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The Phase III Expansion of the White Street Sanitary Landfill

Greensboro, North Carolina

Construction Permit Application

November 1995

Prepared by:

HDR Engineering, Inc.
of North Carolina
128 S. Tryon Street, Suite 1400
Charlotte, NC 28202-5001

APPROVED
DIVISION OF SOLID WASTE MANAGEMENT
DATE 3-17-97 BY Sessoms

HDR Engineering, Inc.
of North Carolina

CITY OF GREENSBORO

NORTH CAROLINA

P.O. BOX 3136
GREENSBORO, NC 27402-3136

January 8, 1997

Mr. Williams D. Sessoms, P.E.
Division of Waste Management
N.C. Dept. of Environmental, Health,
and Natural Resources
P.O. Box 27687

Re: Greensboro White Street Landfill
Phase III Construction Permit Application
Final Submittal
HDR Project No. 067700-021-018

Dear Mr. Sessoms:

Enclosed please find five(5) copies of the Final Phase III Construction Permit Application. This application has been revised to address comments included in your letter of December 3, 1996, with attached memorandum from Mr. Bobby Lutfy. The appropriate drawings have been changed and are resubmitted in their entirety. All text changes which were previously denoted by underlines and overstrikes have been removed.

Please contact us if you have any questions or concerns.

Respectfully submitted,

City of Greensboro

Cheryl W. Coleman/for

Elizabeth Treadway
Director of Environmental Services

ET/

Enclosures

Received
JAN 1997
Solid Waste
Section

THE PHASE III EXPANSION OF THE WHITE STREET SANITARY LANDFILL GREENSBORO, NORTH CAROLINA

CONSTRUCTION PERMIT APPLICATION

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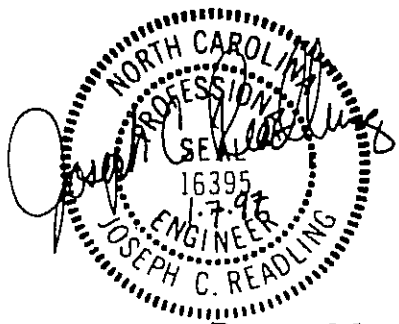

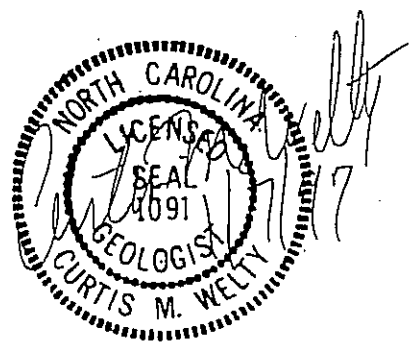

Prepared for:

The City of Greensboro,
North Carolina

Prepared by:

HDR Engineering, Inc. of
North Carolina
Charlotte, NC

Final Report

January 7, 1997

State of North Carolina
Department of Environment,
Health and Natural Resources
Division of Waste Management

James B. Hunt, Jr., Governor
Jonathan B. Howes, Secretary
William L. Meyer, Director

DEHNR

December 3, 1996

MEMORANDUM

TO: Bill Sessoms

FROM: Bobby Lutfy BL

RE: Hydrogeologic Review Of The City Of Greensboro Phase III Expansion Construction Permit Application Revisions

The hydrogeologic review of the proposed Phase III expansion to the Greensboro White Street Landfill Construction Permit Application has been done. There are still a few issues that need further evaluation and revision before the hydrogeologic permit review can be continued. Please have the City of Greensboro and their consultants respond to the following items:

DESIGN HYDROGEOLOGIC REPORT:

Section 2.2 The estimates of the long-term seasonal high water table elevations now appear to be adequate.

Section 2.4.2 The discussion of Vertical Gradients needs some revision.

- According to some previous discussion, the water table data presented for the B-22/22d piezometer nest was thought possibly to be reversed. Has it now been determined that this is not the case and the vertical gradient is indeed upward rather than downward? If there is an upward gradient at this location, could it be due to confining or semi-confining conditions in the deeper bedrock well?
- It appears that the vertical gradients in the table on page 20 have been calculated incorrectly (except for B-1/1D).

Appendix A Boring Logs

- A number of the soil descriptions and/or soil classifications are not consistent with the laboratory soil testing results, as found in Appendix B. I was unable to discern any changes in the revisions that correct these inconsistencies.

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Voice 919-733-4996

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Appendix B Geotechnical Analyses

- There are a still some errors and/or discrepancies between the summary table of Soil Boring Depth And SPT Resistance Data and the information reported in the Boring Logs. The SPT values are still displaced for Borings B-1 and B-1d. B-11 and B-20 SPT values need revision for the 15.0-16.5 depths. And the SPT values for OW-1 in the last two columns are incorrect.
- Many of the soil descriptions and/or soil classifications differ from those indicated in the Boring Logs.

WATER QUALITY MONITORING PLAN:

Background Well:

- Based upon the Geologic Map (Figure No. D-4), both of the proposed background wells shown on Figure No. D-6 are located in gneissic materials. The location of MW-15 appears to be excellent. (However the indistinct horizontal and vertical extent of the granitic intrusion in the vicinity of SB-58 could interfere with a representative gneissic environment monitoring well in this area.) Based upon the Geologic Map, it may be necessary to locate MW-16 in the granitic environment found in the vicinity of the OW piezometers.

Downgradient (Detection) Wells:

- The Water Table Map (Figure No. D-2), the Bedrock Surface Map (Figure No. D-3), and the Base Grade Map (Figure No. C-2) all indicate that the most critical monitoring location is slightly downgradient of Boring B-30. The monitoring well nest should be at this critical monitoring location.
- It would still be good to have one monitoring well located in the weathered Diorite near piezometer B-34.
- With monitoring wells in the vicinity of Boring B-30, consideration may be given to locating MW-20 a little further to the West.

If representatives of the City of Greensboro or HDR Engineering have any questions regarding this memo, they may contact me at (919) 733-0692, extension 258. It would probably be helpful especially in order to clarify the apparent inconsistencies between the soil descriptions in the Boring Logs and those reported in the laboratory soil testing sheets.

November 7, 1996

HDR

Mr. William D. Sessoms, P.E.
Division of Waste Management
N.C. Dept. of Environment, Health,
and Natural Resources
P. O. Box 27687
Raleigh, North Carolina 27611-7687

Re: Greensboro White Street Landfill
Phase III Construction Permit Application
Response to Review Comments dated October 9, 1996
HDR Project No.: 06770-021-018

Dear Mr. Sessoms:

This letter is provided in response to the review comments from your office dated October 9, 1996, regarding your review of the Design Hydrogeologic Report for the Phase III Expansion of the White Street Landfill. Your comments have been retyped in ***bold italics***, with the responses following.

Material attached with this response letter includes:

- Revised Construction Plan Report (entire report). Changes are depicted by underlines and overstrikes.
- Revised Design Hydrogeologic Report (entire report). Changes are depicted by underlines and overstrikes.
- Revised Appendix A cover sheet and core logs to be added to Appendix A; revised Appendix B (replace entire contents); revised cover sheet for Appendix C (slug test data); and new Appendix D (entire).
- Revised Water Quality Monitoring Plan (entire plan). Changes are depicted by underlines and overstrikes.
- Revised Calculations (partial). Refer to references in this letter and new Calculations Table of Contents for insertion and/or removal of Calculation.

HDR Engineering, Inc.
of North Carolina

Employee-owned

Suite 1400
128 S. Tryon Street
Charlotte, North Carolina
28202-5001

Telephone
704 338-6700
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704 338-6760

of the HDPE liner. This is indirectly implied in portions of the Technical Specifications, however, a direct requirement may avoid potential problems.

Section 3.03 of the Soil Liner Specification (Section 02276) has been clarified to require verification of clay liner thickness. The Geomembrane Liner Section (02775), paragraph 3.01,A.3., requires that soil liner is approved prior to placement of HDPE liner. Section 9.7 of the CQA plan requires that the CQA consultant and contractor review thickness measurements of the soil liner prior to placement of the geomembrane liner.

.1624(b)(5) & (6) Indicate on plans the location of the permanent (or proposed permanent) benchmark locations.

Two proposed permanent bench marks have been indicated in the Phase III area. Refer to Drawing C-2.

.1624(b)(7) Provide information demonstrating that post settlement base grade slopes will maintain a minimum 2% grade. If information or assumptions were presented in the application that establish this demonstration, please direct our attention to them.

Calculations have been included conservatively estimating a differential settlement of approximately 0.08% between the middle and edge of the landfill. The majority of the landfill base grades exceed 2%, and some areas of 2% grade will be increased with loading. With the minimal differential settlement, we consider this criteria satisfied.

.1624(b)(8)(A)(i) What is the testing frequency specified for hydraulic conductivity testing of the clay liner?

Hydraulic conductivity (ASTM D-5084) will be tested at a minimum frequency of one test per acre per lift. Refer to Specification Section 02276, 3.03 B.5.

.1624(b)(9)(B)(iii) Provide information demonstrating stability of the anchor trench design. If information or assumptions were presented in the application that establish this demonstration, please direct our attention to them.

Anchor trench design requirements have been included in the calculations.

.1624(b)(9)(B)(iv) Provide information demonstrating that the geomembrane will be adequately protected from the granular leachate drainage material. If information or assumptions were presented in the application that establish this demonstration, please direct our attention to them.

Evaluation of puncturability was performed by the Southwest Research Institute (Daren L. Laine and colleagues) for the EPA in March 1988, in a report entitled "Loading Point Puncturability Analysis of Geosynthetic Liner Materials." The report evaluates various particle sizes (3/8" to 1") placed under a geosynthetic with hydrostatic load applied above. The evaluation verifies that, under the

.1680(c)(3) Provide information demonstrating compliance with this requirement.

The secondary containment will be valved (normally closed) to insure proper containment. Notes have been added to Drawings C-3.

MEMO TO BILL SESSOMS FROM BOBBY LUTFY, DATED SEPTEMBER 3, 1996

DESIGN HYDROGEOLOGIC REPORT

Section 2.2: The estimates of the long-term seasonal-high-water table elevations are not adequate.

- ***While the 3/11/95 ground-water elevations appear to be the most reasonable single set of water table measurements representative of seasonal high conditions for the season of record (12/94 through 10/95), they are not adequate to characterize the long-term seasonal high conditions. There are recorded readings in Table 2-2 at some piezometer locations of up to over five feet above the 3/11/95 levels.***
- ***The estimation of long-term water table elevations (Table 2-3) is based on only four readings spread over a two and a half year period. There is no discussion of precipitation levels prior to the readings or longer term readings from other wells in the area. As referenced in Table 2-3, there are recorded readings of up to 2.68 feet above the March 1995 readings. Most of the pre-existing monitoring wells are located at lower elevations, nearer to the discharge streams, and are therefore likely to have a smaller range of water table elevation variability than the piezometers located at higher topographic elevations.***
- ***Padding the 3/11/95 elevations one foot hardly seems adequate to provide a reasonable estimate of the long-term seasonal high water table elevations, considering there are historic readings of the piezometers over five feet higher and historic readings of the monitoring wells (at lower elevations) almost three feet higher. A more accurate estimate of long-term seasonal high water table elevations must be established for each individual piezometer.***

  Since the previous submittal of the Phase III Expansion Construction Permit Application in November 1995, additional ground-water elevation data from Phase III area piezometers have been collected through August of 1996. These additional data have been tabulated and are summarized in Table 2-2. Based on the evaluation of these new data, a new estimate for the long-term seasonal high ground-water table has been developed (Drawing D-2). Section 2.2.2 of the Design Hydrogeologic Report has been modified to include a discussion on how the new long-term seasonal high was developed.

Section 2.4.2: The discussion of Vertical Gradients needs some revision.

- ***The locations of some of the piezometers do not support the statement made in the second sentence of the second paragraph on page 20.***

  The statement made in the second sentence of the second paragraph on page 20 has been amended to more accurately reflect the location of the piezometers.

Section 2.2.2 has been amended to reflect the changes in the estimated long-term seasonal high water table discussion. Vertical separation criteria shown in Table 11-1 have been altered based upon this additional evaluation.

- ***As discussed repeatedly in previous correspondence, the proposed subgrade does not maintain the four foot vertical separation requirement in the vicinity of piezometers B-19 and B-28. The Solid Waste Management Rules and policy require the subgrade to maintain a minimum of four feet of vertical separation from the bedrock as defined in the hydrogeologic subsurface investigation.***

  As shown in Drawing C-2 and which is summarized in Table 11-1 of the report, a minimum of 4 feet is maintained between the bedrock and the base of the liner system at all boring/ piezometer locations.

- ***The notes below Table 11-1 reference Figures 3-3 and 3-7. These references appear to be incorrect.***

  The notes below Table 11-1 have been amended to reflect the proper reference.

- ***The Subgrade Plan (Drawing C-2) needs to show the exact location of all of the piezometers in order to facilitate interpretation of the vertical separation criteria.***

  The proposed subgrade has been added to Drawing D-6, which also shows all existing soil borings, piezometers, and monitoring wells in and near the Phase III area.

Appendix: Boring Logs.

- ***A number of the soil descriptions and/or soil classifications are not consistent with the laboratory soil testing results, as found in Appendix B.***

  The soil descriptions/classifications found on the laboratory soil testing results included in Appendix B have been amended to reflect the proper soil classifications(s). A number of the classifications were found to be in error based on the grain-size distribution data curves developed by the laboratory.

- ***There are virtually no rock descriptions, recovery values, or RQD values reported for the rock cores.***

  Rock descriptions, recovery values, and RQD values for all cored locations (which were erroneously not included in the original submittal) are included on the core description logs contained in Appendix A.

The Plan has been amended to reflect two background monitoring wells. One well is proposed for installation in the gneissic material (MW-15) and one in the granitic material (MW-16).

- ***Generally it would be better to locate a background well further than 90 feet from the waste boundary, as proposed.***

Background monitoring well MW-15 (Gneiss) has been proposed at approximately 225 feet southwest of the waste boundary. Background monitoring well MW-16 (Granite) has been proposed at approximately 275 feet southeast of the waste boundary.

- ***Generally fifteen-foot well screens are used for monitoring wells screened across the water table in order to allow for seasonal fluctuations in the water table.***

All proposed shallow monitoring wells will be constructed with 15-foot well screens, and the deep monitoring well will be constructed with a 10-foot well screen.

Downgradient (Detection) Wells:

- ***Downgradient monitoring should be located between 100 and 150 feet from the waste boundary. The proposed locations for wells MW-18, MW-19, and MW-20 are too far from the waste boundary.***

All proposed downgradient monitoring wells have been placed approximately 125 feet downgradient of the waste boundary.

- ***Drainage features are sometimes areas of geologic weakness and being more highly fractured are possible preferential groundwater flow pathways. The downgradient wells should therefore be located in these drainage features.***

- ***Based upon the preceding two points, proper location of the monitoring wells may make it necessary to relocate and/or redesign some of the sedimentation control basins.***

- ***Should additional wells be considered . . .***
  - ***at the head of the drainage basin on the west side of the landfill cell, about 500 ft. south of MW-21, or***
  - ***in the weathered Diorite near piezometer B-34 that is two orders of magnitude more conductive than the surrounding material?***

Additional detection monitoring wells have been proposed as follows: installation of MW-24 approximately 500 feet south of proposed well MW-23 at the head of the western drainage basin; installation of MW-18 and MW-18D in the weathered diorite near existing piezometer

- ***Hydrostratigraphic Geologic Cross-sections (D-5A & D-5B): The cross-sections do not characterize the vertical ground-water flow regime, as required by .1623(b)(2)(G). No vertical equipotential lines or flow lines are shown. Also, there are discrepancies between the illustrated information and the information in the Boring Logs. Verification is needed to ensure accurate information is shown for ground surface elevations, water table elevations, boring depths, auger refusal depths, etc.***

  Hydrostratigraphic Geologic Cross-Sections (D-5A & D-5B) have been amended to reflect the vertical ground-water flow regime in accordance with .1623(b)(2)(G). All information shown on the sections has been verified and amendments have been made (as needed).

- ***Drawing D-6, Proposed Monitoring Well Locations: Refer to previous comments on the monitoring system.***

Drawing D-6 showing the proposed monitoring well locations has been amended to reflect the changes made to the Water Quality Monitoring Plan.

Respectfully submitted,

HDR Engineering, Inc. of North Carolina

Joseph C. Readling, P.E.
Project Manager

Curtis M. Welty, P.G.
Senior Geologist

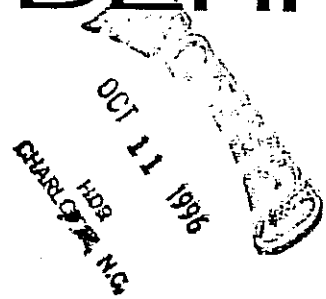
JCR/CMW/nct

6770-021-018

State of North Carolina
Department of Environment,
Health and Natural Resources
Division of Waste Management

James B. Hunt, Jr., Governor
Jonathan B. Howes, Secretary
William L. Meyer, Director

DEHNR



October 9, 1996

Elizabeth Treadway
Director of Environmental Services
City of Greensboro
Post Office Box 3136
Greensboro, North Carolina 27402-3136

Re: Permit to Construct Application
Proposed City of Greensboro Municipal Solid Waste Landfill

Ms. Treadway:

The Division of Waste Management, Solid Waste Section (Section) has completed the initial technical review of the above referenced project. The following items must be provided or addressed in order to continue the review process. Revisions to the application must be made in accordance with 15A NCAC 13B .1603(b).

.1620(d)(1)(A) The Engineering Plan, Section 3.1.2 refers to possible revisions to the base grade elevations. The base grade elevations must be finalized prior to issuance of the permit. Additional comments relating to the base grade elevations are contained in the hydrogeological review memorandum.

.1620(d)(2)(A) & (B) The calculations in the report have been reviewed. However, a brief discussion of the analytical methods, conditions evaluated, and assumptions needs to be included in the engineering report.

.1620(d)(4) Please refer to the attached hydrogeological review memorandum.

.1620(e)(1) Revise the existing topography to reflect actual existing conditions at the site to include all grading and the berm(s) that exist within the facility.

.1620(e)(2) The Section recommends adding a requirement that survey verification of the sub-grade be provided to the CQA consultant prior to placement of clay liner. In a similar fashion, survey verification of the clay liner should be provided to the CQA consultant prior to placement of the HDPE line. This is indirectly implied in portions of the Technical Specifications, however, a direct requirement may avoid potential problems.

.1624(b)(5) & (6) Indicate on plans the location of the permanent (or proposed permanent) benchmark locations.

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The Section reserves the right to request additional information as the review warrants. Operations Plans and Closure/Post Closure Plans are currently being reviewed by Section field staff. Additional comments may be forthcoming for these areas.

If you have any questions or if we can provide any assistance, please do not hesitate to contact this office at (919) 733-0692 extension 266.

Sincerely,

Wm D Sessoms

William D. Sessoms, PE

copy: Bobby Lutfy - DWM
Hugh Jernigan - DWM
Eric Wright, PE - HDR

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State of North Carolina
Department of Environment,
Health and Natural Resources
Division of Waste Management

James B. Hunt, Jr., Governor
Jonathan B. Howes, Secretary
William L. Meyer, Director

DEHNR

September 3, 1996

MEMORANDUM

TO: Bill Sessoms

FROM: Bobby Lutfy B.L.

RE: Hydrogeologic Review Of The City Of Greensboro Phase III Expansion Construction Permit Application

The preliminary hydrogeologic review of the proposed Phase III expansion to the Greensboro White Street Landfill Construction Permit Application has been done. There are a number of issues that must be addressed before the hydrogeologic permit review can be continued. Please have the City of Greensboro and their consultants respond to the following items:

DESIGN HYDROGEOLOGIC REPORT:

Section 2.2 The estimates of the long-term seasonal high water table elevations are not adequate.

- While the 3/11/95 ground-water elevations appear to be the most reasonable single set of water table measurements representative of seasonal high conditions for the season of record (12/94 thru 10/95), they are not adequate to characterize the long-term seasonal high conditions. There are recorded readings in Table 2-2 at some piezometer locations of up to over five feet above the 3/11/95 levels.
- The estimation of long-term water table elevations (Table 2-3) is based on only four readings spread over a two and a half year period. There is no discussion of precipitation levels prior to the readings or longer term readings from other wells in the area. As referenced in Table 2-3, there are recorded readings of up to 2.68 feet above the March 1995 readings. Most of the pre-existing monitoring wells are located at lower elevations, nearer to the discharge streams, and are therefore likely to have a smaller range of water table elevation variability than the piezometers located at higher topographic elevations.

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- The notes below Table 11-1 reference Figures 3-3 and 3-7. These references appear to be incorrect.
- The Subgrade Plan (Drawing C-2) needs to show the exact location of all of the piezometers in order to facilitate interpretation of the vertical separation criteria.

Appendix A Boring Logs
- A number of the soil descriptions and/or soil classifications are not consistent with the laboratory soil testing results, as found in Appendix B.
- There are virtually no rock descriptions, recovery values, or RQD values reported for the rock cores.

Appendix B Geotechnical Analyses
- There are a number of errors and/or discrepancies between the summary table of Soil Boring Depth And SPT Resistance Data and the information reported in the Boring Logs. No information is reported in the summary table for borings B-36, OW-1, OW-2, or OW-3.
- The depths of the soil samples are not identified on the Grain Size Distribution sheets. Many of the soil descriptions and/or soil classifications differ from those indicated in the Boring Logs.

Appendix C Piezometer / Monitoring Well Construction Sheets
- There are no Piezometer or Well Construction Sheets included in Appendix C.
- In the summary table provided for Observation Well Construction Details, the Riser Stick-up information is missing for a number of the piezometers.
- There are a number of errors and/or discrepancies between the summary table and the information provided in the Boring Logs.

WATER QUALITY MONITORING PLAN:

Background Well:
- A complex geologic setting is described with two major geologic types and yet only one background well is proposed. At a minimum there should be one background well in the Gneiss materials and one in the Granite materials.

- While an accurate Drawing D-2 based upon the March 11, 1995, water table data will fulfill the requirement of rule .1623(a)(9), a separate ground-water contour map based upon the estimated long-term seasonal high water table elevations is needed to fulfill .1623(b)(2)(E).
- Hydrostratigraphic Geologic Cross-sections (D-5A & D-5B): The cross-sections do not characterize the vertical ground-water flow regime, as required by .1623(b)(2)(G). No vertical equipotential lines or flow lines are shown. Also, there are discrepancies between the illustrated information and the information in the Boring Logs. Verification is needed to ensure accurate information is shown for ground surface elevations, water table elevations, boring depths, auger refusal depths, etc.
- Drawing D-6, Proposed Monitoring Well Locations: Refer to previous comments on the monitoring system.

CITY OF GREENSBORO

NORTH CAROLINA

P.O. BOX 3136
GREENSBORO, NC 27402-3136

July 30, 1996

Mr. James C. Coffey
Supervisor - Permitting Section
Division of Solid Waste Management
N.C. Department of Environment,
Health and Natural Resources
401 Oberlin Road, Suite 150
Raleigh, NC 27605

Re: Phase III Construction Permit Application
City of Greensboro Landfill

Dear Mr. Coffey:

Enclosed please find two copies of the Phase III Construction Permit Application text and drawings. This application package was withdrawn to incorporate modifications which have been made in response to comments generated by the Site Study review process. This application is hereby being resubmitted for your review and action.

Summary of Major Revisions:

- The drawings have been modified to exclude the Duke Power substation from the 300 foot property line buffer.
- The volume calculations have been updated based on the revised grading plans.
- Seismic and slope stability calculations have been added to support the previous conclusions of landfill stability. Notes have been placed in the text as requested.
- The Design Hydrogeologic Report and the Water Quality Monitoring Plan have been revised to be consistent with the final presentation provided in the Site Study.

Your attention and assistance in completing the permit process is greatly appreciated.

Sincerely,

City of Greensboro

for Elizabeth Treadway
Director, Environmental Services

Enclosures (2 sets)

CITY OF GREENSBORO

NORTH CAROLINA

P.O. BOX 3136
GREENSBORO, NC 27402-3136

November 27, 1995

Mr. William D. Sessoms, P.E.
Permitting Engineer
Solid Waste Section
Division of Solid Waste Management
DEHNR
401 Oberlin Road, Suite 150
P. O. Box 27687
Raleigh, NC 27611

Dear Mr. Sessoms:

Enclosed are two copies of the second phase application for the permitting of a new Subtitle D landfill cell at the White Street Landfill. This represents the construction application for Phase III. These documents were prepared with the assistance of HDR Engineering Inc. and questions or inquiries should be directed to:

Mr. Dale James	Mr. Joe Readling
Solid Waste Manager	HDR Engineering, Inc.
City of Greensboro	704-338-1800
910-373-2035	

Your attention and assistance is greatly appreciated.

Sincerely,

William H. Carstarphen
City Manager

Enclosure (2): Construction Drawings
Application Documents

WHITE STREET SANITARY LANDFILL
GREENSBORO, NORTH CAROLINA

CONSTRUCTION PLAN REPORT

Prepared for:

The City of Greensboro

Prepared by:

HDR Engineering, Inc.
of North Carolina

HDR

Project No. 06770-021-018

Final Report

January 7, 1997

CONSTRUCTION PLAN REPORT

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SECTION 1.0
INTRODUCTION

1.1 Purpose

The purpose of this Construction Permit Application is to obtain a "Permit to Construct" for the new lined landfill unit known as Phase III of the White Street Landfill. This application has been prepared in general accordance with the requirements of North Carolina Administrative Code Title 15.A. Chapter 13, Subchapter 13.B., Section .1617(a)(1).

1.2 General

This Construction Permit Application includes several independent plans under one cover. The format of this Construction Permit Report generally follows the format found in the regulations. Other major documents contained within this application are referenced in appropriate locations.

1.3 Background

The City of Greensboro (City) owns and operates the White Street Landfill located within the boundaries and jurisdiction of the City of Greensboro. The landfill is east of U.S. Highway 29, at the east end of White Street. The landfill is surrounded principally by residential development to the west, south, and east, and undeveloped woods across North Buffalo Creek to the north.

Waste disposal activities in the area now known as the White Street Sanitary Landfill began in 1943, and primarily consisted of the burning of garbage and trash on the site. Burning operations ceased in the mid-1960's, and since that time waste has been buried on site. The current landfill property covers an area of approximately 767 acres. As constructed, the City of Greensboro's White Street Sanitary Landfill is divided into two Phases. Phase I is an 85-acre site that stopped receiving waste prior to 1978. The current fill area, Phase II, consists of approximately 135 acres. Of the 135 acres, approximately 45 acres were closed prior to 1991, and the remaining 90 acres are currently active.

1.4 Regulatory History

On May 5, 1987, the City of Greensboro was issued North Carolina Solid Waste Management Permit No. 41-03 for the White Street Landfill. On March 10, 1992, the permit was amended to allow a vertical expansion of the facility. North Carolina's adoption of "Subtitle D" regulations on October 9, 1993, placed additional requirements on the existing facility.

In April of 1994, a Transition Plan for Phase II was submitted to the state. In April 1995, a Site Study was prepared and submitted for the Phase III landfill expansion. In accordance with NC DEHNR regulations, this application is submitted in support of the City's request for a construction permit to construct the new proposed Phase III unit.

SECTION 2.0
FACILITY REPORT

2.1 Facility Report

The purpose of this section is to present a conceptual plan for the development of the proposed new lined landfill unit known as Phase III of the City of Greensboro's White Street Sanitary Landfill. This report has been prepared in accordance with the requirements of Rule .1619 of the North Carolina Solid Waste Management Rules and Solid Waste Management Law.

2.1.1 Facility Services

Currently, the following activities or services are provided at the White Street Sanitary Landfill:

- Scales/scalehouse facilities
- Administrative offices
- MSW landfill
- Yard waste processing facility
- Equipment maintenance facility

Work is currently underway (design or construction) for the following facilities:

- Lined landfill (three cells constructed over five years)
- Gas recovery facility (reference ongoing permitting by gas agency through NC DEHNR)

With construction of the new lined landfill, the following facilities will be added:

- Leachate management facility

2.1.2 Facility Boundary

Drawing C-1, Existing Conditions, shows the proposed facility boundary. The proposed boundary encompasses the Phase III landfill, a leachate management area and adequate buffers for monitoring.

2.1.3 Types of Waste

Waste which is received at the White Street Sanitary Landfill is categorized as residential, industrial, commercial, construction/demolition, and yard waste. The proposed Phase III facility will accept only residential, industrial, or commercial waste types. Separate areas of the White Street Sanitary Landfill have been designated to receive the construction/demolition waste and the yard waste which are brought to the facility. The yard waste is composted and the construction/ demolition waste is either recycled or disposed of in a separate C&D disposal area.

2.1.4 Disposal Rates and Estimated Variances

Municipal solid wastes anticipated to be received at the White Street Sanitary Landfill for the period 1994 - 2023 are summarized in Table 2-1. As indicated, the MSW stream is projected to grow from approximately 243,600 tons in 1994 to an estimated 384,800 tons in 2023. On a monthly disposal rate basis, these estimates calculate out to be approximately 20,300 tons per month in 1994 to 32,100 tons per month in 2023.

Historically, the quantities of MSW received at the White Street Sanitary Landfill on a month to month basis have been relatively constant. Typically, MSW generation has been highest during the month of August (on average, representing 10% of the annual MSW waste received), and the months of November and December have been the lowest in terms of MSW generation (on average, each month yielding 7% of the annual MSW waste received).

For the purposes of this Report, it has been assumed that waste generation rates shall increase at a rate of 1.3% per year during the years 1994 -2000 (U.S. EPA estimate); after the year 2000 it has been assumed that generation rates shall increase by 2.0% per year. Tonnage projections were not based on per capita

TABLE 2-1
MUNICIPAL SOLID WASTE PROJECTIONS
CITY OF GREENSBORO, WHITE STREET SANITARY LANDFILL

Year	Guilford Co. Pop.[1]	White Street Landfill		Guilford County MSW Tons/Year[4]
		MSW Tons/Year[3]	MSW Tons/Month	
1994	360,886	243,556[2]	20,296	363,557
1995	364,252	246,720	20,560	366,947
1996	366,423	249,890	20,824	369,135
1997	368,594	253,050	21,088	371,322
1998	370,765	256,220	21,352	373,509
1999	372,936	259,390	21,616	375,696
2000	375,107	262,550	21,879	377,883
2001	376,667	277,650	23,138	379,454
2002	378,227	282,520	23,543	381,026
2003	379,788	287,400	23,950	382,598
2004	381,348	292,270	24,356	384,170
2005	382,908	297,140	24,762	385,742
2006	384,530	302,010	25,168	387,376
2007	386,152	306,880	25,573	389,010
2008	387,773	311,750	25,979	390,643
2009	389,395	316,620	26,385	392,277
2010	391,017	321,490	26,791	393,911
2011	392,639	326,360	27,197	395,545
2012	394,261	331,240	27,603	397,179
2013	395,882	336,110	28,009	398,812
2014	397,504	340,980	28,415	400,446
2015	399,126	345,850	28,821	402,080
2016	400,748	350,720	29,227	403,714
2017	402,370	355,590	29,633	405,348
2018	403,991	360,460	30,038	406,981
2019	405,613	365,330	30,444	408,615
2020	407,235	370,200	30,850	410,249
2021	408,857	375,080	31,257	411,883
2022	410,479	379,950	31,663	413,517
2023	412,100	384,820	32,068	415,150

Notes:

1) Population based on 1990 U.S. Census and NC Office of State Planning projections for the years 1995, 2000, 2005, and 2010. Straight line interpolation used for intervening and subsequent years.

2) Based on White Street Sanitary Landfill data recorded for residential, commercial, and industrial waste (MSW) for period 1/1/94 - 12/31/94.

3) Using the MSW tonnage for 1994 as a base year, tonnage projections for subsequent years through 2000 calculated using the U.S. EPA projected increase in waste generation rate of 1.3%/year. Beyond the year 2000, waste generation rates reflect a 2.0% increase per year.

4) Waste projections using NC MSW per capita generation rate of 5.52 pounds per person per day (NC DEHNR, North Carolina Solid Waste Management Annual Report, July 1, 1992 - June 30, 1993) and Guilford County population projections.

generation rates, as it is known that not all waste generated within Guilford County is disposed of in the White Street Sanitary Landfill. For comparative purposes, MSW projections were made using the population estimates for Guilford County and the MSW per capita generation rate of 5.52 pounds per person per day, which was the estimated average for the state of North Carolina during fiscal year 1992-1993. As can be seen from the actual 1994 tonnage received at the White Street Sanitary Landfill, and that projected if the entire Guilford County population were to have disposed of 5.52 pounds of MSW per day, it is apparent that a portion of the County's MSW stream is being disposed of in facilities other than the White Street Sanitary Landfill, or that the per capita generation rate of 5.52 pounds per person per day is inaccurate for Guilford County. The actual 1994 waste stream and linear MSW generation growth rates were used for estimating future waste stream quantities for the purposes of this document.

2.1.5 Service Area

The White Street Sanitary Landfill will accept only those wastes which are generated within Guilford County and from municipalities whose boundaries cross into Guilford County. The waste stream received at the facility consists of approximately 80% municipal solid waste (residential, commercial, and industrial) which will be disposed of in Phase III, and 20% yard waste and construction/demolition waste. It is anticipated that this ratio of MSW to other wastes received at the proposed facility (Phase III) will remain relatively constant, as the service area will remain the same; namely, Phase III shall provide the City of Greensboro and Guilford County with lined landfill disposal capacity for MSW.

2.1.6 Procedures for Waste Segregation

As is currently the procedure for waste segregation, all vehicles arriving at the landfill will check in at the scalehouse, where the vehicle hauling the waste will be weighed. The Scale Attendant will request from the driver of the vehicle entering the landfill a description of the waste it is carrying to ensure that unacceptable waste is not allowed into the landfill. The Attendant will then visually check the vehicle as it crosses the scale. Signs will be conspicuously posted informing users of dumping procedures, the type of waste the facility is

permitted to receive, as well as those wastes banned from disposal at the facility, and shall indicate the location of the disposal area.

Vehicles hauling MSW for which the proposed Phase III facility is permitted to receive will either be directed to the working face of the landfill to dump their load, or, if selected for random waste inspection, will be directed to a lined area separate from the working face where trained landfill personnel will visually inspect the contents of the load. Any materials which pose health hazards, cause fire, or which could impact negatively on the environment will be deemed unacceptable. When unacceptable waste is detected at the scalehouse or in the random waste inspection area, the load will be rejected and not permitted to be dumped into the landfill. If unacceptable waste is found at the tipping area, identification of the truck or persons is made (if possible) and documented, then the unacceptable waste will be identified and removed from the landfill. If the waste is hazardous, it will be placed in a hazardous waste container and taken to a designated hazardous waste staging area for proper disposal. When this occurs, the event will be reported to Mr. Hugh Jernigan of the NC DEHNR Division of Solid Waste Management. Mr. Jernigan is the Waste Management Specialist assigned by the Winston-Salem Field Operations Branch office of the NC DEHNR Division of Solid Waste Management office who is assigned to monitor regulatory compliance at the White Street Sanitary Landfill.

Vehicles hauling yard waste or construction/demolition waste will deposit the contents of their loads in designated facility areas which are separate from the proposed Phase III facility. All C&D debris will be maintained in a location separate from the Phase III location and shall not be commingled with the normal municipal wast stream. In addition, yard waste shall be composted in a location separate from the Phase III location and shall not be commingled with the normal municipal solid waste stream.

2.1.7 Equipment Requirements

The White Street Landfill currently accepts a monthly average of 20,600 tons of refuse per day. The types and sizes of equipment currently in use at the landfill are presented in Table 2-2.

TABLE 2-2
CITY OF GREENSBORO, WHITE STREET SANITARY LANDFILL
CURRENT EQUIPMENT INVENTORY

Description	Make/Model	No.	Comment
Landfill Compactor	826C Cat	3	
Bulldozer	D8N Cat	2	
Grader	140G Cat	1	
Loader	WA250-1 Komatsu 1994 FR20B Fiat Allis	1 1	
Earthmover	627E Cat	2	
Excavator	K916LC-2 Kobelco	1	
Tractor	White	1	w/Lowboy Trailer
Dump Truck	D400D Cat	3	Off Road
Other Trucks	F250D HD Ford 1994 C70 Chevrolet 2500 Chevrolet 1989	1 1 1	 Fuel Truck Maint.
Other (specify):	900 Ford Cheyenne 1993 Chevrolet Ford 8000 Kubota L275 John Deere 2355 Toro Kawasaki Mule	1 1 1 1 1 1 1	Water Truck Maint. Maint. Utility Tractor w/Mower Lawn Mower Utility vehicle

The equipment on-site is currently managing refuse disposal operations with no apparent difficulties. When Phase III is ready to accept refuse, the existing equipment will use the same procedures and technique in spreading, compacting, and covering waste. In the event the waste stream increases significantly, the potential addition of equipment will be evaluated.

2.2 Landfill Capacity

2.2.1 Total Operating Capacity

The proposed Phase III facility boundary encompasses approximately 146 acres. Phase III consists of a 51-acre lined unit which will be divided into three construction cells of approximately 25, 14, and 12 acres, respectively (see Drawing No. C-2 - Subgrade Plan). This application is submitted for permit approval of the entire 51-acre Phase III area. The landfill system developed for Phase III is expected to contain common leachate and gas management facilities that will be operated during the regulated life of the proposed facility. Drawings in support of this permit application are included with this document. The plans provided are not for construction.

The total gross operating capacity for the Phase III area is estimated to be 5,140,000 cubic yards. The net capacity for waste is 3,885,000 cubic yards. The volume translates to approximately 87 months of life, using 22,300 tons per month (the average monthly tonnage based on projections from 1998 to 2002), a compaction factor of 1,000 pounds per cubic yard, and a 4:1 waste-to-cover ratio. Please refer to the attached calculations. An alternative daily cover may be pursued by the City. An alternative daily cover could increase the waste-to-soil ratio to 6.2:1, resulting in a net waste capacity of 4,181,000 cubic yards.

2.2.2 Operating Capacity for Each Cell Development

2.2.2.1 Cell 1 Development

Cell 1 of the lateral expansion has an estimated gross operating capacity of 1,740,000 cubic yards and a net waste capacity of 1,350,000 cubic yards. The area for Cell 1 is approximately 25 acres. Cell 1 is divided into six subcells. The life for Cell 1 is approximately 30 months.

Drawing No. C-5, Cell 1 Development, identifies the configuration of Cell 1. The initial placement of refuse will begin in the northeastern corner of Cell 1. The proposed top elevation for Cell 1 is approximately 846 feet.

2.2.2.2 Cell 2 Development

Cell 2 of the Phase III lateral expansion has an estimated gross operating capacity of 1,550,000 cubic yards and a net waste capacity of 1,170,00 cubic yards. The area for Cell 2 is approximately 14 acres. Cell 2 is divided into six subcells. The life for Cell 2 is approximately 26 months.

Drawing No. C-6, Cell 2 Development, identifies the configuration of Cell 2. The refuse filling of Cell 2 will begin adjacent to Cell 1. The approximate top elevation of Cell 2 along with the tie-in with Cell 1 is 878 feet.

2.2.2.3 Cell 3 Development

Cell 3 of the lateral expansion has an estimated gross operating capacity of 1,850,000 cubic yards and a net waste capacity of 1,365,000 cubic yards. The area for Cell 3 is approximately 12 acres. Cell 3 is divided into three subcells. The life for Cell 3 is approximately 31 months.

Drawing No. C-7, Cell 3 Development, identifies the configuration of Cell 3. This Cell continues the landfill to its final grades. The proposed top elevation for Phase III is approximately 920 feet.

2.2.3 In-Place Ratio of Waste to Soil

The capacities obtained for each Cell Development and the Total Capacity were based on a waste-to-soil ratio of 4 to 1. The assumed refuse density is 1,000 lbs/cy. The assumed filling rate is 22,300 tons per month.

2.2.4 Available Soil Resources and Required Soil Quantities

The available soil resources for the construction of the lateral expansion will come from a combination of on-site excavated soil and off-site resources. The on-site soil source will be screened to obtain as much clay material for construction of the soil liner. Permeability of on-site soils range from 1×10^{-3} cm/sec to 8×10^{-5} cm/sec; therefore, it is assumed that either an off-site source of clay material will be required to complete construction of the 24-inch thick soil component of the Base Liner or bentonite amendment will be required. The

estimated quantity of clay soil (1 x 10^{-7} cm/sec. permeability) that will be required is 170,000 cubic yards. The soil needed to construct structural fills and other appurtenances of the lateral expansion, such as roads, drainage pathways, berms, and operational layers, will be provided from on-site sources and, if required, off-site sources. The requirement for structural fill is estimated at 510,000 cubic yards based on May 1996 existing grades. Approximately 60,000 cubic yards of material will be removed for the construction of Phase III.

The majority of the soils required for operational procedures, such as daily and intermediate cover, are anticipated to come from the on-site borrow area located to the east of Phase III (see Drawing G-1). Approximately 970,000 cubic yards will be required for the life of the expansion.

The construction of the 18-inch thick soil liner component for the final cap will require approximately 120,000 cubic yards of soil. The 18-inch thick vegetative support soil required is approximately 120,000 cubic yards. The 6-inch top soil layer requires approximately 40,000 cubic yards.

2.3 Containment and Environmental Control Systems

The Base Liner and Final Cap System will be constructed in accordance with Section .1624 (b)(8)(9) of the North Carolina Administrative Code, Title 15A, Chapter 13, Subchapter 13B.

2.3.1 Horizontal Separation Requirements

The horizontal separation requirement between the disposal boundary (liner) and the property lines is a minimum of 300 feet, the minimum buffer between private residences and wells and the disposal boundary is 500 feet, and the minimum buffer between any surface water (stream, river, creek) and the disposal boundary is 50 feet. The proposed design satisfies all buffer requirements.

2.3.2 Base Liner System

The Base Liner area for the Phase III expansion is approximately 51 acres and is shown on Drawing No. C-2, Subgrade Plan. The post-settlement bottom elevation of the base liner system will meet the minimum requirement of four feet

above the seasonal high groundwater table and bedrock. As a minimum, the components of the Base Liner from the subgrade will consist of a 24-inch thick material with permeability of no more the 1 x 10^{-7} cm/sec., a 60 mil HDPE geosynthetic liner, a leachate collection system with perforated collection pipes and gravel chimneys to the top of the operational cover, and may be supplemented with a layer consisting of either a geonet with geotextile or 12-inch thick soil with minimum permeability of 1 x 10^{-2} cm/sec. and an operational layer 12 inches thick.

The bottom slope of the cell ranges from 2% to 10%. Based on the boring logs and proposed grading plan, differential settlements were calculated. The critical areas were taken to be the northeast corner and roughly the center of the unit. The calculations are attached and they indicate that differential settlement will be negligible (approximately 0.08%); therefore, post settlement slopes of 2% should be maintained.

2.3.3 Final Cap System

The entire Phase III unit will require a maximum of 51 acres of Final Cap. As a minimum, the components of the Final Cap System from the bottom to the surface will consist of a 12-inch foundation layer (intermediate cover), 18-inch thick low permeability material, FML, 18-inch thick vegetative support layer, and a 6-inch vegetative layer.

The cover will be constructed with drainage swales and down chutes. The landfill is designed with a maximum side slope of 25%, and a minimum of 8%, except along the drainage swales.

2.3.4 Drainage, Erosion and Sediment Control

The Erosion and Sediment Control structures provided will be designed and maintained to manage the run-off generated by the 24-hour, 25-year storm event, and conform to the requirements of the Sedimentation Pollution Control Law (15A, NCAC, 4).

Run-on control structures within the footprint of the landfill include temporary diversion berms and ditches placed across the upgradient areas from the active fill

Cell. The temporary berms and ditches will prevent run-on from either undeveloped areas or previously filled and covered areas from discharging onto the active Cell during a storm event. All storm water collected will be conveyed to either the existing or proposed sediment basins. The storm water collection pipes shown on C-4 are sized for a 25-year/24-hour storm; the calculations are attached.

The regulations specify that the waste shall be covered daily with 6 inches of soil or an alternate cover. The City plans to use either soil or an approved alternate cover on a daily basis. The alternate cover may be used on a daily basis. On weekends and holidays the lift face will be covered with 6 inches of compacted soil.

As part of the Final Cap System, drainage swales will be constructed on top of the vegetative layer to intercept run-off and prevent erosion. The swales will be longitudinally sloped and be approximately 40 vertical feet apart. The swales will carry run-off to strategically located downdrains and/or downchutes. The downchutes are the last carrier of run-off before entering the sediment basins. Perimeter drainage ditches will be constructed to limit the amount of run-off from the site. The sedimentation basins are sized for the greatest area to be drained over the life of the unit. Therefore, at times these basins will be underutilized and may be resized during their life to maintain efficiency. The preliminary sizing calculations are attached.

Plant species meeting the following selection criteria shall be followed as below:

- Vegetation depth of rooting shall not extend to the barrier layer per final cover design;

- Final cover vegetation tolerant to landfill gas and local cover soil conditions;

- Site climate adaptability (temperature, rainfall or drought tolerance, wind effects, exposure, and sunshine);

- Plant species shall be persistent and self-propagating;

- Plant species shall exhibit a high percentage of surface coverage; and

- Plant species shall exhibit low long-term maintenance needs.

2.3.5 Methane Gas Control

Landfill gases are the product of solid waste decomposition under anaerobic conditions. The quantity and types of gas generated depend on the type of waste disposed of. The largest amount of gas generated is generally from waste containing a high percentage of readily degradable organic matter. The rate of generation depends mainly on the moisture content, temperature, and particle size of the waste and the age of the fill. High temperature and moisture content, along with small particle size, tend to result in higher gas production. Gas production from a landfill can last from two to 100 years, but generally peaks after approximately five years, if the moisture content is not limited. Landfill gases predominately consist of methane and carbon dioxide. Initially, the gas is mostly carbon dioxide with methane production beginning later; however, the gas eventually reaches approximately 50% methane by volume.

A gas detection system will be installed between Nealtown Road and the west side of the landfill. This system will monitor for gas migration along the perimeter of the landfill nearest any residential structures. All buildings and enclosed structures on the landfill will be monitored as part of a routine methane monitoring program. In addition, gas extraction wells are proposed to be installed in the final cover. A preliminary layout is shown on Drawing C-8 - Gas Management Plan.

2.4 Leachate Management

2.4.1 Leachate Collection System

The general leachate management system includes the collection, storage, treatment, and disposal of the leachate generated. The collection of leachate will be facilitated by use of perforated HDPE pipe laterals designed (minimum slope of 0.5 percent) to hydraulically convey leachate to a single penetration through the liner and into an HDPE manhole. From there, leachate will be gravity fed through a solid wall HDPE pipe to a lift station located within the leachate

containment area where it will then be pumped into an above ground tank for storage. Clean-out riser pipes will be provided at the edge of the landfill for all of the laterals and header pipes to allow for periodic cleaning. Pretreatment, if required, will be performed on-site to meet the standards for disposal into a sanitary sewer line feeding a Publicly Owned Treatment Works (POTW) facility.

2.4.2 Leachate Generation Rates

The Hydrologic Evaluation of Landfill Performance (HELP) Model Version 3 is typically used to predict the volume of leachate anticipated during three discrete phases, including: active, interim, and closed conditions. Upon modeling the three cases, it was found that the HELP model compared conservatively with the empirical generation rates, which are based upon actual data. Therefore, the HELP model rates have been applied to proposed operational conditions to yield an overall flow rate projection.

In order to determine typical leachate flow rates, the approximate values of 1,920 gallons per acre per day (gpad) for active, 1,200 gpad for interim, and 70 gpad for closed were applied to the proposed operational schedule. For each phase of operation, an operational "snapshot" was developed to depict the typical combination of areas which are being operated, under the three scenarios of active, interim, and closed cases (see attached calculations).

In order to simulate a surge volume, the precipitation event of 5.75 inches for a 24-hour, 25-year storm was applied at the most critical time for each cell. The storm condition was modeled by using the peak daily lateral drainage for one day on the active area, and applying the lateral drainage from the peak month to the filled area. This should be considered as a "worst case" scenario. The model indicates an average flow rate over the life at the landfill to be approximately 27,800 gpd, with a monthly average peak of 72,200 gpd.

2.4.3 Leachate Management Systems

2.4.3.1 Leachate Pipeline Operating Capacity

The selected diameter for the leachate collection laterals and headers (minimum 6 inches) will be sufficient to drain leachate so as not to exceed 1 foot of head

above the Base Liner. The maximum spacing of the laterals is 250 feet. The pipes shown on C-3 are sized and spaced to handle the 25-year, 24-hour storm and not exceed one foot of head on the liner. The chemical properties of the pipes and any materials used in installation will not be adversely affected by the potential corrosiveness of leachate. The physical properties of the pipe will provide adequate structural strength to support the maximum static and dynamic loads and stresses imposed by the overlying materials and any equipment used in construction and operation of the lateral expansion (see attached calculations).

The material surrounding the leachate collection pipes will consist of a coarse aggregate (#57 stone) installed to provide a direct conduit between the pipe and the waste. The aggregate will be chemically compatible with the leachate generated and will be placed to provide adequate support to the pipes.

Calculations for various materials and conditions are included at the end of the application.

2.4.3.2 Leachate Collection Manholes

The leachate collection manholes will be fabricated from high density polyethylene (HDPE) conforming to ASTM standards with material designation PE 3408. All pipe penetrations will be factory fabricated with the manhole. Exterior piping will then be fused to the influent and effluent pipes. Appropriate valves will be installed within the manhole to facilitate maintenance and allow contingency for control of leachate flow. The manhole will be bedded and backfilled as shown on the drawings and as described in the Technical Specifications.

2.4.3.3 Capacity of Storage and Treatment Facilities

The proposed method for storing the extracted leachate from the Phase III expansion will be in the form of an above-ground circular tank. As shown on the drawings, two tanks are proposed for Phase III. Preliminary estimates indicate that a 500,000 gallon tank will be constructed to handle leachate generated from Cells 1 and 2. A 260,000 gallon tank is proposed for the additional leachate expected during the operation of the third cell, if necessary. The requirements for the second tank will be reevaluated once actual generation rate data has been

collected from the first two cells. The tank will be coated to protect against deterioration from the chemical properties of the leachate. The final capacity of the primary tank will be determined after further coordination with the City of Greensboro Utilities Department. A secondary containment system is provided to contain 110 percent of the primary tank volume.

2.4.3.4 Final Disposal Plans and Discharge Limits

The City of Greensboro Utilities Department manages wastewater and intends to internally handle the treatment and disposal of leachate. A sanitary sewer force main is available on landfill property and will be utilized for transporting the leachate to the local POTW. Coordination of the final design is ongoing, and a more detailed layout of the facilities will be provided at a later date, as necessary. (see Section 3.1.7 for additional discussion of leachate management).

SECTION 3.0
ENGINEERING PLAN

3.1 Facility Design

The facility has been designed in general accordance with Section .1620(d) of the Rules. The design includes a composite base-liner system of low permeability clay and synthetic liner.

The proposed horizontal expansion will allow the continued use of existing facilities such as the scalehouse facility, truck scales, paved access road, and the maintenance building. The proposed site development will include excavation of borrow areas, construction of the lined area, perimeter roadway, storm water conveyance, environmental control systems, leachate collection system, and gas management systems.

The facility is currently surrounded on all sides by natural barriers or fencing, to control vehicular access and prevent illegal disposal. All access is limited by gates, and such gates are securable and equipped with locks.

Internal roads will be maintained to be passable in all weather by all vehicles. All operation areas and units will be accessible. Roads will be finished with either gravel or asphalt. Internal roads will be a minimum of 20 feet wide and will not have slopes of more than 8 percent.

3.1.1 General

The Phase III area, with 51 acres of liner, contains airspace for approximately seven years of waste, based on assumptions outlined in Section 2.0 of this document. Because Phase III is a discrete unit and is not expected to be expanded with additional "cells," it is requested that the NC DEHNR Division of Solid Waste Management review the entire Phase III area for permit.

Preparation and development of the facility will require a number of activities including some site clearing, subgrade preparation, soil liner placement, HDPE FML installation, and placement of the leachate collection system.

Construction limits will be set to the minimum area required for site development and landfilling operations. The majority of the area is currently cleared and is within the boundary of the current borrow pit.

Any remaining topsoil will be removed and stockpiled for later use in closure operations. During any site-clearing activity, appropriate erosion and sediment control procedures will be followed to control erosion from disturbed areas. Phase III currently is operating as a borrow pit, with approved erosion control measures in place.

3.1.2 Foundation

The foundation of the landfill is anticipated to consist of the naturally occurring soils and some structural fill material. Based on the geologic exploration of the subsurface (see Design Hydrogeological Report) no areas of gross instabilities are expected. After excavation of the site to the design subgrade, the area will be proofrolled (minimum 20-ton pneumatic tired vehicle) for confirmation and any areas noted to exhibit signs of instability will be excavated and backfilled with structural fill.

As depicted on the drawings, some areas within the borrow pit have been excavated to grades which do not maintain the 4-foot regulatory minimum groundwater separation. These areas will be backfilled with structural fill material to obtain regulatory minimum separation. It is possible, due to the trend of lowered groundwater apparently caused by dewatering of the adjacent ponds, that base grades can be lowered further. This decision will be made, with NC DEHNR approval, as a result of continued groundwater elevation measurements.

Some areas of the proposed landfill also indicate rock outcroppings above proposed base grades or within the 4-foot regulatory minimum separation. As the City continues excavation of the borrow pit, work is ongoing to "rip" the rock down to elevations that maintain the minimum separation. Again, in the areas where rock is to be removed, structural fill will be placed to maintain separation.

3.1.3 Base Liner System

The base liner system is designed to be constructed upon a stable subgrade. A 2-foot layer of low permeability ($<1 \times 10^{-7}$) clay will cover the entire expansion area. The clay will be tightly overlain by a 60 mil HDPE geomembrane. The geomembrane has been checked for failure due to self weight, slipping of operational cover and waste subsidence and failure of the anchor trench and the design is adequate. Calculations are attached.

The leachate collection layer will consist of a geonet on the exterior berm sideslopes. The collection layer will consist of 12 inches of high permeability soil on the bottom of the unit with perforated leachate collection pipes surrounded by stone, and a protective geosynthetic filter fabric. The stone will be constructed like a chimney to the surface of the operational cover, to speed in the removal of leachate from the cells. The LCR system has been designed to allow no more than 1 foot of head on the liner system.

The design as submitted utilizes a drainage media of 12 inches of sand (1×10^{-1} cm/sec) with a 12-inch operational cover of native soil (2×10^{-5} cm/sec).

An operational cover soil provides protection to the LCR system and geomembrane liner from construction and landfill equipment. The operational cover will be a minimum of 24 inches thick on sideslopes and 12 inches elsewhere. Select loads of MSW will form the initial lift to further protect the base liner system. The attached calculations demonstrate stability of the operational cover on sideslopes and the ability of SDR 11 leachate pipes to withstand loading without crushing.

3.1.4 Cap System Design

The final cap system design is placed over the 12 inches of intermediate soil cover. The cap consists of a minimum of 18 inches of low permeability soil ($<1 \times 10^{-5}$ cm/sec) overlain by a geomembrane, a geonet for infiltration collection, 18 inches of cover soil, and 6 inches of top soil. The maximum design slope is 25 percent; vegetation will be established after completion of the cap to control erosion of the soil cover.

3.1.5 Gas Management System

A gas collection system is included as part of the final cap design. At this time, passive wells are depicted. The gas will be directed from the proposed gas wells to the proposed treatment area. The treatment/extraction methods for the Phase II area are currently under discussion. The gas management system for Phase III will likely be an extension of the system currently being developed for Phase II.

3.1.6 Leachate Handling and Storage Facilities

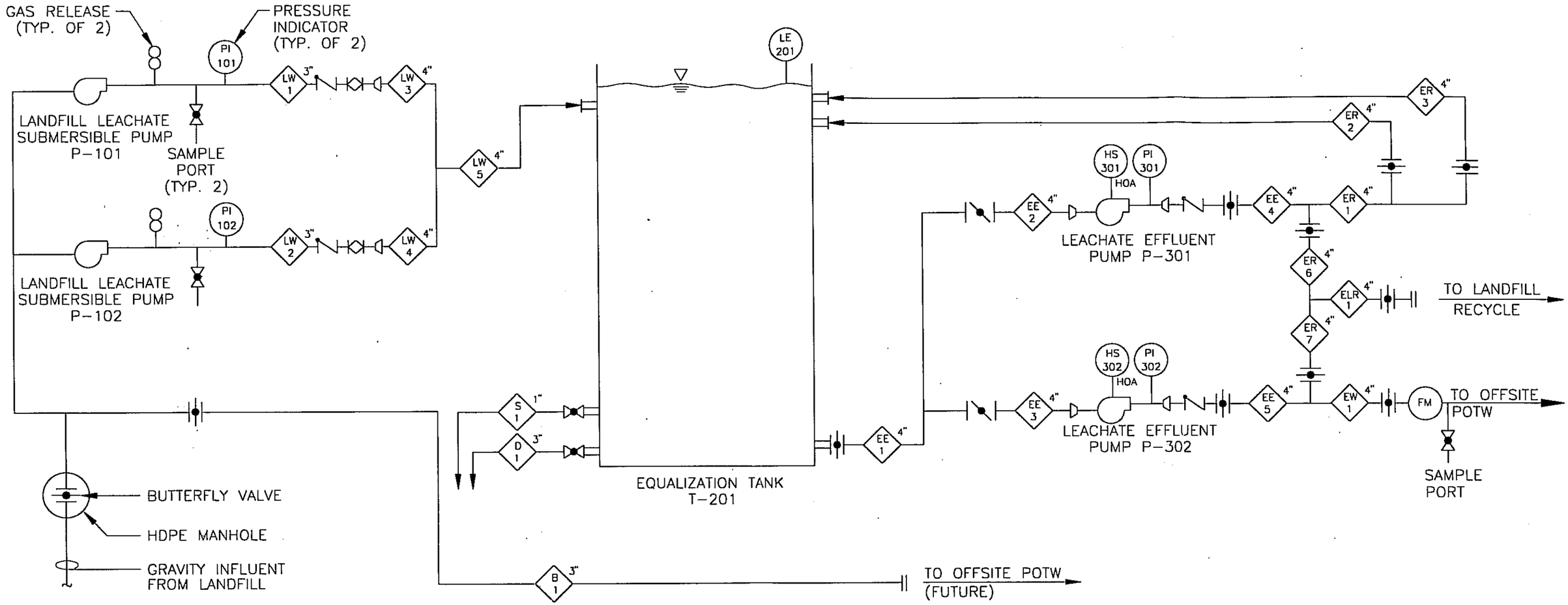
3.1.6.1 General

The most desirable disposal alternative is to pump the leachate from the proposed landfill to the local POTW for initial treatment and discharge.

Due to the variability of leachate generation and water quality, there is no immediate need for extensive wastewater pretreatment facilities. If allowed by the Utilities Department and NC DEHNR, wastewater data will be collected and analyzed for an initial period to determine the need and establish a design basis for future pretreatment facilities. At this time, a storage tank is proposed only for equalization of flow prior to discharge to the City wastewater treatment plant. A process and instrumentation diagram (P&ID) is included for reference.

The proposed leachate equalization tank is located on the eastern side of the landfill expansion area (see Drawing PID-1). The equalization tank and associated pumps will be installed on a concrete foundation. A gravel access road will be extended for access to the facilities by transport trucks, maintenance vehicles, and operations personnel.

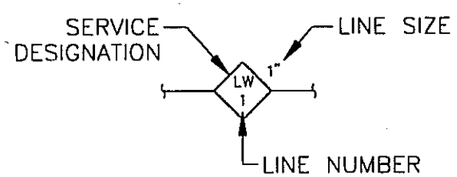
The equalization tank, pumps, and associated above-ground piping are provided with secondary containment. The lined secondary containment area will be constructed around the tanks and will be sized for containment of 110 percent of the largest tank volume. The type of secondary containment is currently expected to consist of concrete floor with steel or concrete walls. The exact type of containment will be determined during the bidding process. This containment area will be piped for drainage of storm water into the adjacent storm water



TYPICAL INSTRUMENTATION ABBREVIATION

LE	LEVEL ELEMENT
PI	PRESSURE INDICATOR
HS	HAND SWITCH
HOA	HAND-OFF-AUTO SELECTOR SWITCH

TYPICAL PIPING CALL-OUT



VALVE LEGEND

	BALL VALVE
	BUTTERFLY VALVE
	CHECK VALVE
	PLUG VALVE
||	CAPPED/FLANGED STUB-OUT

PIPING LINE DESIGNATIONS

LW	LEACHATE WASTEWATER	EE	EQUALIZED EFFLUENT
D	DRAIN	EW	EQUALIZED WASTEWATER
R	RECIRCULATION	ER	EQUALIZED RECIRCULATION
S	SAMPLE LINE	ELR	EQUALIZED LANDFILL RECYCLE

HDR

HDR Engineering, Inc.

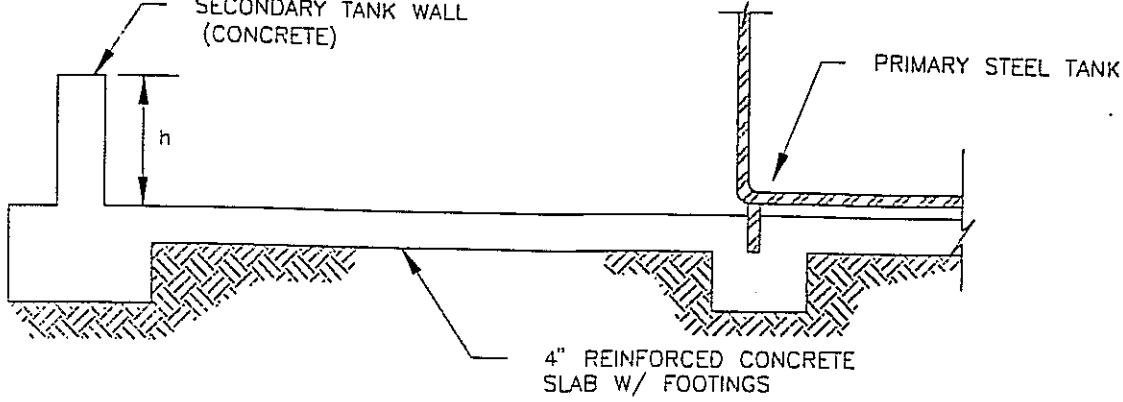
CITY OF GREENSBORO
WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION

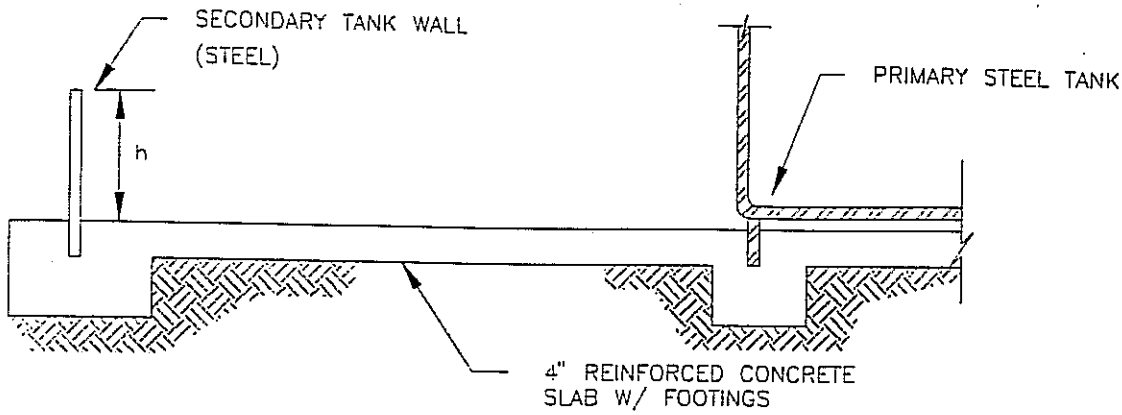
LEACHATE TREATMENT SYSTEM PROCESS AND INSTRUMENTATION DIAGRAM

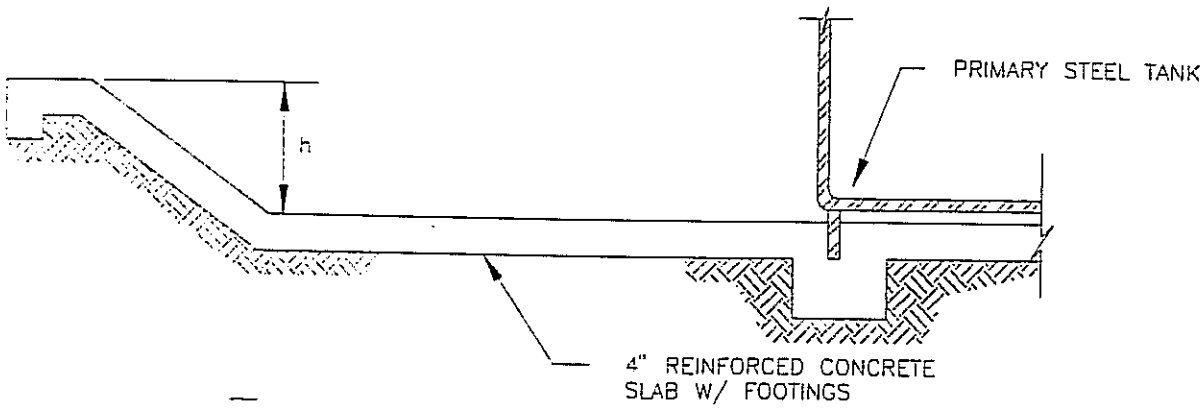
Date 2/15/96

Figure PID-1

P:\GBOF -1A.DWG







NOTES:

1. "h" IS EXPECTED TO BE BETWEEN 3' AND 6'
   FINAL HEIGHT WILL DEPEND ON AREA ENCLOSED.

ALTERNATE
SECONDARY LEACHATE CONTAINMENT CROSS SECTIONS

NO SCALE

basin. However, the pipe will have a manual valve that is to remain closed during normal operations. This arrangement will ensure that any tank failures or accidental spills are identified by the operations staff and properly handled.

3.1.6.2 Final Disposal Plans and Discharge Limits

The leachate collection system includes two submersible pumps located inside an HDPE manhole. A series of float switches mounted inside the manhole will signal the pumps to operate and transfer leachate to the on-site equalization tank. The float switches can be set to turn the pump on and off as well as to signal a high level alarm. Similarly, the leachate storage tank will be equipped with a high level float switch to prevent the pump from over topping the tank. An electronic flow meter will be installed to record the amount of leachate discharged.

In the event of a power failure, a portable generator may be utilized to pump leachate. Under normal operations, the liquid level is maintained at less than 1 foot above the membrane liner.

The HDPE manhole will allow easy removal for operation and maintenance. The two pumps will transfer leachate via a combination of PVC and HDPE piping (force mains) to the equalization tank. All leachate piping systems are equipped for periodic flushing to remove any settled debris or other pipe restrictions.

3.1.6.3 Leachate Equalization

Depending on the time of year, age of landfill, operation of the landfill, and range of storm events, leachate generation will vary. The purpose of equalization of the process wastewater flow is twofold. A large volume is necessary to equalize water quality variation which may result from various landfill operations. Secondly, equalization is required to control hydraulic fluctuations. By dampening both the hydraulic and water quality fluctuations, a more steady and consistent flow can be transferred for treatment.

3.1.6.4 Contingency Measures

The leachate collection and treatment system is driven primarily by electric power. As a result, any major power failure of the supply to the facility would

eliminate treatment and disposal capabilities. In the event of such conditions, the site would be forced to store leachate within the lined landfill. However, excess storage capacity is available within the landfill. Under certain conditions a liquid level greater than 1 foot may be imposed on the membrane liner for periods up to one week.

For extended periods of downtime, the pumps may run from power provided by portable generators. In addition, tanker trucks may be utilized to remove leachate from the tank for eventual disposal at the City wastewater treatment plant.

3.2 Construction Practices

A test pad will be constructed of the soils proposed for use as the clay liner to determine the construction methods necessary to achieve the design criteria as outlined in .1624.(8)(B). The leachate collection system will be constructed in general accordance with rule .1624(10)(B). The geomembrane liner will be constructed in general accordance with rule .1624(9)(B).

3.3 Special Engineering Features

The proposed landfill design was evaluated for seismic and static slope stability. The EPA guidelines for minimum factors of safety against slope failure are 1.5 statically and 1.0 dynamically. These minimum factors of safety are met by this design assuming a conservative cohesion value for waste of 300 pounds per square foot. The complete analysis is included in the calculation section.

3.4 Design Hydrogeologic Report

A copy of the complete report is contained within this application.

SECTION 4.0
CONSTRUCTION QUALITY ASSURANCE PLAN

4.1 Introduction

This Construction Quality Assurance (CQA Plan) has been prepared to provide Owner, Engineer, and CQA consultant the means to govern the construction quality and to satisfy landfill certification requirements under current North Carolina Solid Waste Management regulations. This plan has been developed in general accordance with Rule .1621.

More specifically, this CQA plan addresses the soils and geosynthetic components of the liner and leachate control/removal (LCR) systems. The liner system as referenced herein generally consists of a soil subgrade and a composite liner (consisting of a compacted soil liner and overlying HDPE geomembrane liner). The LCR system consists of a granular drainage material with perforated collection piping, manholes, and fittings. The complete construction quality assurance plan is contained in this application. This section is meant as a brief overview of that plan.

4.2 Responsibilities and Authorities

The CQA plan contains definition of construction quality assurance along with the description of the various parties and their roles in providing a quality product. The parties associated with construction quality assurance and quality control include the owner, project manager, engineer, contractor, geosynthetics manufacturer, geosynthetics installer, CQA consultant, geosynthetics CQA laboratory, Soils CQA laboratory, CQC consultant, geosynthetics CQC laboratory, and Soils CQC laboratory. A diagram illustrating the lines of communication between the various parties is illustrated in the attached plan. A resolution meeting will be held prior to mobilization by the contractor to resolve any anticipated problems with construction, as a result of the contractor's review of the construction documents. A preconstruction meeting will be conducted prior to beginning placement of the liner system. These meetings will review the construction management organization, respective duties during construction, and periodic reporting requirements of tests and construction activities.

4.3 Inspection Activities

A description of all field observations, test equipment, and calibration procedures for field testing equipment that will be used is provided in the CQA Plan included in this application. These activities will ensure that the construction and installation meets or exceeds all design criteria established for the project. Inspection activities will include subgrade preparation, soil liner construction, the geomembrane liner, the leachate collection and removal system, geotextiles, high density polyethylene pipings and fittings, and any geonets and geogrids. A description of all sampling protocols and sample sizes, methods for determining sample locations, and frequency of sampling is presented in the CQA plan.

4.4 Documentation

Documentation will include all reports and tests results prepared by the contractor and the CQC consultant as well as summaries by the CQA consultant progress reports, photographic records, and design or technical specification changes made during construction. The documentation will be safely stored on the site and become property of the owner upon completion of the project.

SECTION 5.0
OPERATION PLAN

5.1 Introduction

The purpose of this section is to identify protocols for the overall operation and maintenance of the White Street Sanitary Landfill, which is owned and operated by the City of Greensboro. The landfill, which is located at the east end of White Street and is currently permitted to accept municipal solid waste generated within the City of Greensboro and Guilford County. This Plan has been prepared in accordance with Rule .1625 and provides details of the procedures and policies which currently are, or shall be, implemented throughout the life of the City of Greensboro's White Street Sanitary Landfill. Detailed drawings for each phase of the landfill's development are presented in the Operational Drawings for this Operational Plan. These Drawings illustrate the existing conditions of the landfill (including known limits of existing and previous disposal areas; and buffer zones), the fill phasing (including the progression of operation including daily operation, transition contours and final contours), and proposed final contours and erosion control plans (including storm water controls; and, stockpile and borrow operations).

5.2 Standard Operating Procedures

5.2.1 Hours and Days of Operation

The landfill is at present, and is anticipated to be, open for operation between the hours of 7:00 AM and 4:50 PM, Monday through Friday, and from 7:00 AM and 1:00 PM on Saturday. The landfill is normally closed on Sundays except where prior permission has been given to receive waste for special instances such as a natural disaster. The observed holidays are New Year's Day, Martin Luther King Jr. Day, Good Friday, Memorial Day, Independence Day, Labor Day, Thanksgiving Day, and Christmas Day.

Special notices are posted at the scalehouse advising users of observed holidays. Such notices are posted at least one week in advance of the holiday.

5.2.2 Traffic Routing

An entrance sign is posted stating the facility name, permit number, and operating hours. Additional signs are posted for allowable speed limit and directional signs indicating the location of the disposal area.

All trucks entering the landfill to dispose of solid waste are weighed at one of two (2) 70' x 10' inbound scales at the scalehouse. Regular users may not be weighed upon leaving if vehicle tare weights are known.

Automobiles and low-sided pickup trucks are required to weigh in. However, the Scale Attendant(s) controls access to the landfill to prevent abuse and misuse. A designated area at the fill face is set aside for these small vehicles to dispose of solid waste. This area is separated from the area being used by the City and private haulers.

Internal roads are hard surface or gravel and are maintained to be passable in all weather by all vehicles so that operation areas and units are accessible.

The total length of roadway from the entrance to the scales and from the scales to the disposal area will be approximately 1,400 feet. This provides sufficient queuing distance for trucks during the peak traffic periods.

Perimeter roads and operational access roads will be built to allow for 2-way truck traffic. The operational access road on the fill has been developed with branch roads extending from the exterior to the interior. A level area for truck turning will be maintained ahead of the active disposal area. The trucks come in via the access road, dump their load, turn around, and exit via the access road.

The approach to the working face is maintained such that two or more vehicles may safely unload side-by-side. A vehicle turn-around area large enough to enable vehicles to arrive and turn around safely with reasonable speed is provided adjacent to the unloading area. The vehicles back to a vacant area near the working face to unload. Upon completion of the unloading operation, the transportation vehicles immediately leave the working face area. Personnel direct traffic as necessary to expedite safe movement of vehicles.

5.2.3 Litter Control

Litter control is a prime requisite in the proper operation of the landfill. In order to control litter and windblown debris, the working face is kept as small as possible and waste is compacted soon after it is unloaded. Cover material is applied daily. If required, portable litter fences will be utilized downwind of and in close proximity to the working areas to catch blowing litter. The area around the work face and the property in general is routinely checked and the litter removed on a regular basis.

5.2.4 Odor, Dust, and Noise Control

Odors which emanate from solid waste as it is placed and compacted are generally limited to within a short distance of the working face. The covering of waste on a daily basis prevents odors from becoming a nuisance.

The access road from the scalehouse to the landfill unit is paved; all other service roads on the operating landfill are graded as necessary to maintain smooth, well-drained surfaces. During extended dry periods, operating roads may be sprayed with water to reduce dust problems. Regular maintenance of soil stockpiles, including frequent wetting or temporary seeding, serves to limit the generation of wind blown dust. Similarly, frequent wetting of on-site roads prevents truck traffic from creating dust.

Noise resulting from landfill equipment is limited to the period of time during operating hours. To reduce the nuisance of noise to neighbors or the administrative function of the landfill, a buffer of trees and other vegetation is maintained between the operating areas and other areas not designated for landfill operations. All on-site equipment is equipped with mufflers or similar noise-dampening devices. Equipment operators, drivers, and other operating personnel will be trained in the use of equipment in an effort to minimize noise generation. These efforts help to ensure that noise does not become a nuisance problem to neighbors or to the administrative function of the landfill.

5.2.5 Inclement Weather Operations

During periods of heavy rainfall, the work area is kept as close to the landfill service roads as practical.

5.2.6 Personnel Structure

Responsibility for overall facility management and operation rests with the Landfill Manager. This individual is designated as the contact person for matters related to regulatory compliance, and is responsible for providing adequate personnel and equipment in order to operate the facility in accordance with the approved permit documents and the North Carolina Solid Waste Management Rules and Solid Waste Management Law.

Landfill supervisory staff includes the Landfill Manager, the Landfill Supervisor, and the Scalehouse Supervisor. In addition to the supervisory staff, the City has twelve other permanent staff available for operations at the landfill. These staff positions include a two person environmental staff that oversees waste screenings, load inspections, groundwater wells maintenance, and methane gas monitoring.

The Scale Attendant(s), stationed at the scalehouse at the site entrance, is responsible for maintaining complete and accurate records of vehicles and visitors entering and leaving the facility. The Scale Attendant(s) also visually inspects incoming vehicles to the extent that the loads are covered properly and determines if the load is acceptable.

An equipment operator doubles as a truck spotter directs incoming vehicles to the proper location to unload refuse at the working face. The primary function of the spotter is to prevent unloading in areas that are not designated for disposal and to visually inspect all loads as they are dumped to assure compliance with posted operating rules. A traffic controller is located at the working face to direct vehicles to the location where the waste is to be unloaded.

Equipment operators are responsible for the safe operation of site equipment. As the personnel most closely involved with the actual landfill operation, these employees are responsible for identifying any potentially dangerous conditions, monitoring waste for unauthorized or hazardous materials, as well as careless or improper actions on the part of other persons while on the premises, and

reporting such observations immediately to the Landfill Supervisor and the environmental specialist. Other services such as sediment basin maintenance, construction, site clean-up, etc. may be contracted to outside firms on a temporary basis.

5.2.7 Personnel Training

The Landfill Manager and the Landfill Supervisor are both Certified Managers of Landfill Operations (MOLO) by the Solid Waste Association of North America (SWANA) as required by GS 130A-309.25. In addition to trained supervisory staff, each landfill employee goes through a 10-hour training course (led by supervisory staff) and is certified by SWANA as Landfill Operations personnel. These staff are then recertified on an annual basis. As part of this training, personnel learn to reorganize loads which may contain regulated hazardous waste or wastes containing PCB's. Landfill personnel are all trained in safety procedures for fire fighting, first aid, CPR, and the handling of hazardous materials.

5.2.8 Management Authority

The management authority, or chain of command for decisions regarding landfill operation is depicted in Figure 5-1.

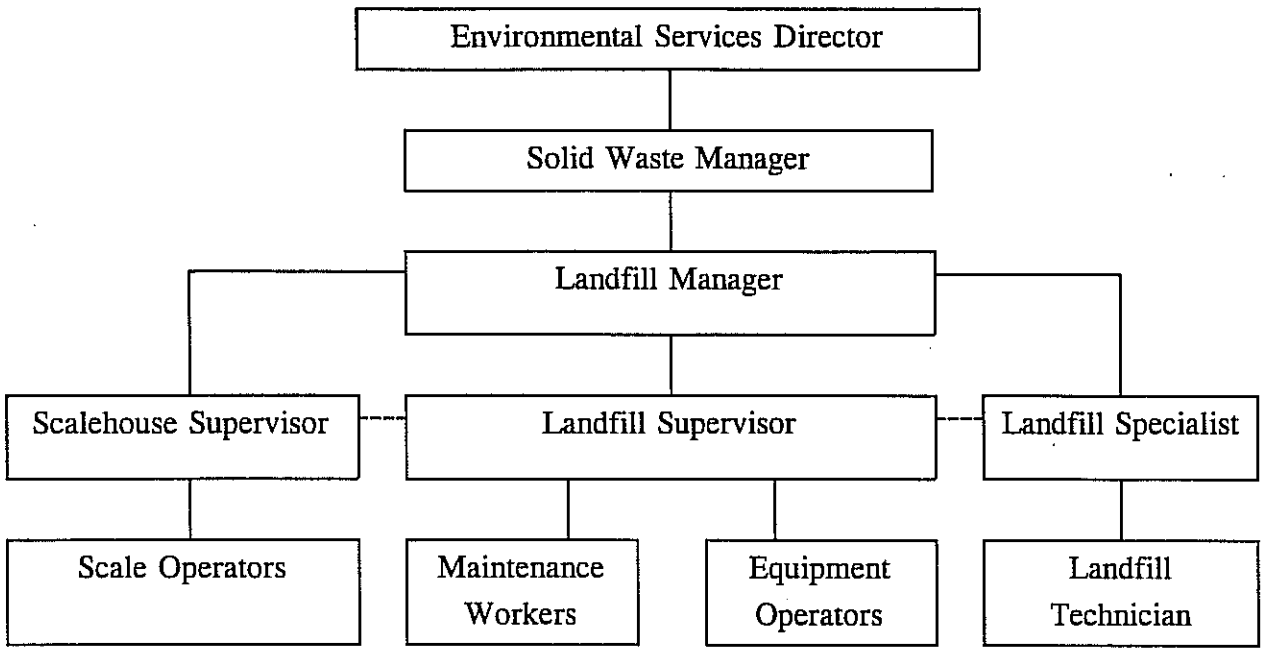
5.2.9 Equipment Requirements

Equipment requirements may vary in accordance with the method or scope of landfill operations at any given time. Additional or different types of equipment may be provided as necessary to enhance operational efficiency. The types and sizes of equipment currently in use at the White Street Sanitary Landfill are presented in Table 5-1.

5.3 Waste Screening Programs

In order to assure that prohibited wastes are not entering the landfill facility, screening programs have been implemented at the White Street Sanitary Landfill. Waste received at both the scalehouse entrance and waste taken to the working face is inspected by trained personnel. These individuals have been trained to spot indications of suspicious wastes, including: hazardous placarding or markings; liquids; powders or dusts; sludges;

FIGURE 5-1
CITY OF GREENSBORO
WHITE STREET SANITARY LANDFILL ORGANIZATIONAL CHART



bright or unusual colors; drums or commercial size containers; and "Chemical" odors. Screening programs for visual and olfactory characteristics of prohibited wastes are an ongoing part of the landfill operation. These programs are implemented in accordance with Rule .1626 Part (1)(f).

5.3.1 Waste Receiving and Inspection

All vehicles must stop at the scalehouse located at the entrance of the landfill facility and visitors are required to sign-in. All refuse transportation vehicles are weighed and the content of the load assessed. Any materials which pose health hazards, cause fire, or which could impact negatively on the environment are deemed unacceptable. The Scale Attendant(s) requests from the driver of the vehicle entering the landfill a description of the waste it is carrying to ensure that unacceptable waste is not allowed into the landfill. The Attendant(s) then visually checks the vehicle as it crosses the scale. Signs are conspicuously posted informing users of the acceptable and unacceptable types of waste.

TABLE 5-1
CITY OF GREENSBORO, WHITE STREET SANITARY LANDFILL
CURRENT EQUIPMENT INVENTORY

Description	Make/Model	No.	Comment
Landfill Compactor	826C Cat	3	
Bulldozer	D8N Cat	2	
Grader	140G Cat	1	
Loader	WA250-1 Komatsu 1994 FR20B Fiat Allis	1 1	
Earthmover	627E Cat	2	
Excavator	K916LC-2 Kobelco	1	
Tractor	White	1	w/Lowboy Trailer
Dump Truck	D400D Cat	3	Off Road
Other Trucks	F250D HD Ford 1994 C70 Chevrolet 2500 Chevrolet 1989	1 1 1	 Fuel Truck Maint.
Other (specify):	900 Ford Cheyenne 1993 Chevrolet Ford 8000 Kubota L275 John Deere 2355 Toro Kawasaki Mule	1 1 1 1 1 1 1	Water Truck Maint. Maint. Utility Tractor w/Mower Lawn Mower Utility vehicle

Each day trucks hauling commercial and industrial loads of waste are selected for screening at random on an appropriate percentage basis. Selected vehicles are directed to a lined area separate from the working face where the vehicle will be unloaded. Waste is carefully spread using suitable equipment. An attendant trained to identify wastes that are unacceptable at the landfill inspects the waste discharged at the screening site.

If waste is detected which is suspected to be unauthorized liquid waste (liquids in containers or non-bulk/non-containerized liquids other than household wastes), the attendant will perform a paint filter test on a sample of the suspect waste. The paint filter test will be performed as follows:

- a 100 milligram sample of waste will be placed in a conical, 400 micron paint filter;
- if liquid passes through the paint filter in five minutes, the conclusion that the waste contains free liquid will be made.

If unacceptable waste is found, including wastes generated from outside of Guilford County, the load will be isolated and secured by berming off the area. The Landfill Manager will then notify the following official of the North Carolina Department of Environment, Health, and Natural Resources, Division of Solid Waste Management within 24 hours of attempted disposal of any waste the landfill is not permitted to receive in order to determine the proper course of action (it should be noted that the hauler is responsible for removing unacceptable waste from the landfill property):

Mr. Hugh Jernigan
Waste Management Specialist
585 Waughtown Street
Winston-Salem, NC 27107
(910) 771-4600

The following records are kept on-site to document all inspections:

- The date and times wastes were received for inspection
- Source and type of wastes
- Vehicle and driver identification
- All observations made by the inspector
- Final disposition of waste after inspection

5.3.2 Prohibited Waste Types

The following wastes are prohibited from disposal within a municipal solid waste landfill (MSWLF) unit:

- Whole Scrap Tires
- Used Oil
- White Goods

- Lead Acid Batteries
- Yard Trash
- Asbestos Waste

In addition, operating criteria prohibit other materials from disposal at the MSWLF unit. These criteria address the following types of waste:

- Hazardous waste as defined within 15A NCAC 13A, including hazardous waste from conditionally exempt small quantity generators.

- Polychlorinated biphenyls (PCB) wastes as defined in 40 CFR 761.

- Bulk or non-containerized liquid wastes unless the waste is household waste other than septic waste and waste oil; or the waste is leachate or gas condensate derived from the MSWLF unit, whether it is a new or existing MSWLF unit or lateral expansion, is designed with a composite liner and leachate collection system.

- Containers holding liquid wastes unless the container is a small container similar in size to that normally found in household waste; the container is designed to hold liquids for use other than storage; or the waste is household waste.

- Wastewater treatment sludges unless they are used as a soil conditioner and incorporated or applied to the vegetative growth layer (at a depth no greater than six inches).

5.3.3 Hazardous Waste Contingency Plan

In the event that identifiable hazardous waste or waste of questionable character is discovered at the landfill, the following procedure shall be instituted immediately:

- The employee that discovers the waste shall see that all personnel, customers, and visitors are evacuated a safe distance upwind from the waste.

- Notify the Landfill Manger, Supervisor, and Landfill Specialist.

- Keep all personnel at a safe distance and maintain security until the Manager, Supervisor, or Specialist arrives and assumes command.

- In the event the waste presents a hazard to human health or the environment, the City of Greensboro Fire Department will be notified and a response by the Hazardous Materials Team requested.

- Notify the Manager of the City Solid Waste Management Division and the Director of the Department of Environmental Services.

- As soon as adequately trained personnel with the proper protective equipment are available, appropriate measures shall be taken to contain the waste and prevent additional contamination.

- Notify the NC DEHNR Division of Solid Waste Management.

If the vehicle disposing of such waste is known, attempts shall be made to prevent that vehicle from leaving the site or, if the vehicle has left the site, notice will be served on the owner of the vehicle that waste for which it has responsibility has been improperly disposed of at the landfill.

Any unauthorized wastes will be removed from the landfill and, if possible, back onto the transporter's vehicle. If the waste cannot be returned to the transporter's vehicle, it will be isolated from the remaining waste and contained to the extent possible. If needed, the waste will be covered with either on-site soils or other tarping material until such time when an appropriate method can be implemented to properly handle the waste. The cost of the removal and disposing of the waste shall be charged to the owner of the vehicle involved. Any vehicle owner or operator who knowingly dumps unacceptable waste in the landfill may be barred from using the landfill and may face prosecution.

Should an incident where prohibited waste is found at the landfill occur, the event shall be documented as follows:

- Date and time of material detection
- Hauler name (company and driver)
- Material(s) detected
- Material generator(s) if able to identify
- Action(s) taken to manage or return material(s)
- Efforts taken if extreme toxicity or hazard was discovered
- Landfill employee in responsible charge

5.4 Waste Disposal

Solid waste transportation vehicles arrive at the working face at random intervals. There may be a number of vehicles unloading waste at the same time, while other vehicles are waiting. In order to maintain control over the off loading of waste, a certain number of vehicles are allowed on the working face at a time. The actual number is determined by the truck spotter. This procedure is used in order to minimize the potential of off loading non-acceptable waste and to control disposal activity. Operations at the working face are conducted in a manner which will encourage the efficient movement of transportation vehicles to and from the working face, and to expedite the unloading of solid waste.

Solid waste unloading at the landfill is controlled to prevent disposal in locations other than those specified by site management. Such control is also used to confine the working face to a minimum width, yet allow safe and efficient operations. The width of the working face is maintained as small as practical in order to maintain the appearance of the site, control windblown waste, and minimize the amount of cover soil required each day. Normally, only one working face is active on any given day, with all deposited waste in other areas covered by either daily, intermediate cover or final cover, as appropriate.

Other services such as sediment basin maintenance, construction, site clean-up, etc. may be contracted to outside firms on a temporary basis.

The sequence of fill will proceed uphill from the low end, subcell by subcell. Using multiple lifts allows filling to occur uniformly across the subcells, eliminates depressed areas and facilitates movement of storm water off site. Less extreme elevation differences occur during construction when using multiple lifts. Waste disposal activities are expected to start in the northeastern corner and progressing south and west across the cells.

All putrescible solid waste delivered to the working face, such as spoiled foods, animal carcasses, abattoir waste, hatchery waste, and other animal waste, is covered immediately. Asbestos waste is not accepted at the landfill.

Use of portable signs with directional arrows and portable traffic barricades facilitates the unloading of wastes to the designated disposal locations. These signs and barricades are placed along the access route to the working face of the landfill or other designated disposal areas which may be established.

5.5 Spreading and Compacting

The procedures for the placement of waste in the landfill include the unloading of trucks, checking of waste for fire, the even spreading of waste, and compaction using the landfill compactor equipment in layers not to exceed eighteen inches in depth. These layers are applied to construct a lift of approximately ten (10) feet in depth after compaction. The level of compactive effort should be sufficient to produce a waste cohesion volume of 300 pounds per square foot. Cover material will be placed over the compacted waste at the end of each day. The size of the working face where unloading, spreading, and compacting takes place will be limited to allow for the most efficient use of cover material.

5.6 Cover Requirements

A significant volume of soil is required to provide for the cover requirements of the White Street Sanitary Landfill. In order to provide for these requirements, on-site borrow areas are excavated in stages to keep pace with the demand for soil. The borrow areas are located south of the entrance road. During normal operations material is excavated, loaded, hauled and then placed over the waste. The development of large stockpiles which result in double handling of materials is avoided. However, stockpiling of material may be necessary prior to the winter when excavating materials is more

difficult due to colder, wetter weather. Off-site soil or alternative cover may be used to reduce the on-site requirements for soil cover.

5.6.1 Daily Cover

In accordance with Rule .1626 (2)(a) disposed solid waste is covered with six inches of earthen material at the end of each operating day, or at more frequent intervals if necessary, to control disease vectors, fires, odors, blowing litter, and scavenging.

The City plans to use either soil or an approved alternative cover on a daily basis. This alternate cover may be used on a daily. On weekends and holidays the lift face will be covered with six inches of compacted soil.

The White Street Sanitary Landfill has an adequate quantity of acceptable earth cover for routine operations.

5.6.2 Intermediate Cover

Intermediate cover consisting of a total thickness of twelve inches is applied to all areas which will not have wastes placed on them for 12 months or more, but where final termination of disposal operation has not occurred. The areas which have received intermediate cover are graded to prevent ponding and temporary grass cover is planted. Any erosion or other damage which has occurred to the intermediate cover is repaired on a routine basis. Litter fences are installed to reduce blowing litter.

5.7 Disease Vector Control

The need for extensive disease vector control (control of rodents, flies, mosquitoes, or other animals, including insects, capable of transmitting disease to humans) is minimized through proper site operation, including on-going compaction and application of daily and final cover. If vector problems develop that require control beyond the measures indicated above, appropriate measures will be taken.

5.8 Explosive Gases Control

Landfill gases are the product of solid waste decomposition under anaerobic conditions. The quantity and types of gas generated depend on the type of waste disposed of. The largest amount of gas generated is generally from waste containing a high percentage of readily degradable organic matter. The rate of generation depends mainly on the moisture content, temperature, and particle size of the waste and the age of the fill. High temperature and moisture content, along with small particle size, tend to result in higher gas production. Gas production from a landfill can last from two to 100 years, but generally peaks after approximately five years, if the moisture content is not limited. Landfill gases predominately consist of methane and carbon dioxide. Initially, the gas is mostly carbon dioxide with methane production beginning later; however, the gas eventually reaches approximately 50% methane by volume.

A gas monitoring system will be constructed along the perimeter of the landfill. This system will be monitored with a mobile combustible gas indicator (CGI) to check for gas migration along the perimeter of the landfill nearest any residential structures. All buildings and enclosed structures on the landfill are monitored as part of a routine methane monitoring program. Routine monitoring for gas migration is performed in accordance with Rule .1626 Part (4)(b) on a quarterly basis to ensure that the following compliance levels for methane concentration are not exceeded: 1) the concentration of methane gas generated by the facility does not exceed 25% of the lower explosive limit (LEL) for methane in facility structures (1.25% methane); and 2) the concentration of methane gas migrating from the landfill does not exceed the LEL for methane at the facility property boundary (5% methane).

If concentrations are measured at greater than 25 percent of the LEL for methane in facility structures then the City will immediately take all necessary steps to ensure protection of human health and shall notify the Division of Solid Waste Management. Within seven days of detection, the methane gas levels detected and a description of the steps taken to protect human health shall be placed in the operating record. Within sixty days of detection, a remediation plan describing the nature and extent of the problem and the proposed remedy for methane gas releases shall be placed in the operating record, the remediation plan shall be implemented, and the Division of Solid Waste Management shall be notified that the remediation plan has been implemented.

5.9 Air Criteria

In accordance with the State Implementation Plan developed under the Clean Air Act Section 110, open burning is prohibited at the site, unless approved by the Division for the infrequent burning of land clearing debris generated on site or debris from emergency clean-up operations. In order to control accidental fires from occurring at the site, the following preventative measures have been taken:

- The Scale Attendant(s) and equipment operators screen incoming waste loads for signs of hot loads, such as smoke, steam or heat being released from the waste, in order to prevent such loads from being off-loaded in the active area of the landfill.

- Smoking is confined to designated areas only, away form active areas of the landfill, fuel stations, methane collection and treatment equipment and other fire-sensitive areas.

- Motorized equipment is not parked near fuel stations longer than necessary for refueling.

- Fuel spills are contained by berming and cleaned up immediately using some type of absorbent material.

- Landfill equipment does not remain in the active area of the site overnight.

- Dead trees, brush, or vegetation adjacent to the landfill are removed immediately, and grass and weeds mowed so that brush fires cannot spread to the landfill. A mower/shredder is available to control grass and brush.

Fire fighting equipment is available on-site to control fires should they occur. In addition, all equipment is equipped with automatic fire extinguisher systems and all landfill personnel have been certified in CPR as of July 1, 1995. In the event that additional fire protection be needed, the City of Greensboro Fire Department will be contacted immediately to provide fire-fighting services. The Division of Solid Waste Management will be notified verbally within 24 hours of any fire occurrence at the landfill, and written notification shall be submitted to the Division within 15 days of the fire incident.

5.10 Access and Safety Requirements

Entry to the site is limited to landfill personnel, approved waste haulers and properly identified persons whose entry is authorized by the site management. The City reserves the right to restrict access to the site. Visitors may be allowed near the active area only when accompanied by a site representative.

An entrance sign is posted stating the facility name, permit number and operating hours. Additional signage regulates traffic flow, provides information on dumping procedures, the type of waste the facility is permitted to receive as well as those wastes banned from disposal at the facility, and indicates the location of the disposal area.

Facility roads are maintained to be passable to ensure that all operation areas and units are accessible in all weather conditions. Dust control measures, including wetting or temporary seeding of soil stockpiles and wetting of on-site roads, are implemented when necessary.

All facilities are surrounded on all sides by natural barriers, fencing, or an equivalent means of controlling vehicular access and preventing illegal disposal. All access is limited by gates, and such gates are securable and equipped with locks.

Scavenging is not permitted at the landfill. If the volume of salvageable goods is sufficient, those items are set aside for salvage disposal by the City of Greensboro; however, under no circumstances are goods to be salvaged from the working face. Items stockpiled for possible salvage are maintained in a neat and orderly fashion.

Barrels and drums are not be disposed of unless they are empty and perforated sufficiently to ensure that no liquid or hazardous waste is contained therein, except fiber drums containing asbestos.

5.11 Sedimentation and Erosion Control

The landfill will be constructed with maximum 4:1 side slopes and minimum 12.5:1 top slopes to promote runoff and prevent ponding over or in the waste. Perimeter drainage channels at the toe of the slope will provide runoff, erosion, and sediment control. The drainage channel allows for the movement of surface water from landfilling activities and provides a settling zone for sediments carried from the site. The channel is constructed to allow drainage via sediment basins through natural outfalls to North Buffalo Creek.

In addition to the drainage channel, sediment basins, silt fences, slope drains, and sediment traps, temporary and permanent seeding will be used to mitigate sedimentation and erosion control problems. All measures will be constructed or installed in accordance with standards specified in the North Carolina Erosion and Sediment Control Planning and Design Manual.

Sediment basins will also prevent the discharge of pollutants that violate requirements of the Clean Water Act, including, but not limited to, NPDES requirements, into the waters and wetlands of the United States.

The landfill will have a comprehensive surface and groundwater monitoring program to provide early detection of any leachate migration problems. In the event any constituents are detected above allowable limits, measures will be taken to begin assessing the extent of contamination and, if necessary, corrective actions will be taken to prevent the pollution of waters and wetlands of the United States, that violate any requirements of an area-wide or state-wide water quality management plan that has been approved under Section 208 or 319 of the Clean Water Act, as amended.

5.12 Drainage Control and Water Protection Requirements

The landfill will be constructed with 4:1 side slopes and 12.5:1 top slopes to promote runoff and prevent ponding over or in the waste. Perimeter drainage channels at the toe of the slope provide runoff, erosion, and sediment control. Sediment basins will also prevent the discharge of pollutants into the waters of the United States, including wetlands, that violates any requirements of the Clean Water Act, including, but not limited to, NPDES requirements.

The landfill has a comprehensive surface and groundwater monitoring program to provide early detection of any leachate migration problems (see Section 11.0). In the event any constituents are detected above allowable limits, measures will be taken to begin assessing the extent of contamination and, if necessary, corrective actions will be taken to prevent the pollution of waters of the United States, including wetlands, that violate any requirements of an area-wide or state-wide water quality management plan that has been approved under Section 208 or 319 of the Clean Water Act, as amended.

5.13 Leachate Management

The leachate collection system will be inspected annually to determine if clean-out of the lines is required. Any unusual fluctuation in leachate quantity or incident affecting the collection system will also trigger a complete inspection of the system. Records will be kept indicating any maintenance performed on the system and all associated test results. Leachate samples will be obtained semi-annually from the pump station for quality analysis. These results will be forwarded to the treatment plant operator and maintained on-site for regulatory review. Provisions will be made for hauling leachate by truck should that become necessary. The tank's final sizing will be determined by the allowable discharge rate into a POTW pipeline and a minimum of one week emergency capacity. The emergency capacity is to account for repairs to system pumps of discharge lines. The plan will be revised after any unexpected condition to reflect the appropriate action in the event of a recurrence.

5.14 Record Keeping

The City of Greensboro maintains detailed records of all activities relating to the landfill. These records are either kept on site or at the office of the City's Public Works Department and include: types and quantities of waste received; source of waste received; revenue generated from waste received; applications for industrial waste disposal and related analyses; well water usage; results from surface and groundwater monitoring, landfill gas monitoring; leachate quantity and quality results; correspondence from regulatory agencies; accident reports; and reports of site and random load inspections. Table 5-2 provides a summary of the records kept, their frequency of completion, and the locations where the records are maintained.

TABLE 5-2
CITY OF GREENSBORO
WHITE STREET SANITARY LANDFILL RECORD KEEPING

Type of Record	Frequency of Completion	Location Maintained
Waste quantities received	Daily	Landfill
Source of waste received	Daily	Landfill
Revenue from waste received	Daily	Landfill
Industrial waste applications and analyses	Before initial waste disposal and annually thereafter	Landfill
Well water usage	Daily	Landfill
Surface and groundwater monitoring data	Semi-annually	Landfill
Related correspondence	As received	Landfill
Accident reports	After each occurrence	Landfill
Site inspections	Daily, quarterly, annually	Landfill
Results of random waste load inspections	After each inspection	Landfill
Gas monitoring results	Quarterly	Landfill
Leachate quality	Semi-annually	Landfill
Leachate quantity	Monthly	Landfill
Closure/ Post Closure estimate	Annually	Landfill

SECTION 6.0
CLOSURE PLAN

6.1 Cap System Background

In compliance with the Solid Waste Management Rules, the landfill will place a final cap system over all waste placed in the Phase III expansion. The cap system will be designed and constructed in accordance with Rule .1624 (b) (8), (9), and (15), to minimize infiltration and erosion. It is estimated that the total landfill volume at completion will be 4,960,000 cubic yards. The maximum area requiring a cap at any one time is approximately 51 acres.

6.2 Cap System Design

The cap system designed will be checked prior to closure and revised and updated as appropriate. Compacted clay liners will be incorporated in the cap system design to provide protection throughout the 30-year post-closure period and beyond. The system will consist of, from bottom up; an 18-inch compacted clay liner (1×10^{-5} cm/sec); a geomembrane; a drainage layer (geonet); an 18-inch vegetative support layer; and, a 6-inch erosion layer.

The landfill may use on-site or off-site borrow material for the low permeability layer. The low-permeability layer will consist of no less than 18 inches of clay material having permeability no greater than 1×10^{-5} cm/sec. In order to assure that the material meets the established criteria, the material will be tested prior to use and after placement. Testing requirements will be outlined in the final closure plan. Construction methods for the compacted clay liner shall be based upon the type and quality of the borrow source and shall be verified in the field by constructing test pad(s). A Professional Engineer shall certify that the compacted clay liner installation conforms with the plans approved by the NC DEHNR Division of Solid Waste Management.

The erosion layer shall consist of 24 inches of cover soil of which no less than six inches of earthen material that is capable of sustaining native plant growth. The landfill anticipates use of on-site borrow material suitable for the erosion layer.

The material of the erosion layer will be selected considering: soil type, nutrient levels, pH, erodibility, and other factors. The vegetation should be selected based upon:

- Species of grasses which are locally adapted and resistant to drought or temperature extremes;
- Having roots which will not disrupt the low permeability layer;
- Ability to thrive in low nutrient soil and develop a good stand to resist erosion;
- Survive and function with little or no maintenance.

All cover material will be free of putresible material, solid waste, vegetation, rocks, construction debris, frozen soil, and other deleterious materials.

6.3 Final Contour Requirements

The final contour requirements for closure are shown on the drawings. These contours have been established to reflect all municipal solid waste expected to be received, intermediate cover material (representing a total of 12 inches), and the final cover system (representing a total of three and one-half feet).

6.4 Cap System Material Requirements

Based on 18 inches of clay placed over the 51 acres that require final closure, 126,000 cubic yards of low-permeability clay are required for the first layer of the cap system. Additionally, 126,000 cubic yards is required for the vegetative support soil. An estimated 42,000 cubic yards of earthen material is required for the 6 inches of top soil layer. An estimated 2,270,000 square feet of geomembrane will be used in final cover of this phase.

6.5 Drainage Control Measures

The landfill is designed to have top slopes of 8 percent and side slopes of 25 percent. Final contours have been established to allow the landfill to drain while limiting erosion potential and maintaining post settlement slopes greater than 5 percent. Surface water

will sheet flow down each of the sideslopes, and into terrace perimeter drainage ditches which will direct flow via down chutes to sedimentation basins located around the unit.

6.6 Permanent Erosion Control Measures

The landfill is situated near North Buffalo Creek at the northern side of the property, which is a tributary to the Haw River. As shown in the Drawings, a system of drainage channels and sedimentation basins will be used to protect the North Buffalo Creek from sediment laden runoff. The sedimentation basins are designed to control the 24-hour/25-year storm event and achieve a minimum of 70 percent efficiency in settling a sediment particle with a diameter of 40 microns. The sedimentation basin design calculations may be found at the end of this application.

6.7 Settlement Subsidence and Displacement

Landfill compaction methods which include the use of steel-wheeled compaction equipment to spread and compact in layers not to exceed two feet in thickness, combined with an adequate number of passes over each layer of waste, will be utilized to reduce voids and minimize differential settlement. Proper placement of daily, intermediate, and final cover will reduce the moisture content of the waste prior to site closure and further reduce settlement. Final slopes of the landfill have been developed to allow for this anticipated subsidence so that positive drainage of the fill will not be hindered.

6.8 Leachate Control

The installation of the final cap system over the fill area will greatly reduce infiltration of surface water and lessen the potential for leachate generation. The landfill has a comprehensive surface and groundwater monitoring program to detect any potential leachate migration problems. This program will be continued throughout the post-closure care period.

6.9 Gas Collection/Venting System

A passive gas venting system will be installed under the cap to allow movement of gas generated from the completed fill area to the gas management area.

6.10 Schedule for Closure

The closure will begin after completion of a portion of the final grades but no later than 30 days after the final receipt of waste. The design of the landfill in combination with the maintenance plan should assure a fairly uncomplicated closure period. The closure of the entire unit, or portions thereof, will be completed within 180 days unless an extension has been requested and received due to changes in the anticipated schedule.

6.11 Notice of Closure and Date of Final Waste Acceptance

A sign indicating the anticipated date of closure and the date of final waste acceptance will be conspicuously posted at the facility at least 30 days in advance of closure. The landfill may take other steps to notify the public of the planned closure. Prior to beginning closure of the unit or portions thereof, the Department of Solid Waste Management will be notified that a notice of intent to close has been placed in the operating record.

6.12 Implementation of Closure Plan

The closure plan will be implemented no more than 30 days from the date of final waste acceptance and completed in accordance with State regulations.

6.13 Closure Verification

The following procedures will be implemented following closure.

- A Construction Quality Assurance (CQA) report shall be submitted to the NC DEHNR Division of Solid Waste Management. This report shall describe the observations and tests used before, during, and upon completion of construction to ensure that the construction materials meet the cap design specifications and the construction and certification requirements. The CQA report shall contain as-built drawings.

- A signed certification from an independent registered professional engineer verifying that closure has been completed in accordance with the closure plan will be submitted to the NC DEHNR Division of Solid Waste Management.

- At least one sign notifying all persons of the closing of the phase and that wastes are no longer accepted will be posted. Suitable barriers will be installed as necessary at former accesses to prevent new waste from being deposited.

- Within 90 days, a survey plat, prepared by a professional land surveyor registered by the State, indicating the location and dimensions of landfill disposal areas, will be submitted to the circuit court clerk of the City of Greensboro.

- A notation shall be recorded on the deed notifying any potential purchaser of the property that the land has been used as a solid waste management unit and that future use is restricted under Paragraph (8) of Rule .1627. A copy of the deed notation as recorded shall be filed with the operating record.

SECTION 7.0
POST-CLOSURE PLAN

7.1 Introduction

This Post-Closure Plan has been developed to outline steps to be taken to ensure the environmental soundness of the landfill during its post-closure care period. The post-closure care period will last at least 30 years after closure completion and at a minimum will consist of the following:

- Maintaining integrity and effectiveness of final cover system
- Performing groundwater and surface water monitoring
- Maintaining and operating a gas monitoring system
- Maintaining run-on/run-off controls

No wastes will remain exposed after closure of the unit. Access to the closed site by the public or domestic livestock will not pose a health hazard.

7.2 Post-Closure Contact

All correspondence and questions concerning the post-closure care of the unit should be directed to:

Mr. Dale James
Solid Waste Manager
City of Greensboro
P.O. Box 3136
Greensboro, NC 27402
(910) 373-2035

7.3 Description of Use

After filling operations cease at Phase III of the White Street Sanitary Landfill and the unit is officially closed in accordance with the Plan described in Section 7.0, the area will be allowed to return to its natural vegetative state.

7.4 Maintenance

7.4.1 Repair of Security Control Devices

All security control devices will be inspected and maintained as necessary to ensure access to the site is controlled. Locks, vehicular gates and fencing will be replaced if functioning improperly. Warning signs will be kept legible at all times and will be replaced if damaged by inclement weather or vandalism.

7.4.2 Erosion Damage Repair

If erosion of the final cover occurs during post-closure, the affected area will be repaired and reseeded as necessary. Excessive slopes will be flattened if possible by adding clean fill material. If necessary, erosion control fabrics will be used to expedite rapid re-vegetation of slopes and to secure topsoil in place. Rough surfaces which cause isolated erosion areas will be smooth and reseeded as necessary.

7.4.3 Correction of Settlement, Subsidence and Displacement

Minimum slopes of five percent will be maintained after settlement in order to prevent ponding and allow for proper drainage without infiltration. If vertical or horizontal displacement occurs due to differential settlement, cracks will be filled with appropriate material and final cover will be reestablished. Excessive vertical displacement is not anticipated.

7.4.4 Repair of Run-On/Run-Off Control Structures

All terraces, ditches, and perimeter channels will be repaired, cleaned, or realigned in order to maintain original condition. Any culverts that are damaged will be replaced.

7.4.5 Gas Collection/Venting System

The landfill gas collection and venting system is anticipated to be maintained a third party. Proper operation of the systems will be verified through testing at the landfill gas monitoring wells and probes.

If methane gas recovery wells do not function as a result of irregular settlement, accumulation of liquids (condensate, leachate, water), binding or corrosion, replacement wells can be installed if necessary. Non-functioning vents will be reset if necessary.

7.4.6 Groundwater Monitoring System

All groundwater monitoring wells have been installed with concrete pads and protective casings to prevent accidental damage by vehicles and equipment. The wells are also equipped with a locking cap to discourage vandalism. Groundwater wells will be inspected regularly (at the time of sampling) to ensure integrity. Persons inspecting a well should look for signs of well tampering, cracking or degradation, and determine whether the well needs to be replaced. If the decision is made to replace and abandon a well, the replacement well should be installed 5-10 feet from the abandoned well in accordance with previous well specifications. Well abandonment should be accomplished by pulling the casing out and grouting the hole.

7.4.7 Leachate Collection System

The leachate collection system will be monitored. The leachate production rates are expected to be reduced significantly following capping. After six months of minimal flows the storage tank system may be evaluated for decommissioning and leachate will be pumped directly into the discharge line from the pump station. The tanks and pipe system will be annually inspected and repaired as necessary.

After closure of the landfill areas has been achieved, the generation of leachate will eventually curtail. The flow rate immediately after closure should decrease to 20 gallons/acre/day (gpad) which for all disposal areas yield approximately 800 gallons/day. Toward the end of the 30-year post-closure period, the flow should approach zero, at which time the storage tank will not be required. The following procedures will be followed to properly close the storage tank:

- Completely drain and remove all liquids, sludges, sediments, etc., from the storage tank.

- Disassemble the tank, piping, and appurtenances and dispose of the contents in a manner approved by NC DEHNR.

- Sample and analyze the soil for appropriate constituents inherent to leachate. Assess the results for evidence of contaminant migration.

- If contamination of underlying soil is exhibited, perform an assessment as to the degree of contamination and develop remedial actions.

- Obtain approval from NC DEHNR for the assessment and associated remedial measures.

- Perform the remedial actions as necessary to limit any threats to public health and the environment.

- Restore the area to closely match pre-existing conditions in the vicinity of the impoundment. Activities may include: filling, grading, topsoiling, and seeding.

7.5 Monitoring Plan

The closed unit shall be monitored for a minimum of 30 years. A series of inspections shall be scheduled to ensure the integrity and effectiveness of the cap system, storm water control system, groundwater monitoring system, gas collection system, leachate collection system, and to protect human health and the environment.

7.5.1 Inspection Frequencies

Inspections to be conducted during the post-closure care period will occur regularly as follows:

Inspection	Frequency
Security Control Devices	Quarterly
Cover drainage system functioning	Semi-annually
Gas collection/venting system	Semi-annually
Groundwater monitoring system	Semi-annually
Erosion damage	Quarterly
Cover settlement, subsidence and displacement	Semi-annually
Vegetative cover condition	Quarterly
Stormwater control system	Quarterly
Benchmark Integrity	Quarterly
Leachate Collection System	

A copy of the Post-Closure Inspection Checklist is shown as Figure 7-1.

7.5.2 Quarterly Inspections

Quarterly inspections of the closed site will include examining the security control devices for signs of deterioration or vandalism to ensure access to the site is limited to authorized persons. The previous disposal area will be checked to ensure that the integrity of the final cover system is maintained, erosion damage is repaired, vegetative cover persists, and that cover settlement, subsidence and displacement are minimal. Drainage ditches will be cleared of litter and debris and benchmark integrity will be noted and maintained.

7.5.3 Semi-Annual Inspections

Semi-annual inspections of the site during the post-closure period will be conducted by the City of Greensboro's consultant engineer with detail attention paid to integrity and drainage of the final cover system and proper functioning of the groundwater and gas monitoring systems.

FIGURE 7-1

POST-CLOSURE INSPECTION CHECKLIST

Date: _____ Time: _____

Weather: _____ Completed By: _____

	Yes	No
I. Security Control Devices:		
Are security control devices in place and functioning?	☐	☐
Are all warning signs prominent and legible?	☐	☐
Are there any signs of unauthorized entry on the site?	☐	☐
Are there signs of illegal dumping on site?	☐	☐
II. Final Cover System:		
Is the final cover free of erosion and depressions?	☐	☐
Is there leachate seeping from the final cover? (If yes, make note of location on comment section below.)	☐	☐
Is the vegetative cover continuous and in good condition, free of bare spots?	☐	☐
Does the site require mowing? (If yes, mow grass and note in comment section below.)	☐	☐
Is there ponding of water on final cover system?	☐	☐
III. Gas Collection System:		
Are the casings in good repair and secure?	☐	☐
IV. Groundwater Monitoring Wells:		
Is the casing upright and unobstructed?	☐	☐
Is the outer casing secure and locked?	☐	☐
Is the ID tag present and legible?	☐	☐
V. Leachate Collection System:		
Are the cleanouts accessible and secured?	☐	☐
Are the valves operational?	☐	☐
Are the tanks and pipelines free of signs of leakage?	☐	☐
VI. Miscellaneous:		
Are all benchmarks visible and intact?	☐	☐
Are all ditches free of debris and litter?	☐	☐
Are any odors present which may indicate landfill gas migration?	☐	☐

Comments

Please use the section below to comment on any area not covered above and also note any areas of concern or needing immediate attention.

Groundwater monitoring will continue on a regular basis throughout the post-closure care period. The parameters chosen for analysis will be no less than the requirements of regulatory agencies. Groundwater monitoring wells will be inspected in accordance with the Ground-water Monitoring Plan. A report of the findings will be sent to City of Greensboro representative via the Post-Closure Inspection Checklist including any recommendations for actions necessary to ensure the site continues to meet the closure performance standard. The engineer will also receive copies of the quarterly inspections reports and respond to any comments that demand immediate attention.

Gas migration will be monitored using an explosimeter around the perimeter of the fill area and between the fill and adjacent buildings and property lines. Monitoring will take place at least quarterly for safety purposes. If it is determined that an active gas venting system is required to control migration, a system including final gas treatment and disposal will be incorporated.

7.6 Engineering Certification

Based on the City's monitoring reports and an engineer's quarterly site visits, annual certifications by the engineer will be placed in the operating record. They will certify that the closure plan has been followed, noting discrepancies along with the corrective actions undertaken. At the end of the post closure period, the individual certifications will be compiled into a final document and forwarded to the Division.

SECTION 8.0
CLOSURE, POST-CLOSURE COST ANALYSIS AND SUMMARY

8.1 Introduction

The purpose of this section is to provide a written estimate in current dollars of all activities and costs associated with all activities specified in the written closure and post-closure plans which have been developed for the City of Greensboro's White Street Sanitary Landfill Phase III (see Sections 6.0 and 7.0). This cost estimate for closure and post-closure care is submitted in compliance with Rule .1628.

8.2 Estimated Closure Costs

Table 8-1 summarizes the estimated costs for the largest area requiring a final cover. This cost estimate is based on a third party providing the necessary services and includes labor in the unit prices given. The estimated closure costs will be reviewed annually or updated as required to reflect adjustments for inflation, rising costs of anticipated closure care, increased costs in construction or materials, or any other adjustments to the Closure Plan described in Section 6.0.

8.3 Estimated Post-Closure Costs

Table 8-2 summarizes the estimated costs for the White Street Sanitary Landfill Phase III post-closure care maintenance activities. This cost estimate is based on a third party providing the necessary services and includes labor in the unit prices given. The estimated post-closure costs will be reviewed annually or updated as required to reflect adjustments for inflation, rising costs of anticipated post-closure care, or any other adjustments to the Post-Closure Plan described in Section 7.0.

TABLE 8-1

CITY OF GREENSBORO WHITE STREET LANDFILL, PHASE III
COST ESTIMATE FOR CLOSURE OF THE UNIT
(BASED ON 51 ACRES)

Item	Quantity	Unit	Unit Cost	Total
Construction:				
Geomembrane (60 mil HDPE)	2,270,000	SF	$0.50	$1,135,000
Geonet Drainage Layer	2,270,000	SF	$0.50	$1,135,000
Infiltration Layer (18 inches):				
Transportation (20 miles @ $2.00/mile/load)	12,600	Load	$40	$504,000
Material	126,000	CY	$3	$378,000
Placing/Grading/Compaction	126,000	CY	$4	$504,000
Vegetative Support Layer (24 inches):				
Transportation (20 miles @ $2.00/mile/load)	16,800	Load	$40	$672,000
Material	168,000	CY	$3	$504,000
Placing/Grading/Compaction	168,000	CY	$4	$672,000
Seeding and Mulching	51	AC	$1500	$76,500
Backfill/Grading/Drainage	1	LS	$100,000	$100,000
Methane Gas Control:				
Wells (1/acre)	51	EA	$1,000	$51,000
Subtotal				$5,731,500
Contingency (20%)				$1,146,300
CQA	52	AC	$5,000	$255,000
TOTAL CONSTRUCTION				**$7,132,800**

Note: These estimates are for a third party and include labor and installation.

TABLE 8-2

CITY OF GREENSBORO, WHITE STREET SANITARY LANDFILL, PHASE III
ESTIMATED AVERAGE ANNUAL POST-CLOSURE COST
(BASED ON 51 ACRES OF PERMITTED AREA)

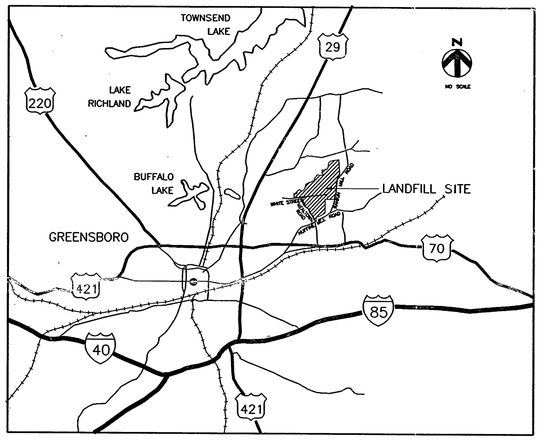
Item	Quantity	Unit	Unit Cost	Total
Post-Closure Costs:				
Engineering Certification	1	LS	$10,000	$10,000
Site Inspection and Recordkeeping:	160	HR	$75	$12,000
Cap Maintenance:				
Mowing (3 times per year)	52	AC	$100	$5,200
Gates/Fences	1	LS	$500	$500
Erosion and Access Control	1	LS	$5,000	$5,000
Surface Water Control	1	LS	$1,000	$1,000
Seeding	1	LS	$2,500	$2,500
Monitoring:				
Methane Gas Monitoring and Report (quarterly)	1	LS	$8,000	$8,000
Groundwater Sampling/Lab and Report (semi annual)	11	Well	$3,000	$33,000
Monitor Well Maintenance	1	LS	$1,200	$1,200
Methane Gas System Repairs	1	LS	$3,000	$3,000
Subtotal				$81,400
Contingency (20%)				$16,280
AVERAGE ANNUAL COST				**$97,680**

Note: These estimates are for a third party and include labor.

CONSTRUCTION PERMIT APPLICATION PLANS

FOR

PHASE III EXPANSION
WHITE STREET SANITARY LANDFILL



LOCATION MAP

DRAWING INDEX

DRAWING NO.	DESCRIPTION
–	COVER SHEET
G1	FACILITY PLAN
C1	EXISTING CONDITIONS
C2	SUBGRADE PLAN
C3	LEACHATE COLLECTION AND REMOVAL SYSTEM
C4	STORMWATER MANAGEMENT
C5	CELL 1 DEVELOPMENT PLAN
C6	CELL 2 DEVELOPMENT PLAN
C7	CELL 3 DEVELOPMENT PLAN
C7A	FINAL CONTOURS AND DRAINAGE PLAN
C8	GAS MANAGEMENT PLAN
C9	LANDFILL CROSS SECTIONS
C10	DETAILS
C11	DETAILS
C12	DETAILS
D1	SOIL BORING AND GROUND–WATER MONITORING WELL LAYOUT
D2	ESTIMATED LONG–TERM SEASONAL HIGH WATER TABLE
D3	BEDROCK SURFACE CONTOUR MAP
D4	GEOLOGIC MAP
D5A	HYDROSTRATIGRAPHIC GEOLOGIC CROSS SECTIONS
D5B	HYDROSTRATIGRAPHIC GEOLOGIC CROSS SECTIONS
D6	PROPOSED MONITORING WELL LAYOUT

Central Files.

APPROVED
DIVISION OF SOLID WASTE MANAGEMENT
DATE 3-17-97 BY [illegible]
41-12

HDR

HDR Engineering, Inc.
of North Carolina

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GREENSBORO, NORTH CAROLINA

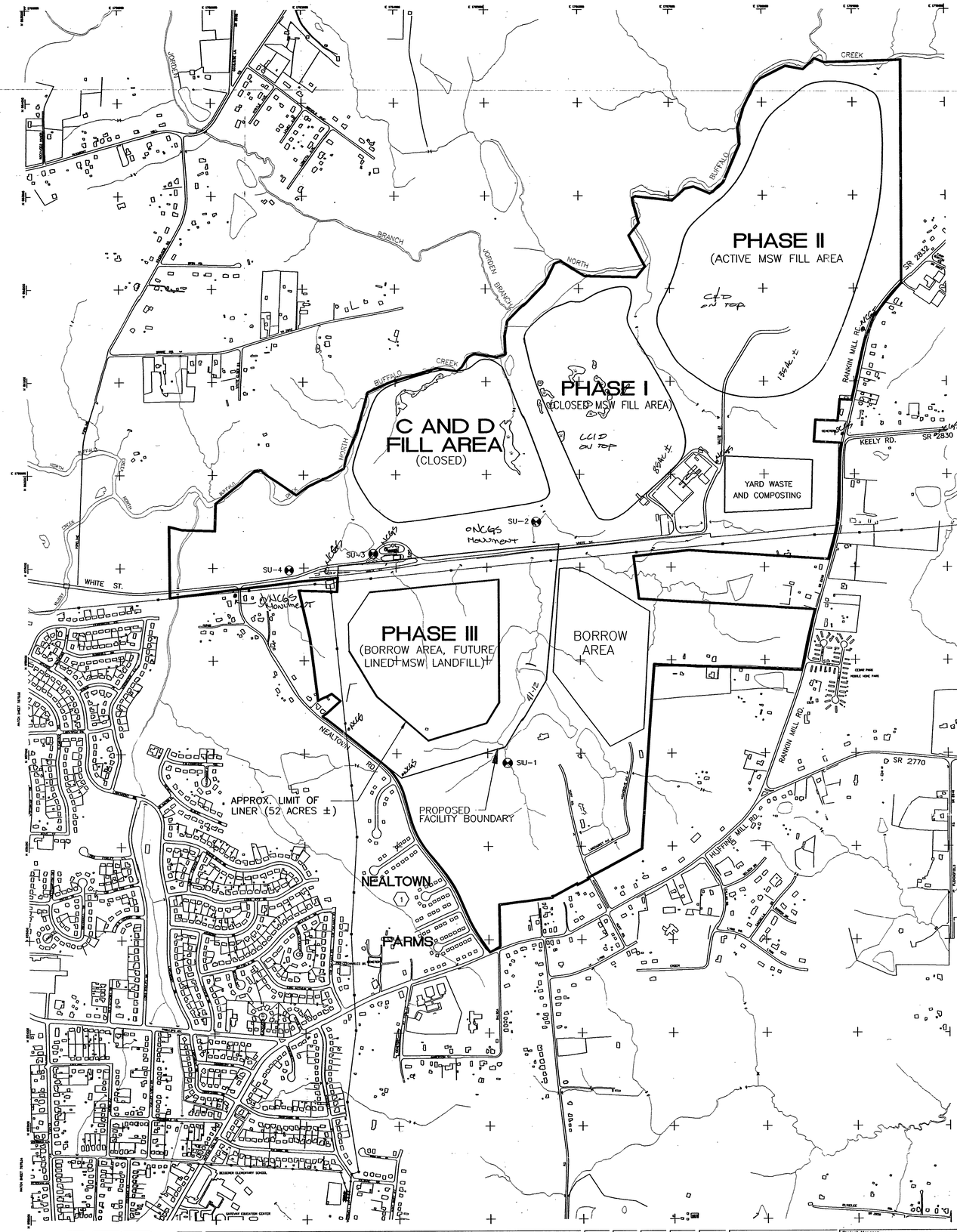
NOVEMBER 1995

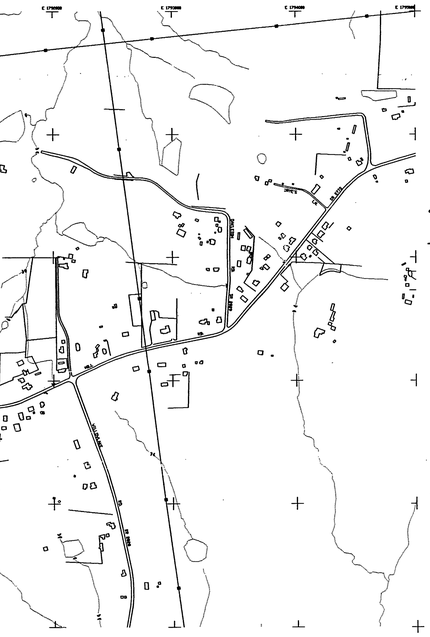
REVISED NOVEMBER 1996

FINAL SUBMITTAL JANUARY 7, 1997

NORTH CAROLINA PROFESSIONAL SEAL 16356 ENGINEER JOSEPH C. REALINI

NOTE: THIS SET OF PLANS ACCOMPANIES AND IS PART OF THE PERMIT APPLICATION TITLED "THE PHASE III EXPANSION OF THE WHITE STREET SANITARY LANDFILL, CONSTRUCTION PERMIT APPLICATION", DATED NOVEMBER 1995.





PLANIMETRIC MAP
CITY OF GREENSBORO
AND VICINITY

LEGEND

ROAD HARD SURFACE
DIRT ROAD
DRIVEWAY
PARKING LOTS
BRIDGE
RAILROAD
DRAINAGE
SWAMP
DAM
CULVERT
BUILDING
TANK
SURFACE WATER MONITORING POINT
FENCE
PIPELINE ABOVEGROUND
PIPELINE BELOWGROUND
TRANSMISSION POLE
TRANSMISSION TOWER AND LINE
CEMETERY
GOLF COURSE
CITY LIMITS - INCORPORATED
COUNTY LINE
STATE LINE
HORIZONTAL CONTROL

N

-500 0 500 1000 1500

SCALE: 1" = 500'

Map compiled by photogrammetric methods from aerial photography dated February, 1991

Grid is based on the North Carolina State Plane Coordinate system, 1983 North American Datum.

This map meets national map accuracy standards.

Prepared by
PIEDMONT AERIAL SURVEYS
GREENSBORO, NC 27419

FACILITY PLAN LEGEND

LANDFILL PROPERTY BOUNDARY

PROPOSED FACILITY BOUNDARY

SPECIFIC NOTES:

(1) INFORMATION FOR NEALTOWN FARMS SUBDIVISION WAS TAKEN FROM AN AERIAL PHOTO BY BRADY SURVEYING DATED NOV. 9, 1994.

FILENAME: P:\GSBRO\21010-2.DWG
FILENAME: P:\GSBRO\21010-1.DWG

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Issue No.	Description	Date	Drawn	Chkd.	Resp. Engr.	Proj. Mgr.
A1	FACILITY BOUNDARY UPDATED	11/7/96	JEG	EAW	JCR	JCR
A	ISSUED FOR NCDEHNR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA PROFESSIONAL SEAL 16395 ENGINEER JOSEPH C. READLING

Project Manager	J. READLING, P.E.
Architect	
Civil	E. WRIGHT, P.E.
Electrical	
Geology	
M/C/Process	
Mechanical	
Structural	
Drawn By	G. HUNEYCUTT

WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

CITY OF GREENSBORO NORTH CAROLINA

FACILITY PLAN

Date	Project No.	Fig No.	Issue
NOV. 1995	6770-021-018	G-1	A1
Scale 1" = 500'			

N

-100 0 50 100 200

SCALE: 1"=100'

GENERAL NOTES:

1. TOPOGRAPHY PROVIDED BY BRADY SURVEYING CO. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 9, 1994. FACILITY AREA UPDATED MAY 18, 1996.
2. PLANIMETRIC FEATURES PROVIDED BY GUILFORD CO. MAPS DATED 1991.
3. BOUNDARY SURVEY PROVIDED BY THE CITY OF GREENSBORO DATED DECEMBER 27, 1994

SPECIFIC NOTES:

1. APPROXIMATE LIMIT OF LINER, 51 ACRES ± THIS LINE REPRESENTS THE LANDFILL COMPLIANCE BOUNDARY WITH RESPECT TO BUFFERS, SEE DRAWING C-2.
2. THE EXISTING CHAIN LINK FENCE SURROUNDS THE PHASE III AREA AND IN SOME LOCATIONS IS BEYOND THE LIMITS OF THE DRAWING.
3. ABANDONED BUILDINGS (3) OWNED BY THE CITY. THESE BUILDINGS WILL BE DEMOLISHED OR CONVERTED FOR NON RESIDENTIAL USE BY THE CITY.
4. THE MAJORITY OF THE PHASE III AREA WAS THE OPERATING BORROW PIT IN SUPPORT OF THE EXISTING PHASE II AREA.
5. THIS IS THE CLOSEST RESIDENCE TO PHASE III. (BUFFER REQUIREMENT 500 FEET)
6. THIS IS THE CLOSEST PROPERTY LINE TO PHASE III, EXCLUDING DUKE POWER SUBSTATION AT NORTHWEST CORNER OF PHASE III. (BUFFER REQUIREMENT 300 FEET.)
7. DUKE POWER TRANSMISSION LINE MAY NOT BE IN THE CENTER OF RIGHT OF WAY.
8. THESE AREAS WERE PREVIOUSLY IMPOUNDED PONDS AND WERE DRAINED DURING JUNE OF 1995.
9. THE LOCATION OF THIS RESIDENCE IS APPROXIMATE IT WAS TAKEN FROM AN AERIAL PHOTOGRAPH BY BRADY SURVEYING DATED NOV. 9, 1994

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Issue No.	Description	Date	Drawn	Chkd	Resp. Engr.	Proj. Mgr.
A1	REVISED: EXISTING TOPOGRAPHY	11/7/96	GRH	EAW	JCR	JCR
A	ISSUED FOR NCDEHNR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 16395 JOSEPH C. READLING

Project Manager	J. READLING, P.E.
Architect	
Civil	E. WRIGHT, P.E.
Electrical	
Geology	
Mech/Process	
Mechanical	
Structural	
Drawn By	JEG

WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

CITY OF GREENSBORO NORTH CAROLINA

EXISTING CONDITIONS

Date	Project No.	Fig No.	Issue
NOV. 1995	6770-021-018	C-1	A1

Scale 1"=100'

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N

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SCALE: 1" = 100'

LEGEND

- LIMITS OF WASTE
- CELL LIMITS
- PROPOSED GRADE
- FACILITY BOUNDARY
- No.2 ▲ 750.04 — EXISTING SURVEY CONTROL
- ▲ — PROPOSED PERMENANT BENCHMARK

NOTES:

1. TOPOGRAPHY PROVIDED BY BRADY SURVEYING CO. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 9, 1994. FACILITY AREA UPDATED MAY 18, 1996.
2. PLANIMETRIC FEATURES PROVIDED BY GUILFORD CO. MAPS DATED 1991.

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Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.
A1	BASE GRADES ADJUSTED FOR REVISED SEASONAL HIGH GROUNDWATER, UPDATED EXISTING TOPO	11/7/96	GRH	EAW	JCR	JCR
A	ISSUED FOR NCDEHNR APPROVAL	11/95	JEG	EAW	JCR	JCR

NORTH CAROLINA PROFESSIONAL SEAL 16395 ENGINEER 11-7-96 JOSEPH C. READING

Project Manager	J. READING, P.E.
Architect	
Civil	E. WRIGHT, P.E.
Electrical	
Geology	
I&C/Process	
Mechanical	
Structural	
Drawn By	JEG

WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

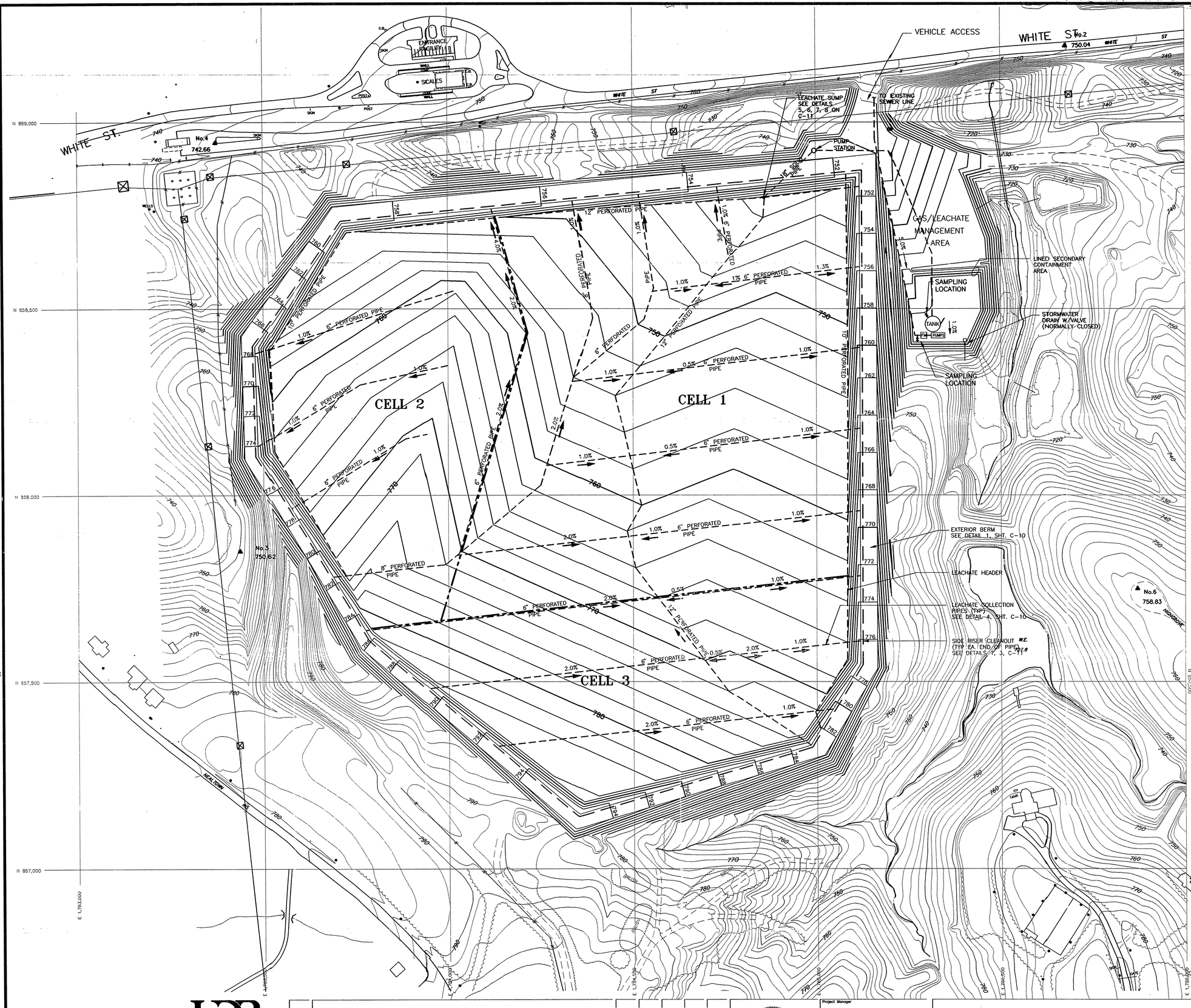
CITY OF GREENSBORO NORTH CAROLINA

BASE GRADE
(BOTTOM OF CLAY LINER)

Date	Project No.	Fig No.	Issue
NOV. 1995	6770-021-018	C-2	A1

Scale 1" = 100'

FILENAME: P:\GSBORO\21010-2R.DWG



N

=100 0 50 100 200

SCALE: 1"=100'

LEGEND

- PROPERTY LINE
- BERM
- CELL LIMITS
- LEACHATE PIPES

NOTES:

1. TOPOGRAPHY PROVIDED BY BRADY SURVEYING CO. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 9, 1994 FACILITY AREA UPDATED MAY 18, 1996.
2. PLANIMETRIC FEATURES PROVIDED BY GUILFORD COUNTY MAPS DATED 1991.
3. BOUNDARY SURVEY PROVIDED BY CITY OF GREENSBORO DATED DECEMBER 27, 1994

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Issue No.	Description	Date	Dsgn.	Chkd.	Resp. Engr.	Proj. Mgr.
A1	REVISED: EXISTING TOPOGRAPHY CELL & MANAGEMENT AREA GRADING & DESIGN.	11/7/96	GRH	EAW	JCR	JCR
A	ISSUED FOR NCDEHNR APPROVAL	11/95	JEG	EAW	JCR	JCR

NORTH CAROLINA PROFESSIONAL SEAL 16395 ENGINEER JOSEPH C. READLING

Project Manager J. READLING, P.E.	
Architect	M/C/Process
Civil E. WRIGHT, P.E.	Mechanical
Electrical	Structural
Geology	Drawn By JEG

WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

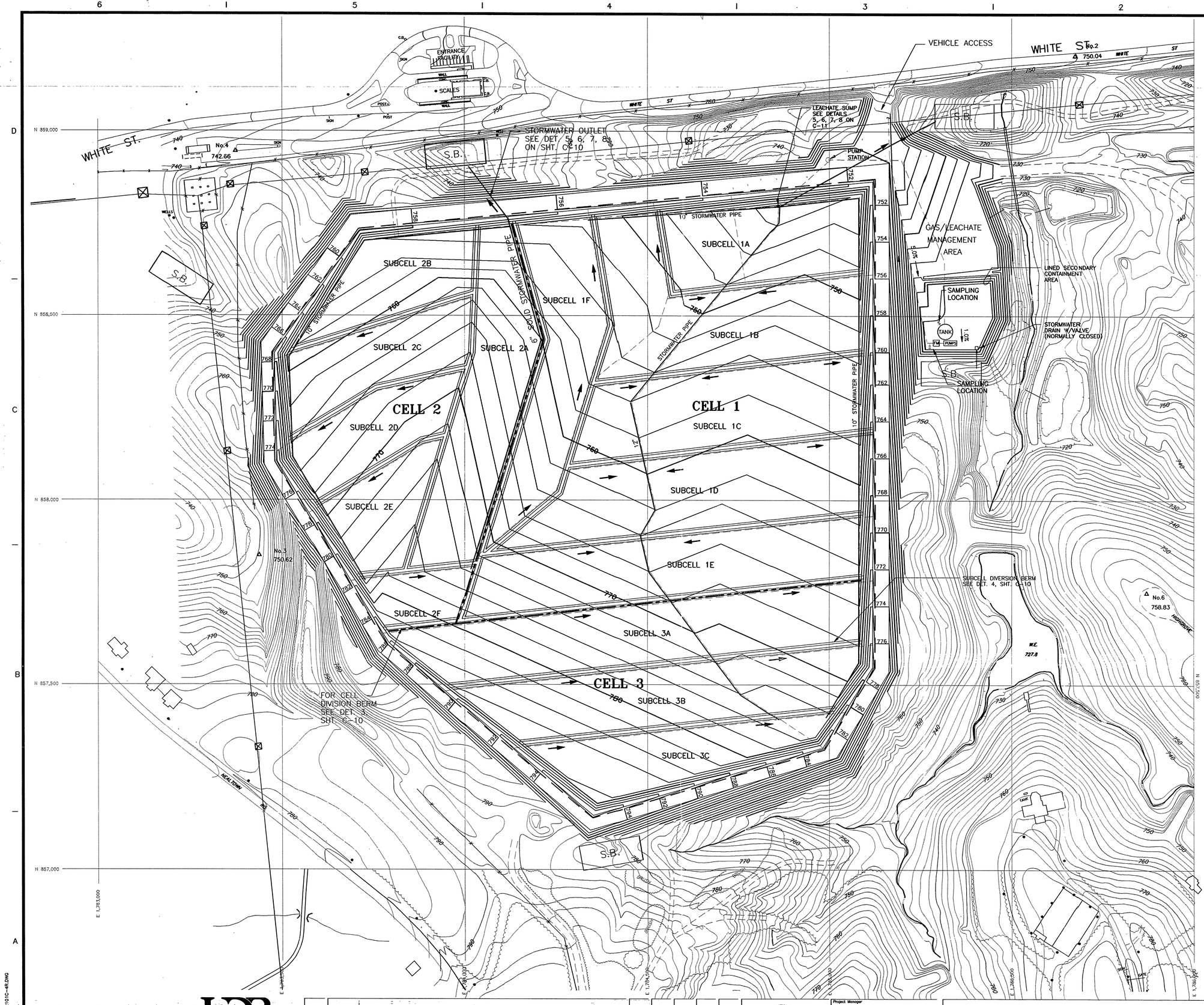
CITY OF GREENSBORO NORTH CAROLINA

LEACHATE COLLECTION AND REMOVAL SYSTEM (TOP OF CLAY LINER)

Date	Project No.	Fig No.	Issue
NOV. 1995	6770-021-018	C-3	A1

Scale 1"=100'

FREEZE LAYER: LEACH
FILENAME: P:\GBORO\21010-SB.DWG



N

−100 0 50 100 200

SCALE: 1"=100'

LEGEND

- PROPERTY LINE
- CELL LIMITS
- SUBCELL BERM
- STORMWATER PIPE
- LEACHATE PIPE

NOTES:

1. TOPOGRAPHY PROVIDED BY BRADY SURVEYING CO. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 9, 1994 FACILITY AREA UPDATED MAY 18, 1996.
2. PLANIMETRIC FEATURES PROVIDED BY GUILFORD COUNTY MAPS DATED 1991.
3. BOUNDARY SURVEY PROVIDED BY CITY OF GREENSBORO DATED DECEMBER 27, 1994
4. LEACHATE PIPES SHOWN FOR RELATIVE PLACEMENT OF SUBCELL BERMS ALSO SEE C-3.

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Issue No.	Description	Date	Drawn.	Check.	Resp. Engr.	Proj. Mgr.
A1	REVISED. EXISTING TOPOGRAPHY CELL GRADING AND DESIGN	11/7/96	GRH	EAW	JCR	JCR
A	ISSUED FOR NCDEHNR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 16395 JOSEPH C. READING

Project Manager	J. READING, P.E.
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Civil	E. WRIGHT, P.E.
Electrical	
Geology	
Mech./Process	
Mechanical	
Structural	
Drawn By	JEG

WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

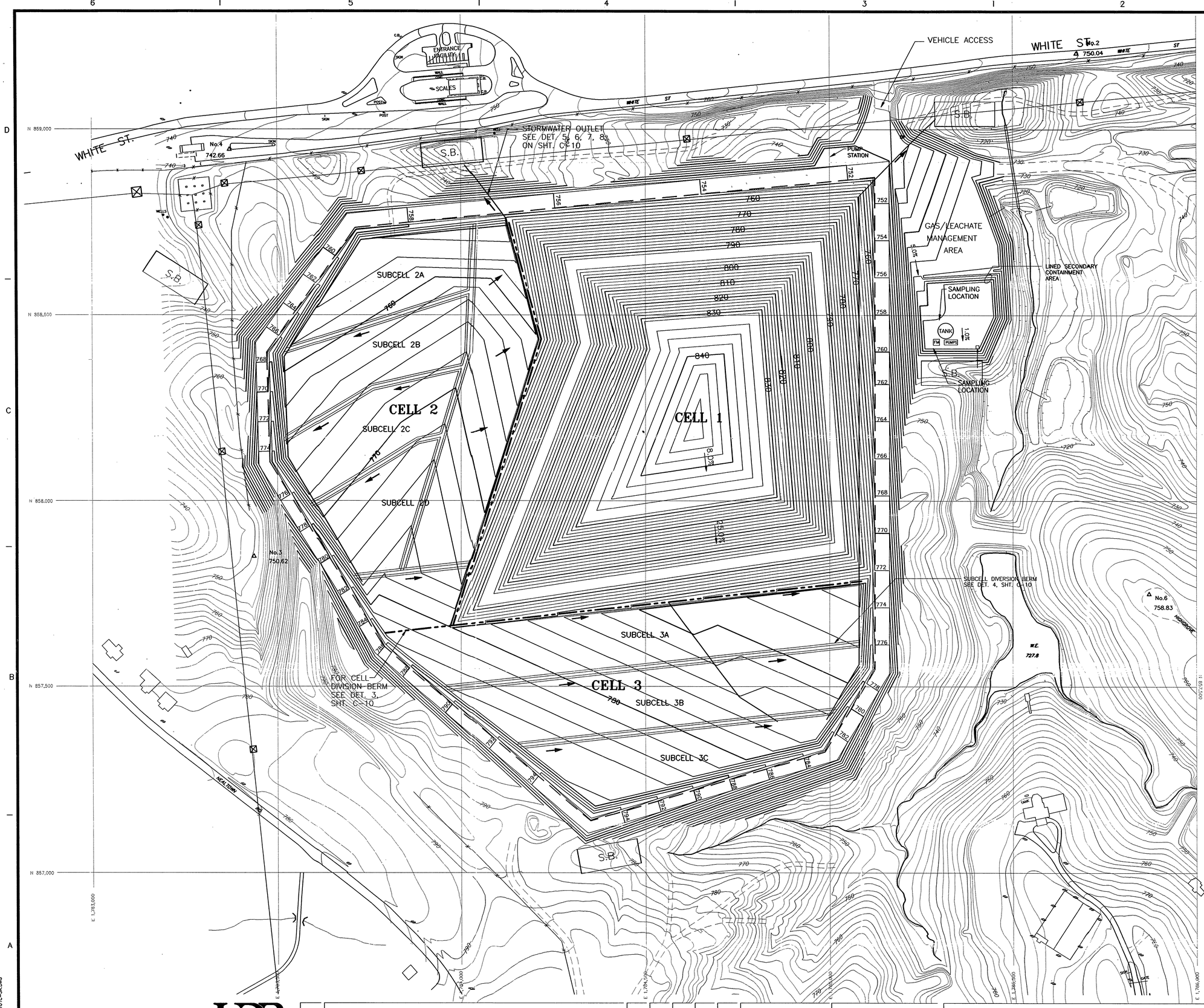
CITY OF GREENSBORO NORTH CAROLINA

STORMWATER MANAGEMENT (CONTOURS DEPICT TOP OF OPERATIONAL COVER)

Date	Project No.	Fig No.	Issue
NOV. 1995	6770-021-018	C-4	A1

Scale 1"=100'

FILENAME: P:\GBORO\21010-4R.DWG



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-100 0 50 100 200

SCALE: 1"=100'

LEGEND

- PROPERTY LINE
- CELL LIMITS
- SUBCELL BERM
- STORMWATER PIPE

NOTES:

1. TOPOGRAPHY PROVIDED BY BRADY SURVEYING CO. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 9, 1994 FACILITY AREA UPDATED MAY 18, 1996.
2. PLANIMETRIC FEATURES PROVIDED BY GUILFORD COUNTY MAPS DATED 1991.
3. BOUNDARY SURVEY PROVIDED BY CITY OF GREENSBORO DATED DECEMBER 27, 1994
4. CELL 1 CONTOURS DEPICT TOP OF INTERMEDIATE/FINAL COVER.
5. CELL 2&3 CONTOURS DEPICT TOP OF OPERATIONAL COVER.

CELL 1 CAPACITY

GROSS AREA = 25 ACRES
GROSS VOLUME = 1,740,000 CY
FINAL COVER = 55,000 CY

ASSUME: REFUSE DENSITY = 1000 LB/CY
REFUSE SOIL RATIO = 4:1
REFUSE INTAKE = 22,300 TONS/MONTH

DAILY & INTERMEDIATE COVER = 335,000 CY
NET REFUSE VOLUME = 1,350,000 CY
LIFE = 30 MONTHS

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Issue No.	Description	Date	Drawn	Chkd.	Resp. Engr.	Proj. Mgr.
A1	REVISED: EXISTING TOPOGRAPHY, CELL 1 DESIGN AND CAPACITY	11/7/96	GRH	EAW	JCR	JCR
A	ISSUED FOR NCDEHNR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 16395 JOSEPH C. READLING

J. READLING, P.E.
Architect | I&C/Process
Civil | Mechanical
E. WRIGHT, P.E.
Electrical | Structural
Geology | Drawn By: JEG

WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

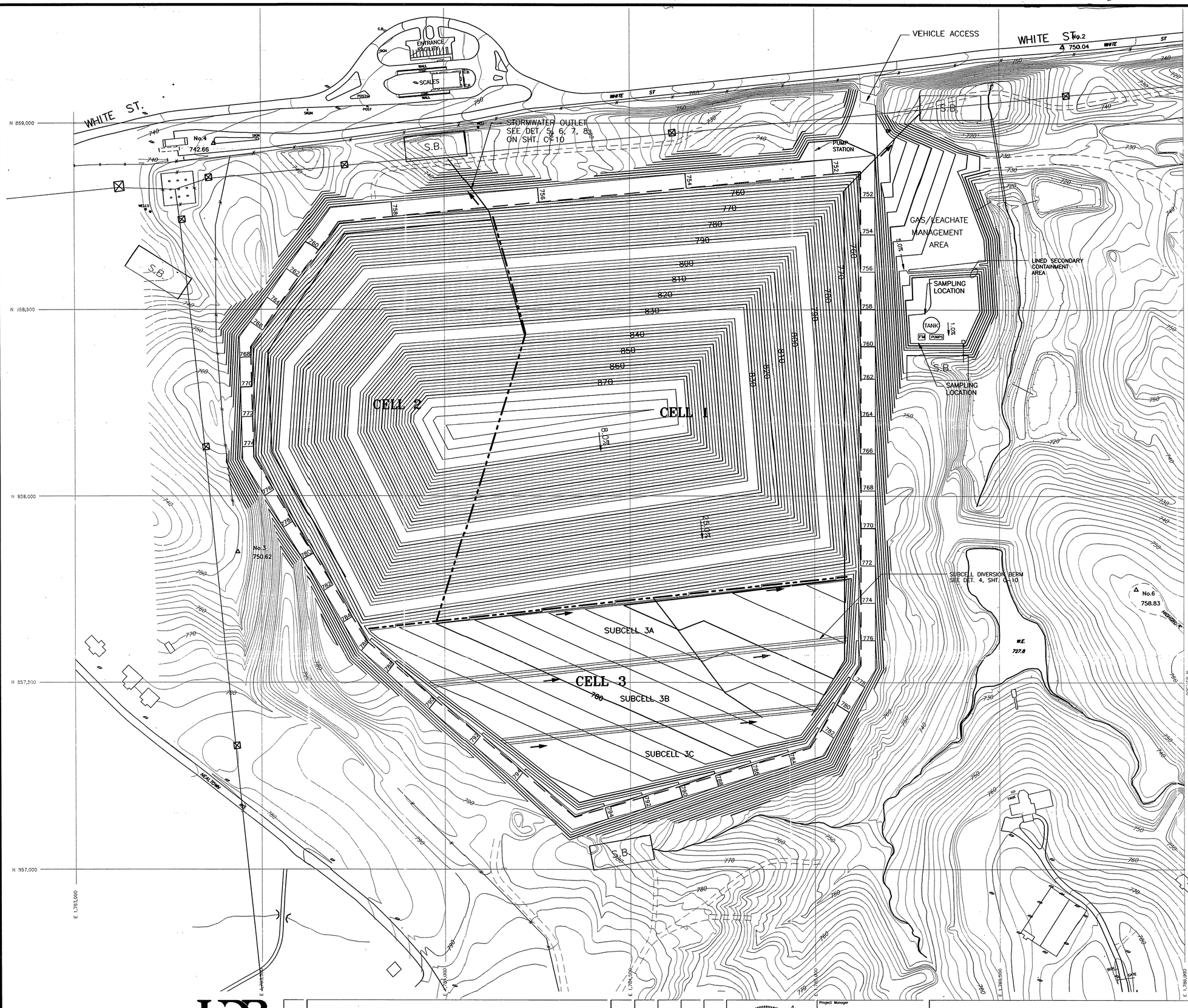
CITY OF GREENSBORO NORTH CAROLINA

CELL 1 - DEVELOPMENT PLAN

Date	Project No.	Fig No.	Issue
NOV. 1995	6770-021-018	C-5	A1

Scale: 1" = 100'

FILENAME: P:\GBORO\21010-SR.DWG



N

−100 0 50 100 200

SCALE: 1" = 100'

LEGEND

- PROPERTY LINE
- CELL LIMITS
- SUBCELL BERM
- STORMWATER PIPE

NOTES:

1. TOPOGRAPHY PROVIDED BY BRADY SURVEYING CO. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 9, 1994 FACILITY AREA UPDATED MAY 18, 1996.
2. PLANIMETRIC FEATURES PROVIDED BY GUILFORD COUNTY MAPS DATED 1991.
3. BOUNDARY SURVEY PROVIDED BY CITY OF GREENSBORO DATED DECEMBER 27, 1994
4. CELL 1 & 2 CONTOURS DEPICT TOP OF INTERMEDIATE/FINAL COVER.
5. CELL 3 CONTOURS DEPICT TOP OF OPERATIONAL COVER.

CELL 2 CAPACITY

GROSS AREA = 14 ACRES
GROSS VOLUME = 1,550,000 CY
FINAL COVER = 85,000 CY

ASSUME: REFUSE DENSITY = 1000 LB/CY
REFUSE SOIL RATIO = 4:1
REFUSE INTAKE = 22,300 TONS/MONTH

DAILY & INTERMEDIATE COVER = 295,000 CY
NET REFUSE VOLUME = 1,170,000 CY
LIFE = 26 MONTHS

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Issue No.	Description	Date	Drawn.	Chkd.	Engr. Engr.	Proj. Mgr.
A1	REVISED: EXISTING TOPOGRAPHY, CELL 2 DESIGN AND CAPACITY	11/7/96	JEG	EAW	JCR	JCR
A	ISSUED FOR NCDEHNR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 16395 JOSEPH C. READLING

Project Manager J. READLING, P.E.	
Architect	I&C/Process
Civil E. WRIGHT, P.E.	Mechanical
Electrical	Structural
Geology	Drawn By JEG

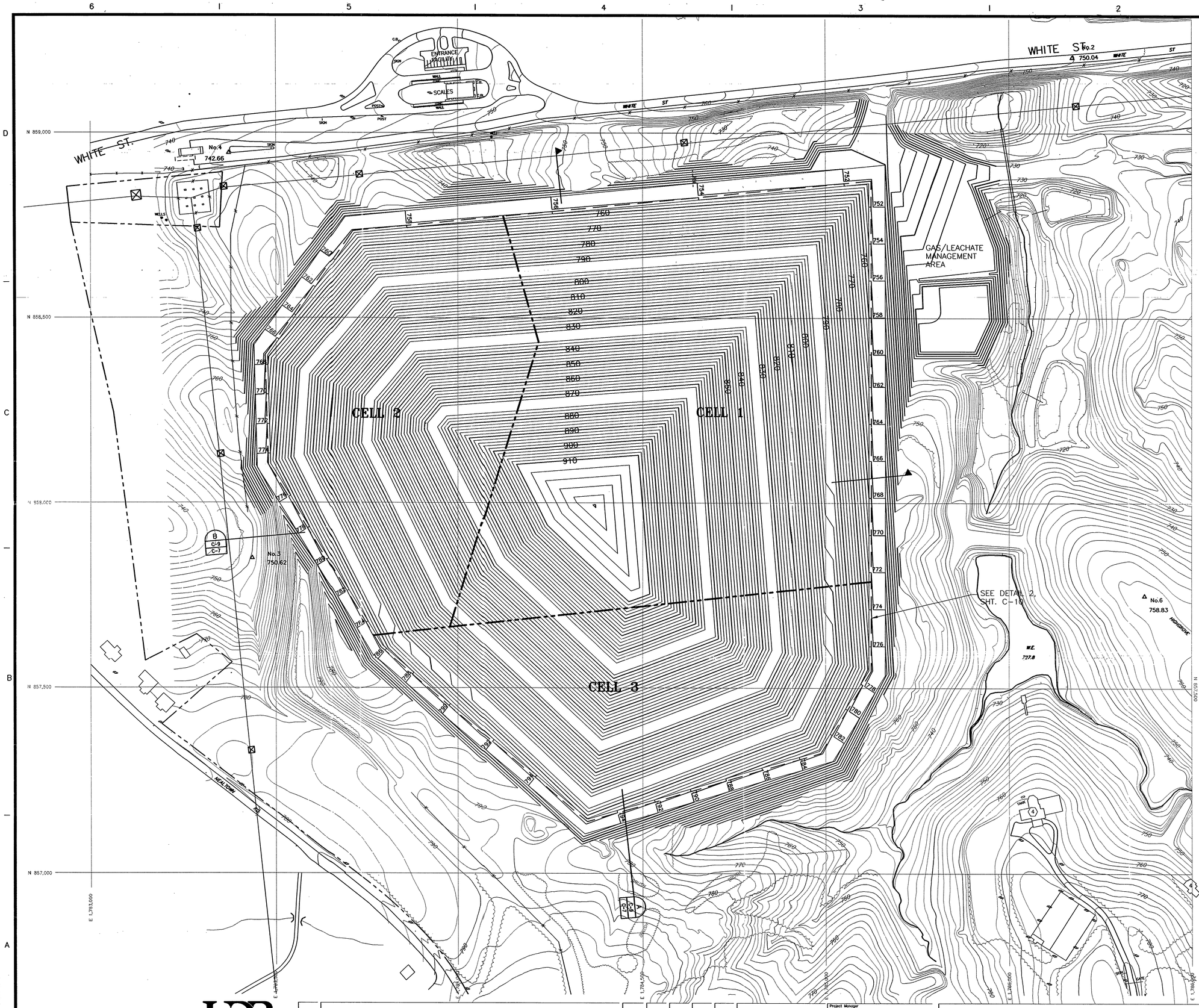
WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

CITY OF GREENSBORO NORTH CAROLINA

CELL 2 - DEVELOPMENT PLAN

Date	Project No.	Fig No.	Issue
NOV. 1995	6770-021-018	C-6	A1
Scale 1" = 100'			

FILENAME: P:\GBORO\2101C-6R.DWG



N

−100 0 50 100 200

SCALE: 1"=100'

LEGEND

PROPERTY LINE

CELL LIMITS

NOTES:

1. TOPOGRAPHY PROVIDED BY BRADY SURVEYING CO. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 9, 1994 FACILITY UPDATED MAY 18, 1996
2. PLANIMETRIC FEATURES PROVIDED BY GUILFORD CO. MAPS DATED 1991.
3. BOUNDARY SURVEY PROVIDED BY CITY OF GREENSBORO DATED DECEMBER 27, 1994
4. CONTOURS DEPICT TOP OF FINAL COVER.

CELL 3 CAPACITY

GROSS AREA = 12 ACRES
GROSS VOLUME = 1,850,000 CY
FINAL COVER = 145,000 CY

ASSUME: REFUSE DENSITY = 1000 LB/CY
REFUSE SOIL RATIO = 4:1
REFUSE INTAKE = 22,300 TONS/MONTH

DAILY & INTERMEDIATE COVER = 340,000 CY
NET REFUSE VOLUME =1,365,000 CY
LIFE =31 MONTHS

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Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.
A1	REVISED: EXISTING TOPOGRAPHY	11/7/96	JEG	EAW	JCR	JCR
A	ISSUED FOR NCDHENR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 16395 JOSEPH C. READLING

Project Manager: J. READLING, P.E.
Architect | M&C/Process
Civil: E. WRIGHT, P.E. | Mechanical
Electrical | Structural
Geology | Drawn By: JEG

WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

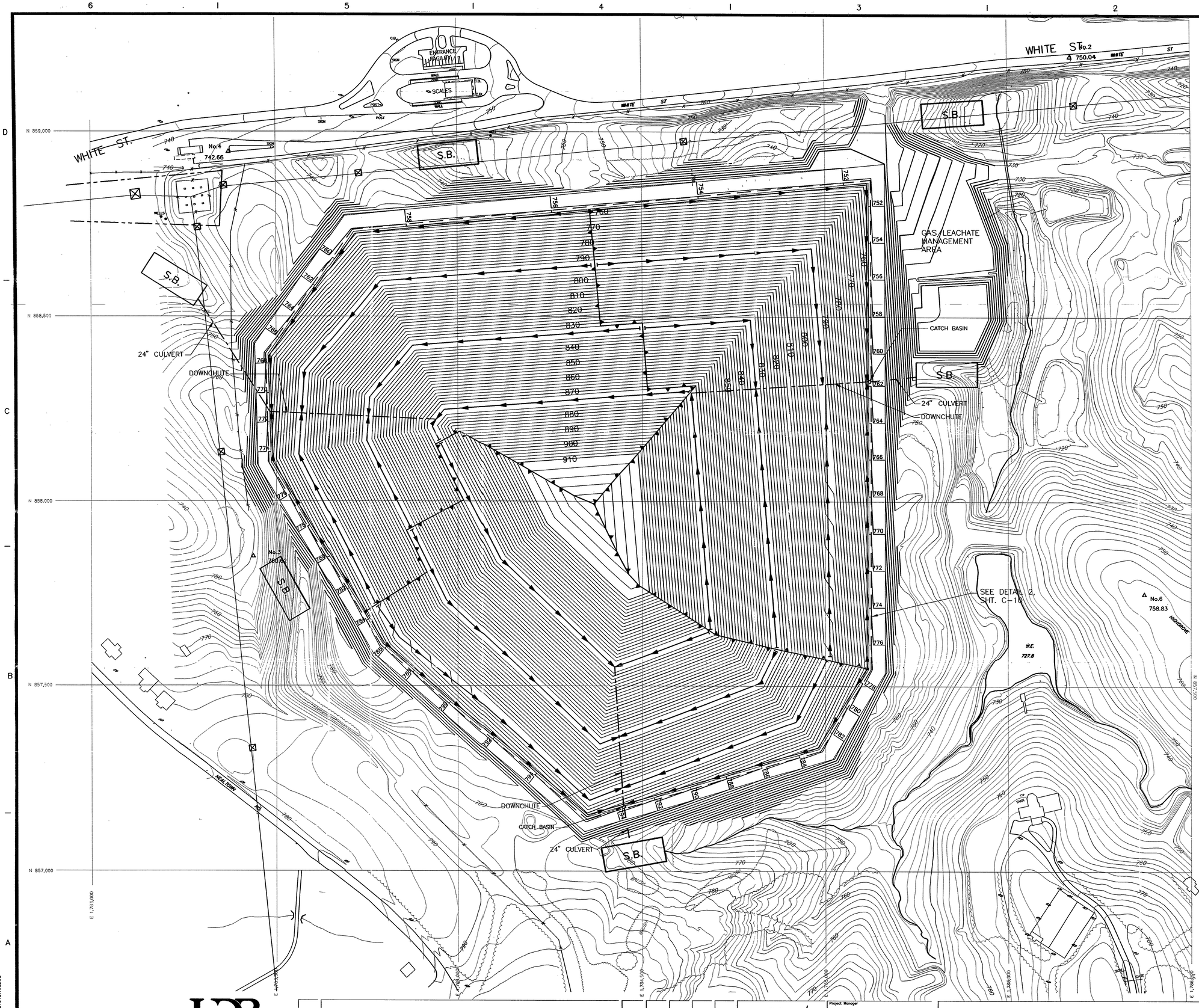
CITY OF GREENSBORO NORTH CAROLINA

CELL 3 - DEVELOPMENT PLAN

Date	Project No.	Fig No.	Issue
NOV. 1995	6770-021-018	C-7	A1

Scale: 1"=100'

FILENAME: P:\GBORO\2101C-7R.DWG



N

−100 0 50 100 200

SCALE: 1"=100'

LEGEND

- PROPERTY LINE
- DRAINAGE DIVIDE
- DRAINAGE DITCH
- S.B. — PROPOSED SEDIMENTATION BASIN

NOTES:

1. TOPOGRAPHY PROVIDED BY BRADY SURVEYING CO. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 9, 1994 FACILITY AREA UPDATED MAY 18, 1996.
2. PLANIMETRIC FEATURES PROVIDED BY GUILFORD CO. MAPS DATED 1991.
3. BOUNDARY SURVEY PROVIDED BY CITY OF GREENSBORO DATED DECEMBER 27, 1994
4. CONTOURS DEPICT TOP OF FINAL COVER
5. TERRACES ARE DEPICTED SCHEMATICALLY; INDICATOR ARROWS SHOW DIRECTION OF FLOW.
6. CATCH BASINS TO BE AREA DRAIN TYPE, NCDOT APPROVED.
7. CULVERTS TO BE CORRUGATED METAL OR REINFORCED CONCRETE.
8. DOWNCHUTES TO BE GABION LINED, TRAPEZOIDAL.
9. REFER TO DRAWING C-12 FOR DRAINAGE DETAILS.

