMP-2	Off	N/A	313.20	333.62	0.00	0.00	0.00	0.00
PUMP-3	Off	N/A	313.00	321.39	0.00	0.00	0.00	0.00
PUMP-4	Off	N/A	314.00	340.28	0.00	0.00	0.00	0.00
PUMP-5	Off	N/A	312.00	322.54	0.00	0.00	0.00	0.00
PUMP-6	On	N/A	314.50	347.74	70.59	33.24	1.00	0.59

Detailed Report for Pump: PUMP-1

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

Scenario Summary

Label	Base		
Demand Alternative	Default-Average Daily	Physical Alternative	Base-Physical
Initial Settings Alternative	Base-Initial Settings	Operational Alternative	Base-Operational Controls
Age Alternative	Default-Age Scenario	Constituent Alternative	Default-Constituent
Trace Alternative	Default-Trace Scenario	Fire Flow Alternative	Base-Fire Flow

Calibration Summary

Demand	<none>	Roughness	<none>

Geometric Summary

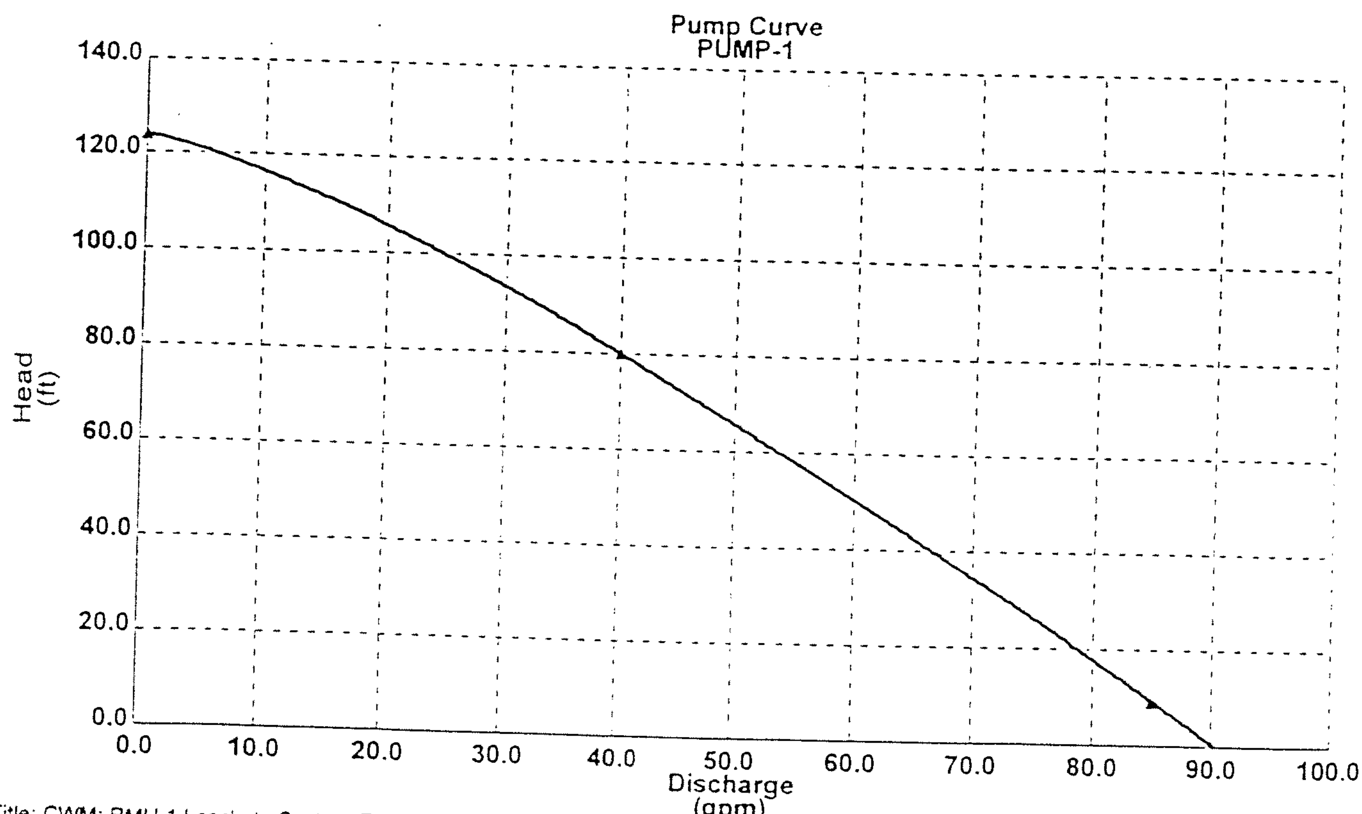
Northing	10,150.71 ft	From Pipe	P-50
Easting	12,315.02 ft	To Pipe	Flex-1
Elevation	308.00 ft		

Initial Condition Summary

Status	Off	Relative Speed Factor	1.00

Pump Definition Summary

Pump Type	Standard (3 Point)		
Shutoff Head	124.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	40.00 gpm
Maximum Operating Head	9.00 ft	Maximum Operating Discharge	85.00 gpm



Detailed Report for Pump: PUMP-1

Calculated Results Summary								
Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Useful Power (Hp)
0.00 hr	Off	N/A	310.00	320.42	0.00	0.00	0.00	0.00

Detailed Report for Pump: PUMP-2

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

Scenario Summary

Label	Base		
Demand Alternative	Default-Average Daily	Physical Alternative	Base-Physical
Initial Settings Alternative	Base-Initial Settings	Operational Alternative	Base-Operational Controls
Age Alternative	Default-Age Scenario	Constituent Alternative	Default-Constituent
Trace Alternative	Default-Trace Scenario	Fire Flow Alternative	Base-Fire Flow

Calibration Summary

Demand	<none>	Roughness	<none>

Geometric Summary

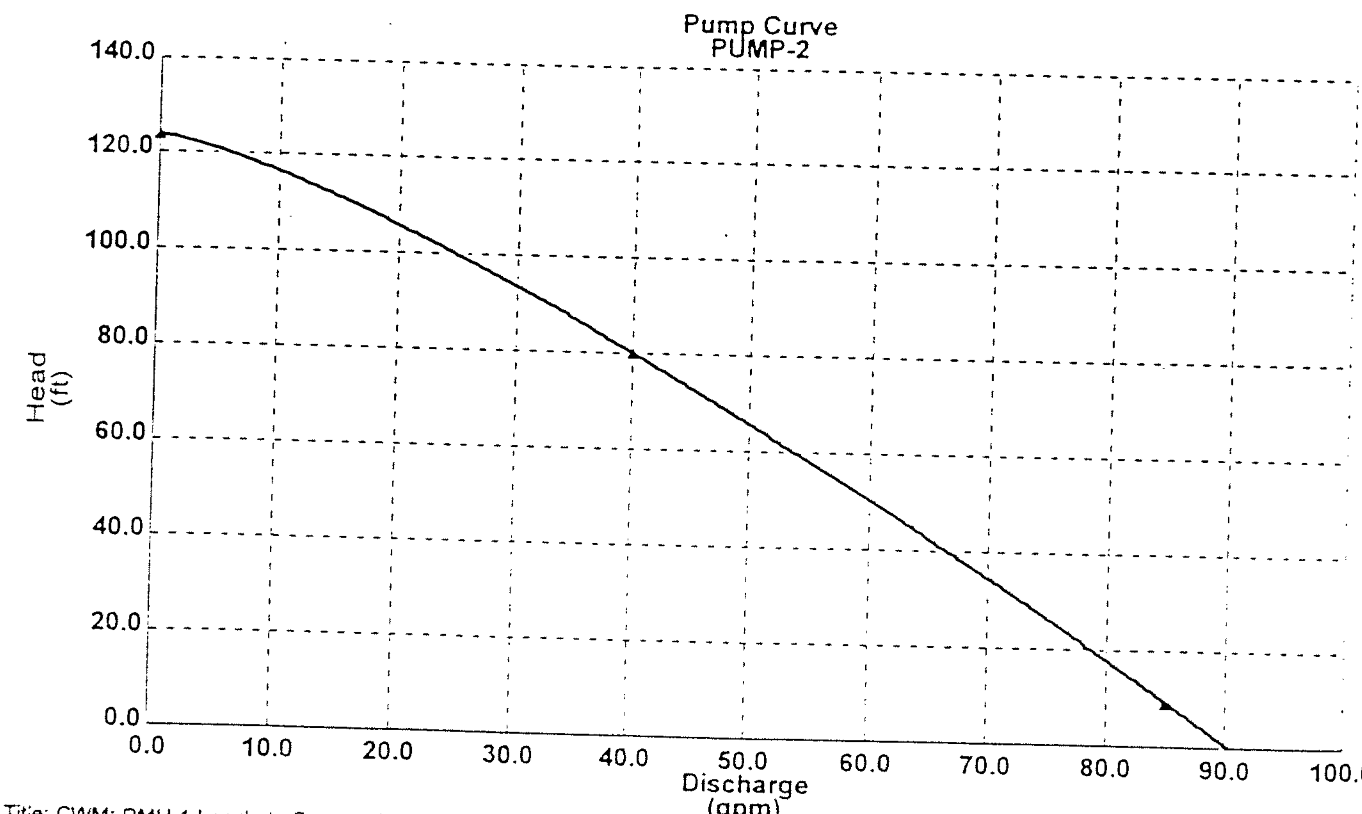
Northing	9,570.47 ft	From Pipe	P-54
Easting	12,305.40 ft	To Pipe	Flex-2
Elevation	311.00 ft		

Initial Condition Summary

Status	Off	Relative Speed Factor	1.00

Pump Definition Summary

Pump Type	Standard (3 Point)		
Shutoff Head	124.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	40.00 gpm
Maximum Operating Head	9.00 ft	Maximum Operating Discharge	85.00 gpm



Detailed Report for Pump: PUMP-2

Calculated Results Summary								
Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Useful Power (Hp)
0.00 hr	Off	N/A	313.20	333.62	0.00	0.00	0.00	0.00

Detailed Report for Pump: PUMP-3

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

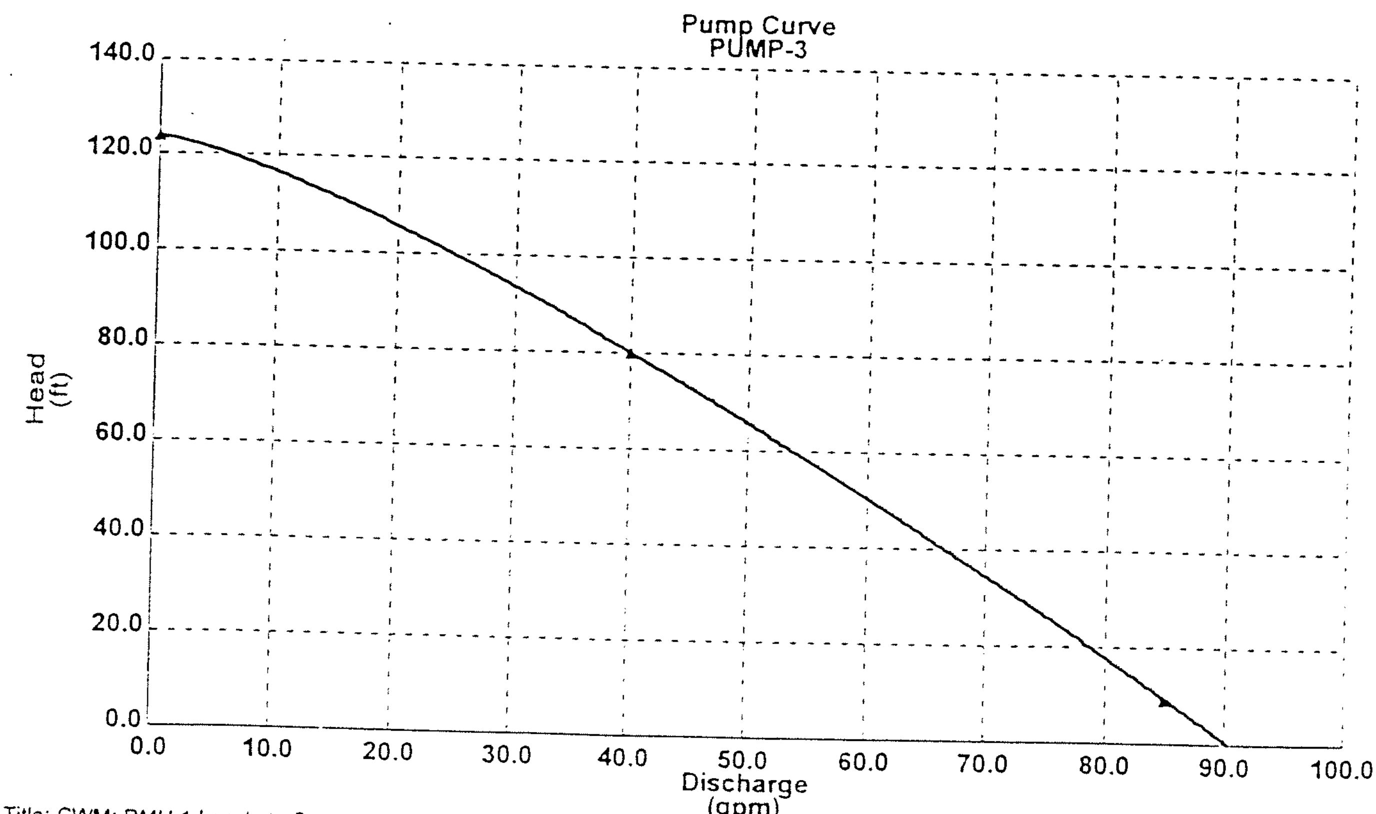
Scenario Summary			
Label	Base		
Demand Alternative	Default-Average Daily	Physical Alternative	Base-Physical
Initial Settings Alternative	Base-Initial Settings	Operational Alternative	Base-Operational Controls
Age Alternative	Default-Age Scenario	Constituent Alternative	Default-Constituent
Trace Alternative	Default-Trace Scenario	Fire Flow Alternative	Base-Fire Flow

Calibration Summary			
Demand	<none>	Roughness	<none>

Geometric Summary			
Northing	10,144.86 ft	From Pipe	P-59
Easting	12,698.18 ft	To Pipe	Flex-3
Elevation	311.00 ft		

Initial Condition Summary			
Status	Off	Relative Speed Factor	1.00

Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	124.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	40.00 gpm
Maximum Operating Head	9.00 ft	Maximum Operating Discharge	85.00 gpm



Detailed Report for Pump: PUMP-3

Calculated Results Summary

Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Useful Power (Hp)
0.00 hr	Off	N/A	313.00	321.39	0.00	0.00	0.00	0.00

Detailed Report for Pump: PUMP-4

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

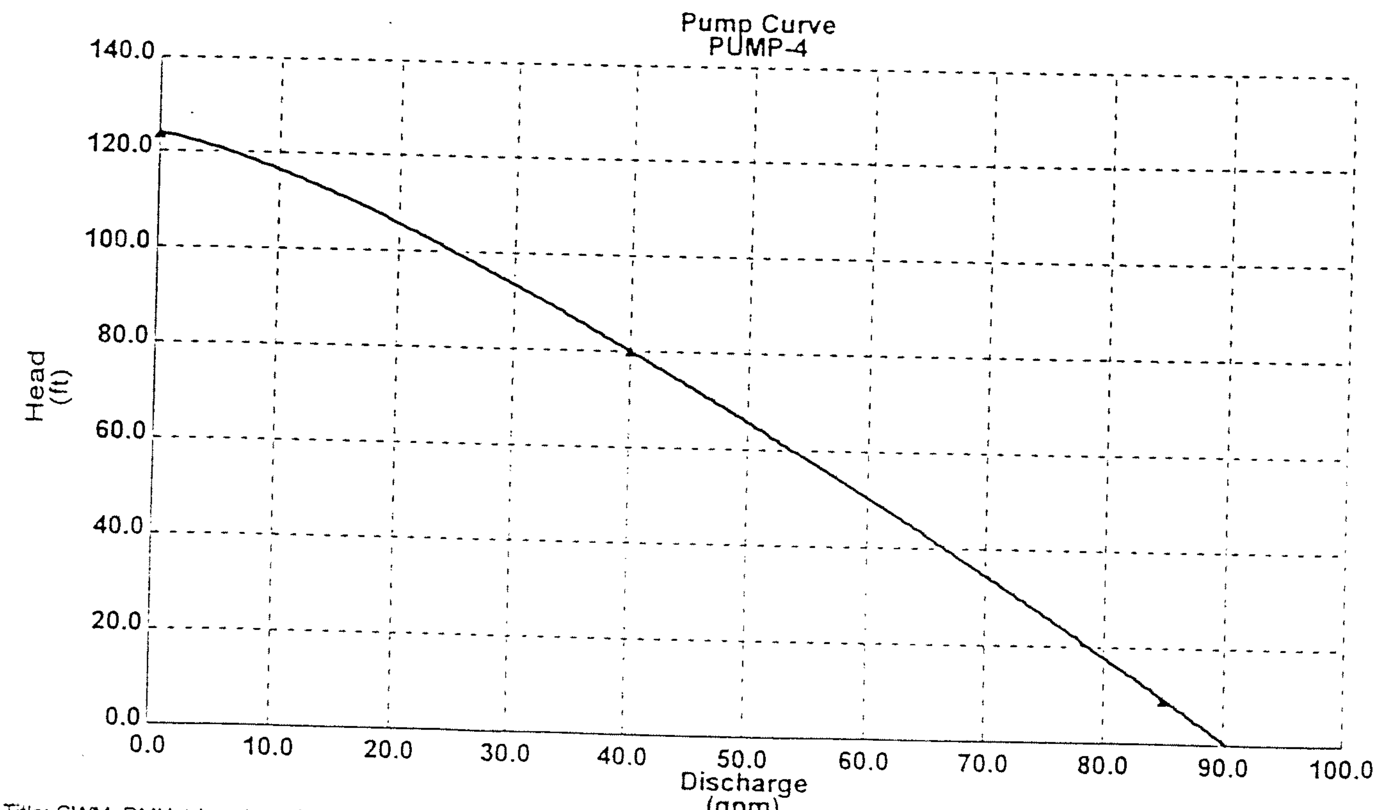
Scenario Summary			
Label	Base		
Demand Alternative	Default-Average Daily	Physical Alternative	Base-Physical
Initial Settings Alternative	Base-Initial Settings	Operational Alternative	Base-Operational Controls
Age Alternative	Default-Age Scenario	Constituent Alternative	Default-Constituent
Trace Alternative	Default-Trace Scenario	Fire Flow Alternative	Base-Fire Flow

Calibration Summary			
Demand	<none>	Roughness	<none>

Geometric Summary			
Northing	9,585.90 ft	From Pipe	P-55
Easting	12,655.50 ft	To Pipe	Flex-4
Elevation	312.00 ft		

Initial Condition Summary			
Status	Off	Relative Speed Factor	1.00

Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	124.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	40.00 gpm
Maximum Operating Head	9.00 ft	Maximum Operating Discharge	85.00 gpm



Detailed Report for Pump: PUMP-4

Calculated Results Summary

Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Useful Power (Hp)
0.00 hr	Off	N/A	314.00	340.28	0.00	0.00	0.00	0.00

Detailed Report for Pump: PUMP-5

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

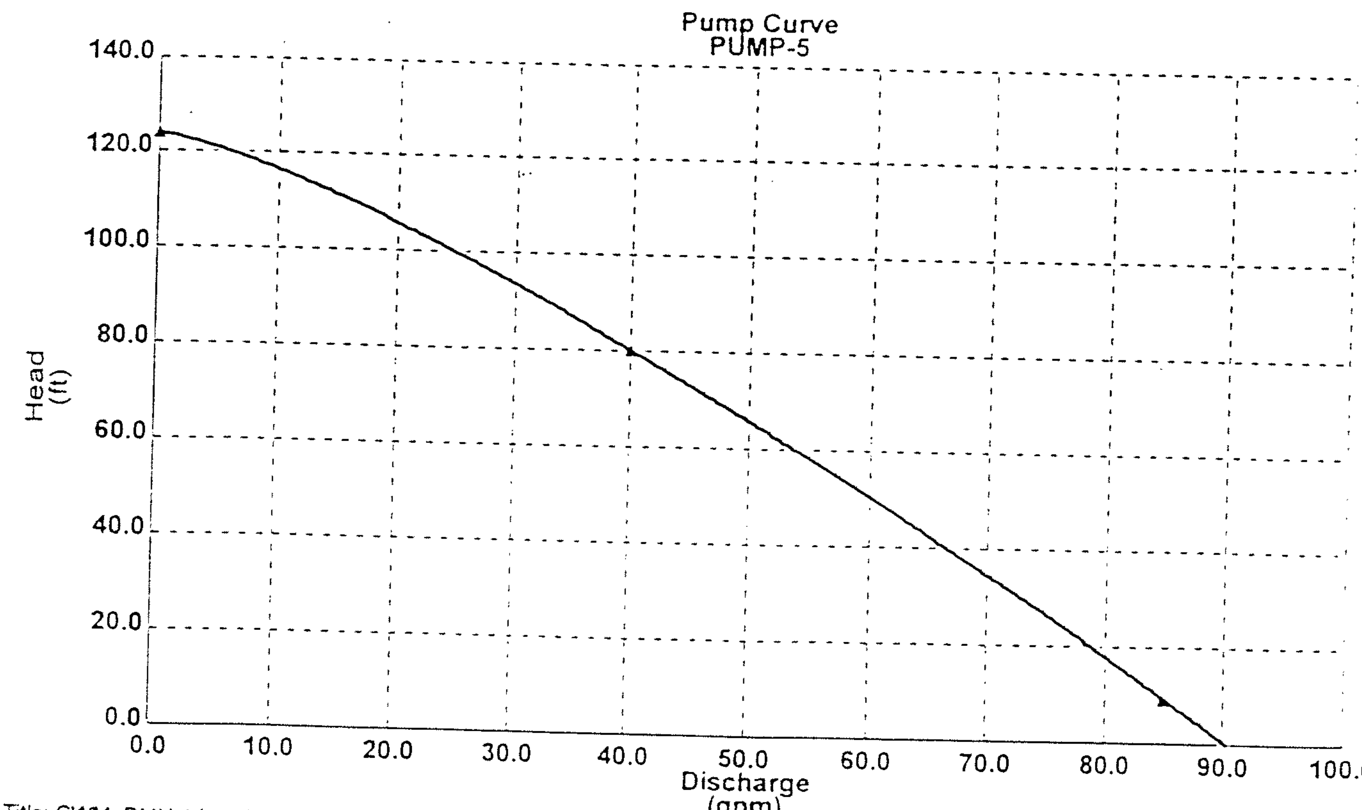
Scenario Summary			
Label	Base		
Demand Alternative	Default-Average Daily	Physical Alternative	Base-Physical
Initial Settings Alternative	Base-Initial Settings	Operational Alternative	Base-Operational Controls
Age Alternative	Default-Age Scenario	Constituent Alternative	Default-Constituent
Trace Alternative	Default-Trace Scenario	Fire Flow Alternative	Base-Fire Flow

Calibration Summary			
Demand	<none>	Roughness	<none>

Geometric Summary			
Northing	10,158.03 ft	From Pipe	P-52
Easting	13,077.21 ft	To Pipe	Flex-5
Elevation	311.00 ft		

Initial Condition Summary			
Status	Off	Relative Speed Factor	1.00

Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	124.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	40.00 gpm
Maximum Operating Head	9.00 ft	Maximum Operating Discharge	85.00 gpm



Detailed Report for Pump: PUMP-5

Calculated Results Summary

Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Useful Power (Hp)
0.00 hr	Off	N/A	312.00	322.54	0.00	0.00	0.00	0.00

Detailed Report for Pump: PUMP-6

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

Scenario Summary

Label	Base		
Demand Alternative	Default-Average Daily	Physical Alternative	Base-Physical
Initial Settings Alternative	Base-Initial Settings	Operational Alternative	Base-Operational Controls
Age Alternative	Default-Age Scenario	Constituent Alternative	Default-Constituent
Trace Alternative	Default-Trace Scenario	Fire Flow Alternative	Base-Fire Flow

Calibration Summary

Demand	<none>	Roughness	<none>

Geometric Summary

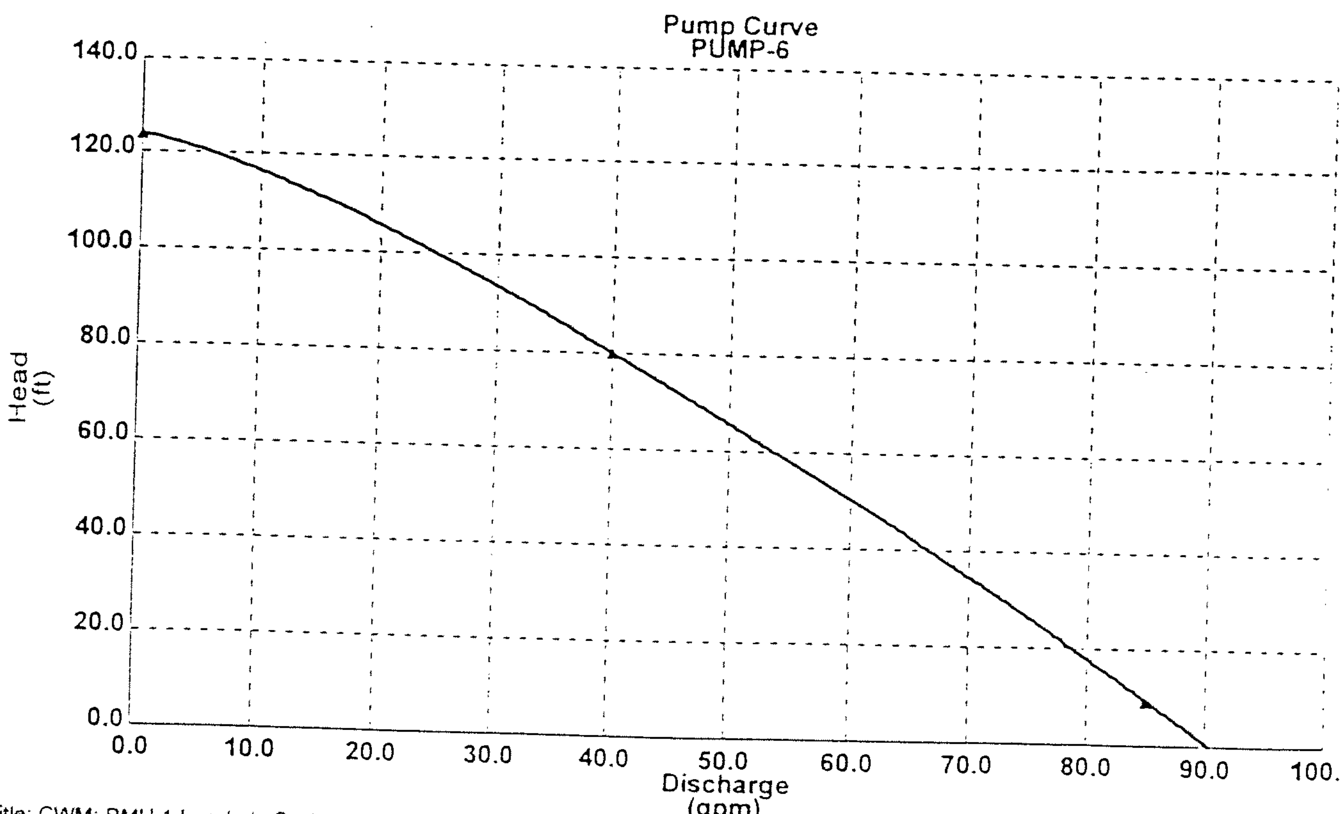
Northing	8,860.85 ft	From Pipe	P-56
Easting	13,586.94 ft	To Pipe	Flex-6
Elevation	312.25 ft		

Initial Condition Summary

Status	On	Relative Speed Factor	1.00

Pump Definition Summary

Pump Type	Standard (3 Point)		
Shutoff Head	124.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	40.00 gpm
Maximum Operating Head	9.00 ft	Maximum Operating Discharge	85.00 gpm



Detailed Report for Pump: PUMP-6

Calculated Results Summary								
Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Useful Power (Hp)
0.00 hr	On	N/A	314.50	347.74	70.59	33.24	1.00	0.59

Detailed Report for Pump: JUMBO 30HH (7)

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

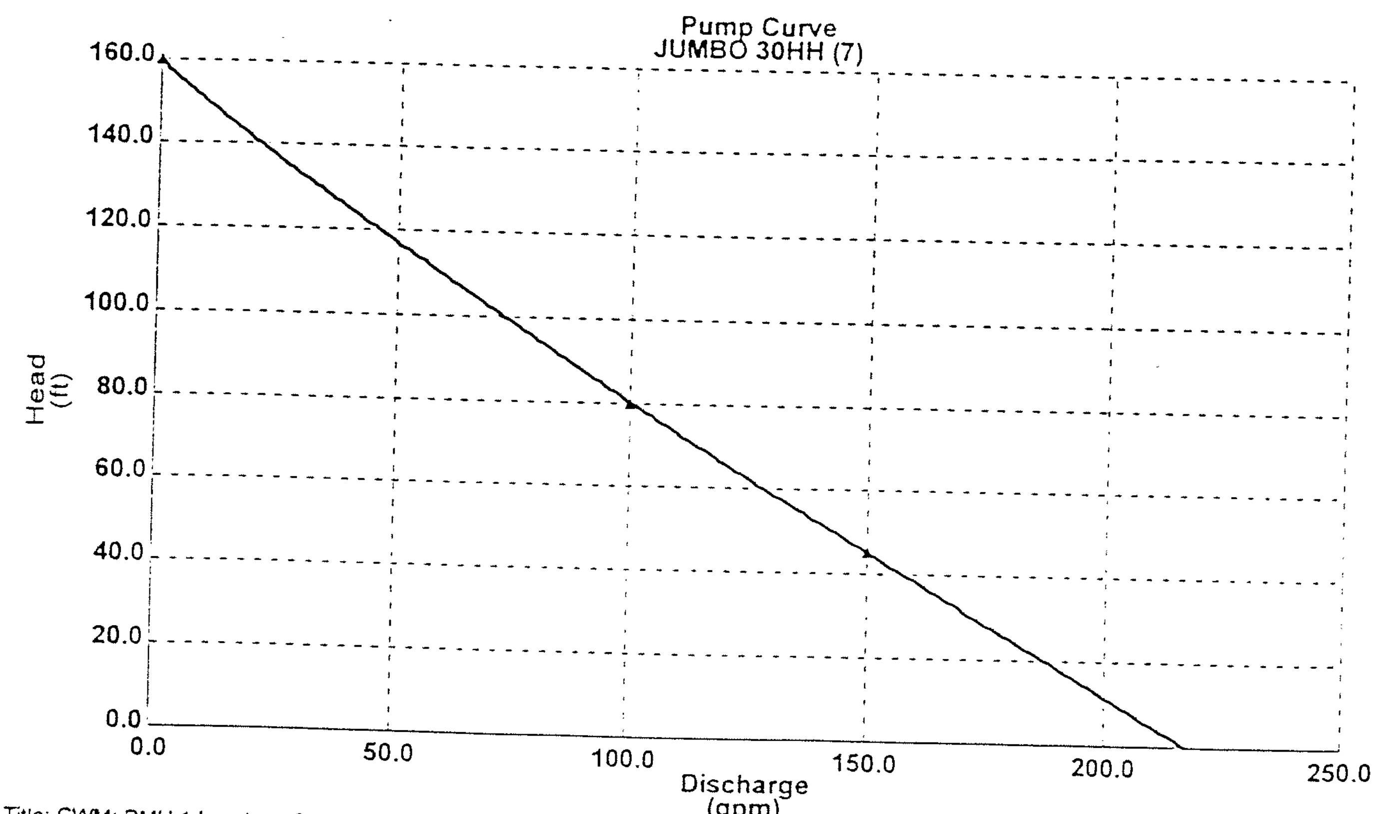
Scenario Summary			
Label	Base		
Demand Alternative	Default-Average Daily	Physical Alternative	Base-Physical
Initial Settings Alternative	Base-Initial Settings	Operational Alternative	Base-Operational Controls
Age Alternative	Default-Age Scenario	Constituent Alternative	Default-Constituent
Trace Alternative	Default-Trace Scenario	Fire Flow Alternative	Base-Fire Flow

Calibration Summary			
Demand	<none>	Roughness	<none>

Geometric Summary			
Northing	10,115.70 ft	From Pipe	P-53
Easting	13,550.28 ft	To Pipe	Flex-7
Elevation	311.00 ft		

Initial Condition Summary			
Status	On	Relative Speed Factor	1.00

Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	160.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	100.00 gpm
Maximum Operating Head	45.00 ft	Maximum Operating Discharge	150.00 gpm



Detailed Report for Pump: JUMBO 30HH (7)

Calculated Results Summary

Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Useful Power (Hp)
0.00 hr	On	N/A	313.94	343.86	172.14	29.92	1.00	1.30

Detailed Report for Pump: JUMBO-30HH (10)

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

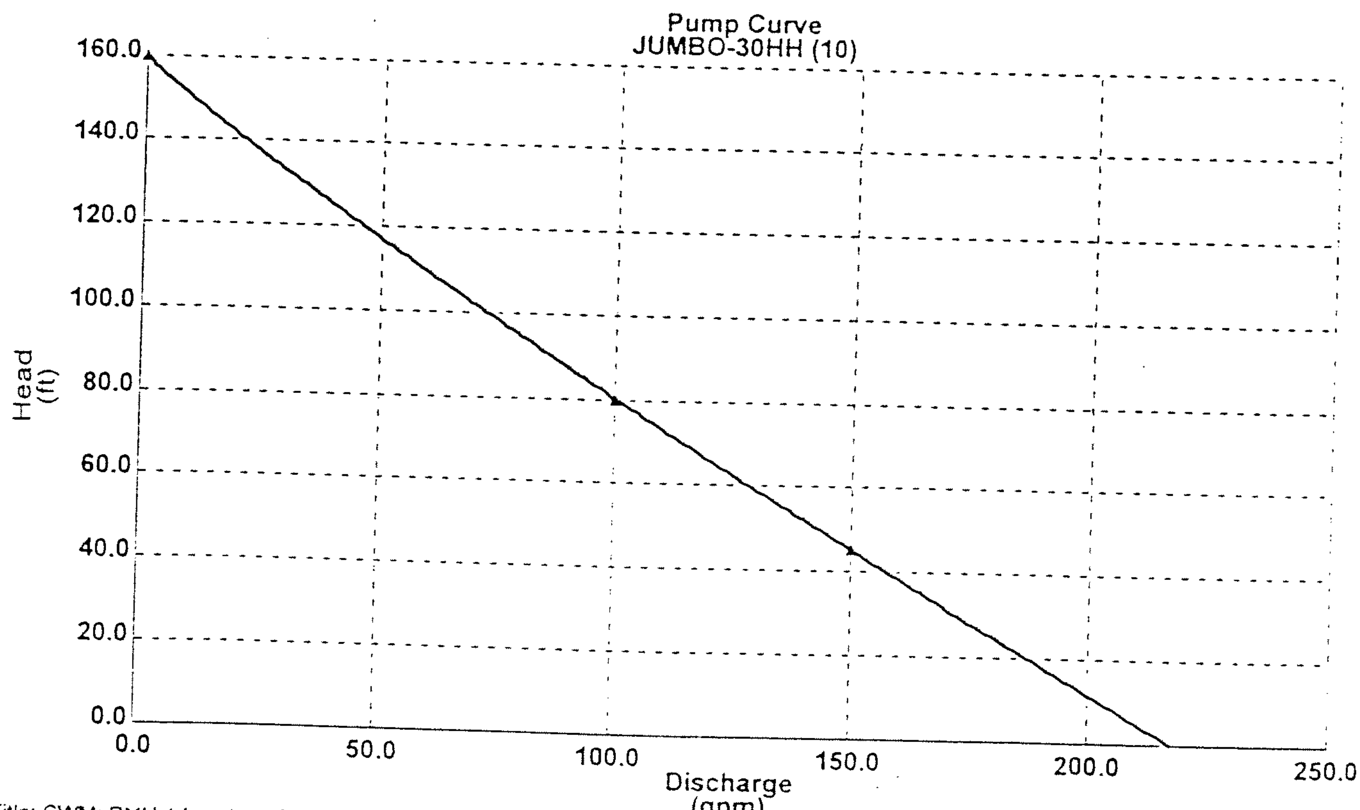
Scenario Summary			
Label	Base		
Demand Alternative	Default-Average Daily	Physical Alternative	Base-Physical
Initial Settings Alternative	Base-Initial Settings	Operational Alternative	Base-Operational Controls
Age Alternative	Default-Age Scenario	Constituent Alternative	Default-Constituent
Trace Alternative	Default-Trace Scenario	Fire Flow Alternative	Base-Fire Flow

Calibration Summary			
Demand	<none>	Roughness	<none>

Geometric Summary			
Northing	8,513.50 ft	From Pipe	P-63
Easting	13,553.04 ft	To Pipe	Flex-10
Elevation	0.00 ft		

Initial Condition Summary			
Status	On	Relative Speed Factor	1.00

Pump Definition Summary			
Pump Type	Standard (3 Point)		
Shutoff Head	160.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	100.00 gpm
Maximum Operating Head	45.00 ft	Maximum Operating Discharge	150.00 gpm



Detailed Report for Pump: JUMBO-30HH (10)

Calculated Results Summary

Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Useful Power (Hp)
0.00 hr	On	N/A	315.50	361.53	148.50	46.03	1.00	1.73

Detailed Report for Pump: JUMBO 30HH (13)

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

Scenario Summary

Label	Base		
Demand Alternative	Default-Average Daily	Physical Alternative	Base-Physical
Initial Settings Alternative	Base-Initial Settings	Operational Alternative	Base-Operational Controls
Age Alternative	Default-Age Scenario	Constituent Alternative	Default-Constituent
Trace Alternative	Default-Trace Scenario	Fire Flow Alternative	Base-Fire Flow

Calibration Summary

Demand	<none>	Roughness	<none>

Geometric Summary

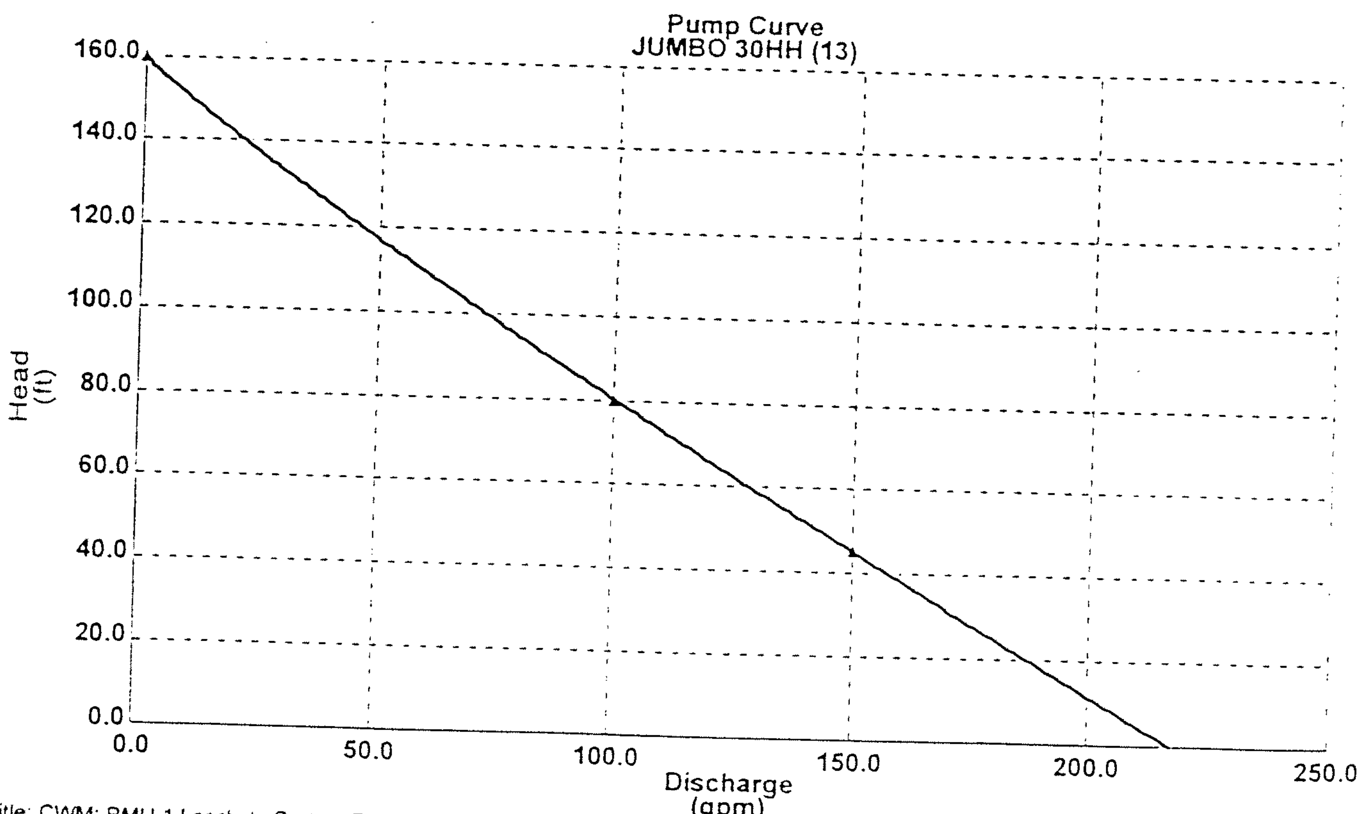
Northing	8,028.51 ft	From Pipe	P-72
Easting	14,273.23 ft	To Pipe	Flex-13
Elevation	0.00 ft		

Initial Condition Summary

Status	On	Relative Speed Factor	1.00

Pump Definition Summary

Pump Type	Standard (3 Point)		
Shutoff Head	160.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	100.00 gpm
Maximum Operating Head	45.00 ft	Maximum Operating Discharge	150.00 gpm



Detailed Report for Pump: JUMBO 30HH (13)

Calculated Results Summary								
Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Useful Power (Hp)
0.00 hr	On	N/A	312.16	368.91	132.99	56.75	1.00	1.91

Detailed Report for Pump: JUMBO-30HH (14)

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

Scenario Summary

Label	Base		
Demand Alternative	Default-Average Daily	Physical Alternative	Base-Physical
Initial Settings Alternative	Base-Initial Settings	Operational Alternative	Base-Operational Controls
Age Alternative	Default-Age Scenario	Constituent Alternative	Default-Constituent
Trace Alternative	Default-Trace Scenario	Fire Flow Alternative	Base-Fire Flow

Calibration Summary

Demand	<none>	Roughness	<none>

Geometric Summary

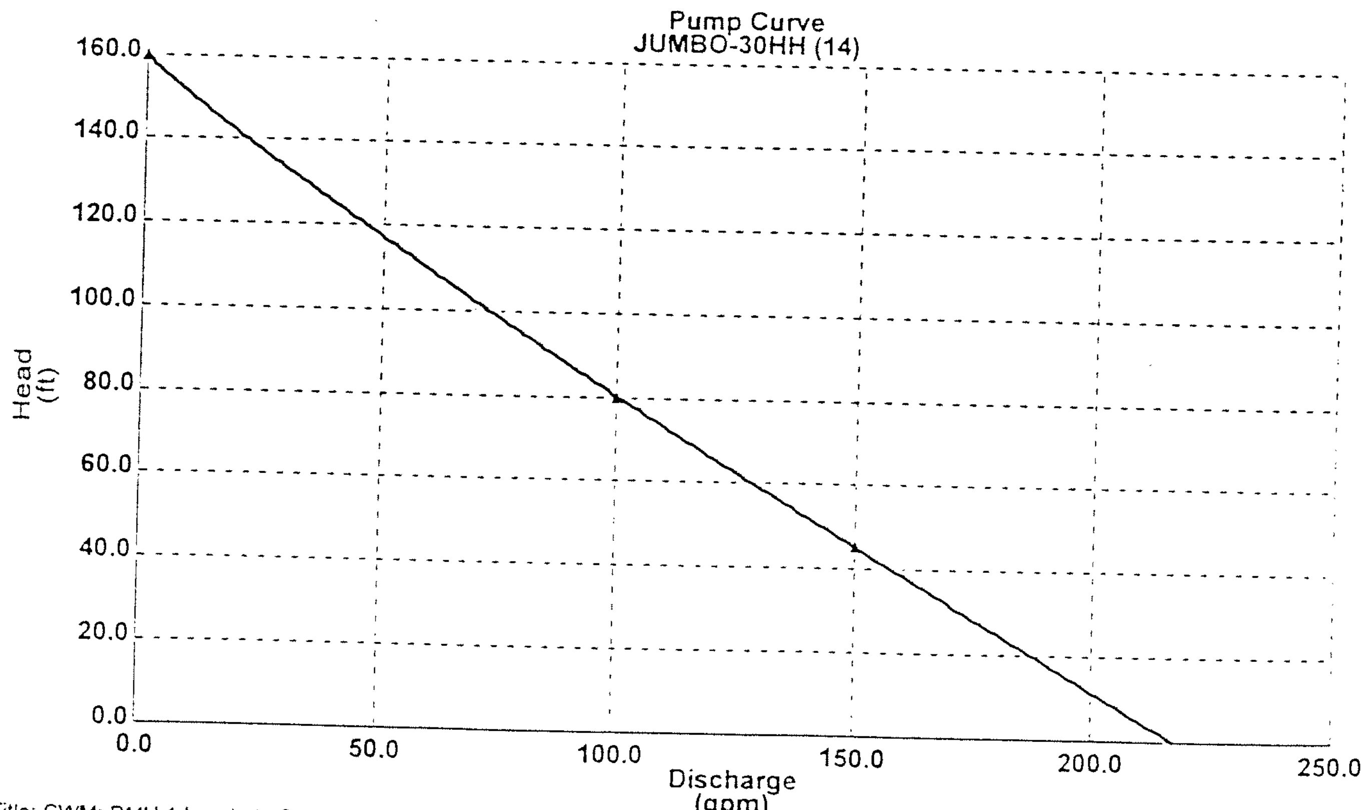
Northing	7,794.78 ft	From Pipe	P-68
Easting	13,466.86 ft	To Pipe	Flex-14
Elevation	0.00 ft		

Initial Condition Summary

Status	On	Relative Speed Factor	1.00

Pump Definition Summary

Pump Type	Standard (3 Point)		
Shutoff Head	160.00 ft	Shutoff Discharge	0.00 gpm
Design Head	80.00 ft	Design Discharge	100.00 gpm
Maximum Operating Head	45.00 ft	Maximum Operating Discharge	150.00 gpm



Detailed Report for Pump: JUMBO-30HH (14)

Calculated Results Summary								
Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Useful Power (Hp)
0.00 hr	On	N/A	312.41	368.18	134.39	55.77	1.00	1.89

Detailed Report for Tank: Lift Station

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

Scenario Summary

Label	Base		
Demand Alternative	Default-Average Daily	Physical Alternative	Base-Physical
Initial Settings Alternative	Base-Initial Settings	Operational Alternative	Base-Operational Controls
Age Alternative	Default-Age Scenario	Constituent Alternative	Default-Constituent
Trace Alternative	Default-Trace Scenario	Fire Flow Alternative	Base-Fire Flow

Calibration Summary

Demand	<none>	Roughness	<none>

Geometric Summary

Northing	9,838.91 ft	Base Elevation	317.00 ft
Easting	11,438.46 ft	Zone	Zone-1

Connecting Pipes

320
P-19

Operating Range Summary

Maximum Elevation	323.00 ft	Maximum Level	6.00 ft
Initial Elevation	318.50 ft	Initial Level	1.50 ft
Minimum Elevation	318.50 ft	Minimum Level	1.50 ft

Storage Summary

Type	Constant Area	Cross Section	Circular
Tank Diameter	9.00 ft	Average Area	63.6 ft²
Inactive Volume	0.00 ft³	Total Active Volume	381.70 ft³
Total Storage Capacity	286.28 ft³		

Calculated Results Summary

Time	Constituent (mg/l)	Hydraulic Grade (ft)	Tank Level (ft)	Pressure (psi)	Percent Full (%)	Current Storage Volume (ft³)	Tank Inflow (gpm)	Tank Outflow (gpm)	Status
0.00 hr	N/A	318.50	1.50	0.65	0.0	0.00	N/A	47.42	Draining

Detailed Report for Pump: JUMBO-200HH

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

Scenario Summary

Label	Base		
Demand Alternative	Default-Average Daily	Physical Alternative	Base-Physical
Initial Settings Alternative	Base-Initial Settings	Operational Alternative	Base-Operational Controls
Age Alternative	Default-Age Scenario	Constituent Alternative	Default-Constituent
Trace Alternative	Default-Trace Scenario	Fire Flow Alternative	Base-Fire Flow

Calibration Summary

Demand	<none>	Roughness	<none>

Geometric Summary

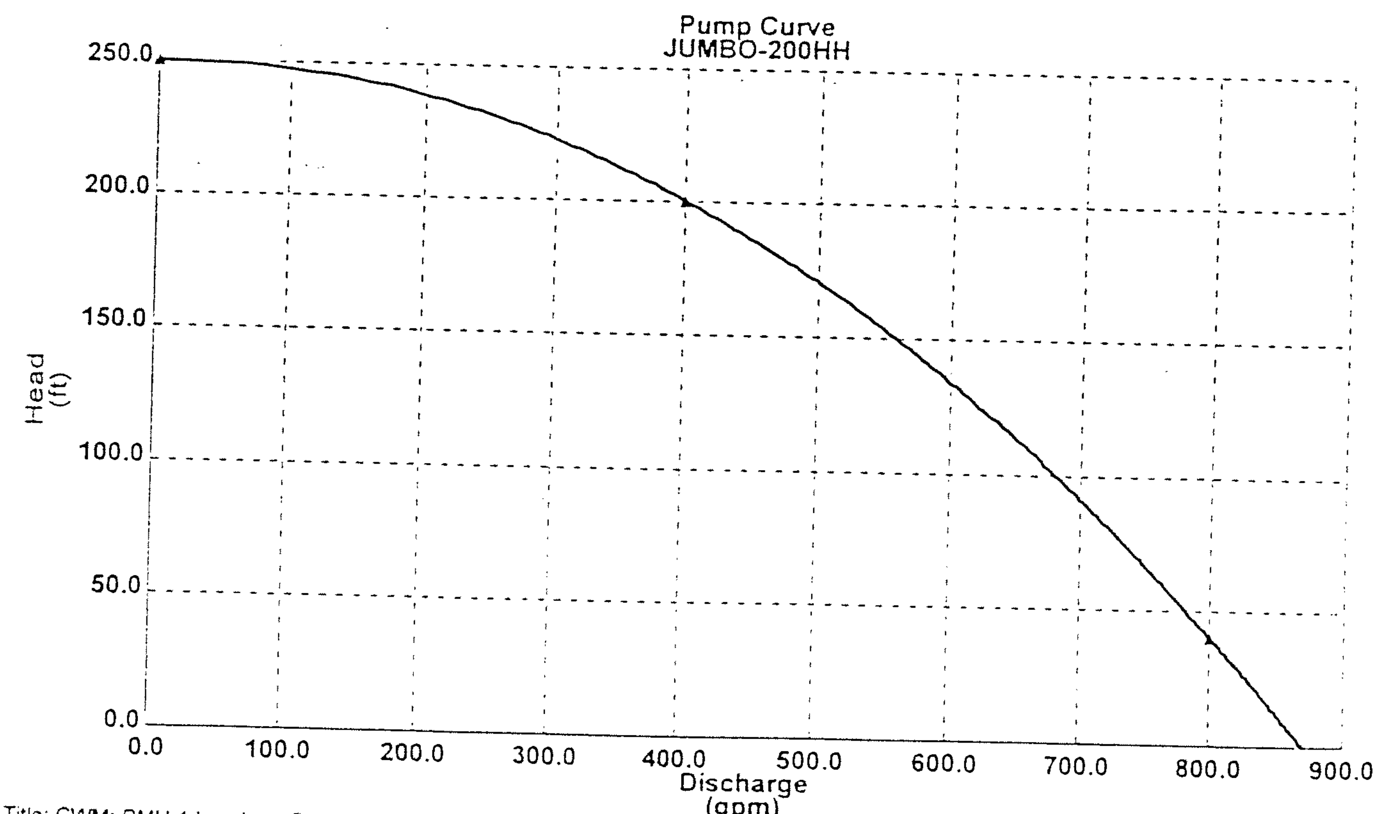
Northing	9,646.47 ft	From Pipe	
Easting	11,235.01 ft	To Pipe	6" HDPE (8 ft.)
Elevation	317.00 ft		

Initial Condition Summary

Status	On	Relative Speed Factor	1.00

Pump Definition Summary

Pump Type	Standard (3 Point)		
Shutoff Head	250.00 ft	Shutoff Discharge	0.00 gpm
Design Head	200.00 ft	Design Discharge	400.00 gpm
Maximum Operating Head	40.00 ft	Maximum Operating Discharge	800.00 gpm



Detailed Report for Pump: JUMBO-200HH

Calculated Results Summary

Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Useful Power (Hp)
0.00 hr	On	N/A	318.50	406.37	706.03	87.87	1.00	15.66

Detailed Report for Pump: Goulds 3888D

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

Scenario Summary

Label	Base		
Demand Alternative	Default-Average Daily	Physical Alternative	Base-Physical
Initial Settings Alternative	Base-Initial Settings	Operational Alternative	Base-Operational Controls
Age Alternative	Default-Age Scenario	Constituent Alternative	Default-Constituent
Trace Alternative	Default-Trace Scenario	Fire Flow Alternative	Base-Fire Flow

Calibration Summary

Demand	<none>	Roughness	<none>

Geometric Summary

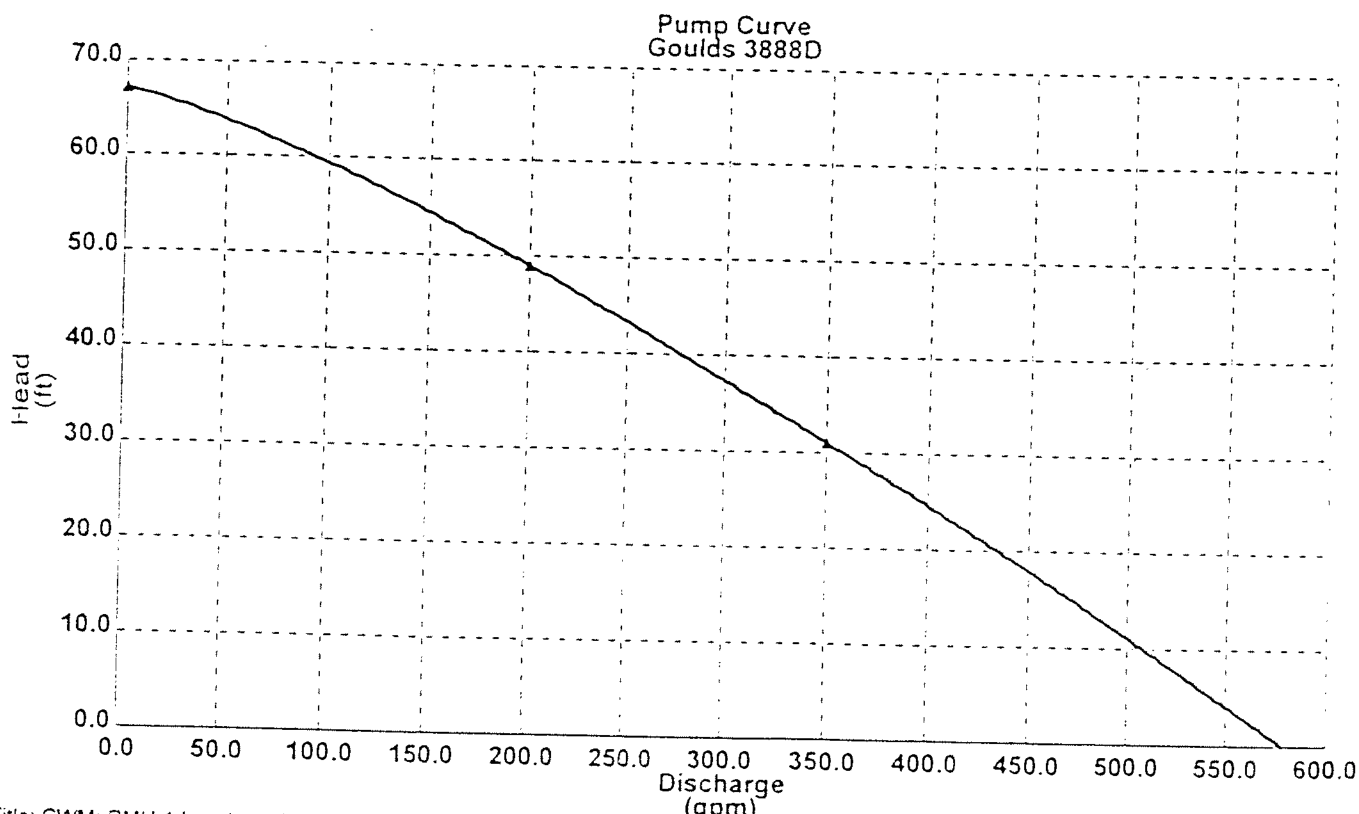
Northing	9,971.56 ft	From Pipe	
Easting	11,242.24 ft	To Pipe	4" Flex Hose (8 ft)
Elevation	316.75 ft		

Initial Condition Summary

Status	Off	Relative Speed Factor	1.00

Pump Definition Summary

Pump Type	Standard (3 Point)		
Shutoff Head	67.00 ft	Shutoff Discharge	0.00 gpm
Design Head	49.00 ft	Design Discharge	200.00 gpm
Maximum Operating Head	31.00 ft	Maximum Operating Discharge	350.00 gpm



Detailed Report for Pump: Goulds 3888D

Calculated Results Summary

Time	Status	Constituent (mg/l)	From Grade (ft)	To Grade (ft)	Flow (gpm)	Head (ft)	Relative Speed	Useful Power (Hp)
0.00 hr	Off	N/A	318.50	325.23	0.00	0.00	0.00	0.00

Detailed Report for Reservoir: OWS

Note:
The input data may have been modified since the last calculation was performed.
The calculated results may be outdated.