HDR Engineering, Inc. of North Carolina
Suite 1400
128 S. Tryon Street
Charlotte, NC 28202-5001
(704) 338-1800

Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.
A1	REVISED: EXISTING TOPOGRAPHY	11/7/96	JEG	EAW	JCR	JCR
A	ISSUED FOR DEINR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 16395 JOSEPH C. READLING

Project Manager: J. READLING, P.E.
Architect | I&C/Process
Civil: E. WRIGHT, P.E. | Mechanical
Electrical | Structural
Geology | Drawn By: JEG

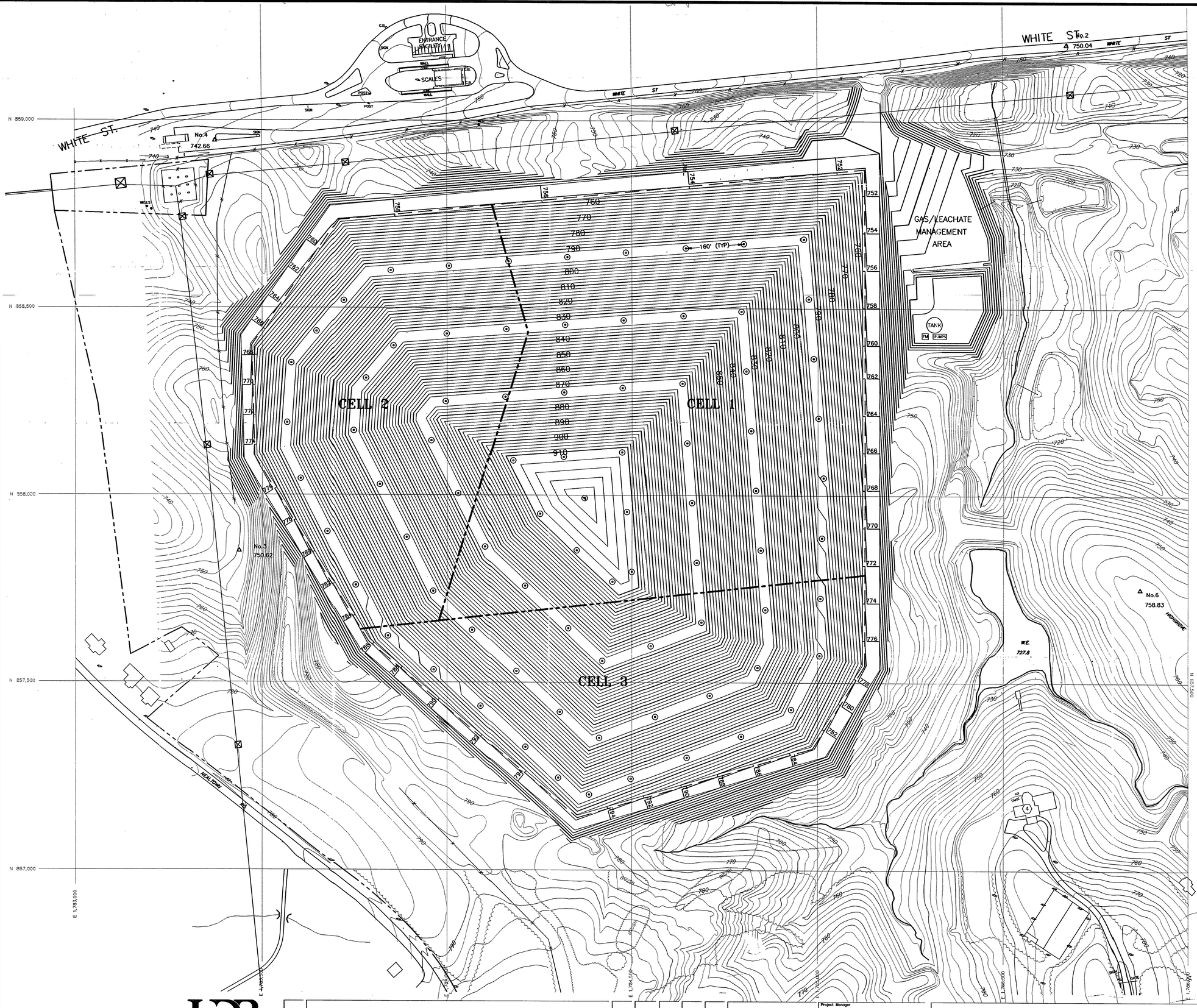
WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

CITY OF GREENSBORO NORTH CAROLINA

FINAL CONTOURS AND DRAINAGE PLAN

Date: NOVEMBER 1995 | Project No.: 6770-021-018 | Fig No.: C-7A | Issue: A1
Scale: 1"=100'

FILENAME: P:\GSBORO\2101C7AR.DWG



N

−100 0 50 100 200

SCALE: 1" = 100'

LEGEND

PROPERTY BOUNDARY

CONSTRUCTION BASELINE

PROPOSED GAS WELL

NOTES:

1. TOPOGRAPHY PROVIDED BY BRADY SURVEYING CO. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 9, 1994 FACILITY AREA UPDATED MAY 18, 1996.
2. PLANIMETRIC FEATURES PROVIDED BY GUILFORD CO. MAPS DATED 1991.
3. BOUNDARY SURVEY PROVIDED BY CITY OF GREENSBORO DATED DECEMBER 27, 1994
4. THE PROPOSED LANDFILL GAS EXTRACTION WELLS ARE ANTICIPATED TO BE SIMILAR TO THE GAS MANAGEMENT SYSTEM BEING PROPOSED BY DUKE ENGINEERING FOR PHASE II LANDFILL

HDR Engineering, Inc. of North Carolina
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Issue No.	Description	Date	Drawn.	Chkd.	Resp. Engr.	Proj. Mgr.
A1	REVISED: EXISTING TOPOGRAPHY AND GRADING FOR GAS/LEACHATE MANAGEMENT AREA	11/7/96	JEG	EAW	JCR	JCR
A	ISSUED FOR NCDEHNR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 16395 11-1-96 ENGINEER JOSEPH C. READLING

Project Manager: J. READLING, P.E.
Architect | I&C/Process
Civil: E. WRIGHT, P.E. | Mechanical
Electrical | Structural
Geology | Drawn By: JEG

WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

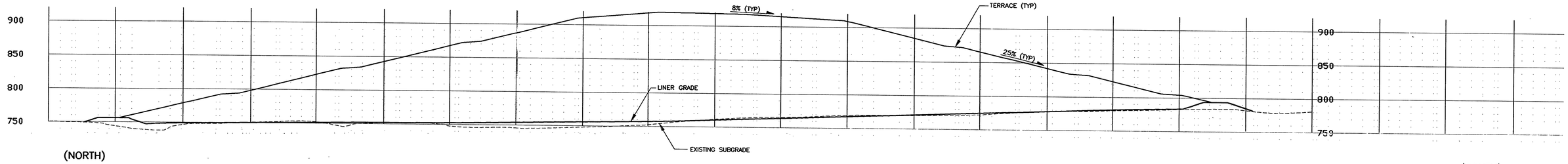
CITY OF GREENSBORO NORTH CAROLINA

GAS MANAGEMENT PLAN

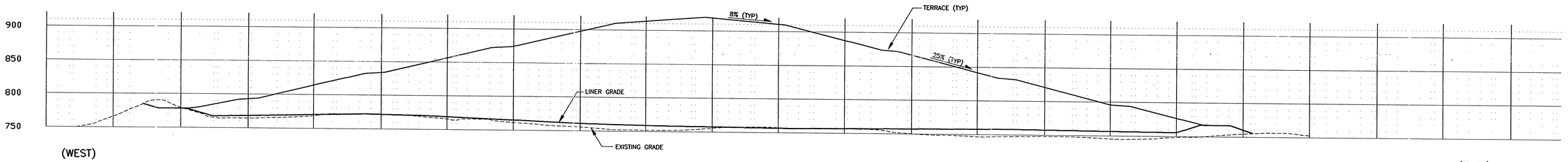
Date	Project No.	Fig No.	Issue
NOV. 1995	6770-021-018	C-8	A1

Scale: 1" = 100'

FILENAME: P:\GSBORO\2101C-6R.DWG



CROSS SECTION A
C-9
C-7



CROSS SECTION B
C-9
C-7

FILENAME: P:\GBORO\2101C-4R.DWG

HDR Engineering, Inc.
of North Carolina
Suite 1400
128 S. Tryon Street
Charlotte, NC 28202-5001
(704) 338-1800

Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.
A1	REVISED: LINER SUBGRADE CONTOURS AND EXISTING TOPOGRAPHY	11/7/96	JEG	EAW	JCR	JCR
A	ISSUED FOR NCDEHNR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA PROFESSIONAL SEAL 16395 ENGINEER JOSEPH C. READLING

Project Manager: J. READLING, P.E.	
Architect	I&C/Process
Civil: E. WRIGHT, P.E.	Mechanical
Electrical	Structural
Geology	Drawn By: G. HUNEYCUTT

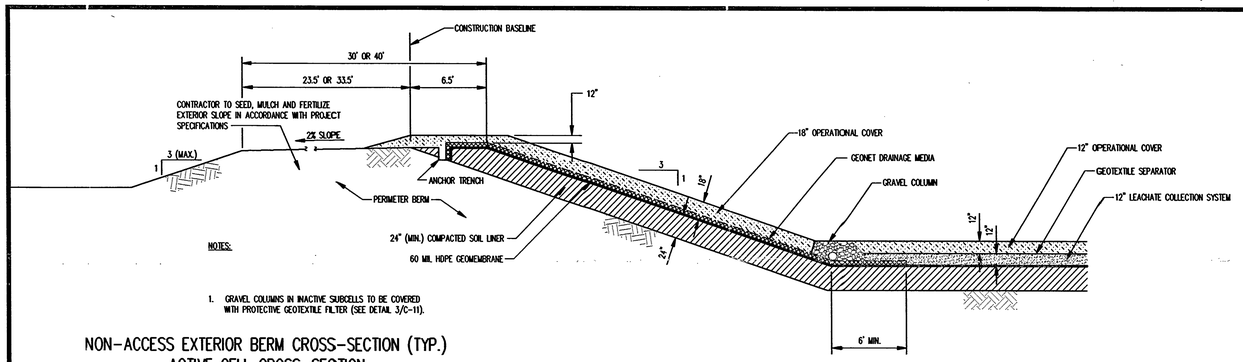
WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

CITY OF GREENSBORO NORTH CAROLINA

LANDFILL CROSS SECTIONS

Date	Project No.	Fig No.	Issue
NOV. 1995	6770-021-018	C-9	A1

Scale: 1" = 60'

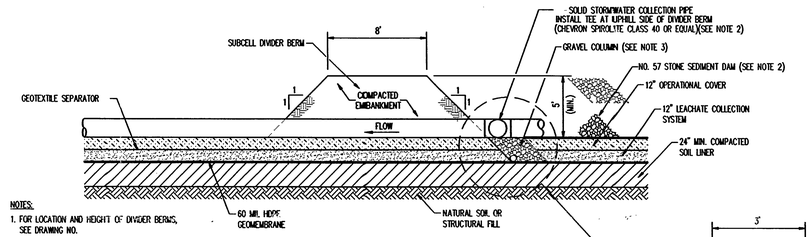


NOTES:

1. GRAVEL COLUMNS IN INACTIVE SUBCELLS TO BE COVERED WITH PROTECTIVE GEOTEXTILE FILTER (SEE DETAIL 3/C-11).

NON-ACCESS EXTERIOR BERM CROSS-SECTION (TYP.)
ACTIVE CELL CROSS-SECTION

DETAIL 1 / C-10

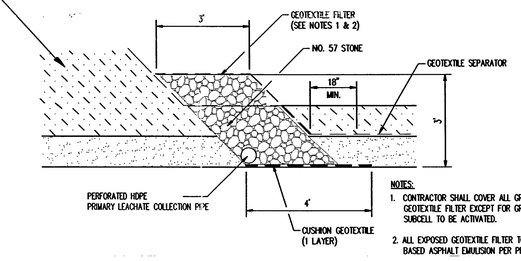


NOTES:

1. FOR LOCATION AND HEIGHT OF DIVIDER BERMS, SEE DRAWING NO.
2. SEDIMENTATION DAM TO HAVE 8' RADIUS ABOVE ENTRANCE OF STORMWATER PIPE MIN. HEIGHT OF DAM IS 18 INCHES.
3. HEIGHT OF GRAVEL COLUMN AROUND STORMWATER PIPE IS TWO FEET AND THREE FEET ELSEWHERE.

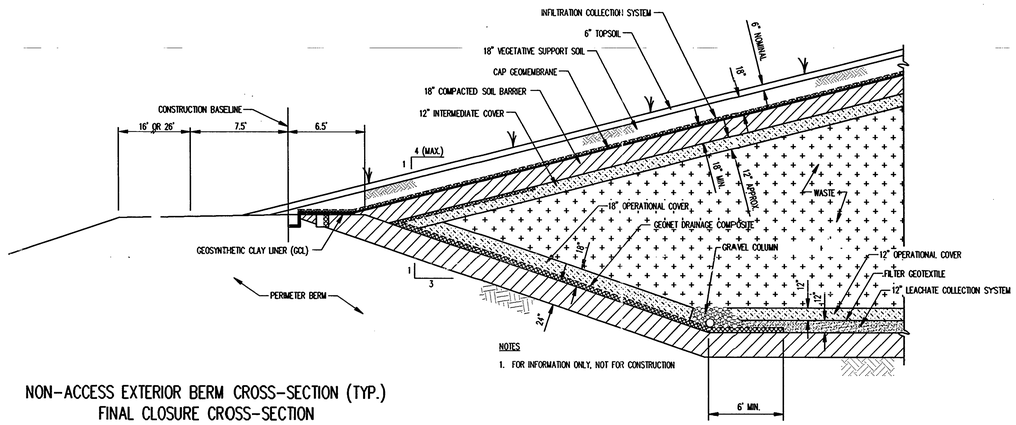
TYPICAL SUBCELL DIVIDER BERM CROSS-SECTION

DETAIL 4 / C-10
N.T.S.



NOTES:

1. CONTRACTOR SHALL COVER ALL GRAVEL DRAINS WITH GEOTEXTILE FILTER EXCEPT FOR GRAVEL DRAINS LOCATED IN FIRST SUBCELL TO BE ACTIVATED.
2. ALL EXPOSED GEOTEXTILE FILTER TO BE SEALED USING WATER BASED ASPHALT EMULSION PER PROJECT SPECIFICATIONS.

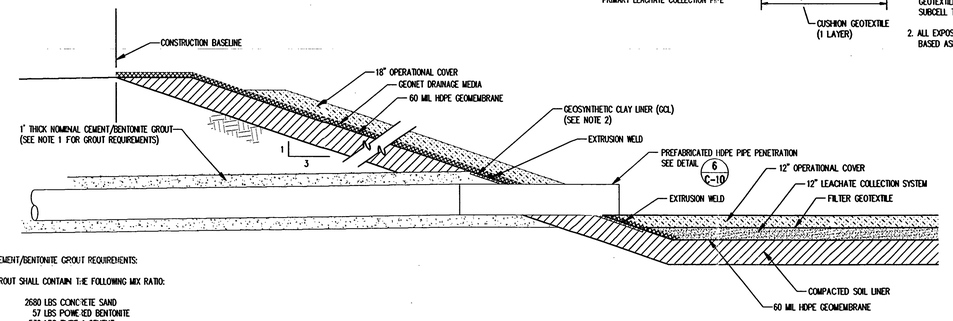


NOTES

1. FOR INFORMATION ONLY, NOT FOR CONSTRUCTION

NON-ACCESS EXTERIOR BERM CROSS-SECTION (TYP.)
FINAL CLOSURE CROSS-SECTION

DETAIL 2 / C-10
SCALE: 1"= 5'-0"

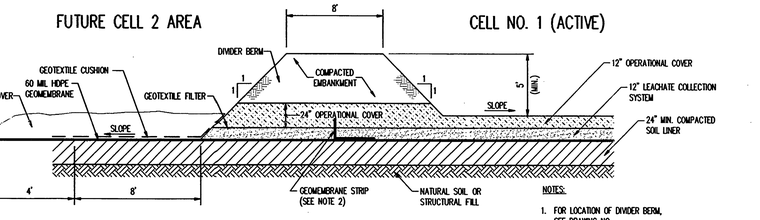


NOTES:

1. CEMENT/BENTONITE GROUT REQUIREMENTS:
   A. GROUT SHALL CONTAIN THE FOLLOWING MIX RATIO:
      2680 LBS CONCRETE SAND
      57 LBS POWDERED BENTONITE
      536 LBS TYPE I CEMENT
   B. THE WATER CONTENT SHALL BE ESTABLISHED IN THE FIELD IN ORDER TO ACHIEVE A SLUMP OF 2 TO 4 INCHES. WATER CONTENT IS SUBJECT TO APPROVAL BY THE ENGINEER AND WILL VARY BASED UPON CONDITIONS AT THE TIME OF CONSTRUCTION.
   C. ALLOW THE MIX TO CURE IN-PLACE FOR AT LEAST 24 HOURS PRIOR TO PLACEMENT OF THE GEOMEMBRANE. OBSERVE MIX FOR SIGNS OF DESICCATION, SHRINKAGE, CRACKING, ETC. BEFORE COVERING.
2. GCL TO BE PLACED OVER HDPE PIPE FLANGE AND SOIL LINER IMMEDIATELY BEFORE PLACEMENT OF GEOMEMBRANE. GCL SHALL OVERLAP PIPE FLANGE BY NO LESS THAN 3 INCHES AND EXTEND BEYOND PIPE FLANGE NO MORE THAN 3 FEET.

STORMWATER PIPE PENETRATION SCHEMATIC

DETAIL 5 / C-10
SCALE: 1"= 5'-0"

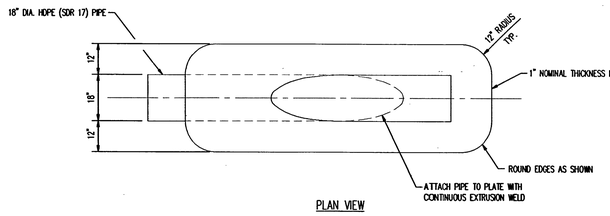


NOTES:

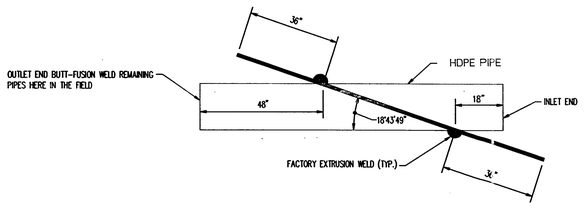
1. FOR LOCATION OF DIVIDER BERM, SEE DRAWING NO.
2. PLACE GEOMEMBRANE STRIP USING ON-SITE SCRAP 60 MIL HDPE GEOMEMBRANE OR OTHER GEOMEMBRANE AS APPROVED BY THE ENGINEER TO HYDRAULICALLY SEPARATE CELL NO. 1 & CELL NO. 2.

DIVIDER BERM BETWEEN CELLS 1 & 2 CROSS-SECTION

DETAIL 3 / C-10
SCALE: 1"= 5'-0"

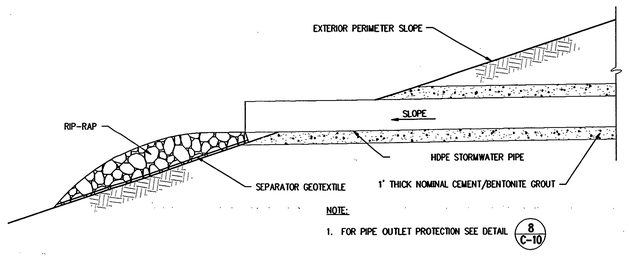


PLAN VIEW



PREFABRICATED PIPE PENETRATION

DETAIL 6 / C-10
SCALE: 1"=2'-0"

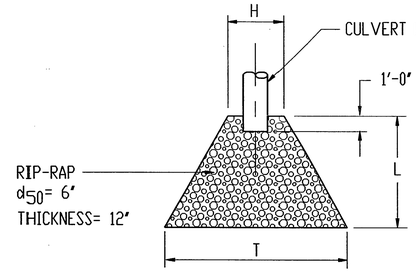


NOTE:

1. FOR PIPE OUTLET PROTECTION SEE DETAIL 8 / C-10

STORMWATER PIPE PENETRATION
OUTLET CONTROL

DETAIL 7 / C-10
N.T.S.



OUTLET PROTECTION PLAN VIEW

DETAIL 8 / C-10
N.T.S.

0 5' 10' 15'
1" = 5'-0"

0 2' 4' 6'
1" = 2'

G.N. RICHARDSON & ASSOCIATES, INC.
Engineering and Geological Services
417 N. BOYLAN AVENUE RALEIGH, N.C. 27603
PHONE-919-828-0577 FAX-919-828-3899

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 9895 GREGORY R. RICHARDSON

HDR Engineering, Inc.

Issue No.	Description	Date	Drawn	Check	Resp. Engr.	Proj. Mgr.
A1	PIPES ARE SHOWN ON PLAN SHEETS. SIZE REFERENCES DELETED FROM DETAILS.	11/7/96	EAW	JCR	JCR	JCR
A	ISSUED FOR NCDEHNR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

Project Manager: J. READLING, P.E.
Architect | I&C/Process
Civil: E. WRIGHT, P.E. | Mechanical
Electrical | Structural
Geology | Drawn By: JEG

WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION
CITY OF GREENSBORO NORTH CAROLINA

DETAILS

Date: NOVEMBER 1995 | Project No.: 6770-021-018 | Fig No.: C-10 | Issue: A1
Scale: AS NOTED

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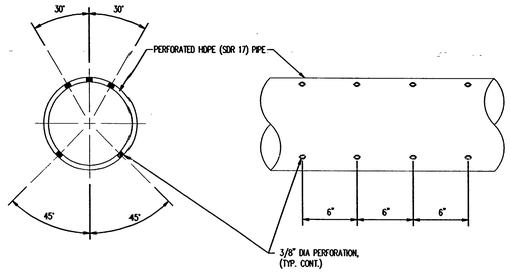
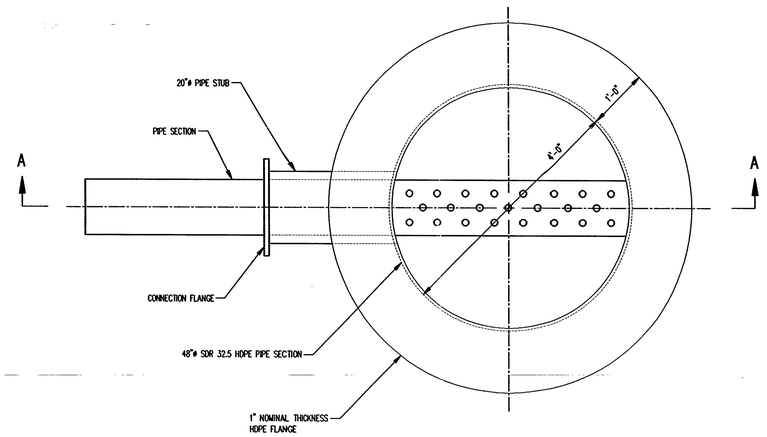
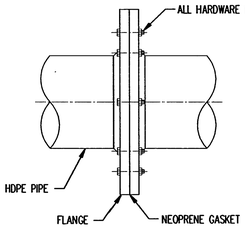


LEACHATE COLLECTION PIPE PERFORATION

DETAIL 1 / C-11 — N.T.S.



PLAN VIEW

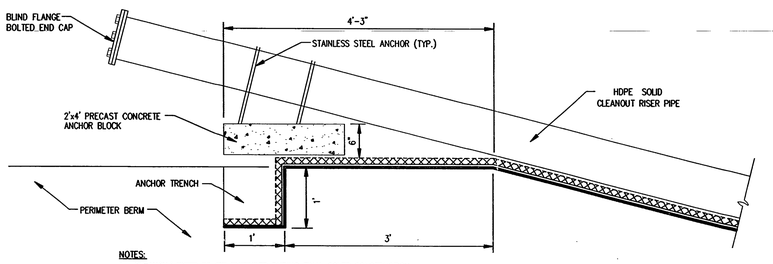


NOTES

1. FLANGE DIMENSIONS, BOLT SPACING, AND HARDWARE VARY BY PIPE DIAMETER PER ANSI STANDARDS.

FLANGED PIPE CONNECTION

DETAIL 7 / C-11 — N.T.S



NOTES:

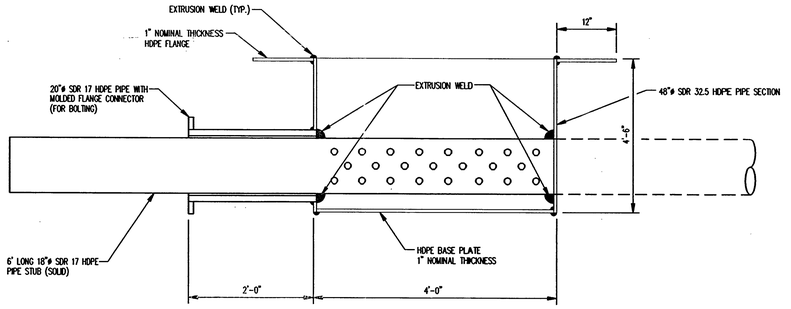
1. CLEANOUT RISER TO BE EXTENDED DURING FINAL COVER CONSTRUCTION.
2. ANCHOR TRENCH TO BE FILLED WITH EXCAVATED SOIL RECOMPACTED TO DENSITY OF SOIL LINER.

LEACHATE COLLECTION PIPE CLEANOUT AND ANCHOR TRENCH DETAIL AT CREST OF SLOPE

DETAIL 2 / C-11 — N.T.S

NOTE:

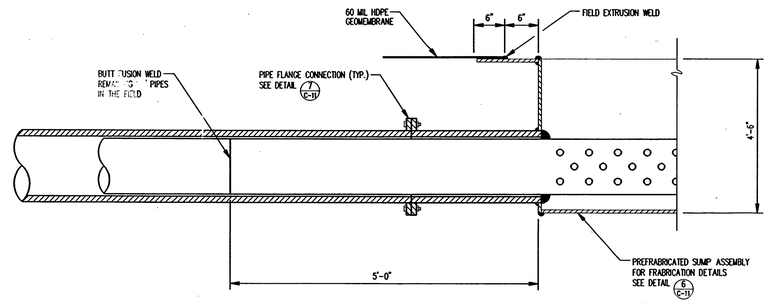
1. ALL WELDS FACTORY CONSTRUCTED.



SECTION A-A

PREFABRICATED HDPE SUMP

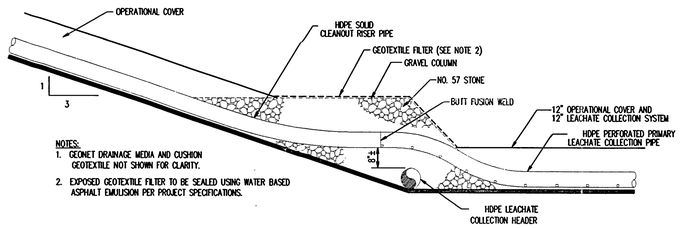
DETAIL 6 / C-11 — SCALE: N.T.S.



SUMP CONNECTIONS

DETAIL 8 / C-11 — SCALE 1"=1'-0"

0 1' 2' 3"
1" = 1'-0"

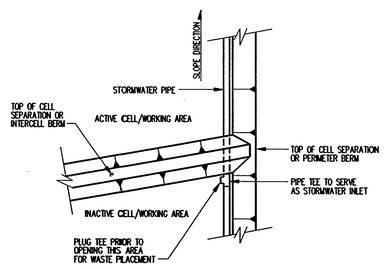


NOTES:

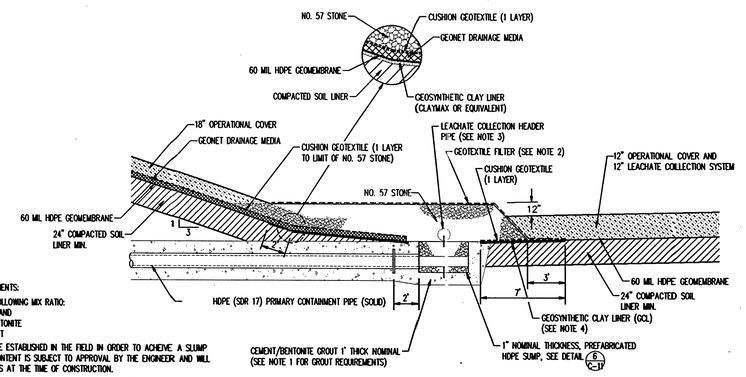
1. GEONET DRAINAGE MEDIA AND CUSHION GEOTEXTILE NOT SHOWN FOR CLARITY.
2. EXPOSED GEOTEXTILE FILTER TO BE SEALED USING WATER BASED ASPHALT EMULSION PER PROJECT SPECIFICATIONS.

LEACHATE COLLECTION PIPE CLEANOUT AT BASE OF SLOPE

DETAIL 3 / C-11 — SCALE: 1"= 2'-0"



PLAN VIEW



NOTES:

1. CEMENT/BENTONITE GROUT REQUIREMENTS:
   A. GROUT SHALL CONTAIN THE FOLLOWING MIX RATIO:
      2680 LBS CONCRETE SAND
      57 LBS POWDERED BENTONITE
      536 LBS TYPE I CEMENT
   B. THE WATER CONTENT SHALL BE ESTABLISHED IN THE FIELD IN ORDER TO ACHIEVE A SLUMP OF 2 TO 4 INCHES. WATER CONTENT IS SUBJECT TO APPROVAL BY THE ENGINEER AND WILL VARY BASED UPON CONDITIONS AT THE TIME OF CONSTRUCTION.
   C. ALLOW THE MIX TO CURE-IN-PLACE FOR AT LEAST 24 HOURS PRIOR TO PLACEMENT OF THE GEOMEMBRANE. OBSERVE MIX FOR SIGNS OF DESICCATION, SHRINKAGE CRACKING, ETC. BEFORE COVERING.
2. EXPOSED GEOTEXTILE FILTER TO BE SEALED USING WATER BASED ASPHALT EMULSION PER PROJECT SPECIFICATIONS.
3. TERMINATE LEACHATE COLLECTION HEADER PIPE OVER SUMP.
4. GCL TO BE PLACED ON SOIL LINER IMMEDIATELY BEFORE PLACEMENT OF GEOMEMBRANE. GCL SHALL EXTEND TO FLANGE OF HDPE SUMP AND HAVE A COVERAGE WIDTH OF 14 FEET.

PREFABRICATED HDPE SUMP

DETAIL 5 / C-11 — SCALE: 1"= 5'-0"

0 5' 10' 15'
1" = 5'-0"

0 2' 4' 6'
1" = 2'

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PHONE-919-828-0577 FAX-919-828-3899

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 8895 GREGORY N. RICHARDSON

HDR Engineering, Inc.

Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.
A1	PIPES ARE SHOWN ON PLAN SHEETS. SIZE REFERENCES DELETED FROM DETAILS.	11/7/96	EAW	JCR	JCR	JCR
A	ISSUED FOR NCDEHNR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

Project Manager: J. READLING, P.E.
Architect | M&C/Process
Civil: E. WRIGHT, P.E. | Mechanical
Electrical | Structural
Geology | Drawn By: JEG

WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION
CITY OF GREENSBORO NORTH CAROLINA

DETAILS

Date: NOV. 1995 | Project No.: 6770-021-018 | Fig No.: C-11 | Issue: A1
Scale: AS NOTED

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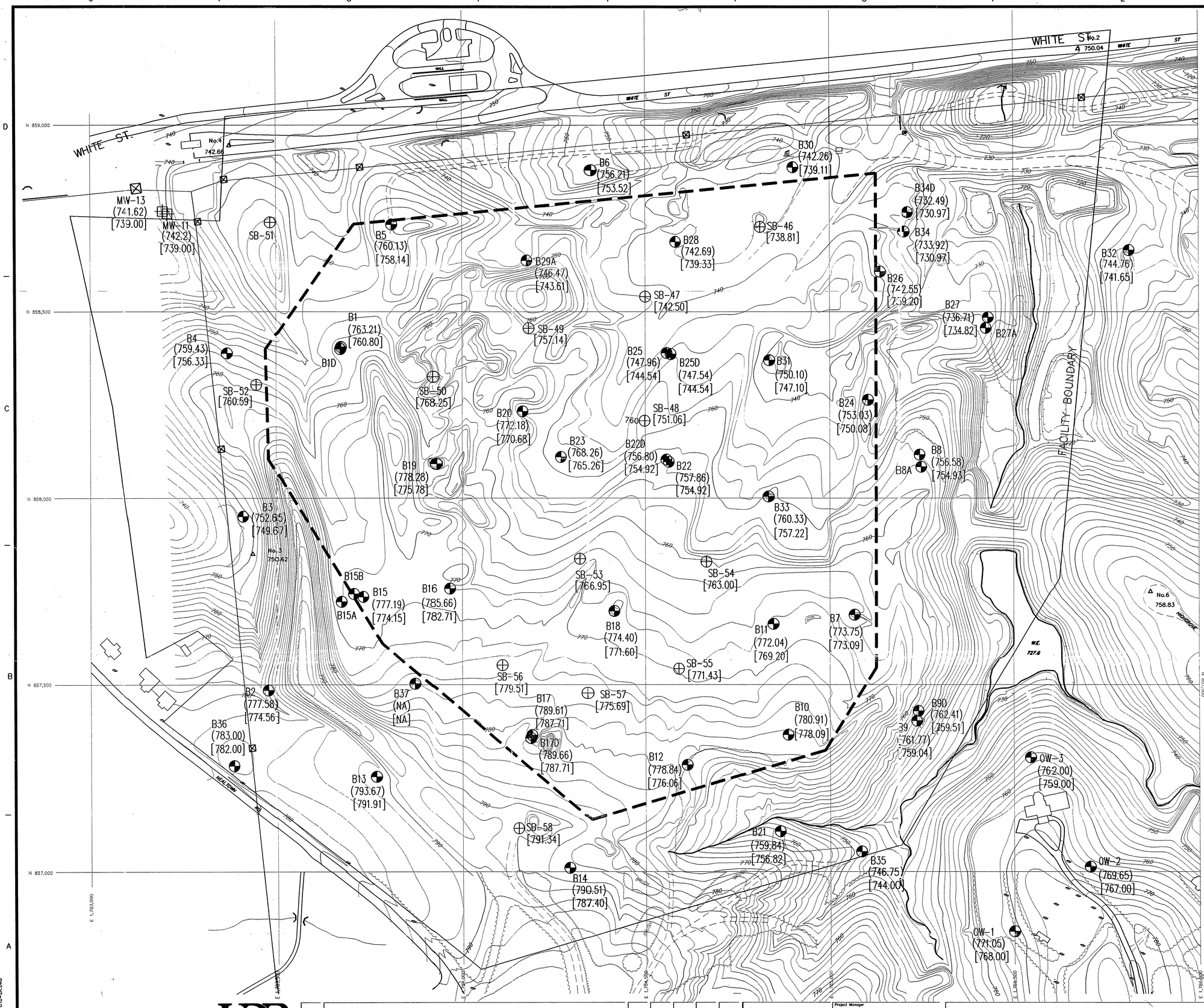

N

-100 0 50 100 200

SCALE: 1"=100'

LEGEND

- LIMITS OF WASTE
- PROPERTY LINE
- B33 (760.33) [757.22] — OBSERVATION WELL/PIEZOMETER (TOC ELEV.) [GROUND ELEV.]
- SB-58 — SHALLOW BORING
- MW-13 (741.62) [739.00] — MONITORING WELL (TOC ELEV.) [GROUND ELEV.]

PIEZOMETER AND WELL INSTALLATION TYPE

B1	SHALLOW ROCK
B1D	DEEP ROCK
B2	SHALLOW SAPROLITE
B3	SHALLOW SAPROLITE
B4	SHALLOW ROCK
B5	SHALLOW ROCK
B6	DEEP ROCK
B7	SHALLOW SAPROLITE
B8	DEEP ROCK
B9	SHALLOW ROCK
B9D	DEEPROCK
B10	SHALLOW SAPROLITE
B11	SHALLOW SAPROLITE
B12	SHALLOW ROCK
B13	DEEP ROCK
B14	SHALLOW SAPROLITE
B15	SHALLOW SAPROLITE
B16	SHALLOW SAPROLITE
B17	SHALLOW ROCK (CORE)
B17D	DEEP ROCK
B18	SHALLOW ROCK (CORE)
B19	SHALLOW ROCK
B20	DEEP ROCK
B21	SHALLOW SAPROLITE
B22	SHALLOW SAPROLITE
B22D	DEEP ROCK
B23	SHALLOW SAPROLITE
B24	SHALLOW SAPROLITE
B25	DEEP SAPROLITE
B25D	DEEP ROCK (CORE)
B26	SHALLOW SAPROLITE)
B27	SHALLOW ROCK
B28	SHALLOW ROCK
B29a	SHALLOW SAPROLITE
B30	SHALLOW SAPROLITE
B31	SHALLOW SAPROLITE
B32	SHALLOW SAPROLITE
B33	SHALLOW SAPROLITE
B34	SHALLOW SAPROLITE
B34D	DEEP ROCK (CORE)
B35	SHALLOW SAPROLITE
B36	SHALLOW SAPROLITE
B37	SHALLOW SAPROLITE
MW-11	DEEP ROCK (CORE)
MW-13	SHALLOW ROCK (CORE)
OW-1	SHALLOW SAPROLITE
OW-2	SHALLOW ROCK
OW-3	SHALLOW ROCK

NOTES:

1. TOPOGRAPHY PROVIDED BY BRADY SURVEYING CO. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 9, 1994. FACILITY AREA UPDATED MAY 18, 1996.
2. PLANIMETRIC FEATURES PROVIDED BY GUILFORD CO. MAPS DATED 1991.
3. BOUNDARY SURVEY PROVIDED BY CITY OF GREENSBORO DATED DECEMEER 27, 1994.

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Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.
A2	REVISED EXISTING CONTOURS, WELL LOCATIONS, CASING AND GROUND SURFACE ELEVATIONS AND ADDED B-37	11/7/96	JEG	EAW	JCR	JCR
A1	ISSUED FOR NCDEHNR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA LICENSED GEOLOGIST SEAL 761 CURTIS W. WELTY

Project Manager: J. READING, P.E.	
Architect	I&C/ Process
Civil: E. WRIGHT	Mechanical
Electrical	Struc.ural
Geology: C. LEE	Drawn By: JEG

WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

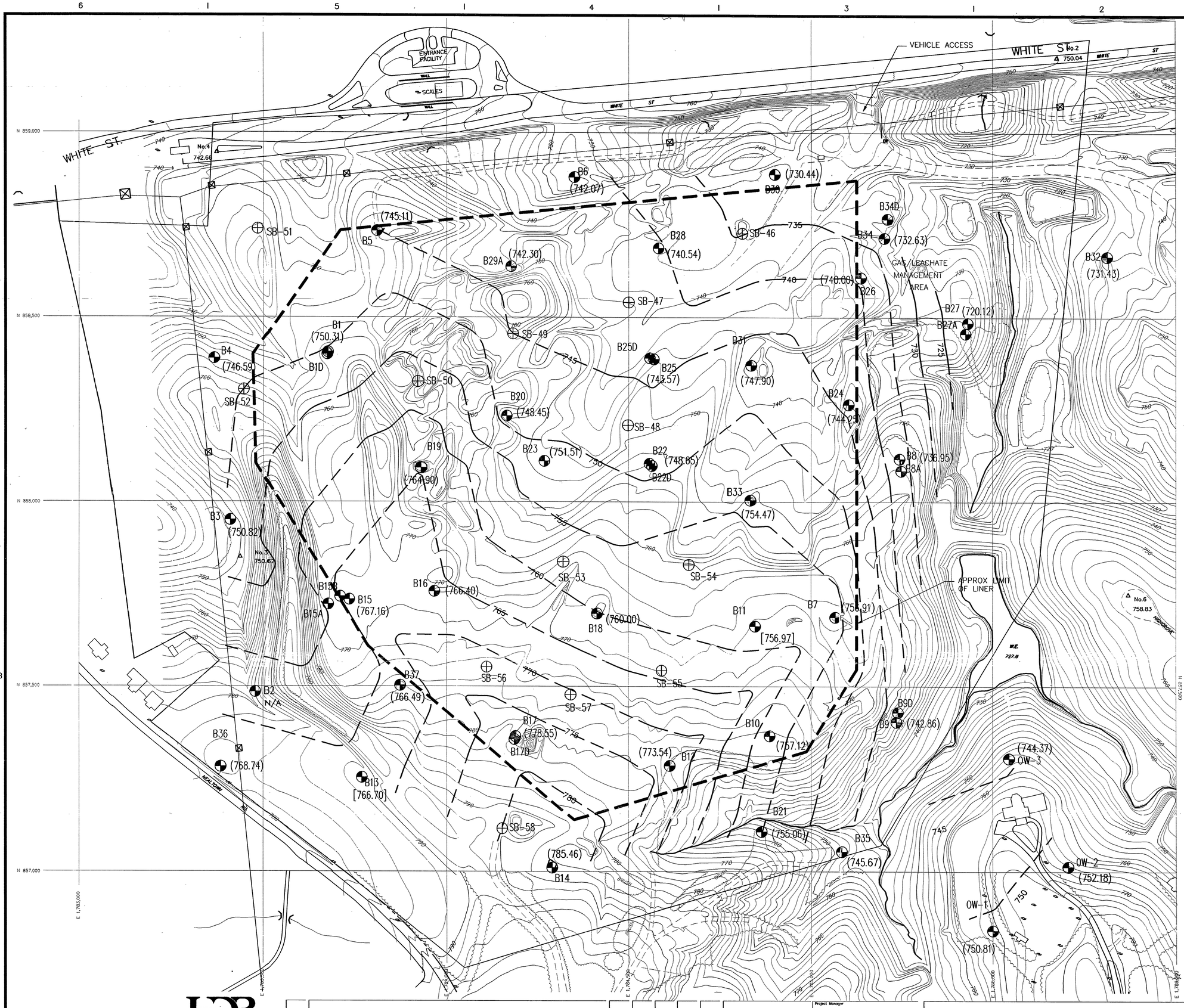
CITY OF GREENSBORO NORTH CAROLINA

SOIL BORING AND GROUND-WATER MONITORING WELL LAYOUT

Date	Project No.	Fig No.	Issue
NOVEMBER 1995	6770-021-018	D-1	A2

Scale: 1"=100'

FILENAME: P:\GSBRO\2101D-2R.DWG



N

−100 0 50 100 200

SCALE: 1" = 100'

LEGEND

- FACILITY BOUNDARY
- GROUNDWATER CONTOUR
- LIMITS OF WASTE
- PROPERTY LINE
- B33 (754.47) — BORING/PIEZOMETER
- SB-58 — SHALLOW BORING
- MW-13 — MONITORING WELL
- (750.47)[4] [750.47][5] — ESTIMATED LONG-TERM SEASONAL HIGH WATER TABLE ELEVATION (FEET MSL)
- 750 — ESTIMATED LONG-TERM SEASONAL HIGH WATER TABLE ELEVATION (CONTOUR) (FEET MSL)
- N/A — (N/A) NOT AVAILABLE (PIEZOMETER REMOVED)

NOTES:

1. TOPOGRAPHY PROVIDED BY BRADY SURVEYING CO. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 9, 1994. FACILITY AREA UPDATED MAY 18, 1996.
2. PLANIMETRIC FEATURES PROVIDED BY GUILFORD COUNTY MAPS DATED 1991.
3. BOUNDARY SURVEY PROVIDED BY CITY OF GREENSBORO DATED DECEMBER 27, 1994.
4. ESTIMATED LONG-TERM SEASONAL HIGH WATER TABLE ELEVATIONS ARE BASED ON ACTUAL SEASONAL HIGH ELEVATIONS MEASURED ON JANUARY 29, 1996 ADJUSTED FOR LONG-TERM SEASONAL HIGH BASED ON USGS GROUNDWATER RECORDS FOR DAVIE COUNTY, NC (SEE THE DESIGN HYDROGEOLOGICAL REPORT) EXCEPTIONS ARE NOTED BELOW.
5. ACTUAL MEASURED SEASONAL HIGH WATER TABLE ELEVATION (SHOWN IN BRACKETS) WITHOUT THE ADJUSTMENT FACTOR ADDED (SEE THE DESIGN HYDROGEOLOGIC REPORT).
6. PIEZOMETER WAS NOT READ ON JANUARY 29, 1996 THE ELEVATION USED FOR B11 WAS INTERPOLATED AND THE THE ADJUSTMENT MADE.

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Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.
A2	REVISED GROUNDWATER CONTOURS, EXISTING TOPOGRAPHY AND BORING LOCATIONS.	11/7/96	GRH	EAW	CGL	JCR
A1	ISSUED FOR NCDEHNR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA LICENSED SEAL 1091 GEOLOGIST CURTIS M. WELTY

Project Manager	J. READLING, P.E.
Architect	I&C/Process
Civil	E. WRIGHT
Electrical	Mechanical
Geology	C. LEE
	Structural
	Drawn By JEG

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ESTIMATED LONG-TERM SEASONAL HIGH WATER TABLE

Date	Project No.	Fig No.	Issue
NOVEMBER 1995	6770-021-018	D-2	A2

Scale: 1" = 100'

FILENAME: P:\GSBRO\21010-28.DWG

N

−100 0 50 100 200

SCALE: 1"=100'
CONTOUR INTERVAL = 5 FEET

LEGEND

- LIMITS OF WASTE
- PROPERTY LINE
- 760 — BEDROCK SURFACE ELEVATION CONTOUR (MSL)
- (764.78) — BEDROCK SURFACE ELEVATION (FEET MSL)
- B33 — BORING/PIEZOMETER
- SB-58 — SHALLOW BORING
- MW-13 — MONITORING WELL

NOTES:

1. TOPOGRAPHY PROVIDED BY BRADY SURVEYING CO. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 9, 1994. FACILITY AREA UPDATED MAY 18, 1996.
2. PLANIMETRIC FEATURES PROVIDED BY GUILFORD CO. MAPS DATED 1991.
3. BOUNDARY SURVEY PROVIDED BY CITY OF GREENSBORO DATED DECEMBER 27, 1994.

Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.
A2	REVISED EXISTING CONTOURS, WELL LOCATIONS AND BEDROCK SURFACE CONTOURS TO MATCH REVISED WELL LOCATIONS.	11/7/96	RNS	JRI	CGL	JCR
A1	INCORPORATED COMMENTS AND REISSUED FOR NCDEHNR APPROVAL	2/21/96	DNC	EAW	JCR	JCR
A	ISSUED FOR NCDEHNR APPROVAL	11/26/95	JEG	EAW	JCR	JCR

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NORTH CAROLINA LICENSED GEOLOGIST SEAL 109 CURTIS M. WESLEY

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Civil	Mechanical
E. WRIGHT	
Electrical	Structural
Geology	Drawn By
C. LEE	JEG

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PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

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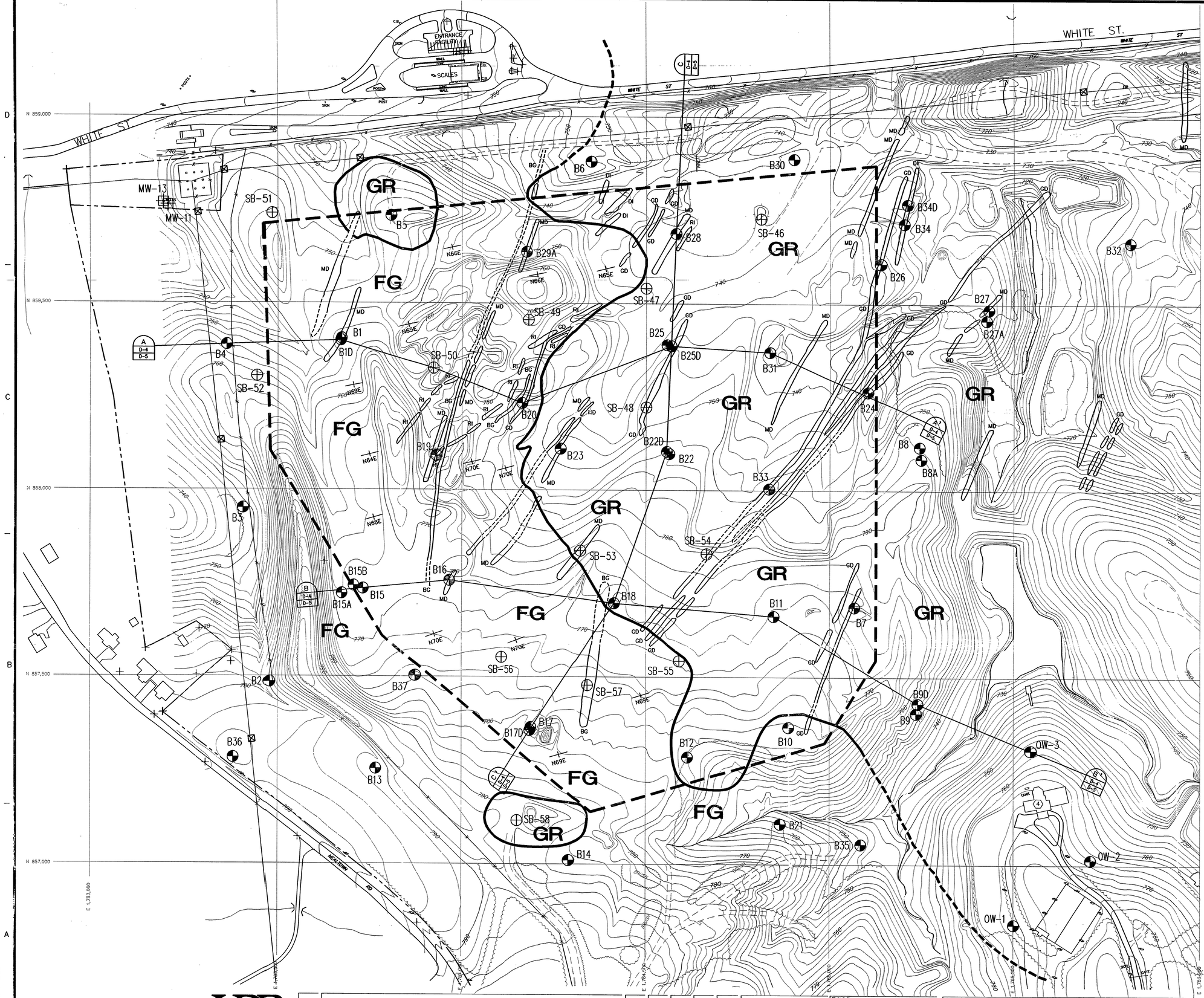
BEDROCK SURFACE CONTOUR MAP

Date	Project No.	Fig No.	Issue
FEBRUARY 1996	6770−021−018	D-3	A2
Scale 1"=100'			

FILENAME: P:\GBORO\21010-3.DWG



N

-100 0 50 100 200

SCALE: 1"=100'

EXPLANATION

	LIMITS OF WASTE
	PROPERTY LINE
B33	BORING/PIEZOMETER
SB-58	SHALLOW BORING
MW-13	MONITORING WELL
FG	FELSIC GNEISS
GR	GRANITE
RI	RHYOLITE INTRUSIVE
MD	MAFIC INTRUSIVE
BG	BASALT/GABBRO
DI	DIORITE
GD	GREENSTONE DIKE
N70E	STRIKE ON NEAR VERTICAL FOLIATIONS
	MAJOR LITHOLOGIC CONTACT (DASHED WHERE UNCERTAIN)
A / D-1 / D-5 — A' / D-1 / D-5	CROSS SECTION LINE

NOTES:

1. TOPOGRAPHY PROVIDED BY BRADY SURVEYING CO. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 9, 1994. FACILITY AREA UPDATED MAY 18, 1996.
2. PLANIMETRIC FEATURES PROVIDED BY GUILFORD CO. MAPS DATED 1991.
3. BOUNDARY SURVEY PROVIDED BY CITY OF GREENSBORO DATED DECEMBER 27, 1994.
4. ABANDONED BUILDINGS (3) OWNED BY THE CITY. THESE BUILDINGS WILL BE DEMOLISHED OR CONVERTED FOR NON RESIDENTIAL USE BY THE CITY.

FILENAME: P:\GBORO\2101D-4A.DWG

HDR

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128 S. Tryon Street
Charlotte, NC 28202-5001
(704) 338-1800

Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.
A2	REVISED EXISTING CONTOURS, WELL LOCATIONS AND ADJUSTED GEOLOGY TO MATCH WITH REVISED WELL LOCATIONS.	11/7/96	GRH	JRI	CGL	JCR
A1	ISSUED FOR NCDEHNR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA LICENSED SEAL 1091 GEOLOGIST CURTIS M. WELTY

Project Manager: J. READLING, P.E.	
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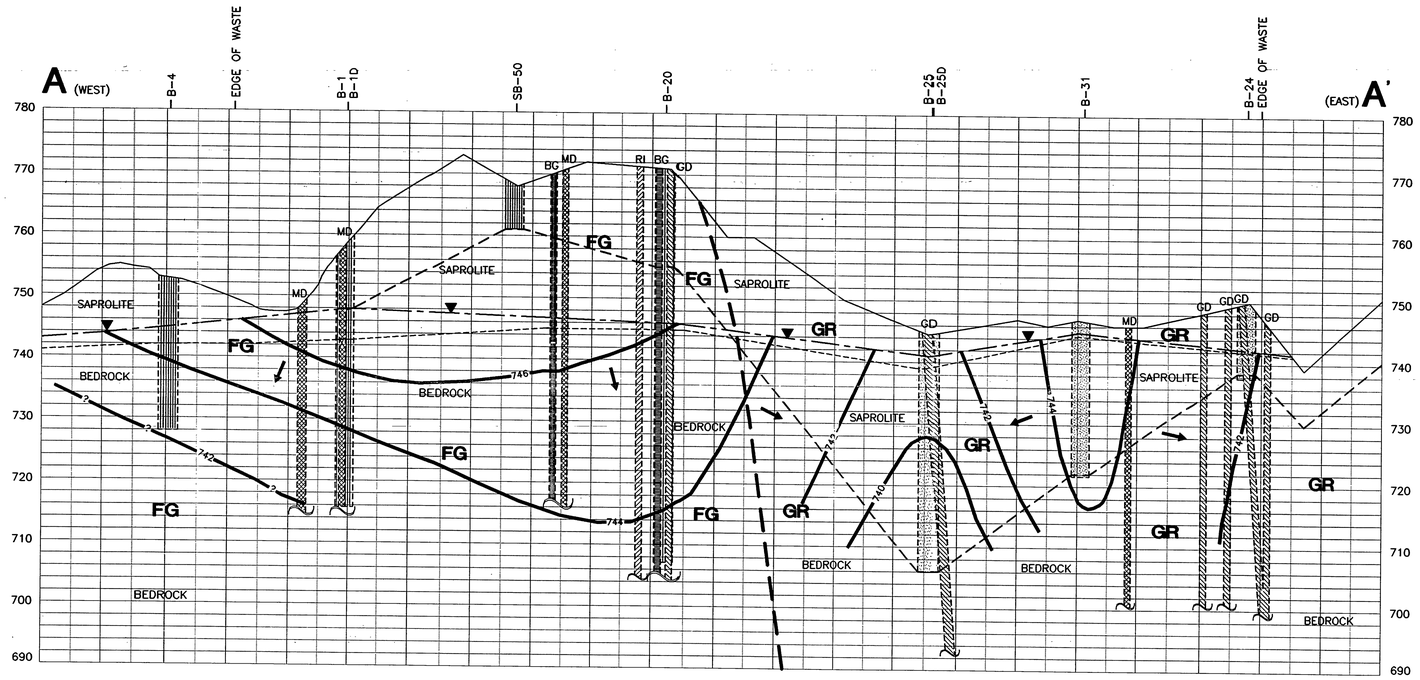
Civil: E. WRIGHT	Mechanical
Electrical	Structural
Geology: C.G. LEE	Drawn By: JEG

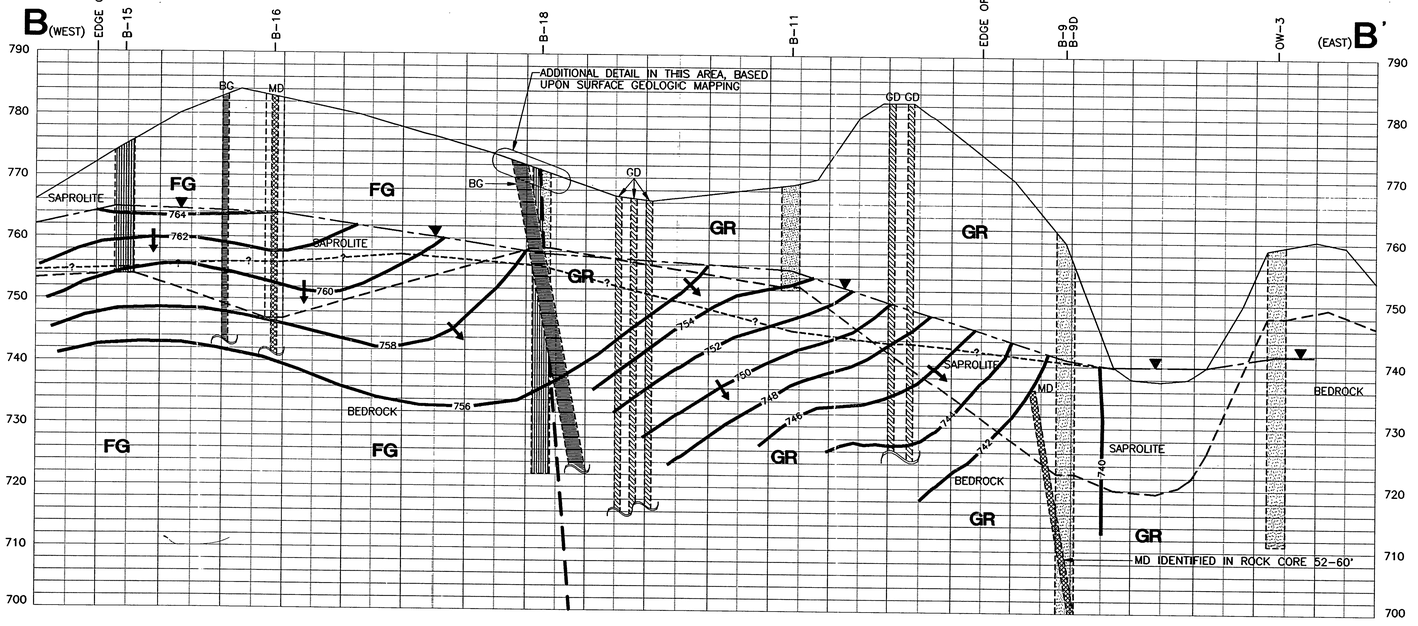
WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

CITY OF GREENSBORO NORTH CAROLINA

GEOLOGIC MAP

Date	Project No.	Fig No.	Issue
NOV. 1995	6770-021-018	D-4	A2
Scale: 1"=100'			





EXPLANATION

- EXISTING GRADE (FROM NOV. 9, 1994 AERIAL TOPOGRAPHY.)
- WATER TABLE (1/29/96 ELEVATIONS, UPPERMOST AQUIFER)
- WATER TABLE (1/29/96 ELEVATIONS, BEDROCK AQUIFER) (UNDIFFERENTIATED, QUERIED WHERE UNCERTAIN)
- SAPROLITE/BEDROCK CONTACT
- MAJOR LITHOLOGIC CONTACT (GRANITE/GNEISS)
- MINOR LITHOLOGIC CONTACT (MAFIC/FELSIC INTRUSIVES)
- 744 WATER TABLE POTENTIOMETRIC CONTOUR (FEET MSL). QUERIED WHERE UNCERTAIN.
- VERTICAL COMPONENT OF GROUND-WATER FLOW (APPARENT)
- FELSIC GNEISS (FG)
- GRANITE (GR)
- RHYOLITE INTRUSIVE (RI)
- MAFIC INTRUSIVE (MD) (UNDIFFERENTIATED)
- GREENSTONE DIKES (GD)
- BASALT/GABBRO (BG)
- DIORITE

SCALE:

HORIZONTAL SCALE: −100 0 50 100 200

VERTICAL SCALE: −10 0 5 10 20

CONTOUR INTERVAL = 2.0 FEET

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Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.
A2	REVISED GROUND-WATER POTENTIOMETRIC ELEVATIONS AND ADDED VERTICAL FLOW DATA	11/7/96	R SATT	JRI	CGL	JCR
A1	ISSUED FOR NCDEHNR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA LICENSED PROFESSIONAL GEOLOGIST CURTIS M. WEAVER

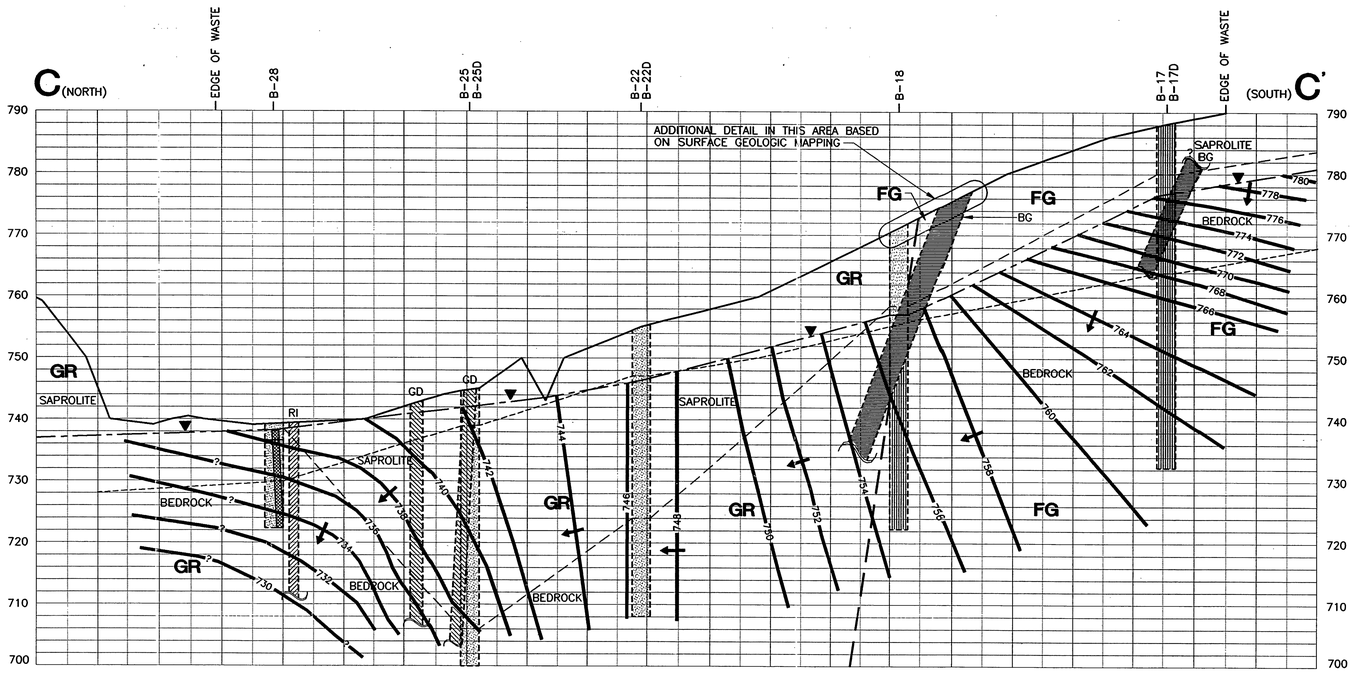
Project Manager	J. READLING, P.E.
Architect	I&C/Process
Civil	Mechanical
Electrical	Structural
Geology	Drawn By
C. LEE	J. GAUL

WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION
CITY OF GREENSBORO NORTH CAROLINA

HYDROSTRATIGRAPHIC GEOLOGIC CROSS-SECTIONS

Date	Project No.	Fig No.	Issue
NOVEMBER 1995	06770-021-018	D-5A	A2
Scale: AS SHOWN			

FILENAME: P:\GBORO\21010-5A.DWG



EXPLANATION

- EXISTING GRADE (FROM NOV. 9, 1994 AERIAL TOPOGRAPHY.)
- WATER TABLE (1/29/96 ELEVATIONS, UPPERMOST AQUIFER)
- WATER TABLE (1/29/96 ELEVATIONS, BEDROCK AQUIFER) (UNDIFFERENTIATED, QUERIED WHERE UNCERTAIN)
- SAPROLITE/BEDROCK CONTACT
- MAJOR LITHOLOGIC CONTACT (GRANITE/GNEISS)
- MINOR LITHOLOGIC CONTACT (MAFIC/FELSIC INTRUSIVES)
- WATER TABLE POTENTIOMETRIC CONTOUR (FEET MSL). QUERIED WHERE UNCERTAIN.
- VERTICAL COMPONENT OF GROUND-WATER FLOW (APPARENT)
- FELSIC GNEISS (FG)
- GRANITE (GR)
- RHYOLITE INTRUSIVE (RI)
- MAFIC INTRUSIVE (MD) (UNDIFFERENTIATED)
- GREENSTONE DIKES (GD)
- BASALT/GABBRO (BG)
- DIORITE

SCALE:

−100 0 50 100 200
HORIZONTAL SCALE

−10 0 5 10 20
VERTICAL SCALE

CONTOUR INTERVAL = 2.0 FEET

FILENAME: P:\GBORO\21010-5B.DWG

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Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.
A2	REVISED GROUND-WATER POTENTIOMETRIC ELEVATIONS AND ADDED VERTICAL FLOW DATA	11/7/96	R SATT	JRI	CGL	JCR
A1	ISSUED FOR NCDHENR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA LICENSED REAL ESTATE GEOLOGIST 1091 CURTIS M. WELTY

Project Manager	J. READLING, P.E.
Architect	I&C/Process
Civil	Mechanical
Electrical	Structural
Geology: C. LEE	Drawn By: J. GAUL

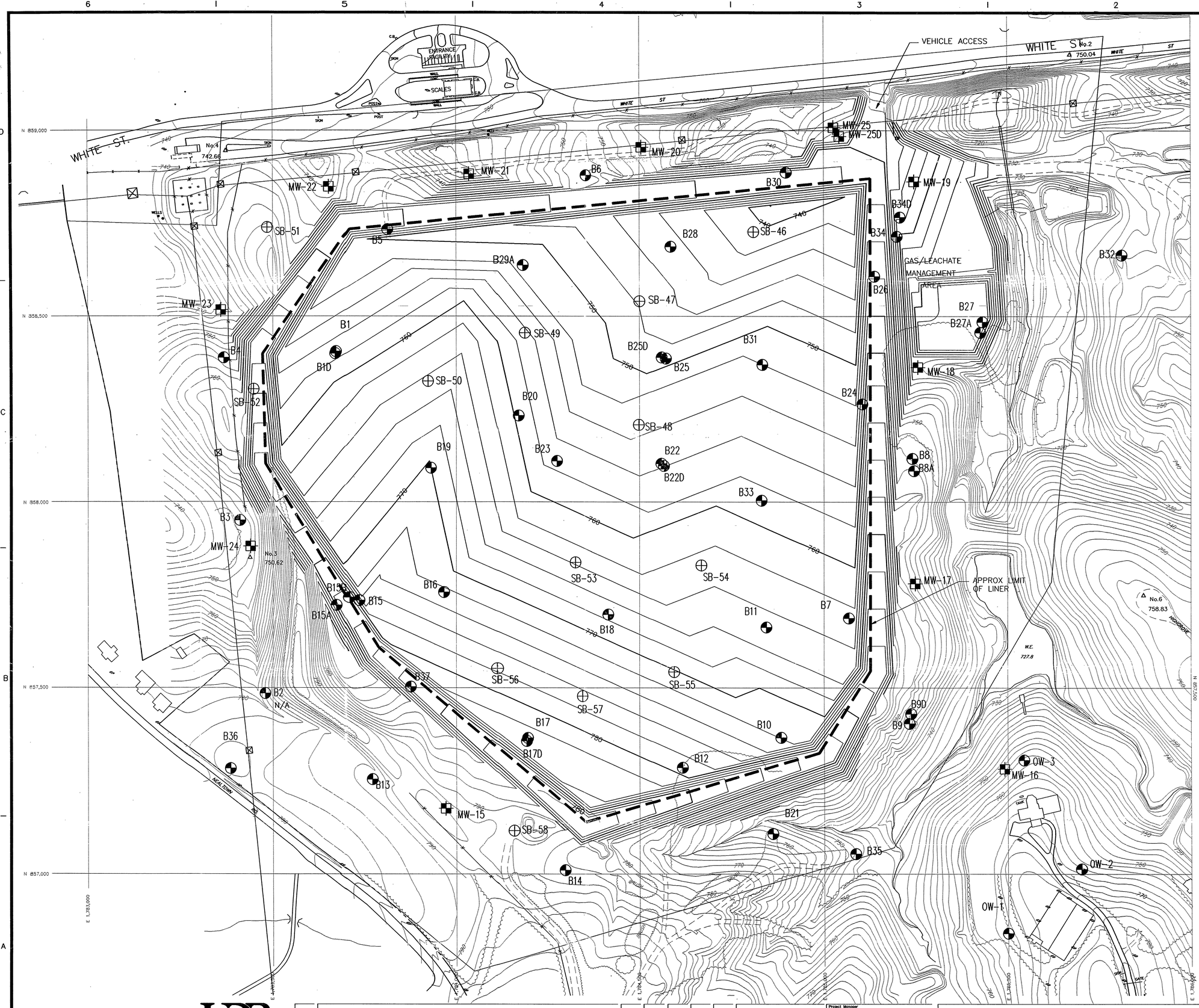
WHITE STREET SANITARY LANDFILL
PHASE III EXPANSION
CONSTRUCTION PERMIT APPLICATION

CITY OF GREENSBORO NORTH CAROLINA

HYDROSTRATIGRAPHIC GEOLOGIC CROSS-SECTIONS

Date	Project No.	Fig No.	Issue
NOVEMBER 1995	06770-021-018	D-5B	A2

Scale: AS SHOWN



N

−100 0 50 100 200

SCALE: 1"=100'

LEGEND

	FACILITY BOUNDARY
	LIMITS OF WASTE
	PROPERTY LINE
B33 (754.47)	BORING/PIEZOMETER
SB-58	SHALLOW BORING
MW-13	MONITORING WELL
MW-15	PROPOSED MONITORING WELL
(750.47)[4] [750.47][5]	ESTIMATED LONG-TERM SEASONAL HIGH WATER TABLE ELEVATION (FEET MSL)
N/A	(N/A) NOT AVAILABLE (PIEZOMETER REMOVED)

NOTES:

1. TOPOGRAPHY PROVIDED BY BRADY SURVEYING CO. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 9, 1994. FACILITY AREA UPDATED MAY 18, 1996.
2. PLANIMETRIC FEATURES PROVIDED BY GUILFORD COUNTY MAPS DATED 1991.
3. BOUNDARY SURVEY PROVIDED BY CITY OF GREENSBORO DATED DECEMBER 27, 1994.
4. PROPOSED CONTOURS SHOWN REPRESENT SUBGRADE (BOTTOM OF CLAY LINER).

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Issue No.	Description	Date	Drawn.	Chkd.	Resp. Engr.	Proj. Mgr.
A3	REVISED LOCATIONS & NUMBERS OF MONITORING WELL PER NCDEHNR COMMENTS	12/12/96	GRH	CGL		
A2	REVISED EXIST. TOPO. AND BORING LOC. ADDED GW MONITORING WELLS MW-15 THRU MW-24	11/7/96	GRH	CGL		
A1	ISSUED FOR NCDEHNR APPROVAL	11/28/95	JEG	EAW	JCR	JCR

NORTH CAROLINA LICENSED SEAL 4091 GEOLOGIST CURTIS M. WELTY

Project Manager: J. READING, P.E.	
Architect	I&C/Process
Civil: E. WRIGHT	Mechanical
Electrical	Structural
Geology: C. LEE	Drawn By: JEG

WHITE STREET SANITARY LANDFILL PHASE III EXPANSION CONSTRUCTION PERMIT APPLICATION

CITY OF GREENSBORO NORTH CAROLINA

PROPOSED MONITORING WELL LOCATIONS

Date	Project No.	Fig No.	Issue
NOVEMBER 1995	6770-021-018	D-6	A3

Scale: 1"=100'

WHITE STREET SANITARY LANDFILL
GREENSBORO, NORTH CAROLINA

DESIGN HYDROGEOLOGIC REPORT

Prepared for:

The City of Greensboro

Prepared by:

HDR Engineering, Inc.
of North Carolina

HDR

Project No. 06770-021-018

Final Report

January 7, 1997

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C Slug Test Data

D Miscellaneous Support Documentation

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D-2	Estimated Long-Term Seasonal High Water Table
D-3	Bedrock Surface Contour Map
D-4	Geologic Map
D-5A	Hydrostratigraphic Geologic Cross-Sections A-A′ and B-B′
D-5B	Hydrostratigraphic Geologic Cross-Sections C-C′
D-6	Proposed Monitoring Well Locations

SECTION 1
INTRODUCTION

1.1 Purpose

The North Carolina Solid Waste Management Rules (SWM Rules) and Solid Waste Management Law require that a Design Hydrogeologic Report be submitted in the application for the Permit to Construct a new Subtitle D solid waste landfill. This Design Hydrogeologic Report for the White Street Landfill expansion in Greensboro presents the results of investigations which follow up and supplement the Draft Site Hydrogeologic Study previously submitted to the Division of Solid and Hazardous Waste.

1.2 Scope

The Design Hydrogeologic Report focuses specifically on the proposed landfill expansion footprint plus a 300-foot buffer zone along its downgradient margin. In accordance with the SWM Rules, this Design Hydrogeologic Report incorporates and extends the boring program completed for the Site Study. To this end, it provides stratigraphic and hydrogeologic cross-sections and water table information including horizontal and vertical dimensions of ground-water flow, ground-water contour maps, a site boring plan map, boring logs and well and piezometer construction records, a bedrock contour map, rock coring logs, and identifies other geologic and hydrogeologic considerations. Specifically, the Design Hydrogeologic Report must also provide the results of supplemental investigations aimed at demonstrating compliance with vertical separation and foundation standards, and detailed and localized data on the hydrogeologic regime of the uppermost aquifer to facilitate design of an effective water quality monitoring system and define the relevant point of compliance for the proposed solid waste management unit.

1.3 Previous Investigations

This Design Hydrogeologic Report is a summary of the information collected through subsurface investigations conducted at the proposed landfill expansion site (the Phase III area) beginning in 1989. It incorporates the results of the previous investigation efforts, along with follow-up field work conducted by HDR in October 1995.

Two monitoring wells (MW-11 and MW-13) were installed in 1989 and 1993, respectively, initially as upgradient monitoring points for the active landfill. These wells are located in the northwest corner of the expansion site, but the bulk of subsurface investigation conducted across the Phase III site occurred between late October 1994 and early January 1995, when G. N. Richardson and Associates, Inc. (GNRA) drilled 49 borings at 39 locations, and installed 45 observation wells/piezometers.

1.4 Design Hydrogeologic Investigation

Field subsurface investigations were initiated by HDR in October 1995 to supplement the previous work. A total of 13 additional shallow borings were advanced in order to gain further data on the major stratigraphic units present within the proposed 51-acre Phase III landfill footprint. A combined total of 64 borings were advanced during all investgations at the Phase III area. The boring, monitoring well, observation well, and piezometer locations are shown on Figure D-1.

A total of 36 soil samples were obtained for the combined site and design hydrogeologic investigations and submitted for geotechnical analysis. Six of these samples were submitted specifically for the design hydrogeologic investigation.

Additional efforts were also undertaken to conduct detailed geologic mapping in the Phase III footprint and make an assessment of the ground-water flow regime in the area.

SECTION 2
INFORMATION FROM SITE HYDROGEOLOGIC REPORT

North Carolina Solid Waste Management Rule .1623(b)(2)(A) requires that information required in .1623(a)(4) through (a)(12) for the Site Hydrogeologic Report be included in the Design Hydrogeologic Report. A Site Hydrogeologic Report following Rule .1623(a) was required for the Phase III expansion area and was submitted April 7, 1995; that report was subsequently revised, the latest revision is dated June 4, 1996. The information presented in this section is a summary compilation of data from the Site Hydrogeologic Report and previous investigations.

2.1 Testing Program for Borings

Rule .1623(a)(4) requires a laboratory testing program for soil samples obtained during the subsurface investigations. Boring logs for each of the 64 borings advanced across the Phase III expansion area are provided in Appendix A. These boring logs include records of standard penetration resistance, particle size analysis, soil classification, and formation descriptions.

A total of 36 soil samples were collected for geotechnical analysis to provide a characterization of each of the lithologic units in the uppermost aquifer, and determine the suitability of on-site soils for use as cover and/or liner materials. The laboratory analyses are compiled in Appendix B.

Thirty split-spoon samples (SPTs) obtained for the Site Study were described and analyzed for grain size distribution, USCS Classification, and Atterburg Limits. Correlation of these tested samples with boring logs and surface geology indicates that 15 samples are from saprolite derived from "granite", eight samples are from saprolite derived from "felsic gneiss", five samples are from "mafic intrusive dikes", and two samples were from "greenstone dikes" that intrude the granite. Although Atterberg limits were completed on only 14 of the samples, the following are the Unified Soil Classification System names for these samples:

Granite Saprolite (average fines content = 27%)
Silty SAND (SM) - 12 samples
Silty Clayey SAND (SC-SM) - 2 samples
Poorly Graded SAND with Silt (SP-SM) - 1 sample

Felsic Gneiss Saprolite (average fines content = 47%)
Silty SAND to Silty Clayey SAND (SM to SC-SM) - 4 samples
Sandy SILT (ML) - 3 samples
Sandy Elastic SILT (MH) - 1 sample)

Mafic Intrusive Saprolite (average fines content = 62%)
Elastic SILT with Sand (MH) - 2 samples
Sandy SILT (ML) - 1 sample
Silty Clayey SAND (SC-SM) - 1 sample
Silty SAND (SM) - 1 sample

Greenstone Dike Saprolite (fines content = 50%)
Clayey SAND (SC) - 1 sample
Sandy Lean CLAY (CL) - 1 sample

Not surprisingly, there is a good correlation between parent rock type and the saprolite produced by its weathering. The coarser grained, quartz-rich granite weathers to the coarsest material, while the mafic intrusives and greenstone intrusives weather to the finest material. The relatively quartz-rich but fine-grained felsic gneiss produces a saprolite with an intermediate texture.

As a function of depth, it is generally true that saprolite soils from the site grade from more highly weathered, fine-grained, clayey soils near the ground surface to less weathered, coarser, silty and sandy soils at depth. The thickness of the saprolite and partially weathered rock ranges from 0.5 to 38.5 feet across the site, with most locations having between 10 and 25 feet of saprolite above bedrock.

Six additional geotechnical samples were analyzed for the Design Study to provide data on moisture content, porosity, and indications of hydraulic conductivity for the uppermost aquifer. This data is also compiled in Appendix B.

Laboratory hydraulic conductivity testing was determined by performing a constant head permeability test on remolded (bulk) and undisturbed (Shelby Tube or pitcher barrel) samples. The remolded samples were compacted in accordance with ASTM D698, while the undisturbed samples were not remolded or compacted. Laboratory results indicate that site soils have remolded permeabilities ranging from 3.3 to 3.9 x 10^{-7} cm/sec (0.34 to 0.40 ft/year). These results indicate that, if on-site soils are used in construction of the clay liner, some bentonite augmentation would be required to achieve the 10^{-7} cm/sec regulatory requirement for clay liners. For those samples which are representative of the saprolite just above the water table (SB-46, SB-47, and SB-50), undisturbed permeability ranged from 1.0 x 10^{-6} to 2.7 x 10^{-6} cm/sec (1.03 to 2.79 ft/year). Porosity of these undisturbed soils ranges from 17.1% to 45%. Understandably, the lowest porosity was from B-47, the sample taken closest to bedrock. It is likely that the porosity measured here is secondary in nature and is associated with fractures just above the top of bedrock. For a more detailed treatment of in-situ permeability as related to ground-water flow, see Section 2.4.

2.2 Water Table Information

Rule .1623(a)(7) requires tabulations of stabilized water table elevations, an estimate of the seasonal high water table, and a discussion of any activities that have the potential for causing water table fluctuations.

A total of 47 piezometers or monitoring wells are currently accessible as water level measurement points in the Phase III area and immediate vicinity. Of these, 45 were installed specifically for the site and design hydrogeologic investigations. See Table 2-1 and Appendix A for piezometer/well construction information.

2.2.1 Stabilized Water Table Elevations

Static water levels were obtained from each of the 45 new piezometers at the time of installation, at 24 hours, and at monthly intervals thereafter. Following completion of the first set of stabilized readings (12/27/94), water level measurements were obtained by GNRA personnel on a monthly schedule. Stabilized water table elevations are presented in Table 2-2.

TABLE 2-1

Observation Well Construction Details
Site Hydrogeologic Investigation
White Street Sanitary Landfill Expansion
Greensboro, North Carolina

WELL NUMBER	WELL DEPTH (Feet)	BOREHOLE DIAMETER (Inches)	SCREEN INTERVAL (Feet)	TOP OF SAND (Feet)	TOP OF BENTONITE (Feet)	RISER STICK-UP (Feet)
B-1	33.00	6.25	23.0 - 33.0	21.0	19.0	2.41
B-1d	43.00	5.75	38.0 - 43.0	36.0	34.0	2.08
B-2	18.50	6.25	8.0 - 18.0	6.0	4.0	3.02
B-3	15.50	6.25	5.5 - 15.5	4.0	2.0	2.98
B-4	25.00	6.25	15.0 - 25.0	13.0	11.0	3.1
B-5	28.00	6.25	18.0 - 28.0	16.0	14.0	1.99
B-6	61.00	6.25	51.0 - 61.0	48.0	45.0	2.69
B-7	24.50	6.25	14.5 - 24.5	13.0	11.0	0.66
B-8	63.00	6.25	48.0 - 63.0	46.5	44.5	1.65
B-9	36.50	6.25	26.5 - 36.5	25.0	23.0	2.73
B-9d	67.00	5.75	62.0 - 67.0	60.0	58.0	2.90
B-10	32.50	6.25	22.5 - 32.5	21.5	19.5	2.82
B-11	16.50	6.25	6.5 - 16.5	5.0	3.0	2.84
B-12	28.00	6.25	13.0 - 28.0	11.0	9.0	2.78
B-13	53.00	6.25	43.0 - 53.0	41.0	38.0	1.76
B-14	16.50	6.25	6.5 - 16.5	5.0	3.0	3.11
B-15	19.50	6.25	9.5 - 19.5	8.0	6.0	3.04
B-16	36.00	6.25	26.0 - 36.0	23.5	21.5	2.95
B-17	28.00	6.25	18.0 - 28.0	16.5	14.5	1.90
B-17d	53.00	5.75	48.0 - 53.0	46.0	44.0	1.95
B-18	49.00	6.25	39.0 - 49.0	38.0	36.0	2.80
B-19	33.00	6.25	23.0 - 33.0	21.5	19.5	2.5
B-20	63.50	6.25	53.5 - 63.5	52.0	50.0	1.5
B-21	11.00	6.25	6.0-11.0	4.5	2.5	3.02

Notes:
1. B and OW series wells installed by G. N. Richardson and Associates, Oct. 1994-Jan. 1995.
2. Total depth and screen interval depths measured from ground surface at time of drilling
3. For borehole diameters, the first value (6.25) represents diameter produced using 4.25-inch ID hollow stem augers and the second value (5.75) represents the diameter produced using a standard NQ core barrel or 5.75-inch air hammer.

TABLE 2-1 (continued)

Observation Well Construction Details
Site Hydrogeologic Investigation
White Street Sanitary Landfill Expansion
Greensboro, North Carolina

WELL NUMBER	WELL DEPTH (Feet)	BOREHOLE DIAMETER (Inches)	SCREEN INTERVAL (Feet)	TOP OF SAND (Feet)	TOP OF BENTONITE (Feet)	RISER STICK-UP (Feet)
B-22	31.00	6.25	21.0 - 31.0	18.5	16.5	2.94
B-22d	46.50	5.75	41.5 - 46.5	39.5	37.5	1.88
B-23	31.00	6.25	21.0 - 31.0	19.5	17.5	3.00
B-24	12.00	6.25	7.0 - 12.0	5.5	3.5	2.95
B-25	38.50	6.25	28.5 -38.5	27.0	25.0	3.42
B-25d	52.00	5.75	47.0 - 52.0	45.0	43.0	3.0
B-26	6.50	6.25	1.5 - 6.5	1.0	0.0	3.35
B-27	33.00	6.25	23.0 - 33.0	21.0	19.0	1.89
B-28	16.80	6.25	6.8 - 16.8	4.8	2.8	3.36
B-29a	6.50	6.25	1.5 - 6.5	1.0	0.0	2.86
B-30	32.00	6.25	22.0 - 32.0	20.5	18.5	3.15
B-31	25.00	6.25	15.0 - 25.0	13.5	11.5	3.00
B-32	21.50	6.25	11.5 - 21.5	10.0	8.0	3.11
B-33	15.00	6.25	5.0 - 15.0	3.5	1.5	3.11
B-34	7.00	6.25	2.0 - 7.0	1.0	0.0	2.95
B-34d	48.50	5.75	33.5 - 48.5	31.5	28.0	1.52
B-35	7.00	6.25	2.0 - 7.0	1.0	0.0	2.75
B-36	20.00	6.25	3.0 - 20.0	2.0	0.0	1.00
OW-1	45.00	5.75	25.0 - 45.0	24.0	22.0	3.05
OW-2	40.00	5.75	20.0 - 40.0	19.0	17.0	2.95
OW-3	48.00	5.75	28.0 - 48.0	27.0	25.0	3.00
MW-11	100.50	5.75	19.5-100.5 Open hole	–	--	3.20
MW-13	32.50	5.75	16.0-31.0	14.0	12.5	2.62

Notes:
1. B and OW series wells installed by G. N. Richardson and Associates, Oct. 1994-Jan. 1995.
2. Total depth and screen interval depths measured from ground surface at time of drilling
3. For borehole diameters, the first value (6.25) represents diameter produced using 4.25-inch ID hollow stem augers and the second value (5.75)represents the diameter produced using a standard NQ core barrel or 5.75-inch air hammer.

Table 2-2
Ground Water Table Elevations
Site Hydrogeological Investigation
White Street Sanitary Landfill Expansion
Greensboro, North Carolina

Well #	Top Casing Elevation	Total Well Depth	12/20/94 GW Elevation	12/27/94 G W Elevation	12/29/94 G W Elevation	1/10/95 G W Elevation	1/25/95 G W Elevation	3/11/95 GW Elevation	4/18/95 GW Elevation	5/22/95 GW Elevation	6/22/95 GW Elevation	7/20/95 GW Elevation	8/16/95 GW Elevation	9/15/95 GW Elevation	10/31/95 GW Elevation	11/30/95 GW Elevation	TOC adjusted December	1/4/96 GW Elevation	1/29/96 GW Elevation	3/13/96 GW Elevation	4/24/96 GW Elevation	5/23/96 GW Elevation	6/27/96 GW Elevation	7/25/96 GW Elevation	8/29/96 GW Elevation
B-1	763.21	34.66	742.46	745.35	-	746.01	746.62	747.57	746.09	745.81	745.63	746.2	745.56	746.14	747.3	747.4		746.7	746.1	747.25	746.13	745.81	745.52	745.52	746.47
B-1d	762.55	45.06	754.83	755.27	-	754.45	721.52	725.29	729.12	731.73	733.63	735.31	736.58	737.87	739.06	741.71		741.78	742.433	743.34	743.95	744.16	744.4	744.49	744.72
B-2	777.58	21.07	765.73	765.49	-	766.21	767.59	768.84	Removed																
B-3	752.85	18.32	748.01	747.56	-	748.59	748.62	748.74	747.08	748.54	748.98	747.16	748.29	748.08	747.47	748.13		747.87	748.81	748.15	747.85	747.37	748.88	748.3	747.47
B-4	759.43	25	-	-	-	742.4	742.14	744.78	740.19	739.63	740.03	740.3	739.55	739.55	741.58	742.55		741.316	744.38	742.17	740.69	740.81	740.17	739.88	740.97
B-5	780.13	28	-	-	-	739.9	739.26	740.89	741	740.78	740.98	741.36	741.19	741.24	741.66	742.04		742.26	742.9	743.16	742.88	742.61	742.13	741.7	741.75
B-6	756.21	61	-	-	-	700.68	701.69	732.42	737.03	736.59	736.25	736.78	736.69	736.35	737.5	738.98		739.56	739.86	740.03	739.64	738.87	738.04	737.15	737.41
B-7	773.75	24.74	754.03	754.01	-	751.61	752.2	753.88	753.59	752.87	752.46	752.48	752.2	751.74	751.57	751.84	767.48	754.14	754.7	755.53	755.8	755.84	755.52	754.9	755.41
B-8	758.58	65.06	-	737.67	-	737.26	735.23	738.95	737.58	737.13	736.73	734.99	733.44	733.07	734.09	734.2		733.95	734.74	734.78	734.62	734.32	733.43	732.85	733.57
B-9	781.77	38.56	-	744.05	744	744.28	744.66	745.12	744.81	744.39	743.7	741.11	740.03	739.51	739.81	739.86		739.74	740.65	740.7	741.62	740.67	740.21	739.78	739.93
B-9d	782.41	71.13	-	742.17	743.02	743.9	744.43	745.37	744.5	744.29	743.8	740.8	739.04	738.97	739.13	739.4		739.37	740.54	740.31	740.77	740.47	739.97	738.77	738.47
B-10	780.91	34.46	753.91	753.82	-	753.68	753.99	754.2	754.75	754.91	754.85	754.84	754.89	754.72	754.55	754.65		754.78	754.91	755.31	755.69	755.97	756.18	756.18	756.1
B-11	772.04	19.26	754.27	754.15	754.11	753.97	754.83	755.91	755.09	754.16	753.82	754.71	753.89	753.98	753.93	753.88		753.27		754.34	753.94	753.55	dry	dry	753.75
B-12	778.84	34.36	-	761.92	751.8	768.66	768.67	770.96	767.75	767.14	767.34	769.17	767.41	767.83	770.22	770.36		768.64	771.33	770.33	769.1	769.49	768.07	768.41	769.78
B-13	783.67	53	-	-	-	783.2	783.46	784.29	784.93	784.78	784.39	784.25	784.04	783.52	783.34	783.73		783.99	784.49	785.54	786.16	786.36	786.17	785.44	785.48
B-14	790.51	19.58	779.16	779.43	-	780.45	780.47	781.91	780.79	780.3	780.49	782.56	780.82	781.2	782.72	782.37		781.72	783.25	783.32	783.12	783.42	782.4	781.31	782.65
B-15	777.19	22.5	-	760.22	-	760.24	761.12	761.03	761.32	761.29	761.3	761.36	760.76	760.45	761.66	762		762.35	764.05	763.91	762.9	762.1	761.03	760.82	760.99
B-16	785.86	37.95	761.48	761.31	761.31	761.2	761.37	761.92	762.31	761.94	761.69	761.84	761.11	760.3	761.71	762.16	770.44	761.85	764.19	762.09	761.4	760.94	759.71	759.27	761.42
B-17	789.61	30.06	-	-	763.52	774.12	774.33	775.23	775.05	774.33	773.68	774.27	773.68	773.55	773.81	774.38	783.22	773.29	776.34	775.32	773.28	773.16	772.84	772.72	774.39
B-17d	789.66	55.52	-	-	753.62	760.57	761.29	762.54	762.76	761.8	760.75	761.55	760.13	760.15	761.09	761.81	783.98	762.22	764	763.56	763	762.32	761.27	760.1	762.21
B-18	774.4	51.82	-	-	753.18	757.22	757.81	758.82	757.5	756.82	756.33	757.2	755.97	755.77	756.2	756.44		756.35	757.79	757.88	757.27	756.81	755.45	754.43	755.94
B-19	778.28	n/a	-	-	-	757.04	756.56	758.34	758.65	758.56	758.88	758.8		758.63	759.82	760.57	772.02	760.15	762.69	761.97	761.51	761.38	760.92	760.23	761.15
B-20	772.18	83.5	-	-	-	744.72	744.95	745.73	743.23	742.89	743.3	743.34	742.33	742.78	744.74	745.17	761.12	744.45	748.24	748.17	745.37	745.1	744.02	742.84	744.28
B-21	759.84	14.11	-	751.23	751.3	751.6	751.69	752.54	751.59	751.25	751.27	751.68		751.21	752.09	752.49		752.1	752.85	752.39	752.14	751.96	751.54	751.03	752.22
B-22	767.86	33.82	747.29	746.36	746.34	746.14	746.21	746.9	745.03	744.41	744.13	744.36	743.7	743.43	744.5	744.87		744.83	746.44	746.03	745.61	745.05	743.84	742.89	743.95
B-22d	756.86	48.86	-	-	740.32	748.26	746.37	747.08	745.17	744.56	744.38	744.8	743.91	743.72	744.33	745.1		745.16	748.58	748.29	748.1	745.35	744.1	743.1	744.18
B-23	788.26	33.54	-	751.51	-	751.2	751.02	748.63	747.61	748.78	748.34	747.55	748.12	748.47	748.64	748.3	754.21	748.83	749	748.75	748.53	748.06	748.8	748.55	748.79
B-24	753.03	14.67	-	740.39	-	740.78	740.98	741.88	740.19	740.18	740.36	740.7	740	740.06	740.9	740.81		740.64	742.04	740.93	740.32	740.25	739.61	739.36	740.27
B-25	747.96	40.64	-	737.9	-	738.82	739.52	741.32	737.3	737.09	738.09	738.16	736.56	736.93	739.11	740.27		740.4	741.36	740.57	739.51	739.02	737.53	736.09	738.21
B-25d	747.54	52	-	-	-	737	737.89	739.19	735.82	735.44	735.82	736.4	735.02	735.17	736.85	737.8		737.95	739.16	738.66	737.93	737.43	736.09	734.7	736.39
B-26	742.55	10.23	-	733.76	-	734.8	734.53	735.98	732.6	733.28	733.13	733.13	732.48	732.61	734.5	735.53		736.82	737.79	736.74	736.4	735.38	733.45	733.11	734.14
B-27	736.71	12.69	-	-	-	717.84	717.84	718.05	717.78	717.78	717.75	717.74	717.72	717.7	717.8	717.74		717.85	717.91	717.78	717.69	717.67	717.63	717.49	717.7
B-28	742.69	n/a	-	-	-	735.15	735.73	736.77	732.84	733.07	733.96	736.21	733.62	734.81	737.73	737.91		737.65	738.33	737.47	735.99	735.54	733.88	732.46	736.82
B-28a	748.47	11.15	-	736.86	-	739.69	738.6	739.44	736.34	736.37	736.58	737.13	735.38	735.41	737.05	738.9		738.88	740.09	739.85	739.58	739.09	738.64	737.22	738.69
B-30	742.26	34.92	-	724.28	-	724.37	725.42	727.38	725.67	724.65	724.17	725.58	725.1	725.23	726.21	727.08		726.88	728.23	728.42	727.94	727.35	726.33	725.18	726.14
B-31	750.1	27.75	-	741.23	741.08	741.68	742.13	743.76	739.77	739.53	739.72	740.24	738.78	738.8	740.63	739.43		745.3	745.69	745.48	745.49	745.26	744.31	744.21	745.29
B-32	744.76	24.69	-	724.62	-	727.29	727.86	731.43	729.76	729.81	729.58	730.49	729.89	729.58	728.74	728.29		727.87	728.65	728.33	728.17	728.04	727.2	725.78	727
B-33	760.33	17.59	-	752.72	752.65	752.68	753.07	754.47	752.3	751.7	751.51	752.36	751.12	751.26	748.45	748.66		748.58	749.15	748.66	748.27	748.02	747.1	746.91	748.55
B-34	733.92	9.41	-	726.6	-	730.31	728.68	729.82	724.6	724.63	724.75	726.32	724.59	dry	726.67	728.97		729.3	730.42	728.87	727.86	726.85	dry	dry	726.7
B-34d	732.49	48.24	-	-	-	708.06	725.36	727.43	722.97	722.11	722.42	724.13	722.18	721.82	724.68	725.79		726.25	727.63	726.66	725.53	724.94	722.81	720.48	722.18
B-35	746.75	9.6	-	-	742.73	741.51	742.88	743.22	742.53	742.24	742.48	742.27	741.36	741.88	743.13	743.52		743.08	743.46	743.01	742.67	742.31	741.8	742.65	742.67
B-36	783	20	-	-	-	764.21	764.78	766.46	766.28	765.84	765.19	765.57	765.05	764.94	765.24	765.89		765.66	766.53	767.31	767.72	767.43	766.88	766.12	766.37
B-37	783.02		-	-	-	-	-	-	-	764.58	764.27	764.18	764	763.5	763.31	763.66		763.78	764.28	765.21	765.54	765.51	765.1		764.74
OW-1	771.05	48.24	-	742.62	-		742.96	749.06	749.36	748.93	748.34	748.1		748.26	747.31	747.75			748.6	749.45	750.08	750.08	749.56	748.74	748.53
OW-2	789.95	42.82	-	750.03	-		750.71	751.41	751.22	751.15	750.97	750	749.55	749.15	749.17	749.16			749.97	750.3	750.59	750.84	750.44	750.62	749.84
OW-3	782	51.24	-	744.04	-	-	-	-	-	744.37	743.26	739.35	738.19	737.55	738.05	738.43			741.46	740.84	740.51	739.95	738.97	738.18	738.2
GSO-11	742.2	103.45	-	718.08	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-
MW-13	741.62	33.97	-	718.5	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-
PW-2	752.91	26.52	-	740.11	-	-	740.69	-	740.86	-	740.31	-	739.67	738.74	740.04	740.6			741.71	742.4	743.06	742.51	741.54	742.75	740.47
PW-3	752.5	26.36	-	743.26	-	-	743.69	-	743.4	-	742.8	742.54	741.75	741.02	741.7	-			743.68	743.14	742.75	742.4	741.63	741.58	741.27

Note: In December, 1995, the top of casing for piezometers B-7, B-16, B-17, B-17d, B-19, B-20 and B-23 were lowered. Readings collected after November, 1995 have been evaluated with the new top of casing elevations.

2.2.2 Estimated Seasonal High Water Table

The evaluation of data for the determination of an estimated long-term seasonal high water table for the Phase III area of the White Street Landfill was performed in several phases. These phases included:

1) Evaluation and determination of the on-site seasonal high water table (minimum of 1 year).
2) Evaluation and determination of long-term regional seasonal high trends using USGS records.
3) Comparison and correction of on-site seasonal high water table elevations with long-term seasonal high correction factor.

During the first phase of the evaluation process, all available on-site water level data for the ground-water piezometers installed in or near the Phase III area were evaluated to determine which monitoring event (e.g., month) seemed to contain the greatest number of high water table readings. The period of data evaluated was from January 1995 through August 1996 (19 months of readings). Based on this evaluation, it was determined that the greatest number of the 40 shallow piezometers/wells in the Phase III area (16 total) experienced their highest potentiometric elevation on January 29, 1996. Based on the evaluation of on-site seasonal data from the White Street Landfill, as well as from other regional landfills located in the Piedmont of North Carolina, it has been previously documented (and reported by HDR) that the seasonal high ground-water table typically occurs during the winter months between January and March. The January 29, 1996, event is supported by this finding (see Table 2-2).

The second phase of the evaluation process involved the evaluation of the on-site seasonal high ground-water data against the long-term regional ground-water data in order to establish a long-term seasonal high correction factor for the White Street data. Based on a review of the "Water Resources Data, North Carolina Water Year 1995, Volume 2. Ground-Water Records," U.S. Geological Survey Water-Data Report NC-95-2 revealed only two ground-water wells near Guilford County. One well is located in Davie County (NC-142) approximately 45 miles west-southwest of the site, and the second well (NC-126) is also located approximately 45 miles east-southeast of the site in Orange County. Based on the published information concerning these wells, it appears that the Davie County

well is the more appropriate of the two wells for ground-water data comparison with the on-site piezometers. The Davie County well is located at an elevation datum of 835 feet MSL along the upper edge of a slope which drains southeasterly to a tributary of Leonard Creek. The Davie County well is a drilled well which is 30.8 feet deep and 6-inches in diameter, whereas the Orange County well is a dug well 48 feet deep with a 36-inch diameter. In addition, the Davie County well is continuously monitored with a digital recorder every 60 minutes, while the Orange County well is only periodically monitored with a steel tape. Moreover, the Orange County well has experienced two dry periods, one between October and December 1940 and another between October 1988 and January 1989. The only apparent similarity between the wells is that both wells are completed within the uppermost aquifer which is composed of a comparable lithology (weathered granite saprolite of Paleozoic age) to the on-site wells at White Street. In addition, unpublished ground-water data for the 1996 Water Year for the Davie County well was also provided by the USGS regional office in Raleigh, North Carolina, in order to check the general trend in this well as compared to the January 29, 1996, on-site seasonal high at White Street. A thorough review of these records (from 1985 through 1996) revealed that the long-term seasonal high for the Davie County well occurred during the winter months in 1993 (specifically the month of March). Well construction, location, and tabulated ground-water data (with hydrographs) for the Davie County well for the period between 1993 and 1996 is included in Appendix D.

In order to determine if a correction factor is needed to adjust the January 29, 1996, on-site seasonal high ground-water data to better approximate the regional long-term seasonal high event in 1993, the elevation on January 29, 1996 (822.15 feet MSL) for the Davie County well was subtracted from the highest elevation in 1993 (824.36 feet MSL). This produced a differential factor of 2.21 feet. See the calculation sheet included in Appendix D.

Since a majority of the on-site piezometers/wells experienced a seasonal high level in January 1996, this single data event was used as the foundation for the long-term seasonal high water table map. The January 1996 data were corrected (by adding) by a factor of 2.21 feet in order to approximate the long-term seasonal high. After this correction factor had been added, the corrected elevations were then rechecked against the available on-site data to make sure that all of the corrected elevations were equal to or higher than all of the actual seasonal high

elevations not experienced during the January 1996 event. After using the correction factor, six of the 40 piezometers/wells still had experienced on-site water elevations which exceeded the corrected January 1996 data (B-8, B-9, B-23, B-32, B-33, and OW-3). At piezometer/well locations B-8 and B-9, the corrected January 1996 value was still slightly lower than the highest recorded elevation ever at these wells. This is due to the late-spring 1995 draining of the lake located to the east-southeast of the proposed cell. The draining of this lake has resulted in the lowering of the water table in the vicinity of these wells. Therefore, this area of the site should not experience seasonal high water table elevations as high as when the lake was filled. Therefore, the corrected January 1996 values were considered conservative and were therefore utilized at these locations. For the four remaining locations (B-23, B-32, B-33, and OW-3), the maximum recorded on-site value was utilized since it was slightly higher than the corrected January 1996 value. Since B-32 and OW-3 are located outside of the proposed lined cell footprint, these approximated elevations were not a factor during the determination of the vertical separation requirements for the liner system.

In addition, since piezometer B-11 was not measured in January 1996, a value for this date was estimated by extrapolation using the trend of the potentiometric surface data using an X-Y graph of the elevation data (see Appendix D). The data immediately prior to the January date indicated a downward trend in the water table elevation was occurring at this location prior to the missing January date. The next monitoring event following the January date (March 13, 1996) showed that the water table elevation in B-11 had increased again and was once again experiencing a downward trend. When the trend in the data curve was extrapolated back through the missing January 29, 1996, event, an elevation of 754.76 feet was read off the graph. This elevation fits well within the data set. The correction factor of 2.21 feet was then added to this elevation for an estimated long-term seasonal high elevation of 756.97 feet. This estimated elevation is 1.06 feet higher than the highest recorded elevation for this piezometer. Figure D-2 depicts the estimated long-term seasonal high water table for the Phase III area based on actual high and/or the corrected January 1996 data.

2.2.3 Water Level Fluctuations

Examination of the water level data (see Table 2-2, August/September/October 1995 levels) shows a small lowering of 2-4 feet of the water table in areas along the eastern margin of the Phase III area as a result of drainage of the two lakes which previously existed in the central valley, and as a result of excavation in the B-26, B-24, B-33, and B-31 areas of the site (see Figure D-1 for piezometer locations). It appears that this drainage and excavation has primarily affected water levels in piezometers located nearest to the former lakes (B-9 and B-8), with very minor effects possibly also occurring in B-7, B-24, B-26, B-31, and B-33. As indicated above, the effect of lake drainage is probably a much more significant factor in causing the localized lowering of the water table than excavation activities were.

General excavation across much of the Phase III footprint has taken place over the last 10 months, since the observation wells/piezometers were installed. As much as 25 feet of soil has been removed in certain areas. The hydrogeologic investigations of the Phase III site were conducted prior to borrow activities as indicated previously. However, based on NCDEHNR and HDR advice, borrow activities have been discontinued in the Phase III area.

Monthly water level measurements continue to be obtained in order to characterize the nature and extent of man's impact on the water table. In spite of the change in topography and surface water hydrology, the data does not indicate a discernible change in water levels beneath the Phase III landfill footprint.

No other man-made activities or natural processes appear to have the potential to cause water table fluctuations on site.

2.3 Geologic and Hydrogeologic Considerations

2.3.1 Regional Geologic Setting

The White Street Landfill (the Landfill) is located in the upland portion of the southern Piedmont physiographic province (Fenneman, N.M., 1938, Physiography of the Eastern United States: New York, McGraw-Hill). The physiography of the Piedmont is characterized by gentle to rough, hilly terrain that becomes more hilly

towards the mountains and is dissected by a mature drainage system. The topography is developed on deeply weathered, belted metamorphic and igneous rocks that generally date from late Precambrian to Paleozoic in age.

The Landfill lies near the western margin of the Carolina Slate Belt, a regionally defined terrain that extends from Virginia to Georgia and includes volcanic and sedimentary rocks of Late Precambrian to Cambrian age that, in the Greensboro area, are metamorphosed to lower greenschist facies and intruded by a variety of plutons (North Carolina Geological Survey, 1985, Geologic map of North Carolina: North Carolina Department of Natural Resources and Community Development, Geological Survey Section). The Carolina Slate Belt, Kings Mountain Belt to the southwest, and the Charlotte Belt to the west are all part of a larger terrain known as the Carolina Terrain. Rock relationships, fossil evidence, and geochemical data from the Carolina Terrain indicate that it was primarily formed in a subduction-related, tectonically active volcanic arc separate from the North American Craton (Butler, J. Robert, and Secor, Donald T., Jr., 1991, in Horton, J. Wright, Jr., and Zullo, Victor A., eds., The Geology of the Carolinas: Carolina Geological Society Fiftieth Anniversary Volume: Knoxville, The University of Tennessee Press, p. 59-78). The Carolina Terrain was probably sutured to North America during the Taconic Orogeny, 470-440 million years ago (Middle Ordovician), at which time deformation and associated metamorphism of the Slate Belt also peaked.

Ground water in the Piedmont occurs both intergranularly in the unconsolidated saprolite and within fractures in the bedrock. Typically, although not always, the water table is within the saprolite. Water supply wells are completed in bedrock.

Porosity in the saprolite is usually relatively high, with measured values commonly in the 40 to 50% range. "Effective" porosity is lower, typically ranging from 20 to 30%. In bedrock, porosity is normally only 3 to 5%, but the fractures are often well connected and hydraulic conductivity is comparable to or higher than that found in the saprolite. As the saprolite and bedrock are hydraulically connected, the contrast between porosities allows the saprolite to act as a ground-water reservoir for wells that pump from the bedrock. Sustained well yields for average, well-constructed bedrock wells in the Piedmont average about 12 to 24 gallons per minute (Daniel, Charles C., III, and Payne, R.A., 1990, Hydrogeologic Unit Map

of the Piedmont and Blue Ridge Provinces of North Carolina, U.S.G.S. Water-Resources Investigations Report 90-4035).

The water table in the Piedmont under natural conditions is a subdued image of the surface topography. Recharge takes place on interfluvial areas, then travels downward and laterally to discharge along perennial creeks and rivers. Thus, the vertical component of ground-water flow is directed downward in interfluvial recharge areas, comprising perhaps 80 to 90% of land surface, and then has an upward component of flow as ground water approaches discharge areas at streams.

2.3.2 Description of Rock Units - Site Geology

Each boring was drilled until at least hollow stem auger refusal depth. For purposes of this report, this depth is also correlated with the top of bedrock at the site. Using these data, a bedrock surface contour map was prepared by HDR and is here presented as Figure D-3. As can be seen on this map, bedrock is relatively shallow along the west and southwest portions of the site, as shown by the presence of two bedrock ridges, one trending north-south and another trending northeast-southwest along the eastern part of the site. A bedrock valley separates the two ridges. Some of this bedrock has recently been exposed by excavation in the west-central portions of the Phase III area.

In both surface outcrops and in borings, several rock units have been identified at the site. HDR has prepared a geologic map (Figure D-4) for the site based upon surface rock outcrops, saprolite character, and data from the borings. Three hydrostratigraphic cross-sections are presented herein on Figures D-5A and D-5B. Seven rock and saprolite types are identified on the map and cross-sections.

Granite (GR): white, coarse-grained, hornblende-bearing, typically massive, metamorphosed.
Felsic Gneiss (FG): tan to gray, medium to fine-grained, biotite-bearing, foliated
Rhyolite Intrusive (RI): white, fine-grained, porphyritic, massive
Diorite (DI): medium gray, medium-grained, equigranular, metamorphosed.
Mafic Intrusive (MD): light gray to dark green and bluish green, fine-grained, possibly metamorphosed basalt/gabbro.
Basalt/Gabbro (BG): dark gray to black, fine to medium grained, unaltered.

Greenstone Dikes (GD): light to dark green and bluish green, fine to medium-grained, sheared parallel to intrusive contacts in places, possibly extensively metamorphosed diorite or mafic intrusive.

Figure D-3 indicates that the deepest weathering has occurred in the granite near its contact with the metamorphic rocks. However, rock hardness is not readily correlated with rock type, as quite resistant granite is found at the east of the site, and both deeply weathered and resistant rocks are found in the western half of the site.

Generally, the granite occupies the east and northeast portions of the site, while the felsic gneiss is found in the western and southwestern portions of the area. The mafic intrusives, basalt/gabbro, and greenstone dikes are most obvious in the light-colored granite, but also cross-cut the felsic gneiss. Field relations indicate that the granite is intrusive into the older gneiss. The fine-grained rhyolite intrusive cross-cuts the granite and the felsic gneiss.

Field relations do not suggest generalized shearing or fracturing along the linear, generally northeast-trending, mafic or felsic intrusive features which are found as both dikes and sills. But, the results of the slug testing and rock coring efforts appear to indicate that the saprolitic portions of some dikes (B-1, B-34d) are well fractured, and may represent localized preferred conduits for ground-water flow. Based upon the hardness of the rhyolite and basalt/gabbro now exposed at the surface, these units are very likely to be barriers to ground-water flow. At depth, the dike bedrock appears to be essentially impermeable. Hydraulic conductivities also appear to be somewhat higher in granite versus the felsic gneiss. Metamorphic foliation orientations in the granitic gneiss were extremely consistent across the site, trending between N65E to N70E. Ground-water flow in the metamorphic portions of the uppermost aquifer would be expected to have a slightly higher velocity parallel to foliation.

2.3.3 Cross-Sections

Rule 1623(a)(6) requires that stratigraphic cross-sections be constructed across the proposed footprint. Three cross-sections are shown on Figures D-5A and D-5B. The lines of section are shown on Figure D-1.

The dips on rock contacts are not generally available, but field observations suggest a very steep northerly dip to these features. In an unusual occurrence in the northern portion of the Phase III area, the granite/gneiss contact dips about 30 degrees to the east, with granite overlying gneiss. Remember also that the vertical exaggeration of the cross-sections creates steeper apparent dips, so they are drawn nearly vertically in these sections. Contacts between mafic, rhyolite, diorite, and greenstone intrusives with the country rock are generally near vertical.

2.4 Synthesis of Site Hydrogeology

2.4.1 Aquifer Characteristics

As discussed above, the typical texture of soils at the Landfill are sandy silts (ML or MH) to silty sands (SM). These are very common soil textures in the Piedmont of North Carolina, and experience suggests the following characteristics for these types of aquifer materials:

total porosity = 40-50%, with effective porosity of about 20-25%
hydraulic conductivity = .5-5 ft/day.

Eleven slug tests have been performed in the study area. The results of these tests are presented in Appendix C. Slug tests were conducted on wells completed in saprolite, shallow and deep rock, in granite, gneiss, mafic dikes, and in diorite. The results of these tests are provided in Table 2-3.

Hydraulic conductivities calculated from slug testing ranged from immeasurably low in deep bedrock dikes to 17.69 ft/day. Hydraulic conductivity in the granitic saprolite averaged about 0.68 ft/day, as compared to gneissic saprolite at about 0.13 ft/day. The highest conductivity measured was on a fractured saprolite dike (diorite) at B-34. As expected, hydraulic conductivities decreased from the shallow saprolite aquifer downward to the deep rock aquifer. Slug test results appear to indicate that the saprolitic portions of the dikes have a relatively high conductivity, but that, at depth, they become extremely tight hydrostratigraphic units. In general, the slug test results also indicate that the degree of fracturing is an important control over hydraulic conductivity.

Table 2-3
Aquifer Characteristics

Boring No.	Rock Type	Aquifer	Total Porosity (%)	Slug Test (cm/sec)
B-1	Mafic Dike	Shallow Rock[s]	5[e]	6.39×10^{-4}
B-1d	Mafic Dike	Deep Rock[d]	0-5[e]	$<10^{-7}$*
B-14	Gneiss	Saprolite	50[e]	4.47×10^{-5}
B-17d	Gneiss	Deep Rock[d]	0-5[e]	1.60×10^{-4}
B-22	Granite	Saprolite	45[a]	4.15×10^{-4}
B-22d	Granite	Shallow Rock[s]	0-5[e]	3.06×10^{-5}
B-25	Granite	Saprolite	45[a]	7.24×10^{-5}
B-25d	Granite	Shallow Rock[s]	0-5[e]	5.58×10^{-5}
B-31	Granite	Half Rock/Half Sap	45[a]	6.11×10^{-5}
B-34	Diorite Dike	Saprolite	45[a]	6.24×10^{-3}
B-34d	Diorite Dike	Deep Rock[d]	0-5[e]	$<10^{-7}$*

Average Hydraulic Conductivities (K values)		Effective Porosity (%)
Saprolite Aquifer	1.86×10^{-3} cm/sec or 5.27 ft/day	20[n]
Shallow Rock Aquifer	2.42×10^{-4} cm/sec or 0.69 ft/day	5(est.)
Deep Bedrock Aquifer	5.34×10^{-5} cm/sec or 0.15 ft/day	0.1[n]
Dike Saprolite Aquifer	6.24×10^{-3} cm/sec or 17.69 ft/day	20[n]
Granite Saprolite Aquifer	2.44×10^{-4} cm/sec or 0.69 ft/day	20[n]
Gneiss Saprolite Aquifer	4.47×10^{-5} cm/sec or 0.13 ft/day	20[n]

Notes:
* = Hydraulic conductivity too small to measure using the slug test method; at depth these dikes are extremely tight. K values well below 10^{-7} cm/sec (estimated).
a = Average total porosity value from laboratory testing of saprolite samples from SB-46, SB-50, SB-53.
d = Deep rock aquifer = screen top greater than 25 feet below auger refusal depth.
e = Estimated based on values presented in Table 2.4, Freeze & Cherry, 1979.
s = Shallow rock aquifer = screen top less than 25 feet below auger refusal depth.
n = Effective porosity values taken from USEPA's RCRA Facility Investigation Guidance Document (1987), pages 10-49.

The permeability of the unsaturated saprolite is lowest near the original ground surface, where finer grained clay-rich soils (silty clays, clayey silts, clayey sands, etc.) are common. Remolded permeability measurements for these soils (see Appendix B) ranged from 2.1 to 2.8 x 10^{-7} cm/sec, values which suggest that they would be suitable for use as daily cover or possibly as clay liner material (if augmented by bentonite). At greater depth in the lower portions of the unsaturated zone, it is expected that the coarser grained soils will have hydraulic conductivities in the 10^{-4} to 10^{-5} cm/sec range. This range is comparable to the slug test results described above for the saprolite aquifer.

2.4.2 Horizontal and Vertical Dimension of Ground-Water Flow

Rule .1623(a)(8) requires a discussion of the horizontal and vertical dimensions of ground-water flow. Rule .1623(a)(9) requires submittal of a ground-water contour map.

As indicated above, Figure D-2 depicts the estimated seasonal high water table at the proposed Landfill site. As shown on this drawing, ground-water flow is strongly influenced by surface topography. Flow is generally away from areas of recharge, represented by the highest areas of natural topography and toward the discharge areas found along the streams. Discharge is taking place locally along the central drainage at the east side of the Phase III area. A significant portion of ground-water flow is moving across the old Phase I and Phase II areas north and northwest toward eventual discharge points along North Buffalo Creek.

In the case of the vertical component of ground-water flow, recharge takes place on interfluvial areas, then travels downward and laterally to discharge along the creeks. Thus, the vertical component of ground-water flow is directed downward in interfluvial recharge areas, comprising perhaps 80 to 90% of land surface, and then has a slight upward component of flow as ground water draws near discharge areas at streams.

The most influential hydrogeological features for the Phase III Area are the unnamed creek east of the site, the topographic ridge/divide along Nealtown Road and Huffine Mill Road to the west and south of the Phase III area, and North Buffalo Creek. As a result of these features, ground-water flow in the surficial aquifer generally trends to the northeast as shown on Figure D-2. The horizontal potentiometric gradients for the surficial aquifer range from 0.004 to 0.056. The horizontal potentiometric

gradients for the shallow and deep rock aquifers range from 0.023 to 0.033 and from 0.018 to 0.022, respectively.

A comparison of hydraulic head differences for nested well pairs in the Phase III area, based upon the historical water level measurements from January 10, 1995, through August 29, 1996, indicates a downward gradient in the vertical direction for every well pair (except for B-22/22D). The gradient data for B-1/1D showed the greatest magnitude change from 0.08 ft/ft to 1.96 ft/ft. All of the other piezometer pairs showed minimal fluctuation over time. Although the vertical gradients measured at B-22/22D are primarily slightly upward, these very low vertical gradients at this well pair indicate virtually horizontal ground-water flow (see Drawing D-5B). Vertical gradient information for the nested piezometers is given below.

Vertical Gradients						
	B-1/1D	B-9/9D	B-17/17D	B-22/22D	B-25/25D	B-34/34D
Delta A	12.83	32.53	27.50	18.00	16.00	36.50
1/10/95	0.658*	-0.012	-0.493	0.007	-0.114	-0.610
1/25/95	-1.956	-0.007	-0.474	0.009	-0.114	-0.091
3/11/95	-1.737	0.008	-0.461	0.010	-0.133	-0.065
4/18/95	-1.323	-0.010	-0.447	0.008	-0.093	-0.050
5/22/95	-1.082	-0.003	-0.456	0.009	-0.103	-0.069
6/22/95	-0.935	0.003	-0.477	0.014	-0.142	-0.064
7/20/95	-0.849	-0.016	-0.463	0.013	-0.110	-0.060
8/18/95	-0.700	-0.030	-0.493	0.012	-0.098	-0.066
9/15/95	-0.645	-0.017	-0.487	0.016	-0.110	NA
10/31/95	-0.595	-0.015	-0.463	-0.009	-0.141	-0.055
11/30/95	-0.443	-0.014	-0.457	0.013	-0.154	-0.087
1/4/96	-0.385	-0.011	-0.403	0.018	-0.153	-0.084
1/29/95	-0.442	-0.003	-0.449	0.008	-0.138	-0.076
3/13/96	-0.305	-0.012	-0.428	0.014	-0.119	-0.061
4/24/96	-0.170	-0.026	-0.374	0.027	-0.099	-0.064
5/23/96	-0.135	-0.006	-0.395	0.017	-0.099	-0.052
6/27/96	-0.087	-0.007	-0.421	0.009	-0.090	NA
7/25/96	-0.080	-0.031	-0.459	0.012	-0.087	NA
8/29/96	-0.135	-0.045	-0.443	0.013	-0.114	-0.124

Notes:
Negative values indicate downward component of flow.
Positive values indicate upward component of flow.
NA - Not available (shallow piezometer was dry).
* Based on subsequent data pairs, this point appears anomalous.

The average linear velocity of ground-water flow can be calculated using the following formula:

$$V_x = \frac{Kdh}{n_e dl}$$

Where: V_x = average linear velocity
K = hydraulic conductivity
dh/dl = hydraulic gradient
n_e = effective porosity

Using the effective porosities given in the RCRA Facility Investigation Guidance Document (1987), the hydraulic conductivities given in Table 2-3, and appropriate horizontal hydraulic gradients, a range of horizontal flow velocities of between 0.01 and 6.60 feet per day results for the uppermost (saprolite) aquifer (see Table 2-4). Note that the dike material (one slug test only) is at least an order of magnitude more conductive than saprolite developed in granite or gneiss, but recall also that, at depth, these dikes may become essentially impermeable (see Table 2-3, B-1d and B-34d).

Table 2-4
Summary of Calculated Groundwater Flow Velocities

Hydrostratigraphic Unit (Aquifer)	Hydraulic Gradient	Porosity (%)	Hydraulic Conductivity (ft/day)	Groundwater Flow Velocity (ft/day)
Saprolite	0.004 - 0.056	20	5.27	0.11-1.48
Granite Saprolite	0.004 - 0.056	20	0.69	0.01 - 0.19
Gneiss Saprolite	0.004 - 0.056	15	0.13	0.0035 - 0.049
Dike Saprolite	0.004 - 0.056	15	17.69	0.47 - 6.60
Shallow Bedrock	0.023 - 0.033	5*	0.69	0.32-0.46
Deep Bedrock	0.018 - 0.022	0.1	0.15	2.70 - 3.30
* Estimated				

In the case of the deep bedrock aquifer, a published value of 0.1% for secondary porosity (Heath, 1980) and a hydraulic gradient of between 0.018 and 0.022 were used to calculate an estimated range of flow velocity of 2.7 to 3.3 ft per day.

Given that the upper portion of the bedrock aquifer is more fractured and has a correspondingly higher secondary porosity (estimated at 5%), and a hydraulic gradient of 0.023 to 0.033, a third intermediate range of ground-water velocity of between 0.32 and 0.46 ft/day was calculated.

These data, along with the information given in Table 2-4, provide a framework for understanding the hydrogeologic flow regime that prevails in the subsurface beneath the study area. First, it is apparent that hydraulic conductivities are generally highest in the saprolite aquifer, lowest in the deep rock aquifer, and intermediate in the shallow rock aquifer. In saprolite, the granite appears to be more conductive than the gneiss, but, where saprolite is developed in a sheared, foliated, or fractured dike, the measured conductivity (B-34) can be as much as an order of magnitude higher than in either gneiss or granite. In terms of ground-water flow velocity in saprolite, the same relative rates prevail with dike material having the highest value (up to 6.60 ft/day or 2,409 ft/year), granite having an intermediate value (up to 0.29 ft/day or 69 ft/year), and gneiss having the lowest pore velocity (up to 0.049 ft/day or only 18 ft/year). It is expected that flow rates should be higher parallel to the orientation of foliations in the gneiss (i.e., N65E-N70E).

The surficial/uppermost aquifer which exists in saprolite in the study area serves as the reservoir that recharges the underlying fractured rock aquifer (called shallow and deep herein). Hydraulic conductivities are lower in the rock aquifer, but actual pore water flow velocities can be relatively high due to the very low effective porosities. In rock, the available hydraulic head is forced to travel through a relatively small volume of fractures which act as conduits for flow. In shallow bedrock where an effective porosity of 5% is appropriate, flow velocities of up to 0.46 feet/day (168 ft/year) can prevail. In deep bedrock, effective porosities of 0.1% result in calculated velocities of up to 3.3 ft/day (1,200 ft/year), rates which are comparable to those found in the sheared saprolitic dike at B-34. This accounts for why recharge rates and yield for deep rock wells can be so high compared to saprolite wells, but it must be remembered that high yields in rock wells are absolutely dependent upon the existence of well connected fracture systems which allow flow of ground water to the well to take place. The intent and purpose of this study is not to define the orientation of bedrock fracture systems or to completely characterize the bedrock aquifer on site, but it is useful to discuss the relationship between the uppermost (saprolite) aquifer and the

bedrock aquifer, if only to provide a conceptual framework for designing a monitoring system.

Finally, it should be noted again that the various dikes at the site have highly variable hydrogeologic characteristics as a function of depth, degree of weathering, fracturing, and shearing, and rock type. As previously mentioned, the saprolite developed by weathering of a diorite dike at B-34 had the highest conductivity measured on site, but at depth this same dike was essentially impermeable.

Indeed, the conductivity of the mafic dike at B-1d (deep rock) is so low that recharge after well development took between four and six months. This data suggests that these dikes would be extremely poor conduits for recharge between the uppermost saprolite aquifer and the bedrock aquifers. They may also act as barriers to horizontal flow depending upon the depths at which they become impermeable.

2.5 Topographic Map of the Site

Rule .1623(a)(10) requires a topographic map with the boring locations. Figure D-1 provides a topographic map with the piezometer and boring locations and the cross-section layout.

SECTION 3
DESIGN OF MONITORING SYSTEM

Rule .1623(b)(2)(B) requires technical information necessary to determine the design of the monitoring system. The proposed Water Quality Monitoring Plan is included in the following chapter of this submittal. See Figure D-6 for a layout of the proposed monitoring system.

SECTION 4
INFORMATION FOR RELEVANT POINT OF COMPLIANCE

Rule .1623(b)(2)(C) requires technical information necessary to determine the relevant point of compliance. Rule .1631(a)(2)(A) states that the relevant point of compliance shall be located no more than 250 feet from the waste boundary and at least 50 feet from the property boundary. All of the monitoring wells that will be installed for the Phase III landfill's ground-water monitoring system will meet this criteria; most will be located within 150 feet of the waste boundary. Further discussion of monitoring well locations is provided in the Water Quality Monitoring Plan.

SECTION 5
ROCK CORE DESCRIPTIONS

Rule .163(b)(2)(D) requires a description of rock cores obtained to provide an understanding of the fractured bedrock conditions.

Rock cores were obtained from borings B-1d, B-9d, B-17d, B-22d, B-25d, B-34d, MW-11, and MW-13. Borings B-9d, B-22d, and B-25d were cored into granite, B-1d and B-34d into mafic intrusives, and B-17, MW-11, and MW-13 into gneiss.

Bedrock was encountered at depths of approximately 0.5 to 38.5 feet below ground surface across the proposed site, but generally at between 10 and 25 feet below ground. Recovery values for core samples ranged from 44 to 100 percent, with an average of 84 percent. Rock Quality Designation (RQD) values ranged from 25 (very poor/poor) to 99 (excellent). The low recovery and RQD values are indicative of poor rock quality due to extensive fracturing in the upper 10 feet of the bedrock. In general, the RQD values were the highest in cores of mafic intrusives and felsic gneiss and lowest in the granite which appears to be quite fractured and is crumbly at least in the upper portion of bedrock. At B-1d and in the lower portion of B-34d, the mafic and diorite dike rock appears to be quite competent. In contrast, the greenstone and diorite encountered at B-9d and the upper part of B-34d was only of poor or fair-poor quality. The variability in the RQD values clearly reflects the differing degrees of fracturing found from one dike to another at the Phase III site.

Published literature indicates that the secondary porosity of granitic rock is approximately 0.1 percent (Heath, 1980). The more extensive fracturing that occurs in the upper portion of the bedrock tends to increase the secondary porosity. A secondary porosity value of five percent was used in Section 2.4 for calculating flow velocities.

A number of types of fractures were present in the recovered samples and included both open and healed fractures, with healed fractures occurring more frequently. Core logs are provided as a part of the boring logs in Appendix A.

SECTION 6
GROUND-WATER CONTOUR MAP

Rule .1623(b)(2)(E) requires a ground-water contour map based on the long-term seasonal high water table. Adjusted ground-water elevations measured on January 29, 1996, were used to construct the contour map (see Figure D-2).

Ground-water flow within the Phase III area is towards the northeast with some localized influence created by the unnamed creek which trends north-south along the eastern margin of the proposed site.

SECTION 7
BEDROCK CONTOUR MAP

Rule .1623(b)(2)(F) requires a bedrock contour map illustrating the contours of the upper surface of the bedrock. Figure D-3 presents the bedrock contour map. The depth to the top of bedrock was determined primarily on auger refusal depths with additional information from blow counts and visual inspection.

The depth to the top of bedrock varies from 0.5 to 38.5 feet across the proposed expansion site. Examination of Figure D-3 shows two major northeast trending bedrock ridges which occur along the eastern and western margins of the expansion area, and a central northeast trending bedrock valley. The bedrock ridges are associated with areas which are intruded by numerous mafic and felsic dikes and sills which apparently are more resistant to chemical weathering than the surrounding granitic and gneissic country rocks. The drainage associated with the unnamed creek along the eastern margin of the Phase III area also appears to be exerting some control over the shape and orientation of bedrock contours.

SECTION 8
GROUND-WATER FLOW NETS

Rule .1623(b)(2)(G) requires several hydrogeologic cross-sections that characterize the vertical ground-water flow regime for the site. Figures D-5A and D-5B present hydrogeologic cross-sections A-A′, B-B′, and C-C′. These cross-sections were constructed using ground-water elevations obtained on January 29, 1996.

Cross-sections A-A′ and B-B′ are oriented perpendicular to the ground-water flow direction, while C-C′ is oriented parallel to ground-water flow direction. The cross-sections indicate that ground-water flow has a strong downward vertical component of flow in the higher elevation and central portions of the proposed Landfill expansion area, with decreasing downward gradients being present at lower elevations and toward the unnamed creek and former lakes. It is expected that ground-water discharge may occur along this drainage feature itself, but no direct data is available to confirm this. According to Heath (1980), the hydrogeologic setting for the Piedmont is characterized by ground-water recharge in upland areas and discharge in lowland areas along creeks/rivers. The available data suggests that this pattern also prevails in the Phase III area.

SECTION 9
GROUND-WATER FLOW REGIME

Rule .1623(b)(2)(H) requires a report on the ground-water flow regime for the site area. Section 2.4.2 provides a detailed discussion on the vertical and horizontal components of ground-water flow.

SECTION 10
BORING/PIEZOMETER ABANDONMENT

Rule .1623(b)(2)(I) requires certification by a Licensed Geologist that all borings not converted to permanent monitoring wells will be properly abandoned. All piezometers located within the Phase III area will be abandoned as delineated in 15A NCAC 2C Rule .0113(a)(2) prior to Landfill construction. Since construction is not expected to begin for several months, the piezometers will be left in place in order to gather additional water level data. . After abandonment has been completed, the City of Greensboro will be responsible for providing documentation that the piezometers have been properly abandoned.

SECTION 11
VERTICAL SEPARATION CRITERIA

Rule .1623(b)(1)(A) requires adequate information to demonstrate compliance with vertical separation requirements. These requirements state that a minimum 4-foot separation shall be maintained between the bottom of the Landfill liner system and the seasonal high water table and the top of bedrock. Table 11-1 presents a summary of the vertical separation criteria and provides a comparison between base grade, top of bedrock, and seasonal high water table elevations.

The uppermost aquifer occurs within the saprolite in the Phase III area. Therefore, depth to the water table is the primary limiting factor for excavation depths. In order to ensure adequate separation, a potentiometric contour map was generated utilizing corrected long-term seasonal high water table elevations (January 29, 1996) at each piezometer (see Figure D-2). This potentiometric contour map was then used to develop the base grade for the bottom of the Phase III Landfill cell (Figure C-2). The base grades were drawn using the seasonal high water table elevations, plus at least 4 feet. As indicated on Table 11-1, the required separation between the high water table and bottom of the liner system will be maintained given the specified base grades. In addition, the required 4 feet of separation between the bottom of the clay liner and the top of rock is maintained. Given the current elevations, it is apparent that some filling will be necessary in the eastern portion of the Phase III area to build up the base grade to the specified elevations.

Table 11-1

Summary Table - Vertical Separation Criteria

Boring Number[a]	Ground Elevation[b]	Base Grade Elevation[c]	Top of Bedrock[d]	Bedrock Separation	Seasonal High Water Table Elevation[e]	Water Table Separation
B-1	760.80	757.40	747.80	9.60	750.31	7.09
B-7	773.09	762.60	748.59	14.01	756.91	5.69
B-10	778.09	772.00	745.59	26.41	757.12	14.88
B-11	769.20	764.80	752.70	12.10	756.97	7.83
B-12	776.06	779.20	765.06	14.14	773.54	5.66
B-16	782.71	772.40	746.71	25.69	766.40	6.00
B-17	787.71	782.60	773.71	8.89	778.55	4.05
B-18	771.60	767.40	758.60	8.80	760.00	7.40
B-19	775.78	770.00	764.78	5.22	764.90	5.10
B-20	770.68	759.60	754.68	4.92	748.45	11.15
B-22	754.92	755.80	723.92	31.88	748.65	7.15
B-23	765.26	757.40	734.26	23.14	751.51	5.89
B-24	750.08	758.00	738.08	19.92	744.25	13.75
B-25	744.54	749.20	706.04	43.16	743.57	5.63
B-26	739.20	755.84	732.70	23.14	740.00	15.84
B-28	739.33	744.64	738.83	5.81	740.54	4.10
B-29A	743.61	751.54	735.61	15.93	742.30	9.24
B-31	747.10	752.00	722.10	29.90	747.90	4.10
B-33	757.22	758.74	742.22	16.52	754.47	4.27

Notes:
(a) Borings located within the proposed Landfill footprint (cell limits).
(b) Ground elevation at time of boring installation.
(c) See Figure C-2.
(d) See Figure D-3.
(e) Adjusted January 29, 1996, water level readings.

APPENDIX A

BORING/CORE LOGS AND PIEZOMETER/MONITORING WELL CONSTRUCTION SHEETS

PROJECT: WHITE STREET LANDFILL (PHASE III) PROJECT NO: 06770-021-018

LOCATION: GREENSBORO, N.C. BORING NUMBER: B-1d PAGE: 1 OF 1

CORE LOG

DATE: 12/17/94

NUMBER	DEPTH	REC	RQD	DESCRIPTION (ROCK)	FRACTURES (W/ANGLE)
	14'			AUGER REFUSAL	SAPROLITE
FIRST CORE RUN	18' 22' 26'	90%	78% GOOD	BASALT: FINE-GRAINED, DARK GRAY TO BLACK, CONTAINS PYRITE, HEALED FRACTURES CONTAINING PLAGIOCLASE (?) OR CHLORITE (?), PYRITE AND MANGANESE OXIDE STAINING, TWO HORIZONTAL FRACTURES WITH IRON OXIDE STAINING VERTICAL CONTACT BETWEEN BASALT AND GABBRO	HORIZONTAL HORIZONTAL
SECOND CORE RUN	30'	91%	83% GOOD	GABBRO: COARSE-GRAINED, DARK GRAY TO BLACK, SMALL PHENOCRYSTS OF PLAGLOCLASE, FEWER HEALED FRACTURES, SOME IRON OXIDE STAINING ALONG FRACTURES	HORIZONTAL HORIZONTAL HORIZONTAL HORIZONTAL
	34' 38'			TD = 31.0'	

COREHOLE COMPLETION: 31' BELOW LAND SURFACE

WATER DEPTH: 755.27 DATE: 12/27/94

DRILLING METHOD: NX CORE (15 FT.)

LOGGED BY: CURT M. WELTY, PG

KEY:
REC-RECOVERY
RQD-ROCK QUALITY DESIGNATION
NA-NOT APPLICABLE

HDR

PROJECT: WHITE STREET LANDFILL (PHASE III) PROJECT NO: 06770-021-018

LOCATION: GREENSBORO, N.C. BORING NUMBER: B-9d PAGE: 1 OF 1

CORE LOG

DATE: 12/20/94

NUMBER	DEPTH	REC	RQD	DESCRIPTION (ROCK)	FRACTURES (W/ANGLE)
				AUGER REFUSAL	SAPROLITE
FIRST CORE RUN	54' – 58'	81%	30% POOR	GREENSTONE: ALTERED BASALT DIKE, FINE-GRAINED, FOLIATED, CHLORITE-RICH, METAMORPHOSED, NUMEROUS, CLOSELY-SPACED (<1") VERTICAL FRACTURES THAT PARALLEL FOLIATION, FRACTURES COATED WITH IRON AND MANGANESE OXIDE, VERTICAL CONTACT WITH GRANITE AT 58'.	FRACTURE ZONE
SECOND CORE RUN	62' – 66'	93%	99% EXCELLENT	GRANITE: CONTAINS QUARTZ, FELDSPAR, BIOTITE AND MINOR EPIDOTE, COARSE-GRAINED, MASSIVE, FRACTURES FROM ≈20° TO 75° FROM HORIZONTAL, ABOUT ONE FRACTURE EVERY 6", IRON OXIDE COATING ON FRACTURE SURFACES	65° 65° 50°
	70'			TD = 67.0'	

COREHOLE COMPLETION: 67' BELOW LAND SURFACE

WATER DEPTH: 753.82 DATE: 12/27/94

DRILLING METHOD: NX CORE (15 FT.)

LOGGED BY: CURT M. WELTY, PG

KEY:
REC-RECOVERY
RQD-ROCK QUALITY DESIGNATION
NA-NOT APPLICAE

HDR

PROJECT: WHITE STREET LANDFILL (PHASE III) PROJECT NO: 06770-021-018

LOCATION: GREENSBORO, N.C. BORING NUMBER: B-17d PAGE: 1 OF 1

CORE LOG

DATE: 12/28/94

NUMBER	DEPTH	REC	RQD	DESCRIPTION (ROCK)	FRACTURES (W/ANGLE)
	4' 8' 12'			AUGER REFUSAL	SAPROLITE
FIRST CORE RUN	16' 20'	100%	83% GOOD	GNEISS: FOLIATED, WHITE, GRAY AND BLACK, FINE TO MEDIUM GRAINED, SLIGHTLY BROKEN TO MASSIVE, HARD TO VERY HARD, CONTAINS QUARTZ, FELDSPAR, BIOTITE MICA, MINOR PYRITE, FOLIATION NEARLY VERTICAL TO 70° FROM HORIZONTAL, OPEN FRACTURES NEARLY HORIZONTAL TO 55°, FELDSPAR HEALED FRACTURES (70-80°) TO NEARLY HORIZONTAL	30° 55° 35°
SECOND CORE RUN	24' 28'	78%	71% FAIR	GNEISS: LESS DISTINCT FOLIATION, FOLIATION AT 55° FROM HORIZONTAL, FRACTURES (60°) SLIGHTLY CONCOIDAL, HARD TO VERY HARD, MASSIVE	60°
	32' 36' 40'			TD = 28.0'	

COREHOLE COMPLETION: 28' BELOW LAND SURFACE

WATER DEPTH: 753.62 DATE: 12/29/94

DRILLING METHOD: NX CORE (14.5 FT.)

LOGGED BY: JOHN R. ISHAM

KEY:
REC-RECOVERY
RQD-ROCK QUALITY DESIGNATION
NA-NOT APPLICABLE

HDR

PROJECT: WHITE STREET LANDFILL (PHASE III) PROJECT NO: 06770-021-018

LOCATION: GREENSBORO, N.C. BORING NUMBER: B-22d PAGE: 1 OF 1

CORE LOG

DATE: 12/29/94

NUMBER	DEPTH	REC	RQD	DESCRIPTION (ROCK)	FRACTURES (W/ANGLE)
	24'				SAPROLITE
	28'			AUGER REFUSAL	
FIRST CORE RUN	32'	81%	46% POOR	GRANITE: BROKEN TO SLIGHTLY BROKEN TO 30.5',MED. HARD, BROKEN FROM 30.5' TO 33', FRACTURED (HORZ. TO 25'), COARSE-GRAINED, QUARTZ, FELDSPAR, BIOTITE MICA, MINOR INTERGRANULAR POROSITY, MORE WEATHERED AND BROKEN 30.5-33.0', IRON OXIDE AND MANGANESE OXIDE STAINING, BECOMES BROKEN TO SLIGHTLY BROKEN 33.0-35.5', HEALED FRACTURES; 35.5-39.5' IS BROKEN, MEDIUM HARD, WHITE TO BUFF GRANITE,HIGHLY FRACTURED, WEDGE-SHAPED PIECES FROM FRACTURE SETS AT 45-50',SOME VERTICAL FRACTURES WITH RIGHT ANGLE BREAKS, IRON OXIDE AND MANGANESE OXIDE STAINING; 39.5-44.5', SLIGHTLY BROKEN TO MASSIVE, MEDIUM HARD, FRACTURES AT 45' TO HORIZONTAL, HEALED FRACTURES.	FRACTURE ZONE 25' 45' 40'
	36'				
SECOND CORE RUN	40'	88%	56% FAIR		FRACTURE 45' 55'
	44'				45' 45'
	48'			TD = 47.5'	

COREHOLE COMPLETION: 44.5' BELOW LAND SURFACE

WATER DEPTH: 740.26 DATE: 12/29/94

DRILLING METHOD: NX CORE (15 FT.)

LOGGED BY: JOHN R. ISHAM

KEY:
REC-RECOVERY
RQD-ROCK QUALITY DESIGNATION
NA-NOT APPLICAT

HDR

PROJECT: WHITE STREET LANDFILL (PHASE III) PROJECT NO: 06770-021-018

LOCATION: GREENSBORO, N.C. BORING NUMBER: B-25d PAGE: 1 OF 1

CORE LOG

DATE: 12/29/94

NUMBER	DEPTH	REC	RQD	DESCRIPTION (ROCK)	FRACTURES (W/ANGLE)
	34'				SAPROLITE
				AUGER REFUSAL	
FIRST CORE RUN	38'	88%	27% POOR	GRANITE:WHITE TO CREAM, SOFT TO MEDIUM HARD, BROKEN TO SLIGHTLY BROKEN, WEATHERED, HIGHLY FRACTURED (45°-70°) WITH CONJUGATE SETS AT 90°, COARSE-GRAINED QUARTZ, FELDSPAR PARTIALLY WEATHERED TO KAOLINITE (EARTHY), PATCHY IRON OXIDE STAINING, DENDRITIC MANGANESE OXIDE COATINGS	FRACTURE ZONE
	42'				45°
					70°
					FRACTURE ZONE
SECOND CORE RUN	46'	79%	25% POOR/ V. POOR	GRANITE: SLIGHTLY BROKEN AND HARD FROM 40-45', WHITE TO CREAM, ABUNDANT CONVEX FRACTURES (45-90°), ABUNDANT HEALED FRACTURES (45-90°), CONTAINS GRAY QUARTZ, WEATHERED FELDSPAR, BIOTITE MICA, DENDRITIC MANGANESE OXIDE STAINING, MINOR VUGULAR POROSITY NEAR FRACTURE SURFACES, MINOR INTERGRANULAR POROSITY	45°
	50'				FRACTURE ZONE
					50°
				TD = 52.0'	
	54'				

COREHOLE COMPLETION: 52' BELOW LAND SURFACE

WATER DEPTH: 737.69 DATE: 1/25/95

DRILLING METHOD: NX CORE (15 FT.)

LOGGED BY: JOHN R. ISHAM

KEY:
REC-RECOVERY
RQD-ROCK QUALITY DESIGNATION
NA-NOT APPLICABLE

HDR

PROJECT: WHITE STREET LANDFILL (PHASE III) PROJECT NO: 06770-021-018

LOCATION: GREENSBORO, N.C. BORING NUMBER: B-34d PAGE: 1 OF 1

CORE LOG

DATE: 12/29/94

NUMBER	DEPTH	REC	RQD	DESCRIPTION (ROCK)	FRACTURES (W/ANGLE)
	4'			AUGER REFUSAL	SAPROLITE
FIRST CORE RUN	8' – 12'	79%	50% FAIR-POOR	DIORITE: METAMORPHOSED, FOLIATED TO NON-FOLIATED DARK GREEN, MEDIUM-GRAINED, PHANERITIC, 7-9' IS SLIGHTLY BROKEN AND HARD TO VERY HARD, FRACTURED (RIGHT ANGLE BREAK), IRON OXIDE AND MANGANESE OXIDE STAINING; 9.0-15.25' IS SLIGHTLY BROKEN TO MASSIVE, HARD TO VERY HARD, FRACTURES SCARCE (35-45°), HEALED FRACTURES WITH FELDSPAR, MINOR CHLORITE ON FRACTURE SURFACES.	FRACTURE ZONE 30°
SECOND CORE RUN	16' – 20'	100%	94% GOOD	DIORITE: SLIGHTLY METAMORPHOSED, MINOR FOLIATION, HARD TO VERY HARD, MINOR FRACTURES (HORIZONTAL TO 35°), CHLORITIZED ZONES, HEALED FRACTURES WITH FELDSPAR, NO IRON OXIDATION ON FRACTURES.	35°
	24' – 28'			TD = 22.0'	

COREHOLE COMPLETION: 22' BELOW LAND SURFACE

WATER DEPTH: 742.73 DATE: 12/29/94

DRILLING METHOD: NX CORE (15 FT.)

LOGGED BY: JOHN R. ISHAM

KEY:
REC-RECOVERY
RQD-ROCK QUALITY DESIGNATION
NA-NOT APPLICAE

HDR

FIELD BOREHOLE LOG

BOREHOLE NUMBER: B-37

PROJECT NUMBER: HORSN-3
PROJECT NAME: CITY OF GREENSBORO
LOCATION: GREENSBORO, NORTH CAROLINA
DRILLING COMPANY: ENGINEERING TECTONICS
RIG TYPE & NUMBER: MOBILE B-53
DRILLING METHOD: HOLLOW STEM AUGER
WEATHER: SUNNY, 70 DEGREES
FIELD PARTY: R. BARRON
GEOLOGIST: J. FINKBEINER
DATE BEGUN: 5/22/95 DATE COMPLETED: 5/22/95

TOP OF CASING ELEVATION: 783.02
TOTAL DEPTH: 25.0 FT
GROUND SURFACE ELEVATION: -
SHEET: 1 OF: 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	20.25	18.44
Time	10:15 AM	2:30 PM
Date	5/22/95	5/22/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION	DEPTH	LITHOLOGY	WELL INSTALLATION
5.0	5 6 10	SS	S1	D		16"		CLAYEY SILT: Brown; with trace mica. Mn staining at 55 degree angle. Some iron staining. Very uniform. Dry.	0.0		
10.0	3 5	SS	S2	M		14"		SILTY CLAY: Brown silty clay to clayey silt; Moist; No mica; some iron staining. Trace Mn staining. Trace to some whitish clay areas. Mottled with lt. brown.	10.0		
15.0	3 5	SS	S3	M		13"		SILTY CLAYEY SAND: light brown to tan. A 1/4" white feldspar layer near top of sample; some mica; Mn staining at 80 degree angle; moist	15.0		
20.0	2 3	SS	S4	M		16"		SILTY CLAYEY SAND: Light brown to tan; moist; one, near vertical, iron stain near top of sample.	20.0		
25.0	4 6	SS	S5	M		14"		Boring Terminated at 25'.	25.0		

DRILLING LOG	DIVISION: Earth Science	INSTALLATION	SHEET 1 OF 2 SHEETS
1. PROJECT: Greensboro Landfill		10. SIZE AND TYPE OF BIT: 2.0" (NQ)	
2. LOCATION (Coordinates or Station): Guilford County, NC		11. DATUM FOR ELEVATION SHOWN (TBM or MSL): TBM	
3. DRILLING AGENCY: Engineering Tectonics, P.A.		12. MANUFACTURER'S DESIGNATION OF DRILL: Mobil B-57	
4. HOLE NO. (As shown on drawing title and title number): MW-11 (CORE LOG)		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 4; UNDISTURBED --	
5. NAME OF DRILLER: David Barron		14. TOTAL NUMBER CORE BOXES: 9	
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED _____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN: 19.5'		16. DATE HOLE: STARTED 4-11-89; COMPLETED 4-13-89	
8. DEPTH DRILLED INTO ROCK: 81.0'		17. ELEVATION TOP OF HOLE: 797.80	
9. TOTAL DEPTH OF HOLE: 100.5'		18. TOTAL CORE RECOVERY FOR BORING: 100 %	
		19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	RQD	DRILL RATE	FRAC. FREQ.	FRAC ANGLE	WATER RETURN
	5	4" PVC Pit Casing	Overburden (See Boring Log)						
	10								
	15								
	20		White and black, hard to v/hard, slight to freshly weathered, foliated to massive, granoblastic, fine to med. grained gneiss with an occasional ¼" quartz vein, fractures iron-stain, some fractures green and schistose, occasional rehealed hairline fractures	100%	60%	4"/min	11/5ft	0-30°	100°/0
	25								
	30			100%	95%	3"/min	5/10ft	30-60°	95%
	35								
	40		Foliation/Preferred orientation 75 to 85 degrees from horizontal, all fractures discolored pale green and slightly schistose.	100%	95%	3.5"/min	13/10ft	15-65°	95%
	45								
	50		NOTE: Increase in mafic mineral content 50-80%, significantly less fracturing.	100%	100%	3"/min	2/10ft	60-85°	95%
	55		White and black, v. hard, freshly weathered, foliated to massive, granoblastic, fine to medium grained gneiss, fractures green and slightly schistose, foliated at 60 to 80 degrees from horizontal.	100%	96%	2.5"/min	8/10ft	30-80°	95%
	60								
	65								

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(TRANSLUCENT)

PROJECT: Greensboro Landfill | HOLE NO. 11

DRILLING LOG

DIVISION

INSTALLATION

SHEET 2 OF 2 SHEETS

1. PROJECT: Greensboro Landfill
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and file number): MW-11
5. NAME OF DRILLER
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	RQD	DRILL RATE	FRAC. FREQ.	FRAC ANGLE	WATER RETURN
	70		Occasional 2-8 mm pheno cryst between 65 to 67.5 feet.	100%	97%	1.5"/min	6/10ft	30-60°	95%
	75		Mafic and felsic mineral content approx. 50/50.	100%	100%	3"min	4/10ft	20-70°	95%
	80		NOTE: Occasional rehealed hairline fractures at 20 to 80 degrees.						
	85								
	90		NOTE: Increase in fracture frequency.	100%	92%	4"/min	11/10ft	20-70°	95%
	95		NOTE: Abundant rehealed fractures from 95 to 97 ft., major fractures oriented at 60 to 80 degrees.	100%	95%	5"/min	3/5ft	20-80°	95%
	100								
	105		Coring Terminated at 100.5'.						

PROJECT | HOLE NO.

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(TRANSLUCENT)

PROJECT: WHITE STREET LANDFILL (PHASE III) PROJECT NO: 06770-021-018

LOCATION: GREENSBORO, N.C. BORING NUMBER: MW-13 PAGE: 2 OF 2

CORE LOG DATE: 1/6/93

NUMBER	DEPTH	REC	RQD	DESCRIPTION (ROCK)	FRACTURES (W/ANGLE)
	14'			PARTIALLY WEATHERED ROCK	
FIRST CORE RUN	18' 22' 26'	92%	79% GOOD	GNEISS: FOLIATED, SLIGHTLY BROKEN TO MASSIVE, HARD TO VERY HARD, CONTAINS QUARTZ, FELDSPAR, BIOTITE MICA, FOLIATION NEARLY VERTICAL TO 70° FROM HORIZONTAL, HEALED FRACTURES WITH SERPENTINE, FINE TO MEDIUM-GRAINED, PYRITE-BEARING FRACTURES	FRACTURE ZONE 60° 65° 50° 50°
SECOND CORE RUN	30' 34'	44%	88% GOOD	GNEISS: FOLIATED, MASSIVE, HARD TO VERY HARD, MOTTLED BLACK, WHITE AND GRAY, CONTAINS QUARTZ, FELDSPAR, BIOTITE MICA, FOLIATION NEARLY VERTICAL TO 70° FROM HORIZONTAL, FRACTURES AT 35° FROM HORIZONTAL, MINIMAL IRON OXIDE STAINING OF FRACTURES	35° 35° 35° 35°
	38'			TD = 34.0'	

COREHOLE COMPLETION: 34' BELOW LAND SURFACE

WATER DEPTH: 718.5 DATE: 12/27/94

DRILLING METHOD: NX CORE (16 FT.)

LOGGED BY: JOHN R. ISHAM

KEY:
REC-RECOVERY
RQD-ROCK QUALITY DESIGNATION
NA-NOT APPLICAE

HDR

FIELD BOREHOLE LOG

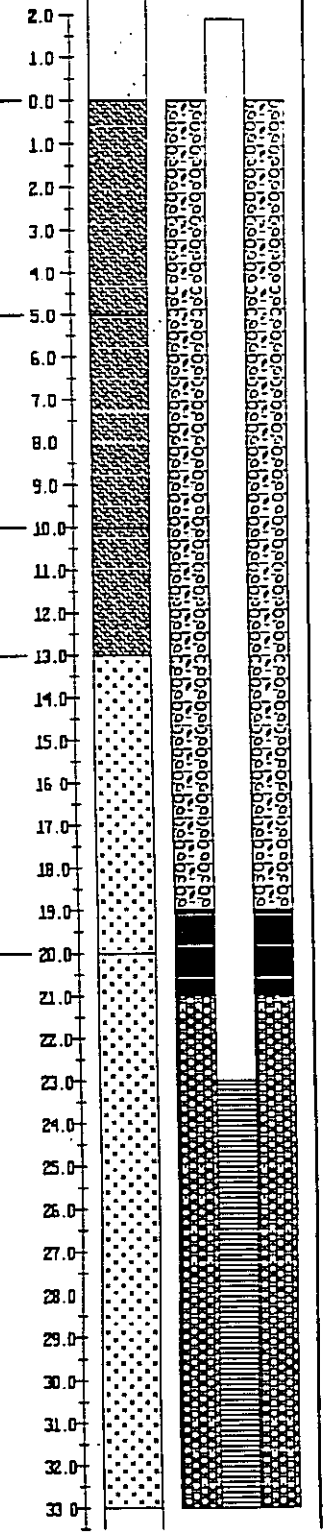
BOREHOLE NUMBER B-1

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY RON BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/15/94 DATE COMPLETED 12/15/94

TOP OF CASING ELEVATION 763.21
TOTAL DEPTH 33.0 FT
GROUND SURFACE ELEVATION 760.80
SHEET 1 OF 1

STATIC WATER LEVEL (BLS): WD=While Drilling AB=After Boring		
Depth ft:	27	18.32
Time	5:15 pm	--
Date	12/15/94	12/20/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0	2 3 5	SS	S1	M	S	15"	HSA	SILTY CLAY: reddish orange; very uniform, some manganese staining and rooting, medium plasticity, soft moist.
5.0	15 25 36	SS	S2	D	H	16"		CLAYEY SILT: has appearance of mafic very weathered rock; similar to a metagabbro; LAB USC: Silty Clayey Sand. (SC-SM)
10.0	50/4	SS	S3	D	VH	4"		CLAYEY SILT: weathered to competent mafic rock; auger refusal at 13 feet below grade, LAB USC: ~~Clayey Sand (SC)~~ Silty Sand (SM)
13.0							AH	MAFIC INTRUSIVE: competent mafic intrusive rock; drilled with an air hammer.
15.0		G		U				
18.0				D				
20.0		G		W				MAFIC INTRUSIVE: competent mafic intrusive rock, dark bluish black; drilled with an air hammer, water seam at 31.0 feet. Boring Terminated at 33.0 feet
28.0		G		W				



FIELD BOREHOLE LOG

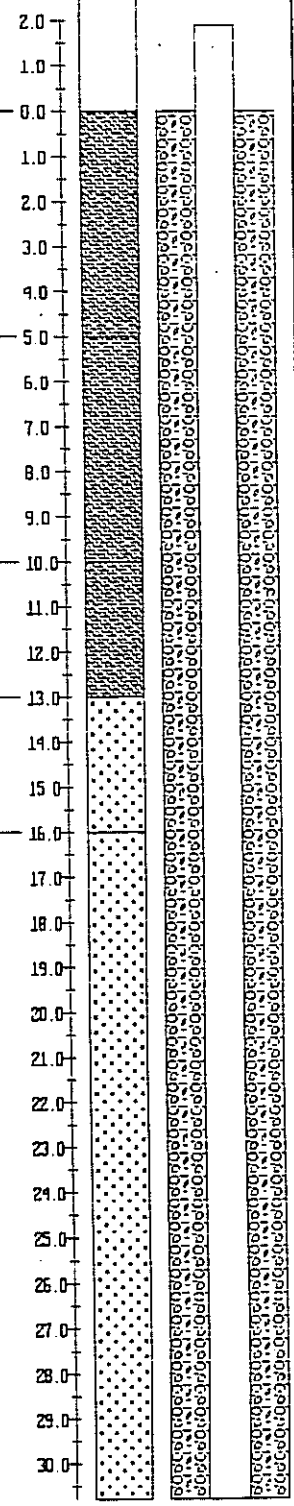
BOREHOLE NUMBER
S-1c

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HSA/AIR ROTARY/CORE/AIR HAMMER
WEATHER SUNNY
FIELD PARTY RON BARRON
GEOLOGIST P. SCHEER
DATE BEGUN 12/16/94 DATE COMPLETED 12/20/94

TOP OF CASING ELEVATION 762.55
TOTAL DEPTH 43.0 FT
GROUND SURFACE ELEVATION 760.47
SHEET 1 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	5.31	4.87
Time	-	3:18 pm
Date	12/20/94	12/27/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0	2 3 5	Ss	S1					SILTY CLAY: reddish orange; very uniform; some manganese staining and roots, medium plasticity, soft and moist.
5.0	15 25 36	Ss	S2					CLAYEY SILT: has appearance of mafic very weathered rock; similar to a mafic intrusive.
10.0	50/6s	Ss	S3					CLAYEY SILT: weathered to competent mafic rock; Auger Refusal at 13 feet.
13.0				W				WEATHERED MAFIC INTRUSIVE: drilled with air rotary from 13 to 16 feet.
16.0								MAFIC INTRUSIVE competent rock; Rock Core from 16 to 31 feet.



FIELD BOREHOLE LOG

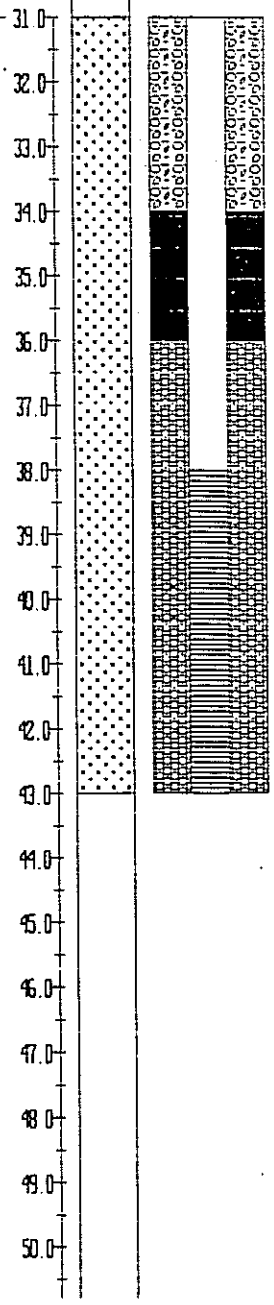
BOREHOLE NUMBER
B-1d

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HSA/AIR ROTARY/CORE/AIR HAMMER
WEATHER SUNNY
FIELD PARTY RON BARRON
GEOLOGIST P. SCHEER
DATE BEGUN 12/16/94 DATE COMPLETED 12/20/94

TOP OF CASING ELEVATION 762.55
TOTAL DEPTH 43.0 FT
GROUND SURFACE ELEVATION 760.47
SHEET 2 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	5.31	4.87
Time	-	3:18 pm
Date	12/20/94	12/27/95

DEPTH	B_OU COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
31.0								MAFIC INTRUSIVE: competent rock; Air Hammer from 31 to 43 feet;
32.0								
33.0								
34.0								
35.0								
36.0								
37.0								
38.0								
39.0								
40.0								
41.0								
42.0								
43.0								Boring Terminated at 43 feet.
44.0								
45.0								
46.0								
47.0								
48.0								
49.0								
50.0								



FIELD BOREHOLE LOG

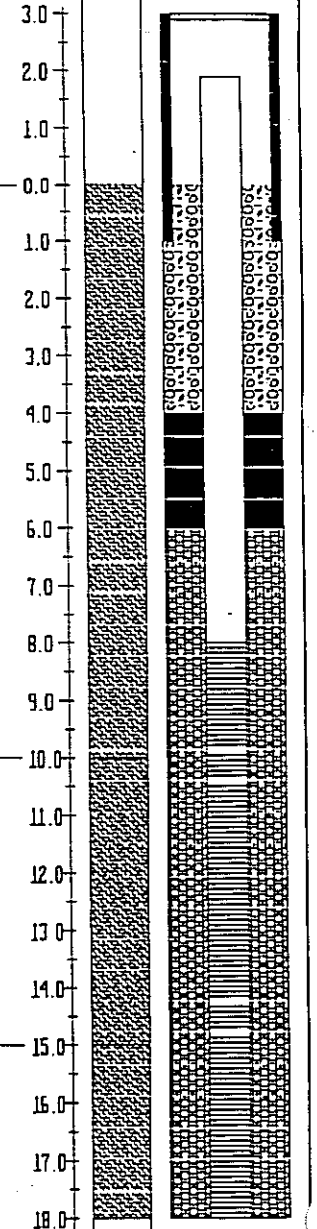
BOREHOLE NUMBER B-2

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY RON BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/15/94 DATE COMPLETED 12/19/94

TOP OF CASING ELEVATION 777.58
TOTAL DEPTH 18.5 FT
GROUND SURFACE ELEVATION 774.56
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	Dry	9.83
Time	1:00 pm	--
Date	12/15/94	12/20/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	6 15 22	Ss	S1	M	VH	16"		CLAYEY SILT dark gray to green, fine grained; micaceous; interbedded with lt. yellow tan silty sand granite; equigranular with biotite and feldspar. FELSIC GNEISS
10.0	6 12 10	Ss	S2	M	H	16"		CLAYEY SILT dark gray to green brown; micaceous with sugary white feldspar vein 1.5 inches thick FELSIC GNEISS
15.0	6 12 23	Ss	S3	W	VH	15"		CLAYEY SILT light greenish brown to yellow brown, micaceous; homogeneous, trace orange staining, FELSIC GNEISS Auger Refusal at 18.5 feet



FIELD BOREHOLE LOG

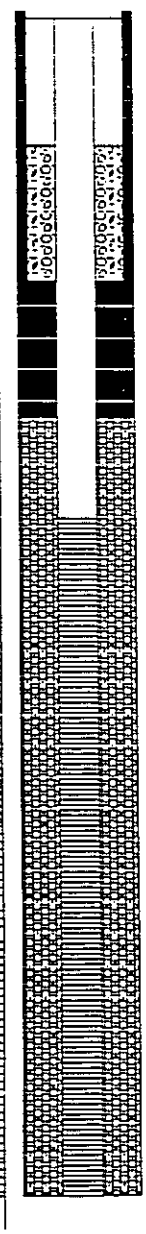
BOREHOLE NUMBER B-3

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY RON BARRON
GEOLOGIST G SIMMERMAN
DATE BEGUN 12/15/94 DATE COMPLETED 12/15/94

TOP OF CASING ELEVATION 752.65
TOTAL DEPTH 15.5 FT
GROUND SURFACE ELEVATION 749.67
SHEET 1 OF 1

STATIC WATER LEVEL (ELS) WD=While Drilling AD=After Boring		
Depth(Ft)	5.09	4.06
Time	-	-
Date	12/17/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0								CLAYEY SILT: moist; dark brown.
5.0	4 6 8	SS	S1	M	F	13"		CLAYEY SILTY SAND: mottled medium gray to orange brown; with 0.5 to 1 inch manganese nodules (black crystals with orange rinds) and a lg. (1 to 1.5 inch) quartz fragment; moist; soft.
10.0	50/3	SS	S2	M	VH	3"	HSA	SANDY SILT: medium to dark gray with clay laminae, very fine textured hornblende/feldspar schist; some orange staining, dry. FELSIC GNEISS
13.0				W				
15.0	50/4	SS	S3	W	VH	5"		SANDY SILT: dark gray amphibole interbedded with quartz veins, auger refusal at 15.3'.



FIELD BOREHOLE LOG

BOREHOLE NUMBER B-4

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR HAMMER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/15/94 DATE COMPLETED 1/6/95

TOP OF CASING ELEVATION 759 43
TOTAL DEPTH 25 0 FT
GROUND SURFACE ELEVATION 756.33
SHEET 1 OF 1

STATIC WATER LEVEL (BLS) WD=While Drilling AB=After Boring		
Depth(Ft)	13 93 AB	14 19
Time	9 40 am	2 00 pm
Date	1/10/95	1/25/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0							HSA	CLAYEY SILT: (ML) yellow brown to tan; homogeneous; trace manganese.
5.0	15 20 25	Ss	S1	D	VH	16"		CLAYEY SILT: (ML) yellow brown to tan homogeneous; trace manganese staining; trace sand; Auger Refusal at 11.0 feet.
10.0	50/6	Ss	S2	D	VH	8	AH	~~GRANITE~~ dark gray weathered material; some feldspar; drilled with air hammer; water seam at 18.0 feet. CLASSIFIED AS FELSIC GNEISS BY HDR
15.0		G						
18.0		G		W				
20.0		G						~~GRANITE~~ dark gray, some mafics, some mica in cuttings; Boring Terminated at 25.0 feet. CLASSIFIED AS FELSIC GNEISS BY HDR

LITHOLOGY

WELL INSTALLATION

FIELD BOREHOLE LOG

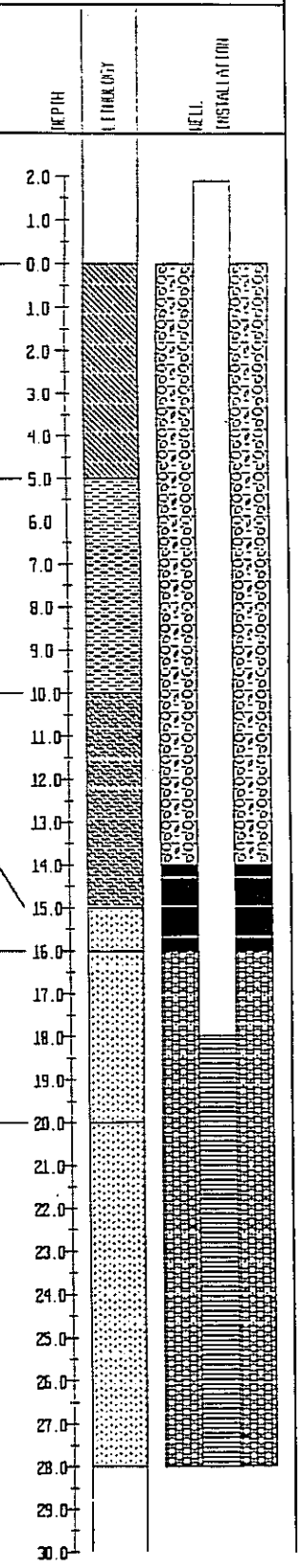
BOREHOLE NUMBER
B-5

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR HAMMER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/16/94 DATE COMPLETED 1/6/95

TOP OF CASING ELEVATION 760.13
TOTAL DEPTH 28.0 FT
GROUND SURFACE ELEVATION 758.14
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
	WD=While Drilling AB=After Boring	
Depth(Ft)	18.24	16.36
Time	11:30am	-
Date	1/10/95	1/25/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0							HSA	CLAYEY SAND: yellow orange; felsic granite.
5.0	9 12 18	Ss	S1	M	VH	12"		SILTY SAND: gray silty fine sand; trace clay; some manganese staining; clear quartz rock fragments 1/8" to 1/4" thick; firm; dry; weathered mafics.
10.0	12 11 12	Ss	S2	D	F	15"		CLAYEY SILT: light greenish gray intermediate felsic, with horizontal iron and manganese staining; damp
15.0	50/3	Ss	S3	D	VH	3		GRANITE weathered to competent; Auger Refusal at 16.0 feet.
16.0							AH	GRANITE competent granitic sand rock drilling with an air hammer
17.0		G	S4	D				
20.0		G	S5	D				GRANITE tannish gray to white granitic sand rock, some mafics including biotite, water seam encountered at 22.0 feet; Boring Terminated at 28 feet.
21.0		G	S6	D				
22.0		G	S7	D				
25.0		G	S8	M				



FIELD BOREHOLE LOG

BOREHOLE NUMBER
B-6

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR HAMMER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/16/94 DATE COMPLETED 1/5/95

TOP OF CASING ELEVATION 756.21
TOTAL DEPTH 61.0 FT
GROUND SURFACE ELEVATION 753.52
SHEET 1 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	DRY at 61'	55.53
Time	11:00 am	11:40 am
Date	1/5/95	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRIL. METHOD
5.0	12 11 13	Ss	S1			16"	
10.0	10 12 19	Ss	S2			18"	
15.0	11 20 50/5	Ss	S3			17"	

LITHOLOGY DESCRIPTION

SANDY CLAY: yellow orange to light tan; medium to coarse grained sandy clay to clayey sand; feldspar relict phenocrysts; feldspar quartz schist; no mafics or accessories; damp; Lab USC: ~~Silty Sand (SM)~~.
F-M Silty Sand (SM)

CLAYEY SAND: yellow orange; grades from sandy clay to clayey sand; felsic (feldspar quartz schist) trace biotite; damp, Lab USC ~~Silty Sand (SM)~~
silty Clayey Sand (SC-SM)

SANDY CLAY: yellow tan sandy clay to clayey sand, weathered grading to competent rock; auger refusal at 17.0 feet; Lab USC ~~Silty Sand (SM)~~
silty Clayey Sand (SC-SM)

GRANITE very felsic, some biotite; trace chlorite

LITHOLOGY

WELL INSTALLATION

FIELD BOREHOLE LOG

BOREHOLE NUMBER
B-6

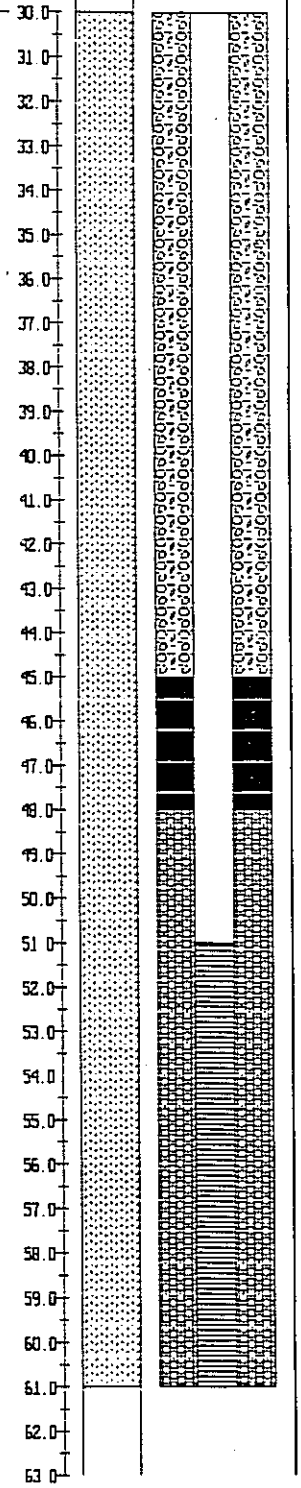
PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR HAMMER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/16/94 DATE COMPLETED 1/5/95

TOP OF CASING ELEVATION 756.21
TOTAL DEPTH 61.0 FT
GROUND SURFACE ELEVATION 753.52
SHEET 2 OF 2

STATIC WATER LEVEL (WLS)		
WD-While Drilling AB-After Boring		
Depth(Ft)	DRY at 61'	55.53
Time	11:00 am	11:40 am
Date	1/5/95	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
30.0								GRANITE: white; very felsic; some biotite; trace chlorite;
31.0								
32.0								
33.0								
34.0								
35.0								
36.0								
37.0								
38.0								
39.0								
40.0								
41.0								
42.0								
43.0								
44.0								
45.0								
46.0								
47.0								
48.0								
49.0								
50.0								
51.0								
52.0								
53.0								
54.0								
55.0								
56.0								
57.0								
58.0								
59.0								
60.0								
61.0								Boring Terminated at 61.0 feet.
62.0								
63.0								

DEPTH | LITHOLOGY | WELL INSTALLATION



FIELD BOREHOLE LOG

BOREHOLE NUMBER B-7

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/16/94 DATE COMPLETED 12/16/94

TOP OF CASING ELEVATION 773 75
TOTAL DEPTH 24.5 FT
GROUND SURFACE ELEVATION 773.09
SHEET 1 OF 1

STATIC WATER LEVEL (ALS)		
WD-While Drilling AB-After Boring		
Depth(Ft)	19 08	19 10
Time	-	-
Date	12/20/94	12/27/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	11 10 17	Ss	S1	M	H		HSA	SILTY SAND: lt. tan orange; medium to coarse grained; trace clay; very granular sand (quartz feldspar quartzite) trace iron and manganese staining; damp; LAB USC: Silty ~~Clayey~~ Sand (SM).
10.0	16 26 50/5	Ss	S2	D	VH			SILTY SAND same as above but slightly darker, with iron and manganese staining and notable feldspar grains; LAB USC: Silty ~~Clayey~~ Sand (SM).
15.0	27 50/6	Ss	S3	D	VH			SILTY SAND whitish tan; fresh; hard and dry, Silty ~~Clayey~~ Sand (SM).
20.0	22 22 24	Ss	S4	D	VH			SILTY SAND whitish tan to lt. orange with white feldspar throughout; hard, dry, LAB USC: Silty ~~Clayey~~ Sand (SM) Auger Refusal at 24.5 feet.
24.0	50/0	Ss	S5	W	VH			

LITHOLOGY

WELL INSTALLATION

FIELD BOREHOLE LOG

BOREHOLE NUMBER: B-8

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR HAMMER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/16/94 DATE COMPLETED 12/27/94

TOP OF CASING ELEVATION 756.58
TOTAL DEPTH 63.0 FT
GROUND SURFACE ELEVATION 754.93
SHEET 1 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	17.26	17.67
Time	4:55 pm	1:30 pm
Date	12/27/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	19 50/5	Ss	S1	D	VH	9"	HSA	SILTY SAND: lt. orange to white tan; quartz and feldspar; medium to coarse grained; dry; trace of weathered biotite; weathered granite.
10.0	50/5	Ss	S2	D	VH	5"		SILTY SAND: same as above; hard white, dry; auger refusal at 11'.
11.0		C	S3	D			AH	GRANITE: weathered; tan to white saprolite; soft seam at 14.0 feet.
15.0		C	S4	M				GRANITE: gray brown; hard; fine grained, water seam at 17.0 feet.
18.0								GRANITE: hard, white to gray; water seam at 53.0 feet; Boring Terminated at 63.0 feet.
20.0		C	S5	D				

LITHOLOGY

WELL INSTALLATION

FIELD BOREHOLE LOG

BOREHOLE NUMBER
B-8

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR HAMMER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/16/94 DATE COMPLETED 12/27/94

TOP OF CASING ELEVATION 756 58
TOTAL DEPTH 63 0 FT
GROUND SURFACE ELEVATION 754.93
SHEET 2 OF 2

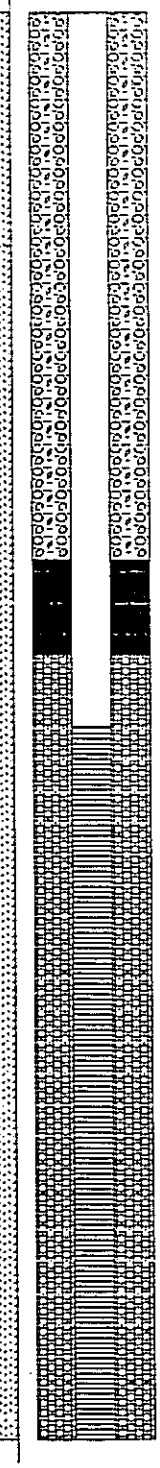
STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	17.26	17 67
Time	4 55 pm	1 30 pm
Date	12/27/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
33.0								GRANITE hard; white to gray; water seam at 53.0 feet; Boring Terminated at 63.0 feet.
34.0								
35.0		G						
36.0								
37.0								
38 0								
39.0								
40 0								
41.0								
42.0								
43.0								
44 0								
45 0								
46 0								
47 0								
48 0								
49 0								
50 0								
51 0								
52 0								
53 0								
54 0								
55 0								
56 0								
57 0								
58 0								
59 0								
60 0								
61 0								
62.0								
63 0								

DEPTH

LITHOLOGY

WELL INSTALLATION



FIELD BOREHOLE LOG

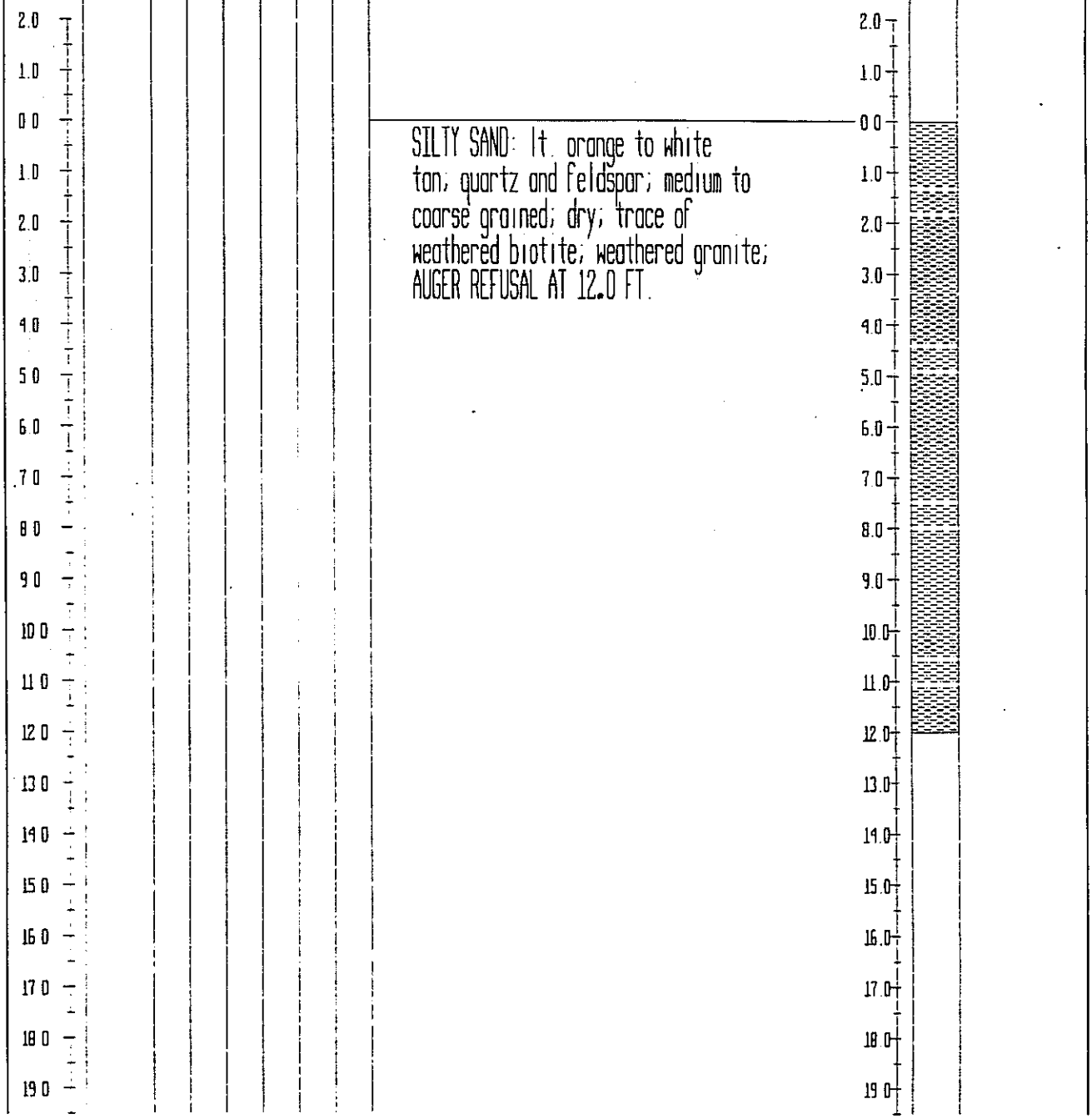
BOREHOLE NUMBER
B-9A

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR HAMMER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/16/94 DATE COMPLETED 12/16/94

TOP OF CASING ELEVATION -
TOTAL DEPTH 12.0 FT
GROUND SURFACE ELEVATION -
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	DRY	-
Time	-	-
Date	12/16/94	-

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0								SILTY SAND: lt. orange to white tan; quartz and feldspar; medium to coarse grained; dry; trace of weathered biotite; weathered granite; AUGER REFUSAL AT 12.0 FT.



FIELD BOREHOLE LOG

BOREHOLE NUMBER B-3

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/16/94 DATE COMPLETED 12/16/94

TOP OF CASING ELEVATION 761.77
TOTAL DEPTH 36.5 FT
GROUND SURFACE ELEVATION 759.04
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	15.41	14.99
Time	-	-
Date	12/16/94	12/27/94

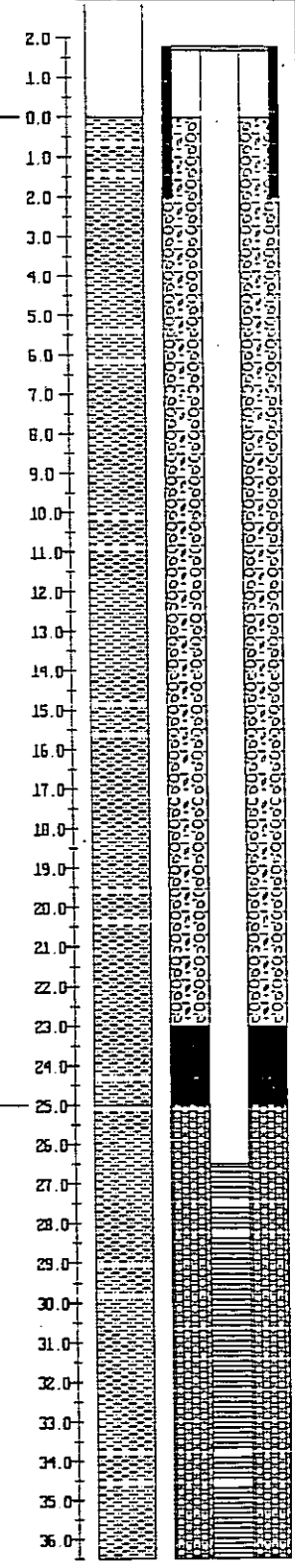
DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD
5.0	18 24 50/3	SS	S1	D		16"	
10.0	18 50/5	SS	S2	D		14"	
15.0	34 50/5	SS	S3	M		12"	
20.0	50/6	SS	S4	M		4"	
25.0	50/4	SS	S5	W		12"	
30.0	34 50/6	SS	S6	W		12"	
35.0	50/2	SS	S7	W		3"	

HSA

SILTY SAND: orange tan to white silty sand; quartz, feldspar granite with trace biotite; interspersed with manganese modules; ~~Lab USC: Silty Sand (SM)~~.

Lab USC: Silty Sand (SM)

SILTY SAND orange tan to white silty sand; quartz, feldspar granite with trace biotite, thin, 1/8" clay lens; wet; Auger Refusal at 36.5 feet.



FIELD BOREHOLE LOG

BOREHOLE NUMBER
B-9a

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD ROLLER CONE/ROCK CORE
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST P. SCHEER
DATE BEGUN 12/20/94 DATE COMPLETED 12/20/94

TOP OF CASING ELEVATION 762 41
TOTAL DEPTH 67.0 FT
GROUND SURFACE ELEVATION 759 51
SHEET 1 OF 2

STATIC WATER LEVEL (BLS) WD=While Drilling AB=After Boring		
Depth(ft)	17.39	16.99
Time	5:00 pm	-
Date	12/27/94	12/29/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0	3 8 11	SS	S1					SILT AND SAND: brown to white orange mottled silt and coarse sand; moist; weathered rock.
3.0	18 39 40	SS	S2					SILT AND SAND: same as above with more sand; some dark staining; wet at 23 feet.
8.0	29 50/3	SS	S3					
13.0	50/1	SS	S4					
18.0	50/1	SS	S5					
23.0	50/1	SS	S6	W				
28.0	36 50/6	SS	S7					WEATHERED GRANITE: weathered granitic sand rock, very weathered at top to a gray brown mottled silty sand with relict structure, soft zone at 36 feet.
33.0	50/0	SS	S8					

DEPTH

LITHOLOGY

WELL INSTALLATION

FIELD BOREHOLE LOG

BOREHOLE NUMBER: S-9a

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD ROLLER CONE/ROCK CORE
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST P. SCHEER
DATE BEGUN 12/20/94 DATE COMPLETED 12/20/94

TOP OF CASING ELEVATION 762 41
TOTAL DEPTH 67.0 FT
GROUND SURFACE ELEVATION 759.51
SHEET 2 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	17.34	16 49
Time	5 00 pm	-
Date	12/27/94	12/29/94

DEPTH	B.OM COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
33.0	50/6	Ss	S8					WEATHERED GRANITE: weathered granitic sand rock; very weathered at top to a gray brown mottled silty sand with relict structure; soft zone at 36 feet.
38.0								SILTY SAND: below weathered rock is brown to greenish silty sand; slightly moist.
43.0								WEATHERED GRANITE: weathered granite, difficult drilling; Roller Cone Refusal at 52 feet
52.0								GRANITE: light tan to white, some biotite and horneblende, rock core from 52.0 to 67.0 feet; Boring Terminated at 67.0 feet

DEPTH: 33.0, 34.0, 35.0, 36.0, 37.0, 38.0, 39.0, 40.0, 41.0, 42.0, 43.0, 44.0, 45.0, 46.0, 47.0, 48.0, 49.0, 50.0, 51.0, 52.0, 53.0, 54.0, 55.0, 56.0, 57.0, 58.0, 59.0, 60.0, 61.0, 62.0, 63.0, 64.0, 65.0, 66.0, 67.0

LITHOLOGY

WELL INSTALLATION

FIELD BOREHOLE LOG

BOREHOLE NUMBER
B-10

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/16/94 DATE COMPLETED 12/16/94

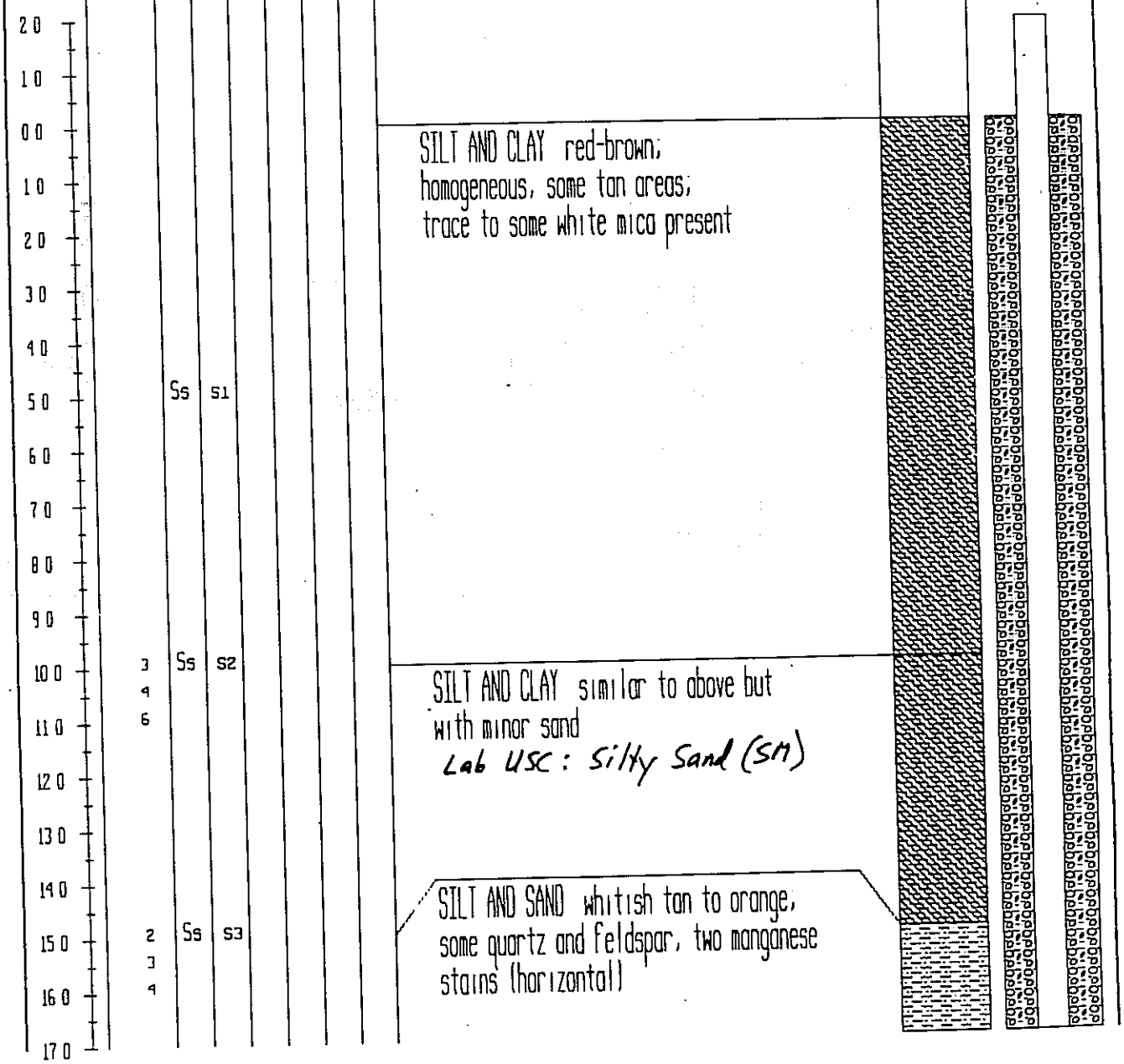
TOP OF CASING ELEVATION - 780.91
TOTAL DEPTH 32.5 FT
GROUND SURFACE ELEVATION - 778.09
SHEET 1 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	-	
Time	-	
Date	-	

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	CGI	LITHOLOGY DESCRIPTION
50		Ss	S1					SILT AND CLAY red-brown; homogeneous, some tan areas; trace to some white mica present
100	3 4 6	Ss	S2					SILT AND CLAY similar to above but with minor sand Lab USC: Silty Sand (SM)
150	2 3 4	Ss	S3					SILT AND SAND whitish tan to orange, some quartz and feldspar, two manganese stains (horizontal)

LITHOLOGY

WELL INSTALLATION



FIELD BOREHOLE LOG

BOREHOLE NUMBER
B-10

JJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/16/94 DATE COMPLETED 12/16/94

TOP OF CASING ELEVATION - 780.91
TOTAL DEPTH 32.5 FT
GROUND SURFACE ELEVATION - 778.09
SHEET 2 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)		
Time	-	
Date	-	

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	CGI	LITHOLOGY DESCRIPTION
17 0								
18 0								
19 0								
20 0	3 4 4	Ss	S4	W		12"		SILT AND SAND whitish tan to orange, some quartz and feldspar, two manganese stains (horizontal)
21 0								SILT AND SAND whitish tan to lt orange relict granite structure, small fracture at 45 degree angle, minor manganese staining, trace mica, some feldspar, trace potassium feldspar, moist Lab USC: Sandy Elastic Silt (MH)
22 0								
23 0								
24 0								
25 0	3 4 6	Ss	S5			15"		SILT AND SAND lt tan, relict granite structure, 3 horizontal manganese stains and one at a 45 degree angle, some feldspar and mica, more biotite near bottom of sample, one folded biotite or manganese stained layer
26 0								
27 0								
28 0								
29 0								
30 0	10 18 50/2	Ss	S6			12"		GRANITE weathered to competent, very felsic, biotite abundant, one folded biotite layer, auger refusal
32 0								

LITHOLOGY

WELL INSTALLATION

FIELD BOREHOLE LOG

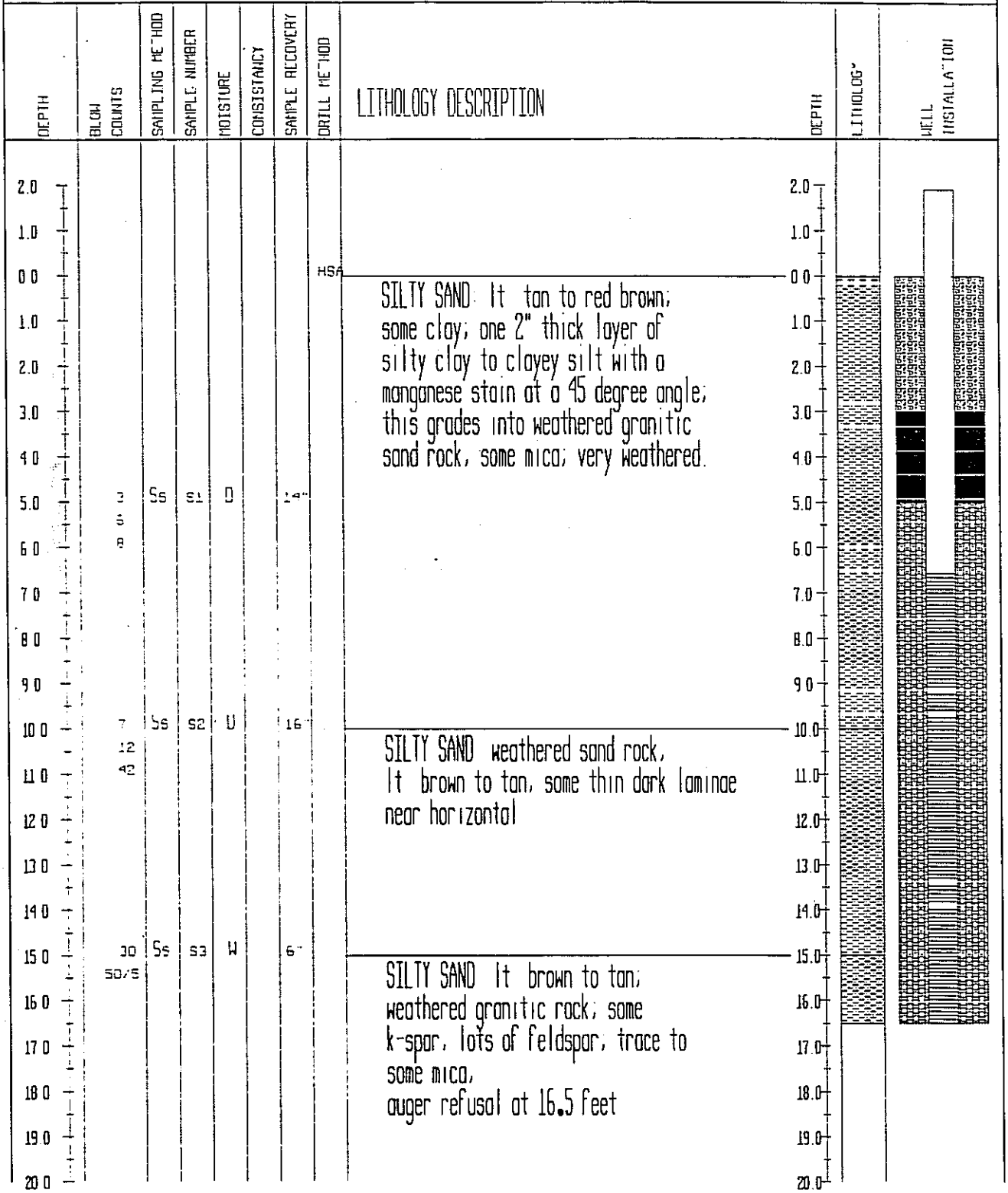
BOREHOLE NUMBER S-11

PROJECT NUMBER 99016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY RON BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/19/99 DATE COMPLETED 12/19/99

TOP OF CASING ELEVATION 772.09
TOTAL DEPTH 16.5 FT
GROUND SURFACE ELEVATION 769.20
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	14.75	14.87
Time	-	-
Date	12/20/99	12/27/99

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	3 6 8	SS	S1	D		14"	HSA	SILTY SAND lt tan to red brown; some clay; one 2" thick layer of silty clay to clayey silt with a manganese stain at a 45 degree angle; this grades into weathered granitic sand rock, some mica; very weathered.
10.0	7 12 42	SS	S2	D		16"		SILTY SAND weathered sand rock, lt brown to tan, some thin dark laminae near horizontal
15.0	30 50/5	SS	S3	W		6"		SILTY SAND lt brown to tan; weathered granitic rock; some k-spar, lots of feldspar, trace to some mica, auger refusal at 16.5 feet



FIELD BOREHOLE LOG

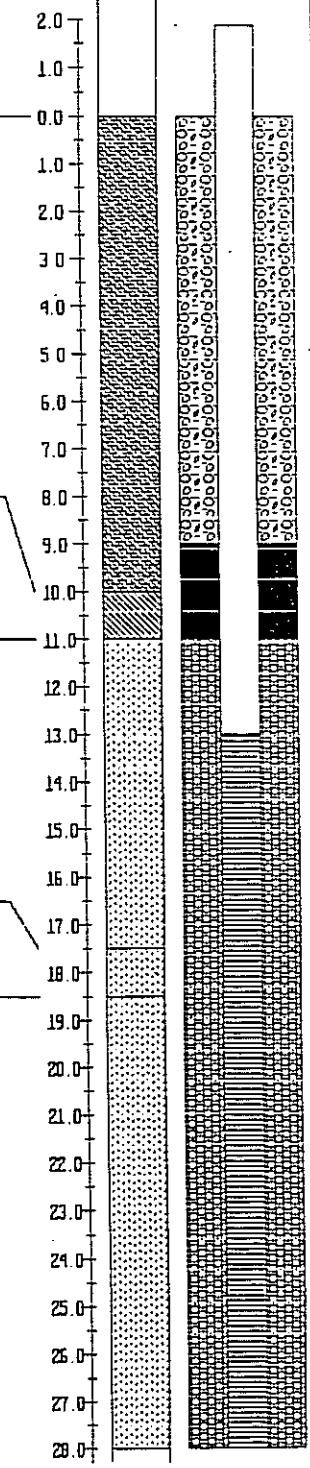
BOREHOLE NUMBER
B-12

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR HAMMER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/19/94 DATE COMPLETED 12/27/94

TOP OF CASING ELEVATION 778 84
TOTAL DEPTH 28.0 FT
GROUND SURFACE ELEVATION 776.06
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	14.14 AB	7 42
Time	11 45 am	12 15 pm
Date	12/27/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	8 12 16	Ss	S1				HSA	SILTY CLAY: red brown; some sand; one 1" thick layer of dark possibly weathered biotite; one manganese stain at a 10 degree angle; some very weathered feldspar.
10.0	7 50/6	Ss	S2				AR	CLAY: clean white clay grading downward into granitic sand rock; Auger Refusal at 11.0 feet.
							AH	GRANITE: hard; white.
17.0				W				GRANITE: orange with clay, water bearing seam.
								GRANITE: hard, white. Boring Terminated at 28 feet



FIELD BOREHOLE LOG

BOREHOLE NUMBER
B-13

PROJECT NUMBER .94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR HAMMER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/19/94 DATE COMPLETED 1/9/95

TOP OF CASING ELEVATION 793.67
TOTAL DEPTH 53.0 FT
GROUND SURFACE ELEVATION 791.91
SHEET 1 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AR=After Boring		
Depth(Ft)	28.71	28.45
Time	10:40 am	4:00 pm
Date	1/10/95	1/25/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD
5.0	6 7 13	SS	S1			12"	HSA
10.0	6 8 10	SS	S2			12"	
15.0	5 6 7	SS	S3			14"	
20.0	15 25 50/5	SS	S4		VH	16"	

LITHOLOGY DESCRIPTION

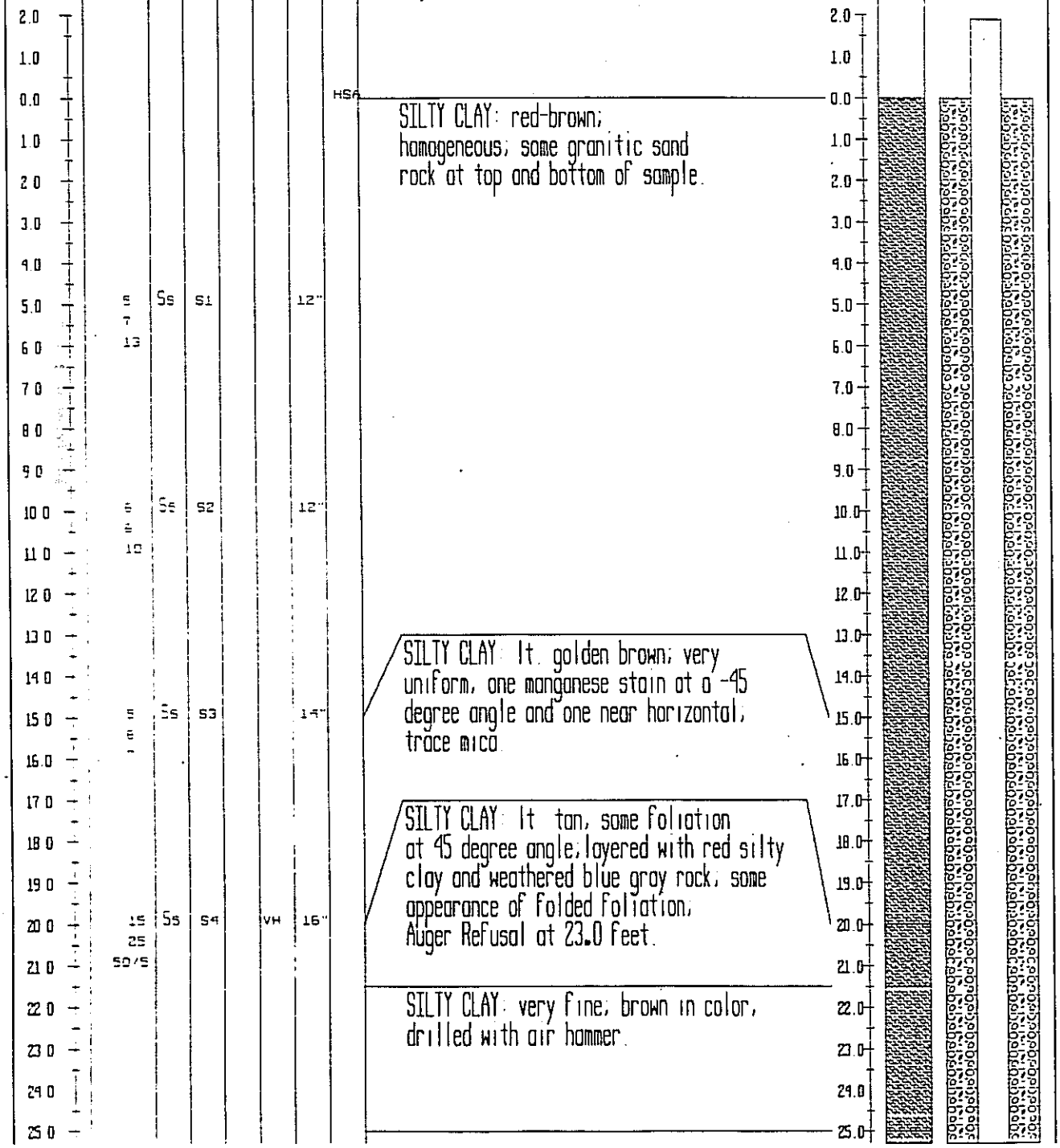
SILTY CLAY: red-brown; homogeneous; some granitic sand rock at top and bottom of sample.

SILTY CLAY: lt. golden brown; very uniform, one manganese stain at a ~45 degree angle and one near horizontal; trace mica

SILTY CLAY: lt tan, some foliation at 45 degree angle; layered with red silty clay and weathered blue gray rock; some appearance of folded foliation. Auger Refusal at 23.0 feet.

SILTY CLAY: very fine; brown in color, drilled with air hammer.

DEPTH | LITHOLOGY | WELL INSTALLATION



FIELD BOREHOLE LOG

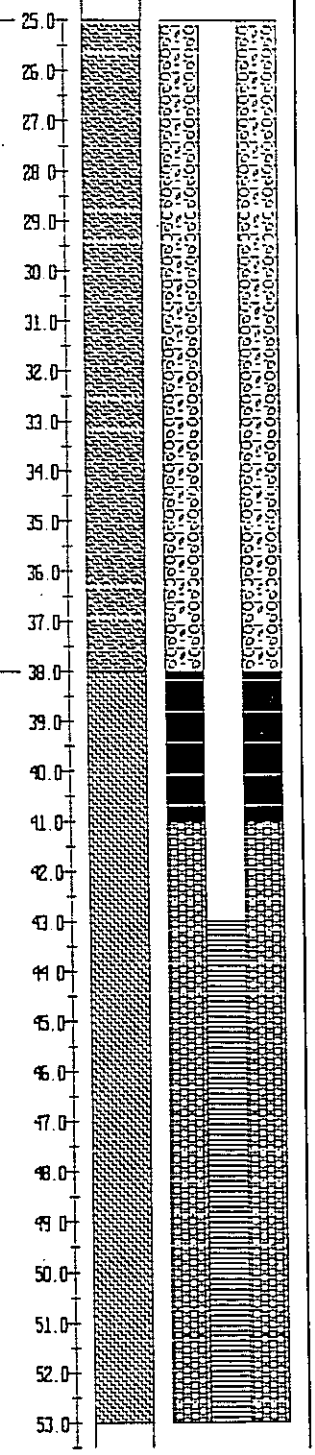
BOREHOLE NUMBER
B-13

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR HAMMER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/19/94 DATE COMPLETED 1/9/95

TOP OF CASING ELEVATION 793 67
TOTAL DEPTH 53 0 FT
GROUND SURFACE ELEVATION 791.91
SHEET 2 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AD=After Boring		
Depth(Ft)	28 71	28 45
Time	10 40 am	9:00 pm
Date	1/10/95	1/25/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
25.0								SILTY CLAY: brown, coarsening downward with increasing rock chip content in grab samples.
38.0								GNEISS feldspathic/granitic gneiss, water seam at 46 to 47 Feet, Boring Terminated at 53 Feet.
53.0								



FIELD BOREHOLE LOG

BOREHOLE NUMBER B-14

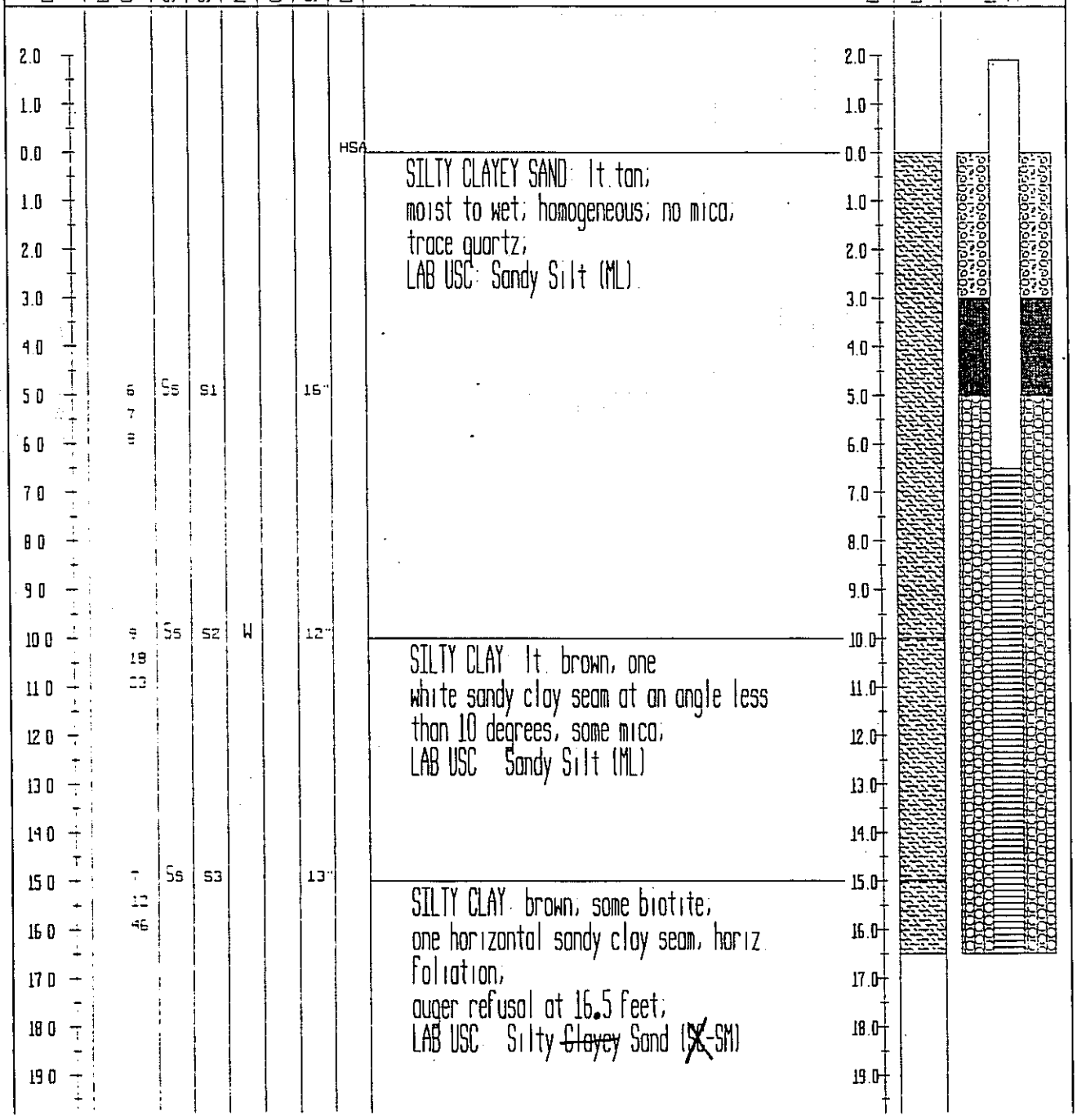
PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/19/94 DATE COMPLETED 12/19/94

TOP OF CASING ELEVATION 790.51
TOTAL DEPTH 16.5 FT
GROUND SURFACE ELEVATION 787.40
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	8.24	7.97
Time	-	2.30pm
Date	12/20/94	12/27/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	6 7 8	SS	S1			16"	HSA	SILTY CLAYEY SAND lt.tan; moist to wet; homogeneous; no mica; trace quartz; LAB USC: Sandy Silt (ML)
10.0	9 19 23	SS	S2	W		12"		SILTY CLAY lt. brown, one white sandy clay seam at an angle less than 10 degrees, some mica; LAB USC Sandy Silt (ML)
15.0	7 12 46	SS	S3			13"		SILTY CLAY brown, some biotite; one horizontal sandy clay seam, horiz foliation; auger refusal at 16.5 feet; LAB USC Silty ~~Clayey~~ Sand (SX-SM)

DEPTH | LITHOLOGY | WELL INSTALLATION



FIELD BOREHOLE LOG

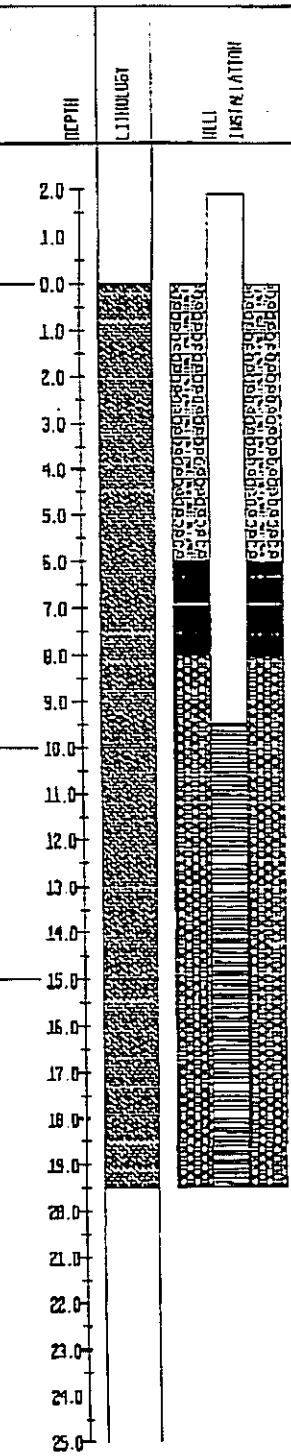
BOREHOLE NUMBER
B-15

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J FINKBEINER
DATE BEGUN 12/20/94 DATE COMPLETED 12/20/94

TOP OF CASING ELEVATION 777.19
TOTAL DEPTH 19.5 FT
GROUND SURFACE ELEVATION 774.15
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	WD	13.93
Time	-	-
Date	12/21/94	12/27/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	7 11 13	SS	S1	D		13"		
10.0	11 40 50/3	SS	S2	M		8"		SILTY CLAY: red brown; horizontal to less than 10 degree foliation; some 1/4" thick felsic bands; more mafic near top of sample, gneissic bands. SILTY CLAY: dark green to black; amphibole present; very weathered foliation at a ~30 degree angle; trace biotite; amphibolite gneiss.
15.0	50/4	SS	S3	W		4"		SILTY CLAY: weathered to competent dark rock; micaceous; foliated; auger refusal at 19.5 feet.



FIELD BOREHOLE LOG

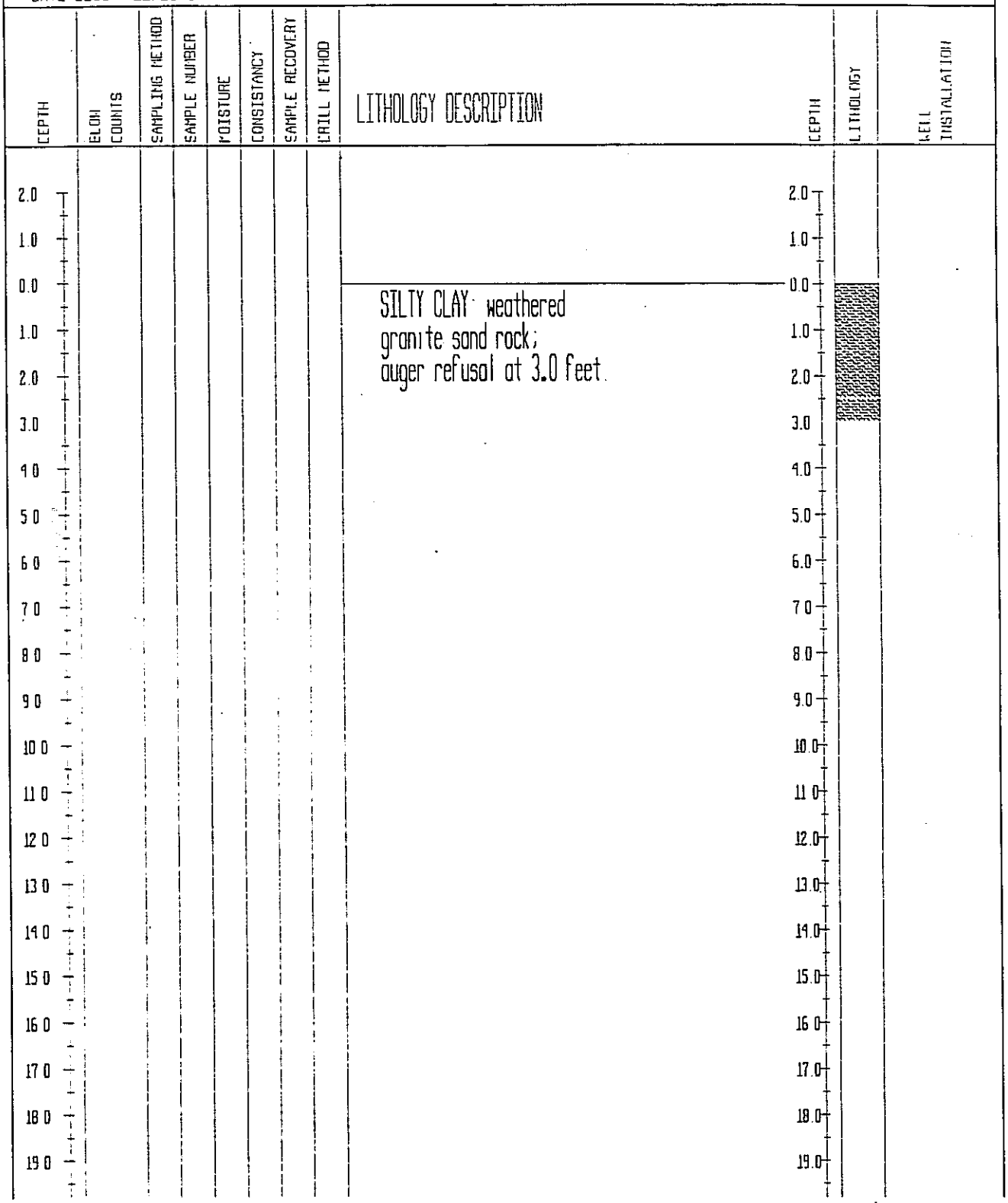
BOREHOLE NUMBER: B-15c

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/20/94 DATE COMPLETED 12/20/94

TOP OF CASING ELEVATION -
TOTAL DEPTH 3.0 FT
GROUND SURFACE ELEVATION -
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	DRY	-
Time	-	-
Date	12/20/94	-

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0								SILTY CLAY: weathered granite sand rock; auger refusal at 3.0 feet.



FIELD BOREHOLE LOG

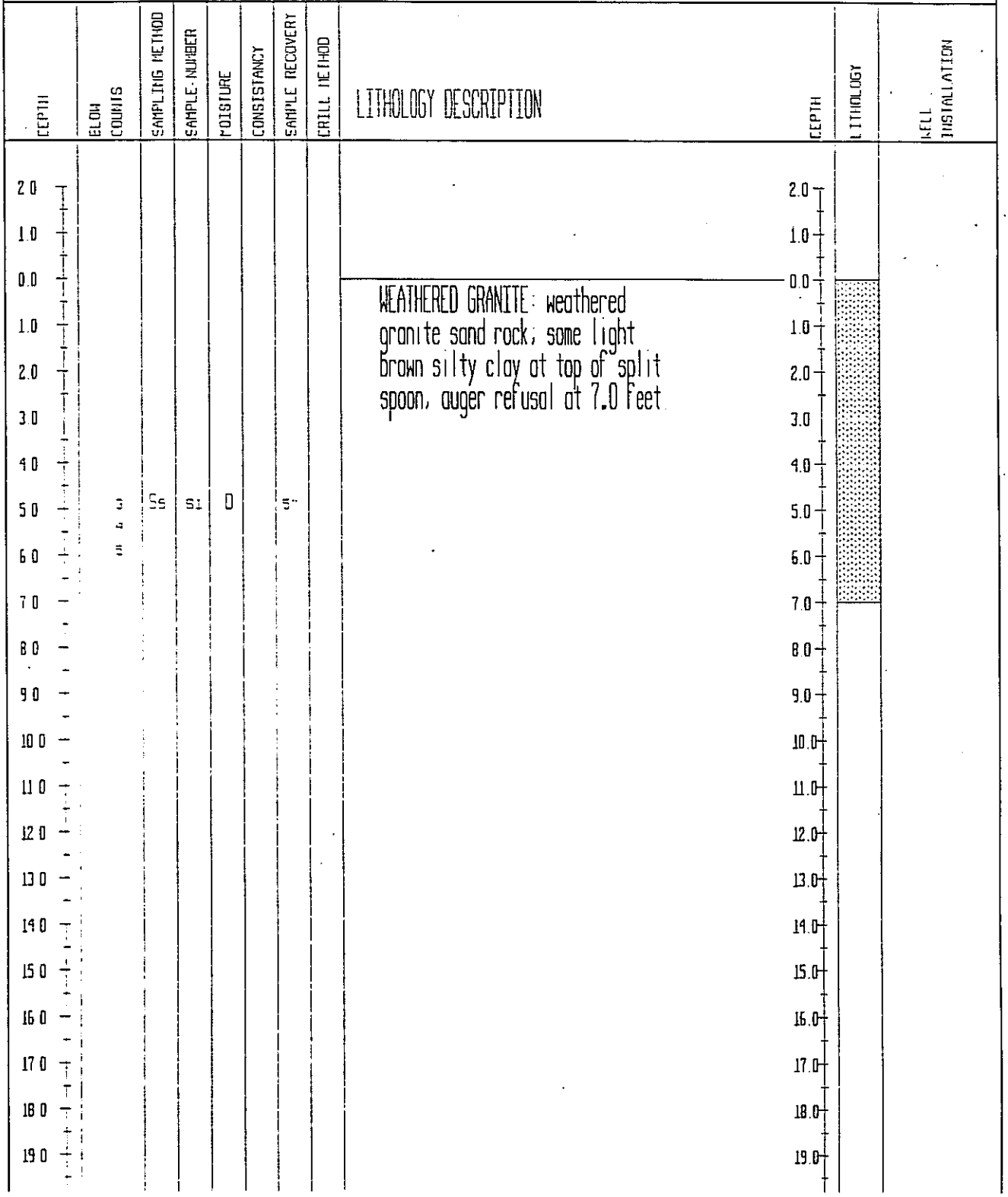
BOREHOLE NUMBER
B-15D

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/19/94 DATE COMPLETED 12/19/94

TOP OF CASING ELEVATION -
TOTAL DEPTH 7.0 FT
GROUND SURFACE ELEVATION -
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	DRY	-
Time	-	-
Date	12/20/94	-

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION	DEPTH	LITHOLOGY	WELL INSTALLATION
5.0	3 4 4	SS	S1	D		5"		WEATHERED GRANITE: weathered granite sand rock; some light brown silty clay at top of split spoon, auger refusal at 7.0 feet	0.0		
									7.0		



FIELD BOREHOLE LOG

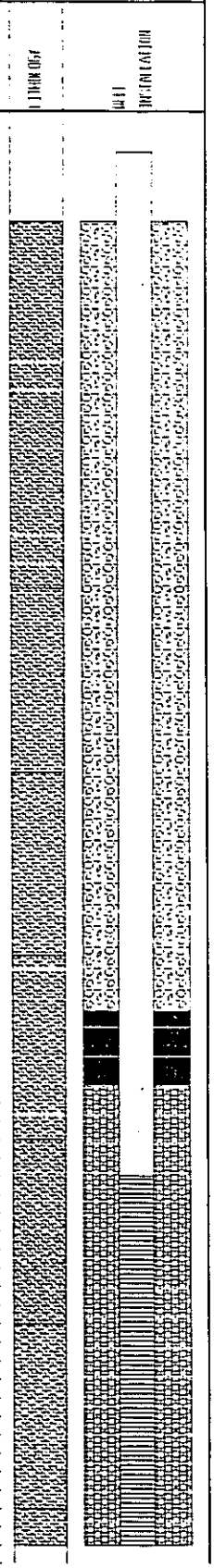
BOREHOLE NUMBER
S-12

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/19/94 DATE COMPLETED 12/19/94

TOP OF CASING ELEVATION 785 66
TOTAL DEPTH 36.0 FT
GROUND SURFACE ELEVATION 782 71
SHEET 1 OF 1

STATIC WATER LEVEL (SLS)		
WO=While Drilling AB=After Boring		
Depth(Ft)	24.35	24.46
Time	-	-
Date	12/27/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	3 5 5	SS	S1	D		12"	HSA	SILTY CLAYEY SAND brown to green, some iron staining, very weathered mafic rock; amphiboles in sample. Lab usc: Sandy Silt (mL)
10.0	3 3 4	SS	S2	D		15		SILTY CLAY lt tan with green, amphibole present, iron stains at horizontal and at ~45 degree angle, homogeneous
15.0	3 6 11	SS	S3	M		16		SILTY CLAY lt tan with green, weathered amphiboles, one manganese stain near horizontal Lab usc: Elastic Silt with Sand (mH)
20.0	4 6 8	SS	S4	M		16		SILTY CLAY green, 1/4" white sandy, rest is weathered mafic rock
25.0	9 12 14	SS	S5	M		16		SILTY CLAY green, three horizontal manganese stains, several small ovals of very weathered biotite, overall weathered mafic rock, LAB USC Elastic SILT with SAND (MH)
30.0	12 16 23	SS	S6	M		16		SILTY CLAY two manganese stains at 45 degree angle, bottom of sample has a horizontal foliation, some amphiboles
35.0	32 50.3	SS	S7	W		7"		SILTY CLAY dk green, weathered mafic rock; auger refusal



FIELD BOREHOLE LOG

BOREHOLE NUMBER B-17

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR HAMMER/CORE
WEATHER SUNNY, COOL
FIELD PARTY DAVID BARRON
GEOLOGIST J FINKBEINER
DATE BEGUN 12/19/94 DATE COMPLETED 12/28/94

TOP OF CASING ELEVATION 789.61
TOTAL DEPTH 28.0 FT
GROUND SURFACE ELEVATION 787.71
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD-While Drilling AB-After Boring		
Depth(Ft)	22.29	13.59
Time	-	-
Date	12/29/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0							HSA	
5.0	3 4 5	SS	S1			15"		SILTY CLAY: brown; two horizontal manganese stains; one of these is 1/4" thick; one thin vertical manganese stain; dark nodes of biotite in bottom of the sample; LAB USC: Sandy SILT (ML).
10.0	3 6 12	SS	S2			13"		SILTY CLAY: brown, some sand; homogeneous; one manganese stain at a less than 10 degree angle; LAB USC Silty Sand (SM) Auger Refusal at 14.0 Feet.
13.0							AH	
14.0							C	GRANITE GNEISS very hard, granite to granite gneiss, drilled by ND rock core; one very fractured section at 14.1 feet, fresh break at 23.0 feet; no fractures from 23.5 to 28.5 feet; first 10 foot core run recovered 96%; second 5 foot core run recovered 71%; Boring Terminated at 28.0 feet.

WELL INSTALLATION

FIELD BOREHOLE LOG

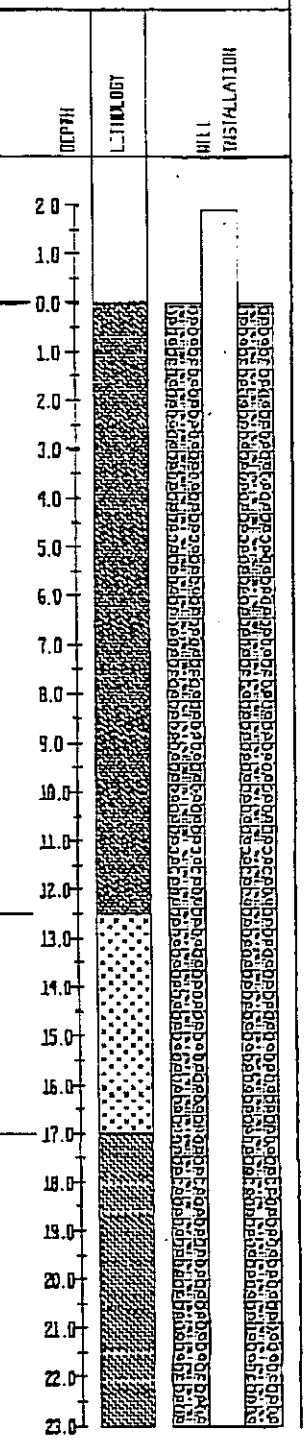
BOREHOLE NUMBER B-17d

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/28/94 DATE COMPLETED 12/28/94

TOP OF CASING ELEVATION 789.66
TOTAL DEPTH 53.0 FT
GROUND SURFACE ELEVATION 787.71
SHEET 1 OF 2

STATIC WATER LEVEL (BLS)		
WD-While Drilling AB-After Boring		
Depth(Ft)	29.09	34.09
Time	11:05am	-
Date	1/10/95	12/29/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0							HSA	SILTY CLAY: brown; some manganese stains; dark nodes of biotite in bottom of the sample.
5.0				D				
10.0				D				Auger Refusal at 12.5 Feet.
12.0							AH	MAFIC INTRUSIVE: blue in color; competent rock.
15.0				D				
17.0								GNEISS: granite gneiss with dark biotite banding
20.0				D				



FIELD BOREHOLE LOG

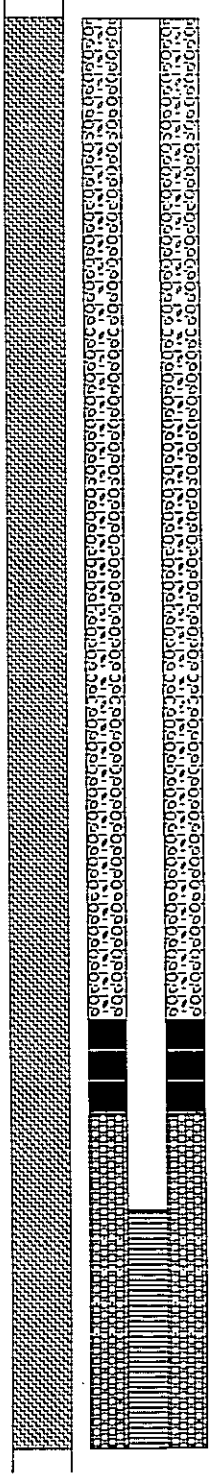
BOREHOLE NUMBER
B-17d

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/28/94 DATE COMPLETED 12/28/94

TOP OF CASING ELEVATION 789.66
TOTAL DEPTH 53.0 FT
GROUND SURFACE ELEVATION 787.71
SHEET 2 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	29.09	34.09
Time	11:05am	-
Date	1/10/95	12/29/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
23.0								GNEISS more felsic than above; slightly moist at 33.5 feet; a second water seam at 50 feet; 53 feet below grade is a water seam with the most water production; Boring Terminated at 53.0 ft.
24.0				D				
25.0								
26.0								
27.0								
28.0								
29.0				D				
30.0								
31.0								
32.0				M				
33.0								
34.0				D				
35.0								
36.0								
37.0								
38.0								
39.0				D				
40.0								
41.0								
42.0								
43.0								
44.0				D				
45.0								
46.0								
47.0								
48.0								
49.0				W				
50.0								
51.0								
52.0								
53.0				W				



FIELD BOREHOLE LOG

BOREHOLE NUMBER: B-18

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR HAMMER
WEATHER SUNNY, COOL
FIELD PARTY DAVID BARRON
GEOLOGIST J FINKBEINER
DATE BEGUN 12/19/94 DATE COMPLETED 12/27/94

TOP OF CASING ELEVATION 774.40
TOTAL DEPTH 49.0 FT
GROUND SURFACE ELEVATION 771.60
SHEET 1 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	15.64	14.38
Time	-	-
Date	12/29/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD
5.0	3 4 6	Ss	S1	D		12"	
10.0	4 6 7	Ss	S2	D		12"	

LITHOLOGY DESCRIPTION

SILTY CLAY: brown; one near vertical iron stain; bottom of sample varies from dk. green clay to white clay.

SILTY CLAY weathered white granitic sand rock, some quartz; no mica
Auger Refusal at 13 feet.

MAFIC INTRUSIVE air hammer drilling blue mafic rock, Boring Terminated at 49'

LITHOLOGY

WELL INSTALLATION

FIELD BOREHOLE LOG

BOREHOLE NUMBER
B-18

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR HAMMER
WEATHER SUNNY, COOL
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/19/94 DATE COMPLETED 12/27/94

TOP OF CASING ELEVATION 774.90
TOTAL DEPTH 49.0 FT
GROUND SURFACE ELEVATION 771.60
SHEET 2 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	15.64	14.38
Time	-	-
Date	12/29/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION	DEPTH	LITHOLOGY	WELL INSTALLATION
25.0								MAFIC INTRUSIVE: air hammer drilling blue mafic rock; Boring Terminated at 49'.	25.0		
26.0									26.0		
27.0									27.0		
28.0									28.0		
29.0									29.0		
30.0									30.0		
31.0									31.0		
32.0									32.0		
33.0									33.0		
34.0									34.0		
35.0									35.0		
36.0									36.0		
37.0									37.0		
38.0									38.0		
39.0									39.0		
40.0									40.0		
41.0									41.0		
42.0									42.0		
43.0									43.0		
44.0									44.0		
45.0									45.0		
46.0									46.0		
47.0									47.0		
48.0									48.0		
49.0									49.0		

FIELD BOREHOLE LOG

BOREHOLE NUMBER
B-19

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY/ROLLERCONE
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/20/94 DATE COMPLETED 1/2/95

TOP OF CASING ELEVATION 778.28
TOTAL DEPTH 33.0 FT
GROUND SURFACE ELEVATION 775.78
SHEET 1 OF 1

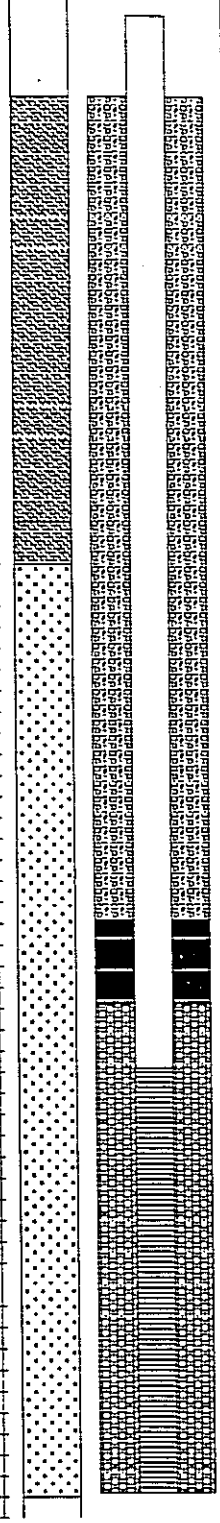
STATIC WATER LEVEL (BLS)		
WO=While Drilling AB=After Boring		
Depth(Ft)	18.74	19.22
Time	-	-
Date	1/10/94	1/25/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	12 24 30	Ss	S1			15"		
10.0	10 50/5	Ss	S2			12"		
26.0				M				

SILTY CLAY: dk. green to brown; weathered mafic rock; some manganese staining, no foliation.

SILTY CLAY: weathered mafic rock; individual amphiboles seen; no foliation; auger refusal at 11.0'.

MAFIC INTRUSIVE: hard mafic rock; boring terminated at 33 feet.



FIELD BOREHOLE LOG

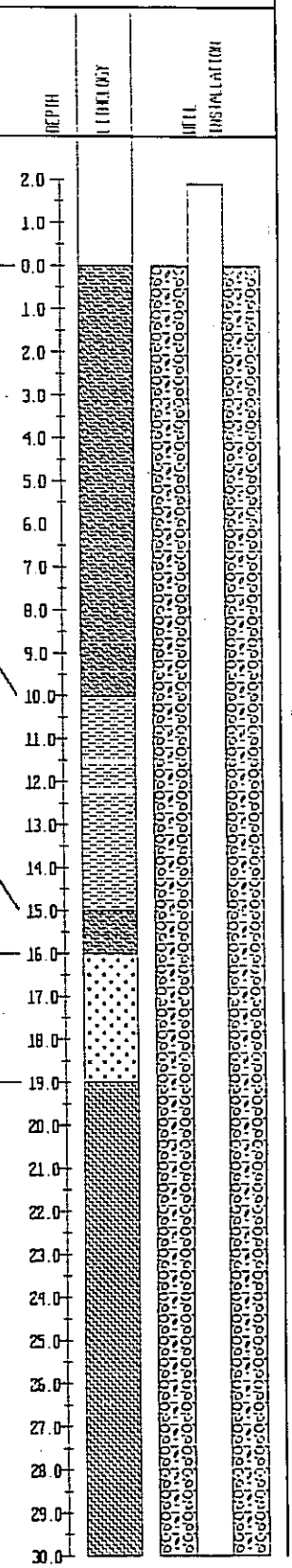
BOREHOLE NUMBER: B-20

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/20/94 DATE COMPLETED 1/3/95

TOP OF CASING ELEVATION 772.18
TOTAL DEPTH 63.5 FT
GROUND SURFACE ELEVATION 770.68
SHEET 1 OF 2

STATIC WATER LEVEL (BLS)		
WD-While Drilling AB-After Boring		
Depth(ft)	25.96	25.73
Time	1:10pm	-
Date	1/10/95	1/25/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	12 24 32	SS	S1					SILTY CLAY: bottom of sample is weathered mafic rock with amphiboles in a honeycomb of thin felsic veins; some iron staining; vertical foliation; above this in the sample is 5" thick layer of granitic sand rock; some quartz; trace to no mica; contact between the sand rock and the mafic is at a 45 degree angle, above the sand rock is more weathered mafic rock with a similar contact between; Lab USC: Sandy Lean Clay (CL).
10.0	20 33 50/5	SS	S2					SILTY SAND: dk. brown granitic sand rock; some quartz; some biotite; upper 4" of sample is dk. green and has more clay; weathered contact has biotite; vertical foliation in bottom of spoon; Lab USC: Silty Clayey Sand (SC-SM)
15.0	50/4	SS	S3					SILTY CLAY: weathered mafic micaceous rock; auger refusal at 16.0'
16.0								MAFIC INTRUSIVE: hard mafic rock, drilling with air hammer, cuttings are green in color
19.0								GNEISS: cuttings are grayish, progressively more banding noted in samples as we progress downward



FIELD BOREHOLE LOG

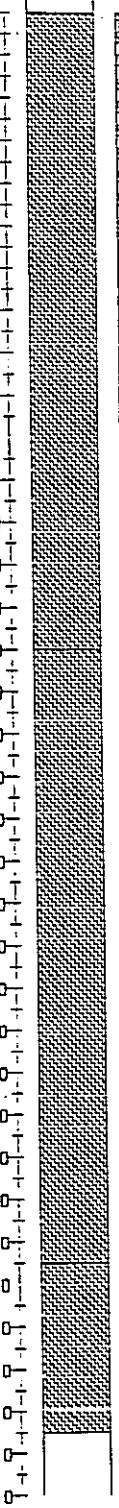
BOREHOLE NUMBER S-20

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/20/94 DATE COMPLETED 1/3/95

TOP OF CASING ELEVATION 772.18
TOTAL DEPTH 63.5 FT
GROUND SURFACE ELEVATION 770 68
SHEET 2 OF 2

STATIC WATER LEVEL (BLS) WD=While Drilling AB=After Boring		
Depth(ft)	27 96	25 73
Time	1 10pm	
Date	1/10/95	1/25/95

DEPTH	PEN RM	COMMTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
30.0									GNEISS: cuttings are grayish; progessively more banding noted in samples as we progress downward.
45.0									GNEISS Felsic, banding visible in cuttings.
60.0					W				GNEISS Felsic, water seam at 59 5 feet; Boring Terminated at 63 5 feet



FIELD BOREHOLE LOG

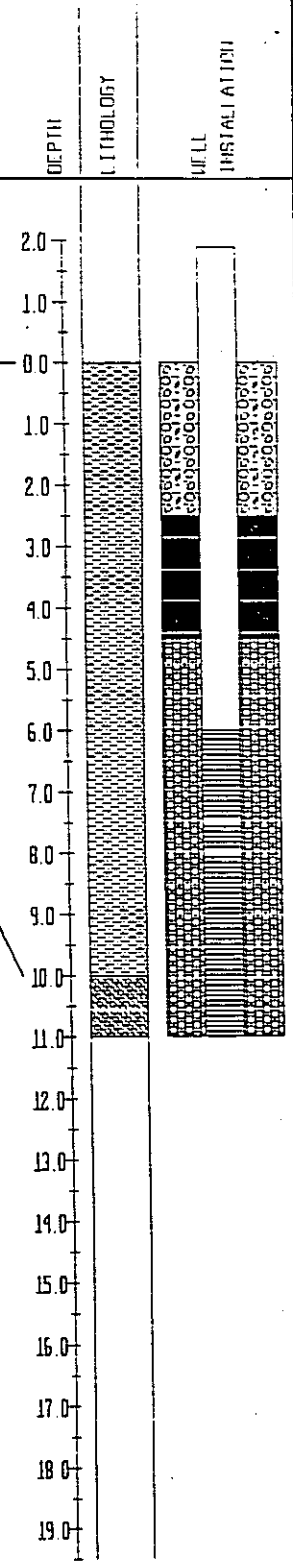
BOREHOLE NUMBER B-21

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/20/94 DATE COMPLETED 12/22/94

TOP OF CASING ELEVATION 759.84
TOTAL DEPTH 11.0 FT
GROUND SURFACE ELEVATION 756.82
SHEET 1 OF 1

STATIC WATER LEVEL (ELS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	5.02	5.13
Time	11:55am	-
Date	1/10/95	1/25/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHIOLOGY DESCRIPTION
5.0	12 50/4	SS	S1			8"		SILTY SAND: white granitic sand rock; weathered feldspar and quartz; some kaolinitic clay; one 2" thick section iron stained. GRANITE
10.0	40 50/6	SS	S2			7"		SILTY CLAY mafic weathered rock; some mica and iron staining; auger refusal at 11.0 ft



FIELD BOREHOLE LOG

BOREHOLE NUMBER B-22

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J FINKBEINER
DATE OCCUN 12/20/94 DATE COMPLETED 12/20/94

TOP OF CASING ELEVATION 757.86
TOTAL DEPTH 31.0 FT
GROUND SURFACE ELEVATION 754.92
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	10.27	8.56
Time	-	-
Date	12/20/94	12/27/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD
5.0	17 50/6	SS	S1			13"	
10.0	15 24 30	SS	S2			16"	
15.0	24 50/6	SS	S3			13"	
20.0	24 32 38	SS	S4	M		11"	
25.0	24 28 50/5	SS	S5	M		12"	
30.0	24 36 50/5	SS	S6	M		6"	

LITHOLOGY DESCRIPTION

SAND: white granitic sand rock; quartz; no mica; some feldspar;
Lab USC: Silty ~~Clayey~~ Sand (~~SC~~-SM)

SAND granitic sand rock; some kaolin, quartz and iron staining; muscovite and biotite present;
Lab USC: Silty ~~Clayey~~ Sand (~~SC~~-SM)

SAND granitic sand rock, same as above with more biotite.

SAND granitic sand rock; abundant quartz and biotite; some muscovite and iron staining;
Lab USC: Silty ~~Clayey~~ Sand (~~SC~~-SM)

SAND granitic sand rock, same as above with pale green clay and less mica; auger refusal at 31.0'

DEPTH | LITHOLOGY | WELL INSTALLATION

FIELD BOREHOLE LOG

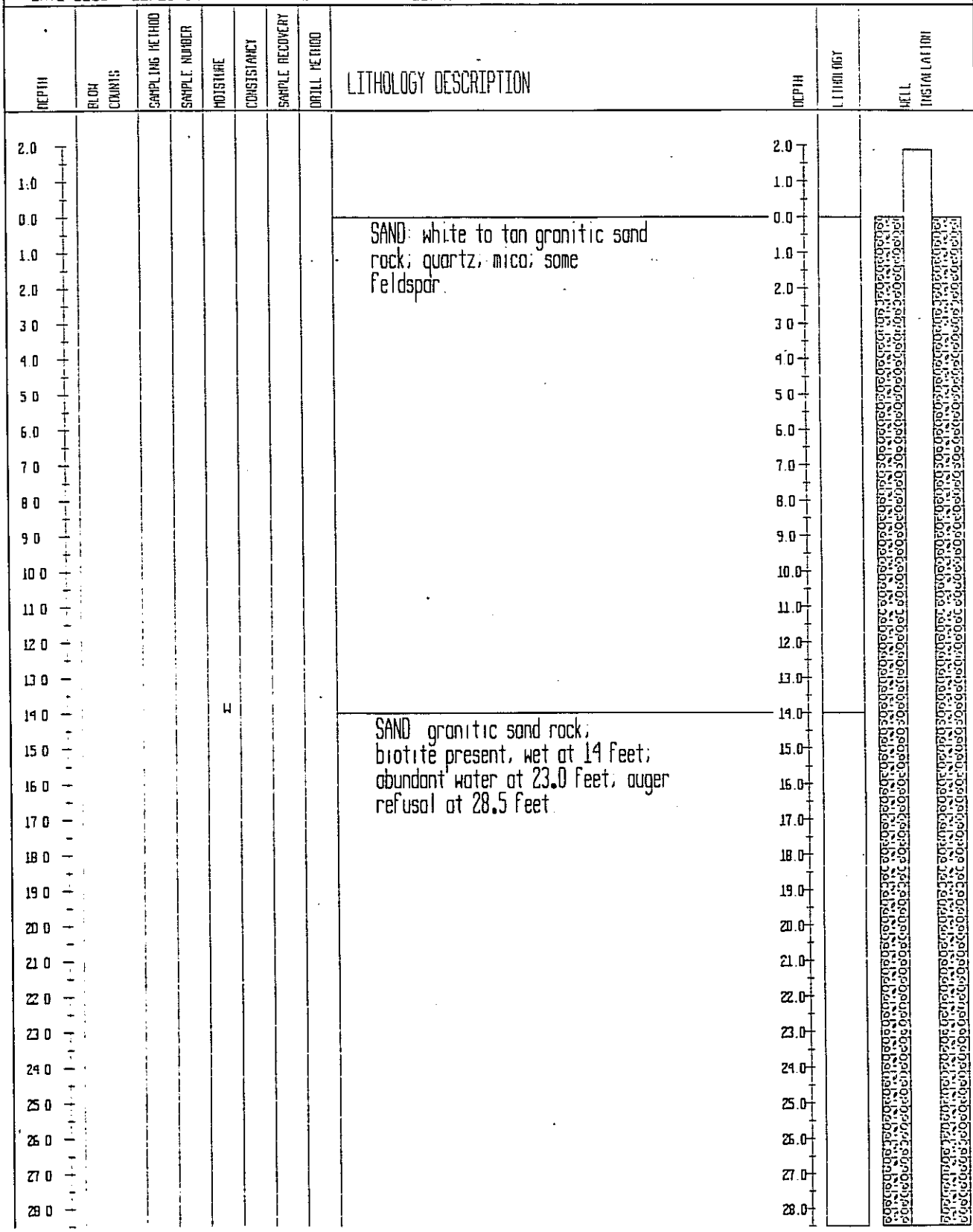
BOREHOLE NUMBER
B-22a

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/28/94 DATE COMPLETED 12/29/94

TOP OF CASING ELEVATION 756.80
TOTAL DEPTH 46.5 FT
GROUND SURFACE ELEVATION 754.92
SHEET 1 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	14.66	8.72
Time	-	-
Date	12/29/94	1/10/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0								SAND: white to tan granitic sand rock; quartz, mica; some feldspar.
14.0				W				SAND granitic sand rock; biotite present, wet at 14 feet; abundant water at 23.0 feet; auger refusal at 28.5 feet



FIELD BOREHOLE LOG

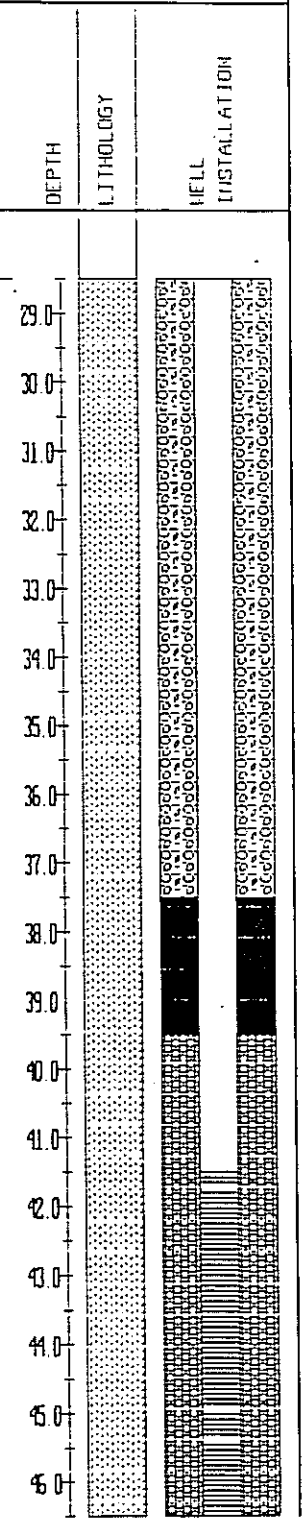
BOREHOLE NUMBER
B-22d

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/28/94 DATE COMPLETED 12/29/94

TOP OF CASING ELEVATION 756 80
TOTAL DEPTH 46 5 FT
GROUND SURFACE ELEVATION 754 92
SHEET 2 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	14.66	8.72
Time	-	-
Date	12/29/94	1/10/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
29.0								GRANITE: highly weathered tan to white granite with biotite; soft seam at 45 to 46 feet.
30.0								
31.0								
32.0								
33.0								
34.0								
35.0								
36.0								
37.0								
38.0								
39.0								
40.0								
41.0								
42.0								
43.0								
44.0								
45.0								
46.0								



FIELD BOREHOLE LOG

BOREHOLE NUMBER
S-23

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J FINKBEINER
DATE BEGUN 12/21/94 DATE COMPLETED 12/21/94

TOP OF CASING ELEVATION 768.26
TOTAL DEPTH 31.0 FT
GROUND SURFACE ELEVATION 765.26
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	13.75	14.06
Time	-	-
Date	12/27/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION	DEPTH	LITHOLOGY	WELL INSTALLATION
0.0									0.0		
5.0	10 19 30	SS	S1			15"		SAND: white to tan granitic sand rock; abundant biotite in bottom of sample, trace k-spar; some quartz.	5.0		
10.0	15 50/6	SS	S2			13"		SAND granitic sand rock; has biotite, quartz and clay; upper portion of sample is lt. tan and has gneissic banding.	10.0		
15.0	9 50/6	SS	S3			11"		SAND granitic sand rock, same as above with no banding.	15.0		
20.0	35 50/5	SS	S4	M		8		SAND granitic sand rock; overlain by a manganese stained clay (1" thick) and quartz fragments; moist	20.0		
25.0	50.2	SS	S5	M		2"		SAND granitic sand rock, sample has biotite feldspar and quartz, auger refusal at 31.0 feet	25.0		
30.0	50.2	SS	S6	W		2"			30.0		
31.0									31.0		

FIELD BOREHOLE LOG

BOREHOLE NUMBER
B-24

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/21/94 DATE COMPLETED 12/22/94

TOP OF CASING ELEVATION 753.03
TOTAL DEPTH 12.0 FT
GROUND SURFACE ELEVATION 750.08
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	9.69	9.30
Time	-	-
Date	12/27/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION	DEPTH	LITHOLOGY	WELL INSTALLATION
5.0	33 50/6	SS	S1			9"		SAND: large grained white to lt. tan granitic sand rock; abundant quartz and trace to little mica; Lab USC: Poorly Graded Sand with Silt (SP-SM)	5.0		
10.0	33 38 50/5	SS	S2	W		14"		SILT AND CLAY: weathered mafic rock, blue in color; some mica and iron stains; auger refusal at 12 ft. Lab USC ~~Silty~~ Clayey Sand (SC-~~SM~~)	10.0		

FIELD BOREHOLE LOG

BOREHOLE NUMBER B-2S

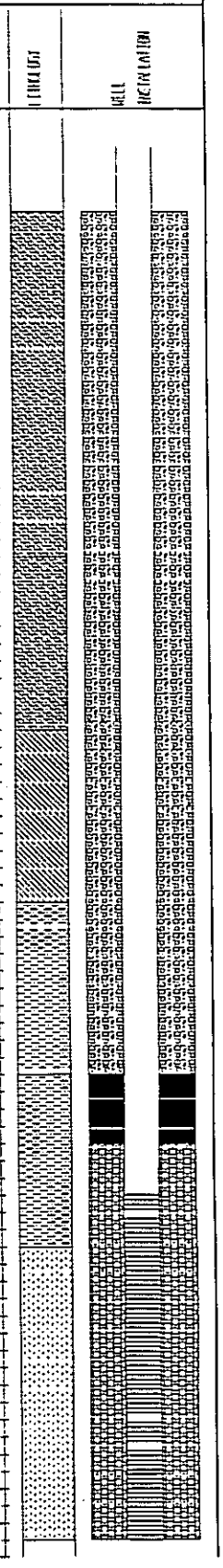
PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/21/94 DATE COMPLETED 12/21/94

TOP OF CASING ELEVATION 747.96
TOTAL DEPTH 38.5 FT
GROUND SURFACE ELEVATION 744.54
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)
WD=While Drilling AB=After Boring

Depth(ft)	6.64	15.72
Time	12:33	--
Date	12/27/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	50/6	SS	S1			6"		
10.0	41 50/5	SS	S2			10"		SILTY CLAY: white; weathered sand rock; slight pink hue; abundant quartz; trace mica.
15.0	18 36 32	SS	S3	M		10"		SILTY CLAY: white very weathered granitic sand rock; abundant quartz and feldspar; some biotite; no structure.
20.0	50/6	SS	S4			3"		CLAY wet; weathered kaolinitic claystone, white, iron stained at a -45 degree angle; some biotite and quartz also present at top of sample.
25.0	50/6	SS	S5			6"		SILTY SAND whitish to light tan granitic sand rock, quartz and feldspar abundant, some areas of kaolin clay
30.0	34 50/5	SS	S6			9"		SILTY SAND lt tan, weathered granitic sand rock, lg quartz and feldspar crystals, some biotite, no structure, wet
35.0	50/3	SS	S7			3"		GRANITE weathered to competent; abundant quartz, some biotite and feldspar, auger refusal at 38.5 ft



FIELD BOREHOLE LOG

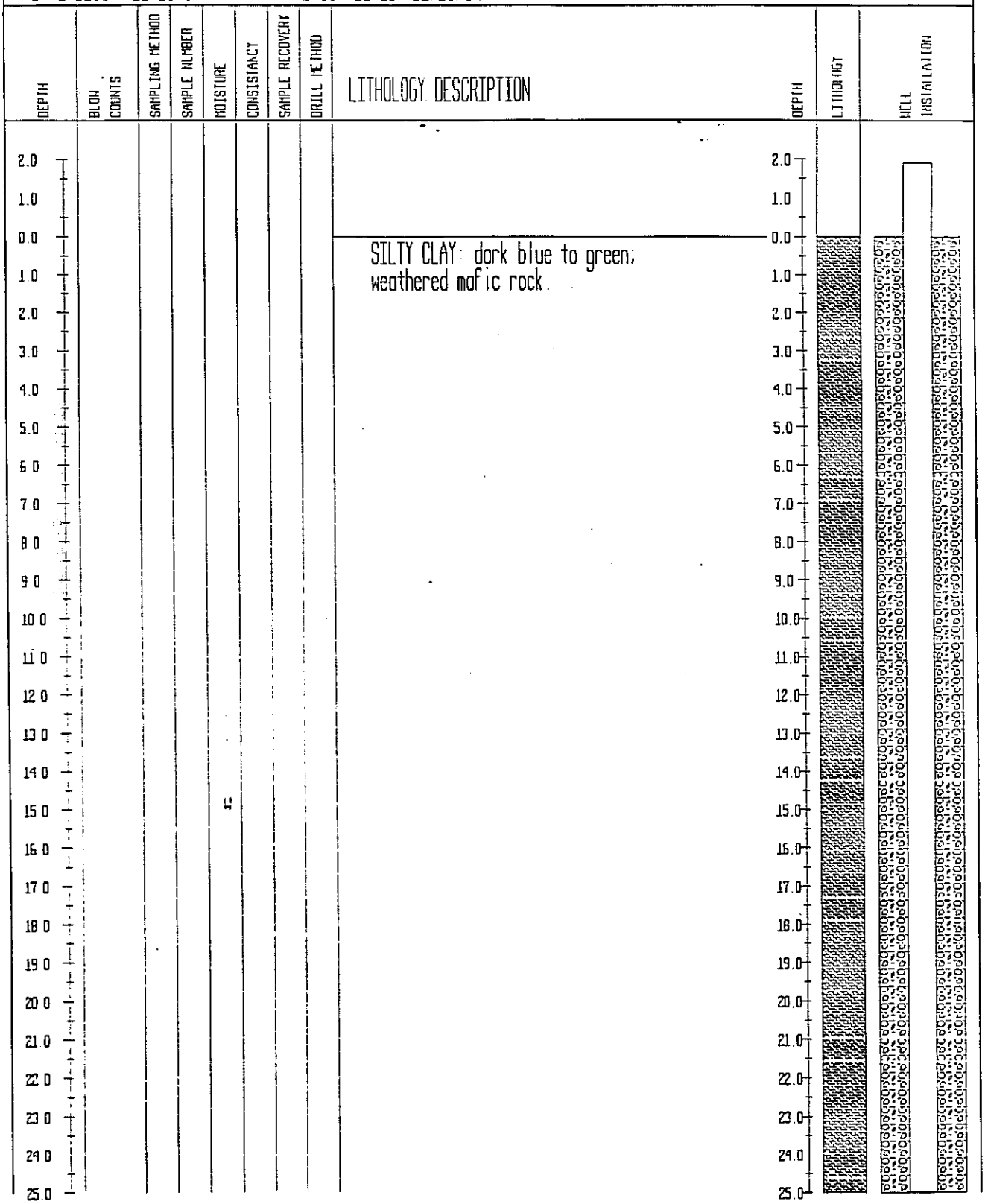
BOREHOLE NUMBER
B-25c

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/ROCK CORE/AIR HAMMER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/29/94 DATE COMPLETED 12/29/94

TOP OF CASING ELEVATION 747.54
TOTAL DEPTH 52.0 FT
GROUND SURFACE ELEVATION 744.54
SHEET 1 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AR=After Boring		
Depth(Ft)	7.54	6.85
Time	9:55am	-
Date	1/10/95	1/25/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0								SILTY CLAY: dark blue to green; weathered mafic rock.



FIELD BOREHOLE LOG

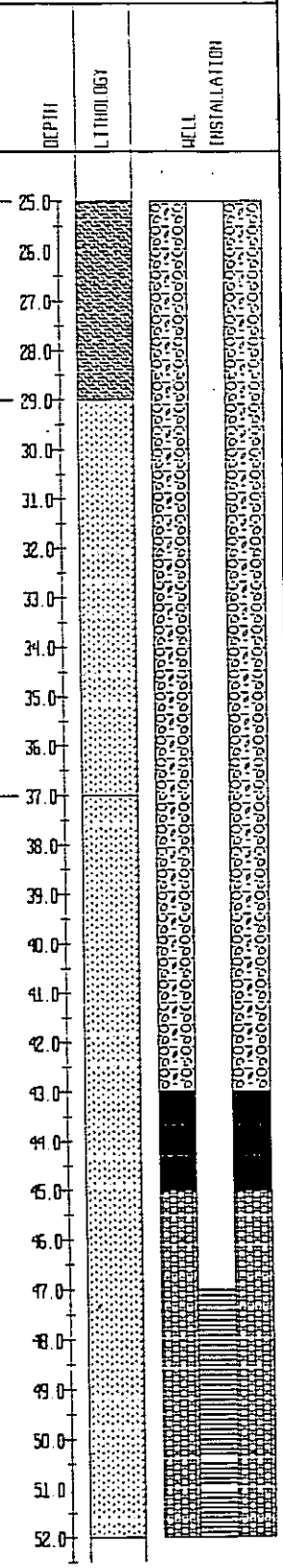
BOREHOLE NUMBER
B-25a

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/ROCK CORE/AIR HAMMER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/29/94 DATE COMPLETED 12/29/94

TOP OF CASING ELEVATION 747.54
TOTAL DEPTH 52.0 FT
GROUND SURFACE ELEVATION 744.54
SHEET 2 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	7.54	6.85
Time	9:55am	-
Date	1/10/95	1/25/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
25.0								SILTY CLAY: dark blue to green; weathered mafic rock; auger refusal at 29 feet.
29.0								GRANITE: weathered; drilled with a rollercone bit.
37.0								GRANITE weathered to competent granitic sand rock, drilled with rock core in three runs - 3' run (2' recovery), 5'run (5' recovery), 7' run (3' recovery); Reamed out with air hammer drilling.



FIELD BOREHOLE LOG

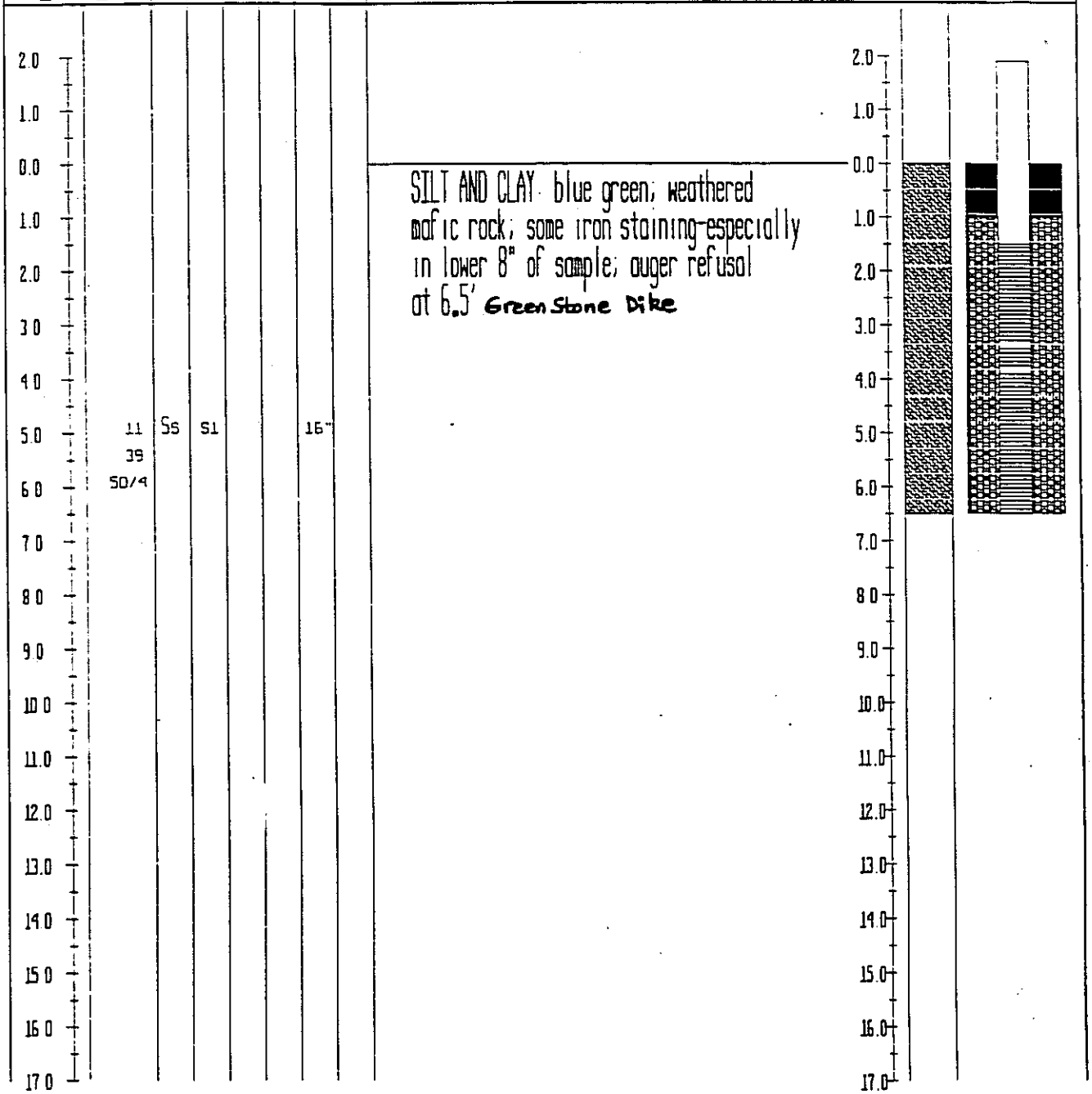
BOREHOLE NUMBER
B-26

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/21/94 DATE COMPLETED 12/22/94

TOP OF CASING ELEVATION 742.55
TOTAL DEPTH 6.5 FT
GROUND SURFACE ELEVATION 739.20
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	12.36	9.92
Time	10:09	12:15PM
Date	12/27/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	11 39 50/4	SS	S1			16"		SILT AND CLAY: blue green; weathered mafic rock; some iron staining-especially in lower 8" of sample; auger refusal at 6.5' Greenstone Dike



FIELD BOREHOLE LOG

BOREHOLE NUMBER B-27

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/21/94 DATE COMPLETED 1/2/95

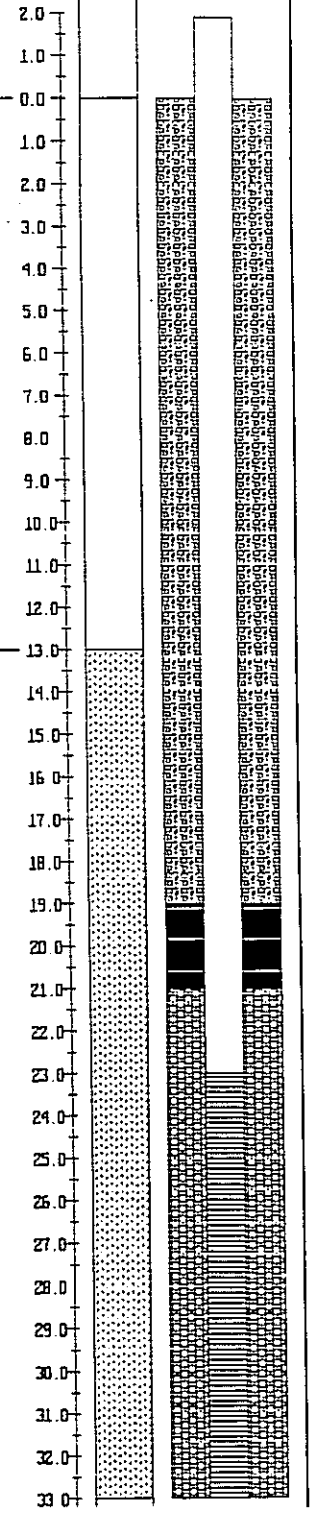
TOP OF CASING ELEVATION 736.71
TOTAL DEPTH 33.0 FT
GROUND SURFACE ELEVATION 734 82
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	19.18	16 98
Time	-	-
Date	1/2/95	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	50/6	Ss	S1					
10.0	50/5	Ss	S2					
28				W				

SAND: weathered granitic sand rock; some biotite; some greenish biotite; trace of potassium feldspar; auger refusal at 13 feet.

GRANITE: white granite drilled with air hammer; water seam at 28 feet



FIELD BOREHOLE LOG

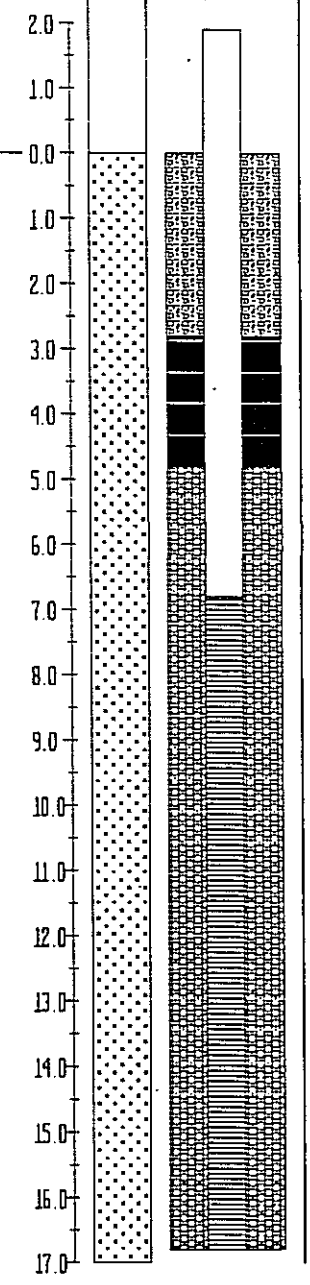
BOREHOLE NUMBER
B-28

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD AIR HAMMER
WEATHER SUNNY
FIELD PARTY RONNY BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 1/2/95 DATE COMPLETED 1/2/95

TOP OF CASING ELEVATION 742.69
TOTAL DEPTH 16.8 FT
GROUND SURFACE ELEVATION 739.33
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	9.73	9.18
Time	-	-
Date	1/2/95	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0							AH	MAFIC INTRUSIVE: mafic intrusive; dark brown to dark gray; drilled with an air hammer; some water sat 9.0 feet, dry at 11.0 feet, wet at 12.5 feet; auger refusal at 0.5'.
9.0				M				
12.0				W				



FIELD BOREHOLE LOG

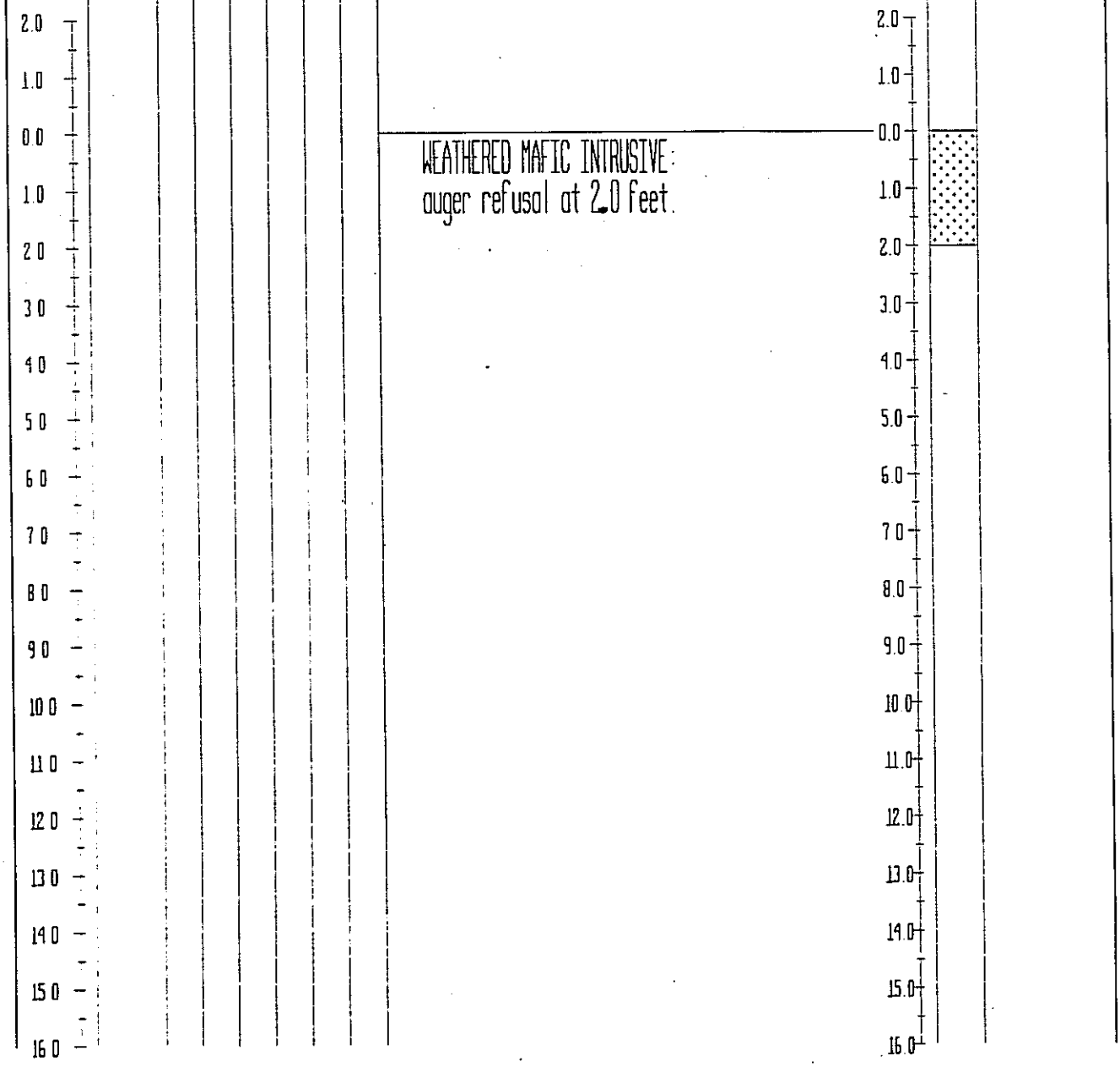
BOREHOLE NUMBER
B-29

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/22/94 DATE COMPLETED 12/22/94

TOP OF CASING ELEVATION -
TOTAL DEPTH 2.0 FT
GROUND SURFACE ELEVATION -
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AD=After Boring		
Depth(ft)	DRY	-
Time	-	-
Date	12/22/94	-

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0								WEATHERED MAFIC INTRUSIVE: auger refusal at 2.0 feet.



FIELD BOREHOLE LOG

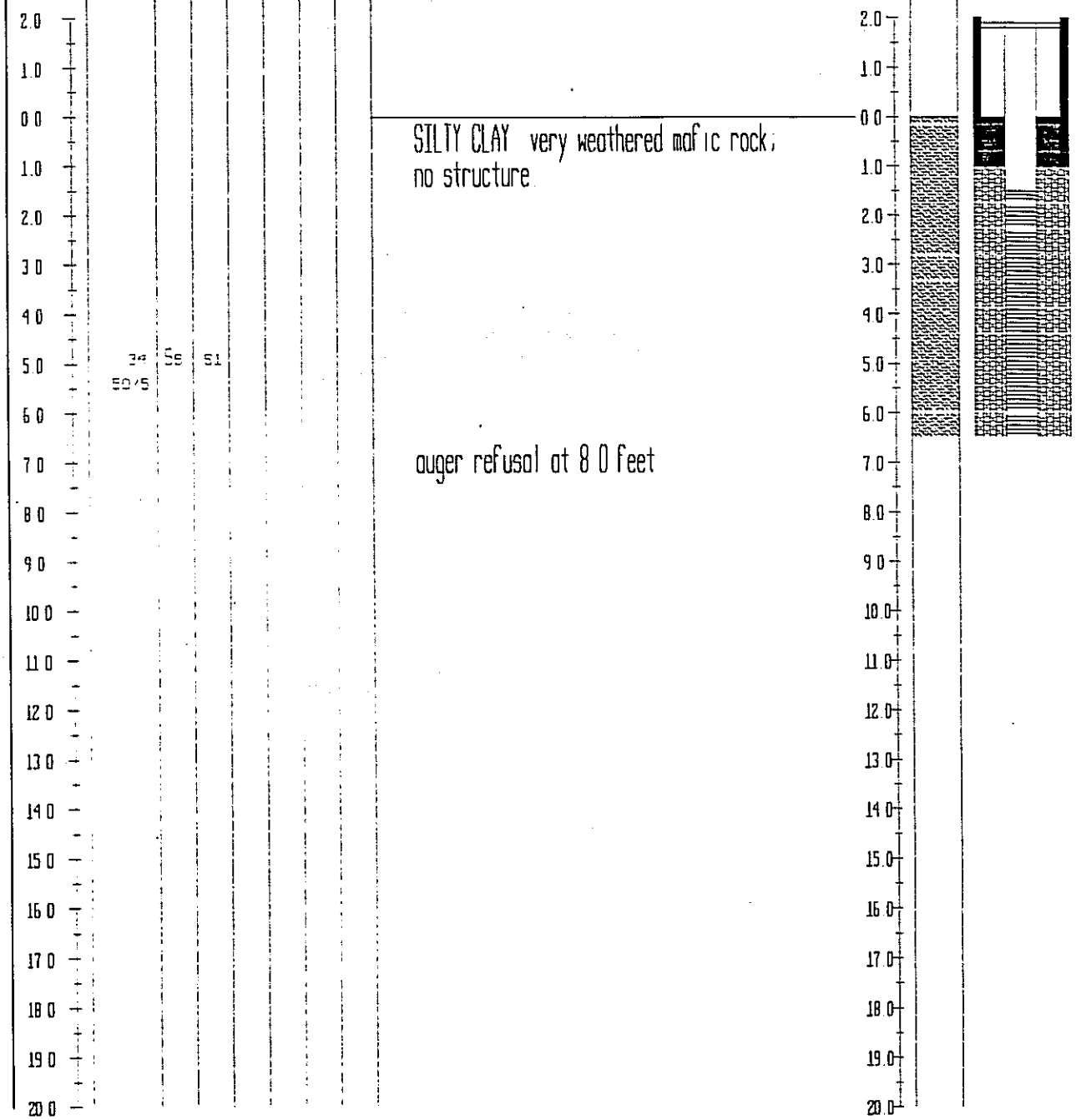
BOREHOLE NUMBER B-294

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN DATE COMPLETED 12/22/94

TOP OF CASING ELEVATION - 746.47
TOTAL DEPTH 8.0 FT
GROUND SURFACE ELEVATION - 743.61
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)	
WD=While Drilling AB=After Boring	
Depth(Ft)	-
Time	-
Date	-

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	34 50/5	SS	S1					SILTY CLAY very weathered mafic rock; no structure
8.0								auger refusal at 8.0 feet



FIELD BOREHOLE LOG

BOREHOLE NUMBER
B-30

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORD
LOCATION GREENSBORD, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR RODTARY
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/22/94 DATE COMPLETED 12/22/94

TOP OF CASING ELEVATION 742.26
TOTAL DEPTH 32.0 FT
GROUND SURFACE ELEVATION 739.11
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=AFter Boring		
Depth(Ft)	14.83	14.74
Time	5:26	-
Date	12/27/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION	DEPTH	LITHOLOGY	WELL INSTALLATION
0.0									0.0		
5.0	6 10 15	Ss	S1	D		14"		SAND: white granite sand rock; some biotite and some quartz; Lab USC: Silty ~~Clayey~~ Sand (SC-SM).	5.0		
10.0	8 12 17	Ss	S2	D		14"		SAND: white granite sand rock with biotite and quartz, no structure; Lab USC: Silty ~~Clayey~~ Sand (SC-SM).	10.0		
15.0	11 17 25	Ss	S3	D		13"			15.0		
20.0	12 28 50/2	Ss	S4	M		12"		SAND white to tan granite sand rock; some biotite, quartz	20.0		
25.0	35 50/4	Ss	S5	W		7"		SAND white granite sand rock, quartz; Feldspar, biotite almost forms bands, although somewhat discontinuous, also some green biotite; Lab USC Silty ~~Clayey~~ Sand (SC-SM).	25.0		
30.0	50/6	Ss	S6	W		5"		SAND white granite sand rock; some biotite, and a few biotite layers; auger refusal at 32 feet.	30.0		
32.0									32.0		

FIELD BOREHOLE LOG

BOREHOLE NUMBER B-31

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/22/94 DATE COMPLETED 12/22/94

TOP OF CASING ELEVATION 750.1
TOTAL DEPTH 25.0 FT
GROUND SURFACE ELEVATION 747.1
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AR=After Boring		
Depth(Ft)	5.87	5.42
Time	5:35	-
Date	12/27/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	50/4	SS	S1			3"		SANDY SILT: Weathered lt. brown granite sand rock; abundant biotite.
10.0	50/2	SS	S2			2"		SANDY SILT: Weathered granite sand rock; with quartz.
15.0	50/1	SS	S3			1"		SANDY SILT: Brown granite sand rock with some quartz.
20.0	50/1	SS	S4			1"		SANDY SILT: Brown granite sand rock in cohesive chunks; auger refusal at 25 feet.

LITHOLOGY

WELL INSTALLATION

FIELD BOREHOLE LOG

BOREHOLE NUMBER
B-32

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 12/22/94 DATE COMPLETED 12/22/94

TOP OF CASING ELEVATION 744.76
TOTAL DEPTH 21.5 FT
GROUND SURFACE ELEVATION 741.65
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	17.03	14.36
Time	5:20	1:35
Date	12/27/94	1/10/95

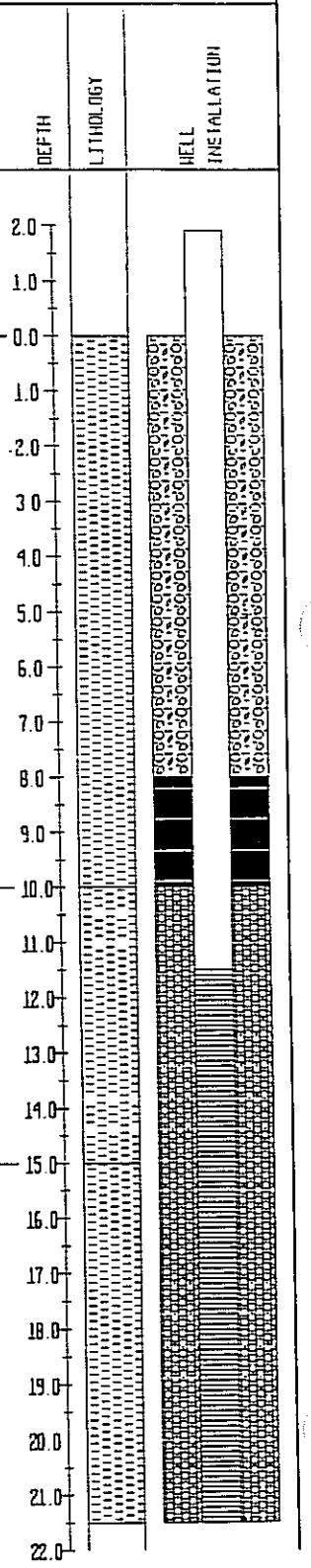
DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD
5.0	24 50/6	SS	S1			12"	
10.0	50/1	SS	S2			1"	
15.0	50/1	SS	S3			1"	
20.0	50/1	SS	S4			0"	

LITHOLOGY DESCRIPTION

SANDY SILT: Light tan granite sand rock; little mica; no structure.

SANDY SILT Light tan granite sand rock, no structure

SANDY SILT Light tan granite sand rock, some quartz; little biotite; auger refusal at 21.5 feet.



FIELD BOREHOLE LOG

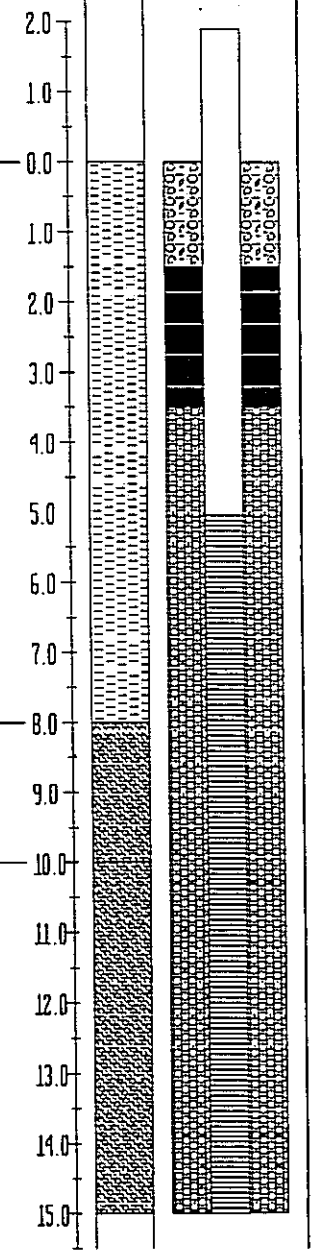
BOREHOLE NUMBER
B-33

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/27/94 DATE COMPLETED 12/27/94

TOP OF CASING ELEVATION 760.33
TOTAL DEPTH 15.0 FT
GROUND SURFACE ELEVATION 757.22
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	5.11	4.54
Time	12:21	1:50
Date	12/27/94	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	16 30 50/3	SS	S1			13"		SANDY SILT: tannish white, coarse grained; biotite flakes locally; white weathered feldspar clay; some iron staining; granitic; moist.
8.0				W				CLAYEY SILT: mafic dike; water at 8.0 feet
10.0	12 16 30	SS	S2			13"		CLAYEY SILT: Dark bluish green to light tan green; some very fine whitish mineral grains visible, locally orangerind iron staining; moist to wet; weathered mafic intrusive; auger refusal at 15.0 ft.
15.0	50/3	SS	S3			8"		



FIELD BOREHOLE LOG

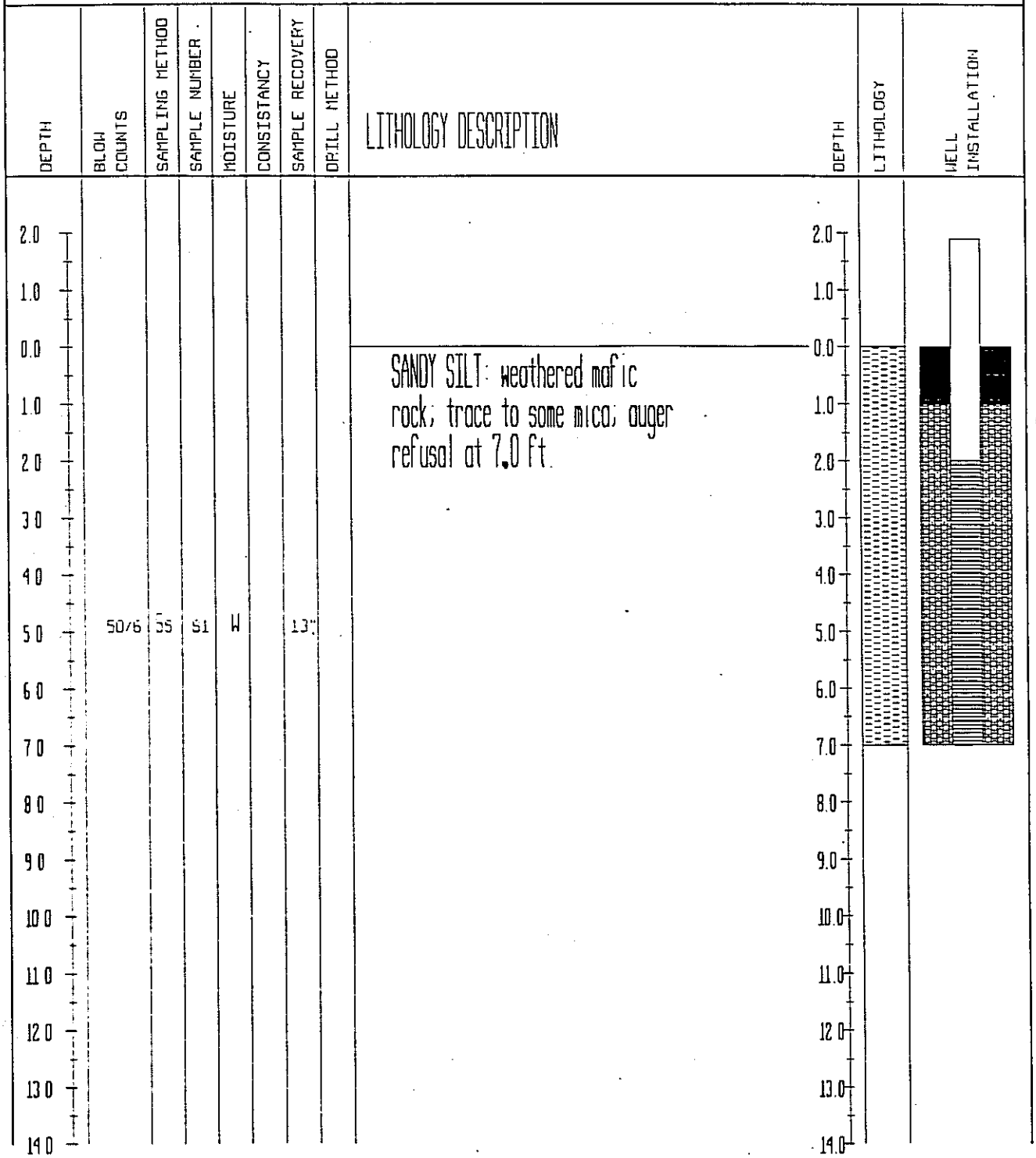
BOREHOLE NUMBER
B-34

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/28/94 DATE COMPLETED 12/28/94

TOP OF CASING ELEVATION 733.92
TOTAL DEPTH 7.0 FT
GROUND SURFACE ELEVATION 730.97
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	2.58	3.61
Time	-	11:05
Date	1/2/95	1/10/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	50/6	SS	S1	W		13"		SANDY SILT: weathered mafic rock; trace to some mica; auger refusal at 7.0 ft.



FIELD BOREHOLE LOG

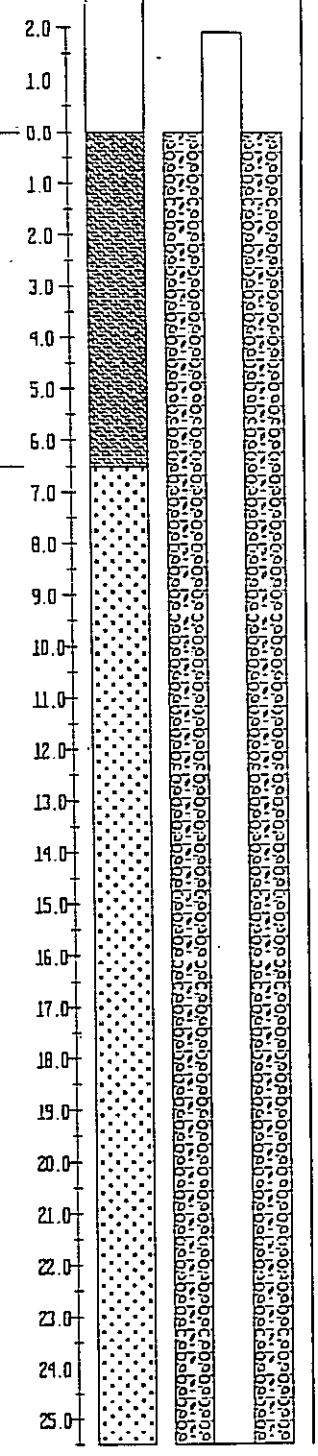
BOREHOLE NUMBER
B-34d

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD ROLLER BIT/AIR ROTARY/ROCK CORE
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/29/94 DATE COMPLETED 12/29/94

TOP OF CASING ELEVATION 732.49
TOTAL DEPTH 48.5 FT
GROUND SURFACE ELEVATION 730.97
SHEET 1 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	5.61	3.54
Time	-	-
Date	1/25/95	3/11/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0								SILTY CLAY: blue green; weathered mafic rock; trace to some mica.
7.0								MAFIC INTRUSIVE: numerous 30 degree angle fractures in rock core; Rock core from 7.0 to 22 feet below grade; core run #1 from 7.0 ft. to 10 ft. - core blockage at 10 ft. Core #2 from 10 ft. to 20 ft.; Core run #3 from 20 ft. to 22 ft.; boring reamed out to 48.5 ft. with air hammer



FIELD BOREHOLE LOG

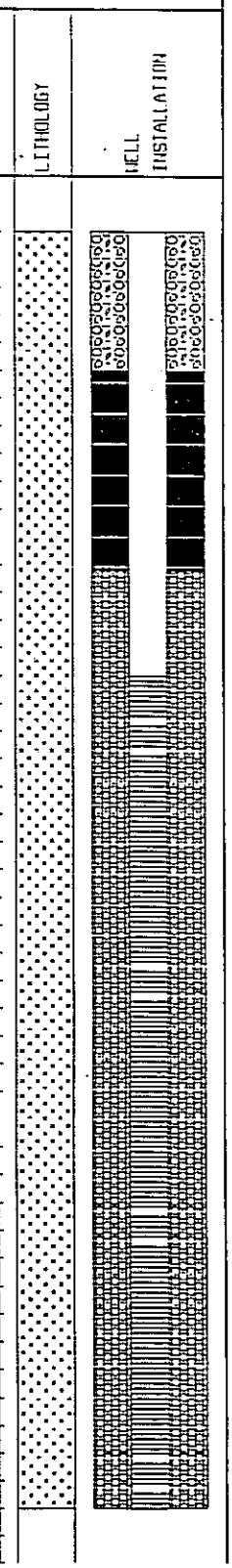
BOREHOLE NUMBER B-34d

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD ROLLER BIT/AIR ROTARY/ROCK CORE
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/29/94 DATE COMPLETED 12/29/94

TOP OF CASING ELEVATION 732.49
TOTAL DEPTH 48.5 FT
GROUND SURFACE ELEVATION 730.97
SHEET 2 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	5.61	3.54
Time	-	-
Date	1/25/95	3/11/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
26.0								MAFIC INTRUSIVE: numerous 30 degree angle fractures in rock core; Rock core from 7.0 to 22 feet below grade; core run #1 from 7.0 ft. to 10 ft. - core blockage at 10 ft. Core #2 from 10 ft. to 20 ft.; Core run #3 from 20 ft. to 22 ft.; boring reamed out to 48.5 ft. with air hammer.
27.0								
28.0								
29.0								
30.0								
31.0								
32.0								
33.0								
34.0								
35.0								
36.0								
37.0								
38.0								
39.0								
40.0								
41.0								
42.0								
43.0								
44.0								
45.0								
46.0								
47.0								
48.0								
49.0								



FIELD BOREHOLE LOG

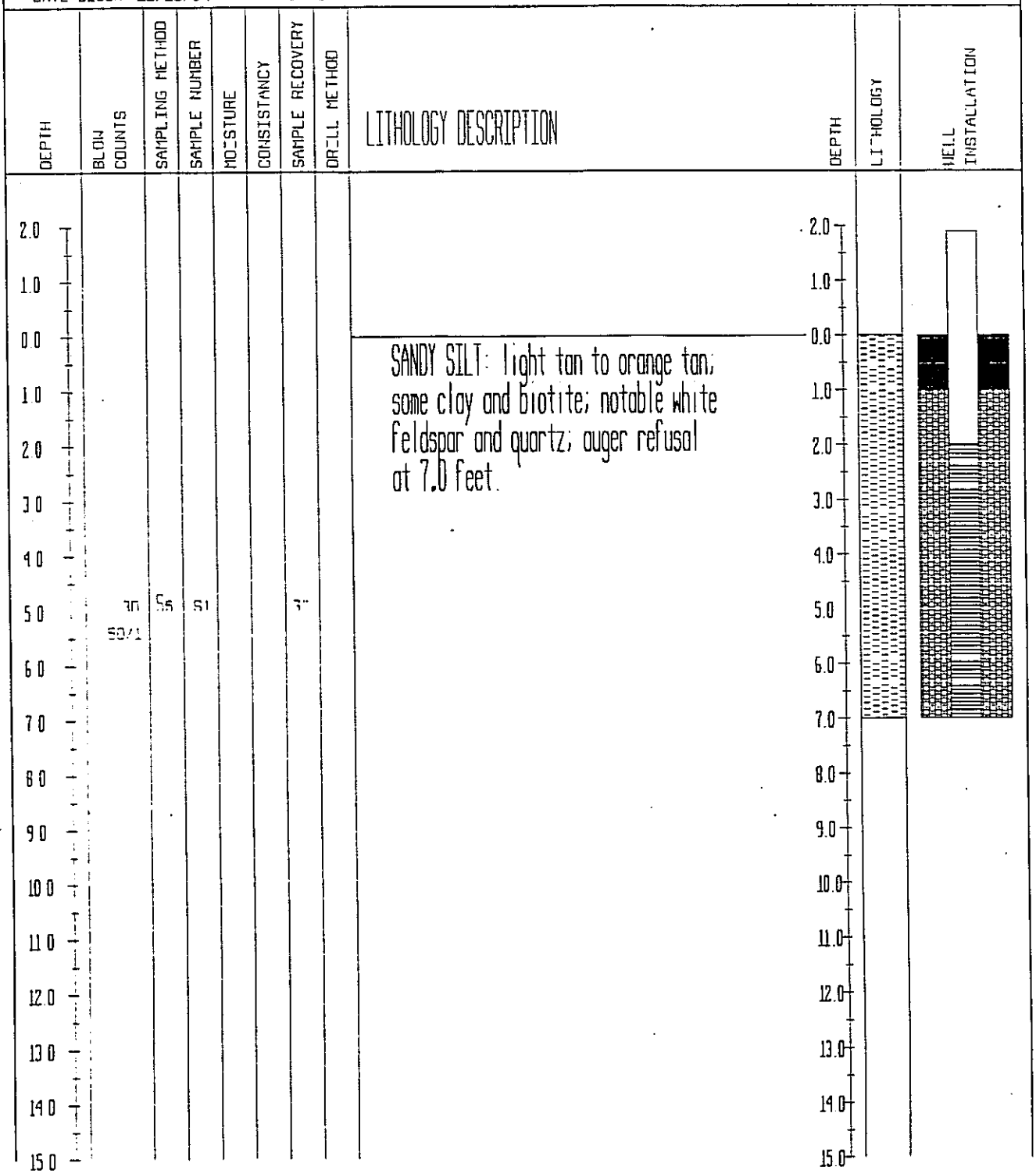
BOREHOLE NUMBER
B-35

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY
FIELD PARTY DAVID BARRON
GEOLOGIST G. SIMMERMAN
DATE BEGUN 12/28/94 DATE COMPLETED 12/28/94

TOP OF CASING ELEVATION 746.75
TOTAL DEPTH 7.0 FT
GROUND SURFACE ELEVATION 744.00
SHEET 1 OF 1

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	2.49	1.12
Time	11:05am	-
Date	1/10/95	1/25/95

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
5.0	30 50/1	SS	S1			3"		SANDY SILT: light tan to orange tan; some clay and biotite; notable white feldspar and quartz; auger refusal at 7.0 feet.



FIELD BOREHOLE LOG

BOREHOLE NUMBER
B-36

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER
WEATHER SUNNY, COOL
FIELD PARTY RONNY BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN DATE COMPLETED 1/5/95

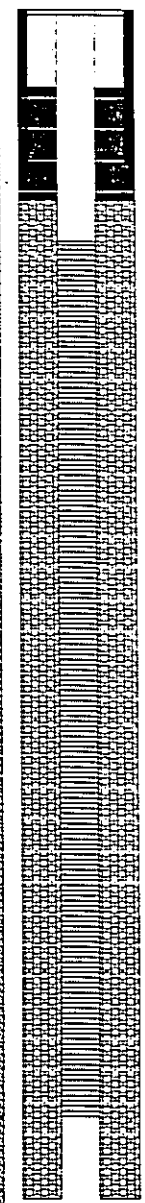
TOP OF CASING ELEVATION 783.0
TOTAL DEPTH 22.0 FT
GROUND SURFACE ELEVATION 782.0
SHEET 1 OF 1

STATIC WATER LEVEL (BGS)	
WD=While Drilling AR=After Boring	
Depth(Ft)	-
Time	-
Date	-

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION	DEPTH
0.0	2	SS	S1			9"	HSA	SILTY CLAY brown; Mn stained; v uniform; trace amphiboles.	0.0
	3								
1.0	3								1.0
	10	SS	S2			10"		SILTY CLAY tan to green; v. uniform	
2.0	9								2.0
	15								
3.0	12	SS	S3			12"		SILTY CLAY brown to green; subvertical Mn stain	3.0
	16								
4.0	40								4.0
	17	SS	S4			10"		SILTY CLAY mica, brown, tan, green; Mn stained	
5.0	24								5.0
	31								
6.0	10	SS	S5			12"			6.0
	16								
7.0	27							SILTY CLAY mica, Mn stained at 30 and 45 degree angles.	7.0
	18	SS	S6			12"			
8.0	27								8.0
	18								
9.0	11	SS	S7			10"			9.0
	16		S8					SILTY CLAY lower portion of sample abundant biotite, appears to be foliated GNEISS	
10.0	50/6								10.0
11.0									11.0
12.0									12.0
13.0									13.0
14.0									14.0
15.0	18	SS	S9			12"			15.0
	19							SILTY CLAY medium brown, Mn stained from 0 to 10 degree angles, micaceous near top	
16.0	22								16.0
17.0									17.0
18.0									18.0
19.0									19.0
20.0	50/3	SS	S10	M		3"			20.0
								CLAYEY SILTY SAND red brown to white, weathered granitic sand rock	
21.0									21.0
22.0								Boring Terminated at 22.0 feet	22.0
23.0									23.0
24.0									24.0
25.0									25.0

LITHOLOGY

WELL INSTALLATION



FIELD BOREHOLE LOG

BOREHOLE NUMBER: OW-1

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY RON BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 10/24/94 DATE COMPLETED 10/25/94

TOP OF CASING ELEVATION 771.05
TOTAL DEPTH 45.0
GROUND SURFACE ELEVATION 768
SHEET 1 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AR=After Boring		
Depth(ft)	20.93 DB	25.38
Time	8:45	-
Date	10/25/94	12/27/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD
0.0	2	SS	S1				
	5						
1.0	5						
5.0	10	SS	S2				
	9						
6.0	16						
10.0	6	SS	S3				
	9						
11.0	11						
15.0	3	SS	S4	W			
	3						
16.0	6						
20.0	6	SS	S5				
	12						
21.0	30						
25.0	50/4	SS	S6				

LITHOLOGY DESCRIPTION

0.0 – 5.0: SILTY CLAY: brown to tan; some manganese staining; roots in upper six inches.

5.0 – 10.0: SILTY SAND: with some clay; brown to light tan; some very weathered potassium feldspar and plagioclase; possibly some very weathered amphibole.

10.0 – 15.0: SAND brown to tan, minor clay; horizontal manganese staining; one 2 inch thick layer of mica rich brown clay (mica schist).

15.0 – 20.0: SILTY CLAY: weathered greenstone, some horizontal manganese stains; wet.

20.0 – 25.0: SILTY CLAY: dark green to black; weathered mafic rock; iron stained near top; dry.

LITHOLOGY

WELL INSTALLATION

FIELD BOREHOLE LOG

BOREHOLE NUMBER
OW-1

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD HOLLOW STEM AUGER/AIR ROTARY
WEATHER SUNNY
FIELD PARTY RON BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 10/24/94 DATE COMPLETED 10/25/94

TOP OF CASING ELEVATION 771.05
TOTAL DEPTH 45.0
GROUND SURFACE ELEVATION 768
SHEET 2 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	20.93 DB	25.38
Time	8:45	-
Date	10/25/94	12/27/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD
25.0	50/4	SS	S6				
30.0	25	SS	S7				
	36						
	45						

LITHOLOGY DESCRIPTION

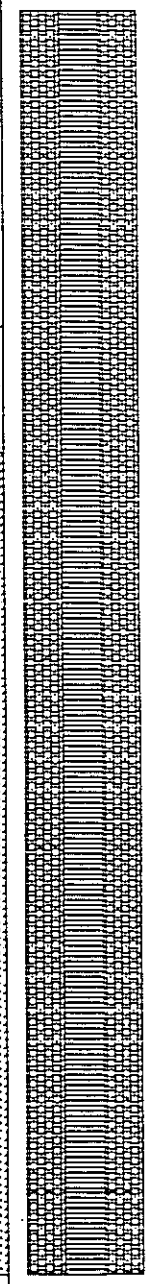
MAFIC INTRUSIVE: weathered; dark greenish black.

MAFIC INTRUSIVE: weathered; minor iron staining; some very fine felsic streaks; Auger Refusal at 32 feet.

GRANITE bedrock, white with some black staining, significant quartz and feldspar.
Boring Terminated at 45 feet.

DEPTH: 25.0, 26.0, 27.0, 28.0, 29.0, 30.0, 31.0, 32.0, 33.0, 34.0, 35.0, 36.0, 37.0, 38.0, 39.0, 40.0, 41.0, 42.0, 43.0, 44.0, 45.0

LITHOLOGY



WELL INSTALLATION

FIELD BOREHOLE LOG

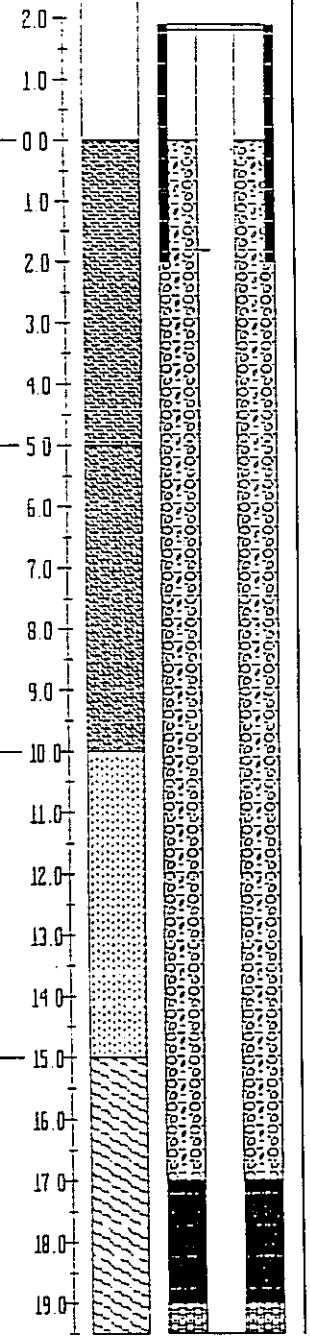
BOREHOLE NUMBER
OW-2

PROJECT NUMBER 94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD ROLLER CONE WITH AIR/AIR HAMMER
WEATHER SUNNY
FIELD PARTY RON BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 10/25/94 DATE COMPLETED 10/25/94

TOP OF CASING ELEVATION 769.95
TOTAL DEPTH 40.0
GROUND SURFACE ELEVATION 767
SHEET 1 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	22.94 WD	16.8
Time	12:45	-
Date	10/25/94	11/3/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0	5	SS	S1					SILTY CLAY brown to tan, some broken glass in split spoon.
1.0	5							
2.0	4							
3.0								
4.0								
5.0	11	SS	S2					SANDY SILTY CLAY light tan; some very weathered rock at 5 feet, some feldspar clay
6.0	21							
7.0	29							
8.0								
9.0								
10.0	35	SS	S3					GRANITE very weathered, potassium feldspar and plagioclase, some manganese staining, little to no biotite; some weathered chlorite present.
11.0	37							
12.0	38							
13.0								
14.0								
15.0	31	SS	S4					GREENSTONE tan/brown, some iron staining, weathered; minor feldspar clay
16.0	36							
17.0	50/6"							
18.0								
19.0								



FIELD BOREHOLE LOG

BOREHOLE NUMBER: OW-2

PROJECT NUMBER: 94016
PROJECT NAME: CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER: MOBILE DRILL ATV RIG
DRILLING METHOD ROLLER CONE WITH AIR/AIR HAMMER
WEATHER SUNNY
FIELD PARTY: RON BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN 10/25/94 DATE COMPLETED 10/25/94

TOP OF CASING ELEVATION 769.95
TOTAL DEPTH 40.0
GROUND SURFACE ELEVATION 767
SHEET: 2 OF: 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(ft)	22.94 WD	16.8
Time	12:45	-
Date:	10/25/94	11/3/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION	DEPTH	LITHOLOGY	WELL INSTALLATION
20.0	50/4"	SS	S5					GRANITE: potassium feldspar; plagioclase, some amphibole	20.0		
21.0									21.0		
22.0									22.0		
23.0									23.0		
24.0									24.0		
25.0	50/0"	SS	S6					GRANITE: some water; Roller Cone refusal at 25 feet.	25.0		
26.0									26.0		
27.0									27.0		
28.0									28.0		
29.0									29.0		
30.0									30.0		
31.0									31.0		
32.0									32.0		
33.0									33.0		
34.0								GRANITE: harder than above	34.0		
35.0									35.0		
36.0									36.0		
37.0								GRANITE: very hard; good water bearing fracture at 38 feet Boring Terminated at 40 feet.	37.0		
38.0									38.0		
39.0									39.0		
40.0									40.0		

FIELD BOREHOLE LOG

BOREHOLE NUMBER: DW-3

PROJECT NUMBER .94016
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD ROLLER CONE WITH AIR/AIR HAMMER
WEATHER SUNNY
FIELD PARTY RON BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN DATE COMPLETED 10/25/94

TOP OF CASING ELEVATION 762
TOTAL DEPTH 48.0
GROUND SURFACE ELEVATION 759
SHEET 1 OF 2

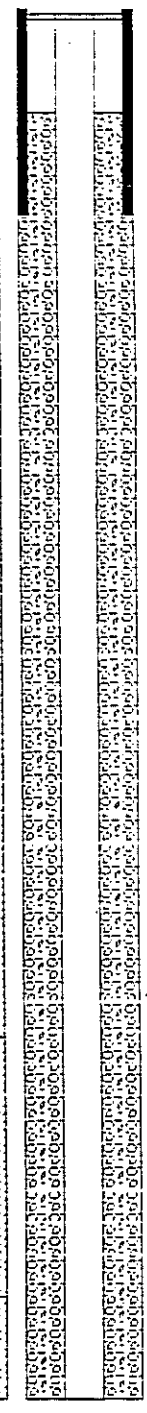
STATIC WATER LEVEL (BLS)		
WD=While Drilling AR=After Boring		
Depth(ft)	23 DRY WD	15.11
Time		
Date	10/25/94	11/3/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION
0.0	5 8 6	Ss	S1					CLAY AND SILT: buff to tan; some roots in split spoon.
5.0	50/6	Ss	S2					SAND AND CLAY: light tan; minor mica; some very weathered rock; some feldspar clay, hard drilling @ 7 feet
10.0	50/3	Ss	S3					GRANITE very weathered; quartz, feldspar, roller bill refusal at 11.0 feet
18.0								GRANITE hard, feldspar, potassium feldspar
22.0								GRANITE possibly granodiorite, rock is granitic but has more mafic constituents than above.

DEPTH: 2.0, 1.0, 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0, 17.0, 18.0, 19.0, 20.0, 21.0, 22.0, 23.0, 24.0, 25.0

LITHOLOGY

WELL INSTALLATION



FIELD BOREHOLE LOG

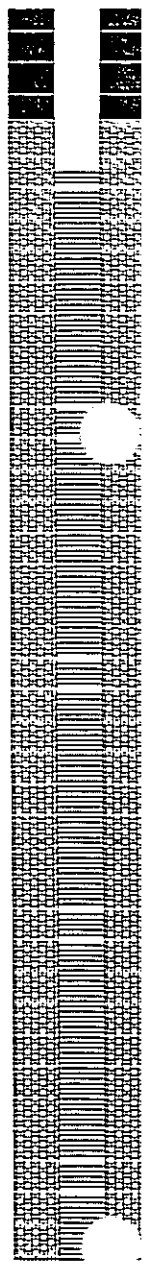
BOREHOLE NUMBER
GW-3

PROJECT NUMBER 94015
PROJECT NAME CITY OF GREENSBORO
LOCATION GREENSBORO, NORTH CAROLINA
DRILLING COMPANY ENGINEERING TECTONICS
RIG TYPE & NUMBER MOBILE DRILL ATV RIG
DRILLING METHOD ROLLER CONE WITH AIR/AIR HAMMER
WEATHER SUNNY
FIELD PARTY RON BARRON
GEOLOGIST J. FINKBEINER
DATE BEGUN DATE COMPLETED 10/25/94

TOP OF CASING ELEVATION 762
TOTAL DEPTH 48.0
GROUND SURFACE ELEVATION 759
SHEET 1 OF 2

STATIC WATER LEVEL (BLS)		
WD=While Drilling AB=After Boring		
Depth(Ft)	23 DRY WD	15 11
Time		
Date	10/25/94	11/3/94

DEPTH	BLOW COUNTS	SAMPLING METHOD	SAMPLE NUMBER	MOISTURE	CONSISTANCY	SAMPLE RECOVERY	DRILL METHOD	LITHOLOGY DESCRIPTION	DEPTH	LITHOLOGY	WELL INSTALLATION
25.0								GRANITE possibly granodiorite; rock is granitic but has more mafic constituents than above; water bearing zones at 28, 33 and 44 feet below grade; each zone produces more water than the one above it	25.0		
26.0									26.0		
27.0									27.0		
28.0									28.0		
29.0									29.0		
30.0									30.0		
31.0									31.0		
32.0									32.0		
33.0									33.0		
34.0									34.0		
35.0									35.0		
36.0									36.0		
37.0									37.0		
38.0									38.0		
39.0									39.0		
40.0									40.0		
41.0									41.0		
42.0									42.0		
43.0									43.0		
44.0									44.0		
45.0									45.0		
46.0									46.0		
47.0									47.0		
0								Boring Terminated at 48 feet	48.0		
49.0									49.0		
50.0									50.0		



OWNER: City of Greensboro	BORING NUMBER: B-11 (GSO-11)
PROJECT NAME: Greensboro Landfill	ARCHITECT-ENGINEER: MW-11
SITE LOCATION: Greensboro, NC	JOB. NO.: 88-387-E

UNCONFINED COMPRESSIVE STRENGTH TONS/FT.² (1, 2, 3, 4, 5)

PLASTIC LIMIT % (X) — WATER CONTENTS % (⊕) — LIQUID LIMIT % (Δ) (10, 20, 30, 40, 50)

● STANDARD PENETRATION BLOWS/FT. (10, 20, 30, 40, 50)

DEPTH IN FEET	SAMPLE NO.	SAMPLE TYPE	SAMPLE DEPTH FROM-TO	DESCRIPTION OF MATERIAL
				SURFACE ELEVATION
	1	ss	2.5 4.0	SILT, w/little sand, brown, black, tan, mottled, firm, (ML). NOTE: Residual Soil/Saprolite with trace quartz rock fragments.
5	2	ss	5.0 6.5	CLAYEY SILT, w/trace sand, brown, tan, v/hard, (ML). NOTE: Residual Soil/ Saprolite.
	3	ss	7.5 9.0	SANDY SILT, w/trace clay, green, brown, black, tan, v/hard, (ML). NOTE: Saprolite/Weathered greenstone.
10	4	ss	10.0 11.5	
				NOTE: Layered weathered greenstone/ schist (sample described from auger cuttings).
15	5	ss	15.0 16.5	
				Auger Refusal at 17.5'.
20				
25				
30				

● 28

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDRY LINES BETWEEN SOIL TYPES: IN-STU. THE TRANSITION MAY BE GRADUAL

WATER TABLE DATA — DEPTH BELOW SURFACE	BORING STARTED 4-11-89		BORING COMPLETED 4-13-89
Dry (BAR) ● 0 HRS.	RIG B-50	FOREMAN R. Barron	APP'D BY ABN
15.81' ● Below TOC HRS.			AUGER 6" H
7-12-89			

ENGINEERING TECTONICS, P. A.

Division of Health Services

WELL COMPLETION RECORD

COMPLETE ALL INFORMATION REQUESTED BELOW FOR EACH WELL INSTALLED, AND RETURN FORM TO THE N.C. DEPARTMENT OF HUMAN RESOURCES, SOLID AND HAZARDOUS WASTE MANAGEMENT BRANCH, P. BOX 2091, RALEIGH, N.C. 27602

NAME OF SITE: Greensboro Landfill

PERMIT NO.: Well No. 11

ADDRESS: Off White Street in Greensboro, NC

OWNER (print): City Of Greensboro

DRILLING CONTRACTOR: Engineering Tectonics, P.A.

REGISTRATION NO.: 835

Casing Type: SCH 80 PVC dia. 4 in.
Casing Depth: from 0 to 19.5 ft. - dia. 4 in.
Screen Type: Bedrock Open Hole dia. 2 in.
Screen Depth: from - to - ft. - dia. - in.

Grout Depth: from 0 to 19.5 ft. - dia. 6 in.
Bentonite Seal: from - to - ft. - dia. - in.
Sand/Gravel PK: from - to - ft. - dia. - in.
Total Well Depth: from 0 to 100.5 ft. - dia. 2 in.

Static Water Level: 19.81 feet from top of casing

Date Measured 7 / 12 / 89

Yield (gpm): Moderate Method of Testing: Bail

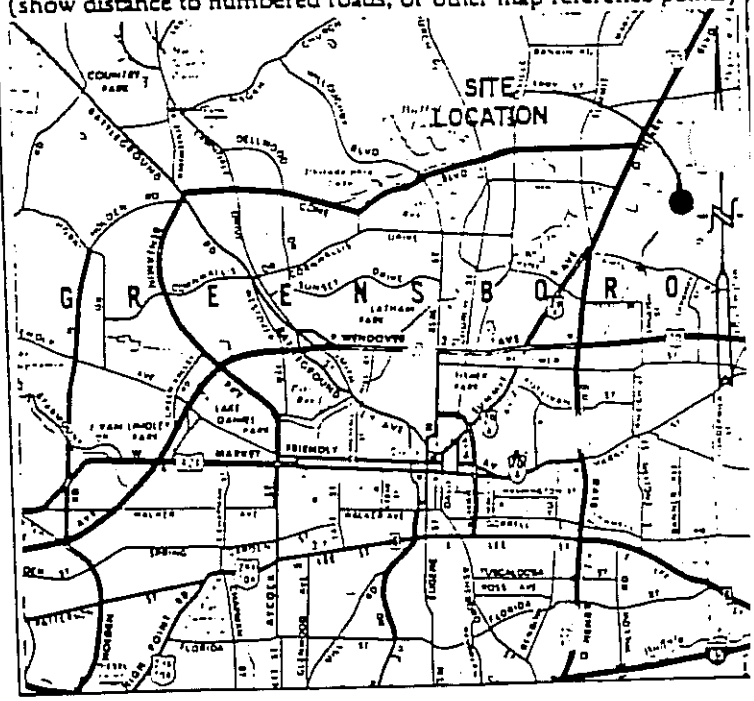
Casing is 1.40 feet above land surface

DRILLING LOG

DEPTH FROM	TO	FORMATION DESCRIPTION
		See Attached Boring Log/Core Log

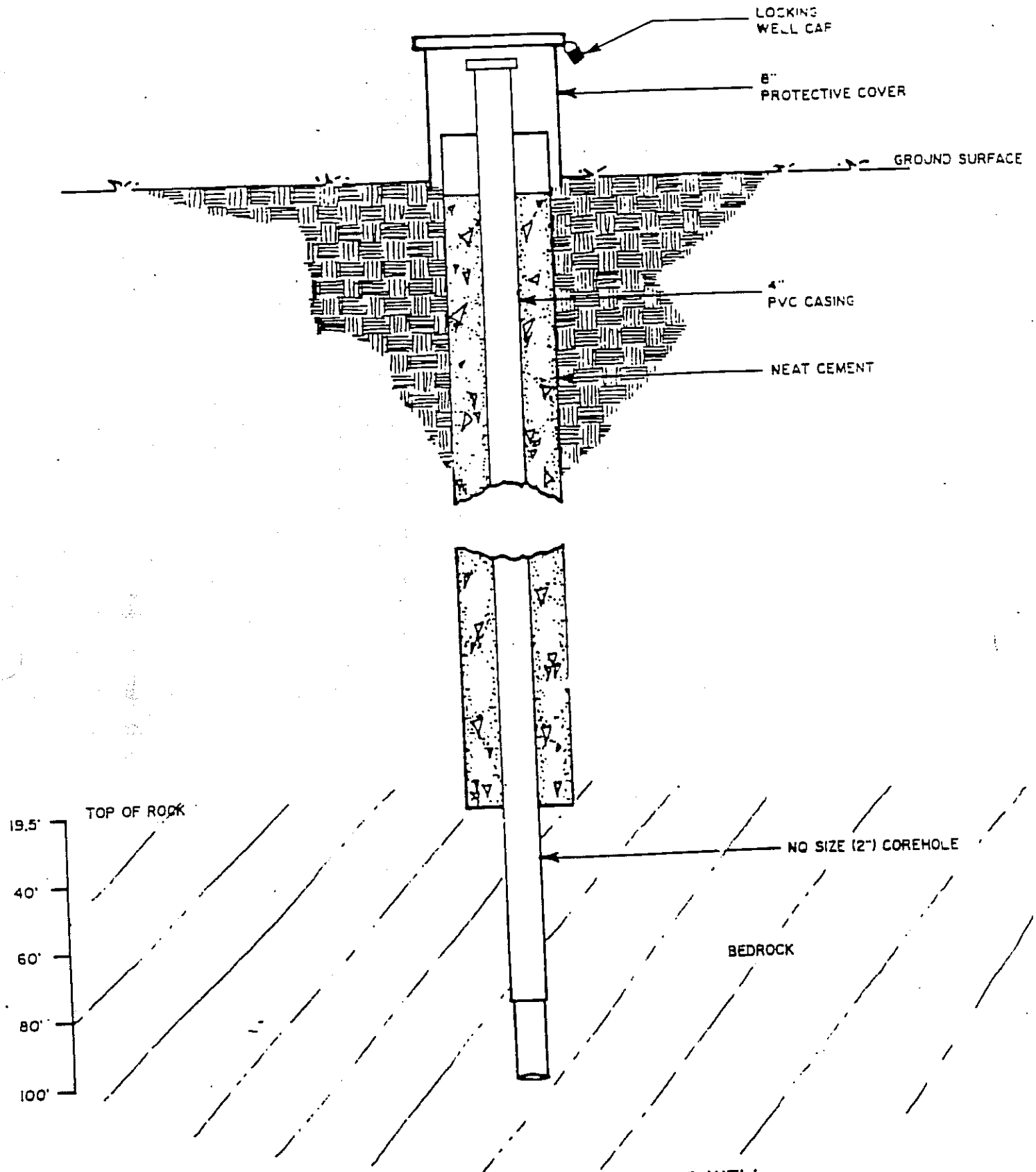
LOCATION SKETCH

(show distance to numbered roads, or other map reference points)



REMARKS:

DATE: 7-14-89 SIGNATURE:



SCHEMATIC OF BEDROCK MONITORING WELL
MW - 11
NOT TO SCALE

DRILLING LOG | DIVISION | INSTALLATION | SHEET 2 OF 2 SHEETS

1. PROJECT: Greensboro Landfill
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and title number): MW-11
5. NAME OF DRILLER
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	RQD	DRILL RATE	FRAC. FREQ.	FRAC ANGLE	WATER RETURN
	70		Occasional 2-8 mm pheno cryst between 65 to 67.5 feet.	100%	97%	1.5"/min	6/10ft	30-60°	95%
	75		Mafic and felsic mineral content approx. 50/50.	100%	100%	3"min	4/10ft	20-70°	95%
	80		NOTE: Occasional rehealed hairline fractures at 20 to 80 degrees.						
	85								
	90		NOTE: Increase in fracture frequency.	100%	92%	4"/min	11/10ft	20-70°	95%
	95		NOTE: Abundant rehealed fractures from 95 to 97 ft., major fractures oriented at 60 to 80 degrees.	100%	95%	5"/min	3/5ft	20-80°	95%
	100								
	105		Coring Terminated at 100.5'.						

PROJECT | HOLE NO.

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

(TRANSLUCENT)

PROJECT: GREENSBORO SOLID WASTE LANDFILL PROJECT NO: 6770-021-018

LOCATION: WHITE STREET, GREENSBORO, N.C. BORING NUMBER: MW-13 PAGE: 1 OF 1

BORING LOG

DATE: 1/6/93

NUMBER	DEPTH	SPT	T	WL	SI	DESCRIPTION (USCS)	COMMENTS
SS-01 SS-02	4' 8' 12' 16' 20' 24' 28' 32'	53 82+	SS SS			0-1.0' TOPSOIL; 0-0.5' THEN ORANGE SLIGHTLY SANDY SILT 1-2.5' ORANGE CLAYEY, MICACEOUS SANDY SILT; 1.5-2.5' VERY HARD, BROWN AND BLACK SLIGHTLY SANDY, SLIGHTLY CLAYEY SILT, PARTIALLY WEATHERED ROCK 3.5-5.0' BROWN AND BLACK, FINE-GRAINED SLIGHTLY SANDY SILT, VERY HARD PARTIALLY WEATHERED ROCK AUGER REFUSAL AT 5.0' MUD ROTARY DRILLING 5.0-18.5' BG CORE DRILLED FROM 18.5-32.5' OBTAINED 14.0' OF NX CORE (SEE CORE LOG)	SAPROLITE PARTIALLY WEATHERED ROCK BEDROCK
	36' 40'					TD = 32.5'	

BOREHOLE COMPLETION: XXX

WATER DEPTH: 718.5 DATE:

DRILLING METHOD: 6 1/4" HOLLOW-STEM AUGER, TRICONE BIT

LOGGED BY: CHARLES G. LEE, PG

KEY:
SI - SCREEN
SS - SPLITSPOON
SPT - SOIL PENETRATI
TEST-N NUMBE
ST - SHELBY TUBE
T - TYPE
WL - WATER LEVEL

HDR

PROJECT: WHITE STREET LANDFILL (PHASE III) PROJECT NO: 06770-021-018

LOCATION: GREENSBORO, N.C. BORING NUMBER: MW-13 PAGE: 2 OF 2

CORE LOG DATE: 1/6/93

NUMBER	DEPTH	REC	RQD	DESCRIPTION (ROCK)	FRACTURES (W/ANGLE)
	14'			PARTIALLY WEATHERED ROCK	
FIRST CORE RUN	18' 22' 26'	92%	79% GOOD	GNEISS: FOLIATED, SLIGHTLY BROKEN TO MASSIVE, HARD TO VERY HARD, CONTAINS QUARTZ, FELDSPAR, BIOTITE MICA, FOLIATION NEARLY VERTICAL TO 70° FROM HORIZONTAL, HEALED FRACTURES WITH SERPENTINE, FINE TO MEDIUM-GRAINED, PYRITE-BEARING FRACTURES	FRACTURE ZON 60° 65° 50° 50°
SECOND CORE RUN	30' 34'	44%	88% GOOD	GNEISS: FOLIATED, MASSIVE, HARD TO VERY HARD, MOTTLED BLACK, WHITE AND GRAY, CONTAINS QUARTZ, FELDSPAR, BIOTITE MICA, FOLIATION NEARLY VERTICAL TO 70° FROM HORIZONTAL, FRACTURES AT 35° FROM HORIZONTAL, MINIMAL IRON OXIDE STAINING OF FRACTURES	35° 35° 35° 35°
	38'			TD = 34.0'	

COREHOLE COMPLETION: 34' BELOW LAND SURFACE

WATER DEPTH: 718.5 DATE: 12/27/94

DRILLING METHOD: NX CORE (16 FT.)