Scenario Summary			
Label	Base		
Demand Alternative	Default-Average Daily	Physical Alternative	Base-Physical
Initial Settings Alternative	Base-Initial Settings	Operational Alternative	Base-Operational Controls
Age Alternative	Default-Age Scenario	Constituent Alternative	Default-Constituent
Trace Alternative	Default-Trace Scenario	Fire Flow Alternative	Base-Fire Flow

Calibration Summary			
Demand	<none>	Roughness	<none>

Geometric Summary			
Northing	9,892.10 ft	Hydraulic Grade Line	326.23 ft
Easting	8,800.45 ft	Zone	Zone-1

Connecting Pipes
Steel Pipe in OWS
Steel Pipe in OWS

Calculated Results Summary

Time	Constituent (mg/l)	Hydraulic Grade (ft)	Reservoir Inflow (gpm)	Reservoir Outflow (gpm)
0.00 hr	N/A	326.23	706.03	N/A

APPENDIX H
Supplemental Calculations

Cell 7 Primary 8 inch Cleanout Transition in Sump

CLIENT CWM MODEL CITY
PROJECT CELL 7 RMU-1 CONSTRUCTION
SUBJECT PRIMARY 8" LEACHATE PIPE TRANSITION IN SUMP
Prepared By SG Date 7/1/97
Reviewed By JPC Date 7/1/97
Approved By ______ Date ____

TASK: PROVIDE A TRANSITION OR SWEEP OF THE PRIMARY 8 INCH DIAMETER LEACHATE COLLECTION PIPE IN THE CELL 7 SUMP. IT IS TO TRANSITION FROM A TWO (2) FOOT OFFSET OF THE CELL CENTERLINE TO THE CELL CENTERLINE.

REFFRANCES:

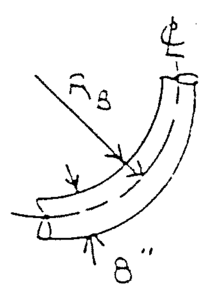
1. CSR POLYPIPE 1994 FUNDAMENTALS FOR DESIGN INDUSTRIAL AND MINING APPLICATIONS
2. PERMIT DRAWING No. 13D

1. CALCULATE ALLOWABLE PIPE RADIUS FOR SWEEP FROM REFERANCE NO. 1

FOR SDR 13.5 A MINIMUM BENDING RADIUS IS 11X PIPE O.D.

OR $11 \times 8.625\text{ IN.} \times \frac{\text{FT.}}{12\text{ IN.}} = 7.906\text{ FT.}$

ASSUME BENDING RADIUS IS FOR PIPE INNER RADIUS



THEREFORE AT THE PIPE CENTERLINE THE BENDING RADIUS IS

$$\begin{array}{rl} 94.875 & (11 \times 8.625) \\ +\ 4.3125 & (8.625 \div 2) \\ \hline 99.1875 = & 8.27\text{ FT.} \end{array}$$

ALLOWABLE PIPE BENDING RADIUS = 8.27 FT.

2. CALCULATE ALLOWABLE DISTANCE FOR SWEEPING THE 8" PIPE OVER A TWO (2) FOOT OFFSET (SEE FIGURE 1)

RUST ENVIRONMENT & INFRASTRUCTURE

CALCULATION SHEET

PROJECT NO. 200346

CLIENT CWM MODEL CITY

JECT CELL 7 RMU-1 CONSTRUCTION

SUBJECT PRIMARY 8" LEACHATE PIPE TRANSITION IN SUMP

Prepared By CB Date 7/1/97

Reviewed By JPB Date 7/1/97

Approved By ______ Date ______

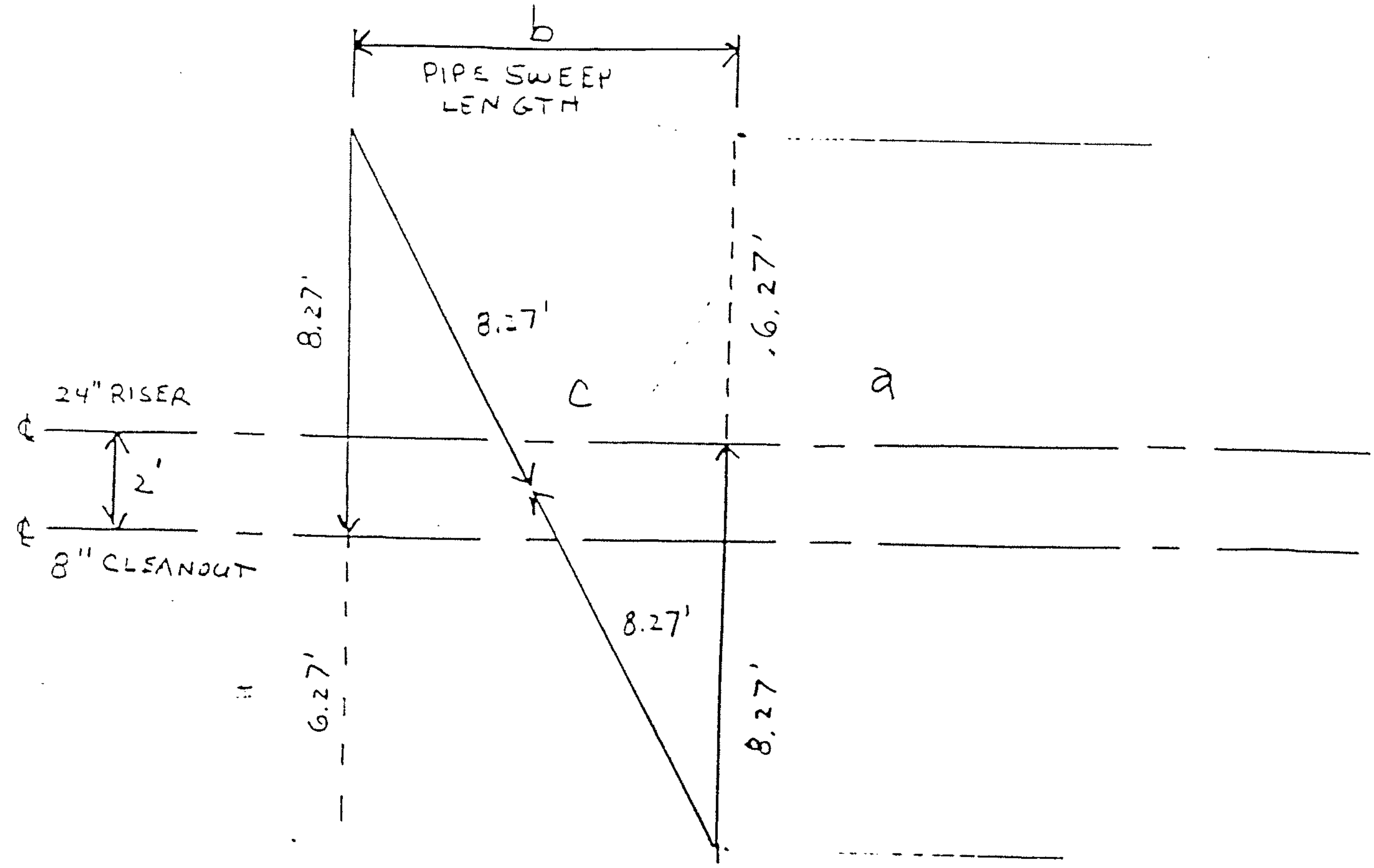


FIGURE 1
SCALE 1" = 4'

FROM FIGURE 1 USING PATHAGOREAN THEOREM $a^2 + b^2 = c^2$

$b^2 = c^2 - a^2$

WHERE $a = 8.27' + 6.27' = 14.54'$

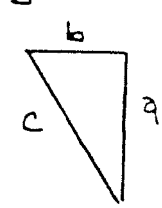
$b = ?$

$c = 8.27' + 8.27' = 16.54'$

$b^2 = 16.54^2 - 14.54^2$

$b^2 = 62.16'$

$b = 7.88'$



THE MINIMUM DISTANCE ALLOWED FOR THE PIPE SWEEP 7.88 FT.

3. CALCULATE DISTANCE FROM THE END OF THE RISER PIPE TO SUMP EDGE

RUST ENVIRONMENT & INFRASTRUCTURE

CALCULATION SHEET

PAGE 3 OF 3
PROJECT NO. 200346

CLIENT CWM MODEL CITY
SUBJECT CELL 7 RMU-1 CONSTRUCTION

SUBJECT PRIMARY 8" LEACHATE PIPE TRANSITION IN SUMP

Prepared By CB Date 7/1/97
Reviewed By JPG Date 7/1/97
Approved By ____ Date ____

END OF PRIMARY RISER PIPE
N 9999.12
E 2450.00

EDGE OF SUMP PL 17
N 9989.69
E 2450.00

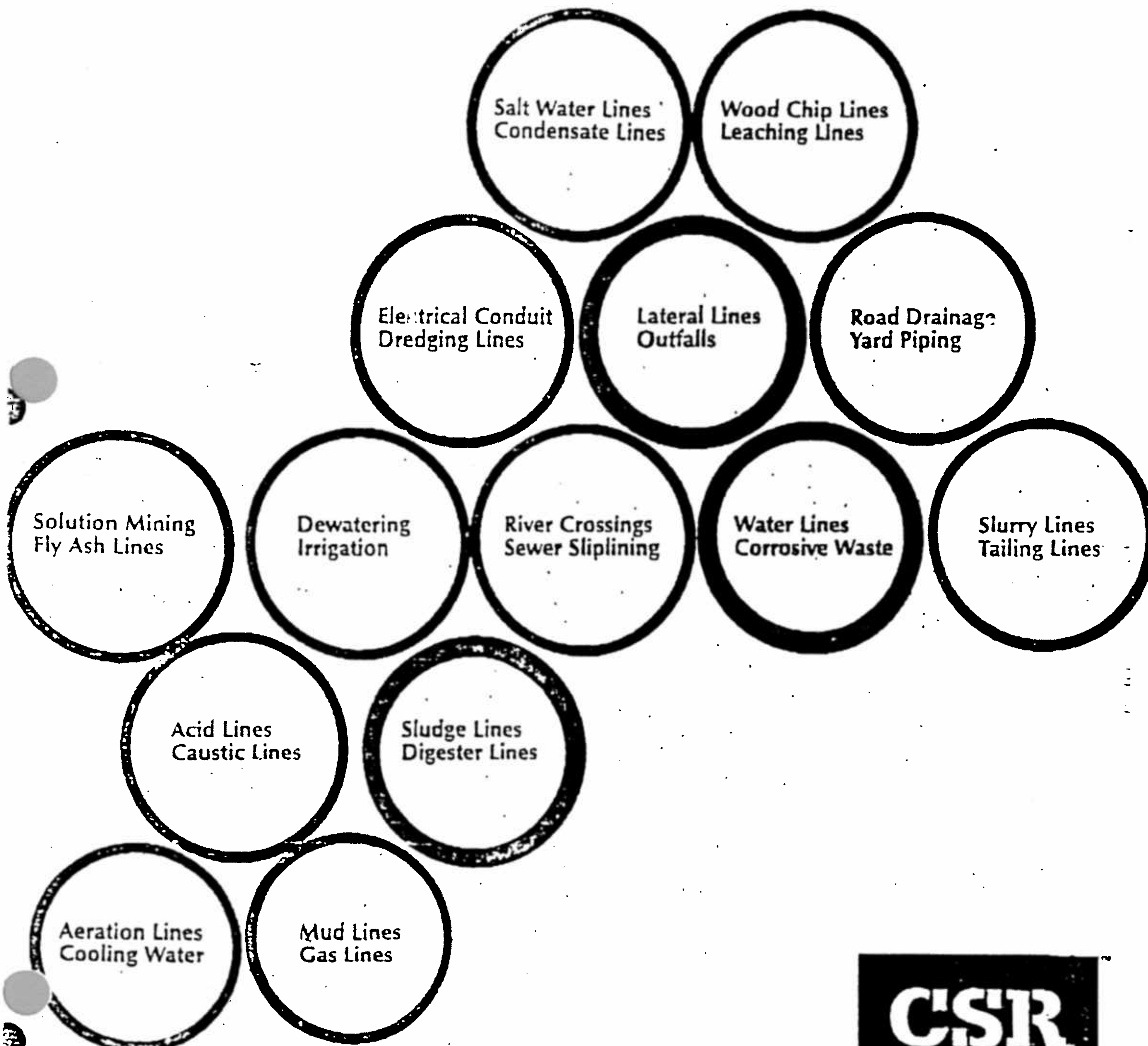
ALLOWABLE DISTANCE WITHIN SUMP

N 9999.12
− N 9989.69

= 9.43 FT. > 7.88 FT

PIPE SWEEP CAN FIT WITHIN AREA FROM END OF RISER PIPE TO EDGE OF SUMP

FUNDAMENTALS FOR DESIGN
INDUSTRIAL AND MINING APPLICATIONS



CSR
PolyPipe

BENDING RADIUS

One of PolyPipe®'s inherent advantages is its flexibility and resiliency. Many times the pipe can be bent around obstructions without adding fittings. However, when pipe is used in pressure applications, the longitudinal stress created by the sum of the bending radius, internal pressure, and other stress loads on the pipe should not exceed the material's design stress rating.

The minimum bending radius is based on the SDR of the pipe. This radius can be determined by multiplying the outside diameter of the pipe by the radius factor for the corresponding SDR.

SDR	RADIUS FACTOR
32.5	20
26	18
21	16
17	13
15.5	12
13.5	11
11	10
9	10
7.3	10

From an installation viewpoint, a radius factor of 1.5 times the above may be more practical for pipe 24" and larger when installation temperature and/or operating temperature fluctuations are taken into account. Tight bends in polyethylene pipelines should be buried or restrained.

See CSR PolyPipe's Design & Engineering Guide, Section F "Underground Installations," for detailed information on this subject.

SLURRY APPLICATIONS AND ABRASION RESISTANCE

High molecular weight PolyPipe® has an extremely high resistance to abrasion created by slurries. When compared to traditional materials, PolyPipe® generally has superior wear characteristics. For example, PolyPipe® will outlast steel by as much as 4 to 1 for a given situation.

Additionally, PolyPipe® is lighter in weight and easier to install than steel in typical slurry line installations. An added benefit is that PolyPipe® is easy to maintain and can easily be rotated once wear has taken place to increase pipeline longevity.

Wear characteristics of polyethylene slurry lines are related to the type of slurry, velocity, and other pipeline conditions. Most important is "critical velocity," or the point at which solids leave the state of suspension and begin to settle out in a slurry. Critical velocity depends on a number of variables:

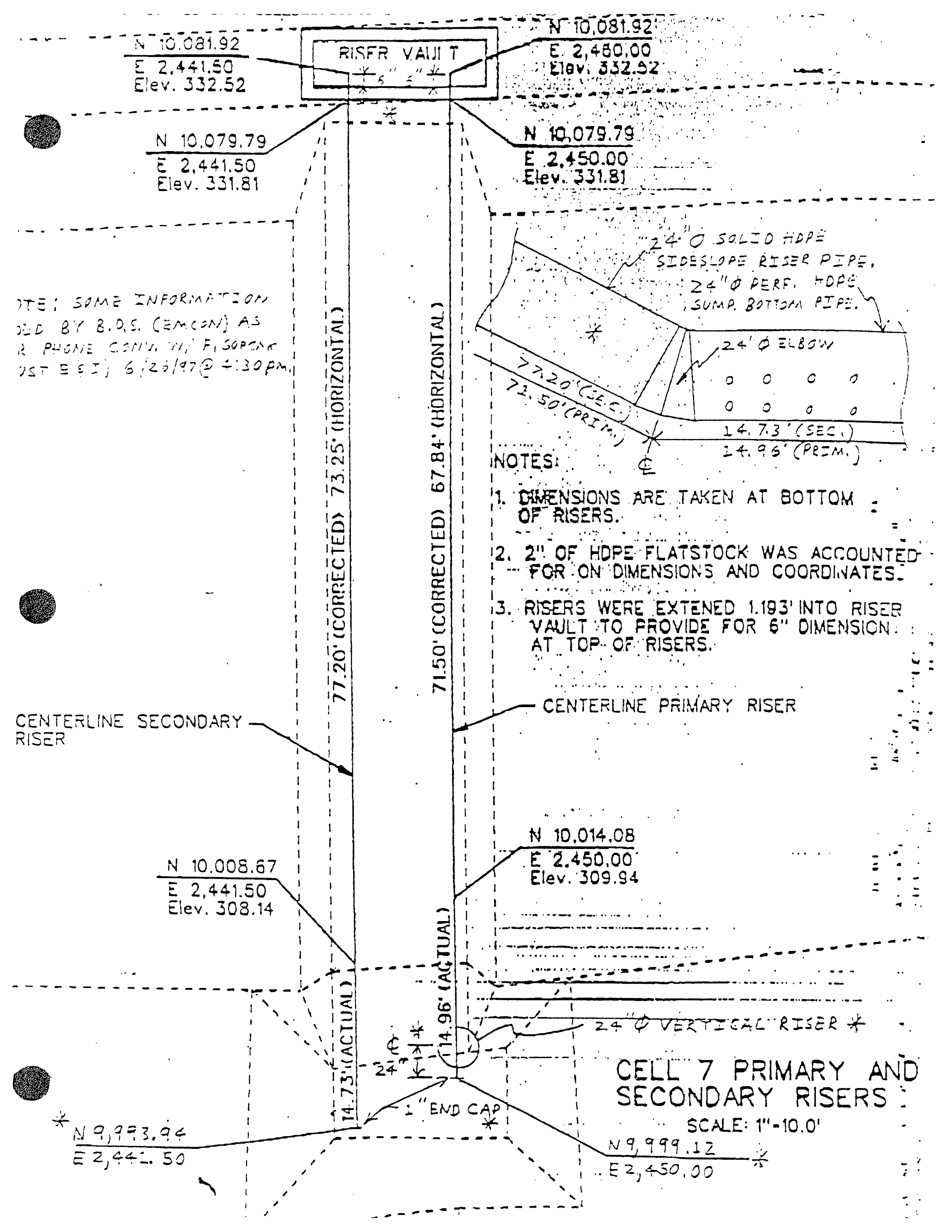
1. Particle size
2. Particle shape
3. Particle size distribution
4. Particle density
5. Concentration
6. Carrier fluid density

It is important that critical velocity be established for any slurry application, as flow velocities below the critical level can result in higher than normal wear rates.

Because of the many variables involved in slurry applications, it is very difficult to establish a definitive table of wear rates for various types of materials. Details of specific applications are available from your CSR PolyPipe distributor or directly from the factory.

See CSR PolyPipe's Design & Engineering Guide, Section H "Slurry Application," for detailed information on this subject.

OD			SDR	Nominal ID		Minimum Wall		Weight	
Nominal in.	Actual in.	Actual mm.		in.	mm.	in.	mm.	lb. per foot	kg. per meter
			7	6.062	153.97	1.232	31.29	12.32	18.33
			7.3	6.167	156.64	1.182	30.02	11.90	17.71
			9	6.632	168.45	0.958	24.33	9.94	14.79
			9.3	6.696	170.08	0.927	23.55	9.66	14.37
			11	6.994	177.65	0.784	19.91	8.32	12.38
8	8.625	219.08	11.5	7.065	179.45	0.750	19.05	7.99	11.89
			13.5	7.296	185.32	0.639	16.23	6.90	10.27
			15.5	7.468	189.69	0.556	14.12	6.07	9.03
			17	7.570	192.28	0.507	12.88	5.57	8.29
			21	7.771	197.38	0.411	10.44	4.56	6.79
			26	7.935	201.55	0.332	8.43	3.72	5.54
			32.5	8.073	205.05	0.265	6.73	3.00	4.46
			7	7.556	191.92	1.536	39.01	19.14	28.48
			7.3	7.687	195.25	1.473	37.41	18.48	27.50
			9	8.266	209.96	1.194	30.25	15.44	22.97
			9.3	8.346	211.99	1.156	29.36	15.00	22.32
			11	8.717	221.41	0.977	24.82	12.92	19.22
10	10.750	273.05	11.5	8.806	223.67	0.935	23.75	12.41	18.47
			13.5	9.094	230.99	0.796	20.22	10.72	15.95
			15.5	9.307	236.40	0.694	17.63	9.43	14.03
			17	9.435	239.65	0.632	16.05	8.65	12.87
			21	9.685	246.00	0.512	13.00	7.09	10.55
			26	9.890	251.21	0.413	10.49	5.78	8.60
			32.5	10.062	255.57	0.331	8.41	4.66	6.93
			7	8.961	227.61	1.821	46.25	26.93	40.07
			7.3	9.117	231.57	1.747	44.37	26.00	38.69
			9	9.803	249.00	1.417	35.99	21.72	32.32
			9.3	9.898	251.41	1.371	34.82	21.10	31.40
			11	10.339	262.61	1.159	29.44	18.17	27.04
12	12.750	323.85	11.5	10.444	265.28	1.109	28.17	17.46	25.98
			13.5	10.786	273.96	0.944	23.98	15.08	22.44
			15.5	11.039	280.39	0.823	20.90	13.27	19.75
			17	11.190	284.23	0.750	19.05	12.17	18.11
			21	11.487	291.77	0.607	15.42	9.97	14.84
			26	11.730	297.94	0.490	2.45	8.13	12.10
			32.5	11.934	303.12	0.392	9.96	6.56	9.76
			7	9.840	249.94	2.000	50.80	32.46	48.30
			7.3	10.011	254.28	1.918	48.72	31.34	46.63
			9	10.764	273.41	1.556	39.52	26.19	38.97
			9.3	10.869	276.07	1.505	38.23	25.44	37.85
			11	11.353	288.37	1.273	32.33	21.91	32.60
14	14.000	355.60	11.5	11.468	291.29	1.217	30.91	21.05	31.32
			13.5	11.843	300.81	1.037	26.34	18.18	27.05
			15.5	12.121	307.87	0.903	22.94	16.00	23.81
			17	12.287	312.09	0.824	20.93	14.68	21.84
			21	12.613	320.37	0.667	16.94	12.02	17.89
			26	12.880	327.15	0.538	13.67	9.81	14.60
			32.5	13.104	332.84	0.431	10.95	7.91	11.77



CELL 7 PRIMARY AND SECONDARY RISERS

SCALE: 1"-10.0'

APPENDIX I

SURFACE WATER DRAINAGE AND EROSION CALCULATIONS

5/18/99
Revised: ~~Date Approved~~

TABLE OF CONTENTS

SURFACE WATER DRAINAGE AND EROSION CALCULATIONS

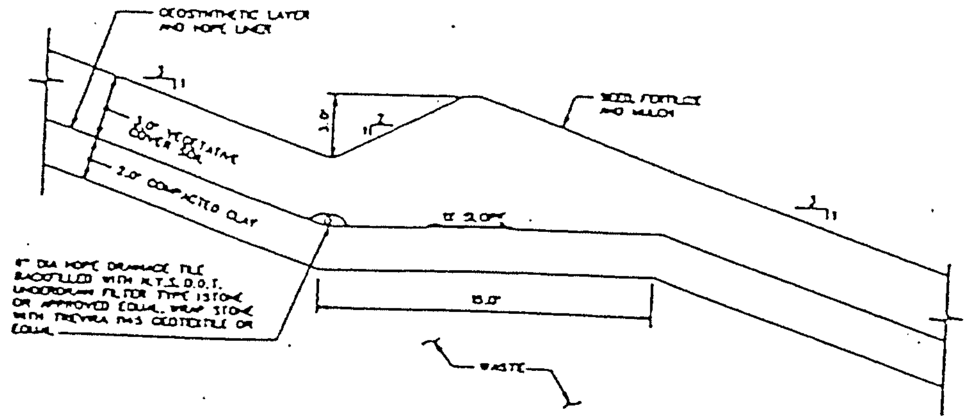
Revised: Date : August 2012

SURFACE WATER DRAINAGE CALCULATIONS

I. SUMMARY OF DESIGN

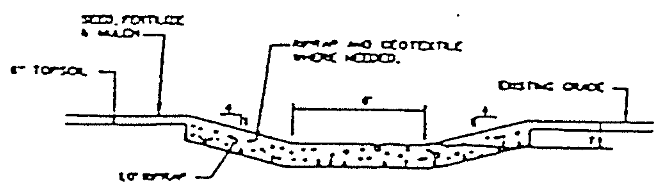
A. Drainage Ditch Types

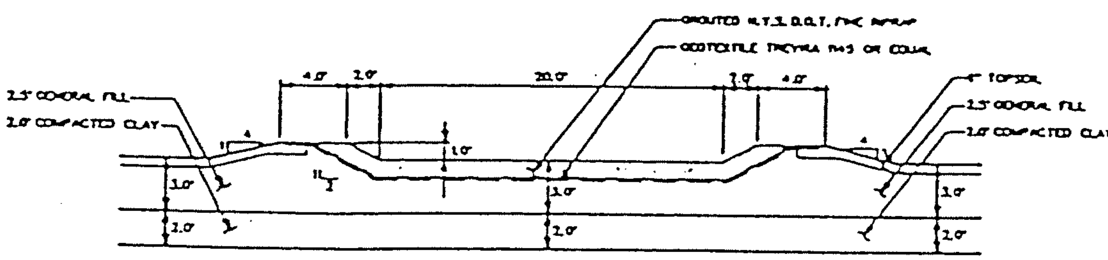
1. Interceptor Ditches: (Surface water diversion berm) - Type 1.



Slope = 1.0 to 2.0 percent
Channel Lining = Grass
Permissible Velocity = 4 ft/sec

2. Riprap Channel/Downflume Design - Type 2

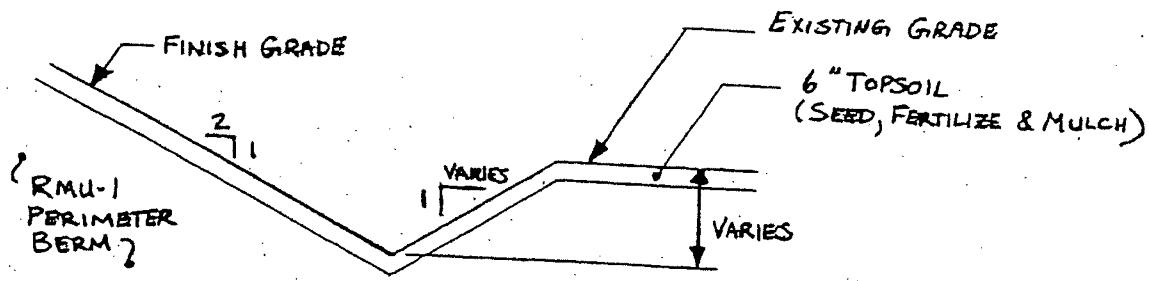




Slope = 3.0 to 39.0 percent
Channel Lining = Grouted Riprap (d_{50} = 1.5")

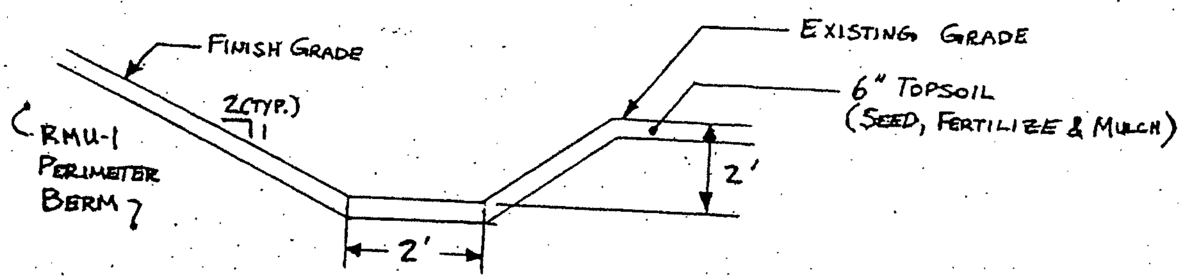
Since discharge velocities entering the perimeter ditch from the downflume will exceed the 4.0 ft/sec design criteria, riprap will be required at the point of inflow into the perimeter ditch. Riprap will be cement grouted in place to ensure stability of the flume during storm events greater than the design.

3. Perimeter Ditch – Type 3



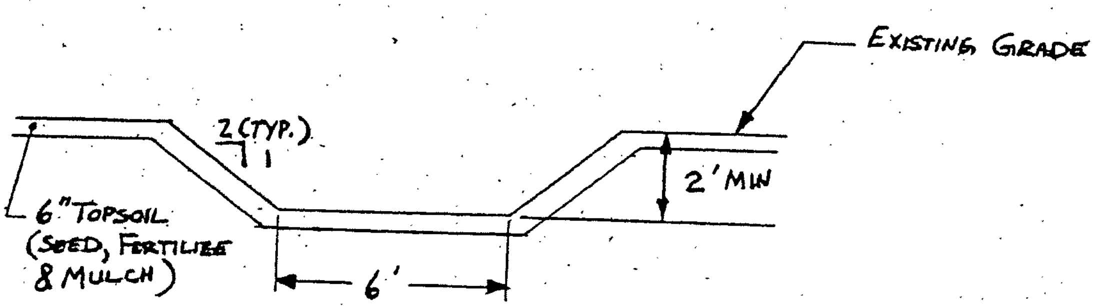
Slope = 0.2 to 0.5 percent
Channel Lining = Grass
Permissible Velocity = 4 ft/sec

OR,



Slope = 0.25 percent
Channel Lining = Grass
Permissible Velocity = 4 ft/sec

4. Perimeter Ditch – Type 4



Slope = 0.2 percent
Channel Lining = Grass
Permissible Velocity = 4 ft/sec

B. Culvert Sizes

To handle a combined peak flow of 73.5 cfs, use the following:

1. *Culvert No. 1 (North to East Basin)*
   Three 30-inch diameter corrugated high density polyethylene pipes with mitered headwalls;

2. *Culvert No. 2 (North Central to East Basin)*
   One 12-inch diameter corrugated high density polyethylene pipe with mitered headwalls;

3. *Culvert No. 3 (South Central to East Basin)*
   One 12-inch diameter corrugated high density polyethylene pipe with mitered headwalls;

4. *Culvert No. 4 (South to East Basin)*
   One 30-inch diameter corrugated high density polyethylene pipe with mitered headwalls;

C. Riprap Downflumes

1. Downflume 1 - Discharges to Culvert No. 1. It will handle a design flow of 54.53 cfs.

2. Downflume 2 - Discharges to the north. It will handle a design flow of 53.75 cfs.

D. East Stormwater Retention Basin

The basin provides 8.375 acre-feet (364,815 cubic feet) of storage at the invert elevation of the emergency spillway (321.7 feet).

The design high water elevation associated with the 25-year, 24-hour storm event is 321.08 feet under the interim condition. The storage at this elevation is 6.872 acre-feet (299,344 cubic feet), including 1.141 acre-feet (49,702 cubic feet) of annual sediment accumulation. The basin provides 0.62 feet of freeboard at this elevation. The 25-year, 24-hour estimated peak discharge into the basin under the interim condition is 86.05 cfs. The 25-year, 24-hour estimated peak discharge from the basin after the discharge valve is opened is 4.15 cfs under the interim condition.

The design high water elevation associated with the 25-year, 24-hour storm event is 320.18 feet under the final condition. The storage at this elevation is 4.817 acre-feet (209,829 cubic feet), including 0.023 acre-feet (1,002 cubic feet) of annual sediment accumulation. The basin provides 1.52 feet of freeboard at this elevation. The 25-year, 24-hour estimated peak discharge into the basin under the final condition is 71.20 cfs. The 25-year, 24-hour estimated peak discharge from the basin after the discharge valve is opened is 3.33 cfs under the final condition.

E. Summary of Runoff Curve Numbers

The runoff curve numbers (CNs) presented in Section II for the design of channels and culverts for RMU-1 (Sections III and V, respectively) are based on a hydrologic soil group of "C" and the assumption that the watersheds are covered with a poor stand of vegetation. These conditions are considered representative of newly capped areas of RMU-1 during the establishment of the initial stand of vegetation. A CN of 86 is selected for this initial condition based on CNs for "open spaces" as presented in Table 2-2a of Technical Release 55 (TR-55) entitled "Urban Hydrology for Small Watersheds" prepared by the U.S. Department of Agriculture's Natural Resources Conservation Service (formerly the Soil Conservation Service). In the original RMU-1 surface water calculations, the drainage areas to the various channels and culverts were assumed to be homogeneous and a CN of 86 was applied to all of the drainage areas. More recent calculations have adopted the use of composite CNs in which a CN of 86 is used to represent vegetated areas and a CN of 89 is used to represent the perimeter road (based on CNs for "gravel roads" as presented in Table 2-2a of TR-55). Composite CNs are calculated for the various drainage areas as area-weighted averages of the individual CNs.

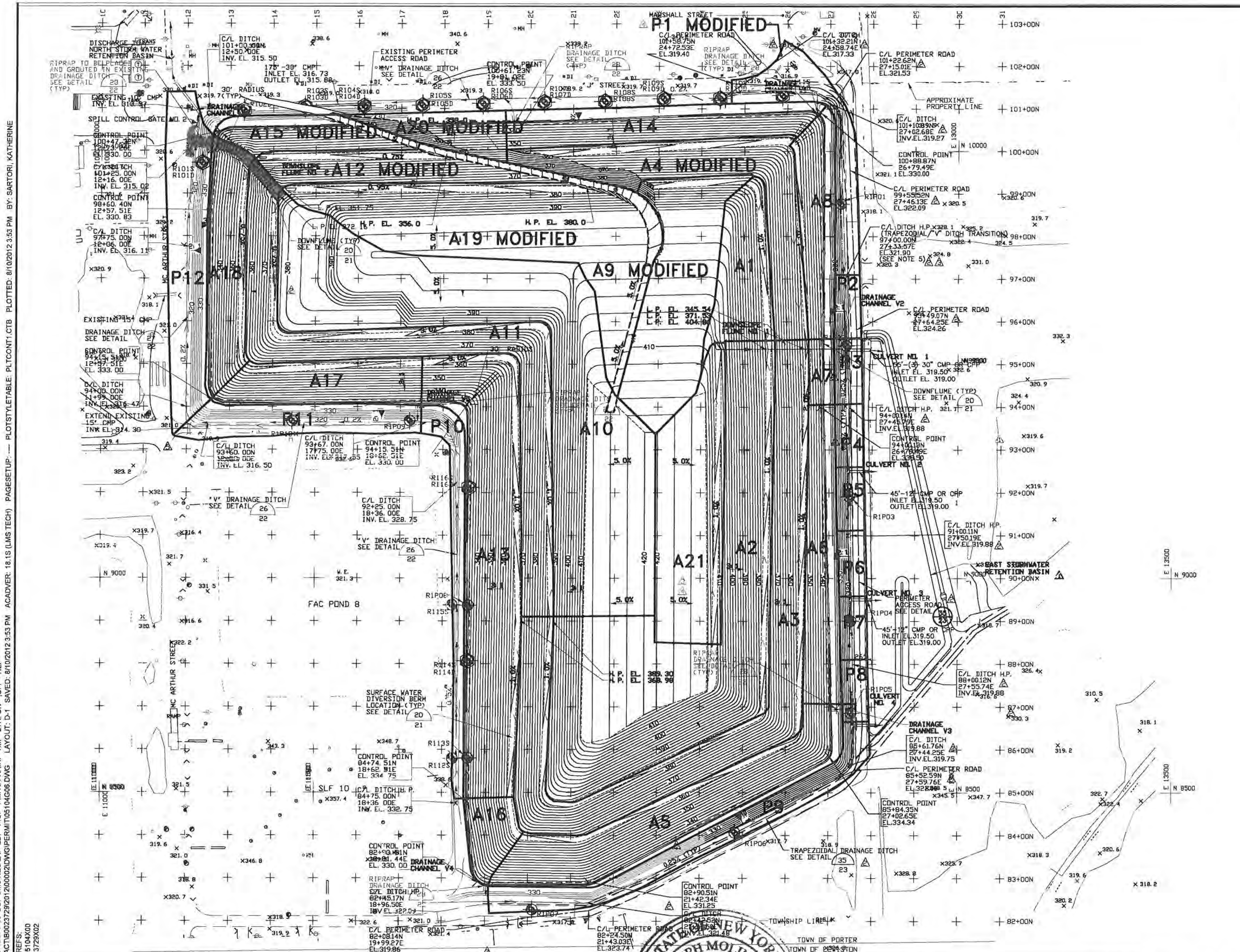
The CNs for the design of the East Stormwater Retention Basin (Section IV [the ESRB]) are also based on a hydrologic soil group of "C". The stormwater runoff volume to the ESRB is expected to decrease over time as the final cover vegetation becomes more established. In recognition of this, two conditions are modeled for the design of the ESRB. The first condition (the "interim condition") is intended to represent runoff conditions into the basin before the final cover vegetation is fully established. Under the interim condition, approximately half of the acreage in each drainage area (with the exception of any acreage covered by perimeter roads) is assumed to be newly graded and unvegetated (CN of 91 based on CNs for "newly graded areas" as presented in Table 2-2a of TR-55). The remainder of the drainage area is assumed to be moderately vegetated (CN of 79 based on CNs for "open spaces" with a fair stand of vegetation as presented in Table 2-2a of TR-55). Due to the significant size of the ESRB drainage area (approximately 28 acres), it is unlikely that even half of the drainage area would ever be unvegetated at any given time. Consequently, the interim condition is deemed conservative. The second condition (the "final condition") is intended to represent runoff conditions into the basin once the final cover vegetation is established over the entire drainage area. A CN of 79 is used for all vegetated areas under the final condition. Other CNs used in the ESRB design include 89 for perimeter roads and 100 for the basin water surface. (These CNs are constant for both interim and final conditions.)

II. PEAK FLOWS

A. Drainage Areas

Table I-1
Drainage Subareas
CWM Chemical Services, LLC
Model City Facility

Subarea No.	Measured Area (sq. ft.)	Area (acres)
A1	47,430	1.09
A2	239,485	5.50
A3	161,355	3.70
A4 Modified	84,942	1.95
A5	100,130	2.30
A6	54,560	1.25
A7	10,075	0.23
A8	41,230	0.95
A9 Modified	95,396	2.19
A10	280,986	6.45
A11	124,930	2.87
A12 Modified	46,797	1.07
A13	143,220	3.29
A14	60,113	1.38
A15 Modified	32,670	0.75
A16	20,150	0.46
A17	44,795	1.03
A18	51,770	1.19
A19 Modified	161,172	3.70
A20 Modified	25,700	0.59
A21	93,995	2.16
P1 Modified	41,900	0.96
P2	26,136	0.60
P3	8,276	0.19
P4	9,148	0.21
P5	9,148	0.21
P6	8,712	0.20
P7	8,276	0.19
P8	7,841	0.18
P9	45,738	1.05
P10	31,620	0.73
P11	57,505	1.32
P12	70,990	1.63
P13 (East Basin)	132,422	3.04



LEGEND:

- 320 EXISTING GRADE
- 320 PROPOSED GRADE
- LIMIT OF SUBBASE
- 3:1 SLOPE INDICATOR
- DRAINAGE DITCH
- ACCESS ROAD
- TOP OF BERM
- APPROXIMATE PROPERTY LINE
- TOWNSHIP LINE
- GROUNDWATER MONITORING WELL
- GROUNDWATER MONITORING WELL NEST
- SOIL BORING
- PERMANENT CONTROL MONUMENT
- CULVERT
- VAULT

NOTES:

1. TOPOGRAPHIC BASE MAP WAS PROVIDED BY AIR SURVEY CORP. STERLING, VIRGINIA. DATE OF PHOTOGRAPHY, DECEMBER, 1996.
2. COORDINATES LABELED ON THESE PLANS ARE ACCORDING TO RMU-1 SITE GRID.REFER TO DRAWING NO. 2 FOR PLANT COORDINATES.
3. PROPOSED GRADES INDICATED ARE TOP OF VEGETATIVE COVER SOIL.
4. DRAINAGE TILE TO BE PLACED UNDER SURFACE WATER DRAINAGE DITCH. SEE DETAIL 17.
5. WELLS SHOWN ON THIS DRAWING ARE THE EXISTING MONITORING WELLS FOR RMU-1.

NOT FOR CONSTRUCTION
FOR REGULATORY REVIEW ONLY

⚠ NOTES:

1. THIS DRAWING IS BASED ON A DRAWING ENTITLED "DRAINAGE SUBAREA MAP", PREPARED BY EARTH TECH (DATED JUNE 1997).
2. BBL IMPLEMENTED REVISIONS ARE AS NOTED IN THE REVISION BLOCK.

DRAWING REVISED BY BLASLAND, BOUCK & LEE, INC. THROUGH ITS PROFESSIONAL ENGINEER. WORK OF EARTHTECH (FORMERLY RUST ENVIRONMENT & INFRASTRUCTURE) NOT INDEPENDENTLY REVIEWED.

CITY: SYRACUSE DIV/GROUP: 85 DB: GMS NES LAF LD: PIC: PM: R. PARINI TM: LYR: ON=*;OFF=*REF* G:\ENVCAD\SYRACUSE\ACT\B0023729\2012\00002\DWG\PERMIT\05104G06.DWG LAYOUT: D-1 SAVED: 8/10/2012 3:53 PM ACADVER: 18.1S (LMS TECH) PAGESETUP: --- PLOTSTYLETABLE: PLTCONT1.CTB PLOTTED: 8/10/2012 3:53 PM BY: SARTORI, KATHERINE

XREFS: 05104X00 23729X02

Graphic Scale: 120' 0 120' 240'

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No.	Date	Revisions	Init
5	8/12	REVISED WATERSHED LIMITS FOR ACCESS ROAD CONSTRUCTION	
4	3/08	REVISED PROPOSED GRADES AND P1 WATERSHED	
3	12/03	REV. DRAIN BOUNDARIES, PERIM. DITCH, H.P., LANDFILL CONTOURS, AND NOTES	
2	6/02	REVISED PERIMETER DITCH, ACESS ROAD, AND CULVERTS	
1	6/01	REVISIONS TO STORMWATER RETENTION BASIN	

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Project Mgr. TJF
Designed by BMS/CAA
Drawn by SLM
Checked by PHB
Prof. Eng. JOSEPH MOLINA III
PE License NY 072644

STATE OF NEW YORK · JOSEPH MOLINA III · 072644 · LICENSED PROFESSIONAL ENGINEER

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

CWM CHEMICAL SERVICES, LLC. • MODEL CITY FACILITY
RESIDUALS MANAGEMENT UNIT 1

DRAINAGE SUBAREA MAP

GENERAL

File Number 050.42.005
Date DECEMBER 2003
Blasland, Bouck & Lee, Inc. Corporate Headquarters 6723 Towpath Road Syracuse, NY 13214 315-446-9120

D-1

II. PEAK FLOWS

B. Time of Concentration

RUST ENVIRONMENT & INFRASTRUCTURE

'ime of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 — By: BPB — Date: 07-Jul-97

Location: Model City, NY — Chk: HKK — Date: 06/01/97

Underline one: Present Developed — Area 1

Underline one: Tc Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)

	Units	Segment ID	AB		
1. Surface description (Table 3-1)			Short Grass		
2. Manning's roughness coefficient, n (Table 3-1)			0.15		
3. Flow length, L (total L <= 300 feet)	ft		300		
4. Two-year, 24-hour rainfall, P2	in		2.3		
5. Land slope, s	ft/ft		0.050		
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	hr	Compute Tt	0.322		

= 0.32

Shallow Concentrated Flow

	Units	Segment ID	BC	CD		
7. Surface description (paved or unpaved)			Unpaved	Unpaved		
8. Flow length, L	ft		175	50		
9. Watercourse slope	ft/ft		0.05	0.333		
10. Average velocity, V (figure 3-1)	ft/sec		3.6	9.3		
11. Tt= L/(3600*V)	hr	Compute Tt	0.014	0.001		

= 0.02

Channel Flow

	Units	Segment ID	DE		
12. Cross sectional area, a	ft^2		22.50		
13. Wetted Perimeter, Pw	ft		16.20		
14. Hydraulic radius, r= (a/Pw)	ft	Compute r	1.40		
15. Channel slope, s	ft/ft		0.010		
16. Manning's roughness coefficient, n			0.038		
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	ft/sec	Compute v	4.9		
18. Flow length, L	ft		400		
19. Tt= L/(3600*V)	hr	Compute Tt	0.023		

= 0.02

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)

hr	=	0.36
Minimum Tt hr	=	0.10
Use Tt	=	0.36

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

RUST ENVIRONMENT & INFRASTRUCTURE

Time of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 By: JPD Date: 02-Feb-99

Location: Model City, NY Chk: Km Date: 2/2/99

Underline one: Present **Developed** Area 2

Underline one: **Tc** Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)

		Segment ID	AB				
1.	Surface description (Table 3-1)		Short Grass				
2.	Manning's roughness coefficient, n (Table 3-1)		0.15				
3.	Flow length, L (total L <= 300 feet)	ft	100				
4.	Two-year, 24-hour rainfall, P2	in	2.3				
5.	Land slope, s	ft/ft	0.050				
6.	Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	Compute Tt hr	0.134				= 0.13

Shallow Concentrated Flow

		Segment ID	BC	CD		
7.	Surface description (paved or unpaved)		Unpaved	Unpaved		
8.	Flow length, L	ft	40	70		
9.	Watercourse slope	ft/ft	0.05	0.333		
10.	Average velocity, V (figure 3-1)	ft/sec	3.6	9.3		
11.	Tt= L/(3600*V)	Compute Tt hr	0.003	0.002		= 0.01

Channel Flow

		Segment ID	CD			
12.	Cross sectional area, a	ft^2	22.50			
13.	Wetted Perimeter, Pw	ft	16.20			
14.	Hydraulic radius, r= (a/Pw)	Compute r ft	1.40			
15.	Channel slope, s	ft/ft	0.0100			
16.	Manning's roughness coefficient, n		0.038			
17.	v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	Compute v ft/sec	4.9			
18.	Flow length, L	ft	1810			
19.	Tt= L/(3600*V)	Compute Tt hr	0.103			= 0.10

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)

	hr	=	0.24
Minimum Tt	hr	=	0.10
Use Tt		=	0.24

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

RUST ENVIRONMENT & INFRASTRUCTURE

'ime of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 By: BPB Date: 07-Jul-97

Location: Model City, NY Chk: HKK Date: 08/01/97

Underline one: Present Developed Area 3

Underline one: Tc Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)

	Segment ID	AB				
1. Surface description (Table 3-1)		Short Grass				
2. Manning's roughness coefficient, n (Table 3-1)		0.15				
3. Flow length, L (total L <= 300 feet)	ft	65				
4. Two-year, 24-hour rainfall, P2	in	2.3				
5. Land slope, s	ft/ft	0.333				
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	Compute Tt hr	0.044				= 0.04

Shallow Concentrated Flow

	Segment ID					
7. Surface description (paved or unpaved)						
8. Flow length, L	ft					
9. Watercourse slope	ft/ft					
10. Average velocity, V (figure 3-1)	ft/sec					
11. Tt= L/(3600*V)	Compute Tt hr					=

Channel Flow

	Segment ID	BC				
12. Cross sectional area, a	ft²	22.50				
13. Wetted Perimeter, Pw	ft	16.20				
14. Hydraulic radius, r= (a/Pw)	Compute r ft	1.40				
15. Channel slope, s	ft/ft	0.010				
16. Manning's roughness coefficient, n		0.038				
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	Compute v ft/sec	4.9				
18. Flow length, L	ft	2080				
19. Tt= L/(3600*V)	Compute Tt hr	0.118				= 0.12

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)

hr	=	0.16
Minimum Tt hr	=	0.10
Use Tt	=	0.16

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

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TIME OF CONCENTRATION CALCULATOR
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Segment #1:  Tc: TR-55 Sheet

Mannings n          .1500
Hydraulic Length    34.00 ft
2yr, 24hr P        2.3000 in
Slope             .500000 ft/ft

Avg.Velocity          .42 ft/sec

                                         Segment #1 Time:     .0224 hrs
------------------------------------------------------------------------

Segment #2:  Tc: Length & Vel.