LOGGED BY: JOHN R. ISHAM

KEY:
REC-RECOVERY
RQD-ROCK QUALITY DESIGNATI
NA-NOT APPLIC

HDR

PROJECT: GREENSBORO SOLID WASTE LANDFILL PROJECT NO: 6770-021-018

LOCATION: WHITE STREET, GREENSBORO, N.C. BORING NUMBER: B-46 PAGE: 1

BORING LOG

DATE: 10/6/95

NUMBER	DEPTH	SPT	T	WL	SI	DESCRIPTION (USCS)	COMMENTS
ST-46		NA	ST			PARTIALLY WEATHERED ROCK AND SAPROLITE (GRANITIC), 24" RECOVERY	GRANITIC INTRUSIVE
SS-46/1	4'	6	SS			WHITE AND GRAY CLAYEY SAND (SC), PARTIALLY WEATHERED ROCK (QUARTZ/ FELDSPAR), DRY	
	8'					T.D. 5.0'	
	12'					Lab USC: Silty Coarse to Fine Sand (SM)	
	16'						
	20'						
	24'						
	28'						
	32'						
	36'						
	40'						

BOREHOLE COMPLETION: 5.0' BELOW LAND SURFACE

WATER DEPTH: NA DATE:

DRILLING METHOD: WASH BORING TO 1' BLS, ST AND SS SAMPLING

LOGGED BY: J. ISHAM

KEY:

SI - SCREEN
SS - SPLITSPOON
SPT - SOIL PENETR
TEST-H
ST - SHELBY TU
T - TYPE
WL - WATER LEV

HD

PROJECT: GREENSBORO SOLID WASTE LANDFILL PROJECT NO: 6770-021-018

LOCATION: WHITE STREET, GREENSBORO, N.C. BORING NUMBER: B-47 PAGE: 1

BORING LOG

DATE: 10/6/95

NUMBER	DEPTH	SPT	T	WL	SI	DESCRIPTION (USCS)	COMMENTS
BP-47			PB			PARTIALLY WEATHERED GRANITIC ROCK AND SAPROLITE, ABUNDANT FELDSPAR, BRITTLE, DRY, MOTTLED	GRANITIC INTRUSIVE
SS-47/1	4'	50+	SS			WHITE AND GRAY PARTIALLY WEATHERED ROCK AND CLAYEY SAND (SAPROLITE), GRANITIC TEXTURE, DRY, BRITTLE	
						T.D. 5.0'	
						Lab USC: Silty Coarse to Fine Sand (SM)	

8'
12'
16'
20'
24'
28'
32'
36'
40'

BOREHOLE COMPLETION: 5.0' BELOW LAND SURFACE

WATER DEPTH: NA DATE: 10/6/95

DRILLING METHOD: PB SAMPLER AND SS SAMPLER

LOGGED BY: J. ISHAM

KEY:

PB - PITCHER BA
SI - SCREEN
SS - SPLITSPOON
SPT - SOIL PENETRA
TEST-N NUMB
ST - SHELBY TUB
T - TYPE
WL - WATER

PROJECT: GREENSBORO SOLID WASTE LANDFILL PROJECT NO: 6770-021-018

LOCATION: WHITE STREET, GREENSBORO, N.C. BORING NUMBER: B-48 PAGE: 1

BORING LOG

DATE: 10/6/95

NUMBER	DEPTH	SPT	T	WL	SI	DESCRIPTION (USCS)	COMMENTS
SS-48/1		16	SS			LIGHT GREEN CLAYEY SAND (SC), PHANERITIC TEXTURE, SOFT, FINE GRAINED, DRY	MAFIC INTRUSIVE
SS-48/2	4'	33	SS			LIGHT GREEN SAND (SM) WITH MINOR CLAY, SOFT, IRON OXIDE STAINED FRACTURE TRACES, DRY	
						T.D. 5.0'	

8'
12'
16'
20'
24'
28'
32'
36'
40'

BOREHOLE COMPLETION: 5.0' BELOW LAND SURFACE

WATER DEPTH: NA DATE:

DRILLING METHOD: WASH BORING (6"), SS SAMPLER

LOGGED BY: J. ISHAM

KEY:
SI - SCREEN
SS - SPLITSPOON
SPT - SOIL PENETRATIC
TEST-N NUMBE
ST - SHELBY TUBE
T - TYPE
WL - WATER LEVEL

HDR

PROJECT: GREENSBORO SOLID WASTE LANDFILL PROJECT NO: 06770-021-018

LOCATION: WHITE STREET, GREENSBORO, NC BORING NUMBER: B-49 PAGE: 1

BORING LOG

DATE: 10/6/95

NUMBER	DEPTH	SPT	T	WL	SI	DESCRIPTION (USCS)	COMMENTS
SS-49/1		25	SS			LIGHT GREEN SILT (ML), UNIFORM PHANERITIC TEXTURE, SOFT, SLIGHTLY CLAYEY, IRON OXIDE STAINING, NEARLY VERTICAL VEIN FILLINGS	INTERMEDIATE IGNEOUS INTRUSIVE (DIORITE)
SS-49/2	4'	50+	SS				
	8'					T.D. 5.0'	
	12'						
	16'						
	20'						
	24'						
	28'						
	32'						
	36'						
	40'						

BOREHOLE COMPLETION: 5.0' BELOW LAND SURFACE

WATER DEPTH: NA DATE:

DRILLING METHOD: WASH BORING (6'), SS SAMPLER

LOGGED BY: J. ISHAM

KEY:

SI - SCREEN
SS - SPLITSPOON
SPT - SOIL PENETRAT
TEST-N NUMBE
ST - SHELBY TUBE
T - TYPE
WL - WATER

PROJECT: GREENSBORO SOLID WASTE LANDFILL PROJECT NO: 6770-021-018

LOCATION: WHITE STREET, GREENSBORO, N.C. BORING NUMBER: B-50 PAGE: 1

BORING LOG

DATE: 10/9/95

NUMBER	DEPTH	SPT	T	WL	SI	DESCRIPTION (USCS)	COMMENTS
SS-50/1		20	SS			LIGHT BROWN TO TAN CLAYEY SAND(SC) RELICT GNEISSIC BANDING, MOTTLED, MOIST, NEARLY VERTICAL FOLIATION (QUARTZ, BIOTITE, FELDSPAR)	SHELBY TUBE FROM GROUND SURFACE TO 3' BLS.
SS-50/2	4'	50/4"	SS			WEATHERED GRANITIC ROCK FRAGMENTS, 2" RECOVERED (GNEISSIC FOLIATION)	FELSIC GRANITIC GNEISS
	8'					T.D. 6.0' AUGER REFUSAL	
	12'					Lab USC: Silty Medium to Fine Sand (SM)	
	16'						
	20'						
	24'						
	28'						
	32'						
	36'						
	40'						

BOREHOLE COMPLETION: 6.0' BELOW LAND SURFACE

WATER DEPTH: NA DATE:

DRILLING METHOD: 3 1/4" HOLLOW STEM AUGERS, SS AND ST SAMPLERS

LOGGED BY: J. ISHAM

KEY:

SI - SCREEN
SS - SPLITSPOON
SPT - SOIL PENETRA
TEST-N NUMB
ST - SHELBY TUB
T - TYPE
WL - WATER LEVE

HD

PROJECT: GREENSBORO SOLID WASTE LANDFILL PROJECT NO: 6770-021-018

LOCATION: WHITE STREET, GREENSBORO, NC BORING NUMBER: B-51 PAGE: 1

BORING LOG

DATE: 10/9/95

NUMBER	DEPTH	SPT	T	WL	SI	DESCRIPTION (USCS)	COMMENTS
						REDDISH-ORANGE TO BROWN CLAY (CL) ROOTED, NO STRUCTURE	FILL MATERIAL
SS-51/1		6	SS				
						BROWN CLAYEY SAND (SC), WEATHERED GNEISS FRAGMENTS, FOLIATION IN ROCK SAMPLES, DRY, BRITTLE	FELSIC GRANITIC GNEISS
SS-51/2	4'	50/5"	SS				
						GREEN SILTY CLAY (CL), VERY BRITTLE, DRY, MINOR HORIZONTAL PARTINGS, MOTTLED	MAFIC INTRUSIVE
SS-51/3		31	SS				
	8'					GREEN SILTY CLAY (CL), PHANERITIC TEXTURE, VERY DRY, BRITTLE, WEATHERED	
SS-51/4		31	SS				
	12'					T.D. 10.0'	
	16'						
	20'						
	24'						
	28'						
	32'						
	36'						
	40'						

BOREHOLE COMPLETION: 10.0' BELOW LAND SURFACE

WATER DEPTH: NA DATE:

DRILLING METHOD: 3 1/4" HOLLOW STEM AUGERS, SS SAMPLERS

LOGGED BY: J ISHAM

KEY:
SI - SCREEN
SS - SPLITSPOON
SPT - SOIL PENETRA
TEST-N NUMB
ST - SHELBY TUB
T - TYPE
WL - WATER

HD

PROJECT: GREENSBORO SOLID WASTE LANDFILL PROJECT NO: 6770-021-018

LOCATION: WHITE STREET, GREENSBORO, N.C. BORING NUMBER: B-52 PAGE: 1

BORING LOG

DATE: 10/9/95

NUMBER	DEPTH	SPT	T	WL	SI	DESCRIPTION (USCS)	COMMENTS
						LIGHT BROWN TO TAN SANDY CLAY (CL), MOIST, ROCK FRAGMENTS, NO STRUCTURE	FILL MATERIAL
SS-52/1		6	SS				
	4'					GREEN SILTY CLAY (CL), PHANERITIC TEXTURE, MOTTLED WHITE AND BLACK, SOFT, DRY	
SS-52/2		26	SS				
						LIGHT GREEN TO BROWN SILTY CLAY (CL), VERTICAL IRO-STAINED FRACTURES, PHANERITIC TEXTURE, SOFT, DRY	INTERMEDIATE IGNEOUS INTRUSIVE (DIORITE)
SS-52/3		22	SS				
	8'					SAME AS ABOVE, SLIGHTLY BRITTLE IN NATURE	
SS-52/4		22	SS				
	12'					T.D. 10.0'	
	20'						
	24'						
	28'						
	32'						
	36'						
	40'						

BOREHOLE COMPLETION: 10.0' BELOW LAND SURFACE

WATER DEPTH: NA DATE:

DRILLING METHOD: 3 1/4" HOLLOW STEM AUGERS, SS SAMPLERS

LOGGED BY: J. ISHAM

KEY:

SI - SCREEN
SS - SPLITSPOON
SPT - SOIL PENETRA
TEST-N NUMB
ST - SHELBY TUB
T - TYPE
WL - WATER LEVE

HD

PROJECT: GREENSBORO SOLID WASTE LANDFILL PROJECT NO: 6770-021 -018

LOCATION: WHITE STREET, GREENSBORO, N.C. BORING NUMBER: B-53 PAGE: 1

BORING LOG

DATE: 10/6/95

NUMBER	DEPTH	SPT	T	WL	SI	DESCRIPTION (USCS)	COMMENTS
ST-53			ST			GREENISH-BROWN PARTIALLY WEATHERED ROCK AND SAPROLITE (SILTY SAND), IRON STAINING, NEARLY VERTICAL FRACTURES, CLAY PARTINGS BETWEEN FRACTURES	MAFIC INTRUSIVE
	4'					GREENISH-BROWN PARTIALLY WEATHERED ROCK AND SAPROLITE (SILTY SAND), IRON STAINING, CLAY PARTINGS BETWEEN FRACTURES	
SS-53/1		9	SS			SAME AS ABOVE WITH LAYERING OF SILTY CLAY (CL) AND WEATHERED ROCK, MOIST	
	8'						
SS-53/2		8	SS				
	12'					T.D. 10.0'	
	16'					Lab USC at 0.5-3.0': Sandy Clayed Silt (MH)	
	20'						
	24'						
	28'						
	32'						
	36'						
	40'						

BOREHOLE COMPLETION: 10.0' BELOW LAND SURFACE

WATER DEPTH: NA DATE:

DRILLING METHOD: WASH BORING (6"), ST AND SS SAMPLERS

LOGGED BY: J. ISHAM

KEY:
SI - SCREEN
SS - SPLITSPOON
SPT - SOIL PENETRATI
TEST-H NUMBE
ST - SHELBY TUBE
T - TYPE
WL - WATER

HD

PROJECT: GREENSBORO SOLID WASTE LANDFILL PROJECT NO: 6770-021-018

LOCATION: WHITE STREET, GREENSBORO, N.C. BORING NUMBER: B-54 PAGE: 1

BORING LOG

DATE: 10/6/95

NUMBER	DEPTH	SPT	T	WL	SI	DESCRIPTION (USCS)	COMMENTS
SS-54/1		10	SS			LIGHT TAN TO WHITE CLAY SAND (SC), RELICT PHANERITIC TEXTURE, MOTTLED, SOFT, SLIGHTLY BRITTLE, DRY	GRANITIC INTRUSIVE
SS-54/2	4'	25	SS			SAME AS ABOVE, MORE WEATHERED ROCK FRAGMENTS	
						T.D. 5.0'	

8'
12'
16'
20'
24'
28'
32'
36'
40'

BOREHOLE COMPLETION: 5.0' BELOW LAND SURFACE

WATER DEPTH: NA DATE:

DRILLING METHOD: 3 1/4" HOLLOW STEM AUGERS, SS SAMPLERS

LOGGED BY: J. ISHAM

KEY:
SI - SCREEN
SS - SPLITSPOON
SPT - SOIL PENETRATI
TEST-N NUMBE
ST - SHELBY TUBE
T - TYPE
WL - WATER LEVEL

HD

PROJECT: GREENSBORO SOLID WASTE LANDFILL PROJECT NO: 6770-021-018

LOCATION: WHITE STREET, GREENSBORO, N.C. BORING NUMBER: B-55 PAGE: 1 OF 1

BORING LOG

DATE: 10/9/95

NUMBER	DEPTH	SPT	T	WL	SI	DESCRIPTION (USCS)	COMMENTS
SS-55/1		11	SS			GREENISH-GRAY CLAYEY SAND (SC), RELICT PHANERITIC TEXTURE, ABUNDANT MAFIC MINERALS KAOLINITE ABUNDANT, IRON STAINING, DRY	
SS-55/2	4'	17	SS			GREENISH-GRAY CLAYEY SAND (SC), DRY	GNEISS
SS-55/3		40	SS			GREENISH-GRAY CLAYEY SAND (SC), DRY, WEATHERED ROCK FRAGMENTS	
	8'						
						TD = 8.5 FT.	
						Lab Usc for 0-5': Sandy Silt (ML)	
	12'						
	16'						
	20'						
	24'						
	28'						
	32'						
	36'						
	40'						

BOREHOLE COMPLETION: 8.5 FT BELOW LAND SURFACE

WATER DEPTH: NA DATE:

DRILLING METHOD: 3 1/4" HOLLOW-STEM AUGER, SS SAMPLER

LOGGED BY: J. ISHAM

KEY:

SI - SCREEN
SS - SPLITSPOON
SPT - SOIL PENETRATION TEST-N NUMBER
ST - SHELBY TUBE
T - TYPE
WL - WATER L

HDR

PROJECT: GREENSBORO SOLID WASTE LANDFILL PROJECT NO: 6770-021-018

LOCATION: WHITE STREET, GREENSBORO, N.C. BORING NUMBER: B-56 PAGE: 1

BORING LOG

DATE: 10/6/95

NUMBER	DEPTH	SPT	T	WL	SI	DESCRIPTION (USCS)	COMMENTS
						REDDISH-ORANGE AND YELLOW SILTY CLAY (CL), SLIGHTLY MICACEOUS, MANGANESE OXIDE STAINING	
SS-56/1		3	SS				
	4'					TAN TO BROWN CLAYEY SAND (SC), MANGANESE VEINLETS, MOTTLED, 2.5" GRANITIC VEIN AT 4.0', DRY, SOFT	FELSIC
SS-56/2		10	SS				
SS-56/3		4	SS			REDDISH-ORANGE SILTY CLAY (CL), VERTICAL MANGANESE VEINS, DRY, SOFT, SLIGHTLY MICACEOUS, MOTTLED	GNEISS
	8'						
SS-56/4		4	SS				
						T.D. 10.0'	
	12'					Lab USC for 0.5': Sandy Silt (ML)	
	16'						
	20'						
	24'						
	28'						
	32'						
	36'						
	40'						

BOREHOLE COMPLETION: 10.0' BELOW LAND SURFACE

WATER DEPTH: NA DATE:

DRILLING METHOD: 3 1/4" HOLLOW STEM AUGER, SS SAMPLER

LOGGED BY: J. ISHAM

KEY:

SI - SCREEN
SS - SPLITSPO
SPT - SOIL PENE
TEST-HI
ST - SHELBY T
T - TYPE
WL - WATER LI

HD

PROJECT: GREENSBORO SOLID WASTE LANDFILL PROJECT NO: 6770-021-018

LOCATION: WHITE STREET, GREENSBORO, N.C. BORING NUMBER: B-57 PAGE: 1

BORING LOG

DATE: 10/

NUMBER	DEPTH	SPT	T	WL	SI	DESCRIPTION (USCS)	COMMENTS
SS-57/1		9	SS			GREENISH-GRAY CLAYEY SAND (SC), RELICT PHANERITIC TEXTURE, ABUNDANT MAFIC MINERALS, KAOLINITE ABUNDANT, IRON STAINING, DRY	
SS-57/2	4'	48	SS			GREENISH-GRAY CLAYEY SAND (SC), DRY	MAFIC INTRUSIVE GREENSTONE DIKE
SS-57/3	8'	11	SS			GREENISH-GRAY CLAYEY SAND (SC), DRY	
SS-57/4		50/3"	SS			SAME AS ABOVE, WEATHERED ROCK FRAGMENTS	
	12'					T.D. 10.0'	
	20'					Lab USC for 0-5': Sandy Silt (ML)	
	24'						
	28'						
	32'						
	36'						
	40'						

BOREHOLE COMPLETION: 10.0' BELOW LAND SURFACE

WATER DEPTH: NA DATE:

DRILLING METHOD: 3 1/4" HOLLOW STEM AUGER, SS SAMPLER

LOGGED BY: J. ISHAM

KEY:

SI - SCREEN
SS - SPLITSPO
SPT - SOIL PEN
TEST-HI
ST - SHELBY
T - TYPE
WL - WATER

PROJECT: GREENSBORO SOLID WASTE LANDFILL | PROJECT NO: 6770-021-018

LOCATION: WHITE STREET, GREENSBORO, N.C. | BORING NUMBER: B-58 | PAGE: 1

BORING LOG

DATE: 10/6/95

NUMBER	DEPTH	SPT	T	WL	SI	DESCRIPTION (USCS)	COMMENTS
						REDDISH-BROWN SANDY CLAY (CL), SOFT, MOIST, SLIGHTLY PLASTIC	BAG SAMPLE FROM UPPER 5'
SS-58/1		6	SS				
	4'					TAN TO LIGHT BROWN SILTY SAND (SM); UNIFORM PHANERITIC TEXTURE, DRY	GRANITIC INTRUSIVE
SS-58/2		10	SS				
						PARTIALLY WEATHERED GRANITIC ROCK, BRITTLE, DRY, MOTTLED APPEARANCE	
SS-58/3		50+	SS				AUGER REFUSAL
	8'					T.D. 7.5'	
	12'					Lab USC for 0-5': Sandy Silt (ML)	
	16'						
	20'						
	24'						
	28'						
	32'						
	36'						
	40'						

BOREHOLE COMPLETION: 7.5' BELOW LAND SURFACE

WATER DEPTH: NA | DATE:

DRILLING METHOD: 3 1/4" HOLLOW STEM AUGERS, SS SAMPLERS

LOGGED BY: J. ISHAM

KEY:
SI - SCREEN
SS - SPLITSPOON
SPT - SOIL PENETRATI
TEST-N NUMBE
ST - SHELBY TUBE
T - TYPE
WL - WATER LEVEL

HDR

APPENDIX B

GEOTECHNICAL ANALYSES

Soil Boring Depth and SPT Resistance Data
Site Hydrogeologic Investigation
White Street Sanitary Landfill Expansion
Greensboro, North Carolina

Boring Number	Auger Refusal Depth (feet)	Standard Penetration Test Values						
		5.0 - 6.5	10.0 -11.5	15.0 -16.5	20.0 - 21.5	25.0 - 26.5	30.0 -31.5	35.5 - 36.5
B - 1	13.0	2-3-5	15-25-36	50/4"				
B - 1d	13.0	2-3-5	15-25-36	50/4"				
B - 2	18.5	6-15-22	6-12-10	6-12-25				
B - 3	15.3	4-9-8	50/3"	50/4"				
B - 4	11.0	15-20-25	50/6"					
B - 5	16.0	9-32-18	12-11-12	50/3"				
B - 6	17.0	12-11-13	10-12-19	11-20-50/5"				
B - 7	24.5	11-10-12	16-26-50/5"	27-50/6"	22-22-24	50/0.5"		
B - 8	11.0	19-50/5"	50/5"					
B - 8a	12.0	n/a						
B - 9	36.5	18-24-50/3"	18-50/5"	34-50/5"	50/6"	50/4"	34-50/6"	50/2"
B-9d	52.0*	18-39-40	29-50/3"	50/1"	50/1"	50/1"	36-50/6"	50/0"
B - 10	32.5	n/a	3-4-6	2-3-4	3-4-4	3-4-6	10-18-50/2"	
B - 11	16.5	3-6-8	7-12-42	30-50/2"				
B - 12	11.0	6-12-16	7-50/6"					
B - 13	23.0	5-7-13	6-6-10	5-6-7	15-25-50/5"			

*Roller cone refusal.

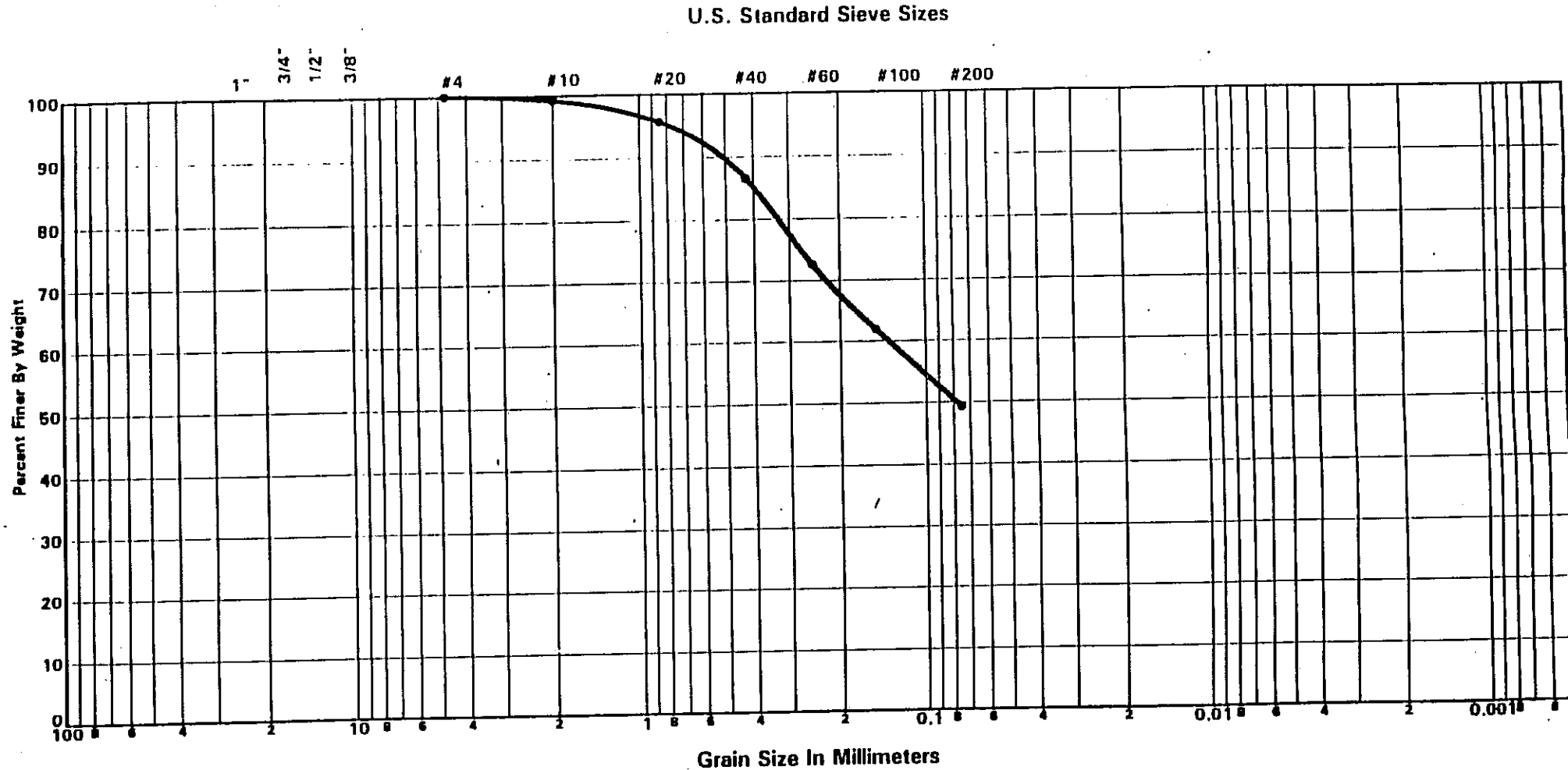
Soil Boring Depth and SPT Resistance Data
Site Hydrogeologic Investigation
White Street Sanitary Landfill Expansion
Greensboro, North Carolina

Boring Number	Auger Refusal Depth (feet)	Standard Penetration Test Values						
		5.0 - 6.5	10.0 -11.5	15.0 -16.5	20.0 - 21.5	25.0 - 26.5	30.0 -31.5	35.5 - 36.5
B - 14	16.5	6-7-8	9-18-23	7-12-46				
B - 15	19.5	7-11-13	11-40-50/5"	50/4"				
B - 15a	3.0	n/a						
B - 15b	7.0	3-4-5						
B - 16	36.0	3-5-9	3-5-8	3-8-11	7-6-7	9-12-17	12-16-23	32-50/3"
B - 17	14.0	3-4-5	3-6-12					
B - 17d	12.5	n/a						
B - 18	13.0	3-4-6	4-6-11					
B - 19	11.0	12-24-30	10-50/5"					
B - 20	16.0	12-24-32	20-33-50/5"					
B - 21	11.0	12-50/4"	40-50/6"					
B - 22	31.0	17-50/6"	15-24-30	24-50/6"	24-32-38	24-28-50/5"	4-36-50/5"	
B - 22d	28.5	n/a						
B - 23	31.0	10-19-30	15-50/6"	9-50/6"	35-50/5"	50/2"	50/2"	
B - 24	12.0	33-50/6"	33-38-50/5"					
B - 25	38.5	50/6"	41-50/5"	18-36-32	50/6"	50/6"	34-50/5"	50/3"

Soil Boring Depth and SPT Resistance Data
Site Hydrogeologic Investigation
White Street Sanitary Landfill Expansion
Greensboro, North Carolina

Boring Number	Auger Refusal Depth (feet)	Standard Penetration Test Values						
		5.0 - 6.5	10.0 -11.5	15.0 -16.5	20.0 - 21.5	25.0 - 26.5	30.0 -31.5	35.5 - 36.5
B - 25d	29.0	n/a						
B - 26	6.5	11-39-50/4"						
B - 27	13.0	50/6"	50/5"					
B - 28	0.5	n/a						
B - 29	2.0	n/a						
B - 29a	8.0	34-50/5"						
B - 30	32.0	6-10-15	8-12-17	11-17-25	12-28-50/2"	35-50/4"	50/6"	
B - 31	25.0	50/4"	50/2"	50/1"	50/1"			
B - 32	21.5	24-50/6"	50/1"	50/1"	50/1"			
B - 33	15.0	18-30-50/3"	12-16-30	50/3"				
B - 34	7.0	50/6"						
B - 34d	7.0*	n/a						
B - 35	7.0	30-50/1"						
B-36	n/a	17-24-31	11-18-50/6"	18-19-22	50/3"			
OW-1	32.0	10-9-16	6-9-11	3-3-6	6-12-30	50/4"	50/4"	25-36-45
OW-2	25.0*	11-21-28	26-27-38	31-36-50/6"	50/4"	50/0"		
OW-3	11.0*	50/6"	50/3"					

*Roller cone refusal.



GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-1 S-2	5.0'-6.5'	10.9	25.1	20.8	4.3	MAFIC Rock Green SILTY CLAYEY SAND (SC-SM)

Project:
Greensboro Landfill
Greensboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

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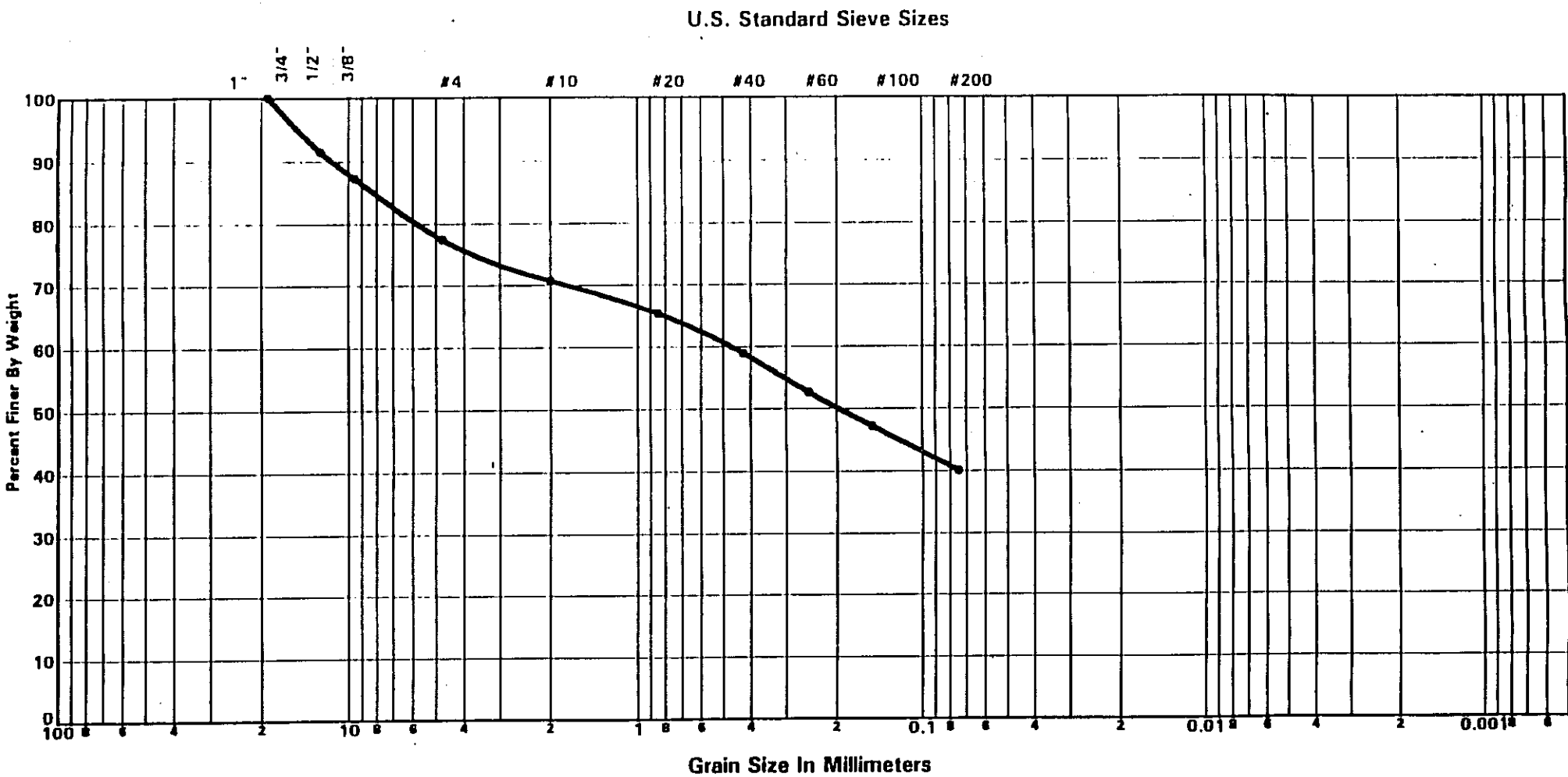

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-1 S-3	10.0'-11.5'	13.8	29.1	19.6	9.5	MAFIC ROCK Brown Green SILTY SAND (SM)

Project:
Greensboro Landfill
Greensboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

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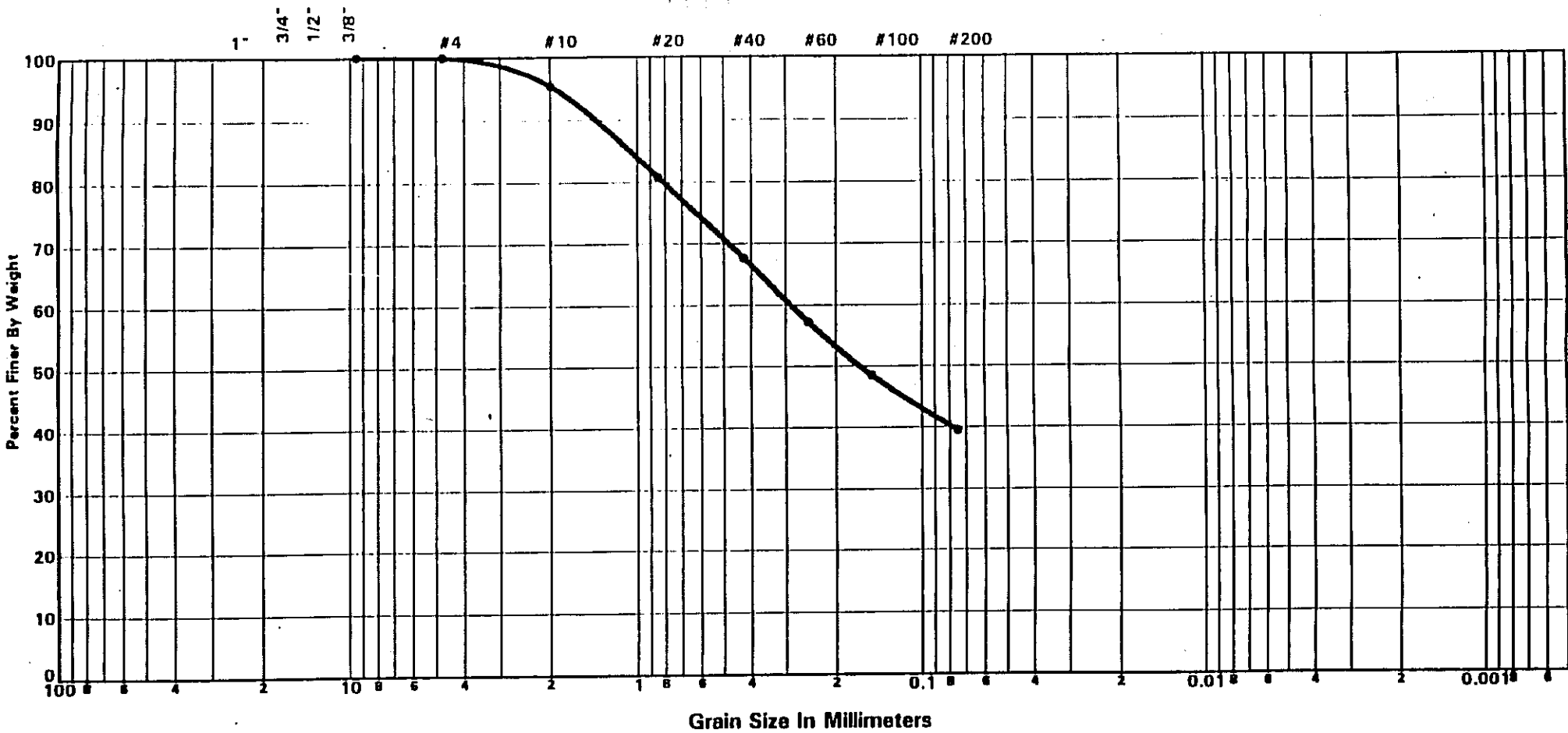

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-6 S-1	5.0'-6.5'	18.9	28.5	22.6	5.9	GRANITE Yellow Tan F-M SILTY SAND (SM)

Project:
Greensboro Landfill
Greensboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

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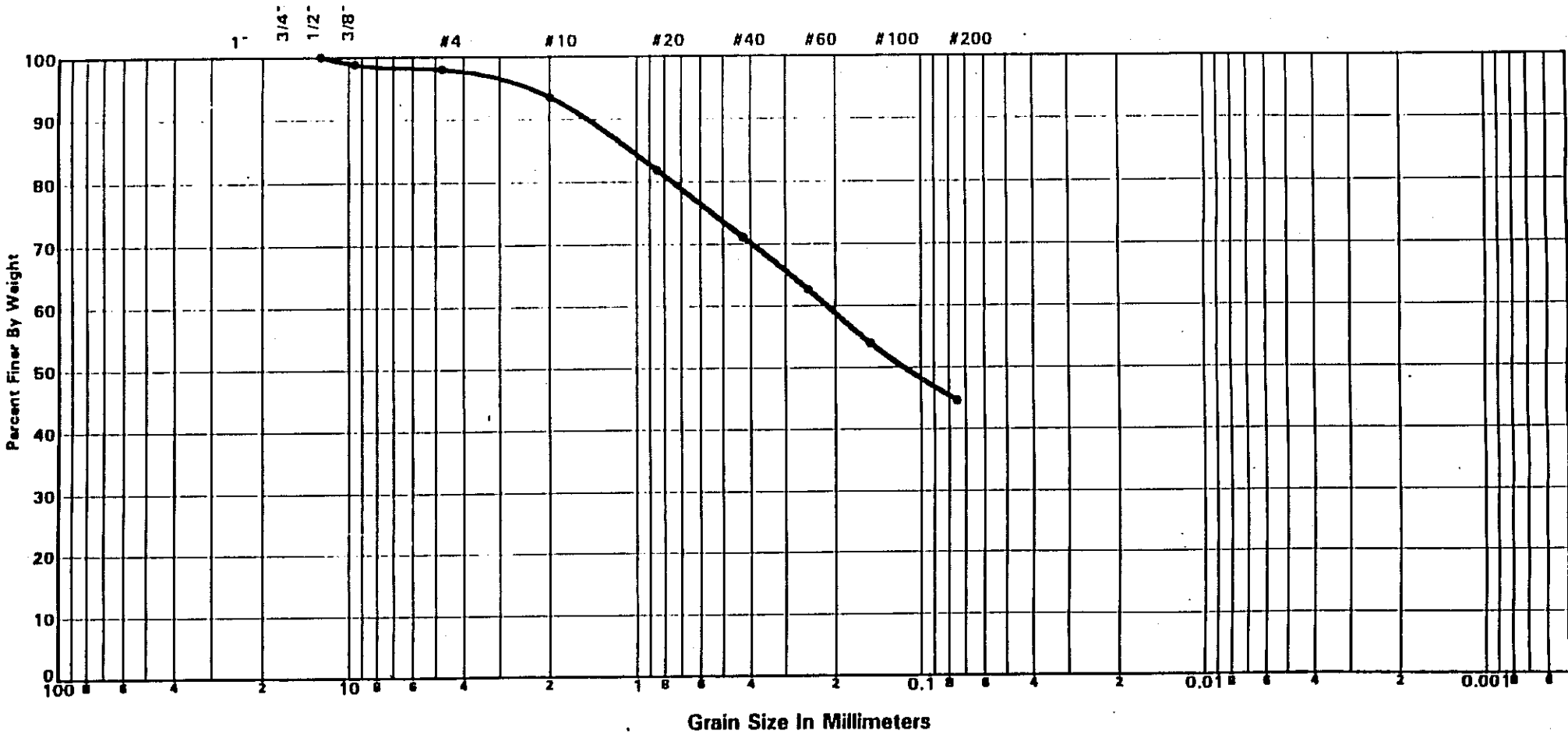
U.S. Standard Sieve Sizes



Grain Size In Millimeters

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.
B-6 S-2	10.0'-11.5'	16.5	26.1	21.0	5.1

Soil Description or Classification

GRANITE
Yellow Tan
SILTY CLAYEY SAND (SC-SM)

Project:
Gre boro Landfill
Gre boro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

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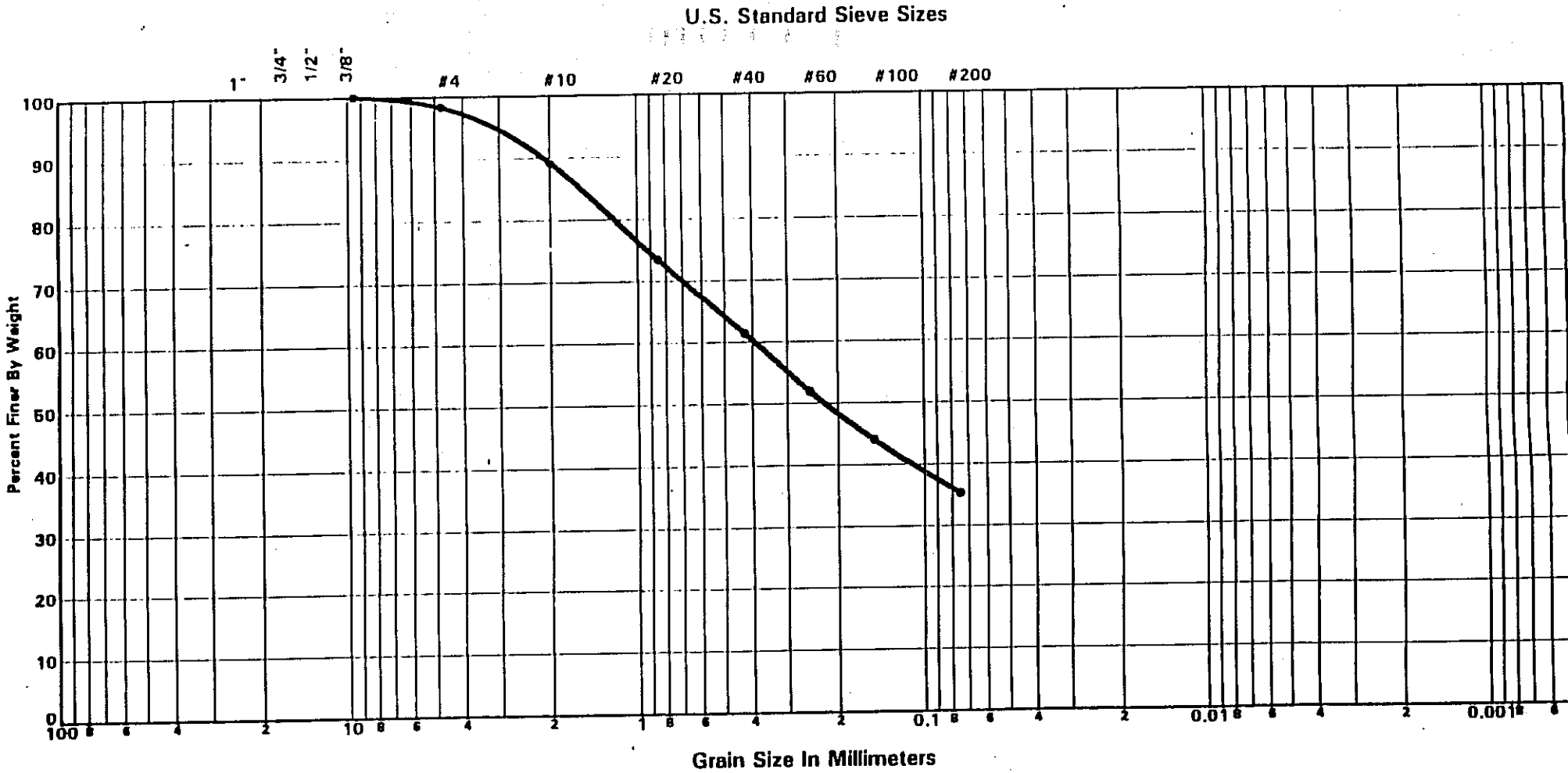

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.
B-6 S-3	15.0'-16.5'	10.9	NP	NP	NP

Soil Description or Classification

Tan Brown GRANITE

SILTY CLAYEY SAND (SC-SM)

Project:

Greensboro Landfill

Greensboro, North Carolina

Job No.: 1-95-085 CA

GRAIN SIZE DISTRIBUTION

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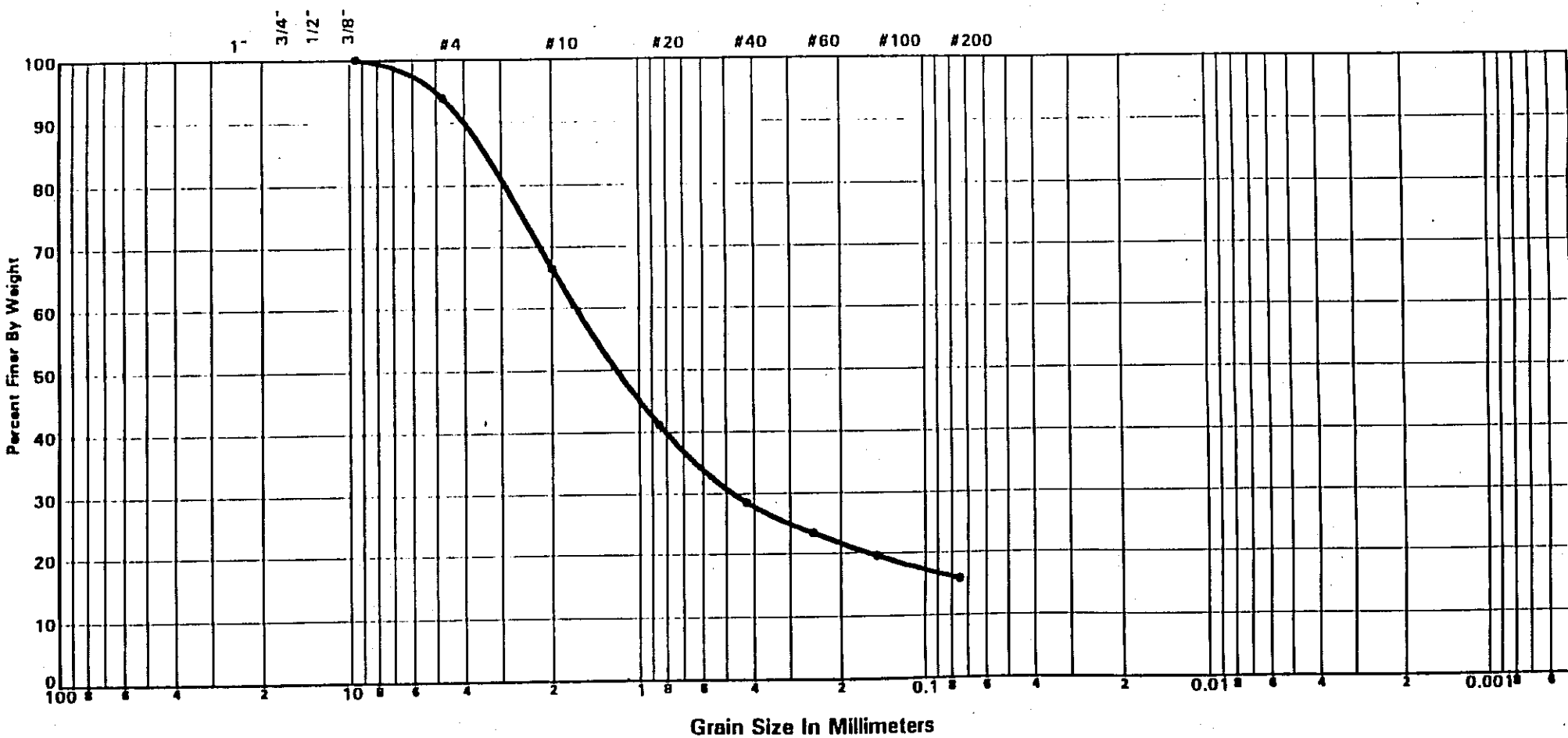
U.S. Standard Sieve Sizes



Grain Size In Millimeters

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-7 S-1	5.0'-6.5'	7.0	NP	NP	NP	GRANITE Tan Brown Fine-Coarse SAND SILTY SAND (SM)

Project:
Gr sboro Landfill
Gr sboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

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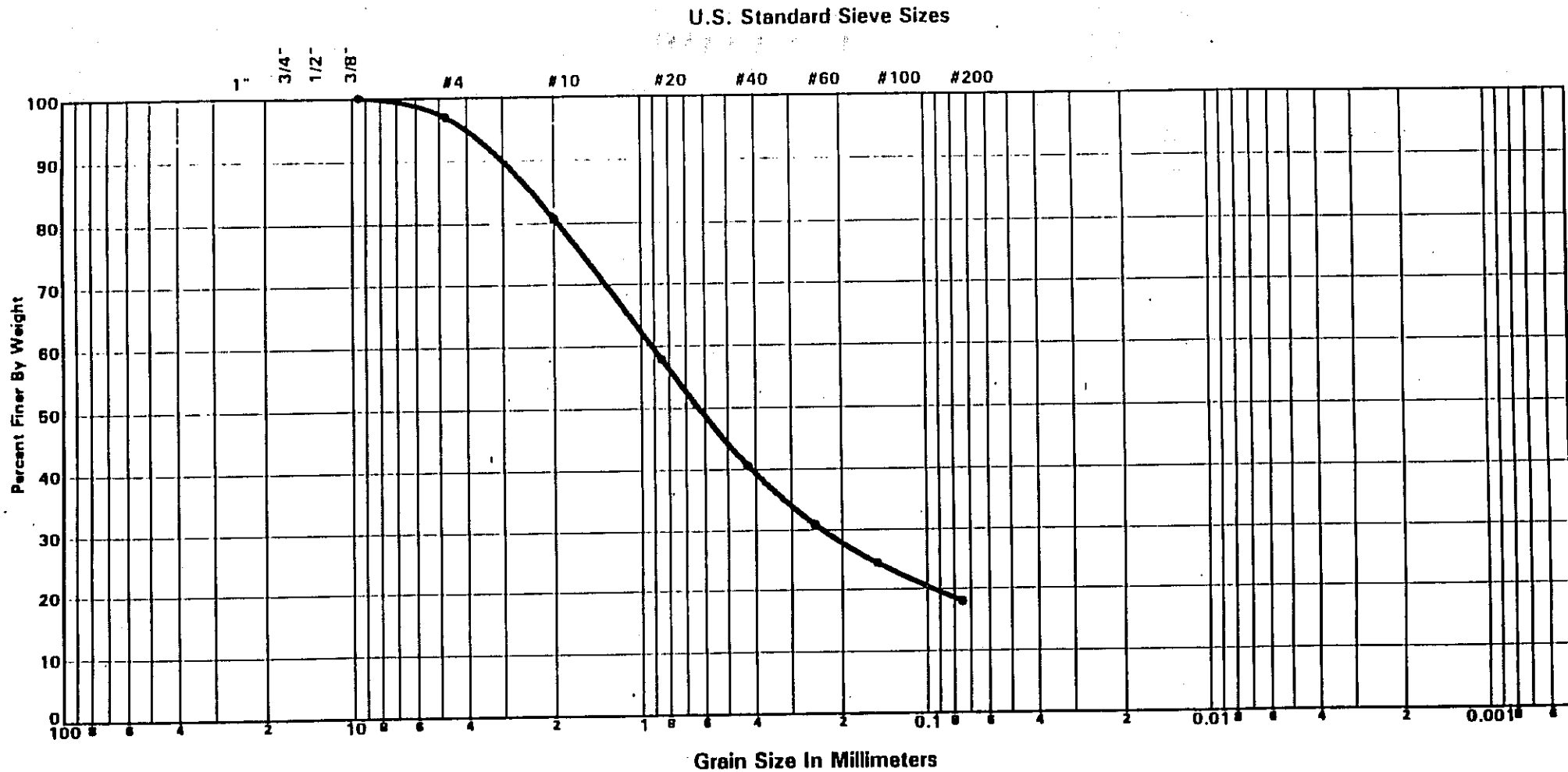

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-7 S-2	10.0'-11.5'	6.5	NP	NP	NP	GRANITE Tan Brown Medium-Coarse SAND SILTY SAND (SM)

Project:
Greensboro Landfill
Greensboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

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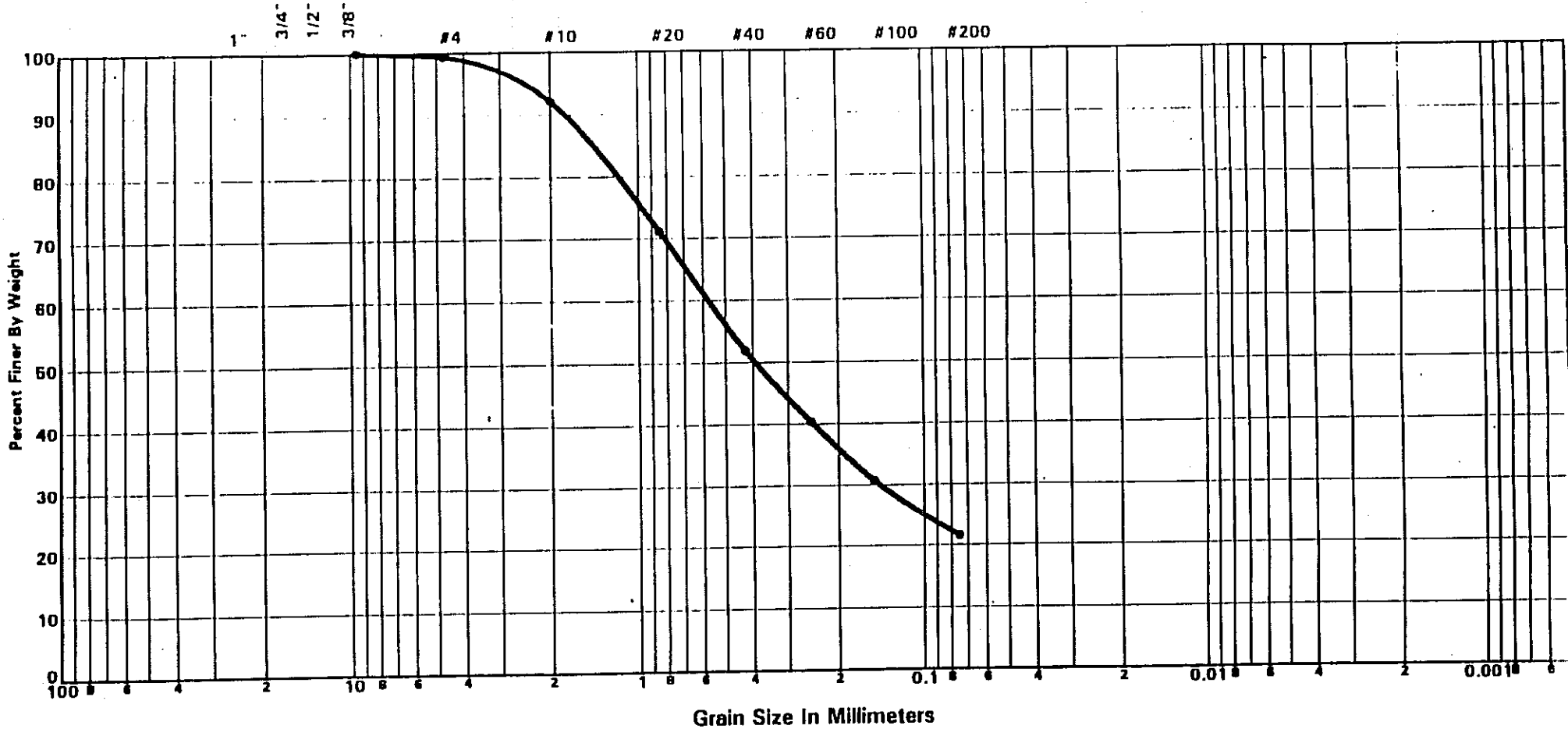
U.S. Standard Sieve Sizes



GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-7 S-3	15.0'-16.5'	6.1	NP	NP	NP	GRANITE Tan Brown Fine-Medium SAND SILTY SAND (SM)

Project:
Gr sboro Landfill
Gr sboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/9

GRAIN SIZE DISTRIBUTION

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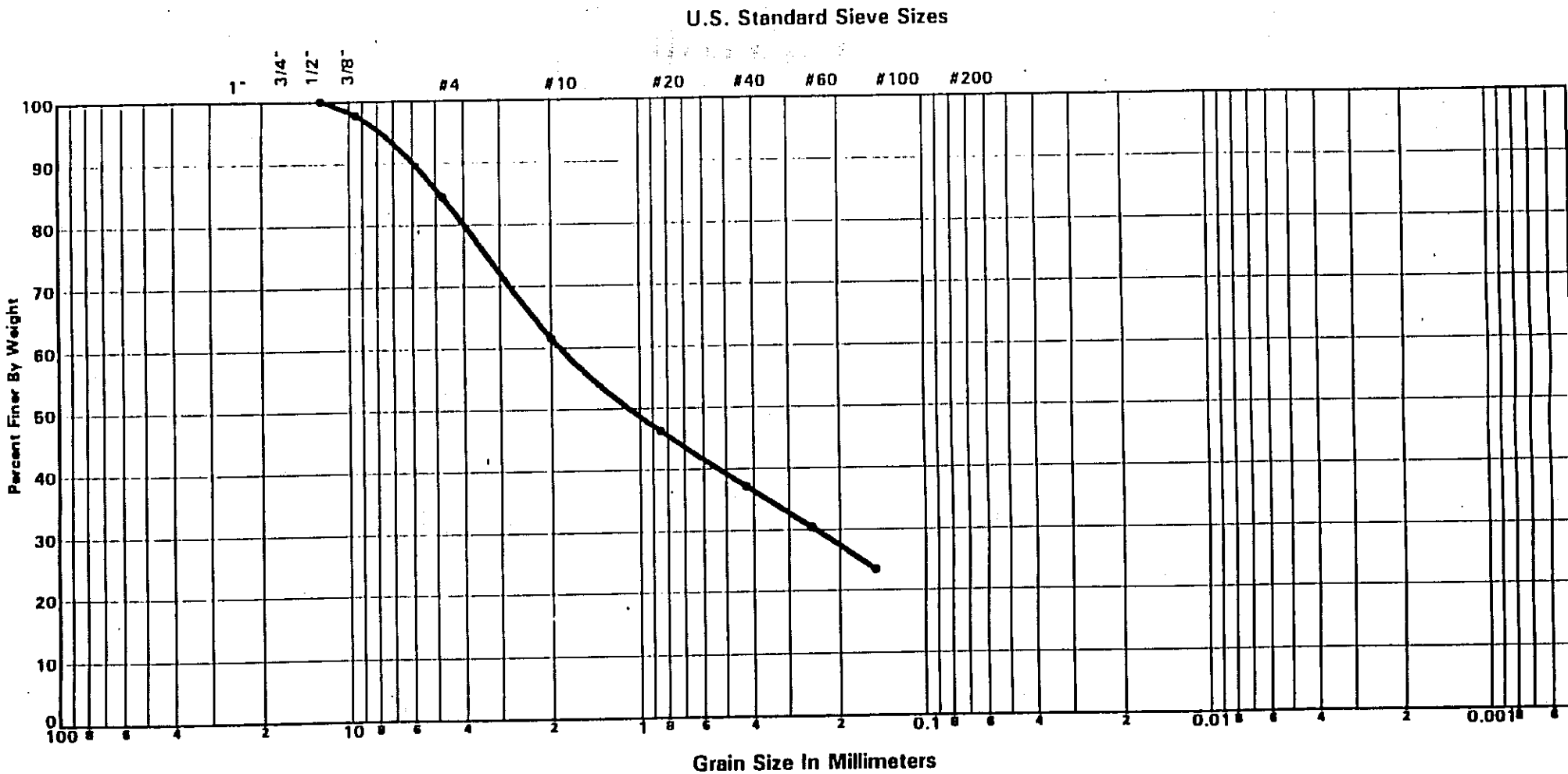

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-7 S-4	20.0'-21.5'	8.1	NP	NP	NP	Tan Brown Fine-Medium SAND (SM) GRANITE

Project:
Greensboro Landfill
Greensboro, North Carolina

Job No.: 1-95-085 CA

GRAIN SIZE DISTRIBUTION

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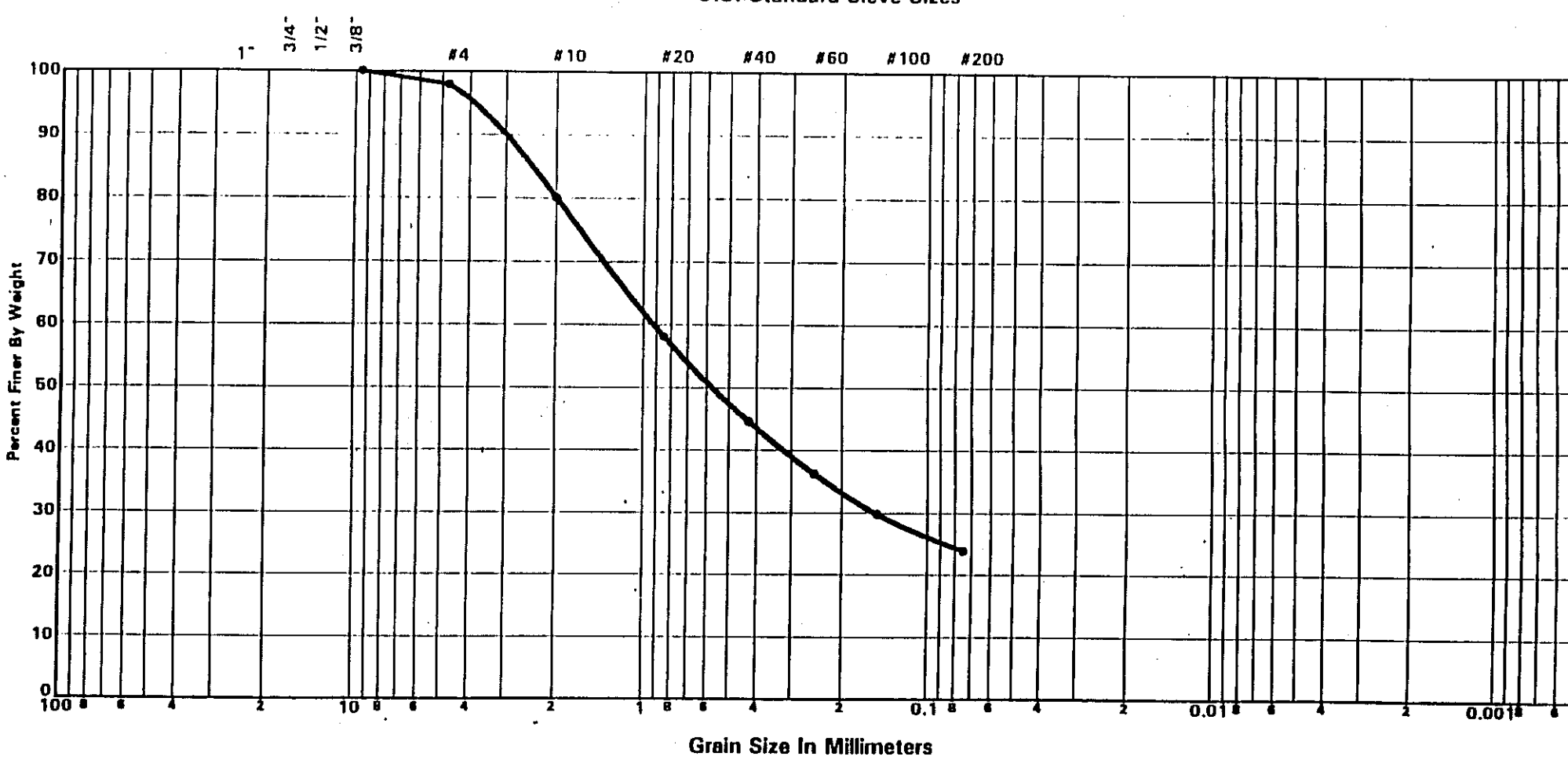

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-9 S-3	15.0'-16.5'	7.0	NP	NP	NP	Tan Brown Fine-Medium SAND (GRANITE) SILTY SAND (SM)

Project:
Greensboro Landfill
Gre boro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

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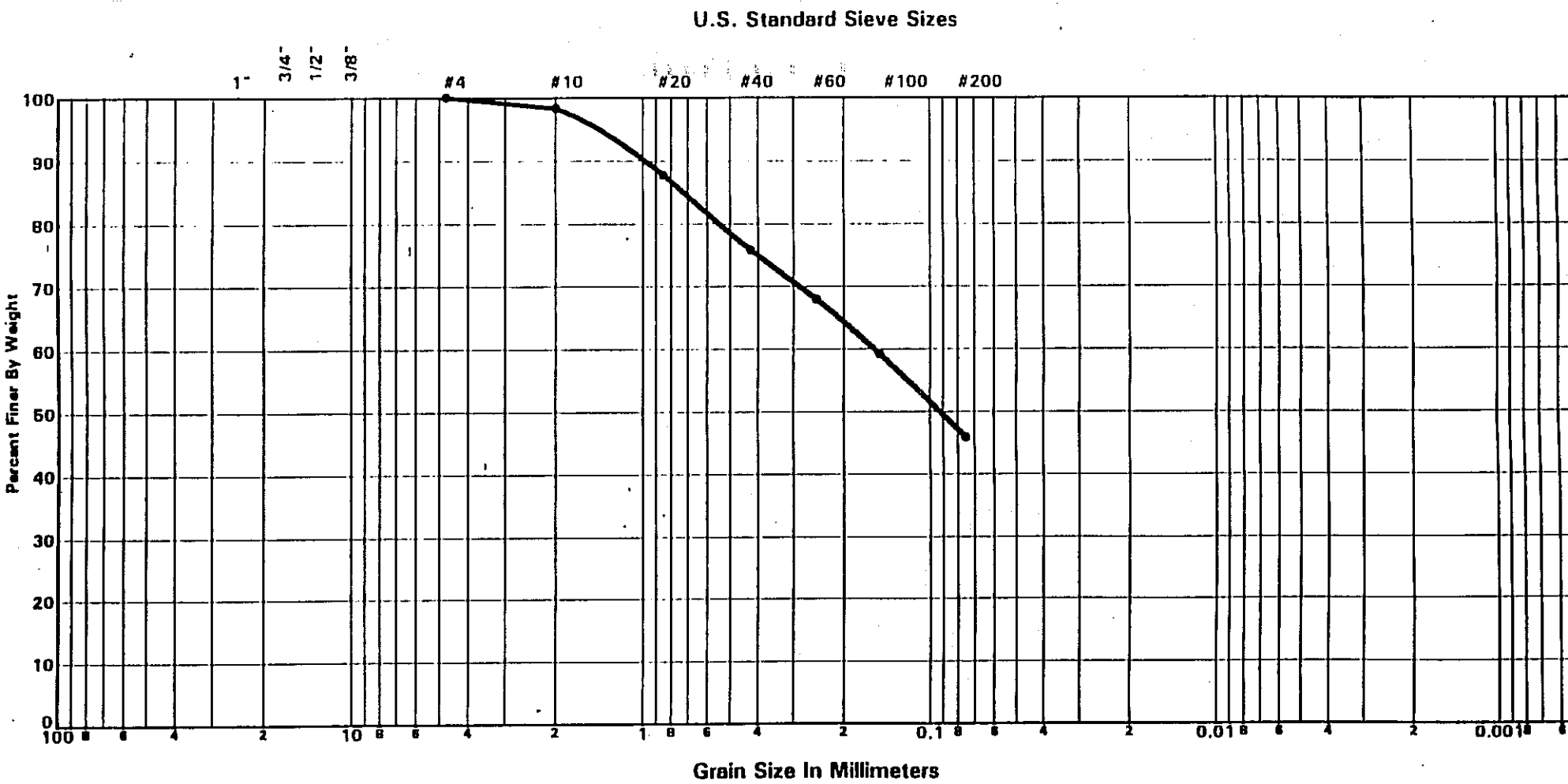

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-10 S-2	10.0'-11.5'	37.6	39.2	37.7	1.6	Light Tan SILTY SAND GNEISS

Project:
Greensboro Landfill
Greensboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

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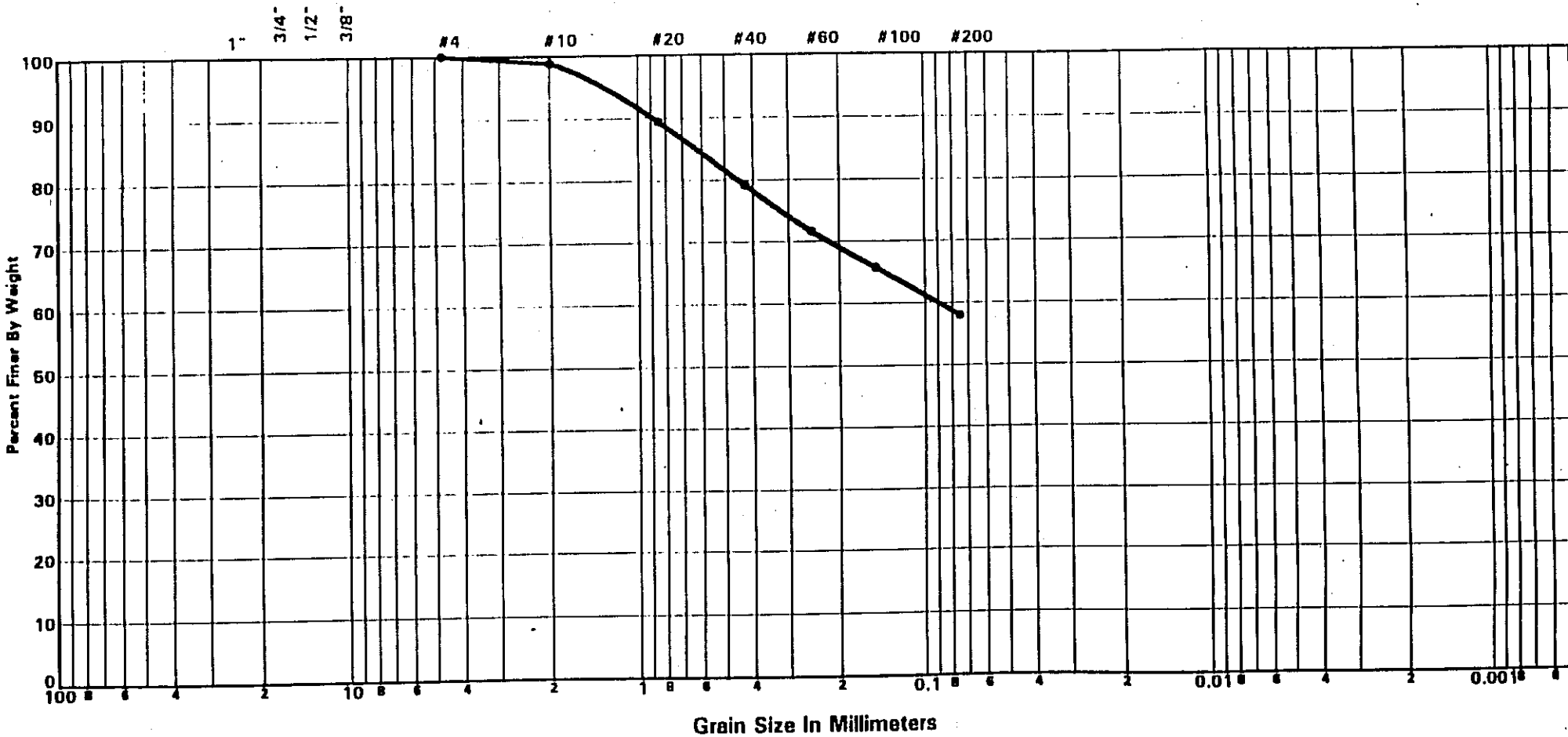
U.S. Standard Sieve Sizes



Grain Size In Millimeters

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-10 S-4	20.0'-21.5'	27.5	53.0	34.7	18.3	Orange GNEISS SANDY ELASTIC SILT (MH)

Project:
Gr sboro Landfill
Gr sboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/9

GRAIN SIZE DISTRIBUTION

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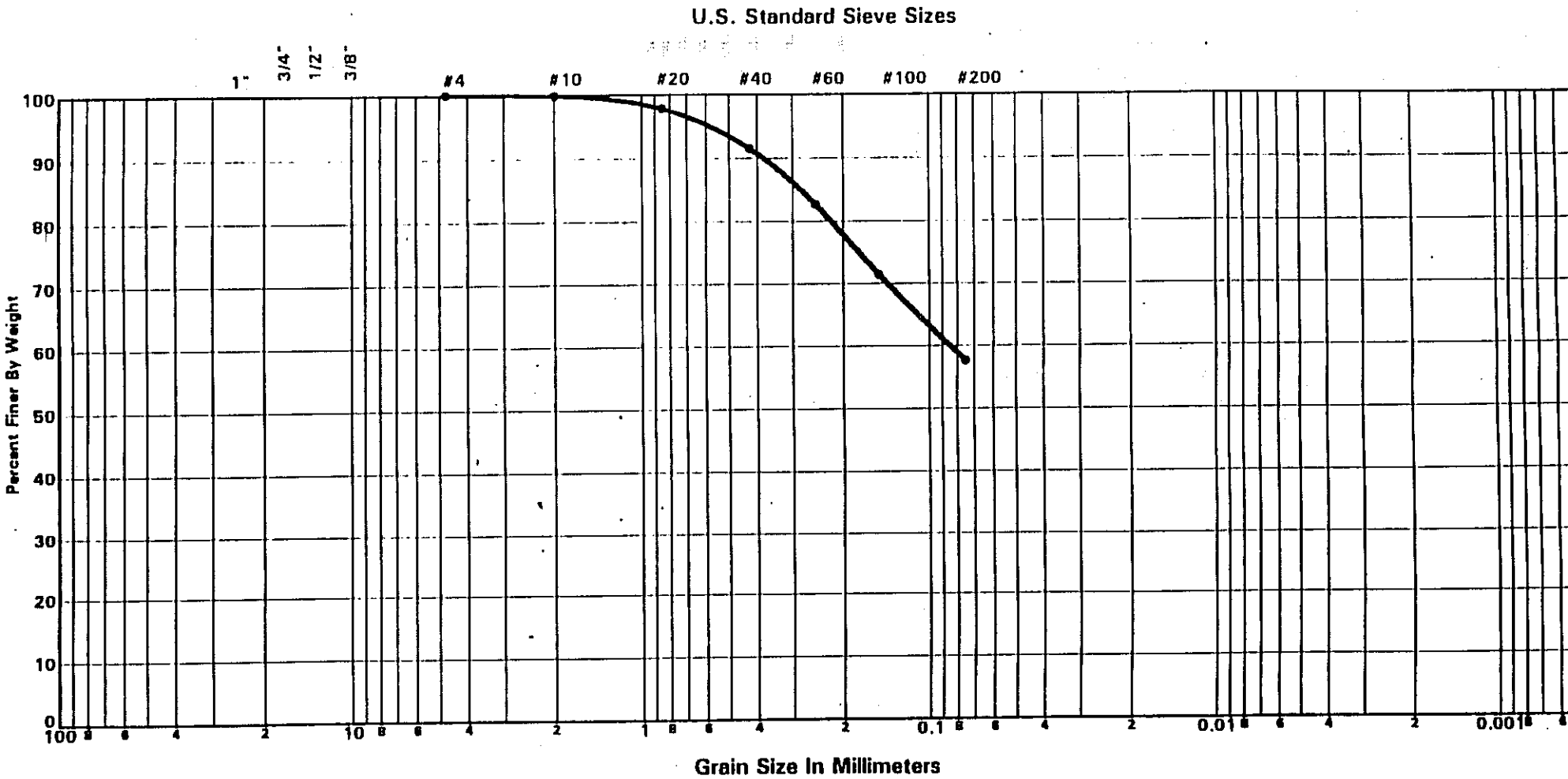

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-14 S-1	5.0'-6.5'	24.9	42.2	26.3	15.9	Tan GNEISS SANDY SILT (ML)

Project:
Greensboro Landfill
Greensboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

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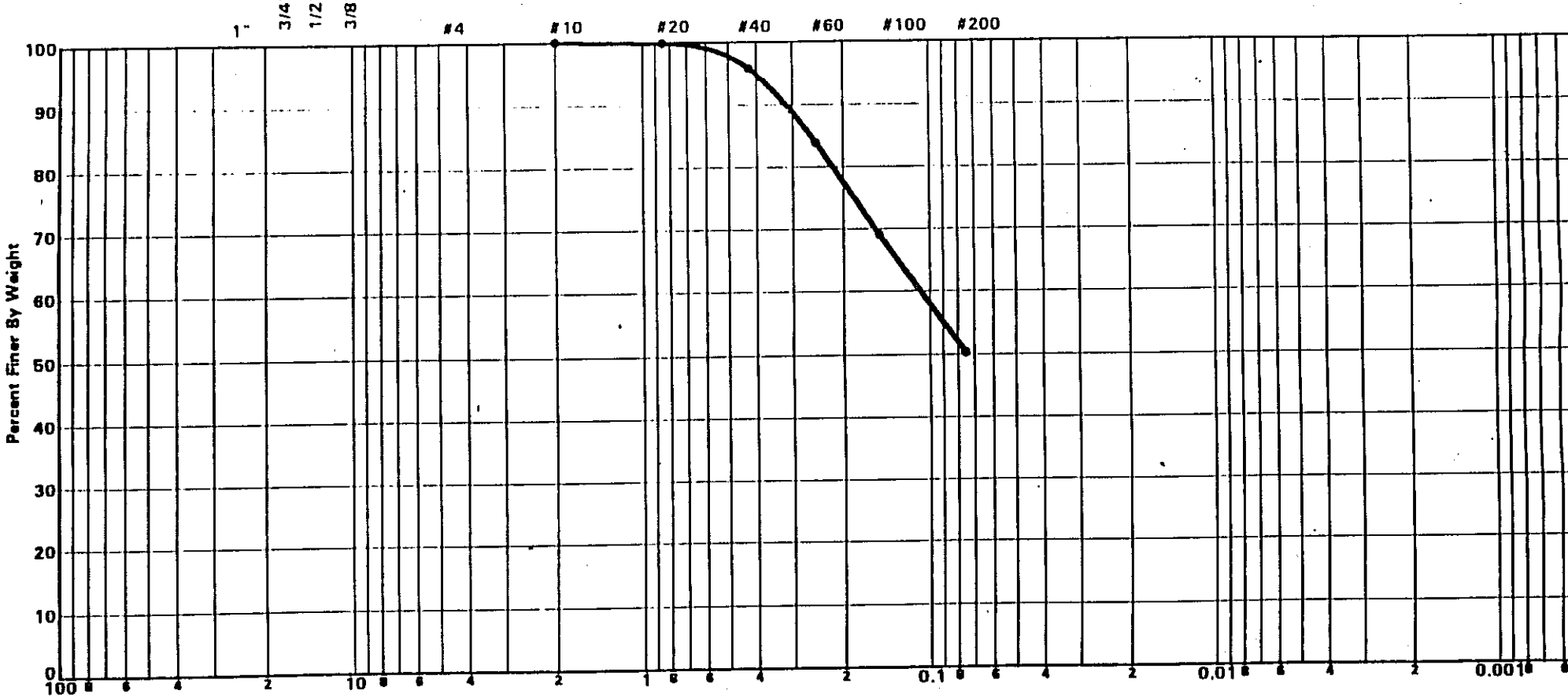
U.S. Standard Sieve Sizes



Grain Size In Millimeters

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-14 S-2	10.0'- 11.5'	22.0	38.8	25.8	13.0	Green Brown GNEISS SANDY SILT (ML)

Project:
Greensboro Landfill
G sboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/9

GRAIN SIZE DISTRIBUTION

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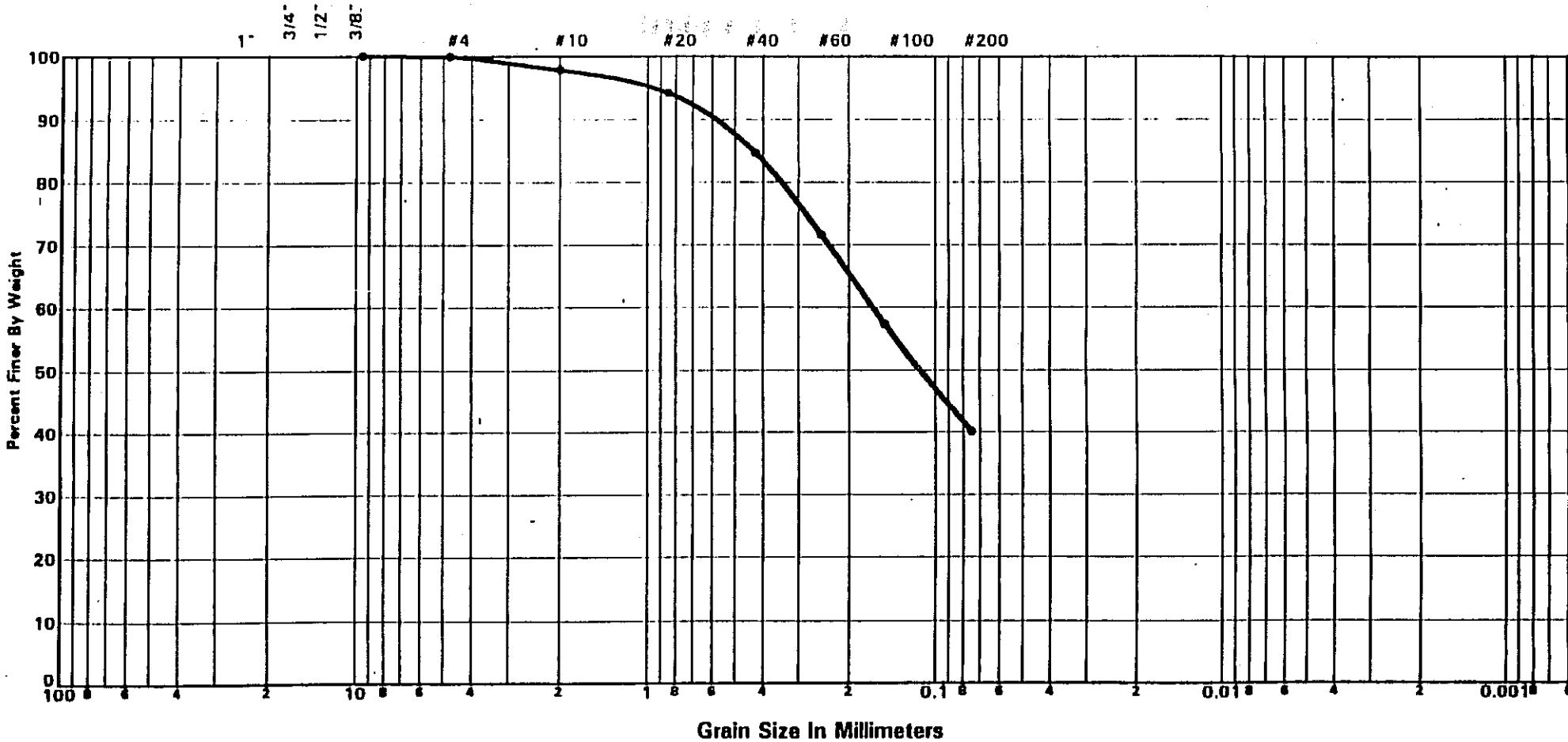
U.S. Standard Sieve Sizes



GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-14	15.0'-16.5'	22.8	33.5	27.5	6.9	Green Brown GNEISS SILTY SAND (SM)
S-3						

Project:
Greensboro Landfill
Greensboro, North Carolina

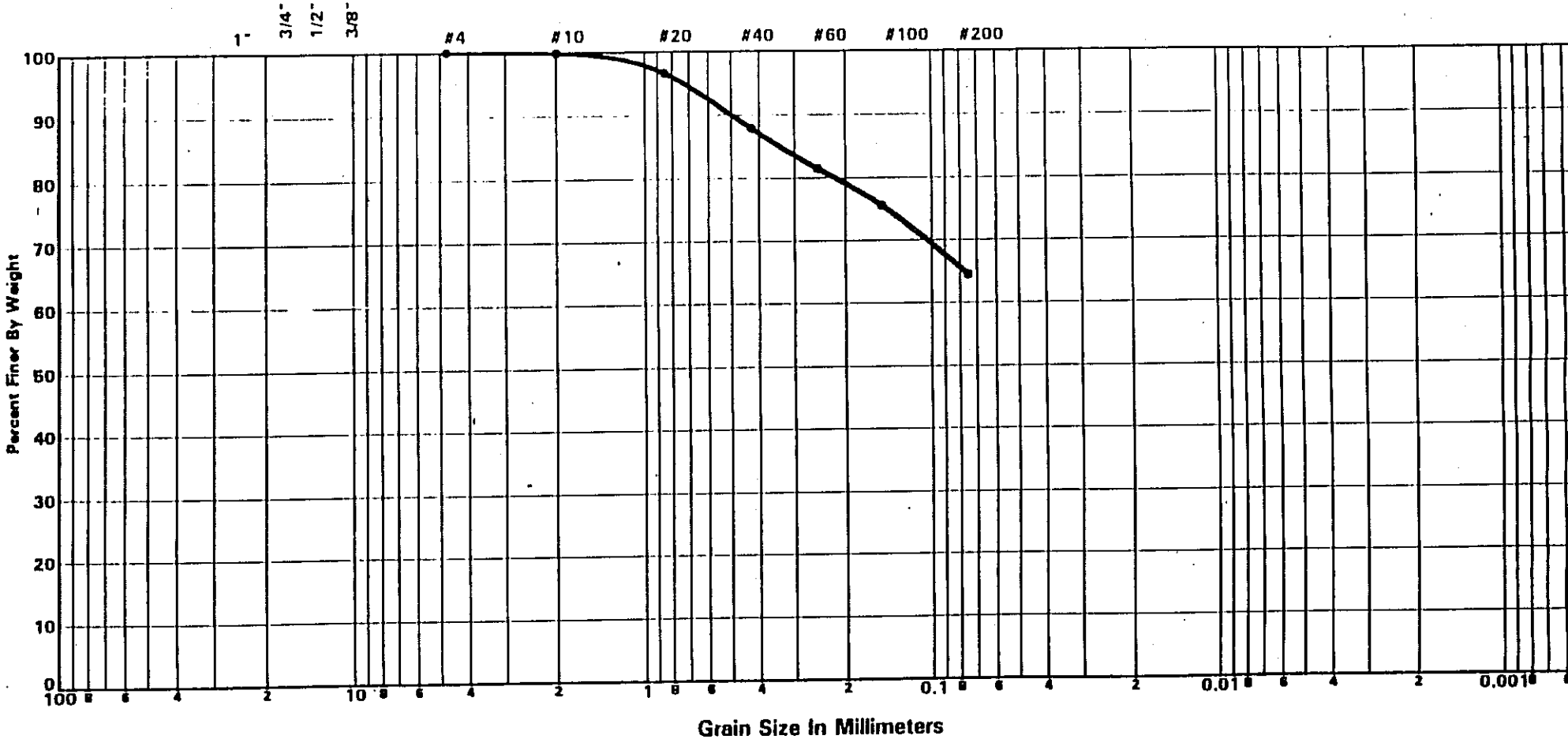
Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

GeoTechnologies, Inc.

U.S. Standard Sieve Sizes



GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-16 S-1	5.0'-6.5'	25.3	48.8	40.2	8.6	Green Tan MAFIC ROCK SANDY SILT (ML)

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Greensboro Landfill
Greensboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/9

GRAIN SIZE DISTRIBUTION

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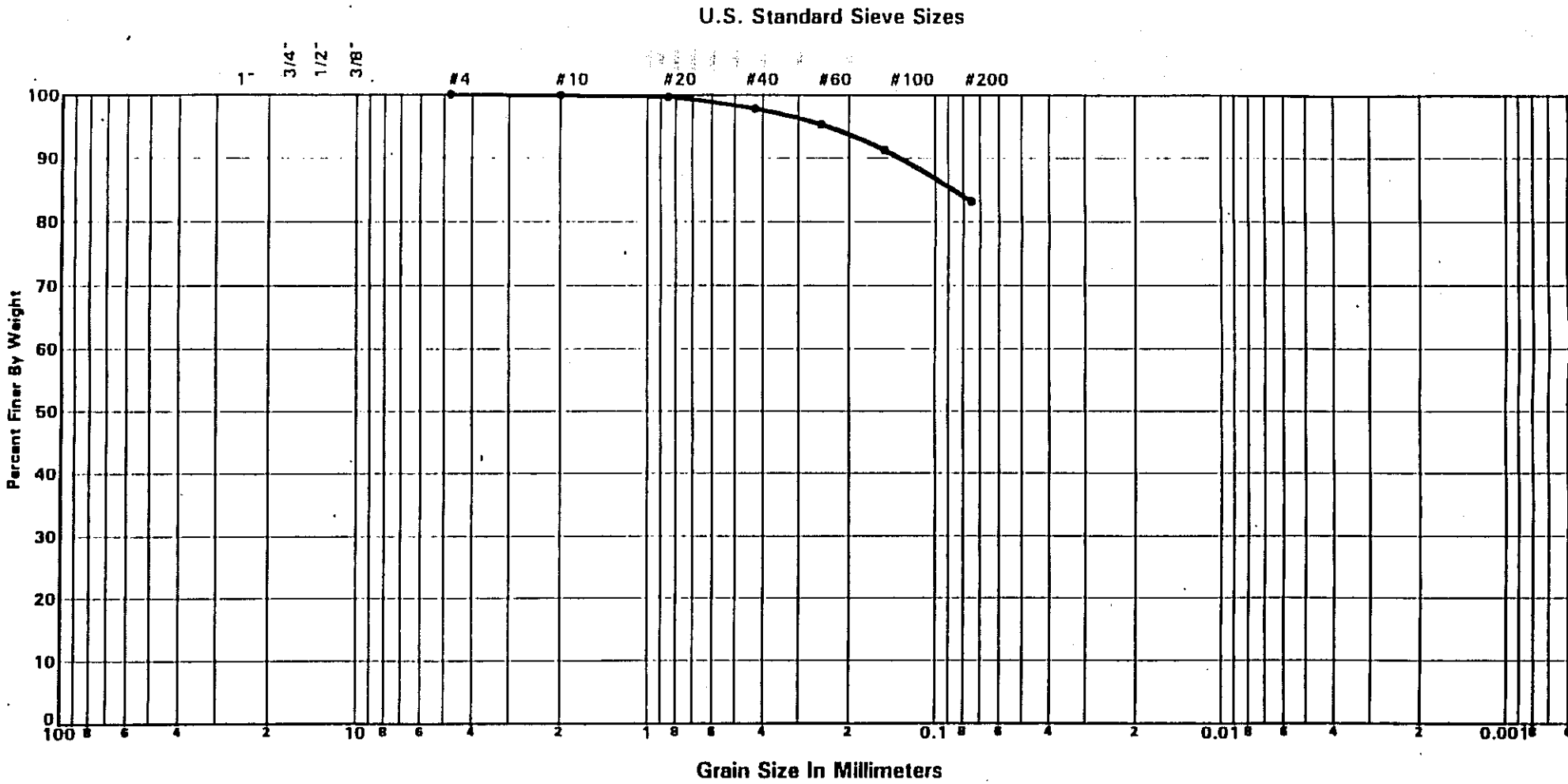

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-16 S-3	15.0'-16.5'	33.6	52.4	31.1	21.3	Yellow Brown MAFIC ROCK ELASTIC SILT WITH SAND (MH)

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Greensboro Landfill
Greensboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

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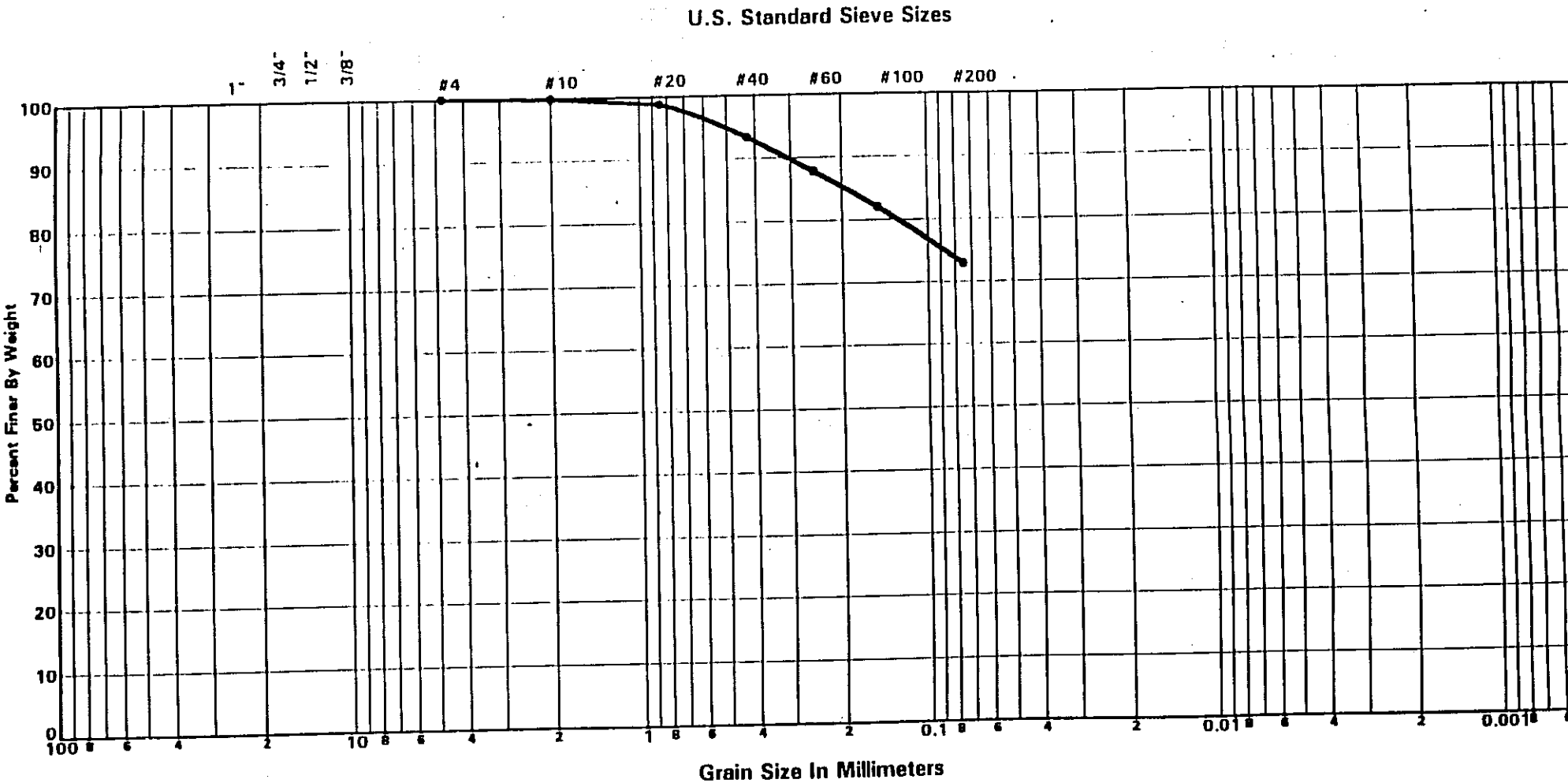

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-16 S-5	25.0'-26.5'	32.9	52.7	34.0	18.7	MAFIC ROCK brown Green ELASTIC SILT WITH SAND (MH)

Project:
Greensboro Landfill
Greensboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/9

GRAIN SIZE DISTRIBUTION

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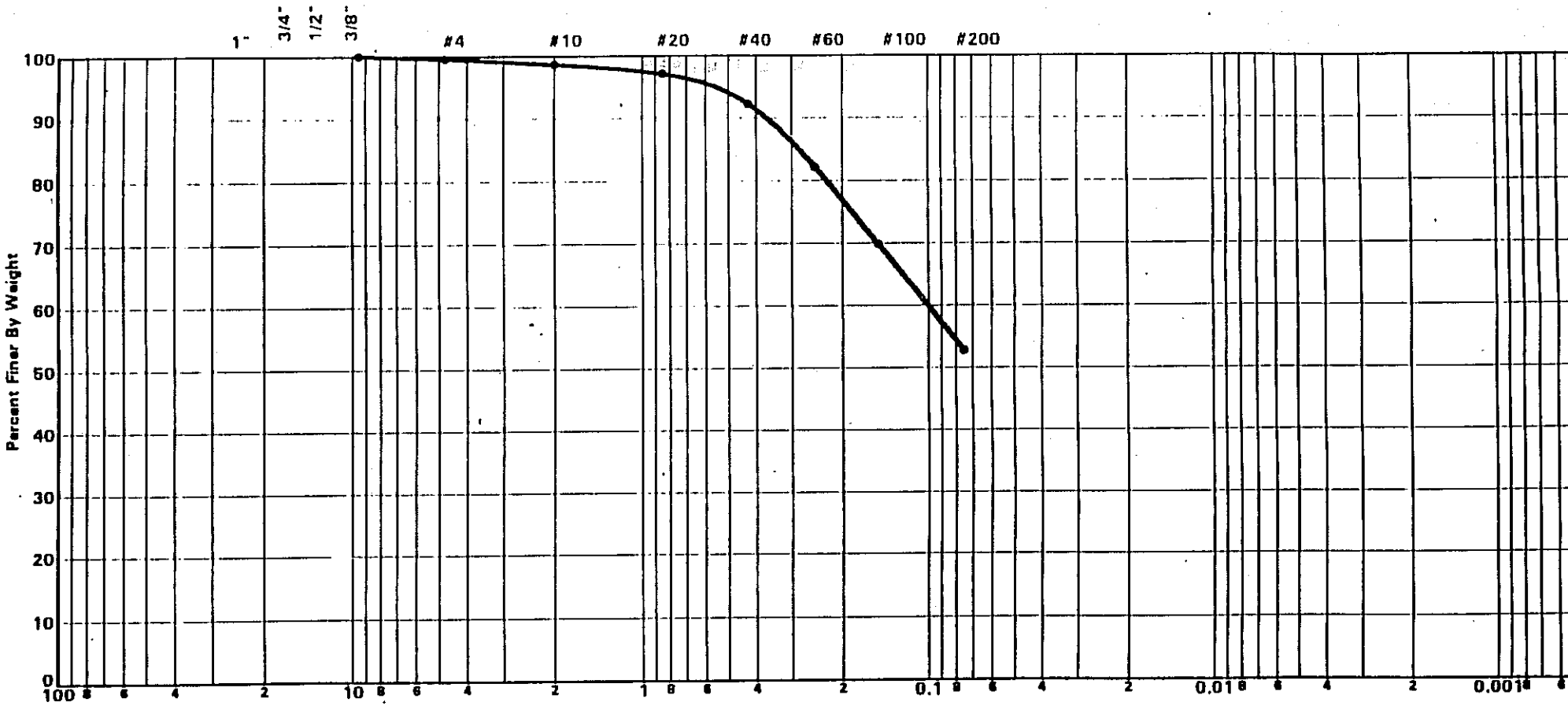
U.S. Standard Sieve Sizes



GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-17 S-1	5.0'-6.5'	34.0	NP	NP	NP	Yellow Red Brown Sandy SILT GNEISS SANDY SILT (ML)

Project:
Greensboro Landfill
Greensboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

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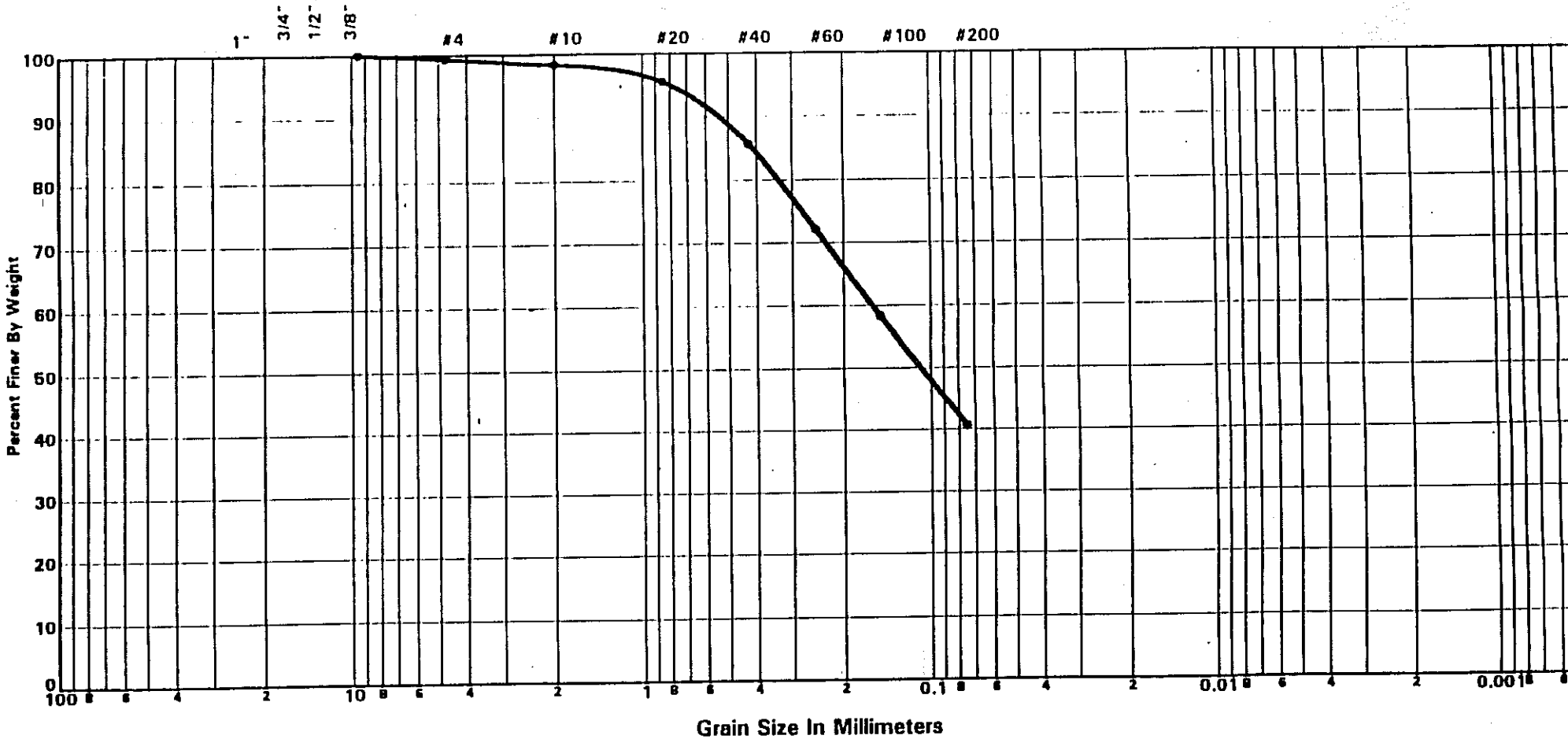
U.S. Standard Sieve Sizes



GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-17 S-2	10.0'–11.5'	24.2	21.9	23.3	NP	Yellow Brown SILTY SAND (SM) GNEISS

Project:
Gr[illegible]nsboro Landfill
G[illegible]nsboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/9[illegible]

GRAIN SIZE DISTRIBUTION

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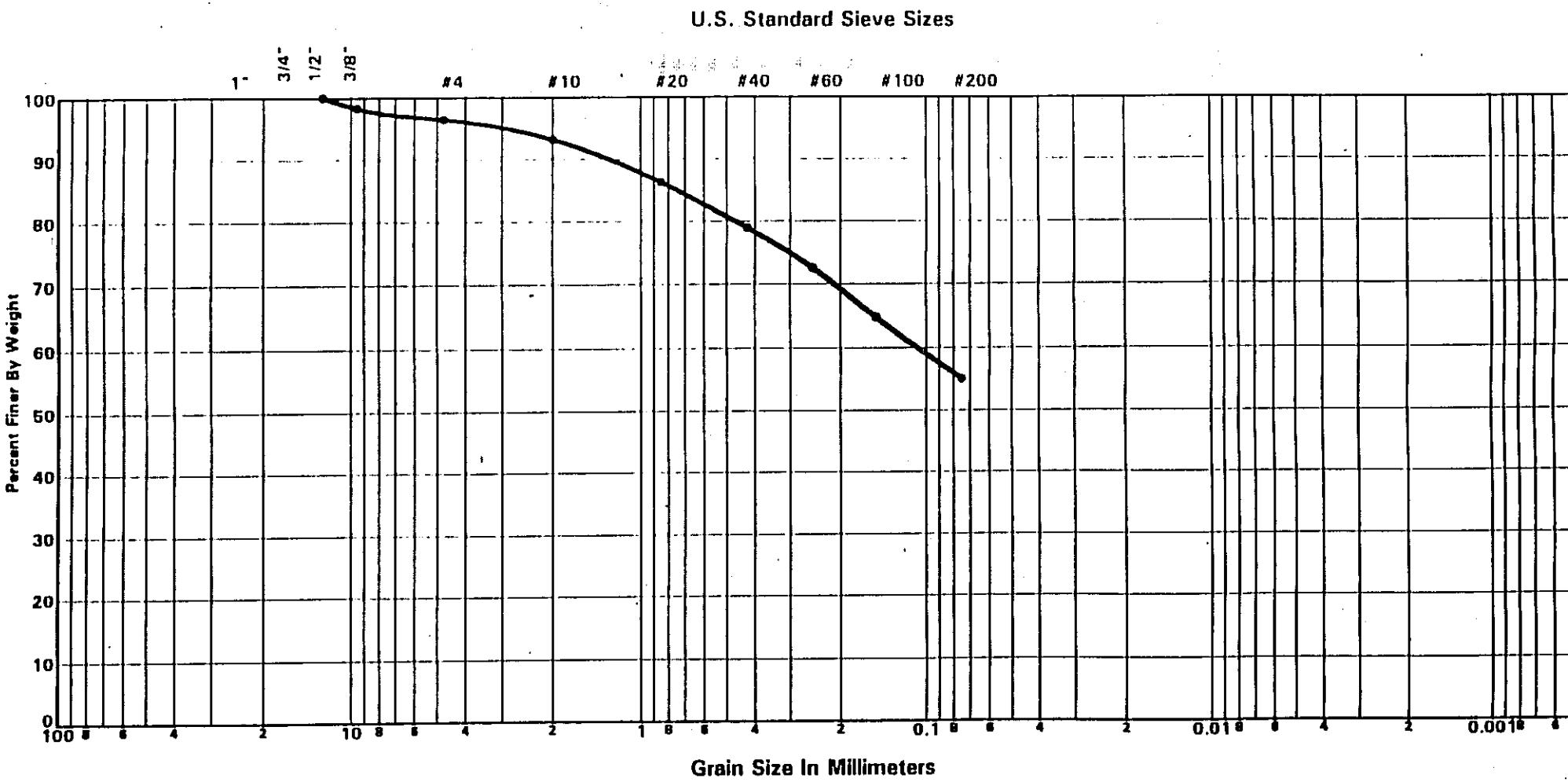

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-20 S-1	5.0'- 6.5'	15.3	27.4	19.2	8.2	Green Brown SANDY LEAN CLAY (CL) GREENSTONE DIKE

Project:
Greensboro Landfill
Greensboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

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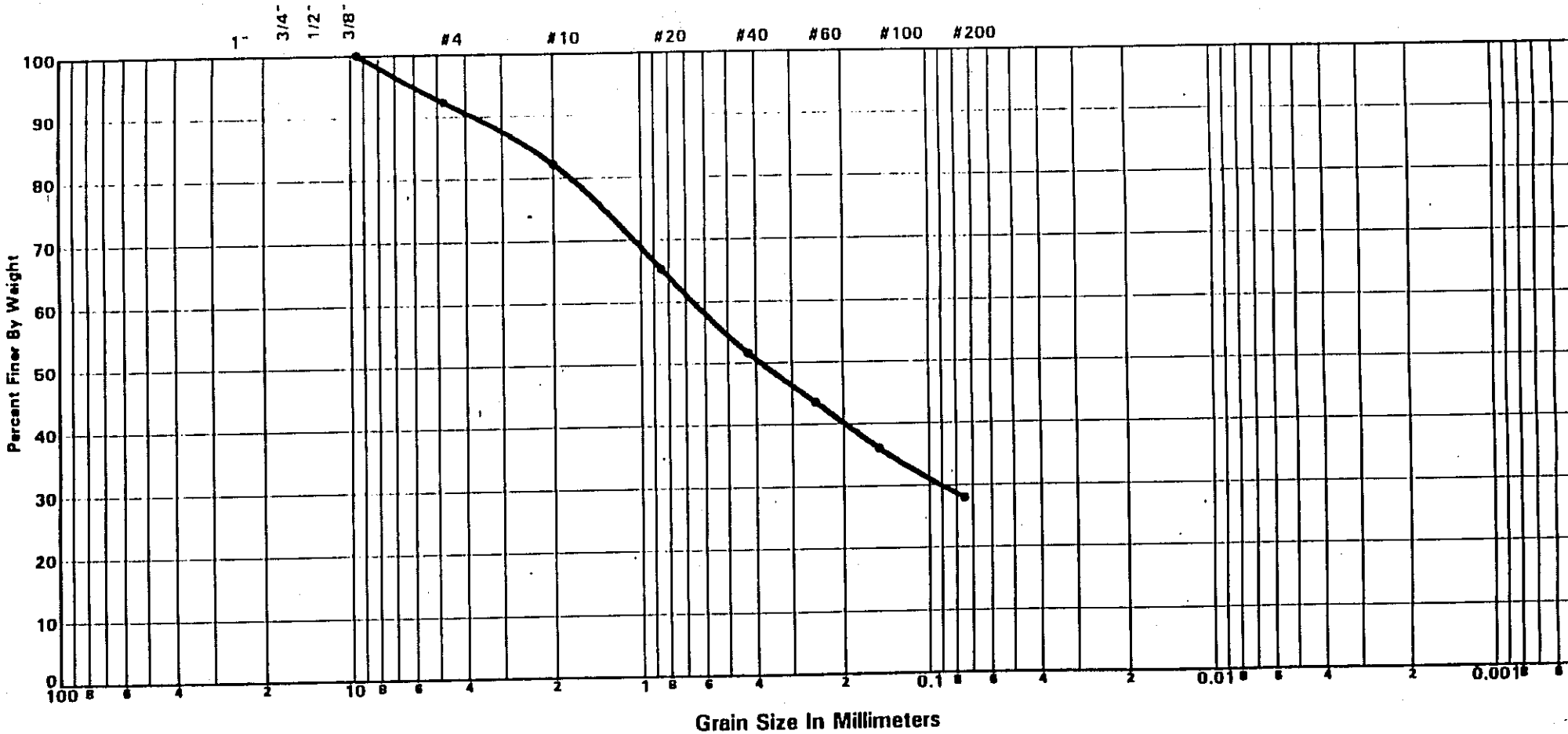


Grain Size In Millimeters

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-20 S-2	10.0' - 11.5'	9.2	NP	NP	NP	Brown Fine-Medium GNEISS SILTY CLAYEY SAND (SC-SM)

Project:
Gr[illegible]sboro Landfill
G[illegible]sboro, North Carolina

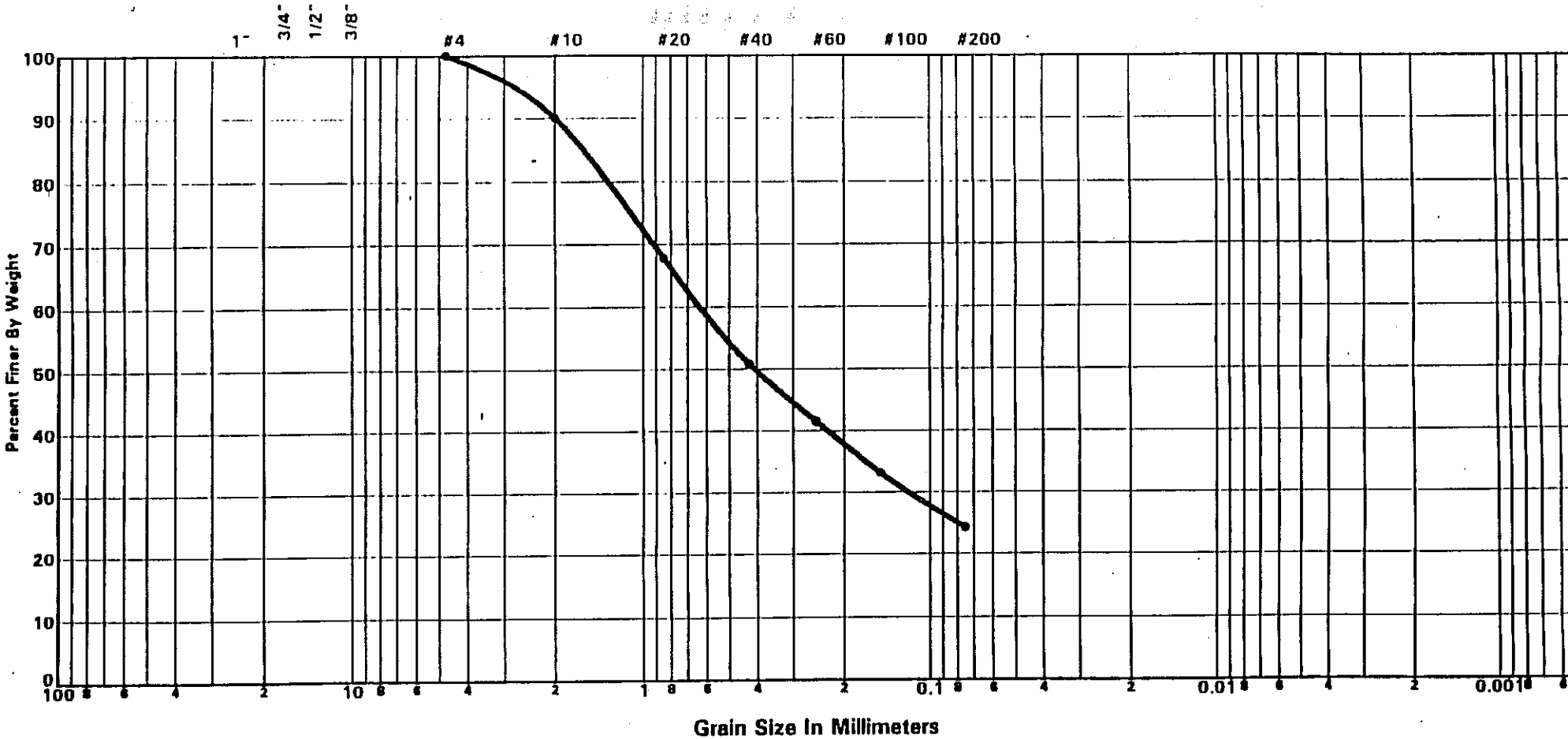
Job No.: 1-95-085 CA

Date: 1/30/9[illegible]

GRAIN SIZE DISTRIBUTION

GeoTechnologies, Inc.

U.S. Standard Sieve Sizes



Grain Size In Millimeters

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.
B-22 S-1	5.0'-6.5'	9.5	NP	NP	NP

Soil Description or Classification

GRANITE
Tan Fine-Medium SAND
SILTY SAND (SM)

Project:
Greensboro Landfill
Greensboro, North Carolina

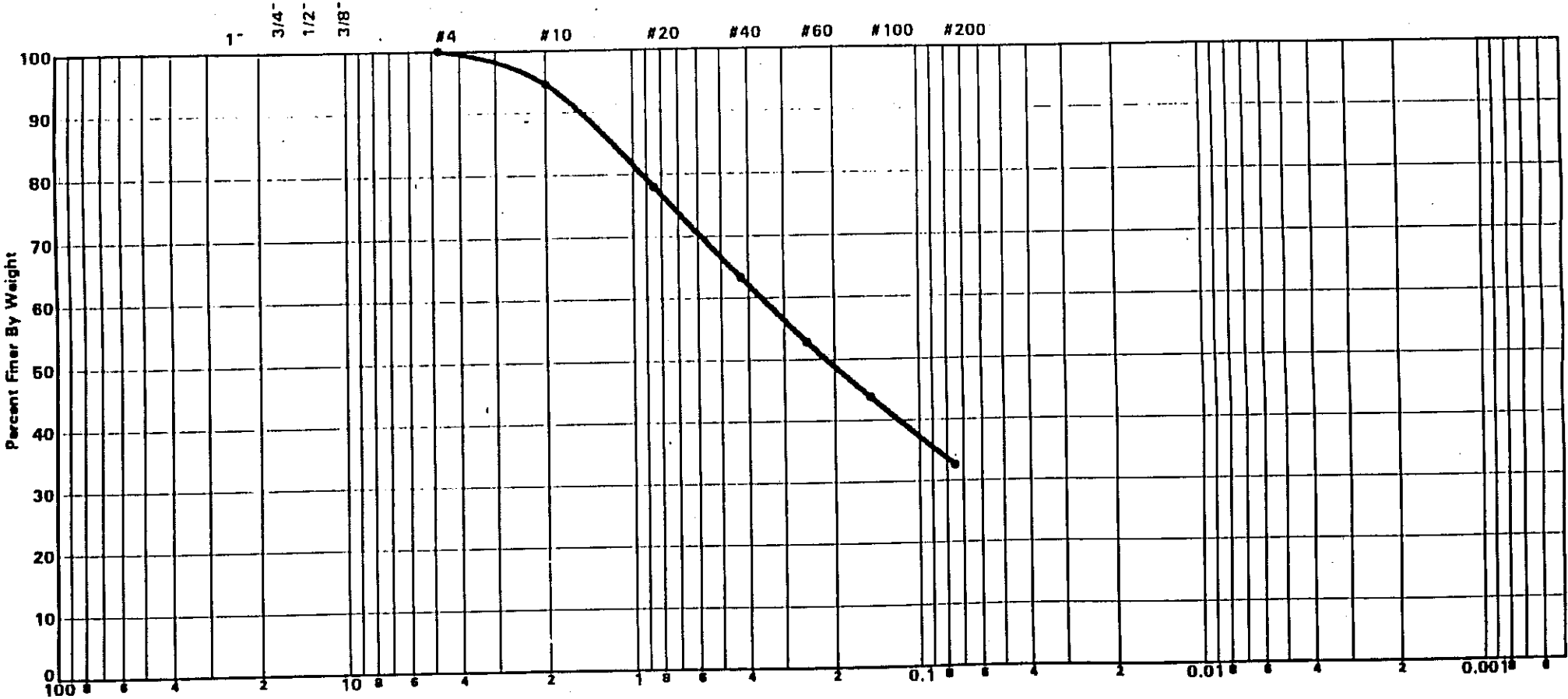
Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

GeoTechnologies, Inc.

U.S. Standard Sieve Sizes



Grain Size In Millimeters

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

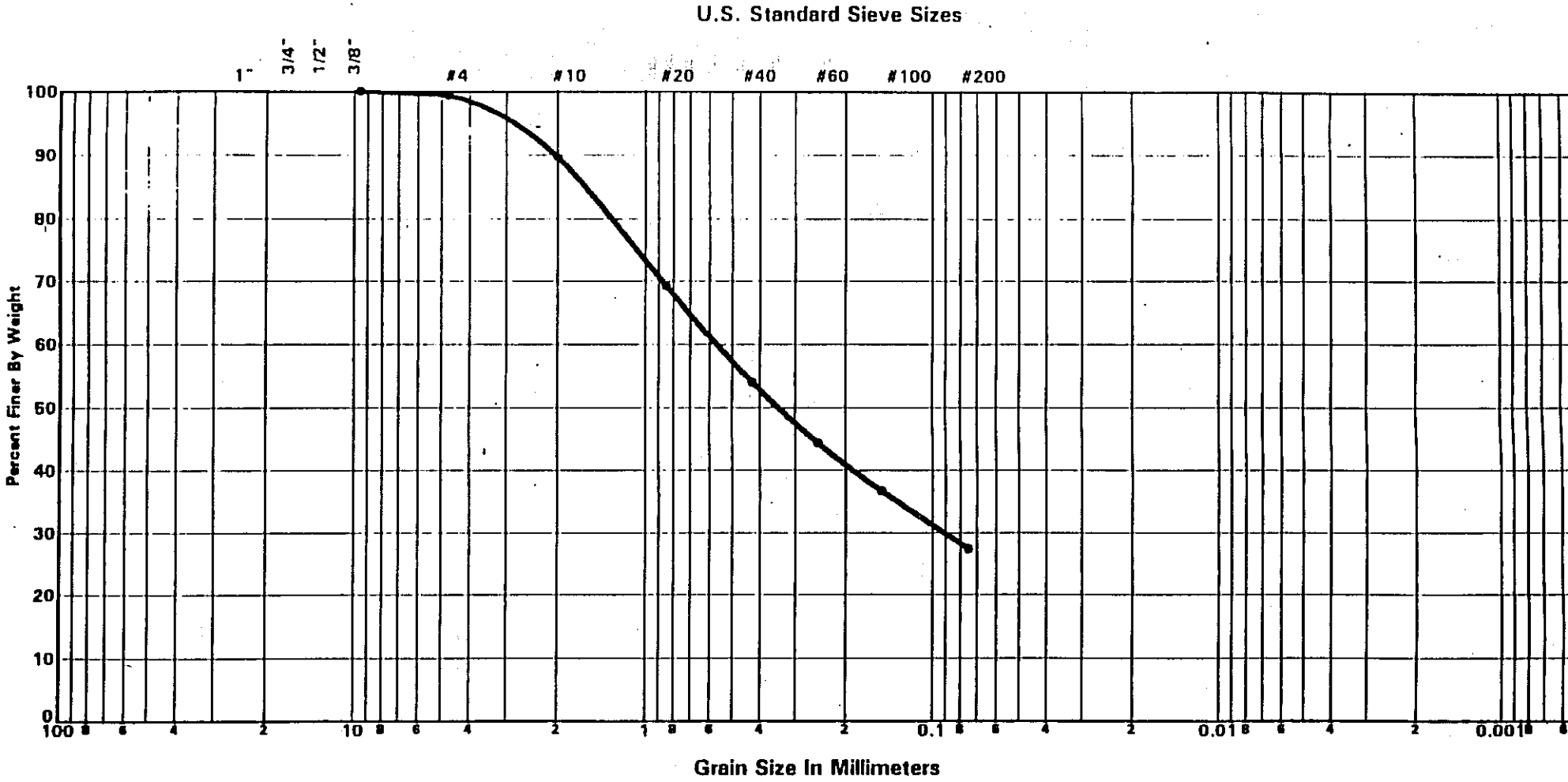
Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-22 S-3	15.0'-16.5'	9.7	NP	NP	NP	GRANITE Tan Fine-Medium SAND SILTY SAND (SM)

Project: Gre[illegible]boro Landfill

Job No.: 1-95-085 CA

GRAIN SIZE DISTRIBUTION

GeoTechnologies, Inc.



GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.
B-22 S-5	25.0'-26.5'	12.4	NP	NP	NP

Soil Description or Classification

Tan Brown Fine-Medium SAND GRANITE
SILTY SAND (SM)

Project:
Greensboro Landfill
Greensboro, North Carolina

Job No.: 1-95-085 CA

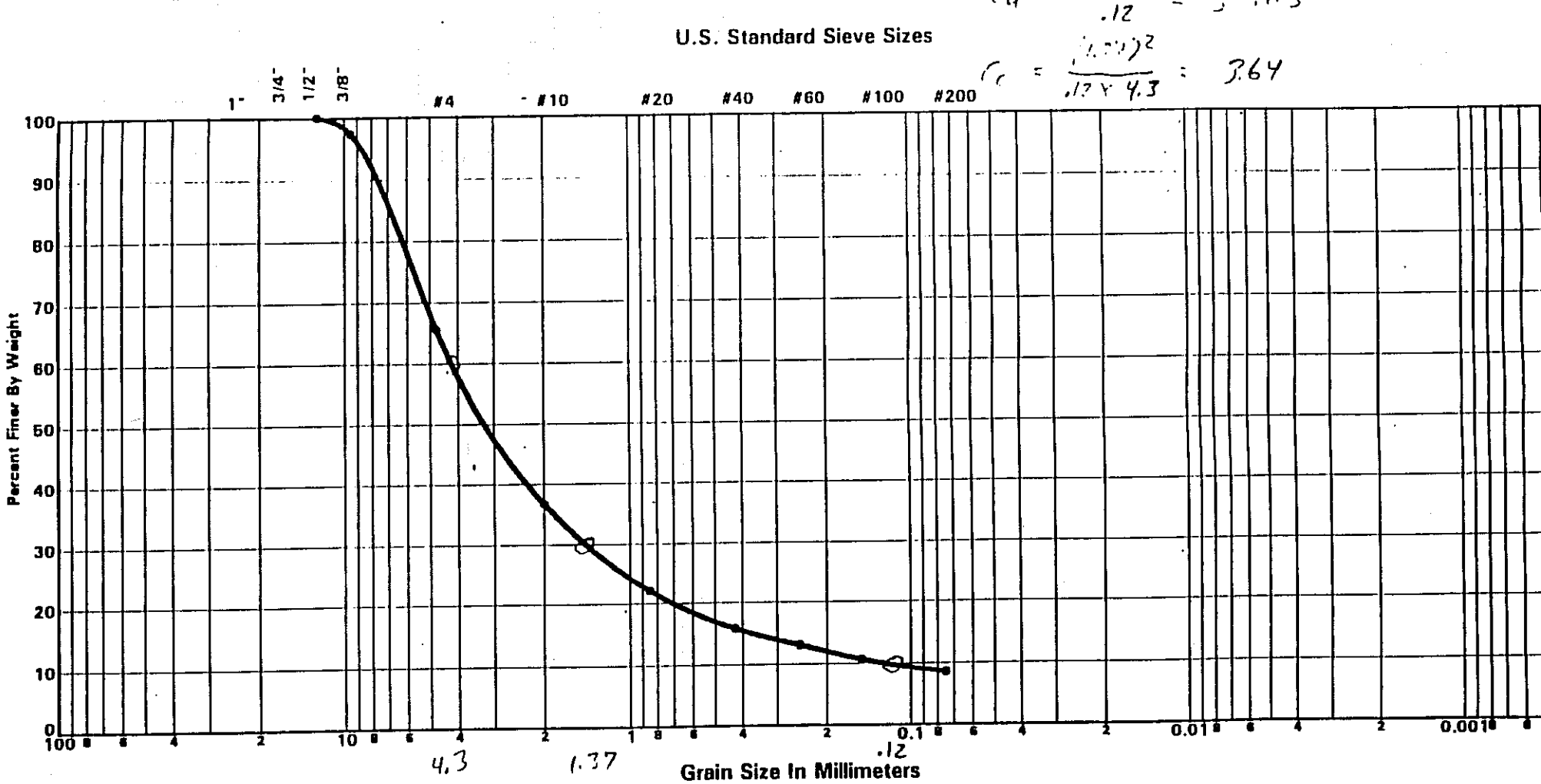
Date: 1/30/95

GRAIN SIZE DISTRIBUTION

GeoTechnologies, Inc.

$C_u = \frac{4.3}{.12} = 35.83$

$C_c = \frac{(1.37)^2}{.12 \times 4.3} = 3.64$



GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-24 S-1	5.0'-6.5'	6.6	NP	NP	NP	Brown Tan SAND GRANITE POORLY GRADED SAND WITH SILT (SP-SM)

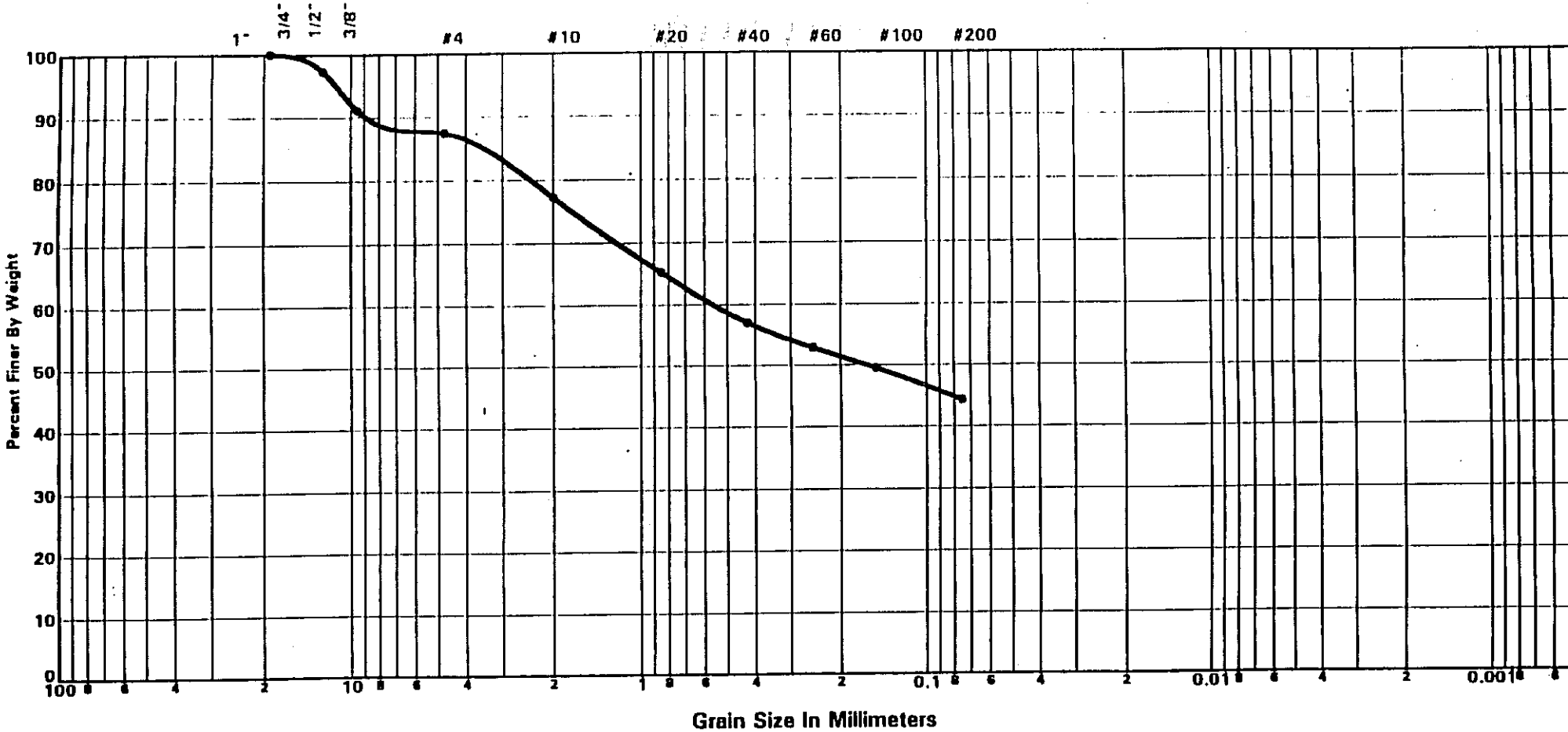
Project:
Gr[illegible]sboro Landfill
[illegible] Greensboro, North Carolina

Job No.: 1-95-085 CA

GRAIN SIZE DISTRIBUTION

GeoTechnologies, Inc.

U.S. Standard Sieve Sizes



Grain Size In Millimeters

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-24 S-2	10.0'-11.5'	8.2	NP	NP	NP	Brown Fine SAND CLAYEY SAND (SC) GREENSTONE DIKE

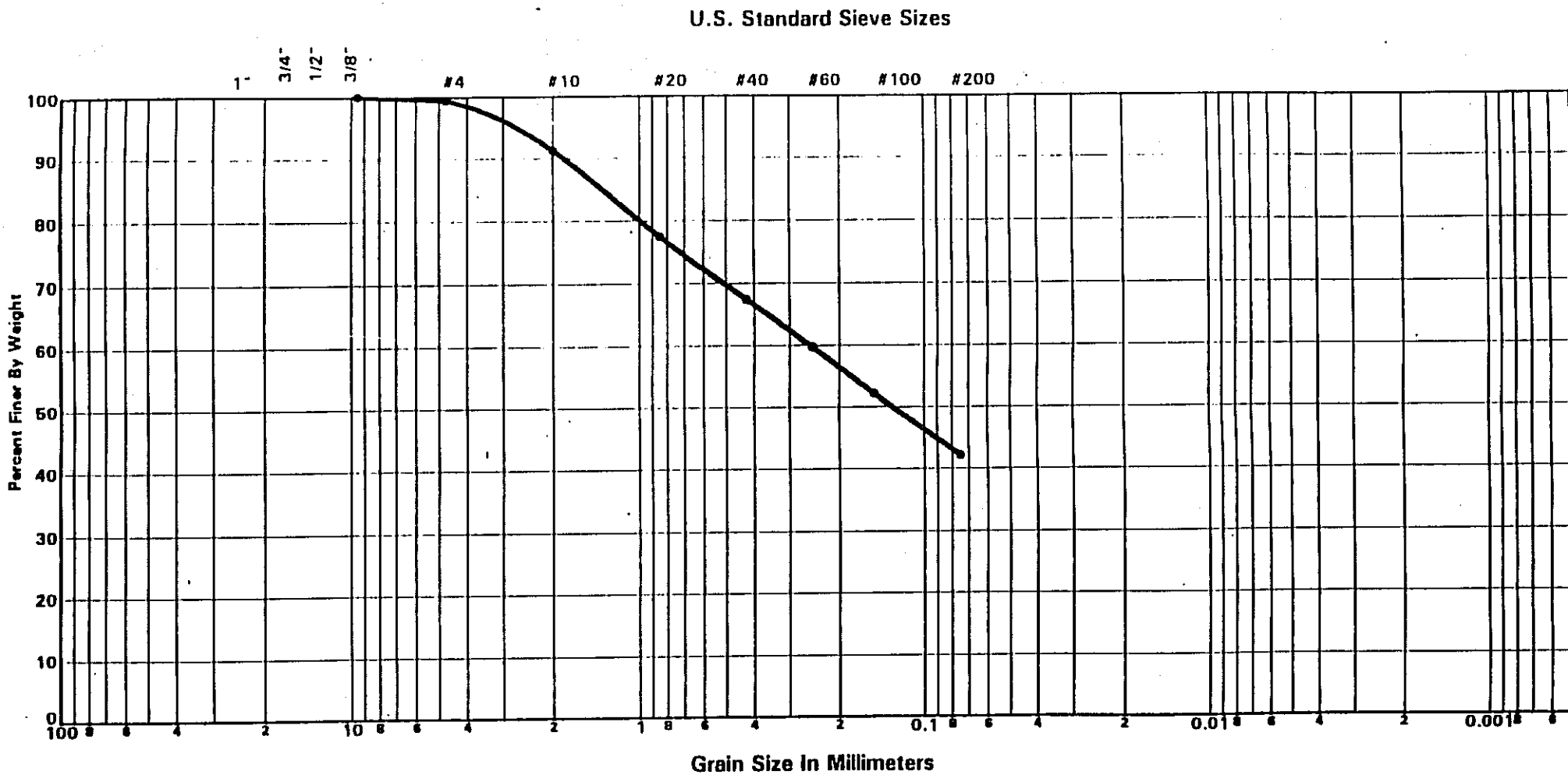
Project:
Greensboro Landfill
Greensboro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

GeoTechnologies, Inc.



GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-30 S-1	5.0'-6.5'	17.7	NP	NP	NP	GRANITE Tan Fine-Medium SAND SILTY SAND (SM)

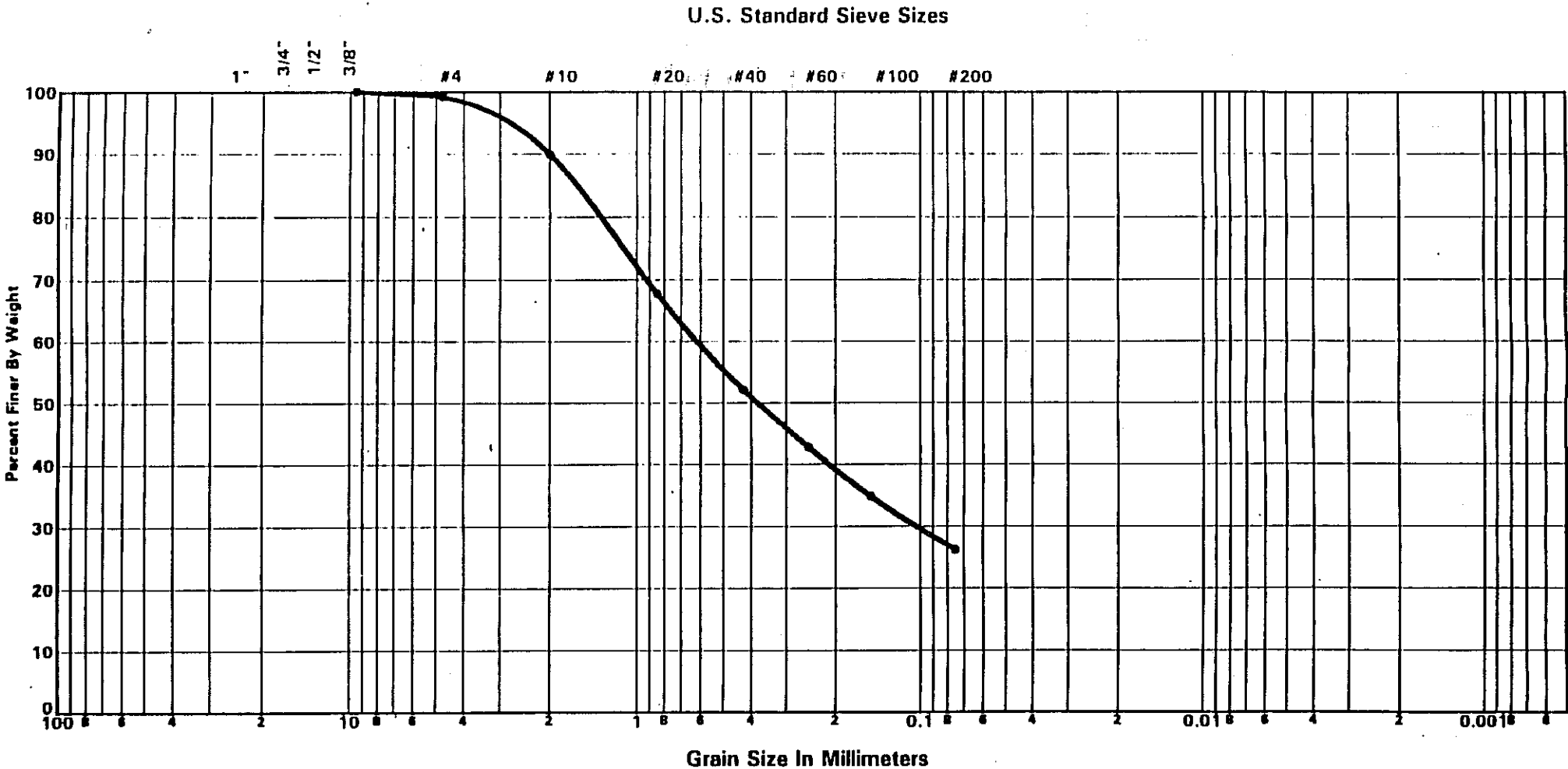
Project:
Greensboro Landfill
Gre boro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

GeoTechnologies, Inc.



GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-30 S-3	15.0'-16.5'	8.2	NP	NP	NP	Tan Fine-Medium SAND (SM) GRANITE SILTY SAND

Project:
Greensboro Landfill
Greensboro, North Carolina

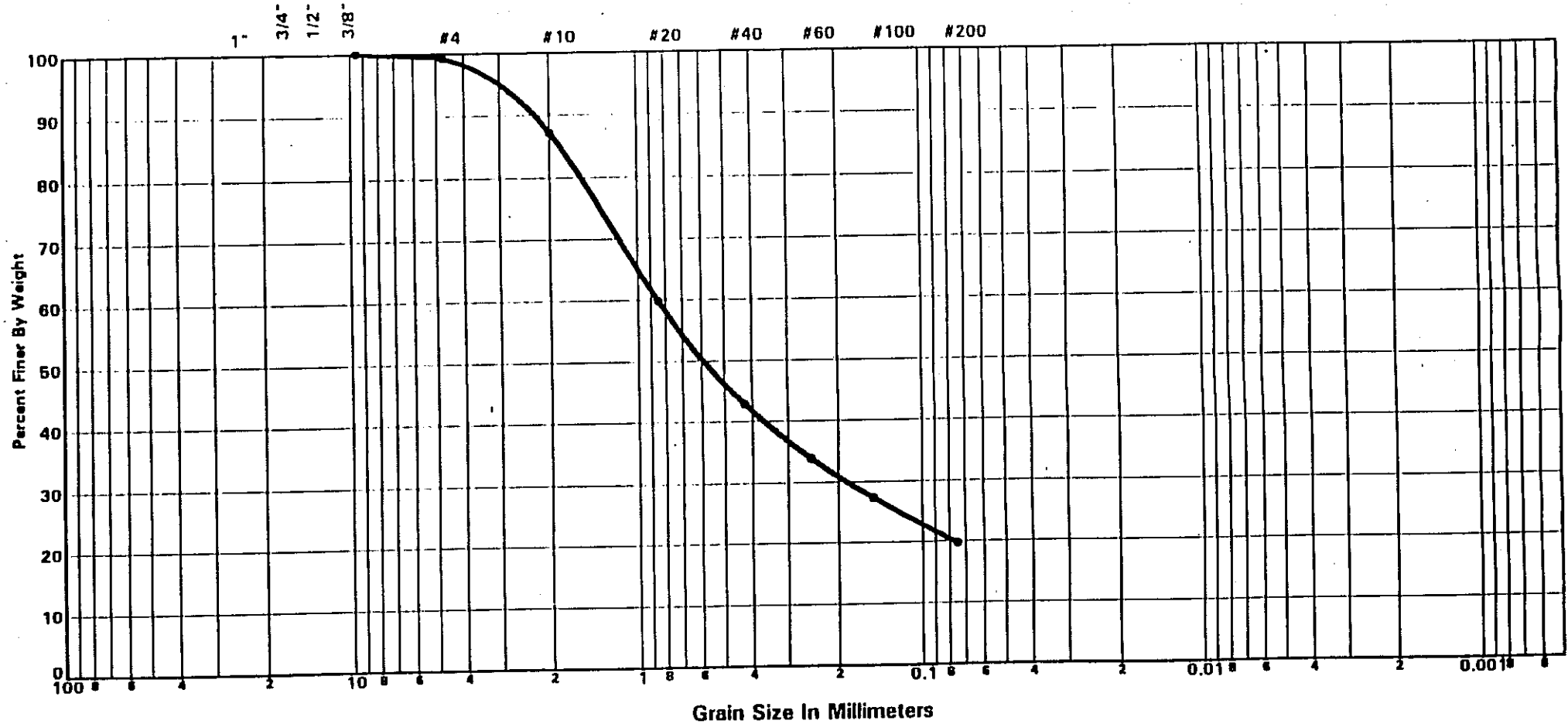
Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

GeoTechnologies, Inc.

U.S. Standard Sieve Sizes



Grain Size In Millimeters

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
B-30 S-5	25.0'-26.5'	10.2	NP	NP	NP	Tan Fine-Medium SAND (SM) GRANITE

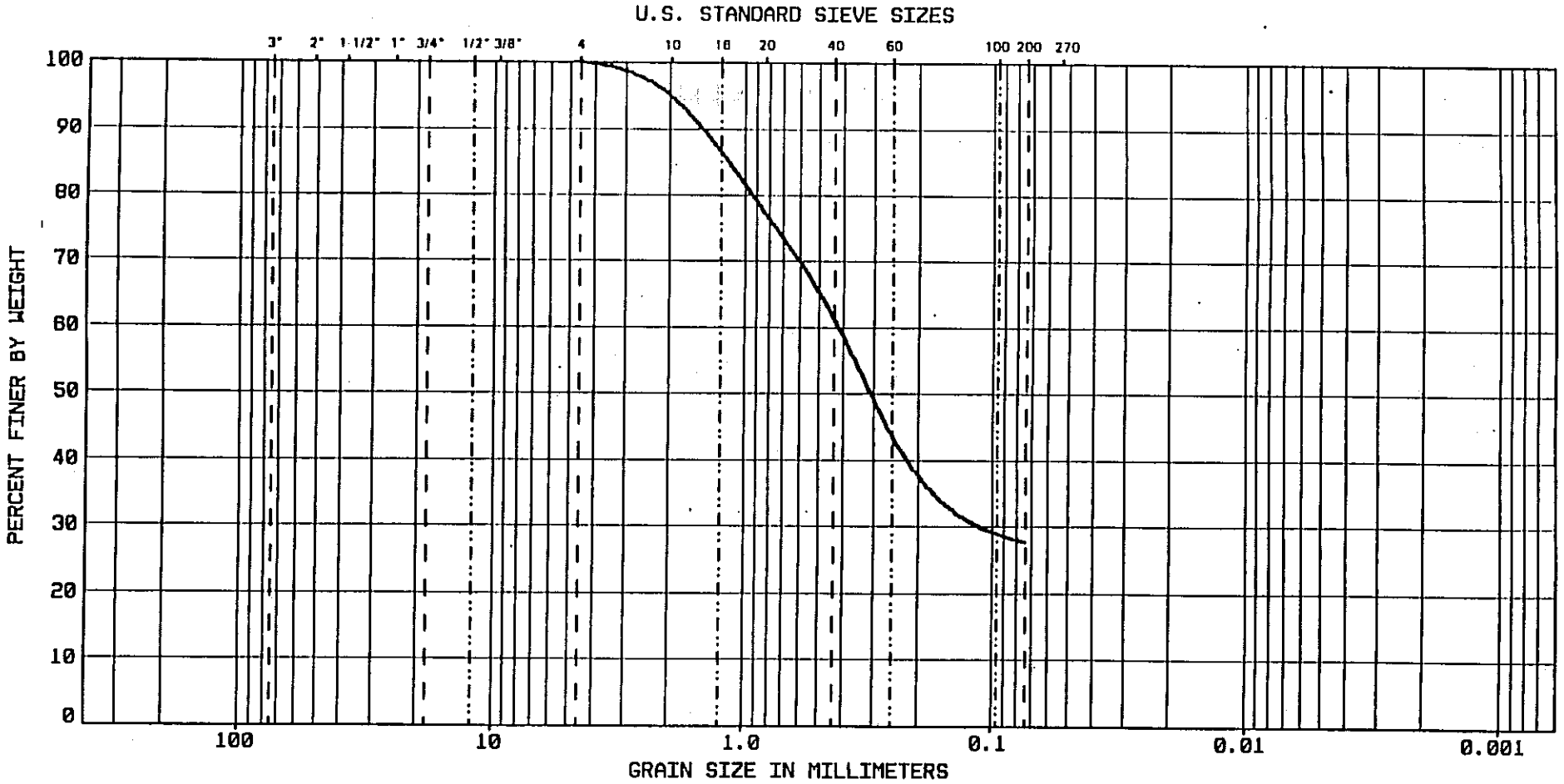
Project:
Gre boro Landfill
Gre. .boro, North Carolina

Job No.: 1-95-085 CA

Date: 1/30/95

GRAIN SIZE DISTRIBUTION

GeoTechnologies, Inc.



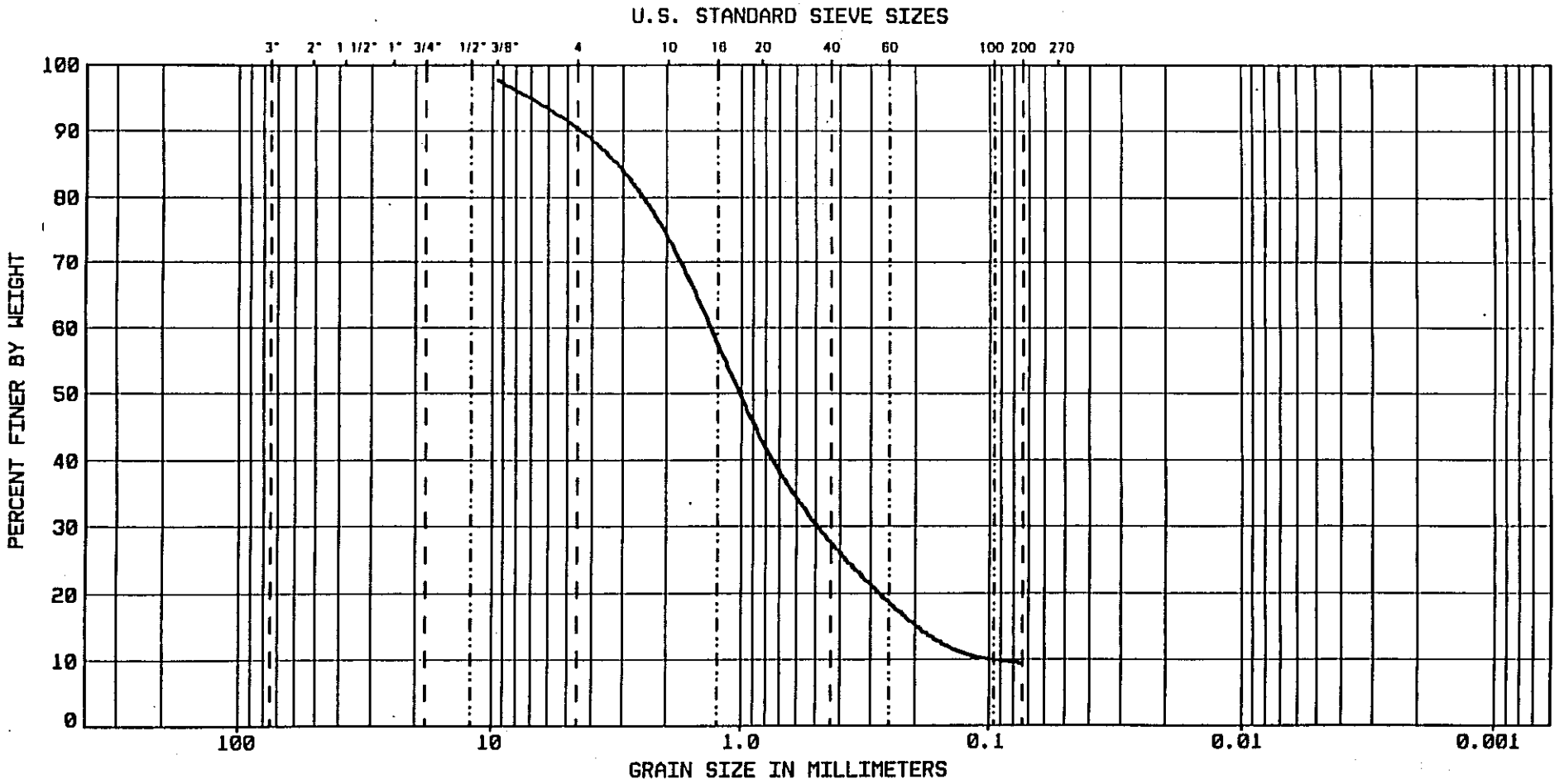
BOULDERS	COBBLES	GRAVEL		SAND			FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

BORING NO.	DEPTH(FT)	NMC %	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
B-46	1.0-3.0	21.4	36	NP	NP	Tan-Brown Silty Coarse to Fine SAND(SM)

GRAIN SIZE DISTRIBUTION

JOB NO. 011-95-177

TRIGON



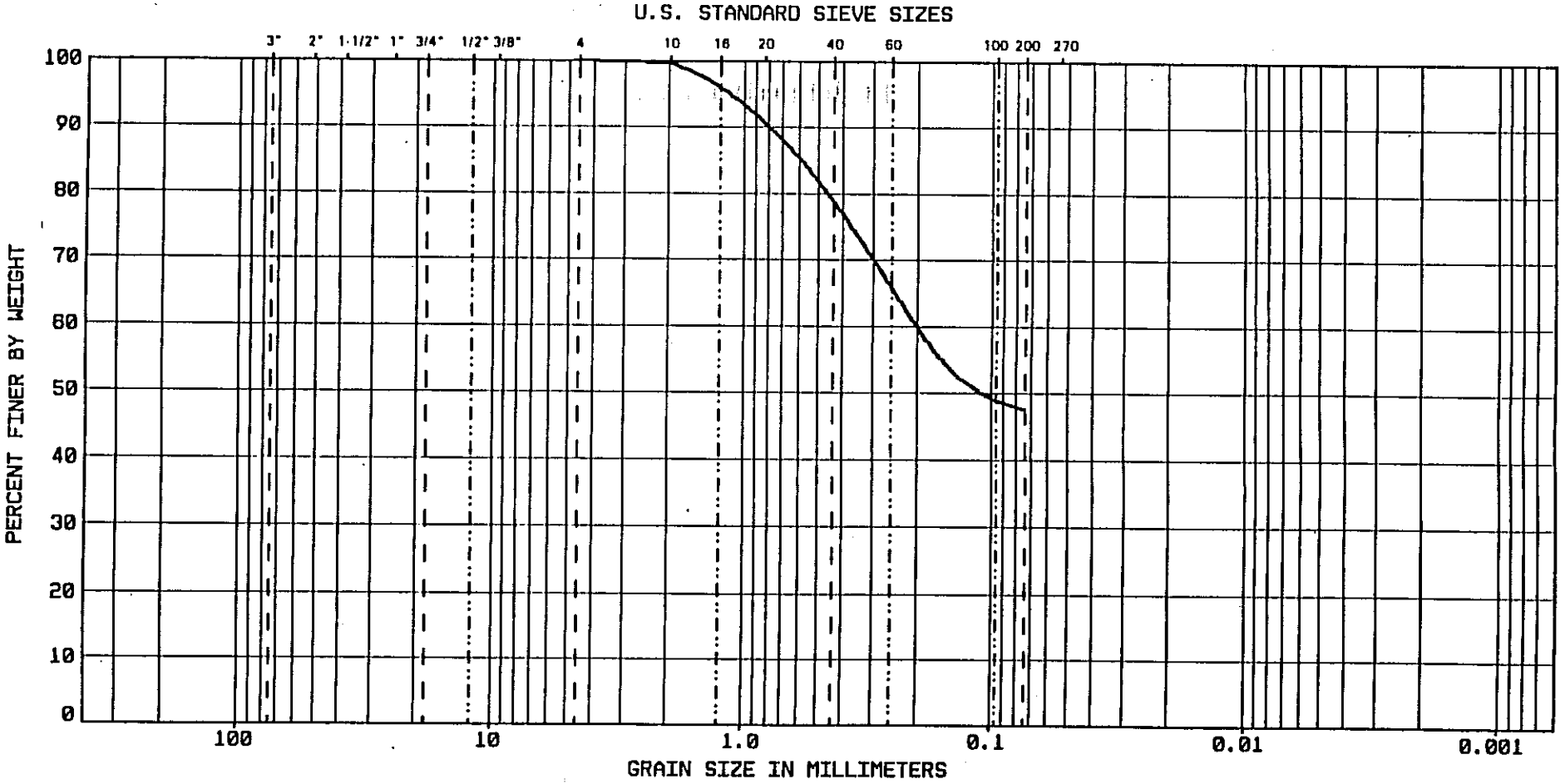
BOULDERS	COBBLES	GRAVEL		SAND			FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

BORING NO.	DEPTH(FT)	NMC %	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
B-47	1.0-4.0	6.8	24	NP	NP	White-Tan-Brown Sli. Mic. Silty Coarse to Fine SAND(SM)

GRAIN SIZE DISTRIBUTION

JOB NO. 011-95-177

TRIGON



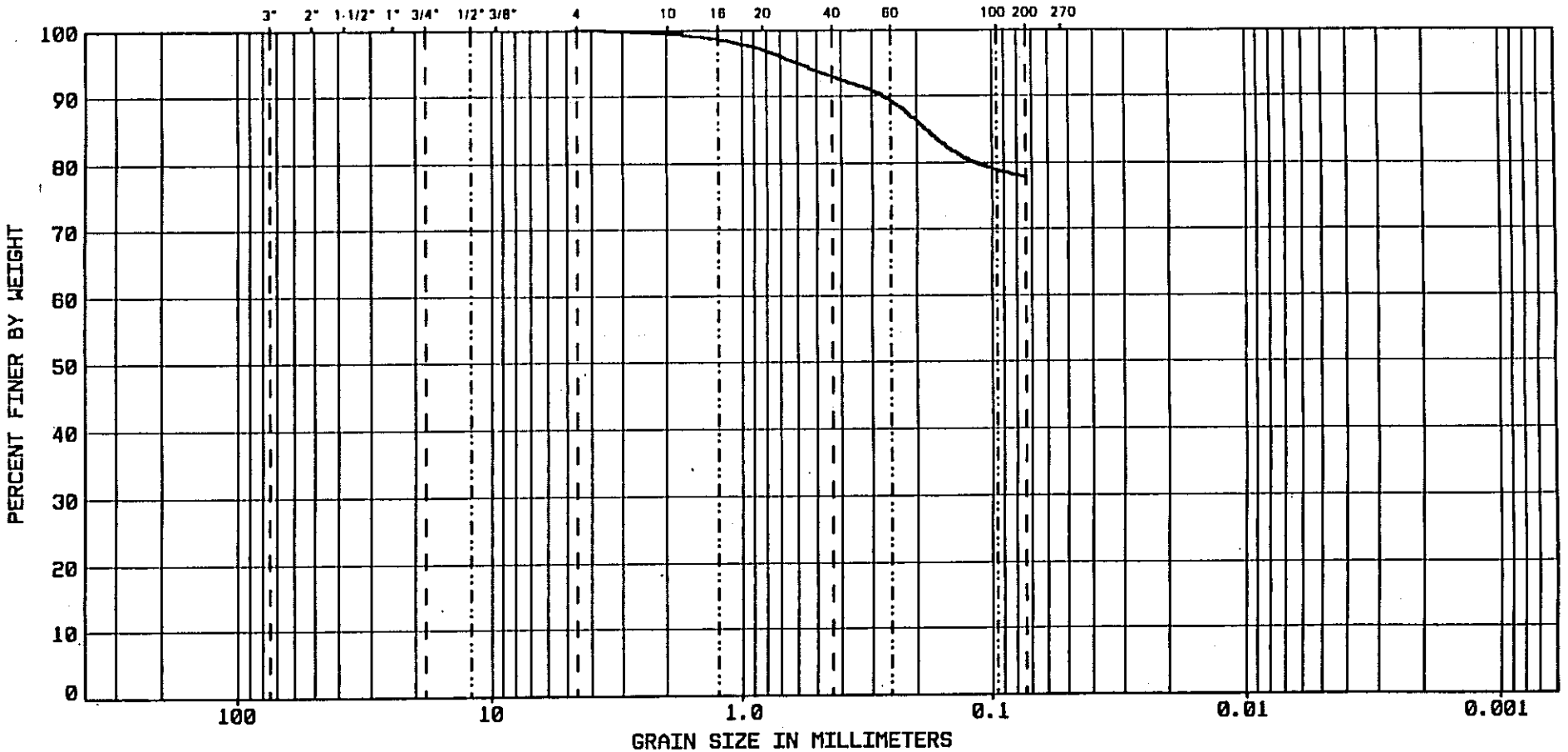
BOULDERS	COBBLES	GRAVEL		SAND			FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

BORING NO.	DEPTH(FT)	NMC %	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
B-50	0.0-3.0	12.8	31	NP	NP	Tan Silty Medium to Fine SAND(SM)

GRAIN SIZE DISTRIBUTION

JOB NO. 011-95-177

TRIGON



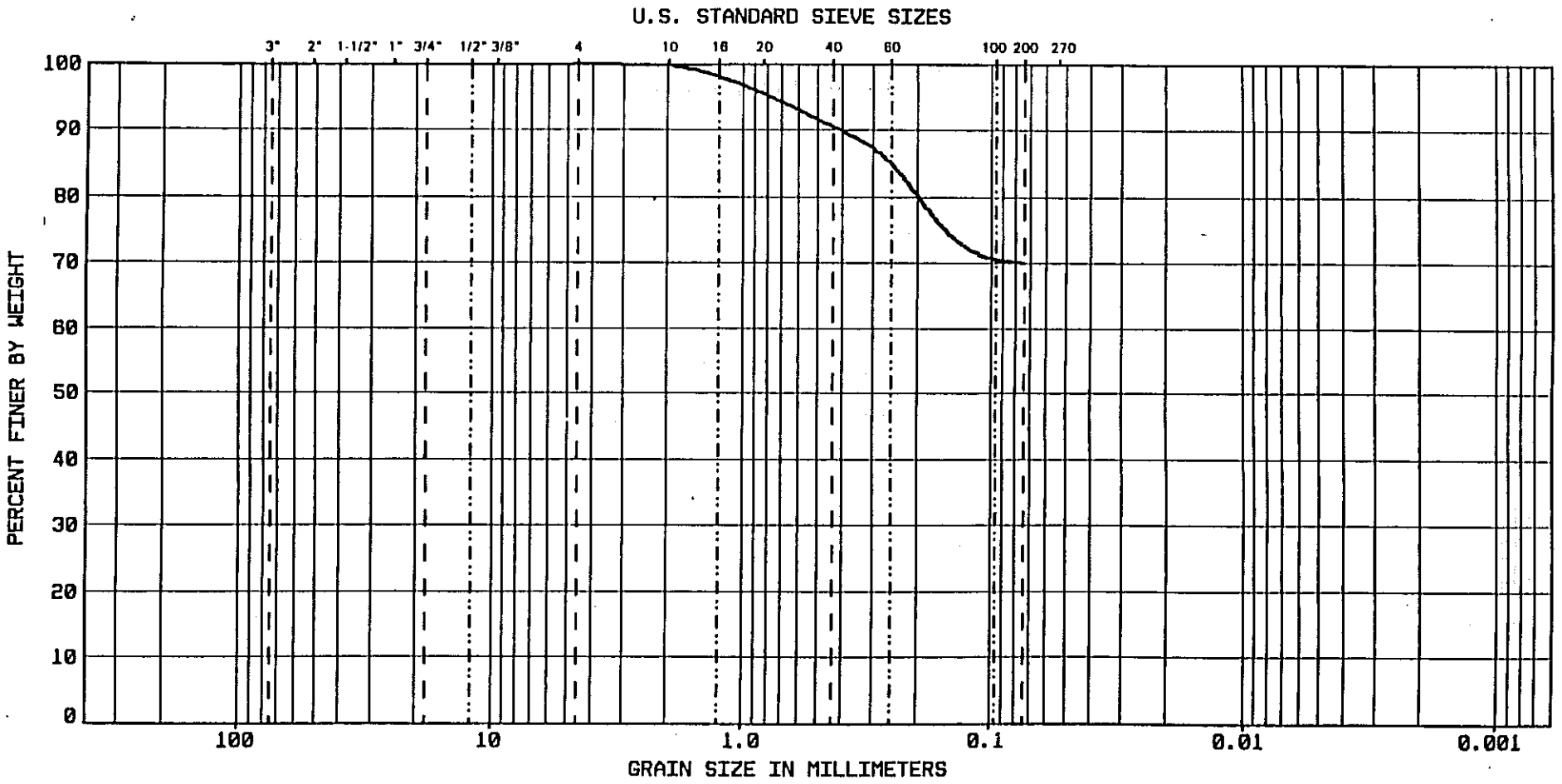
BOULDERS	COBBLES	GRAVEL		SAND			FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

BORING NO.	DEPTH(FT)	NMC %	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
B-53	0.5-3.0	47.9	58	47	11	Tan-Brown Medium to Fine Sandy Clayey SILT(MH)

GRAIN SIZE DISTRIBUTION

JOB NO. 011-95-177

TRIGON



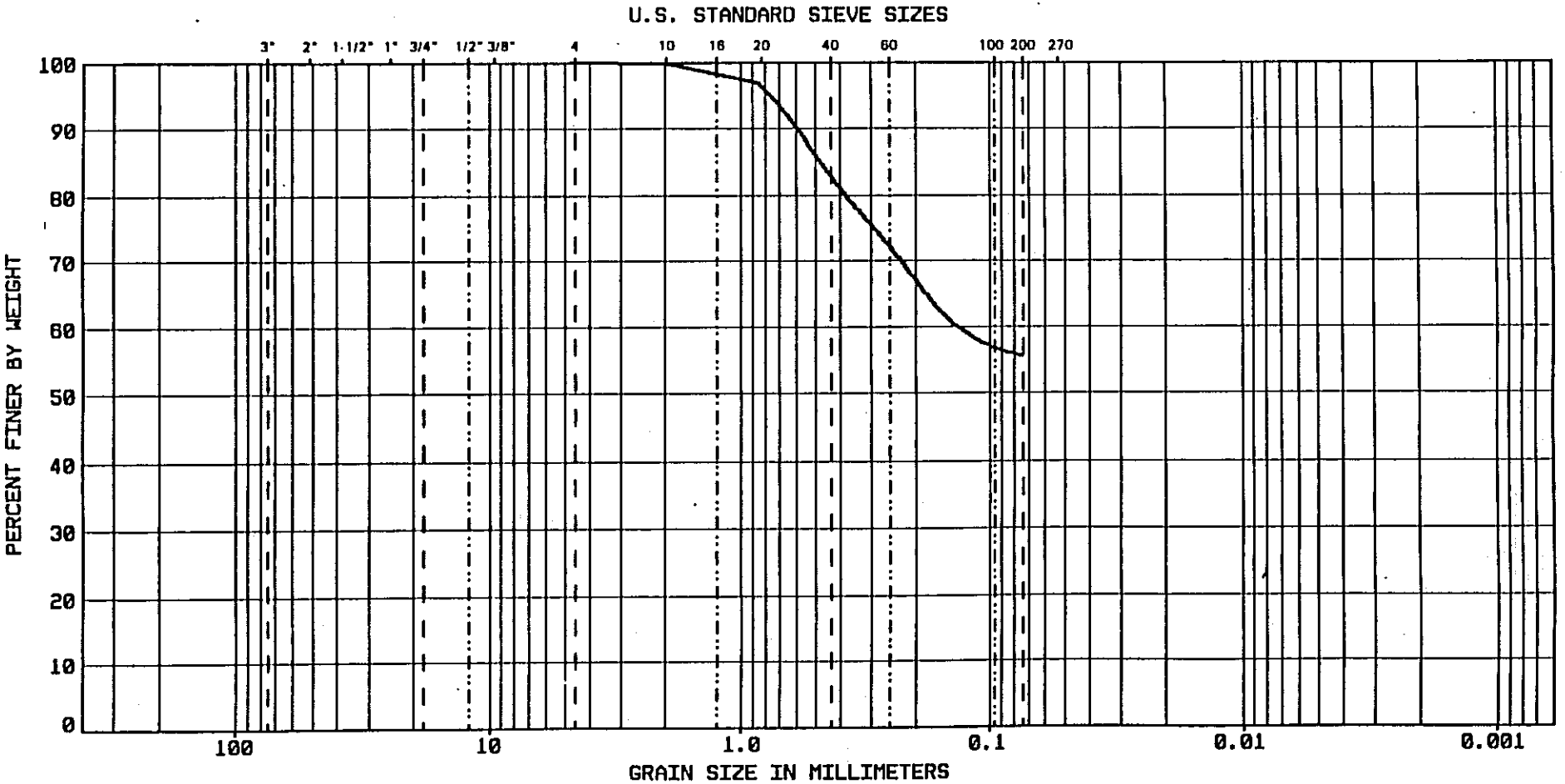
BOULDERS	COBBLES	GRAVEL		SAND			FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

BORING NO.	DEPTH(FT)	NMC %	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
B-55/56	0.0-5.0	33.6	45	40	5	Orange-Brown Slightly Clayey Medium to Fine Sandy SILT (ML)

GRAIN SIZE DISTRIBUTION

JOB NO. 011-95-177

TRIGON



BOULDERS	COBBLES	GRAVEL		SAND			FINES	
		COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

BORING NO.	DEPTH(FT)	NMC %	LL	PL	PI	DESCRIPTION OR CLASSIFICATION
B-57/58	0.0-5.0	10.4	24	NP	NP	Grey-Tan Medium to Fine Sandy SILT (ML)

GRAIN SIZE DISTRIBUTION

JOB NO. 011-95-177

TRIGON

SUMMARY OF LABORATORY, TEST DATA[1]

Boring No.	Sample Depth (ft.)	Sample Type[2]	Natural Moisture Content (%)	USCS Class.	Atterberg Limits			Standard Proctor Curve		Undisturbed Data		Permeability* (cm/sec)	Porosity (%)	Percent Passing Sieve No. 200
					L.L.	P.L.	P.I.	Max. Dry Density (pcf)	Opt. Water Content (%)	Dry Unit Weight (pcf)	Moisture Content (%)			
B-46	1.0 - 3.0	UD		SM	36	NP	NP			90.6	21.4	~~5.9 E-7~~	~~42.8~~	27.8
B-47	1.0 - 4.0	PB		SM	24	NP	NP			143.8	6.8	1.0 E-6	17.1	9.5
B-50	0 - 3.0	UD		SM	31	NP	NP			115.2	12.8	~~6.0 E-7~~	31.9	47.6
B-53	0.5 - 3.0	UD		MH	58	47	11			75.6	47.9	~~4.1 E-7~~	57.0	77.9
B-55 B-56	0 - 5.0	Bag	33.6	ML	45	40	5	87.9	32.5			~~2.1 E-7~~		70.1
B-57	0 - 5.0	Bag	10.4	ML	24	NP	NP	124.7	12.8			~~2.8 E-7~~		55.6
B-58	0 - 5.0	Bag	21.1											

[1]Graphic Presentations of Results of Triaxial, Consolidation, CBR, Proctor, Grain Size, and other tests follow this summary.
[2]SS = Split Spoon Sample (ASTM D-1586)
UD = Undisturbed Sample (ASTM D-1587)
PB = Pitcher Barrel
* = Permeability Tests re-run after using improper equipment

TRIGON ENGINEERING CONSULTANTS, INC
GREENSBORO, NORTH CAROLINA

JOB NUMBER: 011-95-177

SUMMARY OF LABORATORY TEST DATA[1]

RE-TEST DATA

Boring No.	Sample Depth (ft.)	Sample Type[2]	Natural Moisture Content (%)	USCS Class.	Atterberg Limits			Standard Proctor Curve		Undisturbed Data		Permeability (cm/sec)	Porosity (%)	Percent Passing Sieve, No. 200
					L.L.	P.L.	P.I.	Max. Dry Density (pcf)	Opt. Water Content (%)	Dry Unit Weight (pcf)	Moisture Content (%)			
B-46	1.0 - 3.0	UD										2.7 E-6	45.0	
B-50	0.5 - 3.0	UD*										2.6 E-6		
B-53	0.5 - 2.0	UD*										3.7 E-7		
B-55 B-56	0 - 5.0	Bag**										3.3 E-7		
B-57	0 - 5.0	Bag**										3.9 E-7		

[1]Graphic Presentations of Results of Triaxial, Consolidation, CBR, Proctor, Grain Size, and other tests follow this summary.
[2]SS = Split Spoon Sample (ASTM D-1586)
UD = Undisturbed Sample (ASTM D-1587)
PB = Pitcher Barrel
*New UD
**New Remolded Sample

TRIGON ENGINEERING CONSULTANTS, INC
GREENSBORO, NORTH CAROLINA

JOB NUMBER: 011-95-177

Porosity Calculations

RETESTED B-46 1.0 - 3.0

W_s = 100.00

W_p = 166.0

W_{pw} = 664.1

T_i = 22°

W_{pws} = 726.3

T_x = 22°

$$G_s = \frac{.9996(100)}{100 + 664.1 - 726.3} = 2.64$$

$$n = \left(1 - \frac{90.6}{(2.64)(62.4)}\right) \times 100 = 45.0\ \%$$

B-46 1.0 - 3.0

W_s = 100.00

W_p = 166.0

W_{pw} = 664.0

T_i = 21°

W_{pws} = 724.7

T_x = 21°

$$G_s = \frac{.9998(100)}{100 + 664.0 - 724.7} = 2.54$$

$$n = \left(1 - \frac{90.6}{(2.54)(62.4)}\right) \times 100 = 42.8\ \%$$

B-47 1.0 - 4.0

W_s = 100.0

W_p = 166.0

W_{pw} = 664.0

T_i = 23°

W_{pws} = 728.0

T_x = 23°

$$G_s = \frac{.9993(100)}{100 + 664 - 728.0} = 2.78$$

$$n = \left(1 - \frac{143.8}{(2.78)(62.4)}\right) \times 100 = 17.1\ \%$$

B-50 0 - 3.0

w_s = 100.0

w_p = 165.3

w_{pw} = 663.5

T_1 = 23°

w_{pws} = 726.6

T_2 = 23°

$$G_s = \frac{.9993(100)}{100 + 663.5 - 726.6} = 2.71$$

$$\eta = \left(1 - \frac{115.2}{(2.71)(62.4)}\right) \times 100 = 31.9\ \%$$

B-53 0.5 - 3.0

w_s = 100.0

w_p = 165.3

w_{pw} = 663.5

T_1 = 21°

w_{pws} = 728.0

T_2 = 21°

$$G_s = \frac{.9998(100)}{100 + 663.5 - 728.0} = 2.82$$

$$\eta = \left(1 - \frac{75.6}{(2.82)(62.4)}\right) \times 100 = 57.0\ \%$$

APPENDIX C

SLUG TEST DATA

HDR Engineering, Inc.

Client: White Street Landfill

Project: Rising Head Tests

Project No. 06770-021-018
Sheet 1/1
Date: 11/27/95
Well B-1
Reference: Bouwer, 1989

Hydraulic Conductivity, K = ((Req^2)ln(Re/Rw)/2Le)*(1/T)*ln(Yo/Yt)

Where: Req = [(Rc^2) + n(Rw^2 - Rc^2)]exp^1/2 (Correction for sand pack)

ln(Re/Rw)=[1.1/ln(Lw/Rw)+(A+Bln[(H-Lw)/Rw])/Le/Rw]exp^-1

Lw = Ht. of Water Column in Well =	19.63	(water in
Le = Screen Interval Open to Aquifer =	10	casing)
Rw = Radius of Well Including Sand Pack =	0.375	
Rc = Radius of Casing =	0.083	
H = Aquifer Thickness to First Aquitard =	33	
Yo = Relative Ht. of Water at Time Zero =	0.31	
Yt = Relative Ht. of Water at Time t =	0.085	
n = Porosity =	0.35	
T = Time (in minutes) =	0.8333	

A & B are Constants to be Determined

Correction for Sand Pack (not necessary in this case)

Req = 0.083

Evaluation of A & B

Le/Rw = 26.66667

from attached graph of A & B

A =	2.25
B =	0.48

Determination of ln Term

ln Re/Rw = 2.343951

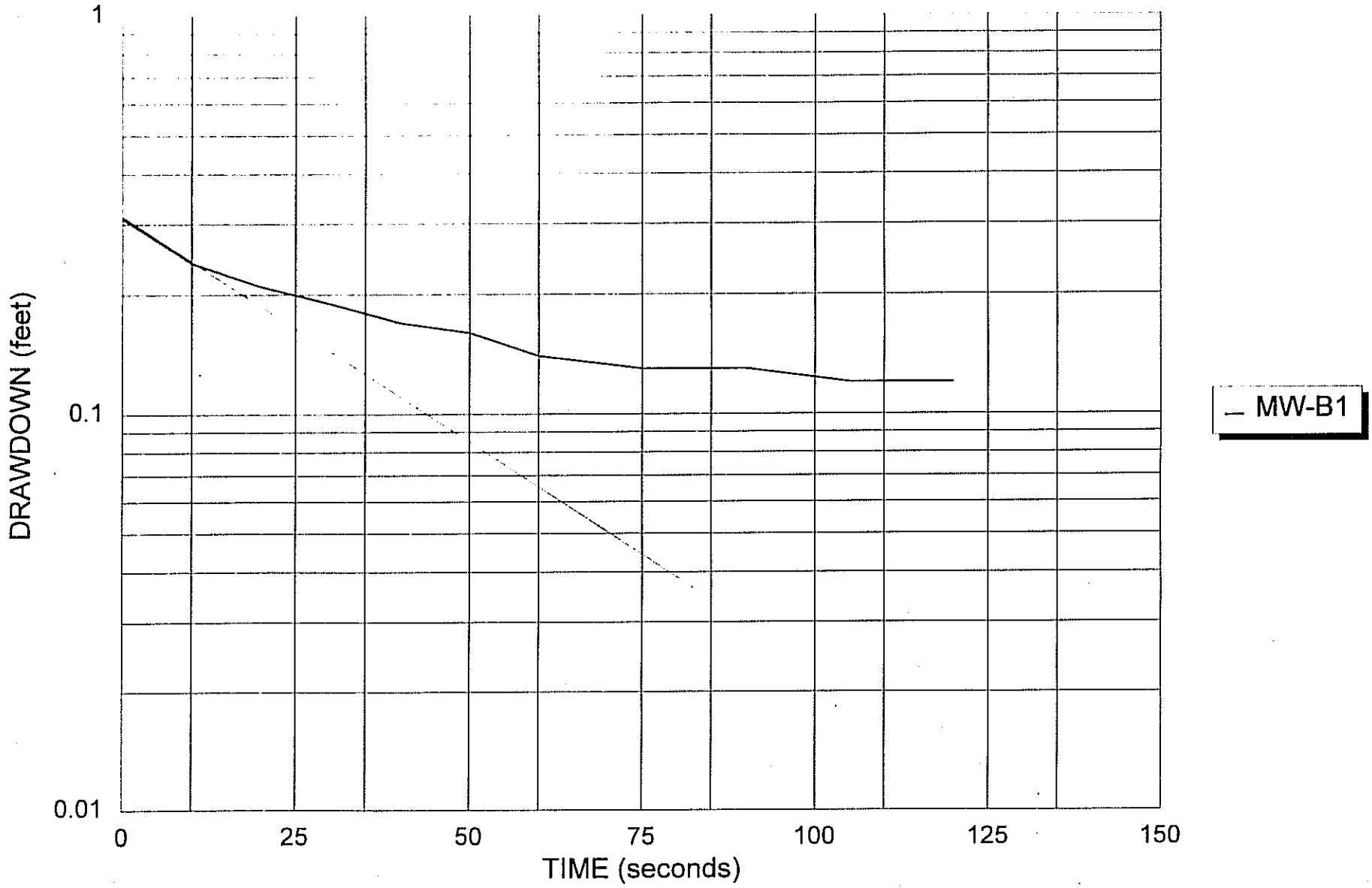
Determination of Hydraulic Conductivity

K = 0.001254 feet/min.

1.805276 feet/day = 6.369×10^{-4} cm/sec

RISING HEAD TEST: MW-B1

Greensboro White Street Landfill



HDR Engineering, Inc.

Client: White Street Landfill

Project: Falling Head Tests

Project No. 06770-021-018
Sheet 1/1
Date: 11/27/95
Well B-1
Reference: Bouwer, 1989

Hydraulic Conductivity, K = ((Req^2)ln(Re/Rw)/2Le)*(1/T)*ln(Yo/Yt)

Where: **Req = [(Rc^2) + n(Rw^2 - Rc^2)]exp^1/2 (Correction for sand pack)**

ln(Re/Rw)=[1.1/ln(Lw/Rw)+(A+Bln[(H-Lw)/Rw])/Le/Rw]exp^-1

Lw = Ht. of Water Column in Well =	19.56	(water in
Le = Screen Interval Open to Aquifer =	10	casing)
Rw = Radius of Well Including Sand Pack =	0.375	
Rc = Radius of Casing =	0.083	
H = Aquifer Thickness to First Aquitard =	33	
Yo = Relative Ht. of Water at Time Zero =	0.25	
Yt = Relative Ht. of Water at Time t =	0.05	
n = Porosity =	0.35	
T = Time (in minutes) =	2.5	

A & B are Constants to be Determined

Correction for Sand Pack (not necessary in this case)

Req = 0.083

Evaluation of A & B

Le/Rw = 26.66667

from attached graph of A & B

A =	2.25
B =	0.48

Determination of ln Term

ln Re/Rw = 2.342056

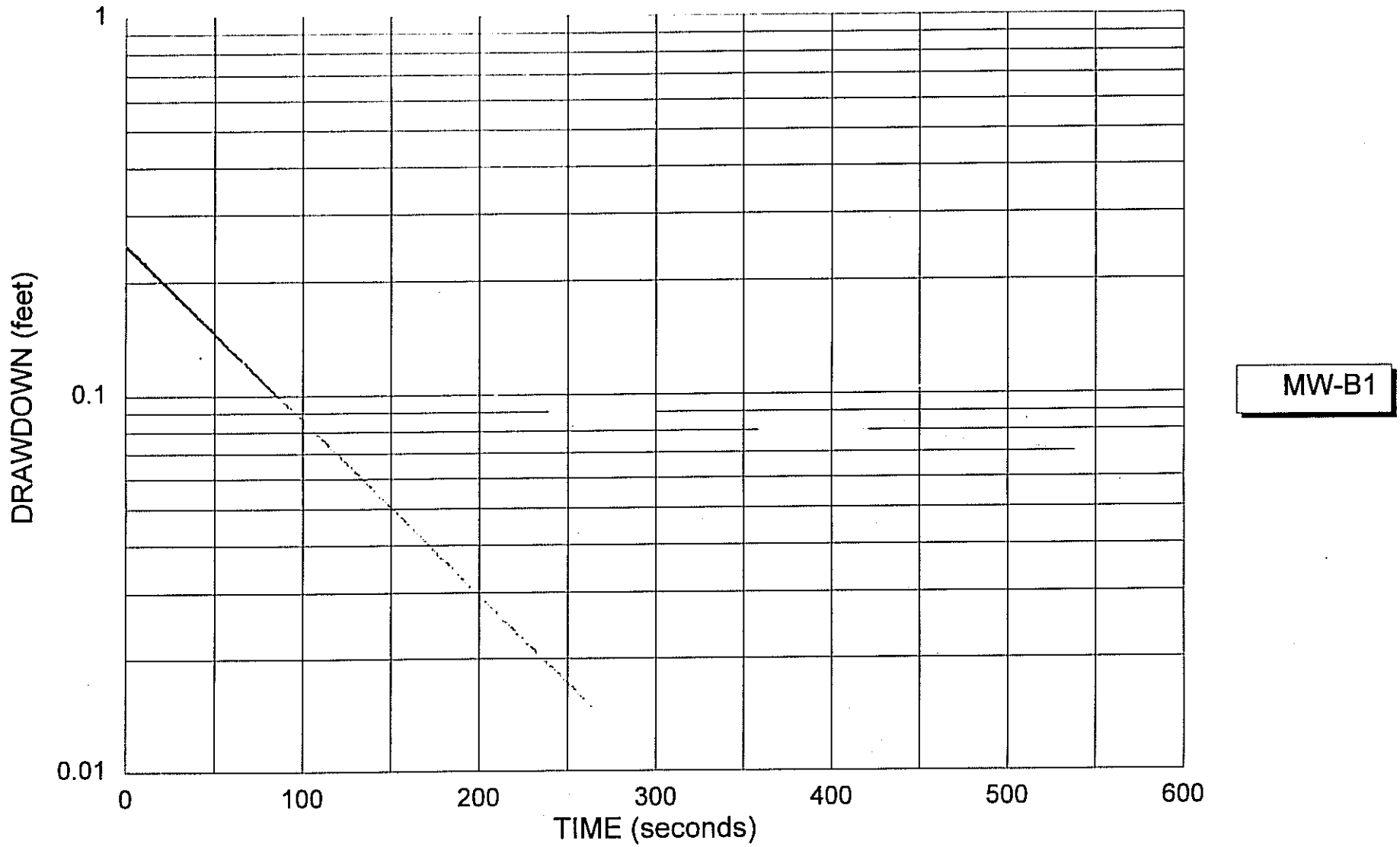
Determination of Hydraulic Conductivity

K = 0.000519 feet/min.

0.74786 feet/day

FALLING HEAD TEST: MW-B1

Greensboro White Street Landfill



HDR Engineering, Inc.

Client: White Street Landfill

Project: Falling Head Tests

Project No. 06770-021-018
Sheet 1/1
Date: 11/27/95
Well B-14
Reference: Bouwer, 1989

Hydraulic Conductivity, K = ((Req^2)ln(Re/Rw)/2Le)*(1/T)*ln(Yo/Yt)

Where: Req = [(Rc^2) + n(Rw^2 - Rc^2)]exp^1/2 (Correction for sand pack)

ln(Re/Rw)=[1.1/ln(Lw/Rw)+(A+Bln[(H-Lw)/Rw])/Le/Rw]exp^-1

Lw = Ht. of Water Column in Well =	11.73	(water in
Le = Screen Interval Open to Aquifer =	10	casing)
Rw = Radius of Well Including Sand Pack =	0.375	
Rc = Radius of Casing =	0.083	
H = Aquifer Thickness to First Aquitard =	16	
Yo = Relative Ht. of Water at Time Zero =	1.24	
Yt = Relative Ht. of Water at Time t =	0.7	
n = Porosity =	0.35	
T = Time (in minutes) =	5	

A & B are Constants to be Determined

Correction for Sand Pack (not necessary in this case)

Req = 0.083

Evaluation of A & B

Le/Rw = 26.66667

from attached graph of A & B

A =	2.25
B =	0.48

Determination of ln Term

ln Re/Rw = 2.233889

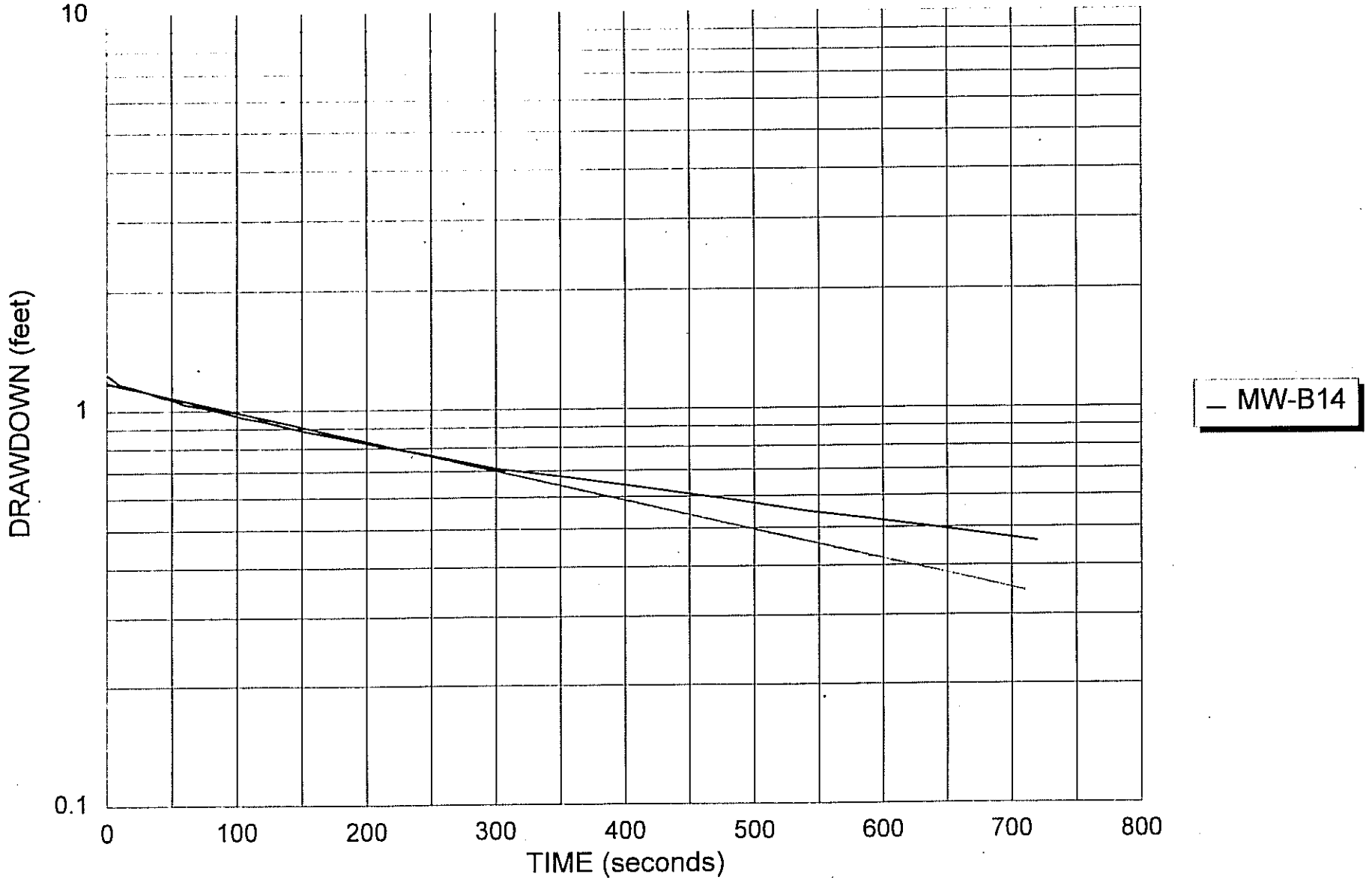
Determination of Hydraulic Conductivity

K = 0.000088 feet/min.

0.126711 feet/day = 4.47×10^{-5} cm/sec

FALLING HEAD TEST: MW-B14

Greensboro White Street Landfill



HDR Engineering, Inc.

Client: White Street Landfill

Project: Falling Head Tests

Project No. 06770-021-018
Sheet 1/1
Date: 11/27/95
Well B-17d
Reference: Bouwer, 1989

Hydraulic Conductivity, K = ((Req^2)ln(Re/Rw)/2Le)*(1/T)*ln(Yo/Yt)

Where: Req = [(Rc^2) + n(Rw^2 - Rc^2)]exp^1/2 (Correction for sand pack)

ln(Re/Rw)=[1.1/ln(Lw/Rw)+(A+Bln[(H-Lw)/Rw])/Le/Rw]exp^-1

Lw = Ht. of Water Column in Well =	27.96	(water in
Le = Screen Interval Open to Aquifer =	5	casing)
Rw = Radius of Well Including Sand Pack =	0.375	
Rc = Radius of Casing =	0.083	
H = Aquifer Thickness to First Aquitard =	53	
Yo = Relative Ht. of Water at Time Zero =	1.76	
Yt = Relative Ht. of Water at Time t =	0.8	
n = Porosity =	0.35	
T = Time (in minutes) =	3.33	

A & B are Constants to be Determined

Correction for Sand Pack (not necessary in this case)

Req = 0.083

Evaluation of A & B

Le/Rw = 13.33333

from attached graph of A & B

A =	1.9
B =	0.38

Determination of ln Term

ln Re/Rw = 1.93288

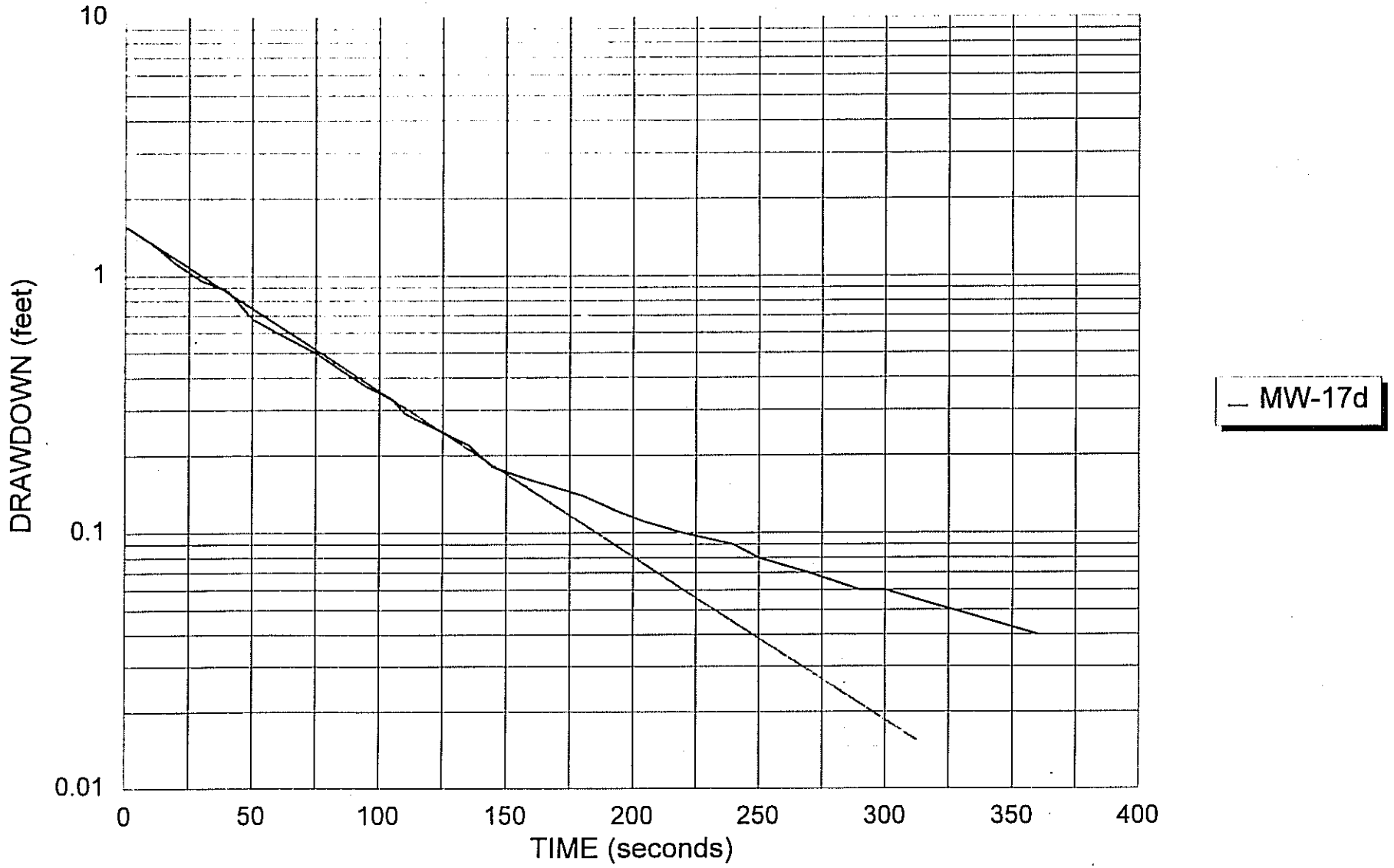
Determination of Hydraulic Conductivity

K = 0.000315 feet/min.

0.454002 feet/day = 1.60×10^{-4} cm/sec

FALLING HEAD TEST: MW-17d

Greensboro White Street Landfill



HDR Engineering, Inc.

Client: White Street Landfill

Project: Rising Head Tests

Project No. 06770-021-018
Sheet 1/1
Date: 11/27/95
Well B-22
Reference: Bouwer, 1989

Hydraulic Conductivity, K = ((Req^2)ln(Re/Rw)/2Le)*(1/T)*ln(Yo/Yt)

Where: Req = [(Rc^2) + n(Rw^2 - Rc^2)]exp^1/2 (Correction for sand pack)

ln(Re/Rw)=[1.1/ln(Lw/Rw)+(A+Bln[(H-Lw)/Rw])/Le/Rw]exp^-1

Lw = Ht. of Water Column in Well =	20.89	(water in
Le = Screen Interval Open to Aquifer =	10	casing)
Rw = Radius of Well Including Sand Pack =	0.375	
Rc = Radius of Casing =	0.083	
H = Aquifer Thickness to First Aquitard =	31	
Yo = Relative Ht. of Water at Time Zero =	1.62	
Yt = Relative Ht. of Water at Time t =	0.09	
n = Porosity =	0.35	
T = Time (in minutes) =	2.92	

A & B are Constants to be Determined

Correction for Sand Pack (not necessary in this case)

Req = 0.083

Evaluation of A & B

Le/Rw = 26.66667

from attached graph of A & B

A =	2.25
B =	0.48

Determination of ln Term

ln Re/Rw = 2.396367

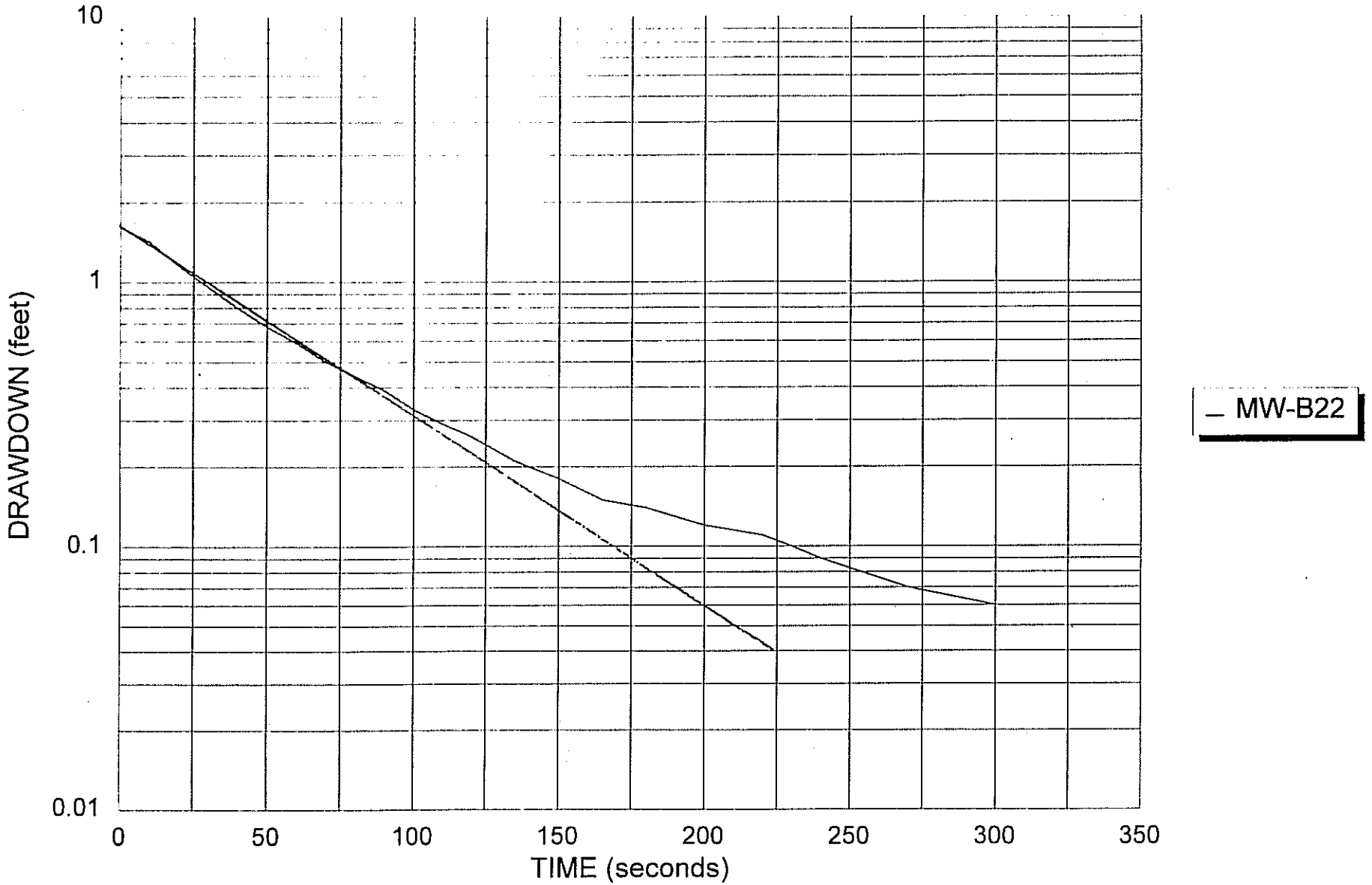
Determination of Hydraulic Conductivity

K = 0.000817 feet/min.

1.176557 feet/day = 4.15×10^{-4} cm/sec

RISING HEAD TEST: MW-B22

Greensboro White Street Landfill



HDR Engineering, Inc.

Client: White Street Landfill

Project: Falling Head Tests

Project No. 06770-021-018
Sheet 1/1
Date: 11/27/95
Well B-22
Reference: Bouwer, 1989

Hydraulic Conductivity, K = ((Req^2)ln(Re/Rw)/2Le)*(1/T)*ln(Yo/Yt)

Where: **Req = [(Rc^2) + n(Rw^2 - Rc^2)]exp^1/2 (Correction for sand pack)**

ln(Re/Rw)=[1.1/ln(Lw/Rw)+(A+Bln[(H-Lw)/Rw])/Le/Rw]exp^-1

Lw = Ht. of Water Column in Well =	20.87	(water in
Le = Screen Interval Open to Aquifer =	10	casing)
Rw = Radius of Well Including Sand Pack =	0.375	
Rc = Radius of Casing =	0.083	
H = Aquifer Thickness to First Aquitard =	31	
Yo = Relative Ht. of Water at Time Zero =	1.56	
Yt = Relative Ht. of Water at Time t =	0.75	
n = Porosity =	0.35	
T = Time (in minutes) =	0.83	

A & B are Constants to be Determined

Correction for Sand Pack (not necessary in this case)

Req = 0.083

Evaluation of A & B

Le/Rw = 26.66667

from attached graph of A & B

A =	2.25
B =	0.48

Determination of ln Term

ln Re/Rw = 2.395788

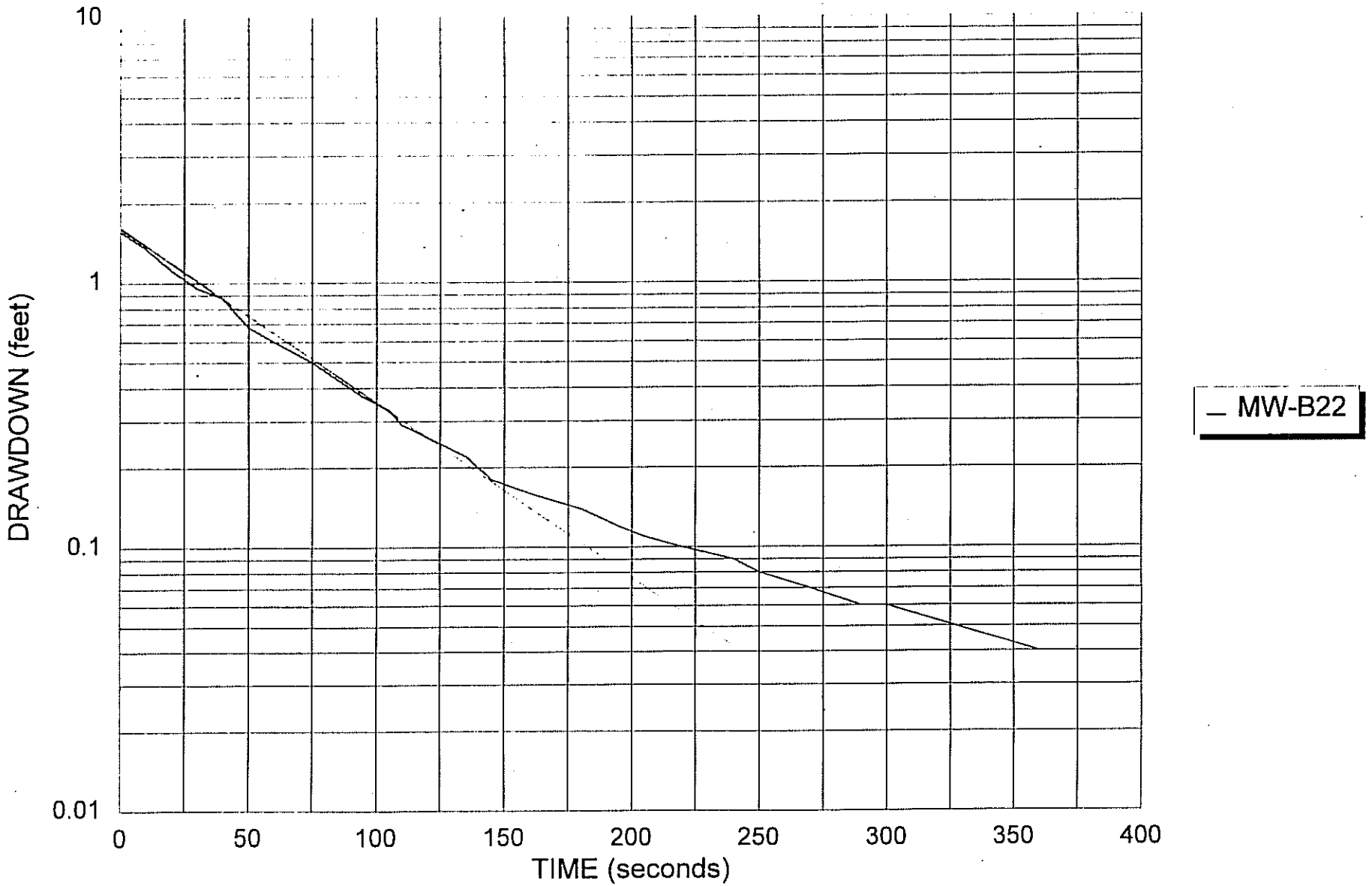
Determination of Hydraulic Conductivity

K = 0.000728 feet/min.

1.048548 feet/day

FALLING HEAD TEST: MW-B22

Greensboro White Street Landfill



HDR Engineering, Inc.

Client: White Street Landfill

Project: Falling Head Tests

Project No. 06770-021-018
Sheet 1/1
Date: 11/27/95
Well B-22d
Reference: Bouwer, 1989

Hydraulic Conductivity, K = ((Req^2)ln(Re/Rw)/2Le)*(1/T)*ln(Yo/Yt)

Where: Req = [(Rc^2) + n(Rw^2 - Rc^2)]exp^1/2 (Correction for sand pack)

ln(Re/Rw)=[1.1/ln(Lw/Rw)+(A+Bln[(H-Lw)/Rw])/Le/Rw]exp^-1

Lw = Ht. of Water Column in Well =	36.53	(water in
Le = Screen Interval Open to Aquifer =	5	casing)
Rw = Radius of Well Including Sand Pack =	0.375	
Rc = Radius of Casing =	0.083	
H = Aquifer Thickness to First Aquitard =	46	
Yo = Relative Ht. of Water at Time Zero =	2.07	
Yt = Relative Ht. of Water at Time t =	2	
n = Porosity =	0.35	
T = Time (in minutes) =	0.83	

A & B are Constants to be Determined

Correction for Sand Pack (not necessary in this case)

Req = 0.083

Evaluation of A & B

Le/Rw = 13.33333

from attached graph of A & B

A =	1.9
B =	0.38

Determination of ln Term

ln Re/Rw = 2.106352

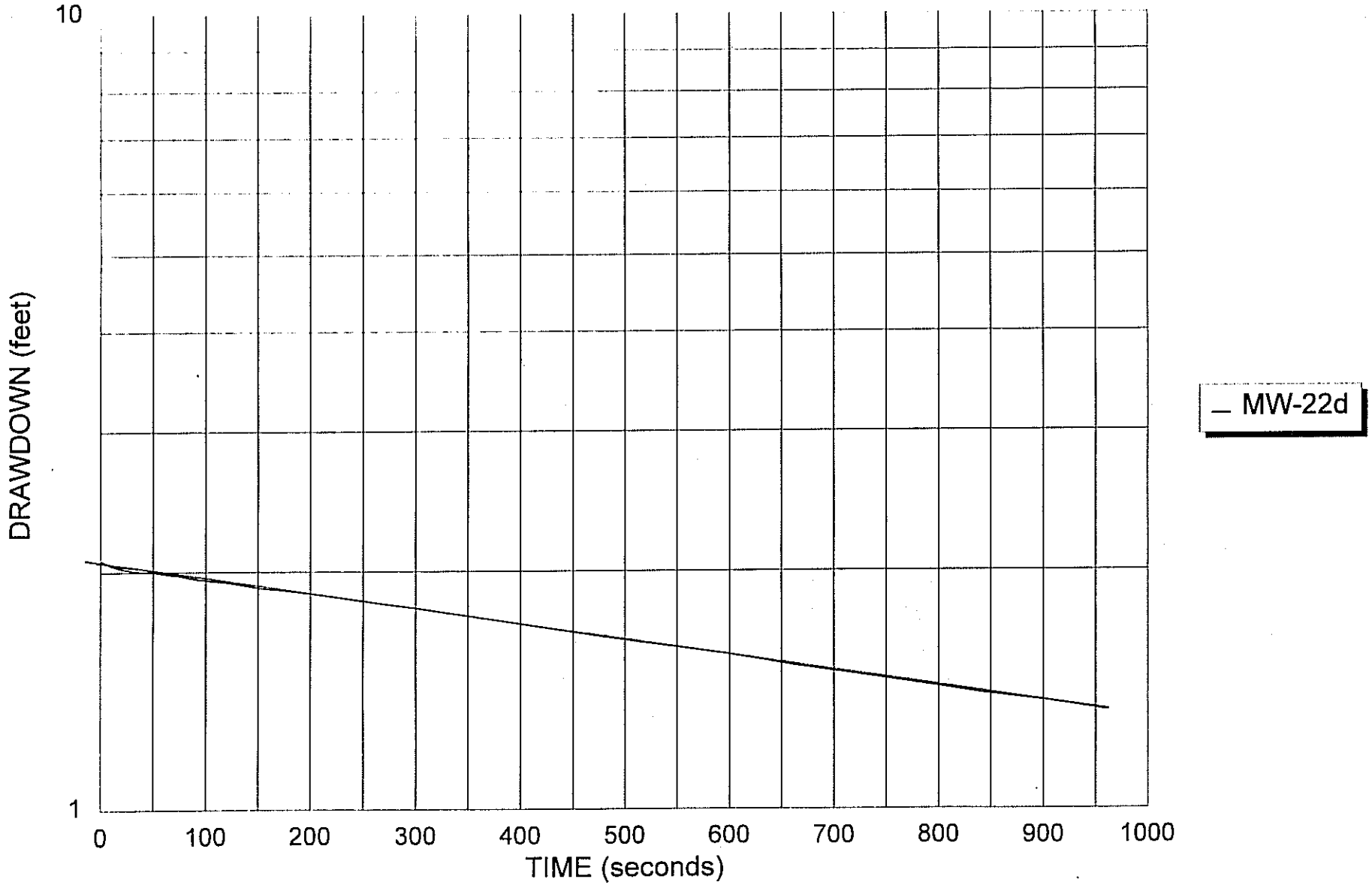
Determination of Hydraulic Conductivity

K = 0.00006 feet/min.

0.086606 feet/day = 3.06×10^{-5} cm/sec

FALLING HEAD TEST: MW-B22d

Greensboro White Street Landfill



HDR Engineering, Inc.

Client: White Street Landfill

Project: Falling Head Tests

Project No. 06770-021-018
Sheet 1/1
Date: 11/27/95
Well B-25s
Reference: Bouwer, 1989

Hydraulic Conductivity, K = ((Req^2)ln(Re/Rw)/2Le)*(1/T)*ln(Yo/Yt)

Where: Req = [(Rc^2) + n(Rw^2 - Rc^2)]exp^1/2 (Correction for sand pack)

ln(Re/Rw)=[1.1/ln(Lw/Rw)+(A+Bln[(H-Lw)/Rw])/Le/Rw]exp^-1

Lw = Ht. of Water Column in Well =	32.39	(water in
Le = Screen Interval Open to Aquifer =	10	casing)
Rw = Radius of Well Including Sand Pack =	0.375	
Rc = Radius of Casing =	0.083	
H = Aquifer Thickness to First Aquitard =	38	
Yo = Relative Ht. of Water at Time Zero =	1.95	
Yt = Relative Ht. of Water at Time t =	0.6	
n = Porosity =	0.35	
T = Time (in minutes) =	7.5	

A & B are Constants to be Determined

Correction for Sand Pack (not necessary in this case)

Req = 0.083

Evaluation of A & B

Le/Rw = 26.66667

from attached graph of A & B

A =	2.25
B =	0.48

Determination of ln Term

ln Re/Rw = 2.633092

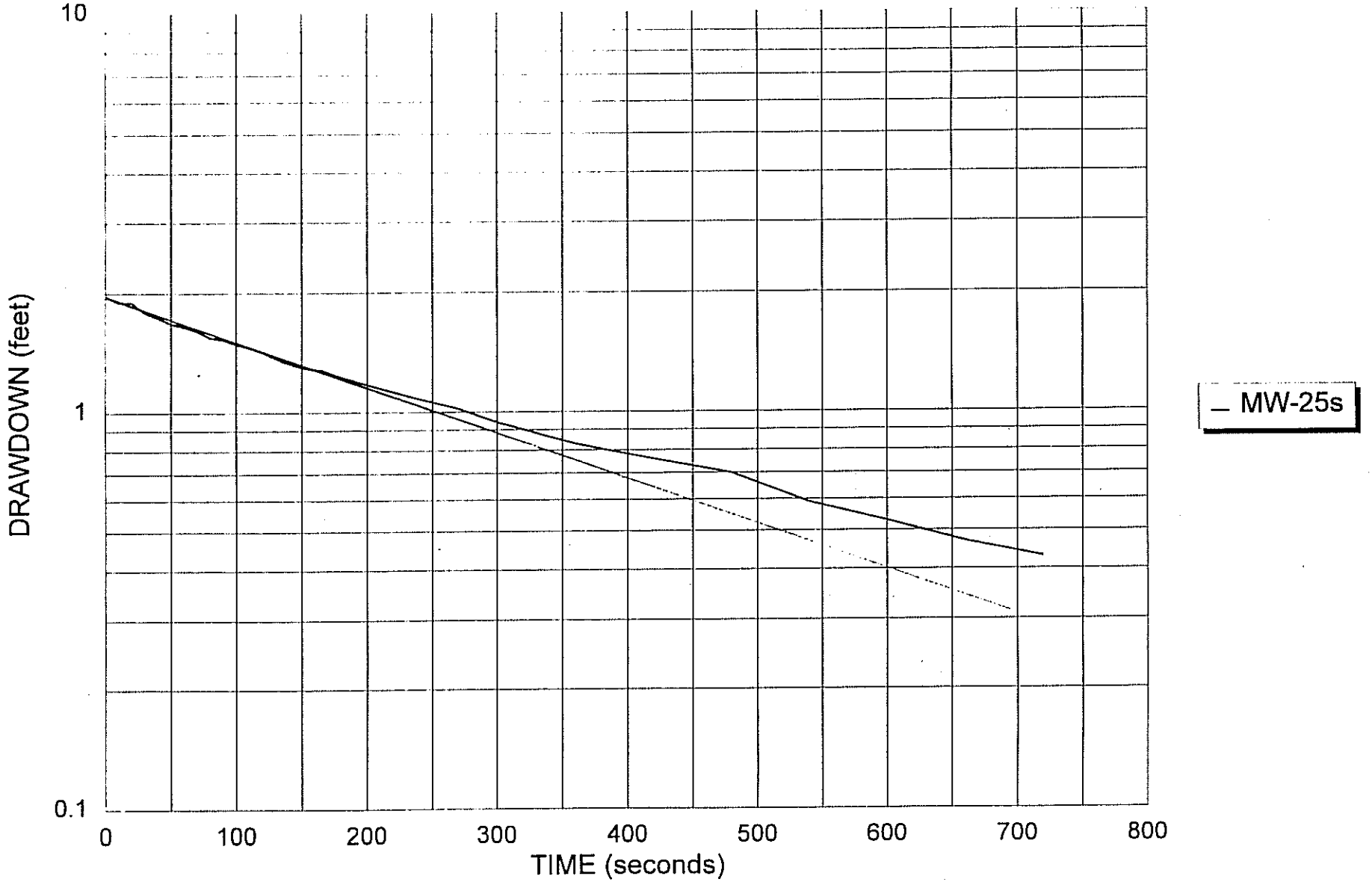
Determination of Hydraulic Conductivity

K = 0.000143 feet/min.

0.205249 feet/day = 7.24×10^{-5} cm/sec

FALLING HEAD TEST: MW-25s

Greensboro White Street Landfill



HDR Engineering, Inc.

Client: White Street Landfill
Project: Falling Head Tests

Project No. 06770-021-018
Sheet 1/1
Date: 11/27/95
Well B-25d
Reference: Bouwer, 1989

Hydraulic Conductivity, K = ((Req^2)ln(Re/Rw)/2Le)*(1/T)*ln(Yo/Yt)

Where: Req = [(Rc^2) + n(Rw^2 - Rc^2)]exp^1/2 (Correction for sand pack)

ln(Re/Rw)=[1.1/ln(Lw/Rw)+(A+Bln[(H-Lw)/Rw])/Le/Rw]exp^-1

Lw = Ht. of Water Column in Well =	42.05	(water in
Le = Screen Interval Open to Aquifer =	5	casing)
Rw = Radius of Well Including Sand Pack =	0.375	
Rc = Radius of Casing =	0.083	
H = Aquifer Thickness to First Aquitard =	52	
Yo = Relative Ht. of Water at Time Zero =	1.9	
Yt = Relative Ht. of Water at Time t =	0.9	
n = Porosity =	0.35	
T = Time (in minutes) =	10	

A & B are Constants to be Determined

Correction for Sand Pack (not necessary in this case)
Req = 0.083

Evaluation of A & B
Le/Rw = 13.33333

from attached graph of A & B

A =	1.9
B =	0.38

Determination of ln Term

ln Re/Rw = 2.132193

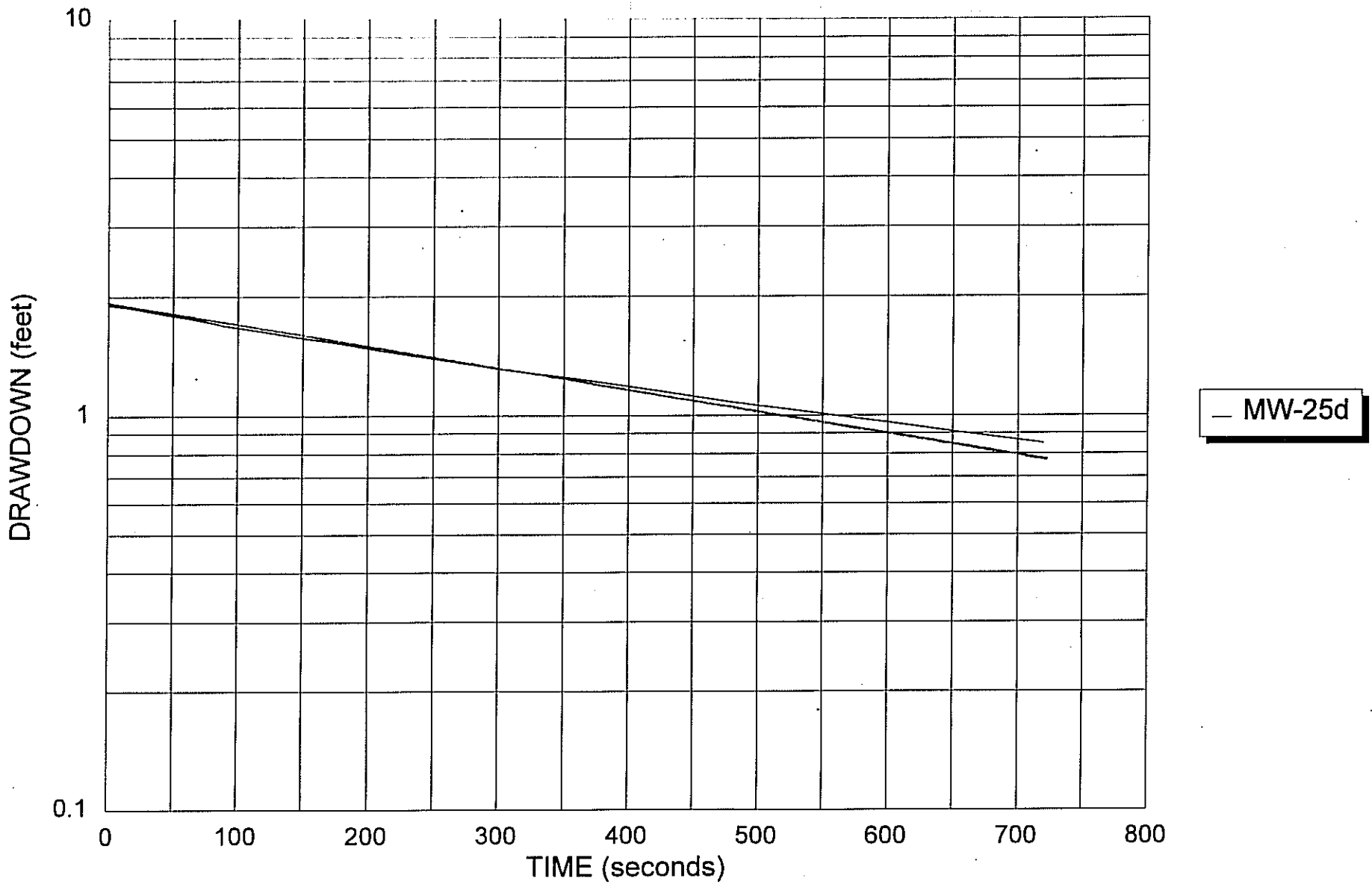
Determination of Hydraulic Conductivity

K = 0.00011 feet/min.

0.158049 feet/day = 5.58×10^{-5} cm/sec

FALLING HEAD TEST: MW-25d

Greensboro White Street Landfill



HDR Engineering, Inc.

Client: White Street Landfill

Project: Falling Head Tests

Project No. 06770-021-018
Sheet 1/1
Date: 11/27/95
Well B-31
Reference: Bouwer, 1989

Hydraulic Conductivity, K = ((Req^2)ln(Re/Rw)/2Le)*(1/T)*ln(Yo/Yt)

Where: Req = [(Rc^2) + n(Rw^2 - Rc^2)]exp^1/2 (Correction for sand pack)

ln(Re/Rw)=[1.1/ln(Lw/Rw)+(A+Bln[(H-Lw)/Rw])/Le/Rw]exp^-1

Lw = Ht. of Water Column in Well =	16.92	(water in
Le = Screen Interval Open to Aquifer =	10	casing)
Rw = Radius of Well Including Sand Pack =	0.375	
Rc = Radius of Casing =	0.083	
H = Aquifer Thickness to First Aquitard =	25	
Yo = Relative Ht. of Water at Time Zero =	1.97	
Yt = Relative Ht. of Water at Time t =	0.5	
n = Porosity =	0.35	
T = Time (in minutes) =	9.17	

A & B are Constants to be Determined

Correction for Sand Pack (not necessary in this case)

Req = 0.083

Evaluation of A & B

Le/Rw = 26.66667

from attached graph of A & B

A =	2.25
B =	0.48

Determination of ln Term

ln Re/Rw = 2.334245

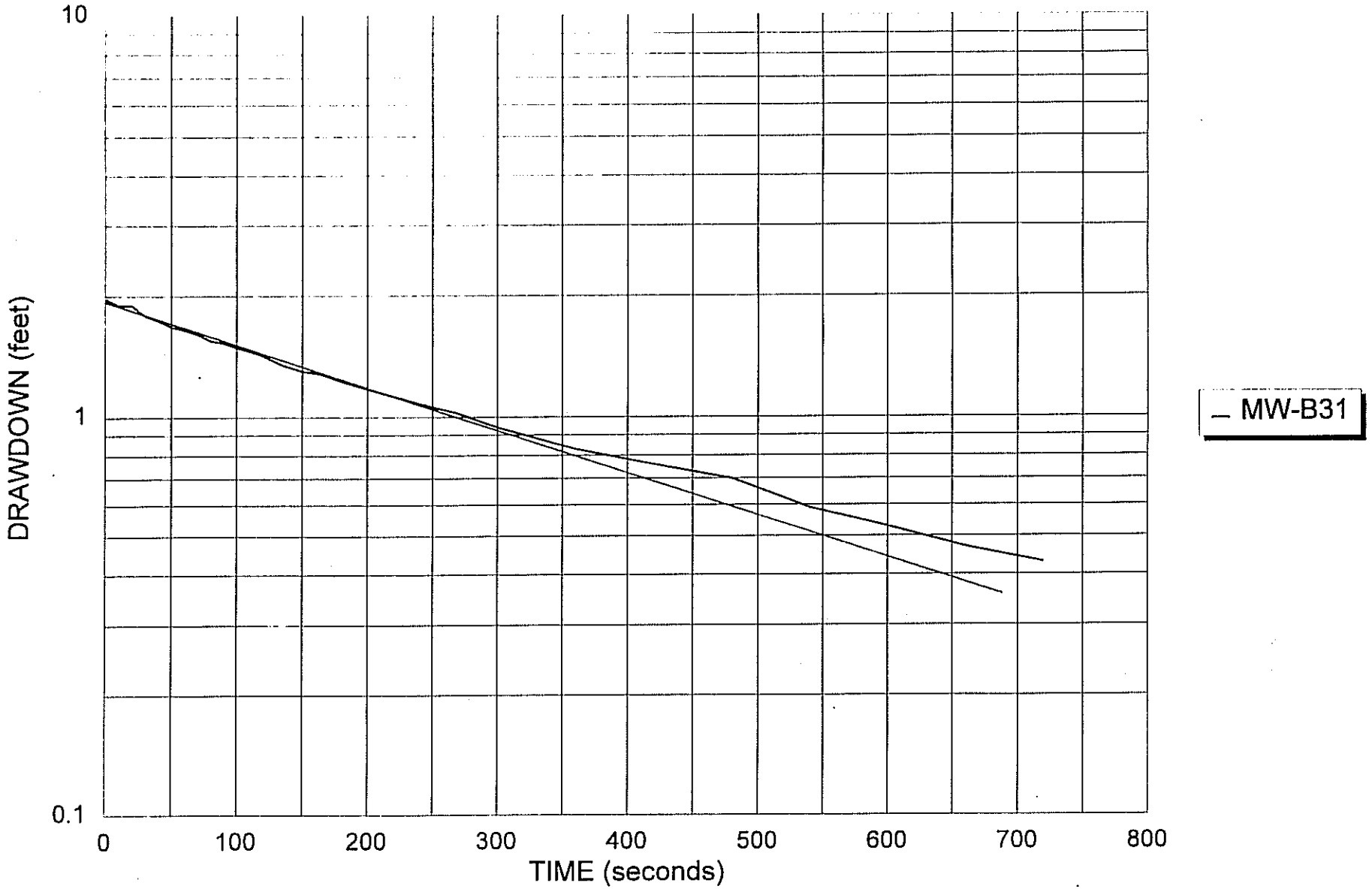
Determination of Hydraulic Conductivity

K = 0.00012 feet/min.

0.173125 feet/day = 6.11×10^{-5} cm/sec

FALLING HEAD TEST: MW-B31

Greensboro White Street Landfill



HDR Engineering, Inc.

Client: White Street Landfill

Project: Rising Head Tests

Project No. 06770-021-018
Sheet 1/1
Date: 11/27/95
Well B-34
Reference: Bouwer, 1989

Hydraulic Conductivity, K = ((Req^2)ln(Re/Rw)/2Le)*(1/T)*ln(Yo/Yt)

Where: Req = [(Rc^2) + n(Rw^2 - Rc^2)]exp^1/2 (Correction for sand pack)

ln(Re/Rw)=[1.1/ln(Lw/Rw)+(A+Bln[(H-Lw)/Rw])/Le/Rw]exp^-1

Lw = Ht. of Water Column in Well =	3.4	(water in
Le = Screen Interval Open to Aquifer =	5	casing)
Rw = Radius of Well Including Sand Pack =	0.375	
Rc = Radius of Casing =	0.083	
H = Aquifer Thickness to First Aquitard =	7	
Yo = Relative Ht. of Water at Time Zero =	0.744	
Yt = Relative Ht. of Water at Time t =	0.06	
n = Porosity =	0.35	
T = Time (in minutes) =	0.2	

A & B are Constants to be Determined

Correction for Sand Pack (not necessary in this case)

Req = 0.083

Evaluation of A & B

Le/Rw = 13.33333

from attached graph of A & B

A =	1.9
B =	0.38

Determination of ln Term

ln Re/Rw = 1.416599

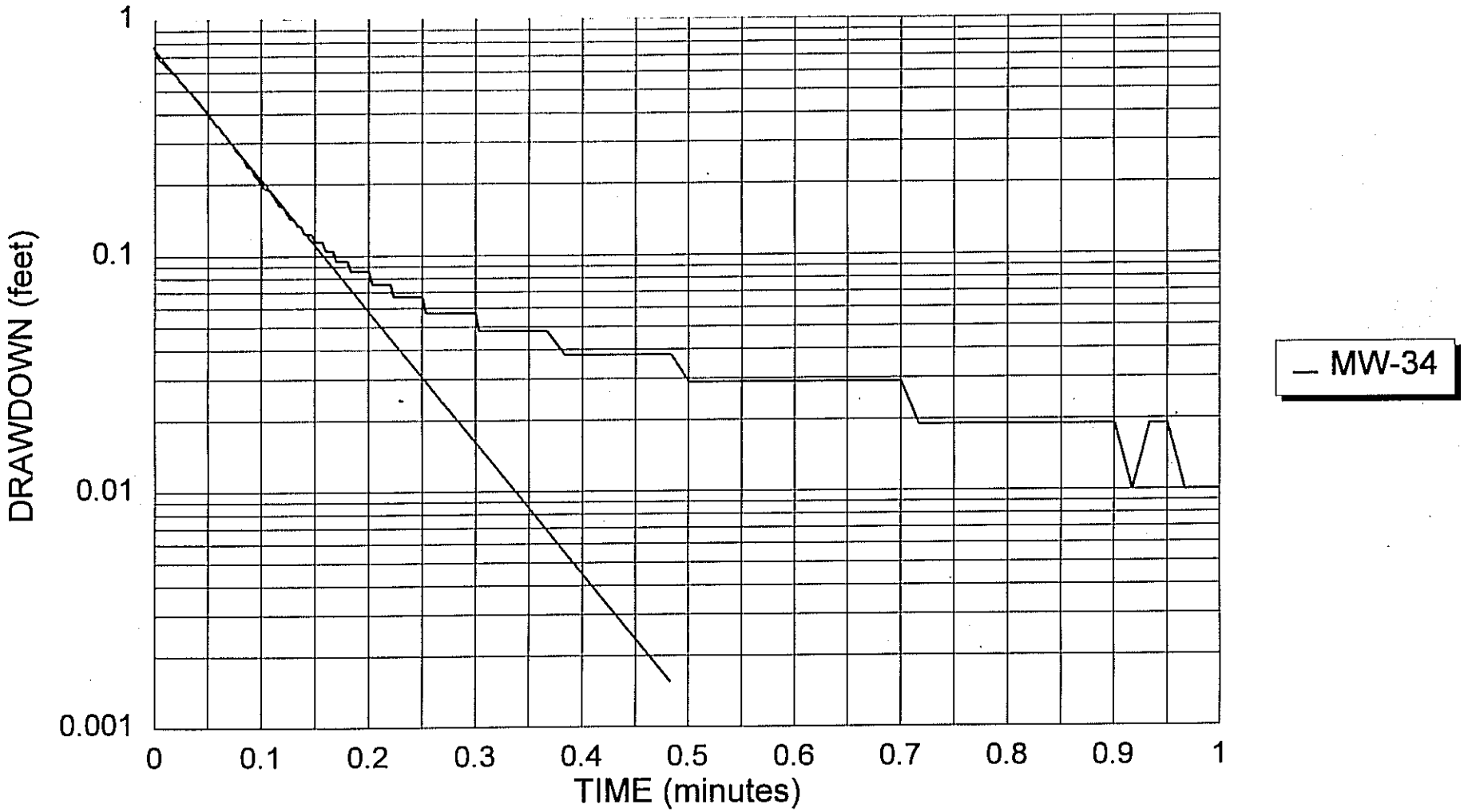
Determination of Hydraulic Conductivity

K = 0.012285 feet/min.

17.69046 feet/day

RISING HEAD TEST: MW-34

Greensboro White Street Landfill



APPENDIX D

MISCELLANEOUS SUPPORT DOCUMENTATION

Job No. 06770-021-018 | No.

HDR Computation

HDR

Project GREENSBORO WHITE STREET LANDFILL	Computed JRI	Date 10/29/96
Subject ESTIMATED LONG-TERM SEASONAL HIGH WATER TABLE	Checked	Date
Task CALCULATION OF LONG-TERM SEASONAL HIGH FACTOR	Sheet 1	Of 1

PROBLEM: SEASONAL HIGH WATER TABLE DATA FOR ON-SITE WELLS DOES NOT TAKE INTO ACCOUNT LONG-TERM EXTREMES IN WATER LEVEL FLUCTUATION.

SOLUTION: DETERMINE MAXIMUM FLUCTUATION IN WATER TABLE FOR THE REGION USING THE HIGHEST HISTORICAL MONTH ON RECORD FOR THE PAST 11 YEARS.

SOURCE OF DATA: USGS WATER RESOURCES DATA, NORTH CAROLINA WATER YEAR 1995 (AND UNPUBLISHED 1996).

CALCULATION:

HIGHEST RECORDED WATER LEVEL IN NC-142 (DAVIE COUNTY)

MARCH 28, 1993 AT 10.64 FT BLS.

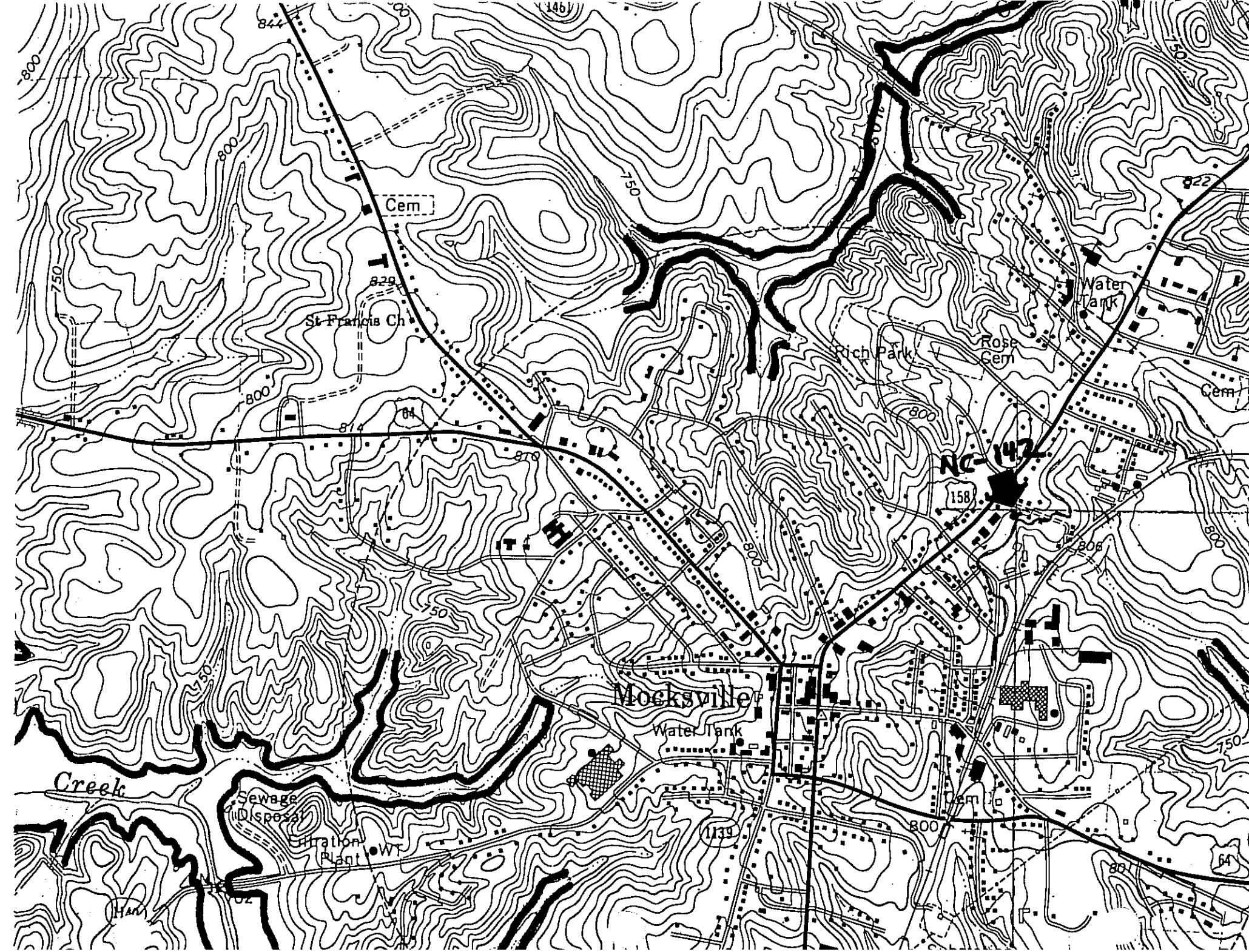
ACTUAL RECORDED WATER LEVEL IN NC-142 ON THE DATE WHICH REPRESENTS THE ON-SITE SEASONAL HIGH (JANUARY 29, 1996)

12.85 FT BLS.

RESULTING DIFFERENCE: 12.85' − 10.64' = 2.21 FT.

ALL ON-SITE DATA FOR THE JANUARY 29, 1996 EVENT WILL BE ADJUSTED TO APPROXIMATE THE LONG-TERM SEASONAL HIGH WATER TABLE BY THE ADDITION OF 2.21 FEET.

ATTACHMENTS: USGS TOPO MAP WITH WELL LOCATION
USGS DATA WITH HYDROGRAPHS FOR NC-142 (1985-1996)


Cem
St Francis Ch
Water Tank
Rich Park
Rose Cem
Cem
NC-142
158
Mocksville
Water Tank
Creek
Sewage Disposal
Filtration Plant
WT
Cem
1139
64

DAVIE COUNTY

355359080331701. Local number, NC-142.

LOCATION.--Lat 35°53'59", long 80°33'17", Hydrologic Unit 03040102, 0.5 mi northeast of Mocksville on U.S. Highway 158 at B.C. Brocks Community Center. Owner: U.S. Geological Survey.

AQUIFER.--Unconfined weathered granite of Paleozoic age.

WELL CHARACTERISTICS.--Drilled observation well, drilled to 30.8 ft, diameter 6 in., cased to 30.8 ft, open end, backfilled with gravel from 20 to 30.8 ft.

INSTRUMENTATION.--Digital recorder with a 60-minute punch interval.

DATUM.--Land-surface datum is 835 ft above sea level (from topographic map). Measuring point: Top of casing, 1.00 ft above land-surface datum.

REMARKS.--In October 1982, well replaced nearby NC-110. Well is part of terrane-effects network.

PERIOD OF RECORD.--October 1981 to current year.

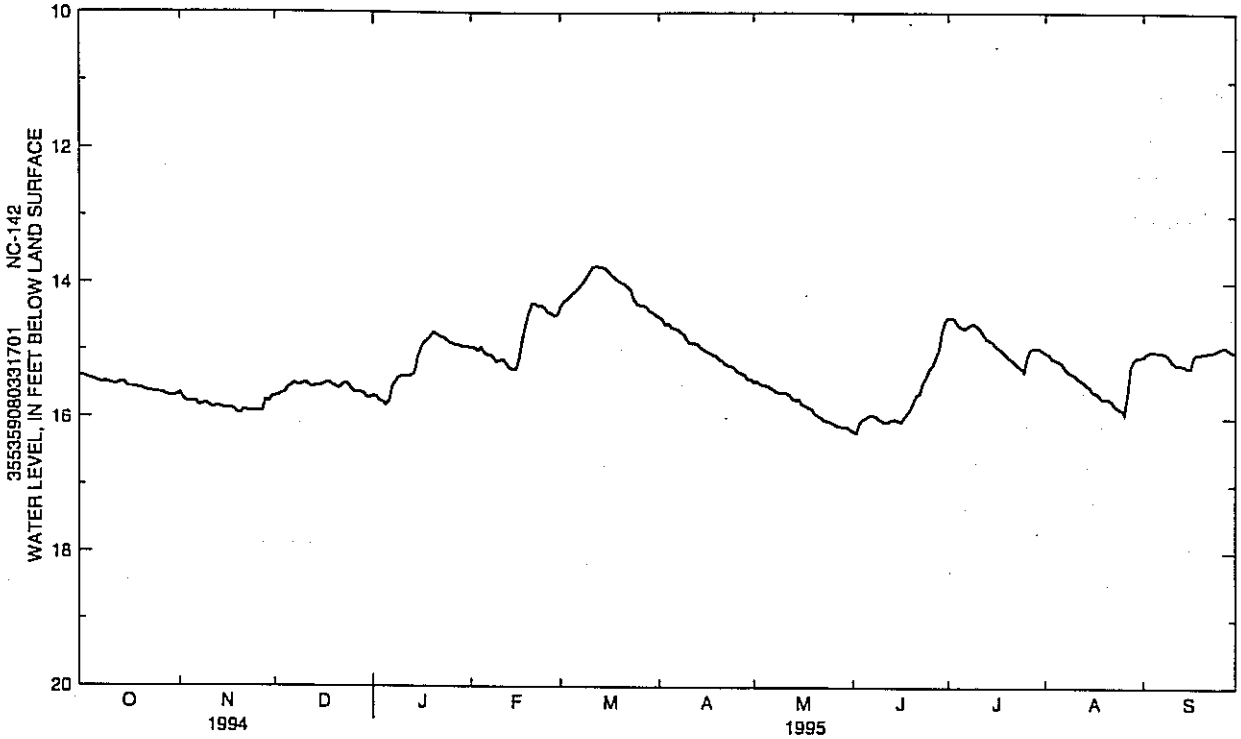
EXTREMES FOR PERIOD OF RECORD.--Highest water level recorded, 10.64 ft below land-surface datum, Mar. 28, 1993; lowest water level recorded, 20.98 ft below land-surface datum, Oct. 24, 25, and 26, 1981.

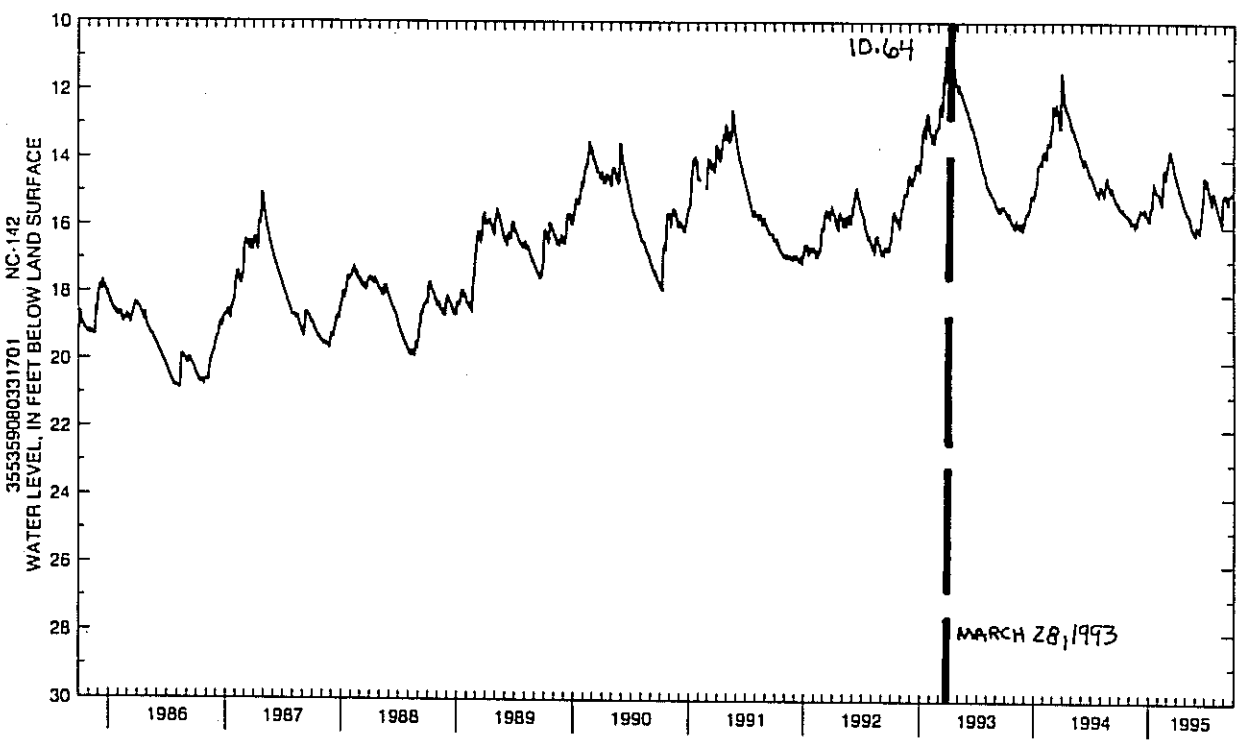
WATER LEVEL, IN FEET BELOW LAND SURFACE DATUM, WATER YEAR OCTOBER 1994 TO SEPTEMBER 1995

DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	15.39	15.64	15.69	15.68	14.97	14.36	14.51	15.47	16.20	14.51	15.04	15.09
2	15.39	15.72	15.68	15.70	14.98	14.29	14.55	15.46	16.22	14.51	15.06	15.04
3	15.41	15.77	15.65	15.76	15.02	14.25	14.62	15.50	16.08	14.54	15.12	15.02
4	15.43	15.77	15.63	15.77	14.97	14.20	14.61	15.52	16.02	14.62	15.14	15.02
5	15.44	15.77	15.56	15.82	15.04	14.15	14.67	15.52	16.00	14.65	15.16	15.02
6	15.46	15.77	15.53	15.76	15.09	14.11	14.68	15.55	15.96	14.68	15.19	15.03
7	15.48	15.83	15.49	15.55	15.08	14.06	14.70	15.58	15.96	14.65	15.26	15.03
8	15.49	15.82	15.52	15.48	15.13	14.00	14.74	15.61	15.97	14.61	15.31	15.05
9	15.48	15.79	15.52	15.42	15.18	13.93	14.78	15.63	16.02	14.60	15.34	15.09
10	15.49	15.82	15.49	15.40	15.16	13.85	14.85	15.63	16.04	14.64	15.36	15.15
11	15.51	15.86	15.49	15.39	15.15	13.77	14.90	15.63	16.07	14.69	15.41	15.20
12	15.51	15.85	15.54	15.39	15.22	13.75	14.90	15.66	16.06	14.76	15.44	15.21
13	15.51	15.84	15.54	15.39	15.27	13.76	14.90	15.72	16.03	14.83	15.47	15.21
14	15.48	15.85	15.53	15.35	15.30	13.77	14.95	15.74	16.02	14.85	15.51	15.22
15	15.50	15.87	15.53	15.13	15.29	13.78	14.99	15.73	16.04	14.88	15.55	15.26
16	15.55	15.87	15.52	14.98	15.14	13.83	15.02	15.80	16.06	14.93	15.61	15.25
17	15.55	15.87	15.49	14.90	14.85	13.88	15.04	15.82	16.00	14.97	15.63	15.09
18	15.56	15.88	15.48	14.86	14.62	13.93	15.07	15.85	15.93	15.01	15.67	15.05
19	15.57	15.93	15.52	14.81	14.45	13.97	15.09	15.87	15.87	15.06	15.72	15.05
20	15.57	15.95	15.54	14.75	14.32	14.00	15.13	15.94	15.76	15.11	15.72	15.04
21	15.60	15.89	15.57	14.77	14.31	14.02	15.16	15.97	15.67	15.14	15.72	15.03
22	15.61	15.90	15.54	14.81	14.36	14.06	15.20	16.00	15.63	15.18	15.76	15.03
23	15.62	15.91	15.49	14.82	14.34	14.11	15.23	16.04	15.48	15.22	15.82	15.02
24	15.63	15.91	15.51	14.85	14.39	14.25	15.23	16.05	15.40	15.26	15.85	15.00
25	15.63	15.90	15.57	14.89	14.45	14.32	15.27	16.07	15.28	15.31	15.88	14.97
26	15.64	15.91	15.63	14.91	14.46	14.34	15.32	16.09	15.22	15.11	15.93	14.95
27	15.65	15.90	15.63	14.93	14.50	14.34	15.34	16.12	15.10	14.99	15.64	14.94
28	15.66	15.75	15.63	14.93	14.48	14.37	15.37	16.13	14.99	14.97	15.23	14.98
29	15.69	15.77	15.65	14.96	---	14.43	15.43	16.13	14.72	14.97	15.14	15.01
30	15.69	15.70	15.71	14.96	---	14.45	15.43	16.13	14.56	14.97	15.10	15.03
31	15.68	---	15.71	14.96	---	14.49	---	16.17	---	15.01	15.10	---

WTR YR 1995 MEAN 15.25 HIGH 13.75 LOW 16.22


355359080331701 NC-142
WATER LEVEL, IN FEET BELOW LAND SURFACE
10
12
14
16
18
20
O
N
D
J
F
M
A
M
J
J
A
S
1994
1995


355359080331701 NC-142
WATER LEVEL, IN FEET BELOW LAND SURFACE
10
12
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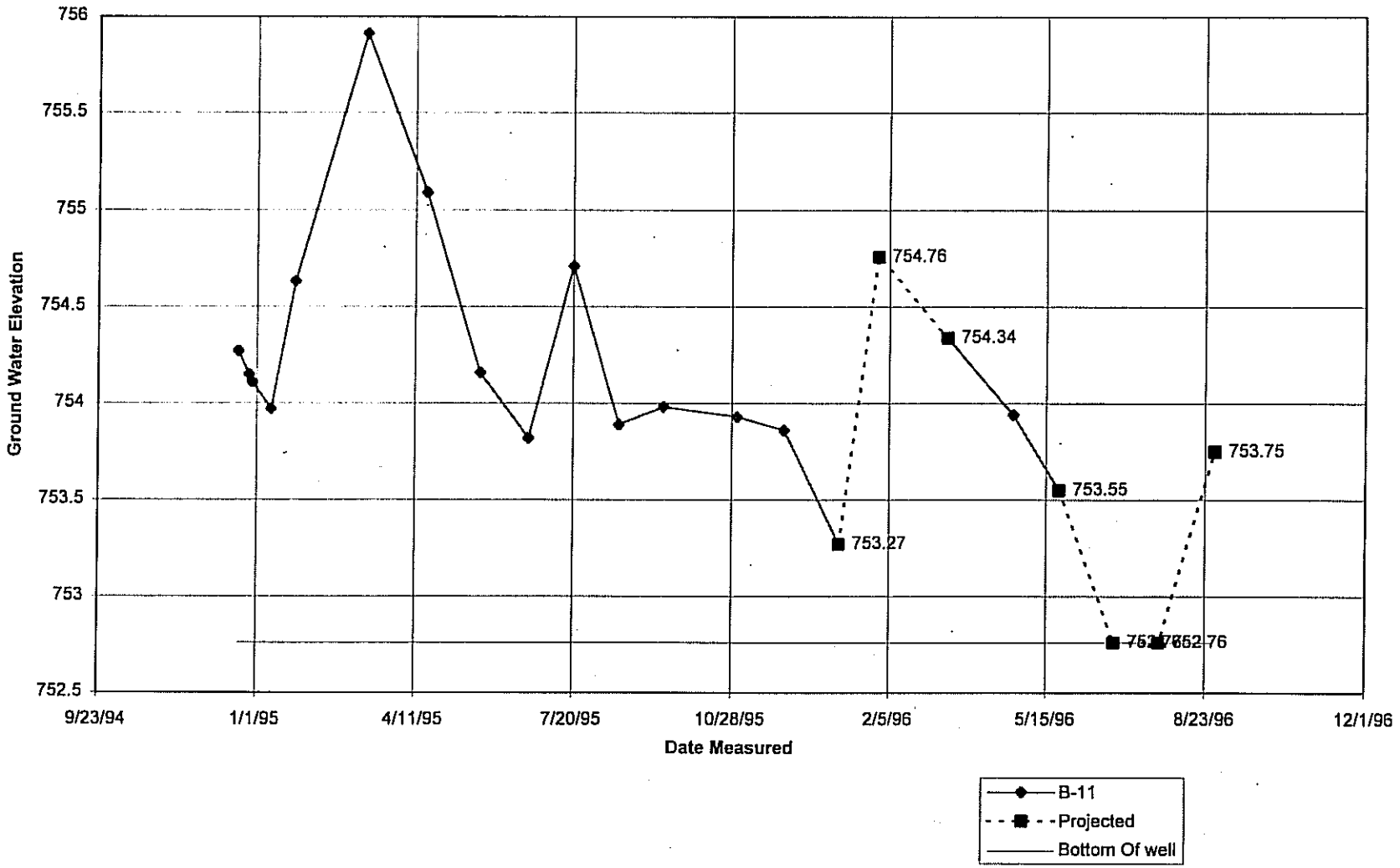
UNITED STATES DEPARTMENT OF THE INTERIOR - GEOLOGICAL SURVEY - NORTH CAROLINA DISTRICT 10/09/96

STATION NUMBER 355359080331701 DV-025 (NC-142) MOCKSVLL WELL SOURCE AGENCY USGS
LATITUDE 355359 LONGITUDE 0803317 WELL DEPTH 30.75 GEOLOGIC UNIT 000SPRL DATUM 835.00
PROVISIONAL DATA SUBJECT TO REVISION

DEPTH BELOW LAND SURFACE (WATER LEVEL) (FEET), WATER YEAR OCTOBER 1995 TO SEPTEMBER 1996
DAILY MEAN VALUES

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	15.03	14.33	14.16	14.29	12.90	13.14	12.62	12.95	13.82	14.47	15.23	15.72
2	15.03	14.29	14.24	14.28	12.85	13.13	12.67	12.89	13.84	14.49	15.23	15.77
3	15.04	14.27	14.25	14.26	12.71	13.24	12.65	12.89	13.84	14.50	15.25	15.79
4	15.03	14.32	14.27	14.30	12.71	13.31	12.62	12.89	13.86	14.55	15.28	15.74
5	14.79	14.32	14.31	14.39	12.70	13.24	12.69	12.94	13.89	14.61	15.29	15.67
6	14.66	14.29	14.32	14.41	12.68	13.19	12.70	12.98	13.92	14.63	15.31	15.58
7	14.59	14.17	14.33	14.35	12.65	13.13	12.71	13.08	13.93	14.64	15.34	15.53
8	14.56	14.09	14.36	14.25	12.57	13.05	12.77	13.06	13.96	14.66	15.36	15.50
9	14.57	14.06	14.28	14.35	12.51	13.02	12.76	13.08	13.96	14.69	15.38	15.49
10	14.57	14.03	14.26	14.29	12.49	13.00	12.78	13.11	13.93	14.78	15.42	15.49
11	14.59	13.92	14.24	14.33	12.42e	12.92	12.79	13.09	13.90	14.83	15.44	15.45
12	14.63	13.93	14.23	14.26	12.54	12.84	12.77	13.15	13.90	14.84	15.43	15.30
13	14.64	13.87	14.22	14.19	12.57	12.83	12.78	13.22	13.92	14.84	15.40	15.22
14	14.61	13.80	14.19	14.22	12.48	12.86	12.82	13.26	13.95	14.88	15.39	15.22
15	14.59	13.84	14.18	14.14	12.58	12.85	12.82	13.27	13.96	14.93	15.41	15.22
16	14.66	13.87	14.21	14.02	12.64	12.94	12.82	13.24	13.99	14.98	15.43	15.22
17	14.74	13.90	14.29	13.86	12.72	12.97	12.93	13.26	14.02	14.99	15.44	15.19
18	14.75	13.88	14.27	13.68	12.77	12.98	12.93	13.33	14.03	15.02	15.47	15.20
19	14.75	13.88	14.12	13.45	12.84	12.82	12.93	13.36	14.05	15.03	15.49	15.21
20	14.72	13.90	14.20	13.38	12.84	12.79	12.95	13.38	14.07	15.06	15.51	15.22
21	14.68	13.89	14.22	13.26	12.87	12.79	12.97	13.41	14.09	15.12	15.52	15.23
22	14.68	13.96	14.23	13.23	12.86	12.80	12.96	13.48	14.13	15.14	15.54	15.23
23	14.68	13.97	14.24	13.22	12.90	12.84	12.93	13.56	14.17	15.19	15.57	15.26
24	14.66	14.04	14.24	13.16	12.99	12.85	13.00	13.59	14.23	15.22	15.59	15.29
25	14.65	14.05	14.22	13.25	13.04	12.84	12.97	13.62	14.26	15.23	15.61	15.28
26	14.65	14.04	14.25	13.21	13.01	12.88	12.95	13.64	14.32	15.23	15.62	15.34
27	14.63	14.04	14.26	13.02	13.04	12.98	13.06	13.65	14.35	15.23	15.62	15.35
28	14.42	14.09	14.32	12.97	13.05	12.87	13.11	13.68	14.37	15.24	15.63	15.35
29	14.40	14.13	14.35	12.85	13.15	12.70	13.07	13.66	14.41	15.24	15.65	15.38
30	14.37	14.18	14.34	12.78	---	12.69	12.98	13.74	14.43	15.23	15.67	---
31	14.35	---	14.29	12.79	---	12.64	---	13.78	---	15.23	15.70	---
MEAN	14.67	14.04	14.25	13.76	12.76	12.94	12.85	13.30	14.05	14.93	15.46	---
MAX	15.04	14.33	14.36	14.41	13.15	13.31	13.11	13.78	14.43	15.24	15.70	---
MIN	14.35	13.80	14.12	12.78	12.42	12.64	12.62	12.89	13.82	14.47	15.23	---

Estimation of Water Elevation
January 29, 1996
for Monitor Well B-11



WHITE STREET SANITARY LANDFILL
GREENSBORO, NORTH CAROLINA

WATER QUALITY MONITORING PLAN

Prepared for:

The City of Greensboro

Prepared by:

HDR Engineering, Inc.
of North Carolina

HDR

Project No. 06770-021-018

Final Report

January 7, 1997

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SECTION 1.0
WATER QUALITY MONITORING PLAN

1.1 Purpose and Intent

The purpose of this plan is to provide a program which describes the collection and evaluation of ground-water monitoring samples collected from compliance wells installed within the uppermost aquifer adjacent to the proposed expansion area and surface water quality samples from the same vicinity. The intent of this plan is to provide detection monitoring throughout the active life and post closure care period at the White Street Sanitary Landfill Subtitle D MSWLF expansion.

This plan was prepared in accordance with the rules codified under North Carolina Solid Waste Management Rules 15A NCAC 13B, Sections .1630 through .1637 under the guidance of a North Carolina Licensed Geologist, and it is certified that this water quality monitoring plan for the White Street Sanitary Landfill Subtitle D MSWLF expansion is effective in providing early detection of any release of hazardous constituents (from any point in this expansion) to the uppermost aquifer, so as to be protective of public health and the environment.

1.2 Description of Plan Components

The following is a brief description of the main components of this water quality monitoring plan.

1.2.1 Water Quality Sampling Locations

The following sections discuss the general rationale used to select the upgradient (background) compliance well and the downgradient (detection) compliance wells based on the geologic and hydrogeologic data obtained during the development of the Hydrogeologic Design Report. All well locations were selected on their basis to provide water quality data from the uppermost aquifer beneath the facility. The rationale for selection of surface water monitoring points is also discussed.

1.2.1.1 Background Well(s)

Using the historical water-table elevation data collected during multiple ground-water monitoring events at the facility, and the geology of the site, two background compliance wells were selected on the basis of hydraulic position in relation to the solid waste management unit. Background well MW-15 is hydraulically "upgradient" of the unit and will be completed in the gneissic material. Background well MW-16 is hydraulically sidegradient of the unit and will be completed in the granitic material. Table 1-1 summarizes the proposed background monitoring wells for this plan and their approximate distance from the edge of the proposed solid waste cell. The location of these proposed wells are shown on Drawing D-6.

1.2.1.2 Downgradient (Detection) Wells

The hydrogeologic and geologic characteristics of the facility and surrounding land, the quantity, quality, and direction of ground-water flow were evaluated to determine the appropriate selection of downgradient (detection) wells. In addition to the criteria above, the distance of each proposed well relative to the waste unit (100 to 150 feet) and the boundary of the property (50 feet or greater) were also considered. Table 1-1 summarizes the proposed downgradient (detection) monitoring wells for this plan and their estimated distance from the subject compliance boundary. The location of these proposed wells is shown on Drawing D-6.

Each downgradient well will be installed with a screened interval of Schedule 40 PVC well screen with a 0.010-inch slotted opening.

TABLE 1-1
SUMMARY OF PROPOSED DETECTION MONITORING SAMPLE LOCATIONS
White Street Sanitary Landfill
Phase III
Greensboro, North Carolina

SAMPLE ID	SAMPLE TYPE	INTERVAL MONITORED	SAMPLE LOCATION AND POSITION		DETECTION MONITORING FUNCTION
			Distance and Direction From Waste Cell Boundary	Hydrogeologic Position	
MW-15	Ground Water	Uppermost Aquifer Gneissic Material	225 Feet Southwest	Upgradient	Provide Background Water Quality Data
MW-16	Ground Water	Uppermost Aquifer Granitic Material	450 Feet Southeast	Sidegradient	Provide Background Water Quality Data
MW-17	Ground Water	Uppermost Aquifer	125 Feet East	Downgradient	Provide Release Detection Data
MW-18	Ground Water	Uppermost Aquifer	135 Feet East	Downgradient	Provide Release Detection Data
MW-19	Ground Water	Uppermost Aquifer	110 Feet Northeast	Downgradient	Provide Release Detection Data
MW-20	Ground Water	Uppermost Aquifer	125 Feet North	Downgradient	Provide Release Detection Data
MW-21	Ground Water	Uppermost Aquifer	125 Feet West	Downgradient	Provide Release Detection Data
MW-22	Ground Water	Uppermost Aquifer	150 Feet North-Northwest	Downgradient	Provide Release Detection Data
MW-23	Ground Water	Uppermost Aquifer	150 Feet West-Northwest	Downgradient	Provide Release Detection Data
MW-24	Ground Water	Uppermost Aquifer	150 Feet West	Downgradient	Provide Release Detection Data
MW-25	Ground Water	Uppermost Aquifer	135 Feet North	Downgradient	Provide Release Detection Data
MW-25D	Ground Water	Deeper Portions of Uppermost Aquifer	125 Feet North	Downgradient	Provide Release Detection Data
SU-1	Surface Water	Tributary/Stream	See Drawing G-1	Upstream	Provide Background Water Quality Data
SU-2	Surface Water	Tributary/Stream	See Drawing G-1	Downstream	Provide Surface Water Quality Data
SU-3	Surface Water	Tributary/Stream	See Drawing G-1	Downstream	Provide Surface Water Quality Data
SU-4	Surface Water	Tributary/Stream	See Drawing G-1	Downstream	Provide Surface Water Quality Data

Shallow wells will have 15-foot screens and deep wells will have 10-foot screens. The construction of the final ground-water monitoring wells will be in general accordance with the North Carolina Well Construction Standards. A schematic showing general well construction details is shown on Construction Permit Application Drawing C-12.

The number and location of the proposed monitoring wells have been selected based on several considerations. First, knowledge of ground-water flow at the proposed expansion area, as described in the accompanying "Design Hydrogeologic Report," indicates that these wells encompass the downgradient area of the expansion. Second, each shallow well will be completed in the uppermost aquifer, with well screens that span the water table. Third, the lateral spacing of these wells was chosen because it is more than adequately close together considering the fine-grained nature of the saprolite aquifer in which dispersion is high. Finally, a well was located downgradient of the leachate collection sump, an area that the State considers particularly vulnerable. Well MW-25 will monitor the northeastern sump, as well as providing monitoring for that general portion of the lined facility.

In addition, a deep well, MW-25D, will be installed as a nest at MW-25. Note also that this well pair is located along the axis of the prominent bedrock surface valley that trends through that area. The actual construction details for the deep well will be worked out in consultation with the State, during installation.

1.2.1.3 Surface Water Sample Locations

Four surface water sample locations have been proposed to monitor the quality of surface water near the solid waste unit. A surface water sample representing background water quality will be collected from the upstream portion of the creek that flows to the east of the disposal area. The downstream surface water samples will be collected from

streams that will receive run-off from the landfill area. The location of these proposed surface water sampling locations can be seen on Drawing G-1.

1.2.2 Monitoring Well Data Collection

The following data will be collected and reported during the period of performance for this water quality plan. A brief discussion on the collection of and analysis of these data is provided in the sections to follow.

1.2.2.1 Ground-Water Level Data Measurements

Static ground-water levels (and total well depth) will be obtained from the proposed ground-water compliance monitoring wells immediately prior to purging during each required water quality sampling event. An electronic water level meter capable of measuring differences in water levels of 0.01 feet will be used to obtain these measurements.

All measurements will be obtained from a reference point at the top of each PVC well casing which has an elevation established by a North Carolina registered land surveyor. The horizontal position of each well will be established using North Carolina Plane Coordinates. These data will be used to calculate the volume of standing water in each well and will provide information concerning well integrity (e.g., identify the presence of excessive siltation or casing breaches). All measuring equipment will be decontaminated between use at each well by washing in a non-phosphate detergent solution and rinsing in distilled or deionized water.

1.2.2.2 Ground-Water Direction and Flow Measurements

Water table elevations will be calculated for each monitoring well using surveyed top-of-casing elevations prepared by a North Carolina registered land surveyor. Calculated potentiometric surface elevations, for each sampling event, will be placed on a scaled base map of the facility beside each respective monitoring point and contoured to

produce a water table potentiometric surface map depicting potential ground-water flow direction(s) across the expansion area. In addition, estimated ground-water flow velocities for each compliance monitoring point will be calculated for each water quality sampling event. Using the static water table potentiometric data, effective porosities for each well, hydraulic conductivities determined from slug tests of each well, and the calculated hydraulic gradients at each monitoring well for the respective sample event, an estimated seepage (pore water) velocity at each monitoring well will be calculated to evaluate potential contaminant migration.

1.2.3 Sample Parameters and Frequency

1.2.3.1 Analytical Methods

All water quality samples will be analyzed for the constituents listed in Appendix I of 40 CFR Part 258 entitled "Constituents for Detection Monitoring." Table 1-2 lists the Appendix I constituents as well as the preferred analytical method and Practical Quantitation Limit (PQL) for each constituent.

Prior to ground-water quality sampling, each well will be purged of 3 to 5 volumes of standing water or until dry. The volume of water to be removed will be calculated using the measured static water level, well depth, and well diameter of each well. Purge water will be managed in a manner which reduces the likelihood of impact to the surrounding soil.

During the purging process, field measurements (i.e., pH, temperature, and specific conductance) will be collected at each sample location in order to evaluate the effectiveness of purging procedures. These measurements will be obtained from a field-calibrated instrument in accordance with the manufacturers' specifications and industry standards (SW-846). If these field indicators do not appear to have stabilized after 5 well volumes, then well purging efforts will continue until "stabilized" conditions occur.

TABLE 1-2
SUMMARY OF WATER QUALITY ANALYTICAL PARAMETERS

White Street Sanitary Landfill
Greensboro, North Carolina

Metals:

PARAMETER	CERTIFICATION	METHOD	PQL
Antimony	low level	7041	30
Arsenic	low level	7060,7061	10
Barium	(20)	7080,6010	500
Beryllium	low level	7091	2
Cadmium	low level	7131	1
Chromium	low level	7191	10
Cobalt	low level	7201	10
Copper	regular level	7210,6010	200
Lead	low level	7421	10
Nickel	regular level	7520,6010	50
Selenium	low level	7740,7741	20
Silver	low level	7761	10
Thallium	low level	7841	10
Vanadium	low level	7911	40
Zinc	regular level	7950,6010	50

PQL - Practical Quantitation Limit in parts per billion (ppb).

TABLE 1-2 (continuation)
SUMMARY OF WATER QUALITY ANALYTICAL PARAMETERS

White Street Sanitary Landfill
Greensboro, North Carolina

Volatile Organics:

ORGANIC CONSTITUENT	METHOD	PQL
Acetone	8240/8260	100
Acrylonitrile	8240/8260	200
Benzene	8240/8260	5
Bromochloromethane	8240/8260	5
Bromodichloromethane	8240/8260	5
Bromoform	8240/8260	5
Carbon Disulfide	8240/8260	100
Carbon Tetrachloride	8240/8260	10
Chlorobenzene	8240/8260	5
Chloroethane	8240/8260	10
Chloroform	8240/8260	5
Chlorodibromomethane	8240/8260	5
1,2-Dibromo-3-Chloropropane	8240/8260	25
Ethylene Dibromide	8240/8260	5
O-Dichlorobenzene	8240/8260	5
P-Dichlorobenzene	8240/8260	5
T-1,4-Dichloro-2-Butene	8240/8260	100
1,1-Dichloroethane	8240/8260	5
Ethylene Dichloride	8240/8260	5
Vinylidene Chloride	8240/8260	5
Cis-1,2-Dichloroethene	8240/8260	5
T-1,2-Dichloroethene	8240/8260	5
Propylene Dichloride	8240/8260	5
Cis-1,3-Dichloropropene	8240/8260	10

PQL - Practical Quantitation Limit in micrograms per liter (µg /l).

TABLE 1-2 (continuation)
SUMMARY OF WATER QUALITY ANALYTICAL PARAMETERS

White Street Sanitary Landfill
Greensboro, North Carolina

Volatile Organics:

ORGANIC CONSTITUENT	METHOD	PQL
T-1,3-Dichloropropene	8240/8260	10
Ethylbenzene	8240/8260	5
Methyl Butyl Ketone	8240/8260	50
Methyl Bromide	8240/8260	10
Methyl Chloride	8240/8260	10
Methylene Bromide	8240/8260	10
Methylene Chloride	8240/8260	10
MEK; 2-Butanone	8240/8260	100
Methyl Iodide	8240/8260	10
Methyl Isobutyl Ketone	8240/8260	100
Styrene	8240/8260	10
1,1,1,2-Tetrachloroethane	8240/8260	5
1,1,2,2-Tetrachloroethane	8240/8260	5
Tetrachloroethylene	8240/8260	5
Toluene	8240/8260	5
1,1,1-Trichloroethane	8240/8260	5
1,1,2-Trichloroethane	8240/8260	5
Trichloroethylene	8240/8260	5
Trichlorofluoromethane	8240/8260	5
1,2,3-Trichloropropane	8240/8260	15
Vinyl Acetate	8240/8260	50
Vinyl Chloride	8240/8260	10
Xylenes	8240/8260	5

PQL - Practical Quantitation Limit in micrograms per liter (µg /l).

Water quality samples will be collected from the proposed monitoring wells using either a new, disposable fluorocarbon resin (Teflon) or non-dedicated Teflon bailer. If disposable Teflon bailers are used, they will be certified to have been cleaned according to EPA protocol. If non-dedicated sampling equipment is to be used, the portions of the equipment which are placed down or come in contact with any portion of the well will be decontaminated using EPA Region IV decontamination procedures under laboratory conditions

All samples will be transferred directly to the appropriate laboratory-prepared sample containers in a manner which minimizes sample agitation and cross-contamination. The more volatile sample parameters (i.e., volatile organics) will be collected first with the less sensitive parameters (i.e., metals) being the last parameter sampled. A Chain-of-Custody Record will accompany the samples during each sampling event to document changes in the custody of the samples during shipment from the site to the North Carolina certified laboratory.

One trip blank and one equipment blank will be taken during each sampling event to provide QA/QC evaluation of decontamination procedures, sample handling procedures, and container shipping procedures. Trip blanks will be analyzed for volatile organics only, while equipment blanks will be analyzed for volatile organics and metals. A duplicate water quality sample will be collected at least once a year from a selected monitoring well in order to check laboratory accuracy and QA/QC. Duplicate samples will be analyzed for the entire parameter list.

1.2.3.2 Sampling Frequency

Ground-water samples will be obtained during four independent events during the first six months of baseline sampling in order to provide enough data to adequately determine background/natural ground-water conditions or trends. For the remainder of the required

monitoring period, water quality samples from all sample points will be collected on a semiannual basis.

1.3 Statistical Evaluation of Monitoring Data

Five methods have been deemed acceptable by the NCDEHNR for the statistical evaluation of ground-water quality data from MSWLF facilities (as referenced in Section .1632 of the Ground-Water Sampling and Analysis Requirements, 15A NCAC 13B). Each of these tests have inherent advantages and disadvantages which render them more or less useful, depending on site and data set characteristics. Each method is briefly described below. In addition to the statistical analysis of the data, all sampling analytical data will be compared to the North Carolina Ground-Water Standards, 15A NCAC 2L, .0202.

1.3.1 ANOVA (Parametric)

A parametric analysis of variance (ANOVA) followed by multiple comparison procedures to identify specific sources of difference is the preferred method for a facility in the early stages of monitoring. The procedures include estimation and testing of the contrasts between the mean concentrations at each compliance well and those at the background well for each constituent.

Analysis-of-variance models are used to analyze the effects of an independent variable on a dependent variable. For ground-water monitoring data, a well or group of wells is the independent variable, and the aqueous concentration of certain constituents or of a specified contaminant or contaminants is the dependent variable. An analysis-of-variance can determine whether observed variations (differences) in aqueous concentrations between compliance and background wells are statistically significant. Use of analysis-of-variance models is appropriate in situations where background concentrations of specific constituents can be determined and the data are normally or log normally distributed. The constituents which are most appropriately evaluated using ANOVA approaches are naturally occurring metals and other geochemical parameters such as chloride, nitrate-N, and specific conductivity.

1.3.2 ANOVA (Non-Parametric)

A non-parametric analysis of variance (ANOVA) based on ranks followed by multiple comparison procedures to identify specific sources of difference can be used when the data are not normally distributed and cannot be transformed into a log-normal distribution. The procedure includes estimation and testing of the contrasts between the median of each compliance well and the background well for each constituent. This is a non-parametric procedure, which means that the laboratory values are not used; only the relative ranks are used.

1.3.3 Tolerance/Prediction Intervals

A tolerance interval or a prediction interval for each constituent is established from the background data. The concentration of each constituent in each compliance well is compared to set upper (or lower) tolerance or prediction limits.

Tolerance intervals define, with a specified probability, a range of values that are expected to contain a discrete percentage of the sample population (95%). Tolerance intervals are most appropriate for facilities which do not have high degrees of spatial variability between background and compliance well (e.g., areas underlain by homogeneous geologic materials such as granitic saprolite). With ground-water monitoring data, tolerance intervals can be constructed from concentrations found in the background well(s); these intervals are most often expressed as limits defined by the mean background well concentration plus a population size determined multiple of the standard deviation of the mean. Possible ground-water contamination is indicated when concentrations of the specified constituent(s) at the compliance well(s) plot above the calculated tolerance interval limits.

Prediction intervals are intervals in which the user is confident at a specified percentage (95%) that the next observation will lie within the interval, and are based on the number of previous observations, the number of new measurements to be made, and the level of confidence that the user wishes to obtain. This method of statistical analysis can be used in both detection and compliance monitoring programs. The mean concentration and standard

deviation are estimated from the background wells. In a compliance monitoring program, prediction intervals are constructed from compliance well concentrations beginning at the time the facility entered the compliance monitoring program. Each compliance well observation is tested to determine if it lies within the prediction interval. If it is greater (or lower) than the historical prediction limits, water quality has deteriorated to such a point that further action may be warranted.

1.3.4 Control Charts

A control chart approach provides control limits for each constituent which can be used to evaluate data produced by repeated sampling and analysis for each well in the monitoring network. This is an intrawell approach which does not involve a comparison between background and compliance wells. If any compliance well has a value or a sequence of values that lie outside of the control limits for that constituent, this may constitute statistically significant evidence of contamination.

Control charts are based on repeated independent sampling events conducted over time and may be developed for each constituent of interest. Different statistical measurements, such as the means, standard deviation and mean of replicate values at a point in time, are computed and plotted graphically together with upper predetermined limits on a chart in which the x-axis represents time. When a data point plots above these boundaries, the process is "out of control," and when it plots below the boundaries the process is "in control." Control charts can be used to analyze the inherent statistical variation of ground-water monitoring data, to note aberrations and to detect trends in the data. Further investigation of "out of control" points is necessary before taking any direct action. A control chart can be constructed for each constituent in each well to monitor the concentration of that constituent over time. New samples can be compared to the historical data from the well to determine if the well is "in or out of control." Control charts can also be used to evaluate ground-water monitoring data when these data have been adjusted and/or transformed as appropriate.

1.3.5 Other Statistical Methods

Other statistical methods submitted by the facility owner or operator and approved by the NCDEHNR may also be used. This could include development of confidence intervals in which data are compared to Federal or State established maximum contaminant limits (MCLs) or alternate contaminant limits (ACLs).

1.4 Detection Monitoring Reporting

The reporting of detection monitoring data will occur within 14 days from the completion of the statistical analysis of the ground-water quality analytical data. A report will be prepared which summarizes the sampling event; including field observations relating to the condition of the monitoring wells, field data, laboratory data, statistical analysis, sampling methodologies, quality assurance and quality control data, information on ground-water flow direction, and calculations of ground-water flow rate.

Construction Quality Assurance Plan

WHITE STREET SANITARY LANDFILL
GREENSBORO, NORTH CAROLINA

CONSTRUCTION QUALITY ASSURANCE PLAN

Prepared for:

The City of Greensboro

Prepared by:

HDR Engineering, Inc.
of North Carolina

HDR

Project No. 06770-021-018

Final Report

January 7, 1997

CONSTRUCTION QUALITY ASSURANCE PLAN

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SECTION 1.0

GENERAL

SECTION 1.0
GENERAL

1.1 INTRODUCTION

This Construction Quality Assurance (CQA) Plan has been prepared to provide the Owner, Engineer, and CQA Consultant the means to govern the construction quality and to satisfy landfill certification requirements under current solid waste management regulations.

More specifically, this CQA Plan addresses the soils and geosynthetics components of the liner and leachate collection/removal (LCR) systems. The liner system, as referenced herein, generally consists of a soil subgrade and a composite liner (consisting of a compacted soil liner and an overlying HDPE geomembrane liner). The LCR system consists of a granular drainage material with perforated collection piping, manholes, and fittings. General references in this Plan to the various components as the "liner or LCR system(s)" are intended to be as described herein.

The CQA Plan is divided into the following sections:

- Section 1.0 General
- Section 2.0 Soil Liner Construction Quality Assurance
- Section 3.0 Geomembrane Liner Construction Quality Assurance
- Section 4.0 LCR Construction Quality Assurance
- Section 5.0 Geotextile Construction Quality Assurance
- Section 6.0 High Density Polyethylene Pipe, Manholes, and Fittings Construction Quality Assurance
- Section 7.0 Geonet Construction Quality Assurance
- Section 8.0 GCL Construction Quality Assurance
- Section 9.0 Surveying Construction Quality Control
- Section10.0 Construction Quality Assurance Documentation

1.2 DEFINITIONS RELATING TO CONSTRUCTION QUALITY

1.2.1 Construction Quality Assurance (CQA)

In the context of this Plan, construction quality assurance is defined as a planned and systematic program employed by the Owner to assure conformity of the liner systems, LCR systems, and protective cover system installation with Contract Drawings, and the project specifications. CQA is provided by the CQA Consultant as a representative of the Owner and is independent from the Contractor and all manufacturers. The CQA program is designed to provide adequate confidence that items or services meet contractual and regulatory requirements and will perform satisfactorily in service.

1.2.2 Construction Quality Control (CQC)

Construction Quality Control refers to actions taken by manufacturers, fabricators, installers, or the Contractor to ensure that the materials and the workmanship meet the requirements of this CQA Plan and the project specifications. In the case of the liner and LCR systems, CQC is provided by the Contractor's CQC Consultant. In the case of geosynthetic components, material quality control (QC) is provided by the manufacturer's certification and the CQC for the installation of the various geosynthetics is provided by the Contractor's CQC Consultant. The manufacturer's specifications and quality control (QC) requirements are included in this CQA Plan by reference only. A complete updated version of each geosynthetic component manufacturer's QC Plan will be incorporated as part of the Contractor's CQC Plan.

1.2.3 CQC/CQA Certification Document

At the completion of construction and prior to placement of waste in the landfill, a certification document will be prepared by the CQA Consultant and be submitted to State Solid Waste Regulators. The certification report will include all QC testing performed by the Geosynthetics Manufacturers, all CQC testing performed by the CQC Consultant, or Geosynthetic Installers, and all CQA conformance testing performed by the CQA Consultant.

1.2.4 Discrepancies Between Documents

The CQA Plan is intended to be a supporting document to improve the overall documentation of the Work. The CQA Plan is less specific from the project specifications, and conflicts may exist between the documents. The Contractor is instructed to bring discrepancies to the attention of the Engineer or CQA Consultant for resolution. The Engineer has the sole authority to determine resolution of discrepancies existing within the Contract Documents. Unless otherwise determined by the Engineer, the more stringent requirement shall be the controlling resolution. Reference is made to the project specifications, Section 00700 - General Conditions.

1.3 PARTIES TO CONSTRUCTION QUALITY ASSURANCE

1.3.1 Description of the Parties

The parties to Construction Quality Assurance and Quality Control include the Owner, Project Manager, Engineer, Contractor, Geosynthetics Manufacturer, Geosynthetics Installer, CQA Consultant, Geosynthetics CQA Laboratory, Soils CQA Laboratory, CQC Consultant, Geosynthetics CQC Laboratory, and Soils CQC Laboratory. The lines of authority and communications between each of the parties involved in the CQA and CQC are illustrated in Figure 1 (Page 4).

1.3.1.1 Owner

The Owner is the City of Greensboro, who owns and/or is responsible for the facility.

1.3.1.2 Project Manager

The Project Manager is the official representative of the Owner. The Project Manager serves as communications coordinator for the project, initiating the resolution, preconstruction, and construction meetings outlined in Section 1.7. The Project Manager shall also be responsible for proper resolution of all quality issues that arise during construction. The Project Manager is HDR Engineering, Inc. of Charlotte, NC.

1.3.1.3 Engineer

The Engineer is responsible for the engineering design, drawings, plans and project specifications for the liner system and protective cover system. The Engineer is HDR Engineering, Inc. of Charlotte, NC.

1.3.1.4 Contractor

The Contractor is responsible for the construction of the subgrade, construction of the subbase (as applicable), soil liner berms, soil and geomembrane liners, anchor trench excavation and backfill, and for placement of the LCR system. The Contractor is responsible for submittal coordination and the overall CQC on the project.

1.3.1.5 Geosynthetics Manufacturer

The Geosynthetics Manufacturer(s) is(are) responsible for the production of geomembranes, geonets, and geotextiles. The manufacturers are responsible for Quality Control (QC) during manufacture of the geosynthetic components, certification of the properties of the geosynthetic components, and field installation criteria.

1.3.1.6 Geosynthetics Installer

The Geosynthetics Installer(s) is(are) a subcontractor of the Contractor and is(are) responsible for field handling, storing, placing, seaming, protection of (against wind, etc.), and other aspects of the geosynthetics installations, including the geomembranes and geotextiles. The Installer may also be responsible for transportation of these materials to the site, and for the preparation and completion of anchor trenches.

Figure 1 - CQA/CQC Lines of Authority and Communication

1.3.1.7 Construction Quality Assurance Consultant

The CQA Consultant is a representative of the Owner and is responsible for observing, testing, and documenting activities related to the CQC/CQA of the earthworks at the site, and the installation of the geosynthetic components of the liner and leachate collection/removal systems. The CQA Consultant is also responsible for issuing a facility certification report, sealed by a Professional Engineer registered in North Carolina.

1.3.1.8 Geosynthetics Construction Quality Assurance Laboratory

The Geosynthetics CQA Laboratory is a party, independent from the Owner, that is responsible for conducting tests on conformance samples of geosynthetics used in the liner and LCR systems. The Geosynthetics CQA Laboratory service cannot be provided by any party involved with the manufacture, fabrication, or installation of any of the geosynthetic components.

1.3.1.9 Soils Construction Quality Assurance Laboratory

The Soils Construction Quality Assurance Laboratory is a party, independent from the Owner, that is responsible for conducting geotechnical tests on conformance samples of soils used in the liner system. The Soils CQA Laboratory service cannot be provided by any party involved with the Contractor.

1.3.1.10 Construction Quality Control Consultant

The CQC Consultant is a representative of the Contractor and is responsible for the earthwork and soil liner quality control sampling and testing. The term CQC Consultant shall be used to designate the Engineer in charge of the quality control work. The personnel of the CQC Consultant also includes Quality Control Monitors who are also located at the site for construction observation and monitoring. The CQC Consultant is responsible for the timely conveyance of CQC testing results to the CQA Consultant.

1.3.1.11 Geosynthetics Construction Quality Control Laboratory

The Geosynthetics CQC Laboratory is a party, independent from the Contractor, that is responsible for conducting tests on conformance samples of geosynthetics used in the liner and LCR systems.

1.3.1.12 Soils Construction Quality Control Laboratory

The Soils Construction Quality Control Laboratory is a party, independent from the Contractor, that is responsible for conducting geotechnical tests on conformance samples of soils used in the liner system.

1.3.2 Qualifications of the Parties

The following qualifications are required of all parties involved with the manufacture, fabrication, installation, transportation, and CQC/CQA of all materials for the liner and LCR systems. Where applicable, these qualifications must be submitted by the Contractor to the Project Manager for review and approval.

1.3.2.1 Contractor

Qualifications of the Contractor are specific to the construction contract and independent of this CQA Plan.

1.3.2.2 Geosynthetics Manufacturers

Each Geosynthetics Manufacturer must satisfy the qualifications presented in the project specifications and must be prequalified and approved by the Project Manager.

The physical properties of each geosynthetic product must be certified by the geosynthetics manufacturer. The properties certified must include, at a minimum, those identified in the project specifications. Manufacturers certification must be approved by the CQA Consultant before the product is used.

1.3.2.3 Geosynthetic Installer(s)

The Geosynthetic Installer(s) will be trained and qualified to install the geosynthetics components of the liner system. Each Geosynthetics Installer must meet the requirements of the project specifications and be approved by the Project Manager. The Geomembrane Installer must be approved by the Geomembrane Manufacturer.

1.3.2.4 Construction Quality Assurance Consultant

The CQA Consultant will act as the Owner's CQA Representative and will report to the Project Manager. The CQA Consultant will perform conformance testing to satisfy the requirements of this CQA Plan, will observe the CQC work performed by the CQC Consultant, and will prepare the certification document incorporating both CQA and CQC test data. The CQA Consultant will have experience in the CQC/CQA aspects of landfill liner system construction and soils testing, and be familiar with ASTM and other related industry standards. The activities of the CQA Consultant will be performed under the supervision of a Registered Professional Engineer.

1.3.2.5 Construction Quality Control Consultant

The CQC Consultant will be a party, independent from the Contractor. The CQC Consultant will be experienced with soils, including soil liners, and geosynthetics, including geomembranes, geonets, and geotextiles. The CQC Consultant will satisfy

the requirements of the project specifications and be approved by the Project Manager. The activities of the CQC Consultant will be performed under the supervision of a Registered Professional Engineer.

1.3.2.6 Geosynthetics Construction Quality Control Laboratory

The Geosynthetics CQC Laboratory is a subcontractor of the CQC Consultant and will have experience in testing geosynthetics and be familiar with ASTM, NSF, and other applicable test standards. The Geosynthetics CQC Laboratory will be capable of providing test results within 24 hours or a reasonable time after, as agreed to at the outset of the project, receipt of samples, and will maintain that standard throughout the installation.

1.4 SCOPE OF CONSTRUCTION QUALITY ASSURANCE PLAN

The scope of this CQA Plan includes the CQA of the soils and geosynthetic components of the liner and LCR systems for the subject facility. The CQA for the selection, evaluation, and placement of the soils is included in the scope. This document is intended to be used in concert with the CQC requirements presented in the project specifications.

1.5 UNITS

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

1.6 REFERENCES

The CQA Plan includes references to the most recent version of the test procedures of the American Society of Testing and Materials (ASTM), the Federal Test Method Standards (FTMS), the "Standards for Flexible Membrane Liners" of the National Sanitation Foundation (NSF), and the "Geosynthetic Research Institute" (GRI).

1.7 SITE AND PROJECT CONTROL

To guarantee a high degree of quality during installation, clear, open channels of communication are essential. To that end, meetings are critical.

1.7.1 CQA/CQC Resolution Meeting

Prior to field mobilization by the Contractor, a Resolution Meeting will be held. This meeting will include all parties then involved, including the Project Manager, the CQA Consultant, the Engineer, the Contractor, and the CQC Consultant.

The purpose of this meeting is to begin planning for coordination of tasks, anticipate any problems which might cause difficulties and delays in construction, and, above all,

review the CQA and CQC Plans to all of the parties involved. It is very important that the rules regarding testing, repair, etc., be known and accepted by all.

This meeting should include all of the following activities:

- communicate to all parties any relevant documents;
- review critical design details of the project;
- review the seam layout drawing provided by the Geomembrane/Geosynthetic Installer.
- review the site-specific CQA and CQC Plans;
- make any appropriate modifications to the CQA and CQC Plans to ensure that they specify all testing activities that are necessary;
- reach a consensus on the CQA/CQC quality control procedures, especially on methods for determining acceptability of the soils and geosynthetics;
- review the proposed liner system and protective cover system;
- decide the number of spare seaming units for geomembranes to be maintained on site by the Geomembrane/Geosynthetic Installer (this number depends on the number of seaming crews and on the type of seaming equipment);
- select testing equipment and review protocols for testing and placement of general earthwork materials;
- confirm methods for the soil liner material selection testing, acceptable zone determinations, and test strip installation;
- confirm the methods for documenting and reporting, and for distributing documents and reports; and
- confirm the lines of authority and communication.

The meeting will be documented by the Project Manager and minutes will be transmitted to all parties.

1.7.2 CQA/CQC Preconstruction Meeting

A Preconstruction Meeting will be held at the site prior to placement of the geomembrane liner. At a minimum, the meeting will be attended by the Project Manager, Engineer, the CQA Consultant, the Contractor, the CQC Consultant, and the Geosynthetic/Geomembrane Installation Superintendent.

Specific topics considered for this meeting include:

- make any appropriate modifications to the CQA and CQC Plans;
- review the responsibilities of each party;
- review lines of authority and communication;
- review methods for documenting and reporting, and for distributing documents and reports;
- establish protocols for testing;
- establish protocols for handling deficiencies, repairs, and retesting;
- review the time schedule for all operations;
- establish rules for writing on the geomembrane, i.e., who is authorized to write, what can be written, and in which color;
- outline procedures for packaging and storing archive samples;
- review panel layout and numbering systems for panels and seams;
- establish procedures for use of the extrusion seaming apparatus, if applicable;
- establish procedures for use of the fusion seaming apparatus, if applicable;
- finalize field cutout sample sizes;
- review seam testing procedures;
- review repair procedures; and
- establish soil stockpiling locations (if any).

The meeting will be documented by the Project Manager and minutes will be transmitted to all parties. The Resolution Meeting and the Preconstruction Meeting may be held as one meeting or separate meetings, depending on the direction of the Project Manager.

1.7.3 Daily and Weekly CQA/CQC Progress Meetings

A weekly progress meeting will be held between the Project Manager, the CQA Consultant, the Contractor, the CQC Consultant, the Geosynthetic/Geomembrane Installation Superintendent, and representatives from any other involved parties. This meeting will discuss current progress, planned activities for the next week, and any new business or revisions to the work. The CQA Consultant will log any problems, decisions, or questions arising at this meeting in his daily report. Any matter requiring action which is raised in this meeting will be reported to the appropriate parties.

A daily meeting will be held between the CQA Consultant, the CQC Consultant, the Geosynthetic/ Geomembrane Installation Superintendent, and representatives from any other involved parties. This meeting will discuss current progress, planned activities for the next shift, and any new business or revisions to the work. The CQA Consultant will log any problems, decisions, or questions arising at this meeting in his daily report. Any matter requiring action which is raised in this meeting will be reported to the appropriated parties.

Meeting frequency will depend on the schedule of the project and the mutual agreement of all parties involved.

1.7.4 Problem or Work Deficiency Meetings

A special meeting will be held when and if a problem or deficiency is present or likely to occur. At a minimum, the meeting will be attended by all interested parties, the Contractor, the Project Manager, and the CQA Consultant. If the problem requires a design modification, the Engineer should also be present. The purpose of the meeting is to define and resolve the problem or work deficiency as follows:

- define and discuss the problem or deficiency;
- review alternative solutions; and
- implement an action plan to resolve the problem or deficiency.

The meeting will be documented by the Project Manager and minutes will be transmitted to affected parties.

SECTION 2.0

SOIL LINER CONSTRUCTION QUALITY ASSURANCE

SECTION 2.0
SOIL LINER CONSTRUCTION QUALITY ASSURANCE

2.1 INTRODUCTION

This section of the CQA Plan addresses the soil components of the liner system, and outlines the soils CQA program to be implemented with regard to materials confirmation, laboratory and field confirmation test requirements, overview and interfacing with the Contractor's CQC Program, and resolution of problems.

2.2 EARTHWORK CONSTRUCTION

2.2.1 Subgrade

The subgrade material below the controlled fill will be prepared by the Contractor prior to the placement of fill. The CQC Consultant will provide density testing of the pre-fill subgrade at the frequency specified in the project specifications. The CQA Consultant will observe the proofroll by the Contractor, review the density test data provided by the CQC Consultant, and provide verification that the pre-fill subgrade is acceptable. The CQA Consultant may conduct confirmation density testing as deemed appropriate.

2.2.2 Structural/Controlled Fill

The Contractor shall place fill in accordance with the project specifications. The CQC Consultant shall provide testing of the controlled fill material in accordance with the project specifications. The CQA Consultant will provide confirmation testing of the controlled fill as deemed appropriate.

2.3 SOIL LINER SYSTEM

2.3.1 Soil Liner Subgrade

Testing will be conducted by the CQC Consultant as observed by the CQA Consultant. The subgrade material below the subbase is composed of controlled fill and in situ soils. The surface of the subgrade will be prepared prior to the construction of the subbase. The CQA Consultant will visually examine the surface of the subgrade to verify that any potentially deleterious materials have been removed.

2.3.2 Soil Liner Material

The soil liner material shall be placed and compacted in accordance with the project specifications. The CQC Consultant shall conduct field density and moisture tests at the frequency presented in the project specifications. The CQA Consultant shall provide conformance tests at a frequency of approximately 10 percent of the required CQC tests. Additional CQA conformance testing may be performed at the discretion of the CQA Consultant.

Hydraulic Conductivity, Atterberg Limits, and Percent Fines testing of the soil liner material shall be performed by the CQC Consultant in accordance with the project specifications. Additional CQA conformance testing may be performed at the discretion of the CQA Consultant.

Thickness measurement shall be conducted in accordance with the project specifications by the CQC Consultant and observed by the CQA Consultant.

2.4 SOILS TESTING

2.4.1 Test Methods

All testing used to evaluate the suitability or conformance of soils materials will be carried out in accordance with the project specifications.

2.4.2 Soils Testing Requirements

The soil CQC testing must comply with the minimum frequencies presented in the project specifications. The frequency of CQA testing required will be determined by the CQA Consultant in light of the potential variability of materials and the acceptance/failure rate of the CQC testing.

2.5 SOILS CONSTRUCTION QUALITY ASSURANCE

CQA will be performed on all soil components of the liner construction. CQA evaluation will consist of: (1) monitoring the work and observing the CQC testing; and (2) performing laboratory and field conformance tests. Laboratory CQA conformance tests will be conducted on samples taken at the borrow source, stockpile, and during the course of the work prior to construction. Field CQA conformance tests will be conducted during the course of the work.

2.5.1 Monitoring

The CQA Consultant shall monitor and document the construction of all soil components. Monitoring the construction work for the subbase soil, and the soil component of the liner system, includes the following:

- observing CQC testing to determine the water content and other physical properties of the subbase and soil component of the liner system during compaction and compilation of the data;
- monitoring the loose thickness of lifts as placed;
- monitoring the action of the compaction and/or heavy hauling equipment on the construction surface (i.e., penetration, pumping, cracking. etc.); and
- monitoring the number of passes used to compact each lift.

2.5.2 Construction Quality Assurance Judgmental Testing

During construction, the frequency of conformance testing may be increased at the discretion of the CQA Consultant when visual observations of construction performance indicate a potential problem. Additional testing for suspected areas will be considered when:

- the rollers slip during rolling operation;
- the lift thickness is greater than specified;
- the fill material is at an improper moisture content;
- fewer than the specified number of roller passes are made;
- dirt-clogged rollers are used to compact the material;
- the rollers may not have used optimum ballast;
- the fill materials differ substantially from those specified; or
- the degree of compaction is doubtful.

2.5.3 Perforations in Soil Liner

Perforations that must be filled will include, but not be limited to, the following:

- nuclear density test probe locations;
- permeability sampling locations; and/or
- thickness checks.

Unless otherwise noted, or as directed by the Project Manager, all perforations of the subbase by probes or sample tubes will be backfilled in accordance with project specifications. The CQA Consultant will observe and confirm that adequate procedures are being employed.

2.5.4 Deficiencies

If a defect is discovered in the earthwork product, the CQC Consultant will immediately determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQC Consultant will determine the extent of the deficient area by additional tests, observations, a review of records, or other appropriate means. If the defect is related to adverse site conditions, such as overly wet soils or surface desiccation, the CQC Consultant will define the limits and nature of the defect.

2.5.5.1 Notification

After determining the extent and nature of a defect, the CQC Consultant will notify the Project Manager, the CQA Consultant, and Contractor and schedule appropriate retests when the work deficiency is corrected. The CQA Consultant shall observe all retests on defects.

2.5.5.2 Repairs and Retesting

The Contractor will correct the deficiency to the satisfaction of the CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQC Consultant will develop and present to the Project Manager and CQA Consultant suggested solutions for approval.

All retests recommended by the CQC Consultant must verify that the defect has been corrected before any additional work is performed by the Contractor in the area of the deficiency. The CQA Consultant will verify that all installation requirements are met and that all submittals are provided.

2.5.5.3 Penalties

Refer to Specification Section 02775.

SECTION 3.0

GEOMEMBRANE LINER CONSTRUCTION QUALITY ASSURANCE

SECTION 3.0
GEOMEMBRANE LINER
CONSTRUCTION QUALITY ASSURANCE

3.1 GEOMEMBRANE MANUFACTURER'S CERTIFICATION, AND CQA CONFORMANCE TESTING

3.1.1 Geomembrane Manufacturer's Certification

Compliance testing will be performed by the Geomembrane Manufacturer to demonstrate that the product meets the manufacturers' quality control and conformance test minimum standards for geomembrane specifications and exceeds the project specifications. Additional testing will be performed by the CQA Consultant for purposes of conformance evaluation. If the results of the Geomembrane Manufacturer's and the CQA Consultant's testing differ, the testing will be repeated by the CQA Consultant's laboratory, and the Geomembrane Manufacturer will be allowed to monitor this testing. The results of this latter series of tests will prevail, provided that the applicable test methods have been followed.

3.1.1.1 Raw Material

Prior to the installation of any geomembrane material, the Geomembrane Manufacturer will provide the CQA Consultant and the CQC Consultant with the following information as a bound document with the individual sections clearly identified:

- the origin (Resin Supplier's name and resin production plant), identification (brand name, number), and production date of the resin;
- a copy of the quality control certificates issued by the Resin Supplier;
- reports on the tests conducted by the Geomembrane Manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the project; and
- a statement that the percentage of reclaimed polymer added to the resin is in accordance with the project specifications.

The CQA Consultant will review these documents and report any discrepancies with the above requirements to the Project Manager.

3.1.1.2 Geomembrane Manufacturing

Prior to the installation, the Geomembrane Manufacturer will provide the Contractor and the CQA Consultant with the following:

- a properties sheet including, at a minimum, all specified properties, measured using test methods indicated in the project technical specifications, or equivalent;
- the sampling procedure and results of testing; and
- a certification that property values given in the properties sheet are minimum average roll values and are guaranteed by the Geomembrane Manufacturer.

The CQA Consultant will review these documents and verify that:

- the reported property values certified by the Geomembrane Manufacturer meet all of the project technical specifications;
- the measurements of properties by the Geomembrane Manufacturer are properly documented and that the test methods used are acceptable; and
- Report any discrepancies with the above requirements to the Project Manager.

3.1.1.3 Rolls and Sheets

Prior to shipment, the Geomembrane Manufacturer will provide the CQA Consultant and the CQC Consultant with a quality control certificate for each roll (HDPE geomembrane) or sheet (non-HDPE geomembrane) of geomembrane provided. The quality control certificate will be signed by a responsible party employed by the Geomembrane Manufacturer, such as the Production Manager. The quality control certificate will include:

- roll numbers and identification; and
- sampling procedures and results of quality control tests -- as a minimum, results will be given for thickness, tensile characteristics and tear resistance, evaluated in accordance with the methods indicated in the project specifications or equivalent methods approved by the Engineer.

The quality control certificate will be bound and included as part of the report required in Section 3.1.1.1.

The CQA Consultant will:

- verify that the quality control certificates have been provided at the specified frequency and that each certificate identified the rolls or sheets related to it;
- review the quality control certificates and verify that the certified roll or sheet properties meet the project technical specifications; and
- report any discrepancies with the above requirements to the Project Manager.

3.2 GEOMEMBRANE INSTALLATION

3.2.1 Transportation, Handling, and Storage

3.2.1.1 Transportation and Handling

The CQA Consultant will verify that:

- handling equipment used on the site is adequate, meets manufacturer's recommendations, and does not pose any risk of damage to the geomembrane; and
- the Geomembrane Installer's personnel handle the geomembranes with care.

Upon delivery at the site, the CQA Consultant will conduct a surface observation of all rolls and sheets for defects and damage. This examination will be conducted without unrolling rolls or unfolding sheets unless defects or damages are found or suspected. The CQA Consultant will indicate to the Project Manager:

- any rolls or sheets, or portions thereof, that should be rejected and removed from the site because they have severe flaws; and
- any rolls or sheets that have minor repairable flaws.

Refer to ASTM D4873 for detailed methods.

3.2.1.2 Storage

The CQA Consultant will document that the Contractor's storage of the geomembrane provides adequate protection against moisture, dirt, shock, and other sources of damage or contamination.

3.2.2 Earthwork

3.2.2.1 Surface Preparation

The CQC Consultant and the Geomembrane Installer will certify in writing that the surface on which the geomembrane will be installed meets line and grade, and the surface preparation requirements of the project specifications. The certificate of acceptance will be given by the CQC Consultant to the CQA Consultant prior to commencement of geomembrane installation in the area under consideration. The CQA Consultant will give a copy of this certificate to the Project Manager.

To ensure a timely covering of the soil liner surface, the Project Manager may allow subgrade acceptance in areas as small as one acre. After the supporting soil has been accepted by the Geomembrane Installer, it will be the Geomembrane Installer's responsibility to indicate to the Project Manager of any change in the supporting soil condition that may require repair work. If the CQA Consultant concurs with the Geomembrane Installer, then the Project Manager will ensure that the supporting soil is repaired.

3.2.2.2 Anchorage System

The CQA Consultant will verify that anchor trenches have been constructed and backfilled according to project specifications and design drawings.

3.2.3 Geomembrane Placement

3.2.3.1 Field Panel Identification

The CQA Consultant will document that the Geomembrane Installer labels each field panel with an "identification code" (number or letter-number consistent with the layout plan) agreed upon by the CQC Consultant, Geomembrane Installer, and CQA Consultant at the CQA/CQC Preconstruction Meeting, Section 1.7.2.

The Geomembrane Installer will establish a table or chart showing correspondence between roll numbers and field panel identification codes. This documentation shall be submitted to the CQC Consultant and CQA Consultant weekly for review and verification. The field panel identification code will be used for all quality control and quality assurance records.

3.2.3.2 Field Panel Placement

3.2.3.2.1 Location

The CQA Consultant will verify that field panels are installed at the location indicated in the Geomembrane Installer's layout plan, as approved or modified in Section 3.2.3.1.

3.2.3.2.2 Installation Schedule

The CQA Consultant will evaluate every change in the schedule proposed by the Geomembrane Installer and advise the Project Manger on the acceptability of that change. The CQA Consultant will verify that the condition of the supporting soil has not changed detrimentally during installation.

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

3.2.3.2.3 Placement of Geomembrane

The CQA Consultant will verify that project specification related restrictions on placement of geomembrane are fulfilled. Additionally, the CQA Consultant will verify that the supporting soil has not been damaged by weather conditions.

The CQA Consultant will inform the Project Manager if the above conditions are not fulfilled.

3.2.3.2.4 Damage

The CQA Consultant will visually observe each panel, after placement and prior to seaming, for damage. The CQA Consultant will advise the Project Manager which panels, or portion of panels, should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels which have been rejected will be marked and their removal from the work area recorded by the CQA Consultant. Repairs will be made according to procedures described in the project specifications.

As a minimum, the CQA Consultant will document that:

- the panel is placed in such a manner that it is unlikely to be damaged; and
- any tears, punctures, holes, thin spots, etc., are either marked by the Geomembrane Installer for repair or the panel is rejected.

3.2.4 Field Seaming

3.2.4.1 Seam Layout

The Geomembrane Installer will provide the CQA Consultant with a seam layout drawing, i.e., a drawing of the facility to be lined showing all expected seams. The CQA Consultant and Engineer will review the seam layout drawing and verify that it is consistent with the accepted state of practice and this CQA Plan. In addition, no panels not specifically shown on the seam layout drawing may be used without the Project Manager's prior approval.

A seam numbering system compatible with the panel numbering system will be agreed upon at the Resolution and/or Preconstruction Meeting, Section 1.7. An on-going written record of the seams and repair areas shall be maintained by the Geomembrane Installer with weekly review by the CQA Consultant.

3.2.4.2 Requirements of Personnel

The Geomembrane Installer will provide the CQA Consultant with a list of proposed seaming personnel and their experience records. This document will be reviewed by the Project Manager and the CQA Consultant for compliance with project specifications.

3.2.4.3 Seaming Equipment and Products

Field seaming processes must comply with project specifications. Proposed alternate processes will be documented and submitted to the CQA Consultant for his approval. Only seaming apparatus which have been specifically approved by make and model will be used. The CQA Consultant will submit all documentation to the Engineer for his concurrence.

3.2.4.4 Nondestructive Seam Continuity Testing

The Geomembrane Installer will nondestructively test all field seams over their full length using test methods approved by the project specifications. The CQA Consultant shall periodically observe the nondestructive testing to ensure conformance with this CQA Plan and the project specifications.

For approximately 10% of the noncomplying tests, the CQA Consultant will:

- observe continuity testing of the repaired areas performed by the Geomembrane Installer;

- confirm the record location, date, test unit number, name of tester, and compile the record of testing provided by the Geomembrane Installer;

- provide a walkthrough inspection of all impacted seam areas and verify that the areas have been tested in accordance with the CQA Plan and project specifications; and

- verify that the Geomembrane Installer has marked repair areas with the appropriate color-coded marking pencil.

3.2.4.5 Destructive Seam Testing

Destructive seam tests will be performed by the CQC consultant at locations and a frequency in accordance with the project specifications. The CQA Consultant will perform conformance tests on a minimum of 10% of the CQC destructive seam test samples obtained. Additional destructive seam tests may be required at the CQA Consultant's discretion. Selection of such locations may be prompted by suspicion of contamination, excessive grinding, offcenter and/or offset seams, or any other potential cause of imperfect seaming.

3.2.4.5.1 Geosynthetics Construction Quality Assurance Laboratory Testing

Destructive test samples will be packaged and shipped by the CQA Consultant in a manner that will not damage the test sample. The Project Manager will be responsible for storing the archive samples. These procedures will be fully outlined at the Resolution Meeting, Section 1.7. Test samples will be tested by the Geosynthetics CQA Laboratory.

Conformance testing will include "Seam Strength" and "Peel Adhesion" (ASTM D638 using one-inch strips and a strain rate of two inches per minute) in accordance with ASTM D4437 and project specifications. All geomembrane destructive test samples that fail to meet project specifications shall be saved and sent to the CQA Consultant for observation.

The Geosynthetics CQA Laboratory will provide preliminary test results no more than 24 hours after they receive the samples. The CQA Consultant will review laboratory test results as soon as they become available.

3.2.4.5.2 Defining Extent of Destructive Seam Test Failure

All defective seam test failures must be bounded by seam tests from which destructive samples passing laboratory tests have been taken. The CQA Consultant will document repair actions taken in conjunction with all destructive seam test failures.

3.2.5 Defects and Repairs

All seams and nonseam areas of the geomembrane will be examined by the CQC Consultant for identification of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. Each suspected location, both in seam and nonseam areas, will be nondestructively tested using methods in accordance with the project specifications. Each location which fails the nondestructive testing will be marked by the CQC Consultant and repaired by the Geomembrane Installer. Repair procedures will be in accordance with project specifications or procedures agreed to by the Project Manager in the preconstruction meeting. The CQA Consultant will observe all repair procedures and advise the Project Manager of any problems.

3.2.6 Backfilling of Anchor Trench

Anchor trenches will be will be backfilled and compacted as outlined in the project specifications. The CQA Consultant will review the backfilling operation and advise the Project Manager of any problems.

3.2.7 Liner System Acceptance

The Geomembrane Installer and the Geosynthetic Manufacturers will retain all ownership and responsibility for the geosynthetics in the landfill cell until acceptance by the Owner.

The geomembrane component of the liner system will be accepted by the Owner when:

- the installation is finished;
- verification of the adequacy of all seams and repairs, including associated testing, is complete;
- CQC Consultant provides the CQA Consultant and Project Manager with a final copy of the nondestructive test documentation, repair information, and as-built drawings.
- CQA Consultant furnishes the Project Manager with certification that the geomembrane was installed in accordance with the Geosynthetic Manufacturer's recommendations as well as the Plans and project specifications;
- all documentation of installation is completed including the CQA Consultant's final report; and

- certification by the CQA Consultant, including Record Drawing(s), sealed by a Professional Engineer registered in the state in which the project is located, has been received by the Project Manger.

The CQA Consultant will certify that the installation has proceeded in accordance with this CQA Plan and the project specifications for the project except as noted to the Project Manager.

3.2.8 Materials in Contact with Geomembranes

The quality assurance procedures indicated in this Subsection are only intended to assure that the installation of these materials does not damage the geomembrane. Although protective geosynthetics and geotextiles have been incorporated into the liner system, all reasonable measures to protect the geomembrane and provide additional quality assurance procedures are necessary to assure that systems built with these materials will be constructed to ensure proper performance.

3.2.8.1 Soils

Prior to placement, the CQA Consultant will visually confirm that all soil materials to be placed against the geomembrane comply with project specifications. The Geomembrane Installer will provide the CQA Consultant a written surface acceptance certificate in accordance with Section 3.2. 1. All soil materials shall be placed and compacted in accordance with project specifications.

3.2.8.2 Sumps and Appurtenances

The CQA Consultant will verify that:

- installation of the geomembrane in appurtenance areas, and connection of the geomembrane to appurtenances have been made according to the project specifications;
- extreme care is taken while seaming around appurtenances since neither nondestructive nor destructive testing may be feasible in these areas;
- the geomembrane has not been visibly damaged while making connections to appurtenances;
- The installation of the geomembrane shall be exercised so as not to damage sumps; and

- the CQA Consultant will inform the Project Manager if the above conditions are not fulfilled.

SECTION 4.0

LCR CONSTRUCTION QUALITY ASSURANCE

SECTION 4.0
LCR CONSTRUCTION QUALITY ASSURANCE

4.1 INTRODUCTION

This section of the CQA plan addresses the sand and gravel drains, and the soil buffer layer of the LCR system. By reference to Sections 5.0 and 6.0 of this CQA Plan, this section also addresses the perforated plastic pipes and geotextile filters and cushions that are included in the LCR system. This section outlines the CQA program to be implemented with regard to materials confirmation, laboratory and field test requirements, overview and interfacing with the Contractor's CQC Program, and resolution of problems.

4.2 GRANULAR LEACHATE COLLECTION SYSTEM

4.2.1 Protective Cover (Leachate Collection Layer) Material

The LCR layer shall be placed and compacted in accordance with the project specifications. The CQC Consultant will provide gradation and density testing of the granular material at the frequency specified in the project specifications. The CQA Consultant will observe that placement of the granular material is done in a manner to protect the geomembrane, and review the gradation and density test data provided by the CQC Consultant. The CQA Consultant may conduct confirmation gradation and density testing as deemed appropriate.

4.2.2 Sump and LCR Pipe Drain Material

The drain material placed in the sumps and surrounding the LCR drainage pipe shall be placed in accordance with the project specifications. The CQC Consultant will provide gradation and mineralogical testing of the gravel material at the frequency specified in the project specifications. The CQA Consultant will observe that placement of the gravel is done in a manner to protect the geomembrane and plastic pipe and review the gradation and density test data provided by the CQC Consultant. The CQA Consultant may conduct confirmation gradation and additional testing as deemed appropriate.

4.3 RELATED MATERIALS

4.3.1 Geotextile Cushion and Filter Material

The geotextile cushion placed beneath the gravel drain material, and the geotextile filter placed between the sand drainage layer and the soil buffer layer shall be placed in accordance with project specifications. The CQA program for these materials is presented in Section 5.0 of this CQA Plan.

4.3.2 High Density Polyethylene (HDPE) Pipe Material

The perforated HDPE pipe placed within the gravel drain material shall be placed in accordance with project specifications. The CQA program for this material is presented in Section 6.0 of this CQA Plan.

4.3.3 Soil Buffer Layer Material

The soil buffer layer material shall be placed and compacted in accordance with project specifications. The CQC Consultant will provide classification testing of the material at the frequency specified in the project specifications. The CQA Consultant will observe that the placement of the soil buffer is done in a manner to protect the filter geotextile and review the classification data provided by the CQC Consultant. The CQA Consultant may conduct confirmation classification testing as deemed appropriate.

4.4 MATERIALS TESTING

4.4.1 Test Methods

All testing used to evaluate the suitability or conformance of LCR materials will be carried out in accordance with the project specifications.

4.4.2 Material Testing Requirements

The material CQC testing must comply with the minimum frequencies presented in the project specifications. The frequency of CQA testing will be determined by the CQA Consultant in light of the potential variability of the materials and the acceptance/failure rate of the CQC testing.

4.5 LCR CONSTRUCTION QUALITY ASSURANCE

CQA will be performed on all components of the LCR system construction. CQA evaluation will consist of: (1) monitoring the work and observing the CQC testing, and (2) performing laboratory and field conformance tests. Laboratory CQA conformance tests will be conducted on samples taken at the borrow source, stockpile, and during the course of work prior to construction. Field conformance tests will be conducted during the course of the work.

4.5.1 Monitoring

The CQA Consultant shall monitor and document the construction of all LCR components. Monitoring the construction work for the natural materials of the LCR system includes the following:

- reviewing CQC testing for gradation and other physical properties of the natural materials and compilation of the data;
- monitoring the minimum vertical buffer maintained between field equipment and the geomembrane; and
- monitoring the placement of the natural materials does not fold or damage the geomembrane in any way.

4.5.2 Deficiencies

If a defect is discovered in the earthwork product, the CQC Consultant will immediately determine the extent and nature of the defect and report it to the CQA Consultant. If the defect is indicated by an unsatisfactory test result, the CQC Consultant will determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the CQA Consultant deems appropriate.

4.5.2.1 Notification

After determining the extent and nature of a defect, the CQC Consultant will notify the Project Manager and Contractor and schedule appropriate retests when the work deficiency is corrected. The CQA Consultant shall observe all retests on defects.

4.5.2.2 Repairs and Retesting

The Contractor will correct the deficiency to the satisfaction of the CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQC Consultant will develop and present to the Project Manager suggested solutions for his approval.

All retests recommended by the CQC Consultant must verify that the defect has been corrected before any additional work is performed by the Contractor in the area of the deficiency. The CQA Consultant will verify that all installation requirements are met and that all submittals are provided.

4.5.2.3 Penalties

Refer to Specification Section 02775.

SECTION 5.0

GEOTEXTILE MATERIAL AND INSTALLATION QUALITY ASSURANCE

SECTION 5.0
GEOTEXTILE MATERIAL AND INSTALLATION QUALITY ASSURANCE

5.1 MANUFACTURING

The Contractor will provide the CQA Consultant with a list of guaranteed minimum average roll value" properties (as defined by the Federal Highway Administration), for the type of geotextile to be delivered. The Contractor will also provide the CQA Consultant with a written certification from the Geotextile Manufacturer that the materials actually delivered have "minimum average roll value" properties which meet or exceed all property values guaranteed for that type of geotextile.

The CQA Consultant will examine all manufacturer certifications to ensure that the property values listed on the certifications meet or exceed those specified for the particular type of geotextile. Any deviations will be reported to the Project Manager.

The inspection methods, handling techniques, and property values identified in this section for the filter geotextile shall also apply to geotextile portion of the geocomposite drain which will be heat bonded to the geonet (see Section 7.0 for more detail).

5.2 LABELING

The Geotextile Manufacturer will identify all rolls of geotextile in conformance with the project specifications. The CQA Consultant will examine rolls upon delivery and any deviation from the above requirements will be reported to the Project Manager.

5.3 SHIPMENT AND STORAGE

During shipment and storage, the geotextile will be protected as required by manufacturer's recommendations and the project specifications. The CQA Consultant will observe rolls upon delivery at the site and any deviation from the above requirements will be reported to the Project Manager.

5.4 HANDLING AND PLACEMENT

The Geosynthetic Installer will handle all geotextiles in such a manner as required by the project specifications. Any noncompliance will be noted by the CQA Consultant and reported to the Project Manager.

5.5 SEAMS AND OVERLAPS

All geotextiles will be seamed or overlapped in accordance with project specifications or as approved by the CQA Consultant and Engineer.

5.6 REPAIR

Any holes or tears in the geotextile will be repaired in accordance with the project specifications. The CQA Consultant will observe any repair and note any noncompliance with the above requirements and report them to the Project Manager.

5.7 PLACEMENT AND MATERIALS

All soil materials located on top of a geotextile shall be placed in accordance with the project specifications. Any noncompliance will be noted by the CQA Consultant and reported to the Project Manager.

SECTION 6.0

HIGH DENSITY POLYETHYLENE MANHOLES, PIPE AND FITTINGS CONSTRUCTION QUALITY ASSURANCE

SECTION 6.0

HIGH DENSITY POLYETHYLENE MANHOLES, PIPE AND FITTINGS CONSTRUCTION QUALITY ASSURANCE

6.1 MATERIAL REQUIREMENTS

All HDPE manholes, pipe, and fittings shall be produced in accordance with the project specifications.

6.2 MANUFACTURER

Prior to the installation of HDPE manholes or pipes, the Manufacturer will provide to the Contractor and the CQA Consultant the following:

- a properties sheet including, at a minimum, all specified properties, measured using test methods indicated in the project technical specifications;
- a list of quantities and descriptions of materials other than the base resin which comprise the pipe;
- the sampling procedure and results of testing; and
- a certification by the HDPE Pipe Manufacturer that values given in the properties sheet are minimum values and are guaranteed by the HDPE Pipe Manufacturer.

The CQA Consultant will review these documents and verify that:

- the property values certified by the HDPE Pipe Manufacturer meet all of the project technical specifications; and
- the measurements of properties by the HDPE Pipe Manufacturer are properly documented and that the test methods used are acceptable.
- Report any discrepancies with the above requirements to the Project Manager.

6.2.1 Verification and Identification

Prior to shipment, the Contractor will provide the Project Manager and the CQA Consultant with a quality control certification for each lot/batch of HDPE pipe provided. The quality control certificate will be signed by a responsible party

employed by the HDPE Pipe Manufacturer, such as the Production Manger. The quality control certificate will include:

- lot/batch number and identification; and
- sampling procedures and results of quality control tests.

The CQA Consultant will:

- verify that the quality control certificates have been provided at the specified frequency for all lots/batches of pipe, and that each certificate identifies the pipe lot/batch related to it; and
- review the quality control certificates and verify that the certified properties meet the project technical specifications.

6.3 NONDESTRUCTIVE TESTING

6.3.1 Nondestructive Testing of Joints

All nonperforated HDPE joints must be nondestructively tested. These pipe joints will be tested using the pressure test as provided in the project technical specifications. Other nondestructive test methods may be used only when:

- the Geosynthetic Installer can prove its effectiveness;
- the method is approved by the Pipe Manufacturer; and
- the method is approved by the Engineer.

The Project Manager and the CQA Consultant will verify the effectiveness and validity of the alternative test method,

The CQA Consultant will report any nonconformance of testing methods to the Project Manager.

SECTION 7.0

HDPE GEONET CONSTRUCTION QUALITY ASSURANCE

Note: Throughout this section, references to geonet shall be interpreted and applied to the geonet portion of the geocomposite drain. The HDPE geonet will have a nonwoven geotextile heat bonded on each side to form the geocomposite drain. CQA considerations for the nonwoven geotextile are presented in Section 5.0.

SECTION 7.0
HDPE GEONET CONSTRUCTION QUALITY ASSURANCE

7.1 MATERIAL REQUIREMENTS

All HDPE geonet shall be produced in accordance with the project specifications.

7.2 MANUFACTURING

The Geonet Manufacturer will provide the Contractor and the CQC Consultant with a written certification, signed by a responsible party, that the geonets actually delivered have properties which meet or exceed the guaranteed properties.

The CQA Consultant will examine all manufacturer's certifications to ensure that the property values listed on the certifications meet or exceed the project specifications. Any deviations will be reported to the Project Manager.

7.3 LABELING

The Geonet Manufacturer will identify all rolls of geonet in accordance with project specifications. The CQA Consultant will examine rolls upon delivery and any deviation from the above requirements will be reported to the Project Manager.

7.4 SHIPMENT AND STORAGE

Geonet cleanliness is essential to its performance; therefore, the shipping and storage of geonet must be in accordance with the project specifications. The CQA Consultant will examine rolls upon delivery and any deviation from the above requirements will be reported to the Project Manager.

The CQA Consultant will verify that geonets are free of dirt and dust just before installation. The CQA Consultant will report the outcome of this verification to the Project Manager; and, if the geonets are judged dirty or dusty, they will be washed by the Geonet Installer prior to installation.

Washing operations will be observed by the CQA Consultant and improper washing operations will be reported to the Project Manager.

7.5 HANDLING AND PLACEMENT

The Geonet Installer will handle all geonets in a manner in accordance with the project specifications. The CQA Consultant will note any noncompliance and report it to the Project

Manager.

7.6 STACKING AND JOINING

When several layers of geonets are stacked, care should be taken to ensure that stacked geonets are placed in the same direction. A stacked geonet will never be laid in perpendicular directions to the underlying geonet (unless otherwise specified by the Engineer). The CQA Consultant will observe the stacking of geonets and will note any noncompliance and report it to the Project Manager.

Adjacent geonets will be joined according to construction drawings and project specifications. The CQA Consultant will note any noncompliance and report it to the Project Manager.

7.7 REPAIR

Any holes or tears in the geonet will be repaired in accordance with project specifications. The CQA Consultant will observe any repair, note any noncompliance with the above requirements, and report them to the Project Manager.

7.8 PLACEMENT OF SOIL MATERIALS

All soil materials placed over the geonet should be placed in accordance with project specifications so as to ensure:

- the geonet and underlying geomembrane are not damaged;
- minimal slippage of the geonet on the underlying geomembrane occurs; and
- no excess tensile stresses occur in the geonet.

Any noncompliance will be noted by the CQA Consultant and reported to the Project Manager.

SECTION 8.0

GEOSYNTHETIC CLAY LINER (GCL) MATERIAL AND INSTALLATION QUALITY ASSURANCE

SECTION 8.0
GEOSYNTHETIC CLAY LINER (GCL) MATERIAL AND INSTALLATION QUALITY ASSURANCE

8.1 MANUFACTURING

The Contractor will provide the CQA Consultant with a list of guaranteed "minimum average roll value" properties (as defined by the Federal Highway Administration) for the GCL to be delivered. The Contractor will also provide the CQA Consultant with a written certification from the GCL Manufacturer that the materials actually delivered have "minimum average roll value" properties which meet or exceed all property values guaranteed for the GCL.

The CQA Consultant will examine all manufacturer certifications to determine if the property values listed on the certifications meet or exceed those specified for the GCL. Any deviations will be reported to the Engineer.

8.2 LABELING

The GCL Manufacturer will identify all rolls of GCL in conformance with the project specifications. The CQA Consultant will examine rolls upon delivery and any deviation from the above requirements will be reported to the Engineer.

8.3 SHIPMENT AND STORAGE

During shipment and storage, the GCL will be protected as required by the project specifications. The CQA Consultant will observe rolls upon delivery at the site and any deviation from the above requirements will be reported to the Engineer.

8.4 HANDLING AND PLACEMENT

The Geosynthetic Installer will handle the GCL in such a manner as required by the project specifications. Any noncompliance will be noted by the CQA Consultant and reported to the Engineer.

8.5 SEAMS AND OVERLAPS

The GCL will be seamed or overlapped in accordance with project specifications or as approved by the CQA Consultant and Engineer.

8.6 REPAIR

Any holes or tears in the GCL will be repaired in accordance with the project specifications. The CQA Consultant will observe any repair and note any noncompliance with the above requirements and report them to the Engineer.

8.7 PLACEMENT AND MATERIALS

All soil materials located on top of the GCL shall be placed in accordance with the project specifications. Any noncompliance will be noted by the CQA Consultant and reported to the Engineer.

SECTION 9.0

SURVEYING CONSTRUCTION QUALITY CONTROL

SECTION 9.0
SURVEYING CONSTRUCTION QUALITY CONTROL

9.1 INTRODUCTION

Surveying of lines and grades is conducted on an ongoing basis during construction of the component liner and leachate collection systems. Close CQC of the surveying is absolutely essential to ensure that slopes are properly constructed. The surveying conducted at the site shall be performed by the Contractor.

9.2 SURVEY CONTROL

Permanent benchmarks and baseline control points are to be established for the site at locations convenient for daily tie-in. The vertical and horizontal controls for this benchmark will be established within normal land surveying standards.

9.3 SURVEYING PERSONNEL

The Contractor's survey crew will consist of a Senior Surveyor, and as many Surveying CQC Monitors as are required to satisfactorily undertake the requirements for the work. All Surveying CQC personnel will be experienced in the provision of these services, including detailed, accurate documentation.

All surveying will be performed under the direct supervision of a Registered Professional Engineer (PE) or Licensed Land Surveyor (PLS) licensed in the state in which the project is located. The Licensed Land Surveyor may be the Senior Surveyor.

9.4 PRECISION AND ACCURACY

A wide variety of survey equipment is available to meet the requirements of this project. The survey instruments used for this work should be sufficiently precise and accurate to meet the needs of the project. All survey instruments should be capable of reading to a precision of 0.01 foot and with a setting accuracy of 20 seconds. (5.6×10^{-3} degrees).

9.5 LINES AND GRADES

The following surfaces shall be surveyed to verify the lines and grades achieved during construction. The survey should at least include (as deemed appropriate by the Engineer and CQA Consultant):

- one or more construction baselines;
- a working grid with a sufficient number of benchmarks;

- surface of the subgrade;
- all existing structures;
- surface of the soil liner component;
- invert elevation of and location of leachate collection/header and force main piping at each lateral intersection and endpoint, and every 50 feet between the intersections and endpoints;
- inverts of sumps and manholes;
- surface of the leachate collection layer (protective cover);
- elevations of and locations of temporary berms;
- top/toe of all perimeter berms, roads, and channels;
- location of edge of liner, tie-in seam to adjacent existing liner system (as applicable);
- corners/intersections of all geosynthetic rolls or panels; and
- location of anchor trenches.

Laser planes are highly recommended for achieving the correct lines and grades during construction of each surface.

9.6 FREQUENCY AND SPACING

All surveying will be carried out immediately upon completion of a given installation to facilitate progress and avoid delaying commencement of the next installation. In addition, spot checks, as determined by the Senior Surveyor, CQA Consultant, or Project Manager, during construction may be necessary to assist the Contractor in complying with the required grades.

The following spacings and locations will be provided by the CQC Surveyor, as a minimum, for survey points:

- surfaces with slopes less than 10 percent will be surveyed on a square grid not wider than 100 feet;
- on slopes greater than 10 percent, a square grid not wider than 100 feet will be used, but, in any case, a line of survey points at the crest, midpoint, and toe of the slope will be taken;

- a line of survey points no farther than 100 feet apart will be taken along any slope break (this will include the inside edge and outside edge of any bench on a slope);

- a line of survey points not farther than 50 feet apart will be taken for all piping used for leachate collection/detection lines, in particular, at the lateral intersection and line end points;

- at a minimum, a line of survey points no farther than 50 feet apart will be taken for all cleanout risers;

- at a minimum, every 100 feet along the perimeter of the primary and secondary liner system; and

- at a minimum, a line of survey points no farther than 50 feet apart will be taken for all piping used for the leachate collection/detection lines.

9.7 THICKNESS MEASUREMENTS

The CQC surveyor as a representative of the Contractor shall obtain top and bottom elevations of the soil liner at a maximum 100-foot grid points and at all grade break lines prior to placement of the geomembrane liner system. The procedure for obtaining top and bottom elevations of the soil liner shall be agreed to by the CQA Consultant and Engineer prior to construction. The CQC Surveyor shall review the survey information with the Contractor to ensure that the survey demonstrates compliance with the project technical specifications. The Contractor is responsible for identifying and reporting to the CQA Consultant any areas of non-compliance evidenced by the survey, and for repairing such areas. The CQA Consultant and Contractor shall review the thickness measurements of the soil liner component prior to placement of the geomembrane liner.

9.8 TOLERANCES

Except for liner components where no minus tolerances are acceptable, the following are maximum tolerances for survey points:

- on surfaces, the maximum tolerances shall be 0.2 foot. This tolerance must be set to the record elevation of the surface below it and not the design elevation;

- on piping for leachate collection/detection lines, the maximum tolerance shall be 0.02 foot. This tolerance must be set to the record elevation of the surface below it and not the design elevation; and

- on cleanout risers, the tolerance shall be 0.2 foot This tolerance must be set to the record elevation of the surface below it and not the design elevation.

9.9 DOCUMENTATION

All field survey notes will be retained by the Senior Surveyor. The results from the field surveys will be documented on a set of Survey Record (As-Built) Drawings by the Contractor for submittal to the CQA Consultant. The Contractor shall certify to the CQA Consultant and Engineer that the results of the survey demonstrates compliance with the Contract Documents. These drawings shall, at a minimum, show the final elevations and locations of all surfaces and appurtenances surveyed in Subsection 2.5 of this CQA/CQC Plan.

SECTION 10.0

CONSTRUCTION QUALITY ASSURANCE DOCUMENTATION

SECTION 10.0
CONSTRUCTION QUALITY ASSURANCE DOCUMENTATION

10.1 DOCUMENTATION

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

This CQA plan integrates the testing and inspection performed by the CQC Consultant in accordance with the project specifications with the CQA overview and conformance testing performed by the CQA Consultant, in accordance with this CQA Plan.

The CQA Consultant will provide the Project Manager with the CQC Consultant's daily and weekly reports including signed descriptive remarks, data sheets, and logs to verify that all CQC monitoring activities have been carried out. The CQA Consultant will also provide the Project manager with a weekly report summarizing CQA activities and identifying potential quality assurance problems. The CQA Consultant will also maintain at the job site a complete file of Plans, Reports, project specifications, a CQA Plan, checklists, test procedures, daily logs, and other pertinent documents.

10.2 RECORDKEEPING

The CQC Consultant's reporting procedures will include preparation of a daily report which, at a minimum, will consist of: (a) field notes, including memoranda of meetings and/or discussions with the Contractor; (b) observation logs and testing data sheets; and © construction problem and solution data sheets. The daily report must be completed at the end of each CQC Consultant's shift, prior to leaving the site. This information will be submitted weekly to and reviewed by the CQA Consultant.

The CQC Consultant's weekly reports must summarize the major events that occurred during that week. Critical problems that occur shall be communicated verbally to the Project Manager or CQA Consultant immediately as well as being included in the weekly reports. The CQC Consultant's weekly report must be submitted to the CQA Consultant no later than the Monday following the week reported.

The CQA Consultant's weekly report must summarize the CQC Consultant's weekly and daily reports, CQA conformance testing activities, construction problems that occurred, and the resolution of construction problems. The CQA Consultant's weekly report should identify all potential or actual compliance problems outstanding. The CQA Consultant's weekly report must be submitted to the Project Manager on the Wednesday following the week reported.

10.2.1 Memorandum of Discussion with CQC Consultant or Geosynthetic Installer

A report will be prepared summarizing each discussion between the CQA Consultant and the CQC Consultant or Geosynthetic Installer. At a minimum, the report will include the following information:

- date, project name, location, and other identification;
- name of parties to discussion at the time;
- relevant subject matter or issues;
- activities planned and schedule; and
- signature of the CQA Consultant.

10.2.2 CQA Observation Logs and Testing Data Sheets

CQA observation logs and conformance testing data sheets will be prepared by the CQA Consultant on a weekly basis. At a minimum, these logs and data sheets will include the following information:

- an identifying sheet number for cross referencing and document control;
- date, project name, location, and other identification;
- data on weather conditions;
- a reduced-scale Site Plan showing all proposed work areas and test locations;
- descriptions and locations of ongoing construction;
- descriptions and specific locations of areas, or units, of work being tested and/or observed and documented;
- locations where tests and samples were taken;
- a summary of test results;
- calibrations or recalibrations of test equipment, and actions taken as a result of recalibration;

- off-site materials received, including quality verification documentation;
- decisions made regarding acceptance of units of work, and/or corrective actions to be taken in instances of substandard quality; and
- the CQA Consultant's signature.

10.2.3 CQA Construction Problem and Solution Data Sheets

CQA sheets describing special construction situations will be cross-referenced with specific CQA observation logs and testing data sheets, and must include the following information, where available:

- an identifying sheet number for cross referencing and document control;
- a detailed description of the situation or deficiency;
- the location and probable cause of the situation or deficiency;
- how and when the situation or deficiency was found or located;
- documentation of the response to the situation or deficiency;
- final results of any responses;
- any measures taken to prevent a similar situation from occurring in the future; and
- the signature of the CQA Consultant, and signature of the Project Manager indicating concurrence if required by this CQA Plan.

The Project Manager will be made aware of any significant recurring non-conformance with the project specifications. The Project Manager will then determine the cause of the non-conformance and recommend appropriate changes in procedures or specification. When this type of evaluation is made, the results will be documented, and any revision to procedures or project specifications will be approved by the Owner and Engineer.

10.3 CQA PHOTOGRAPHIC REPORTING DATA SHEETS

Photographic reporting data sheets, where used, will be cross-referenced with CQA observation logs and testing data sheets and/or CQA construction problem and solution data sheets. Photographs shall be taken at regular intervals during the construction process and in all areas deemed critical.

These photographs will serve as a pictorial record of work progress, problems, and mitigation activities. The basic file will contain color prints; negatives will also be stored in a separate file in chronological order. These records will be presented to the Project Manager upon completion of the project.

In lieu of photographic documentation, videotaping may be used to record work progress, problems, and mitigation activities. The Project Manager may require that a portion of the documentation be recorded by photographic means in conjunction with video taping.

10.4 DESIGN AND/OR PROJECT TECHNICAL SPECIFICATION CHANGES

Design and/or project specification changes may be required during construction. In such cases, the CQA Consultant will notify the Project Manager and the Engineer. The Project Manager will then notify the appropriate agency, if necessary.

Design and/or project specification changes will be made only with the written agreement of the Project Manager and the Engineer, and will take the form of an addendum to the project specifications. All design changes shall include a detail (if necessary) and state which detail it replaces in the plans.

10.5 CQA PROGRESS REPORTS

The CQA Consultant will prepare a summary progress report each week, or at time intervals established at the pre-construction meeting. As a minimum, this report will include the following information;

- a unique identifying sheet number for cross-referencing and document control;
- the date, project name, location, and other information;
- a summary of work activities during progress reporting period;
- a summary of construction situations, deficiencies, and/or defects occurring during the progress reporting period;
- summary of all test results, failures and retests, and

- signature of the CQA Consultant.

10.6 SIGNATURE AND FINAL REPORT

At the completion of each major construction activity at the landfill unit, the CQA Consultant will certify all required forms, observation logs, field and laboratory testing data sheets including sample location plans, construction problems and solution data sheets. The CQA Consultant will also provide a final report which will certify that the work has been performed in compliance with the plans and project technical specifications, and that the supporting documents provide the necessary information.

The CQA Consultant will also provide summaries of all the data listed above with the report. The Record Drawings will include scale drawings depicting the location of the construction and details pertaining to the extent of construction (e.g., depths, plan dimensions, elevations, soil component thicknesses, etc.). All surveying and base maps required for development of the Record Drawings will be done by the Construction Surveyor. These documents will be certified by the Contractor and CQC Consultant and delivered to the CQA Consultant and included as part of the CQA documentation (Certification) report.

It may be necessary to prepare interim certifications, as allowed by the regulatory agency to expedite completion and review.

10.7 STORAGE OF RECORDS

All handwritten data sheet originals, especially those containing signatures, will be stored by the Project Manager in a safe repository on site. Other reports may be stored by any standard method which will allow for easy access. All written documents will become property of the Owner.

WHITE STREET SANITARY LANDFILL
GREENSBORO, NORTH CAROLINA

CALCULATIONS

Prepared for:

The City of Greensboro

Prepared by:

HDR Engineering, Inc.
of North Carolina

Project No. 06770-021-018

Final Report

January 7, 1997

CALCULATIONS

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HDR Computation

HDR

Project CITY OF GREENSBORO	Computed DTD	Date 11/6/96
Subject VOLUMES	Checked CDM	Date 11/7/96
Task	Sheet	Of

VOLUME/SITE LIFE CALCULATIONS ARE BASED ON HAND-COMPUTED (PLANIMETER) CALCULATIONS. THE COMPUTER CALCULATIONS WERE PERFORMED TO VERIFY VOLUMES CALCULATED USING A PLANIMETER.

CB0803

11/6/96

Site Volume Table: Unadjusted

Cut yards	Fill yards	Net yards	Method
Site: cell1-v3			
Stratum: vol-3 opcov 1-opc			
35199.51	1782716.98	1747517.47 (F)	End area
32505.03	1780632.54	1748127.51 (F)	Grid
cell 1&2			
Site: cell2-v4			
Stratum: vol-4 opcov 2-opc			
35322.48	3356754.68	3321432.21 (F)	End area
30547.08	3354635.48	3324088.40 (F)	Grid

cut is match error

CB0803

Site Volume Table: Unadjusted

Cut yards	Fill yards	Net yards	Method
Site: cell3-v			
Stratum: vol-5 opcov cell3			
0.00	5236765.81	5236765.81 (F)	End area
0.00	5223310.78	5223310.78 (F)	Grid

Phase III final cover vs. operational cover

JOB NO. [illegible] | NO

HDR Computation

Project	CITY OF GREENSBORO	Computed ITD	Date 11/6/96
Subject	CELL 1	Checked CDM	Date 11/7/96
Task	VOLUME / AIRSPACE AVAILABLE	Sheet 1	Of 3

DWG C-5R & C-4R

VOLUMES TAKEN FROM TOP OF OPERATIONAL COVER.

ELEV.	AREA, FT²	VOLUME, CY (TRUNCATED PYRAMID)
744'	13,600	
		15,900
750'	154,900	
		139,100
760'	653,600	
		293,700
770'	941,100	
		663,700
792'	694,300	
		47,800
794'	598,600	
		539,800
831'	203,200	
		35,700
836'	53,600	
		5,100
846'	2,700	

CAP => 6" TOPSOIL
18" VEGETATIVE SUPPORT LAYER
18" COMPACTED SOIL BARRIER

CAP = 3.5' × 10 AC × 43560 ÷ 27 = 55,000 CY

1,740,000 CY − 55,000 CY = 1,685,000 CY

1,740,000 CY: VOLUME REPRESENTS AIRSPACE FOR WASTE, D&I COVER, & CAP

1,685,000 CY: CELL 1 VOLUME AVAILABLE FOR WASTE & D&I COVER

HDR Computation

Project	City of Carlsbad	Computed DTD	Date 11/6/96
Subject	Cell 2	Checked CDM	Date 11/7/96
Task	Volume/Airspace Available	Sheet 2	Of 3

DWG C-4R + C-6E

Elev.	Area, Ft²	Volume CY (Truncated Pyramid)
754'	19,200	
		11,200
760'	107,800	
		84,800
770'	377,300	
		170,700
780'	549,700	
		240,100
792'	530,700	
		38,500
794'	508,400	
		602,300
832'	352,200	
		24,800
834'	317,800	
		74,200
846'	403,900 - 53,600 (230,300)	
		76,800
846'	343,200 - 2,700	
		213,900
872'	122,000	
		12,800
878'	12,200	

Volumes Taken From Top Of Operational Cover.

Cap => 6" Topsoil
18" Vegetative Support Layer
18" Compacted Soil Barrier

Cover = 3.5' x 15 Ac x 43560 ÷ 27 = 85,000 CY

1,550,000 CY - 85,000 CY = 1,465,000 CY

↑ Volume Represents Airspace For Waste, D&I Cover, & Cap

↑ Cell 2 Volume Available For Waste & D&I Cover

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11/6/96
Subject	CELL 3	Checked CDM	Date 11/7/96
Task	VOLUME/AIRSPACE AVAILABLE	Sheet 3	Of 3

ELEV	AREA, FT²	VOLUME, CY (TRUNCATED PYRAMID)
766'	4,900	
		64,400
780'	327,500	
		199,000
792'	579,700	
		43,800
794'	603,600	
		251,300
806'	527,900	
		469,900
832'	449,100	
		32,400
834'	426,500	
		510,100
872'	301,900	
		18,200
874'	274,600 - 80,900	
		36,300
878'	312,600 - 12,200	
		214,800
910'	84,200	
		10,400
920'	0	

VOLUMES TAKEN FROM TOP OF OPERATIONAL COVER.