Hydraulic Length  1140.00 ft
Avg.Velocity         3.00 ft/sec

                                         Segment #2 Time:     .1056 hrs
------------------------------------------------------------------------

                                               =========================
                                                Total Tc:     .1280 hrs
                                               =========================
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RUST ENVIRONMENT & INFRASTRUCTURE

'ime of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 By: BPB Date: 07-Jul-97

Location: Model City, NY Chk: HKK Date: 08/01/97

Underline one: Present Developed Area 5

Underline one: Tc Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)

	Unit						
Segment ID		AB					
1. Surface description (Table 3-1)		Short Grass					
2. Manning's roughness coefficient, n (Table 3-1)		0.15					
3. Flow length, L (total L <= 300 feet)	ft	75					
4. Two-year, 24-hour rainfall, P2	in	2.3					
5. Land slope, s	ft/ft	0.333					
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	Compute Tt hr	0.050				=	0.05

Shallow Concentrated Flow

	Unit						
Segment ID							
7. Surface description (paved or unpaved)							
8. Flow length, L	ft						
9. Watercourse slope	ft/ft						
10. Average velocity, V (figure 3-1)	ft/sec						
11. Tt= L/(3600*V)	Compute Tt hr					=	

Channel Flow

	Unit						
Segment ID		BC					
12. Cross sectional area, a	ft^2	6.34					
13. Wetted Perimeter, Pw	ft	7.96					
14. Hydraulic radius, r= (a/Pw)	Compute r ft	0.80					
15. Channel slope, s	ft/ft	0.005					
16. Manning's roughness coefficient, n		0.038					
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	Compute v ft/sec	2.4					
18. Flow length, L	ft	980					
19. Tt= L/(3600*V)	Compute Tt hr	0.113				=	0.11

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)

	hr	=	0.16
Minimum Tt	hr	=	0.10
Use Tt		=	0.16

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

RUST ENVIRONMENT & INFRASTRUCTURE

Time of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 By: BPB Date: 07-Jul-97

Location: Model City, NY Chk: JPD Date: 10-Mar-97

Underline one: Present Developed Area 6

Underline one: Tc Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)

	Segment ID	AB				
1. Surface description (Table 3-1)		Short Grass				
2. Manning's roughness coefficient, n (Table 3-1)		0.15				
3. Flow length, L (total L <= 300 feet)	ft	45				
4. Two-year, 24-hour rainfall, P2	in	2.3				
5. Land slope, s	ft/ft	0.333				
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	Compute Tt hr	0.033			=	0.03

Shallow Concentrated Flow

	Segment ID					
7. Surface description (paved or unpaved)						
8. Flow length, L	ft					
9. Watercourse slope	ft/ft					
10. Average velocity, V (figure 3-1)	ft/sec					
11. Tt= L/(3600*V)	Compute Tt hr				=	

Channel Flow

	Segment ID	BC				
12. Cross sectional area, a	ft²	6.34				
13. Wetted Perimeter, Pw	ft	7.96				
14. Hydraulic radius, r= (a/Pw)	Compute r ft	0.80				
15. Channel slope, s	ft/ft	0.005				
16. Manning's roughness coefficient, n		0.038				
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	Compute v ft/sec	2.4				
18. Flow length, L	ft	710				
19. Tt= L/(3600*V)	Compute Tt hr	0.082			=	0.08

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)

hr	=	0.11
Minimum Tt hr	=	0.10
Use Tt	=	0.11

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

RUST ENVIRONMENT & INFRASTRUCTURE

Time of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 By: BPB Date: 07-Jul-97

Location: Model City, NY Chk: HKK Date: 06/01/97

Underline one: Present Developed Area 7

Underline one: Tc Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)

	Segment ID	AB				
1. Surface description (Table 3-1)		Short Grass				
2. Manning's roughness coefficient, n (Table 3-1)		0.15				
3. Flow length, L (total L <= 300 feet)	ft	45				
4. Two-year, 24-hour rainfall, P2	in	2.3				
5. Land slope, s	ft/ft	0.333				
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	Compute Tt hr	0.033			=	0.03

Shallow Concentrated Flow

	Segment ID					
7. Surface description (paved or unpaved)						
8. Flow length, L	ft					
9. Watercourse slope	ft/ft					
10. Average velocity, V (figure 3-1)	ft/sec					
11. Tt= L/(3600*V)	Compute Tt hr				=	

Channel Flow

	Segment ID	BC				
12. Cross sectional area, a	ft²	6.34				
13. Wetted Perimeter, Pw	ft	7.96				
14. Hydraulic radius, r= (a/Pw)	Compute r ft	0.80				
15. Channel slope, s	ft/ft	0.012				
16. Manning's roughness coefficient, n		0.038				
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	Compute v ft/sec	3.7				
18. Flow length, L	ft	150				
19. Tt= L/(3600*V)	Compute Tt hr	0.011			=	0.01

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)

	hr	=	0.04
Minimum Tt	hr	=	0.10
Use Tt		=	0.10

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

RUST ENVIRONMENT & INFRASTRUCTURE

Time of Concentration (Tc) or travel-time (Tt) Worksheet

Project: Model City RMU-1 By: BPB Date: 07-Jul-97

Location: Model City, NY Chk: HKK Date: 08/01/97

Underline one: Present Developed Area 8

Underline one: Tc Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)

		Segment ID				
1. Surface description (Table 3-1)		AB				
2. Manning's roughness coefficient, n (Table 3-1)		Short Grass				
3. Flow length, L (total L <= 300 feet)	ft	0.15				
4. Two-year, 24-hour rainfall, P2	in	40				
5. Land slope, s	ft/ft	2.3				
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	Compute Tt hr	0.333				
		0.030			=	0.03

Shallow Concentrated Flow

		Segment ID				
7. Surface description (paved or unpaved)						
8. Flow length, L	ft					
9. Watercourse slope	ft/ft					
10. Average velocity, V (figure 3-1)	ft/sec					
11. Tt= L/(3600*V)	Compute Tt hr				=	

Channel Flow

		Segment ID				
		BC				
12. Cross sectional area, a	ft²	6.34				
13. Wetted Perimeter, Pw	ft	7.96				
14. Hydraulic radius, r= (a/Pw)	Compute r ft	0.80				
15. Channel slope, s	ft/ft	0.012				
16. Manning's roughness coefficient, n		0.038				
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	Compute v ft/sec	3.7				
18. Flow length, L	ft	555				
19. Tt= L/(3600*V)	Compute Tt hr	0.042			=	0.04

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)

	hr	=	0.07
Minimum Tt	hr	=	0.10
Use Tt		=	0.10

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

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TIME OF CONCENTRATION CALCULATOR
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::


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Segment #1:  Tc: TR-55 Sheet

Mannings n          .1500
Hydraulic Length   100.00 ft
2yr, 24hr P        2.3000 in
Slope             .050000 ft/ft

Avg.Velocity          .21 ft/sec

                                        Segment #1 Time:     .1335 hrs
------------------------------------------------------------------------

Segment #2:  Tc: TR-55 Shallow

Hydraulic Length   442.00 ft
Slope             .050000 ft/ft
Unpaved

Avg.Velocity         3.61 ft/sec

                                        Segment #2 Time:     .0340 hrs
------------------------------------------------------------------------

Segment #3:  Tc: TR-55 Shallow

Hydraulic Length    62.00 ft
Slope             .330000 ft/ft
Unpaved

Avg.Velocity         9.27 ft/sec

                                        Segment #3 Time:     .0019 hrs
------------------------------------------------------------------------

                                              =========================
                                               Total Tc:     .1694 hrs
                                              =========================
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RUST ENVIRONMENT & INFRASTRUCTURE

Time of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 By: JPD Date: 02-Feb-99

Location: Model City, NY Chk: Km Date: 2/2/99

Underline one: Present Developed Area 10

Underline one: Tc Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)

		Segment ID	AB				
1.	Surface description (Table 3-1)		Short Grass				
2.	Manning's roughness coefficient, n (Table 3-1)		0.15				
3.	Flow length, L (total L <= 300 feet)	ft	100				
4.	Two-year, 24-hour rainfall, P2	in	2.3				
5.	Land slope, s	ft/ft	0.050				
6.	Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	Compute Tt hr	0.134			=	0.13

Shallow Concentrated Flow

		Segment ID	BC	CD			
7.	Surface description (paved or unpaved)		Unpaved	Unpaved			
8.	Flow length, L	ft	40	70			
9.	Watercourse slope	ft/ft	0.05	0.333			
10.	Average velocity, V (figure 3-1)	ft/sec	3.6	9.3			
	Tt= L/(3600*V)	Compute Tt hr	0.003	0.002		=	0.01

Channel Flow

		Segment ID	DE				
12.	Cross sectional area, a	ft²	22.50				
13.	Wetted Perimeter, Pw	ft	16.20				
14.	Hydraulic radius, r= (a/Pw)	Compute r ft	1.40				
15.	Channel slope, s	ft/ft	0.0100				
16.	Manning's roughness coefficient, n		0.038				
17.	v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	Compute v ft/sec	4.9				
18.	Flow length, L	ft	1600				
19.	Tt= L/(3600*V)	Compute Tt hr	0.091			=	0.09

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)

	hr	=	0.23
Minimum Tt	hr	=	0.10
Use Tt		=	0.23

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

RUST ENVIRONMENT & INFRASTRUCTURE

'ime ~~of~~ Concentration (Tc) or travel time (Tt) Worksheet

Project:	Model City RMU-1	By: BPB	Date: 07-Jul-97
Location:	Model City, NY	Chk: HKK	Date: 08/01/97
Underline one:	Present Developed	Area 11	
Underline one:	Tc Tt through subarea		

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)

		Segment ID	AB			
1. Surface description (Table 3-1)			Short Grass			
2. Manning's roughness coefficient, n (Table 3-1)			0.15			
3. Flow length, L (total L <= 300 feet)	ft		65			
4. Two-year, 24-hour rainfall, P2	in		2.3			
5. Land slope, s	ft/ft		0.333			
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	hr	Compute Tt	0.044			= 0.04

Shallow Concentrated Flow

		Segment ID				
7. Surface description (paved or unpaved)						
8. Flow length, L	ft					
9. Watercourse slope	ft/ft					
10. Average velocity, V (figure 3-1)	ft/sec					
11. Tt= L/(3600*V)	hr	Compute Tt				=

Channel Flow

		Segment ID	BC			
12. Cross sectional area, a	ft²		22.50			
13. Wetted Perimeter, Pw	ft		16.20			
14. Hydraulic radius, r= (a/Pw)	ft	Compute r	1.40			
15. Channel slope, s	ft/ft		0.010			
16. Manning's roughness coefficient, n			0.038			
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	ft/sec	Compute v	4.9			
18. Flow length, L	ft		1710			
19. Tt= L/(3600*V)	hr	Compute Tt	0.097			= 0.10

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19) hr = 0.14

Minimum Tt hr = 0.10

Use Tt = 0.14

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

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TIME OF CONCENTRATION CALCULATOR
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Segment #1:  Tc: TR-55 Sheet

Mannings n           .1500
Hydraulic Length    89.00 ft
2yr, 24hr P        2.3000 in
Slope            .330000 ft/ft

Avg.Velocity          .43 ft/sec

                                         Segment #1 Time:     .0572 hrs
------------------------------------------------------------------------

Segment #2:  Tc: Length & Vel.

Hydraulic Length   380.00 ft
Avg.Velocity         3.00 ft/sec

                                         Segment #2 Time:     .0352 hrs
------------------------------------------------------------------------

                                               =========================
                                                Total Tc:     .0924 hrs

                                                Calculated Tc < Min.Tc:
                                                Use Minimum Tc...
                                                Use Tc =      .1000 hrs
                                               =========================
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RUST ENVIRONMENT & INFRASTRUCTURE

'ime of Concentration (Tc) or travel time (Tt) Worksheet

Project:	Model City RMU-1	By:	BPB	Date:	07-Jul-97
Location:	Model City, NY	Chk:	HKK	Date:	08/01/97
Underline one:	Present	Developed	Area 13		
Underline one:	Tc	Tt through subarea			

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)		Segment ID	AB				
1. Surface description (Table 3-1)			Short Grass				
2. Manning's roughness coefficient, n (Table 3-1)			0.15				
3. Flow length, L (total L <= 300 feet)	ft		100				
4. Two-year, 24-hour rainfall, P2	in		2.3				
5. Land slope, s	ft/ft		0.333				
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	hr	Compute Tt	0.063				= 0.06

Shallow Concentrated Flow		Segment ID					
7. Surface description (paved or unpaved)							
8. Flow length, L	ft						
9. Watercourse slope	ft/ft						
10. Average velocity, V (figure 3-1)	ft/sec						
11. Tt= L/(3600*V)	hr	Compute Tt					=

Channel Flow		Segment ID	BC				
12. Cross sectional area, a	ft²		6.34				
13. Wetted Perimeter, Pw	ft		7.96				
14. Hydraulic radius, r= (a/Pw)	ft	Compute r	0.80				
15. Channel slope, s	ft/ft		0.005				
16. Manning's roughness coefficient, n			0.038				
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	ft/sec	Compute v	2.4				
18. Flow length, L	ft		1045				
19. Tt= L/(3600*V)	hr	Compute Tt	0.121				= 0.12

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)	hr	=	0.18
Minimum Tt	hr	=	0.10
Use Tt		=	0.18

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

RUST ENVIRONMENT & INFRASTRUCTURE

Time of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 By: JPD Date: 02-Feb-99

Location: Model City, NY Chk: Km Date: 2/2/99

Underline one: Present Developed Area 14

Underline one: Tc Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)		Segment ID	AB				
1. Surface description (Table 3-1)			Short Grass				
2. Manning's roughness coefficient, n (Table 3-1)			0.15				
3. Flow length, L (total L <= 300 feet)	ft		70				
4. Two-year, 24-hour rainfall, P2	in		2.3				
5. Land slope, s	ft/ft		0.333				
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]		Compute Tt hr	0.047			=	0.05

Shallow Concentrated Flow		Segment ID					
7. Surface description (paved or unpaved)							
8. Flow length, L	ft						
9. Watercourse slope	ft/ft						
10. Average velocity, V (figure 3-1)	ft/sec						
Tt= L/(3600*V)		Compute Tt hr				=	

Channel Flow		Segment ID	BC				
12. Cross sectional area, a	ft²		6.34				
13. Wetted Perimeter, Pw	ft		7.96				
14. Hydraulic radius, r= (a/Pw)	ft	Compute r	0.80				
15. Channel slope, s	ft/ft		0.0300				
16. Manning's roughness coefficient, n			0.038				
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	ft/sec	Compute v	5.8				
18. Flow length, L	ft		735				
19. Tt= L/(3600*V)		Compute Tt hr	0.035			=	0.04

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)

	hr	=	0.09
Minimum Tt	hr	=	0.10
Use Tt		=	0.10

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

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TIME OF CONCENTRATION CALCULATOR
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Segment #1:  Tc: TR-55 Sheet

Mannings n          .1500
Hydraulic Length    68.00 ft
2yr, 24hr P        2.3000 in
Slope            .330000 ft/ft

Avg.Velocity          .41 ft/sec

                                        Segment #1 Time:     .0461 hrs
------------------------------------------------------------------------

Segment #2:  Tc: Length & Vel.

Hydraulic Length   262.00 ft
Avg.Velocity         3.00 ft/sec

                                        Segment #2 Time:     .0243 hrs
------------------------------------------------------------------------

                                              =========================
                                               Total Tc:     .0704 hrs

                                               Calculated Tc < Min.Tc:
                                               Use Minimum Tc...
                                               Use Tc =      .1000 hrs
                                              =========================
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RUST ENVIRONMENT & INFRASTRUCTURE

Time of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 | By: BPB | Date: 07-Jul-97

Location: Model City, NY | Chk: HKK | Date: 08/01/97

Underline one: Present | Developed | Area 16

Underline one: Tc | Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)

	Segment ID		AB			
1. Surface description (Table 3-1)			Short Grass			
2. Manning's roughness coefficient, n (Table 3-1)			0.15			
3. Flow length, L (total L <= 300 feet)		ft	100			
4. Two-year, 24-hour rainfall, P2		in	2.3			
5. Land slope, s		ft/ft	0.333			
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	Compute Tt	hr	0.063			= 0.06

Shallow Concentrated Flow

	Segment ID					
7. Surface description (paved or unpaved)						
8. Flow length, L		ft				
9. Watercourse slope		ft/ft				
10. Average velocity, V (figure 3-1)		ft/sec				
11. Tt= L/(3600*V)	Compute Tt	hr				=

Channel Flow

	Segment ID		BC			
12. Cross sectional area, a		ft²	6.34			
13. Wetted Perimeter, Pw		ft	7.96			
14. Hydraulic radius, r= (a/Pw)	Compute r	ft	0.80			
15. Channel slope, s		ft/ft	0.025			
16. Manning's roughness coefficient, n			0.038			
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	Compute v	ft/sec	5.3			
18. Flow length, L		ft	210			
19. Tt= L/(3600*V)	Compute Tt	hr	0.011			= 0.01

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19) hr = 0.07

Minimum Tt hr = 0.10

Use Tt = 0.10

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

RUST ENVIRONMENT & INFRASTRUCTURE

Time of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 By: BPB Date: 07-Jul-97

Location: Model City, NY Chk: HKK Date: 08/01/97

Underline one: Present Developed Area 17

Underline one: Tc Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)

	Segment ID	AB					
1. Surface description (Table 3-1)		Short Grass					
2. Manning's roughness coefficient, n (Table 3-1)		0.15					
3. Flow length, L (total L <= 300 feet)	ft	105					
4. Two-year, 24-hour rainfall, P2	in	2.3					
5. Land slope, s	ft/ft	0.333					
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	Compute Tt hr	0.065				=	0.07

Shallow Concentrated Flow

	Segment ID						
7. Surface description (paved or unpaved)							
8. Flow length, L	ft						
9. Watercourse slope	ft/ft						
10. Average velocity, V (figure 3-1)	ft/sec						
11. Tt= L/(3600*V)	Compute Tt hr					=	

Channel Flow

	Segment ID	BC					
12. Cross sectional area, a	ft²	6.34					
13. Wetted Perimeter, Pw	ft	7.96					
14. Hydraulic radius, r= (a/Pw)	Compute r ft	0.80					
15. Channel slope, s	ft/ft	0.005					
16. Manning's roughness coefficient, n		0.038					
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	Compute v ft/sec	2.4					
18. Flow length, L	ft	470					
19. Tt= L/(3600*V)	Compute Tt hr	0.054				=	0.05

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)	hr	=	0.12
	Minimum Tt hr	=	0.10
	Use Tt	=	0.12

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

RUST ENVIRONMENT & INFRASTRUCTURE

Time of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 By: BPB Date: 07-Jul-97

Location: Model City, NY Chk: HKK Date: 07/01/97

Underline one: Present Developed Area 18

Underline one: Tc Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)							
	Segment ID	AB					
1. Surface description (Table 3-1)		Short Grass					
2. Manning's roughness coefficient, n (Table 3-1)		0.15					
3. Flow length, L (total L <= 300 feet)	ft	105					
4. Two-year, 24-hour rainfall, P2	in	2.3					
5. Land slope, s	ft/ft	0.333					
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	Compute Tt hr	0.065				=	0.07

Shallow Concentrated Flow							
	Segment ID						
7. Surface description (paved or unpaved)							
8. Flow length, L	ft						
9. Watercourse slope	ft/ft						
10. Average velocity, V (figure 3-1)	ft/sec						
11. Tt= L/(3600*V)	Compute Tt hr					=	

Channel Flow							
	Segment ID	BC					
12. Cross sectional area, a	ft^2	6.34					
13. Wetted Perimeter, Pw	ft	7.96					
14. Hydraulic radius, r= (a/Pw)	Compute r ft	0.80					
15. Channel slope, s	ft/ft	0.005					
16. Manning's roughness coefficient, n		0.038					
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	Compute v ft/sec	2.4					
18. Flow length, L	ft	605					
19. Tt= L/(3600*V)	Compute Tt hr	0.07				=	0.07

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)	hr	=	0.14
	Minimum Tt hr	=	0.10
	Use Tt	=	0.14

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

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TIME OF CONCENTRATION CALCULATOR
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Segment #1:  Tc: TR-55 Sheet

Mannings n          .1500
Hydraulic Length   100.00 ft
2yr, 24hr P        2.3000 in
Slope             .050000 ft/ft

Avg.Velocity          .21 ft/sec

                                         Segment #1 Time:     .1335 hrs
------------------------------------------------------------------------

Segment #2:  Tc: TR-55 Shallow

Hydraulic Length   315.00 ft
Slope             .050000 ft/ft
Unpaved

Avg.Velocity         3.61 ft/sec

                                         Segment #2 Time:     .0243 hrs
------------------------------------------------------------------------

Segment #3:  Tc: Length & Vel.

Hydraulic Length   655.00 ft
Avg.Velocity         3.00 ft/sec

                                         Segment #3 Time:     .0606 hrs
------------------------------------------------------------------------

                                               =========================
                                                Total Tc:     .2184 hrs
                                               =========================
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TIME OF CONCENTRATION CALCULATOR
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Segment #1:  Tc: TR-55 Sheet

Mannings n           .1500
Hydraulic Length    87.00 ft
2yr, 24hr P        2.3000 in
Slope            .330000 ft/ft

Avg.Velocity          .43 ft/sec

                                         Segment #1 Time:     .0561 hrs
------------------------------------------------------------------------

Segment #2:  Tc: Length & Vel.

Hydraulic Length   225.00 ft
Avg.Velocity         3.00 ft/sec

                                         Segment #2 Time:     .0208 hrs
------------------------------------------------------------------------

                                                 =========================
                                                  Total Tc:     .0770 hrs

                                                  Calculated Tc < Min.Tc:
                                                  Use Minimum Tc...
                                                  Use Tc =      .1000 hrs
                                                 =========================
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RUST ENVIRONMENT & INFRASTRUCTURE

Time of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 By: JPD Date: 02-Feb-99

Location: Model City, NY Chk: [illegible] Date: 2/2/99

Underline one: Present **Developed** Area 21

Underline one: **Tc** Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)

	Unit	Segment ID AB		
1. Surface description (Table 3-1)		Short Grass		
2. Manning's roughness coefficient, n (Table 3-1)		0.15		
3. Flow length, L (total L <= 300 feet)	ft	100		
4. Two-year, 24-hour rainfall, P2	in	2.3		
5. Land slope, s	ft/ft	0.050		
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	Compute Tt hr	0.134	=	0.13

Shallow Concentrated Flow

	Unit	Segment ID BC		
7. Surface description (paved or unpaved)		Unpaved		
8. Flow length, L	ft	40		
9. Watercourse slope	ft/ft	0.05		
10. Average velocity, V (figure 3-1)	ft/sec	3.6		
Tt= L/(3600*V)	Compute Tt hr	0.003	=	

Channel Flow

	Unit	Segment ID CD		
12. Cross sectional area, a	ft²	22.50		
13. Wetted Perimeter, Pw	ft	16.20		
14. Hydraulic radius, r= (a/Pw)	Compute r ft	1.40		
15. Channel slope, s	ft/ft	0.0100		
16. Manning's roughness coefficient, n		0.038		
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	Compute v ft/sec	4.9		
18. Flow length, L	ft	700		
19. Tt= L/(3600*V)	Compute Tt hr	0.04	=	0.04

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)

	hr	=	0.17
Minimum Tt	hr	=	0.10
Use Tt		=	0.17

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project CWM CHEMICAL SERVICES By TAS Date 12/03

Location MODEL CITY, NY Checked ____ Date ____

Circle one: Present Developed

Circle one: T_c T_t through subarea P1 MODIFIED

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

		Segment ID	AB		
1.	Surface description (table 3-1)		GRASS		
2.	Manning's roughness coeff., n (table 3-1)		0.15		
3.	Flow length, L (total L $\leq$ ~~300~~ 150 ft)	ft	30		
4.	Two-yr 24-hr rainfall, P_2	in	2.3		
5.	Land slope, s	ft/ft	0.50		
6.	$T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr	0.020	+	= 0.020

Shallow concentrated flow

		Segment ID			
7.	Surface description (paved or unpaved)				
8.	Flow length, L	ft			
9.	Watercourse slope, s	ft/ft			
10.	Average velocity, V (figure 3-1)	ft/s			
11.	$T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

Channel flow

		Segment ID	BC	CD	
12.	Cross sectional flow area, a	ft^2	8.00	8.00	
13.	Wetted perimeter, p_w	ft	8.94	8.94	
14.	Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft	0.90	0.90	
15.	Channel slope, s	ft/ft	0.0015	0.0078	
16.	Manning's roughness coeff., n		0.038	0.038	
17.	$V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	1.42	3.23	
18.	Flow length, L	ft	411	256	
19.	$T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.080	+ 0.022	= 0.102
20.	Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			0.122

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project CWM CHEMICAL SERVICES By TAS Date 1/2/03

Location MODEL CITY, NY Checked ____ Date ____

Circle one: Present Developed

Circle one: T_c T_t through subarea P2

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

		Segment ID	AB		
1.	Surface description (table 3-1)		GRASS		
2.	Manning's roughness coeff., n (table 3-1) ..		0.15		
3.	Flow length, L (total L $\leq$ ~~300~~ 150 ft)	ft	21		
4.	Two-yr 24-hr rainfall, P_2	in	2.3		
5.	Land slope, s	ft/ft	0.50		
6.	$T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr	0.015	+	= 0.015

Shallow concentrated flow

		Segment ID			
7.	Surface description (paved or unpaved)				
8.	Flow length, L	ft			
9.	Watercourse slope, s	ft/ft			
10.	Average velocity, V (figure 3-1)	ft/s			
11.	$T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

Channel flow

		Segment ID	BC		
12.	Cross sectional flow area, a	ft^2	12.00		
13.	Wetted perimeter, p_w	ft	10.94		
14.	Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft	1.10		
15.	Channel slope, s	ft/ft	0.0026		
16.	Manning's roughness coeff., n		0.038		
17.	$V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	2.08		
18.	Flow length, L	ft	150		
19.	$T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.020	+	= 0.020

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.035

∴ USE MIN. T_c = 0.10 HR.

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project CWM CHEMICAL SERVICES By BMS Date 5/14/02

Location MODEL CITY, NY Checked ____ Date ____

Circle one: Present Developed

Circle one: T_c T_t through subarea P3

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

		Segment ID	AB		
1.	Surface description (table 3-1)		GRASS		
2.	Manning's roughness coeff., n (table 3-1) ..		0.15		
3.	Flow length, L (total L $\leq$ 300 ft)	ft	36		
4.	Two-yr 24-hr rainfall, P_2	in	2.3		
5.	Land slope, s	ft/ft	0.50		
6.	$T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr	0.023	+	= 0.023

Shallow concentrated flow

		Segment ID			
7.	Surface description (paved or unpaved)				
8.	Flow length, L	ft			
9.	Watercourse slope, s	ft/ft			
10.	Average velocity, V (figure 3-1)	ft/s			
11.	$T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

Channel flow

		Segment ID	BC		
12.	Cross sectional flow area, a	ft^2	12.00		
13.	Wetted perimeter, P_w	ft	10.94		
14.	Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft	1.10		
15.	Channel slope, s	ft/ft	0.0025		
16.	Manning's roughness coeff., n		0.038		
17.	$V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	2.08		
18.	Flow length, L	ft	155		
19.	$T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.021	+	= 0.021

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.044

∴ USE MINIMUM
T_c = 0.10 hr

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project CWM CHEMICAL SERVICES By BMS Date 5/14/02

Location MODEL CITY, NY Checked ____ Date ____

Circle one: Present Developed

Circle one: T_c T_t through subarea P4

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

	Segment ID	AB		
1. Surface description (table 3-1)		GRASS		
2. Manning's roughness coeff., n (table 3-1) ..		0.15		
3. Flow length, L (total L ≤ 300 ft)	ft	36		
4. Two-yr 24-hr rainfall, P_2	in	2.3		
5. Land slope, s	ft/ft	0.50		
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr	0.023	+	= 0.023

Shallow concentrated flow

	Segment ID			
7. Surface description (paved or unpaved)				
8. Flow length, L	ft			
9. Watercourse slope, s	ft/ft			
10. Average velocity, V (figure 3-1)	ft/s			
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+	=

Channel flow

	Segment ID	BG		
12. Cross sectional flow area, a	ft^2	12.00		
13. Wetted perimeter, p_w	ft	10.94		
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft	1.10		
15. Channel slope, s	ft/ft	0.0025		
16. Manning's roughness coeff., n		0.038		
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V	ft/s	2.08		
18. Flow length, L	ft	146		
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	0.019	+	= 0.019

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.042

∴ USE MINIMUM $T_c = 0.10$ hr

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project CWM CHEMICAL SERVICES By BMS Date 5/14/02

Location MODEL CITY, NY Checked ____ Date ____

Circle one: Present Developed

Circle one: T_c T_t through subarea P5

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

		Unit			
	Segment ID		AB		
1.	Surface description (table 3-1)		GRASS		
2.	Manning's roughness coeff., n (table 3-1) ..		0.15		
3.	Flow length, L (total L $\leq$ 300 ft)	ft	36		
4.	Two-yr 24-hr rainfall, P_2	in	2.3		
5.	Land slope, s	ft/ft	0.50		
6.	$T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{\ 0.5}\ s^{0.4}}$ Compute T_t	hr	0.023	+	= 0.023

Shallow concentrated flow

		Unit			
	Segment ID				
7.	Surface description (paved or unpaved)				
8.	Flow length, L	ft			
9.	Watercourse slope, s	ft/ft			
10.	Average velocity, V (figure 3-1)	ft/s			
11.	$T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

Channel flow

		Unit			
	Segment ID		BC		
12.	Cross sectional flow area, a	ft^2	12.00		
13.	Wetted perimeter, p_w	ft	10.94		
14.	Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft	1.10		
15.	Channel slope, s	ft/ft	0.0025		
16.	Manning's roughness coeff., n		0.038		
17.	$V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	2.08		
18.	Flow length, L	ft	149		
19.	$T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.020	+	= 0.020

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.043

∴ USE MINIMUM
T_c = 0.10 hr

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project CWM CHEMICAL SERVICES By BMS Date 5/14/02

Location MODEL CITY, NY Checked ______ Date ______

Circle one: Present Developed

Circle one: T_c T_t through subarea P6

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)	Units	Segment 1	Segment 2	Total
Segment ID		AB		
1. Surface description (table 3-1)		GRASS		
2. Manning's roughness coeff., n (table 3-1) ..		0.15		
3. Flow length, L (total L $\leq$ 300 ft)	ft	35		
4. Two-yr 24-hr rainfall, P_2	in	2.3		
5. Land slope, s	ft/ft	0.50		
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr	0.023	+	= 0.023

Shallow concentrated flow	Units	Segment 1	Segment 2	Total
Segment ID				
7. Surface description (paved or unpaved)				
8. Flow length, L	ft			
9. Watercourse slope, s	ft/ft			
10. Average velocity, V (figure 3-1)	ft/s			
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

Channel flow	Units	Segment 1	Segment 2	Total
Segment ID		BC		
12. Cross sectional flow area, a	ft^2	12.00		
13. Wetted perimeter, P_w	ft	10.94		
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft	1.10		
15. Channel slope, s	ft/ft	0.0025		
16. Manning's roughness coeff., n		0.038		
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	2.08		
18. Flow length, L	ft	153		
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.020	+	= 0.020
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			0.043

∴ USE MINIMUM T_c = 0.10 hr

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project CWM Chemical Services By BMS Date 5/14/02

Location Model City, NY Checked ____ Date ____

Circle one: Present Developed

Circle one: T_c T_t through subarea P7

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

		Segment ID	AB		
1.	Surface description (table 3-1)		Grass		
2.	Manning's roughness coeff., n (table 3-1) ..		0.15		
3.	Flow length, L (total L $\leq$ 300 ft)	ft	30		
4.	Two-yr 24-hr rainfall, P_2	in	2.3		
5.	Land slope, s	ft/ft	0.50		
6.	$T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr	0.020	+	= 0.020

Shallow concentrated flow

		Segment ID			
7.	Surface description (paved or unpaved)				
8.	Flow length, L	ft			
9.	Watercourse slope, s	ft/ft			
10.	Average velocity, V (figure 3-1)	ft/s			
11.	$T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

Channel flow

		Segment ID	BC		
12.	Cross sectional flow area, a	ft^2	12.00		
13.	Wetted perimeter, p_w	ft	10.94		
14.	Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft	1.10		
15.	Channel slope, s	ft/ft	0.0025		
16.	Manning's roughness coeff., n		0.038		
17.	$V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	2.08		
18.	Flow length, L	ft	148.		
19.	$T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.020	+	= 0.020

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.040

∴ Use minimum $T_c = 0.10$ hr

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project CWM CHEMICAL SERVICES By BMS Date 5/14/07

Location MODEL CITY, NY Checked _____ Date _____

Circle one: Present **Developed**

Circle one: **T_c** T_t through subarea P8

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

	Unit	Segment ID AB		
1. Surface description (table 3-1)		GRASS		
2. Manning's roughness coeff., n (table 3-1)		0.15		
3. Flow length, L (total L $\leq$ 300 ft)	ft	30		
4. Two-yr 24-hr rainfall, P_2	in	2.3		
5. Land slope, s	ft/ft	0.50		
6. $T_t = \frac{0.007 (nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t	hr	0.020	+	= 0.020

Shallow concentrated flow

	Unit	Segment ID		
7. Surface description (paved or unpaved)				
8. Flow length, L	ft			
9. Watercourse slope, s	ft/ft			
10. Average velocity, V (figure 3-1)	ft/s			
11. $T_t = \frac{L}{3600 V}$ Compute T_t	hr		+	=

Channel flow

	Unit	Segment ID BC		
12. Cross sectional flow area, a	ft^2	12.00		
13. Wetted perimeter, P_w	ft	10.94		
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft	1.10		
15. Channel slope, s	ft/ft	0.0025		
16. Manning's roughness coeff., n		0.038		
17. $V = \frac{1.49 r^{2/3} s^{1/2}}{n}$ Compute V	ft/s	2.08		
18. Flow length, L	ft	145		
19. $T_t = \frac{L}{3600 V}$ Compute T_t	hr	0.019	+	= 0.019

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.039

∴ USE MINIMUM T_c = 0.10 hr

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project CWM CHEMICAL SERVICES By BMS Date 5/14/02

Location MODEL CITY, NY Checked ____ Date ____

Circle one: Present Developed

Circle one: T_c T_t through subarea P9

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

Segment ID		AB			
1. Surface description (table 3-1)		GRASS			
2. Manning's roughness coeff., n (table 3-1) ..		0.15			
3. Flow length, L (total L $\leq$ 300 ft)	ft	14			
4. Two-yr 24-hr rainfall, P_2	in	2.3			
5. Land slope, s	ft/ft	0.50			
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr	0.011	+		= 0.011

Shallow concentrated flow

Segment ID					
7. Surface description (paved or unpaved)					
8. Flow length, L	ft				
9. Watercourse slope, s	ft/ft				
10. Average velocity, V (figure 3-1)	ft/s				
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+		=

Channel flow

Segment ID		BC			
12. Cross sectional flow area, a	ft^2	12.00			
13. Wetted perimeter, P_w	ft	10.94			
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft	1.10			
15. Channel slope, s	ft/ft	0.0025			
16. Manning's roughness coeff., n		0.038			
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	2.08			
18. Flow length, L	ft	1060			
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.142	+		= 0.142

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.153

RUST ENVIRONMENT & INFRASTRUCTURE

ʻime of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 By: BPB Date: 07-Jul-97

Location: Model City, NY Chk: HTK Date: 08/01/97

Underline one: Present Developed Area P10

Underline one: Tc Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)							
	Segment ID	AB					
1. Surface description (Table 3-1)		Short Grass					
2. Manning's roughness coefficient, n (Table 3-1)		0.15					
3. Flow length, L (total L <= 300 feet)	ft	12					
4. Two-year, 24-hour rainfall, P2	in	2.3					
5. Land slope, s	ft/ft	0.500					
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	Compute Tt hr	0.010				=	0.01

Shallow Concentrated Flow							
	Segment ID						
7. Surface description (paved or unpaved)							
8. Flow length, L	ft						
9. Watercourse slope	ft/ft						
10. Average velocity, V (figure 3-1)	ft/sec						
11. Tt= L/(3600*V)	Compute Tt hr					=	

Channel Flow								
		Segment ID	BC					
12. Cross sectional area, a		ft²	8.00					
13. Wetted Perimeter, Pw		ft	8.94					
14. Hydraulic radius, r= (a/Pw)	Compute r	ft	0.90					
15. Channel slope, s		ft/ft	0.005					
16. Manning's roughness coefficient, n			0.038					
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	Compute v	ft/sec	2.6					
18. Flow length, L		ft	945					
19. Tt= L/(3600*V)		Compute Tt hr	0.101				=	0.10

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)	hr	=	0.11
	Minimum Tt hr	=	0.10
	Use Tt	=	0.11

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

RUST ENVIRONMENT & INFRASTRUCTURE

Time of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 By: BPB Date: 07-Jul-97

Location: Model City, NY Chk: HKK Date: 08/01/97

Underline one: Present Developed Area P11

Underline one: Tc Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)

		Segment ID	AB					
1. Surface description (Table 3-1)			Short Grass					
2. Manning's roughness coefficient, n (Table 3-1)			0.15					
3. Flow length, L (total L <= 300 feet)		ft	30					
4. Two-year, 24-hour rainfall, P2		in	2.3					
5. Land slope, s		ft/ft	0.500					
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	Compute Tt	hr	0.020				=	0.02

Shallow Concentrated Flow

		Segment ID						
7. Surface description (paved or unpaved)								
8. Flow length, L		ft						
9. Watercourse slope		ft/ft						
10. Average velocity, V (figure 3-1)		ft/sec						
11. Tt= L/(3600*V)	Compute Tt	hr					=	

Channel Flow

		Segment ID	BC					
12. Cross sectional area, a		ft²	8.00					
13. Wetted Perimeter, Pw		ft	8.94					
14. Hydraulic radius, r= (a/Pw)	Compute r	ft	0.90					
15. Channel slope, s		ft/ft	0.002					
16. Manning's roughness coefficient, n			0.038					
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	Compute v	ft/sec	1.6					
18. Flow length, L		ft	435					
19. Tt= L/(3600*V)	Compute Tt	hr	0.076				=	0.08

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)

	hr	=	0.10
Minimum Tt	hr	=	0.10
Use Tt		=	0.10

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

RUST ENVIRONMENT & INFRASTRUCTURE

·ime of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City RMU-1 By: BPB Date: 07-Jul-97

Location: Model City, NY Chk: HKK Date: 08/01/97

Underline one: Present Developed Area P12

Underline one: Tc Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)		Segment ID	AB					
1. Surface description (Table 3-1)			Short Grass					
2. Manning's roughness coefficient, n (Table 3-1)			0.15					
3. Flow length, L (total L <= 300 feet)		ft	50					
4. Two-year, 24-hour rainfall, P2		in	2.3					
5. Land slope, s		ft/ft	0.500					
6. Tt= [0.007 × (nL)^0.8] / [(P2^0.5) × (s^0.4)]	Compute Tt	hr	0.031				=	0.03

Shallow Concentrated Flow		Segment ID						
7. Surface description (paved or unpaved)								
8. Flow length, L		ft						
·. Watercourse slope		ft/ft						
·0. Average velocity, V (figure 3-1)		ft/sec						
11. Tt= L/(3600*V)	Compute Tt	hr					=	

Channel Flow		Segment ID	BC					
12. Cross sectional area, a		ft²	20.00					
13. Wetted Perimeter, Pw		ft	14.90					
14. Hydraulic radius, r= (a/Pw)	Compute r	ft	1.30					
15. Channel slope, s		ft/ft	0.002					
16. Manning's roughness coefficient, n			0.038					
17. v = {[(1.49 × r^(0.67) × s^(0.5)] / n}	Compute v	ft/sec	2.1					
18. Flow length, L		ft	725					
19. Tt= L/(3600*V)	Compute Tt	hr	0.096				=	0.10

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)		hr	=	0.13
	Minimum Tt	hr	=	0.10
	Use Tt		=	0.13

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project CWM CHEMICAL SERVICES By BMS Date 5/9/01

Location MODEL CITY, NY Checked ____ Date ____

Circle one: Present Developed

Circle one: T_c T_t through subarea P13 (EAST BASIN)

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

	Segment ID		AB		
1.	Surface description (table 3-1)		GRASS		
2.	Manning's roughness coeff., n (table 3-1)		0.15		
3.	Flow length, L (total L ≤ 300 ft)	ft	7		
4.	Two-yr 24-hr rainfall, P_2	in	2.3		
5.	Land slope, s	ft/ft	0.33		
6.	$T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr	0.007	+	= 0.007

Shallow concentrated flow

	Segment ID				
7.	Surface description (paved or unpaved)				
8.	Flow length, L	ft			
9.	Watercourse slope, s	ft/ft			
10.	Average velocity, V (figure 3-1)	ft/s			
11.	$T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+	= 0

Channel flow

	Segment ID				
12.	Cross sectional flow area, a	ft^2			
13.	Wetted perimeter, p_w	ft			
14.	Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15.	Channel slope, s	ft/ft			
16.	Manning's roughness coeff., n				
17.	$V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V	ft/s			
18.	Flow length, L	ft			
19.	$T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+	= 0

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.007

∴ USE MINIMUM $T_c = 0.10$ hr

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project CWM CHEMICAL SERVICES By BMS Date 5/13/02

Location MODEL CITY, NY Checked ____ Date ____

Circle one: Present Developed A5

Circle one: T_c T_t through subarea P9

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

	Units	Segment ID		
1. Surface description (table 3-1)				
2. Manning's roughness coeff., n (table 3-1)				
3. Flow length, L (total L $\leq$ 300 ft)	ft			
4. Two-yr 24-hr rainfall, P_2	in			
5. Land slope, s	ft/ft			
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr		+	=

Shallow concentrated flow

	Units	Segment ID		
7. Surface description (paved or unpaved)				
8. Flow length, L	ft			
9. Watercourse slope, s	ft/ft			
10. Average velocity, V (figure 3-1)	ft/s			
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

Channel flow

	Units	Segment ID AB		
12. Cross sectional flow area, a	ft^2	12.00		
13. Wetted perimeter, P_w	ft	10.94		
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft	1.10		
15. Channel slope, s	ft/ft	0.0025		
16. Manning's roughness coeff., n		0.038		
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	2.08		
18. Flow length, L	ft	1060		
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.142	+	= 0.142

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.142

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project CWM CHEMICAL SERVICES By BMS Date 5/9/01

Location MODEL CITY, NY Checked ______ Date ______

Circle one: Present Developed A9

Circle one: T_c T_t through subarea A1

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)		Segment ID			
1. Surface description (table 3-1)					
2. Manning's roughness coeff., n (table 3-1) ..					
3. Flow length, L (total L $\leq$ 300 ft)	ft				
4. Two-yr 24-hr rainfall, P_2	in				
5. Land slope, s	ft/ft				
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr		+		=

Shallow concentrated flow		Segment ID			
7. Surface description (paved or unpaved)					
8. Flow length, L	ft				
9. Watercourse slope, s	ft/ft				
10. Average velocity, V (figure 3-1)	ft/s				
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+		=

Channel flow		Segment ID			
		AB			
12. Cross sectional flow area, a	ft^2	9.36			
13. Wetted perimeter, P_w	ft	15.85			
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft	0.59			
15. Channel slope, s	ft/ft	0.01			
16. Manning's roughness coeff., n		0.038			
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	2.8			
18. Flow length, L	ft	400			
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.040	+		= 0.040

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.040

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project CWM CHEMICAL SERVICES By BMS Date 5/13/02

Location MODEL CITY, NY Checked ______ Date ______

Circle one: Present Developed

Circle one: T_c T_t through subarea A16 P9

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)

	Unit	Segment ID		
1. Surface description (table 3-1)				
2. Manning's roughness coeff., n (table 3-1) ..				
3. Flow length, L (total L $\leq$ 300 ft)	ft			
4. Two-yr 24-hr rainfall, P_2	in			
5. Land slope, s	ft/ft			
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr		+	=

Shallow concentrated flow

	Unit	Segment ID		
7. Surface description (paved or unpaved)				
8. Flow length, L	ft			
9. Watercourse slope, s	ft/ft			
10. Average velocity, V (figure 3-1)	ft/s			
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

Channel flow

	Unit	Segment ID AB		
12. Cross sectional flow area, a	ft^2	12.00		
13. Wetted perimeter, p_w	ft	10.94		
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft	1.10		
15. Channel slope, s	ft/ft	0.0025		
16. Manning's roughness coeff., n		0.038		
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s	2.08		
18. Flow length, L	ft	1060		
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.142	+	= 0.142

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.142

II. PEAK FLOWS

C. Peak Flow Calculations

Quick TR-55 Version: 5.46 S/N:

Page 1

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:45:00
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\AREA1.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A1
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A1	1.09	86.0	0.40	0.00	4.00	2.55	I.08	.10
A9	3.42	86.0	0.20	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 4.51 acres or 0.00705 sq.mi
Peak discharge = 13 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A1	0.36	0.00	0.40	0.00	No	Computed Ia/p < .1
A9	0.19	0.02	0.20	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:45:38
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\AREA2.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A2
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A2	5.50	86.0	0.20	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 5.50 acres or 0.00859 sq.mi
Peak discharge = 18 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A2	0.24	0.00	0.20	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 13:48:12
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:AREA3.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A3
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A3	3.70	86.0	0.20	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 3.70 acres or 0.00578 sq.mi
Peak discharge = 12 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A3	0.16	0.00	0.20	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Quick TR-55 Version: 5.46 S/N:

Page 1

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:46:10
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\AREA4.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A4
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A4	2.04	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 2.04 acres or 0.00319 sq.mi
Peak discharge = 8 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	* Tt (hr)	Rounded Values Tc (hr)	* Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A4	0.10	0.00	**	**	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

SCS UNIT HYDROGRAPH METHOD

MODEL CITY RMU-1

Drainage Channel A5
25 Year, 24 Hour Peak Discharge

```
STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = C:\HAESTAD\PPKW\RAINFALL\
Rain File -ID = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir        = X:\TMPROJ\050\ESRB REDESIGN\
HYG File - ID =  - A5 25yr
Tc             = .1600 hrs
Drainage Area = 2.300 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .02133 hrs
Computed Peak Time             =  11.9680 hrs
Computed Peak Flow             =     8.00 cfs

Time Increment for HYG File    =    .0500 hrs
Peak Time, Interpolated Output =  12.0000 hrs
Peak Flow, Interpolated Output =     7.91 cfs
============================================

                DRAINAGE AREA
              -------------------
              ID:None Selected
              CN   =   86
              Area =        2.300 acres
              S    =   1.6279 in
              0.2S =    .3256 in

               Cumulative Runoff
              -------------------
                     2.5463 in
                       .488 ac-ft

HYG Volume...            .488 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .16000 hrs (ID: None Selected)
Computational Incr, Tm =   .02133 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =    .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,           qp =    16.29 cfs
Unit peak time       Tp =   .10667 hrs
Unit receding limb,  Tr =   .42667 hrs
Total unit time,     Tb =   .53333 hrs
```

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 13:48:59
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:AREA6.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A6
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A6	1.25	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 1.25 acres or 0.00195 sq.mi
Peak discharge = 5 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A6	0.11	0.00	0.10	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 13:49:12
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:AREA7.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A7
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A7	0.23	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 0.23 acres or 0.00036 sq.mi
Peak discharge = 1 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A7	0.10	0.00	**	**	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 13:49:25
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:AREA8.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A8
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A8	0.95	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 0.95 acres or 0.00148 sq.mi
Peak discharge = 4 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	* Tt (hr)	Rounded Values Tc (hr)	* Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A8 .	0.10	0.00	**	**	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:47:47
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\AREA9.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A9
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A9	3.43	86.0	0.20	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 3.43 acres or 0.00536 sq.mi
Peak discharge = 11 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A9	0.19	0.00	0.20	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:48:20
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\AREA10.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A10
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A10	6.45	86.0	0.20	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 6.45 acres or 0.01008 sq.mi
Peak discharge = 21 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A10	0.23	0.00	0.20	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 13:50:19
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:AREA11.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A11
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A11	2.87	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 2.87 acres or 0.00448 sq.mi
Peak discharge = 12 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A11	0.14	0.00	0.10	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Quick TR-55 Version: 5.46 S/N:

Page 1
Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:49:15
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\AREA12.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A12
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A12	1.00	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 1.00 acres or 0.00156 sq.mi
Peak discharge = 4 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A12	0.10	0.00	**	**	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 13:53:56
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:AREA13.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A13
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used
A13	3.29	86.0	0.20	0.00	4.00	2.55	I.08 .10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 3.29 acres or 0.00514 sq.mi
Peak discharge = 10 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A13	0.18	0.00	0.20	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Table of Contents

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = C:\HAESTAD\PPKW\RAINFALL\
Rain File -ID  = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type  = Default Curvilinear
HYG Dir        = F:\TMPROJ\050\05042\PERMIT MOD (05042005)\
HYG File - ID  =  - A14 25yr
Tc             = .1000 hrs
Drainage Area  = 1.390 acres  Runoff CN= 86

============================================
Computational Time Increment    =   .01333 hrs
Computed Peak Time              =  11.9333 hrs
Computed Peak Flow              =     5.35 cfs

Time Increment for HYG File     =    .0200 hrs
Peak Time, Interpolated Output  =  11.9401 hrs
Peak Flow, Interpolated Output  =     5.31 cfs
============================================

              DRAINAGE AREA
             -------------------
             ID:None Selected
             CN    =   86
             Area  =       1.390 acres
             S     =   1.6279 in
             0.2S  =    .3256 in

             Cumulative Runoff
             -------------------
                  2.5463 in
                   .295 ac-ft

HYG Volume...          .295 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .10000 hrs (ID: None Selected)
Computational Incr, Tm =   .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =    .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =    15.75 cfs
Unit peak time      Tp =   .06667 hrs
Unit receding limb, Tr =   .26667 hrs
Total unit time,    Tb =   .33333 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = C:\HAESTAD\PPKW\RAINFALL\
Rain File -ID  = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type  = Default Curvilinear
HYG Dir        = F:\TMPROJ\050\05042\PERMIT MOD (05042005)\
HYG File - ID  =  - A8 25yr
Tc             = .1000 hrs
Drainage Area  = .950 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .01333 hrs
Computed Peak Time             =  11.9333 hrs
Computed Peak Flow             =     3.66 cfs

Time Increment for HYG File    =    .0200 hrs
Peak Time, Interpolated Output =  11.9401 hrs
Peak Flow, Interpolated Output =     3.63 cfs
============================================

              DRAINAGE AREA
           -------------------
           ID:None Selected
           CN   =   86
           Area =         .950 acres
           S    =   1.6279 in
           0.2S =    .3256 in

            Cumulative Runoff
           -------------------
                  2.5463 in
                   .202 ac-ft

HYG Volume...            .202 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .10000 hrs (ID: None Selected)
Computational Incr, Tm =   .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =    10.76 cfs
Unit peak time      Tp =   .06667 hrs
Unit receding limb, Tr =   .26667 hrs
Total unit time,    Tb =   .33333 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = C:\HAESTAD\PPKW\RAINFALL\
Rain File -ID  = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type  = Default Curvilinear
HYG Dir        = F:\TMPROJ\050\05042\PERMIT MOD (05042005)\
HYG File - ID  =  - P1 MODIFIED 25yr
Tc             = .1000 hrs
Drainage Area  = .960 acres  Runoff CN= 88

===========================================
Computational Time Increment    =    .01333 hrs
Computed Peak Time              =   11.9333 hrs
Computed Peak Flow              =      3.93 cfs

Time Increment for HYG File     =     .0200 hrs
Peak Time, Interpolated Output  =   11.9201 hrs
Peak Flow, Interpolated Output  =      3.91 cfs
===========================================

              DRAINAGE AREA
            ------------------
            ID:None Selected
            CN    =   88
            Area  =          .960 acres
            S     =   1.3636 in
            0.2S  =    .2727 in

            Cumulative Runoff
            ------------------
                  2.7289 in
                    .218 ac-ft

HYG Volume...              .218 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .10000 hrs (ID: None Selected)
Computational Incr, Tm =   .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

Unit peak,          qp =   10.88 cfs
Unit peak time      Tp =  .06667 hrs
Unit receding limb, Tr =  .26667 hrs
Total unit time,    Tb =  .33333 hrs
```

SUMMARY FOR HYDROGRAPH ADDITION
at Node: CHANNEL P1 MOD.

HYG Directory: F:\TMPROJ\050\05042\PERMIT MOD (05042005)\

Upstream Link ID	Upstream Node ID	HYG file	HYG ID	HYG tag
A 10	A14		A14	25yr
A 20	A8		A8	25yr
A 30	P1 MODIFIED		P1 MODIFIED	25yr

INFLOWS TO: CHANNEL P1 MOD.

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	A14	25yr	.295	11.9200	5.31
	A8	25yr	.202	11.9200	3.63
	P1 MODIFIED	25yr	.218	11.9200	3.91

TOTAL FLOW INTO: CHANNEL P1 MOD.

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	CHANNEL P1 MOD.	25yr	.715	11.9200	12.85

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:50:33
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\AREA15.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A15
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A15	0.79	86.0	0.10	0.00	4.00	2.55	I.08	.10
A20	0.53	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 1.32 acres or 0.00206 sq.mi
Peak discharge = 5 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A15	0.10	0.00	**	**	No	Computed Ia/p < .1
A20	0.10	0.03	0.10	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Quick TR-55 Version: 5.46 S/N:

Page 1
Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 13:54:44
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:AREA16.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A16
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A16	0.46	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 0.46 acres or 0.00072 sq.mi
Peak discharge = 2 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A16	0.10	0.00	**	**	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 13:54:57
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:AREA17.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A17
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A17	1.03	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 1.03 acres or 0.00161 sq.mi
Peak discharge = 4 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A17	0.12	0.00	0.10	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 13:55:12
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:AREA18.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A18
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A18	1.19	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 1.19 acres or 0.00186 sq.mi
Peak discharge = 5 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A18	0.14	0.00	0.10	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Quick TR-55 Version: 5.46 S/N:

Page 1
Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:51:08
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\AREA19.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A19
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A19	2.52	86.0	0.20	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 2.52 acres or 0.00394 sq.mi
Peak discharge = 8 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A19	0.18	0.00	0.20	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:51:38
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\AREA20.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A20
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A20	0.54	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 0.54 acres or 0.00084 sq.mi
Peak discharge = 2 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	* Tt (hr)	Rounded Values Tc (hr)	* Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A20	0.10	0.00	**	**	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:52:09
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\AREA21.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL A21
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A21	2.16	86.0	0.20	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 2.16 acres or 0.00338 sq.mi
Peak discharge = 7 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A21	0.17	0.00	0.20	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:53:25
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\FLUME1.HYD

MODEL CITY RMU-1

DOWNSLOPE FLUME 1
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A1	1.09	86.0	0.40	0.00	4.00	2.55	I.08	.10
A2	5.50	86.0	0.20	0.00	4.00	2.55	I.08	.10
A3	3.70	86.0	0.20	0.00	4.00	2.55	I.08	.10
A4	2.04	86.0	0.10	0.00	4.00	2.55	I.08	.10
A9	3.42	86.0	0.20	0.00	4.00	2.55	I.08	.10
A7	0.23	86.0	0.10	0.00	4.00	2.55	I.08	.10
A21	2.16	86.0	0.20	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 18.14 acres or 0.02834 sq.mi
Peak discharge = 56 cfs

WARNING: Drainage areas of two or more subareas differ by a factor of 5 or greater.

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A1	0.36	0.00	0.40	0.00	No	Computed Ia/p < .1
A2	0.24	0.00	0.20	0.00	No	Computed Ia/p < .1
A3	0.16	0.00	0.20	0.00	No	Computed Ia/p < .1
A4	0.10	0.00	**	**	No	Computed Ia/p < .1
A9	0.19	0.02	0.20	0.00	No	Computed Ia/p < .1
A7	0.10	0.00	**	**	No	Computed Ia/p < .1
A21	0.17	0.00	0.20	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:54:10
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\FLUME2.HYD

MODEL CITY RMU-1

DOWNSLOPE FLUME 2
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A15	0.79	86.0	0.10	0.00	4.00	2.55	I.08	.10
A18	1.19	86.0	0.10	0.00	4.00	2.55	I.08	.10
A19	2.52	86.0	0.20	0.00	4.00	2.55	I.08	.10
A20	0.54	86.0	0.10	0.10	4.00	2.55	I.08	.10
A10	6.15	86.0	0.20	0.00	4.00	2.55	I.08	.10
A11	2.87	86.0	0.10	0.00	4.00	2.55	I.08	.10
A12	1.32	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 15.38 acres or 0.02403 sq.mi
Peak discharge = 51 cfs

WARNING: Drainage areas of two or more subareas differ by a factor of 5 or greater.

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A15	0.10	0.00	**	**	No	Computed Ia/p < .1
A18	0.14	0.00	0.10	0.00	No	Computed Ia/p < .1
A19	0.18	0.00	0.20	0.00	No	Computed Ia/p < .1
A20	0.10	0.05	0.10	0.10	No	Computed Ia/p < .1
A10	0.23	0.00	0.20	0.00	No	Computed Ia/p < .1
A11	0.14	0.00	0.10	0.00	No	Computed Ia/p < .1
A12	0.10	0.00	**	**	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:54:51
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\AREAP1.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL P1
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
P1	2.52	86.0	0.30	0.00	4.00	2.55	I.08	.10
A8	0.95	86.0	0.10	0.30	4.00	2.55	I.08	.10
A14	1.39	86.0	0.10	0.30	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 4.86 acres or 0.00759 sq.mi
Peak discharge = 12 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
P1	0.31	0.00	0.30	0.00	No	Computed Ia/p < .1
A8	0.10	0.29	0.10	0.30	No	Computed Ia/p < .1
A14	0.10	0.29	0.10	0.30	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

```
Type.... SCS Unit Hyd. Summary
Name.... AREA P2                 Tag: 25yr                     Page 1.01
File.... F:\TMPROJ\050\05042\PERMIT MOD (05042005)\P2.PPW    Event: 25 yr
Storm... TypeII  24hr   Tag: 25yr

              SCS UNIT HYDROGRAPH METHOD

              STORM EVENT: 25 year storm
              Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
              Rain Dir       = C:\HAESTAD\PPKW\RAINFALL\
              Rain File -ID = SCSTYPES.RNF - TypeII  24hr
              Unit Hyd Type = Default Curvilinear
              HYG Dir        = F:\TMPROJ\050\05042\PERMIT MOD (05042005)\
              HYG File - ID =  - AREA P2 25yr
              Tc             = .1000 hrs
              Drainage Area = .290 acres  Runoff CN= 87
```

$$= \frac{(0.08_{Ac})(89) + (0.21_{Ac})(86)}{0.29}$$

```
              ==========================================
              Computational Time Increment   =    .01333 hrs
              Computed Peak Time             =   11.9333 hrs
              Computed Peak Flow             =      1.15 cfs

              Time Increment for HYG File    =     .0200 hrs
              Peak Time, Interpolated Output =   11.9201 hrs
              Peak Flow, Interpolated Output =      1.14 cfs
              ==========================================

                        DRAINAGE AREA
                      ------------------
                      ID:None Selected
                      CN    =    87
                      Area =          .290 acres
                      S     =   1.4943 in
                      0.2S =    .2989 in

                       Cumulative Runoff
                      ------------------
                            2.6367 in
                              .064 ac-ft

             HYG Volume...            .064 ac-ft (area under HYG curve)

             ***** UNIT HYDROGRAPH PARAMETERS *****

             Time Concentration, Tc =    .10000 hrs (ID: None Selected)
             Computational Incr, Tm =    .01333 hrs = 0.20000 Tp

             Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
             K =  483.43/645.333,   K =    .7491 (also, K = 2/(1+(Tr/Tp))
             Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

             Unit peak,            qp =     3.29 cfs
             Unit peak time        Tp =   .06667 hrs
             Unit receding limb,   Tr =   .26667 hrs
             Total unit time,      Tb =   .33333 hrs
```

```
Type.... SCS Unit Hyd. Summary                                    Page 1
Name.... P3                   Tag: 25yr                     Event: 25 yr
File.... F:\TMPROJ\050\05004\PERMIT MOD\DRAIN AREA P3.PPW
Storm... TypeII  24hr   Tag: 25yr

          SCS UNIT HYDROGRAPH METHOD

          STORM EVENT: 25 year storm
          Duration        = 24.0000 hrs     Rain Depth = 4.0000 in
          Rain Dir        = C:\HAESTAD\PPKW\RAINFALL\
          Rain File -ID   = SCSTYPES.RNF - TypeII  24hr
          Unit Hyd Type   = Default Curvilinear
          HYG Dir         = F:\TMPROJ\050\05004\PERMIT MOD\
          HYG File - ID   =  - P3 25yr
          Tc              = .1000 hrs
          Drainage Area   = .190 acres  Runoff CN= 87 = (0.04)(89)+(0.15)(86)
                                                              0.19
          ===========================================
          Computational Time Increment   =    .01333 hrs
          Computed Peak Time             =   11.9333 hrs
          Computed Peak Flow             =       .75 cfs

          Time Increment for HYG File    =     .0500 hrs
          Peak Time, Interpolated Output =   11.9500 hrs
          Peak Flow, Interpolated Output =       .74 cfs
          WARNING: The difference between calculated peak flow
          and interpolated peak flow is greater than 1.50%
          ===========================================

                         DRAINAGE AREA
                      -------------------
                      ID:P3
                      CN    =   87
                      Area  =        .190 acres
                      S     =   1.4943 in
                      0.2S  =    .2989 in

                        Cumulative Runoff
                      -------------------
                           2.6367 in
                             .042 ac-ft

         HYG Volume...            .042 ac-ft (area under HYG curve)

         ***** UNIT HYDROGRAPH PARAMETERS *****

         Time Concentration, Tc =    .10000 hrs (ID: None Selected)
         Computational Incr, Tm =    .01333 hrs = 0.20000 Tp

         Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
         K =  483.43/645.333,  K =    .7491 (also, K = 2/(1+(Tr/Tp))
         Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

         Unit peak,           qp =     2.15 cfs
         Unit peak time       Tp =   .06667 hrs
         Unit receding limb,  Tr =   .26667 hrs
         Total unit time,     Tb =   .33333 hrs
```

```
Type.... SCS Unit Hyd. Summary                                    Page 1
Name.... P4                Tag: 25yr                         Event: 25 yr
File.... F:\TMPROJ\050\05004\PERMIT MOD\DRAIN AREA P4.PPW
Storm... TypeII  24hr   Tag: 25yr
```

SCS UNIT HYDROGRAPH METHOD

```
STORM EVENT: 25 year storm
Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir      = C:\HAESTAD\PPKW\RAINFALL\
Rain File -ID = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir       = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID =  - P4 25yr
Tc            = .1000 hrs
Drainage Area = .210 acres  Runoff CN= 87
```

$= \frac{(0.04)(89)+(0.17)(86)}{0.21}$

```
==========================================
Computational Time Increment    =    .01333 hrs
Computed Peak Time              =   11.9333 hrs
Computed Peak Flow              =       .83 cfs

Time Increment for HYG File     =     .0500 hrs
Peak Time, Interpolated Output  =   11.9500 hrs
Peak Flow, Interpolated Output  =       .82 cfs
WARNING: The difference between calculated peak flow
and interpolated peak flow is greater than 1.50%
==========================================

              DRAINAGE AREA
            ------------------
            ID:P4
            CN    =    87
            Area =           .210 acres
            S     =    1.4943 in
            0.2S =     .2989 in

             Cumulative Runoff
            ------------------
                  2.6367 in
                    .046 ac-ft

HYG Volume...            .046 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =    .10000 hrs (ID: None Selected)
Computational Incr, Tm =    .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

Unit peak,          qp =     2.38 cfs
Unit peak time      Tp =   .06667 hrs
Unit receding limb, Tr =   .26667 hrs
Total unit time,    Tb =   .33333 hrs
```

```
Type.... SCS Unit Hyd. Summary
Name.... P5                    Tag: 25yr                        Page 1
File.... F:\TMPROJ\050\05004\PERMIT MOD\DRAIN AREA P5.PPW   Event: 25 yr
Storm... TypeII  24hr    Tag: 25yr

           SCS UNIT HYDROGRAPH METHOD

           STORM EVENT: 25 year storm
           Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
           Rain Dir      = C:\HAESTAD\PPKW\RAINFALL\
           Rain File -ID = SCSTYPES.RNF - TypeII  24hr
           Unit Hyd Type = Default Curvilinear
           HYG Dir       = F:\TMPROJ\050\05004\PERMIT MOD\
           HYG File - ID =  - P5 25yr
           Tc            = .1000 hrs
           Drainage Area = .210 acres  Runoff CN= 87 = (0.04)(89) + (0.17)(86)
                                                            0.21
           =========================================
           Computational Time Increment   =    .01333 hrs
           Computed Peak Time             =   11.9333 hrs
           Computed Peak Flow             =       .83 cfs

           Time Increment for HYG File    =     .0500 hrs
           Peak Time, Interpolated Output =   11.9500 hrs
           Peak Flow, Interpolated Output =       .82 cfs
           WARNING: The difference between calculated peak flow
           and interpolated peak flow is greater than 1.50%
           =========================================

                            DRAINAGE AREA
                         ------------------
                         ID:P5
                         CN    =    87
                         Area =          .210 acres
                         S     =   1.4943 in
                         0.2S =     .2989 in

                          Cumulative Runoff
                         ------------------
                               2.6367 in
                                 .046 ac-ft

          HYG Volume...             .046 ac-ft (area under HYG curve)

          ***** UNIT HYDROGRAPH PARAMETERS *****

          Time Concentration, Tc =    .10000 hrs (ID: None Selected)
          Computational Incr, Tm =    .01333 hrs = 0.20000 Tp

          Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
          K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
          Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

          Unit peak,           qp =     2.38 cfs
          Unit peak time       Tp =   .06667 hrs
          Unit receding limb,  Tr =   .26667 hrs
          Total unit time,     Tb =   .33333 hrs
```

```
Type.... SCS Unit Hyd. Summary                                Page 1
Name.... P6              Tag: 25yr                        Event: 25 yr
File.... F:\TMPROJ\050\05004\PERMIT MOD\DRAIN AREA P6.PPW
Storm... TypeII  24hr    Tag: 25yr

              SCS UNIT HYDROGRAPH METHOD

              STORM EVENT: 25 year storm
              Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
              Rain Dir      = C:\HAESTAD\PPKW\RAINFALL\
              Rain File -ID = SCSTYPES.RNF - TypeII  24hr
              Unit Hyd Type = Default Curvilinear
              HYG Dir       = F:\TMPROJ\050\05004\PERMIT MOD\
              HYG File - ID =  - P6 25yr
              Tc            = .1000 hrs
              Drainage Area = .200 acres  Runoff CN= 87
```

$$= \frac{(0.05)(89)+(0.15)(86)}{0.20}$$

```
              ============================================
              Computational Time Increment    =   .01333 hrs
              Computed Peak Time              =  11.9333 hrs
              Computed Peak Flow              =      .79 cfs

              Time Increment for HYG File     =    .0500 hrs
              Peak Time, Interpolated Output  =  11.9500 hrs
              Peak Flow, Interpolated Output  =      .78 cfs
              WARNING: The difference between calculated peak flow
              and interpolated peak flow is greater than 1.50%
              ============================================

                        DRAINAGE AREA
                     -------------------
                     ID:P6
                     CN    =   87
                     Area  =          .200 acres
                     S     =   1.4943 in
                     0.2S  =    .2989 in

                       Cumulative Runoff
                     -------------------
                            2.6367 in
                              .044 ac-ft

             HYG Volume...            .044 ac-ft (area under HYG curve)

             ***** UNIT HYDROGRAPH PARAMETERS *****

             Time Concentration, Tc =   .10000 hrs (ID: None Selected)
             Computational Incr, Tm =   .01333 hrs = 0.20000 Tp

             Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
             K =  483.43/645.333,  K =    .7491 (also, K = 2/(1+(Tr/Tp))
             Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

             Unit peak,          qp =     2.27 cfs
             Unit peak time      Tp =   .06667 hrs
             Unit receding limb, Tr =   .26667 hrs
             Total unit time,    Tb =   .33333 hrs
```

SCS UNIT HYDROGRAPH METHOD

```
STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = C:\HAESTAD\PPKW\RAINFALL\
Rain File -ID  = SCSTYPES.RNF - TypeII 24hr
Unit Hyd Type  = Default Curvilinear
HYG Dir        = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID  =  - P7 25yr
Tc             = .1000 hrs
Drainage Area  = .190 acres  Runoff CN= 87

==========================================
Computational Time Increment   =    .01333 hrs
Computed Peak Time             =   11.9333 hrs
Computed Peak Flow             =       .75 cfs

Time Increment for HYG File    =     .0500 hrs
Peak Time, Interpolated Output =   11.9500 hrs
Peak Flow, Interpolated Output =       .74 cfs
WARNING: The difference between calculated peak flow
and interpolated peak flow is greater than 1.50%
==========================================

           DRAINAGE AREA
         ------------------
         ID:P7
         CN   =   87
         Area =          .190 acres
         S    =   1.4943 in
         0.2S =     .2989 in

         Cumulative Runoff
         ------------------
               2.6367 in
                 .042 ac-ft

HYG Volume...              .042 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =    .10000 hrs (ID: None Selected)
Computational Incr, Tm =    .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,            qp =      2.15 cfs
Unit peak time        Tp =    .06667 hrs
Unit receding limb,   Tr =    .26667 hrs
Total unit time,      Tb =    .33333 hrs
```

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```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir      = C:\HAESTAD\PPKW\RAINFALL\
Rain File -ID = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir       = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID =  - A6 25yr
Tc            = .1100 hrs
Drainage Area = 1.250 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .01467 hrs
Computed Peak Time             =  11.9387 hrs
Computed Peak Flow             =     4.72 cfs

Time Increment for HYG File    =    .0500 hrs
Peak Time, Interpolated Output =  11.9500 hrs
Peak Flow, Interpolated Output =     4.68 cfs
============================================

               DRAINAGE AREA
             -------------------
             ID:A6
             CN   =    86
             Area =        1.250 acres
             S    =    1.6279 in
             0.2S =     .3256 in

              Cumulative Runoff
             -------------------
                   2.5463 in
                     .265 ac-ft

HYG Volume...            .265 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .11000 hrs (ID: None Selected)
Computational Incr, Tm =   .01467 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =    12.88 cfs
Unit peak time      Tp =   .07333 hrs
Unit receding limb, Tr =   .29333 hrs
Total unit time,    Tb =   .36667 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir      = C:\HAESTAD\PPKW\RAINFALL\
Rain File -ID = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir       = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID =  - P8 25yr
Tc            = .1000 hrs
Drainage Area = .180 acres  Runoff CN= 87
```

$= \frac{(89)(0.04)+(86)(0.14)}{0.18}$

```
===========================================
Computational Time Increment    =    .01333 hrs
Computed Peak Time              =   11.9333 hrs
Computed Peak Flow              =       .72 cfs

Time Increment for HYG File     =     .0500 hrs
Peak Time, Interpolated Output =   11.9500 hrs
Peak Flow, Interpolated Output =       .70 cfs
WARNING: The difference between calculated peak flow
and interpolated peak flow is greater than 1.50%
===========================================

              DRAINAGE AREA
           -------------------
           ID:P8
           CN    =    87
           Area =          .180 acres
           S     =    1.4943 in
           0.2S =      .2989 in

             Cumulative Runoff
           -------------------
                 2.6367 in
                   .040 ac-ft

HYG Volume...          .040 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .10000 hrs (ID: None Selected)
Computational Incr, Tm =   .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

Unit peak,          qp =     2.04 cfs
Unit peak time      Tp =   .06667 hrs
Unit receding limb, Tr =   .26667 hrs
Total unit time,    Tb =   .33333 hrs
```

Type.... Node: Addition Summary
Name.... CHANNEL P8
File.... F:\TMPROJ\050\05004\PERMIT MOD\DRAIN AREA P8.PPW
Storm... TypeII 24hr Tag: 25yr

SUMMARY FOR HYDROGRAPH ADDITION
at Node: CHANNEL P8

HYG Directory: F:\TMPROJ\050\05004\PERMIT MOD\

Upstream Link ID	Upstream Node ID	HYG file	HYG ID	HYG tag
A 20	A6		A6	25yr
A 10	P8		P8	25yr

INFLOWS TO: CHANNEL P8

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	A6	25yr	.265	11.9500	4.68
	P8	25yr	.040	11.9500	.70

TOTAL FLOW INTO: CHANNEL P8

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	CHANNEL P8	25yr	.305	11.9500	5.38

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SCS UNIT HYDROGRAPH METHOD

```
STORM EVENT: 25 year storm
Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir      = C:\HAESTAD\PPKW\RAINFALL\
Rain File -ID = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir       = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID =  - A16 25yr
Tc            = .2420 hrs
Drainage Area = .460 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .03227 hrs
Computed Peak Time             =  12.0355 hrs
Computed Peak Flow             =     1.43 cfs

Time Increment for HYG File    =    .0500 hrs
Peak Time, Interpolated Output =  12.0500 hrs
Peak Flow, Interpolated Output =     1.41 cfs
============================================

                DRAINAGE AREA
              -------------------
              ID:None Selected
              CN    =   86
              Area =          .460 acres
              S     =   1.6279 in
              0.2S =     .3256 in

               Cumulative Runoff
              -------------------
                    2.5463 in
                      .098 ac-ft

HYG Volume...            .098 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .24200 hrs (ID: None Selected)
Computational Incr, Tm =   .03227 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =    .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =     2.15 cfs
Unit peak time      Tp =   .16133 hrs
Unit receding limb, Tr =   .64533 hrs
Total unit time,    Tb =   .80667 hrs
```

SCS UNIT HYDROGRAPH METHOD

```
STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = C:\HAESTAD\PPKW\RAINFALL\
Rain File -ID = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir        = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID =  - A5 25yr
Tc             = .3020 hrs
Drainage Area = 2.300 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .04027 hrs
Computed Peak Time             =  12.0800 hrs
Computed Peak Flow             =     6.55 cfs

Time Increment for HYG File    =    .0500 hrs
Peak Time, Interpolated Output =  12.0500 hrs
Peak Flow, Interpolated Output =     6.47 cfs
============================================

              DRAINAGE AREA
            -------------------
            ID:None Selected
            CN   =   86
            Area =        2.300 acres
            S    =   1.6279 in
            0.2S =    .3256 in

             Cumulative Runoff
            -------------------
                  2.5463 in
                    .488 ac-ft

HYG Volume...            .488 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =    .30200 hrs (ID: None Selected)
Computational Incr, Tm =    .04027 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

Unit peak,          qp =     8.63 cfs
Unit peak time      Tp =   .20133 hrs
Unit receding limb, Tr =   .80533 hrs
Total unit time,    Tb =  1.00667 hrs
```

SCS UNIT HYDROGRAPH METHOD

```
STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = C:\HAESTAD\PPKW\RAINFALL\
Rain File -ID = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir        = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID =  - P9 25yr
Tc             = .1530 hrs
Drainage Area = 1.050 acres  Runoff CN= 87
```

$= \frac{(89)(0.24)+(86)(0.81)}{1.05}$

```
============================================
Computational Time Increment   =   .02040 hrs
Computed Peak Time             =  11.9748 hrs
Computed Peak Flow             =     3.81 cfs

Time Increment for HYG File    =    .0500 hrs
Peak Time, Interpolated Output =  11.9500 hrs
Peak Flow, Interpolated Output =     3.74 cfs
WARNING: The difference between calculated peak flow
and interpolated peak flow is greater than 1.50%
============================================
```

DRAINAGE AREA

```
--------------------
ID:P9
CN    =   87
Area =       1.050 acres
S     =   1.4943 in
0.2S =    .2989 in
```

Cumulative Runoff

```
-------------------
       2.6367 in
        .231 ac-ft
```

```
HYG Volume...          .231 ac-ft (area under HYG curve)
```

***** UNIT HYDROGRAPH PARAMETERS *****

```
Time Concentration, Tc =   .15300 hrs (ID: None Selected)
Computational Incr, Tm =   .02040 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

Unit peak,           qp =     7.78 cfs
Unit peak time       Tp =   .10200 hrs
Unit receding limb, Tr =   .40800 hrs
Total unit time,     Tb =   .51000 hrs
```

SUMMARY FOR HYDROGRAPH ADDITION
at Node: CHANNEL P9

HYG Directory: F:\TMPROJ\050\05004\PERMIT MOD\

Upstream Link ID	Upstream Node ID	HYG file	HYG ID	HYG tag
A 30	A16		A16	25yr
A 20	A5		A5	25yr
A 10	P9		P9	25yr

INFLOWS TO: CHANNEL P9

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	A16	25yr	.098	12.0500	1.41
	A5	25yr	.488	12.0500	6.47
	P9	25yr	.231	11.9500	3.74

TOTAL FLOW INTO: CHANNEL P9

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	CHANNEL P9	25yr	.816	12.0500	11.14

Quick TR-55 Version: 5.46 S/N:

Page 1
Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 14:02:36
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:AREAP10.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL P10
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
P10	0.73	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 0.73 acres or 0.00114 sq.mi
Peak discharge = 3 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
P10	0.11	0.00	0.10	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 14:02:49
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:AREAP11.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL P11
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
P11	1.32	86.0	0.10	0.00	4.00	2.55	I.08	.10
A13	3.29	86.0	0.20	0.10	4.00	2.55	I.08	.10
A17	1.03	86.0	0.10	0.10	4.00	2.55	I.08	.10
P10	0.73	86.0	0.10	0.10	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 6.37 acres or 0.00995 sq.mi
Peak discharge = 16 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
P11	0.10	0.00	**	**	No	Computed Ia/p < .1
A13	0.18	0.08	0.20	0.10	No	Computed Ia/p < .1
A17	0.12	0.08	0.10	0.10	No	Computed Ia/p < .1
P10	0.11	0.08	0.10	0.10	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 14:03:03
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:AREAP12.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL P12
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input	Ia/p used
P12	1.63	86.0	0.10	0.00	4.00	2.55	I.08	.10
P11	1.32	86.0	0.10	0.20	4.00	2.55	I.08	.10
P10	0.73	86.0	0.10	0.20	4.00	2.55	I.08	.10
A13	3.29	86.0	0.20	0.20	4.00	2.55	I.08	.10
A17	1.03	86.0	0.10	0.20	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I - Subarea where user specified interpolation between Ia/p tables.

Total area = 8.00 acres or 0.01250 sq.mi
Peak discharge = 19 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
P12	0.13	0.00	0.10	0.00	No	Computed Ia/p < .1
P11	0.10	0.18	0.10	0.20	No	Computed Ia/p < .1
P10	0.11	0.18	0.10	0.20	No	Computed Ia/p < .1
A13	0.18	0.18	0.20	0.20	No	Computed Ia/p < .1
A17	0.12	0.18	0.10	0.20	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:55:43
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\CHANV1.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL V1
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A8	0.95	86.0	0.10	0.00	4.00	2.55	I.08	.10
A14	1.39	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 2.34 acres or 0.00366 sq.mi
Peak discharge = 10 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A8	0.10	0.00	**	**	No	Computed Ia/p < .1
A14	0.10	0.00	**	**	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:56:17
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\CHANV2.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL V2
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A1	1.09	86.0	0.40	0.00	4.00	2.55	I.08	.10
A2	5.50	86.0	0.20	0.00	4.00	2.55	I.08	.10
A3	3.70	86.0	0.20	0.00	4.00	2.55	I.08	.10
A4	2.04	86.0	0.10	0.00	4.00	2.55	I.08	.10
A21	2.16	86.0	0.20	0.00	4.00	2.55	I.08	.10
A7	0.23	86.0	0.10	0.00	4.00	2.55	I.08	.10
A9	3.43	86.0	0.20	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 18.15 acres or 0.02836 sq.mi
Peak discharge = 56 cfs

WARNING: Drainage areas of two or more subareas differ by a factor of 5 or greater.

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A1	0.36	0.00	0.40	0.00	No	Computed Ia/p < .1
A2	0.24	0.00	0.20	0.00	No	Computed Ia/p < .1
A3	0.16	0.00	0.20	0.00	No	Computed Ia/p < .1
A4	0.10	0.00	**	**	No	Computed Ia/p < .1
A21	0.17	0.00	0.20	0.00	No	Computed Ia/p < .1
A7	0.10	0.00	**	**	No	Computed Ia/p < .1
A9	0.19	0.02	0.20	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 14:04:28
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:CHANV3.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL V3
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used
A6	1.25	86.0	0.10	0.00	4.00	2.55	I.08 .10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 1.25 acres or 0.00195 sq.mi
Peak discharge = 5 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A6	0.11	0.00	0.10	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 14:04:42
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:CHANV4.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL V4
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A5	2.30	86.0	0.20	0.00	4.00	2.55	I.08	.10
A16	0.46	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 2.76 acres or 0.00431 sq.mi
Peak discharge = 9 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A5	0.16	0.00	0.20	0.00	No	Computed Ia/p < .1
A16	0.10	0.00	**	**	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Quick TR-55 Version: 5.46 S/N:

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 07-07-1997 14:05:03
Watershed file: --> L:MDLCITY .MOP
Hydrograph file: --> L:CHANV5.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL V5
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A13	3.29	86.0	0.20	0.00	4.00	2.55	I.08	.10
A17	1.03	86.0	0.10	0.00	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 4.32 acres or 0.00675 sq.mi
Peak discharge = 14 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A13	0.18	0.00	0.20	0.00	No	Computed Ia/p < .1
A17	0.12	0.00	0.10	0.00	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.

Return Frequency: 25 years

TR-55 TABULAR HYDROGRAPH METHOD
Type II. Distribution
(24 hr. Duration Storm)

Executed: 02-03-1999 11:56:48
Watershed file: --> A:\MDLCITY .MOP
Hydrograph file: --> A:\CHANV6.HYD

MODEL CITY RMU-1

DRAINAGE CHANNEL V6
25 YEAR, 24 HOUR PEAK DISCHARGE

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A10	6.45	86.0	0.20	0.00	4.00	2.55	I.08	.10
A11	2.87	86.0	0.10	0.00	4.00	2.55	I.08	.10
A12	1.00	86.0	0.10	0.00	4.00	2.55	I.08	.10
A15	0.79	86.0	0.10	0.00	4.00	2.55	I.08	.10
A18	1.19	86.0	0.10	0.00	4.00	2.55	I.08	.10
A19	2.52	86.0	0.20	0.00	4.00	2.55	I.08	.10
A20	0.54	86.0	0.10	0.10	4.00	2.55	I.08	.10

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

Total area = 15.36 acres or 0.02400 sq.mi
Peak discharge = 51 cfs

WARNING: Drainage areas of two or more subareas differ by a factor of 5 or greater.

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A10	0.23	0.00	0.20	0.00	No	Computed Ia/p < .1
A11	0.14	0.00	0.10	0.00	No	Computed Ia/p < .1
A12	0.10	0.00	**	**	No	Computed Ia/p < .1
A15	0.10	0.00	**	**	No	Computed Ia/p < .1
A18	0.14	0.00	0.10	0.00	No	Computed Ia/p < .1
A19	0.18	0.00	0.20	0.00	No	Computed Ia/p < .1
A20	0.10	0.05	0.10	0.10	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

Table of Contents

******************** RUNOFF HYDROGRAPHS ********************

********************** HYG ADDITION **********************

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25yr year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = C:\PROGRA~1\HAESTAD\PPKW\RAINFALL\
Rain File -ID = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir        = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID =  - A1 25yr24
Tc             = .3600 hrs
Drainage Area = 1.090 acres  Runoff CN= 86

============================================
Computational Time Increment    =   .04800 hrs
Computed Peak Time              =  12.0960 hrs
Computed Peak Flow              =     2.86 cfs

Time Increment for HYG File     =    .0500 hrs
Peak Time, Interpolated Output =  12.1000 hrs
Peak Flow, Interpolated Output =     2.85 cfs
============================================

                 DRAINAGE AREA
              -------------------
              ID:None Selected
              CN   =   86
              Area =       1.090 acres
              S    =   1.6279 in
              0.2S =    .3256 in

               Cumulative Runoff
              -------------------
                     2.5463 in
                       .231 ac-ft

HYG Volume...            .231 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .36000 hrs (ID: None Selected)
Computational Incr, Tm =   .04800 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =     3.43 cfs
Unit peak time      Tp =   .24000 hrs
Unit receding limb, Tr =   .96000 hrs
Total unit time,    Tb =  1.20000 hrs
```

SCS UNIT HYDROGRAPH METHOD

```
STORM EVENT: 25yr year storm
Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir      = C:\PROGRA~1\HAESTAD\PPKW\RAINFALL\
Rain File -ID = SCSTYPES.RNF - TypeII 24hr
Unit Hyd Type = Default Curvilinear
HYG Dir       = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID =  - A2 25yr24
Tc            = .2400 hrs
Drainage Area = 5.500 acres  Runoff CN= 86

============================================
Computational Time Increment  =   .03200 hrs
Computed Peak Time            =  12.0320 hrs
Computed Peak Flow            =    17.18 cfs

Time Increment for HYG File   =    .0500 hrs
Peak Time, Interpolated Output =  12.0500 hrs
Peak Flow, Interpolated Output =    16.95 cfs
============================================

          DRAINAGE AREA
        -------------------
        ID:None Selected
        CN   =   86
        Area =       5.500 acres
        S    =   1.6279 in
        0.2S =    .3256 in

         Cumulative Runoff
        -------------------
               2.5463 in
                1.167 ac-ft

HYG Volume...           1.167 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .24000 hrs (ID: None Selected)
Computational Incr, Tm =   .03200 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =    25.97 cfs
Unit peak time      Tp =   .16000 hrs
Unit receding limb, Tr =   .64000 hrs
Total unit time,    Tb =   .80000 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25yr year storm
Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir      = C:\PROGRA~1\HAESTAD\PPKW\RAINFALL\
Rain File -ID = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir       = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID =  - A21 25yr24
Tc            = .1700 hrs
Drainage Area = 2.160 acres  Runoff CN= 86

============================================
Computational Time Increment   =    .02267 hrs
Computed Peak Time             =   11.9907 hrs
Computed Peak Flow             =      7.42 cfs

Time Increment for HYG File    =     .0500 hrs
Peak Time, Interpolated Output =   12.0000 hrs
Peak Flow, Interpolated Output =      7.37 cfs
============================================

              DRAINAGE AREA
            ------------------
            ID:None Selected
            CN   =   86
            Area =         2.160 acres
            S    =   1.6279 in
            0.2S =     .3256 in

             Cumulative Runoff
            ------------------
                   2.5463 in
                     .458 ac-ft

HYG Volume...             .458 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .17000 hrs (ID: None Selected)
Computational Incr, Tm =   .02267 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

Unit peak,          qp =    14.40 cfs
Unit peak time      Tp =   .11333 hrs
Unit receding limb, Tr =   .45333 hrs
Total unit time,    Tb =   .56667 hrs
```

SCS UNIT HYDROGRAPH METHOD

```
STORM EVENT: 25yr year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = C:\PROGRA~1\HAESTAD\PPKW\RAINFALL\
Rain File -ID = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir        = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID =  - A3 25yr24
Tc             = .1600 hrs
Drainage Area = 3.700 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .02133 hrs
Computed Peak Time             =  11.9680 hrs
Computed Peak Flow             =    12.87 cfs

Time Increment for HYG File    =    .0500 hrs
Peak Time, Interpolated Output =  12.0000 hrs
Peak Flow, Interpolated Output =    12.73 cfs
============================================

           DRAINAGE AREA
         -------------------
         ID:None Selected
         CN   =   86
         Area =       3.700 acres
         S    =   1.6279 in
         0.2S =    .3256 in

          Cumulative Runoff
         ------------------
                2.5463 in
                  .785 ac-ft

HYG Volume...           .785 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .16000 hrs (ID: None Selected)
Computational Incr, Tm =   .02133 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =    .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =    26.20 cfs
Unit peak time      Tp =   .10667 hrs
Unit receding limb, Tr =   .42667 hrs
Total unit time,    Tb =   .53333 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25yr year storm
Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir      = C:\PROGRA~1\HAESTAD\PPKW\RAINFALL\
Rain File -ID = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir       = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID =  - A4 25yr24
Tc            = .1000 hrs
Drainage Area = 2.040 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .01333 hrs
Computed Peak Time             =  11.9333 hrs
Computed Peak Flow             =     7.86 cfs

Time Increment for HYG File    =    .0500 hrs
Peak Time, Interpolated Output =  11.9500 hrs
Peak Flow, Interpolated Output =     7.69 cfs
WARNING: The difference between calculated peak flow
and interpolated peak flow is greater than 1.50%
============================================

              DRAINAGE AREA
            -------------------
            ID:None Selected
            CN   =   86
            Area =       2.040 acres
            S    =   1.6279 in
            0.2S =    .3256 in

             Cumulative Runoff
            ------------------
                    2.5463 in
                      .433 ac-ft

HYG Volume...           .433 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .10000 hrs (ID: None Selected)
Computational Incr, Tm =   .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =    23.11 cfs
Unit peak time      Tp =   .06667 hrs
Unit receding limb, Tr =   .26667 hrs
Total unit time,    Tb =   .33333 hrs
```

SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25yr year storm
Duration = 24.0000 hrs Rain Depth = 4.0000 in
Rain Dir = C:\PROGRA~1\HAESTAD\PPKW\RAINFALL\
Rain File -ID = SCSTYPES.RNF - TypeII 24hr
Unit Hyd Type = Default Curvilinear
HYG Dir = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID = - A7 25yr24
Tc = .1000 hrs
Drainage Area = .230 acres Runoff CN= 86

==
Computational Time Increment = .01333 hrs
Computed Peak Time = 11.9333 hrs
Computed Peak Flow = .89 cfs

Time Increment for HYG File = .0500 hrs
Peak Time, Interpolated Output = 11.9500 hrs
Peak Flow, Interpolated Output = .87 cfs
WARNING: The difference between calculated peak flow
and interpolated peak flow is greater than 1.50%
==

DRAINAGE AREA

ID:None Selected
CN = 86
Area = .230 acres
S = 1.6279 in
0.2S = .3256 in

Cumulative Runoff

2.5463 in
.049 ac-ft

HYG Volume... .049 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc = .10000 hrs (ID: None Selected)
Computational Incr, Tm = .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor = 483.432 (37.46% under rising limb)
K = 483.43/645.333, K = .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp = 1.6698 (solved from K = .7491)

Unit peak, qp = 2.61 cfs
Unit peak time Tp = .06667 hrs
Unit receding limb, Tr = .26667 hrs
Total unit time, Tb = .33333 hrs

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25yr year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = C:\PROGRA~1\HAESTAD\PPKW\RAINFALL\
Rain File -ID  = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type  = Default Curvilinear
HYG Dir        = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID  =  - A9 25yr24
Tc             = .2300 hrs
Drainage Area  = 3.430 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .03067 hrs
Computed Peak Time             =  12.0213 hrs
Computed Peak Flow             =    10.84 cfs

Time Increment for HYG File    =    .0500 hrs
Peak Time, Interpolated Output =  12.0500 hrs
Peak Flow, Interpolated Output =    10.68 cfs
WARNING: The difference between calculated peak flow
and interpolated peak flow is greater than 1.50%
============================================

              DRAINAGE AREA
           -------------------
           ID:None Selected
           CN   =   86
           Area =       3.430 acres
           S    =   1.6279 in
           0.2S =    .3256 in

            Cumulative Runoff
           -------------------
                  2.5463 in
                    .728 ac-ft

HYG Volume...           .728 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .23000 hrs (ID: None Selected)
Computational Incr, Tm =   .03067 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =    16.90 cfs
Unit peak time      Tp =   .15333 hrs
Unit receding limb, Tr =   .61333 hrs
Total unit time,    Tb =   .76667 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25yr year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = C:\PROGRA~1\HAESTAD\PPKW\RAINFALL\
Rain File -ID = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir        = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID =  - P2 25yr24
Tc             = .1000 hrs
Drainage Area = .600 acres  Runoff CN= 87

============================================
Computational Time Increment   =   .01333 hrs
Computed Peak Time             =  11.9333 hrs
Computed Peak Flow             =     2.38 cfs

Time Increment for HYG File    =    .0500 hrs
Peak Time, Interpolated Output =  11.9500 hrs
Peak Flow, Interpolated Output =     2.33 cfs
WARNING: The difference between calculated peak flow
and interpolated peak flow is greater than 1.50%
============================================

              DRAINAGE AREA
           -------------------
           ID:P2
           CN   =   87
           Area =        .600 acres
           S    =   1.4943 in
           0.2S =    .2989 in

            Cumulative Runoff
           ------------------
                  2.6367 in
                    .132 ac-ft

HYG Volume...          .132 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .10000 hrs (ID: None Selected)
Computational Incr, Tm =   .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =     6.80 cfs
Unit peak time      Tp =   .06667 hrs
Unit receding limb, Tr =   .26667 hrs
Total unit time,    Tb =   .33333 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25yr year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = C:\PROGRA~1\HAESTAD\PPKW\RAINFALL\
Rain File -ID  = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type  = Default Curvilinear
HYG Dir        = F:\TMPROJ\050\05004\PERMIT MOD\
HYG File - ID  =  - P3 25yr24
Tc             = .1000 hrs
Drainage Area  = .190 acres  Runoff CN= 87

============================================
Computational Time Increment   =    .01333 hrs
Computed Peak Time             =   11.9333 hrs
Computed Peak Flow             =       .75 cfs

Time Increment for HYG File    =     .0500 hrs
Peak Time, Interpolated Output =   11.9500 hrs
Peak Flow, Interpolated Output =       .74 cfs
WARNING: The difference between calculated peak flow
and interpolated peak flow is greater than 1.50%
============================================

              DRAINAGE AREA
           -------------------
           ID:P3
           CN   =    87
           Area =         .190 acres
           S    =    1.4943 in
           0.2S =     .2989 in

            Cumulative Runoff
           -------------------
                  2.6367 in
                    .042 ac-ft

HYG Volume...            .042 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .10000 hrs (ID: None Selected)
Computational Incr, Tm =   .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =     2.15 cfs
Unit peak time      Tp =   .06667 hrs
Unit receding limb, Tr =   .26667 hrs
Total unit time,    Tb =   .33333 hrs
```

MODEL CITY RMU-1
CV-1, CV-2, CV-3 AND CV-4
Total Combined Peak Flow
25-Year, 24-Hour Peak Discharge

Network Storm Collection: Model City

Return Event	Total Depth in	Rainfall Type	RNF ID
25	4.0000	Synthetic Curve	TypeII 24hr

MASTER NETWORK SUMMARY
SCS Unit Hydrograph Method

(*Node=Outfall; +Node=Diversion;)
(Trun= HYG Truncation: Blank=None; L=Left; R=Rt; LR=Left&Rt)

Node ID	Type	Return Event	HYG Vol ac-ft	Trun	Qpeak hrs	Max Qpeak cfs	Max WSEL ft	Pond Storage ac-ft
A1	AREA	25	.223		11.9300	4.06		
A16	AREA	25	.098		12.0300	1.43		
A2	AREA	25	1.126		11.9800	18.51		
A21	AREA	25	.442		12.0200	6.69		
A3	AREA	25	.758		11.9800	12.45		
A4	AREA	25	.418		11.9300	7.59		
A5	AREA	25	.471		12.0800	6.36		
A6	AREA	25	.256		11.9400	4.57		
A7	AREA	25	.047		11.9300	.86		
A9	AREA	25	.702		12.0800	9.48		
*ESRB	IN POND	25	5.079		11.9900	76.72		

MASTER NETWORK SUMMARY
SCS Unit Hydrograph Method

(*Node=Outfall; +Node=Diversion;)
(Trun= HYG Truncation: Blank=None; L=Left; R=Rt; LR=Left&Rt)

Node ID	Type	Return Event	HYG Vol ac-ft	Trun	Qpeak hrs	Max Qpeak cfs	Max WSEL ft	Pond Storage ac-ft
P2	AREA	25	.064		11.9300	1.15		
P3	AREA	25	.040		11.9300	.73		
P4	AREA	25	.045		11.9300	.81		
P5	AREA	25	.045		11.9300	.81		
P6	AREA	25	.042		11.9300	.77		
P7	AREA	25	.040		11.9300	.73		
P8	AREA	25	.038		11.9300	.69		
P9	AREA	25	.223		11.9600	3.71		

MODEL CITY RMU-1
East Stormwater Retention Basin- Interim Condition
25-Year, 24- Hour Peak Discharge

Network Storm Collection: Model City

Return Event	Total Depth in	Rainfall Type	RNF ID
25	4.0000	Synthetic Curve	TypeII 24hr

MASTER NETWORK SUMMARY
SCS Unit Hydrograph Method

(*Node=Outfall; +Node=Diversion;)
(Trun= HYG Truncation: Blank=None; L=Left; R=Rt; LR=Left&Rt)

Node ID	Type	Return Event	HYG Vol ac-ft	Trun	Qpeak hrs	Max Qpeak cfs	Max WSEL ft	Pond Storage ac-ft
A1	AREA	25	.223		12.1000	2.76		
A16	AREA	25	.098		12.0300	1.43		
A2	AREA	25	1.126		12.0300	16.60		
A21	AREA	25	.442		11.9900	7.19		
A3	AREA	25	.758		11.9800	12.45		
A4	AREA	25	.418		11.9300	7.59		
A5	AREA	25	.471		12.0800	6.36		
A6	AREA	25	.256		11.9400	4.57		
A7	AREA	25	.047		11.9300	.86		
A9	AREA	25	.703		12.0200	10.48		
*ESRB	IN POND	25	6.004		12.0000	88.00		

MASTER NETWORK SUMMARY
SCS Unit Hydrograph Method

(*Node=Outfall; +Node=Diversion;)
(Trun= HYG Truncation: Blank=None; L=Left; R=Rt; LR=Left&Rt)

Node ID	Type	Return Event	HYG Vol ac-ft	Trun	Qpeak hrs	Max Qpeak cfs	Max WSEL ft	Pond Storage ac-ft
P13 (BASIN)	AREA	25	.925		11.9200	15.14		
P2	AREA	25	.064		11.9300	1.15		
P3	AREA	25	.040		11.9300	.73		
P4	AREA	25	.045		11.9300	.81		
P5	AREA	25	.045		11.9300	.81		
P6	AREA	25	.042		11.9300	.77		
P7	AREA	25	.040		11.9300	.73		
P8	AREA	25	.038		11.9300	.69		
P9	AREA	25	.223		11.9600	3.71		

MODEL CITY RMU-1
East Stormwater Retention Basin- Final Condition
25-Year, 24-Hour Peak Discharge

Network Storm Collection: Model City

Return Event	Total Depth in	Rainfall Type	RNF ID
25	4.0000	Synthetic Curve	TypeII 24hr

MASTER NETWORK SUMMARY
SCS Unit Hydrograph Method

(*Node=Outfall; +Node=Diversion;)
(Trun= HYG Truncation: Blank=None; L=Left; R=Rt; LR=Left&Rt)

Node ID	Type	Return Event	HYG Vol ac-ft	Trun	Qpeak hrs	Max Qpeak cfs	Max WSEL ft	Pond Storage ac-ft
A1	AREA	25	.178		12.1000	2.20		
A16	AREA	25	.081		12.0300	1.20		
A2	AREA	25	.900		12.0300	13.30		
A21	AREA	25	.353		11.9900	5.78		
A3	AREA	25	.605		11.9900	10.04		
A4	AREA	25	.334		11.9300	6.08		
A5	AREA	25	.376		12.0800	5.10		
A6	AREA	25	.205		11.9400	3.66		
A7	AREA	25	.038		11.9300	.69		
A9	AREA	25	.561		12.0300	8.39		
*ESRB	IN POND	25	5.007		12.0000	73.57		

MASTER NETWORK SUMMARY
SCS Unit Hydrograph Method

(*Node=Outfall; +Node=Diversion;)
(Trun= HYG Truncation: Blank=None; L=Left; R=Rt; LR=Left&Rt)

Node ID	Type	Return Event	HYG Vol ac-ft	Trun	Qpeak hrs	Max Qpeak cfs	Max WSEL ft	Pond Storage ac-ft
P13 (BASIN)	AREA	25	.925		11.9200	15.14		
P2	AREA	25	.053		11.9300	.97		
P3	AREA	25	.034		11.9300	.61		
P4	AREA	25	.037		11.9300	.68		
P5	AREA	25	.037		11.9300	.68		
P6	AREA	25	.037		11.9300	.67		
P7	AREA	25	.035		11.9300	.64		
P8	AREA	25	.032		11.9300	.58		
P9	AREA	25	.186		11.9800	3.12		

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir      = G:\TMProj\CWM Model City\Calculations\
Rain File -ID =  - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir       = G:\TMProj\CWM Model City\Calculations\
HYG File - ID =  - A1 25
Tc            = .4000 hrs
Drainage Area = 1.090 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .05333 hrs
Computed Peak Time             =  12.1067 hrs
Computed Peak Flow             =     2.69 cfs

Time Increment for HYG File    =    .0100 hrs
Peak Time, Interpolated Output =  12.1102 hrs
Peak Flow, Interpolated Output =     2.69 cfs
============================================

                 DRAINAGE AREA
              -------------------
              ID:A1
              CN   =   86
              Area =       1.090 acres
              S    =   1.6279 in
              0.2S =    .3256 in

               Cumulative Runoff
              -------------------
                      2.5463 in
                        .231 ac-ft

HYG Volume...           .231 ac-ft (area under HYG curve)

***** SCS UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .40000 hrs (ID: A1)
Computational Incr, Tm =   .05333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =    .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =     3.09 cfs
Unit peak time      Tp =   .26667 hrs
Unit receding limb, Tr =  1.06667 hrs
Total unit time,    Tb =  1.33333 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = G:\TMProj\CWM Model City\Calculations\
Rain File -ID =  - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir        = G:\TMProj\CWM Model City\Calculations\
HYG File - ID =  - A2 25
Tc             = .2000 hrs
Drainage Area = 5.500 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .02667 hrs
Computed Peak Time             =  12.0000 hrs
Computed Peak Flow             =    18.12 cfs

Time Increment for HYG File    =    .0100 hrs
Peak Time, Interpolated Output =  12.0002 hrs
Peak Flow, Interpolated Output =    18.12 cfs
============================================

                 DRAINAGE AREA
              -------------------
              ID:A2
              CN   =   86
              Area =       5.500 acres
              S    =   1.6279 in
              0.2S =    .3256 in

               Cumulative Runoff
              -------------------
                      2.5463 in
                       1.167 ac-ft

HYG Volume...          1.167 ac-ft (area under HYG curve)

***** SCS UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .20000 hrs (ID: A2)
Computational Incr, Tm =   .02667 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =    31.16 cfs
Unit peak time      Tp =   .13333 hrs
Unit receding limb, Tr =   .53333 hrs
Total unit time,    Tb =   .66667 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = G:\TMProj\CWM Model City\Calculations\
Rain File -ID =  - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir        = G:\TMProj\CWM Model City\Calculations\
HYG File - ID =  - A3 25
Tc             = .2000 hrs
Drainage Area = 3.700 acres  Runoff CN= 86