CAP => 6" TOPSOIL
18" VEGETATIVE SUPPORT LAYER
18" COMPACTED SOIL BARRIER

CELL 3 CAP = 3.5' x 26.32 AC x 43560 ÷ 27 = 145,000 CY

TOTAL CAP = 3.5 x 51.32 AC x 43560 ÷ 27 = 290,000 CY

CELL 1 => 1,740,000 CY
CELL 2 => 1,550,000 CY
CELL 3 => + 1,850,000 CY
5,140,000 CY
CAP => - 290,000 CY
4,850,000 CY ← CELLS 1, 2, +
VOLUME AVAILABLE FOR WASTE & D+I COVER

1,850,000 CY − 145,000 CY = 1,705,000 CY

↑ VOLUME REPRESENTS AIRSPACE FOR WASTE, D+I COVER, & CAP

↑ CELL 3 VOLUME AVAILABLE FOR WASTE & D+I COVER

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11/6/96
Subject	SITE LIFE	Checked CDM	Date 11/7/96
Task		Sheet 1	Of 2

CELL 1

GROSS VOLUME = 1,740,000 CY
CAP VOLUME = - 55,000 CY
1,685,000 CY

WASTE-TO-SOIL = 4:1
D&I COVER = $\frac{1,685,000}{5}$ = 335,000 CY
NET REFUSE VOLUME = 1,685,000 - 335,000 = 1,350,000 CY
REFUSE DENSITY = 1000 LB/CY
INTAKE = 22,300 TONS/MONTH
LIFE = 30 MONTHS

CELL 2

GROSS VOLUME = 1,550,000 CY
CAP VOLUME = 85,000 CY
1,465,000 CY

WASTE-TO-SOIL = 4:1
D&I COVER = $\frac{1,465,000}{5}$ = 295,000 CY
NET REFUSE VOLUME = 1,465,000 - 295,000 = 1,170,000 CY
REFUSE DENSITY = 1000 LB/CY
INTAKE = 22,300 TONS/MONTH
LIFE = 26 MONTHS

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11/6/96
Subject	SITE LIFE	Checked CDM	Date 11/7/96
Task		Sheet 2	Of 2

CELL 3

GROSS VOLUME = 1,850,000 CY
CAP VOLUME = - 145,000 CY
1,705,000 CY

WASTE-TO-SOIL = 4:1
DAILY COVER = $\frac{1,705,000}{5}$ = 340,000 CY
NET REFUSE VOLUME = 1,705,000 - 340,000 = 1,365,000 CY
REFUSE DENSITY = 1000 LB/CY
INTAKE = 22,300 TONS/MONTH
LIFE = 31 MONTHS

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11/6/96
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

DURING INITIAL PHASES OF CONSTRUCTION STORMWATER PIPES WILL DRAIN RUNOFF INTO THE SURROUNDING BASINS. THE 10" Φ STORMWATER PIPE ON THE EAST SIDE WILL DRAIN APPROXIMATELY 13 ACRES. THE CENTER 12" Φ STORMWATER PIPE WILL DRAIN APPROXIMATELY 19 ACRES. THE NORTHERN 10" Φ STORMWATER PIPE WILL DRAIN APPROXIMATELY 6 ACRES. THE WESTERN 6" Φ STORMWATER PIPE WILL DRAIN APPROXIMATELY 5 ACRES. THE WESTERN 10" Φ STORMWATER PIPE WILL DRAIN APPROXIMATELY 9 ACRES.

SUBCELL BERMS WILL DIVERT RUNOFF TO THE PIPE, OF WHICH RUNOFF WILL ENTER THROUGH A "T" SECTION. AS REFUSE IS PLACED IN A SUBCELL, THE OPENING AT THE "T" WILL BE SEALED CLOSED. THE RUNOFF INTO THE STORMWATER PIPES SHALL CAUSE SOME PONDING AT THE ENTRANCE OF EACH "T" SECTION. A MINIMAL AMOUNT OF HEADWATER WILL BE MAINTAINED SO AS TO NOT EXCEED THE HEIGHT OF THE SUBCELL BERM.

DURING THE INITIAL PHASES OF FILLING RUNOFF WILL DRAIN TO THE NORTH AND NORTHEAST SEDIMENT BASINS. THE NORTH SEDIMENT BASIN IS CAPABLE OF HANDLING A DRAINAGE AREA OF 15 ACRES (SEE SEDIMENT BASIN CALC'S), BUT WILL ONLY BE ACCEPTING 14 ACRES. THE NORTHEAST SEDIMENT BASIN WILL ACCEPT AN AREA OF 37 ACRES (DESIGN AND ACTUAL DRAINAGE SIZE, SEE SEDIMENT BASIN DESIGN CALCULATIONS).

THE NORTHWEST, EAST, AND SOUTH SEDIMENT BASINS WERE DESIGNED TO ACCEPT DRAINAGE FROM THE FINAL GRADES. PLEASE REFER TO SEDIMENT BASIN DESIGN CALCULATIONS.

Job No. 6770-021-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-22
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

DESIGN CULVERT FOR SOUTH SEDIMENT BASIN, Q_{25} = 71 CFS FOR 55 ACRE PHASE. EAST SEDIMENT BASIN PROVIDES DRAINAGE FOR 15.8 ACRES.

$Q = {}^{15.8}/_{55} = 0.29 \Rightarrow 71 \text{ CFS} \times 0.29 = \underline{20.6 \text{ CFS}}$

TRY 24" C.M.P. CULVERT

CHECK INLET CONTROL

${}^{HW}/_{D} = 1.5$ (FROM CHART 2)

$HW = 1.5(2)$

$HW = \underline{3.0 \text{ FT}}$

CHECK OUTLET CONTROL

$S = \frac{80 \text{ FT}}{756 - 729} = 0.21$

$d_c = 1.6$ (FROM CHART 4)

FROM HEADLOSS NOMOGRAPH (CHART 6) $\Rightarrow$ $H = 3.4$ FT

$h_o = \frac{d_c + D}{2} = \frac{1.6 + 2}{2} = 1.8$

$LS_o = 80(0.21) = 16.8$

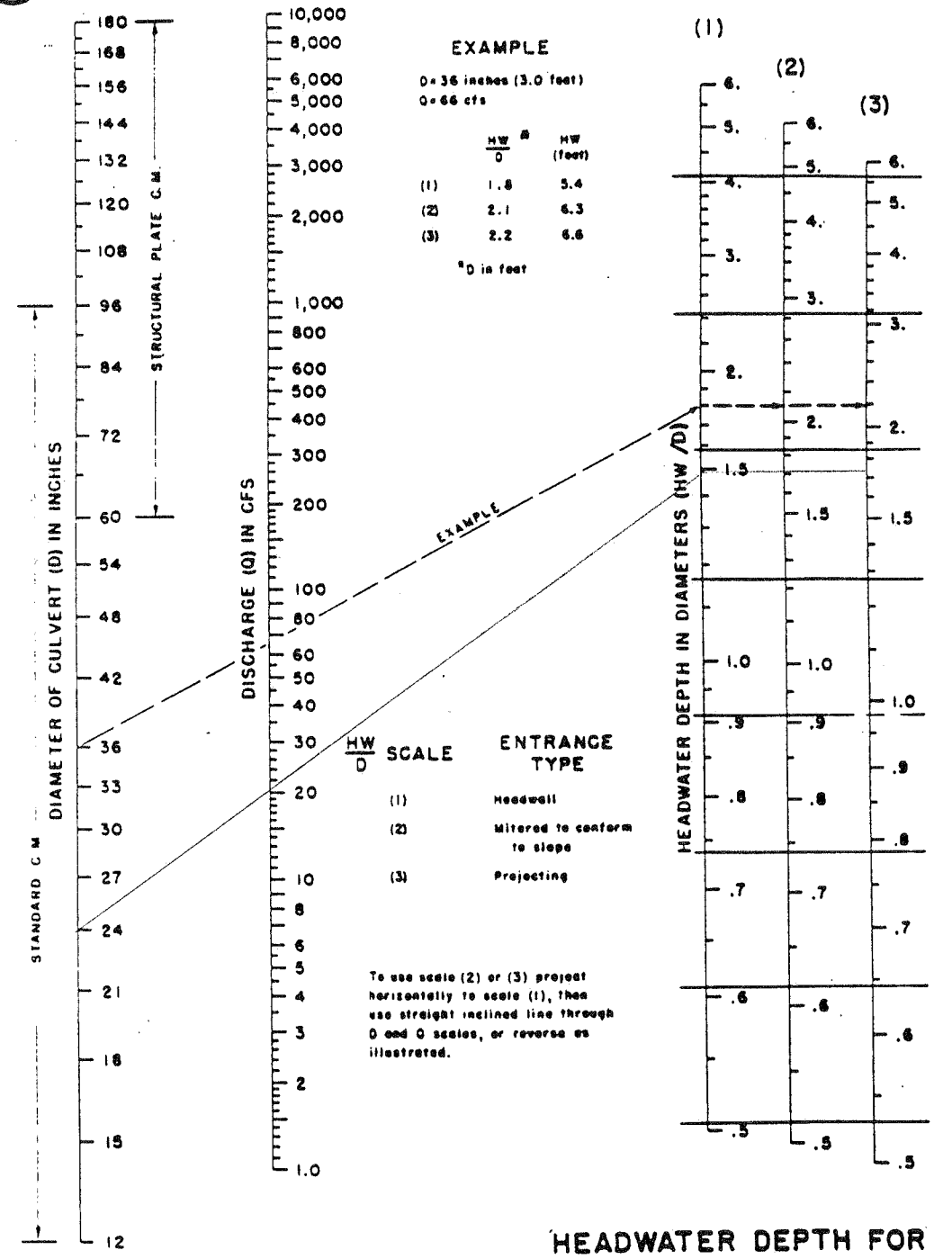
$H_{in} = H + h_o - LS_o$

$= 3.4 + 1.8 - 16.8$

$= -11.6 \text{ FT}$

SAY $\underline{0 \text{ FT}}$

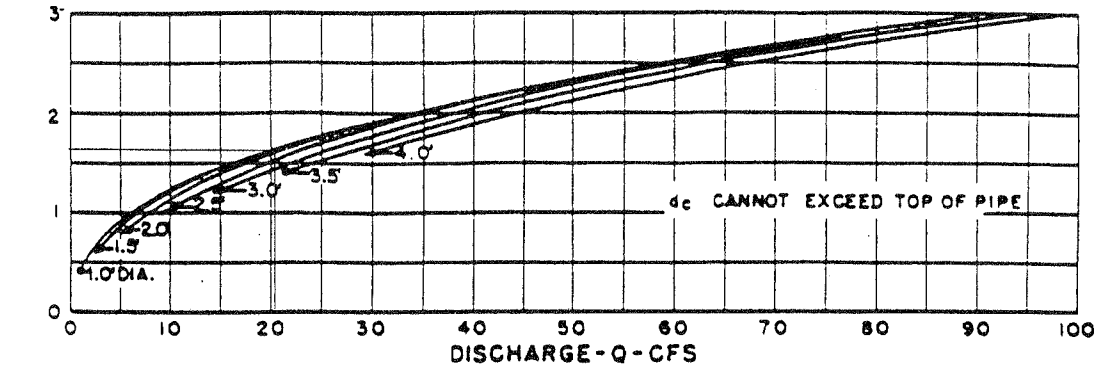
CHART 2

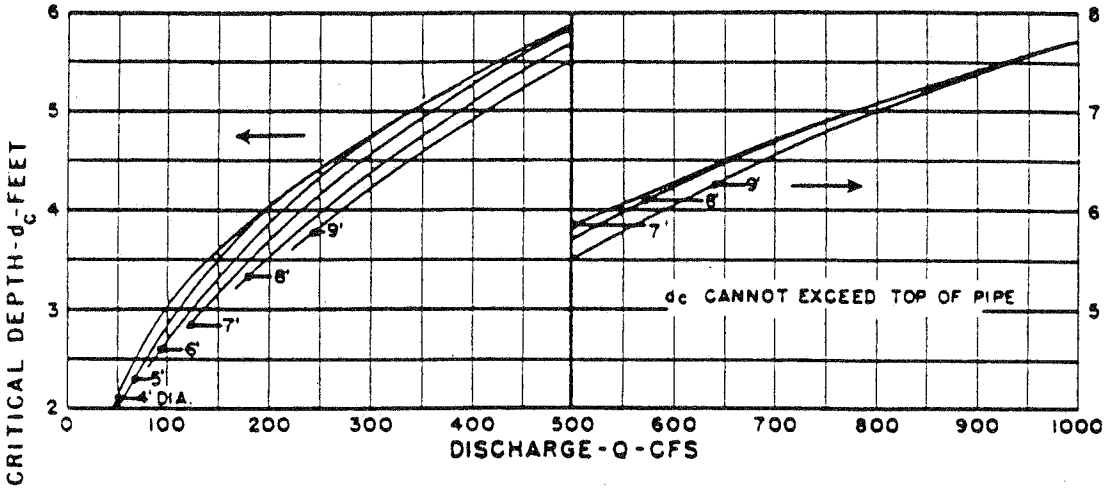


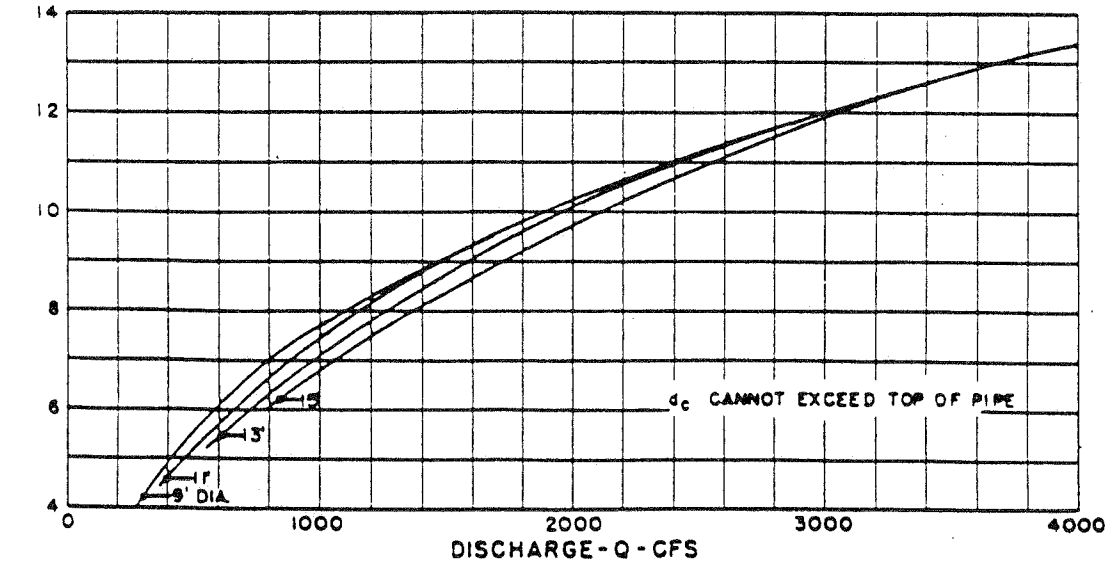
HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

CHART 4





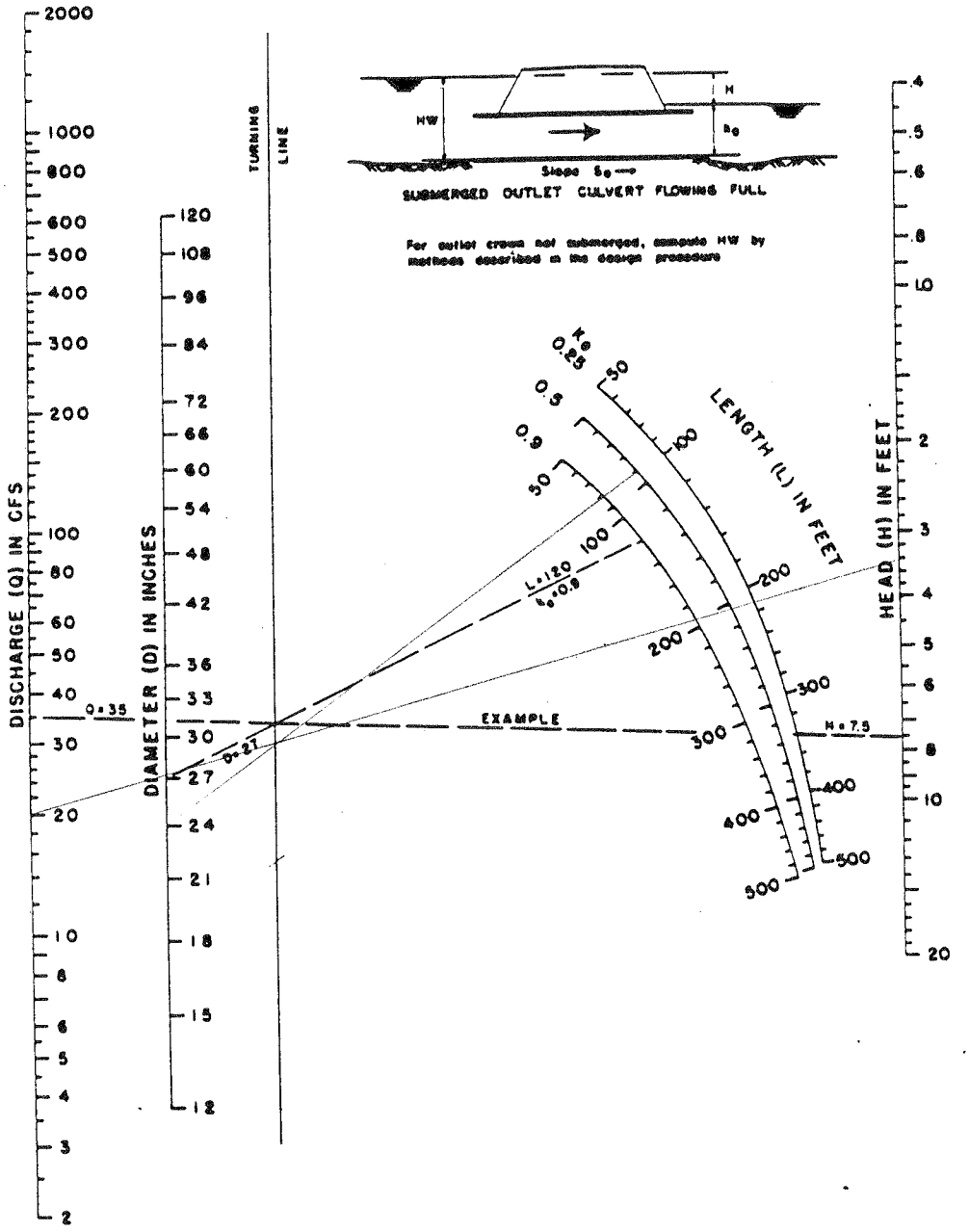


BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

CHART 6



HEAD FOR
STANDARD
C. M. PIPE CULVERTS
FLOWING FULL
n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

Job No. 6770-021-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-22-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

DESIGN CULVERT FOR NORTHWEST SEDIMENT BASIN. $Q_{25} = 71$ CFS FOR 55 ACRE PHASE. EAST SEDIMENT BASIN PROVIDES DRAINAGE FOR 17.5 ACRES.

$Q \Rightarrow {}^{17.5}/_{55} = 0.32 \Rightarrow 71 \text{ CFS} \times .32 = \underline{22.7 \text{ CFS}}$

TRY 24" ϕ C.M.P. CULVERT

CHECK INLET CONTROL

$HW/D = 1.6$ (FROM CHART 2)

$HW = 1.6(2)$

$HW = \underline{3.2 \text{ FT}}$

CHECK OUTLET CONTROL

$L = 120$ FT $\qquad d_c = 1.75$ (CHART 4)

$S = \frac{76 - 736}{120} = 0.25$

FROM HEADLOSS NOMOGRAPH (CHART 6) $\Rightarrow H = 5.8$ FT

$h_o = \frac{d_c + D}{2} = \frac{1.75 + 2}{2} = 1.875$

$LS_o = 120(0.25) = 30$

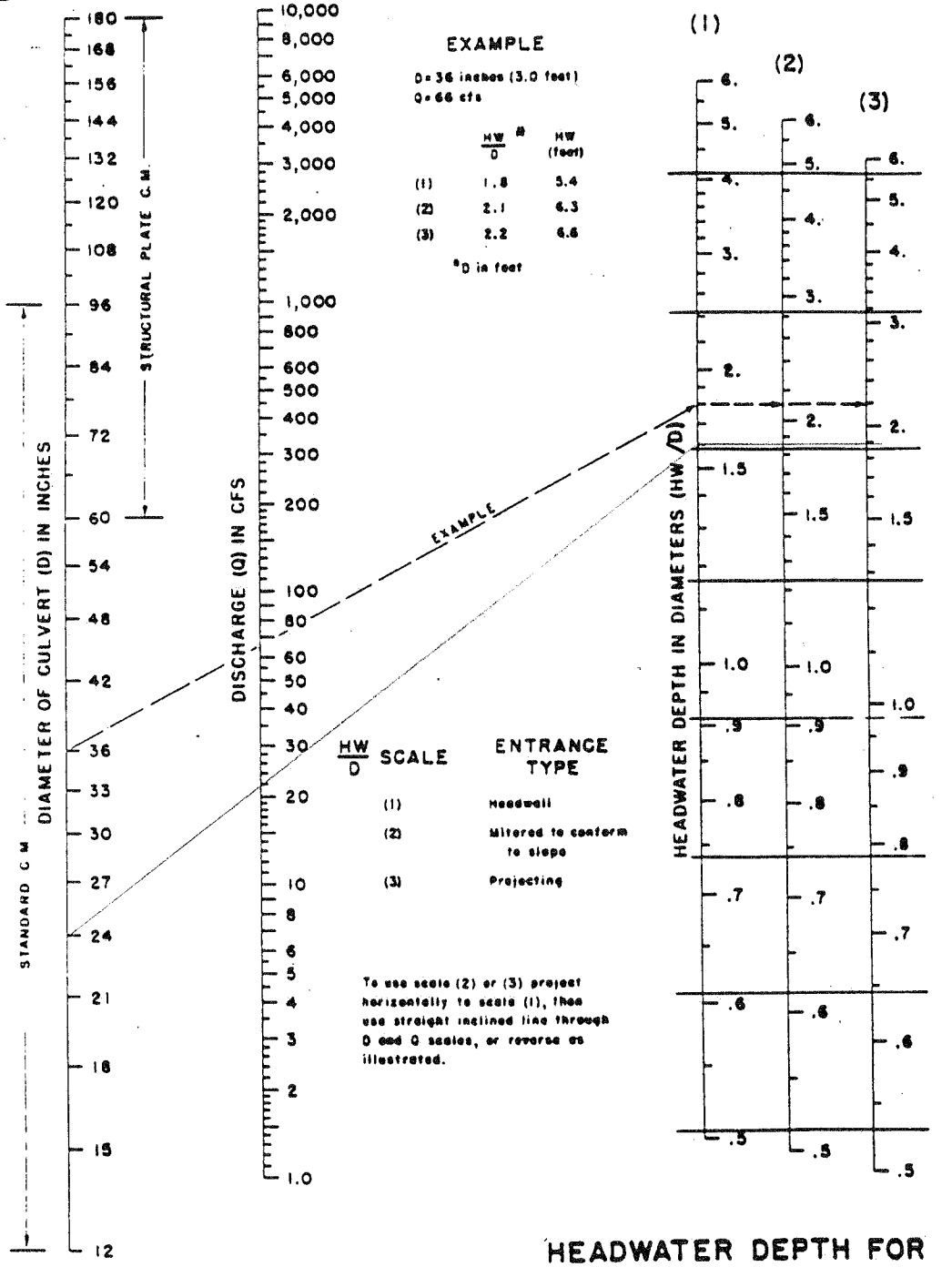
$HW = H + h_o - LS_o$

$= 5.8 + 1.875 - 30$

$= -22.3$ FT

SAY $\underline{0 \text{ FT.}}$

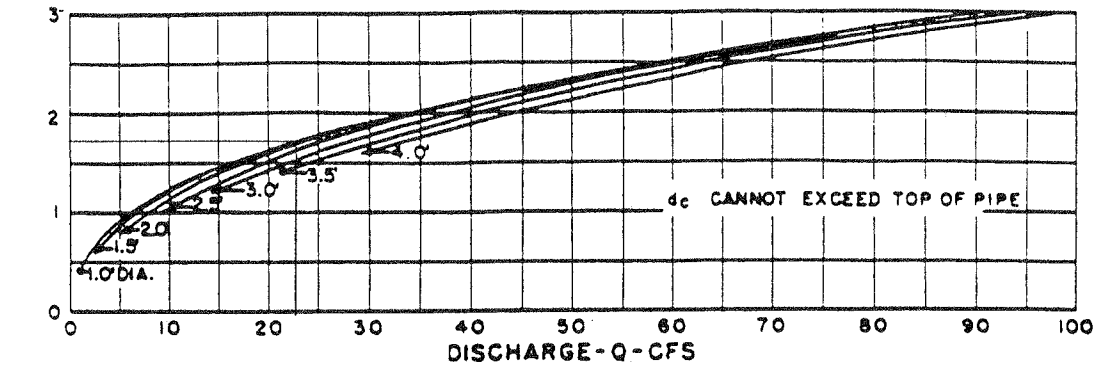
CHART 2

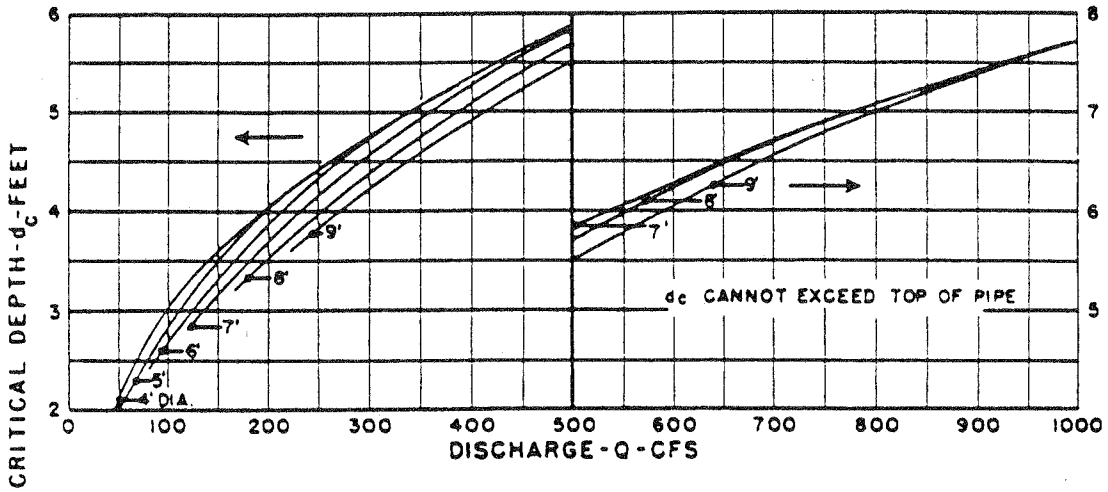


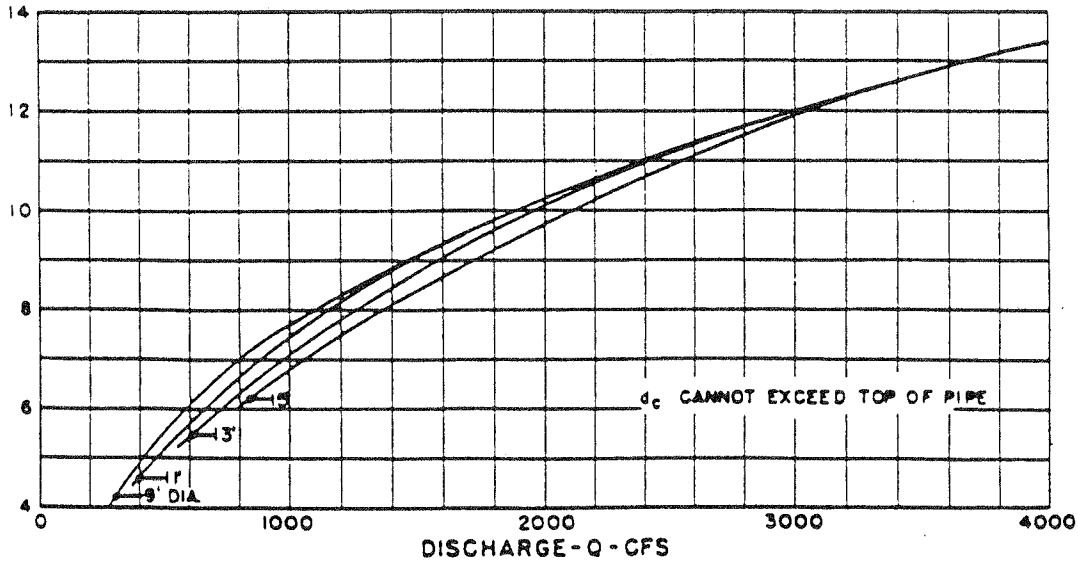
HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

CHART 4





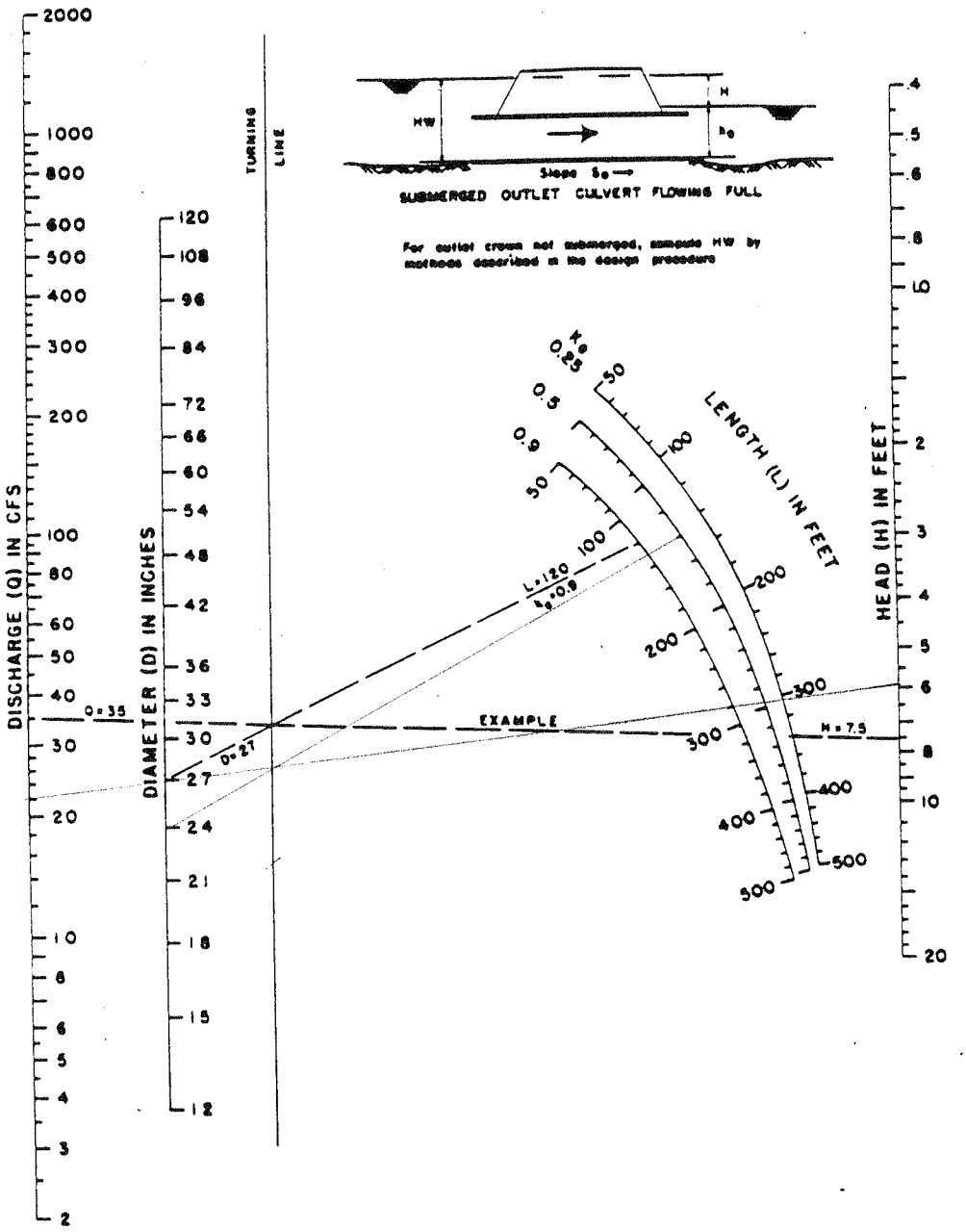


BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

CHART 6



HEAD FOR
STANDARD
C. M. PIPE CULVERTS
FLOWING FULL
n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

Job No. 6770-021-013 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed	Date
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

DESIGN CULVERT FOR EAST SEDIMENT BASIN. $Q_{25} = 71$ CFS FOR 55 ACRE PHASE. EAST SEDIMENT BASIN PROVIDES DRAINAGE FOR 18.4 ACRES.

$Q \Rightarrow {}^{18.4}/_{55} = .33 \Rightarrow 71 \text{ CFS} \times .33 = \underline{23.4 \text{ CFS}}$

TRY 24" ϕ C.M.P. CULVERT

CHECK INLET CONTROL

$H_W/_D = 1.6$ (FROM CHART 2)

$H_W = 1.6(2)$

$H_W = \underline{3.2 \text{ FT}}$

CHECK OUTLET CONTROL

$L = 120$ FT $\qquad d_c = 1.75$ FT (CHART 4)

$S = \frac{760 - 736}{120} = 0.2$

FROM HEADLOSS NOMOGRAPH (CHART 6) $\Rightarrow H = 5.8$ FT

$h_o = \frac{d_c + D}{2} = \frac{1.75 + 2}{2} = 1.875$

$LS_o = 120(0.2) = 24$

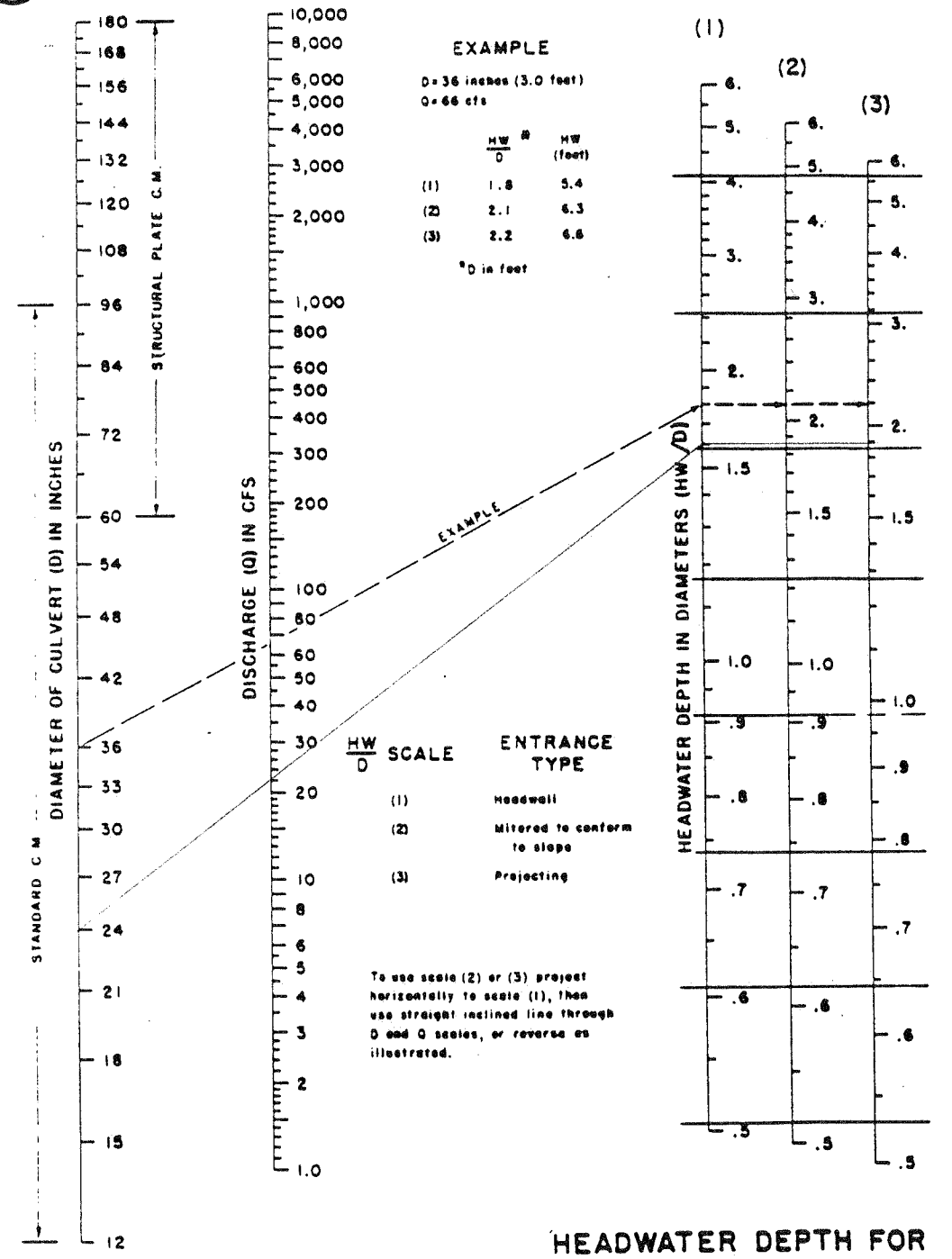
$H_W = H + h_o - LS_o$

$= 5.8 + 1.875 - 24$

$= -16.3$ FT

SAY $\underline{0 \text{ FT.}}$

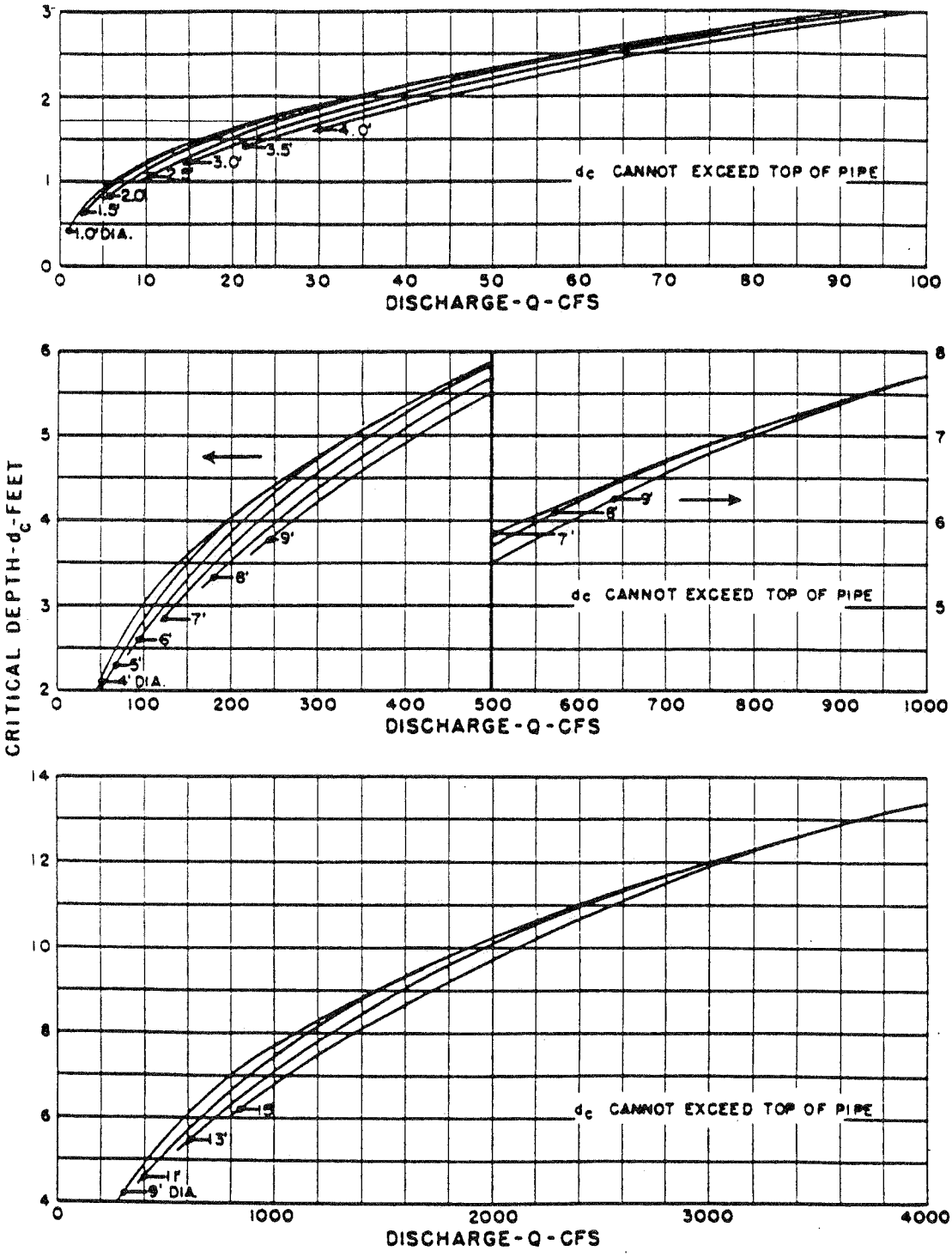
CHART 2



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

CHART 4

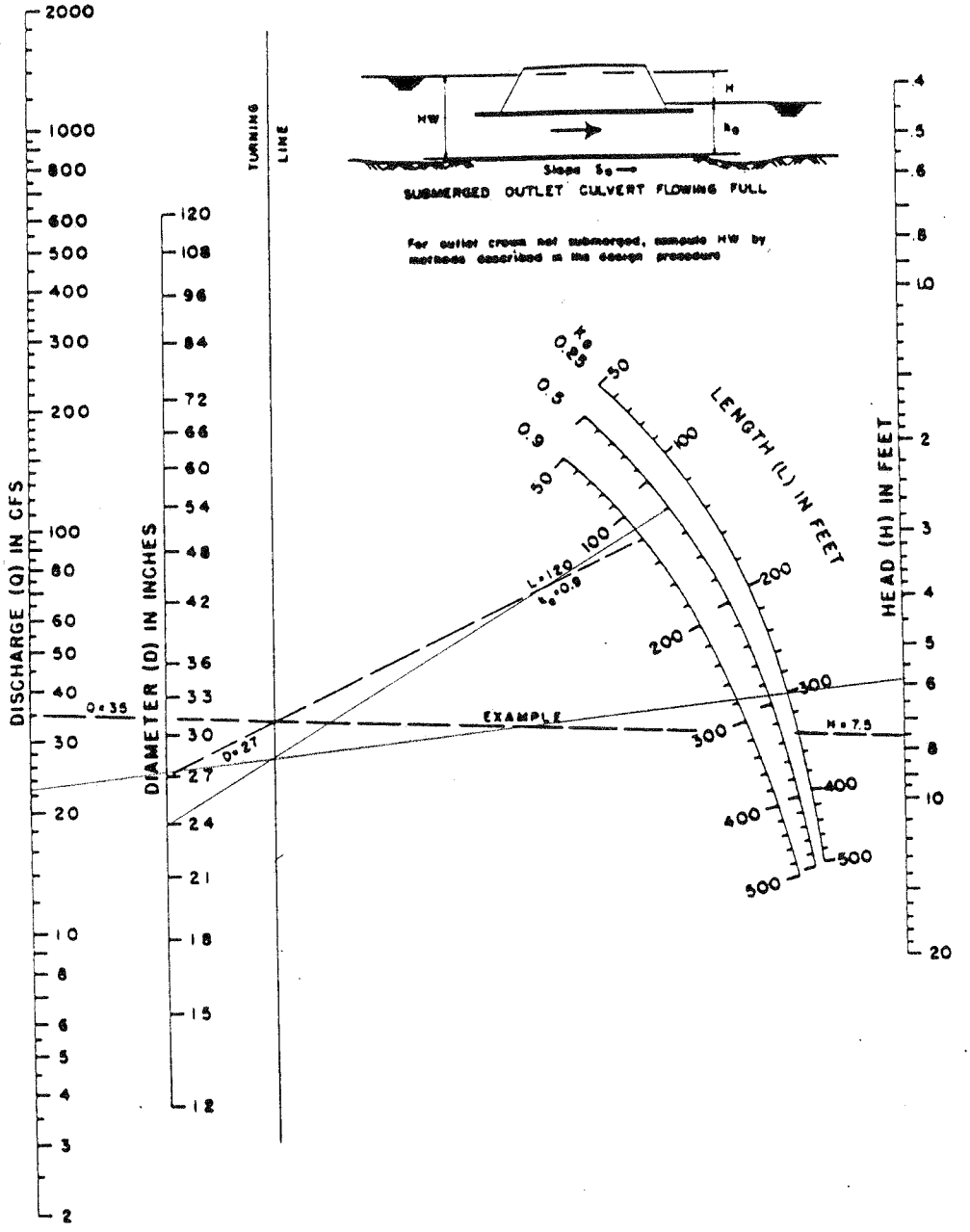


BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

CHART 6



HEAD FOR STANDARD C. M. PIPE CULVERTS FLOWING FULL n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

PROJECT HDR - GBORO. LF

SUBJECT Temporary Stormwater Pipe Sizing

SHEET 1 OF 2
JOB NO. HDRGN-2
DATE 11/21/95
COMPUTED BY PKS
CHECKED BY

- Objective: Evaluate the required size of temporary stormwater pipes based on the 25 yr storm.

- Assumptions:
  1. Allow no overtopping of berms.
  2. Assume entire storm acts on system at one time. (Very Conservative)

- Analysis: Use the Rational Method to calculate peak flow (Q_p) in each pipe, based on area, intensity, infiltration, & design storm depth. Use Manning's Equation to size the pipe based on slope(s), peak flow, and Manning's number (n).

Equations:

Rational Method:

$$Q_p = CIA$$

Where: Q_p = Peak Flow (cfs)
C = Runoff Coef.
I^* = Rainfall Intensity (in/hr)
A = Contributing Area (Ac)

*I is based on time of Concentration (t_c). Choose min. t_c = 5 min (Conservative)

Manning's Equation:

$$D_{req} = 16\left[\frac{Q_p \cdot n}{\sqrt{S}}\right]^{.375}$$

- For Pipe Flowing Just Full

G.N. RICHARDSON & ASSOCIATES
CONSULTING ENGINEERING

DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

G.N. Richardson & Associates

ENGINEERING AND GEOLOGICAL SERVICES

SHEET: 2/2
JOB #: HDRGN-2
DATE: 11/21/95
BY: PKS
CHKD BY:

City of Greensboro
Analysis of Internal Cell Runoff
Temporary Stormwater Pipe Sizing

25 Year, 24 Hour Design Storm Depth = **6** inches (From NOAA HYDRO-35)

Size of Subcells:

Subcell #	Area (Ac.)	Subcell #	Area (Ac.)
1A	5.4	2C	3.9
1B	3.7	2D	2.5
1C	5.6	3A	6.7
1D	5.3	3B	6.0
2A	4.5	3C	4.1
2B	4.2		

Pipe Section	Pipe Slope (%)	Manning's Number	Contributing Subcells	Drainage Area (Ac.)	Runoff Coef. (c)	Volume (cf)	Qreq (cfs)	Dreq (in)	Pipe Selected (in)
Cell 1 Outlet	2.0	0.01	1B,1C,1D	14.6	0.5	317988	3.7	9.7	**12" HDPE**
Cell 1 Temporary	2.0	0.01	1B,1C,1D	14.6	0.5	317988	3.7	9.7	**12" N12**
Cell 2 Outlet	2.0	0.01	2A,2B,2C,2D	15.1	0.5	328878	3.8	9.8	**12" HDPE**
Cell 2 Temporary	2.5	0.01	2A,2B,2C,2D	15.1	0.5	328878	3.8	9.4	**12" N12**
Cell 3 Outlet	2.0	0.01	3A,3B,3C	16.8	0.5	365904	4.2	10.2	**12" HDPE**
Cell 3 Temporary	2.0	0.01	3A,3B,3C	16.8	0.5	365904	4.2	10.2	**12" N12**

USE 15" PIPE FOR EAST SIDE,
12" PIPE FOR INTERIOR DRAIN PIPE (CELL 1/2 INTERFACE)

TEMPPIP.WB1

Job No. 6770-021-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-21-95
Subject	WHITE STREET U/F	Checked	Date
Task	DRAINAGE	Sheet	Of

CHECK PIPE SIZE OF 15 ϕ STORMWATER PIPE DURING TOP OF OPERATIONAL COVER PHASE (SHEET C-4) FROM PREVIOUS SED BASIN CALC. BY EAW $Q_{25} = 71$ CFS FOR 55 ACRES. THIS PARTICULAR PIPE WILL HANDLE 20 ACRES. THEREFORE Q FOR THIS PIPE IS

$20/55 = .36 \Rightarrow Q = 71 \times .36 = \underline{25.6 \text{ CFS}}$.

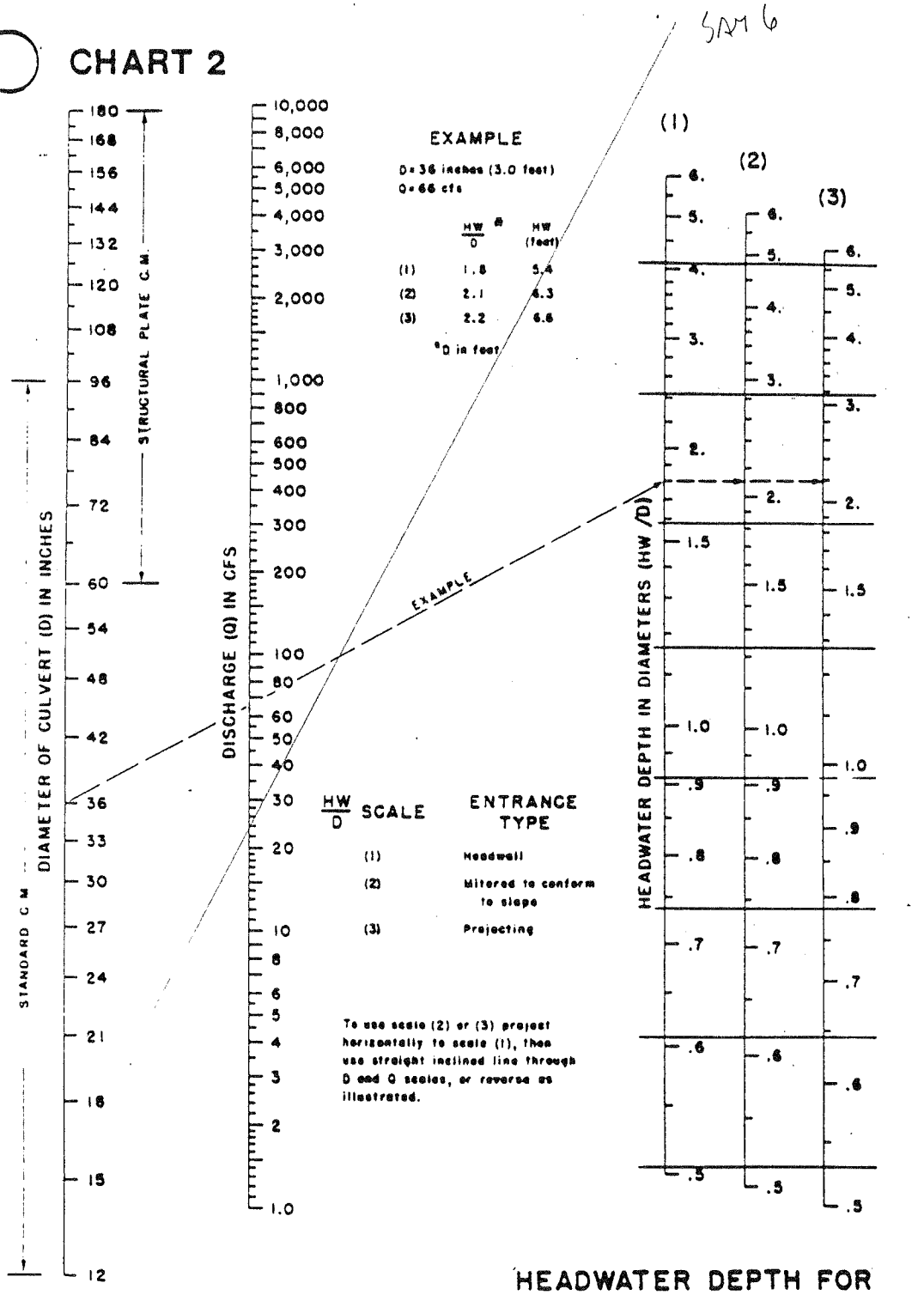
CHECK INLET CONTROL

$Hw/D = 6.0$ (FROM CHART 2)

$Hw = 1.25 (6.0)$

$Hw = \underline{7.5 \text{ FT}}$

CHART 2



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Job No. 6770-021-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-22-95
Subject	WHITE STREET L/F	Checked	Date
Task	DRAINAGE	Sheet	Of

CHECK PIPE SIZE OF 12" ϕ STORMWATER PIPE DURING TOP OF OPERATIONAL COVER PHASE (SHEET C-4). FROM PREVIOUS SED. BASIN CALC. BY EAW $Q_{25} = 71$ CFS. FOR 55 ACRES. THIS PARTICULAR PIPE WILL HANDLE 15 ACRES, THEREFORE Q FOR THIS PIPE IS $15/55 = .27 \Rightarrow Q = 71 \times .27 = \underline{5.7 \text{ CFS}}$.

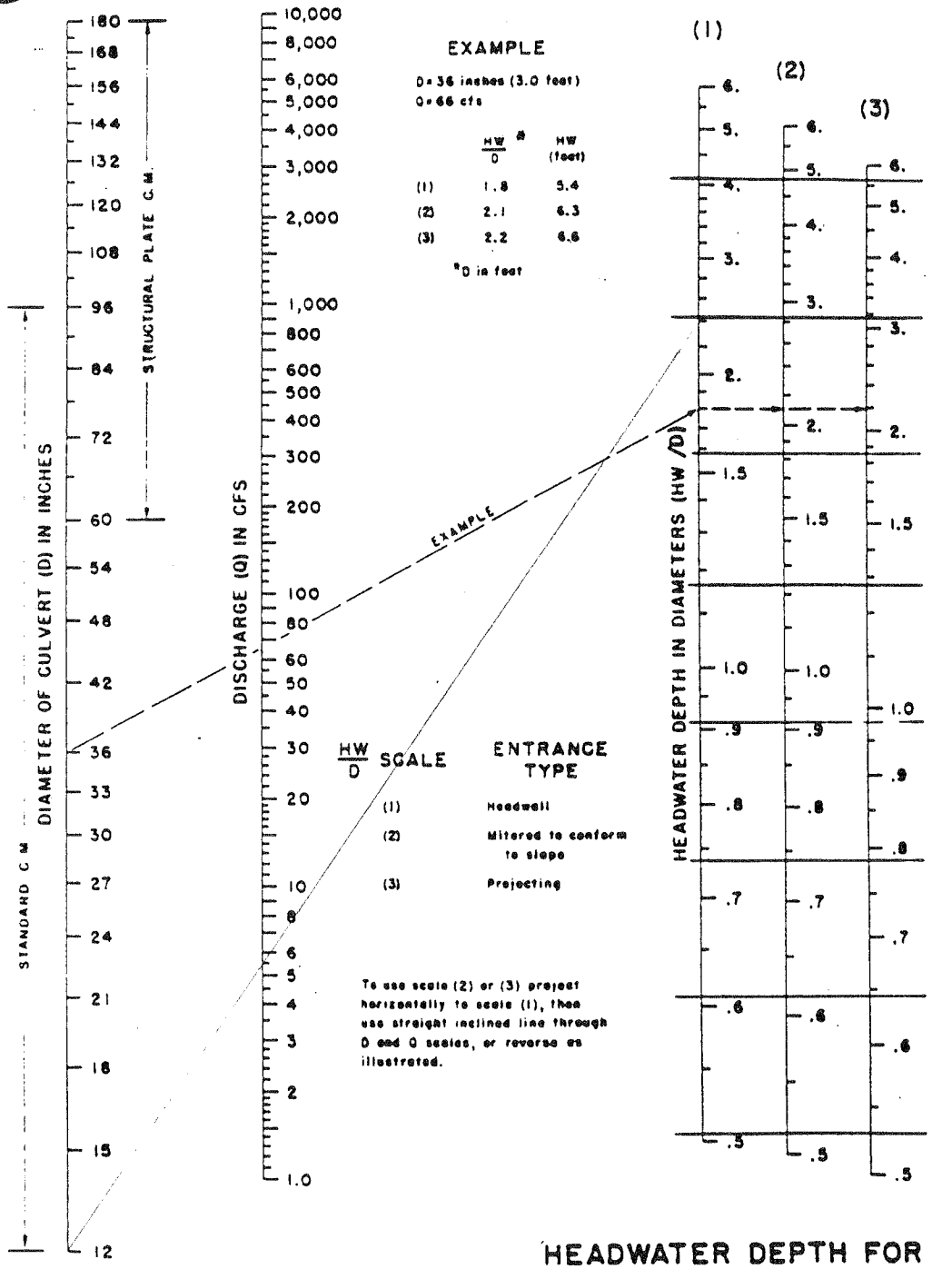
CHECK INLET CONTROL

$H_W/D = 2.4$ (FROM CHART 2)

$H_W = 1.0\,(2.4)$

$H_W = \underline{2.4 \text{ FT}}$

CHART 2



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Job No. 6110-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	TUMBLING FLOW CHANNEL	Sheet	Of

DESIGN CHANNEL LINING BETWEEN ELEMENTS

EVALUATE RIPRAP LINING USING THE FOLLOWING FORMULA AND FIGURE 165 FROM "HYDRAULIC DESIGN OF STILLING BASINS AND ENERGY DISSIPATORS"

$$V_{CR}' = .663\left(2g\,\frac{W_s - W}{W}\right)^{1/2} \times d_{50}^{1/2} \times (3.38\cos\alpha - \sin\alpha)^{1/2}$$

V_{CR} = CRITICAL VELOCITY (FT/SEC)
g = gravitational acceleration FT/SEC^2
W_s = Specific gravity of stone = 2.65
W = Specific gravity of water = 1.00
d_{50} = STONE SIZE (50% PASSING) USE FIG. 165 = 6" = .5'
α = ANGLE MADE BY SURFACE W/ HORIZ. (°) = 14°

$$V_{CR} = .663\left(2(32.2)\,\frac{2.65-1.0}{1.0}\right)^{1/2} \times (.5)^{1/2} \times (3.38\cos 14° - \sin 14°)^{1/2}$$

$$= .663(10.31)(.707)(1.74) = 8.4 \text{ FT/SEC}$$

THE CRITICAL VELOCITY AS DEFINED IN REF (1) IS THE VALUE AT WHICH THE RIPRAP WILL BECOME UNSTABLE THEREFORE THE FOLLOWING COMPARISON IS MADE:

SLOPE CRITICAL VELOCITY (V_{CR}) = 8.4 FT/SEC

DESIGN VELOCITY (V_c) = 5.2 FT/SEC

1 "CRITICAL VELOCITY AND SHEAR PROTECTION AT HYDRAULIC STRUCTURES" S. V. CIHITALE

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	TUMBLING FLOW CHANNEL	Sheet	Of

CALCULATE DISTANCE BETWEEN ELEMENT

L/K IS 8.5 TO 10

$\therefore \quad L = 8.5(K) = 8.5(0.41) = 3.5$

$10(K) = 10(0.41) = 4.1$

CALCULATE CRITICAL VELOCITY

$$V_c = (g\,g)^{1/3}$$

$$V_c = \left((32.2)(4.25)\right)^{1/3}$$

$$V_c = 5.2 \quad FT/SEC$$

REVIEW PARAMETERS

$Q_p =$ 17 CFS
$b =$ 4 FT
$S =$ 25 Z
$K =$ 0.41 FT
$Y_1 =$ 0.92 FT
$L =$ 4.0 FT , $\therefore L/2 =$ 2 FT
$V_c =$ 5.2 FT/SEC
FREEBOARD = 0.5'

CALCULATE TOTAL DEPTH OF CHANNEL

$D_T = K + Y_1 + 0.5' = 1.83$ FT USE 2 FT

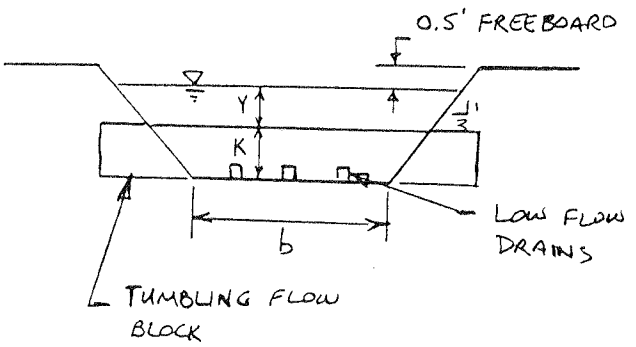
Job No. [illegible] No.

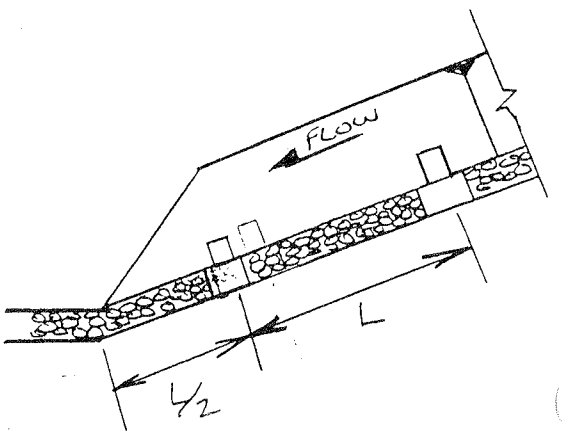
HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-9[illegible]
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	TUMBLING FLOW CHANNEL	Sheet	Of

- THE DESIGN BASIS FOR TUMBLING FLOW CHANNELS IS PRESENTED IN THE TECHNICAL PAPER ENTITLED " HYDRAULICS OF ENERGY DISSIPATION IN STEEP ROUGH CHANNELS" BY HENRY MADISON MORRIS, NOVEMBER 1968, VIRGINIA POLYTECHNIC INSTITUTE, BLACKSBURG, VIRGINA. ALSO IN A TECHNICAL PAPER TITLED " INNOVATION IN STORMWATER MANAGEMENT FOR LANDFILL CLOSURE" BY STEVEN M. GAMELSICY, SCS ENGINEERS
- THE DESIGN CONSISTS OF A TRAPEZOIDAL CHANNEL WITH CONCRETE OR TREATED LUMBER ACTING AS THE ENERGY DISSIPATOR ELEMENT WHICH ARE SPACED EVENLY THROUGHOUT THE DOWN CHUTE
- THE LAST BLOCK IS SPACED HALF THE SEPARATION DISTANCE UP SLOPE FROM THE PERIMETER CHANNEL





Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	TUMBLING FLOW CHANNEL	Sheet	Of

THE BASIC EQUATIONS WHICH GOVERN THE DESIGN ARE AS FOLLOWS:

1. $q = (16.5 - .206\ S)\ (K^{3/2})$

2. $Y_c = (q^2/g)^{1/3}$

3. $Y_1 = .35\ q^{2/3}$

4. $V_c = (gq)^{1/3}$

5. $L/K = 8.5$ to 10.0

6. $C_D = 1.4 \left(\frac{(K)^3}{Y1} + 4 \frac{(K)^2}{Y1} + 2.2 \frac{(K)}{Y1} + .6 \right)$

7. $F_D = \frac{.97\ k\ q^2\ (C_D)}{(K + Y_1)^2}$

Where:

q = Unit discharge, cfs/ft of base width
S = Slope in percent
K = Height of element in ft.
g = 32.2 ft/sec^2
Y_1 = Control depth on maximum rise of water over element
V_c = Critical velocity; also the outlet velocity
C_D = Force coefficient
F_D = Force on elements, lbs/ft of transverse width
L = Length between elements, ft

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HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
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Task	TUMBLING FLOW CHANNEL	Sheet	Of

GIVEN A 25-YEAR, 24-HOUR STORM EVENT YIELDS A PEAK FLOW OF Q_p = 17 CFS FOR CHANNEL 3, DETERMINE A SIZE FOR A TUMBLING FLOW CHANNEL GIVEN THE BASIC EQUATIONS FOUND ON SHEET 2 :

ASSUME A BASE WIDTH (b) = 4 FT

CALCULATE UNIT DISCHARGE (q)

$$q = \frac{17 \text{ CFS}}{4 \text{ FT}} = 4.25 \text{ CFS/FT WIDTH}$$

CHANNEL SLOPE (S) = 25 (%)

CALCULATE THICKNESS (K) OF ENERGY DISSIPATOR ELEMENT

$$q = (16.5 - .206\,S)(K^{3/2})$$

SOLVE FOR K,

$$K = \left[\frac{4.25}{16.5 - .206(.25)}\right]^{2/3}$$

$$= 0.4056 \quad \text{USE } 0.41$$

CALCULATE MAXIMUM RISE OF FLOW DEPTH OVER ELEMENT

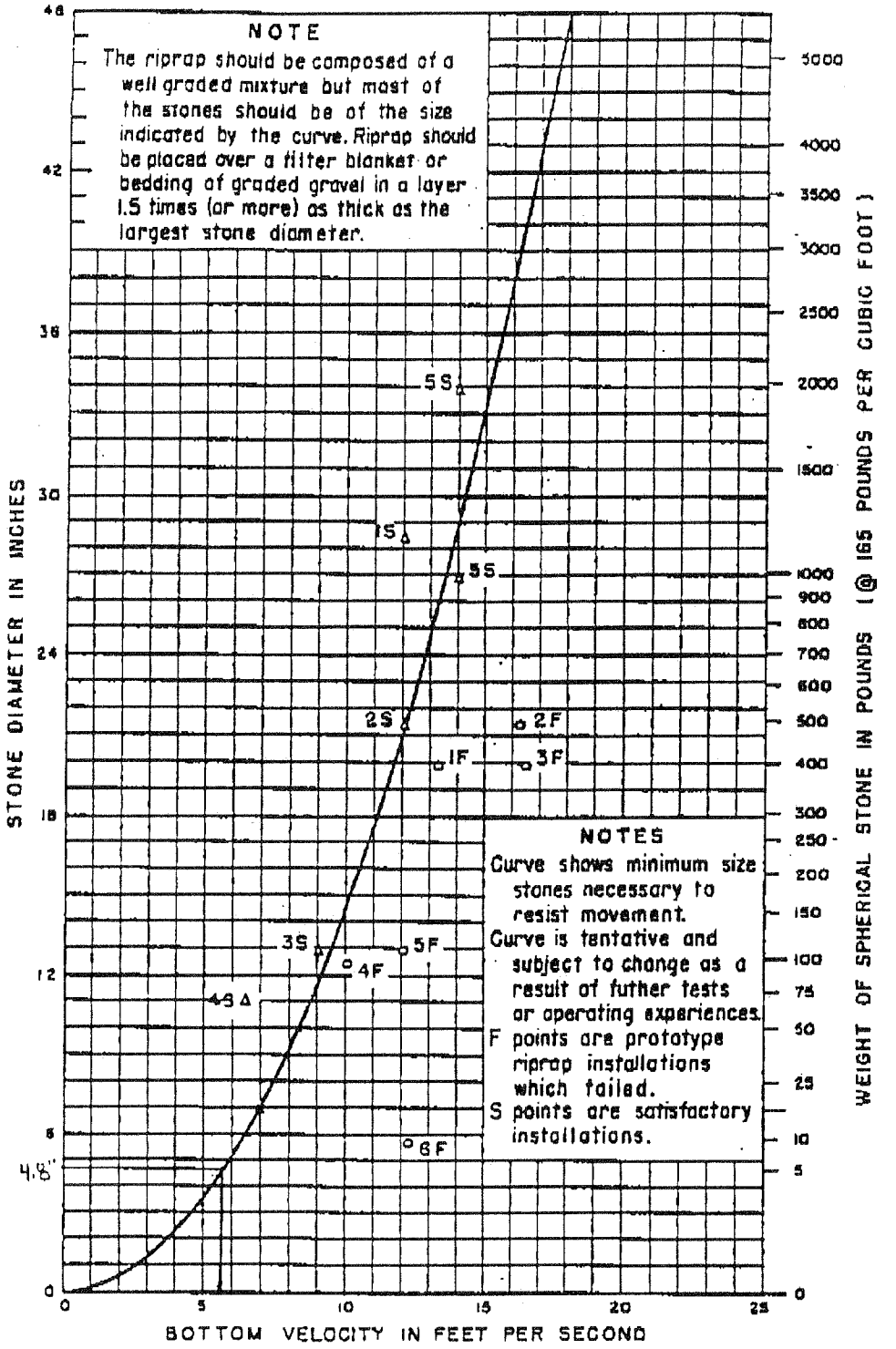
$$Y_1 = .35\, q^{2/3}$$

$$= .35\,(4.25)^{2/3}$$

$$= 0.92$$

Job No. 94093.PE
Sheet No. 5 of 5

SIZE OF RIPRAP TO BE USED DOWNSTREAM FROM STILLING BASINS 209



Use 4.8"

FIGURE 165.—*Curve to determine maximum stone size in riprap mixture.*

Source: Hydraulic Design of Stilling Basins and Energy Dissipators

Job No. 6770-021-018	No.

HDR Computation

Project	CITY OF GREENSBORO	Computed	DTD	Date	11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked		Date	
Task	DRAINAGE	Sheet		Of	

MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{27{,}000\ FT^3}{17{,}900\ FT^2} = 1.5\ FT\ DEEP \quad (IF\ SIDE\ SLOPES\ WERE\ 0:1)$$

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$27{,}000\ FT^3 = \left(\frac{17{,}990\ FT^2 + A_2}{2}\right)(H)$$

H	A_2	
1.5'	18,010 FT²	
2.0'	9,010 FT²	⇐ USE 2.0' DEPTH MIN.
3.0'	10 FT²	

$A_1 = 17{,}990\ FT^2$ BASIN SURFACE AREA (95' × 190')

$A_2 = 9{,}010\ FT^2$ BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 9{,}010\ FT^2$

$B = 67\ FT$

67' × 134'

Job No. 6770-021-018 | No.

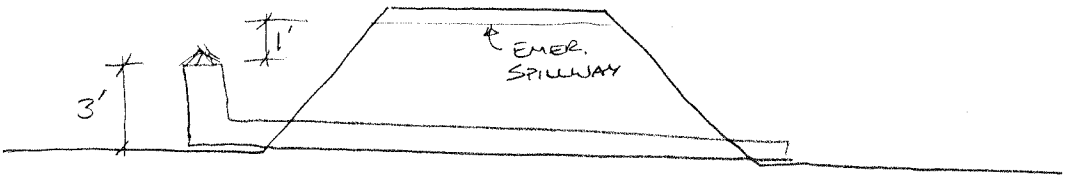
HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (15 ACRES) = 3 CFS

RISER HEIGHT
2x BARREL
DIAMETER



TRY 18" ϕ BARREL

$$H = 3' - \frac{18"\phi}{2(12)} = 2.25 \text{ FT}$$

FROM TABLE 8.07a, A 18" ϕ BARREL WILL CARRY A MIN OF 7.73 CFS

USE 18" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 24" ϕ RISER
FOR A 24" ϕ RISER WITH H = 1 FT., Q = 20.0 CFS

20 CFS > 7.73 CFS ∴ BARREL CONTROLS, OKAY

USE 24" ϕ RISER C.M.P.

Job No. 6770-021-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

EMERGENCY SPILLWAY:

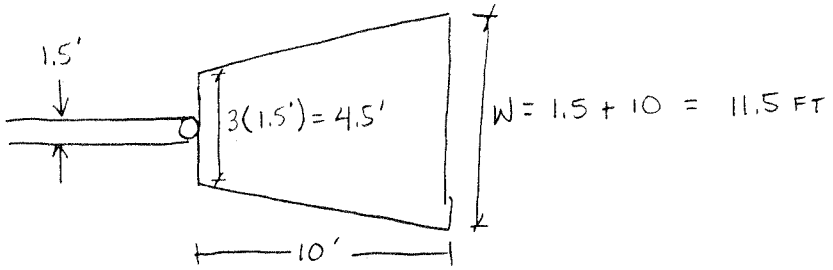
$$Q_e = Q_{25} - Q_p$$
$$= 41.3 \text{ CFS} - 7.73 \text{ CFS}$$
$$= 33.6 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 35 CFS
BOTTOM WIDTH = 24 FT
MAX. SLOPE = 14.1 %
STAGE = 0.77 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 7.73 CFS

FROM FIGURE 8.06 a: d_{50} = 6" ; L_a = 10 FT



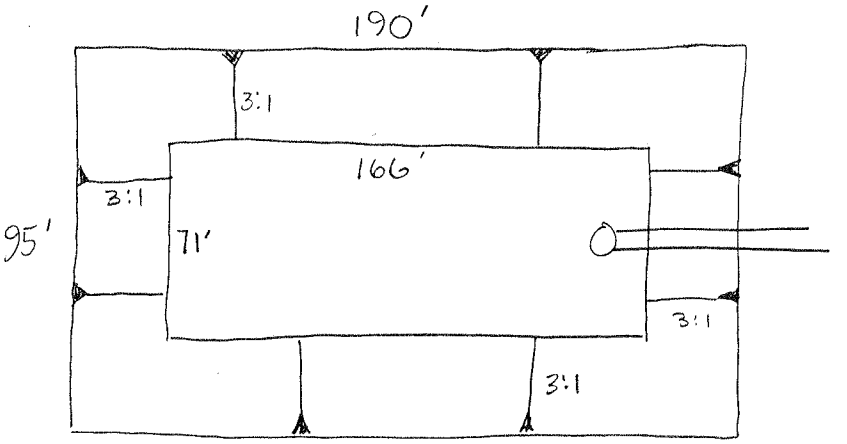
$d_{max} = 1.5\, d_{50} = 9"$

DEPTH = $1.5\, d_{max}$ = 13.5"

Job No. 6770-021-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-9_
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

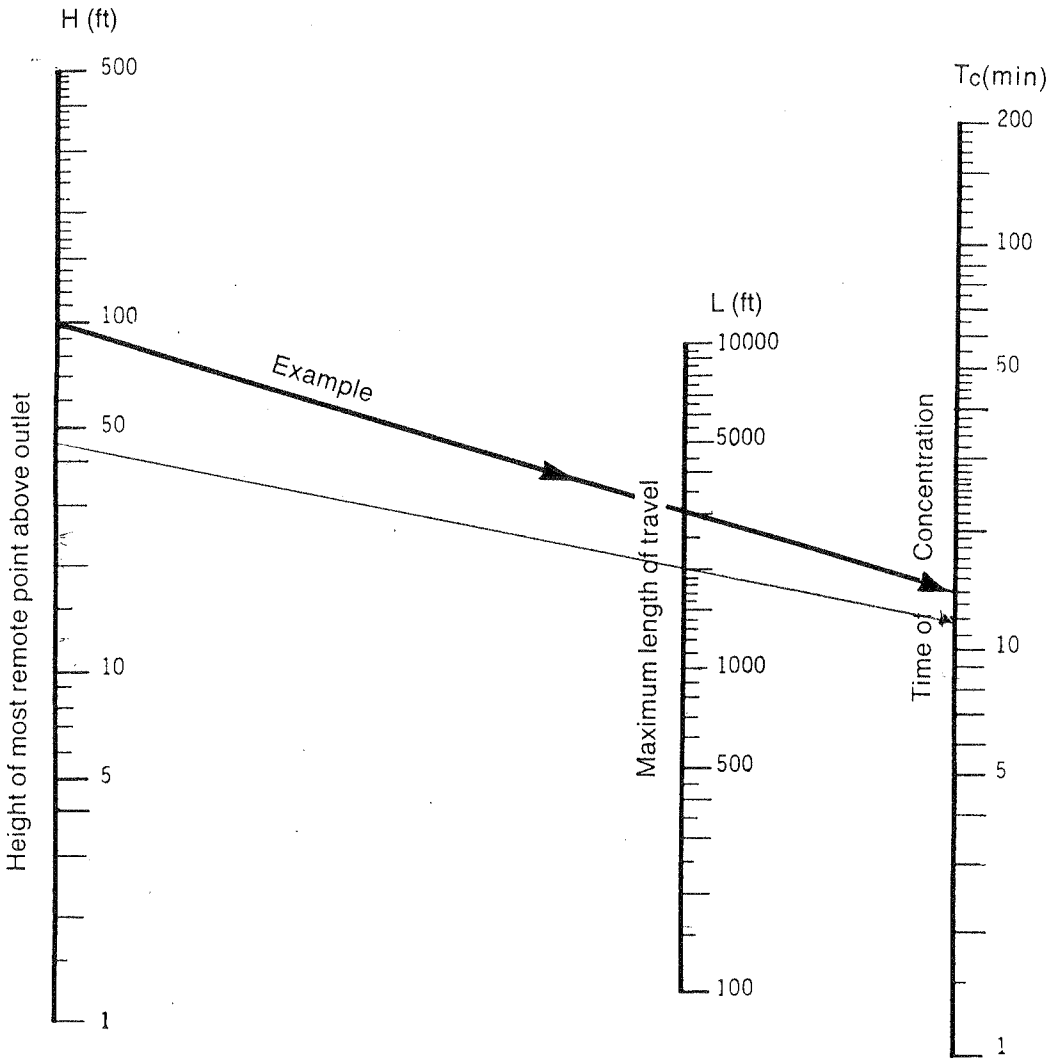


TOTAL VOLUME = A_1 = 18,050 FT^2

A_2 = 11,786 FT^2

H = 4 FT

VOL = 59,672 FT^3 > 27,000 FT^3 N



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

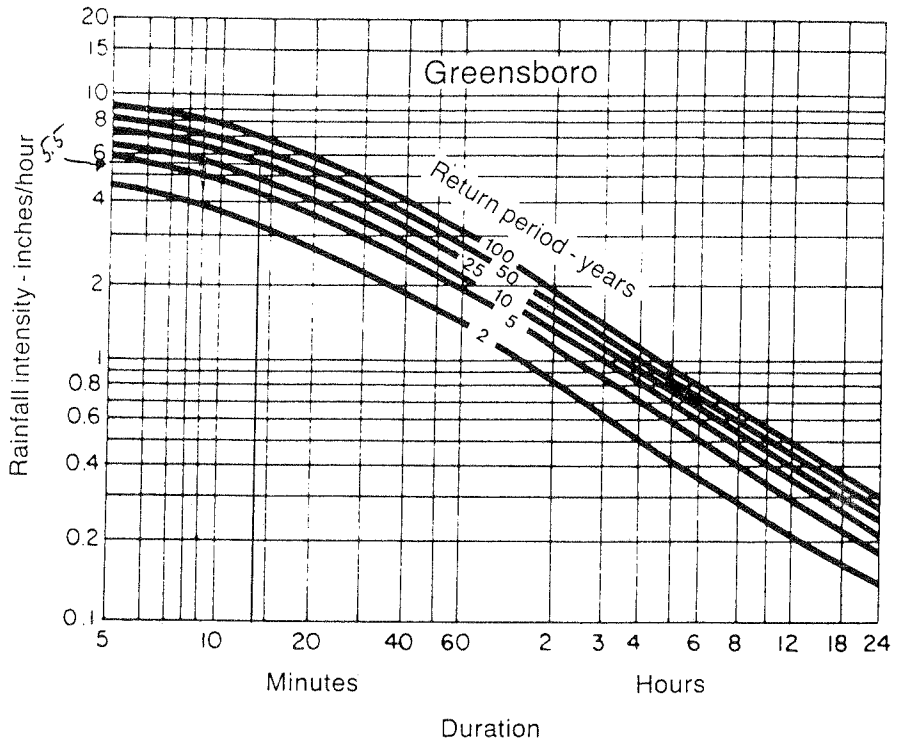


Figure 8.03d Rainfall intensity duration curves—Greensboro.

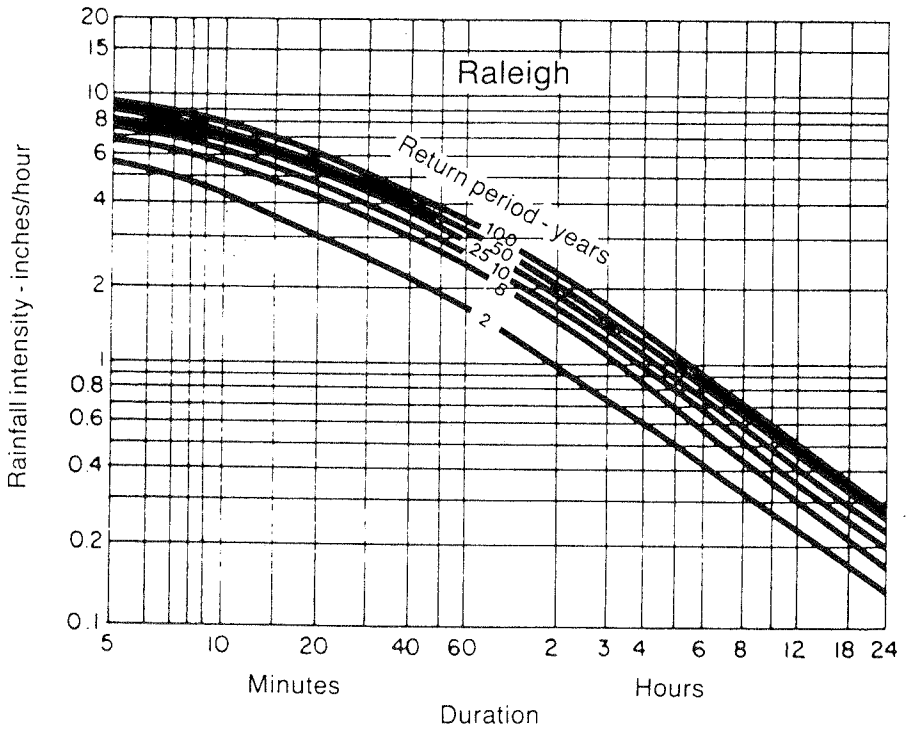


Figure 8.03e Rainfall intensity duration curves—Raleigh.

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes–3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.6	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.6	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.6	28	.97
70	2.5	2.8	8	1.88
	2.6	3.3	12	1.60
	2.6	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.6	3.6	16	1.51
	2.7	4.3	20	1.35

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.6	12	1.84
	2.5	3.1	16	1.81
	2.6	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.6	3.3	20	1.54
	2.6	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.6	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.6	3.6	32	1.47
	2.6	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.6	3.4	36	1.49
	2.6	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.6	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.6	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.6	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%.

Find: Bottom width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. Stage in Reservoir will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = .040. Maximum velocity = 5.50 ft per sec.

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HDR Computation

HDR

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NORTHWEST SEDIMENT BASIN (FIGURES AND TABLES COME FROM NC MANUAL)

TOTAL DRAINAGE AREA = 17.5 ACRES

$Q = CIA$ WHERE Q = RUNOFF, CFS

C = RUNOFF COEFFICIENT

I = RAINFALL INTENSITY, IN/HR

A = DRAINAGE AREA, ACRES

C = 0.5 ASSUMED (TABLE 8.03a)

L = 1860 FT

H = 94 FT

T_c = 8 min (FIG 8.03a)

I = 6.8 IN/HR (FIG. 8.03d)

$Q_{25} = 0.5\ (6.8)(17.5) =$ 59.5 CFS

STORAGE REQUIRED = 1800 FT^3/ACRE × 17.5 ACRES = 31,500 FT^3

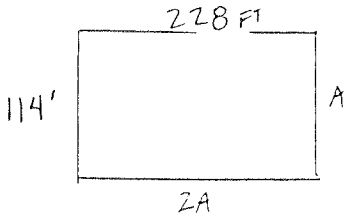
FOR 75% TRAPPING EFFICIENCY SURFACE AREA SHOULD BE:

.01 ACRE/CFS × 59.5 CFS = 0.595 ACRE = 25,918 FT^2

APPROXIMATE SURFACE DIMENSIONS:

$2A^2 = 25{,}918\ FT^2$

$A = 114$ FT



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HDR Computation

HDR

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MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{31,500 \text{ FT}^3}{25,918 \text{ FT}^2} = 1.2 \text{ FT DEEP} \quad \text{(IF SIDE SLOPES WERE 0:1)}$$

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$31,500 \text{ FT}^3 = \left(\frac{25,918 \text{ FT}^2 + A_2}{2}\right)(H)$$

H	A_2	
1.2'	26,582 FT²	
2.0'	5,582 FT²	⇐ USE 2.0' DEPTH MIN.
3.0'	-4,918 FT²	

$A_1 = 25,918 \text{ FT}^2$ BASIN SURFACE AREA (114' x 228')

$A_2 = 5,582 \text{ FT}^2$ BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 5,582 \text{ FT}^2$

$B = 53 \text{ FT}$

53' x 106'

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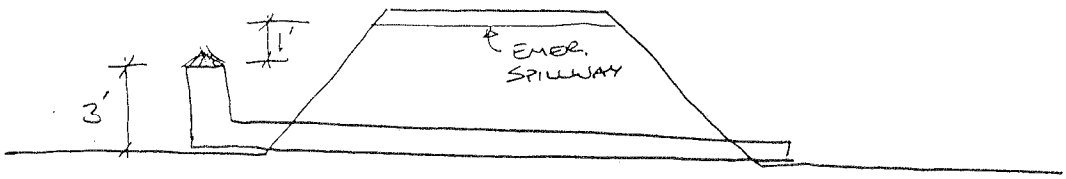
SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (17.5 ACRES) = 3.5 CFS

RISER HEIGHT
2x BARREL
DIAMETER



TRY 18" ϕ BARREL

$$H = 3' - \frac{18"\phi}{2(12)} = 2.25 \text{ FT}$$

FROM TABLE 8.07a, A 18" ϕ BARREL WILL CARRY A MIN. OF 7.73 CFS

USE 18" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 24" ϕ RISER
FOR A 24" ϕ RISER WITH H = 1 FT., Q = 20.0 CFS

20.0 CFS > 7.73 CFS ∴ BARREL CONTROLS, OKAY

USE 24"ϕ RISER C.M.P.

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HDR

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EMERGENCY SPILLWAY:

$$Q_e = Q_{25} - Q_p$$
$$= 59.5 \text{ CFS} - 7.73 \text{ CFS}$$
$$= 51.8 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 50 CFS

BOTTOM WIDTH = 24 FT

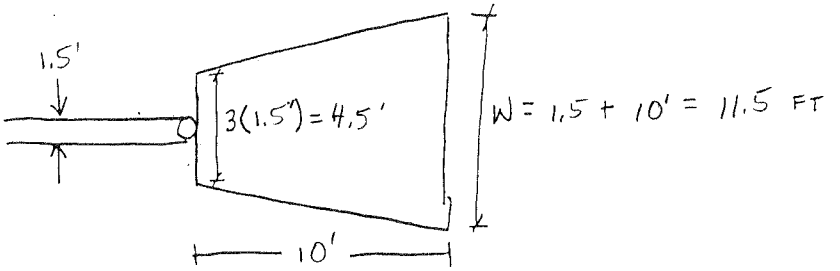
MAX. SLOPE = 9.0 %

STAGE = 0.94 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 7.73 CFS

FROM FIGURE 8.06 a: $d_{50} = 6''$; $L_2 = 10$ FT



$d_{max} = 1.5\, d_{50} = 9''$

DEPTH = $1.5\, d_{max} = 13.5''$

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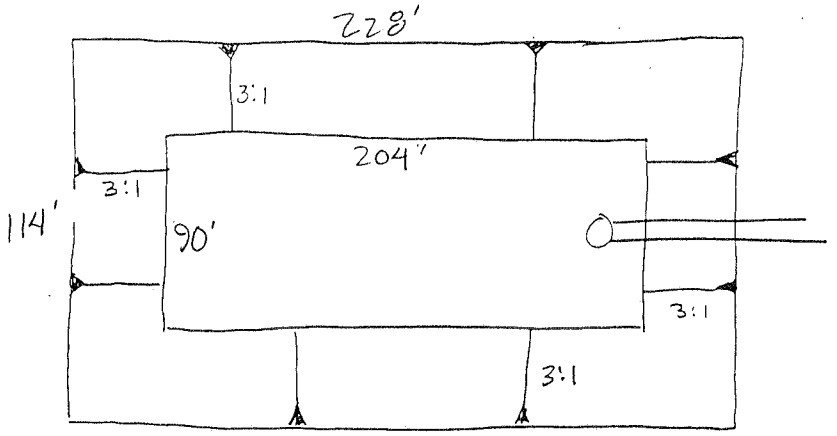
HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-9
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

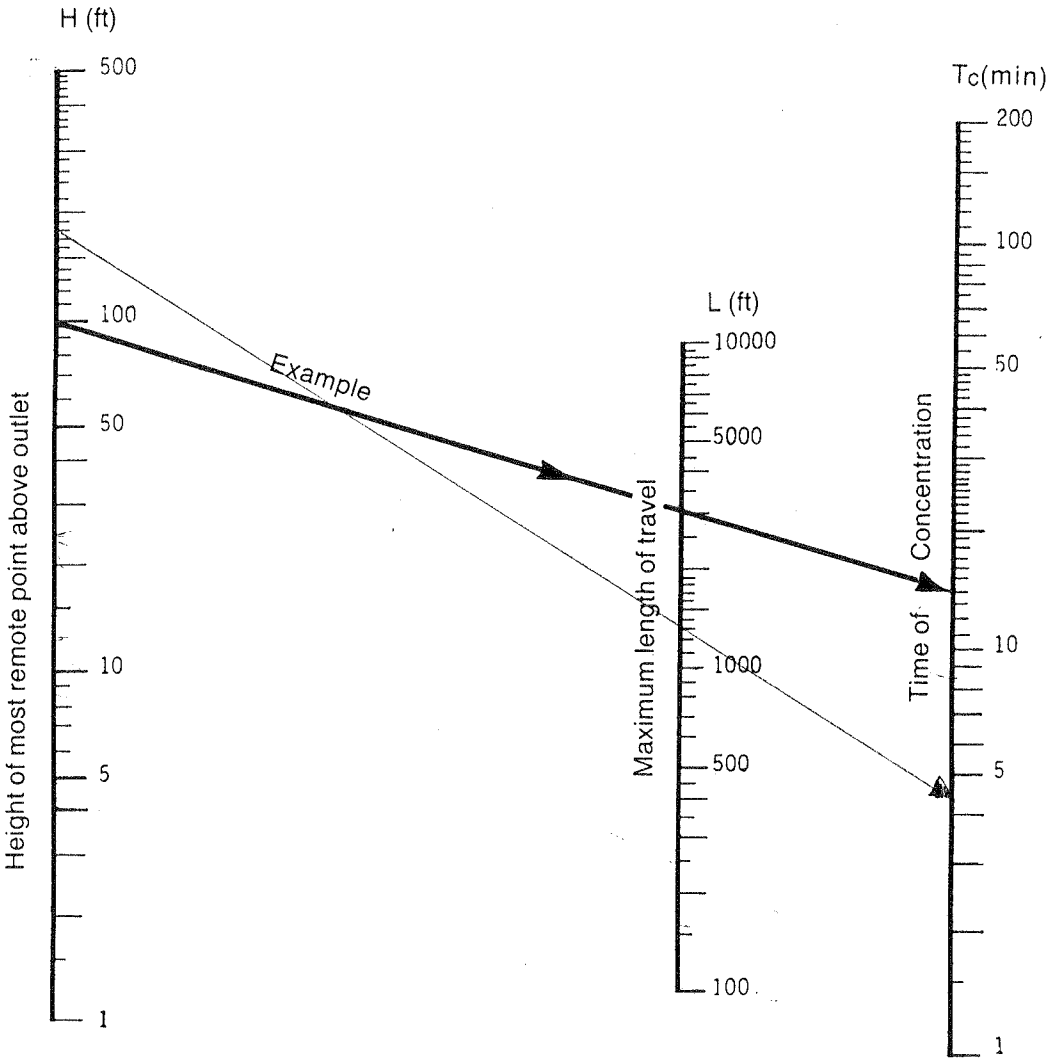


TOTAL VOLUME = A_1 = 25,992 FT^2

A_2 = 18,360 FT^2

H = 4 FT

VOL = 88,704 FT^3 > 31,500 FT^3 M



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

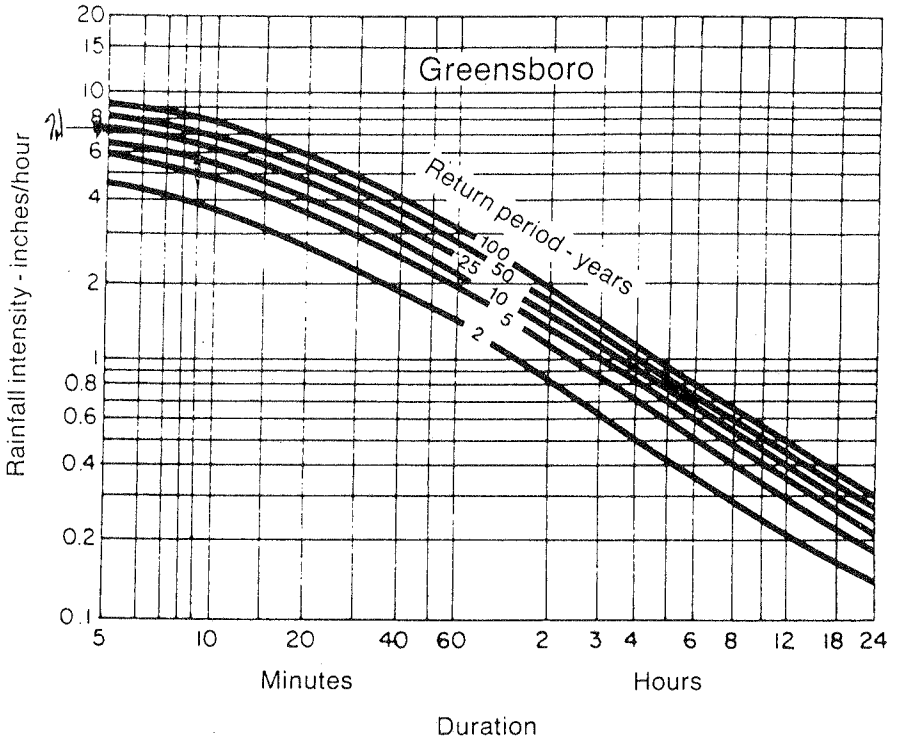


Figure 8.03d Rainfall intensity duration curves—Greensboro.

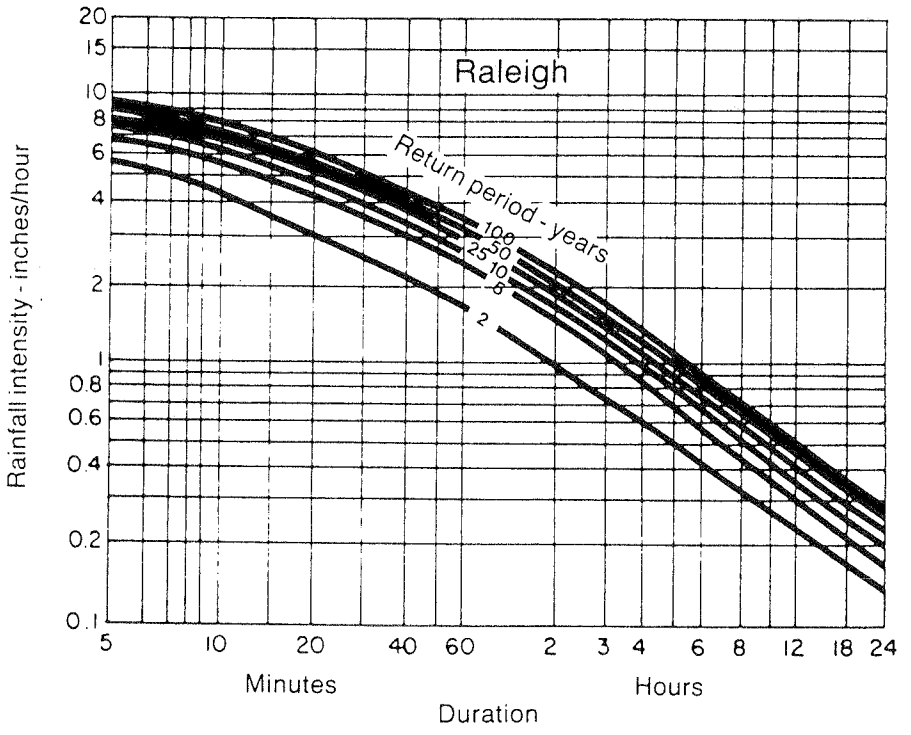


Figure 8.03e Rainfall intensity duration curves—Raleigh.

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes–3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.8	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.8	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.8	28	.97
70	2.5	2.8	8	1.88
	2.8	3.3	12	1.60
	2.8	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.8	3.8	16	1.51
	2.7	4.3	20	1.35

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.8	12	1.84
	2.5	3.1	16	1.61
	2.8	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.8	3.3	20	1.54
	2.8	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.8	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.8	3.6	32	1.47
	2.8	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.8	3.4	36	1.49
	2.8	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.8	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.8	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.8	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%.

Find: Bottom width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. Stage in Reservoir will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = .040. Maximum velocity = 5.50 ft per sec.

HDR Computation

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SOUTHWEST SEDIMENT BASIN (FIGURES AND TABLES COME FROM NC MANUAL)

TOTAL DRAINAGE AREA = 5.2 ACRES

$Q = CIA$ WHERE Q = RUNOFF, CFS
C = RUNOFF COEFFICIENT
I = RAINFALL INTENSITY, IN/HR
A = DRAINAGE AREA, ACRES

C = 0.5 ASSUMED (TABLE 8.03a)
L = 600 FT
H = 30 FT
T_c = 3.5 min (FIG 8.03a)
I = 7.1 IN/HR (FIG. 8.03d)

$Q_{25} = 0.5\ (7.1)(5.2) =$ 18.5 CFS

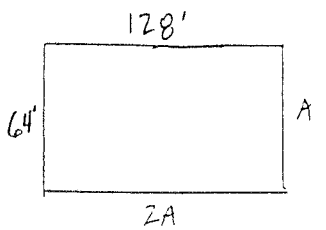
STORAGE REQUIRED = 1800 FT^3/ACRE × 5.2 ACRES = 9,360 FT^3

FOR 75% TRAPPING EFFICIENCY SURFACE AREA SHOULD BE:

.01 ACRE/CFS × 18.5 CFS = 0.185 ACRE = 8,059 FT^2

APPROXIMATE SURFACE DIMENSIONS:

$2A^2 = 8,059\ FT^2$
$A = 64$ FT



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HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
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MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{9{,}360 \text{ FT}^3}{8{,}059 \text{ FT}^2} = 1.2 \text{ FT DEEP} \quad (\text{IF SIDE SLOPES WERE } 0:1)$$

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$9{,}360 \text{ FT}^3 = \left(\frac{8{,}059 \text{ FT}^2 + A_2}{2}\right)(H)$$

H	A_2
1.5	4,421 FT²
2.0	1,301 FT² ⟸ USE 2.0' DEPTH MIN.
3.0	-1,819 FT²

$A_1 = 8{,}059 \text{ FT}^2$ BASIN SURFACE AREA (64' x 128')

$A_2 = 1{,}301 \text{ FT}^2$ BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 1{,}301 \text{ FT}^2$

$B = 26 \text{ FT}$

26' x 52'

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HDR Computation

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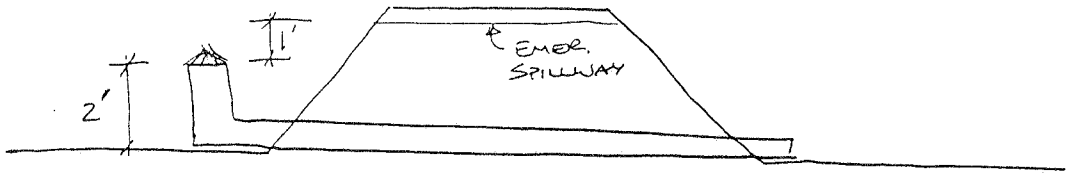
SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (5.2 ACRES) = 1.04 CFS

RISER HEIGHT
2x BARREL
DIAMETER



TRY 12" ϕ BARREL

$H = 2' - \frac{12"\phi}{2(12)} = 1.5$ FT

FROM TABLE 8.07a, A 12" ϕ BARREL WILL CARRY A MIN. OF 2.84 CFS

USE 12" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 18" ϕ RISER
FOR A 18" ϕ RISER WITH H = 1 FT., Q = 15.5 CFS

15.5 CFS > 2.84 CFS ∴ BARREL CONTROLS, OKAY

USE 18" ϕ RISER C.M.P.

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HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

EMERGENCY SPILLWAY:

$$Q_e = Q_{25} - Q_p$$
$$= 18.5 \text{ CFS} - 2.84 \text{ CFS}$$
$$= 15.7 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 15 CFS

BOTTOM WIDTH = 12 FT

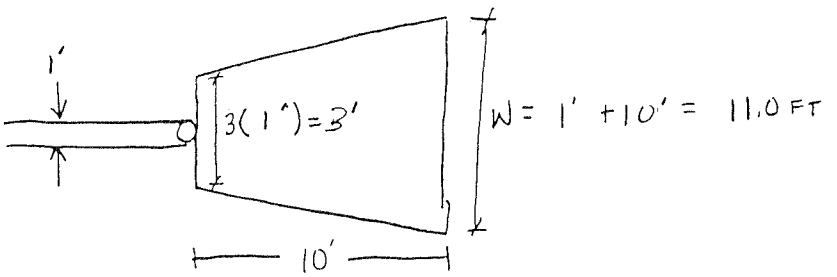
MAX. SLOPE = 18.2 %

STAGE = 0.69 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 2.84 CFS

FROM FIGURE 8.06 a: d_{50} = 6" ; L_a = 10 FT



$d_{max} = 1.5\, d_{50} = 9"$

DEPTH = $1.5\, d_{max}$ = 13.5"

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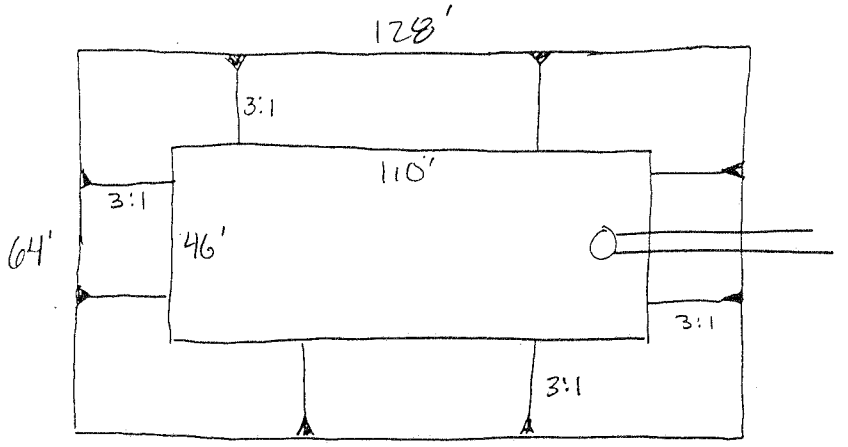
HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-9
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

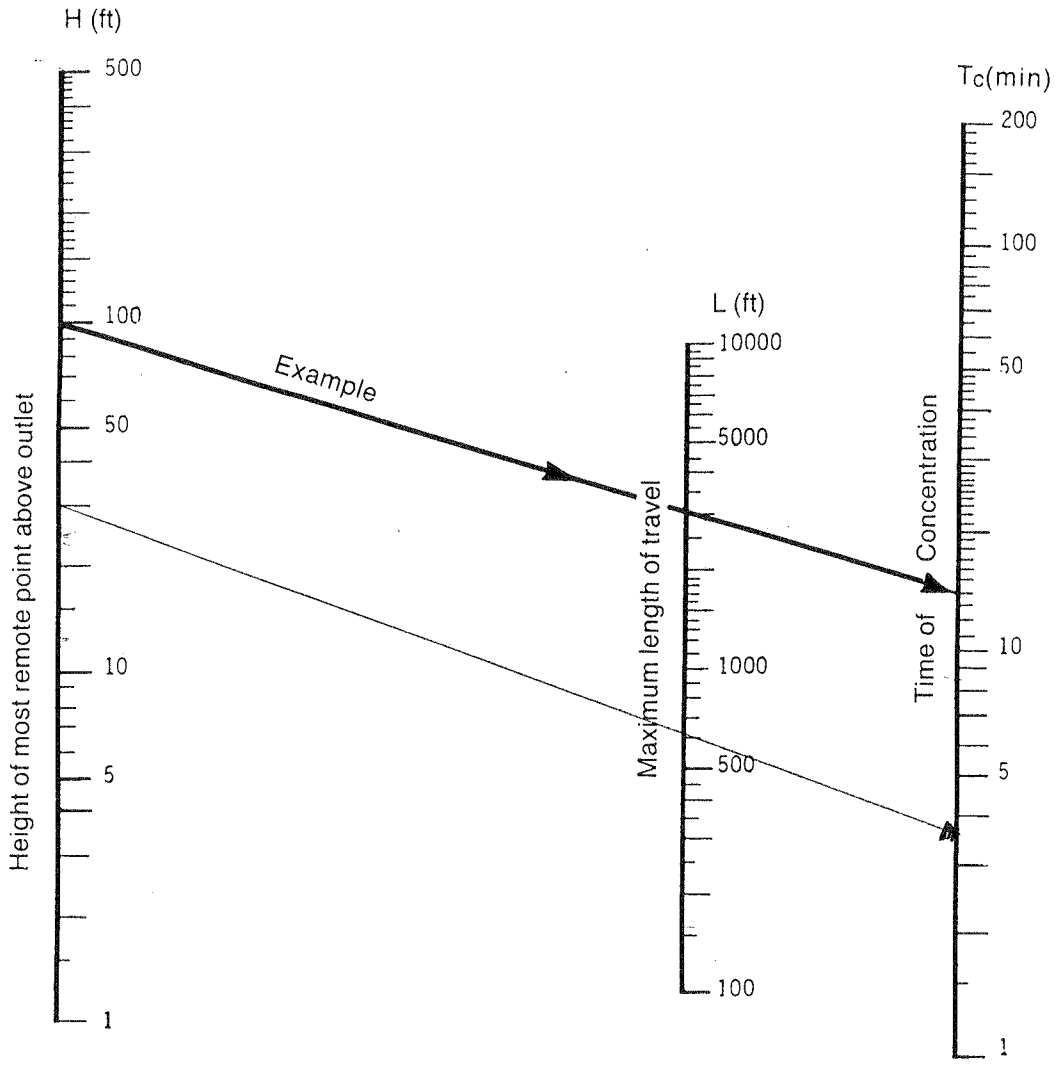


TOTAL VOLUME = A_1 = 8,059 FT²

A_2 = 5,060 FT²

H = 3 FT

VOL = 19,679 FT³ > 9,360 FT³ M



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

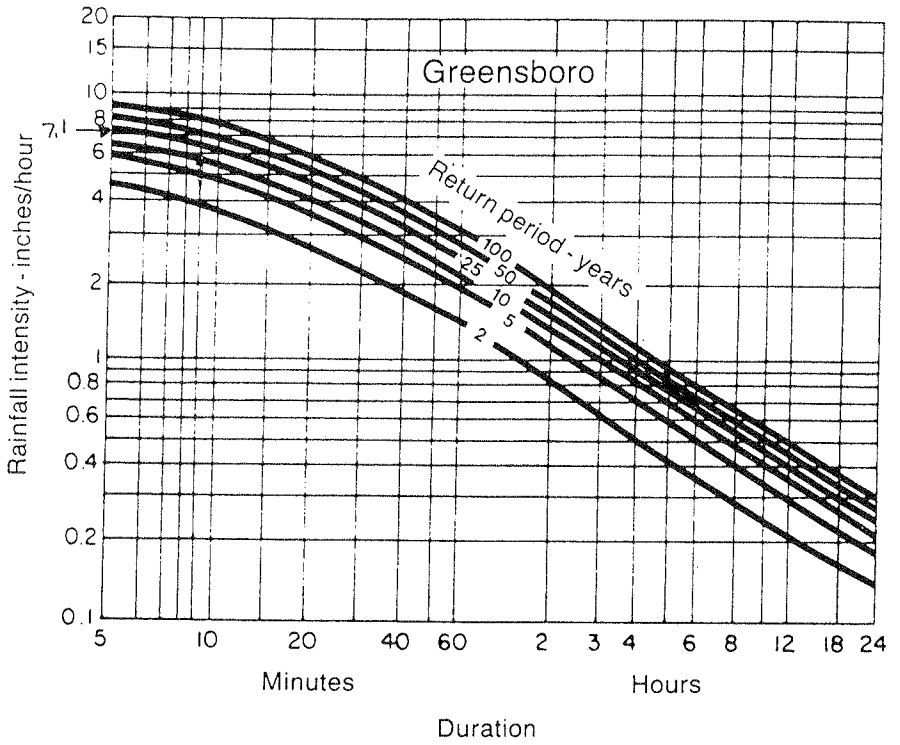


Figure 8.03d Rainfall intensity duration curves—Greensboro.

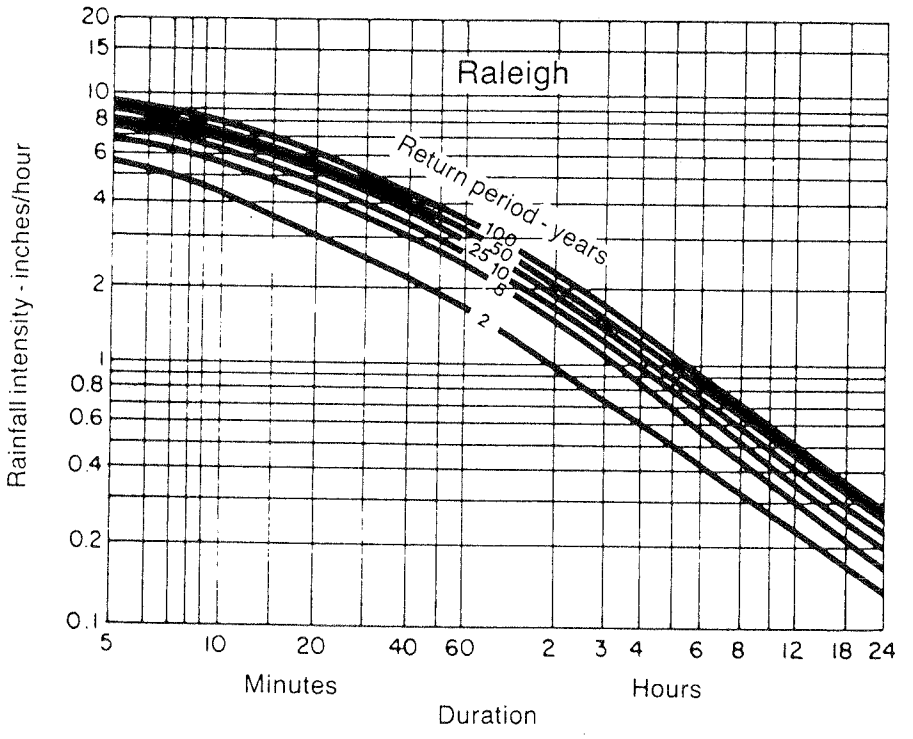


Figure 8.03e Rainfall intensity duration curves—Raleigh.

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes–3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.6	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.6	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.6	28	.97
70	2.5	2.8	8	1.88
	2.6	3.3	12	1.60
	2.6	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.6	3.6	16	1.51
	2.7	4.3	20	1.35

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.6	12	1.84
	2.5	3.1	16	1.61
	2.6	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.6	3.3	20	1.54
	2.6	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.6	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.6	3.6	32	1.47
	2.6	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.6	3.4	36	1.49
	2.6	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.6	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.6	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.6	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%.

Find: Bottom width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. Stage in Reservoir will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = .040. Maximum velocity = 5.50 ft per sec.

Job No. 6770-021-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{28{,}440\ FT^3}{24{,}437\ FT^2} = 1.2\ FT\ DEEP \quad (IF\ SIDE\ SLOPES\ WERE\ 0:1)$$

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$28{,}440\ FT^3 = \left(\frac{24{,}437\ FT^2 + A_2}{2}\right)(H)$$

H	A_2
1.5	13,403 FT^2
2.0	4,003 FT^2 ⟸ USE 2.0' DEPTH MIN.
3.0	-5,477 FT^2

$A_1 = 24{,}437\ FT^2$ BASIN SURFACE AREA (111' x 222')

$A_2 = 4{,}003\ FT^2$ BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 4{,}003\ FT^2$

$B = 45\ FT$

45' x 90'

Job No. 6770-021-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{28{,}440\ FT^3}{24{,}437\ FT^2} = 1.2\ FT\ DEEP \quad (IF\ SIDE\ SLOPES\ WERE\ 0:1)$$

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$28{,}440\ FT^3 = \left(\frac{24{,}437\ FT^2 + A_2}{2}\right)(H)$$

H	A_2
1.5	13,403 FT^2
2.0	4,003 FT^2 ⟸ USE 2.0' DEPTH MIN.
3.0	-5,477 FT^2

$A_1 = 24{,}437\ FT^2$ BASIN SURFACE AREA (111' x 222')

$A_2 = 4{,}003\ FT^2$ BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 4{,}003\ FT^2$

$B = 45\ FT$

45' x 90'

Job No. 6770-021-018 | No.

HDR Computation

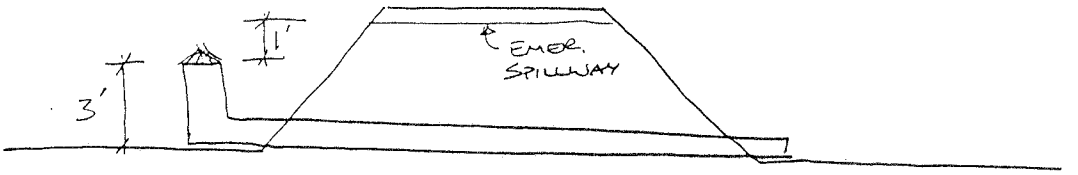
HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (15.8 ACRES) = 3.2 CFS

RISER HEIGHT
2x BARREL
DIAMETER



TRY 18" ϕ BARREL

$H = 3' - \frac{18"\phi}{2(12)} = 2.25$ FT

FROM TABLE 8.07a, A 18" ϕ BARREL WILL CARRY A MIN. OF 7.73 CFS

USE 18" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 24" ϕ RISER
FOR A 24" ϕ RISER WITH H = 1 FT., Q = 20.0 CFS

20.0 CFS > 7.73 CFS ∴ BARREL CONTROLS, OKAY

USE 24" ϕ RISER C.M.P.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

EMERGENCY SPILLWAY:

$$Q_e = Q_{25} - Q_p$$
$$= 56.1 \text{ CFS} - 7.73 \text{ CFS}$$
$$= 48.4 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 50 CFS

BOTTOM WIDTH = 24 FT

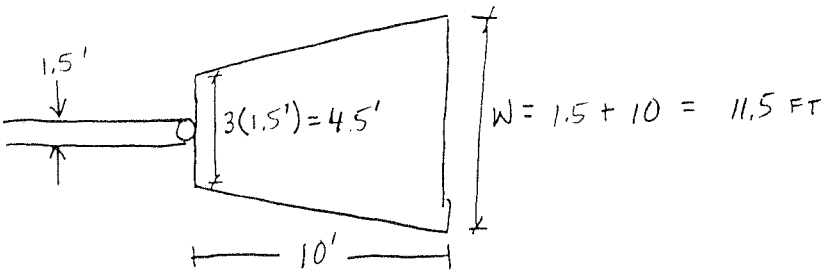
MAX. SLOPE = 9.0 %

STAGE = 0.94 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 7.73 CFS

FROM FIGURE 8.06 a: $d_{50} = 6''$; $L_a = 10$ FT



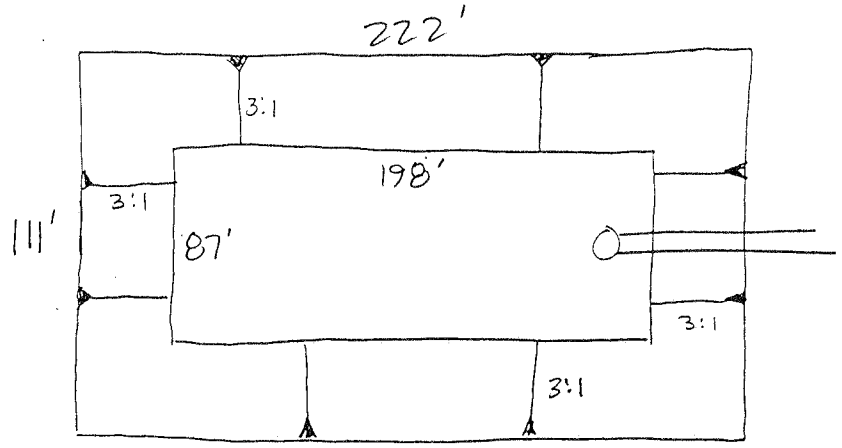
$d_{max} = 1.5\, d_{50} = 9''$

DEPTH = $1.5\, d_{max} = 13.5''$

Job No. 6770-021-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-9
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

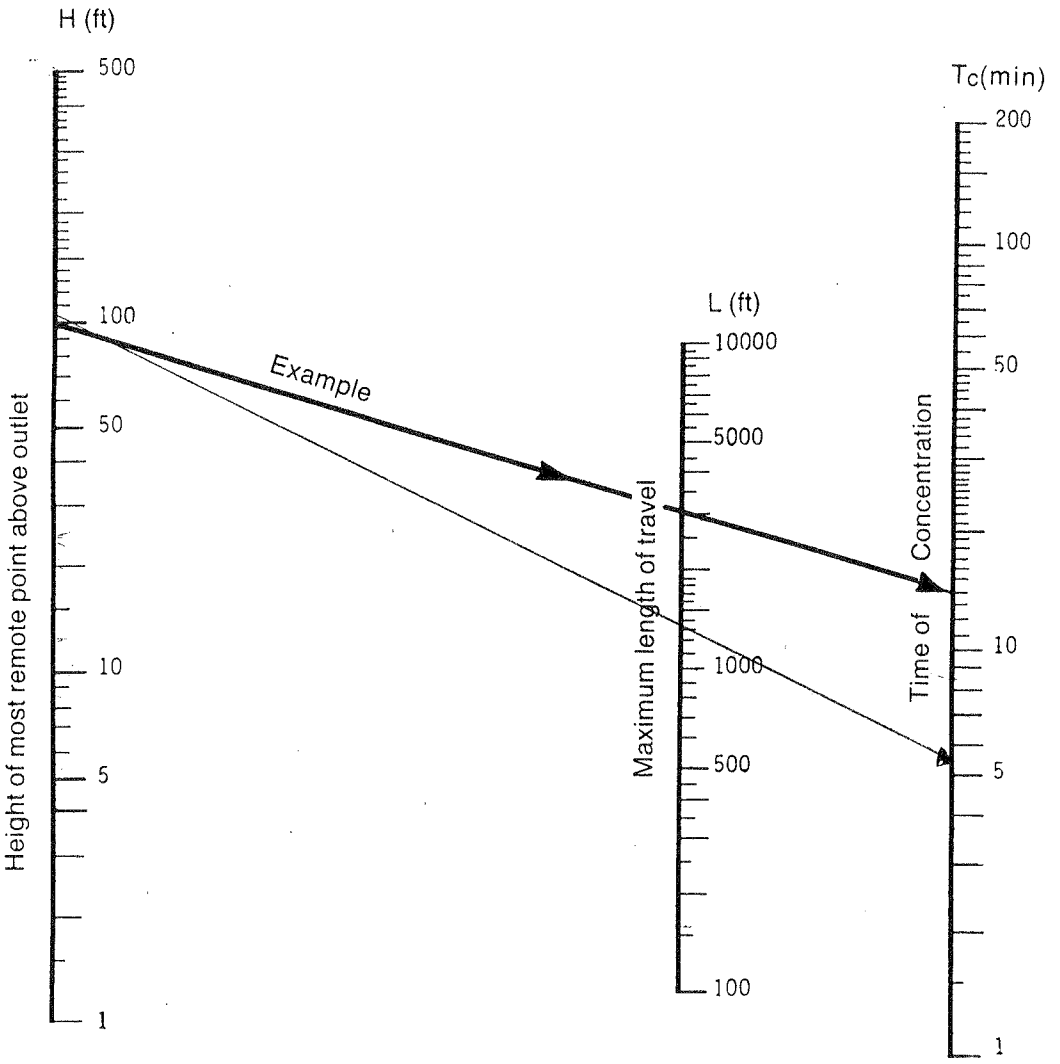


TOTAL VOLUME = A_1 = 24,437 FT^2

A_2 = 17,226 FT^2

H = 4 FT

VOL = 83,326 FT^3 > 28,440 FT^3 M



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

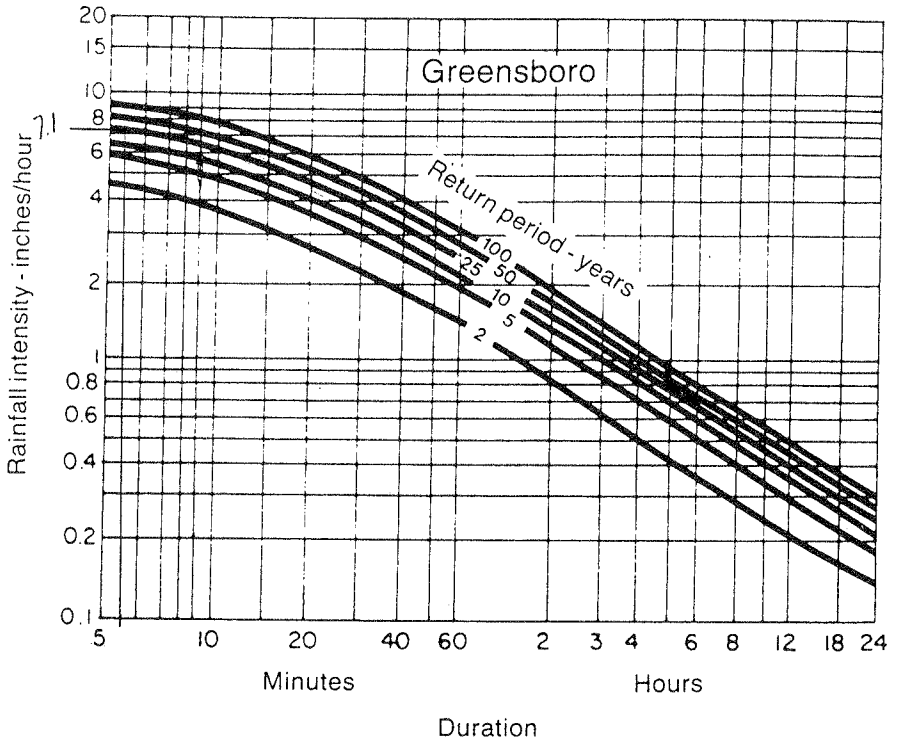


Figure 8.03d Rainfall intensity duration curves—Greensboro.

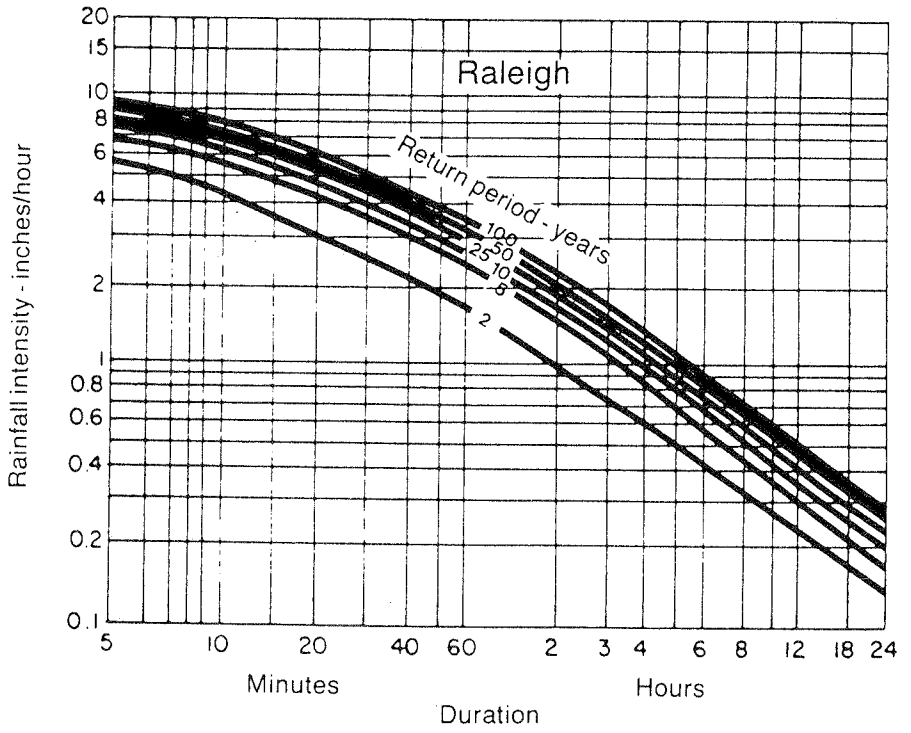


Figure 8.03e Rainfall intensity duration curves—Raleigh.

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes–3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.8	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.8	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.8	28	.97
70	2.5	2.8	8	1.88
	2.8	3.3	12	1.60
	2.8	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.8	3.8	16	1.51
	2.7	4.3	20	1.35

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.8	12	1.84
	2.5	3.1	16	1.61
	2.8	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.8	3.3	20	1.54
	2.8	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.8	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.8	3.6	32	1.47
	2.8	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.8	3.4	36	1.49
	2.8	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.8	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.8	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.8	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%.

Find: Bottom width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. Stage in Reservoir will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = .040. Maximum velocity = 5.50 ft per sec.

Job No. 6170-001-010 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

SOUTH SEDIMENT BASIN (FIGURES AND TABLES COME FROM NC MANUAL)

TOTAL DRAINAGE AREA = 15.8 ACRES

$Q = CIA$ WHERE Q = RUNOFF, CFS

C = RUNOFF COEFFICIENT

I = RAINFALL INTENSITY, IN/HR

A = DRAINAGE AREA, ACRES

C = 0.5 ASSUMED (TABLE 8.03a)

L = 1,330 FT

H = 106 FT

T_c = 5.5 min (FIG 8.03a)

I = 7.1 IN/HR (FIG. 8.03d)

$Q_{25} = 0.5\ (7.1)(15.8) =$ 56.1 CFS

STORAGE REQUIRED = 1800 FT^3/ACRE × 15.8 ACRES = 28,440 FT^3

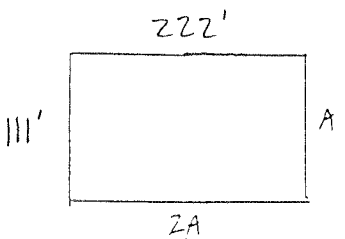
FOR 75% TRAPPING EFFICIENCY SURFACE AREA SHOULD BE:

.01 ACRE/CFS × 56.1 CFS = 0.561 ACRE = 24,437 FT^2

APPROXIMATE SURFACE DIMENSIONS:

$2A^2 = 24{,}437\ FT^2$

$A = 111$ FT



Job No. 6770-021-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{28{,}440\ FT^3}{24{,}437\ FT^2} = 1.2\ FT\ DEEP \quad (IF\ SIDE\ SLOPES\ WERE\ 0:1)$$

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$28{,}440\ FT^3 = \left(\frac{24{,}437\ FT^2 + A_2}{2}\right)(H)$$

H	A_2
1.5	13,403 FT^2
2.0	4,003 FT^2 ⟸ USE 2.0' DEPTH MIN.
3.0	-5,477 FT^2

$A_1 = 24{,}437\ FT^2$ BASIN SURFACE AREA (111' x 222')

$A_2 = 4{,}003\ FT^2$ BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 4{,}003\ FT^2$

$B = 45\ FT$

45' x 90'

Job No. 6770-021-018 | No.

HDR Computation

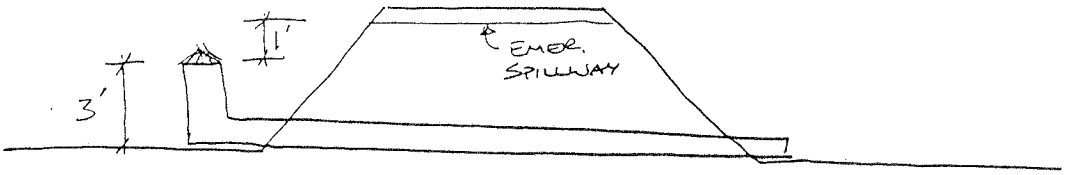
HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (15.8 ACRES) = 3.2 CFS

RISER HEIGHT
2x BARREL
DIAMETER



TRY 18" ϕ BARREL

$H = 3' - \frac{18"\phi}{2(12)} = 2.25$ FT

FROM TABLE 8.07a, A 18" ϕ BARREL WILL CARRY A MIN. OF 7.73 CFS

USE 18" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 24" ϕ RISER
FOR A 24" ϕ RISER WITH H = 1 FT., Q = 20.0 CFS

20.0 CFS > 7.73 CFS ∴ BARREL CONTROLS, OKAY

USE 24" ϕ RISER C.M.P.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

EMERGENCY SPILLWAY:

$$Q_e = Q_{25} - Q_p$$
$$= 56.1 \text{ CFS} - 7.73 \text{ CFS}$$
$$= 48.4 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 50 CFS

BOTTOM WIDTH = 24 FT

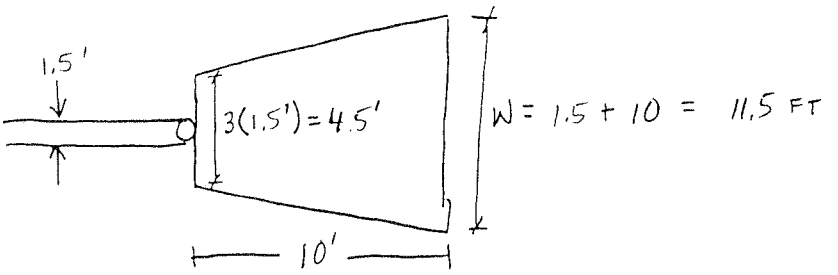
MAX. SLOPE = 9.0 %

STAGE = 0.94 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 7.73 CFS

FROM FIGURE 8.06 a: $d_{50} = 6''$; $L_a = 10$ FT



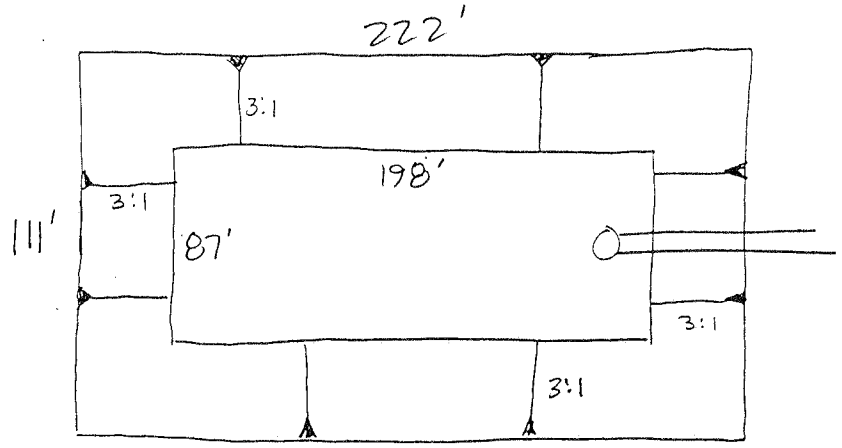
$d_{max} = 1.5\, d_{50} = 9''$

DEPTH = $1.5\, d_{max} = 13.5''$

Job No. 6770-021-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-9
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

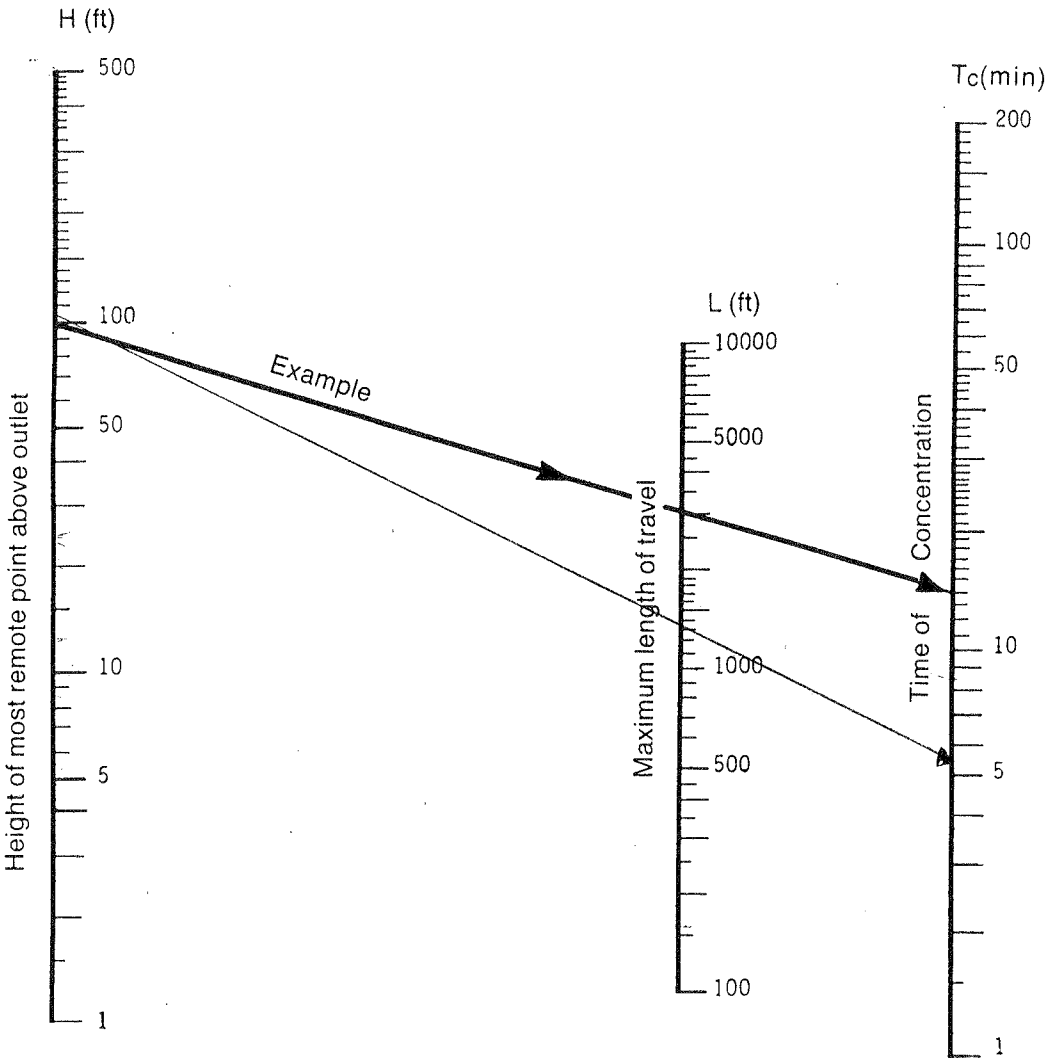


TOTAL VOLUME = A_1 = 24,437 FT^2

A_2 = 17,226 FT^2

H = 4 FT

VOL = 83,326 FT^3 > 28,440 FT^3 M



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

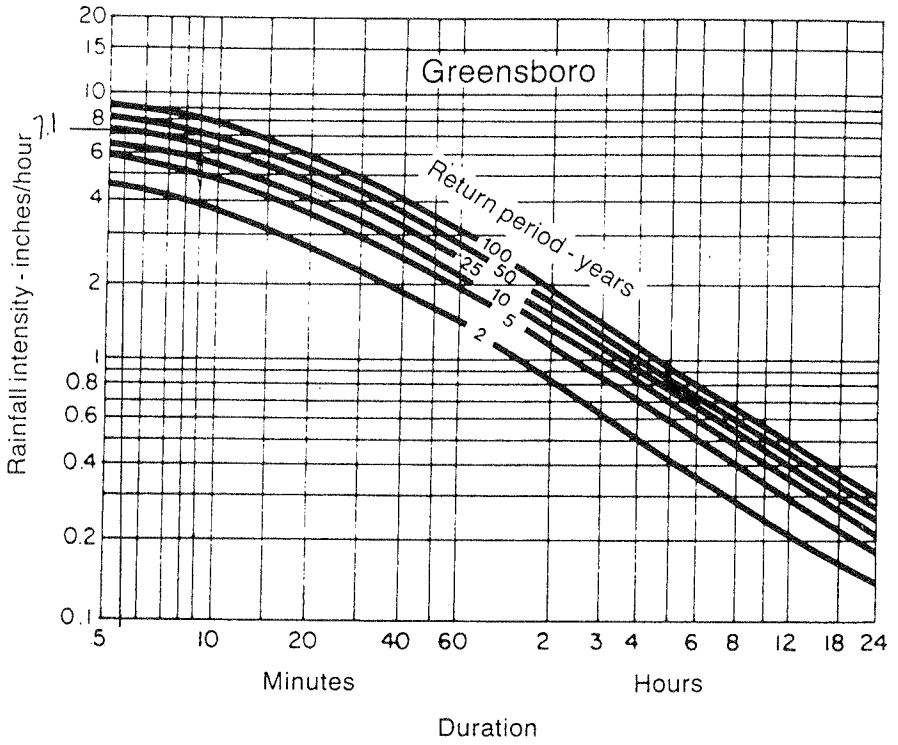


Figure 8.03d Rainfall intensity duration curves—Greensboro.

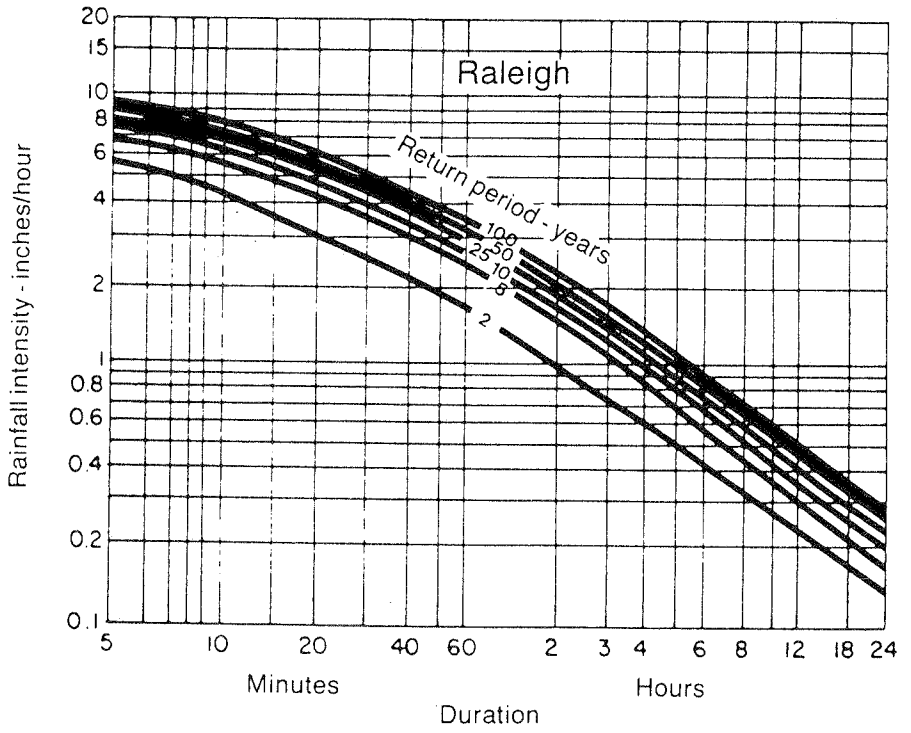


Figure 8.03e Rainfall intensity duration curves—Raleigh.

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes–3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.8	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.8	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.8	28	.97
70	2.5	2.8	8	1.88
	2.8	3.3	12	1.60
	2.8	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.8	3.8	16	1.51
	2.7	4.3	20	1.35

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.8	12	1.84
	2.5	3.1	16	1.61
	2.8	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.8	3.3	20	1.54
	2.8	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.8	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.8	3.6	32	1.47
	2.8	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.8	3.4	36	1.49
	2.8	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.8	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.8	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.8	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%.

Find: Bottom width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. Stage in Reservoir will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = .040. Maximum velocity = 5.50 ft per sec.

Job No. 6 [illegible] No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

EAST SEDIMENT BASIN (FIGURES AND TABLES COME FROM NC MANUAL)

TOTAL DRAINAGE AREA = 18.4 ACRES

$Q = CIA$ WHERE Q = RUNOFF, CFS
C = RUNOFF COEFFICIENT
I = RAINFALL INTENSITY, IN/HR
A = DRAINAGE AREA, ACRES

C = 0.5 ASSUMED (TABLE 8.03a)
L = 1,300 FT
H = 180 FT
T_c = 4.5 min (FIG 8.03a)
I = 7.1 IN/HR (FIG. 8.03d)

$Q_{25} = 0.5\,(7.1)(18.4) = \underline{65.3 \text{ CFS}}$

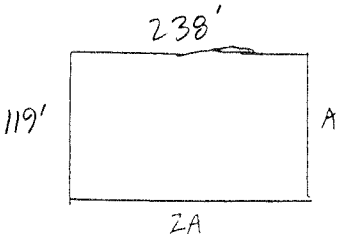
STORAGE REQUIRED = 1800 FT³/ACRE × 18.4 ACRES = 33,120 FT³

FOR 75% TRAPPING EFFICIENCY SURFACE AREA SHOULD BE:

.01 ACRE/CFS × 65.3 CFS = 0.653 ACRE = 28,445 FT²

APPROXIMATE SURFACE DIMENSIONS:

$2A^2 = 28{,}445 \text{ FT}^2$
$A = 119 \text{ FT}$



Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
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MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{33{,}120\ FT^3}{28{,}445\ FT^2} = 1.2\ FT\ DEEP \quad (IF\ SIDE\ SLOPES\ WERE\ 0:1)$$

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$33{,}120\ FT^3 = \left(\frac{28{,}445\ FT^2 + A_2}{2}\right)(H)$$

H	A_2
1.5	15,715 FT^2
2.0	4,675 FT^2 ⟸ USE 2.0' DEPTH MIN.
2.5	-1,949 FT^2

$A_1 = 28{,}445\ FT^2$ BASIN SURFACE AREA (119' x 238')

$A_2 = 4{,}675\ FT^2$ BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 4{,}675\ FT^2$

$B = 48\ FT$

48' x 96'

Job No. 6770-021-018 | No.

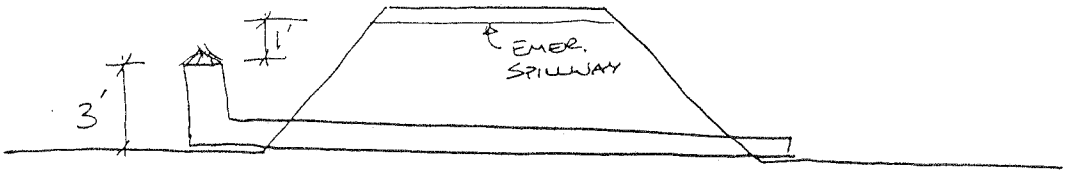
HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-22-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (18.4 ACRES) = 3.7 CFS

RISER HEIGHT = 2x BARREL DIAMETER



TRY 18" ϕ BARREL

$H = 3' - \frac{18,"\phi}{2(12)} = 2.25$ FT

FROM TABLE 8.07a, A 18" ϕ BARREL WILL CARRY A MIN. OF 7.73 CFS

USE 18" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 24" ϕ RISER

FOR A 24" ϕ RISER WITH H = 1 FT., Q = 20.0 CFS

20.0 CFS > 7.73 CFS ∴ BARREL CONTROLS, OKAY

USE 24" ϕ RISER C.M.P.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

EMERGENCY SPILLWAY:

$$Q_e = Q_{25} - Q_p$$
$$= 65.3 \text{ CFS} - 7.73 \text{ CFS}$$
$$= 57.6 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 60 CFS

BOTTOM WIDTH = 28 FT

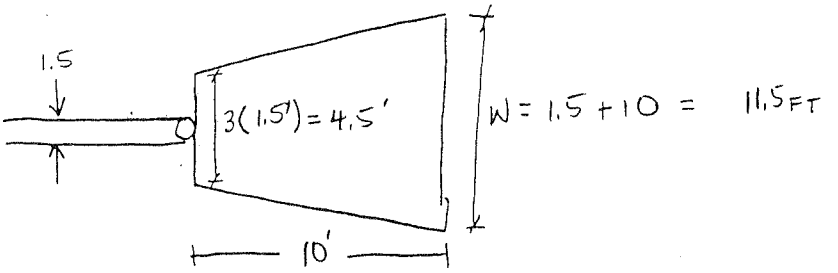
MAX. SLOPE = 8.6 %

STAGE = 0.97 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 7.73 CFS

FROM FIGURE 8.06 a: $d_{50} = 6''$; $L_a = 10$ FT



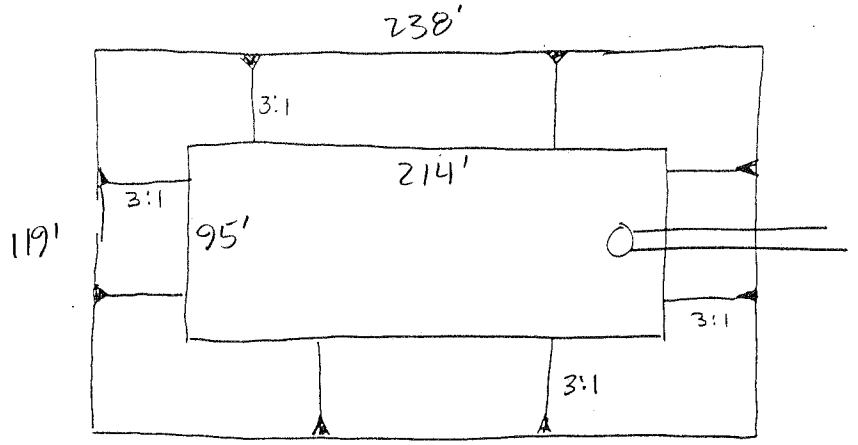
$d_{max} = 1.5\, d_{50} = 9''$

DEPTH = $1.5\, d_{max} = 13.5''$

Job No. 6710-021-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-9
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

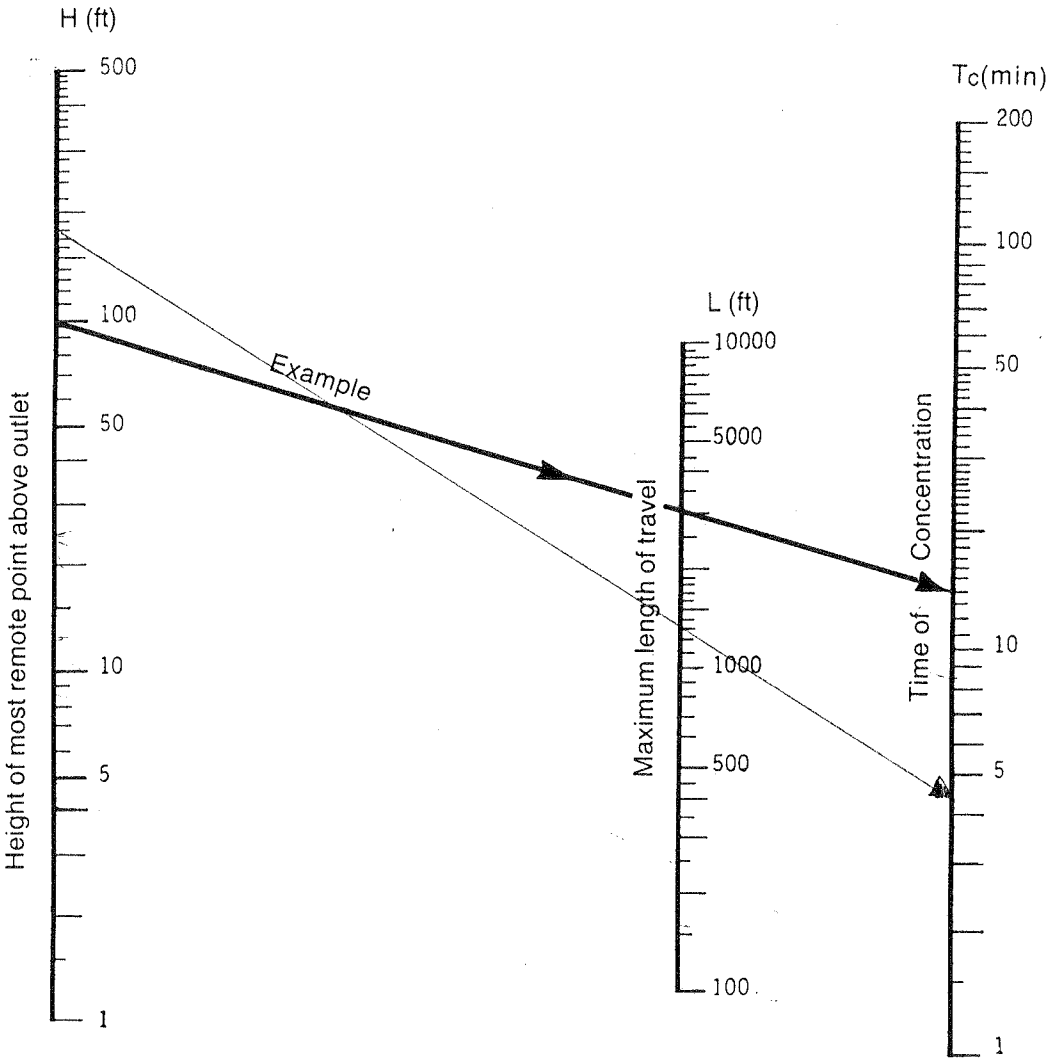


TOTAL VOLUME = A_1 = 28,445 FT^2

A_2 = 20,330 FT^2

H = 4 FT

VOL = 195,100 FT^3 > 33,120 FT^3 M



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

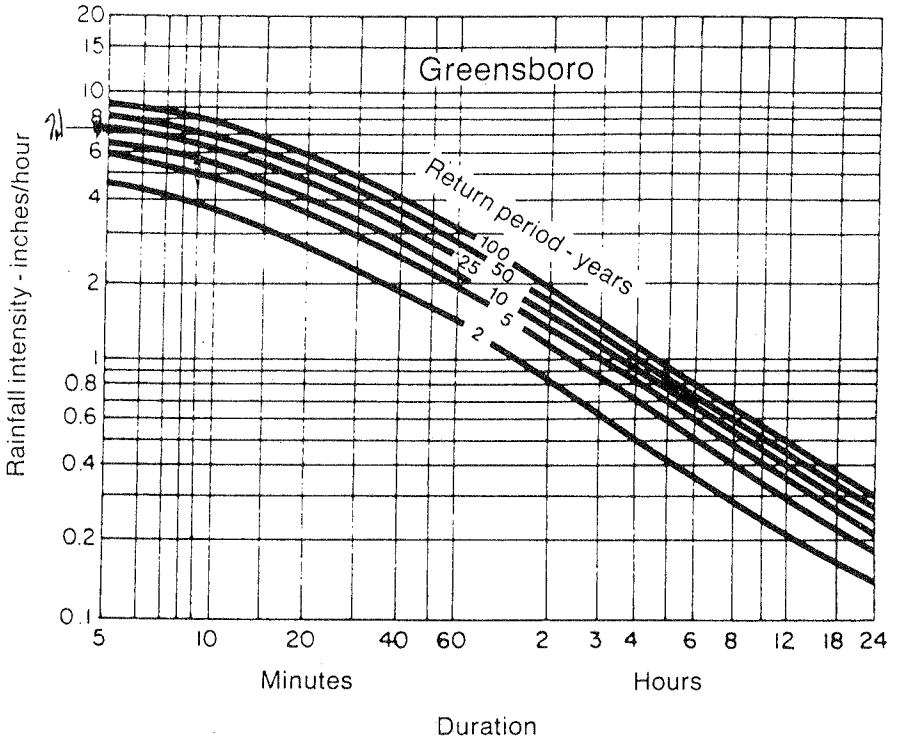


Figure 8.03d Rainfall intensity duration curves—Greensboro.

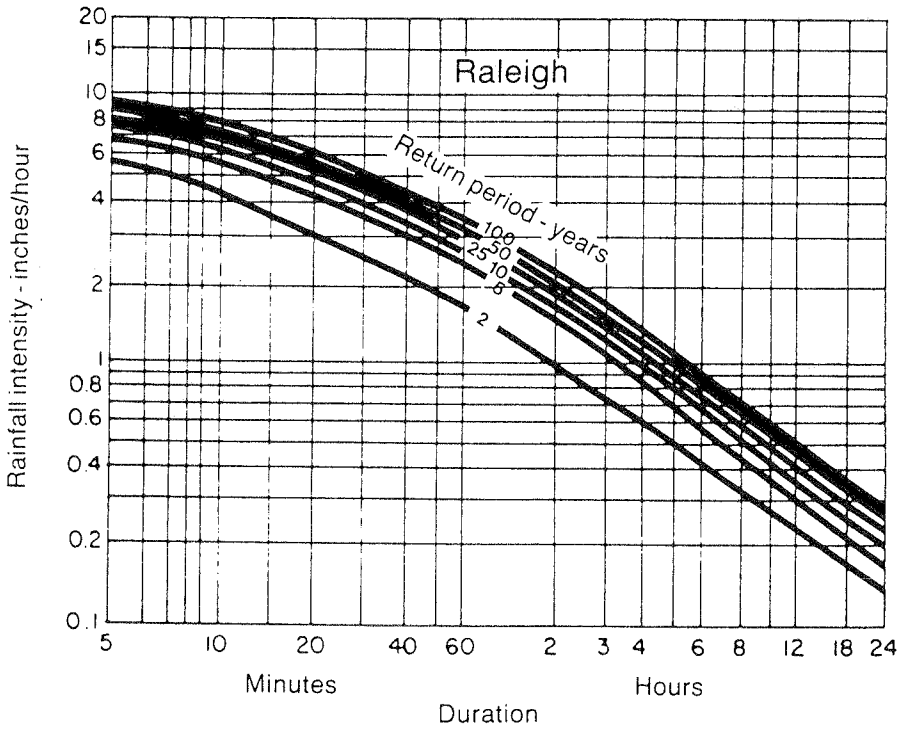


Figure 8.03e Rainfall intensity duration curves—Raleigh.

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes–3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.8	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.8	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.8	28	.97
70	2.5	2.8	8	1.88
	2.8	3.3	12	1.60
	2.8	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.8	3.8	16	1.51
	2.7	4.3	20	1.35
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.8	12	1.84
	2.5	3.1	16	1.61
	2.8	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.8	3.3	20	1.54
	2.8	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.8	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.8	3.8	32	1.47
	2.8	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.8	3.4	36	1.49
	2.8	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.8	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.8	3.8	48	1.45
220	2.4	2.8	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.8	44	1.70
	2.5	2.9	48	1.62
	2.8	3.2	52	1.54
260	2.4	2.8	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.8	52	1.70
300	2.5	2.8	58	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%.

Find: Bottom width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. Stage in Reservoir will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = .040. Maximum velocity = 5.50 ft per sec.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

NORTHEAST SEDIMENT BASIN (* FIGURES AND TABLES COME FROM NC MANUAL)

TOTAL DRAINAGE AREA = 37 ACRES (OF THE 52 ACRES, 15 AC WILL DRAIN INTO NORTH BASIN)

$Q = CIA$ WHERE Q = RUNOFF, CFS
C = RUNOFF COEFFICIENT
I = RAINFALL INTENSITY, IN/HR
A = DRAINAGE AREA, ACRES

C = 0.5 ASSUMED (TABLE 8.03a)
L = 2600 FT
H = 58 FT
T_c = 14.5 min (FIG 8.03a)
I = 5.6 IN/HR (FIG. 8.03d)

$Q_{CS} = 0.5\ (5.6)(37) = 103.6$ CFS

STORAGE REQUIRED = 1800 $FT^3/ACRE$ × 37 ACRES = 66,600 FT^3

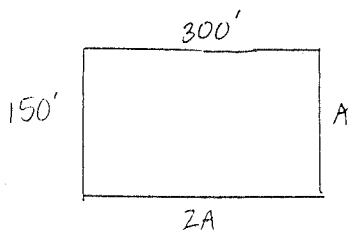
FOR 75% TRAPPING EFFICIENCY SURFACE AREA SHOULD BE:

.01 ACRE/CFS × 103.6 CFS = 1.036 ACRE = 45,128 FT^2

APPROXIMATE SURFACE DIMENSIONS:

$2A^2 = 45{,}128\ FT^2$

$A = 150$ FT



Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
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MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{66{,}600\ FT^3}{45{,}128\ FT^2} = 1.5\ FT\ DEEP \quad (IF\ SIDE\ SLOPES\ WERE\ 0:1)$$

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$66{,}600\ FT^3 = \left(\frac{45{,}128\ FT^2 + A_2}{2}\right)(H)$$

H	A_2
1.5	43,672 FT^2
2.0	21,472 FT^2 ⟸ USE 2.0' DEPTH MIN.
3.0	-728 FT^2

$A_1 = 45{,}128\ FT^2$ BASIN SURFACE AREA (150' x 300')

$A_2 = 21{,}472\ FT^2$ BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 21{,}472\ FT^2$

$B = 104\ FT$

104' x 208'

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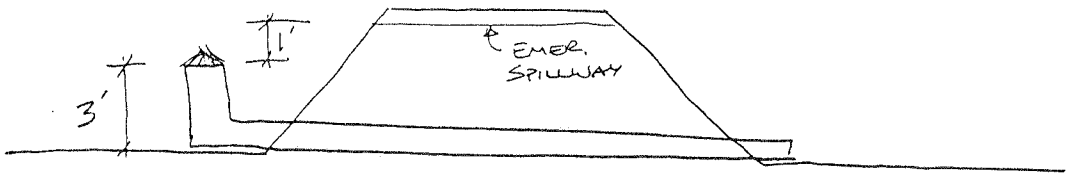
HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-22-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (37 ACRES) = 7.4 CFS

RISER HEIGHT
2x BARREL
DIAMETER



TRY 18" ϕ BARREL

$H = 3' - \frac{18"\phi}{2(12)} = 2.25$ FT

FROM TABLE 8.07a, A 18" ϕ BARREL WILL CARRY A MIN. OF 7.73 CFS

USE 18" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 24" ϕ RISER
FOR A 24" ϕ RISER WITH H = 1 FT., Q = 20.0 CFS

20 CFS > 7.73 CFS ∴ BARREL CONTROLS, OKAY

USE 24" ϕ RISER C.M.P.

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HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

EMERGENCY SPILLWAY:

$$Q_e = Q_{25} - Q_p$$
$$= 103.6 \text{ CFS} - 7.73 \text{ CFS}$$
$$= 95.9 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 90 CFS

BOTTOM WIDTH = 32 FT

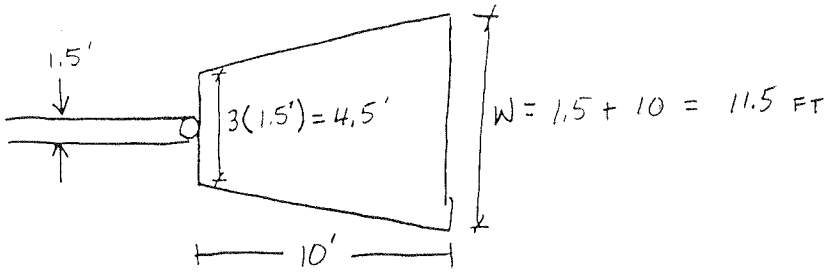
MAX. SLOPE = 6.1 %

STAGE = 1.14 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 7.73 CFS

FROM FIGURE 8.06 a: $d_{50} = 6''$; $L_2 = 10$ FT



$d_{max} = 1.5\, d_{50} = 9''$

DEPTH = $1.5\, d_{max} = 13.5''$

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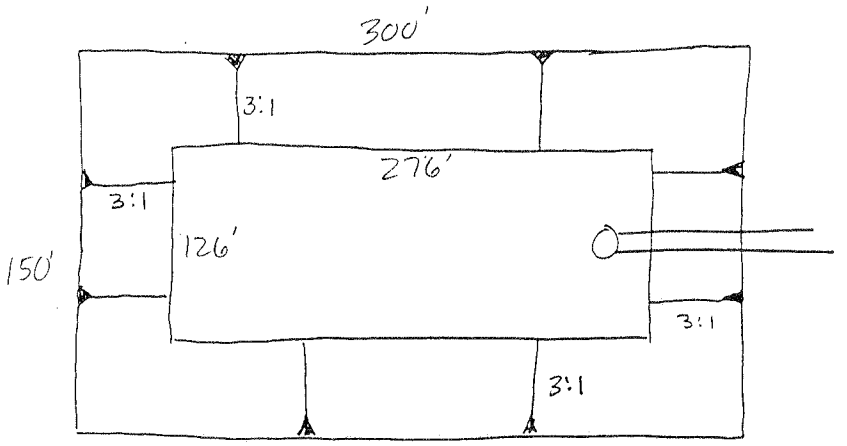
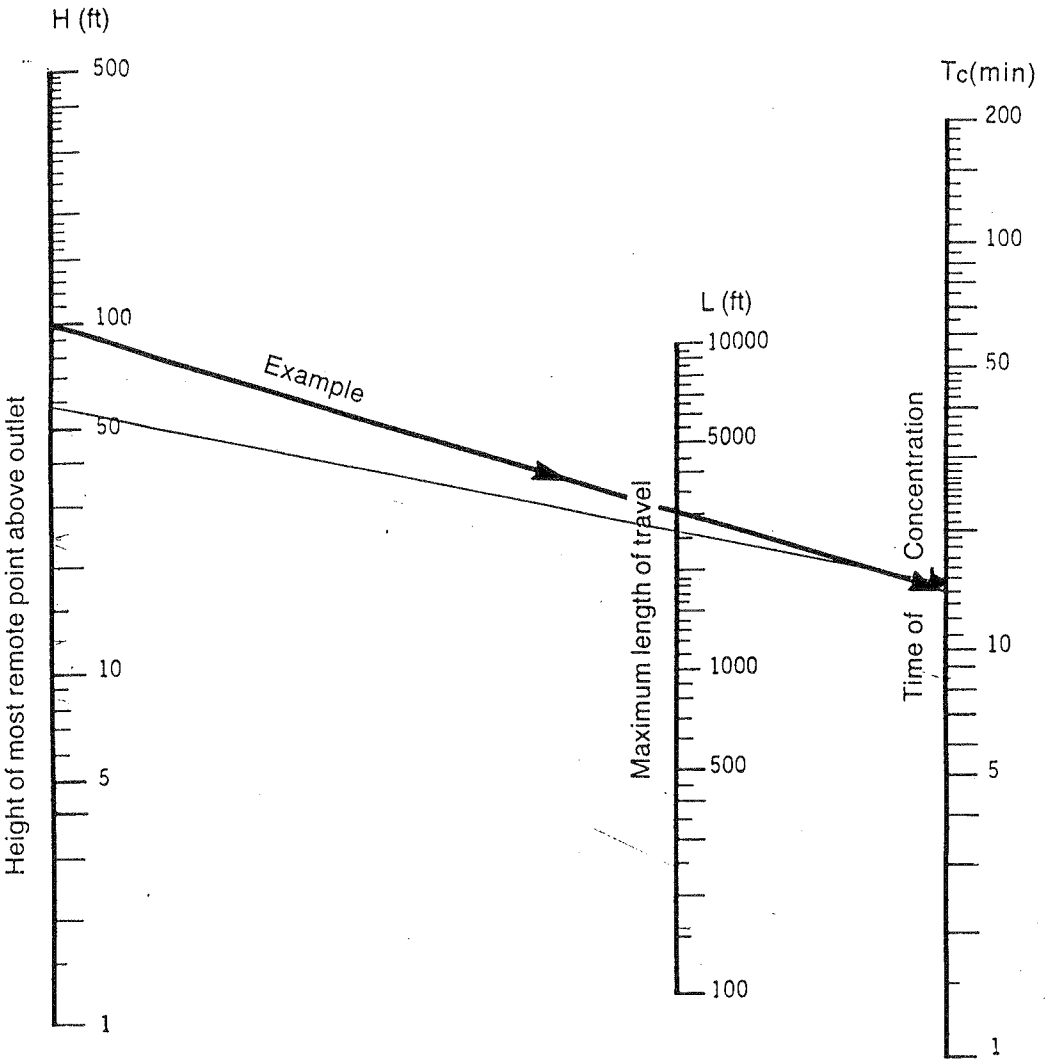


TOTAL VOLUME = A_1 = 45,128 FT^2

A_2 = 34,776 FT^2

H = 4 FT

VOL = 159,808 FT^3 > 66,600 FT^3 M



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

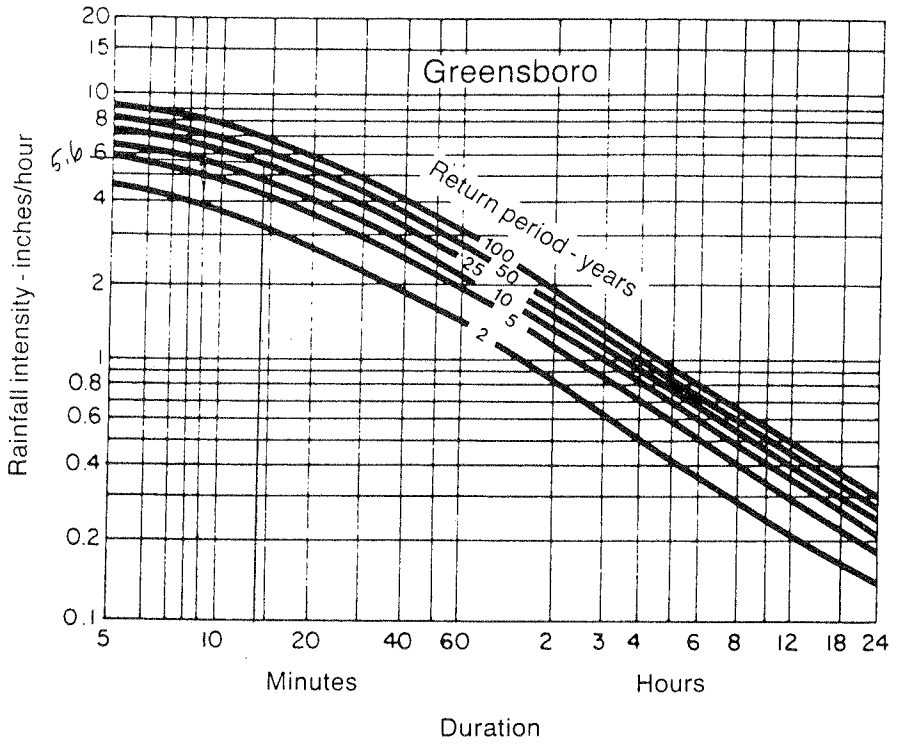


Figure 8.03d Rainfall intensity duration curves—Greensboro.