============================================
Computational Time Increment   =    .02667 hrs
Computed Peak Time             =  12.0000 hrs
Computed Peak Flow             =    12.19 cfs

Time Increment for HYG File    =    .0100 hrs
Peak Time, Interpolated Output =  12.0002 hrs
Peak Flow, Interpolated Output =    12.19 cfs
============================================

                DRAINAGE AREA
              -------------------
              ID:A3
              CN    =   86
              Area =        3.700 acres
              S     =   1.6279 in
              0.2S =    .3256 in

               Cumulative Runoff
              -------------------
                     2.5463 in
                       .785 ac-ft

HYG Volume...           .785 ac-ft (area under HYG curve)

***** SCS UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .20000 hrs (ID: A3)
Computational Incr, Tm =   .02667 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,           qp =    20.96 cfs
Unit peak time       Tp =   .13333 hrs
Unit receding limb,  Tr =   .53333 hrs
Total unit time,     Tb =   .66667 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir      = G:\TMProj\CWM Model City\Calculations\
Rain File -ID =  - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir       = G:\TMProj\CWM Model City\Calculations\
HYG File - ID =  - A4 MODIFIED 25
Tc            = .1280 hrs
Drainage Area = 1.950 acres  Runoff CN= 86

============================================
Computational Time Increment   =    .01706 hrs
Computed Peak Time             =  11.9447 hrs
Computed Peak Flow             =     7.13 cfs

Time Increment for HYG File    =    .0100 hrs
Peak Time, Interpolated Output =  11.9502 hrs
Peak Flow, Interpolated Output =     7.12 cfs
============================================

                DRAINAGE AREA
              -------------------
              ID:A4 MODIFIED
              CN   =   86
              Area =       1.950 acres
              S    =   1.6279 in
              0.2S =    .3256 in

               Cumulative Runoff
              -------------------
                      2.5463 in
                        .414 ac-ft

HYG Volume...            .414 ac-ft (area under HYG curve)

***** SCS UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .12798 hrs (ID: A4 MODIFIED)
Computational Incr, Tm =   .01706 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

Unit peak,          qp =    17.26 cfs
Unit peak time      Tp =   .08532 hrs
Unit receding limb, Tr =   .34128 hrs
Total unit time,    Tb =   .42660 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = G:\TMProj\CWM Model City\Calculations\
Rain File -ID =  - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir        = G:\TMProj\CWM Model City\Calculations\
HYG File - ID =  - A7 25
Tc (Min. Tc)  = .1000 hrs
Drainage Area = .230 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .01333 hrs
Computed Peak Time             =  11.9333 hrs
Computed Peak Flow             =      .89 cfs

Time Increment for HYG File    =    .0100 hrs
Peak Time, Interpolated Output =  11.9302 hrs
Peak Flow, Interpolated Output =      .88 cfs
============================================

                 DRAINAGE AREA
              -------------------
              ID:A7
              CN   =   86
              Area =         .230 acres
              S    =   1.6279 in
              0.2S =    .3256 in

               Cumulative Runoff
              -------------------
                      2.5463 in
                        .049 ac-ft

HYG Volume...            .049 ac-ft (area under HYG curve)

***** SCS UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .10000 hrs (ID: A7)
Computational Incr, Tm =   .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

Unit peak,          qp =     2.61 cfs
Unit peak time      Tp =   .06667 hrs
Unit receding limb, Tr =   .26667 hrs
Total unit time,    Tb =   .33333 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = G:\TMProj\CWM Model City\Calculations\
Rain File -ID =  - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir        = G:\TMProj\CWM Model City\Calculations\
HYG File - ID =  - A9 MODIFIED 25
Tc             = .1694 hrs
Drainage Area = 2.190 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .02259 hrs
Computed Peak Time             =  11.9936 hrs
Computed Peak Flow             =     7.53 cfs

Time Increment for HYG File    =    .0100 hrs
Peak Time, Interpolated Output =  11.9902 hrs
Peak Flow, Interpolated Output =     7.52 cfs
============================================

                DRAINAGE AREA
              -------------------
              ID:A9 MODIFIED
              CN   =   86
              Area =        2.190 acres
              S    =   1.6279 in
              0.2S =    .3256 in

               Cumulative Runoff
              -------------------
                      2.5463 in
                        .465 ac-ft

HYG Volume...            .465 ac-ft (area under HYG curve)

***** SCS UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .16940 hrs (ID: A9 MODIFIED)
Computational Incr, Tm =   .02259 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =    14.65 cfs
Unit peak time      Tp =   .11293 hrs
Unit receding limb, Tr =   .45174 hrs
Total unit time,    Tb =   .56467 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = G:\TMProj\CWM Model City\Calculations\
Rain File -ID =  - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir        = G:\TMProj\CWM Model City\Calculations\
HYG File - ID =  - A10 25
Tc             = .2000 hrs
Drainage Area = 6.150 acres  Runoff CN= 86

============================================
Computational Time Increment   =    .02667 hrs
Computed Peak Time             =  12.0000 hrs
Computed Peak Flow             =     20.27 cfs

Time Increment for HYG File    =     .0100 hrs
Peak Time, Interpolated Output =  12.0002 hrs
Peak Flow, Interpolated Output =     20.27 cfs
============================================

                DRAINAGE AREA
             -------------------
             ID:A10
             CN    =   86
             Area =        6.150 acres
             S     =   1.6279 in
             0.2S =     .3256 in

              Cumulative Runoff
             -------------------
                     2.5463 in
                      1.305 ac-ft

HYG Volume...             1.305 ac-ft (area under HYG curve)

***** SCS UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .20000 hrs (ID: A10)
Computational Incr, Tm =   .02667 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

Unit peak,          qp =    34.84 cfs
Unit peak time      Tp =   .13333 hrs
Unit receding limb, Tr =   .53333 hrs
Total unit time,    Tb =   .66667 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir      = G:\TMProj\CWM Model City\Calculations\
Rain File -ID =  - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir       = G:\TMProj\CWM Model City\Calculations\
HYG File - ID =  - A12 MODIFIED 25
Tc (Min. Tc)  = .1000 hrs
Drainage Area = 1.074 acres  Runoff CN= 86

============================================
Computational Time Increment   =    .01333 hrs
Computed Peak Time             =   11.9333 hrs
Computed Peak Flow             =      4.14 cfs

Time Increment for HYG File    =     .0100 hrs
Peak Time, Interpolated Output =   11.9302 hrs
Peak Flow, Interpolated Output =      4.13 cfs
============================================

                DRAINAGE AREA
              -------------------
              ID:A12 MODIFIED
              CN   =   86
              Area =       1.074 acres
              S    =   1.6279 in
              0.2S =    .3256 in

               Cumulative Runoff
              -------------------
                      2.5463 in
                        .228 ac-ft

HYG Volume...            .228 ac-ft (area under HYG curve)

***** SCS UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .10000 hrs (ID: A12 MODIFIED)
Computational Incr, Tm =   .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

Unit peak,          qp =    12.17 cfs
Unit peak time      Tp =   .06667 hrs
Unit receding limb, Tr =   .26667 hrs
Total unit time,    Tb =   .33333 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = G:\TMProj\CWM Model City\Calculations\
Rain File -ID =  - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir        = G:\TMProj\CWM Model City\Calculations\
HYG File - ID =  - A15 MODIFIED 25
Tc (Min. Tc)  = .1000 hrs
Drainage Area = .750 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .01333 hrs
Computed Peak Time             =  11.9333 hrs
Computed Peak Flow             =     2.89 cfs

Time Increment for HYG File    =    .0100 hrs
Peak Time, Interpolated Output =  11.9302 hrs
Peak Flow, Interpolated Output =     2.88 cfs
============================================

                 DRAINAGE AREA
              -------------------
              ID:A15 MODIFIED
              CN   =   86
              Area =         .750 acres
              S    =   1.6279 in
              0.2S =    .3256 in

               Cumulative Runoff
              -------------------
                     2.5463 in
                       .159 ac-ft

HYG Volume...           .159 ac-ft (area under HYG curve)

***** SCS UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .10000 hrs (ID: A15 MODIFIED)
Computational Incr, Tm =   .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =     8.50 cfs
Unit peak time      Tp =   .06667 hrs
Unit receding limb, Tr =   .26667 hrs
Total unit time,    Tb =   .33333 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir      = G:\TMProj\CWM Model City\Calculations\
Rain File -ID =  - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir       = G:\TMProj\CWM Model City\Calculations\
HYG File - ID =  - A18 25
Tc (Min. Tc)  = .1000 hrs
Drainage Area = 1.190 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .01333 hrs
Computed Peak Time             =  11.9333 hrs
Computed Peak Flow             =     4.58 cfs

Time Increment for HYG File    =    .0100 hrs
Peak Time, Interpolated Output =  11.9302 hrs
Peak Flow, Interpolated Output =     4.57 cfs
============================================

                DRAINAGE AREA
              -------------------
              ID:A18
              CN    =   86
              Area =       1.190 acres
              S     =  1.6279 in
              0.2S =    .3256 in

               Cumulative Runoff
              -------------------
                      2.5463 in
                        .253 ac-ft

HYG Volume...            .252 ac-ft (area under HYG curve)

***** SCS UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .10000 hrs (ID: A18)
Computational Incr, Tm =   .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =    13.48 cfs
Unit peak time      Tp =   .06667 hrs
Unit receding limb, Tr =   .26667 hrs
Total unit time,    Tb =   .33333 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir      = G:\TMProj\CWM Model City\Calculations\
Rain File -ID =  - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir       = G:\TMProj\CWM Model City\Calculations\
HYG File - ID =  - A19 MODIFED 25
Tc            = .2184 hrs
Drainage Area = 3.700 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .02912 hrs
Computed Peak Time             =  12.0273 hrs
Computed Peak Flow             =    11.90 cfs

Time Increment for HYG File    =    .0100 hrs
Peak Time, Interpolated Output =  12.0202 hrs
Peak Flow, Interpolated Output =    11.87 cfs
============================================

                  DRAINAGE AREA
              -------------------
              ID:A19 MODIFED
              CN   =   86
              Area =        3.700 acres
              S    =   1.6279 in
              0.2S =    .3256 in

               Cumulative Runoff
              -------------------
                     2.5463 in
                       .785 ac-ft

HYG Volume...           .785 ac-ft (area under HYG curve)

***** SCS UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .21841 hrs (ID: A19 MODIFED)
Computational Incr, Tm =   .02912 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =   .7491)

Unit peak,          qp =    19.19 cfs
Unit peak time      Tp =   .14561 hrs
Unit receding limb, Tr =   .58243 hrs
Total unit time,    Tb =   .72804 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration      = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir      = G:\TMProj\CWM Model City\Calculations\
Rain File -ID =  - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir       = G:\TMProj\CWM Model City\Calculations\
HYG File - ID =  - A20 MODIFIED 25
Tc (Min. Tc)  = .1000 hrs
Drainage Area = .590 acres  Runoff CN= 86

============================================
Computational Time Increment   =   .01333 hrs
Computed Peak Time             =  11.9333 hrs
Computed Peak Flow             =     2.27 cfs

Time Increment for HYG File    =    .0100 hrs
Peak Time, Interpolated Output =  11.9302 hrs
Peak Flow, Interpolated Output =     2.27 cfs
============================================

                 DRAINAGE AREA
              -------------------
              ID:A20 MODIFIED
              CN    =   86
              Area =         .590 acres
              S     =   1.6279 in
              0.2S =     .3256 in

               Cumulative Runoff
              -------------------
                     2.5463 in
                       .125 ac-ft

HYG Volume...            .125 ac-ft (area under HYG curve)

***** SCS UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .10000 hrs (ID: A20 MODIFIED)
Computational Incr, Tm =   .01333 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

Unit peak,           qp =     6.68 cfs
Unit peak time       Tp =   .06667 hrs
Unit receding limb, Tr =   .26667 hrs
Total unit time,     Tb =   .33333 hrs
```

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = G:\TMProj\CWM Model City\Calculations\
Rain File -ID =  - TypeII  24hr
Unit Hyd Type = Default Curvilinear
HYG Dir        = G:\TMProj\CWM Model City\Calculations\
HYG File - ID =  - A21 25
Tc             = .2000 hrs
Drainage Area = 2.160 acres  Runoff CN= 86

============================================
Computational Time Increment    =    .02667 hrs
Computed Peak Time              =  12.0000 hrs
Computed Peak Flow              =     7.12 cfs

Time Increment for HYG File     =    .0100 hrs
Peak Time, Interpolated Output =  12.0002 hrs
Peak Flow, Interpolated Output =     7.12 cfs
============================================

              DRAINAGE AREA
             -------------------
             ID:A21
             CN    =   86
             Area =        2.160 acres
             S     =   1.6279 in
             0.2S =    .3256 in

              Cumulative Runoff
             -------------------
                     2.5463 in
                       .458 ac-ft

HYG Volume...            .458 ac-ft (area under HYG curve)

***** SCS UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .20000 hrs (ID: A21)
Computational Incr, Tm =   .02667 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

Unit peak,          qp =    12.24 cfs
Unit peak time      Tp =   .13333 hrs
Unit receding limb, Tr =   .53333 hrs
Total unit time,    Tb =   .66667 hrs
```

SUMMARY FOR HYDROGRAPH ADDITION
at Node: A1 CHANNEL

HYG Directory: G:\TMProj\CWM Model City\Calculations\

Upstream Link ID	Upstream Node ID	HYG file	HYG ID	HYG tag
ADDLINK 160	A1 CHANNEL		A1 CHANNEL	25
ADDLINK 10	A9 MOD CHANNEL		A9 MOD CHANNEL	25

INFLOWS TO: A1 CHANNEL

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	A1 CHANNEL	25	.231	12.1100	2.69
	A9 MOD CHANNEL	25	.465	12.0200	7.04

TOTAL FLOW INTO: A1 CHANNEL

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	A1 CHANNEL	25	.696	12.0400	9.35

SUMMARY FOR HYDROGRAPH ADDITION
at Node: A15 CHANNEL

HYG Directory: G:\TMProj\CWM Model City\Calculations\

Upstream Link ID	Upstream Node ID	HYG file	HYG ID	HYG tag
ADDLINK 180	A20 MOD CHANNEL		A20 MOD CHANNEL	25
ADDLINK 170	A15 MOD CHANNEL		A15 MOD CHANNEL	25

INFLOWS TO: A15 CHANNEL

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	A20 MOD CHANNEL	25	.125	11.9300	2.27
	A15 MOD CHANNEL	25	.159	11.9300	2.88

TOTAL FLOW INTO: A15 CHANNEL

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	A15 CHANNEL	25	.284	11.9300	5.15

SUMMARY FOR HYDROGRAPH ADDITION
at Node: FLUME 1

HYG Directory: G:\TMProj\CWM Model City\Calculations\

Upstream Link ID	Upstream Node ID	HYG file	HYG ID	HYG tag
ADDLINK 20	A1		A1	25
ADDLINK 90	A3		A3	25
ADDLINK 100	A7		A7	25
ADDLINK 110	A21		A21	25
ADDLINK 40	A9 MODIFIED		A9 MODIFIED	25
ADDLINK 80	A2		A2	25
ADDLINK 30	A4 MODIFIED		A4 MODIFIED	25

INFLOWS TO: FLUME 1

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	A1	25	.231	12.1100	2.69
	A3	25	.785	12.0000	12.19
	A7	25	.049	11.9300	.88
	A21	25	.458	12.0000	7.12
	A9 MODIFIED	25	.465	11.9900	7.52
	A2	25	1.167	12.0000	18.12
	A4 MODIFIED	25	.414	11.9500	7.12

TOTAL FLOW INTO: FLUME 1

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	FLUME 1	25	3.569	12.0000	54.53

SUMMARY FOR HYDROGRAPH ADDITION
at Node: FLUME 2

HYG Directory: G:\TMProj\CWM Model City\Calculations\

Upstream Link ID	Upstream Node ID	HYG file	HYG ID	HYG tag
ADDLINK 70	A20 MODIFIED		A20 MODIFIED	25
ADDLINK 150	A11		A11	25
ADDLINK 50	A12 MODIFIED		A12 MODIFIED	25
ADDLINK 140	A10		A10	25
ADDLINK 60	A15 MODIFIED		A15 MODIFIED	25
ADDLINK 120	A18		A18	25
ADDLINK 130	A19 MODIFED		A19 MODIFED	25

INFLOWS TO: FLUME 2

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	A20 MODIFIED	25	.125	11.9300	2.27
	A11	25	.609	11.9300	11.03
	A12 MODIFIED	25	.228	11.9300	4.13
	A10	25	1.305	12.0000	20.27
	A15 MODIFIED	25	.159	11.9300	2.88
	A18	25	.252	11.9300	4.57
	A19 MODIFED	25	.785	12.0200	11.87

TOTAL FLOW INTO: FLUME 2

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	FLUME 2	25	3.464	11.9700	53.75

SUMMARY FOR HYDROGRAPH ADDITION
at Node: V2

HYG Directory: G:\TMProj\CWM Model City\Calculations\

Upstream Link ID	Upstream Node ID	HYG file	HYG ID	HYG tag
ADDLINK 20	A1		A1	25
ADDLINK 90	A3		A3	25
ADDLINK 100	A7		A7	25
ADDLINK 110	A21		A21	25
ADDLINK 40	A9 MODIFIED		A9 MODIFIED	25
ADDLINK 80	A2		A2	25
ADDLINK 30	A4 MODIFIED		A4 MODIFIED	25

INFLOWS TO: V2

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	A1	25	.231	12.1100	2.69
	A3	25	.785	12.0000	12.19
	A7	25	.049	11.9300	.88
	A21	25	.458	12.0000	7.12
	A9 MODIFIED	25	.465	11.9900	7.52
	A2	25	1.167	12.0000	18.12
	A4 MODIFIED	25	.414	11.9500	7.12

TOTAL FLOW INTO: V2

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	V2	25	3.569	12.0000	54.53

SUMMARY FOR HYDROGRAPH ADDITION
at Node: V6

HYG Directory: G:\TMProj\CWM Model City\Calculations\

Upstream Link ID	Upstream Node ID	HYG file	HYG ID	HYG tag
ADDLINK 70	A20 MODIFIED		A20 MODIFIED	25
ADDLINK 150	A11		A11	25
ADDLINK 50	A12 MODIFIED		A12 MODIFIED	25
ADDLINK 140	A10		A10	25
ADDLINK 60	A15 MODIFIED		A15 MODIFIED	25
ADDLINK 120	A18		A18	25
ADDLINK 130	A19 MODIFED		A19 MODIFED	25

INFLOWS TO: V6

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	A20 MODIFIED	25	.125	11.9300	2.27
	A11	25	.609	11.9300	11.03
	A12 MODIFIED	25	.228	11.9300	4.13
	A10	25	1.305	12.0000	20.27
	A15 MODIFIED	25	.159	11.9300	2.88
	A18	25	.252	11.9300	4.57
	A19 MODIFED	25	.785	12.0200	11.87

TOTAL FLOW INTO: V6

HYG file	HYG ID	HYG tag	Volume ac-ft	Peak Time hrs	Peak Flow cfs
	V6	25	3.464	11.9700	53.75

III. DRAINAGE DITCH DESIGN

TASK: To check the existing design of the drainage channels to be constructed on the top of the vegetative cover contours for the final buildout at the Model City Facility RMU-1.

REFERENCES:

1. FlowMaster v4.1b Computer Program by Haestad Methods, Inc.
2. New York Guidelines for Urban Erosion and Sediment Control.
3. Urban Hydrology for Small Watersheds, USDA, SCS, TR55.
4. Quick TR-55 Computer Program, Version 5.46, by Haestad Methods, Inc.
5. Engineering Report for Residuals Management Unit 1, SEC Donohue, June 1992, (Appendix I, Surface Water Drainage and Erosion Calculations).
6. Drawing No. 21, "Final Cover Details," Revised June 1997, Rust Environment & Infrastructure.
7. Drawing No. 21A, "Site Details," Revised June 1997, Rust Environment & Infrastructure.
8. Drawing No. 12, "Top of Vegetative Cover Grades," Revised July 1997, Rust Environment & Infrastructure.
9. Drawing No. 23, " Access Road Layout and Details," Revised June 1992, SEC Donohue.

ASSUMPTIONS:

1. Channels are designed for the 25 year, 24 hour storm event.
2. No freeboard is required where good vegetation can be grown and is maintained (See Ref. 2).
3. The 2 year and 25 year, 24 hour storm events are 2.3 inches and 4.0 inches, respectively.
4. The run-off curve number (CN) for the poor grass cover in hydrologic soil group C (Niagara County) is assumed to be 86 (See Ref. 3).
5. A Manning's "n" for the grass lined channels is assumed to be 0.038.
6. Channel P12 takes an additional 4.9 cfs from SLF-10 via the existing culvert under the southwest access road. See storm containment evaluation and Design Report prepared by Wehran Envirotech for CWM Chemical Services, Inc., April 1990.

CALCULATIONS:

1. Using a digital hand planimeter, the subareas (See attached subarea map) which contribute to the perimeter channel were calculated (See attached table).
2. The time of concentration for each subarea was calculated as the time for runoff to travel from the hydraulically most distant point of the subarea to the downslope end of the drainage channel. (See attached worksheets for time of concentration calculations)
3. Using Reference 4, the peak flows in each drainage channel was determined. (See attached Quick TR-55 output)
4. For the channel design, assume a grass lined channel initially and using the FlowMaster program determine the flow depth.
5. If the velocity is greater than 4 ft/s, then riprap lining should be used.

6. Use an iterative process to determine the riprap size and the flow depth using the following equation:

   $n = y^{1/6}/[(21.6 \log_{10} y/d_{50}) + 14.0]$ (SCS Nomograph - Reference 2)

7. If the minimum depth is greater than the design depth, then the channel dimensions or lining need to be redesigned.
8. The vertical "downflume" channels are designed as rectangular grouted NYSDOT fine riprap (d_{50} = 1.5") lined channels.

Table I-2
Channel Schedule
CWM Chemical Services, LLC
Model City Facility

Channel No.	Channel Type	Slope (ft/ft)	Sideslopes		Bottom Width (ft)	Peak Discharge (cfs)	Flow Depth (ft)	Flow Velocity (ft/s)	Lining Type	Lining Thickness (ft)	Design Depth (min, ft)
			LH:V	RH:V							
A1	Diversion Berm	0.010	3:1	2:1	0.0	2.7	0.75	1.93	Grass	N/A	3.00
A2	Diversion Berm	0.010	3:1	2:1	0.0	18.0	1.52	3.10	Grass	N/A	3.00
A3	Diversion Berm	0.010	3:1	2:1	0.0	12.0	1.31	2.80	Grass	N/A	3.00
A4 Mod	Diversion Berm	0.010	3:1	2:1	0.0	7.5	1.10	2.50	Grass	N/A	3.00
A5	Perimeter Berm	0.005	1:1	2:1	0.0	7.0	1.52	2.02	Grass	N/A	2.50
A6	Perimeter Berm	0.005	1:1	2:1	0.0	5.0	1.34	1.86	Grass	N/A	2.50
A7	Perimeter Berm	0.012	1:1	2:1	0.0	1.0	0.62	1.73	Grass	N/A	2.50
A8	Perimeter Berm	0.012	1:1	2:1	0.0	4.0	1.04	2.44	Grass	N/A	2.50
A9 Mod	Diversion Berm	0.010	3:1	2:1	0.0	7.5	1.10	2.50	Grass	N/A	3.00
A10, R1	Diversion Berm	0.010	3:1	2:1	0.0	21.0	1.61	3.22	Grass	N/A	3.00
A10, R2	Diversion Berm	0.030	3:1	2:1	0.0	21.0	1.19	5.96	d_{50} = 1.5"	1	3.00
A10, R3	Diversion Berm	0.008	3:1	2:1	0.0	21.0	1.70	2.89	Grass	N/A	3.00
A11	Diversion Berm	0.010	3:1	2:1	0.0	11.0	1.27	2.75	Grass	N/A	3.00
A12 Mod	Diversion Berm	0.008	3:1	2:1	0.0	4.1	0.93	1.93	Grass	N/A	3.00
A13	Perimeter Berm	0.005	1:1	2:1	0.0	10.0	1.74	2.21	Grass	N/A	2.50
A14	Perimeter Berm	0.005	1:1	2:1	0.0	6.0	1.43	1.95	Grass	N/A	2.50
A15 Mod	Perimeter Berm	0.005	1:1	2:1	0.0	5.1	1.35	1.87	Grass	N/A	2.50
A16	Perimeter Berm	0.025	1:1	2:1	0.0	2.0	0.70	2.71	Grass	N/A	2.50
A17	Perimeter Berm	0.005	1:1	2:1	0.0	4.0	1.23	1.76	Grass	N/A	2.50
A18	Perimeter Berm	0.005	1:1	2:1	0.0	5.0	1.34	1.86	Grass	N/A	2.50
A19 Mod	Perimeter Berm	0.010	3:1	2:1	0.0	11.7	1.31	2.74	Grass	N/A	3.00
A20 Mod	Perimeter Berm	0.005	1:1	2:1	0.0	2.3	1.00	1.53	Grass	N/A	2.50
A21	Diversion Berm	0.010	3:1	2:1	0.0	7.0	1.07	2.45	Grass	N/A	3.00
Flume 1	Downslope Flume	0.333	2:1	2:1	20.0	54.5	0.28	9.45	d_{50} = 1.5" (Grouted)	1	1.00
Flume 2	Downslope Flume	0.250	2:1	2:1	20.0	53.8	0.30	8.63	d_{50} = 1.5" (Grouted)	1	1.00
P1 Mod	Toe of Perimeter Berm	0.0078	2:1	2:1	0.0	12.9	1.54	2.71	Grass	N/A	2.00
P2	Toe of Perimeter Berm	0.0025	2:1	2:1	2.0	2.4	0.65	1.13	Grass	N/A	2.00
P3	Toe of Perimeter Berm	0.0025	2:1	2:1	2.0	0.8	0.36	0.82	Grass	N/A	2.00
P4	Toe of Perimeter Berm	0.0025	2:1	2:1	2.0	0.8	0.36	0.82	Grass	N/A	2.00
P5	Toe of Perimeter Berm	0.0025	2:1	2:1	2.0	0.8	0.36	0.82	Grass	N/A	2.00
P6	Toe of Perimeter Berm	0.0025	2:1	2:1	2.0	0.8	0.36	0.82	Grass	N/A	2.00
P7	Toe of Perimeter Berm	0.0025	2:1	2:1	2.0	0.8	0.36	0.82	Grass	N/A	2.00
P8	Toe of Perimeter Berm	0.0025	2:1	2:1	2.0	5.4	0.97	1.40	Grass	N/A	2.00
P9	Toe of Perimeter Berm	0.0025	2:1	2:1	2.0	11.1	1.38	1.69	Grass	N/A	2.00
P10	Toe of Perimeter Berm	0.005	2:1	2:1	0.0	3.0	0.97	1.59	Grass	N/A	2.00
P11	Toe of Perimeter Berm	0.002	2:1	2:1	0.0	16.0	2.16	1.71	Grass	N/A	2.50
P12	Toe of Perimeter Berm	0.002	2:1	2:1	6.0	23.9	1.48	1.81	Grass	N/A	2.00
V1	Vertical Channel on Perimeter Berm Sideslope	0.390	4:1	4:1	6.0	10.0	0.21	7.37	d_{50} = 1.5" (Grouted)	1	1.00
V2	Vertical Channel on Perimeter Berm Sideslope	0.390	2:1	2:1	20.0	54.5	0.27	9.94	d_{50} = 1.5" (Grouted)	1	1.00
V3	Vertical Channel on Perimeter Berm Sideslope	0.390	4:1	4:1	6.0	5.0	0.15	5.17	d_{50} = 1.5" (Grouted)	1	1.00
V4	Vertical Channel on Perimeter Berm Sideslope	0.390	4:1	4:1	6.0	9.0	0.19	6.85	d_{50} = 1.5" (Grouted)	1	1.00
V5	Vertical Channel on Perimeter Berm Sideslope	0.390	4:1	4:1	6.0	15.0	0.25	8.59	d_{50} = 1.5" (Grouted)	1	1.00
V6	Vertical Channel on Perimeter Berm Sideslope	0.390	2:1	2:1	20.0	53.7	0.26	9.89	d_{50} = 1.5" (Grouted)	1	1.00

Notes:
The riprap lined channels will be lined with grouted New York State Department of Transportation fine riprap (d50 = 1.5") or equivalent.
ft - feet
cfs - cubic feet per second
ft/s - feet per second
N/A - not applicable

By : JPD (ET) Date: 2/3/1999
Revised: BPS (ET Date: 7/28/2000
Revised: BMS (BE Date: 5/11/2001
Revised: BMS (BE Date: 6/25/2001
Revised: BMS (BE Date: 5/15/2002
Revised: BMS (AF Date: 3/28/2008
Revised: PTO (AR Date: 8/15/2012

Project: CWM Model City
Project No.:23729.2012
Subject: RMU-1 Permit Modification

Prepared by: PTO
Date: 8/2012

Channel A1

Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	2.69
Base Width (ft)	0.00
Left Side Slope (x:1)	3.00
Right Side Slope (x:1)	2.00
Bed Slope	0.0100
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	2.69
Required Flow Depth (ft)	0.75
Resulting Flow Velocity (ft/s)	1.93
Resulting Flow Width at Top (ft)	3.73
Resulting Flow Area (ft^2)	1.39
Resulting Wetted Perimeter (ft)	4.03
Resulting Hydraulic Radius (ft)	0.35

Drainage Channel A2
Worksheet for Triangular Channel

Project Description	
Project File	c:\jpd\mc99\modlcty.fm2
Worksheet	Diversion Berms
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.038	
Channel Slope	0.010000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	2.00	H : V
Discharge	18.00	ft^3/s

Results		
Depth	1.52	ft
Flow Area	5.81	ft^2
Wetted Perimeter	8.23	ft
Top Width	7.62	ft
Critical Depth	1.26	ft
Critical Slope	0.027161	ft/ft
Velocity	3.10	ft/s
Velocity Head	0.15	ft
Specific Energy	1.67	ft
Froude Number	0.63	
Flow is subcritical.		

Drainage Channel A3
Worksheet for Triangular Channel

Project Description	
Project File	c:\programs\fmw\modlcty.fm2
Worksheet	Diversion Berms
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.038	
Channel Slope	0.010000 ft/ft	
Left Side Slope	3.00	H : V
Right Side Slope	2.00	H : V
Discharge	12.00	ft^3/s

Results		
Depth	1.31	ft
Flow Area	4.28	ft^2
Wetted Perimeter	7.07	ft
Top Width	6.55	ft
Critical Depth	1.07	ft
Critical Slope	0.028668 ft/ft	
Velocity	2.80	ft/s
Velocity Head	0.12	ft
Specific Energy	1.43	ft
Froude Number	0.61	
Flow is subcritical.		

Project: CWM Model City **Prepared by:** PTO
Project No.: 23729.2012 **Date:** 8/2012
Subject: RMU-1 Permit Modification

Drainage Channel A4 Modified
Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	7.13
Base Width (ft)	0.00
Left Side Slope (x:1)	3.00
Right Side Slope (x:1)	2.00
Bed Slope	0.010
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	7.13
Required Flow Depth (ft)	1.08
Resulting Flow Velocity (ft/s)	2.46
Resulting Flow Width at Top (ft)	5.38
Resulting Flow Area (ft^2)	2.89
Resulting Wetted Perimeter (ft)	5.81
Resulting Hydraulic Radius (ft)	0.50

Drainage Channel A5
Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	7.00
Base Width (ft)	0.00
Left Side Slope (x:1)	1.00
Right Side Slope (x:1)	2.00
Bed Slope	0.005
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	7.00
Required Flow Depth (ft)	1.52
Resulting Flow Velocity (ft/s)	2.02
Resulting Flow Width at Top (ft)	4.55
Resulting Flow Area (ft^2)	3.46
Resulting Wetted Perimeter (ft)	5.54
Resulting Hydraulic Radius (ft)	0.62

Project: CWM Model City
Project No.: 050.11
Subject: RMU-1 Permit Modification

Prepared by: BMS
Date: 6/4/01

Drainage Channel A6
Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	5.00
Base Width (ft)	0.00
Left Side Slope (x:1)	1.00
Right Side Slope (x:1)	2.00
Bed Slope	0.005
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	5.00
Required Flow Depth (ft)	1.34
Resulting Flow Velocity (ft/s)	1.86
Resulting Flow Width at Top (ft)	4.02
Resulting Flow Area (ft^2)	2.69
Resulting Wetted Perimeter (ft)	4.89
Resulting Hydraulic Radius (ft)	0.55

Project: CWM Model City
Project No.: 050.11
Subject: RMU-1 Permit Modification

Prepared by: BMS
Date: 6/4/01

Drainage Channel A7
Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	1.00
Base Width (ft)	0.00
Left Side Slope (x:1)	1.00
Right Side Slope (x:1)	2.00
Bed Slope	0.012
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	1.00
Required Flow Depth (ft)	0.62
Resulting Flow Velocity (ft/s)	1.73
Resulting Flow Width at Top (ft)	1.86
Resulting Flow Area (ft^2)	0.58
Resulting Wetted Perimeter (ft)	2.27
Resulting Hydraulic Radius (ft)	0.26

Project: CWM Model City
Project No.: 050.11
Subject: RMU-1 Permit Modification

Prepared by: BMS
Date: 6/4/01

Drainage Channel A8
Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	4.00
Base Width (ft)	0.00
Left Side Slope (x:1)	1.00
Right Side Slope (x:1)	2.00
Bed Slope	0.012
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	4.00
Required Flow Depth (ft)	1.04
Resulting Flow Velocity (ft/s)	2.44
Resulting Flow Width at Top (ft)	3.13
Resulting Flow Area (ft^2)	1.64
Resulting Wetted Perimeter (ft)	3.81
Resulting Hydraulic Radius (ft)	0.43

Project: CWM Model City
Project No.: 23729.2012
Subject: RMU-1 Permit Modification

Prepared by: PTO
Date: 08/2012

Drainage Channel A9 Modified
Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	7.53
Base Width (ft)	0.00
Left Side Slope (x:1)	3.00
Right Side Slope (x:1)	2.00
Bed Slope	0.010
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	7.53
Required Flow Depth (ft)	1.10
Resulting Flow Velocity (ft/s)	2.50
Resulting Flow Width at Top (ft)	5.49
Resulting Flow Area (ft^2)	3.01
Resulting Wetted Perimeter (ft)	5.93
Resulting Hydraulic Radius (ft)	0.51

Drainage Channel A10, Reach 1
Worksheet for Triangular Channel

Project Description	
Project File	c:\jpd\mc99\modlcty.fm2
Worksheet	Diversion Berms
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.038	
Channel Slope	0.010000 ft/ft	
Left Side Slope	3.00	H : V
Right Side Slope	2.00	H : V
Discharge	21.00	ft^3/s

Results		
Depth	1.61	ft
Flow Area	6.52	ft^2
Wetted Perimeter	8.72	ft
Top Width	8.07	ft
Critical Depth	1.34	ft
Critical Slope	0.026608 ft/ft	
Velocity	3.22	ft/s
Velocity Head	0.16	ft
Specific Energy	1.78	ft
Froude Number	0.63	
Flow is subcritical.		

Drainage Channel A10, Reach 2 (d50=1.5")
Worksheet for Triangular Channel

Project Description	
Project File	c:\jpd\mc99\modlcty.fm2
Worksheet	Diversion Berms
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.029	
Channel Slope	0.030000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	2.00	H : V
Discharge	21.00	ft^3/s

Results		
Depth	1.19	ft
Flow Area	3.53	ft^2
Wetted Perimeter	6.41	ft
Top Width	5.94	ft
Critical Depth	1.34	ft
Critical Slope	0.015497	ft/ft
Velocity	5.96	ft/s
Velocity Head	0.55	ft
Specific Energy	1.74	ft
Froude Number	1.36	
Flow is supercritical.		

Drainage Channel A10, Reach 3
Worksheet for Triangular Channel

Project Description	
Project File	c:\jpd\mc99\modlcty.fm2
Worksheet	Diversion Berms
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.038	
Channel Slope	0.007500	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	2.00	H : V
Discharge	21.00	ft^3/s

Results		
Depth	1.70	ft
Flow Area	7.26	ft^2
Wetted Perimeter	9.20	ft
Top Width	8.52	ft
Critical Depth	1.34	ft
Critical Slope	0.026608	ft/ft
Velocity	2.89	ft/s
Velocity Head	0.13	ft
Specific Energy	1.83	ft
Froude Number	0.55	
Flow is subcritical.		

Channel A11

Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	11.05
Base Width (ft)	0.00
Left Side Slope (x:1)	3.00
Right Side Slope (x:1)	2.00
Bed Slope	0.0100
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	11.05
Required Flow Depth (ft)	1.27
Resulting Flow Velocity (ft/s)	2.75
Resulting Flow Width at Top (ft)	6.34
Resulting Flow Area (ft^2)	4.02
Resulting Wetted Perimeter (ft)	6.85
Resulting Hydraulic Radius (ft)	0.59

Drainage Channel A12 Modified
Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	4.14
Base Width (ft)	0.00
Left Side Slope (x:1)	3.00
Right Side Slope (x:1)	2.00
Bed Slope	0.008
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	4.14
Required Flow Depth (ft)	0.93
Resulting Flow Velocity (ft/s)	1.93
Resulting Flow Width at Top (ft)	4.63
Resulting Flow Area (ft^2)	2.14
Resulting Wetted Perimeter (ft)	5.00
Resulting Hydraulic Radius (ft)	0.43

Project: CWM Model City
Project No.: 050.11
Subject: RMU-1 Permit Modification

Prepared by: BMS
Date: 6/4/01

Drainage Channel A13
Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	10.00
Base Width (ft)	0.00
Left Side Slope (x:1)	1.00
Right Side Slope (x:1)	2.00
Bed Slope	0.005
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	10.00
Required Flow Depth (ft)	1.74
Resulting Flow Velocity (ft/s)	2.21
Resulting Flow Width at Top (ft)	5.21
Resulting Flow Area (ft^2)	4.52
Resulting Wetted Perimeter (ft)	6.34
Resulting Hydraulic Radius (ft)	0.71

Project: CWM Model City
Project No.: 050.11
Subject: RMU-1 Permit Modification

Prepared by: BMS
Date: 6/4/01

Drainage Channel A14
Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	6.00
Base Width (ft)	0.00
Left Side Slope (x:1)	1.00
Right Side Slope (x:1)	2.00
Bed Slope	0.005
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	6.00
Required Flow Depth (ft)	1.43
Resulting Flow Velocity (ft/s)	1.95
Resulting Flow Width at Top (ft)	4.30
Resulting Flow Area (ft^2)	3.08
Resulting Wetted Perimeter (ft)	5.23
Resulting Hydraulic Radius (ft)	0.59

Project: CWM Model City
Project No.: 23729.2012
Subject: RMU-1 Permit Modification

Prepared by: PTO
Date: 8/2012

Drainage Channel A15 Modified
Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	2.88
Base Width (ft)	0.00
Left Side Slope (x:1)	1.00
Right Side Slope (x:1)	2.00
Bed Slope	0.005
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	2.88
Required Flow Depth (ft)	1.09
Resulting Flow Velocity (ft/s)	1.62
Resulting Flow Width at Top (ft)	3.26
Resulting Flow Area (ft^2)	1.78
Resulting Wetted Perimeter (ft)	3.97
Resulting Hydraulic Radius (ft)	0.45

Drainage Channel A16
Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	2.00
Base Width (ft)	0.00
Left Side Slope (x:1)	1.00
Right Side Slope (x:1)	2.00
Bed Slope	0.025
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	2.00
Required Flow Depth (ft)	0.70
Resulting Flow Velocity (ft/s)	2.71
Resulting Flow Width at Top (ft)	2.11
Resulting Flow Area (ft^2)	0.74
Resulting Wetted Perimeter (ft)	2.56
Resulting Hydraulic Radius (ft)	0.29

Project: CWM Model City
Project No.: 050.11
Subject: RMU-1 Permit Modification

Prepared by: BMS
Date: 6/4/01

Drainage Channel A17
Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	4.00
Base Width (ft)	0.00
Left Side Slope (x:1)	1.00
Right Side Slope (x:1)	2.00
Bed Slope	0.005
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	4.00
Required Flow Depth (ft)	1.23
Resulting Flow Velocity (ft/s)	1.76
Resulting Flow Width at Top (ft)	3.69
Resulting Flow Area (ft^2)	2.27
Resulting Wetted Perimeter (ft)	4.49
Resulting Hydraulic Radius (ft)	0.51

Project: CWM Model City
Project No.: 050.11
Subject: RMU-1 Permit Modification

Prepared by: BMS
Date: 6/4/01

Drainage Channel A18
Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	5.00
Base Width (ft)	0.00
Left Side Slope (x:1)	1.00
Right Side Slope (x:1)	2.00
Bed Slope	0.005
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	5.00
Required Flow Depth (ft)	1.34
Resulting Flow Velocity (ft/s)	1.86
Resulting Flow Width at Top (ft)	4.02
Resulting Flow Area (ft^2)	2.69
Resulting Wetted Perimeter (ft)	4.89
Resulting Hydraulic Radius (ft)	0.55

Drainage Channel A19
Worksheet for Triangular Channel

Project Description	
Project File	c:\jpd\mc99\modlcty.fm2
Worksheet	Diversion Berms
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.038	
Channel Slope	0.009500	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	2.00	H : V
Discharge	8.00	ft^3/s

Results		
Depth	1.14	ft
Flow Area	3.22	ft^2
Wetted Perimeter	6.13	ft
Top Width	5.68	ft
Critical Depth	0.91	ft
Critical Slope	0.030260	ft/ft
Velocity	2.48	ft/s
Velocity Head	0.10	ft
Specific Energy	1.23	ft
Froude Number	0.58	
Flow is subcritical.		

Drainage Channel A20 Modified

Worksheet for Triangular Channel

Channel Design (Input)	
Flow Capacity (cfs)	2.27
Base Width (ft)	0.00
Left Side Slope (x:1)	1.00
Right Side Slope (x:1)	2.00
Bed Slope	0.005
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	2.27
Required Flow Depth (ft)	1.00
Resulting Flow Velocity (ft/s)	1.53
Resulting Flow Width at Top (ft)	2.99
Resulting Flow Area (ft^2)	1.49
Resulting Wetted Perimeter (ft)	3.64
Resulting Hydraulic Radius (ft)	0.41

Drainage Channel A21
Worksheet for Triangular Channel

Project Description	
Project File	c:\jpd\mc99\modlcty.fm2
Worksheet	Diversion Berms
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.038	
Channel Slope	0.010000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	2.00	H : V
Discharge	7.00	ft^3/s

Results		
Depth	1.07	ft
Flow Area	2.86	ft^2
Wetted Perimeter	5.77	ft
Top Width	5.35	ft
Critical Depth	0.87	ft
Critical Slope	0.030804	ft/ft
Velocity	2.45	ft/s
Velocity Head	0.09	ft
Specific Energy	1.16	ft
Froude Number	0.59	
Flow is subcritical.		

Project: CWM Model City
Project No.: 23729.2012
Subject: RMU-1 Permit Modification

Prepared by: PTO
Date: 8/2012

Drainage Flume 1 (D_{50} = 1.5" grouted)

Worksheet for Trapezoidal Channel

Channel Design (Input)	
Flow Capacity (cfs)	54.53
Base Width (ft)	20.00
Left Side Slope (x:1)	2.00
Right Side Slope (x:1)	2.00
Bed Slope	0.330
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	54.53
Required Flow Depth (ft)	0.28
Resulting Flow Velocity (ft/s)	9.45
Resulting Flow Width at Top (ft)	21.12
Resulting Flow Area (ft^2)	5.77
Resulting Wetted Perimeter (ft)	21.26
Resulting Hydraulic Radius (ft)	0.27

Project: CWM Model City
Project No.:23729.2012
Subject: RMU-1 Permit Modification

Prepared by: PTO
Date: 8/2012

Drainage Flume 2 (D_{50} = 1.5" grouted)
Worksheet for Trapezoidal Channel

Channel Design (Input)	
Flow Capacity (cfs)	53.75
Base Width (ft)	20.00
Left Side Slope (x:1)	2.00
Right Side Slope (x:1)	2.00
Bed Slope	0.250
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	53.75
Required Flow Depth (ft)	0.30
Resulting Flow Velocity (ft/s)	8.63
Resulting Flow Width at Top (ft)	21.21
Resulting Flow Area (ft^2)	6.23
Resulting Wetted Perimeter (ft)	21.35
Resulting Hydraulic Radius (ft)	0.29

Project: CWM Model City
Project No.: 050.42
Subject: RMU-1 Permit Modification

Prepared by: TAS
Date: 12/03

Channel P1 Modified

Worksheet for Trapezoidal Channel

Channel Design Inputs	
Flow Capacity (cfs)	12.90
Base Width (ft)	0.00
Left Side Slope (x:1)	2.00
Right Side Slope (x:1)	2.00
Bed Slope	0.0078
Manning "n"	0.038

Flow Conditions Output	
Flowrate from Manning Equation (cfs)	12.90
Required Flow Depth (ft)	1.54
Resulting Flow Velocity (ft/s)	2.71
Resulting Flow Width at Top (ft)	6.18
Resulting Flow Area (ft^2)	4.77
Resulting Wetted Perimeter (ft)	6.91
Resulting Hydraulic Radius (ft)	0.69

Project: CWM Model City
Project No.: 050.42
Subject: RMU-1 Permit Modification

Prepared by: TAS
Date: 12/03

Channel P2

Worksheet for Trapezoidal Channel

Channel Design Input	
Flow Capacity (cfs)	1.20
Base Width (ft)	2.00
Left Side Slope (x:1)	2.00
Right Side Slope (x:1)	2.00
Bed Slope	0.0026
Manning "n"	0.038

Flow Conditions Output	
Flowrate from Manning Equation (cfs)	1.20
Required Flow Depth (ft)	0.44
Resulting Flow Velocity (ft/s)	0.94
Resulting Flow Width at Top (ft)	3.77
Resulting Flow Area (ft^2)	1.28
Resulting Wetted Perimeter (ft)	3.98
Resulting Hydraulic Radius (ft)	0.32

Project: CWM Model City
Project No.:050.04
Subject: RMU-1 ESRB Permit Mod

Prepared by: BMS
Date: 5/14/02

Drainage Channel P3
Worksheet for Trapezoidal Channel

Channel Design (Inputs)	
Flow Capacity (cfs)	0.80
Base Width (ft)	2.00
Left Side Slope (x:1)	2.00
Right Side Slope (x:1)	2.00
Bed Slope	0.0025
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	0.80
Required Flow Depth (ft)	0.36
Resulting Flow Velocity (ft/s)	0.82
Resulting Flow Width at Top (ft)	3.44
Resulting Flow Area (ft^2)	0.98
Resulting Wetted Perimeter (ft)	3.61
Resulting Hydraulic Radius (ft)	0.27

Project: CWM Model City
Project No.: 050.04
Subject: RMU-1 ESRB Permit Mod

Prepared by: BMS
Date: 5/14/02

Drainage Channel P4
Worksheet for Trapezoidal Channel

Initial Design Inputs	
Flow Capacity (cfs)	0.80
Base Width (ft)	2.00
Left Side Slope (x:1)	2.00
Right Side Slope (x:1)	2.00
Bed Slope	0.0025
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	0.80
Required Flow Depth (ft)	0.36
Resulting Flow Velocity (ft/s)	0.82
Resulting Flow Width at Top (ft)	3.44
Resulting Flow Area (ft^2)	0.98
Resulting Wetted Perimeter (ft)	3.61
Resulting Hydraulic Radius (ft)	0.27

Project: CWM Model City
Project No.: 050.04
Subject: RMU-1 ESRB Permit Mod

Prepared by: BMS
Date: 5/14/02

Drainage Channel P5
Worksheet for Trapezoidal Channel

Channel Design (Input)	
Flow Capacity (cfs)	0.80
Base Width (ft)	2.00
Left Side Slope (x:1)	2.00
Right Side Slope (x:1)	2.00
Bed Slope	0.0025
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	0.80
Required Flow Depth (ft)	0.36
Resulting Flow Velocity (ft/s)	0.82
Resulting Flow Width at Top (ft)	3.44
Resulting Flow Area (ft^2)	0.98
Resulting Wetted Perimeter (ft)	3.61
Resulting Hydraulic Radius (ft)	0.27

Project: CWM Model City
Project No.:050.04
Subject: RMU-1 ESRB Permit Mod

Prepared by: BMS
Date: 5/14/02

Drainage Channel P6
Worksheet for Trapezoidal Channel

Channel Design (Input)	
Flow Capacity (cfs)	0.80
Base Width (ft)	2.00
Left Side Slope (x:1)	2.00
Right Side Slope (x:1)	2.00
Bed Slope	0.0025
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	0.80
Required Flow Depth (ft)	0.36
Resulting Flow Velocity (ft/s)	0.82
Resulting Flow Width at Top (ft)	3.44
Resulting Flow Area (ft^2)	0.98
Resulting Wetted Perimeter (ft)	3.61
Resulting Hydraulic Radius (ft)	0.27

Project: CWM Model City
Project No.: 050.04
Subject: RMU-1 ESRB Permit Mod

Prepared by: BMS
Date: 5/14/02

Drainage Channel P7
Worksheet for Trapezoidal Channel

Channel Design (Input)	
Flow Capacity (cfs)	0.80
Base Width (ft)	2.00
Left Side Slope (x:1)	2.00
Right Side Slope (x:1)	2.00
Bed Slope	0.0025
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	0.80
Required Flow Depth (ft)	0.36
Resulting Flow Velocity (ft/s)	0.82
Resulting Flow Width at Top (ft)	3.44
Resulting Flow Area (ft^2)	0.98
Resulting Wetted Perimeter (ft)	3.61
Resulting Hydraulic Radius (ft)	0.27

Project: CWM Model City
Project No.:050.04
Subject: RMU-1 ESRB Permit Mod

Prepared by: BMS
Date: 5/14/02

Drainage Channel P9
Worksheet for Trapezoidal Channel

Channel Design (Input)	
Flow Capacity (cfs)	11.10
Base Width (ft)	2.00
Left Side Slope (x:1)	2.00
Right Side Slope (x:1)	2.00
Bed Slope	0.0025
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	11.10
Required Flow Depth (ft)	1.38
Resulting Flow Velocity (ft/s)	1.69
Resulting Flow Width at Top (ft)	7.51
Resulting Flow Area (ft^2)	6.55
Resulting Wetted Perimeter (ft)	8.16
Resulting Hydraulic Radius (ft)	0.80

Drainage Channels P10
Worksheet for Triangular Channel

Project Description	
Project File	c:\programs\fmw\modlcty.fm2
Worksheet	Perimeter Channels
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.038	
Channel Slope	0.005000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Discharge	3.00	ft^3/s

Results		
Depth	0.97	ft
Flow Area	1.89	ft^2
Wetted Perimeter	4.35	ft
Top Width	3.89	ft
Critical Depth	0.67	ft
Critical Slope	0.035074	ft/ft
Velocity	1.59	ft/s
Velocity Head	0.04	ft
Specific Energy	1.01	ft
Froude Number	0.40	
Flow is subcritical.		

Drainage Channels P11
Worksheet for Triangular Channel

Project Description	
Project File	c:\programs\fmw\modlcty.fm2
Worksheet	Perimeter Channels
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.038	
Channel Slope	0.002000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Discharge	16.00	ft^3/s

Results		
Depth	2.16	ft
Flow Area	9.36	ft^2
Wetted Perimeter	9.67	ft
Top Width	8.65	ft
Critical Depth	1.32	ft
Critical Slope	0.028057	ft/ft
Velocity	1.71	ft/s
Velocity Head	0.05	ft
Specific Energy	2.21	ft
Froude Number	0.29	
Flow is subcritical.		

Drainage Channel P12
Worksheet for Trapezoidal Channel

Project Description	
Project File	c:\programs\fmw\modlcty.fm2
Worksheet	Perimeter Channel
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.038	
Channel Slope	0.002000	ft/ft
Left Side Slope	2.00	H : V
Right Side Slope	2.00	H : V
Bottom Width	6.00	ft
Discharge	23.90	ft^3/s

Results		
Depth	1.48	ft
Flow Area	13.23	ft^2
Wetted Perimeter	12.61	ft
Top Width	11.91	ft
Critical Depth	0.73	ft
Critical Slope	0.026131	ft/ft
Velocity	1.81	ft/s
Velocity Head	0.05	ft
Specific Energy	1.53	ft
Froude Number	0.30	
Flow is subcritical.		