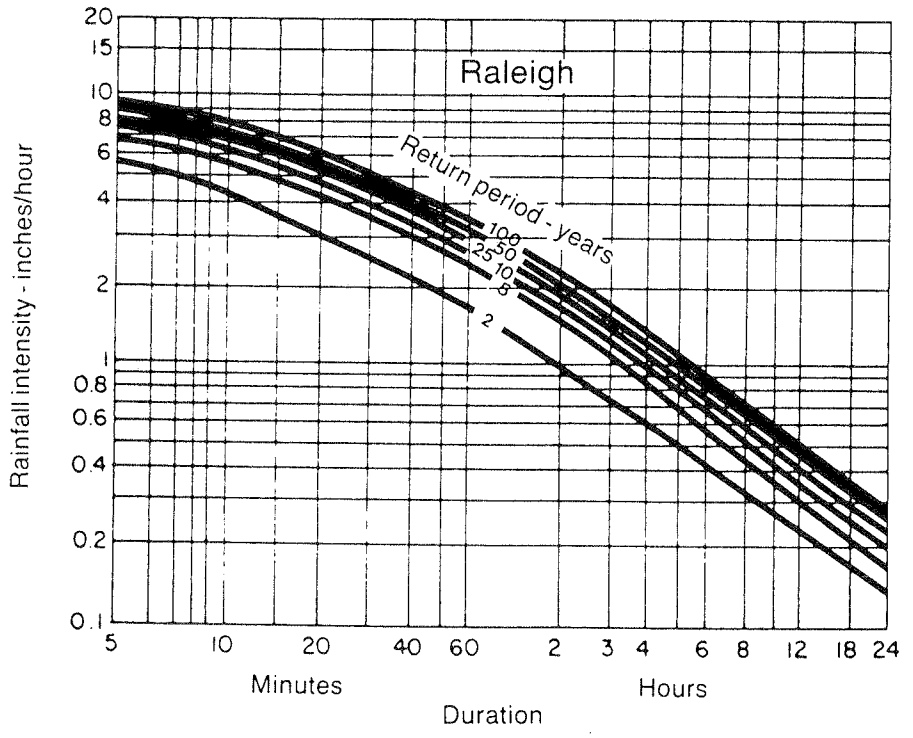


Figure 8.03e Rainfall intensity duration curves—Raleigh.

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes–3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.6	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.6	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.6	28	.97
70	2.5	2.8	8	1.88
	2.6	3.3	12	1.60
	2.6	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.6	3.6	16	1.51
	2.7	4.3	20	1.35

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.6	12	1.84
	2.5	3.1	16	1.61
	2.6	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.6	3.3	20	1.54
	2.6	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.6	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.6	3.6	32	1.47
	2.6	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.6	3.4	36	1.49
	2.6	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.6	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.6	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.6	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%.

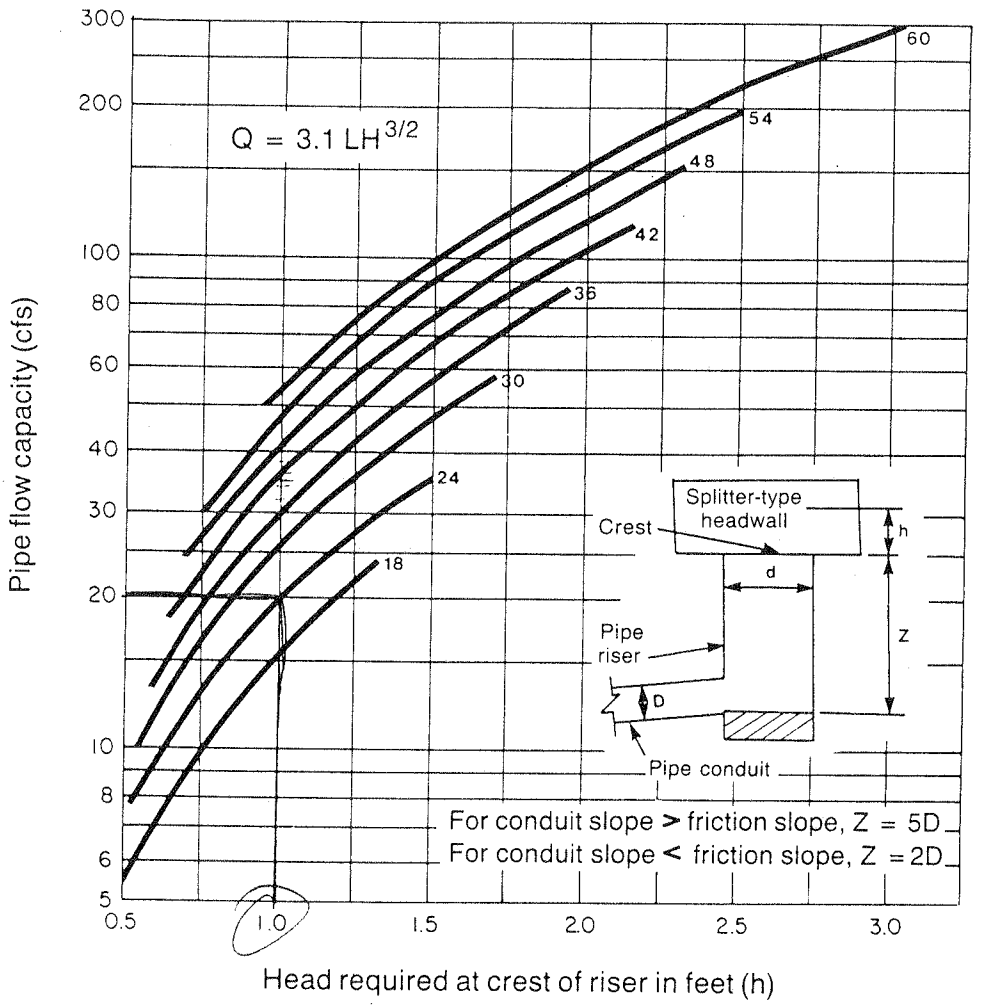
Find: Bottom width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. Stage in Reservoir will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = .040. Maximum velocity = 5.50 ft per sec.

24" CMP RISER

Circular risers with splitter wall



Inlet Proportions	
Pipe Conduit (D) - in	Pipe Riser (D) - in
8-12	18
15	21
18	24
21	30
24	30
30	36
36	48
42	54
48	60

Pipe drop inlet spillway design:

For a given Q and H, refer to Table 8.07a or 8.07b for conduit size. Then determine the riser diameter (d) from the Inlet Proportions Table on this figure. Next, refer to the above curves, using the conduit capacity and riser diameter, and find the head (h) required above the crest of the riser. The height of the riser should not be less than 5D - h, except as noted in the above sketch.

Example - Given: CMP; Q = 20 cfs; H = 14 ft, h max. 1.0 ft; L = 70 ft. From Table 8.07a find conduit size (D) = 18 inches. From Inlet Proportions Table, riser size = 24 inches. Head (h) required for Q = 20 and d = 24 is 1.0 ft.

Figure 8.07b Design chart for riser outlet.

18" C.M.P. Barrel

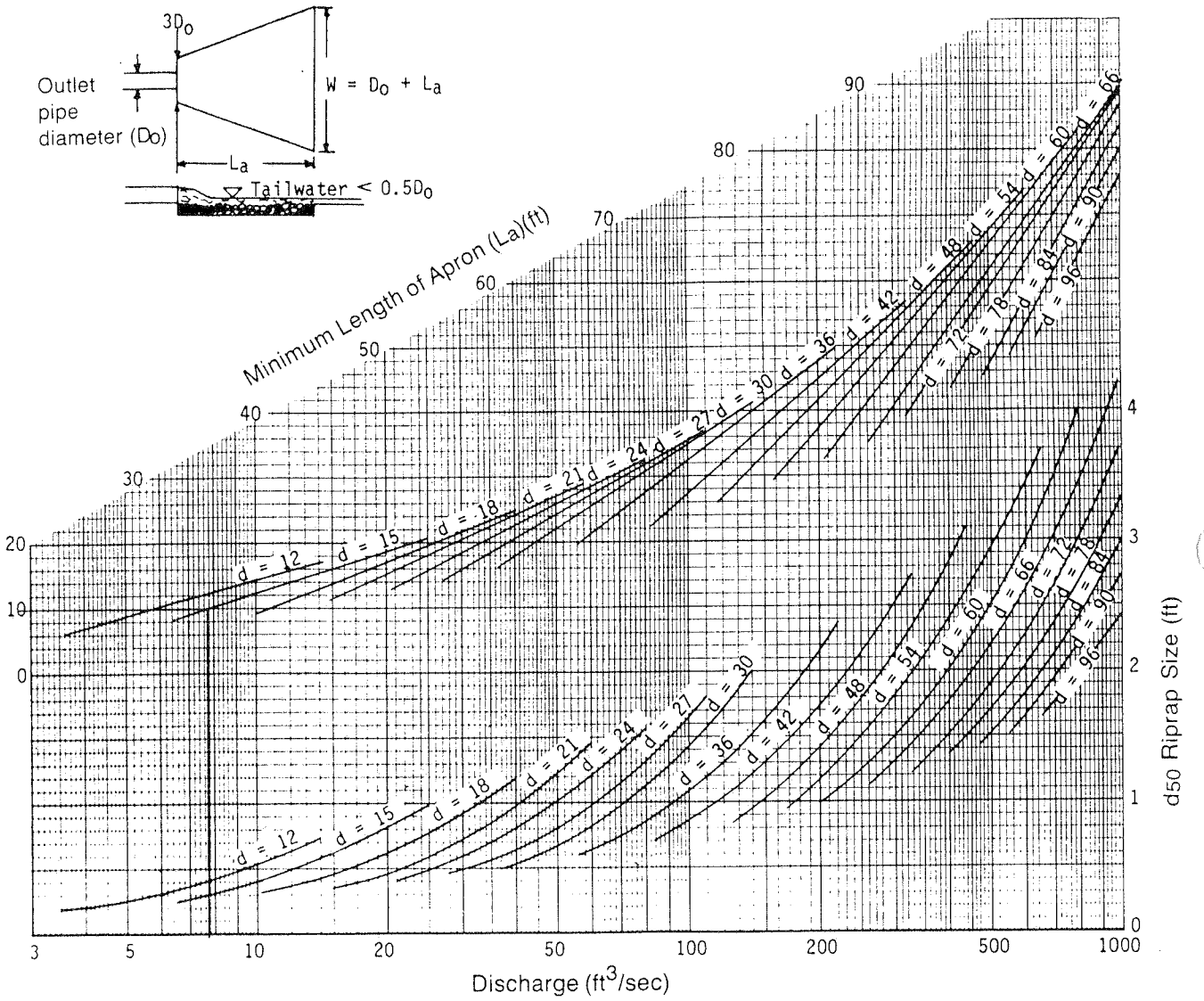
Table 8.07a
Pipe Flow Chart for Design of Corrugated Metal Outlet Conduit
(Q in cubic ft/sec)

For Corrugated Metal Pipe Inlet $K_e + K_b = 1.0$ and 70 feet of Corrugated Metal Pipe Conduit n = 0.025. Note correction factors for other pipe lengths.

2.25' →

Dia. / H	12"	15"	18"	21"	24"	30"	36"	42"
2	2.84	4.92	7.73	11.30	15.60	26.60	40.77	58.12
3	3.48	6.03	9.47	13.84	19.10	32.58	49.93	71.19
4	4.02	6.96	10.94	15.98	22.06	37.62	57.66	82.20
5	4.49	7.78	12.23	17.87	24.66	42.06	64.46	91.90
6	4.92	8.52	13.40	19.57	27.01	46.07	70.60	100.65
7	5.32	9.21	14.47	21.14	29.19	49.77	76.28	108.75
8	5.68	9.84	15.47	22.60	31.19	53.19	81.53	116.23
9	6.03	10.44	16.41	23.97	33.09	56.43	86.49	123.30
10	6.36	11.00	17.30	25.26	34.88	59.48	91.16	129.96
11	6.67	11.54	18.14	26.50	36.59	62.39	95.63	136.33
12	6.96	12.05	18.95	27.68	38.21	65.16	99.87	142.37
13	7.25	12.55	19.72	28.81	39.77	67.83	103.96	148.21
14	7.52	13.02	20.47	29.90	41.27	70.39	107.88	153.80
15	7.78	13.48	21.19	30.95	42.72	72.85	111.66	159.18
16	8.04	13.92	21.88	31.96	44.12	75.24	115.32	164.40
17	8.29	14.35	22.55	32.94	45.48	77.55	118.87	169.46
18	8.53	14.77	23.21	33.90	46.80	79.81	122.33	174.39
19	8.76	15.17	23.84	34.83	48.08	81.99	125.67	179.15
20	8.99	15.56	24.46	35.73	49.33	84.12	128.93	183.80
21	9.21	15.95	25.07	36.62	50.55	86.21	132.13	188.36
22	9.43	16.32	25.65	37.47	51.73	88.22	135.21	192.76
23	9.64	16.69	26.23	38.32	52.90	90.21	138.27	197.12
24	9.85	17.05	26.80	39.14	54.04	92.15	141.24	201.35
25	10.05	17.40	27.35	39.95	55.15	94.05	144.15	205.50
L	Correction Factors For Other Pipe Lengths							
40	1.23	1.22	1.20	1.19	1.16	1.14	1.13	1.11
50	1.14	1.13	1.12	1.11	1.10	1.09	1.08	1.07
60	1.07	1.06	1.06	1.05	1.05	1.04	1.04	1.03
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	0.95	0.95	0.95	0.96	0.96	0.96	0.97	0.97
90	0.90	0.91	0.91	0.92	0.92	0.93	0.94	0.94
100	0.86	0.87	0.88	0.89	0.89	0.90	0.91	0.92

Rip Rap Apron 18" CMP Barrel



Curves may not be extrapolated.

Figure 8.06a Design of outlet protection protection from a round pipe flowing full, minimum tailwater condition (T_w < 0.5 diameter).

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HDR Computation

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EAST SEDIMENT BASIN (FIGURES AND TABLES COME FROM NC MANUAL)

TOTAL DRAINAGE AREA = 18.4 ACRES

$Q = CIA$ WHERE Q = RUNOFF, CFS
C = RUNOFF COEFFICIENT
I = RAINFALL INTENSITY, IN/HR
A = DRAINAGE AREA, ACRES

C = 0.5 ASSUMED (TABLE 8.03a)
L = 1,300 FT
H = 180 FT
T_c = 4.5 min (FIG 8.03a)
I = 7.1 IN/HR (FIG. 8.03d)

$Q_{25} = 0.5\,(7.1)(18.4) = \underline{65.3 \text{ CFS}}$

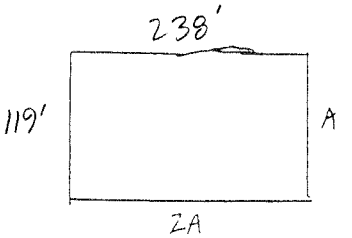
STORAGE REQUIRED = 1800 FT³/ACRE × 18.4 ACRES = 33,120 FT³

FOR 75% TRAPPING EFFICIENCY SURFACE AREA SHOULD BE:

.01 ACRE/CFS × 65.3 CFS = 0.653 ACRE = 28,445 FT²

APPROXIMATE SURFACE DIMENSIONS:

$2A^2 = 28{,}445 \text{ FT}^2$
$A = 119 \text{ FT}$



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Task	DRAINAGE	Sheet	Of

MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{33{,}120\ FT^3}{28{,}445\ FT^2} = 1.2\ FT\ DEEP \quad (IF\ SIDE\ SLOPES\ WERE\ 0:1)$$

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$33{,}120\ FT^3 = \left(\frac{28{,}445\ FT^2 + A_2}{2}\right)(H)$$

H	A_2
1.5	15,715 FT^2
2.0	4,675 FT^2 ⟸ USE 2.0' DEPTH MIN.
2.5	-1,949 FT^2

$A_1 = 28{,}445\ FT^2$ BASIN SURFACE AREA (119' x 238')

$A_2 = 4{,}675\ FT^2$ BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 4{,}675\ FT^2$

$B = 48\ FT$

48' x 96'

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Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
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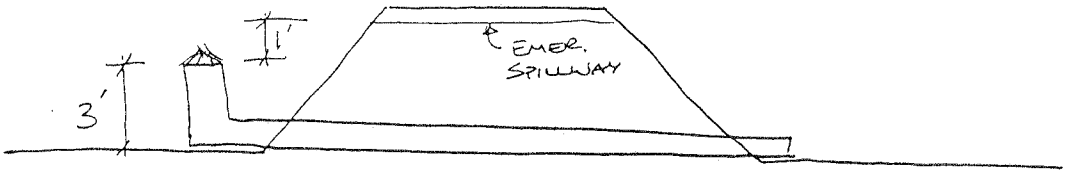
SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (18.4 ACRES) = 3.7 CFS

RISER HEIGHT = 2x BARREL DIAMETER



TRY 18" ϕ BARREL

$H = 3' - \frac{18,"\phi}{2(12)} = 2.25$ FT

FROM TABLE 8.07a, A 18" ϕ BARREL WILL CARRY A MIN. OF 7.73 CFS

USE 18" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 24" ϕ RISER

FOR A 24" ϕ RISER WITH H = 1 FT., Q = 20.0 CFS

20.0 CFS > 7.73 CFS ∴ BARREL CONTROLS, OKAY

USE 24" ϕ RISER C.M.P.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

EMERGENCY SPILLWAY:

$$Q_e = Q_{25} - Q_p$$
$$= 65.3 \text{ CFS} - 7.73 \text{ CFS}$$
$$= 57.6 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 60 CFS

BOTTOM WIDTH = 28 FT

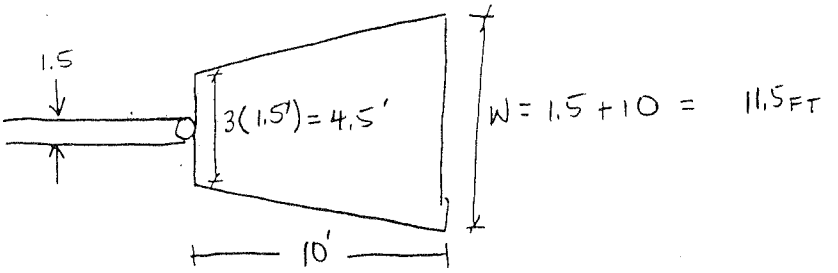
MAX. SLOPE = 8.6 %

STAGE = 0.97 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 7.73 CFS

FROM FIGURE 8.06 a: $d_{50} = 6''$; $L_a = 10$ FT



$d_{max} = 1.5\, d_{50} = 9''$

DEPTH = $1.5\, d_{max} = 13.5''$

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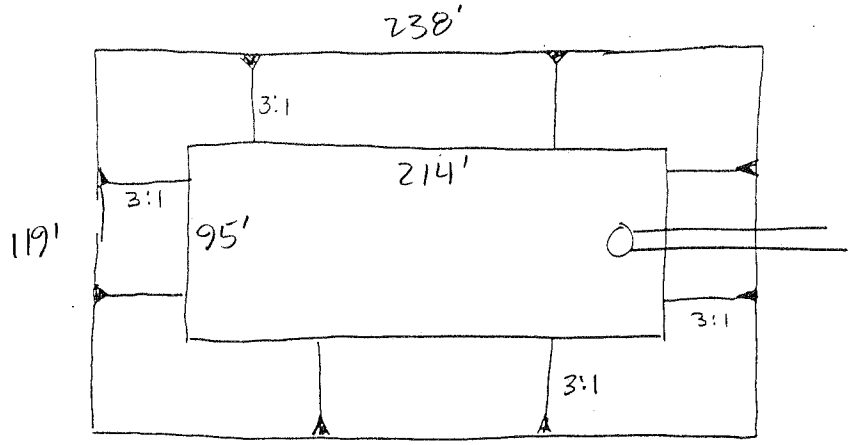
HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-9
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

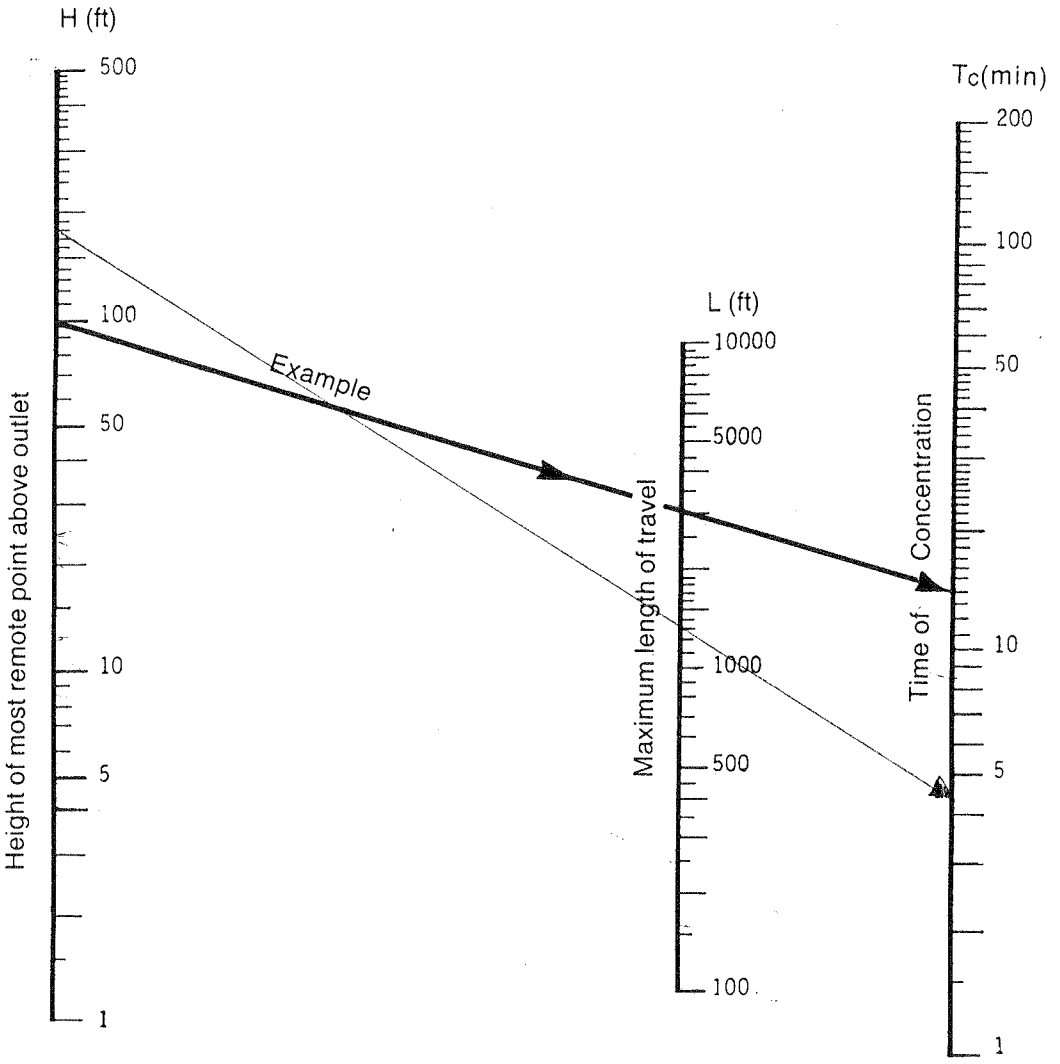


TOTAL VOLUME = A_1 = 28,445 FT^2

A_2 = 20,330 FT^2

H = 4 FT

VOL = 195,100 FT^3 > 33,120 FT^3 M



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

NORTHEAST SEDIMENT BASIN (* FIGURES AND TABLES COME FROM NC MANUAL)

TOTAL DRAINAGE AREA = 37 ACRES (OF THE 52 ACRES, 15 AC WILL DRAIN INTO NORTH BASIN)

$Q = CIA$ WHERE Q = RUNOFF, CFS
C = RUNOFF COEFFICIENT
I = RAINFALL INTENSITY, IN/HR
A = DRAINAGE AREA, ACRES

C = 0.5 ASSUMED (TABLE 8.03a)
L = 2600 FT
H = 58 FT
T_c = 14.5 min (FIG 8.03a)
I = 5.6 IN/HR (FIG. 8.03d)

$Q_{CS} = 0.5\ (5.6)(37) = 103.6$ CFS

STORAGE REQUIRED = 1800 $FT^3/ACRE$ × 37 ACRES = 66,600 FT^3

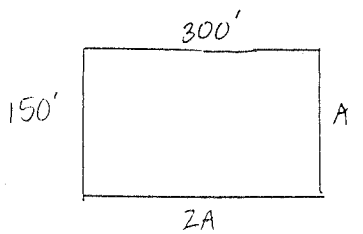
FOR 75% TRAPPING EFFICIENCY SURFACE AREA SHOULD BE:

.01 ACRE/CFS × 103.6 CFS = 1.036 ACRE = 45,128 FT^2

APPROXIMATE SURFACE DIMENSIONS:

$2A^2 = 45{,}128\ FT^2$

$A = 150$ FT



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MIN. DEPTH IN ORDER TO MEET STORAGE REQUIRED:

$$\frac{66{,}600\ FT^3}{45{,}128\ FT^2} = 1.5\ FT\ DEEP \quad (IF\ SIDE\ SLOPES\ WERE\ 0:1)$$

USE SIDE SLOPES 3:1

$$V = \left(\frac{A_1 + A_2}{2}\right)(H)$$

$$66{,}600\ FT^3 = \left(\frac{45{,}128\ FT^2 + A_2}{2}\right)(H)$$

H	A_2
1.5	43,672 FT^2
2.0	21,472 FT^2 ⟸ USE 2.0' DEPTH MIN.
3.0	-728 FT^2

$A_1 = 45{,}128\ FT^2$ BASIN SURFACE AREA (150' x 300')

$A_2 = 21{,}472\ FT^2$ BASIN FLOOR AREA

BASIN FLOOR DIMENSIONS: $2B^2 = 21{,}472\ FT^2$

$B = 104\ FT$

104' x 208'

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Project	CITY OF GREENSBORO	Computed DTD	Date 11-22-95
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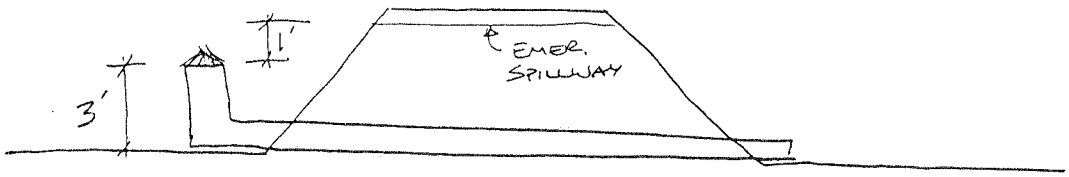
Task	DRAINAGE	Sheet	Of

SIZE BARREL: MINIMUM CAPACITY FOR Q_P IS 0.2 CFS/ACRE

0.2 CFS/ACRE (37 ACRES) = 7.4 CFS

RISER HEIGHT
2x BARREL
DIAMETER



TRY 18" ϕ BARREL

$H = 3' - \frac{18"\phi}{2(12)} = 2.25$ FT

FROM TABLE 8.07a, A 18" ϕ BARREL WILL CARRY A MIN. OF 7.73 CFS

USE 18" ϕ BARREL C.M.P.

SIZE RISER: FROM FIGURE 8.07b, H = 1 FT TRY A 24" ϕ RISER
FOR A 24" ϕ RISER WITH H = 1 FT., Q = 20.0 CFS

20 CFS > 7.73 CFS ∴ BARREL CONTROLS, OKAY

USE 24" ϕ RISER C.M.P.

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EMERGENCY SPILLWAY:

$$Q_e = Q_{25} - Q_p$$
$$= 103.6 \text{ CFS} - 7.73 \text{ CFS}$$
$$= 95.9 \text{ CFS}$$

FROM TABLE 8.07 c FOR Q = 90 CFS

BOTTOM WIDTH = 32 FT

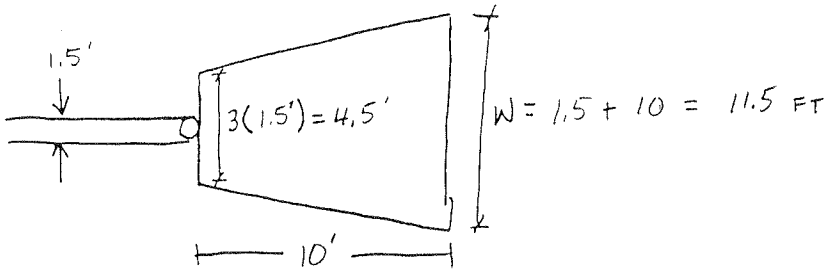
MAX. SLOPE = 6.1 %

STAGE = 1.14 FT.

OUTLET STABILIZATION:

BARREL DISCHARGE = 7.73 CFS

FROM FIGURE 8.06 a: $d_{50} = 6''$; $L_2 = 10$ FT



$d_{max} = 1.5\, d_{50} = 9''$

DEPTH = $1.5\, d_{max} = 13.5''$

Job No. 6710-011-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-9
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
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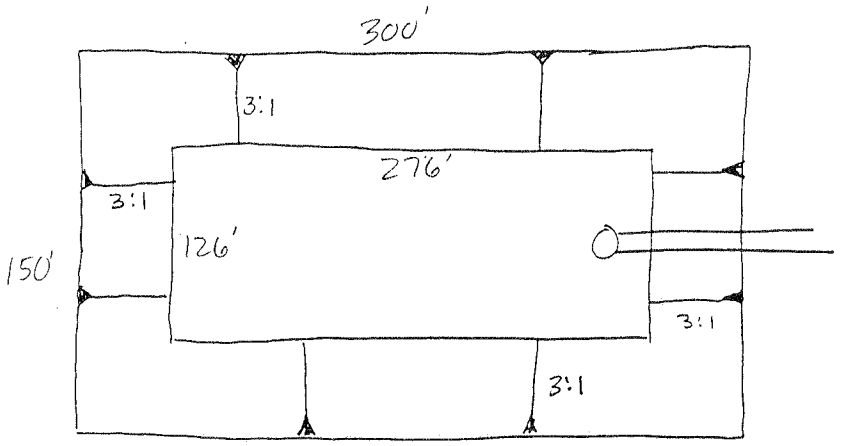
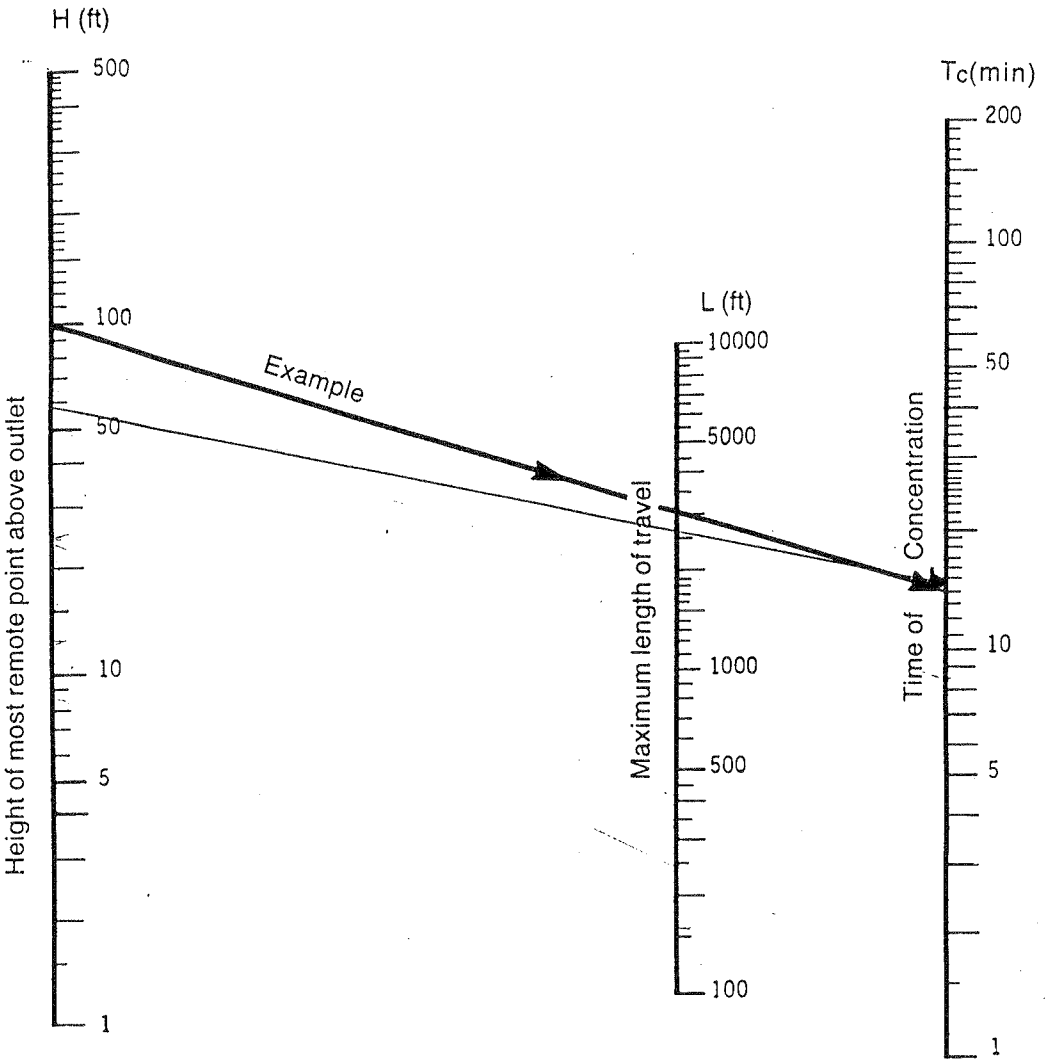


TOTAL VOLUME = A_1 = 45,128 FT^2

A_2 = 34,776 FT^2

H = 4 FT

VOL = 159,808 FT^3 > 66,600 FT^3 M



Note:
Use nomograph Tc for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.

For overland flow, grassed surfaces, multiply Tc by 2.

For overland flow, concrete or asphalt surfaces, multiply Tc by 0.4.

For concrete channels, multiply Tc by 0.2.

Figure 8.03a Time of concentration of small drainage basins.

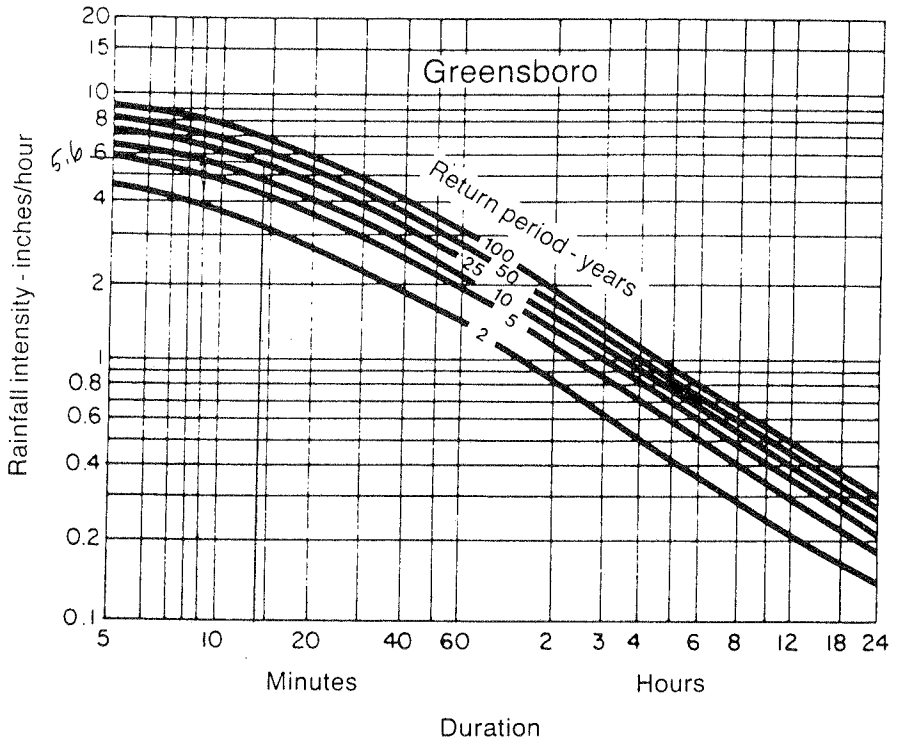


Figure 8.03d Rainfall intensity duration curves—Greensboro.

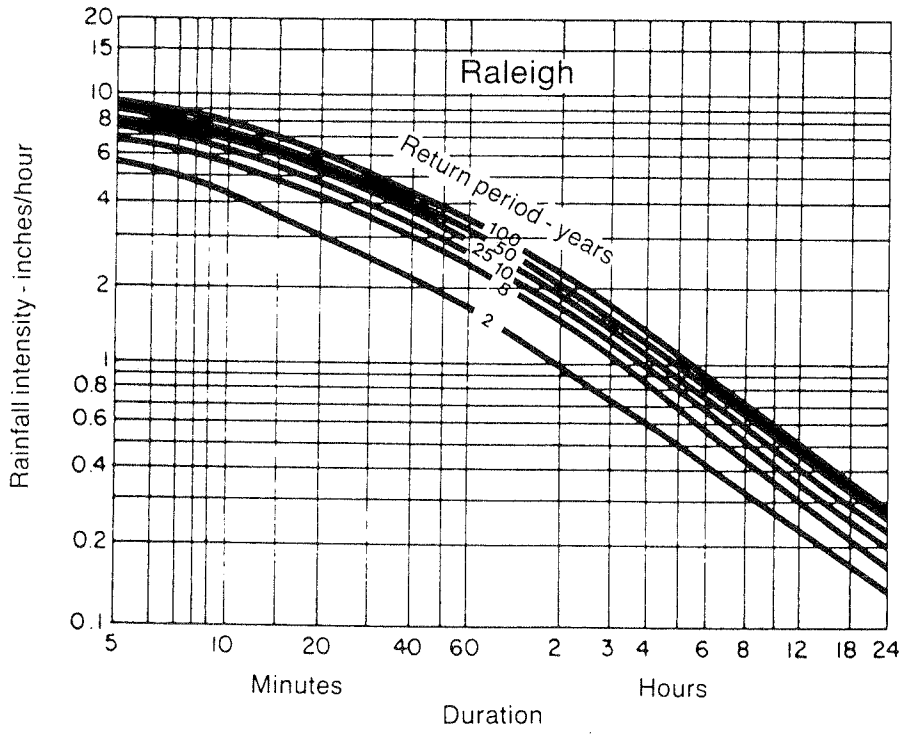


Figure 8.03e Rainfall intensity duration curves—Raleigh.

Table 8.07c
Design Table for Vegetated Spillways Excavated in Erosion Resistant Soils
(side slopes–3 horizontal:1 vertical)

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
15	3.3	12.2	8	.83
	3.5	18.2	12	.69
20	3.1	8.9	8	.97
	3.2	13.0	12	.81
	3.3	17.3	16	.70
25	2.9	7.1	8	1.09
	3.2	9.9	12	.91
	3.3	13.2	16	.79
	3.3	17.2	20	.70
30	2.9	6.0	8	1.20
	3.0	8.2	12	1.01
	3.0	10.7	16	.88
	3.3	13.8	20	.78
35	2.8	5.1	8	1.30
	2.9	6.9	12	1.10
	3.1	9.0	16	.94
	3.1	11.3	20	.85
	3.2	14.1	24	.77
40	2.7	4.5	8	1.40
	2.9	6.0	12	1.18
	2.9	7.6	16	1.03
	3.1	9.7	20	.91
	3.1	11.9	24	.83
45	2.6	4.1	8	1.49
	2.8	5.3	12	1.25
	2.9	6.7	16	1.09
	3.0	8.4	20	.98
	3.0	10.4	24	.89
50	2.7	3.7	8	1.57
	2.8	4.7	12	1.33
	2.8	6.0	16	1.16
	2.9	7.3	20	1.03
	3.1	9.0	24	.94
60	2.6	3.1	8	1.73
	2.7	3.9	12	1.47
	2.7	4.8	16	1.28
	2.9	5.9	20	1.15
	2.9	7.3	24	1.05
	3.0	8.6	28	.97
70	2.5	2.8	8	1.88
	2.6	3.3	12	1.60
	2.6	4.1	16	1.40
	2.7	5.0	20	1.26
	2.8	6.1	24	1.15
	2.9	7.0	28	1.05
80	2.5	2.9	12	1.72
	2.6	3.6	16	1.51
	2.7	4.3	20	1.35

Discharge Q CFS	Slope Range Minimum Percent	Slope Range Maximum Percent	Bottom Width Feet	Stage Feet
80	2.8	5.2	24	1.24
	2.8	5.9	28	1.14
	2.9	7.0	32	1.06
90	2.5	2.6	12	1.84
	2.5	3.1	16	1.61
	2.6	3.8	20	1.45
	2.7	4.5	24	1.32
	2.8	5.3	28	1.22
	2.8	6.1	32	1.14
100	2.5	2.8	16	1.71
	2.6	3.3	20	1.54
	2.6	4.0	24	1.41
	2.7	4.8	28	1.30
	2.7	5.3	32	1.21
	2.8	6.1	36	1.13
120	2.5	2.8	20	1.71
	2.6	3.2	24	1.56
	2.7	3.8	28	1.44
	2.7	4.2	32	1.34
	2.7	4.8	36	1.26
140	2.5	2.7	24	1.71
	2.5	3.2	28	1.58
	2.6	3.6	32	1.47
	2.6	4.0	36	1.38
	2.7	4.5	40	1.30
160	2.5	2.7	28	1.70
	2.5	3.1	32	1.58
	2.6	3.4	36	1.49
	2.6	3.8	40	1.40
	2.7	4.3	44	1.33
180	2.4	2.7	32	1.72
	2.4	3.0	36	1.60
	2.5	3.4	40	1.51
	2.6	3.7	44	1.43
200	2.5	2.7	36	1.70
	2.5	2.9	40	1.60
	2.5	3.3	44	1.52
	2.6	3.6	48	1.45
220	2.4	2.6	40	1.70
	2.5	2.9	44	1.61
	2.5	3.2	48	1.53
240	2.5	2.6	44	1.70
	2.5	2.9	48	1.62
	2.6	3.2	52	1.54
260	2.4	2.6	48	1.70
	2.5	2.9	52	1.62
280	2.4	2.6	52	1.70
300	2.5	2.6	56	1.69

Example of Use

Given: Discharge, Q = 87 c.f.s. Spillway slope, Exit section (from profile) = 4%.

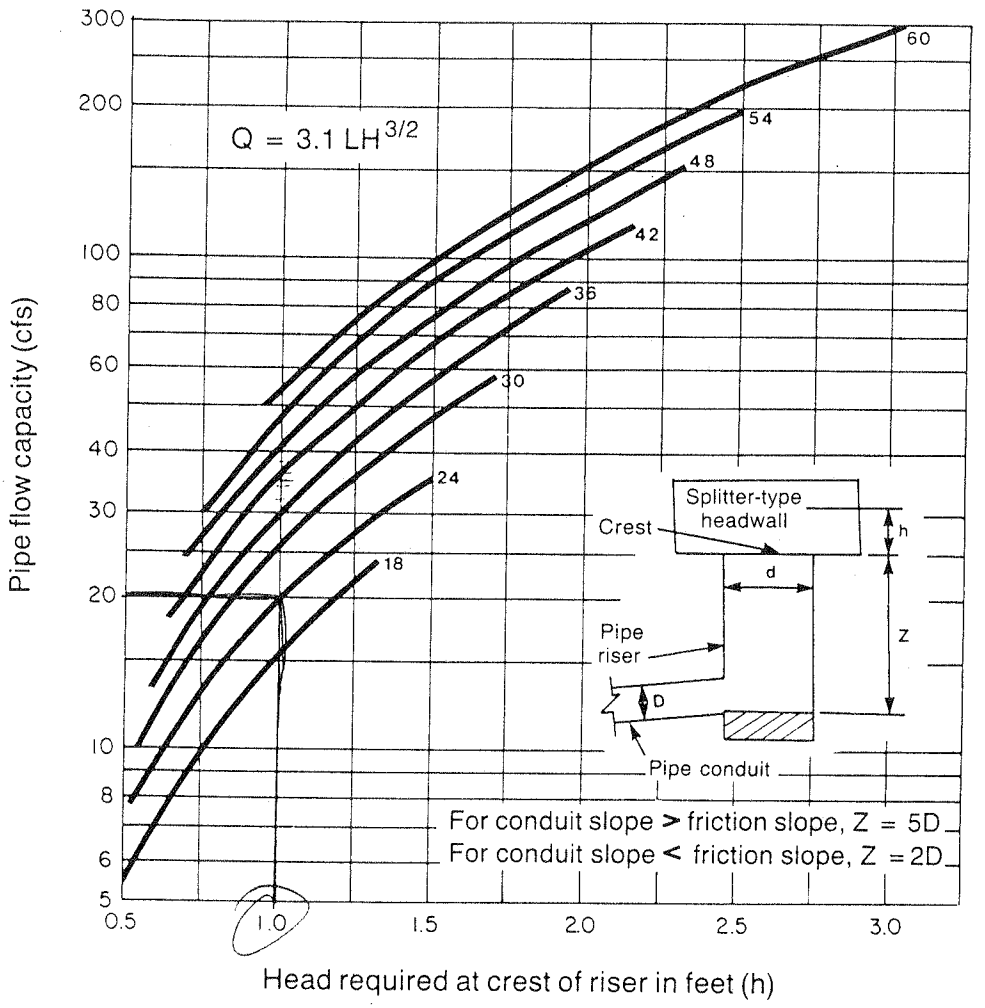
Find: Bottom width and Stage in Reservoir.

Procedure: Enter table from left at 90 c.f.s. Note that spillway slope (4%) falls within slope ranges corresponding to bottom widths of 24, 28, and 32 ft. Use bottom width, 32 ft, to minimize velocity. Stage in Reservoir will be 1.14 ft.

Note: Computations based on: Roughness coefficient, n = .040. Maximum velocity = 5.50 ft per sec.

24" CMP RISER

Circular risers with splitter wall



Inlet Proportions	
Pipe Conduit (D) - in	Pipe Riser (D) - in
8-12	18
15	21
18	24
21	30
24	30
30	36
36	48
42	54
48	60

Pipe drop inlet spillway design:

For a given Q and H, refer to Table 8.07a or 8.07b for conduit size. Then determine the riser diameter (d) from the Inlet Proportions Table on this figure. Next, refer to the above curves, using the conduit capacity and riser diameter, and find the head (h) required above the crest of the riser. The height of the riser should not be less than 5D - h, except as noted in the above sketch.

Example - Given: CMP; Q = 20 cfs; H = 14 ft, h max. 1.0 ft; L = 70 ft. From Table 8.07a find conduit size (D) = 18 inches. From Inlet Proportions Table, riser size = 24 inches. Head (h) required for Q = 20 and d = 24 is 1.0 ft.

Figure 8.07b Design chart for riser outlet.

18" C.M.P. Barrel

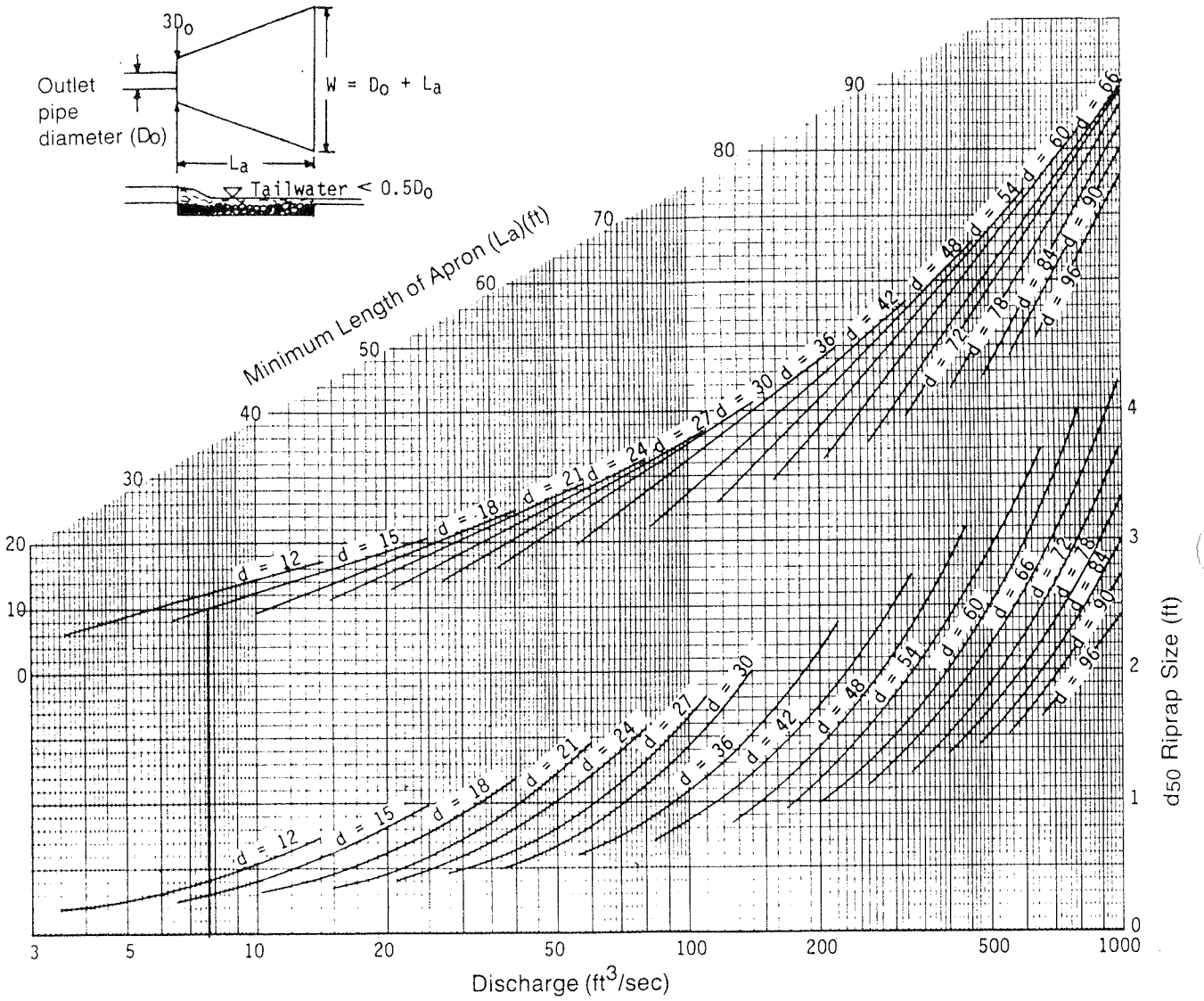
Table 8.07a
Pipe Flow Chart for Design of Corrugated Metal Outlet Conduit
(Q in cubic ft/sec)

For Corrugated Metal Pipe Inlet $K_e + K_b = 1.0$ and 70 feet of Corrugated Metal Pipe Conduit n = 0.025. Note correction factors for other pipe lengths.

2.25' →

Dia. / H	12"	15"	18"	21"	24"	30"	36"	42"
2	2.84	4.92	7.73	11.30	15.60	26.60	40.77	58.12
3	3.48	6.03	9.47	13.84	19.10	32.58	49.93	71.19
4	4.02	6.96	10.94	15.98	22.06	37.62	57.66	82.20
5	4.49	7.78	12.23	17.87	24.66	42.06	64.46	91.90
6	4.92	8.52	13.40	19.57	27.01	46.07	70.60	100.65
7	5.32	9.21	14.47	21.14	29.19	49.77	76.28	108.75
8	5.68	9.84	15.47	22.60	31.19	53.19	81.53	116.23
9	6.03	10.44	16.41	23.97	33.09	56.43	86.49	123.30
10	6.36	11.00	17.30	25.26	34.88	59.48	91.16	129.96
11	6.67	11.54	18.14	26.50	36.59	62.39	95.63	136.33
12	6.96	12.05	18.95	27.68	38.21	65.16	99.87	142.37
13	7.25	12.55	19.72	28.81	39.77	67.83	103.96	148.21
14	7.52	13.02	20.47	29.90	41.27	70.39	107.88	153.80
15	7.78	13.48	21.19	30.95	42.72	72.85	111.66	159.18
16	8.04	13.92	21.88	31.96	44.12	75.24	115.32	164.40
17	8.29	14.35	22.55	32.94	45.48	77.55	118.87	169.46
18	8.53	14.77	23.21	33.90	46.80	79.81	122.33	174.39
19	8.76	15.17	23.84	34.83	48.08	81.99	125.67	179.15
20	8.99	15.56	24.46	35.73	49.33	84.12	128.93	183.80
21	9.21	15.95	25.07	36.62	50.55	86.21	132.13	188.36
22	9.43	16.32	25.65	37.47	51.73	88.22	135.21	192.76
23	9.64	16.69	26.23	38.32	52.90	90.21	138.27	197.12
24	9.85	17.05	26.80	39.14	54.04	92.15	141.24	201.35
25	10.05	17.40	27.35	39.95	55.15	94.05	144.15	205.50
L	Correction Factors For Other Pipe Lengths							
40	1.23	1.22	1.20	1.19	1.16	1.14	1.13	1.11
50	1.14	1.13	1.12	1.11	1.10	1.09	1.08	1.07
60	1.07	1.06	1.06	1.05	1.05	1.04	1.04	1.03
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	0.95	0.95	0.95	0.96	0.96	0.96	0.97	0.97
90	0.90	0.91	0.91	0.92	0.92	0.93	0.94	0.94
100	0.86	0.87	0.88	0.89	0.89	0.90	0.91	0.92

Rip Rap Apron 18" CMP Barrel

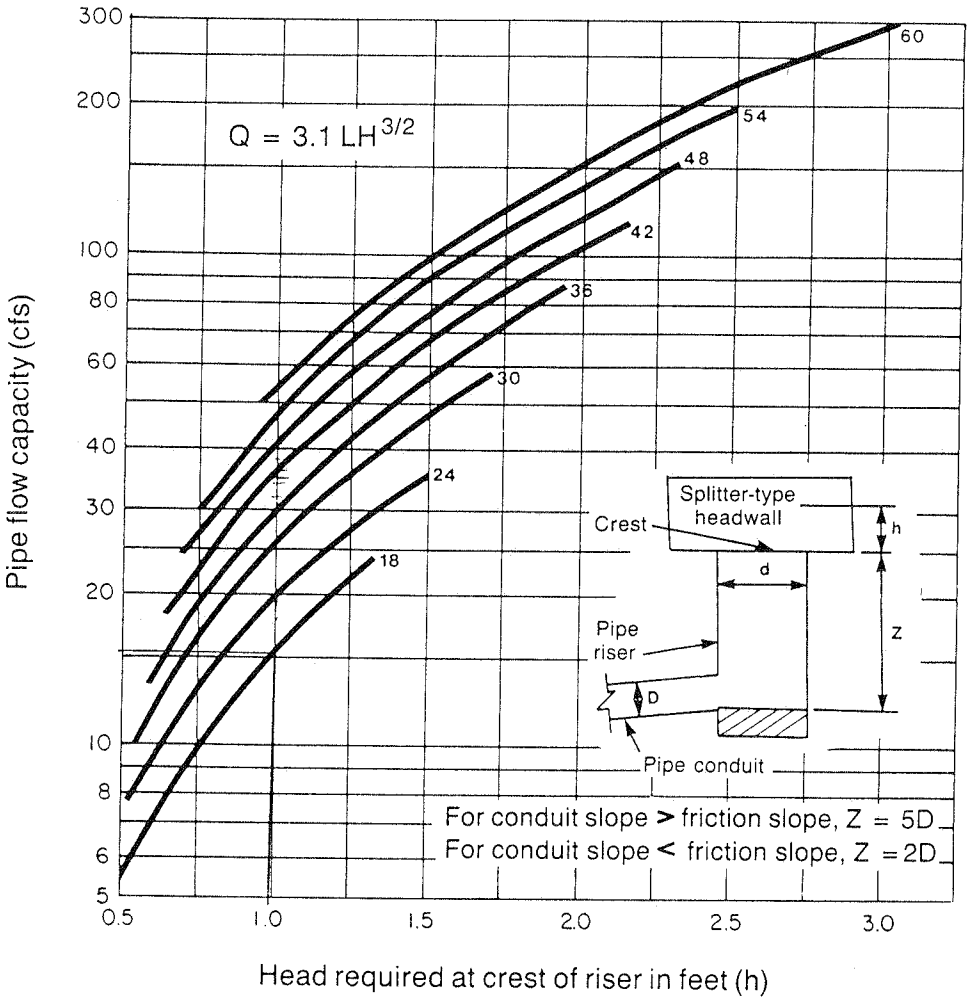


Curves may not be extrapolated.

Figure 8.06a Design of outlet protection protection from a round pipe flowing full, minimum tailwater condition (T_w < 0.5 diameter).

Southwest Basin only 18" CMP RISER

Circular risers with splitter wall



Inlet Proportions	
Pipe Conduit (D) - in	Pipe Riser (D) - in
8-12	18
15	21
18	24
21	30
24	30
30	36
36	48
42	54
48	60

Pipe drop inlet spillway design:

For a given Q and H, refer to Table 8.07a or 8.07b for conduit size. Then determine the riser diameter (d) from the Inlet Proportions Table on this figure. Next, refer to the above curves, using the conduit capacity and riser diameter, and find the head (h) required above the crest of the riser. The height of the riser should not be less than 5D - h, except as noted in the above sketch.

Example - Given: CMP; Q = 20 cfs; H = 14 ft, h max. 1.0 ft; L = 70 ft. From Table 8.07a find conduit size (D) = 18 inches. From Inlet Proportions Table, riser size = 24 inches. Head (h) required for Q = 20 and d = 24 is 1.0 ft.

Figure 8.07b Design chart for riser outlet.

8

Southwest Basin only 12" CMP Barrel

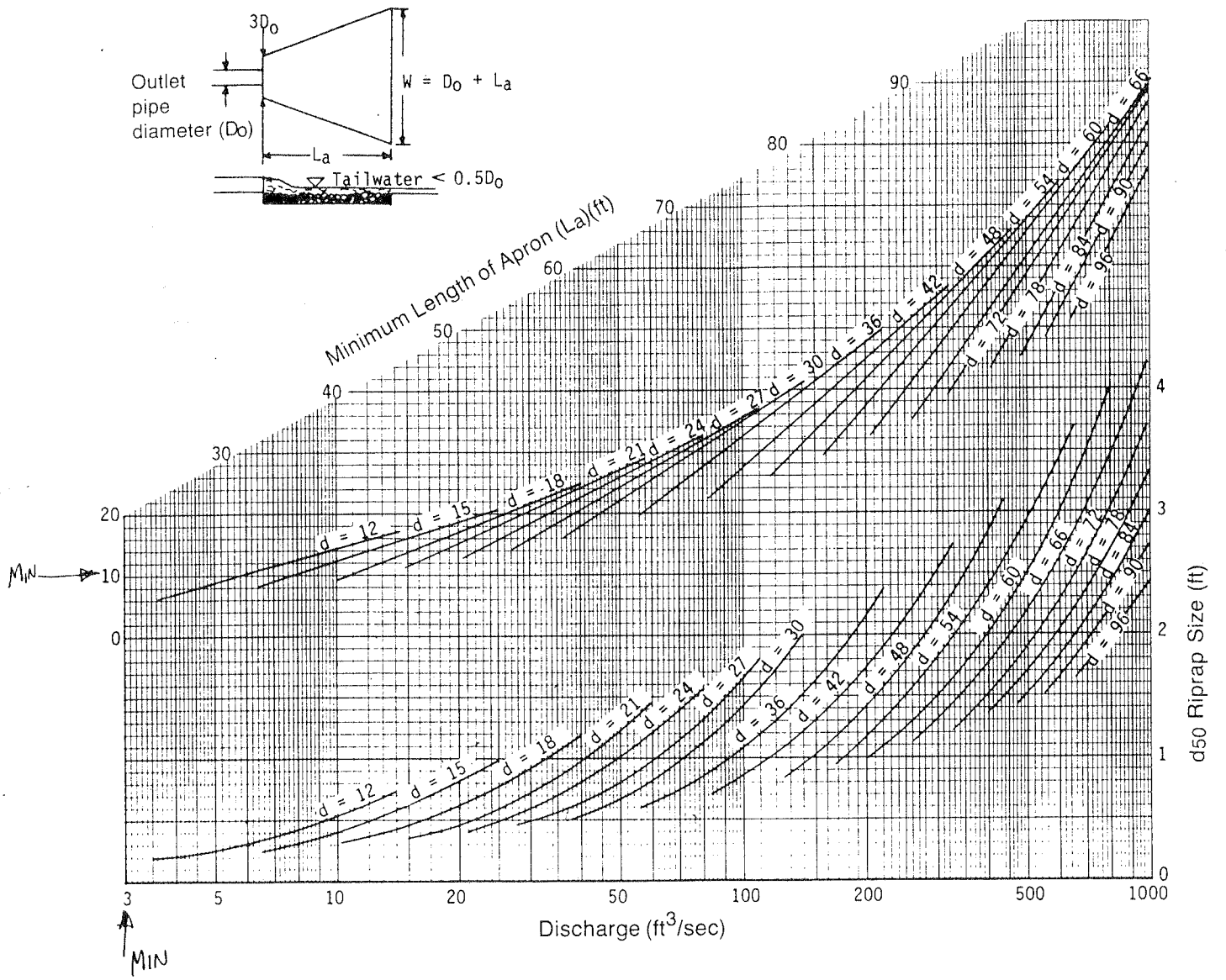
Table 8.07a
Pipe Flow Chart for Design of Corrugated Metal Outlet Conduit
(Q in cubic ft/sec)

For Corrugated Metal Pipe Inlet $K_e + K_b = 1.0$ and 70 feet of Corrugated Metal Pipe Conduit n = 0.025. Note correction factors for other pipe lengths.

1.5 →

Dia. / H	12"	15"	18"	21"	24"	30"	36"	42"
2	2.84	4.92	7.73	11.30	15.60	26.60	40.77	58.12
3	3.48	6.03	9.47	13.84	19.10	32.58	49.93	71.19
4	4.02	6.96	10.94	15.98	22.06	37.62	57.66	82.20
5	4.49	7.78	12.23	17.87	24.66	42.06	64.46	91.90
6	4.92	8.52	13.40	19.57	27.01	46.07	70.60	100.65
7	5.32	9.21	14.47	21.14	29.19	49.77	76.28	108.75
8	5.68	9.84	15.47	22.60	31.19	53.19	81.53	116.23
9	6.03	10.44	16.41	23.97	33.09	56.43	86.49	123.30
10	6.36	11.00	17.30	25.26	34.88	59.48	91.16	129.96
11	6.67	11.54	18.14	26.50	36.59	62.39	95.63	136.33
12	6.96	12.05	18.95	27.68	38.21	65.16	99.87	142.37
13	7.25	12.55	19.72	28.81	39.77	67.83	103.96	148.21
14	7.52	13.02	20.47	29.90	41.27	70.39	107.88	153.80
15	7.78	13.48	21.19	30.95	42.72	72.85	111.66	159.18
16	8.04	13.92	21.88	31.96	44.12	75.24	115.32	164.40
17	8.29	14.35	22.55	32.94	45.48	77.55	118.87	169.46
18	8.53	14.77	23.21	33.90	46.80	79.81	122.33	174.39
19	8.76	15.17	23.84	34.83	48.08	81.99	125.67	179.15
20	8.99	15.56	24.46	35.73	49.33	84.12	128.93	183.80
21	9.21	15.95	25.07	36.62	50.55	86.21	132.13	188.36
22	9.43	16.32	25.65	37.47	51.73	88.22	135.21	192.76
23	9.64	16.69	26.23	38.32	52.90	90.21	138.27	197.12
24	9.85	17.05	26.80	39.14	54.04	92.15	141.24	201.35
25	10.05	17.40	27.35	39.95	55.15	94.05	144.15	205.50
L	Correction Factors For Other Pipe Lengths							
40	1.23	1.22	1.20	1.19	1.16	1.14	1.13	1.11
50	1.14	1.13	1.12	1.11	1.10	1.09	1.08	1.07
60	1.07	1.06	1.06	1.05	1.05	1.04	1.04	1.03
70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
80	0.95	0.95	0.95	0.96	0.96	0.96	0.97	0.97
90	0.90	0.91	0.91	0.92	0.92	0.93	0.94	0.94
100	0.86	0.87	0.88	0.89	0.89	0.90	0.91	0.92

Southwest Basin Rip Rap Apron for 12" CMP Barrel



Curves may not be extrapolated.

Figure 8.06a Design of outlet protection protection from a round pipe flowing full, minimum tailwater condition (T_w < 0.5 diameter).

Job No. 6770-021-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-9~
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

SEDIMENT

BASIN	FLOW (CFS)	VOL. (FT^3)	MIN. VOL (FT^3)	RISER	BARREL
NORTH (15 AC)	41.3	59,672	27,000	24" C.M.P.	18" C.M.P.
NORTHWEST (17.5 AC)	59.5	88,704	31,500	24" C.M.P.	18" C.M.P.
SOUTHWEST (5.2 AC)	18.5	19,679	9,360	18" C.M.P.	12" C.M.P.
SOUTH (15.8 AC)	56.1	83,326	28,440	24" C.M.P.	18" C.M.P.
EAST (18.4 AC)	65.3	195,100	33,120	24" C.M.P.	18" C.M.P.
NORTHEAST (37 AC)	103.6	159,808	66,600	24" C.M.P.	18" C.M.P.

Table 8.03a
Value of Runoff Coefficient (C) for Rational Formula

Land Use	C
Business:	
Downtown areas	0.70-0.95
Neighborhood areas	0.50-0.70
Residential:	
Single-family areas	0.30-0.50
Multi units, detached	0.40-0.60
Multi units, attached	0.60-0.75
Suburban	0.25-0.40
Industrial:	
Light areas	0.50-0.80
Heavy areas	0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.20-0.35
Railroad yard areas	0.20-0.40
Unimproved areas	0.10-0.30
Streets:	
Asphalt	0.70-0.95
Concrete	0.80-0.95
Brick	0.70-0.85
Drives and walks	0.75-0.85
Roofs	0.75-0.85

Land Use	C
Lawns:	
Sandy soil, flat, 2%	0.05-0.10
Sandy soil, ave., 2-7%	0.10-0.15
Sandy soil, steep, 7%	0.15-0.20
Heavy soil, flat, 2%	0.13-0.17
Heavy soil, ave., 2-7%	0.18-0.22
Heavy soil, steep, 7%	0.25-0.35
Agricultural land:	
Bare packed soil	
Smooth	0.30-0.60
Rough	0.20-0.50
Cultivated rows	
Heavy soil no crop	0.30-0.60
Heavy soil with crop	0.20-0.50
Sandy soil no crop	0.20-0.40
Sandy soil with crop	0.10-0.25
Pasture	
Heavy soil	0.15-0.45
Sandy soil	0.05-0.25
Woodlands	0.05-0.25

NOTE: The designer must use judgment to select the appropriate C value within the range for the appropriate land use. Generally, larger areas with permeable soils, flat slopes, and dense vegetation should have lowest C values. Smaller areas with slowly permeable soils, steep slopes, and sparse vegetation should be assigned highest C values.

Source: American Society of Civil Engineers

The overland flow portion of flow time may be determined from Figure 8.03a. The flow time (in minutes) in the channel can be estimated by calculating the average velocity in feet per minute and dividing the length (in feet) by the average velocity.

Step 4. Determine the rainfall intensity, frequency, and duration (Figures 8.03b through 8.03g—source: North Carolina State Highway Commission; Jan. 1973). Select the chart for the locality closest to your location. Enter the "duration" axis of the chart with the calculated time of concentration, T_C. Move vertically until you intersect the curve of the appropriate design storm, then move horizontally to read the rainfall intensity factor, i, in inches per hour.

Step 5. Determine peak discharge, Q (ft^3/sec), by multiplying the previously determined factors using the rational formula (Sample Problem 8.03a).

Job No. 6770-021-018 | No.

HDR Computation

Project	CITY OF GREENSBORO	Computed DTD	Date 11-27-95
Subject	WHITE STREET SANITARY LANDFILL	Checked	Date
Task	DRAINAGE	Sheet	Of

NORTH SEDIMENT BASIN (FIGURES AND TABLES COME FROM NC MANUAL)

TOTAL DRAINAGE AREA = 15 ACRES

$Q = CIA$ WHERE Q = RUNOFF, CFS
C = RUNOFF COEFFICIENT
I = RAINFALL INTENSITY, IN/HR
A = DRAINAGE AREA, ACRES

C = 0.5 ASSUMED (TABLE 8.03a)
L = 2050 FT
H = 46 FT
T_c = 12 min (FIG 8.03a)
I = 5.5 IN/HR (FIG. 8.03d)

$Q_{25} = 0.5\ (5.5)(15) = \underline{41.3\ CFS}$

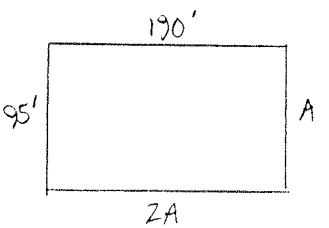
STORAGE REQUIRED = 1800 $FT^3/ACRE$ × 15 ACRES = 27,000 FT^3

FOR 75% TRAPPING EFFICIENCY SURFACE AREA SHOULD BE:

.01 ACRE/CFS × 41.3 CFS = 0.413 ACRE = 17,990 FT^2

APPROXIMATE SURFACE DIMENSIONS:

$2A^2 = 17,990\ FT^2$
$A = 95\ FT$



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**                                                                              **
**                                                                              **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                   **
**                HELP MODEL VERSION 3.06    (17 AUGUST 1996)                  **
**                   DEVELOPED BY ENVIRONMENTAL LABORATORY                      **
**                     USAE WATERWAYS EXPERIMENT STATION                        **
**              FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                 **
**                                                                              **
**                                                                              **
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PRECIPITATION DATA FILE: G:\HELP3\GBORO.D4
TEMPERATURE DATA FILE: g:\help3\GBORO.D7
SOLAR RADIATION DATA FILE: g:\help3\GBORO.D13
EVAPOTRANSPIRATION DATA: g:\help3\GBORO.D11
SOIL AND DESIGN DATA FILE: g:\help3\GBORO3.D10
OUTPUT DATA FILE: g:\help3\GBORO3.OUT

TIME: 16:02 DATE: 11/ 6/1996

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TITLE: Greensboro White Street Landfill (20' Waste, 5.75" storm)

****

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 11

THICKNESS	=	6.00	INCHES
POROSITY	=	0.4640	VOL/VOL
FIELD CAPACITY	=	0.3100	VOL/VOL
WILTING POINT	=	0.1870	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3485	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.639999998000E-04	CM/SEC

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	240.00	INCHES
POROSITY	=	0.6710	VOL/VOL
FIELD CAPACITY	=	0.2920	VOL/VOL
WILTING POINT	=	0.0770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3038	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02	CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.4640	VOL/VOL
FIELD CAPACITY	=	0.3100	VOL/VOL
WILTING POINT	=	0.1870	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3710	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999995000E-04	CM/SEC

LAYER 4

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00	INCHES
POROSITY	=	0.3970	VOL/VOL
FIELD CAPACITY	=	0.0320	VOL/VOL
WILTING POINT	=	0.0130	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0389	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000	CM/SEC
SLOPE	=	2.00	PERCENT
DRAINAGE LENGTH	=	250.0	FEET

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 36

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.399999993000E-12	CM/SEC
FML PINHOLE DENSITY	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	4.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4270	VOL/VOL
FIELD CAPACITY	=	0.4180	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #11 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 250. FEET.

SCS RUNOFF CURVE NUMBER	=	94.50	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	9.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.919	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.797	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.353	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	90.167	INCHES
TOTAL INITIAL WATER	=	90.167	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM GREENSBORO NORTH CAROLINA

STATION LATITUDE	=	36.10 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	90
END OF GROWING SEASON (JULIAN DATE)	=	305
EVAPORATIVE ZONE DEPTH	=	9.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	7.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.51	3.37	3.88	3.16	3.37	3.93
4.27	4.19	3.64	3.18	2.59	3.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	39.90	48.00	58.30	66.50	73.50
77.20	76.30	69.90	58.40	48.50	40.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR GREENSBORO NORTH CAROLINA AND STATION LATITUDE = 36.10 DEGREES

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MONTHLY TOTALS (IN INCHES) FOR YEAR 1

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	1.44	3.88	2.94	1.20	1.91	5.16
	4.38	5.28	3.89	4.33	0.00	6.42
RUNOFF	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	1.781	2.091	3.197	1.414	1.830	4.872
	3.511	4.395	2.438	3.138	0.740	1.079
LATERAL DRAINAGE COLLECTED FROM LAYER 4	1.8374	1.9010	0.8789	0.9691	0.2061	0.0969
	0.0789	0.5413	0.4888	0.4082	2.4411	0.4982
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON TOP OF LAYER 5	1.307	1.498	0.625	0.713	0.147	0.071
	0.056	0.385	0.359	0.290	1.795	0.354
STD. DEVIATION OF DAILY HEAD ON TOP OF LAYER 5	0.869	0.738	0.567	0.410	0.042	0.009
	0.004	0.425	0.159	0.347	0.478	0.172

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MONTHLY TOTALS (IN INCHES) FOR YEAR 2

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	4.31	3.06	6.00	3.04	5.84	7.42
	3.81	1.15	7.07	1.80	1.47	4.21
RUNOFF	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	1.179	1.877	3.052	3.244	3.837	4.578
	3.679	0.742	3.455	2.130	1.228	0.723
LATERAL DRAINAGE COLLECTED FROM LAYER 4	1.4284	2.8002	2.5128	2.7265	1.6737	2.1667
	2.7049	0.8277	0.1664	2.4129	1.3812	0.2294
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.0001	0.0002	0.0002	0.0002	0.0001	0.0001
	0.0002	0.0001	0.0000	0.0001	0.0001	0.0000

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON TOP OF LAYER 5	1.016	2.206	1.788	2.005	1.191	1.593
	1.925	0.589	0.122	1.717	1.016	0.163
STD. DEVIATION OF DAILY HEAD ON TOP OF LAYER 5	0.692	0.348	0.468	0.399	0.771	0.488
	0.481	0.365	0.035	0.881	0.655	0.054

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MONTHLY TOTALS (IN INCHES) FOR YEAR 3

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	7.53	4.25	2.16	1.38	2.92	7.72
	13.86	8.83	5.92	0.91	2.07	2.87
RUNOFF	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	1.585	2.151	1.852	1.517	1.662	5.910
	6.281	3.938	3.731	2.192	1.319	1.234
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.3545	3.3672	3.7101	3.1750	0.5960	0.4562
	2.1318	3.9077	4.4774	3.3254	2.5379	0.3680
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.0000	0.0002	0.0002	0.0002	0.0000	0.0000
	0.0001	0.0002	0.0003	0.0002	0.0002	0.0000

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON TOP OF LAYER 5	0.252	2.653	2.640	2.334	0.424	0.335
	1.517	2.780	3.292	2.366	1.866	0.262
STD. DEVIATION OF DAILY HEAD ON TOP OF LAYER 5	0.245	0.932	0.323	0.567	0.244	0.257
	0.447	0.910	0.414	0.380	0.747	0.153

MONTHLY TOTALS (IN INCHES) FOR YEAR 4

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	3.40	3.86	2.07	2.88	2.76	2.84
	4.10	4.14	2.01	2.28	2.85	1.00
RUNOFF	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	1.287	2.104	2.880	3.298	2.224	2.783
	3.568	3.936	1.664	2.369	1.427	1.461
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.7263	1.8112	2.0633	0.4087	0.1487	0.2354
	0.1430	0.2760	0.3814	0.1516	0.1287	0.5819
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON TOP OF LAYER 5	0.517	1.378	1.468	0.300	0.106	0.173
	0.102	0.196	0.280	0.108	0.095	0.414
STD. DEVIATION OF DAILY HEAD ON TOP OF LAYER 5	0.376	0.328	0.490	0.137	0.031	0.024
	0.009	0.185	0.093	0.023	0.015	0.280

MONTHLY TOTALS (IN INCHES) FOR YEAR 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION	1.37	3.33	6.84	2.47	5.58	0.77
	7.03	5.42	5.87	5.26	1.80	2.57
RUNOFF	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	1.399	1.094	3.124	2.794	4.554	0.804
	4.895	3.613	4.212	2.989	2.121	1.596
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.3169	0.1225	0.2902	1.9623	2.1744	1.6050
	0.5087	1.7902	0.6285	1.9793	2.1649	0.7011
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001
	0.0000	0.0001	0.0000	0.0001	0.0001	0.0000

MONTHLY SUMMARIES FOR DAILY HEADS (INCHES)

AVERAGE DAILY HEAD ON TOP OF LAYER 5	0.225	0.097	0.206	1.443	1.547	1.180
	0.362	1.274	0.462	1.408	1.592	0.499
STD. DEVIATION OF DAILY HEAD ON TOP OF LAYER 5	0.075	0.016	0.153	0.685	0.751	0.481
	0.145	0.527	0.181	0.343	0.540	0.289

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.61	3.68	4.00	2.19	3.80	4.78
	6.64	4.96	4.95	2.92	1.64	3.41
STD. DEVIATIONS	2.53	0.48	2.25	0.85	1.79	2.98
	4.24	2.76	2.00	1.81	1.05	2.03
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	1.446	1.863	2.821	2.453	2.821	3.789
	4.387	3.325	3.100	2.564	1.367	1.219
STD. DEVIATIONS	0.240	0.443	0.554	0.924	1.296	2.014
	1.202	1.470	1.032	0.467	0.496	0.342

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	0.9327	2.0004	1.8911	1.8483	0.9598	0.9120
	1.1135	1.4686	1.2285	1.6555	1.7308	0.4757
STD. DEVIATIONS	0.6746	1.2329	1.3521	1.1608	0.9142	0.9199
	1.2194	1.4786	1.8240	1.3495	1.0041	0.1836

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000
STD. DEVIATIONS	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.6636	1.5660	1.3456	1.3590	0.6829	0.6706
	0.7923	1.0449	0.9033	1.1779	1.2726	0.3385
STD. DEVIATIONS	0.4800	0.9734	0.9621	0.8535	0.6505	0.6763
	0.8676	1.0521	1.3411	0.9602	0.7383	0.1306

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES		CU. FEET	PERCENT
PRECIPITATION	46.59	(9.847)	169107.2	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	31.156	(2.0128)	113097.78	66.879
LATERAL DRAINAGE COLLECTED FROM LAYER 4	16.21682	(8.57408)	58867.070	34.81051
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00099	(0.00049)	3.603	0.00213
AVERAGE HEAD ON TOP OF LAYER 5	0.985	(0.521)		
CHANGE IN WATER STORAGE	-0.788	(1.1724)	-2861.28	-1.692

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	5.75	20872.500
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 4	0.18367	666.73828
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000010	0.03756
AVERAGE HEAD ON TOP OF LAYER 5	4.051	
MAXIMUM HEAD ON TOP OF LAYER 5	6.526	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	48.6 FEET	
SNOW WATER	1.73	6282.1865

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4601
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1503

*** 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	1.8548	0.3091
2	69.8186	0.2909
3	4.1993	0.3499
4	0.4988	0.0416
5	0.0000	0.0000
6	10.2480	0.4270
SNOW WATER	0.000	

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** HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE **
** HELP MODEL VERSION 3.01 (14 OCTOBER 1994) **
** DEVELOPED BY ENVIRONMENTAL LABORATORY **
** USAE WATERWAYS EXPERIMENT STATION **
** FOR USEPA RISK REDUCTION ENGINEERING LABORATORY **
**
**
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PRECIPITATION DATA FILE: C:\HELP3\GBRONC.D4
TEMPERATURE DATA FILE: C:\HELP3\GBRONCT.D7
SOLAR RADIATION DATA FILE: C:\HELP3\GBRONCS.D13
EVAPOTRANSPIRATION DATA: C:\HELP3\GBRONCE.D11
SOIL AND DESIGN DATA FILE: C:\HELP3\ACT100CL.D10
OUTPUT DATA FILE: C:\HELP3\ACT100CL.OUT

TIME: 11:55 DATE: 11/28/1995

****

TITLE: Greensboro, NC Landfill Closed

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NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 10

THICKNESS	=	24.00	INCHES
POROSITY	=	0.3980	VOL/VOL
FIELD CAPACITY	=	0.2440	VOL/VOL
WILTING POINT	=	0.1360	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3980	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.119999997000E-03	CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 1.80 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 37

THICKNESS	=	0.04	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999999000E-10	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	5.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 15

THICKNESS	=	18.00	INCHES
POROSITY	=	0.4750	VOL/VOL
FIELD CAPACITY	=	0.3780	VOL/VOL
WILTING POINT	=	0.2650	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4750	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.170000003000E-04	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 100. FEET.

SCS RUNOFF CURVE NUMBER	=	86.80	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	21.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	8.358	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	8.358	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.856	INCHES
INITIAL SNOW WATER	=	1.799	INCHES
INITIAL WATER IN LAYER MATERIALS	=	18.102	INCHES
TOTAL INITIAL WATER	=	19.901	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
GREENSBORO NORTH CAROLINA

MAXIMUM LEAF AREA INDEX	= 1.00	
START OF GROWING SEASON (JULIAN DATE)	= 90	
END OF GROWING SEASON (JULIAN DATE)	= 305	
AVERAGE ANNUAL WIND SPEED	= 7.60	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	= 66.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	= 68.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	= 74.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	= 70.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.51	3.37	3.88	3.16	3.37	3.93
4.27	4.19	3.64	3.18	2.59	3.38

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
37.50	39.90	48.00	58.30	66.50	73.50
77.20	76.30	69.90	58.40	48.50	40.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR GREENSBORO NORTH CAROLINA

STATION LATITUDE = 35.13 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	2.71	3.27	4.10	2.81	3.05	3.96
	4.76	5.13	3.82	2.52	2.60	3.80

STD. DEVIATIONS	1.65	1.38	1.92	1.36	1.29	2.53
	1.98	2.38	2.39	1.71	1.91	1.80

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	1.280	1.882	3.485	4.842	5.412	4.816
	5.434	4.587	3.466	2.972	1.839	1.468
STD. DEVIATIONS	0.419	0.325	0.265	0.324	1.419	1.838
	1.476	1.249	1.214	0.654	0.541	0.206

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	0.0858	0.0783	0.0897	0.0862	0.0815	0.0709
	0.0678	0.0657	0.0674	0.0736	0.0698	0.0798
STD. DEVIATIONS	0.0104	0.0081	0.0031	0.0037	0.0118	0.0143
	0.0192	0.0211	0.0200	0.0198	0.0204	0.0143

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ACROSS LAYER 3

AVERAGES	22.5078	22.9367	23.7522	23.5842	21.5602	19.3588
	17.8756	17.3175	18.3702	19.4382	19.0293	21.1069
STD. DEVIATIONS	2.6933	2.4014	0.8220	1.0100	3.1579	3.9495
	5.1472	5.6761	5.5557	5.3095	5.6688	3.8325

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	INCHES		CU. FEET	PERCENT
PRECIPITATION	42.52	(7.072)	154363.9	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	41.484	(5.8474)	150587.59	97.554
PERCOLATION/LEAKAGE THROUGH FROM LAYER 3	0.91641	(0.12464)	3326.554 ≈ 68.2 gpad	2.15501

AVERAGE HEAD ACROSS TOP OF LAYER 3	20.570 (2.830)		
CHANGE IN WATER STORAGE	0.124 (4.2898)	449.79	0.291

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	3.76	13648.800
RUNOFF	0.000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.002924	10.61491
AVERAGE HEAD ACROSS LAYER 3	24.000	
SNOW WATER	11.58	42038.9375

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3980
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1332

****

****

FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	9.5519	0.3980
2	0.0000	0.0000
3	8.5500	0.4750
SNOW WATER	0.000	

****
****

Leachate Generation

Greensboro Phase III MSW Landfill, North Carolina
HELP version 3.06 Model: 20' waste with 25 year, 24 hour storm.

PER ACRE FLOWS	Days	inches	cubic feet	gallons	gpad	Scenario
Avg Annual	365	16.21682	58,867	440,384	1,207	Filled
Highest Avg Month (Feb)	28.25	2.0004	7,261	54,323	1,923	Active
Peak Daily	1	0.18367	667	4,988	4,988	Storm Active
Peak Monthly Avg (Sept)	30	4.4774	16,253	121,588	4,053	Storm Filled
Closed Avg Annual	365	0.91641	3,327	24,886	68	Closed

Assumptions:

	30	Days/month
	1000	#/cy
	4	:1 Waste to cover soil ratio
initial	267,666	tons of waste/year
initial	535,332	cy of waste/year
	0.00%	Annual Change in Disposal Rate
	4	:1 Final cover slope
	5	years in avg subcell

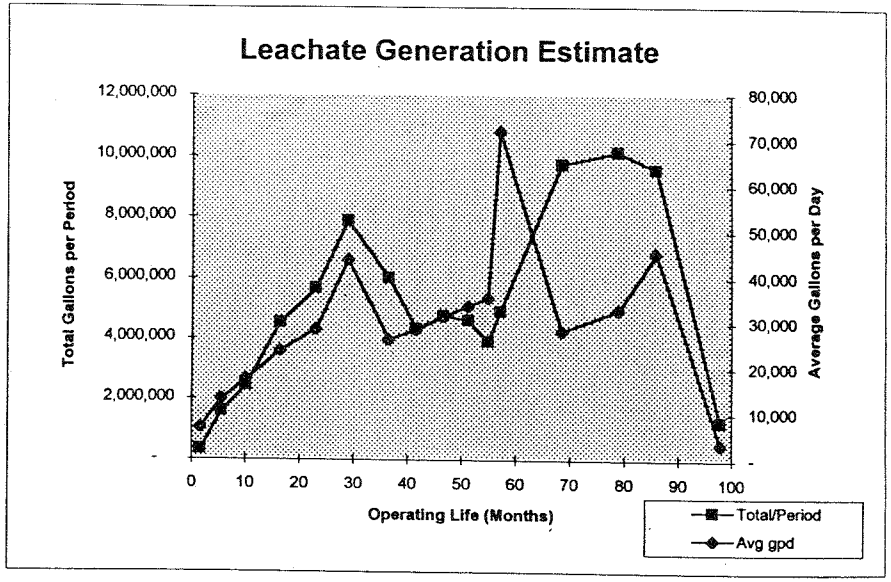
Tank Sizing

14	Holding Time (days)

Legend
user input

Acres	Volume
51.3	5,158,065

Shape Factor 0.93 adjustment for subcell volume estimate



SUBCELL	Disposal Rate Est. TPM	Estimated Acres	Cumulative Volume Cubic Yards	Total Landfill Life	Acreage Active	Acreage Filled	Acreage Closed	Months Normal	Months Storm	Gallons of Leachate Generated per Period: Normal Weather Active	Normal Weather Filled	Normal Weather Closed	Storm (25yr 24hr) Active	Storm (25yr 24hr) Filled	Total/Period	Period Avg gpd	Required Tank Size (gallons)
1A	22,306	3.6	90,117	2	3.6	0.0	0.0	1.6	0	337,480	-	-	-	-	337,480	6,961	97,454
1B	22,306	4.7	313,998	6	4.7	3.6	0.0	4.0	0	1,088,554	526,060	-	-	-	1,614,614	13,405	187,676
1C	22,306	4.1	569,242	10	4.1	8.3	0.0	4.6	0	1,069,409	1,378,436	-	-	-	2,447,844	17,826	249,567
1D	22,306	4.7	921,147	17	4.7	12.4	0.0	6.3	0	1,703,747	2,825,553	-	-	-	4,529,300	23,924	334,938
1E	22,306	4.3	1,288,021	23	4.3	17.1	0.0	6.6	0	1,620,613	4,060,227	-	-	-	5,680,840	28,782	402,952
1F	22,306	3.5	1,620,809	29	3.5	21.3	0.0	5.0	1	1,011,640	3,833,653	-	432,507	2,592,265	7,870,065	43,958	615,418
2A	22,306	4.1	2,041,220	37	4.1	14.9	10.0	7.5	0	1,796,214	4,052,368	154,208	-	-	6,002,790	26,541	371,568
2B	22,306	2.6	2,323,093	42	2.6	19.0	10.0	5.1	0	761,077	3,472,632	103,392	-	-	4,337,101	28,601	400,409
2C	22,306	2.5	2,604,250	47	2.5	21.6	10.0	5.0	0	727,148	3,940,124	103,129	-	-	4,770,401	31,538	441,535
2D	22,306	2.2	2,856,827	51	2.2	24.1	10.0	4.5	0	567,005	3,949,464	92,646	-	-	4,609,115	33,920	474,879
2E	22,306	1.7	3,061,280	55	1.7	26.3	10.0	3.7	0	361,680	3,484,960	74,994	-	-	3,921,634	35,654	499,150
2F	22,306	1.0	3,187,910	57	1.0	28.0	10.0	1.3	1	76,244	1,286,595	25,994	127,424	3,400,828	4,917,085	72,177	1,010,483
3A	22,306	5.1	3,826,564	69	5.1	14.0	25.0	11.5	0	3,336,494	5,807,798	585,649	-	-	9,729,942	28,319	396,464
3B	22,306	4.3	4,398,827	79	4.3	19.1	25.0	10.3	0	2,539,729	7,079,906	524,770	-	-	10,144,405	32,950	461,306
3C	22,306	2.8	4,790,630	86	2.8	23.4	25.0	6.0	1	983,807	5,093,129	308,150	346,741	2,839,089	9,570,916	45,406	635,689
Closure	0	51.2	4,810,300	98	0.0	0.0	51.2	12.0	0	-	-	1,256,221	-	-	1,256,221	3,490	48,853

Life (years) 7.2

Average Leachate Generation (gpd)	27,800	
Peak Leachate Generation (gpd)		72,200
Minimum Required Tank Size		1,010,000

PROJECT HDR - GBORO. LF

SUBJECT Leachate Collection Pipe Spacing

SHEET 1 OF 2
JOB NO. HDRGN-2
DATE 11/21/95
COMPUTED BY DKS
CHECKED BY

- **Objective:** Evaluate the leachate collection pipe spacing which will maintain at most 1 Foot of head on the geomembrane under Normal Operating Conditions.

- **Analysis:** The US EPA mounding equation found in SW 869 will be used to calculate the required spacings. The equation is:

$$h_{max} = \frac{L\sqrt{C}}{2}\left[\frac{\tan^2\alpha}{C} + 1 - \frac{\tan\alpha}{C}\sqrt{\tan^2\alpha + C}\right]$$

Where: h_{max} = Max. Allowable Head (Ft)

L = Pipe Spacing (Ft)

$C = q/k$

q = Infiltration Rate (cm/sec)
k = Drainage Layer Perm (cm/sec)

Note: The infiltration rate, q, is assumed to be either the rainfall intensity or the operational cover permeability, whichever is smaller. For the long-term duration rainfall events of interest here, the operational cover permeability controls.

α = Bottom Slope Angle (degrees)

- Determine L based on the following graph where h_{max} = 1 Ft (constant).

G.N. RICHARDSON & ASSOCIATES
CONSULTING ENGINEERING

DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

Job No. 6770-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date
Subject	LEACHATE PIPE SPACING	Checked CDM	Date 11/7/96
Task		Sheet 1	Of 1

ASSUME:

METHOD: US EPA MOUNDING EQ -> SW 869

OPERATIONAL COVER PERMEABILITY = 2×10^{-5} cm/sec
DRAINAGE LAYER PERMEABILITY = 1×10^{-1} cm/sec
} FROM SPEC'S.

$$C = \frac{O.C.}{D.L.} = \frac{2 \times 10^{-5}}{1 \times 10^{-1}} = .0002$$

C	SLOPE	(α) SLOPE (DEG)	$\frac{C^{1/2}}{2}$	$\frac{\tan^2\alpha}{C}$	$\frac{\tan\alpha}{C}\sqrt{\tan^2\alpha + C}$	L
.0002	2%	1.15	0.0071	2.0148	2.4646	256 FT
.0002	3%	1.72	0.0071	4.5086	4.9836	268 FT
.0002	4%	2.29	0.0071	7.9957	8.4816	274 FT

USE 250 FT

$$h_{max} = \frac{L\sqrt{C}}{2}\left[\frac{\tan^2\alpha}{C} + 1 - \frac{\tan\alpha}{C}\sqrt{\tan^2\alpha + C}\right]$$

WHERE: h_{max} = MAX. ALLOWABLE HEAD (FT) = 1 FT
L = PIPE SPACING (FT)

PROJECT HDR - GBORO, LF

SUBJECT Leachate Collection Pipe Sizing

SHEET 1 OF 2
JOB NO. HDRGN-2
DATE 11/21/95
COMPUTED BY PKS
CHECKED BY

- Objective: Evaluate the required size of leachate collector, header, & outlet pipes based on the 25 yr, 24 hr storm.

- Assumptions:
  1. Assume entire storm acts on system at one time. (Very Conservative)
  2. Neglect influence of waste. (Conservative)
  3. Drain rainfall From cell in at most 24 hrs. From end of rainfall event, neglecting removal during the storm. (Conservative)
  4. All runoff is retained within the cell.

- Analysis:
  1. Calculate volumes to be drained by each pipe.
  2. Calculate required flow volumes to drain cell in 24 hrs.
  3. Size each pipe.
  4. Equations:

Volume = Depth of Storm (Ft) x Area (Ft^2)

Q_{Req} = Required Flow Volume To Drain in 24 hrs. (cfs)

= Volume / 86400 sec/24hrs.

Reqd. Pipe Diameter (D_{Req}) = $16 \left[\frac{Q_{Req} \cdot n}{\sqrt{S}}\right]^{.375}$ - Manning's Eq'n. For Circ. Pipes Flowing just Full

n = Manning's Coef. S = slope of pipe

G.N. RICHARDSON & ASSOCIATES
CONSULTING ENGINEERING

DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

Project: Greensboro Phase III Lined Landfill Expansion

Task: Size Landfill Pipes (leachate & stormwater) based on the 25 year 24 hour storm

Date: 11/5/96 Calc'd by: EAW Checked by:

Circular pipe flowing just full: D=16(Qn/(s)^.5)^(3/8)
Q=(((D/16)^(8/3))/n)*(s)^.5

n = 0.01 HDPE

25 yr 24 hr storm 5.75 inches

Pipe Slope

Diameter (inches)	Q (cubic feet per second)					
	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%
4	0.2	0.2	0.3	0.4	0.4	0.4
6	0.5	0.7	0.9	1.0	1.2	1.3
8	1.1	1.6	1.9	2.2	2.5	2.7
10	2.0	2.9	3.5	4.0	4.5	4.9
12	3.3	4.6	5.7	6.6	7.3	8.0
14	5.0	7.0	8.6	9.9	11.1	12.1
15	6.0	8.4	10.3	11.9	13.3	14.6
16	7.1	10.0	12.2	14.1	15.8	17.3
18	9.7	13.7	16.8	19.4	21.6	23.7
20	12.8	18.1	22.2	25.6	28.7	31.4
22	16.5	23.4	28.6	33.1	37.0	40.5
24	20.8	29.5	36.1	41.7	46.6	51.1

Diameter (inches)	Area Drained (acres per day)					
	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%
4	0.7	1.0	1.3	1.5	1.6	1.8
6	2.1	3.0	3.7	4.3	4.8	5.2
8	4.6	6.5	8.0	9.2	10.3	11.3
10	8.4	11.8	14.5	16.7	18.7	20.5
12	13.6	19.2	23.5	27.2	30.4	33.3
14	20.5	29.0	35.5	41.0	45.8	50.2
15	24.6	34.8	42.7	49.3	55.1	60.4
16	29.3	41.4	50.7	58.5	65.4	71.7
18	40.1	56.7	69.4	80.1	89.6	98.2
20	53.1	75.1	91.9	106.1	118.7	130.0
22	68.4	96.8	118.5	136.9	153.0	167.6
24	86.3	122.0	149.5	172.6	193.0	211.4

Leachate Pipe

Stormwater Pipe

PROJECT HDR-GBORO. LF
SUBJECT Leachate Collection Pipe Stresses (HDPE PIPE)

SHEET 1 OF 4
JOB NO. HDRGN-2
DATE 11/28/95
COMPUTED BY PKS
CHECKED BY

— Objective: Evaluate leachate collection pipe stresses due to static (overburden) and dynamic (equipment) loads. Check both crushing and buckling failure modes.

Cases To Be Evaluated:

1. Maximum Static Loading
2. Equipment Loads as Follows:
   A. Construction
   B. Operation

— Analysis: Follow Driscopipe Systems Design Manual

Minimum F.S. ⟹ Static = 1.8
Dynamic = 1.4

— Equations:

— Crushing Stress:

$$S_A = \left[\frac{SDR-1}{2}\right] P_T$$ (Driscopipe p.36)

Where: S_A = Stress in Pipe Wall (psi)
SDR = Standard Dimension Ratio
= Outside Diam./Wall Thickness
P_T = External Pressure (psi)

$$F.S._{crushing} = \sigma_{yield\ (HDPE=1500psi)} / S_A$$

PROJECT HDR- GBORO, LF.
SUBJECT Leachate Collection Pipe Stresses

SHEET 2 OF 4
JOB NO. HDRGN-2
DATE 11/28/95
COMPUTED BY PKS
CHECKED BY

- Wall Buckling:

$$P_{cb} = 0.8\sqrt{E'(P_c)} \qquad \text{(Driscopipe p.37)}$$

Where: P_{cb} = Critical Buckling Soil Pressure @ Top of Pipe (psi)

E' = Base Soil Modulus (psi)

$$E' = \frac{P_T}{\epsilon_s} = \frac{\text{Vertical Soil Pressure}}{\text{Vertical Soil Strain}}$$

* Use $E' = 1500$ psi For Compacted soil liner

P_c = Hydrostatic Critical Collapse Differential Pressure (psi)

$$P_c = \frac{2.32E}{(SDR)^3}$$

E = Stress/Time Dependent Tensile Modulus of Elasticity (psi)

$$F.S._{buckling} = P_{cb}/P_T$$

- Equipment Loading:

Point Loads: ①

$$P_T = P_P = \frac{3Wz^3}{2\pi z^5}$$

Line Loads: ②

$$P_T = P_L = \frac{2Wz^3}{\pi z^4}$$

Where: W = Dynamic Equipment Load (1.5 times weight of machine) (lbs or lbs/Ft)

z = Vertical Distance From The Point Load To Top of Pipe (ft)

① Driscopipe p.44

② Holtz & Kovacs, An Intro. To Geotech. Eng., p.348

PROJECT HDR- GBORO, LF.

SUBJECT Leachate Collection Pipe Stresses

SHEET 3 OF 4
JOB NO. HDRGN-2
DATE 11/28/95
COMPUTED BY PRS
CHECKED BY

Values of E':

A.

TABLE 3.4 Average Values of Modulus of Soil Reaction, E' (For Initial Flexible Pipe Deflection)

Soil type-pipe bedding material (Unified Classification System*)	E' for degree of compaction of bedding, lb/in²			
	Dumped	Slight, < 85% proctor, < 40% relative density	Moderate, 85%–95% proctor, 40%–70% relative density	High, > 95% proctor, > 70% relative density
Fine-grained soils (LL > 50)† Soils with medium to high plasticity CH, MH, CH-MH	No data available; consult a competent soils engineer; Otherwise use E' = 0			
Fine-grained soils (LL < 50) Soils with medium to no plasticity CL, ML, ML-CL, with less than 25% coarse-grained particles	50	200	400	1000
Fine-grained soils (LL < 50) Soils with medium to no plasticity CL, ML, ML-CL, with more than 25% coarse-grained particles Coarse-grained soils with fines GM, GC, SM, SC contains more than 12% fines	100	400	1000	2000
Coarse-grained soils with little or no fines GW, GP, SW, SP‡ contains less than 12% fines	200	1000	2000	3000
Crushed rock	1000	3000	3000	3000
Accuracy in terms of percentage deflection§	± 2	± 2	± 1	± 0.5

*ASTM Designation D2487, USBR Designation E-3
†LL = liquid limit
‡Or any borderline soil beginning with one of these symbols (i.e., GM-GC, GC-SC)
§For ± 1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

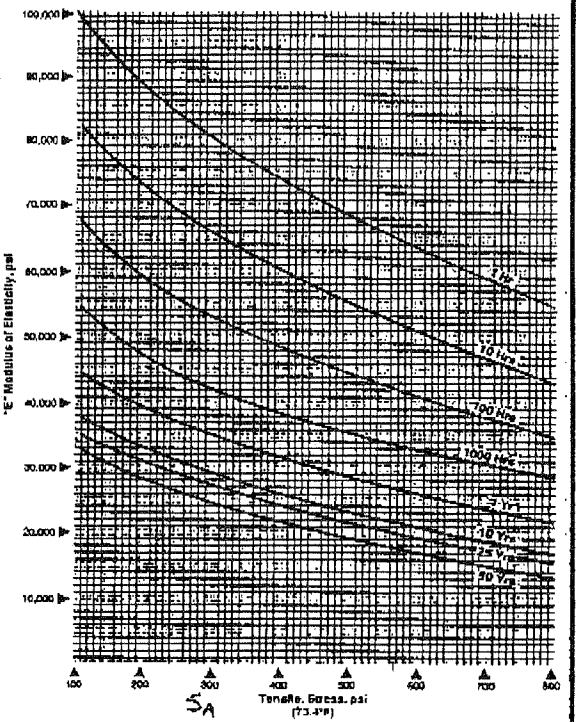
NOTE: Values applicable only for fills less than 50 ft (15 m). Table does not include any safety factor. For use in predicting initial deflections only, appropriate deflection lag factor must be applied for long-term deflections. If bedding falls on the borderline between two compaction categories, select lower E' value or average the two values. Percentage *proctor* based on laboratory maximum dry density from test standards using about 12,500 ft·lb/ft³ (598,000 J/m³) (ASTM D698, AASHO T-99, USBR Designation E-11). 1 lb/in² = 6.9 kN/m².

SOURCE: Amster K. Howard, "Soil Reaction for Buried Flexible Pipe," U.S. Bureau of Reclamation, Denver, Colo. Reprinted with Permission from American Society of Civil Engineers *J. Geotech. Eng. Div.*, January 1977, pp. 33–43.

B.

Chart 25

Time Dependent Modulus of Elasticity for Polyethylene Pipe vs. Stress Intensity (73.4°F)



NOTE: The short term modulus of elasticity of Driscopipe per ASTM D 638 is approximately 100,000 psi. Due to the cold flow (creep) characteristic of the pipe material, this modulus is dependent upon the stress intensity and the time duration of the applied stress.

C.

TABLE 19.5 TYPICAL RANGE OF VALUES FOR MODULUS OF ELASTICITY.

Type of Soil	Modulus of Elasticity psi	Modulus of Elasticity kp/cm²
Very soft clay	50–400	3.5–30
Soft clay	250–500	20–50
Medium clay	600–1,200	40–80
Hard clay	1,000–7,500	70–150
Sandy clay	4,000–6,000	300–400
Silty sand	1,000–3,000	70–200
Loose sand	1,500–3,500	100–250
Dense sand	7,000–12,000	500–800
Dense sand and gravel	14,000–28,000	1,000–2,000
Wood	1,200,000–1,500,000	80,000–100,000
Concrete	2,800,000–4,000,000	200,000–300,000
Steel	30,000,000	2,150,000

References:

A. Moser, Buried Pipe Design

B. Winterkorn & Fang, Foundation Engineering Handbook

C. Driscopipe Design Manual

G.N. RICHARDSON & ASSOCIATES
CONSULTING ENGINEERING

DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

G.N. Richardson & Associates
ENGINEERING AND GEOLOGICAL SERVICES

SHEET: 4/4
JOB #: HDRGN-2
DATE: 11/21/95
BY: PKB
CHKD BY:

City of Greensboro
Analysis of Leachate Collection Pipe Stresses

Case 1: Maximum Static Loading

Leachate Collection Sand:		Compacted Soil Cover:	
Thickness (ft) =	0.5	Thickness (ft) =	2
Unit Weight (pcf) =	120	Unit Weight (pcf) =	120
Operational Cover:		Agricultural Cover:	
Thickness (ft) =	2	Thickness (ft) =	2
Unit Weight (pcf) =	120	Unit Weight (pcf) =	120
Waste & Daily Cover:			
Thickness (ft) =	180	Max. Vertical Stress (Pt) (psi) =	89
Unit Weight (pcf) =	60		

Calculate Safety Factors Against Crushing and Buckling:

SDR	SA (psi)	E (psi)	Pc (psi)	Pcb (psi)	FS crush	FS buckle	Comment
19	724	17500	5.92	75.38	2.07	0.94	No Good
17	643	19000	8.97	92.61	2.33	1.15	Marginal
15.5	583	20000	12.46	109.37	2.87	1.36	Marginal
11	402	24000	41.83	200.40	3.73	2.49	O.K.

Case 2: Dynamic (Equipment) Loading

SDR (Determine From Static Loading Analysis) = 11

Line Loads:

Equipment	Weight* (lbs)	Track Length (ft)	Dynamic Line Loads (psi) 6" Cover	12" cover	18" Cover	SA 6" Cover	12" cover	18" Cover	FS 6" Cover	12" cover	18" Cover
D4 Bulldozer (D4C-II)	19485	6.74	19	10	6	98	48	32	15.6	31.3	46.9
D6 Bulldozer (D6H-II)	46305	8.63	36	16	12	178	89	59	8.4	16.9	25.3
D6 Bulldozer (D6L)	95838	10.5	61	30	20	303	151	101	5.0	9.9	14.9
953 Track Loader	37560	7.5	33	17	11	166	83	55	9.0	18.1	27.1
963Track Loader	48914	8.08	40	20	13	201	100	67	7.5	14.9	22.4

* Includes Blades, Loaded Buckets, etc.

Point Loads:

Equipment	Weight* (lbs)	Number of Tires	Dynamic Point Loads (psi) 6" Cover	12" cover	18" Cover	SA 6" Cover	12" cover	18" Cover	FS 6" Cover	12" cover	18" Cover
950 Wheel Loader	46828	4	242	89	27	1209	302	134	1.2	5.0	11.2
615 Scraper	91000	4	453	113	50	2263	566	251	0.7	2.7	6.0
621 Scraper	115195	4	573	143	64	2865	716	318	0.5	2.1	4.7
816B Compactor	45477	4	226	57	25	1131	283	126	1.3	5.3	11.9
826C Compactor	69733	4	347	87	39	1734	434	193	0.9	3.5	7.8

* Includes Blades, Loaded Buckets, etc.

SDR 11 Pipe OK. – As an alternative to smooth wall HDPE, corrugated HDPE such as Advanced Drainage Systems N12 or equivalent may be used.

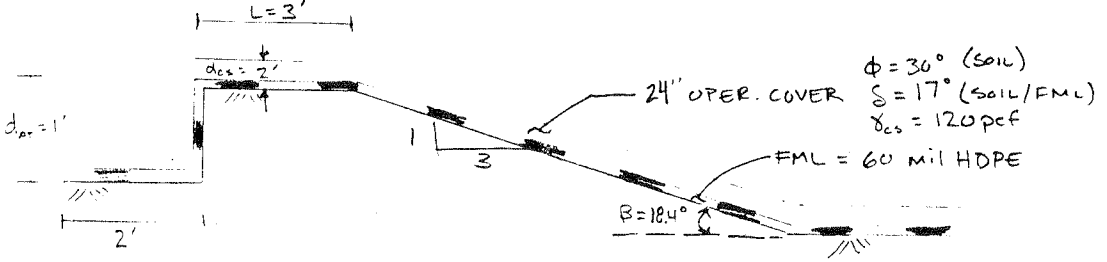
Job No. 06770-021-018 | No.

HDR Computation

Project	GREENSBORO WHITE STREET L/F	Computed DTD	Date 10/16/96
Subject	PHASE III EXPANSION	Checked EAW	Date 10/16/96
Task	ANCHOR TRENCH	Sheet 1	Of 2

OBJECTIVE: CALCULATE ANCHOR CAPACITY FOR FML. with operational cover.

REF: "GEOSYNTHETIC DESIGN GUIDANCE FOR HAZARDOUS WASTE LANDFILL CELLS AND SURFACE IMPOUNDMENTS," BY GREG RICHARDSON AND ROBERT KOERNER.



$$q = \gamma_{cs} \times d_{cs} = 120\ pcf \times 2\ ft = 240\ psf$$

active	passive	initial
$K_a = \frac{1-\sin\phi}{1+\sin\phi}$	$K_p = \frac{1+\sin\phi}{1-\sin\phi}$	$K_o = 1-\sin\phi$
$= \frac{1-\sin 30°}{1+\sin 30°}$	$= \frac{1+\sin 30°}{1-\sin 30°}$	$= 1-\sin 30°$
$= 0.33$	$= 3.0$	$= 0.5$

Trench Tension, T

$$T = \frac{qL\tan\delta + (K' + K_A)\tan\delta\left[0.5\gamma_{cs} d_{AT}^2 + q d_{AT}\right]}{d_{AT}\cos\beta - \sin\beta\tan\delta} \qquad \text{WHERE } K' = K_p \text{ OR } K_a$$

$$T_{kp} = \frac{240(3)(\tan 17°) + (3.0+0.33)(\tan 17°)\left[0.5(120)(1)^2 + 240(1)\right]}{(1)\cos 18.4° - \sin 18.4°(\tan 17°)} = \underline{617\ ^{lb}/_{ft}} \leftarrow \text{GOVERNS}$$

$$T_{ko} = \frac{240(3)(\tan 17°) + (0.5+0.33)(\tan 17°)\left[0.5(120)(1)^2 + 240(1)\right]}{(1)\cos 18.4° - \sin 18.4°(\tan 17°)} = 348\ ^{lb}/_{ft}$$

Ultimate Strength of 60 mil HDPE => σ_y = 2000 psi

$$\Rightarrow F_{all} = \sigma_y t = 2000(.06) = 120\ ^{lb}/_{in}$$

$$F_{ALL} = 1440\ ^{lb}/_{ft}$$

Active Forces

$F_{SELF-WT}$	3.9 $^{lb}/_{ft}$	see GNPI SPREADSHEET
$F_{downdrag}$	58 $^{lb}/_{ft}$	
F_{WASTE}	102 $^{lb}/_{ft}$	
F_{TOT}	163.9 $^{lb}/_{ft}$	

$F_{TOT} < T < F_{ALL}$

$163.9\ ^{lb}/_{ft} < 617\ ^{lb}/_{ft} < 1440\ ^{lb}/_{ft}$

OKAY

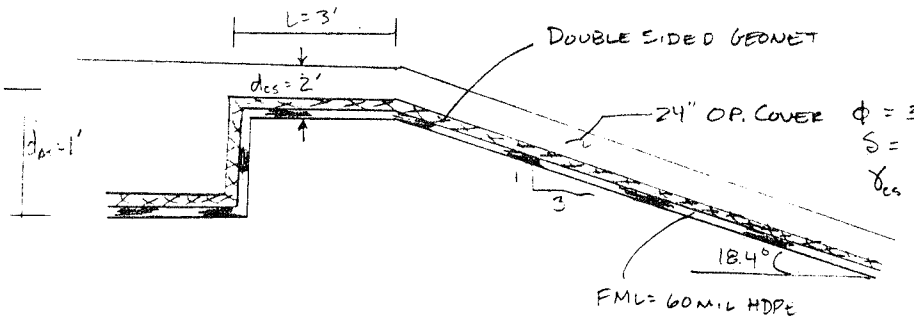
Job No. 6110-021-018 | No.

HDR Computation

HDR

Project	CITY OF GREENSBORO	Computed DTD	Date 11/7/96
Subject	PHASE III EXPANSION	Checked	Date
Task	ANCHOR TRENCH	Sheet 2	Of 2

OBJECTIVE: CALCULATE ANCHOR TRENCH CAPACITY FOR GEOCOMPOSITE ON FML WITH OPERATIONAL COVER.



$q = \gamma_{cs} \times d_{cs} = 120\ pcf \times 2\ ft = 240\ psf$

ACTIVE: $K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 30°}{1+\sin 30°} = 0.33$

PASSIVE: $K_p = \frac{1+\sin\phi}{1-\sin\phi} = \frac{1+\sin 30°}{1-\sin 30°} = 3.0$

INITIAL: $K_o = 1-\sin\phi = 1-\sin 30° = 0.5$

$$T = \frac{qL\tan\delta + (K' + K_a)\tan\delta\,[0.5\gamma_{cs} d_{AT}^2 + q d_{AT}]}{d_{AT}\cos\beta - \sin\beta\tan\delta}$$

WHERE $K' = K_p$ OR K_o

$$T_{K_p} = \frac{240(3)\tan 8° + (3+0.33)\tan 8°\,[0.5(120)(1)^2 + 240(1)]}{1\cos 18.4° - \sin 18.4°\tan 8°} = \underline{267\ lb/ft} \leftarrow \text{GOVERNS}$$

$$T_{K_o} = \frac{240(3)\tan 8° + (0.5+0.33)\tan 8°\,[0.5(120)(1)^2 + 240(1)]}{1\cos 18.4° - \sin 18.4°\tan 8°} = 151\ lb/ft$$

GEOCOMPOSITE ULTIMATE STRENGTH = 40 lb/in = 480 lb/ft

FROM PREVIOUS PAGE → ACTIVE FORCES = 163.9 lb/ft

$$163.9\ lb/ft < 267\ lb/ft < 480\ lb/ft$$

OKAY

PROJECT HDR-GBORO. LF

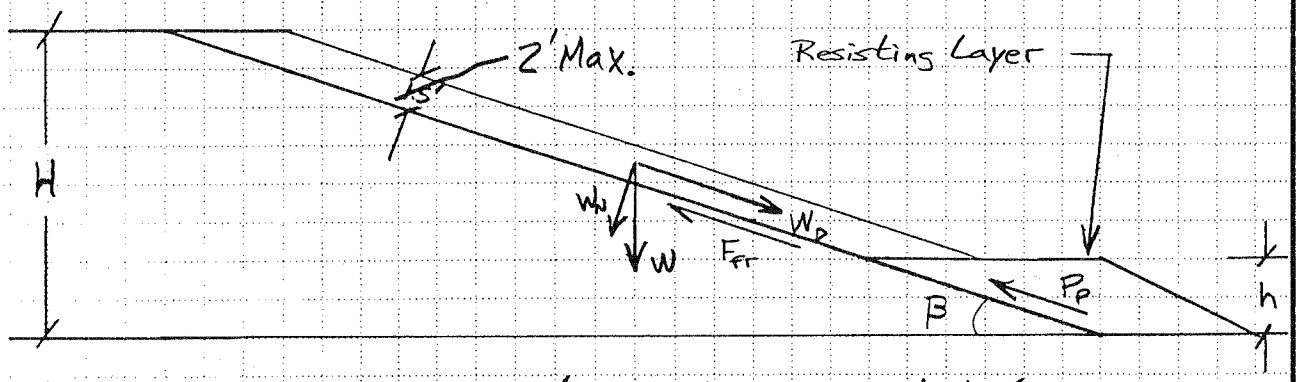
SUBJECT Operational Cover Stability

SHEET 1 OF 3
JOB NO. HDRGN-2
DATE 11/21/95
COMPUTED BY PKS
CHECKED BY

— Objective: Evaluate the stability of the operational cover veneer against sliding. Utilize the gravel toe drain (if applicable) as a toe buttress. Analyze the maximum slope height.

— Analysis: Use the sliding block method to derive the driving and resisting forces in the slope. Use a procedure in NAVFAC 7.2 to evaluate the passive pressure generated from the gravel toe drain (where applicable) or from the leachate collection & op. cover layers on the landfill bottom. Ignore adhesion (conservative).

Typical Cross-Section:



Soil Data: Op. Cover: $\phi_1, c_1, \gamma_1, t_1$ Gravel: ϕ_2, c_2, γ_2

Friction Angle (Op. Cover to Geonet): Analyze 10°-25°

Sideslope Forces:

$W = L \gamma t = (H/\sin\beta)\gamma_1 t_1$

$W_N = W \cos\beta$

$W_D = W \sin\beta$

$F_{fr} = W_N \tan\delta$ (δ = 10°-25°)

$P_p = (K_p \gamma_2 h^2)/2$

(K_p ⇒ From NAVFAC 7.2 p. 7.2-67)

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DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

PROJECT HDR - GBORO. LF

SUBJECT Operational Cover Stability

SHEET 2 OF 3
JOB NO. HDRGN-2
DATE 11/21/95
COMPUTED BY PKS
CHECKED BY

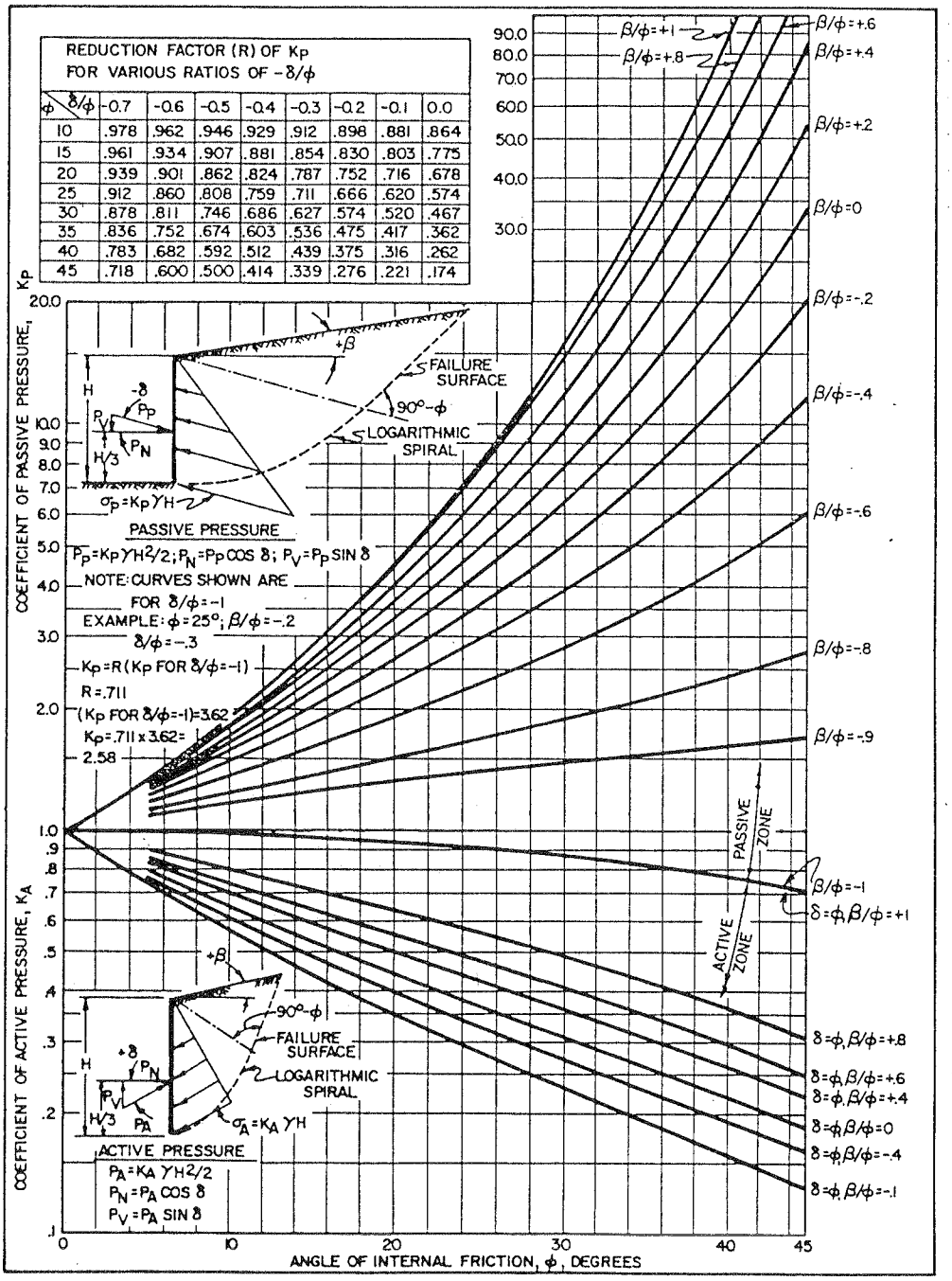

FIGURE 6
Active and Passive Coefficients with Wall Friction
(Sloping Backfill)
7.2-67

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DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

G.N. Richardson & Associates

ENGINEERING AND GEOLOGICAL SERVICES

SHEET: ~~3/4~~ 3/3
JOB #: HDRGN-2
DATE: 11/21/95
BY: PKS
CHKD BY:

City of Greensboro
Analysis of Operational Cover Stability

Input Parameters: (User Input)

Sideslope Angle (Beta):		18.4	degrees
Max. Slope Height (H):		16	ft
Operational Cover:	Thickness:	1.5	ft
	Unit Weight:	110	pcf
Resisting Layer:	Height (h):	3	ft
(Gravel Column)	Unit Weight:	140	pcf
	Phi:	40	degrees
	Beta/Phi:	-0.46	

Passive Pressure Coefficient = 6.6 (from NAVFAC Chart)

Calculate FS Against Sliding:

Interface Fric. Angle	W	WN	WD	Ffr	Pp	Resisting Force	Driving Force	FS slide
10	8364	7936	2640	1399	4158	5557	2640	2.11
15	8364	7936	2640	2126	4158	6284	2640	2.38
20	8364	7936	2640	2889	4158	7047	2640	2.67
25	8364	7936	2640	3701	4158	7859	2640	2.98

OPCOVR.WB1

G · N · Richardson & Associates
CONSULTING ENGINEERING

December 7, 1995

Joseph C. Readling, P.E.
HDR Engineering, Inc.
128 South Tryon Street, Suite 1400
Charlotte, NC 28202-5001

RE: Seismic and Slope Stability Analysis
White Street Landfill
Greensboro, North Carolina

Dear Joe:

This report was prepared in response to your request. The report is consistent with our letter proposal dated November 3, 1995 and meets 40 CFR 258 requirements as expressed in the EPA guidance document EPA/600/R-95/051.

Site Specific Seismic Considerations

On October 9, 1993, RCRA Subtitle D regulations (40 CFR Part 258) governing landfills receiving municipal solid waste (MSW) went into effect. These regulations require that

- Section 258.13 : landfills cannot be sited within 200-feet of a fault that has been active during the Holocene Epoch (past 11,000 years) unless it can be demonstrated that a lesser set back is safe.

- Section 258.14 : landfills must be designed for seismic conditions if they are within a seismic impact zone defined as having a peak bedrock acceleration exceeding 0.1 g based on a 90% probability of non-exceedance over a 250 year time period.

The recent EPA guidance for seismic design guidance for municipal solid waste landfills (EPA/600/R-95/051) clearly indicates that only two faults east of the Rocky Mountains have been shown to be active. The region of capable faults is shown on Figure 1 and extends eastward only to the Meers fault in Oklahoma. Thus the Greensboro site satisfies the requirements of 258.13.

The peak bedrock acceleration at the Greensboro site is obtained from USGS MF-2120 which is partially reproduced on Figure 2. This indicates that a peak bedrock acceleration of 0.10g can be assigned to the Greensboro site. This peak acceleration represents a 90% probability of not being exceeded in 250 years. This corresponds to a site earthquake having a return period exceeding 2400 years.

The peak bedrock acceleration must be modified for site conditions to predict the peak ground surface acceleration at the site. The site amplification or attenuation of the peak bedrock acceleration can be evaluated using one-dimensional wave propagation analysis either specifically performed for the site or based on parametric studies. Since the Greensboro site is only marginally associated with a seismic impact zone, the site amplification or attenuation is estimated using the parametric relationships shown on Figure 3. Soil borings performed by Engineering Tectonics under the direction of GNRA personnel indicate that much of the Greensboro site is underlain by primarily dense to stiff sandy silts (ML or MH) to silty sands (SM). Due to the limited overburden at the site after borrow activities, the ground surface acceleration is taken from Figure 3 as equal to the peak bedrock acceleration of 0.10g.

Liquefaction Evaluation

The first step in any liquefaction evaluation is to assess whether the potential for liquefaction of cohesionless soils exists at a site. A variety of screening techniques exists to distinguish sites that are clearly safe with respect to liquefaction from those sites that require more detailed study (EPA/600/R-95/051). The following five screening criteria are most commonly used to make this assessment:

- Geologic age and origin. Liquefaction potential decreases with increasing age of a soil deposit. Pre-Holocene age soil deposits generally do not liquefy, though liquefaction has occasionally been observed in Pleistocene-age deposits.

  The deposits beneath the Greensboro site are of the Late Precambrian to Cambrian period and greatly predate the Pleistocene.

- Fines content and plasticity index. Liquefaction potential decreases with increasing fines content and increasing plasticity index, PI. Soils having greater than 15 percent (by weight) finer than 0.005 mm, a liquid limit greater than 35 percent, and an in-situ water content less than 0.9 times the liquid limit generally do not liquefy (Seed and Idriss, 1982).

  Grain size distributions performed by Geotechnologies and Trigon indicate that most of the soil layers have in excess of 20% fines.

- Saturation. Although partially saturated soils have been reported to liquefy, at least 80 to 85 percent saturation is generally deemed to be a necessary condition for soil liquefaction. In many locations, the water table is subject to seasonal oscillation. In general, it is prudent that the highest anticipated seasonal water table elevation be considered for initial screening.

- Depth below ground surface. While failures due to liquefaction of end-bearing

piles resting on sand layers up to 100 ft (30 m) below the ground surface have been reported, surface effects from liquefaction is generally not likely to occur more than 50 ft (15 m) below the ground surface.

- Soil Penetration Resistance. According to the data presented in Seed and Idriss (1985), liquefaction has not been observed in soil deposits having normalized Standard Penetration Test (SPT) blowcount larger than 22. Marcuson, et al. (1990) suggest a normalized SPT value of 30 as the threshold value above which liquefaction will not occur. However, Chinese experience, as quoted in Seed et al. (1983), suggests that in extreme conditions liquefaction is possible in soils having normalized SPT blowcounts as high as 40.

  Based on the work performed by Engineering Tectonics, normalized blowcounts in the soils underlying the landfill are generally in excess of 30. Soils where normalized blowcounts were less than 30 were found to be above the water table.

If three or more of the above criteria indicate that liquefaction is not likely, the potential for liquefaction may be considered to be small. If, however, based on the above initial screening criteria, the potential for liquefaction of a cohesionless soil layer beneath the site of a planned landfill (new construction or lateral expansion) cannot be dismissed, more rigorous analysis of liquefaction potential is needed.

Based on the above screening criteria it is apparent that liquefaction is not likely at the White Street Landfill and a more rigorous analysis of this potential is not necessary.

Slope Stability Evaluation

EPA guidance, EPA/600/R-95/051, requires that the completed landfill have minimum factors of safety against slope failures of 1.5 statically and 1.0 dynamically. The slope stability evaluations for the Greensboro Landfill were obtained using the computer program STABL5. A block failure was assumed for the analysis such that the liner formed a major portion of the block. The STABL5 search algorithm looked for the lowest factor of safety for a failure block defined by the geomembrane surface and a plane up through the refuse. Additional slope stability analyses were performed assuming circular failure surfaces through the refuse.

Slope stability evaluations were performed at three sections through the final proposed refuse contours. The sections were selected at locations of maximum steepness of final cover combined with liner slopes to produce minimum slope factors of safety. The locations of the slope stability cuts are shown on Figure 4.

Computer output for the STABL5 studies is presented in Attachment 1 for static and dynamic

loadings. The minimum factors of safety are 1.4 for static conditions and 1.1 for dynamic loading conditions (see Table 1). Note that the minimum static factor of safety was not met (1.4<1.5). However, a second analysis of the same failure surface with a slightly increased cohesion value for the waste (c = 300 psf versus c = 200 psf) produced an adequate factor of safety of 1.5. The waste parameters used in the second analysis are still considered to be quite conservative for municipal solid waste.

The slope stability analyses were performed assuming the minimum interface friction angle of the liner system is 10 degrees. This low friction angle is representative of smooth HDPE and rounded sands or a nonwoven geotextile. This assumption is conservative for the proposed liner system (geomembrane over 2 feet of compacted clay liner). The project specifications should indicate that the minimum interface friction angle of the liner system shall be 10 degrees and require contractor verification. This would require direct shear testing of the geomembrane/geosynthetic material interface.

A veneer stability analysis of the final cover was performed assuming a minimum interface friction angle of 25 degrees and is included in Attachment 2. This interface friction angle is appropriate for geotextile/soil or geotextile/textured geomembrane interfaces. The minimum seismic veneer slope stability factor of safety using this assumption is 1.26. This exceeds EPA guidelines.

Summary

This seismic impact evaluation clearly demonstrates that the lined landfill proposed in Greensboro will satisfy all of the criteria expressed in 40 CFR 258. No site liquefaction or interface friction failures are anticipated for this project.

Cordially,
G.N. Richardson & Associates

Pieter K. Scheer, EIT
Staff Engineer

Gregory N. Richardson, Ph.D., P.E.
President

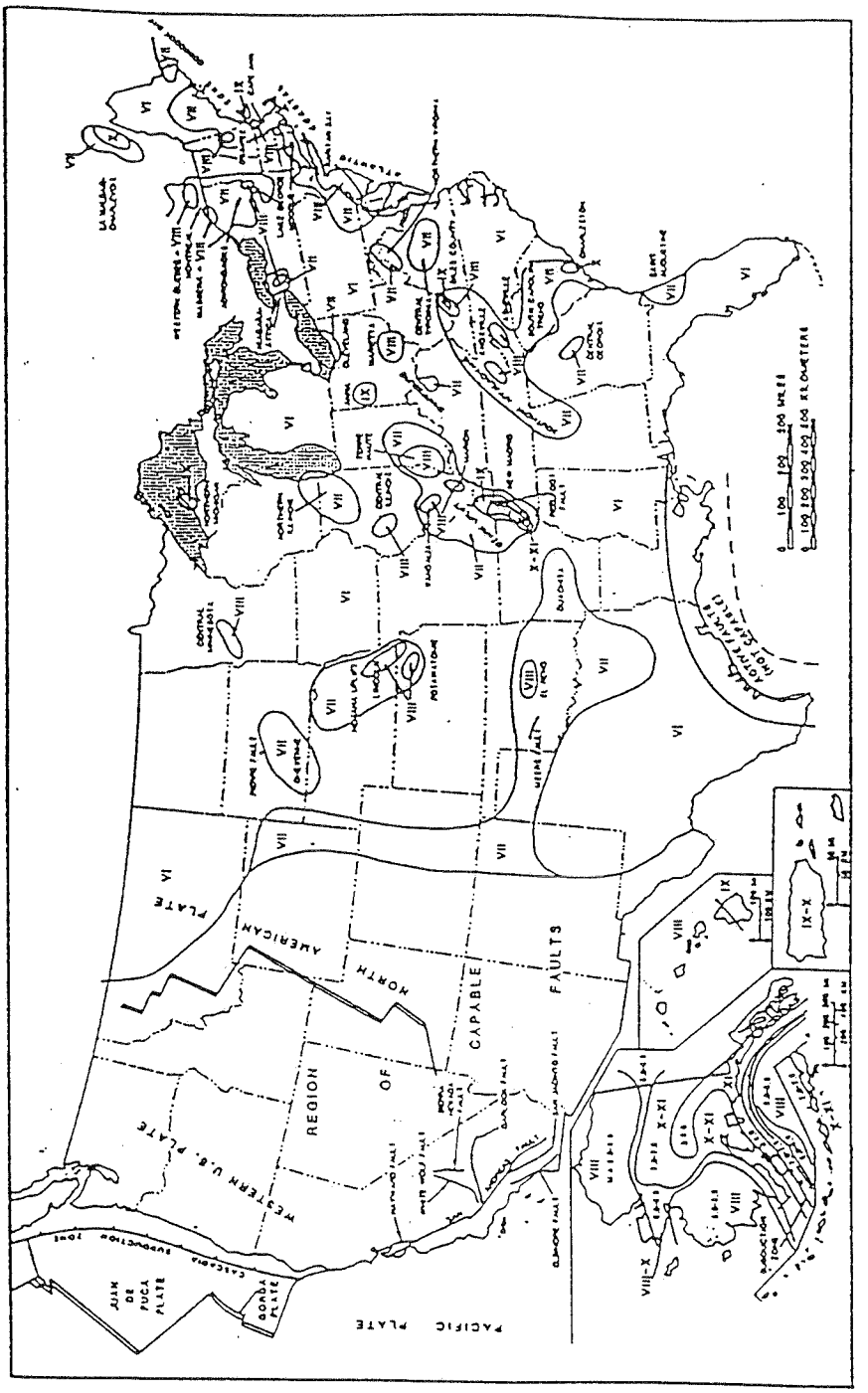
References

Algermissen, S.T., Perkins, D.M., P.C. Thenhaus, S.L. Hanson, and B.L. Bender (1990), "Probabilistic Earthquake Acceleration and Velocity Maps for the United States and Puerto Rico," U.S. Geological Survey Map MF-2120.

Krinitzsky, E.L., Gould, J.P., and P.H. Edinger (1993), Fundamentals of Earthquake-Resistant Construction, John Wiley & Sons, New York.

Richardson, G.N., Kavazanjian, E., and N. Matasovi (1995), RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities, EPA/600/R-95/051, U.S. Environmental Protection Agency, Washington, D.C.

Seed, H.B. and Idriss, I.M. (1982), "Ground Motions and Soil Liquefaction During Earthquakes," Monograph No. 5, Earthquake Engineering Research Institute, Berkeley, California.



CAPABLE FAULTS MAP
(KRINITZSKY et al., 1993)

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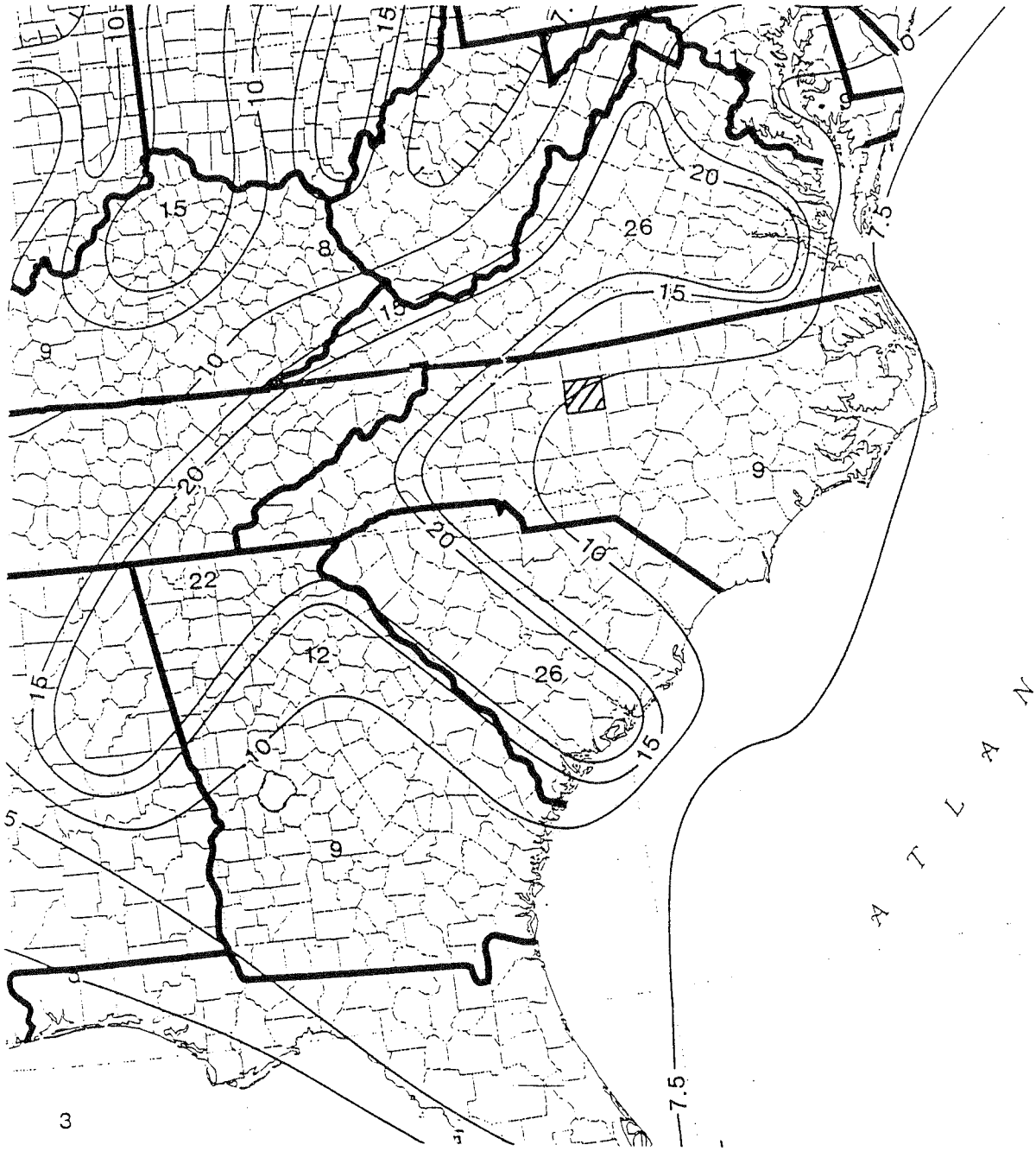
SCALE:	DRAWN BY:	CHECKED BY:	DATE:	PROJECT NO.	FIGURE NO.
AS SHOWN		PKS	12/6/95	HDRGN-2	1



USGS MF-2120
PEAK BEDROCK ACCELERATIONS AS A PERCENT OF GRAVITY (90% PROBABILITY OF NOT BEING EXCEEDED IN 250 YEARS)

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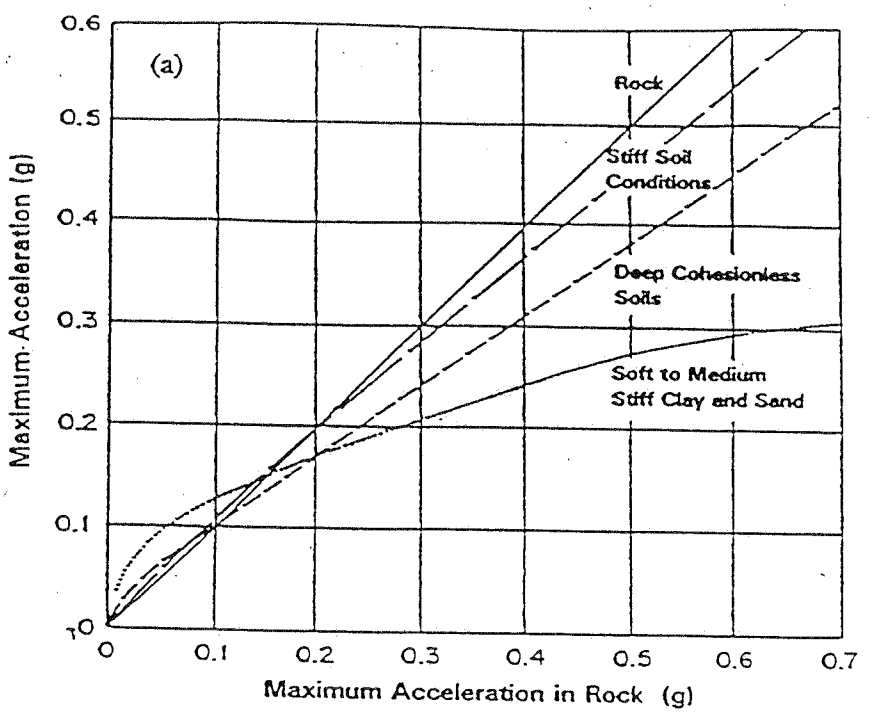
SCALE:	DRAWN BY:	CHECKED BY:	DATE:	PROJECT NO.	FIGURE NO.
1"-625,000 FT		PKS	12/6/95	HDRGN-2	2



SITE AMPLIFICATION/ATTENUATION RELATIONSHIPS
(SEED & IDRISS, 1982)

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SCALE:	DRAWN BY:	CHECKED BY:	DATE:	PROJECT NO.	FIGURE NO.
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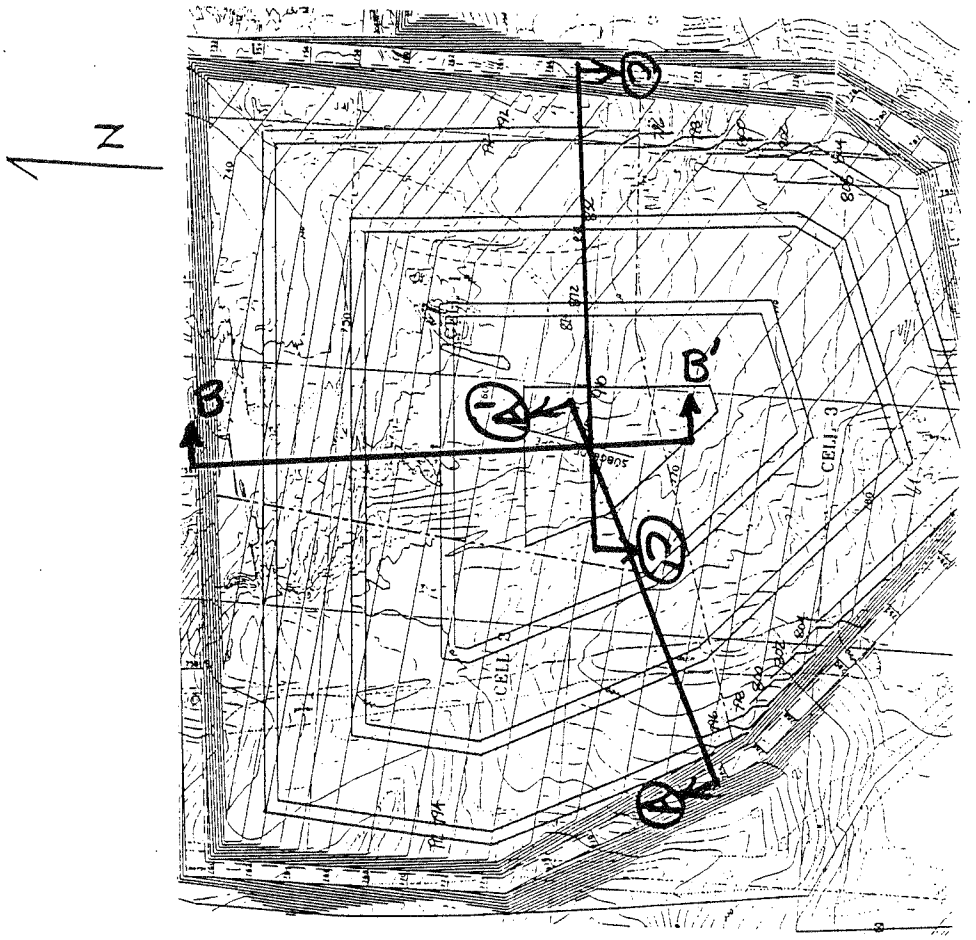

LOCATION OF SLOPE STABILITY
CROSS SECTIONS

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SCALE:	DRAWN BY:	CHECKED BY:	DATE:	PROJECT NO.	FIGURE NO.
1"=400'		PKS	12/6/95	HDRGN-2	4

Table 1 Results of Slope Stability Analyses
White Street Landfill
Greensboro, NC

Cross Section	Failure Type	Failure Type	
		Static	Dynamic*
A	Block	1.9	1.4
	Circular	2.0	1.6
B	Block	1.5	1.2
	Circular	2.0	1.6
C	Block	1.4	1.1
	Block #	1.5	-----
	Circular	2.0	1.6
Cover Veneer	Infinite Slope**	1.87	1.26

* Horizontal and Vertical Coefficients = +0.05g (= ½ Peak Ground Surface Acceleration)

** Interface Friction Angle = 25°

\# c (MSW) = 300 psf

Attachment 1

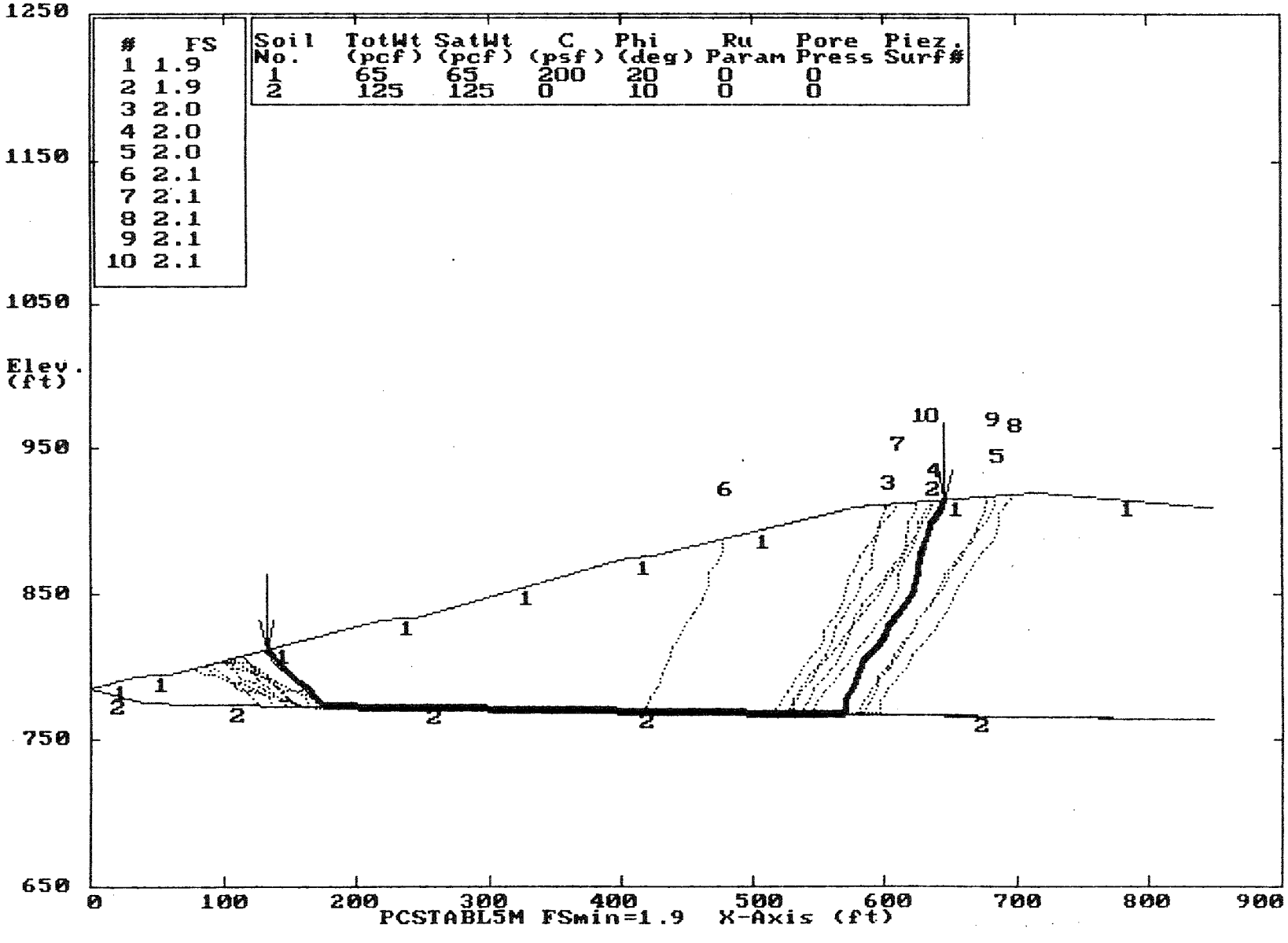
Computer Output

Static and Dynamic Loadings

Greensboro Landfill - Section A-A' Block Stability Along Liner - STATIC
Ten Most Critical. A:GNAA.PLT By: PKS 12-07-95 1:28pm

#	FS
1	1.9
2	1.9
3	2.0
4	2.0
5	2.0
6	2.1
7	2.1
8	2.1
9	2.1
10	2.1

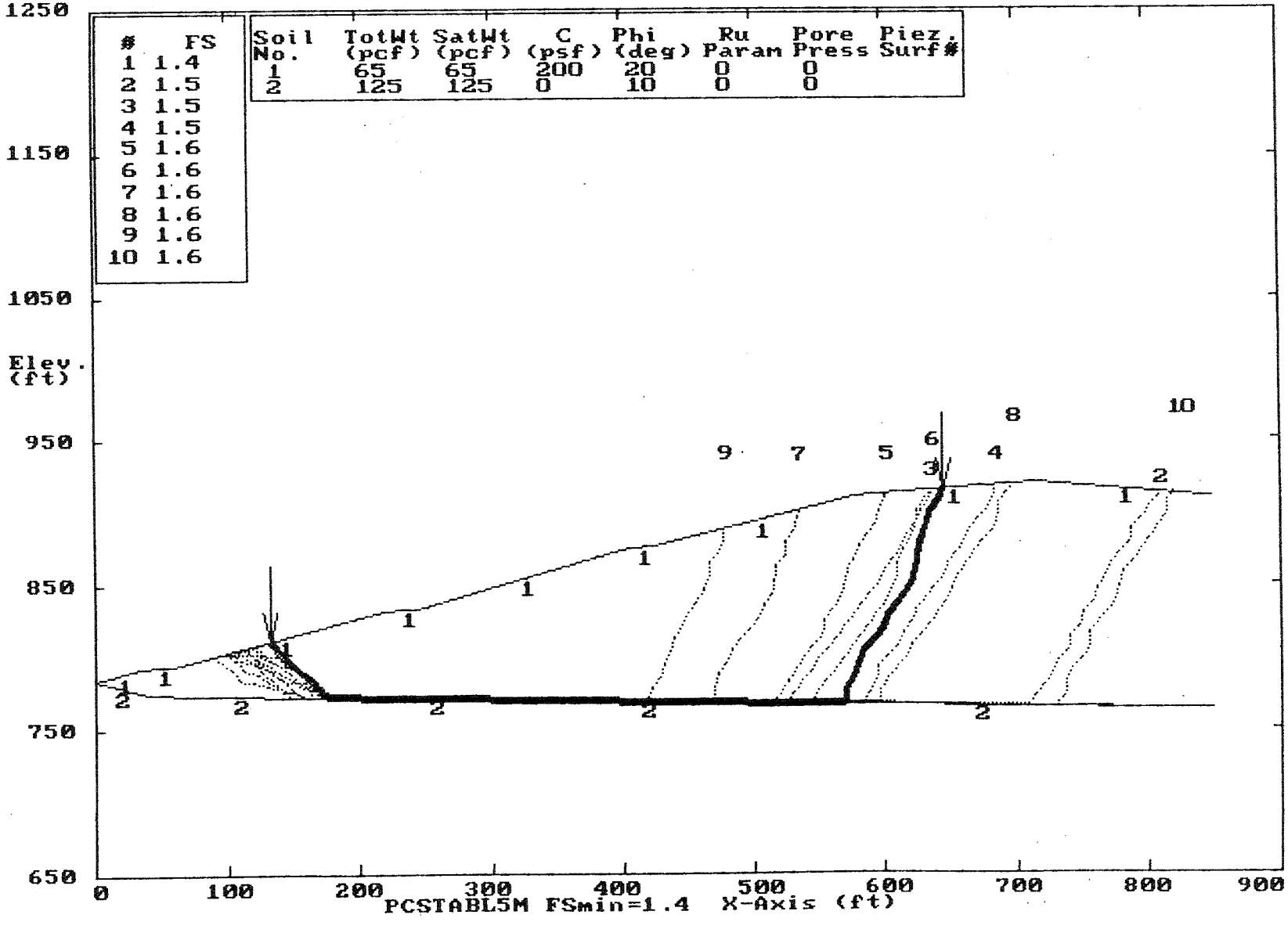
Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	



Greensboro Landfill - Section A-A' Block Stability Along Liner - EQUAKE
Ten Most Critical. A:GNAAE.PLT By: PKS 12-07-95 1:31pm

#	FS
1	1.4
2	1.5
3	1.5
4	1.5
5	1.6
6	1.6
7	1.6
8	1.6
9	1.6
10	1.6

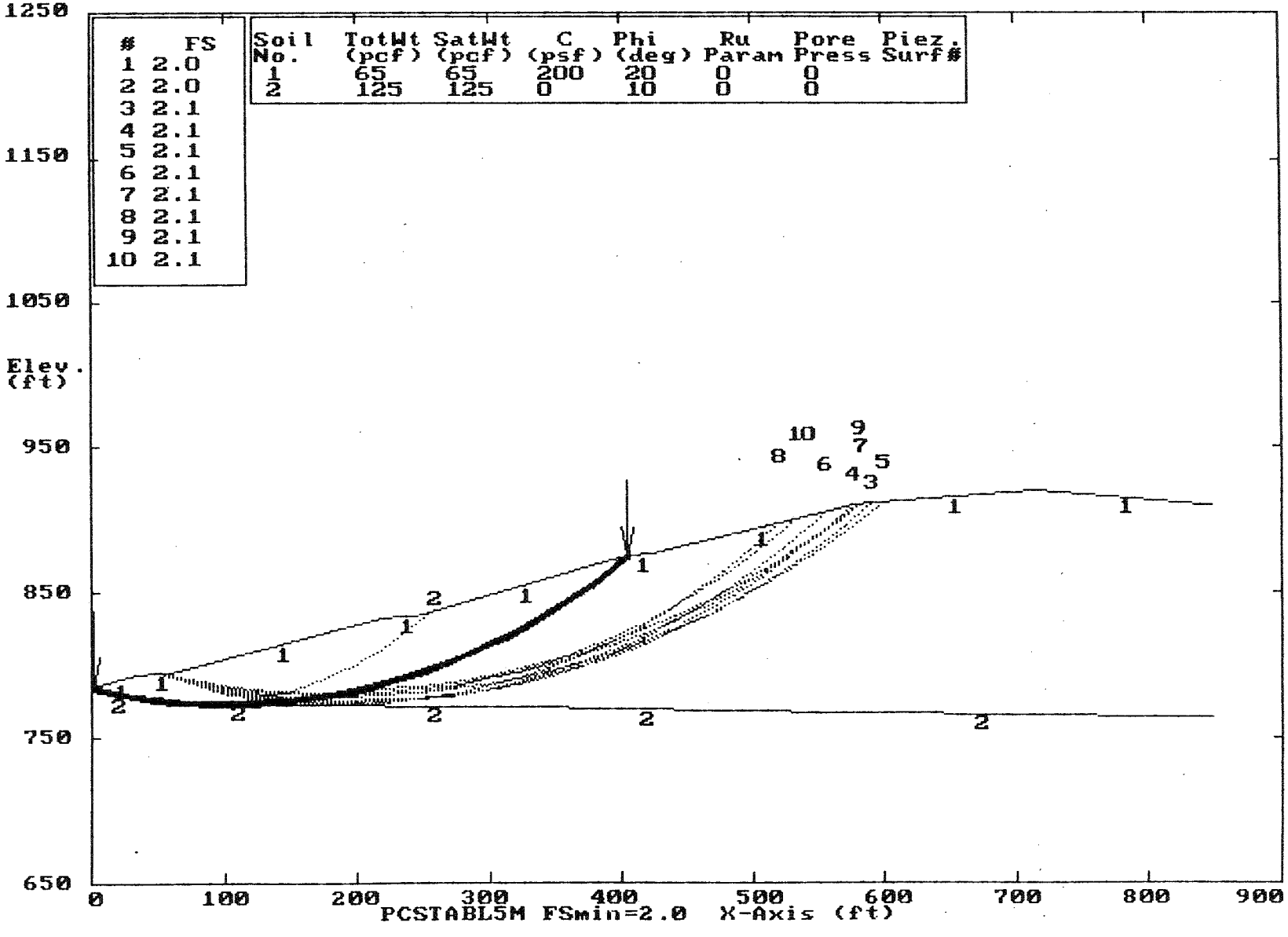
Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	

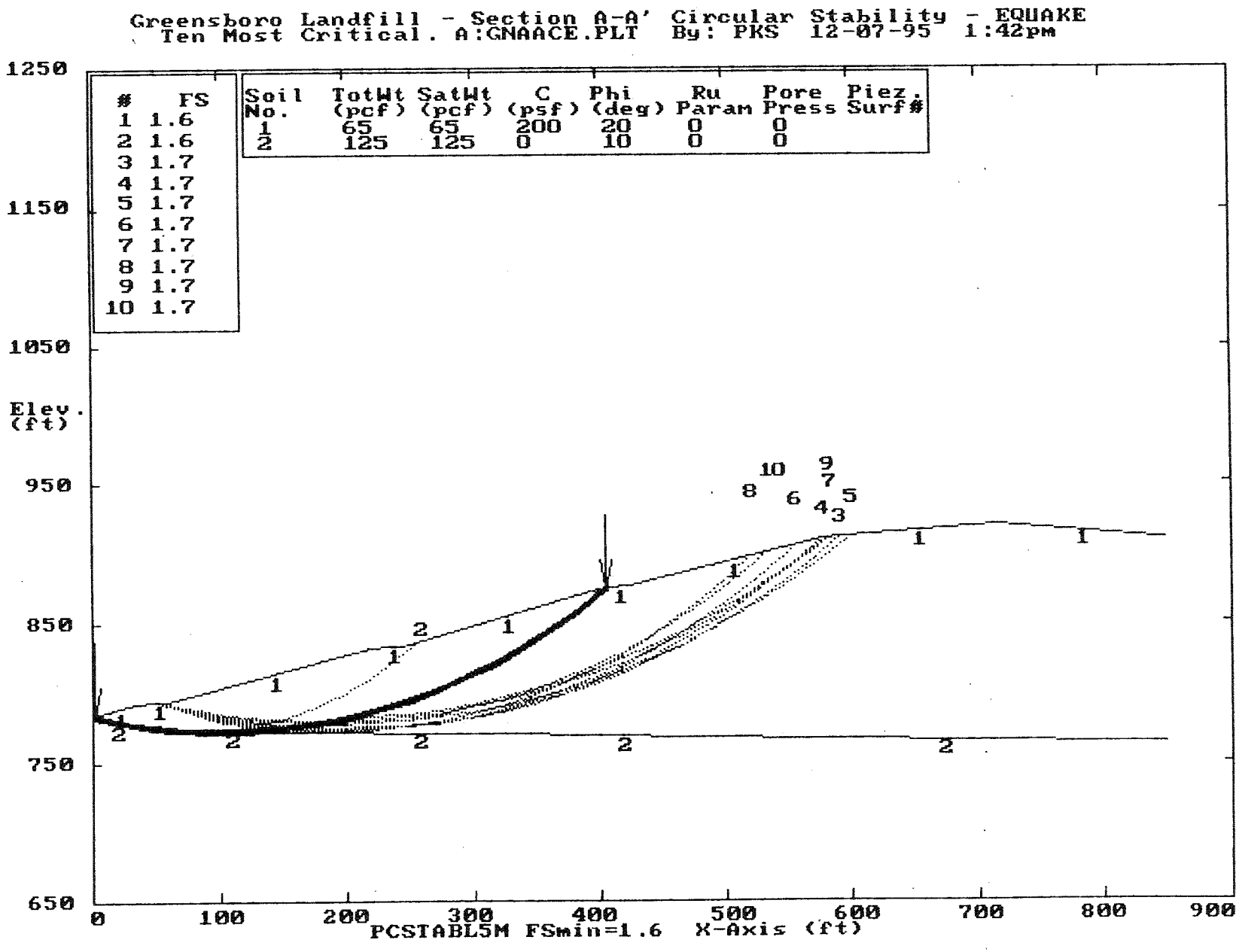


Greensboro Landfill - Section A-A' Circular Stability - STATIC
Ten Most Critical. A:GNAAC.PLT By: PKS 12-07-95 1:37pm

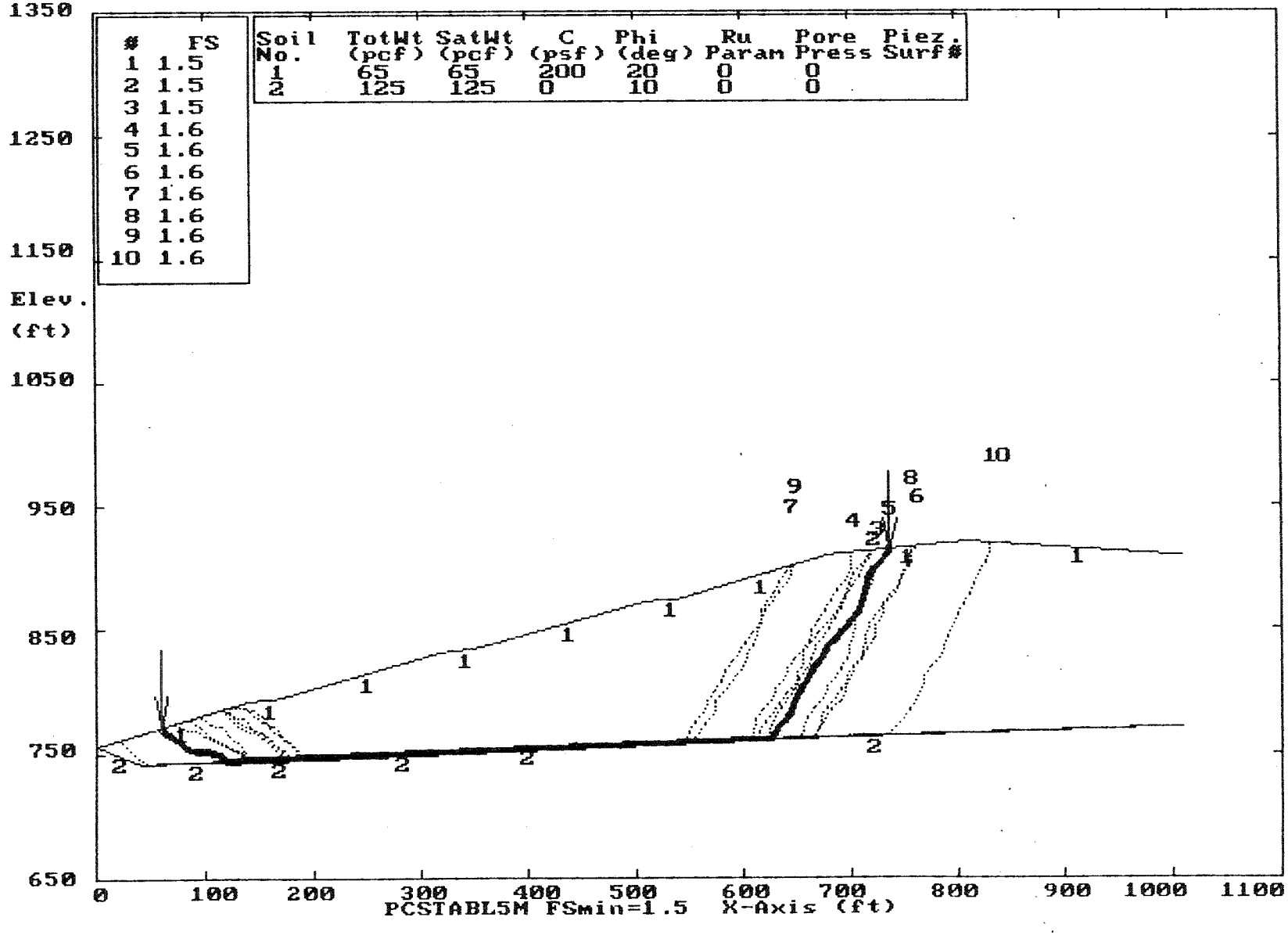
#	FS
1	2.0
2	2.0
3	2.1
4	2.1
5	2.1
6	2.1
7	2.1
8	2.1
9	2.1
10	2.1

Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	




Greensboro Landfill - Section A-A' Circular Stability - EQUAKE
Ten Most Critical. A:GNAACE.PLT By: PKS 12-07-95 1:42pm
FS
1 1.6
2 1.6
3 1.7
4 1.7
5 1.7
6 1.7
7 1.7
8 1.7
9 1.7
10 1.7
Soil No. | TotWt (pcf) | SatWt (pcf) | C (psf) | Phi (deg) | Ru Param | Pore Press | Piez. Surf#
1 | 65 | 65 | 200 | 20 | 0 | 0
2 | 125 | 125 | 0 | 10 | 0 | 0
1250
1150
1050
950
850
750
650
Elev. (ft)
0
100
200
300
400
500
600
700
800
900
PCSTABL5M FSmin=1.6 X-Axis (ft)

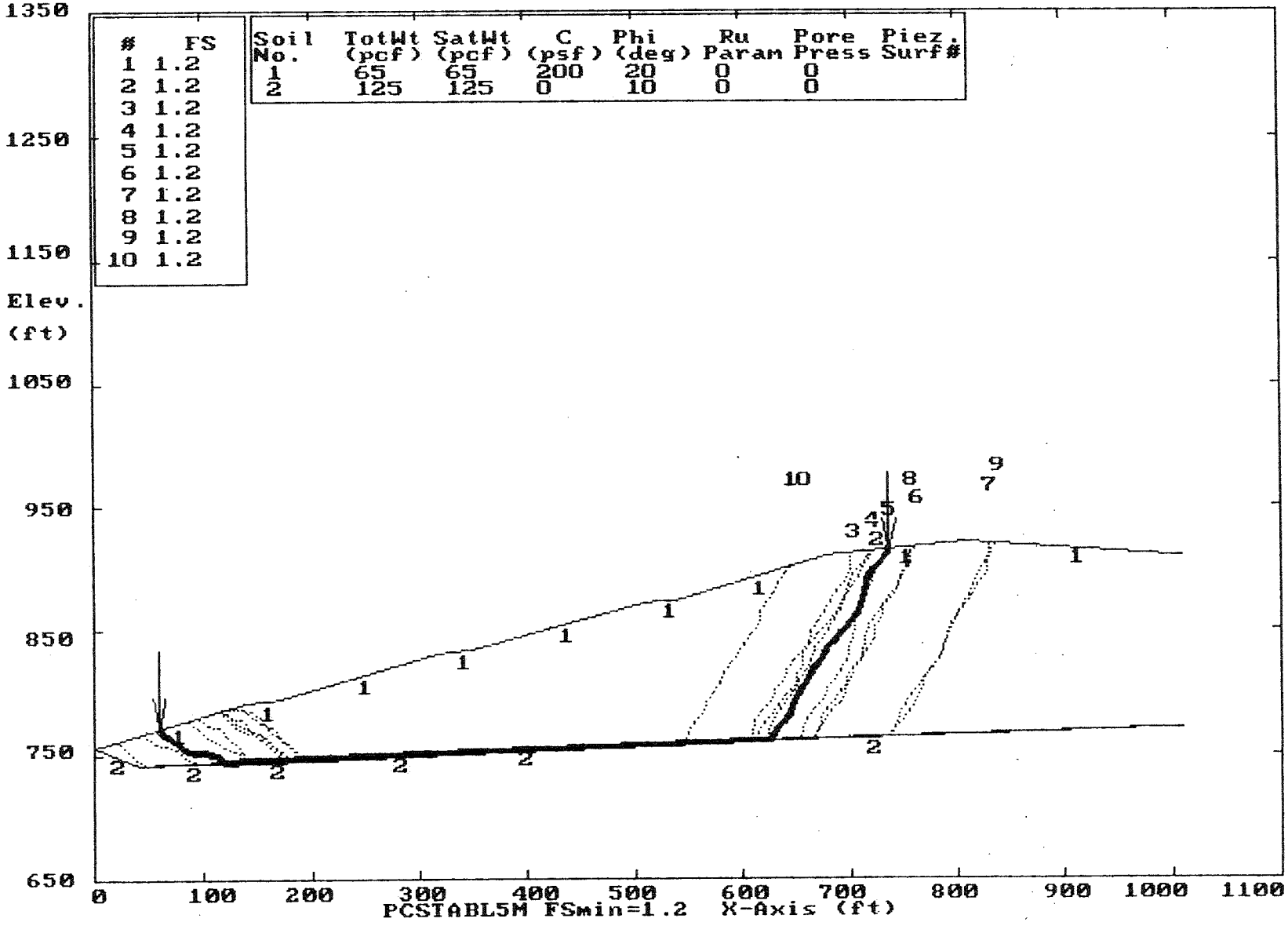
Greensboro Landfill - Section B-B' Block Stability Along Liner - STATIC
Ten Most Critical. A:GNBB.PLT By: PKS 12-07-95 2:06pm