Drainage Channel V1 (Grouted d50=1.5")
Worksheet for Trapezoidal Channel

Project Description	
Project File	c:\jpd\mc99\modlcty.fm2
Worksheet	Vertical Perimeter Berm Channels
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Discharge

Input Data		
Mannings Coefficient	0.041	
Channel Slope	0.390000	ft/ft
Depth	0.21	ft
Left Side Slope	4.00	H : V
Right Side Slope	4.00	H : V
Bottom Width	6.00	ft

Results		
Discharge	10.58	ft^3/s
Flow Area	1.44	ft^2
Wetted Perimeter	7.73	ft
Top Width	7.68	ft
Critical Depth	0.42	ft
Critical Slope	0.035543	ft/ft
Velocity	7.37	ft/s
Velocity Head	0.84	ft
Specific Energy	1.05	ft
Froude Number	3.00	
Flow is supercritical.		

Project: CWM Model City
Project No.: 23729.2012
Subject: RMU-1 Permit Modification

Prepared by: PTO
Date: 8/2012

Drainage Channel V2 (D_{50} = 1.5" grouted)
Worksheet for Trapezoidal Channel

Channel Design (Input)	
Flow Capacity (cfs)	54.53
Base Width (ft)	20.00
Left Side Slope (x:1)	2.00
Right Side Slope (x:1)	2.00
Bed Slope	0.390
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	54.53
Required Flow Depth (ft)	0.27
Resulting Flow Velocity (ft/s)	9.94
Resulting Flow Width at Top (ft)	21.07
Resulting Flow Area (ft^2)	5.48
Resulting Wetted Perimeter (ft)	21.19
Resulting Hydraulic Radius (ft)	0.26

Drainage Channel V3 (Grouted d50 = 1.5")
Worksheet for Trapezoidal Channel

Project Description	
Project File	c:\programs\fmw\modlcty.fm2
Worksheet	Vertical Perimeter Berm Channels
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.047	
Channel Slope	0.390000	ft/ft
Left Side Slope	4.00	H : V
Right Side Slope	4.00	H : V
Bottom Width	6.00	ft
Discharge	5.00	ft^3/s

Results		
Depth	0.15	ft
Flow Area	0.97	ft^2
Wetted Perimeter	7.21	ft
Top Width	7.17	ft
Critical Depth	0.26	ft
Critical Slope	0.053252	ft/ft
Velocity	5.17	ft/s
Velocity Head	0.42	ft
Specific Energy	0.56	ft
Froude Number	2.48	
Flow is supercritical.		

Drainage Channel V4 (Grouted d50 = 1.5")
Worksheet for Trapezoidal Channel

Project Description	
Project File	c:\programs\fmw\modlcty.fm2
Worksheet	Vertical Perimeter Berm Channels
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.042	
Channel Slope	0.390000	ft/ft
Left Side Slope	4.00	H : V
Right Side Slope	4.00	H : V
Bottom Width	6.00	ft
Discharge	9.00	ft^3/s

Results		
Depth	0.19	ft
Flow Area	1.31	ft^2
Wetted Perimeter	7.60	ft
Top Width	7.55	ft
Critical Depth	0.38	ft
Critical Slope	0.038336	ft/ft
Velocity	6.85	ft/s
Velocity Head	0.73	ft
Specific Energy	0.92	ft
Froude Number	2.90	
Flow is supercritical.		

Drainage Channel V5 (Grouted d50 = 1.5")
Worksheet for Trapezoidal Channel

Project Description	
Project File	c:\programs\fmw\modlcty.fm2
Worksheet	Vertical Perimeter Berm Channels
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.039	
Channel Slope	0.390000	ft/ft
Left Side Slope	4.00	H : V
Right Side Slope	4.00	H : V
Bottom Width	6.00	ft
Discharge	15.00	ft^3/s

Results		
Depth	0.25	ft
Flow Area	1.75	ft^2
Wetted Perimeter	8.06	ft
Top Width	8.00	ft
Critical Depth	0.51	ft
Critical Slope	0.030357	ft/ft
Velocity	8.59	ft/s
Velocity Head	1.15	ft
Specific Energy	1.40	ft
Froude Number	3.24	
Flow is supercritical.		

Project: CWM Model City
Project No.:23729.2012
Subject: RMU-1 Permit Modification

Prepared by: PTO
Date: 8/2012

Drainage Channel V6 (D_{50} = 1.5" grouted)

Worksheet for Trapezoidal Channel

Channel Design (Input)	
Flow Capacity (cfs)	53.75
Base Width (ft)	20.00
Left Side Slope (x:1)	2.00
Right Side Slope (x:1)	2.00
Bed Slope	0.390
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	53.75
Required Flow Depth (ft)	0.26
Resulting Flow Velocity (ft/s)	9.89
Resulting Flow Width at Top (ft)	21.06
Resulting Flow Area (ft^2)	5.44
Resulting Wetted Perimeter (ft)	21.18
Resulting Hydraulic Radius (ft)	0.26

IV. EAST STORMWATER RETENTION BASIN SIZING

CLIENT: CWM Chemical Services, LLC **PROJECT:** Model City, NY **Prepared By:** BMS **Date:** 12/2/03
TITLE: RMU-1 Permit Modification **Reviewed By:** ______ **Date:** ______
Revised By: PTO **Date:** 8/15/2012

SUBJECT: East Stormwater Retention Basin

TASK:

Redesign the East Stormwater Retention Basin (ESRB) to contain runoff from the 25-year, 24-hour design storm, provide storage for at least one year of accumulated sediment, and demonstrate a minimum of one foot of freeboard under final conditions. Demonstrate that the ESRB redesign can contain runoff from the 25-year, 24-hour design storm and provide storage for one year of accumulated sediment under interim conditions. Incorporate an emergency spillway which provides adequate hydraulic capacity to route the 100-year, 24-hour design storm.

REFERENCES:

1. Appendix I to the Engineering Report for Residuals Management Unit 1 entitled "Surface Water Drainage and Erosion Calculations."

2. "New York Guidelines for Urban Erosion and Sediment Control," April 1997.

3. "Conservation Practice Standard Code 378 (Pond)," Natural Resources Conservation Service, October 1987.

4. Technical Release 55 "Urban Hydrology for Small Watersheds," Soil Conservation Service, June 1986.

5. PondPack for Windows, Version 7.5, hydrology modeling program, Haestad Methods, Inc.

6. "Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada," Northeast Regional Climate Center, September 1993.

7. RMU-1 Permit Drawing No. 22-a entitled "Site Surface Water Plan and Details," BBL June 2003, Last Revised March 2008

METHODOLOGY:

Approximately 26.39 acres of RMU-1 and peripheral areas, including the gravel road at the toe of the perimeter berm and the basin area itself, drain into the ESRB. The ESRB redesign is evaluated under two scenarios, each with different stormwater runoff conditions, annual sediment accumulations, and freeboard conditions. The first scenario ("interim" condition) assumes that approximately half of the RMU-1 area tributary to the ESRB (with the exception of the basin area itself and any gravel roads) is newly graded and unvegetated. The remainder of the RMU-1 area tributary to the ESRB is assumed to be moderately vegetated ("fair" condition as defined in Table 2-2a. of reference 4). This scenario is intended to model RMU-1 as establishment of final cover vegetation progresses. The second scenario (the "final" condition) assumes that the entire RMU-1 area tributary to the ESRB is moderately vegetated ("fair" condition as defined in Table 2-2a. of reference 4) and is intended to model RMU-1 following establishment of the final cover vegetation.

The ESRB redesign has been sized to accommodate a minimum of one year of sediment accumulation under each scenario in addition to the 25-year, 24-hour runoff volume. The methodology used to redesign the basin is outlined below.

1. Annual Sediment Accumulation

As discussed above, annual sediment accumulations are calculated for both scenarios (interim and final). The annual sediment loading on the basin under the interim condition reflects increased soil loss conditions associated with newly graded areas.

CLIENT: CWM Chemical Services, LLC **PROJECT:** Model City, NY **Prepared By:** BMS **Date:** 12/2/03
TITLE: RMU-1 Permit Modification **Reviewed By:** ______ **Date:** ______
Revised By: PTO **Date:** 8/15/2012

SUBJECT: East Stormwater Retention Basin

According to soil loss calculations in the final cover soil loss calculations contained in Section VI of reference 1, approximately 1.79 tons/acre/year will be lost from the final cover once vegetation is established. Since the "C" value in the Universal Soil Loss Equation for unvegetated conditions is approximately 100 times that for vegetated conditions, BBL estimates that approximately 179 tons/acre/year will be lost from newly graded areas of the final cover. Consequently, annual sediment loading on the basin under the interim condition is based on 179 tons/acre/year from half of the basin watershed (minus the basin area itself), or 11.68 acres (representative of newly graded final cover) and 1.79 tons/acre/year from the remainder of the area of RMU-1 that is tributary to the ESRB (representative of established vegetation). The annual sediment loading on the basin under the final condition is based on the final cover soil loss calculations contained in Section VI of reference 1.

2. Runoff Curve Numbers and 25-year, 24-hour Stormwater Runoff Volumes

Stormwater runoff volumes for the design storm are calculated for both scenarios using a composite runoff curve number for each subarea in the ESRB watershed. The perimeter subareas (i.e., A16 and those designated with a "P") presented in Figure D-1 in Section II of reference 1, include runoff from half of the perimeter road and therefore, have a composite runoff curve number due to the RMU-1 and gravel road areas. Under the interim condition, the interior subareas (i.e., those designated with an "A" except A16) also presented in Figure D-1 have a composite runoff curve number based on half of the RMU-1 area in each subarea being newly graded and the other half being vegetated. Under the final condition, the interior subareas are homogenous and are assigned a single curve number based on a vegetated condition.

3. Design High Water Elevations and Freeboards

The design high water elevations for both the interim and final conditions are obtained directly by interpolating from the basin rating curve. The design high water elevation for each scenario is the basin elevation corresponding to one year of accumulated sediment plus the 25-year, 24-hour stormwater runoff volume. Freeboard is based on the lowest berm crest elevation of 321.7 (i.e., the invert elevation of the emergency spillway).

4. Estimated Peak Basin Discharge and Time to Drain

The ESRB will function as a retention basin, meaning that its outlet valve will be closed for the duration of the design storm. The peak discharge from the basin will occur immediately after opening the manually operated outlet valve and is dependent on the design high water elevation and the configuration of the outlet structure. The outlet structure for the revised ESRB consists of a perforated standpipe (created by installing holes through the walls of a concrete manhole structure), fabric filter, and outlet valve. The majority of the stormwater discharges through ten 2-inch diameter orifices created in the standpipe at elevation 318.4. Sediment dewatering and drawdown of the basin to the basin floor is accomplished through three 10-foot lengths of 4-inch diameter perforated corrugated HDPE pipe. To minimize the potential for migration of sediment from the basin, the sediment dewatering pipes and the 2-inch diameter orifices will be covered with crushed stone. A filter fabric will also be included over the perforated pipes to further reduce the potential for sediment migration. Additional details pertaining to the outlet structure design are depicted in reference 7. The ESRB time to drain is based on the design high water and the basin floor elevation (317.0).

5. Emergency Spillway Design

An emergency spillway will be incorporated in the ESRB design to route the 100-year, 24-hour design storm. The invert of the emergency spillway is established at the design high water elevation for the final watershed condition plus 1.33 feet. Thus, the freeboard under the final watershed condition is 1.33 feet. The emergency spillway dimensions are based on the peak discharge over the spillway during the 100-year, 24-hour design storm. Peak discharges over the emergency spillway are calculated assuming the basin is dry at the beginning of the 100-year, 24-hour design storm and that the basin outlet gate is closed. Therefore, the ESRB functions as a complete retention basin until the basin elevation equals the invert elevation of the emergency spillway, at which point it functions as a detention basin.

6. Adherence to Basin Design Criteria

The basin and outlet structure design criteria presented in references 2 and 3 are discussed and compared with the revised ESRB design to assess compliance and justify any deviations.

ASSUMPTIONS:

1. The following runoff curve numbers (CN values) are based on reference 4 and assume a hydrologic group "C" (consistent with reference 1):

   - Vegetated areas of RMU-1 = 79 (open space, fair condition);
   - Newly graded areas of RMU-1 = 91 (newly graded areas);
   - Perimeter roads = 89 (gravel roads); and
   - Basin water surface = 100 (100% runoff).

2. The basin water surface area (for the purposes of calculating runoff from the CN=100 area) is conservatively based on the elevation contour 321.5, which is above the high water elevations for both the interim and final conditions.

3. The time of concentration and acreage for each subarea in the ESRB watershed are based on Reference 1.

4. The minimum required freeboard under the final condition is 1.0 foot. Due to its temporary nature, less than 1.0 foot of freeboard is acceptable under the interim condition.

5. The basin is dry and contains one year of accumulated sediment at the beginning of the design storm.

6. The 25-year, 24-hour design storm produces 4.00 inches of rainfall.

7. The 100-year, 24-hour design storm produces 5.65 inches of rainfall.

CALCULATIONS:

1. Annual Sediment Accumulation

Interim Condition

Annual sediment accumulation for the interim condition is based on calculated final cover soil loss rates (Section VI of reference 1) and estimated soil loss rates for the newly graded areas (i.e., 100 times the calculated final cover soil loss rate as described above):

Annual Sediment Accumulation = (179 tons/acre/year)(11.68 acres) + (1.79 tons/acre/year)(11.68 acres)
= 2,111.6 tons/year

Based on a unit weight of 85 lbs/cu.ft. for silty clay (reference 2), the annual sediment accumulation in terms of volume is:

Annual Sediment Accumulation = (2,111.6 tons/year)(2,000)(1/85)(1/43,560)
= **1.141 acre-feet**

Final Condition

Annual sediment accumulation for the final condition is based on calculated final cover soil loss rates (Section VI of reference 1):

Annual Sediment Accumulation = (1.79 tons/acre/year)(23.35 acres)
= 41.797 tons/year

Based on a unit weight of 85 lbs/cu.ft. for silty clay (reference 2), the annual sediment accumulation in terms of volume is:

Annual Sediment Accumulation = (41.8 tons/year)(2,000)(1/85)(1/43,560)
= **0.023 acre-feet**

2. Runoff Curve Numbers and 25-year, 24-hour Stormwater Runoff Volumes

Interim Condition

The following table summarizes the acreages and runoff curve numbers (both the individual CN components and the composite CN value) for the ESRB watershed subareas under the interim condition.

Subarea ID	Total Area [acres]	Tc [hr]	Individual CN Components				Composite CN
			CN=79	CN=91	CN=89	CN=100	
A1	1.09	0.36	0.54	0.55	-	-	85
A2	5.50	0.24	2.75	2.75	-	-	85
A3	3.70	0.16	1.85	1.85	-	-	85
A4 Modified	1.95	0.13	0.98	0.98	-	-	85
A5	2.30	0.30	1.15	1.15	-	-	85
A6	1.25	0.11	0.62	0.63	-	-	85
A7	0.23	0.10	0.11	0.12	-	-	85
A9 Modified	2.19	0.17	1.08	1.08	0.03	-	85

Subarea ID	Total Area [acres]	Tc [hr]	Individual CN Components				Composite CN
			CN=79	CN=91	CN=89	CN=100	
A16	0.46	0.24	0.19	0.20	0.07	-	86
A21	2.16	0.17	1.08	1.08	-	-	85
P2	0.29	0.10	0.10	0.11	0.08	-	86
P3	0.19	0.10	0.07	0.08	0.04	-	86
P4	0.21	0.10	0.08	0.09	0.04	-	86
P5	0.21	0.10	0.08	0.09	0.04	-	86
P6	0.20	0.10	0.07	0.08	0.05	-	86
P7	0.19	0.10	0.07	0.07	0.05	-	86
P8	0.18	0.10	0.07	0.07	0.04	-	86
P9	1.05	0.15	0.40	0.41	0.24	-	86
P13 (Basin)	3.04	0.10	0.25	-	0.37	2.42	97

The resulting 25-year, 24-hour stormwater runoff volume is 5.731 acre-feet and the resulting peak discharge into the basin is 85.05 cfs under the interim condition.

Final Condition

The following table summarizes the acreages and runoff curve numbers (both the individual CN components and the composite CN value) for the ESRB watershed subareas under the final condition.

Subarea ID	Total Area [acres]	Tc [hr]	Individual CN Components				Composite CN
			CN=79	CN=91	CN=89	CN=100	
A1	1.09	0.36	1.09	-	-	-	79
A2	5.50	0.24	5.50	-	-	-	79
A3	3.70	0.16	3.70	-	-	-	79
A4 Modified	1.95	0.13	1.95	-	-	-	79
A5	2.30	0.30	2.30	-	-	-	79
A6	1.25	0.11	1.25	-	-	-	79

Subarea ID	Total Area [acres]	Tc [hr]	Individual CN Components				Composite CN
			CN=79	CN=91	CN=89	CN=100	
A7	0.23	0.10	0.23	-	-	-	79
A9 Modified	2.19	0.17	2.16	-	0.03	-	79
A16	0.46	0.24	0.39	-	0.07	-	81
A21	2.16	0..17	2.16	-	-	-	79
P2	0.29	0.10	0.21	-	0.08	-	82
P3	0.19	0.10	0.15	-	0.04	-	81
P4	0.21	0.10	0.17	-	0.04	-	81
P5	0.21	0.10	0.17	-	0.04	-	81
P6	0.20	0.10	0.15	-	0.05	-	82
P7	0.19	0.10	0.14	-	0.05	-	82
P8	0.18	0.10	0.14	-	0.04	-	81
P9	1.05	0.15	0.81	-	0.24	-	81
P13 (Basin)	3.04	0.10	0.25	-	0.37	2.42	97

The resulting 25-year, 24-hour stormwater runoff volume is 4.794 acre-feet and the resulting peak discharge into the basin is 71.20 cfs under the final condition.

3. Design High Water Elevations and Freeboards

Interim Condition

The design high water elevation under the interim condition is the basin elevation corresponding to 6.872 acre-feet of storage volume (1.141 acre-feet of sediment + 5.731 acre-feet of stormwater runoff). Based on the basin rating curve, this volume is achieved at 321.08 feet. The resulting freeboard is 0.62 feet (321.7 – 321.08).

Final Condition

The design high water elevation under the final condition is the basin elevation corresponding to 4.817 acre-feet of storage volume (0.023 acre-feet of sediment + 4.794 acre-feet of stormwater runoff). Based on the basin rating curve, this volume is achieved at 320.18 feet. The resulting freeboard is 1.52 feet (321.7 – 320.18), which exceeds the minimum required freeboard of 1 foot.

4. Estimated Basin Peak Discharge and Time to Drain

Interim Condition

The estimated peak discharge from the basin under the interim condition is 4.15 cfs, which will occur immediately after the basin outlet valve is open. The estimated time to drain from the design high water elevation of 321.08 is 2.5 days (60.7 hours).

Final Condition

The estimated peak discharge from the basin under the final condition is 3.33 cfs, which will occur immediately after the basin outlet valve is open. The estimated time to drain from the design high water elevation of 320.18 is 2.3 days (54.0 hours).

5. Emergency Spillway Design

Estimated peak discharges over the emergency spillway during the 100-year, 24-hour design storm are 4.08 cfs and 0.79 cfs under interim and final watershed conditions, respectively. The invert of the spillway will be reinforced with erosion control mat. The outboard face of the basin berm immediately downgradient of the spillway will be armored with a 12-inch thick layer of riprap. A 12-inch thick riprap apron measuring approximately 10 feet long by 18 feet wide will be located at the berm toe to reduce outflow velocities. All riprap will be NYSDOT fine riprap and be underlain with non-woven geotextile.

6. Adherence to Basin Design Criteria

The following is a list of applicable design criteria presented in references 2 and 3 and whether the ESRB redesign meets the criteria. Justification is presented for deviations from the design criteria.

Criteria Presented in Reference 2

1. *Permanent basins (to function more than 36 months) shall be designed and constructed to conform to SCS Standard and Specification No. 378 for ponds.*

   See list of criteria presented in reference 3 below.

2. *The sediment storage volume of the basin shall be at least 1,800 cu. ft. per acre of disturbed area draining to the basin. Where possible, the entire drainage area is used for the computation rather than the disturbed area to maximize trapping efficiency.*

   The sediment storage volume of the basin for the interim condition is 1.312 acre-feet, which equates to 2,341cu.ft. per acre of the entire basin watershed.

3. *The shape of the basin should provide at least a 2:1 length to width ratio. For basins having multiple inflow points, any inflow point that contributes 30% or more of the total peak flowrate should adhere to the 2:1 ratio.*

   Of the four culverts that discharge into the basin, only Culvert No. 1 (located at the northern end of the basin) contributes 30% or more of the total peak flowrate into the basin. The length from the discharge point of Culvert No. 1 to the basin outlet is 700 ft. The effective width of the basin is approximately 151 ft using the formula in reference 2 (W_e=A/L, where A=basin surface area at elevation 321.5 =2.42 acres=105,415 ft^2 and L=length from culvert discharge point to basin outlet=700 ft). Therefore, the length to width ratio is approximately 4.6:1. Although it contributes less than 30% of the total peak flowrate into the basin, the flow from Culvert No. 4 (located at the southern end of the basin) will be redirected north around an earthen berm to increase the flow path length and achieve a length to width ratio of approximately 3.1:1 (W_e=105,415 ft^2 ÷ 575 ft = 183 ft and L=575 ft).

4. *The basin shall have a spillway consisting of a vertical pipe joined to a pipe which shall extend through the embankment.*

   Although many aspects of the spillway criteria in reference 2 pertain to detention and not retention basins, the outlet structure has been designed in general accordance with the "Device-II" detail on page 5A.61 of reference 2.

5. *Provisions shall be incorporated to dewater the sediment.*

   The outlet structure design provides three perforated sediment dewatering pipes that will be covered with crushed stone and non-woven geotextile to minimize entry of sediment into the pipes.

6. *The riser base shall have sufficient weight to prevent flotation.*

   The riser will be a precast concrete manhole and will have sufficient weight to resist buoyant forces.

7. *Anti-Seep collars shall be installed around all conduits through earthen berms.*

   Anti-seep collars are not necessary since a gasketed connection between the basin outlet pipe and the concrete outlet structure will minimize the migration of basin water along the exterior of the outlet pipe.

8. *Freeboard shall be at least 1 ft.*

   The basin provides 1.52 ft. of freeboard under the final condition. As discussed between the NYSDEC and CWM, the interim condition is allowed to utilize this minimum freeboard because it is a temporary condition.

9. *The basin berm sideslopes shall be 2:1 or flatter and have a minimum top width of 8 ft.*

   The basin berm sideslopes are 3:1 and have a top width of 8 ft.

10. *An anti-vortex device and trash rack shall be securely installed on top of the riser.*

    Since the design high water is below the top of the basin outlet structure, vortices are not expected to form. A combination of small diameter orifices and crushed stone mounded over the orifices will prevent the entry of debris into the outlet structure.

11. *An emergency spillway must be provided unless the principal spillway is large enough to pass the peak discharge from a 10-year frequency rainfall event.*

    The basin outlet structure provides sufficient flowrate to pass the peak basin outflow resulting from a 25-year, 24-hour storm. Additionally, an emergency spillway has been incorporated into the design to allow controlled discharge of runoff from the 100-year, 24-hour storm.

<u>Criteria Presented in Reference 3</u>

1. *Minimum top width for basin embankment shall be 6 ft.*

   The basin embankment top width is 8 ft.

2. *Combined upstream and downstream sideslopes of embankment shall not be less than 5:1 and neither slope shall be steeper than 2:1.*

   The basin berm sideslopes are 3:1.

3. *The minimum elevation of the top of the settled embankment shall be 1 ft. above the water surface in the basin with the emergency spillway flowing at design depth.*

   The design provides 1.33 feet of freeboard between the design high water elevation (under the final condition) and the lowest berm crest elevation.

4. *The basin outlet pipe shall have a minimum diameter of 4 in.*

   The basin outlet pipe will be 15 in.

5. *For dams 20 ft. or less in effective height, acceptable pipe conduit materials for the basin outlet include plastic.*

   The outlet pipe will be smooth-bore corrugated high density polyethylene.

6. *Seepage control shall be provided along the pipe conduit if the effective height of dam is greater than 15 ft. or the conduit is of smooth pipe larger than 8 inches in diameter or the conduit is of corrugated pipe larger than 12 inches in diameter.*

   Anti-seep collars are not necessary since a gasketed connection between the basin outlet pipe and the concrete outlet structure will minimize the migration of basin water along the exterior of the outlet pipe.

7. *Closed conduit spillways designed for pressure flow must have adequate anti-vortex devices.*

   Since the design high water is below the top of the basin outlet structure, vortices are not expected to form. Additionally, the capacity of the basin outlet pipe is sufficient to prevent pressure flow from occurring.

8. *To prevent clogging of the conduit, an appropriate trash guard shall be installed at the inlet.*

   A combination of small diameter orifices and crushed stone mounded over the orifices will prevent the entry of debris into the outlet structure.

9. *An emergency spillway must be provided unless the principal spillway is large enough to pass the peak discharge from the routed design hydrograph without overtopping the basin.*

   The basin outlet structure provides sufficient flowrate to pass the peak basin outflow resulting from a 25-year, 24-hour storm. Since the ESRB is a retention basin, it cannot overtop for a storm event of intensity equal to or less than the design event. An emergency spillway has been incorporated to allow controlled discharge of runoff from the 100-year, 24-hour storm event.

Rating Curve and Outlet Structure Information

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Elevation (ft)	Planimeter (sq.in)	Area (acres)	A1+A2+sqr(A1*A2) (acres)	Volume (ac-ft)	Volume Sum (ac-ft)
317.00	-----	.0301	.0000	.000	.000
317.50	-----	.5465	.7049	.117	.117
318.00	-----	1.3458	2.7499	.458	.576
318.50	-----	1.8359	4.7536	.792	1.368
319.00	-----	2.0030	5.7565	.959	2.327
319.50	-----	2.0870	6.1346	1.022	3.350
320.00	-----	2.1714	6.3872	1.065	4.414
320.50	-----	2.2563	6.6411	1.107	5.521
321.00	-----	2.3415	6.8963	1.149	6.671
321.50	-----	2.4273	7.1528	1.192	7.863
322.00	-----	2.6948	7.6797	1.280	9.143

POND VOLUME EQUATIONS

* Incremental volume computed by the Conic Method for Reservoir Volumes.

Volume = (1/3) * (EL2-EL1) * (Area1 + Area2 + sq.rt.(Area1*Area2))

where: EL1, EL2 = Lower and upper elevations of the increment
Area1,Area2 = Areas computed for EL1, EL2, respectively
Volume = Incremental volume between EL1 and EL2

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REQUESTED POND WS ELEVATIONS:

Min. Elev.= 317.00 ft
Increment = 1.00 ft
Max. Elev.= 322.00 ft

****

OUTLET CONNECTIVITY

****

---> Forward Flow Only (UpStream to DnStream)
<--- Reverse Flow Only (DnStream to UpStream)
<---> Forward and Reverse Both Allowed

Structure	No.		Outfall	E1, ft	E2, ft
Weir-Rectangular	we	--->	TW	321.500	322.000
Orifice-Circular	P2	--->	CV	318.390	322.000
Orifice-Circular	P1	--->	CV	317.000	322.000
Culvert-Circular	CV	--->	TW	317.000	322.000
TW SETUP, DS Channel					

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OUTLET STRUCTURE INPUT DATA

```
Structure ID      = we
Structure Type    = Weir-Rectangular
-----------------------------------
# of Openings     =        1
Crest Elev.       =    321.50 ft
Weir Length       =      8.00 ft
Weir Coeff.       =  2.700000

Weir TW effects     (Use adjustment equation)



Structure ID      = P2
Structure Type    = Orifice-Circular
-----------------------------------
# of Openings     =        1
Invert Elev.      =    318.39 ft
Diameter          =     .1670 ft
Orifice Coeff.    =     3.000


Structure ID      = P1
Structure Type    = Orifice-Circular
-----------------------------------
# of Openings     =        1
Invert Elev.      =    317.00 ft
Diameter          =     .1670 ft
Orifice Coeff.    =    12.000
```

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OUTLET STRUCTURE INPUT DATA

```
Structure ID       = CV
Structure Type     = Culvert-Circular
------------------------------------
No. Barrels        =        1
Barrel Diameter    =    1.2500 ft
Upstream Invert    =    317.00 ft
Dnstream Invert    =    316.50 ft
Horiz. Length      =    100.00 ft
Barrel Length      =    100.00 ft
Barrel Slope       =    .00500 ft/ft

OUTLET CONTROL DATA...
Mannings n         =     .0110
Ke                 =     .5000  (forward entrance loss)
Kb                 =   .016629  (per ft of full flow)
Kr                 =     .5000  (reverse entrance loss)
HW Convergence     =      .001  +/- ft

INLET CONTROL DATA...
Equation form      =        1
Inlet Control K    =     .0098
Inlet Control M    =    2.0000
Inlet Control c    =    .03980
Inlet Control Y    =     .6700
T1 ratio (HW/D)    =     1.158
T2 ratio (HW/D)    =     1.304
Slope Factor       =     -.500
```

```
Use unsubmerged inlet control Form 1 equ. below T1 elev.
Use   submerged inlet control Form 1 equ. above T2 elev.

In transition zone between unsubmerged and submerged inlet control,
interpolate between flows at T1 & T2...
At T1 Elev =     318.45 ft  --->  Flow =       4.80 cfs
At T2 Elev =     318.63 ft  --->  Flow =       5.49 cfs
```

```
Structure ID       = TW
Structure Type     = TW SETUP, DS Channel
------------------------------------
FREE OUTFALL CONDITIONS SPECIFIED

CONVERGENCE TOLERANCES...
Maximum Iterations=    10
Min. TW tolerance =    .05 ft
Max. TW tolerance =    .05 ft
Min. HW tolerance =    .05 ft
Max. HW tolerance =    .05 ft
Min.  Q tolerance =    .25 cfs
Max.  Q tolerance =    .25 cfs
```

Type.... Composite Rating Curve
Name.... DETAILED OUTLET

File.... F:\TMPROJ\050\05004\PERMIT MOD\ESRB INTERIM 2002.PPW

***** COMPOSITE OUTFLOW SUMMARY ****

WS Elev, Total Q		Converge		Notes
Elev. ft	Q cfs	TW Elev ft	Error +/-ft	Contributing Structures
317.00	.00	Free Outfall		(no Q: we,P2,P1,CV)
318.00	1.16	Free Outfall		P1,CV (no Q: we,P2)
318.39	1.59	Free Outfall		P1,CV (no Q: we,P2)
319.00	2.47	Free Outfall		P2,P1,CV (no Q: we)
320.00	3.49	Free Outfall		P2,P1,CV (no Q: we)
321.00	4.26	Free Outfall		P2,P1,CV (no Q: we)
321.50	4.60	Free Outfall		P2,P1,CV (no Q: we)
322.00	12.48	Free Outfall		we,P2,P1,CV

Basin Outflow Hydrograph and Time to Drain
25-Year, 24-Hour Storm - Interim Condition

Interim

POND ROUTED TOTAL OUTFLOW HYG...
HYG file =
HYG ID = MDRAIN 10 OUT
HYG Tag =

Peak Discharge = 4.15 cfs
Time to Peak = .1000 hrs
HYG Volume = 6.857 ac-ft

WARNING: Hydrograph truncated on left side.

HYDROGRAPH ORDINATES (cfs)
Output Time increment = .1000 hrs
Time on left represents time for first value in each row.

Time hrs					
.0000	4.16	4.15	4.14	4.13	4.13
.5000	4.12	4.11	4.10	4.08	4.07
1.0000	4.05	4.04	4.03	4.01	4.00
1.5000	3.98	3.97	3.96	3.94	3.93
2.0000	3.92	3.90	3.89	3.88	3.86
2.5000	3.85	3.84	3.82	3.81	3.80
3.0000	3.78	3.77	3.76	3.75	3.73
3.5000	3.72	3.71	3.69	3.68	3.67
4.0000	3.66	3.64	3.63	3.62	3.61
4.5000	3.59	3.58	3.57	3.56	3.55
5.0000	3.53	3.52	3.51	3.50	3.48
5.5000	3.47	3.46	3.45	3.44	3.43
6.0000	3.41	3.40	3.39	3.38	3.37
6.5000	3.36	3.34	3.33	3.32	3.31
7.0000	3.30	3.29	3.28	3.26	3.25
7.5000	3.24	3.23	3.22	3.21	3.20
8.0000	3.19	3.18	3.17	3.16	3.15
8.5000	3.14	3.14	3.13	3.12	3.11
9.0000	3.10	3.10	3.09	3.08	3.07
9.5000	3.06	3.06	3.05	3.04	3.03
10.0000	3.02	3.02	3.01	3.00	2.99
10.5000	2.99	2.98	2.97	2.96	2.95
11.0000	2.95	2.94	2.93	2.92	2.92
11.5000	2.91	2.90	2.89	2.89	2.88
12.0000	2.87	2.86	2.86	2.85	2.84
12.5000	2.83	2.83	2.82	2.81	2.81
13.0000	2.80	2.79	2.78	2.78	2.77
13.5000	2.76	2.76	2.75	2.74	2.73

HYDROGRAPH ORDINATES (cfs)
Output Time increment = .1000 hrs
Time on left represents time for first value in each row.

Time hrs					
14.0000	2.73	2.72	2.71	2.71	2.70
14.5000	2.69	2.68	2.68	2.67	2.66
15.0000	2.66	2.65	2.64	2.64	2.63
15.5000	2.62	2.62	2.61	2.60	2.60
16.0000	2.59	2.58	2.58	2.57	2.56
16.5000	2.56	2.55	2.54	2.54	2.53
17.0000	2.52	2.50	2.49	2.47	2.45
17.5000	2.44	2.42	2.41	2.39	2.38
18.0000	2.36	2.35	2.33	2.32	2.30
18.5000	2.29	2.27	2.26	2.24	2.23
19.0000	2.21	2.20	2.18	2.17	2.16
19.5000	2.14	2.13	2.11	2.10	2.09
20.0000	2.07	2.06	2.05	2.03	2.02
20.5000	2.01	1.99	1.98	1.97	1.95
21.0000	1.94	1.93	1.92	1.90	1.89
21.5000	1.88	1.87	1.86	1.84	1.83
22.0000	1.82	1.81	1.80	1.78	1.77
22.5000	1.76	1.75	1.74	1.73	1.72
23.0000	1.70	1.69	1.68	1.67	1.66
23.5000	1.65	1.64	1.63	1.62	1.61
24.0000	1.60	1.59	1.58	1.57	1.56
24.5000	1.56	1.55	1.54	1.53	1.52
25.0000	1.51	1.50	1.50	1.49	1.48
25.5000	1.47	1.46	1.45	1.45	1.44
26.0000	1.43	1.42	1.41	1.41	1.40
26.5000	1.39	1.38	1.37	1.37	1.36
27.0000	1.35	1.34	1.34	1.33	1.32
27.5000	1.31	1.31	1.30	1.29	1.29
28.0000	1.28	1.27	1.26	1.26	1.25
28.5000	1.24	1.24	1.23	1.22	1.22
29.0000	1.21	1.18	1.16	1.14	1.12
29.5000	1.11	1.09	1.07	1.05	1.03
30.0000	1.01	1.00	.98	.96	.95
30.5000	.93	.91	.90	.88	.87
31.0000	.85	.84	.82	.81	.79
31.5000	.78	.77	.75	.74	.73
32.0000	.72	.70	.69	.68	.67
32.5000	.66	.65	.63	.62	.61
33.0000	.60	.59	.58	.57	.56
33.5000	.55	.54	.53	.52	.51
34.0000	.51	.50	.49	.48	.47
34.5000	.46	.46	.45	.44	.43
35.0000	.43	.42	.41	.40	.40
35.5000	.39	.38	.38	.37	.36
36.0000	.36	.35	.35	.34	.33

HYDROGRAPH ORDINATES (cfs)
Output Time increment = .1000 hrs
Time on left represents time for first value in each row.

Time hrs					
36.5000	.33	.32	.32	.31	.31
37.0000	.30	.30	.29	.29	.28
37.5000	.28	.27	.27	.26	.26
38.0000	.25	.25	.24	.24	.24
38.5000	.23	.23	.22	.22	.22
39.0000	.21	.21	.21	.20	.20
39.5000	.19	.19	.19	.18	.18
40.0000	.18	.18	.17	.17	.17
40.5000	.16	.16	.16	.16	.15
41.0000	.15	.15	.14	.14	.14
41.5000	.14	.14	.13	.13	.13
42.0000	.13	.12	.12	.12	.12
42.5000	.12	.11	.11	.11	.11
43.0000	.11	.10	.10	.10	.10
43.5000	.10	.10	.09	.09	.09
44.0000	.09	.09	.09	.08	.08
44.5000	.08	.08	.08	.08	.08
45.0000	.07	.07	.07	.07	.07
45.5000	.07	.07	.07	.07	.06
46.0000	.06	.06	.06	.06	.06
46.5000	.06	.06	.06	.05	.05
47.0000	.05	.05	.05	.05	.05
47.5000	.05	.05	.05	.05	.05
48.0000	.04	.04	.04	.04	.04
48.5000	.04	.04	.04	.04	.04
49.0000	.04	.04	.04	.04	.03
49.5000	.03	.03	.03	.03	.03
50.0000	.03	.03	.03	.03	.03
50.5000	.03	.03	.03	.03	.03
51.0000	.03	.03	.03	.03	.02
51.5000	.02	.02	.02	.02	.02
52.0000	.02	.02	.02	.02	.02
52.5000	.02	.02	.02	.02	.02
53.0000	.02	.02	.02	.02	.02
53.5000	.02	.02	.02	.02	.02
54.0000	.02	.02	.02	.01	.01
54.5000	.01	.01	.01	.01	.01
55.0000	.01	.01	.01	.01	.01
55.5000	.01	.01	.01	.01	.01
56.0000	.01	.01	.01	.01	.01
56.5000	.01	.01	.01	.01	.01
57.0000	.01	.01	.01	.01	.01
57.5000	.01	.01	.01	.01	.01
58.0000	.01	.01	.01	.01	.01
58.5000	.01	.01	.01	.01	.01

File.... G:\TMProj\CWM Model City\Calculations\permit mod\ESRB INTERIM 2012- NO OUTLET.ppw

HYDROGRAPH ORDINATES (cfs)
Output Time increment = .1000 hrs
Time on left represents time for first value in each row.

Time hrs					
59.0000	.01	.01	.01	.01	.01
59.5000	.01	.01	.01	.01	.01
60.0000	.01	.01	.01	.01	.01
60.5000	.01	.00	.00	.00	.00
61.0000	.00	.00	.00	.00	.00
61.5000	.00	.00	.00	.00	.00
62.0000	.00	.00	.00	.00	.00
62.5000	.00	.00	.00	.00	.00
63.0000	.00	.00	.00	.00	.00
63.5000	.00	.00			

Basin Outflow Hydrograph and Time to Drain
25-Year, 24-Hour Storm - Final Condition

Final

POND ROUTED TOTAL OUTFLOW HYG...
HYG file =
HYG ID = MDRAIN FINALOUT
HYG Tag =

Peak Discharge = 3.33 cfs
Time to Peak = .1000 hrs
HYG Volume = 4.808 ac-ft

WARNING: Hydrograph truncated on left side.

HYDROGRAPH ORDINATES (cfs)
Output Time increment = .1000 hrs
Time on left represents time for first value in each row.

Time hrs					
.0000	3.35	3.33	3.32	3.31	3.30
.5000	3.29	3.27	3.26	3.25	3.24
1.0000	3.23	3.22	3.21	3.20	3.19
1.5000	3.18	3.17	3.16	3.15	3.14
2.0000	3.13	3.13	3.12	3.11	3.10
2.5000	3.09	3.09	3.08	3.07	3.06
3.0000	3.05	3.05	3.04	3.03	3.02
3.5000	3.02	3.01	3.00	2.99	2.98
4.0000	2.98	2.97	2.96	2.95	2.95
4.5000	2.94	2.93	2.92	2.92	2.91
5.0000	2.90	2.89	2.89	2.88	2.87
5.5000	2.86	2.86	2.85	2.84	2.83
6.0000	2.83	2.82	2.81	2.80	2.80
6.5000	2.79	2.78	2.78	2.77	2.76
7.0000	2.75	2.75	2.74	2.73	2.73
7.5000	2.72	2.71	2.70	2.70	2.69
8.0000	2.68	2.68	2.67	2.66	2.66
8.5000	2.65	2.64	2.64	2.63	2.62
9.0000	2.62	2.61	2.60	2.59	2.59
9.5000	2.58	2.57	2.57	2.56	2.55
10.0000	2.55	2.54	2.54	2.53	2.52
10.5000	2.50	2.48	2.47	2.45	2.44
11.0000	2.42	2.41	2.39	2.37	2.36
11.5000	2.34	2.33	2.31	2.30	2.28
12.0000	2.27	2.25	2.24	2.22	2.21
12.5000	2.20	2.18	2.17	2.15	2.14
13.0000	2.13	2.11	2.10	2.08	2.07
13.5000	2.06	2.04	2.03	2.02	2.00

HYDROGRAPH ORDINATES (cfs)
Output Time increment = .1000 hrs
Time on left represents time for first value in each row.

Time hrs					
14.0000	1.99	1.98	1.97	1.95	1.94
14.5000	1.93	1.91	1.90	1.89	1.88
15.0000	1.87	1.85	1.84	1.83	1.82
15.5000	1.81	1.79	1.78	1.77	1.76
16.0000	1.75	1.74	1.73	1.71	1.70
16.5000	1.69	1.68	1.67	1.66	1.65
17.0000	1.64	1.63	1.62	1.61	1.60
17.5000	1.59	1.58	1.57	1.56	1.55
18.0000	1.55	1.54	1.53	1.52	1.51
18.5000	1.50	1.49	1.49	1.48	1.47
19.0000	1.46	1.45	1.44	1.44	1.43
19.5000	1.42	1.41	1.40	1.40	1.39
20.0000	1.38	1.37	1.37	1.36	1.35
20.5000	1.34	1.34	1.33	1.32	1.31
21.0000	1.31	1.30	1.29	1.28	1.28
21.5000	1.27	1.26	1.26	1.25	1.24
22.0000	1.23	1.23	1.22	1.21	1.20
22.5000	1.18	1.16	1.14	1.12	1.10
23.0000	1.08	1.06	1.05	1.03	1.01
23.5000	.99	.98	.96	.94	.93
24.0000	.91	.90	.88	.86	.85
24.5000	.84	.82	.81	.79	.78
25.0000	.77	.75	.74	.73	.71
25.5000	.70	.69	.68	.67	.65
26.0000	.64	.63	.62	.61	.60
26.5000	.59	.58	.57	.56	.55
27.0000	.54	.53	.52	.51	.50
27.5000	.50	.49	.48	.47	.46
28.0000	.45	.45	.44	.43	.42
28.5000	.42	.41	.40	.40	.39
29.0000	.38	.38	.37	.36	.36
29.5000	.35	.34	.34	.33	.33
30.0000	.32	.32	.31	.30	.30
30.5000	.29	.29	.28	.28	.27
31.0000	.27	.27	.26	.26	.25
31.5000	.25	.24	.24	.24	.23
32.0000	.23	.22	.22	.22	.21
32.5000	.21	.20	.20	.20	.19
33.0000	.19	.19	.18	.18	.18
33.5000	.17	.17	.17	.17	.16
34.0000	.16	.16	.15	.15	.15
34.5000	.15	.14	.14	.14	.14
35.0000	.13	.13	.13	.13	.13
35.5000	.12	.12	.12	.12	.12
36.0000	.11	.11	.11	.11	.11

HYDROGRAPH ORDINATES (cfs)
Output Time increment = .1000 hrs
Time on left represents time for first value in each row.

Time hrs					
36.5000	.10	.10	.10	.10	.10
37.0000	.10	.09	.09	.09	.09
37.5000	.09	.09	.08	.08	.08
38.0000	.08	.08	.08	.08	.07
38.5000	.07	.07	.07	.07	.07
39.0000	.07	.07	.07	.06	.06
39.5000	.06	.06	.06	.06	.06
40.0000	.06	.06	.05	.05	.05
40.5000	.05	.05	.05	.05	.05
41.0000	.05	.05	.05	.05	.04
41.5000	.04	.04	.04	.04	.04
42.0000	.04	.04	.04	.04	.04
42.5000	.04	.04	.04	.03	.03
43.0000	.03	.03	.03	.03	.03
43.5000	.03	.03	.03	.03	.03
44.0000	.03	.03	.03	.03	.03
44.5000	.03	.03	.03	.02	.02
45.0000	.02	.02	.02	.02	.02
45.5000	.02	.02	.02	.02	.02
46.0000	.02	.02	.02	.02	.02
46.5000	.02	.02	.02	.02	.02
47.0000	.02	.02	.02	.02	.02
47.5000	.02	.02	.01	.01	.01
48.0000	.01	.01	.01	.01	.01
48.5000	.01	.01	.01	.01	.01
49.0000	.01	.01	.01	.01	.01
49.5000	.01	.01	.01	.01	.01
50.0000	.01	.01	.01	.01	.01
50.5000	.01	.01	.01	.01	.01
51.0000	.01	.01	.01	.01	.01
51.5000	.01	.01	.01	.01	.01
52.0000	.01	.01	.01	.01	.01
52.5000	.01	.01	.01	.01	.01
53.0000	.01	.01	.01	.01	.01
53.5000	.01	.01	.01	.01	.01
54.0000	.00	.00	.00	.00	.00
54.5000	.00	.00	.00	.00	.00
55.0000	.00	.00	.00	.00	.00
55.5000	.00	.00	.00	.00	.00
56.0000	.00	.00	.00	.00	.00
56.5000	.00	.00	.00	.00	.00
57.0000	.00	.00	.00	.00	.00
57.5000	.00	.00	.00	.00	.00
58.0000	.00	.00	.00	.00	.00
58.5000	.00	.00	.00	.00	.00

HYDROGRAPH ORDINATES (cfs)
Output Time increment = .1000 hrs
Time on left represents time for first value in each row.

Time hrs					
59.0000	.00	.00	.00	.00	.00
59.5000	.00	.00	.00	.00	.00
60.0000	.00	.00	.00	.00	.00
60.5000	.00	.00	.00	.00	.00
61.0000	.00	.00	.00	.00	.00
61.5000	.00	.00	.00	.00	.00
62.0000	.00	.00	.00	.00	.00
62.5000	.00	.00	.00	.00	.00
63.0000	.00	.00	.00	.00	.00
63.5000	.00	.00	.00	.00	.00
64.0000	.00	.00	.00	.00	.00
64.5000	.00	.00	.00	.00	.00
65.0000	.00	.00	.00	.00	.00
65.5000	.00	.00	.00	.00	.00
66.0000	.00	.00	.00	.00	.00
66.5000	.00	.00	.00	.00	.00
67.0000	.00	.00	.00	.00	.00
67.5000	.00	.00	.00	.00	.00
68.0000	.00	.00	.00	.00	.00
68.5000	.00	.00	.00	.00	.00
69.0000	.00	.00	.00	.00	.00
69.5000	.00	.00	.00	.00	.00
70.0000	.00				

100-Year, 24-Hour Peak Flow Over Emergency Spillway
Interim Condition

```
                    LEVEL POOL ROUTING SUMMARY

  HYG Dir          = G:\TMProj\CWM Model City\Calculations\permit mod\
  Inflow  HYG file = NONE STORED - ESRB         IN  100
  Outflow HYG file = NONE STORED - ESRB         OUT 100

  Pond Node   Data = ESRB
  Pond Volume Data = ESRB
  Pond Outlet Data = EMERGENCY SPILL

  No Infiltration

  INITIAL CONDITIONS
  ----------------------------------
  Starting WS Elev   =   318.40 ft
  Starting Volume    =    1.190 ac-ft
  Starting Outflow   =      .00 cfs
  Starting Infiltr.  =      .00 cfs
  Starting Total Qout=      .00 cfs
  Time Increment     =    .0100 hrs


  INFLOW/OUTFLOW HYDROGRAPH SUMMARY
  =====================================================
  Peak Inflow       =    133.20 cfs    at   11.9700 hrs
  Peak Outflow      =      4.08 cfs    at   15.2000 hrs
  -----------------------------------------------------
  Peak Elevation    =    321.62 ft
  Peak Storage =          8.157 ac-ft
  =====================================================


  MASS BALANCE (ac-ft)
  --------------------------
+ Initial Vol  =       1.190
+ HYG Vol IN   =       9.092
- Infiltration =        .000
- HYG Vol OUT  =       2.356
- Retained Vol =       7.922
                  ----------
  Unrouted Vol =       -.003 ac-ft  (.034% of Inflow Volume)


  WARNING: Outflow hydrograph truncated on right side.
```

100-Year, 24-Hour Peak Flow Over Emergency Spillway
Final Condition

LEVEL POOL ROUTING SUMMARY

```
HYG Dir           = G:\TMProj\CWM Model City\Calculations\permit mod\
Inflow  HYG file = NONE STORED - ESRB         IN  100
Outflow HYG file = NONE STORED - ESRB         OUT 100

Pond Node   Data = ESRB
Pond Volume Data = ESRB
Pond Outlet Data = Emergency Spill

No Infiltration

INITIAL CONDITIONS
----------------------------------
Starting WS Elev   =   317.10 ft
Starting Volume    =     .005 ac-ft
Starting Outflow   =      .00 cfs
Starting Infiltr.  =      .00 cfs
Starting Total Qout=      .00 cfs
Time Increment     =    .0100 hrs


INFLOW/OUTFLOW HYDROGRAPH SUMMARY
=====================================================
Peak Inflow       =    117.71 cfs    at   11.9700 hrs
Peak Outflow      =       .79 cfs    at   24.1000 hrs
-----------------------------------------------------
Peak Elevation    =    321.52 ft
Peak Storage =          7.919 ac-ft
=====================================================


MASS BALANCE (ac-ft)
--------------------------
+ Initial Vol  =        .005
+ HYG Vol IN   =       7.951
- Infiltration =        .000
- HYG Vol OUT  =        .061
- Retained Vol =       7.894
                  ----------
Unrouted Vol =       -.002 ac-ft  (.021% of Inflow Volume)


WARNING: Outflow hydrograph truncated on right side.
```

V. CULVERT SIZING

CLIENT: CWM Chemical Services, LLC PROJECT: Model City, NY
TITLE: RMU-1 Permit Modification
SUBJECT: ESRB Culvert Design

Prepared By: BMS/TAS Date: 12/2/03
Reviewed By: ______ Date: ______
Revised By: PTO Date: 3/08

OBJECTIVE:

Demonstrate that the selected culvert configurations for the inlet culverts to the East Stormwater Retention Basin (ESRB) provide hydraulic capacity to convey the estimated peak discharge from the 25-year, 24-hour storm.

REFERENCES:

1. Appendix I to the Engineering Report for Residuals Management Unit 1 entitled "Surface Water Drainage and Erosion Calculations."

2. RMU-1 Permit Drawing No. 5-a entitled "Subbase Grades," June 2003, Blasland, Bouck & Lee, Inc.

3. PondPack for Windows, Version9.0, hydrology modeling program, Haestad Methods, Inc.

4. Manufacturer literature, Advanced Drainage Systems, Inc. (attached).

ASSUMPTIONS:

1. During significant rainfall, the water surface elevation in the ditch along the eastern perimeter berm toe will exceed the elevation of the intermediate high points along the ditch. Consequently, the four culverts will function collectively to convey stormwater runoff into the ESRB. All culvert pipes are smooth-bore corrugated HDPE pipes having Manning "n" values of 0.012 based on reference 4. The inlet and outlet of each culvert pipe are fitted with flared end sections or are mitered to conform to the sideslope of the perimeter ditch to reduce entrance and exit energy losses. As indicated on reference 2, the following configurations are proposed for the four culverts leading into the ESRB:

   - CV-1: Three 30-inch diameter pipes
   - CV-2: One 12-inch diameter pipe
   - CV-3: One 12-inch diameter pipe
   - CV-4: One 30-inch diameter pipe

   The upstream and downstream inverts for each culvert pipe are 319.5 and 319.0 respectively, based on reference 2. The culvert lengths vary for each culvert location and are obtained from reference 2.

2. The flow capacities of the culverts are modeled using reference 3. Reference 3 accounts for both pipe friction losses and energy losses at the culvert entrance and exit.

3. The proposed culvert configurations are therefore deemed acceptable if the total combined design capacity of the four culverts can convey the 25-year, 24-hour estimated total combined peak discharge without causing a headwater condition that exceeds the high point elevation in the perimeter ditch to the north of CV-1. The ditch high point elevation is 321.9 based on reference 2.

4. The 25-year, 24-hour estimated total combined peak discharge to the four culverts is obtained from Section II.C of reference 1.

BLASLAND, BOUCK & LEE, INC.
engineers & scientists

CLIENT: CWM Chemical Services, LLC **PROJECT:** Model City, NY
TITLE: RMU-1 Permit Modification
Prepared By: BMS/TAS **Date:** 12/2/03
Reviewed By: **Date:**
Revised By: PTO **Date:** 8/2012

SUBJECT: ESRB Culvert Design

CALCULATIONS:

The following table summarizes the hydraulic capacity of each culvert with a headwater elevation of 321.9 (which is equal to the high point elevation in the perimeter ditch to the north of CV-1). Also presented in the table are the 25-year, 24-hour estimated total combined peak discharge entering the ESRB (excluding the area of the basin itself) and the total combined capacity of the four culverts.

Culvert ID	Hydraulic Capacity with Headwater El. = 321.9 [cfs]	25-year, 24-hour Estimated Total Combined Peak Discharge [cfs]
CV-1	57.0	**73.5**
CV-2	5.2	
CV-3	5.2	
CV-4	19.0	
Total	**86.4**	

SUMMARY:

The total combined hydraulic capacity of the culverts leading into the ESRB exceeds the estimated total combined peak discharge from the 25-year, 24-hour storm. The rating curve for each culvert, as determined using reference 3, is included as an attachment.

Type.... Outlet Input Data
Name.... CV-1

File.... F:\TMPROJ\050\05004\PERMIT MOD\ESRB INLET CULVERTS.PPW

REQUESTED POND WS ELEVATIONS:

Min. Elev.= 319.50 ft
Increment = .50 ft
Max. Elev.= 322.00 ft

****
OUTLET CONNECTIVITY
****

---> Forward Flow Only (UpStream to DnStream)
<--- Reverse Flow Only (DnStream to UpStream)
<---> Forward and Reverse Both Allowed

Structure	No.		Outfall	E1, ft	E2, ft
Culvert-Circular	cv	--->	TW	319.500	322.000
TW SETUP, DS Channel					

File.... F:\TMPROJ\050\05004\PERMIT MOD\ESRB INLET CULVERTS.PPW

OUTLET STRUCTURE INPUT DATA

```
Structure ID       = cv
Structure Type     = Culvert-Circular
------------------------------------
No. Barrels        =        3
Barrel Diameter    =    2.5000 ft
Upstream Invert    =    319.50 ft
Dnstream Invert    =    319.00 ft
Horiz. Length      =     52.60 ft
Barrel Length      =     52.60 ft
Barrel Slope       =    .00951 ft/ft

OUTLET CONTROL DATA...
Mannings n         =     .0120
Ke                 =     .5000  (forward entrance loss)
Kb                 =   .007854  (per ft of full flow)
Kr                 =     .5000  (reverse entrance loss)
HW Convergence     =      .001  +/- ft

INLET CONTROL DATA...
Equation form      =         1
Inlet Control K    =     .0098
Inlet Control M    =    2.0000
Inlet Control c    =    .03980
Inlet Control Y    =     .6700
T1 ratio (HW/D)    =     1.155
T2 ratio (HW/D)    =     1.302
Slope Factor       =     -.500
```

Use unsubmerged inlet control Form 1 equ. below T1 elev.
Use   submerged inlet control Form 1 equ. above T2 elev.

In transition zone between unsubmerged and submerged inlet control,
interpolate between flows at T1 & T2...

```
At T1 Elev =     322.39 ft  --->  Flow =     27.16 cfs
At T2 Elev =     322.76 ft  --->  Flow =     31.05 cfs
```

```
Structure ID       = TW
Structure Type     = TW SETUP, DS Channel
------------------------------------
FREE OUTFALL CONDITIONS SPECIFIED

CONVERGENCE TOLERANCES...
Maximum Iterations=    30
Min. TW tolerance =    .01 ft
Max. TW tolerance =    .01 ft
Min. HW tolerance =    .01 ft
Max. HW tolerance =    .01 ft
Min.  Q tolerance =    .10 cfs
Max.  Q tolerance =    .10 cfs
```

File.... F:\TMPROJ\050\05004\PERMIT MOD\ESRB INLET CULVERTS.PPW

***** COMPOSITE OUTFLOW SUMMARY ****

WS Elev, Total Q		Converge		Notes
Elev. ft	Q cfs	TW Elev ft	Error +/-ft	Contributing Structures
319.50	.00	Free Outfall		None contributing
320.00	3.12	Free Outfall		cv
320.50	11.80	Free Outfall		cv
321.00	25.11	Free Outfall		cv
321.50	41.86	Free Outfall		cv
322.00	60.93	Free Outfall		cv

File.... F:\TMPROJ\050\05004\PERMIT MOD\ESRB INLET CULVERTS.PPW

REQUESTED POND WS ELEVATIONS:

Min. Elev.= 319.50 ft
Increment = .50 ft
Max. Elev.= 322.00 ft

****
OUTLET CONNECTIVITY
****

---> Forward Flow Only (UpStream to DnStream)
<--- Reverse Flow Only (DnStream to UpStream)
<---> Forward and Reverse Both Allowed

Structure	No.		Outfall	E1, ft	E2, ft
Culvert-Circular	cv	--->	TW	319.500	322.000
TW SETUP, DS Channel					

OUTLET STRUCTURE INPUT DATA

```
Structure ID      = cv
Structure Type    = Culvert-Circular
------------------------------------
No. Barrels       =        1
Barrel Diameter   =    1.0000 ft
Upstream Invert   =    319.50 ft
Dnstream Invert   =    319.00 ft
Horiz. Length     =     42.50 ft
Barrel Length     =     42.50 ft
Barrel Slope      =    .01176 ft/ft

OUTLET CONTROL DATA...
Mannings n        =     .0120
Ke                =     .5000  (forward entrance loss)
Kb                =   .026647  (per ft of full flow)
Kr                =     .5000  (reverse entrance loss)
HW Convergence    =      .001  +/- ft

INLET CONTROL DATA...
Equation form     =        1
Inlet Control K   =     .0098
Inlet Control M   =    2.0000
Inlet Control c   =    .03980
Inlet Control Y   =     .6700
T1 ratio (HW/D)   =     1.154
T2 ratio (HW/D)   =     1.301
Slope Factor      =     -.500
```

Use unsubmerged inlet control Form 1 equ. below T1 elev.
Use   submerged inlet control Form 1 equ. above T2 elev.

In transition zone between unsubmerged and submerged inlet control,
interpolate between flows at T1 & T2...

```
At T1 Elev =    320.65 ft  --->  Flow =      2.75 cfs
At T2 Elev =    320.80 ft  --->  Flow =      3.14 cfs
```

```
Structure ID      = TW
Structure Type    = TW SETUP, DS Channel
------------------------------------
FREE OUTFALL CONDITIONS SPECIFIED

CONVERGENCE TOLERANCES...
Maximum Iterations=    30
Min. TW tolerance =    .01 ft
Max. TW tolerance =    .01 ft
Min. HW tolerance =    .01 ft
Max. HW tolerance =    .01 ft
Min.  Q tolerance =    .10 cfs
Max.  Q tolerance =    .10 cfs
```

File.... F:\TMPROJ\050\05004\PERMIT MOD\ESRB INLET CULVERTS.PPW

***** COMPOSITE OUTFLOW SUMMARY ****

WS Elev.	Total Q			Notes
			Converge	
Elev. ft	Q cfs	TW Elev ft	Error +/-ft	Contributing Structures
319.50	.00	Free Outfall		None contributing
320.00	.60	Free Outfall		CV
320.50	2.05	Free Outfall		CV
321.00	3.60	Free Outfall		CV
321.50	4.55	Free Outfall		CV
322.00	5.33	Free Outfall		CV

File.... F:\TMPROJ\050\05004\PERMIT MOD\ESRB INLET CULVERTS.PPW

REQUESTED POND WS ELEVATIONS:

Min. Elev.= 319.50 ft
Increment = .50 ft
Max. Elev.= 322.00 ft

****

OUTLET CONNECTIVITY

****

---> Forward Flow Only (UpStream to DnStream)
<--- Reverse Flow Only (DnStream to UpStream)
<---> Forward and Reverse Both Allowed

Structure	No.		Outfall	E1, ft	E2, ft
Culvert-Circular	cv	--->	TW	319.500	322.000
TW SETUP, DS Channel					

File.... F:\TMPROJ\050\05004\PERMIT MOD\ESRB INLET CULVERTS.PPW

OUTLET STRUCTURE INPUT DATA

```
Structure ID       = cv
Structure Type     = Culvert-Circular
------------------------------------
No. Barrels        =        1
Barrel Diameter    =    2.5000 ft
Upstream Invert    =    319.50 ft
Dnstream Invert    =    319.00 ft
Horiz. Length      =     48.80 ft
Barrel Length      =     48.80 ft
Barrel Slope       =    .01025 ft/ft

OUTLET CONTROL DATA...
Mannings n         =     .0120
Ke                 =     .5000  (forward entrance loss)
Kb                 =   .007854  (per ft of full flow)
Kr                 =     .5000  (reverse entrance loss)
HW Convergence     =      .001  +/- ft

INLET CONTROL DATA...
Equation form      =         1
Inlet Control K    =     .0098
Inlet Control M    =    2.0000
Inlet Control c    =    .03980
Inlet Control Y    =     .6700
T1 ratio (HW/D)    =     1.155
T2 ratio (HW/D)    =     1.302
Slope Factor       =     -.500
```

```
Use unsubmerged inlet control Form 1 equ. below T1 elev.
Use   submerged inlet control Form 1 equ. above T2 elev.

In transition zone between unsubmerged and submerged inlet control,
interpolate between flows at T1 & T2...
At T1 Elev =     322.39 ft  --->  Flow =     27.16 cfs
At T2 Elev =     322.75 ft  --->  Flow =     31.05 cfs
```

```
Structure ID       = TW
Structure Type     = TW SETUP, DS Channel
------------------------------------
FREE OUTFALL CONDITIONS SPECIFIED

CONVERGENCE TOLERANCES...
Maximum Iterations=    30
Min. TW tolerance =    .01 ft
Max. TW tolerance =    .01 ft
Min. HW tolerance =    .01 ft
Max. HW tolerance =    .01 ft
Min.  Q tolerance =    .10 cfs
Max.  Q tolerance =    .10 cfs
```

***** COMPOSITE OUTFLOW SUMMARY ****

WS Elev, Total Q		Converge		Notes
Elev. ft	Q cfs	TW Elev ft	Error +/-ft	Contributing Structures
319.50	.00	Free Outfall		None contributing
320.00	1.04	Free Outfall		cv
320.50	3.93	Free Outfall		cv
321.00	8.37	Free Outfall		cv
321.50	13.96	Free Outfall		cv
322.00	20.31	Free Outfall		cv

VI. EROSION CALCULATIONS

TASK: To calculate the soil loss from the final cover slope conditions at the Model City RMU-1 Facility not to exceed 2 tons per acre per year under long-term (vegetated) conditions as established by the EPA Guidelines.

REFERENCES:

1. Evaluating Cover Systems for Solid and Hazardous Waste (SW-867), September 1980, USEPA.
2. "Erosion and Sediment Control Handbook," S. J. Goldman, K. Jackson, T. A. Bursztynsky, P.E., Mc-Graw-Hill Book Company, 1986.

CALCULATIONS:

1. Soil loss is calculated using the Universal Soil Loss Equation (USLE):

   A = (R)(K)(LS)(C)(P)

   Where, A = Soil loss in tons/acre/year
   R = Rainfall factor
   K = Soil erodability factor
   LS = Slope factor
   C = Cover and management factor
   P = Support practive factor

2. Maximum soil loss for 3H:1V cover slope:

   The maximum length of 3H:1V slope on the final buildout is 117 ft.

   R = 75 (see attached Figure 5.2 from Reference 2)
   K = 0.26 (for silty clay)
   C = 0.01 (undisturbed native vegetation, assumed for long-term conditions, Table 5.6 of Ref. 2)
   P = 0.9 (assumed for non-smooth surfaces, see Table 5.7 of Ref. 2)

   $LS = [(65.41 \times s^2)/(s^2 + 10{,}000) + (4.56 \times s)/(s^2 + 10{,}000)^{1/2} + 0.065] \times (L/72.5)^{0.5}$
   (Wischmeier's empirical equation)

   Where, s = Slope in percent
   L = Slope length (ft)

   For L = 117 and s = 33.3 %, LS = 10.21

   A = (75)(0.26)(10.21)(0.01)(0.9) = 1.79 tons/acre/year < 2 tons/acre/year maximum (Ref. 1)

3. Maximum soil loss for 5% cover slope:

The maximum length on the 5% slope area on the final buildout is 721 ft.

$R = 75$
$K = 0.26$
$C = 0.01$
$P = 0.9$

For $L = 721$ and $s = 5\%$, $LS = 1.44$

$A = (75)(0.26)(1.44)(0.01)(0.9) = 0.25$ tons/acre/year < 2 tons/acre/year maximum

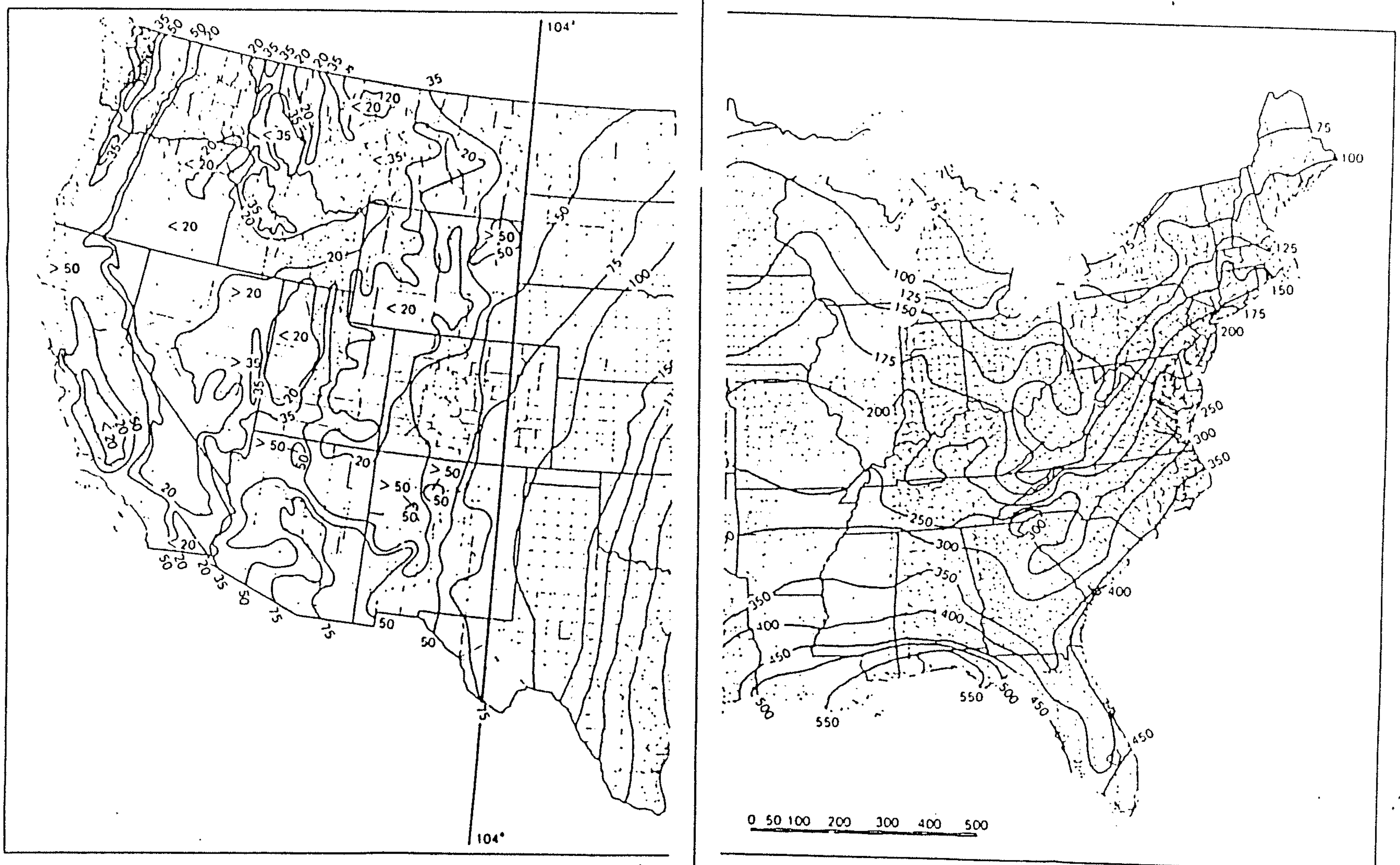


Fig. 5.2 *R* values for areas east of 104°. Because of irregular topography in the west United States, calculate *R* values in this region by using local rainfall data. *R* is in u of 100 ft · tons/acre per in/hr. To convert *R* to units of 10^7 J/ha per mm/hr, multiply 1.70. (20) Scale is in miles.

VII. NORTH PERIMETER BERM CHANNEL & CULVERT DESIGN

Relocation of High Point in Perimeter Ditch North of CV-1

The high point in the perimeter ditch to the north of CV-1, which defines the drainage area divide between Area P1 and Area P2, has been relocated approximately 255 feet to the south. Consequently, the size of Area P1 is increased by 0.31 acres, and the size of Area P2 is reduced by 0.31 acres.

The increase in Area P1 results in an increase in the total size of the drainage area for the north perimeter berm culvert system (identified as "Area 14 Modified" in Section VII of Appendix I). The revised Area 14 Modified also includes 0.71 acres of Area 8 that was not acoounted for in the original design calculations. The total drainage area for Area 14 Modified in the original design was 2.10 acres. The total revised drainage area for the revised Area 14 Modified is 3.12 acres (2.10 + 0.31 + 0.71 = 3.12), an overall increase of 1.02 acres. The peak flow resulting from the revised Area 14 Modified is 13.5 cfs, which is an increase of 3.5 cfs over the originally calculated peak flow of 10 cfs. This revised peak flow is still less than the minimum design capacity of the culvert system of 14 cfs, as calculated in the original design.

TASK: To design the culvert and drop inlets along the south side of J Street. These culverts and drop inlets will take the surfacewater runoff from the area below the landfill access road and from J Street between stations 16+00E and 23+20E. This new culvert is necessary due to the regrading of the outer slope of the landfill perimeter berm in this area.

REFERENCES:

1. Drawing No. 1, "Base Topographic Plan, Project Title: RMU-1 Construction Cell-5", By King Consulting Engineers, Survey Dated 5/2/95.
2. Figure No. 6, "Stages 1 Through 8 Filling Grades", By SEC Donohue, Drawing Dated November 1992.
3. Surface Water Drainage Calculations for Area A-14 from the RMU-1 Permit Engineering Report By SEC Donohue Dated November 1992.
4. Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986..
5. Flow Master Channel Program by Haestads Methods, Inc.
6. Federal Highway Administration (FHWA) Culvert Analysis Program HY-8, Version 3.2.

ASSUMPTIONS:

1. A new culvert will be installed in the existing channel adjacent to the south side of J Street from Sta. 16+00E to Sta. 23+20E. Drop Inlets will be installed along this culvert in the general location of the existing monitoring wells. The drop inlets will allow surfacewater runoff to enter the new culvert.
2. The new culverts will be designed to control the 25 year, 24 hour storm event without over topping J Street.
3. The regraded perimeter berm slope will be recessed around the existing monitoring wells, but these drop inlet areas will be regraded as necessary to provide a minimum 12 inch cover over the new culvert.

CALCULATIONS:

1. Determine Peak Inflow Using TR55.
   Q= 10 cfs
   See Attached Sheets
2. Determine Minimum Culvert Size Using HY-8.
   For CMP, Culvert Diameter = 2.5ft
   For CPP, Culvert Diameter = 2.0 ft
   See Attached Sheets

2/

RUST ENVIRONMENT & INFRASTRUCTURE

: of Concentration (Tc) or travel time (Tt) Worksheet

Project: Model City Facility By: RJZ Date: 04-Jun-96

Location: Midel City, New York Chk: BPB Date: 6/5/96

Underline one: Present Developed Area 14, Modified

Underline one: Tc Tt through subarea

Note:
Include a map, schematic, or description of flow segments

Sheet Flow (Applicable to Tc only)

			Segment ID	AB		
1. Surface description (Table 3-1)				Short Grass		
2. Manning's roughness coefficient, n (Table 3-1)				0.15		
3. Flow length, L		ft		20		
4. Two-year, 24-hour rainfall, P2		in		2.3		
5. Land slope, s		ft/ft		0.500		
6. Tt= [0.007 * (nL)^0.8] / [(P2^0.5) * (s^0.4)]	Compute Tt	hr		0.015	=	0.02

Shallow Concentrated Flow

			Segment ID			
7. Surface description (paved or unpaved)						
8. Flow length, L		ft				
'atercourse slope		ft/ft				
Average velocity, V (figure 3-1)		ft/sec				
11. Tt= L/(3600*V)	Compute Tt	hr			=	

Channel Flow

			Segment ID	BC	CD		
12. Cross sectional area, a		ft²		10.00	10.00		
13. Wetted Perimeter, Pw		ft		10.80	10.80		
14. Hydraulic radius, r= (a/Pw)	Compute r	ft		0.90	0.90		
15. Channel slope, s		ft/ft		0.012	0.002		
16. Manning's roughness coefficient, n				0.038	0.038		
17. v = {[(1.49 * r^(0.67) * s^(0.5)] / n}	Compute v	ft/sec		4.0	1.6		
18. Flow length, L		ft		255	330		
19. Tt= L/(3600*V)	Compute Tt	hr		0.018	0.057	=	0.08

20. Watershed or subarea Tc or Tt (add Tt in steps 6, 11, and 19)

	hr	=	0.10
Minimum Tt	hr	=	0.10
Use Tt		=	0.10

Reference: Technical Release 55, Urban Hydrology for Small Watersheds, United States Department of Agriculture, Soil Conservation Service, June 1986.

3

Model City Perimeter Channel
Worksheet for Triangular Channel

Project Description	C1
Project File	untitled
Worksheet	Model City Perimeter Channel
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Discharge

Input Data		
Mannings Coefficient	0.038	
Channel Slope	0.002000	ft/ft
Depth	2.00	ft
Left Side Slope	2.00	H : V
Right Side Slope	3.00	H : V

Results		
Discharge	16.62	ft^3/s
Flow Area	10.00	ft^2
Wetted Perimeter	10.80	ft
Top Width	10.00	ft
Critical Depth	1.22	ft
Critical Slope	0.027451	ft/ft
Velocity	1.66	ft/s
Velocity Head	0.04	ft
Specific Energy	2.04	ft
Froude Number	0.29	
Flow is subcritical.		

7

Model City Perimeter Channel
Worksheet for Triangular Channel

Project Description	BC
Project File	untitled
Worksheet	Model City Perimeter Channel
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Discharge

Input Data		
Mannings Coefficient	0.038	
Channel Slope	0.012000	ft/ft
Depth	2.00	ft
Left Side Slope	2.00	H : V
Right Side Slope	3.00	H : V

Results		
Discharge	40.70	ft^3/s
Flow Area	10.00	ft^2
Wetted Perimeter	10.80	ft
Top Width	10.00	ft
Critical Depth	1.75	ft
Critical Slope	0.024361	ft/ft
Velocity	4.07	ft/s
Velocity Head	0.26	ft
Specific Energy	2.26	ft
Froude Number	0.72	
Flow is subcritical.		

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 06-04-1996 09:01:02
Watershed file: --> C:MODELCTY.WSD
Hydrograph file: --> C:MODELCTY.HYD

MODEL CITY FACILITY
25 YEAR, 24 HOUR RAINFALL EVENT
FOR AREA A14, MODIFIED

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input/used	
A14,MODIFIED	2.10	90.0	0.10	0.00	4.00	2.92	.06	.10

* Travel time from subarea outfall to composite watershed outfall point.
Total area = 2.10 acres or 0.00328 sq.mi
Peak discharge = 10 cfs

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hr)	Input Values * Tt (hr)	Rounded Values Tc (hr)	Rounded Values * Tt (hr)	Ia/p Interpolated (Yes/No)	Ia/p Messages
A14,MODIFIED	0.10	0.00	**	**	No	Computed Ia/p < .1

* Travel time from subarea outfall to composite watershed outfall point.
** Tc & Tt are available in the hydrograph tables.

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 06-04-1996 09:01:02
Watershed file: --> C:MODELCTY.WSD
Hydrograph file: --> C:MODELCTY.HYD

MODEL CITY FACILITY
25 YEAR, 24 HOUR RAINFALL EVENT
FOR AREA A14, MODIFIED

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
A14,MODIFIED	10	12.1
Composite Watershed	10	12.1

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 06-04-1996 09:01:02
Watershed file: --> C:MODELCTY.WSD
Hydrograph file: --> C:MODELCTY.HYD

MODEL CITY FACILITY
25 YEAR, 24 HOUR RAINFALL EVENT
FOR AREA A14, MODIFIED

Composite Hydrograph Summary (cfs)

Subarea Description	11.0 hr	11.3 hr	11.6 hr	11.9 hr	12.0 hr	12.1 hr	12.2 hr	12.3 hr	12.4 hr
A14,MODIFIED	0	0	1	3	6	10	6	2	1
Total (cfs)	0	0	1	3	6	10	6	2	1

Subarea Description	12.5 hr	12.6 hr	12.7 hr	12.8 hr	13.0 hr	13.2 hr	13.4 hr	13.6 hr	13.8 hr
A14,MODIFIED	1	1	1	1	1	1	0	0	0
Total (cfs)	1	1	1	1	1	1	0	0	0

Subarea Description	14.0 hr	14.3 hr	14.6 hr	15.0 hr	15.5 hr	16.0 hr	16.5 hr	17.0 hr	17.5 hr
A14,MODIFIED	0	0	0	0	0	0	0	0	0
Total (cfs)	0	0	0	0	0	0	0	0	0

Subarea Description	18.0 hr	19.0 hr	20.0 hr	22.0 hr	26.0 hr
A14,MODIFIED	0	0	0	0	0
Total (cfs)	0	0	0	0	0

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 06-04-1996 09:01:02
Watershed file: --> C:MODELCTY.WSD
Hydrograph file: --> C:MODELCTY.HYD

MODEL CITY FACILITY
25 YEAR, 24 HOUR RAINFALL EVENT
FOR AREA A14, MODIFIED

Time (hrs)	Flow (cfs)	Time (hrs)	Flow (cfs)
11.0	0	14.8	0
11.1	0	14.9	0
11.2	0	15.0	0
11.3	0	15.1	0
11.4	0	15.2	0
11.5	1	15.3	0
11.6	1	15.4	0
11.7	2	15.5	0
11.8	2	15.6	0
11.9	3	15.7	0
12.0	6	15.8	0
12.1	10	15.9	0
12.2	6	16.0	0
12.3	2	16.1	0
12.4	1	16.2	0
12.5	1	16.3	0
12.6	1	16.4	0
12.7	1	16.5	0
12.8	1	16.6	0
12.9	1	16.7	0
13.0	1	16.8	0
13.1	1	16.9	0
13.2	1	17.0	0
13.3	0	17.1	0
13.4	0	17.2	0
13.5	0	17.3	0
13.6	0	17.4	0
13.7	0	17.5	0
13.8	0	17.6	0
13.9	0	17.7	0
14.0	0	17.8	0
14.1	0	17.9	0
14.2	0	18.0	0
14.3	0	18.1	0
14.4	0	18.2	0
14.5	0	18.3	0
14.6	0	18.4	0

TR-55 TABULAR HYDROGRAPH METHOD
Type II Distribution
(24 hr. Duration Storm)

Executed: 06-04-1996 09:01:02
Watershed file: --> C:MODELCTY.WSD
Hydrograph file: --> C:MODELCTY.HYD

MODEL CITY FACILITY
25 YEAR, 24 HOUR RAINFALL EVENT
FOR AREA A14, MODIFIED

Time (hrs)	Flow (cfs)
18.6	0
18.7	0
18.8	0
18.9	0
19.0	0
19.1	0
19.2	0
19.3	0
19.4	0
19.5	0
19.6	0
19.7	0
19.8	0
19.9	0
20.0	0
20.1	0
20.2	0
20.3	0
20.4	0
20.5	0
20.6	0
20.7	0
20.8	0
20.9	0
21.0	0
21.1	0
21.2	0
21.3	0
21.4	0
21.5	0
21.6	0
21.7	0
21.8	0
21.9	0
22.0	0
22.1	0
22.2	0
22.3	0

Time (hrs)	Flow (cfs)
22.4	0
22.5	0
22.6	0
22.7	0
22.8	0
22.9	0
23.0	0
23.1	0
23.2	0
23.3	0
23.4	0
23.5	0
23.6	0
23.7	0
23.8	0
23.9	0
24.0	0
24.1	0
24.2	0
24.3	0
24.4	0
24.5	0
24.6	0
24.7	0
24.8	0
24.9	0
25.0	0
25.1	0
25.2	0
25.3	0
25.4	0
25.5	0
25.6	0
25.7	0
25.8	0
25.9	0

URRENT DATE: 06-04-1996
'RRENT TIME: 09:06:18

FILE DATE: 06-03-1996
FILE NAME: MDLCITY

FHWA CULVERT ANALYSIS
HY-8, VERSION 3.2

C U L V #	SITE DATA			CULVERT SHAPE, MATERIAL, INLET				
	INLET ELEV. (FT)	OUTLET ELEV. (FT)	CULVERT LENGTH (FT)	BARRELS SHAPE MATERIAL	SPAN (FT)	RISE (FT)	MANNING n	INLET TYPE
1	316.49	314.33	720.00	1 CPP	2.00	2.00	.012	CONVENTIONAL
2								
3								
4								
5								
6								

SUMMARY OF CULVERT FLOWS (CFS) FILE: MDLCITY DATE: 06-03-1996

ELEV (FT)	TOTAL	1	2	3	4	5	6	ROADWAY	ITR
316.49	0	0	0	0	0	0	0	0	1
317.01	1	1	0	0	0	0	0	0	1
7.24	2	2	0	0	0	0	0	0	1
.7.42	3	3	0	0	0	0	0	0	1
317.58	4	4	0	0	0	0	0	0	1
317.70	5	5	0	0	0	0	0	0	1
317.83	6	6	0	0	0	0	0	0	1
317.95	7	7	0	0	0	0	0	0	1
318.07	8	8	0	0	0	0	0	0	1
318.18	9	9	0	0	0	0	0	0	1
318.29	10	10	0	0	0	0	0	0	1
319.00	15	15	0	0	0	0	0	OVERTOPPING	

SUMMARY OF ITERATIVE SOLUTION ERRORS FILE: MDLCITY DATE: 06-03-1996

HEAD ELEV(FT)	HEAD ERROR(FT)	TOTAL FLOW(CFS)	FLOW ERROR(CFS)	% FLOW ERROR
316.49	0.00	0	0	0.00
317.01	0.00	1	0	0.00
317.24	0.00	2	0	0.00
317.42	0.00	3	0	0.00
317.58	0.00	4	0	0.00
317.70	0.00	5	0	0.00
317.83	0.00	6	0	0.00
317.95	0.00	7	0	0.00
318.07	0.00	8	0	0.00
318.18	0.00	9	0	0.00
318.29	0.00	10	0	0.00

<1> TOLERANCE (FT) = 0.010 <2> TOLERANCE (%) = 1.000

'RRENT DATE: 06-04-1996
'T TIME: 09:06:18

FILE DATE: 06-03-1996
FILE NAME: MDLCITY

****
************************* CULVERT # 1 ***************************
****

PERFORMANCE CURVE FOR 1 BARREL(S)

Q (cfs)	HWE (ft)	TWE (ft)	ICH (ft)	OCH (ft)	FLOW TYPE	CCE (ft)	FCE (ft)	TCE (ft)	VO (fps)
0	316.49	314.33	0.00	-2.16	0-NF	0.00	316.49	0.00	0.00
1	317.01	314.33	0.46	0.52	2-M2	0.00	0.00	0.00	2.86
2	317.24	314.33	0.67	0.75	2-M2	0.00	0.00	0.00	3.40
3	317.42	314.33	0.83	0.93	2-M2	0.00	0.00	0.00	3.75
4	317.58	314.33	0.97	1.09	2-M2	0.00	0.00	0.00	4.11
5	317.70	314.33	1.11	1.21	2-M2	0.00	0.00	0.00	4.36
6	317.83	314.33	1.24	1.34	2-M2	0.00	0.00	0.00	4.64
7	317.95	314.33	1.37	1.46	2-M2	0.00	0.00	0.00	4.88
8	318.07	314.33	1.48	1.58	2-M2	0.00	0.00	0.00	5.09
9	318.18	314.33	1.60	1.69	2-M2	0.00	0.00	0.00	5.30
10	318.29	314.33	1.70	1.80	2-M2	0.00	0.00	0.00	5.49

El. inlet face invert 316.49 ft El. outlet invert 314.33 ft
El. inlet throat invert 0.00 ft El. inlet crest 0.00 ft

****

SITE DATA ***** CULVERT INVERT **************

INLET STATION (FT)	0.00
INLET ELEVATION (FT)	316.49
OUTLET STATION (FT)	720.00
OUTLET ELEVATION (FT)	314.33
NUMBER OF BARRELS	1.00
SLOPE (V-FT/H-FT)	0.0030
CULVERT LENGTH ALONG SLOPE (FT)	720.00

***** CULVERT DATA SUMMARY ************************

BARREL SHAPE	CIRCULAR
BARREL DIAMETER	2.00 FT
BARREL MATERIAL	POLYETHYLENE
BARREL MANNING'S N	0.012
INLET TYPE	CONVENTIONAL
INLET EDGE AND WALL	SQUARE EDGE WITH HEADWALL
INLET DEPRESSION	NONE

****

"RRENT DATE: 06-04-1996 FILE DATE: 06-03-1996
T TIME: 09:06:18 FILE NAME: MDLCITY

****
************************* TAILWATER *************************
****
****

CONSTANT WATER SURFACE ELEVATION
314.33

****
************************* ROADWAY OVERTOPPING DATA *************************
****

ROADWAY SURFACE	GRAVEL
EMBANKMENT TOP WIDTH (FT)	40.00
CREST LENGTH (FT)	100.00
OVERTOPPING CREST ELEVATION (FT)	319.00

****

JRRENT DATE: 06-04-1996
ᴿRRENT TIME: 09:12:11

FILE DATE: 06-03-1996
FILE NAME: MDLCITY

FHWA CULVERT ANALYSIS
HY-8, VERSION 3.2

C U L V #	SITE DATA			CULVERT SHAPE, MATERIAL, INLET				
	INLET ELEV. (FT)	OUTLET ELEV. (FT)	CULVERT LENGTH (FT)	BARRELS SHAPE MATERIAL	SPAN (FT)	RISE (FT)	MANNING n	INLET TYPE
1	316.49	314.33	720.00	1 CSP	2.50	2.50	.024	CONVENTIONAL
2								
3								
4								
5								
6								

UMMARY OF CULVERT FLOWS (CFS) FILE: MDLCITY DATE: 06-03-1996

ELEV (FT)	TOTAL	1	2	3	4	5	6	ROADWAY	ITR
316.49	0	0	0	0	0	5	0	0	1
317.03	1	1	0	0	0	0	0	0	1
.22	2	2	0	0	0	0	0	0	1
.7.44	3	3	0	0	0	0	0	0	1
317.56	4	4	0	0	0	0	0	0	1
317.75	5	5	0	0	0	0	0	0	1
317.85	6	6	0	0	0	0	0	0	1
318.01	7	7	0	0	0	0	0	0	1
318.10	8	8	0	0	0	0	0	0	1
318.26	9	9	0	0	0	0	0	0	1
318.34	10	10	0	0	0	0	0	0	1
319.00	14	14	0	0	0	0	0	OVERTOPPING	

SUMMARY OF ITERATIVE SOLUTION ERRORS FILE: MDLCITY DATE: 06-03-1996

HEAD ELEV(FT)	HEAD ERROR(FT)	TOTAL FLOW(CFS)	FLOW ERROR(CFS)	% FLOW ERROR
316.49	0.00	0	0	0.00
317.03	0.00	1	0	0.00
317.22	0.00	2	0	0.00
317.44	0.00	3	0	0.00
317.56	0.00	4	0	0.00
317.75	0.00	5	0	0.00
317.85	0.00	6	0	0.00
318.01	0.00	7	0	0.00
318.10	0.00	8	0	0.00
318.26	0.00	9	0	0.00
318.34	0.00	10	0	0.00

<1> TOLERANCE (FT) = 0.010 <2> TOLERANCE (%) = 1.000

'RRENT DATE: 06-04-1996
'T TIME: 09:12:11

FILE DATE: 06-03-1996
FILE NAME: MDLCITY

****
************************ CULVERT # 1 ************************
****

PERFORMANCE CURVE FOR 1 BARREL(S)

Q (cfs)	HWE (ft)	TWE (ft)	ICH (ft)	OCH (ft)	FLOW TYPE	CCE (ft)	FCE (ft)	TCE (ft)	VO (fps)
0	316.49	314.33	0.00	-2.16	0-NF	0.00	316.49	0.00	0.00
1	317.03	314.33	0.44	0.54	2-M2	0.00	0.00	0.00	2.80
2	317.22	314.33	0.63	0.73	2-M2	0.00	0.00	0.00	3.27
3	317.44	314.33	0.77	0.95	2-M2	0.00	0.00	0.00	3.64
4	317.56	314.33	0.90	1.07	2-M2	0.00	0.00	0.00	3.94
5	317.75	314.33	1.02	1.26	2-M2	0.00	0.00	0.00	4.14
6	317.85	314.33	1.12	1.36	2-M2	0.00	0.00	0.00	4.39
7	318.01	314.33	1.21	1.52	2-M2	0.00	0.00	0.00	4.60
8	318.10	314.33	1.31	1.61	2-M2	0.00	0.00	0.00	4.77
9	318.26	314.33	1.40	1.77	2-M2	0.00	0.00	0.00	4.91
10	318.34	314.33	1.49	1.85	2-M2	0.00	0.00	0.00	5.10

El. inlet face invert 316.49 ft El. outlet invert 314.33 ft
El. inlet throat invert 0.00 ft El. inlet crest 0.00 ft

****

: SITE DATA ***** CULVERT INVERT **************

INLET STATION (FT)	0.00
INLET ELEVATION (FT)	316.49
OUTLET STATION (FT)	720.00
OUTLET ELEVATION (FT)	314.33
NUMBER OF BARRELS	1.00
SLOPE (V-FT/H-FT)	0.0030
CULVERT LENGTH ALONG SLOPE (FT)	720.00

***** CULVERT DATA SUMMARY ************************

BARREL SHAPE	CIRCULAR
BARREL DIAMETER	2.50 FT
BARREL MATERIAL	CORRUGATED STEEL
BARREL MANNING'S N	0.024
INLET TYPE	CONVENTIONAL
INLET EDGE AND WALL	SQUARE EDGE WITH HEADWALL
INLET DEPRESSION	NONE

****

"RRENT DATE: 06-04-1996 FILE DATE: 06-03-1996
T TIME: 09:12:11 FILE NAME: MDLCITY

****

************************** TAILWATER **************************

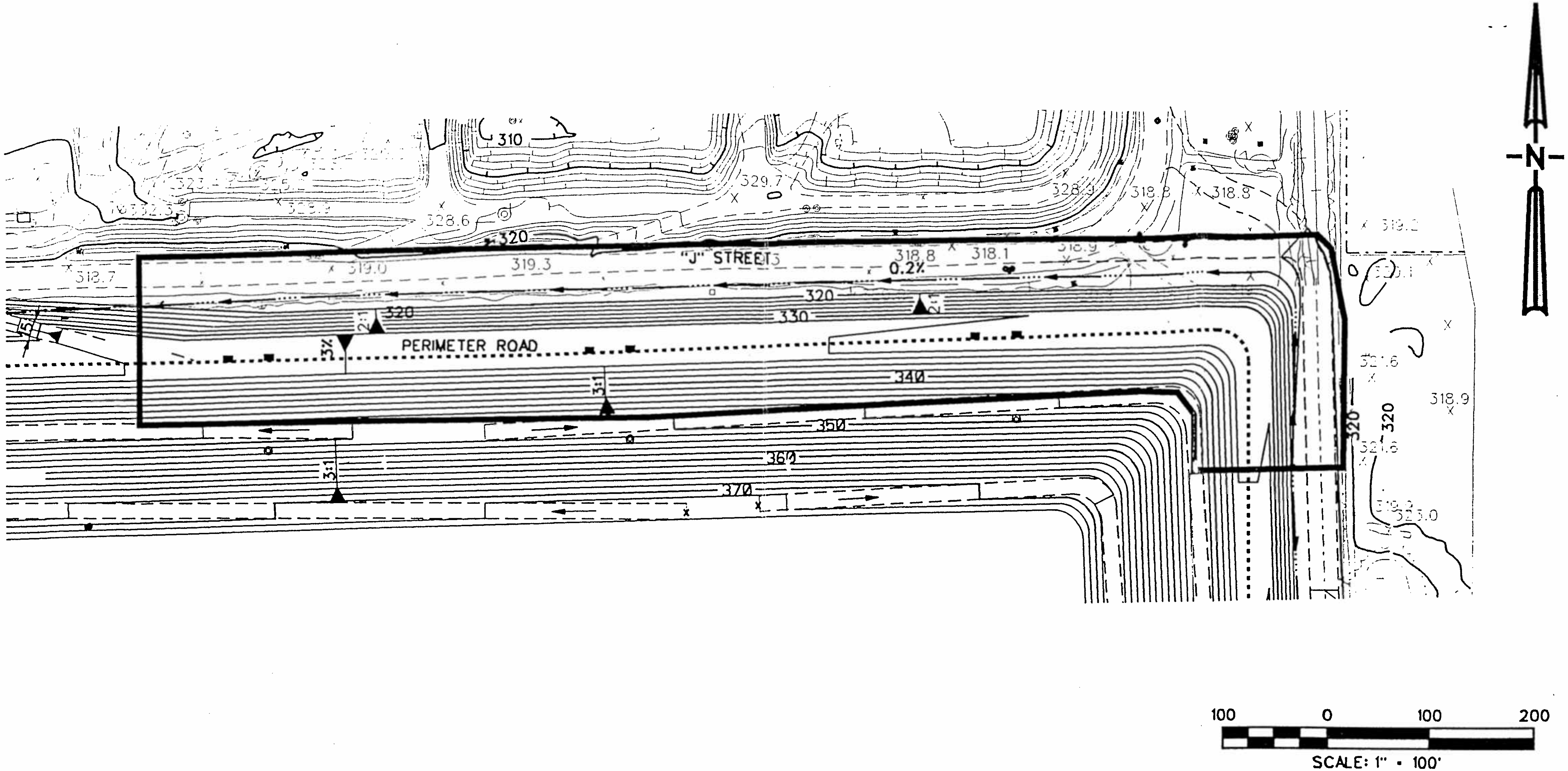
****

CONSTANT WATER SURFACE ELEVATION
314.33

************************** ROADWAY OVERTOPPING DATA **************************

ROADWAY SURFACE	GRAVEL
EMBANKMENT TOP WIDTH (FT)	40.00
CREST LENGTH (FT)	100.00
OVERTOPPING CREST ELEVATION (FT)	319.00

****



REV.	DATE		DRN BY	APP BY

DATE:	SEPTEMBER, 1996	PROJECT NO. 35624	SCALE: AS SHOWN
DES BY	RJZ	PROJECT:	NORTH PERIMETER BERM RESIDUAL MANAGEMENT UNIT 1 MODEL CITY, NIAGARA COUNTY, NEW YORK
DRN BY	VPR	SHEET TITLE:	**NORTH PERIMETER BERM DRAINAGE SHED AREA**
CHK BY	FAS		
REV BY	AWE		
APP BY	CPB		

RUST ENVIRONMENT & INFRASTRUCTURE

CWM Chemical Services, Inc.
Model City Facility

SHEET 1 OF 1

DRAWING NO.

FIGURE 1

VIII. SUPPLEMENTAL CALCULATIONS FOR FINAL CAP AREAS

CLIENT: CWM Chemical Services, LLC PROJECT: RMU-1 Model City Facility Prepared By: BMS Date: 6-25-01
TITLE: RMU-1 Permit Modification Reviewed By: ______ Date: ______
SUBJECT: Perimeter Channel Redesign

TASK:

Demonstrate that the revised cross section for the RMU-1 perimeter channel provides adequate capacity to convey the 25-year, 24-hour estimated peak discharge for newly graded cap areas.

REFERENCES:

1. "Part 373 Permit for Residuals Management Unit 1," prepared by Rust Environment and Infrastructure, June 1997.

2. PondPack for Windows, Version 7.5, hydrology modeling program, Haestad Methods, Inc..

ASSUMPTIONS:

1. The runoff curve number for newly graded cap areas is conservatively assumed to be 96.

2. The 25-year, 24-hour design storm produces 4.00 inches of rainfall.

3. Drainage area A13 is the largest perimeter channel drainage area (3.29 acres according to reference 1) and is therefore used to demonstrate the adequacy of the revised perimeter channel cross section for all perimeter channel drainage areas.

4. The Manning "n" for grass-lined channels is assumed to be 0.038 based on reference 1.

5. No freeboard is required for the perimeter channel based on reference 1.

6. The bed slope of the revised perimeter channel within drainage area A13 remains unchanged from the currently permitted design (i.e., bed slope equals 0.5%).

CALCULATIONS:

The revised perimeter channel cross section retains the triangular configuration and 1:1 outboard sideslope of the currently permitted design. However, the inboard sideslope will be decreased to 2:1 (from the currently permitted 1:1) to reduce the velocity of stormwater runoff as it enters the channel. The reduction in sideslope will also reduce the potential for soil erosion and increase the stability of the perimeter channel sideslope.

1. 25-Year, 24-Hour Estimated Peak Discharge

The following table summarizes the watershed characteristics for drainage area A13 and the estimated peak discharge resulting from the 25-year, 24-hour design storm.

Watershed Area [acres]	Time of Concentration [hr]	Runoff Curve Number [CN]	25-yr, 24-hr Estimated Peak Discharge [cfs]
3.29	0.12	96	15.6

Supporting calculations, including output from PondPack, are included as an attachment.

CLIENT: CWM Chemical Services, LLC PROJECT: RMU-1 Model City Facility Prepared By: BMS Date: 6-25-01
TITLE: RMU-1 Permit Modification Reviewed By: ______ Date: ______
SUBJECT: Perimeter Channel Redesign

2. **Resulting Hydraulic Conditions within the Perimeter Channel**

The Manning equation is used to determine the required perimeter channel flow depth to convey the 25-year, 24-hour estimated peak discharge of 15.6 cfs. The following table summarizes the hydraulic conditions within the perimeter channel.

25-yr, 24-hr Estimated Peak Discharge [cfs]	Perimeter Channel Manning "n"	Bed Slope [%]	Channel Flow Depth at 25-yr, 24-hr Estimated Peak Discharge [ft]	Channel Flow Velocity at 25-yr, 24-hr Estimated Peak Discharge [ft/s]
15.6	0.038	0.5	2.05	2.47

Since the required flow depth of 2.05 feet is less than the channel depth of 2.5 feet, the redesigned perimeter channel provides adequate hydraulic capacity to convey the 25-year, 24-hour estimated peak discharge. Spreadsheet output for the Manning equation is included as an attachment.

File.... F:\UTILS\TMPROJ\050\05011\PERIMETER CHANNEL A13.PPW

TIME OF CONCENTRATION CALCULATOR

Segment #1: Tc: TR-55 Sheet
Description: Bare Soil

Mannings n	.0110	
Hydraulic Length	95.00	ft
2yr, 24hr P	2.3000	in
Slope	.330000	ft/ft
Avg.Velocity	3.54	ft/sec

Segment #1 Time: .0074 hrs

Segment #2: Tc: TR-55 Channel
Description: Perimeter Channel Flow

Flow Area	6.3100	sq.ft
Wetted Perimeter	7.48	ft
Hydraulic Radius	.84	ft
Slope	.005000	ft/ft
Mannings n	.0380	
Hydraulic Length	1020.00	ft
Avg.Velocity	2.48	ft/sec

Segment #2 Time: .1145 hrs

Total Tc: .1219 hrs

File.... F:\UTILS\TMPROJ\050\05011\PERIMETER CHANNEL A13.PPW

Tc Equations used...

==== SCS TR-55 Sheet Flow ====

Tc = (.007 * ((n * Lf)**0.8)) / ((P**.5) * (Sf**.4))

Where:
- Tc = Time of concentration, hrs
- n = Mannings n
- Lf = Flow length, ft
- P = 2yr, 24hr Rain depth, inches
- Sf = Slope, %

==== SCS Channel Flow ====

R = Aq / Wp
V = (1.49 * (R**(2/3)) * (Sf**-0.5)) / n

Tc = (Lf / V) / (3600sec/hr)

Where:
- R = Hydraulic radius
- Aq = Flow area, sq.ft.
- Wp = Wetted perimeter, ft
- V = Velocity, ft/sec
- Sf = Slope, ft/ft
- n = Mannings n
- Tc = Time of concentration, hrs
- Lf = Flow length, ft

```
SCS UNIT HYDROGRAPH METHOD

STORM EVENT: 25 year storm
Duration       = 24.0000 hrs     Rain Depth = 4.0000 in
Rain Dir       = C:\HAESTAD\PPKW\RAINFALL\
Rain File -ID  = SCSTYPES.RNF - TypeII  24hr
Unit Hyd Type  = Default Curvilinear
HYG Dir        = F:\UTILS\TMPROJ\050\05011\
HYG File - ID  =  - A13 25yr
Tc             = .1219 hrs
Drainage Area  = 3.290 acres  Runoff CN= 96

============================================
Computational Time Increment   =   .01625 hrs
Computed Peak Time             =  11.9472 hrs
Computed Peak Flow             =    15.56 cfs

Time Increment for HYG File    =    .0500 hrs
Peak Time, Interpolated Output =  11.9500 hrs
Peak Flow, Interpolated Output =    15.50 cfs
============================================

              DRAINAGE AREA
            -------------------
            ID:None Selected
            CN   =   96
            Area =       3.290 acres
            S    =    .4167 in
            0.2S =    .0833 in

             Cumulative Runoff
            -------------------
                    3.5401 in
                      .971 ac-ft

HYG Volume...           .971 ac-ft (area under HYG curve)

***** UNIT HYDROGRAPH PARAMETERS *****

Time Concentration, Tc =   .12191 hrs (ID: A13)
Computational Incr, Tm =   .01625 hrs = 0.20000 Tp

Unit Hyd. Shape Factor =  483.432 (37.46% under rising limb)
K =  483.43/645.333,  K =     .7491 (also, K = 2/(1+(Tr/Tp))
Receding/Rising, Tr/Tp =   1.6698 (solved from K =    .7491)

Unit peak,          qp =    30.58 cfs
Unit peak time      Tp =   .08127 hrs
Unit receding limb, Tr =   .32509 hrs
Total unit time,    Tb =   .40637 hrs
```

Project: CWM Model City
Project No.: 050.11
Subject: Perimeter Channel Redesign

Drainage Channel A13 - Flow Conditions for Newly Graded Cap Area

Channel Design (Input)	
Flow Capacity (cfs)	15.6
Base Width (ft)	0.00
Left Side Slope (x:1)	2.00
Right Side Slope (x:1)	1.00
Bed Slope	0.005
Maximum Allowable Velocity (ft/s)	4.00
Manning "n"	0.038

Flow Conditions (Output)	
Flowrate from Manning Equation (cfs)	15.6
Required Flow Depth (ft)	2.05
Resulting Flow Velocity (ft/s)	2.47
Resulting Flow Width at Top (ft)	6.15
Resulting Flow Area (ft^2)	6.31
Resulting Wetted Perimeter (ft)	7.48
Resulting Hydraulic Radius (ft)	0.84

IX. RMU-1 PLATEAU ACCESS ROAD DRAINAGE CALCULATIONS

Imagine the result

Calculation Sheet

Client: CWM Chemical Services, LLC

Project Location: Model City, New York

Project: RMU-1 Plateau Access Road Design **Project No.: B0023729.2012**

Subject: Drainage Calculations

Prepared By: NWF/BMS **Date: August 2012**

Reviewed By: PTO/BMS **Date: August 2012**

Checked By: BMS **Date: August 2012**

OBJECTIVE:

Demonstrate that the drainage ditch along the inside edge of the proposed landfill plateau access road provides adequate hydraulic capacity to convey the estimated peak discharge from the 25-year, 24-hour design storm. Demonstrate that the proposed culvert beneath the landfill plateau access road provides adequate hydraulic capacity to convey the estimated peak discharge from the 25-year, 24-hour design storm.

REFERENCES:

1. RMU-1 Permit Drawing No. 12-a entitled "Top of Vegetated Cover Grades," ARCADIS, August 2012.

2. RMU-1 Permit Drawing No. 23A entitled "Landfill Plateau Access Road Details," ARCADIS, August 2012.

3. Technical Release 55 "Urban Hydrology for Small Watersheds," Soil Conservation Service, June 1986.

4. HydroCAD Software Solutions, LLC, HydroCAD. Version 8.5. Computer Software, 2006. (Output attached).

5. Manufacturer's Literature, www.ads-pipe.com, Advanced Drainage Systems, Inc. (attached).

ASSUMPTIONS:

1. A new permanent road is proposed along the northern face of RMU-1 to allow waste hauling trucks and other vehicles access to the landfill's plateau. The road design is shown on Reference 1. The road design includes two new drainage features. A roadside ditch will be installed along the inside edge of the road to convey concentrated runoff down the landfill sideslope and into the existing surface water diversion berms (SWDBs) and perimeter channel. A culvert will be installed beneath the road fill along the perimeter berm to maintain flow within the existing perimeter channel.

2. The proposed roadside ditch has a v-notch geometry with a minimum depth of 1 ft, sideslopes of 3H:1V and 2H:1V, and a variable longitudinal slope. The roadside ditch will be lined with a geomembrane to limit percolation into the existing cover soil. The geomembrane will be covered with a 6-inch-thick layer of loose riprap having a D50 of 3 inches. Two 10-inch-diameter perforated and corrugated high density polyethylene (HDPE) pipes will be installed along the invert of the roadside ditch and buried within the loose riprap. The pipes are provided as a means to convey the majority of

Calculation Sheet

the ditch flow in a non-erosive manner and to limit the required size of the ditch riprap.

3. The invert slope of the roadside ditch matches the longitudinal slope of the access road and varies from 8% to 12%. The ditch is divided into three segments as follows:

   - Upper Ditch Segment – 12% slope draining to upper SWDB.
   - Middle Ditch Segment – 8% slope draining to lower SWDB.
   - Lower Ditch Segment – 12% slope draining to perimeter channel.

4. The capacity of the roadside ditch includes the pipe-full flowrate at the indicated ditch slope, and any open channel flowrate that would occur above the riprap layer. The depth of open channel flow above the riprap considers both the required head to admit water into the perforated pipes as well as the additional flow capacity needed beyond that provided by the perforated pipes.

5. The proposed culvert is necessary to maintain drainage within the perimeter channel at the top of the perimeter berm that would otherwise be blocked by fill placement necessary for the access road construction. A culvert is currently in place in this channel in front of the riser vaults for Cell 3. Because the road fill extends to this existing culvert location, the proposed culvert is essentially an extension of the existing culvert. The extension of the existing culvert pipe is assumed to utilize the same material, diameter, and construction (i.e., 18-inch-diameter corrugated metal pipe). The culvert pipe is assumed to have a Manning “n” of 0.025. The culvert is assumed to have a slope of 0.5%.

6. Both proposed stormwater features (ditches and culvert), are based on the 25-year, 24-hour event, storm event which produces 4.0 inches of rainfall.

7. The runoff curve number for the tributary watershed to each roadside ditch segment and the proposed culvert varies according to surface conditions. The runoff curve number for gravel access roads is 89 based on Reference 3. The roadside ditch is riprap lined with a runoff curve number of 89 also based on Reference 3. The runoff curve number for capped areas is assumed to be 86 to remain consistent with original RMU-1 drainage design calculations (based on the value presented in Table 2-2a of Reference 3 for <50% grass cover, fair, Hydrologic Soil Group “C”).

8. The culvert configuration is deemed acceptable if the design can convey the 25-year, 24-hour estimated peak discharge without causing a headwater depth that exceeds the depth of the perimeter channel in which the culvert is installed. The flow capacity of the culvert is estimated using Reference 4, which accounts for both pipe friction losses and energy losses at the culvert entrance and exit.

Calculation Sheet

CALCULATIONS:

1. Estimated Peak Discharge to the Roadside Ditch

Table 1 summarizes the runoff characteristics for the tributary watersheds draining to each roadside ditch segment and the resulting 25-year, 24-hour peak discharges.

Table 1 – Runoff Characteristics of Tributary Areas Draining to Roadside Ditch Segments

Ditch Segment	Cumulative Watershed Area (acres)	Composite Runoff Curve Number	Time of Concentration (min)	25-yr, 24-hr Estimated Peak Discharge (cfs)
Upper (12% Slope)	1.26	87	10.4	4.87
Middle (8% Slope)	0.36	87	6.0	1.59
Lower (12% Slope)	0.25	87	6.0	1.11

The watersheds are included as Attachment 1 to this calculation sheet. Supporting output from HydroCAD is included as Attachment 2 to this calculation sheet.

2. Roadside Ditch Capacity

As discussed in Assumption 4, the capacity of the roadside ditch includes the capacity of the perforated pipes buried in the riprap and the open channel flow that occurs above the riprap (if any). The pipe-full flow capacity of the perforated pipes is based on the Manning equation:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

where,
- Q = pipe-full flowrate, cfs (unknown)
- A = cross sectional area of pipe flowing full = $\pi D^2/4$
- n = Manning "n" for corrugated HDPE pipe = 0.017 (Reference 5)
- R = hydraulic radius = A/P
- P = wetted perimeter of pipe flowing full = πD
- S = minimum longitudinal slope of pipe = varies, either 0.08 or 0.12

Solving for Q for each longitudinal ditch slope,

Q = 5.76 cfs x 2 pipes = 11.52 cfs total (12% Slopes)
= 4.70 cfs x 2 pipes = 9.40 cfs total (8% Slopes)

Thus, for all ditch segments, the pipe-full capacity exceeds the peak discharge to each segment, meaning the pipes alone can convey the peak flow and there is no need for excessive flow to be conveyed above the riprap layer.

However, in order for the flow to enter the perforated pipes, a certain head outside the pipes is needed. This head is estimated from laboratory testing by the pipe manufacturer (Reference 5), the results of

Calculation Sheet

which are included as Attachment 3 to this calculation sheet. An inflow rate per foot of pipe for each ditch segment is determined using the above-calculated peak discharges. The corresponding head (measured with respect to the pipe invert) is then determined. As indicated in Attachment 3, the head for the middle and lower ditch segments is approximately 1 inch and the head for the upper ditch segment is approximately 6.9 inches. Thus, the water level in the middle and lower roadside ditch segments should remain below the top of the riprap layer during the peak flow period of the design storm. The predicted water depth over the top of the riprap layer in the upper ditch segment is limited (approximately 0.9 inches) and is not sufficient to affect the stability of the riprap lining.

3. Estimated Peak Discharge to the Perimeter Channel Culvert

Table 2 summarizes the runoff characteristics for the tributary watershed draining to the perimeter channel culvert and the resulting 25-year, 24-hour peak discharge.

Table 2 – Contributing Watershed Characteristic and Peak Discharge

Watershed ID	Area (acres)	Runoff Curve Number	Time of Concentration (min)	Resulting Peak Discharge (cfs)
Perimeter Channel Culvert	0.60	87	6.0	2.65

Supporting output from HydroCAD is included as Attachment 4.

4. Perimeter Channel Culvert Capacity

Reference 4 is used to estimate the headwater at the inlet to the culvert to be installed beneath the access road fill. This predicted water surface elevation is compared with the lowest perimeter channel containment elevation to verify that the culvert will not cause the perimeter channel to overtop while conveying the peak flow from the design storm. The results from Reference 4 are summarized in Table 3.

Table 3 – Perimeter Channel Culvert Capacity Calculations

Required Flow Rate (cfs)	Culvert Composition	Pipe Slope	Max. Allowable Water Surface El. in Upstream Perimeter Channel (ft)	Predicted Peak Water Surface El. in Perimeter Channel[1] (ft)
2.65	18-inch CMP	0.5%	333.22	331.97

Notes:
1. Maximum water elevation is based on lowest surveyed elevation at edge of perimeter channel upstream of culvert.

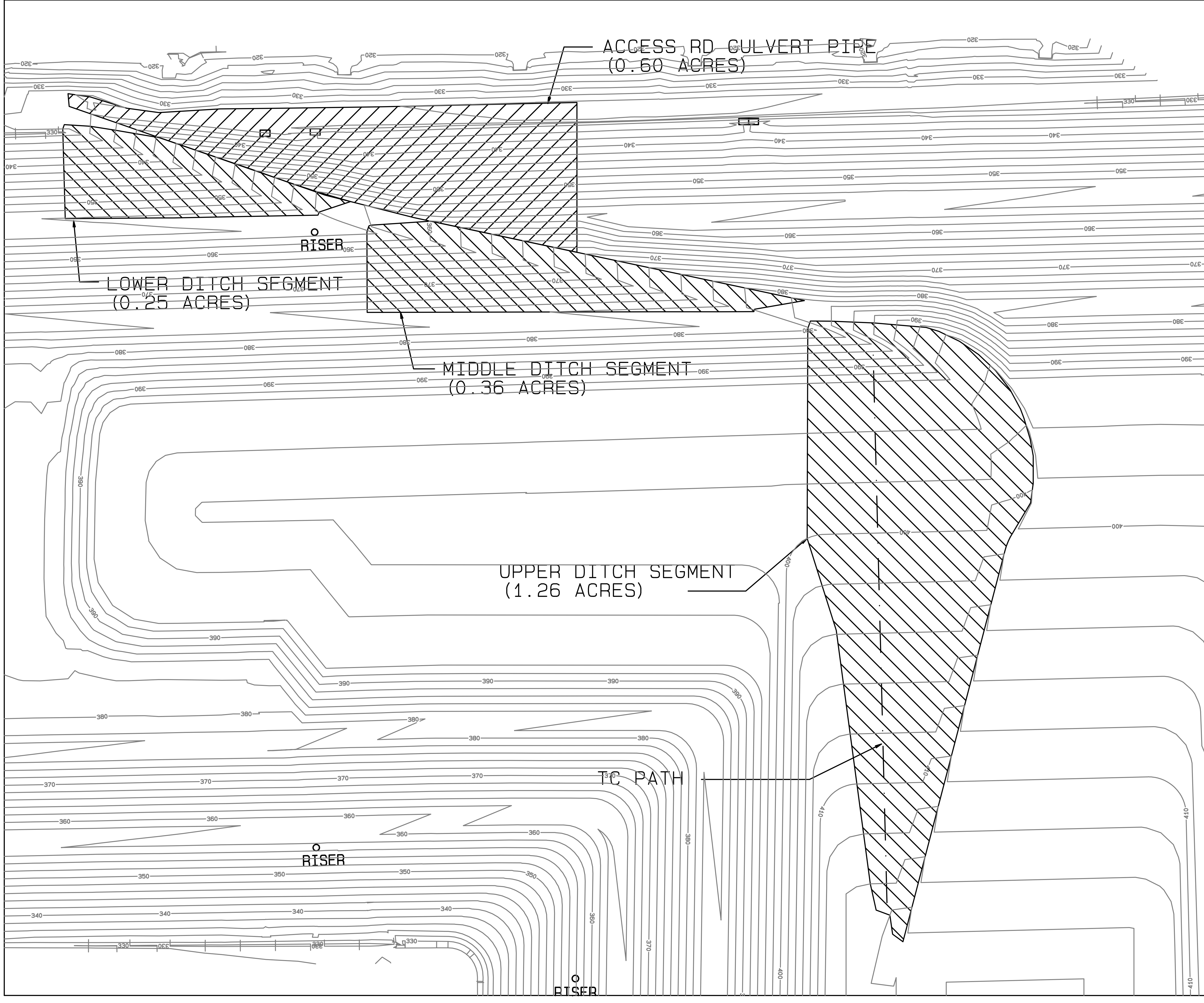
As indicated in Table 3, the predicted peak water surface elevation in the perimeter channel upstream of the culvert is less than the lowest surveyed elevation at the edge of the perimeter channel. Thus, the channel should not overflow while conveying the peak runoff from the design storm and the culvert capacity is therefore sufficient.

SUMMARY:

The proposed roadside ditch and culvert at the bottom of the access road provide adequate hydraulic capacity to convey the peak discharges from the 25-year, 24-hour design storm event.

Attachment 1

Watershed Area Map


ACCESS RD CULVERT PIPE
(0.60 ACRES)
LOWER DITCH SEGMENT
(0.25 ACRES)
MIDDLE DITCH SEGMENT
(0.36 ACRES)
UPPER DITCH SEGMENT
(1.26 ACRES)
TC PATH
RISER
RISER
RISER

Attachment 2

HydroCAD Output for Roadside Ditches

Summary for Subcatchment 1S: Roadside Ditch (Upper Segment)

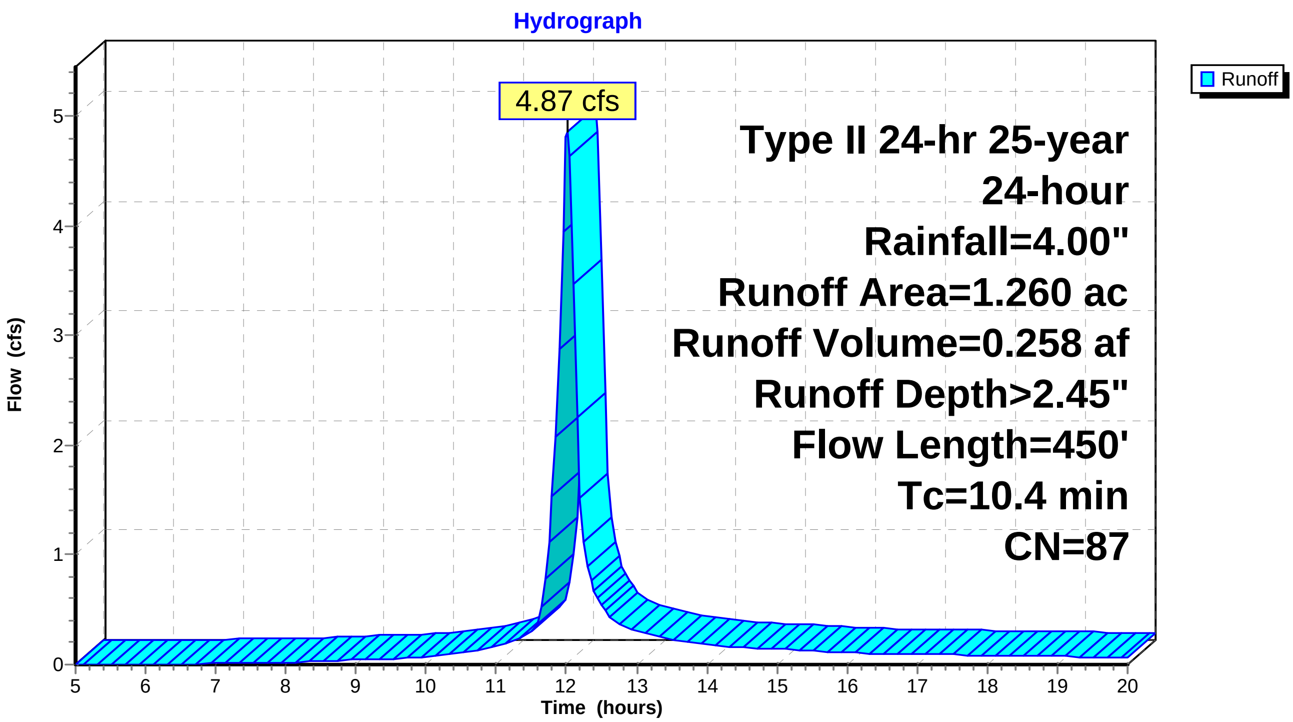
Runoff = 4.87 cfs @ 12.02 hrs, Volume= 0.258 af, Depth> 2.45"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-year, 24-hour Rainfall=4.00"

	Area (ac)	CN	Description
*	0.950	86	<50% Grass cover, Poor, HSG C
	0.310	89	Gravel roads, HSG C
	1.260	87	Weighted Average
	1.260		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.9	100	0.0500	0.24		**Sheet Flow,** Range n= 0.130 P2= 2.50"
3.4	320	0.0500	1.57		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.1	30	0.3333	4.04		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
10.4	450	Total			

Subcatchment 1S: Roadside Ditch (Upper Segment)



Summary for Subcatchment 3S: Roadside Ditch (Middle Section)

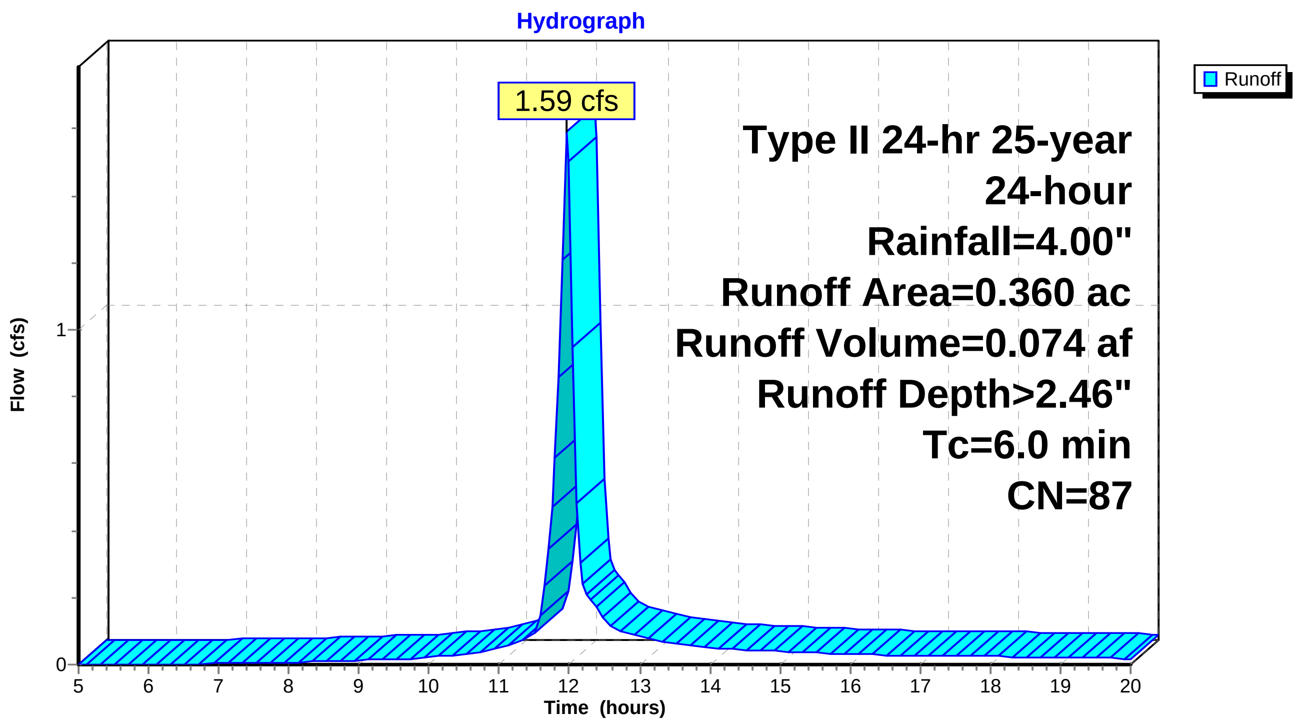
Runoff = 1.59 cfs @ 11.97 hrs, Volume= 0.074 af, Depth> 2.46"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-year, 24-hour Rainfall=4.00"

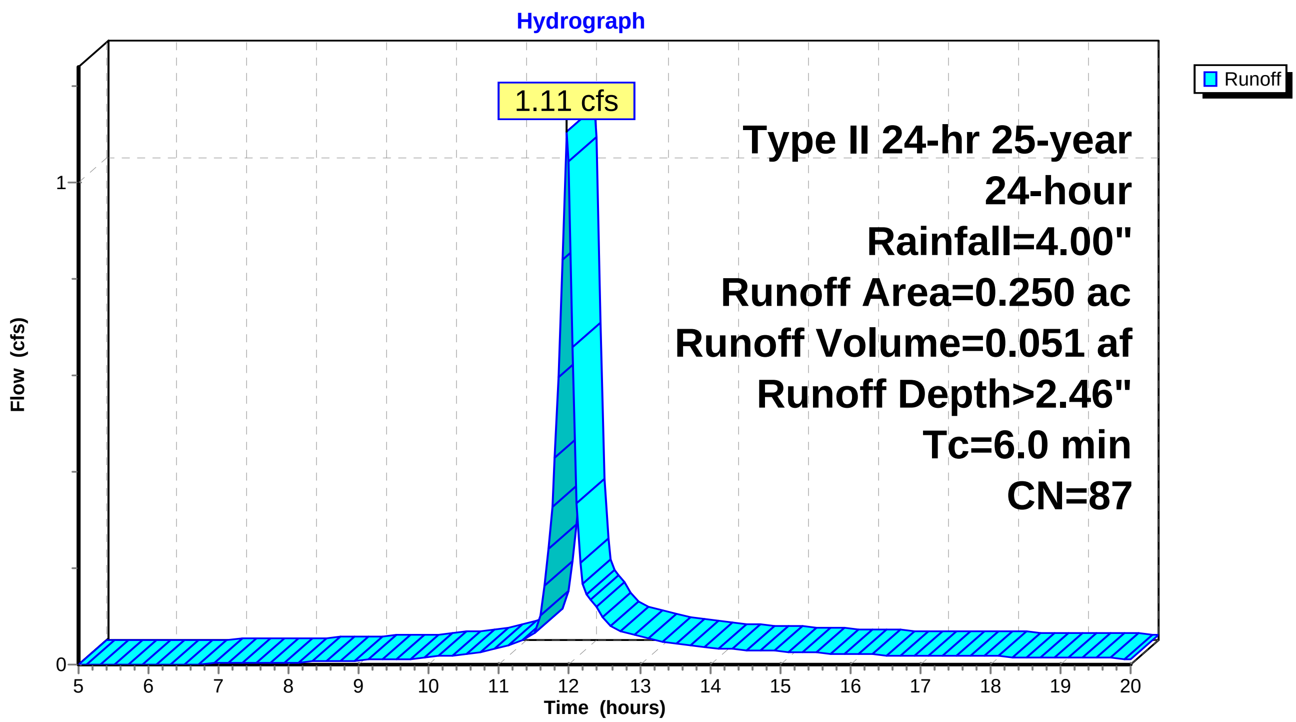
Area (ac)	CN	Description
0.210	86	<50% Grass cover, Poor, HSG C
0.150	89	Gravel roads, HSG C
0.360	87	Weighted Average
0.360		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment 3S: Roadside Ditch (Middle Section)



Subcatchment 2S: Roadside Ditch (Lower Section)



Summary for Subcatchment 2S: Roadside Ditch (Lower Section)

Runoff = 1.11 cfs @ 11.97 hrs, Volume= 0.051 af, Depth> 2.46"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-year, 24-hour Rainfall=4.00"

Area (ac)	CN	Description
0.160	86	<50% Grass cover, Poor, HSG C
0.090	89	Gravel roads, HSG C
0.250	87	Weighted Average
0.250		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Attachment 3

Manufacturer's Literature
(Advanced Drainage
Systems, Inc.)

Technical Notes

ADVANCED DRAINAGE SYSTEMS, INC.

Technical Note 2.109
Re: Flow Capacity
Date: March 1, 1995

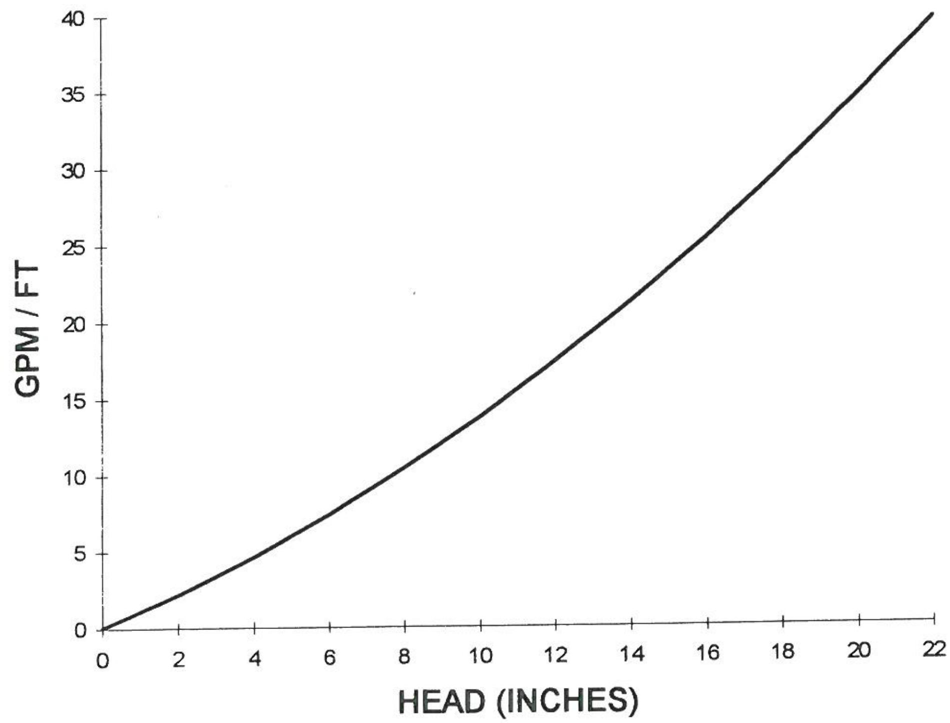
It is the intent of this Technical Note to provide current hydraulic performance data for use by the engineering community. A bibliography is included for the engineer's use if further information or guidance is needed.

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.

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

OUTFLOWS - ADS PIPE
10" SINGLE WALL PIPE TYPE C



FACTORS FOR OUTFLOW CALCULATIONS
ADS 10" SINGLE WALL PIPE TYPE C

OPEN AREA	AO	A1	A2	H2	H	Q=GPM/FT
1.2	0.03997	0.99646	0.03616	0	0	0.04
1.2	0.03997	0.99646	0.03616	4	2	2.18
1.2	0.03997	0.99646	0.03616	16	4	4.60
1.2	0.03997	0.99646	0.03616	36	6	7.32
1.2	0.03997	0.99646	0.03616	64	8	10.33
1.2	0.03997	0.99646	0.03616	100	10	13.62
1.2	0.03997	0.99646	0.03616	144	12	17.20
1.2	0.03997	0.99646	0.03616	196	14	21.08
1.2	0.03997	0.99646	0.03616	256	16	25.24
1.2	0.03997	0.99646	0.03616	324	18	29.69
1.2	0.03997	0.99646	0.03616	400	20	34.43
1.2	0.03997	0.99646	0.03616	484	22	39.46

NOTE: Q = AO + (A1*H) + (A2*H2)

DITCH SEGMENT	CFS (PEAK)	DITCH LENGTH (FT)	GPM/FT ÷ 2 PIPES	HEAD (IN)
UPPER	4.87	125	8.7	6.9
MIDDLE	1.59	310	1.2	1.1
LOWER	1.11	185	1.3	1.2

Attachment 4

HydroCAD Output for Culvert

Summary for Subcatchment 4S: Perimeter Channel Culvert

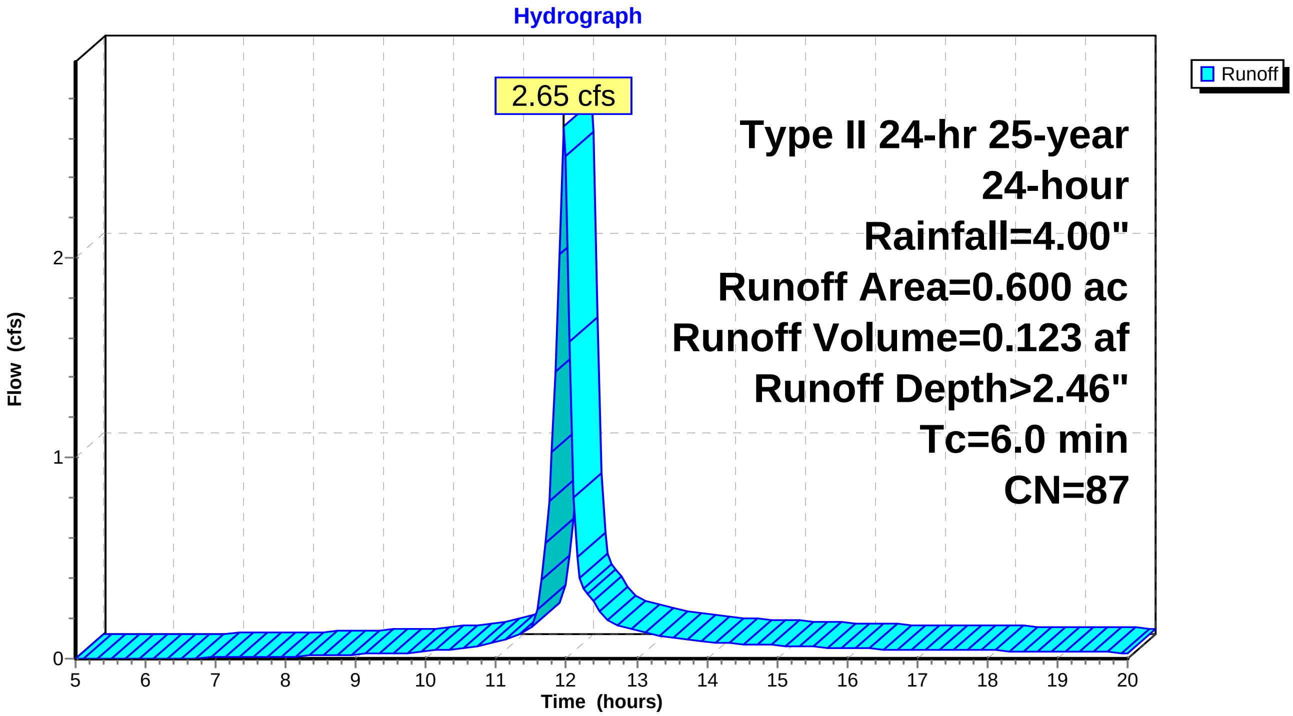
Runoff = 2.65 cfs @ 11.97 hrs, Volume= 0.123 af, Depth> 2.46"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-year, 24-hour Rainfall=4.00"

Area (ac)	CN	Description
0.470	86	<50% Grass cover, Poor, HSG C
0.130	89	Gravel roads, HSG C
0.600	87	Weighted Average
0.600		Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Subcatchment 4S: Perimeter Channel Culvert



Summary for Pond 5P: 18" CMP (Cell 3 Riser Vault CV Extension)

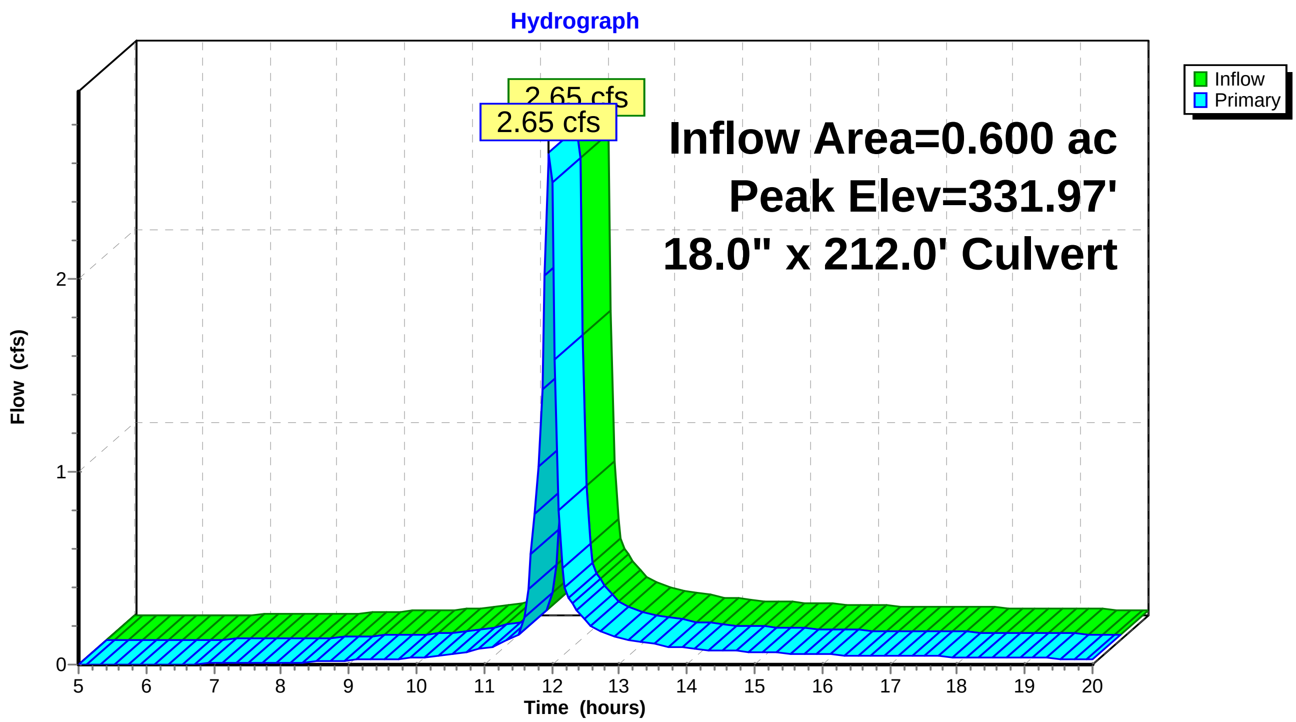
Inflow Area = 0.600 ac, 0.00% Impervious, Inflow Depth > 2.46" for 25-year, 24-hour event
Inflow = 2.65 cfs @ 11.97 hrs, Volume= 0.123 af
Outflow = 2.65 cfs @ 11.97 hrs, Volume= 0.123 af, Atten= 0%, Lag= 0.0 min
Primary = 2.65 cfs @ 11.97 hrs, Volume= 0.123 af

Routing by Stor-Ind method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Peak Elev= 331.97' @ 11.97 hrs
Flood Elev= 333.22'

Device	Routing	Invert	Outlet Devices
#1	Primary	330.79'	**18.0" x 212.0' long Culvert** CPP, projecting, no headwall, Ke= 0.900 Outlet Invert= 329.73' S= 0.0050 '/' Cc= 0.900 n= 0.025 Corrugated metal

Primary OutFlow Max=2.57 cfs @ 11.97 hrs HW=331.95' (Free Discharge)
└**1=Culvert** (Barrel Controls 2.57 cfs @ 2.43 fps)

Pond 5P: 18" CMP (Cell 3 Riser Vault CV Extension)



APPENDIX J

SITE VOLUME CALCULATIONS

5/18/99
Revised: ~~Date Approved~~

CLIENT: CWM Chemical Services, LLC	PROJECT: Model City Facility		
TITLE: RMU-1 Final Cover Modification Application		Prepared By: BMS	Date: December 2003
SUBJECT: Appendix J – Landfill Volume and Site Life Calculation		Reviewed By: PHB	Date: December 2003
		Revised By: RLP	Date: March 2008

OBJECTIVE:

Determine the total net volume available within Residuals Management Unit 1 (RMU-1) for waste placement and the associated site life.

REFERENCES:

1. RMU-1 Permit Drawing No. 11-a entitled "Top of Waste Grades," BBL, December 2003 (last revised March 2008).

2. Terramodel v9.70.01, Spectra Precision Software, Inc.

3. Calculation sheet entitled "Landfill Volume and Site Life Calculations," by EarthTech, dated July 1997 (last revised February 1999).

ASSUMPTIONS:

1. Maximum incoming waste to the facility is approximately 500,000 tons per year (assumed).

2. The total airspace (i.e., the volume between the top of the operations layer and the bottom of the final cover system) of RMU-1 is 3,601,900 in-place cubic yards (cy). This is based on the currently permitted airspace stated in Reference 3 (3,495,030 cy) plus the airspace gain due to the final cover modification (106,870 cy). The airspace gain due to the final cover modification is calculated by multiplying the surface area of the revised final waste grading plan (Reference 1 using Reference 3) within the proposed limit of the geosynthetic clay liner (GCL) final cover area by the difference in thickness between the two final cover systems (3 feet).

3. The volume of select fill placed for access roads, as well as in and around vertical risers throughout the cell areas is estimated to be 86,600 in-place cy (based on historical percentage of gross volume).

4. Bulking of the placed waste material will be a direct result from the inclusion of stabilizing agents to the fraction of waste requiring stabilization. For the following calculation, it has been assumed that approximately 25% of the incoming waste will need stabilization. Stabilized waste is assumed to contain 20%, by volume, stabilizing agents. The volume of stabilizing agents is expected to be offset by the compaction of the waste due to construction/operation equipment. Therefore, the stabilizing agents are assumed to not consume additional airspace.

5. The total surface area of the RMU-1 waste surface is approximately 40.80 acres. An average 6-inch-thick soil layer will be constructed above the final waste grades. Therefore, the volume occupied by a 6-inch-thick soil layer over the top of waste grades is estimated to be 32,900 in-place cy (40.80 acres x 0.5 feet x 1,613 cy/ac-ft) rounded to the nearest 100 cy. Within the compacted clay final cover area, this 6-inch-thick layer is included in the final waste grades depicted on Reference 1. Within the GCL final cover area, this 6-inch-thick layer is excluded from the final waste grades depicted on Reference 1 (i.e., the soil layer will be constructed above the design final waste grades).

6. Assumed unit weights:

- Composite in-place waste material (stabilized and non-stabilized) and select fill = 111.1 pounds per cubic feet (lb/ft^3) (i.e., 1.5 tons per cy)
- Average in-place select fill = 100 lb/ft^3
- Stabilized waste material = 115 lb/ft^3

7. Daily cover will be a spray-on material placed over the waste, which is assumed to consume no volume. Soil daily cover will not be used.

CALCULATIONS:

1. **Total Net Volume Available in RMU-1 for Waste Placement (Volumes Rounded to Nearest 100 cy)**

Total Airspace (from top of operations layer to bottom of final cover)	=	**3,601,900 cy**
Volume of Select Fill for Access Roads and Vertical Risers (Assumption 3)	=	86,600 cy
Volume of 6-Inch-Thick Soil Layer (Assumption 5)	=	32,900 cy
Total Net Volume Available for Waste	=	**3,482,400 cy**

2. **Unit Weight of In-Place Waste**

With the inclusion of stabilizing agents and select fill material into the landfill volume, the actual unit weight of the material in the landfill is greater than the unit weight of the incoming waste material. Assuming the average unit weight of in-place waste and select fill used for access roads, vertical risers, and the 6-inch-thick soil cover is 111.1 lb/ft^3, the following mass balance may be written:

$$V_{SF}*\gamma_{SF} + V_{AW}*\gamma_{AW} = V*\gamma$$

where,

V_{SF} = volume of select fill and soil within RMU-1 = 86,600 cy + 32,900 cy = 119,500 cy
γ_{SF} = in-place unit weight of select fill = 100 lb/ft^3
V_{AW} = volume available within RMU-1 for waste material = 3,482,400 cy
γ_{AW} = average in-place unit weight of waste (unknown)
V = total airspace within RMU-1 = 3,601,900 cy
γ = in-place composite unit weight of waste and select fill = 111.1 lb/ft^3

Thus,

$$\gamma_{AW} = [(111.1 \text{ lb/ft}^3)(3{,}601{,}900 \text{ cy}) - (119{,}500 \text{ cy})(100 \text{ lb/ft}^3)]/\ 3{,}482{,}400 \text{ cy}$$

Average In-Place Unit Weight of Waste
(Including Stabilizing Agents and Excluding Select Fill) = 111.48 lb/ft^3

Since the average in-place unit weight of waste includes both waste material and stabilizing agents, the following expression may be written to determine the in-place unit weight of the waste material alone:

$$\gamma_{AW} = 0.75\ \gamma_W + 0.25\ \gamma_{SW}$$

where,

γ_{AW} = average in-place unit weight of waste (from above) = 111.48 lb/ft^3
γ_W = unit weight of waste material (unknown)
γ_{SW} = unit weight of stabilized waste material = 115 lb/ft^3

Thus,

$$\gamma_w = [111.48 \text{ lb/ft}^3 - (0.25)(115 \text{ lb/ft}^3)]/0.75$$

In-Place Unit Weight of Waste = 110.31 lb/ft^3

3. Estimated RMU-1 Site Life

The site life of RMU-1 is estimated using the total net volume available within RMU-1 for waste, the above-calculated in-place unit weight of waste, and a maximum annual inflow of waste to the facility of 500,000 tons (Assumption 1):

$$L = V_w/Q_w$$

where,

L = site life (unknown)
V_w = volume available within RMU-1 for waste = 3,482,400 cy
Q_w = annual volumetric inflow of waste to RMU-1 = (500,000 tons/yr)/γ_w = 335,754 cy/yr

Thus,

$$L = (3{,}482{,}400 \text{ cy})/(335{,}754 \text{ cy/yr})$$

Estimated RMU-1 Site Life = 10.4 years

SUMMARY:

The total net volume available within RMU-1 for waste placement is approximately 3,482,400 cy. The minimum estimated site life is approximately 10.4 years, assuming 500,000 tons per year incoming waste. Site life will increase if actual incoming annual waste volumes are less.

APPENDIX K

GEOSYNTHETIC CLAY LINER CALCULATIONS

CLIENT	CWM	SUBJECT	BENTOFIX EQUIVALENCY	PROJECT NO.	34282.640
PROJECT	MODEL CITY FACILITYRMU-1		TO PRIMARY SOIL LINER	BY CPB	DATE 11/16/95
	PERMIT MOD. CELLS 5,6&7		HYDRAULIC CONDUCTIVITY	CHK BPB	DATE 11/16/95

TASK: To demonstrate that a layer of Bentofix (GCL) is equivalent in hydraulic conductivity to a 18" primary soil liner layer in Cells 5,6 & 7 at the RMU-1 Model City facility .

REFERENCES:

1. "Geosynthetic Liner Systems: Innovations, Concerns and Designs", Proceedings fo the 7th GRI Seminar, Geosynthetic Research Institute, Drexel University, 12/93.
2. Bentofix Manufacturer's Specifications, National Seal Company.

CALCULATIONS:

Assume that the water flux through a geosynthetic clay liner (GCL) is equal to the water flux through a compacted clay liner (CCL) and that (v) is equal to the steady downward flux of water through an individual layer of porous material with zero water pressure at the base of the layer. From Darcy's law:

$$v = k\,(H + T) / T$$

where,
k = hydraulic conductivity
H = head on the liner
T = thickness of the layer

$$v_{GCL} = v_{CCL}$$

$$k_{GCL}\,(H + T_{GCL}) / T_{GCL} = k_{CCL}\,(H + T_{CCL}) / T_{CCL}$$

$$(k_{GCL})_{required} = k_{CCL}\,T_{GCL}\,(H + T_{CCL}) / T_{CCL}\,(H + T_{GCL})$$

Assume a worst case of 1 foot head on the liner (1 foot + 4.5 feet depth of sump). The required hydraulic conductivity of the primary soil liner layer is 1×10^{-7} cm/sec. The primary soil liner is 18" thick. From manufacturer's data, Bentofix is 6.0 mm thick.

H = 5.5 feet = 167.64 cm
$k_{CCL} = 1 \times 10^{-7}$ cm/sec
T_{CCL} = 18 in = 45.72 cm
T_{GCL} = 0.6 cm

$(k_{GCL})_{required} = (1 \times 10^{-7})(0.6)(167.64 + 45.72) / (45.72)(167.64 + 0.6) = 1.7 \times 10^{-9}$ cm/sec
$k_{bentofix} = 1 \times 10^{-9}$ cm/sec $\leq (k_{GCL})_{required} = 1.7 \times 10^{-9}$ cm/sec
Therefore, the Bentofix is equivalent to the18" primary soil liner layer.

HYDRAULIC ISSUES

The essence of any barrier material is its ability to contain the targeted liquids. The usual liquids are leachate, i.e., the solute, for liner systems beneath the waste and water for the cover system above the waste.

Steady Flux of Water. Water flux is defined as the volume of water flowing across a unit area in a unit time. The steady downward flux of water (v) through an individual layer of porous material with zero water pressure at the base of the layer is defined from Darcy's law as:

$$v = k\,\frac{H+T}{T} \tag{1}$$

where k is the hydraulic conductivity, H is the depth of liquid ponded on the layer, and T is the thickness of the layer.

Equation 1 is applicable only for flow through the bentonite component of a GCL; if the GCL contains a geomembrane, water flux will be controlled by water vapor diffusion through the geomembrane component. The geomembrane component, if present, should be included in the equivalency analysis, e.g., by using appropriate water vapor transmission rates. Also, Eq. 1 applies to a CCL or GCL liner alone and not to composite liners. Composite action with a geomembrane is considered later.

In order to estimate the required hydraulic conductivity of the GCL for equivalency assessment, assume that the water flux through the GCL is equal to the water flux through the CCL:

$$V_{GCL} = V_{CCL} \tag{2}$$

or:

$$k_{GCL}\,\frac{H+T_{GCL}}{T_{GCL}} = k_{CCL}\,\frac{H+T_{CCL}}{T_{CCL}} \tag{3}$$

If the hydraulic conductivity and thickness of the compacted clay liner are known, and the thickness of the GCL is known, the required hydraulic conductivity of the GCL to ensure equivalent performance in terms of steady flux of water is:

$$(k_{GCL})_{Required} = k_{CCL}\,\frac{T_{GCL}}{T_{CCL}}\,\frac{H+T_{CCL}}{H+T_{GCL}} \tag{4}$$

The required hydraulic conductivity of the compacted clay liner (k_{CCL}) is usually 1×10^{-7} cm/s. The thickness of GCLs (T_{GCL}) varies from product to product, but is typically about 7 mm after hydration at low overburden stress. The head of water (H) on the CCL or GCL is assumed to be 300 mm for purposes of illustration. The required hydraulic conductivity of the GCL, based on Eq. 4 and these conditions, is therefore:

- For equivalence to a 300-mm-thick compacted clay liner:
  $$(k_{GCL})_{Required} = 4.6 \times 10^{-9} \text{ cm/sec}$$
- For equivalence to a 600-mm-thick compacted clay liner:
  $$(k_{GCL})_{Required} = 3.4 \times 10^{-9} \text{ cm/sec}$$

As see in Table 1, the hydraulic conductivity of the bentonite component of commercially-produced GCLs is typically ≤ 1 to 5×10^{-9} cm/s. Thus, it is seen that equivalency of a GCL to a CCL, in terms of the steady water flux, can be established for most, if not all, GCLs in their manufactured condition.

CLIENT: CWM Chemical Services, LLC PROJECT: Model City, NY
TITLE: RMU-1 Final Cover Modification Application
SUBJECT: Appendix K-1: Required Hydraulic Conductivity for Final Cover Geosynthetic Clay Liner

Prepared By: BMS Date: December 2003
Reviewed By: PHB Date: December 2003
Revised By: RLP Date: March 2008

OBJECTIVE:

Determine the maximum allowable hydraulic conductivity for the final cover geosynthetic clay liner (GCL) to achieve comparable hydraulic performance to a 2-foot-thick compacted clay layer (CCL) having a maximum hydraulic conductivity of 1 x 10^{-7} centimeters per second (cm/s).

REFERENCES:

1. *Principles of Geotechnical Engineering*, Das, Braja M., pp. 99, 1990.
2. Engineering Report for Residuals Management Unit 1, Appendix G-3 entitled "Hydraulic Calculations for Collection System in GCL Final Cover Areas," Blasland, Bouck & Lee, Inc., December 2003 (last revised March 2008).
3. Engineering Report for Residuals Management Unit 1, Appendix G entitled "Hydraulic Calculations for Collection Systems," June 1992.
4. "Technical Equivalency Assessment of GCLs to CCLs," contained in Proceedings of the 7th GRI Seminar, Koerner, R.M. and D.E. Daniel, December 1993.

ASSUMPTIONS:

1. The final cover GCL is considered to be equivalent to the CCL if the steady-state flux (or vertical flowrate) through both materials is equivalent. For the purposes of this analysis, steady-state flux is determined using Darcy's Law and is based on the liquid head predicted by the HELP model for each cover type. For GCL final cover areas, Reference 2 indicates a peak daily head of 0.021 inches (0.002 feet) on top of the GCL (worst-case of the three slope conditions analyzed in Reference 2). For CCL final cover areas, Reference 3 indicates a peak daily head of 6.8 inches (0.57 feet) on top of the CCL.

2. Although GCL thickness can vary depending on material type, moisture content, and confining pressure, a thickness of 0.7 centimeters (cm) (0.023 feet) is assumed herein. This value is at the lower range of hydrated thicknesses presented in Reference 4.

CALCULATIONS:

1. Steady-State Flux Per Unit Area of CCL

The steady-state flux per unit area of CCL is calculated using Darcy's Law (Reference 1):

$$Q = kiA$$

where,

Q = steady-state flux
k = hydraulic conductivity of the CCL = 1×10^{-7} cm/s = 3.28×10^{-9} feet per second (ft/s)
i = hydraulic gradient = liquid head measured with respect to the bottom of the CCL divided by the thickness of the CCL = $(2 + 0.57)/2 = 1.29$
A = area of final cover = 1 square feet (ft^2)

CLIENT: CWM Chemical Services, LLC PROJECT: Model City, NY
TITLE: RMU-1 Final Cover Modification Application
SUBJECT: Appendix K-1: Required Hydraulic Conductivity for Final Cover Geosynthetic Clay Liner

Prepared By: BMS Date: December 2003
Reviewed By: PHB Date: December 2003
Revised By: RLP Date: March 2008

$\therefore Q = 4.2\text{x}10^{-9}$ cfs/ft^2

2. Maximum Allowable Hydraulic Conductivity of GCL

In order to achieve hydraulic equivalence, the steady-state flux per unit area of GCL must be less than or equal to the value calculated for CCL (i.e., 4.2×10^{-9} cfs/ft^2). The maximum allowable hydraulic conductivity can be determined using Darcy's Law (from above) and the steady-state flux per unit area of CCL:

$k=Q/(iA)$

where,

Q = steady-state flux calculated for the CCL = $4.2\text{x}10^{-9}$ cfs/ft^2
k = maximum allowable hydraulic conductivity of the GCL
i = hydraulic gradient = liquid head measured with respect to the bottom of the GCL divided by the thickness of the GCL = (0.023 ft + 0.002 ft)/0.023 ft = 1.09
A = area of final cover = 1 ft^2

$\therefore k = 3.9\text{x}10^{-9}$ ft/s = $1.2\text{x}10^{-7}$ cm/s

SUMMARY:

In order to provide equivalent hydraulic performance to a 2-foot-thick CCL, the final cover GCL must have a hydraulic conductivity of no greater than 1.2×10^{-7} cm/s. Commonly available GCLs have published hydraulic conductivities of 5×10^{-9} cm/s or less.

Because the hydrated thickness of GCLs can vary depending on material type, moisture content, and confining pressure, it was necessary to assume a thickness for this evaluation. In order to confirm hydraulic equivalence to the CCL, the steady-state flux per unit area of GCL to be used in the GCL final cover areas will be directly tested in the laboratory. This testing will be performed under conditions that are representative of those likely to be experienced in the final cover. Based on Reference 2, representative conditions include an applied load of 260 pounds per square foot (based on the anticipated soil loading) and a hydraulic gradient of 1.09. The measured steady-state flux must be less than or equal to $4.2\text{x}10^{-9}$ cfs/ft^2.