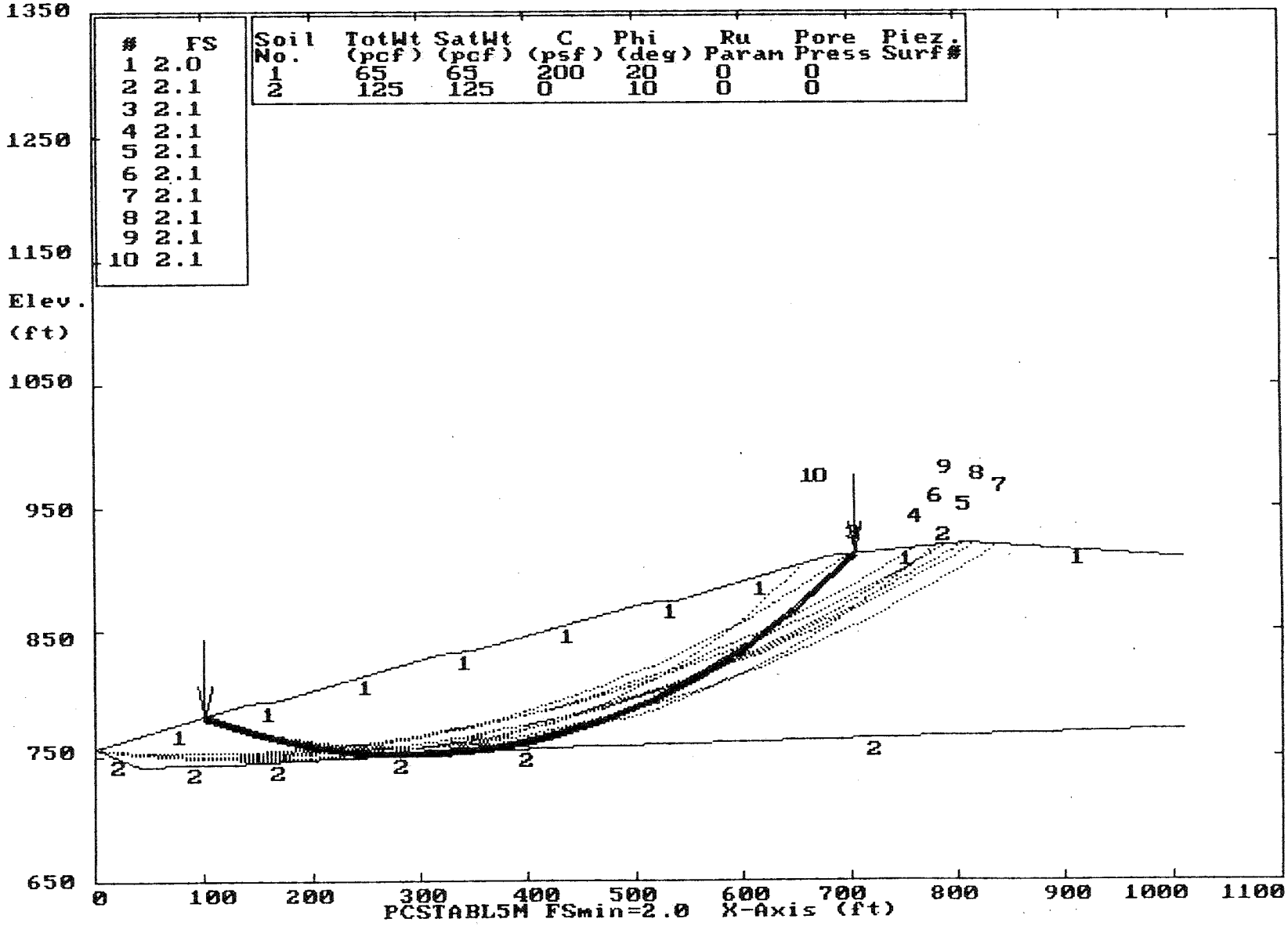
Greensboro Landfill - Section B-B' Block Stability Along Liner - EQUAKE
Ten Most Critical. A:GNBBE.PLT By: PKS 12-07-95 2:09pm

#	FS
1	1.2
2	1.2
3	1.2
4	1.2
5	1.2
6	1.2
7	1.2
8	1.2
9	1.2
10	1.2

Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	



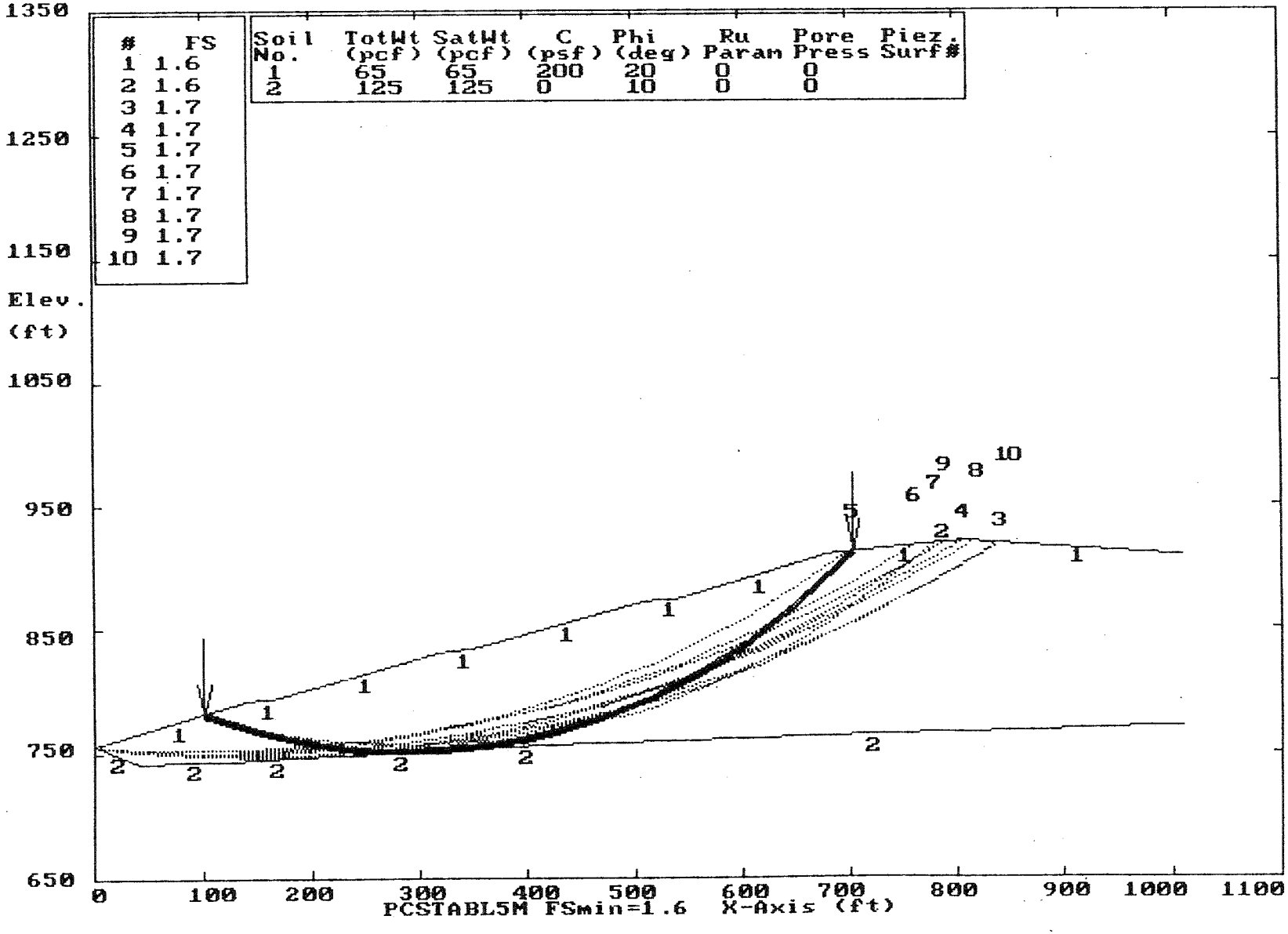
Greensboro Landfill - Section B-B' Circular Stability - STATIC
Ten Most Critical. A:GNBBC.PLT By: PKS 12-07-95 2:02pm



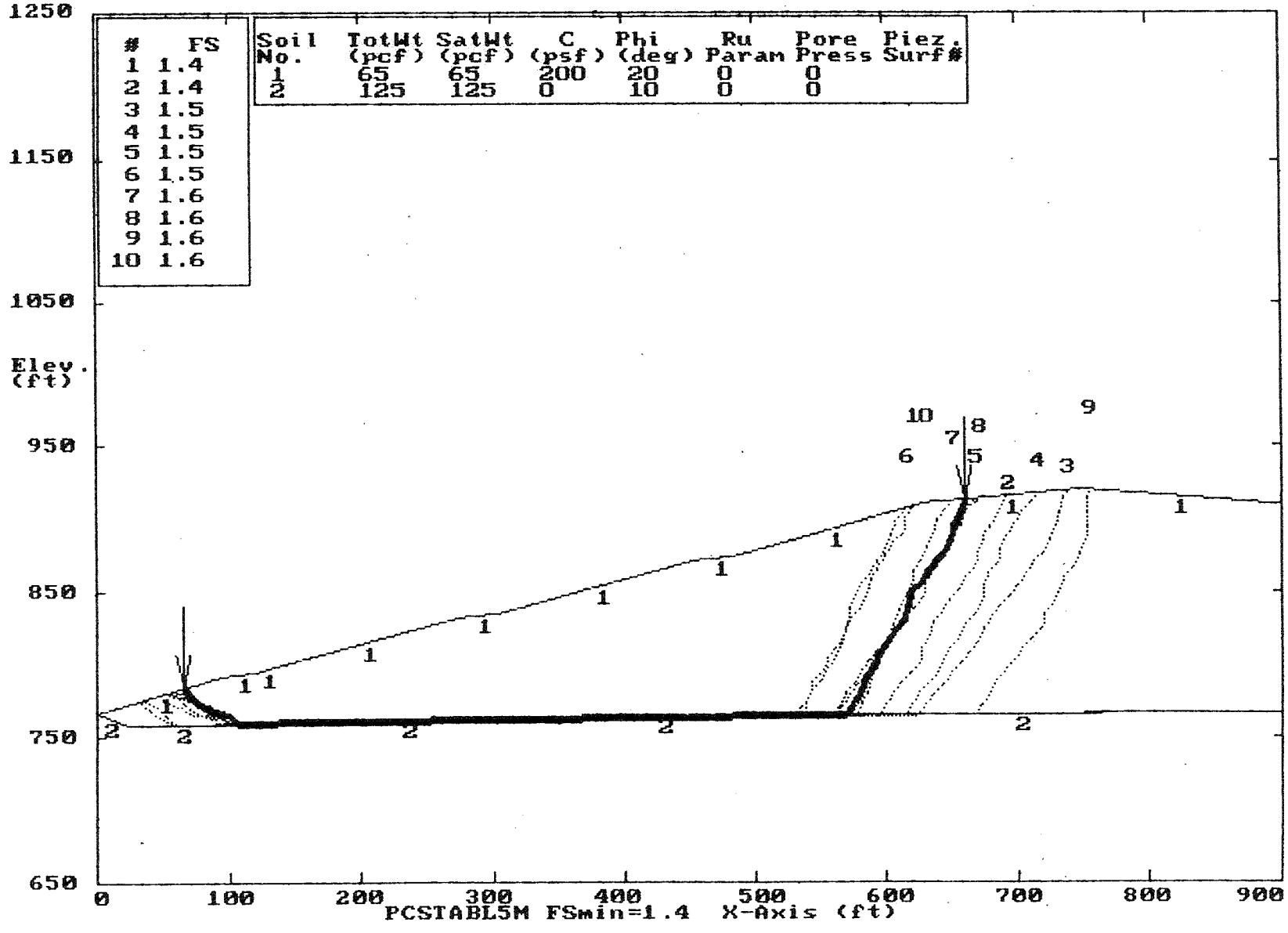
Greensboro Landfill - Section B-B' Circular Stability - EQUAKE
Ten Most Critical. A:GNBBCE.PLT By: PKS 12-07-95 2:00pm

#	FS
1	1.6
2	1.6
3	1.7
4	1.7
5	1.7
6	1.7
7	1.7
8	1.7
9	1.7
10	1.7

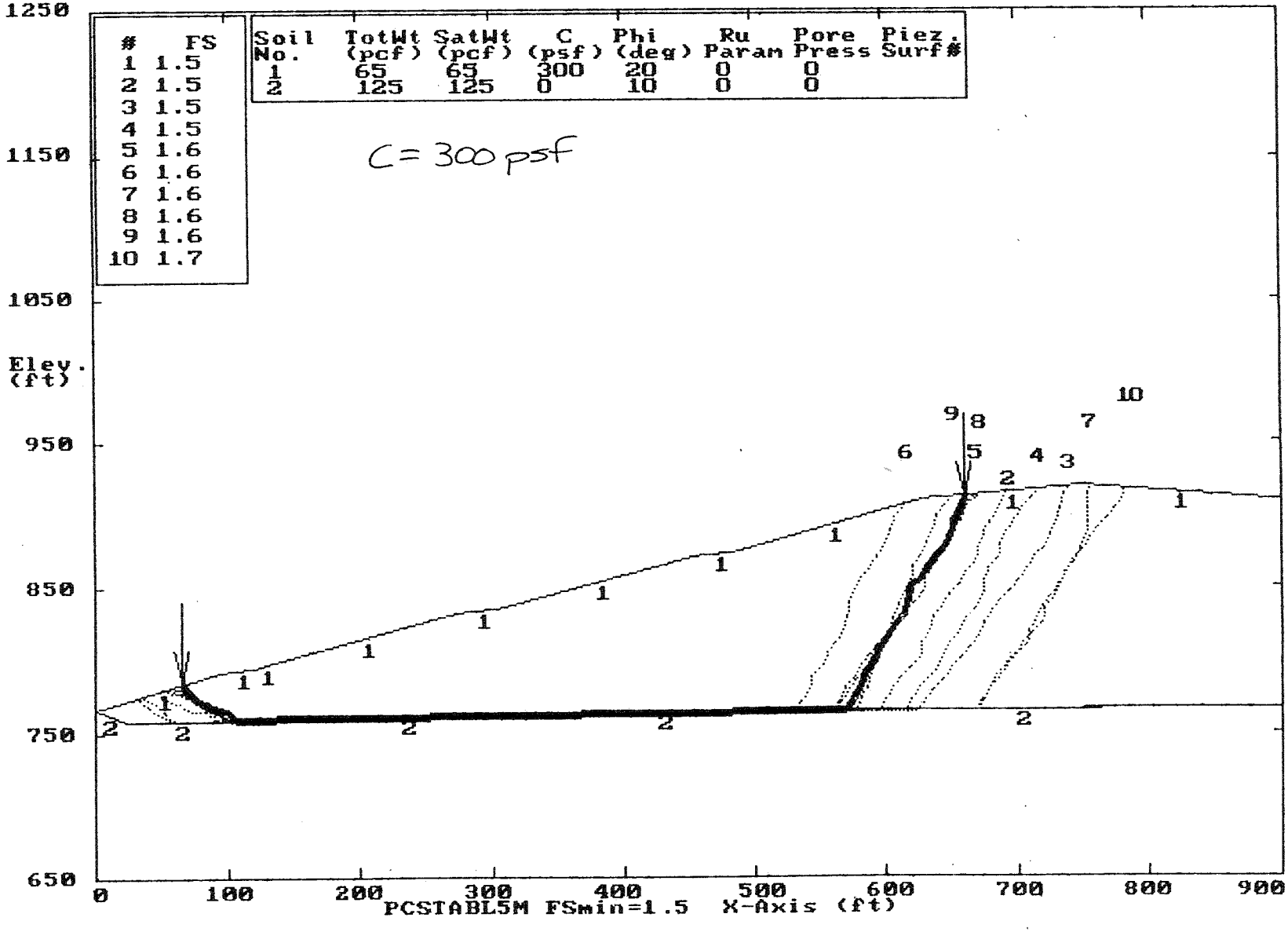
Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	



Greensboro Landfill - Section C-C' Block Stability Along Liner - STATIC
Ten Most Critical. A:GNCC.PLT By: PKS 12-07-95 2:27pm



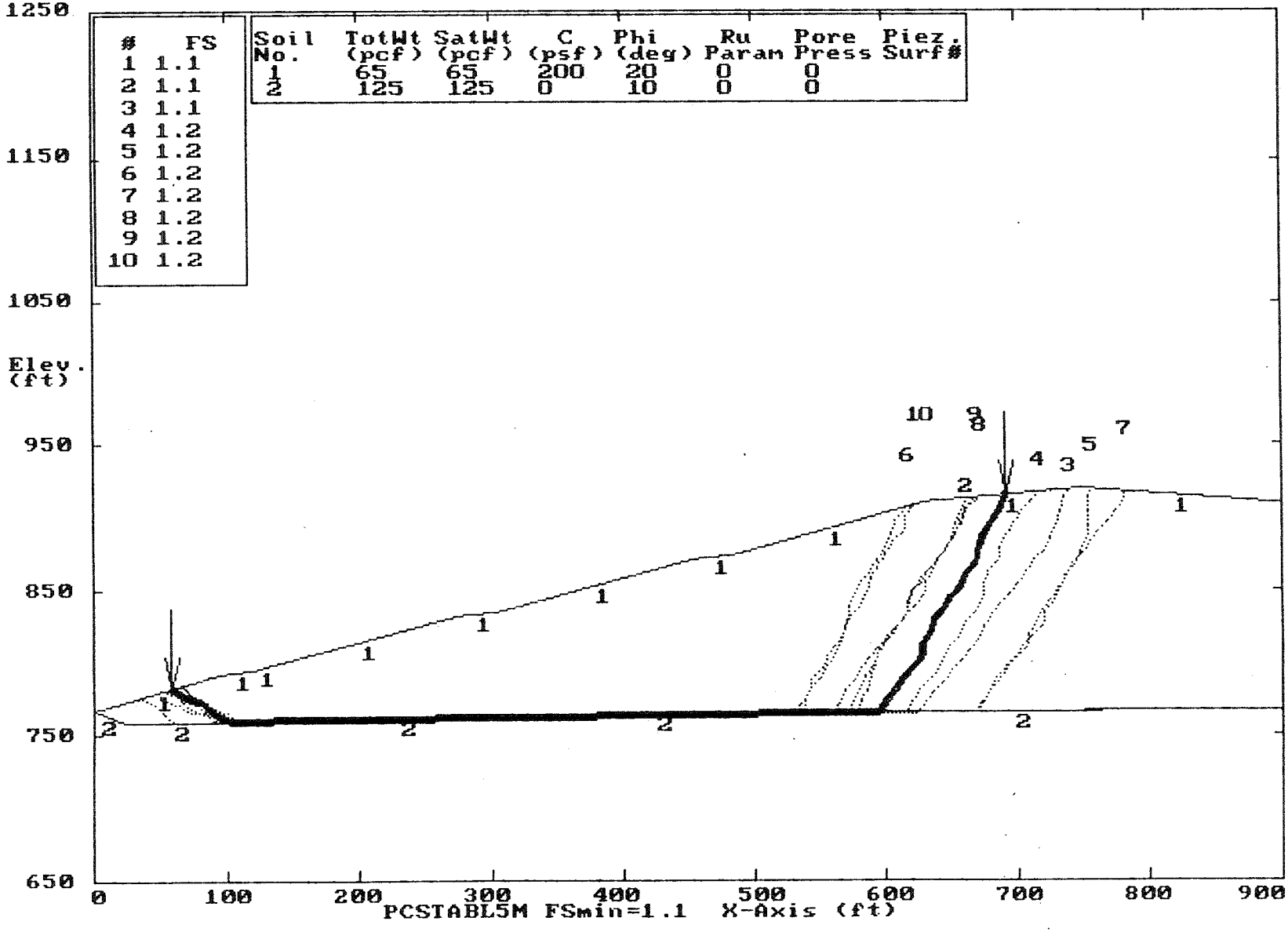
Greensboro Landfill - Section C-C' Block Stability Along Liner - STATIC
Ten Most Critical. A:GNCC1.PLT By: PKS 12-07-95 4:17pm



Greensboro Landfill - Section C-C' Block Stability Along Liner - EQUAKE
Ten Most Critical. A:GNCCE.PLT By: PKS 12-07-95 2:16pm

#	FS
1	1.1
2	1.1
3	1.1
4	1.2
5	1.2
6	1.2
7	1.2
8	1.2
9	1.2
10	1.2

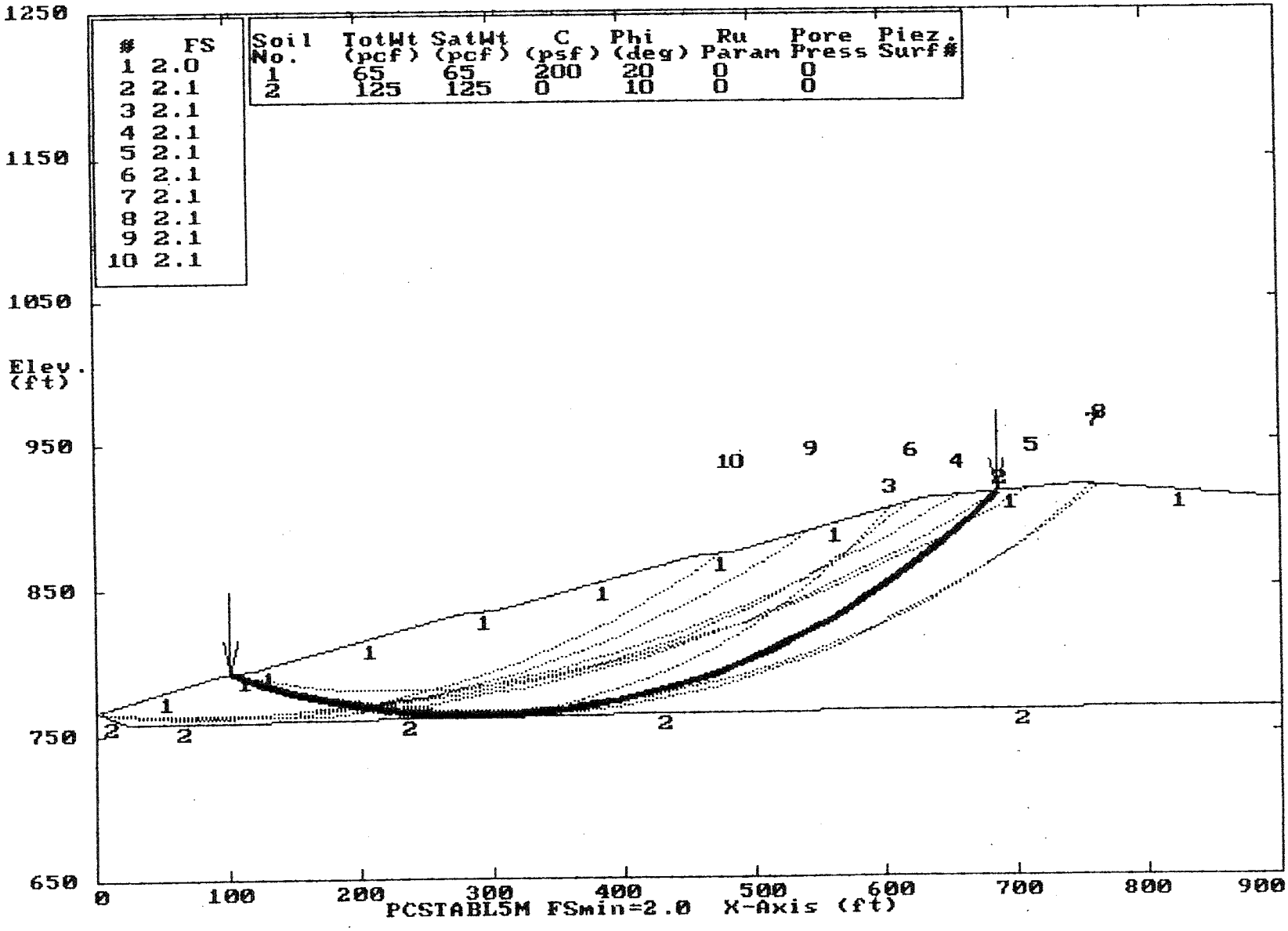
Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	



Greensboro Landfill - Section C-C' Circular Stability - STATIC
Ten Most Critical. A:GNCCC.PLT By: PKS 12-07-95 2:34pm

#	FS
1	2.0
2	2.1
3	2.1
4	2.1
5	2.1
6	2.1
7	2.1
8	2.1
9	2.1
10	2.1

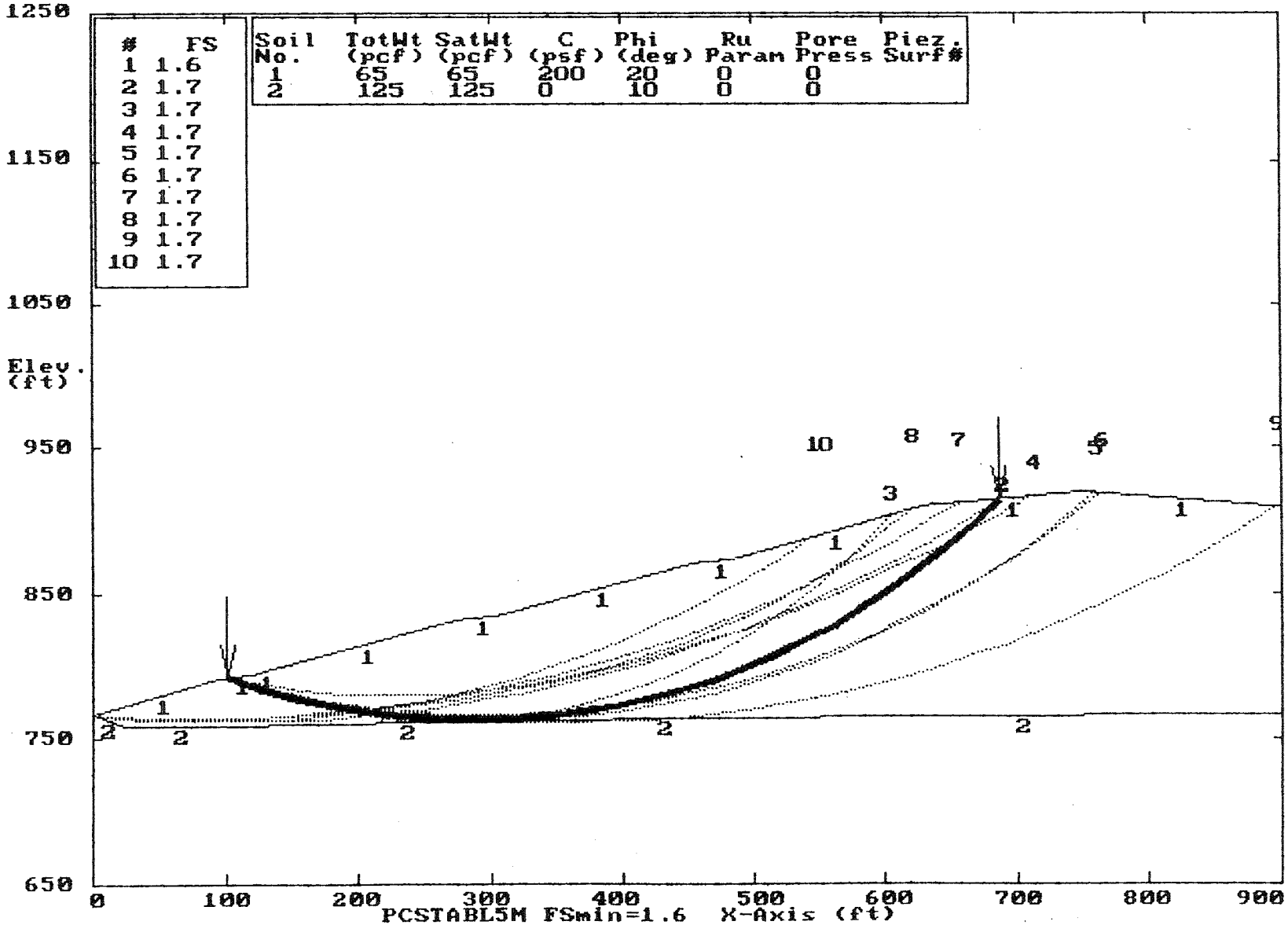
Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	



Greensboro Landfill - Section C-C' Circular Stability - EQUAKE
Ten Most Critical. A:GNCCCE.PLT By: PKS 12-07-95 2:41pm

#	FS
1	1.6
2	1.7
3	1.7
4	1.7
5	1.7
6	1.7
7	1.7
8	1.7
9	1.7
10	1.7

Soil No.	TotWt (pcf)	SatWt (pcf)	C (psf)	Phi (deg)	Ru Param	Pore Press	Piez. Surf#
1	65	65	200	20	0	0	
2	125	125	0	10	0	0	



Attachment 2

Veneer Stability Analysis of Final Cover

PROJECT HDR-GBORO LF

SUBJECT Final Cover Stability Evaluation

SHEET 1 OF 2
JOB NO. HDRGN-2
DATE 12/6/95
COMPUTED BY PKS
CHECKED BY

— Objective: To evaluate the stability of the Final cover veneer against sliding.

— Analysis: Treat the final cover as an infinite slope and use the following equation (Matasović, 1991):

$$FS = \frac{[c/(\gamma \cdot z \cdot \cos^2\beta) + \tan\phi[1 - \gamma_w(z - d_w)/(\gamma \cdot z)] - k_s \cdot \tan\beta]}{k_s + \tan\beta}$$

where: FS = Factor of Safety
k_s = Seismic Coefficient (= 0 for Static Stability)
γ = Unit Weight of Slope Material(s)
γ_w = Unit Weight of Water
c = Cohesion
ϕ = Interface Friction Angle of Assumed Failure Surface
z = Depth To Failure Surface
d_w = Depth To Seepage Surface (= z if slope is Dry)
β = Slope Angle of Cover

— Reference: Matasović, N. (1991), "Selection of Method for Seismic Slope Stability Analysis," Proc. 2nd International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, Vol. 2, pp. 1057–1062.

— Requirements: FS_{min}(Static) = 1.5

FS_{min} (Dynamic) = 1.0 (If Applicable)

G.N. RICHARDSON & ASSOCIATES, INC.
Engineering and Geological Services
417 N. BOYLAN AVENUE RALEIGH, N.C. 27603
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G.N. Richardson & Associates

ENGINEERING AND GEOLOGICAL SERVICES

SHEET: 2/2
JOB #: HDRGN-2
DATE: 12/7/95
BY: PKS
CHKD BY:

HDR - Greensboro Landfill
Analysis of Final Cover Stability

Input Parameters: (User Input)

Sideslope Angle (Beta): 14 degrees

Final Cover:
- Thickness (z): 2 ft
- Unit Weight: 110 pcf
- Cohesion: 0 psf
- Water Depth: 2 ft (= z if Slope is Dry)

Seismic Coefficient (ks):
- 0 Static FS
- 0.10 Dynamic FS (= Peak Ground Acceleration For The Site)

Calculate Static FS Against Sliding:

Interface Fric. Angle	Resisting Force	Driving Force	FS slide	Comment
10	0.18	0.25	0.71	NO GOOD
15	0.27	0.25	1.07	NO GOOD
20	0.36	0.25	1.46	NO GOOD
25	0.47	0.25	1.87	OK

Calculate Dynamic FS Against Sliding:

Interface Fric. Angle	Resisting Force	Driving Force	FS slide	Comment
10	0.15	0.35	0.43	NO GOOD
15	0.24	0.35	0.70	NO GOOD
20	0.34	0.35	0.97	NO GOOD
25	0.44	0.35	1.26	OK

Job No. 06770-021-018 | No.

HDR Computation

HDR

Project GREENSBORO WHITE ST. L/F	Computed DTD	Date 10/15/96
Subject PHASE III EXPANSION	Checked EAW	Date 10/16/96
Task SETTLEMENT	Sheet 1	Of 3

OBJECTIVE: CALCULATE SETTLEMENT AT HIGHEST POINT OF LANDFILL AND NORTHEAST CORNER

REF: "WASTE CONTAINMENT SYSTEMS, WASTE STABILIZATION, AND LANDFILLS; DESIGN AND EVALUATION" BY HARI SHARMA & SANGEETA LEWIS.

$$S = H_t \frac{C_c}{1+e_o} \log \frac{P_o + \Delta P}{P_o}$$

WHERE: S = SETTLEMENT
H_t = LAYER THICKNESS
C_c = COMPRESSION INDEX = $0.208 e_o + 0.0083$ ("PRINCIPLES OF FOUNDATION ENGINEERING" p.39
e_o = INITIAL VOID RATIO
P_o = INITIAL STRESS
ΔP = CHANGE IN STRESS

PARAMETERS @ HIGHEST POINT:

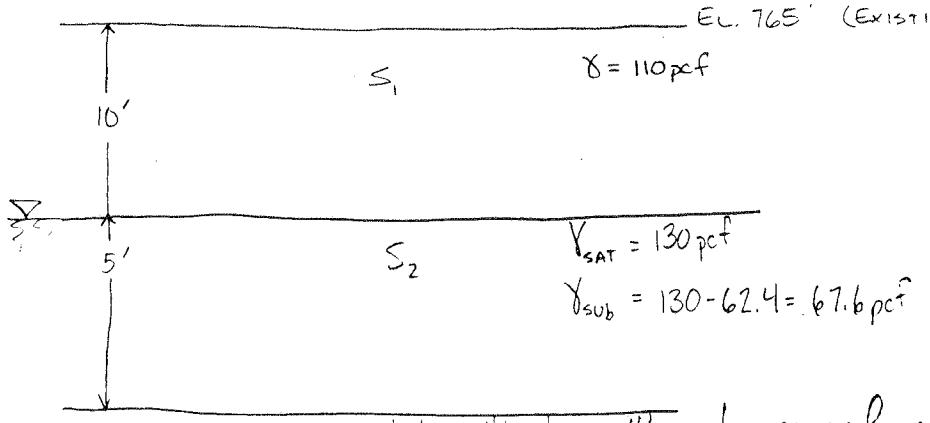
BORING 23 → GROUND EL. = 765'
SUBGRADE = 765' (DRAWING C-2 CONST PERMIT APP 11/95)
TOP OF LANDFILL EL. = 919' (DRAWING C-7A)
CLAY LAYER = 2' × 120 pcf = 240 psf
LCS = 1' × 120 pcf = 120 psf
OPERATIONAL COVER = 1' × 120 pcf = 120 psf
FINAL INTERMEDIATE COVER LAYER = 1' × 120 pcf = 120 psf
FINAL COMPACTED SOIL BARRIER = 1.5' × 120 pcf = 180 psf
FINAL VEGETATIVE SUPPORT SOIL = 1.5' × 120 pcf = 180 psf
FINAL TOPSOIL LAYER = 0.5' × 120 pcf = 60 psf
REFUSE = 919 − 765 − 2 − 1 − 1 − 1.5 − 1.5 − 0.5 = 146.5' × 60 pcf = 8790 psf

9,810 psf

HDR Computation

Project	GREENSBORO WHITE STREET L/F	Computed DTD	Date 10/15
Subject	PHASE III EXPANSION	Checked EAW	Date 10/16/96
Task	SETTLEMENT	Sheet 2	Of 3

B-23



below this elev. settlement assumed negligible based on boring logs

POROSITY, $n = 45\%$ $\quad e = \frac{\frac{n\%}{100\%}}{1 - \frac{n\%}{100\%}} = 0.81 \quad C_c = .208(.81) + .0083 = 0.177$

S_1

$P_{o_1} = \frac{10}{2}(110) = 550$ psf

$P_{f_1} = 9810 + \frac{10}{2}(110) = 10{,}360$ psf

$\Delta P_1 = 9810$ psf

$$S_1 = 10' \frac{0.177}{1+0.81} \log \frac{550+9810}{550} = \underline{1.25 \text{ ft}}$$

S_2

$P_{o_2} = 10(110) + \frac{5}{2}(67.6) = 1269$ psf

$P_{f_2} = 9810 + 10(110) + \frac{5}{2}(67.6) = 11{,}079$ psf

$\Delta P_2 = 9810$

$$S_2 = 5' \frac{0.177}{1+0.81} \log \frac{1269+9810}{1269} = \underline{0.46 \text{ ft}}$$

$$S_{TOT} = S_1 + S_2 = 1.25 + 0.46 = \boxed{1.71 \text{ ft}}$$

Job No. 06770-021-018 | No.

HDR Computation

HDR

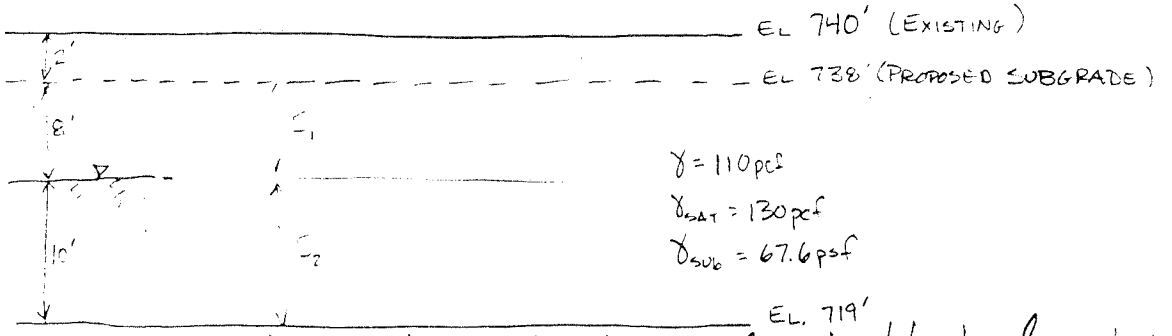
Project	GREENSBORO WHITE STREET L/F	Computed DTD	Date 10/16/96
Subject	PHASE III EXPANSION	Checked EAW	Date 10/16/96
Task	SETTLEMENT	Sheet 3	Of 3

PARAMETERS @ NORTHEAST CORNER

BORING 30 → GROUND EL. = 739'
SUBGRADE = 738' (DRAWING C-2 CONST. PERMIT APP. 11/95)
CAP EL. = 766'
CLAY LINER = 2' × 120 pcf = 240 psf
LCS = 1' × 120 psf = 120 psf
OPERATIONAL COVER = 1' × 120 pcf = 120 pcf
FINAL INTERMEDIATE COVER LAYER = 1' × 120 pcf = 120 psf
FINAL COMPACTED SOIL BARRIER = 1.5' × 120 pcf = 180 psf
FINAL VEGETATIVE SUPPORT SOIL = 1.5' × 120 pcf = 180 psf
FINAL TOP SOIL LAYER = 0.5' × 120 pcf = 60 psf
REFUSE = 766 − 738 − 2 − 1 − 1 − 1.5 − 1.5 − 0.5 = 20.5' × 60 pcf = 1230 psf

} 2,250 psf

B-30



$e = 0.81$
$C_c = 0.177$

$\gamma = 110$ pcf
$\gamma_{SAT} = 130$ pcf
$\gamma_{SUB} = 67.6$ psf

below this elevation settlement assumed negligible based on boring logs

S_1

$P_{o_1} = \frac{10}{2}(110) = 550$ psf
$P_{f_1} = 2{,}250 + \frac{8}{2}(110) = 2690$ psf
$\Delta P_1 = 2{,}690 - 550 = 2{,}140$ psf

$S_1 = 8' \frac{0.177}{1+0.81} \log \frac{550+2140}{550} = 0.54$ FT

S_2

$P_{o_2} = 10(110) + \frac{10}{2}(67.6) = 1{,}438$ psf
$P_{f_2} = 2{,}250 + 8(110) + \frac{10}{2}(67.6) = 3{,}468$ psf
$\Delta P_2 = 3{,}468 - 1{,}438 = 2{,}030$ psf

$S_2 = 10' \frac{0.177}{1+0.81} \log \frac{1438+2030}{1438} = 0.37$ FT

$S_{TOT} = S_1 + S_2 = 0.54 + 0.37 = \boxed{0.91 \text{ FT}}$

Change in slope ~1040' between locations $\frac{1.71' - 0.91'}{1040'} = 0.08\%$ Negligible

PROJECT HDR-GBORO, LF

SUBJECT Geomembrane Stresses

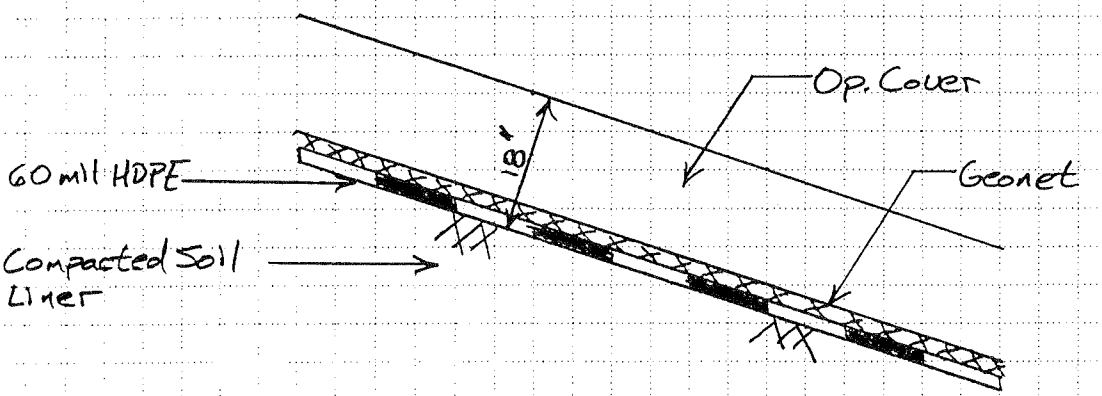
SHEET 1 OF 10
JOB NO. HDRGN-2
DATE 11/21/95
COMPUTED BY PKS
CHECKED BY

- Objective: Calculate the stresses in the geomembrane due to the following cases:

  1. Stress Due To Self-Weight
  2. Stress Due To Operational Cover Sliding
  3. Stress Due To Waste Subsidence

- Analysis: Use methods outlined in "Geosynthetic Design Guidance For Hazardous Waste Landfill Cells and Surface Impoundments" to calculate stresses in the geomembrane.

- Assumptions:
  1. 3H:1V ($\beta = 18.4°$)
  2. Max Height of Slope = 16 Ft
  3. Geomembrane is 60 mil HDPE w/ σ_y = 2000 psi
  4. Sideslope Cross-Section (Typ.):



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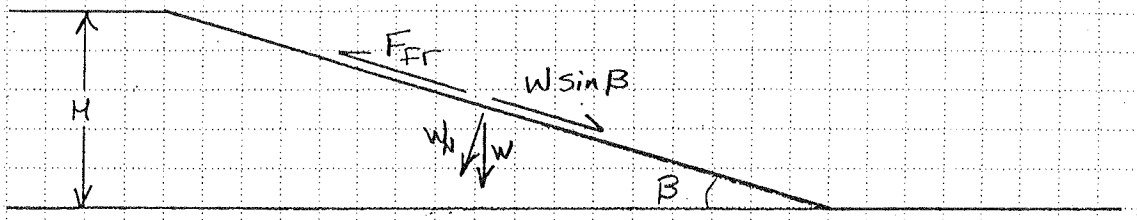
CONSULTING ENGINEERING

DRAWN	JOB NO.	APPROVED	DATE	REVISED DATE

Case 1 : Stress Due To Self Weight :



- $W = W_1 + W_2 + W_3$ (lb/ft)

  where: W_1 = Liner Wt.

  W_2 = Weight of Geonet

  W_3 = Weight of Geotextile (Assume Saturated)

- $W_1 = (G_s \gamma t)(1' \text{Unit Width} \times H/\sin\beta)$

  where G_s = Specific Gravity of HDPE = 0.95

  t = Liner Thickness = .06" (60 mil)

  $L = H/\sin\beta$

- $W_2 = 5\,oz/yd^2$ Geonet $\times L$

$$\frac{5\,oz/yd^2}{16\,oz/lb} = 0.31\ lb/yd^2 \cdot \frac{1\,yd^2}{9\,ft^2} = 0.035\ lb/ft^2/ft$$

$$W_2 = .035(H/\sin\beta)$$

- $W_3 = [8\ oz/yd^2\ Geotextile + Wt.\ Water] \times L$

$$\frac{8\ oz/yd^2}{16\ oz/lb} = 0.50\ lb/yd^2 \cdot \frac{1\ yd^2}{9\ ft^2} = 0.056\ lb/ft^2/ft$$

Wt. Water: Thickness = .07"/12"/ft = .006'
Porosity = .35

$$.35(.006' \times 1' \times 1')(62.4\ lb/ft^2) = 0.13\ lb\ H_2O/ft$$

$$W_3 = [0.056 + 0.13]\,(H/\sin\beta)$$

- Frictional Resistance (F_{Fr}):

Frictional resistance is a function of Friction between geomembrane and compacted soil liner.

$$F_{Fr} = W \cos\beta \tan\delta_L$$

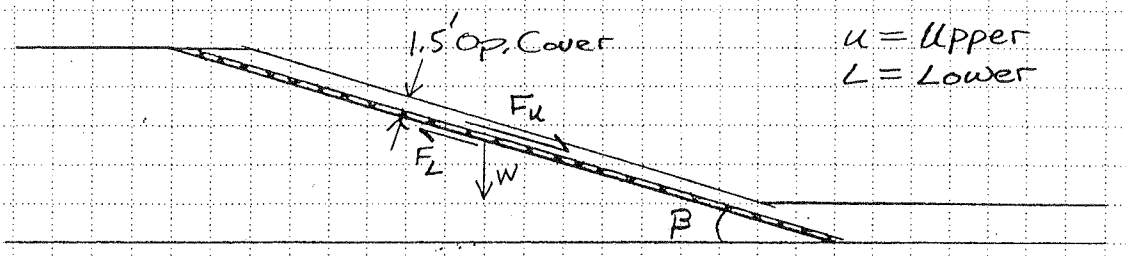
where δ_L ranges From 5 to 20°

- Total Force (T) = $W \sin\beta - F_{Fr}$
- Max. Stress = T_{max}/A

A = Thickness of Geomembrane over Unit Width

- Factor of Safety (F.S.) = $\frac{T_y\ (geomembrane)}{Max.\ Stress}$

- Case 2: Stress Due To Operational Cover Sliding:



- Tension in the Geotextile (T_{GT}) = $F_u - F_L$

$F_u = W \cos\beta \tan\delta_u$

$F_L = W \cos\beta \tan\delta_L$

W = Wt. of Op. Cover, Geomembrane, Geonet, & G.textile

δ_u = Friction Angle Between GT & Op. Cover (Range: 20°-35°)

δ_L = Friction Angle Between GT & Geonet (Range = 18°-28°)

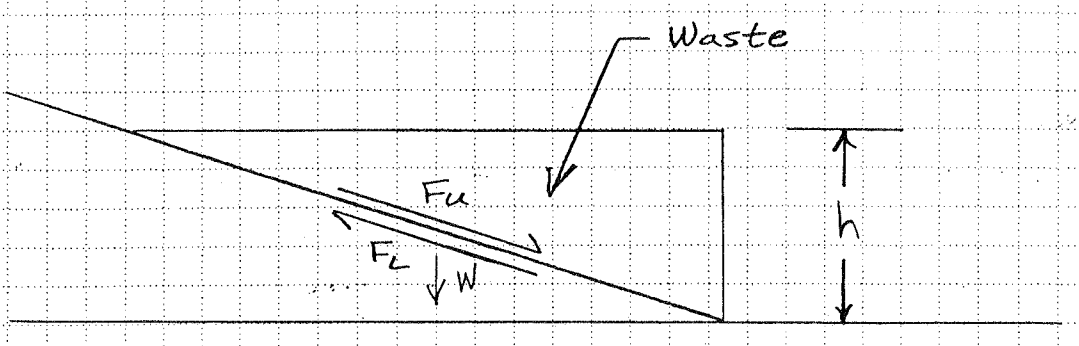
IF $\delta_L > \delta_u$, then No Net Downdrag

- Follow Same Procedure For Tension in Geonet & Geomembrane:

- For Geonet (GN): W = T_{GT} (max.)
  δ_u = Friction Bet. GT & GN (18°-28°)
  δ_L = Friction Bet. GN & GM (10°-12°)

- For Geomembrane (GM): W = T_{GN} (max.)
  δ_u = Friction Bet. GN & GM (10°-12°)
  δ_L = Friction Bet. GM & Clay Liner (5°-15°)

- Case 3: Stress Due To Waste Subsidence:



- Tension in the Geotextile (T_{GT}) = $F_u - F_L$

$F_u = W \cos\beta \tan\delta_u$
$F_L = W \cos\beta \tan\delta_L$

W = Wt. of Waste, Op. Cover, GT, GN, GM

δ_u = Friction Angle Bet. GT & Op. Cover
(Range: 20°-35°)
δ_L = Friction Angle Bet. GT & GN
(Range: 18°-28°)

IF $\delta_L > \delta_u$, then No Downdrag

- Follow Same Procedure For Tension in Geonet & Geomembrane:

- For Geonet: (GN) $W = T_{GT}$ (max.)
δ_u = 18°-28°
δ_L = 10°-12°

- For Geomembrane: (GM) $W = T_{GN}$ (max.)
δ_u = 10°-12°
δ_L = 5°-15°

G.N. Richardson & Associates
ENGINEERING AND GEOLOGICAL SERVICES

SHEET: 6/10
JOB #: HDRGN-2
DATE: 11/21/95
BY: PKS
CHKD BY:

City of Greensboro
Analysis of Geosynthetics
Geomembrane Stresses

Input Parameters:

Sideslope Angle:		18.4	degrees
Max. Slope Height:		16	ft
Geomembrane:	Yield Stress:	2000	psi
	Thickness:	0.06	in
Operational Cover:	Thickness:	18	in
	Unit Weight:	110	lbs/cf
Waste Parameters:	Max. Lift Ht:	10	ft
	Unit Weight:	65	pcf

Case 1: Stress Due To Self Weight

W1 =	15.02	lb/ft
W2 =	1.77	lb/ft
W3 =	9.43	lb/ft
W =	26.23	lb/ft

DELL	tan (DELL)	Ffr (lb/ft)	T (lb/ft)
5	0.087	2.18	6.10
10	0.176	4.39	3.89
15	0.268	6.67	1.61
20	0.364	9.06	

Maximum Stress = ********** psf = 8.5 psi

Factor of Safety = 236

STRESSES.WB1

Case 2: Stress Due To Operational Cover Sliding SHEET: 7/10

Tension in Geotextile:

W = 8390 lbs/ft
FU = 7961 tan (DELU)
FL = 7961 tan (DELL)
T = 7961 (tan(DELU)-tan(DELL))
Stress = T/(A=.09/12)/144 psi

Sensitivity Analysis:

DELU	DELL	tan(DELU)-tan(DELL)	T (lb/ft)	Stress (psi)
20	18	0.0391	311	288
25	18	0.1414	1126	1042
25	20	0.1023	815	754
25	22	0.0623	496	459
30	18	0.2524	2010	1861
30	20	0.2134	1699	1573
30	22	0.1733	1380	1278
30	24	0.1321	1052	974
30	26	0.0896	713	661
30	28	0.0456	363	336
35	18	0.3753	2988	2766
35	20	0.3362	2677	2479
35	22	0.2962	2358	2183
35	24	0.2550	2030	1880
35	26	0.2125	1692	1566
35	28	0.1685	1341	1242
35	30	0.1229	978	906
35	32	0.0753	600	555
35	34	0.0257	205	189

T(max.) = 2988

Case 2 Continued: Stress Due To Operational Cover Sliding SHEET: 8/10

Tension in Geonet:

W = 2988 lbs/ft
FU = 2988 tan (DELU)
FL = 2988 tan (DELL)
T = 2988 (tan(DELU)-tan(DELL))
Stress = T/(A=.2/12)/144 psi

Sensitivity Analysis:

DELU	DELL	tan(DELU)-tan(DELL)	T (lb/ft)	Stress (psi)
18	10	0.1486	444	185
18	12	0.1124	336	140
20	10	0.1876	561	234
20	12	0.1514	452	188
22	10	0.2277	680	283
22	12	0.1915	572	238
24	10	0.2689	803	335
24	12	0.2327	695	290
26	10	0.3114	930	388
26	12	0.2752	822	343
28	10	0.3554	1062	442
28	12	0.3192	954	397

T(max.) = 1062

Case 2 Continued: Stress Due To Operational Cover Sliding

Tension in Geomembrane:

W = 1062 lbs/ft
FU = 1062 tan (DELU)
FL = 1062 tan (DELL)
T = 1062 (tan(DELU)-tan(DELL))
Stress = T/(A=.06/12)/144 psi

Sensitivity Analysis:

DELU	DELL	tan(DELU)-tan(DELL)	T (lb/ft)	Stress (psi)
10	5	0.0888	94	131
10	6	0.0712	76	105
10	7	0.0535	57	79
10	8	0.0358	38	53
10	9	0.0179	19	26
12	5	0.1251	133	184
12	6	0.1075	114	158
12	7	0.0898	95	132
12	8	0.0720	76	106
12	9	0.0542	58	80
12	10	0.0362	38	53
12	11	0.0182	19	27

T(max.) = 133

Factor of Safety = 15.1

Case 3 Continued: Stress Due To Waste Subsidence SHEET: 10/10

Tension in Geonet:

W = 5534 lbs/ft
FU = 5534 tan (DELU)
FL = 5534 tan (DELL)
T = 5534 (tan(DELU)-tan(DELL))
Stress = T/(A=.2/12)/144 psi

Sensitivity Analysis:

DELU	DELL	tan(DELU)-tan(DELL)	T (lb/ft)	Stress (psi)
18	10	0.1486	822	343
18	12	0.1124	622	259
20	10	0.1876	1038	433
20	12	0.1514	838	349
22	10	0.2277	1260	525
22	12	0.1915	1060	441
24	10	0.2689	1488	620
24	12	0.2327	1288	536
26	10	0.3114	1723	718
26	12	0.2752	1523	634
28	10	0.3554	1967	819
28	12	0.3192	1766	736

T(max.) = 1967

Case 3 Continued: Stress Due To Waste Subsidence

Tension in Geomembrane:

W = 1967 lbs/ft
FU = 1967 tan (DELU)
FL = 1967 tan (DELL)
T = 1967 (tan(DELU)-tan(DELL))
Stress = T/(A=.06/12)/144 psi

Sensitivity Analysis:

DELU	DELL	tan(DELU)-tan(DELL)	T (lb/ft)	Stress (psi)
10	5	0.0888	175	243
10	6	0.0712	140	195
10	7	0.0535	105	146
10	8	0.0358	70	98
10	9	0.0179	35	49
12	5	0.1251	246	342
12	6	0.1075	211	293
12	7	0.0898	177	245
12	8	0.0720	142	197
12	9	0.0542	107	148
12	10	0.0362	71	99
12	11	0.0182	36	50

T(max.) = 246

Factor of Safety = 8.1

Originally Submitted Specifications

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SECTION 02220

EARTHWORK

PART 1 - GENERAL

1.01 DESCRIPTION

A. Section Includes:
   1. Earthwork.

B. Related Sections include but are not necessarily limited to:
   1. Division 0 - Bidding Requirements, Contract Forms, and Condition of the Contract.
   2. Division 1 - General Requirements.
   3. Section 02276 Soil Liner System.
   4. Accompanying CQA Plan.

C. Definitions:
   1. Borrow: shall consist of approved material required for the construction of embankments/fills or for other portions of the work and shall be obtained from on-site areas designated on the plans unless directed otherwise by the Project Manager.
   2. Embankment and Fill: shall include construction of all site earthwork including roadways, landfill area, perimeter berm embankments, including preparation of the areas upon which materials are to be placed. All embankment and fill materials may be either (off-site) Select Borrow or (on-site) Borrow unless otherwise noted on drawings or specified by the Project Manager.
   3. Unsuitable Material: is any in-place or excavated material which contains undesirable materials, or is in a state which is not appropriate; in the opinion of the CQA Consultant, for the intended use or support of planned structures, embankment, or excavation. This may include but not be limited to organic material, soft, or materials not meeting required specifications, etc.

1.02 QUALITY ASSURANCE

A. Perform all work in accordance with requirements of local and state codes, with requirements of OSHA, and in accord with federal requirements.

B. Refer to the following standard references or specifications as applicable to this Section of Technical Specifications:
   1. North Carolina State Building Code, Latest Edition.
   2. North Carolina Erosion and Sediment Control Planning and Design Manual, Latest Edition.
   3. North Carolina Department of Transportation Standard Specifications for Roads and Structures, Latest Edition.
   4. American Society for Testing Materials (ASTM).

a. D698, Tests for the Moisture Density Relations of Soils and Soil Aggregate Mixtures Using a 5.5 LB Rammer and a 12 IN Drop.
b. D1557, Tests for Moisture Density Relations of Soils and Soil Aggregate Mixtures Using a 10 LB Rammer and an 18 IN Drop.
c. D2487, Classification of Soils for Engineering Purposes.

C. Refer to "Construction Quality Assurance Plan" prepared by HDR Engineering for additional CQC/CQA procedures related to earthwork.

D. Hire an independent soils laboratory to conduct in-place moisture-density tests for backfilling to assure that all work complies with this Specification.

1.03 SUBMITTALS

A. See Section 01300.

B. Submit to CQA Consultant, for approval, source, test data as applicable, and samples of all off-site materials, a minimum of 14 days prior to intended use.

C. Submittals required by the Contractor or his subcontractors regarding earthwork CQC include the following:
1. All required CQC reports.
2. All required CQC laboratory data.
3. Soils inspection and testing results.

D. Additional information as outlined in Section 02276: Soil Liner System, and the accompanying CQA Plan.

1.04 SOILS/GEOTECHNICAL

A. The Owner will provide for the services of a CQA Consultant on-site to selectively test materials and monitor compliance with the requirements of these specifications. <u>This will be in addition to Construction Quality Control (CQC) provided and paid for by the Contractor performed by the CQC Agency in accordance with these specifications and the CQA Plan.</u>

B. The Contractor will afford these representatives access to the job site for the performance of their duties as described in the Contract Documents.

C. General Duties and Responsibilities of the Contractor CQC Agency:
1. Conduct Borrow Source Characterization Study (BSCS) in accordance with these specifications, Section 02276: Soil Liner System, and the CQA Plan.
2. Perform stockpile and in-place testing of all soil materials used in the work in conformance with these specifications and the CQA Plan.
3. Inspect subgrades and excavations and evaluate suitability of

materials encountered. Determine extent of any overexcavation required to remove unsuitable materials under roadways, structures, or other areas of construction.

4. Document placement of fill materials and perform testing to confirm compliance with these specifications.
5. Evaluate the suitability of existing on-site materials for use in construction of embankments and fills.
6. Measure quantity of unsuitable materials for payment on a unit price basis under contract provisions for authorized overexcavation and backfill.

D. General Duties and Responsibilities of Owner's CQA Consultant:
1. Approve materials proposed for incorporation into the work.
2. Review subgrades and excavations and approve suitability of materials encountered. Approve extent of any overexcavation required to remove unsuitable materials under roadways, structures, or other areas of construction.
3. Observe placement of fill materials and testing by CQC Agency for compliance with these specifications.
4. Review/approve the suitability of existing on-site materials for use in construction of embankments and fills.
5. Review construction operations and monitor for compliance with Contract Documents.
6. Review/approve CQC agency quantity of unsuitable materials for payment on a unit price basis under contract provisions for authorized overexcavation and backfill.

E. Available Subsurface Information: Where provided, data on subsurface soil conditions are not intended as representations or warranties of the continuity of such conditions between borings or indicated sampling locations. It shall be expressly understood that neither the Owner nor the Engineer will be responsible for any interpretation or conclusion drawn therefrom by the Contractor. Data is made available for the convenience of the Contractor.

F. Additional or supplementary soil borings or other exploratory operations may be made by the Contractor at no additional cost to the Owner. The Contractor shall provide the Owner with a copy of any data obtained/developed during such work. Such additional work shall be performed in a timely manner in accordance with and not impacting or changing the project schedule set forth in the Contract Documents.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Fill and Backfill: Selected material approved by Soils Engineer from site excavation.

B. The Contractor shall conduct his own quantity and quality investigations and testing to determine availability of (on-site) borrow

materials, as allowed by the Owner.

PART 3 - EXECUTION

3.01 PROTECTION

A. Protect existing surface and subsurface features on-site and adjacent to site as follows:
   1. Provide barricades, coverings, or other types of protection necessary to prevent damage to existing items indicated to remain in place.
   2. Protect and maintain bench marks, monuments or other established reference points and property corners. If disturbed or destroyed, replace at own expense to full satisfaction of Owner and controlling agency.
   3. Verify location of utilities. Omission or inclusion of utility items does not constitute non-existence or definite location. Secure and examine local utility records for location data.
      a. Take necessary precautions to protect existing utilities from damage due to any construction activity.
      b. Repair damages to utility items at own expense.
      c. In case of damage, notify Engineer at once so required protective measures may be taken.
   4. Maintain free of damage, existing sidewalks, structures, and pavement, not indicated to be removed. Any item known or unknown or not properly located that is inadvertently damaged shall be repaired to original condition. All repairs to be made and paid for by Contractor.
   5. Provide full access to public and private premises, fire hydrants, street crossings, sidewalks and other points as designated by Owner to prevent serious interruption of travel.
   6. Maintain stockpiles and excavations in such a manner to prevent inconvenience or damage to structures on-site or on adjoining property.
   7. Avoid surcharge or excavation procedures which can result in heaving, caving, or slides.
   8. Conduct operation with minimum interference to daily landfill operations.

B. Construction erosion and sedimentation controls prior to beginning earthwork.

C. Dispose of waste materials, legally. Burning, as a means of waste disposal, is not permitted.

3.02 SITE EXCAVATION AND GRADING

A. The work includes all operations in connection with excavation, borrow, construction of fills and embankments, rough grading, and disposal of excess materials in connection with the preparation of the site(s) for construction of the proposed facilities.

B. Excavation and Grading: Perform as required by the Contract Drawings.

1. Contract Drawings may indicate both existing grade and finished grade required for construction of Project. Stake all units, structures, piping, roads, parking areas and walks and establish their elevations. Perform other layout work required. Replace property corner markers to original location if disturbed or destroyed.
2. Preparation of ground surface for embankments or fills: Before fill is started, scarify to a minimum depth of 6 IN in all proposed embankment and fill areas. Where ground surface is steeper than one vertical to four horizontal, plow surface in a manner to bench and break up surface so that fill material will bind with existing surface.
3. Protection of finish grade: During construction, shape and drain embankment and excavations. Maintain ditches and drains to provide drainage at all times. Protect graded areas against action of elements prior to acceptance of work. Reestablish grade where settlement or erosion occurs.

C. Borrow: Provide necessary amount of approved fill compacted to density equal to that indicated in this Specification. Include cost of all borrow material in original proposal. Fill material to be approved by Soils Engineer prior to placement.

D. Construct embankments and fills as required by the Contract Drawings:

1. Construct embankments and fills at locations and to lines of grade indicated. Completed fill shall correspond to shape of typical cross section or contour indicated regardless of method used to show shape, size, and extent of line and grade of completed work.
2. Provide approved fill material which is free from roots, organic matter, trash, frozen material, and stones having maximum dimension greater than 6 IN. Ensure that stones larger than 4 IN are not placed in upper 6 IN of fill or embankment. Do not place material in layers greater than 8 IN loose thickness. Place layers horizontally and compact each layer prior to placing additional fill.
3. Compact by sheepsfoot, pneumatic rollers, vibrators, or by other equipment as required to obtain specified density. Refer to Table A for testing frequencies. Control moisture for each layer necessary to meet requirements of compaction.

E. Upon reaching subgrade elevations shown, proofroll subgrade soils and obtain the CQC Agency's and CQA Consultant's approval. If unsuitable materials are encountered at the subgrade elevation, perform additional excavation as directed by the CQC Agency and reviewed by the CQA Consultant to remove unsuitable materials. Excavation of 1 CY or greater should be preapproved by the CQA Consultant.

TABLE A

Minimum Testing Frequency for Soil Materials
(Refer to CQA/CQC Plan for Methods)

Components	Required Test	Minimum Sample Frequency/Location	Acceptance or Rejection Criteria
Backfill of Unsuitable Areas (Granular)	1. Particle Size	1. 1 Per Source	1. NCDOT No. 78M
	2. In-place Density	2. 1/Area Judged Unsuitable	2. As per Section 02221, paragraph 3.05C.
Structural/Controlled Fill	1. Classification	1. 1 Per Source	1. Meet Select Borrow/ Borrow as Per 2.01 A.
	2. Standard Proctor Density or Relative Density	2. 2 Per Soil Type/Source	2. None.
	3. In-Place Density A. Cohesive Soil	3. 1 Per 10,000 S.F. Per Lift	3.A. 95% maximum density (Standard Proctor; 2%± Opt. Moisture except under Foundations/ Structures 98% Standard Proctor.
	B. Granular Soil		3.B. 75% Relative Density

F. Proofrolling shall be conducted with a pneumatic tired vehicle of at least 20 tons GVW, approved by the CQA Consultant. An alternate approved by the CQA Consultant may be used in constricted areas.

G. Where subgrade materials are determined to be unsuitable, such materials shall be removed to the lengths, widths and depths directed by the CQC Agency and approved by the CQA Consultant and backfilled with suitable material unless further excavation or earthwork is required. No additional payment will be made for such excavation and backfill 2 feet or less than the finished subgrade. Unsuitable material excavation greater than 2 feet beneath the finished subgrade shall be made on a unit price basis for excavation and backfill, only as approved by the CQA Consultant and Project Manager. Unit price for overexcavation and backfill greater than 2 feet in depth shall include disposal of unsuitable materials.

H. The subgrade of areas to receive fill shall be smooth and free of all vegetation, sticks, roots, rocks and debris.

I. Dewatering: Provide and maintain dewatering of all surface water and/or groundwater as required for excavation. Where groundwater is or is expected to be encountered during excavation, install a dewatering system to prevent softening and disturbance of subgrade below foundations and fill material, to allow foundations, fill material, and structures/backfill to be placed in the dry, and maintain a stable excavation. Groundwater shall be maintained at least 4 feet below the bottom of any excavation. Soils and hydrogeologic information may be reviewed before beginning excavation to determine where groundwater is likely to be encountered during excavation. Employ a dewatering specialist for selecting/designing, monitoring and operating the dewatering system as needed. Keep dewatering system in operation until dead load of structure exceeds possible buoyant uplift force on structure or fill material. Dispose of groundwater to an area which will not interfere with construction operations or damage existing construction as approved by the Owner. Install groundwater monitoring points as necessary. Shut off dewatering system at such a rate so as to prevent a quick upsurge of water that might weaken the subgrade. Installation, start-up, monitoring maintenance, and shut-off of the dewatering system shall be at no additional cost to the Owner.

J. Do not place fill when the subgrade to receive fill is frozen, wet loose or soft.

K. Moisture control:
   1. Moisture content of materials prior to, and during compaction, shall be uniform throughout each layer of material.
   2. Granular materials shall be thoroughly wetted during or immediately prior to compaction.
   3. Supplementary water shall be added as required to materials by sprinkling and mixing uniformly throughout layer.
   4. Materials too wet for placing shall be temporarily spread or

aerated until moisture content is acceptable. If these materials cannot be processed in time to use, the Contractor shall find alternatives acceptable to the CQC Agency and the CQA Consultant.

3.03 ROCK EXCAVATION

A. All rock excavation shall be under one classification. This classification shall include solid ledge rock in its natural location that requires systematic quarrying, drilling and/or splitting for its removal and also boulders that exceed 1/2 CY in volume. Rock is defined as natural material that cannot be ripped with a D-9 bulldozer or similar equipment.

B. When rock is encountered immediately notify Engineer. Strip free of earth. Employ an independent surveyor to determine rock quantities before removal operation begins. In computing the volumetric content of rock excavation for payment, the pay lines shall be taken as follows:
   1. For structures: 3 FT outside the exterior limits of foundations and from rock surface to 6 IN below bottom of foundations.
   2. For piping and utilities: A width 18 IN wider than the outside diameter of the pipe or conduit and from rock surface to 6 IN below bottom exterior surface of the pipe or conduit.
   3. For paving: 2 FT outside the exterior limits of paving and from rock surface to 6 IN below bottom of pavement subbase.
   4. For landfill unit: 5 FT below subgrade and from rock surface.

3.04 METHOD OF REMOVAL AND PAYMENT

A. Method of removal to be coordinated during construction.

B. Payment terms to be negotiated at time of identification of rock.

3.05 FINISH GRADING

A. Grade all areas disturbed by construction operations.

B. Grade to smooth, uniformly sloping surfaces to existing elevations or to finish elevations shown on drawings.

C. Grading shall be to a tolerance of 2 IN (plus/minus) unless otherwise noted elsewhere in these specifications or in the accompanying CQA/CQC Plan.

3.06 GRADING ADJACENT TO STRUCTURES

A. Evenly slope finished grade away from structures as shown on drawings to provide drainage.

3.07 FIELD QUALITY CONTROL

A. Moisture density relations, to be established by the Soils Engineer required for all materials to be compacted.

B. Extent of compaction testing will be as necessary to assure compliance with Specifications.

C. Give minimum of 24 HR advance notice to Soils Engineer when ready for compaction or subgrade testing and inspection.

D. Should any compaction density test or subgrade inspection fail to meet Specification requirements, perform corrective work as necessary.

E. Pay for all costs associated with corrective work and retesting resulting from failing compaction density tests.

3.08 COMPACTION DENSITY REQUIREMENTS

A. Obtain approval from Soils Engineer with regard to suitability of soils and acceptable subgrade prior to subsequent operations.

B. Provide dewatering system necessary to successfully complete compaction and construction requirements.

C. Remove frozen, loose, wet, or soft material and replace with approved material as directed by Soils Engineer.

D. Stabilize subgrade with well graded granular materials as directed by Soils Engineer.

E. Assure by testing, at a frequency of a minimum of 1 test per lift per 10,000 square feet, that compaction densities comply with the following requirements:

1. Sitework:

LOCATION	COMPACTION DENSITY
WITHIN CONSTRUCTION BASELINE AND UNDER PAVED AREAS	
Cohesive Soils	95 percent, ASTM D698
Cohesionless Soils	75 percent relative density per ASTM D4253 and D4254
OTHER AREAS:	
Cohesive Soils	95 percent, ASTM D698

Cohesionless Soils	75 percent relative density per ASTM D4253 and D4254

3.08 ACCEPTANCE OF WORK

A. Obtain approval of excavations and pre-fill subgrade from the CQA Consultant before starting any construction. Approval may consist of satisfactory proofroll observed by the CQC Agency and CQA Consultant.

3.09 SPECIAL REQUIREMENTS

A. Erosion Control: Conduct work to minimize erosion of site. Construct stilling areas to settle and detain eroded material. Remove eroded material washed off site. Clean streets daily of any spillage of dirt, rocks or debris from equipment entering or leaving site.

B. The Owner shall provide the Contractor with a current survey. Quantities for mass excavation are defined as the difference between the current survey provided and the base grades shown on Drawing C-2. The Contractor shall confirm the survey to their satisfaction and resolve any differences with the Engineer prior to commencing work.

END OF SECTION

SECTION 02221

TRENCHING, BACKFILLING AND COMPACTING

PART 1 - GENERAL

1.01 DESCRIPTION

A. General:
   1. Furnish all labor, materials, tools, equipment and services for excavation, trenching, backfilling and compacting for all utilities, culverts, pipes, manholes, etc. as indicated, in accord with provisions of Contract Documents.
   2. Completely coordinate with work of all other trades.

B. Work included in the project consists of, but is not limited to, methods of installation of the following:
   1. Surface drainage culverts and piping.
   2. Leachate gravity header piping outside lined areas.

C. Related Work Specified

   1. Section 02220: Earthwork.

   2. Section 02276: Soil Liner System.

   3. Section 02775: Geosynthetic Liner System.

1.02 QUALITY ASSURANCE

A. Referenced Standards.

   1. American Society for Testing and Materials (ASTM)

      C33 Concrete Aggregates
      D2049 Relative Density for Cohesionless Soils
      D2487 Classification of Soils for Engineering Purposes
      D698 The Moisture-Density Relations of Soils using a 5.5-pound Rammer and a 12 IN drop

B. Contractor shall perform all required horizontal and vertical layout work. Such work shall be performed by a qualified surveyor or engineer.

C. Refer to the accompanying CQA Plan.

1.03 SUBMITTALS

A. See Section 01340.

B. Submit test reports and fully document each with specific location or stationing information, date, and other pertinent information.

1.04 JOB CONDITIONS

A. Verify location and existence of utilities.

B. Take necessary precautions to protect existing utilities from damage due to any construction activity. Repair damages to utility items at own expense. Assess no cost to Owner, Engineer, or auxiliary party for any damages.

C. Avoid overloading or surcharging a sufficient distance back from edge of excavations to prevent slides or caving. Maintain and trim excavated materials in such a manner as to be as little inconvenience as possible to the public and adjoining property owners.

D. Protect and maintain bench marks, monuments or other established points and reference points and if disturbed or destroyed, replace items to full satisfaction and at no cost to Owner and controlling agency.

1.05 CLASSIFIED EXCAVATION

A. Remove rock excavation, clay, silt, gravel, hard pan, loose shale, and loose stone as directed by Engineer and dispose of to a site approved by the Owner. All rock excavation shall be considered classified excavation. Separate or additional payment will be made for rock excavation. See Section 02220.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Backfill material: As approved by the CQA Consultant as borrow or select borrow material.
   1. Free of rock, cobbles, roots, sod or other organic matter, and frozen material.
   2. The material used for backfill may be obtained from excavations or borrow stockpiles within the project limits of construction entirely apart from the segment of trench being backfilled.

B. Subgrade stabilization materials:
   1. Provide subgrade stabilization material in areas directed by the CQA Consultant consisting of NCDOT No. 78M.

C. Granular bedding materials:
   1. Unless specified otherwise on the plans, provide granular trench bedding material consisting of well-graded crushed stone or crushed gravel meeting NCDOT Specifications, Size No. 78M requirements.
   2. Where granular backfill materials are indicated, place in full compliance with methods prescribed in these specifications.

3. Other granular material may be accepted by the Project Manager or CQA Consultant.

PART 3 - EXECUTION

3.01 GENERAL

A. Remove and dispose of unsuitable materials at an approved site.

B. Excavate trench, backfill and compact for all underground pipe lines, structures, bases and appurtenant items.

C. Provide dewatering as required for maintaining stable subgrade and for pipe installation.

3.02 EXCAVATION

A. Excavation for appurtenances:
1. Excavate for appurtenant structures to provide at least 12 IN (minimum) clear distance between outer surface and embankment and in full observation to Safety Rules.

B. Trench excavation:
1. Unless allowed otherwise by the CQA Consultant and Project Manager, excavate trenches by open cut method to depth shown on drawings and or necessary to accommodate work.
2. Open trench lengths shall be no more than the distance between two manholes, structures, units, or 500 linear FT, whichever is greater. Trenching limitations may be field adjusted as weather conditions dictate.
3. Do not open a greater length of trench than can be effectively utilized under existing conditions. Schedule work and order materials so that trenches are not left open for a longer period than is reasonably necessary. Any trench or portion of trench, which is opened and remains idle for seven calendar days, or longer, as determined by the Project Manager, may be directed to be immediately refilled, without completion of work, at no additional cost to Owner. Said trench may not be reopened until Project Manager is satisfied that work associated with trench will be prosecuted with dispatch.
4. Observe following trenching criteria:
a. Trench size. Excavate only sufficient width to accommodate free working space. In no case shall trench width at top of pipe or conduit exceed outside diameter of piping and/or conduit service by the following dimensions:

Overall Diameter of Utility Service	Excess Dimension
33 IN and less	18 IN
More than 33 IN	24 IN

b. Cut trench walls vertically from bottom of trench to 1 FT above top of pipe, conduit, or utility service.

c. Keep trenches free of water. Include cost of dewatering in firm base bid price.

d. Support, brace and/or sheet trenches as soil conditions dictate and in full observation of latest OSHA requirements. Do not remove support until backfilling has progressed to a stage that no damage to piping, utility service, or conduit will result due to removal. The support shall be designed by an Registered Profession Engineer experienced in this type of design. Construction site safety is the sole responsibility of the Contractor.

3.03 PREPARATION OF FOUNDATION FOR PIPE LAYING

A. If authorized overexcavation occurs, backfill and compact as per Section 3.05B.

B. Subgrade stabilization: Provide subgrade stabilization when directed by the CQA Consultant in accordance with these specifications and details when shown. Observe the following requirements when unstable trench bottom materials are encountered.
1. Notify Engineer when unstable materials are encountered and define by drawing station locations and limits.
2. Remove unstable trench bottom and replace with subgrade stabilization.
3. No additional compensation will be allowed for unstable conditions resulting from Contractor failure to protect the work.

3.04 BACKFILLING - GENERAL

A. Place backfill in lifts not exceeding 8 IN (loose thickness).

B. Observe specific pipe or conduit manufacturer's recommendations regarding methods of backfilling and compaction.

C. Exercise extreme care in backfilling operations to avoid displacing joints and appurtenances or causing any horizontal or vertical misalignment, separation or distortion. Repair damages, distortions or misalignments to full satisfaction of CQA Consultant.

D. Water flushing for consolidation is not permitted.

3.05 COMPACTION

MINIMUM COMPACTIONS

LOCATION	SOIL TYPE	DENSITY
All applicable areas	Cohesive soils	95 percent of max dry density by ASTM D698
	Cohesionless soils	75 percent of max relative density by ASTM D4253 and D4254

A. Relative density of predominantly granular bedding or backfill may be accepted by the CQC Agency (and approved by the CQA Consultant) based on visual inspection without relative density testing, as deemed appropriate by CQA Consultant.

3.06 FIELD QUALITY CONTROL

A. Testing:
   1. The Contractor's CQC Agency shall perform in-place moisture and density tests as required to ensure that trench bedding and backfill complies with specified requirements. Costs of "Passing" tests shall be paid by Owner. Where backfill compaction does not meet moisture density test requirements and after backfill has been removed as directed by the CQC Agency and situation corrected, additional tests shall be performed until compaction meets or exceeds requirements with cost borne solely by Contractor. Costs associated with "Failing" tests shall be paid by Contractor.
   2. Ensure Owner has at all times immediate access to the test results of all soils related work. Ensure excavations are in a safe condition for testing personnel.
   3. Demonstrate compaction by testing at a frequency of 1 test per lift per 1,000 linear feet.

B. Ensure full compliance to applicable requirements of OSHA.

C. Special attention is directed to Title 29 Labor, Part 1518 - "Safety and Health Regulations for Construction" and detailed requirements of Subpart P "Excavations, Trenching and Shoring."

END OF SECTION

SECTION 02485

SEEDING

PART 1 - GENERAL

1.01 DESCRIPTION

A. General:
   1. Furnish all labor, materials, tools, equipment and services for seeding in accordance with provisions of Contract Documents.
   2. Completely coordinate with work of all other trades.
   3. See Division 1 for General Requirements.

B. Related work specified elsewhere:
   1. Section 02260 - Topsoiling.
   2. Section 02220 - Earthwork.
   3. Section 02221 - Trenching, Backfilling, and Compacting.

C. Location of work: All disturbed areas, exclusive of lined landfill area.

1.02 QUALITY ASSURANCE

A. Fertilizer testing: Current methods of Association of Official Agricultural Chemists.
   1. Testing will be conducted at discretion of Engineer.

1.03 SUBMITTALS

A. See Section 01300.

B. Certificates for each grass seed mixture, stating botanical and common name, percentage by weight, and percentages of purity, germination, and weed seed. Certify that each container of seed delivered is fully labeled in accordance with Federal Seed Act and equals or exceeds specification requirements.

C. Copies of invoices for fertilizer, showing grade furnished and total quantity applied.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Establish a smooth, healthy, uniform, close strand of grass from specified seed.

B. Grass seed: Fresh, clean, new-crop seed.
   1. Species, proportions and minimum percentage of purity, germination, and maximum percentage of weed seed, as specified.

2. Provide following grass seed mixtures:

Botanical and Common Name	Pct. by Weight	Min. pct. Germ	Min. pct. Purity
Kentucky 31 Fescue	100	80	97.0

C. Mulch: Clean, seed-free, thressed straw of oats, wheat, barley, rye, beans, or other locally available mulch material.
1. Do not use mulch containing a quantity of matured noxious weed seeds or other species that will be detrimental to seeding, or provide a menace to surrounding land.
2. Do not use mulch material which is fresh or excessively brittle, or which is decomposed and will smother or retard growth of grass.

D. Fertilizer: Commercial fertilizer of 10-10-10 analysis, meeting applicable requirements of State and Federal law.
1. Do not use cyanamic compounds of hydrated lime.

E. Limestone: agricultural grade ground limestone containing not less than 85 percent of combined calcium and magnesium carbonates.
1. 50 percent passing 100 mesh sieve.
2. 90 percent passing 20 mesh sieve.

F. Asphalt binder: Emulsified asphalt per State Specifications.

G. Water: Potable, free of substances harmful to growth.

H. Erosion Control Matting: Provide "Hold-Grow" type erosion control nets or approved equal. Contractor shall provide erosion control matting as required on slopes and ditchlines to obtain suitable vegetative cover.

2.02 DELIVERY, STORAGE AND HANDLING

A. Deliver seed in standard sealed containers labeled with producer's name and seed analysis, and in accord with US Department of Agriculture Rules and Regulations under Federal Seed Act.

B. Deliver fertilizer in original containers labeled with content analysis.

PART 3 - EXECUTION

3.01 JOB CONDITIONS

A. Perform spring seeding between March 1 and May 1, and fall seeding between September 15 and November 15, or upon approval of the Engineer.

3.02 SOIL PREPARATION

A. Limit preparation to areas which will be planted soon after preparation.

B. Loosen surface to minimum depth of four (4) IN.

C. Remove stones over one (1) IN in any dimension, sticks, roots, rubbish and other extraneous matter.

D. Test soil pH using test kits approved by USDA NRCS. Use test results to determine rate of lime application needed to make soil circumneutral. Engineer will approve application rate prior to its application.

E. Spread lime uniformly over designated areas at rate determined by soil testing.

F. After application of lime, prior to applying fertilizer, loosen areas to be seeded with double disc or other suitable device if soil has become hard or compacted. Correct any surface irregularities in order to prevent pocket or low areas which will allow water to stand.

G. Test soil fertility according to USDA NRCS approved methods. Use test results to determine rate of fertilizer application. Engineer will approve fertilizer application rate prior to application.

H. Distribute fertilizer uniformly over areas to be seeded at a rate determined by soil testing.
   1. Use suitable distributor.
   2. Incorporate fertilizer into soil to depth of at least two (2) IN.
   3. Remove stones or other substances which will interfere with turf development or subsequent mowing.

I. Grade seeded areas to smooth, even surface with loose, uniformly fine texture.
   1. Roll and rake, remove ridges and fill depressions, as required to meet finish grades.
   2. Fine grade just prior to planting.

J. Restore seeded areas to specified condition if eroded or otherwise disturbed between fine grading and planting.

K. If fertilizer application rate is determined (by invoices submitted) to be less than that specified, apply additional fertilizer.

3.03 SEEDING

A. Temporary Seeding:
   1. Do not use seed which is wet, moldy, or otherwise damaged.
   2. Seed the appropriate species for the planting season as specified in 2.01 A.4.
   3. Employ satisfactory methods of sowing using mechanical power

driven drills or seeders, or mechanical hand seeders, or other approved equipment.

4. Evenly apply seed at the following rates:

Species	Rate (lb/acre)
Winter Rye	120

5. Small grains should be planted no more than 1 inch deep, and grasses no more than 1/2 inch deep.
6. Lightly rake seed into soil followed by light rolling or cultipacking.
7. Anchor straw by tacking with emulsified asphalt or netting or other methods approved by Engineer.
8. Inspect all seeded areas and make necessary repairs of re-seedings within planting season, if possible. If stand is over 60% damaged, re-establish planting area following recommendations specified for lime, fertilizer and seeding.
9. Clean-up: Remove any soil or similar material from paved areas within same working day. Upon completion of seeding, remove all excess soil, stones, and other debris from site or dispose as directed by Owner. Repair all damages to existing construction caused by lawn operations to the satisfaction of Architect and Owner at no additional cost to Owner.

B. Do not use seed which is wet, moldy, or otherwise damaged.

C. Use approved mechanical power driven drills or seeders, or mechanical hand seeders, or other approved equipment.

D. Distribute seed evenly over entire area at not less than 7LB/1000 SF, 50 percent sown in one direction, remainder at right angles to first sowing.

E. Stop work when work extends beyond most favorable planting season for species designated, or when satisfactory results cannot be obtained because of drought, high winds, excessive moisture, or other factors.

F. Resume work only when favorable condition develops.

G. Lightly rake seed into soil followed by light rolling or Cultipacking.

H. Immediately protect seeded areas against erosion by mulching or placing netting.
   1. Spread mulch in a continuous blanket using 1-1/2 TON/ACRE to depth of 4 or 5 straws.
   2. Immediately following spreading mulch, secure with evenly distributed emulsified asphalt at rate of 200 gal/acre.
   3. Protect all seeded slopes greater than 2:1 (horizontal to vertical) against erosion with approved erosion control netting or mats.

I. Immediately after planting, water to a depth of 2 inches.

3.04 MAINTENANCE

A. Remulch with new mulch in areas where mulch has been disturbed by wind or maintenance operations sufficiently to nullify its purpose. Anchor as required to prevent displacement.

B. Replant bare areas using same materials specified.

C. Contractor shall supply sufficient water until grass is established.

END OF SECTION

SECTION 02240

OPERATIONAL COVER AND LEACHATE COLLECTION LAYER

PART 1 - GENERAL

1.01 DESCRIPTION

A. General:
   1. Furnish all labor, materials, tools, equipment and services for installation and placement of the operational cover and leachate collection layer, as indicated, in accordance with provisions of Contract Documents.
   2. Completely coordinate with work of all other trades.
   3. Although such work is not supplementary or miscellaneous items, appurtenances and devices incidental to or necessary for a sound, secure, complete and compatible installation.
   4. See Division 1 for General Requirements.

1.02 RELATED WORK SPECIFIED ELSEWHERE

A. Section 02220: Earthwork.

B. Section 02276: Soil Liner System.

C. Section 02775: Geosynthetic Liner System.

D. Section 02900: Geotextiles.

E. Section 15064: Pipe: Plastic.

1.03 QUALITY STANDARDS

A. Referenced Standards
   1. American Society for Testing and Materials:
      a. D422 - Particle Size Analysis.
      b. D2434 - Permeability of Granular Soils.
      c. D4373 - Calcium Carbonate Content of Soils.
      d. D5084 - Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.
   2. North Carolina Department of Transportation (NCDOT), Standard Specifications for Roads and Structures, 1990 or current edition.
   3. Refer to "Construction Quality Assurance Plan" prepared for Hanes Mill Landfill Lateral Expansion.

1.04 SUBMITTALS

A. See Section 01300: Submittals.

B. At least four weeks prior to construction of the leachate collection layer, submit a bulk sample of each material from each

source to the CQA Consultant for approval.

C. Submit all required laboratory test data as required by Subparts 2.01 and 3.02 for materials used in the construction.

1.05 JOB CONDITIONS

A. Take necessary precautions to protect synthetic landfill liner from damage due to any construction activity. Repair damages to liner at own expense. Assess no cost to Owner, Engineer, or auxiliary party for any damages to liner system or pipe resulting from placement of stone or activities of equipment operating on stone.

B. Protect and maintain bench marks, monuments or other established points and reference points and if disturbed or destroyed, replace items to full satisfaction of Owner and controlling agency.

1.06 TOLERANCES

A. Materials shall be placed to the lines and grades as shown on the Contract Drawings except that a 2-inch overbuild is allowed. Material placed beyond these limits shall be removed at Contractor's expense.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Material: The CQC Consultant shall submit source test data to the CQA Engineer from borrow stockpiles prior to delivery to the site.
1. Free of roots, sod or other organic matter, and frozen material. The material shall be of durable and of noncarbonaceous origin.
2. Materials must meet acceptance criteria presented in 3.02 of this Section.

PART 3 - EXECUTION

3.01 GENERAL

A. The leachate collection layer is placed directly over Geomembrane, collector pipes, and Geotextile cushion; thus, extreme caution shall be exercised by the Contractor to prevent damage to these materials.

B. Placement of these materials within the cell shall be conducted only when the CQA Consultant or his representative is present at the site and informed in advance of the intent to complete this work.

C. The Contractor shall exercise care in maintaining a true line and

grade an all piping during placement and spreading of the material.

D. Materials shall be placed over the Geomembrane only after areas have been released by the Geomembrane Installer and the CQA Consultant. The materials shall be placed as specified below.
   1. All materials shall be placed and spread with low ground pressure equipment (6 psi ground pressure or less) as approved by the Engineer to reduce potential damage to the Geomembrane. The Geomembrane surface shall be off limits to construction traffic. Excessive hard turning of tracked equipment on the stone must be avoided.
   2. At least 12 IN (12") of separation between the Geomembrane and equipment shall be maintained.
   3. Material shall not be placed over standing water or ice.
   4. Material shall not be compacted within the cell limits.

E. The leachate collection layer shall be spread in a manner that minimizes development of folds in the Geomembrane. Any portions of the Geomembrane that develop crimp shall be repaired by the Geomembrane Installer at no expense to the Owner.
   1. If during spreading, excessive wrinkles develop, the Contractor shall adjust placement and spreading methods, or cease until the Geomembrane cools and wrinkles decrease in size.
   2. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and spreading methods shall be cut and repaired by the Geomembrane Installer in a method approved by the CQA Consultant.

F. Any damage to the underlying Soil or Geomembrane Liners or Geotextiles or shall be repaired in accordance with the applicable section of these Specifications at Contractor expense.

G. Stockpiling of materials within the limits of the cell shall be subject to advanced approval by the CQA Consultant. Any hauling equipment (dump trucks, etc.) operating within the cell limits, including access ramps, shall have a minimum of 3-ft. of separation between the vehicle wheels and the Geomembrane.

H. Any areas where unauthorized or tracked equipment has operated over the leachate collection system shall be subject to investigation for potential Geomembrane damage. Such investigations may include removal of overlying materials in the affected areas and visual inspection of the Geomembrane. These activities shall be conducted under direction by the CQA Consultant at Contractor's expense.

I. Test areas to evaluate potential damage due to equipment operations may be required by the CQA Consultant to assess equipment to be used by the Contractor. The test area shall be outside the cell limits, use scrap materials not to be used in cell construction, and model construction conditions as closely as is practical. Test area parameters shall be determined by the CQA Consultant and Contractor in advance of construction of the leachate collection

system.

3.02 QUALITY CONTROL

A. The CQC Consultant shall perform testing of the materials.

B. Ensure CQA Consultant has at all times immediate access for the testing of all related work.

TABLE A

Minimum CQC Testing Frequency

Components	Required Test	Minimum Sample Frequency/ Location	Acceptance Criteria
Leachate Collection Stone Layer	1. Permeability (ADTM D2434)	1 per 2000 CY	$K \geq 1 \times 10^{-1}$ cm/sec
	2. Carbonate Content (ASTM D4373)	1 per source	<15% by weight
	3. Thickness	1 per acre	12" to 14"
Leachate Collection Stone Around Piping	1. Gradation (ADTM D422)	1 per 1500 CY	NCDOT No. 57 Stone
	2. Carbonate Content (ASTM D4373)	1 per source	<15% by weight
Operational Cover Soil	1. Permeability (ASTM D2434 or ASTM D5084)	1 per 2000 CY	$K \geq 2 \times 10^{-5}$ cm/sec
	2. Thickness	1 per acre	12" to 14"

END OF SECTION

SECTION 02276

SOIL LINER SYSTEM

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:
1. Contractor to furnish all labor, materials, tools, equipment, and services for soil liner components as indicated, in accordance with provisions of Contract Documents.
2. Completely coordinate with work of all other trades.
3. Although such work is not specifically indicated, furnish and install all supplementary or miscellaneous items, appurtenances and devices incidental to or necessary for a sound, secure and complete installation.

B. Related Sections include but are not necessarily limited to:
1. Section 02110 - Site Clearing.
2. Section 02200 - Earthwork.
3. Section 02775 - Geosynthetic Liner System.
4. Construction Quality Assurance Plan.

1.02 QUALITY STANDARDS

A. Reference Standards:
1. ASTM - American Society for Testing and Materials
   a. ASTM D-422 - Particle Size Analysis
   b. ASTM D-698 - Standard Proctor
   c. ASTM D-854 - Specific Gravity
   d. ASTM D-1140- Fines Content in Soils
   e. ASTM D-1556 - In-situ Density Measurement Using the Sand Cone
   f. ASTM D-1557 - Modified Proctor
   g. ASTM D-2166 - Unconfined Compressive Strength
   h. ASTM D-2216 - Moisture Content Using Over-Dry Method
   i. ASTM D-2487 - Soils Classification
   j. ASTM D-2573 - Field Vane Shear Test
   k. ASTM D-2922 - In-situ Density Using Nuclear Methods
   l. ASTM D-3017 - In-situ Moisture Content Using Nuclear Methods
   m. ASTM D-4318 - Atterberg Limits
   n. ASTM D-5084 - Flexible Wall permeameter
2. USEPA - United States Environmental Protection Agency
   a. EPA/600/R-93/182 -"Quality Assurance and Quality Control for Waste Containment Facilities," September, 1993.
3. Construction Quality Assurance Plan," prepared for Hanes Mill Landfill Expansion, dated September 1995.

1.03 SUBMITTALS

A. See Section 01300 - Submittals.

B. Refer to the CQA Plan.

1.04 JOB CONDITIONS

A. Verify conditions of subgrade prior to commencing work.

1.05 TOLERANCES

A. The soil liner system must exceed the following tolerances:
   1. The saturated hydraulic permeability of the soil liner must be equal to or less than 1.0 x 10-7 cm/sec, as determined by ASTM D5084.
   2. The thickness of the soil liner must be equal to or greater than 24 inches. An overbuild of 2-inches is allowed for the soil liner.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Low Permeability Soil - General:
   1. Contractor shall provide natural, fine-grained soil or bentonite amended soil that is capable of being worked to produce a soil layer of thickness shown on the drawings that has a saturated hydraulic conductivity of 1.0 x 10-7 cm/sec or less, as determined by ASTM D5084.
   2. The potential existence of on-site soil material suitable for use as the low permeability soil (natural, fine-grained soil) has not been evaluated.
   3. In accordance with these specifications, the Contractor is responsible for conducting a borrow soil characterization study (BSCS).
   4. The Contractor is encouraged to investigate all possible sources of low permeable soil including, but not limited, to on-site soils.
   5. Contractor shall provide the CQA Consultant and Owner access to information about the borrow source of the low permeability soil and certify that it is not contaminated with hazardous materials or hazardous wastes.

B. Natural Fine-Grained Soil
   1. Classification: Natural fine-grained soil shall have a classification of CH, CL, MH, or ML as determined by ASTM D2488.
   2. Grain sizes shall be within the following gradation:

Sieve Size	Percent Passing by Weight
No. 4	> 90
No. 200	> 30

No particles shall be greater than 3/4 IN in any dimension.

3. Hydraulic Conductivity: The saturated hydraulic conductivity of the natural fine-grained soil shall be less than 1.0 x 10-7 cm/sec as measured by ASTM D5084, when compacted in accordance with requirements established by the CQC Consultant and Contractor on the basis of the soil liner test strip as specified herein.
4. Other Soil Liner Properties: The liquid limit shall be at least 25 as measured by ASTM D4318. The plasticity index shall be at least 10 and less than 30 as measured by ASTM D4318.
5. Compaction Equipment:
   a. The compaction equipment shall be suitable type and adequate to obtain densities specified, and shall provide satisfactory breakdown of materials to form a low permeability fill free of lift interface voids. The CQC Consultant shall confirm compaction equipment adequacy, and recommend changes if required, based on the soil liner test strip. Such additional equipment will be provided by Contractor at no additional cost.
   b. The compaction equipment shall be maintained and operated in a condition that will deliver manufacturer's rated compactive effort.
   c. Hand-operated equipment shall be capable of achieving specified soil densities.
   d. Natural fine-grained materials shall be compacted using equipment that provides a kneading action, such as a wobble-wheeled roller or a sheepsfoot roller having tines as long as the maximum lose lift thickness to ensure proper lift interface compaction.
   e. If a sheepsfoot is used, the finished surface of the final lift shall be rolled with a smooth steel drum roller or rubber-tired roller to eliminate tine or roller marks and provide a smooth, dense surface for geomembrane placement.
6. Moisture Control Equipment: Equipment for applying water shall be of a type and quality adequate for the work, shall not leak, and shall be equipped with a distributor bar or other approved device to assure uniform application. Equipment for mixing and drying out material shall consist of blades, discs, or other equipment defined by the CQC Consultant as approved by the CQA Consultant. Mixing of natural fine-grained soils may also be required to get even distribution of moisture. Soil liner material must not be compacted within 24 hours of the adjustment of water content by the addition of water.

C. Bentonite Amended Soil (where applicable):
   1. Hydraulic conductivity of constructed bentonite amended soil

shall be 1.0 x 10-7 cm/sec or less when compacted in accordance with requirements established by the CQC Consultant on the basis of test results from the soil liner test strip and the soil borrow source investigation.

2. Soil used in the bentonite amended soil shall be free from roots, organic matter, debris, particles larger than 3/4 IN, and other deleterious material. All soil used in the bentonite amended soil shall be taken from a borrow area approved by the CQC Consultant.
3. Unless approved otherwise by the CQC Consultant, the soil used in the bentonite amended soil shall meet the following washed sieve gradation:

Sieve Size	Percent Passing by Weight
3/4IN	100
No. 4	55-100
No. 20	45-75
No. 200	10-40

4. Bentonite:
   a. Bentonite shall be free-flowing, powdered, high-swelling, sodium montmorillonite clay (bentonite) free of additives.
   b. Acceptable bentonite manufacturers are:
      1) Bentonite Corp.
      2) CETCO.
      3) MI Bentonite.
      4) WYO-BEN.
   c. The Contractor may propose a bentonite supplier other than those listed above if it is demonstrated that its use in the amended soil satisfies the requirements of these specifications.
5. Bentonite Amended Soil Mixing equipment (where applicable):
   a. Contractor shall mix, process, and condition the bentonite amended soil in a pugmill prior to placing and compacting the mixture.
   b. The pugmill shall have the capability to break up soil clumps and mix material to form a homogeneous blend. The pugmill shall have controls that allow a variable rate of discharge from it, to control the degree of mixing. The pugmill shall have automated controls to control the rate of feed of each material to within an accuracy of 2 percent by weight.
   c. The pugmill discharge shall be equipped with a batching bin having a drop outlet for loading hauling vehicles directly from the he pugmill. Pugmill shall be positioned to allow direct discharge to hauling vehicles.
   d. Contractor shall not store amended soil in a manner or for a length of time that will cause any degradation of the

project or amended soil.

6. Compaction Equipment:
   a. Compaction equipment shall be a suitable type and adequate to obtain soil densities specified by the CQC Consultant based on the soil liner test strip.
   b. Contractor shall maintain and operate equipment in such condition that it will deliver manufacturer's rated compactive effort.
   c. Hand-operated equipment shall be capable of achieving specified densities.
   d. Contractor shall compact bentonite amended soil using a pneumatic, tire roller or a sheepsfoot compactor.
7. Moisture Control Equipment: Equipment for applying water shall not leak, and shall be equipped with a distributor bar or other device to assure uniform application as approved by the CQC Consultant.

2.02 SOIL LINER MATERIAL ACCEPTANCE

A. General: All imported, on-site, and processed materials specified in this section are subject to the following requirements:
   1. All tests necessary for the Contractor to locate and define acceptable sources of materials shall be made by the CQC Consultant. Certification that the material conforms to the Specification requirements along with copies of the test results from a qualified commercial testing laboratory shall be submitted to the CQA Consultant for approval at least 10 days before the material is required for use. All material samples shall be furnished by the Contractor at the Contractor's sole expense.
   2. All samples required in this section shall be representative and be clearly marked to show the source of the material and the intended use on the project. Sampling of the material source shall be done by the CQC Consultant in accordance with ASTM D75.
   3. Notify the CQA Consultant at lease 24-hours prior to sampling. The CQA Consultant may, at the CQA Consultant's option, observe the sampling procedures.
   4. Tentative acceptance of the material source shall be based on an inspection of the source by the CQA Consultant and the certified test results of the Borrow Source Characterization Study (BSCS) as submitted by the Contractor to the CQA Consultant. No imported materials shall be delivered to the site until the proposed source and materials tests have been accepted in writing by the CQA Consultant.
   5. Final acceptance of any material will be based on results of tests made on material samples taken from the completed soil liner test strip, combined with the results of the BSCS. If tests conducted by the CQC Consultant or the CQA Consultant indicate that the material does not meet Specification requirements, material placement will be terminated until corrective measures are taken. Material which does not conform to the Specification requirements and is placed in the work

shall be removed and replaced at the Contractor's sole expense.

6. Contractor shall be solely responsible for obtaining all permits required to obtain acceptable sources of materials for use in the work.

B. Sampling and testing required herein shall be done at the Contractor's sole expense.

C. Low Permeability Borrow Source Characterization Study:

1. The Contractor will be responsible for all processing and screening of the soil liner material at his own cost to meet the requirements of the specifications. The Contractor will be responsible for the erosion protection of the stockpile during his operation. The Contractor shall coordinate all aspects of this operation with the CQC Consultant, CQA Consultant, and Project Manager.
2. CQC Consultant shall complete a BSCS of natural fine-grained soils or of soil that will be used in bentonite amended soils.
3. Contractor shall conduct tests, including particle size, Atterberg limits, moisture-density, and hydraulic conductivity tests, as necessary to locate an acceptable source of material.
4. Once a potential source of material has been located, the CQC Consultant shall develop and undertake a testing program to demonstrate the acceptability of the proposed material. Certified results of all tests shall be submitted to the CQA Consultant upon completion of tests. Tentative acceptance of the borrow source by the CQA Consultant will be based upon the results of the study. The testing program shall include the following elements, at a minimum:
   a. An excavation plan for the borrow source indicating proposed surface mining limits and and depths of samples to be taken for testing.
   b. Test pits for borrow source sampling shall be appropriately spaced to reflect site geomorphology and sampled at depth intervals appropriate to the proposed excavation methods.
   c. A minimum of 12 samples shall be collected and tested for the parameters required as described in the following paragraphs.
5. Test Parameters and Reporting for Natural Fine-grained Soils: All samples collected from the proposed borrow area for natural fine-grained soils shall be tested for the following parameters:

Parameter	Test Method
Particle Size (sieve plus hydrometer)	ASTM D422
Atterberg Limits	ASTM D4318
Moisture-Density	ASTM D698

Hydraulic Conductivity(1)	ASTM D5084	

(1) Hydraulic conductivity tests shall be performed on recompacted samples of the proposed material, compacted according to criteria developed by the CQC Consultant using data from tests conducted in accordance with ASTM D698.

6. Test Parameter for Soil to be Used in Bentonite Amended Soil:
   a. Parameters and reporting for soils to be used in bentonite amended soil shall be the same as for natural fine-grained soil.
   b. Tests required under this paragraph are part of the BSCS. Additional tests on the bentonite amended soil product are required for soil liner acceptance. See 2.01E.

D. Natural Fine-Grained Soils Conformance Testing:
   1. Following acceptance of a source for natural fine-grained soils, the following tests shall be performed by the CQC Consultant on samples taken from the excavated soil liner material using the methods and at the frequencies indicated below:

Test	Test Method	Minimum Frequency
Percent Fines	ASTM D422	1 per 5,000 cu yd
Atterberg Limits	ASTM D4318	1 per 5,000 cu yd
Moisture-Density	ASTM D698	1 per 10,000 cu yd

   2. The CQC Consultant shall conduct tests more often if variation in test results is occurring, or if material appears to depart from Specifications.
   3. The CQA Consultant may also conduct independent tests to confirm the accuracy of the testing conducted by the CQC Consultant.
   4. If tests indicate material does not meet Specification requirements, Contractor shall terminate material placement until corrective measures are taken.
   5. Contractor shall remove and replace material which does not meet Specification requirements at no additional cost to the Owner.

E. Bentonite Amended Soil Conformance Testing:
   1. Following acceptance of a source for soils to be used in bentonite amended soils, the CQC Consultant shall perform a Design Mix Analysis and submit certifications for the imported bentonite material as described below.
   2. Design Mix Analysis:
      a. Collect two of the coarsest samples of the soil taken from the approved borrow area (based on percent retained on

#200 sieve). Soil samples for testing shall be as least 100 pounds each.

b. Trial mix samples shall be prepared by mixing each soil sample with three trial application rates of bentonite. Compact each trial mix sample to a dry density equal to 95 percent relative compaction and at a moisture content within the range of optimum to optimum plus 3 percent (ASTM D-698) for the unamended soil.

c. Test the hydraulic conductivity of the trial mix samples using ASTM D5084 and report all data to CQA Consultant. Graph measured hydraulic conductivity vs. percent bentonite.

d. Contractor shall select a minimum bentonite content needed to consistently achieve an in-place hydraulic conductivity of 1.0 x 10-7 cm/sec or less as measured by ASTM D5084.

3. As soil to be used in bentonite amended soil is excavated from the borrow source, the following tests shall be performed by the QC Consultant at the frequencies and using the methods indicated below.

Test	Method	Minimum Frequency
Percent Fines	ASTM D1140	1 per 5,000 cu yd
Moisture-Density	ASTM D698	1 per 10,000 cu yd
Atterberg Limits	ASTM D4318	1 per 5,000 cu yd

4. After selection of a mix design, compaction tests shall be performed according to ASTM D698 or D1557 depending on the compaction equipment to be used. The compaction test will provide the dry density at 95% maximum compaction and optimum moisture content.

5. After mix design and initial testing, CQC Consultant shall conduct tests of the mixed bentonite amended soil, after it has been discharged from the pugmill and before this is placed in the work using the following methods and at the following frequencies.

Test	Method	Minimum Frequency
Particle Size Analysis	ASTM D422	1 per 5,000 cu yd
Moisture-Density	ASTM D698	1 per 10,000 cu yd

6. Bentonite: CQC Consultant shall submit certifications from the supplier of the bentonite material that it meets the requirements specified under PART 2, PRODUCTS.

F. Fine-Grained Material Dewatering, Mixing, and Staging

1. Dewatering of soil liner borrow excavations, if required, shall

be solely at the Contractors expense.

2. Drying, blending, or wetting required to maintain the soil liner soil at a suitable moisture content shall be solely at the Contractors expense.

PART 3 - EXECUTION

3.01 INSTALLATION

A. The subgrade to be lined shall be smooth and free of vegetation, sticks, roots, and debris. It shall be the responsibility of the Contractor to keep the receiving surfaces in the accepted condition until complete installation of the liner is accomplished.

B. The subgrade shall be proofrolled with a pneumatic tired vehicle of at least 20 tons GVW, making passes across the area as directed by the CQC and/or CQA Consultants. The soil liner shall not be placed over areas deemed unacceptable by either the CQC or CQA Consultants based on proofroll observations or inadequate test results.

C. The soil liner shall be installed in four compacted lifts of approximate equal thickness.

D. When particles exceeding 3/4" are observed at the final lift surface, they shall be removed by hand prior to final rolling of the surface.

E. Equipment shall be used such that bonding of the two lifts will occur. Equipment shall have cleats or other protrusions of such length necessary to completely penetrate into the loose lift. Compaction shall be performed using appropriately heavy, properly ballasted, penetrating foot compactor making a minimum number of passes as approved by the CQC Consultant and CQA Consultant based on the soil liner test strip.

F. If desiccation and crusting of the lift surface occurs prior to placement of the next lift, this area shall be scarified to a minimum depth of two inches or until sufficiently moist materials are encountered, whichever is greater. After scarification, the superficial material should be reworked to obtain a moisture content at least two percent above optimum moisture content. Alternately, the drier superficial soil may be stripped and mixed with additional moist soil to achieve a moisture content satisfying the project requirements.

G. No frozen material shall be placed.

H. Material shall not be placed on a previous lift which is frozen. Frozen in-place material shall be removed prior to placement of additional soil material.

I. Material which has been subjected to a freeze/thaw cycle(s) shall be disked and recompacted prior to placement of subsequent lifts.

J. During construction, exposed finished lifts of the soil liner material should be sprinkled with water to minimize desiccation, as necessary. The Contractor is responsible to protect the soil liner from rain, drying, desiccation, erosion and freezing. All defective areas shall be repaired by the Contractor to the satisfaction of the CQC Consultant at no extra compensation.

K. At the end of each day's construction activities, completed lifts or sections of the compacted soil liner should be sealed. Common sealing methods include rolling with a rubber tired or smooth-drum roller, backdragging with a bulldozer, or placement of temporary cover soil over the compacted soil liner. The compacted soil liner should be sprinkled with water, as needed.

L. If testing shows that a lift is significantly thicker than six inches, the top of the lift will be shaved off so that the lift is approximately six inches thick.

3.02 SOIL LINER TEST STRIP

A. Test Strip Installation:

1. Prior to actual soil liner installation, a soil liner test strip of a dimension no less than 100 feet long by 30 feet wide by 2 feet thick shall be constructed by the Contractor over a compacted subgrade within the liner construction site.
2. The soil liner test strip shall be constructed using the same equipment and construction procedures that are anticipated for use during actual liner installation.
3. During test strip installation, the Contractor in coordination with his CQC Consultant and the CQA Consultant shall determine the field procedures that are best suited for his construction equipment to achieve the requirements specified herein.
4. If the test strip fails to achieve the desired results, the soil material of the strip shall be completely removed, and additional test strip(s) shall be constructed until the requirements are met.
5. The CQC Consultant shall document that the subgrade of the test strip liner is properly compacted to at least 95 percent of the maximum dry density, as determined using the Standard Proctor test (ASTM D-698). Field density tests on the subgrade shall be performed by the CQC Consultant and documented at a minimum of three test locations within the test strip area.
6. At least five field density measurements shall be performed by the CQC Consultant on each lift of the liner test strip. The field density tests shall be conducted using a nuclear gauge (ASTM D-2922) or other method, as approved by the CQA Consultant. Corresponding tests for moisture content to determine dry density shall likewise be performed by using a nuclear gauge (ASTM D-3017), or other approved method. On the

test pad, the density measurement if performed by a nuclear gauge shall be verified through performance of one sand cone tests (ASTM D-1556) or drive tube test (ASTM D-2937) at a location selected by the CQA Consultant. The moisture content measurement, if performed by a nuclear gauge shall be verified by recovering at least five samples for oven-dry testing (ASTM D-2216) from the test location.

7. Upon completion of the soil liner test strip, the CQC Consultant, as observed by the CQA Consultant, shall measure the thickness of the test strip at a minimum of five random locations.

8. A minimum of five random samples of the liner construction materials delivered to the site during test strip installation shall be tested by the CQC Consultant for moisture content (ASTM D-2216), sieve analyses (ASTM D-421, D-422) and Atterberg limits (ASTM D-4318).

9. The CQC Consultant shall conduct at least one standard Proctor (ASTM D-698) and one modified Proctor (ASTM D-1557) compaction test on bag samples of the test strip material to determine the moisture-density relationships.

10. A minimum of five undisturbed samples shall be taken from the test strip by the CQC Consultant for laboratory hydraulic conductivity testing. The samples shall be taken within a two-foot radius of the in-situ density and moisture tests. The CQA Consultant may also conduct independent hydraulic conductivity testing. Laboratory hydraulic conductivity testing shall be conducted using constant head, triaxial type permeameters (ASTM D-5084). The test specimens shall be consolidated under an isotropic effective consolidation stress determined by the CQA Consultant and permeated with water under a back pressure of at least 10 pounds per square inch (psi) to achieve saturation. The inflow to and outflow from the specimens shall be monitored with time and the coefficient of permeability calculated for each recorded flow increment. The test shall continue until steady state flow is achieved and relatively constant values of coefficient of permeability are measured.

11. Optional: The data gathered from the test strip sampling (i.e., field density, moisture, undisturbed samples, and in-situ hydraulic conductivity) shall be used along with the Proctor curve for the soil to develop a range of acceptable moisture and density test values which are likely to result in a maximum permeability no greater than 1 x 10-7 cm/sec. This range of moisture/density values will be established by the CQC Consultant and the CQA Consultant and will be utilized as a means to establish Pass/Fail Criteria for the remainder of the area to be lined by the subject material.

12. The test strip will be considered acceptable if the measured hydraulic conductivity of the test strip as determined by ASTM D-5084 meets the requirements of the specifications.

13. If field and laboratory test data indicate that the installed test strip meets the requirements of this Specification, it may be used as part of the liner provided that it is adequately

protected by the Installer from drying and equipment damage after installation. The Installer shall scarify the liner material along the edge of the test strip. A minimum 2-foot overlap per lift is required for mixing and compaction between the test strip and the liner.

14. Upon receipt of the test data from the CQA Consultant, the Project Manager shall inform the Contractor if the test strip can remain in-place as part of the liner.

3.03 FIELD QUALITY CONTROL AND QUALITY ASSURANCE

A. Refer to the CQA Plan.

B. The following field and laboratory quality control tests shall be performed by the CQC Consultant at no additional expense to the Owner during soil liner construction:

1. Density/Moisture: Conduct at least one field density test per 100' x 100' grid area per lift of compacted liner. Field density tests shall be conducted using a nuclear gauge (ASTM D-2922), or other method as approved by the CQA Consultant. Corresponding tests for moisture content to determine dry density shall likewise be performed using a nuclear gauge (ASTM D-3017), or other approved method. As a check of the nuclear methods, perform one drive tube density (ASTM D-2937) determination once for every fifty nuclear tests and a series of five oven-dry (ASTM D-2216) samples after each set of 25 nuclear moisture content tests.
2. Thickness: Using a 1 IN auger and/or probe at a frequency no less than four tests per acre per lift of installed soil liner measure the thickness of the soil liner. Thickness measurements shall be observed by the CQA Consultant.
3. Atterberg Limits: Perform Atterberg Limits on at least one sample per acre per lift of installed liner. This may be waived by the CQA Consultant if permeability requirements are being met.
4. Fines Content: Determined at a minimum frequency of one test (ASTM D-1140) per acre per lift of installed liner.
5. Hydraulic Conductivity (ASTM D-5084): Test at a minimum frequency of one test per acre per lift.
6. Laboratory Compaction Tests: Re-evaluated after each increment of 5,000 cubic yards is placed.
7. If there are indications of a change (e.g., visual appearance) in product quality between shipments, additional tests shall be performed as necessary.
8. Holes in the compacted soil liner created as a result of destructive testing (i.e., thin-walled shelby tube sampling, field density determinations and thickness measurements) shall be backfilled and tamped by rod uniformly in 2 inch thick lifts. The backfill material shall be the same liner construction material or hydrated bentonite powder, if approved by the CQA Consultant. On the surface, the backfill material shall extend slightly beyond the holes to make sure that a good tie in with the surrounding liner is achieved. Repaired areas

shall be observed and documented by the CQC Consultant.

B. Give minimum of 24 HR advance notice to CQA Consultant when ready for soil testing and inspection in completed area of the soil liner.

C. For areas not meeting field and laboratory testing criteria, the Contractor shall scarify the full depth of the lift or replace the material as needed. The material shall be reshaped, rewetted as needed, rehomogenized and recompacted to the specified density. Areas not meeting the thickness requirements shall be augmented with additional materials. The added materials shall be reworked with the soil layer to ensure homogeneity and proper bonding. This may be done by scarification of the surface prior to addition of new material. The repaired area shall be properly documented, and field and laboratory quality control testing shall be performed to ensure the repaired liner section meets the requirements specified herein.

D. The Contractor shall pay for all costs associated with corrective work and retesting resulting from failing compaction density tests.

E. The soil liner materials on the landfill base shall be compacted to no less than 95 percent of the Standard Proctor (ASTM D-698) dry density corresponding to the molding moisture content.

END OF SECTION

SECTION 02515

HDPE MANHOLE STRUCTURES

PART 1 - GENERAL

1.01 DESCRIPTION

A. General:
1. Furnish all labor, materials, tools, equipment and services for all manhole structures with appurtenant items and pipe in accordance with provisions of the Contract Documents.
2. Completely coordinate with work of all other trades.
3. Although such work is not specifically indicated, furnish and install all supplementary or miscellaneous items, appurtenances and devices incidental to or necessary for a sound, secure and complete installation.

B. Work included consists of, but is not necessarily limited to:
1. Leachate management devices and manholes.

C. Related Sections include, but are not necessarily limited to:
1. Section 02221 - Trenching, Backfilling and Compacting
2. Section 02775 - Geosynthetic Liner System.
3. Section 03002 - Concrete.
4. Section 15060 - Pipe and Pipe Fittings: General.
5. Section 15064 - Pipe: Plastic.
6. CQA Plan.

1.02 QUALITY STANDARDS

A. Referenced Standards:

ASTM D- 883	Definition of Term Relating to Plastics
ASTM D-1248	Specification for Polyethylene Plastics Molding and Extrusions Materials
ASTM D-2122	Determining Dimensions of Thermoplastic Pipe and Fittings.

1.03 SUBMITTALS

A. See Section 01300.

B. Include detailed diagrams for manholes showing components and dimensions.

C. Indicate elevation and position of all piping and appurtenances of each manhole.

D. Provide fabrication drawings indicating proposed welding procedures, bracing, and other pertinent information regarding manhole construction.

E. Production Dates: Submit statement of production dates for the resin and the geosynthetic for this work.

F. Factory Test Results and Material Certification: Submit factory test results of materials demonstrating conformance with the requirements of these Specifications. In addition, submit the Manufacturer's certification that the material delivered is similar and the same formulation as that for which test results are submitted. Submittal shall be prior to or concurrent with product delivery.

G. Butt-fused welds created at the factory shall be ultra-sonically tested or by some other appropriate means, as approved by the Project Manager. A written certification of the test results shall be submitted by the manufacturer, prior to delivery to the job site.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following Manufacturers are acceptable:
   1. Manholes:
      a. Advanced Drainage Systems, Inc. (ADS)
      b. Driscopipe 1000
      c. Spirolite by Chevron
      d. Approved equal
   2. Pipe (If used for manhole construction)
      a. Driscopipe 1000
      b. Polypipe PE 3408
      c. Plexco by Chevron
      d. Approved equal

2.02 MANHOLES AND APPURTENANCES AND PIPE

A. Materials:
   1. Manholes: Polyethylene Manholes shall be produced using polyethylene compounds conforming to the requirements of Type III, Category 5, Grade P34, Class C, as defined and described in ASTM D-1248. Clean reworked material or reprocessed material may be used in the manufacture provided that the manhole components meet all of the requirements of this product specification. Manholes may be constructed of factory seamed pipe if the size and SDR are available. In that case, pipe criteria in these specifications applies.
   2. Pipe: High Density Polyethylene Pipe, solid wall shall conform to requirements of ASTM D-1248 Classification Type III, Class C, Category 5, Grade P34; ASTM D-3350 Classification PE345434C. The pipe shall conform to SDR rating as depicted on the drawings.

B. Manufacture:

1. Manholes shall be produced in the rotational molding process. The manhole will consist of an appropriate combination of base, elevation, and top section based on project requirements.
2. Manholes shall be completely constructed, including all outlets, and appurtenances at the facility which manufactures the manhole. Field fabrication of any manhole components by the Contractor is not acceptable.
3. Manholes shall be designed so that a portable ladder can be supported by the installed manhole.
4. The bottoms of the manholes shall be 2" thick and butt-fused to the manhole body.
5. Manway reducers if applicable shall be eccentric with respect to the larger portion of the manhole.

C. Requirements:

1. Workmanship: Exterior and interior surfaces shall be relatively smooth with no sharp projections. The surfaces shall be free of foreign inclusions and major surface defects. Polyethylene pipe shall be as uniform as commercially practical in color, opacity, density, and other physical properties. The product function shall be considered when judging external defects.
2. Dimensions: As depicted on the drawings.
3. Wall Thickness: Wall thickness of all components shall be determined in accordance with ASTM D-2122 and shall have a minimum standard dimension ratio of 32.5, or as shown on the plans.
4. Fabrication: Inlet and outlet openings and connecting devices may be fabricated utilizing extrusion welding techniques. Fittings, gaskets, and accessories shall be chemically compatible with leachate and be as recommended by the manufacturers of the manhole segments.
5. Compressive Strength: Manholes shall have compressive strength which shall be determined in accordance with ASTM D-2412 modified pipe stiffness test. Pipe stiffness values shall be 12 psi min. at 5% deflection, including joints. Axial compressive strength shall exceed 10,000 pounds at deflection less than 3%.

2.03 SOURCE QUALITY CONTROL

A. Tests and Inspections

1. Each manhole shall be permanently labeled at the factory.
2. Each manhole shall be factory tested and certified water tight.
3. Each manhole, upon delivery to the site, shall be accompanied with factory test certification.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Contractor shall examine and verify conditions affecting installation of the manholes prior to commencing work.

3.02 INSTALLATION/ERECTION

A. Manholes
   1. Install in 12" leveling bed of crushed rock or gravel.
   2. Concrete shall be placed around the manhole in the annular space between the outside surface and the excavation to the dimensions shown on drawings.
   3. Install plumb and to grade for entering and exiting piping.
   4. Exercise care to protect in entering and exiting piping.

B. Pipe
   1. Install as indicated on the drawings.
   2. Install to line and grade as indicated.
   3. Only the butt fusion welding of solid pipe is acceptable.
   4. Pipe penetrations through the liner shall only be made by using prefabricated pipe boots.

3.03 QUALITY ASSURANCE AND QUALITY CONTROL

A. The CQA Consultant shall inspect manholes prior to installation for physical damage and report to the Project Manager.

B. The Contractor shall develop and submit schedule for testing of manholes and appurtenant piping.

C. Tests shall be witnessed by the CQA Consultant.

D. The Contractor shall hydrostatically test each manhole and header pipe section by filling with water and securing the opening to prevent evaporation. Duration of test shall be 48 hours.

E. Manholes and piping will be accepted if no water is lost during the 48 hour test period, at the discretion of the Project Manager or CQA Consultant.

F. Manholes and piping which leak shall be repaired by the Contractor at no additional cost to the Owner.

END OF SECTION

SECTION 02775

HDPE GEOMEMBRANE LINER SYSTEM

PART I - GENERAL

1.01 SUMMARY

A. Section Includes:
   1. Furnish all labor, materials, tools, equipment, and perform all work and services necessary for or incidental to the furnishing and installation, complete, of an impermeable, HDPE geomembrane liner as shown on drawings and specified in accordance with provisions of the Contract Documents.
   2. Completely coordinate work with that of all other trades.
   3. Work items in project include, but are not necessarily limited to, the liner for the landfill lateral expansion.
   4. Although such work is not specifically shown or specified, all supplementary or miscellaneous items, appurtenances, and devices incidental to or necessary for a sound, secure, complete, and compatible installation shall be furnished and installed as part of this work.
   5. Furnish CQC Consultant to monitor work of Geomembrane Installer and to perform CQC testing in accordance with provisions of the Contract Documents.
   6. The Contractor, Geomembrane Installer, and CQC Consultant are required to attend the CQA/CQC Resolution Meeting and the CQA/CQC Preconstruction Meeting, Section 01200.

B. Related Sections include but are not necessarily limited to:
   1. Section 02220 - Earthwork.
   2. Section 02221 - Trenching, Backfilling and Compacting.
   3. Section 02240 - Leachate Collection System
   4. Section 02276 - Soil Liner System.

1.02 QUALITY STANDARDS

A. Referenced Standards:
   1. American Society for Testing and Materials (ASTM).
      a. ASTM D-638 Standard Test Method for Tensile Properties of Plastics
      b. ASTM D-751 Standard Test Method for Coated Fabrics
      c. ASTM D-792 Standard Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement
      d. ASTM D-1004 Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting
      e. ASTM D-1238 Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
      f. ASTM D-1603 Standard Test Method for Carbon Black in Olefin Plastics
      g. ASTM D-3015 Standard Practice for Microscopic Examination of Pigment Dispersion in Plastic Compounds, Refer to

Subpart 2.02 for property to be tested.

2. National Sanitation Foundation (NSF) Standard No. 54.
3. The Geosynthetic Research Institute (GRI).
   a. GRI GM5(a) Notched Constant Tensile Load (NCTL) Test for Polyolefin Geomembranes
   b. GRI GM6 Pressurized Air Channel Test for Dual Seam Geomembranes.
4. The accompanying CQA Plan, prepared by HDR Engineering.

B. Qualifications:
   1. Each geomembrane Manufacturing or Installation firm shall demonstrate 5 years continuous experience, including a minimum of 10,000,000 SF of HDPE geomembrane manufacture or installation.
   2. Geomembrane Installer Personnel Qualifications: Installation Superintendent shall have worked in a similar capacity on at least five HDPE geomembrane liner jobs similar in size and complexity to the project described in the Contract Documents. The Master Welder shall have completed a minimum of 5,000,000 square feet of HDPE geomembrane seaming work using the type of seaming apparatus proposed for use on this Project. Other welders shall have seamed a minimum of 1,000,000 square feet of HDPE geomembrane.
   3. The CQC Consultant shall meet the qualification requirements of Section 01410 of these Specifications.

C. CQA PLAN IMPLEMENTATION - Construction Quality Assurance for the HDPE geomembrane installation will be performed for the Owner by the CQA Consultant in accordance with the CQA Plan prepared for this project. The work performed under the CQA Plan is paid for by the Owner and is not a part of this contract. The Contractor, CQC Consultant, and Geomembrane Installer, however, should familiarize themselves with the CQA Plan and are responsible for providing reasonable notice of and access to work elements that the CQA Consultant is required by the CQA Plan to overview.

1.03 SUBMITTALS

A. Submit for Engineer's approval prior to placement of geomembrane liner, including:
   1. Manufacturer's Submittals.
      a. Manufacturer's Quality Control (MQC) Program: Submit for review a complete description of the geosynthetic Manufacturer's formal quality control program for manufacturing HDPE geomembrane. The MQC program shall include as a minimum:
         1) Testing of incoming resin prior to manufacture of geomembrane at a frequency of not less than one per hopper. This testing shall include the following tests and minimum criteria:
            - Specific Gravity (ASTM D792 Method A or ASTM D1505): >0.935.
            - Melt Index (ASTM D1238 Condition 190/2.16):

1.0g/10 min.

2) Routine testing of the manufactured sheet for physical parameters to confirm that the geomembrane meets or exceeds these Specifications (2.02 A.4). Testing for carbon black content and dispersion, tensile strength, and elongation properties shall be at a frequency of not less than one per 40,000 SF of geomembrane. Testing for environmental stress crack resistance shall be at a frequency of not less than one per 400,000 SF of geomembrane. Thickness shall be monitored continuously through the manufacturing process, or measured physically at a frequency of not less than once per 1,000 SF of geomembrane.

3) Extrusion rod. Extrusion rod shall be manufactured from identical resin to that used in geomembrane manufacture. Manufactured extrusion rod shall be tested for carbon black content and dispersion, specific gravity and melt index at a frequency of not less than one test per batch.

4) The Manufacturer shall reject resin and geomembrane that do not conform with the requirements of the approved MQC program.

5) MQC data shall accompany the geomembrane shipment.

b. Manufacturer's Field Installation Procedures Manual: Submit complete geomembrane Manufacturer's specifications, descriptive drawings, and literature for the recommended installation of the HDPE geomembrane liner system, including recommended methods for handling and storage of all materials prior to installation, and field installation guidelines that the manufacturer feels are relevant and important to the success of this project. At a minimum, the manual shall include the following provisions with exceptions noted by the Manufacturer:

1) Geomembrane shall not be placed upon standing water or other conditions which will result in deterioration of the CSL.

2) The Geomembrane Installer shall remove any materials placed to protect the CSL prior to placement of the geomembrane liner.

3) Adjacent rolls of geomembrane shall overlap a minimum of 4 IN.

4) Geomembrane liner shall be handled and placed in a manner which minimizes wrinkles, scratches, and crimps.

5) Geomembrane liners shall be welded using either extrusion or radiant wedge welding equipment. Each piece of welding equipment and each operator shall perform demonstration welds at the start of a shift, whenever equipment is switched on, and at other times at the discretion of the CQC Consultant. These demonstration welds shall be tested using daily record that summarizes panels deployed, seams completed, seam testing, seam repair, personnel on site, and equipment on site using field tensiometer and, at a minimum,

exhibit seam shear strength of greater than 128 LBS per inch of width (smooth), 113 lbs per inch of width (textured) and seam peel shear strength of greater than 98 LBS per inch of width (smooth), 88 lbs per inch of width (textured).

6) Surfaces to be welded shall be clean and dry at the time of welding. Geomembrane shall not be welded when ambient temperatures are below 40 Deg F (5 Deg C) or above 104 Deg F (40 Deg C) unless the Geomembrane installer can demonstrate that the seam quality is not compromised.

7) Geomembrane liners shall be welded continuously without fishmouths or breaks in the weld. Where fishmouths are unavoidable, the geomembrane sheet shall be slit to a point such that the sheet lies flat and with no remaining wrinkle. The two edges of the slit shall be welded together provided that the overlap for this weld shall be a minimum of 3 IN. Areas of the slit which do not achieve an overlap of 3 IN, including the terminus of the slit, shall be provided with a patch as discussed below.

8) Defects in and damage to geomembrane sheets shall be repaired by welding a patch over the defect using extrusion welding equipment. The patch material shall consist of an undamaged piece of geomembrane cut to provide a minimum of 3 IN of overlap in all directions from the defect. Torn or permanently twisted geomembrane shall be replaced at no expense to the Owner.

9) Personnel walking on the geosynthetic shall not engage in activities or wear types of shoes, that could damage the geosynthetic. Smoking shall not be permitted while working on the geomembrane.

10) Vehicular traffic directly on the geosynthetic shall not be permitted. Equipment shall not damage the geosynthetic materials by handling, trafficking, leakage of hydrocarbons, or any other means. The unprotected geomembrane surface shall not be used as a work area, for preparing patches, storing tools and supplies, or other uses.

c. Manufacturer's Material Data: Prior to shipment of geomembrane, submit quality control certificates for each roll demonstrating conformance with the requirements of these Specifications. Submit statement of production dates for the resin and the HDPE geomembrane for this work.

d. Manufacturer's written acceptance of Geomembrane Installer's qualifications for installation of the HDPE geomembrane.

e. Warranty: Submit a warranty signed by the Manufacturer. The warranty shall be against manufacturing defects and workmanship and against deterioration due to ozone, ultra-violet, and other exposure to the elements, for a period of 20 years on a pro rata basis. The warranty shall be limited

to replacement of material, and shall not cover installation of replacement geomembrane.

2. Geomembrane Installer's Submittals.
   a. The Geomembrane Installer will submit written documentation that their personnel satisfy the qualifications of 1.02 B.
   b. Geomembrane Installer's Construction Quality Control Program: Submit for review a complete description of the Geomembrane Installer's formal construction quality control programs to include, but not be limited to, product acceptance testing, installation testing, including both non-destructive and destructive quality control field testing of the sheets and seams during installation of the geomembrane, proposed methods of testing geosynthetic joints and connections at appurtenances for continuity, documentation and changes, alterations, repairs, retests, and acceptance.
   c. Geomembrane Installer's Installation Procedures Manual: submit for approval the Installer's installation manual to include: ambient temperature at which the seams are made, control of panel lift up by wind, acceptable condition of the subsurface beneath the geomembrane, quality and consistency of the welding material, proper preparation of the liner surfaces to be joined, cleanliness of the seam interface (e.g., the amount of airborne dust and debris present), and proposed details for connecting the HDPE liner to appurtenances, i.e. penetrations of the containment facilities. The document shall include a complete description of seaming by extrusion welding and hot-wedge welding. The Geomembrane Installer's Installation Manual will by reference include requirements of the Manufacturer's Installation Manual unless exceptions are noted and approved by the Engineer. After this manual has been approved by the Engineer, the Geomembrane Installer shall not deviate from the procedures included in the manual.
   d. Geomembrane panel layout with proposed size, number, position and sequencing of panels and showing the location and direction of all field joints.
   e. Warranty: The Geomembrane Installer shall agree in writing to warranty the geomembrane system to be free of defects for a period of 2 years following the date of acceptance of the work performed under this contract.
3. CQC Consultants Submittals:
   a. CQC Consultant shall submit written documentation that their personnel satisfy the qualifications of Section 01400.
   b. CQC Consultants CQC Geomembrane Manual: Submit CQC Consultant's written program for meeting the geomembrane material conformance and CQC requirements of these Specifications.
4. Provide all submittals in a single coordinated transmittal. Partial submittals will not be accepted. All submittals must be submitted prior to the Geomembrane Preconstruction Meeting, Section 01200.

D. Submittals for Engineer's Approval Required for Final Acceptance of HDPE Geomembrane Liner System:

1. Geomembrane Installer's Submittals.

a. Warranty: Submit a warranty signed by the Geomembrane Installer that the installed geomembrane liner, attachments and appurtenances are free of defects in material, manufacturing, and workmanship.

b. Record Drawings: Submit reproducible drawings of record showing changes from the approved installation drawings. The record drawings shall include the identity and location of each repair, cap strip, penetration, boot, and sample taken from the installed geosynthetic for testing.

c. Welder Certification: Submit certification for each welder and performance records that include linear feet of weld completed, number of samples tested, and test failure rate for each welder. Submit field notes with daily equipment reports.

2. CQC Consultant's Submittals.

a. Certification: Submit written certification that the geomembrane liner was installed in accordance with this Specification and with the approved shop drawings.

b. CQC Records: Submit copies of all material and seam test results. Each test shall be identified by date of sample, date of test, sample location, name of individual who performed the test, and standard test method used.

c. CQC Weld Test Summary Report: The CQC Consultant shall submit a report showing normal distribution of all CQC seam test results, identifying the high, low, and average of the five coupon samples in each test.

3. Provide all submittals in a single coordinated transmittal. Partial submittals will not be accepted.

1.04 PROJECT CONDITIONS

A. When the weather is of such a nature as to endanger the integrity and quality of the installation, whether this is due to rain, high winds, cold temperatures, or other weather elements, the installation of the geomembrane shall be halted at the direction of, or with the concurrence of, the Owner until the weather conditions are satisfactory.

B. The Contractor shall insure that adequate dust control methods are in effect to prevent the unnecessary accumulation of dust and dirt on geosynthetic surfaces which hamper the efficient field seaming of geosynthetic panels.

C. The Contractor shall maintain natural surface water drainage diversions around the work area and provide for the disposal of water which may collect in the work area directly from precipitation falling within the area or from inadequate diversion structures or practices.

D. The Contractor shall be responsible to coordinate the installation of the leachate collection system which shall be in accordance with Geomembrane Installer's Installation Manual and as specified in these Specifications and shown on the Contract Drawings.

E. Vehicles will not be allowed on the liner area unless at least 24 inch (24") of cover has been placed over the liner except as noted in these Specifications.

F. Vehicles larger than one and one-half ton pick up trucks are prohibited on the exterior berms. Contractor shall repair any damage to exterior berms prior to final payment.

1.05 DEFINITIONS

A. Geomembrane Manufacturer: Manufacturer of geomembranes produces geomembrane sheets from resin and additives. The manufacturer is responsible for producing geomembrane sheet which complies with these Specifications. These responsibilities include but are not limited to:
   1. Acceptance of the resin and additives from chemical formulators. Testing of the raw resin and additives to ensure compliance with the manufacturer's specifications and with this Specification.
   2. Formulation of the resin and additives into geomembrane sheeting using mixing and extrusion equipment.
   3. Testing of the geomembrane sheet to ensure compliance with manufacturer's specification and this Specification.
   4. Shipping of the geomembrane sheet to Installer designated facilities.
   5. Certification of the raw materials and finished geomembrane sheet to comply with this Specification.
   6. Certification of installer's training, experience, and methods for welding and inspection geomembrane installations in compliance with manufacturer's standards.

B. Geomembrane Installer. Installer of geomembranes are responsible for handling, fitting, welding and testing of geomembrane sheets or blankets in the field. These responsibilities include but are not limited to:
   1. Acceptance (in writing) of the geomembrane from the manufacturer.
   2. Acceptance (in writing) of the CSL surface which will serve as a base for the geomembrane. This acceptance shall precede installation of the geomembrane, and shall state that the installer has inspected the surface, and reviewed the Specifications for material and placement, and finds all conditions acceptable for placement of geomembrane liners. The written acceptance shall explicitly state any and all exceptions to acceptance.
   3. Handling, welding, testing, and repair geomembrane liners in compliance with this Specification and the Geomembrane Installer's Installation Procedures Manual.
   4. Performance of QA/QC testing and record keeping as required

by the approved Geomembrane Installer's Field Installation Procedures Manual.

5. Repair or replacement of defects in the geomembrane as required by the CQC Consultant or the CQA Consultant.

D. Engineer: Responsible for approval of submittals from the Contractor.

E. CQC Consultant: Responsible for observing field installation of the geomembrane and performance of material conformance and CQC testing to provide the Contractor with verbal and written documentation of the compliance of the installation with these Specifications. The CQC Consultant reports to the Contractor and is part of this contract.

F. CQA Consultant: Responsible for implementing CQA Plan including overviewing material conformance testing, field installation of the geomembrane, and CQC activities, and to perform limited CQA conformance testing to provide Owner with verbal and written documentation of the compliance of the installation with these Specifications. The CQA Consultant will use the written results of the CQC program and the CQA program in the preparation of the facility Certification Document. The CQA Consultant reports to the Owner and is not part of this contract.

G. Refer to the accompanying CQA Plan for additional definitions.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS AND/OR GEOMEMBRANE INSTALLERS

A. Subject to compliance with the Contract Documents, the following Manufacturers and Geomembrane Installers are acceptable:
   1. HDPE Geomembrane liners:
      a. GSE, Inc., 19103 Gundle Road, Houston, Texas 77073.
      b. National Seal Company, Southeast Office Route 2, Box 161, Eastanollee, Georgia 30538.
      c. The Serrot Corporation, 271 Highway 74 North, Suite 4, Peachtree City, Georgia 30269.
      d. Poly-Flex Inc., 2000 W. Marshall Drive, Grand Prairie, TX 75051.
      e. Other installers may qualify by providing references for a minimum of 10,000,000 SF of liner installations.

B. Submit requests for substitution in accordance with Specification Section 01640.

2.02 MATERIALS

A. HDPE Geomembrane Liners:
   1. Geomembrane liners shall consist of unsupported polyethylene in thickness as shown on Drawings and manufactured from virgin,

first quality resin designed and formulated specifically for liquid containment in hydraulic structures. Reclaimed polymer shall not be added to the resin; except use of polymer recycled during the manufacturing process shall be allowed provided that recycled polymer shall be clean and shall not exceed 2 percent by weight.

2. The geomembrane liner shall be manufactured to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter. Any such defects shall be cause for rejection of the defective geomembrane material. Minor defects may be repaired in accordance with manufacturer's recommendations if this repair is approved by the Engineer.
3. The geomembrane liner shall be manufactured as seamless rolls or as prefabricated panels with a minimum width of 22 FT as delivered to the site. All factory seams shall be inspected and tested for strength and continuity prior to delivery to the site.
4. Geomembrane liner material shall possess properties which meet or exceed the following minimum requirements:

		TEST VALUE	
PROPERTY	TEST METHOD	SMOOTH HDPE	TEXTURED HDPE
1. Sheet Thickness, Mils	ASTM D751	57 to 63	57 to 63
2. Density (g/cc) (Minimum prior to Carbon Black)	ASTM D1238	0.934	0.934
3. Melt Flow Index g/10 min.	ASTM D1238 Condition 190/2.16	0.30-1.00	0.3-1.00
4. Minimum Tensile Properties	ASTM D638, Type IV, Dumb-bell at 2 ipm.(Each direction)		
a. Min. Tensile Strength at Break (lbs/inch)		240	75
b. Min. Tensile Strength at Yield (lbs/inch)		140	140
c. Min. Elongation at Break		700	150

	(Percent)			
d.	Min. Elongation at Yield (Percent)		13	13
5.	Min. Tear Resistance Initiation (lbs)	ASTM D1004 Die C	45	45
6.	Carbon Black	ASTM D1603	2.00-3.00	2.00-3.00
7.	Carbon Black Dispersion	ASTM D3015	A1	A1
8.	Min. Environmental Stress Crack Resistance (hrs)	ASTM D1693 Condition C	1500	1500
9.	Notched Constant Load Test	GRI GM5	Transition Time >100 Hrs @ 35% Yield	Transition Time >100 Hrs @ 35% Yield

5. No additives or fillers may be added to the resin prior to or during manufacture of the geomembrane.
6. Prior to shipment, the Geomembrane Manufacturer will provide the Project Manager and the CQC Consultant with a quality control certificate for each roll of geomembrane provided. The quality control certificate will be signed by a responsible party employed by the Geomembrane Manufacturer and will include:
   a. roll numbers and identification; and
   b. the results of quality control tests.
7. The CQC Consultant will verify that a control certificate has been received for each roll and that the certified roll properties meet the requirements of these Specifications.

2.03 EQUIPMENT

A. Welding Equipment: Extrusion welding equipment shall be provided with thermocouples and temperature readout devices which continuously monitor the temperature of the extrudate. Radiant wedge welding equipment shall be provided with thermocouples and temperature readout devices which continuously monitor the temperature of the wedge. Equipment shall be maintained in adequate number to avoid delaying work, and shall be supplied by a power source capable of providing constant voltage under a combined-line load. Electric generators shall not be placed directly on the membrane.

B. Field Tensiometer: The Geomembrane Installer shall provide a tensiometer for on site shear and peel testing of geomembrane seams. The tensiometer shall be in good working order, built to ASTM D638 (Type IV, 2 ipm) specifications, and accompanied by evidence of

recent calibration. The tensiometer shall be motor driven and be equipped with a gauge that measures the force in unit pounds exerted between the jaws as displayed on a digital readout.

C. Vacuum Box: The Geomembrane Installer shall provide a minimum of 2 vacuum box assemblies consisting of a rigid housing, a transparent viewing window, a soft closed cell neoprene gasket attached to the bottom, a port hole or valve assembly, a vacuum gauge, a vacuum pump assembly equipped with a pressure control, a rubber pressure/vacuum hose with fittings and connections, and a soapy solution and an applicator. The equipment shall be capable of inducing and holding a minimum vacuum of 5 psi.

D. Air Pressure Test: The Geomembrane Installer shall provide the necessary air pump and fittings required to perform the GRI GM6 air pressure test on dual seams.

E. Roll Handling Equipment: The Geomembrane Installer shall provide handling equipment that is adequate and does not pose a risk to the geomembrane rolls. The CQC Consultant shall inspect the equipment and confirm its adequacy.

PART 3 - EXECUTION

3.01 LINER SYSTEM CONSTRUCTION

A. Compacted Soil Liner (CSL) Component:
   1. The CSL component shall be constructed in accordance with Section 02276 and the Contractor shall protect the CSL from freezing, desiccation, flooding with water, and freezing.
   2. Prior to placement of the geomembrane, the CSL must be prepared as follows:
      a. Lines and grade must be verified by a Licensed Land Surveyor;
      b. The surface must be proofrolled to verify the supporting soil condition;
      c. The surface must be inspected for rocks larger than 0.75 IN; and
      d. Steel drum rolled in preparation for the geomembrane.
   3. CSL acceptance: Geomembrane liner materials shall not be placed until the required CSL preparation has been completed and the CSL has been accepted and certified in writing by the Geomembrane Installer and approved by the CQA Engineer.

B. Geomembrane Liner:
   1. The geomembrane liner shall be manufactured in accordance with the approved MQC program. The Manufacturer shall not deviate from the program without written approval of the Engineer.
   2. Transportation and handling of the geomembrane shall meet the following requirements:
      a. Transportation of the geomembrane is the responsibility of the Geomembrane Installer, Contractor, or other party as

agreed upon.

b. All handling on site is the responsibility of the Geomembrane Installer.

c. The CQC Consultant will verify that the handling equipment used on the site is adequate and will not damage the geomembrane.

d. Upon delivery to the site, the Geomembrane Installer and the CQC Consultant will conduct a surface examination of all rolls for defects or damage. This inspection will be conducted without unrolling rolls. The CQC Consultant will ensure that defective rolls are rejected and removed from the site.

e. The Geomembrane Installer will be responsible for the storage of the geomembrane on site. The Project Manager will provide a storage location on site. The Geomembrane Installer shall ensure that the storage space is adequate to protect the geomembrane from theft, vandalism, vehicular damage, etc.

3. Upon delivery of the geomembrane rolls to the site, the CQC Consultant will perform conformance testing of the manufactured geomembrane as follows:

a. Remove samples at a frequency of one test per 100,000 sq.ft. and forward to the Geosynthetics CQC Laboratory for testing to ensure conformance to these Specifications and the manufacturer's list of guaranteed properties. As a minimum, the following conformance tests will be performed:

1) Density: ASTM D792 Method A
2) Carbon black content: ASTM D1603
3) Carbon black dispersion: ASTM D2663
4) Thickness: ASTM D1593
5) Tensile strength: ASTM D368

b. All test results shall be available at the site prior to deployment of the geomembrane.

c. Samples will be taken across the entire width of the roll and will not include the first lineal 3 FT. The CQC Consultant will mark the machine direction on each sample.

d. The following procedure will apply whenever a sample fails a conformance test that is conducted by the CQC Consultant:

1) The Geomembrane Installer will replace the roll of geomembrane that is in nonconformance with a roll in conformance with these Specifications.
2) The Geomembrane Installer will remove conformance samples for testing by the Geosynthetics CQC Laboratory from the closest numerical roll on both sides of the failed roll. These two samples must conform to these Specifications. If either of these samples fail, then the next numerical roll will be tested until a passing roll is found.

4. Field Panel Identification: The CQC Consultant will document that the Geomembrane Installer labels each field panel with an "identification code" consistent with the approved panel layout plan. The location of the label and the color of marker used must be as agreed to in the QA/QC Preconstruction Meeting.

5. Geomembrane installation: Geomembrane liner shall be installed in accordance with the approved Geomembrane Installer's Field Installation Procedure Manual and panel layout drawing. The Geomembrane Installer shall maintain a weekly updated as-built drawing showing the location of all field panels.
6. Geomembrane Testing (Non-destructive): The Geomembrane Installer shall test and document all seam welds continuously using one of the following nondestructive seam tests:
   a. Vacuum testing shall conform to the following procedure: Brush soapy solution on geomembrane. Place vacuum box over the wetted seam area. Ensure that a leak-tight seal is created. Apply a pressure of approximately five (5) psi. Examine the geomembrane through the viewing window for the presence of soap bubbles for not less than fifteen (15) seconds. All areas where soap bubbles appear shall be marked and repaired as described in this Section.
   b. Air Pressure Testing (for double seam with an enclosed space) shall conform to GRI GM6 requirements.
7. Destructive Testing: The Geomembrane Installer shall field test seams destructively at a minimum frequency of one test per 500 LF of weld. Destructive testing of these samples shall also be performed by the CQC Consultant using the CQC Geosynthetics Laboratory. The CQC Consultant shall determine the location of destructive test samples. Conformance testing will be performed by the CQA Consultant in accordance with the project CQA Plan.
   a. The destructive sample shall be 16 inches wide by 42 inches long with the seam centered lengthwise. The sample shall be cut into three (3) equal parts for distribution to the Geomembrane Installer, the CQC Consultant and the CQA Consultant.
   b. All tests shall exhibit a Film Tearing Bond type of separation in which the geomembrane material tears before the weld. At least 5 coupons shall be tested by each test method. Five of five coupons shall meet minimum requirements, as specified below:

Description	Test Method	Value (lbs/in width)
60 mil Smooth HDPE Peel	ASTM D-413	98
60 mil Smooth HDPE Shear	ASTM D-816	126
60 mil Textured HDPE Peel	ASTM D-413	88
60 mil Textured HDPE Shear	ASTM D-816	113

8. Documentation: The following documentation must be maintained at the project site for review by the Project Manager or CQA Consultant:
   a. Geomembrane Installer's Documentation:
      1) Daily Log: daily record that summarizes panels deployed, seams completed, seam testing, seam repair, personnel on site, and equipment on site.
      2) Panel Log: provides geomembrane roll number used and

subgrade acceptance for each panel deployed.

3) Seam Testing Log: provides a complete record of all nondestructive and destructive seam tests performed as part of the Geomembrane Installer's QC program.

4) Seam/Panel Repair Log: provides a complete record of all repairs and vacuum box testing of repairs made to defective seams or panels.

5) As-built Drawing: maintain an as-built drawing updated on a weekly basis.

b. CQC Consultant's Documentation

1) Daily Log: daily record that summarizes panels deployed, seams completed, CQC seam testing, seam repair, personnel on site, equipment on site, weather conditions, etc.

2) CQC Testing Log: record of all seam destructive tests and material conformance tests performed by the CQC Geosynthetics Laboratory.

3) Material Conformance: maintain original conformance certificate(s) from geomembrane manufacturer.

4) Subgrade Acceptance Log: maintained originals of subgrade acceptance forms for each panel and signed by the Geomembrane Installer.

3.02 GEOMEMBRANE ACCEPTANCE

A. The Geomembrane Installer shall retain all Ownership and responsibility for the geomembrane liner system until final acceptance by the Owner. Owner will accept the geosynthetic installation when the installation is finished and all required submittals from the Geomembrane Installer and CQC Consultant have been received and approved, and CQA verification of the adequacy of all field seams and repairs, including associated testing, is complete.

END OF SECTION

SECTION 02800

GEOSYNTHETIC CLAY LINER (GCL)

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:
1. Furnish all labor, material, and equipment to complete installation of the GCL in accordance with the Contract Drawings and these Specifications.
2. Completely coordinate work with that of other trades.
3. Although such work is not specifically shown or specified, all supplementary or miscellaneous items, appurtenances, and devices incidental to or necessary for a sound, secure, complete, and compatible installation shall be furnished and installed as part of this work.
4. Furnish CQC Consultant to monitor the work of GCL Installer and to perform CQC testing in accordance with provisions of the Contract Documents.

B. Related Sections include but are not necessarily limited to:
1. Section 02220 - Earthwork.
2. Section 02775 - HDPE Geomembrane Liner.

1.02 QUALITY STANDARDS

A. Referenced Standards:
1. American Society for Testing and Materials (ASTM).
   a. ASTM D 1777, Method for Measuring Thickness of Textile Materials.
   b. ASTM D 3776, Test Methods for Weight (mass) per Unit Area of Woven Fabric.
   c. ASTM D 4632, Test Method for Grab Breaking Load and Elongation of Geotextile.
   d. ASTM D 4833, Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
   e. ASTM D 5084, Test Method for Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.
   f. ASTM D 5321, Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.

B. Qualifications:
1. Manufacturer: The GCL shall be furnished by a Manufacturer that has previously produced a minimum of 1,000,000 square feet of the material for use in similar projects.

C. CQA Plan Implementation: Construction Quality Assurance documentation for the GCL installation will be performed for the

Owner by the CQA Consultant in accordance with the CQA Plan prepared for this project. The work performed under the CQA Plan is paid for by the Owner and is not a part of this contract. The Contractor, CQC Consultant, and GCL Installer, however, should familiarize themselves with the CQA Plan and are responsible for providing reasonable notice of and access to work elements that the CQA Consultant is required by the CQA Plan to overview.

1.03 SUBMITTALS

A. Pre-Installation: The Contractor shall submit the following information and material to the CQA Consultant prior to installation of the GCL.
   1. Product Data and Factory Test Results: Published product properties and specifications for the proposed GCL, as well as factory test results of materials certified by the GCL manufacturer shall be submitted showing conformance with the requirements of these Specifications. In addition, the Contractor shall submit the Manufacturer's certification stating that the material is similar to and of the same formulation as that for which test results are submitted, and by which actual usage has been demonstrated to be satisfactory for the intended application.
   2. Samples: Samples of the GCL sheeting shall be provided to the CQA Consultant. Samples shall have a width of 6 inches, and a length of 8 inches.
   3. Delivery, Storage, and Handling Instructions: The Manufacturer's recommendations for delivery, storage, and handling shall be submitted to the CQA Consultant for review.
   4. Delivery Date: The CQA Consultant shall be notified of the scheduled delivery date for the materials.
   5. Installation Drawings, Procedures, and Schedules: Installation drawings, procedures, and a schedule for carrying out the work shall be provided by the Contractor to the CQA Consultant for review. Procedures addressed by the Contractor shall include but not be limited to material unloading, storage, installation, repair, and protection to be provided in the event of rain. A schedule showing the order of placement, location of panels, seams, and penetrations shall be submitted for the CQA Consultant's review. Submit drawings showing the panel layout, seams, and associated details including pipe penetrations. Following review, these drawings will be used for installation of the GCL. Any deviations from these drawings must be approved by the CQA Consultant.

B. Post-Installation: Upon completion of GCL installation the Contractor shall submit the following to the CQA Consultant:
   1. A certificate stating that the GCL has been installed in accordance with the Plans, Specifications, and the Manufacturer's recommendations.
   2. Manufacturer's Warranty: The material warranty shall be for defects or failures related to manufacture on a non-prorata basis for five (5) years after date of shipment.

3. GCL Installer's Warranty: The GCL Installer's warranty shall warrant their workmanship to be free of defects on a non-prorata basis for five (5) years after the final acceptance of the Work. This warranty shall include but not be limited to overlapped seams, anchor trenches, attachments to appurtenances, and penetration seals.
4. Record Drawing Information: Record drawings including but not limited to drawings showing the location of all seams, panels, repairs, patches, anchor trenches, pipe penetrations, and other appurtenances, including measurements and dimensions, shall be prepared by the Contractor and submitted to the CQA Consultant following completion of the project.

1.04 PROJECT CONDITIONS

A. The GCL shall not be placed in standing water, high humidity, or while raining. Any material that becomes partially or completely hydrated in the opinion of the CQA Consultant shall be removed and replaced at Contractor's expense.

B. Take necessary precautions to protect underlying soil and geomembrane liners from damage due to any construction activity. Damage to liners shall be repaired at Contractor expense.

PART 2 - PRODUCTS

2.01 MATERIALS

A. General:
1. The GCL shall consist of bentonite encased, front and back, with geotextile. GCL consisting of bentonite backed with geomembrane can be used only if approved by the Project Manager and Engineer. The materials supplied under these Specifications shall be first quality products designed and manufactured specifically for the purposes of this work.
2. The GCL shall be supplied in rolls which have a minimum width of 12 feet. The roll length shall be maximized to provide the largest manageable sheet for the fewest overlaps. Labels on the roll shall identify the sheet number, date of fabrication, proper direction of unrolling, and minimum recommended overlap. A quality control certificate shall be supplied with each roll.
3. The GCL shall be reinforced where placed on slopes of 10H:1V or steeper. The GCL may be non-reinforced on slopes of less than 10H:1V.

B. Physical Properties: Physical properties of GCL shall be as shown in Table 1 of this section.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Shipping , Handling and Storage:

1. During periods of shipment and storage, all GCL shall be protected from direct sunlight, water, mud, dirt, dust, and debris. To the extent possible, the GCL shall be maintained wrapped in heavy-duty protective covering until use. GCL delivered to the project site without protective wrapping shall be rejected.
2. The Engineer shall approve the shipping and delivery schedule prior to shipment. The Engineer shall approve the on-site storage area for the GCL. Unloading and storage of GCL shall be the responsibility of the Contractor.
3. GCL that is damaged during or storage shall be rejected and replaced at Contractor expense.

B. Installation of GCL:

1. GCL shall be placed to the lines and grades shown on the Contract Drawings. At the time of installation, GCL shall be rejected by the CQA Consultant if it has defects, rips, holes, flaws, evidence of deterioration, or other damage.
2. The surface receiving the GCL shall be prepared to a relatively smooth condition, free of obstructions, excessive depressions, debris, and very soft or loose pockets of soil. This surface shall be approved by the CQA Consultant prior to GCL placement.
3. The GCL shall be placed smooth and free of excessive wrinkles.
4. The GCL shall be installed on sideslopes with vertical seams only.
5. When GCL is placed with upslope and downslope portions, the upslope portion shall be lapped such that it is the upper or exposed surface.
6. The GCL shall not be placed in standing water or while raining. Any material that becomes partially/totally hydrated shall be removed and replaced.
7. The GCL seams shall be laid with a minimum overlap equal to 6 inches or the Manufacturer's recommendation, whichever is greater.
8. GCL shall be temporarily secured in a manner approved by the CQA Consultant prior to placement of overlying materials.
9. Any GCL that is torn or punctured shall be repaired or replaced as directed by the CQA Consultant, by the Contractor at no additional cost to the Owner. The repair shall consist of a patch of GCL placed over the failed areas and shall overlap the existing GCL a minimum of 12-inches from any point of the rupture.
10. If in-place GCL is not otherwise protected from hydration due to rainfall, the GCL shall be covered with a minimum of 6 inches of the overlying design material within 24 hours of GCL placement.

3.02 FIELD QUALITY CONTROL

A. The CQA Consultant shall monitor and document the installation of GCL to ensure that the installation and necessary repairs are made

in accordance with these specifications.

3.03 GCL ACCEPTANCE

A. The GCL Installer shall retain all ownership and responsibility for the GCL until final acceptance by the Owner. The Owner will accept the GCL installation when the installation is finished, all required submittals have been received and approved, and CQC/CQA verification of the adequacy of all field seams and repairs, including associated testing, is complete.

TABLE 1: REQUIRED GCL PROPERTIES

GCL PROPERTY	TEST METHOD	VALUE	
		REINFORCED	NON-REINFORCED
Maximum Hydraulic Conductivity	ASTM D 5084 (@ 30 psi effective stress)	$5x10^{-9}$ cm/s	$5x10^{-9}$ cm/s
Minimum Bentonite Content	ASTM D 3776 (@ 20% moisture)	0.95 lb/sf	0.95 lb/sf
Minimum Grab Tensile Strength	ASTM D 4632	88 lbs	75 lbs
Minimum Puncture Resistance	ASTM D 4833	100 lbs	80 lbs
Minimum Shear Strength	ASTM D 5321	500 psf (When Hydrated)	50 psf
Minimum Free Swell	USP-NF-XVII	24 ml.	24 ml.
Maximum Moisture Content	ASTM D4643	30%	40%
Sodium Montmorillonite Content	X-Ray Diffraction	90 (Typ.)	90 (Typ.)

END OF SECTION

SECTION 02900

GEOTEXTILE FABRIC

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:
   1. Geotextile fabric for all uses as shown in drawings including but not limited to:
      a. Cushion geotextile to protect geomembrane from #57 stone;
      b. Separator geotextile between LCR and operational cover;
      c. Protective geotextile when impregnated to limit flow into LCR; and
      d. Other - to suit field conditions

B. Related Sections include but are not necessarily limited to:
   1. Section 02220 - Earthwork.
   2. Section 02775 - Geosynthetic Liner System.
   3. CQA Plan.

1.02 QUALITY STANDARDS

A. Reference Standards:
   1. American Society for Testing and Materials (ASTM):
      a. D3776, Test Method for Mass Per Unit Area of Woven Fabric.
      b. D4354, Practice for Sampling of Geosynthetics for Testing.
      c. D4355, Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water.
      d. D4491, Test Method for Water Permeability of Geotextiles by Permittivity.
      e. D4632, Test Method for Grab Breaking Load and Elongation.
      f. D4751, Determining Apparent Opening Size of a Geotextile.
      g. D4833, Test Method for Index Puncture Resistance of Geotextiles, Geomembrane, and Related Products.
      h. D4873, Guide for Identification, Storage, and Handling of Geotextiles.

B. Construction Quality Assurance Plan.

1.03 SUBMITTALS

A. Shop Drawings:
   1. See Section 01300.
   2. Product technical data.
   3. Manufacturer's delivery, storage, handling, and installation instructions.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following Manufacturers are acceptable:
   1. Geotextiles:
      a. Hoechst Celanese Corp.
      b. Advanced Drainage Systems Inc.
      c. Amoco Fabrics and Fibers Co.
      d. Or approved equal.

2.02 FABRICATION

A. Cushion Geotextile: Non-woven, needle punched; polyester or polypropylene; continuous filament or staple fibers; conforming to the following properties:

Property or Test Method	Required Value
Unit Weight (ASTM D3776)	.16 osy (minimum)
Grab Tensile Strength (ASTM D4632)	300 lb (minimum)

B. Separator Geotextile: Non-woven, needle punched; polyester or polypropylene; continuous filament or staple fibers; conforming to the following properties:

Property or Test Method	Required Value
Unit Weight (ASTM D3776)	.6 osy (minimum)
Grab Tensile Strength (ASTM D4632)	180 lb (minimum)
Elongation (ASTM D4632)	.50% (minimum)
Puncture Strength (ASTM D4833)	70 lb (minimum)
Apparent Opening Size (ASTM D4751)	.#50 US Sieve (minimum)
Permittivity (ASTM D4491)	0.5 sec-1 (minimum)

Alternative Separator Geotextile: Woven; polyester or polypropylene; conforming to the following properties:

Grab Tensile Strength (ASTM D4632)	180 lb (minimum)
Elongation (ASTM D4632)	.50% (minimum)
Puncture Strength (ASTM D4833)	70 lb (minimum)
Apparent Opening Size (ASTM D4751)	.#50 US Sieve (minimum)
Permittivity (ASTM D4491)	0.5 sec-1 (minimum)

C. Protective Geotextile: Nonwoven; polyester or polypropylene; continuous filament or staple fibers; conforming to the following properties:

Property or Test Method	Required Value
Unit Weight (ASTM D3776)	.6 osy (minimum)
Grab Tensile Strength (ASTM D4632)	180 lb (minimum)
Elongation (ASTM D4632)	.50% (minimum)

Puncture Strength (ASTM D4833). . . . . 70 lb (minimum)
Ultraviolet Stability (ASTM D4355) . . . . . .70% (minimum)

Alternative Protective Geotextile: Woven; polyester or polypropylene; conforming to the following properties:

Grab Tensile Strength (ASTM D4632) . . . . . 180 lb (minimum)
Elongation (ASTM D4632) . . . . . .50% (minimum)
Puncture Strength (ASTM D4833). . . . . 70 lb (minimum)
Ultraviolet Stability (ASTM D4355) . . . . . .70% (minimum)

PART 3 - EXECUTION

3.01 INSTALLATION

A. General Handling and Layout
   1. General storage and handling of geotextiles must meet requirements of ASTM D-4873.
   2. Exercise care when installing to prevent damage to geotextile.
   3. Lay out geotextile smooth and free of wrinkles, but loose enough that placement of overlying materials will not stretch or tear the fabric.
   4. Repair or replace geotextile that is torn or punctured. Repair by placing a geotextile patch over the damaged area, overlapping the existing geotextile by 12 IN (minimum) from any part of the damaged area. Repair or replace at no extra cost to Owner.
   5. Overlap rolls or sheets of geotextile 3 FT, minimum in the longitudinal direction.
   6. No equipment may operate directly on geotextiles. A minimum vertical separation of 9 IN must be maintained between all geotextiles and equipment tracks or wheels.

B. Seaming and Joining
   1. Cushion: Join sheets without sewing but with a minimum of 4 IN longitudinal overlap.
   2. Separator: Join sheets with or without sewing or heat bonding.
      a. With Sewing: Overlap adjacent panels a minimum of 4 IN. Use Type SSa (prayer) seam and a Type 401 stitch having a minimum distance from the edge of the geotextile to the stitch line of 2.0 IN or follow recommendations of geotextile manufacturer.
      b. With Heat Bonding: Overlap adjacent panels a minimum of 4 IN. Heat bond seam must develop a minimum of 60% of the tensile strength of the parent geotextile as measured in ASTM D4632.
      c. Without Sewing or Heat Bonding (Nonwoven only): Overlap adjacent rolls or sheets a minimum of 18 IN.
   3. Protective: Join sheets with sewing or heat bonding.
      a. With Sewing: Overlap a minimum of 4 IN. Use Type SSa (prayer) seam and a Type 401 stitch having a minimum distance from the edge of the geotextile to the stitch line of 2.0 IN or follow recommendations of geotextile manufacturer.

b. With Heat Bonding: Overlap adjacent panels a minimum of 4 IN. Heat bond seam must develop a minimum of 60% of the tensile strength of the parent geotextile as measured in ASTM D4632.

C. Cushion Geotextile
1. Place geotextile directly on the geomembrane.
2. Prevent movement of LCR pipe and GT-C geotextile while placing stone.

D. Separator Geotextile
1. Place fabric directly on a relatively smooth subgrade, free of obstructions, abrupt depressions or humps, debris, or deposits of loose or soft soil.
2. Care must be taken to avoid damaging the Type GT-S geotextile during placement of the soil over the geotextile. This may require use of a thicker loose lift or a smooth drum roller to limit damage due to penetration of compactor feet.

E. Protective Geotextile
1. Place geotextile directly on #57 stone.
2. Place operational cover on either side of stone drain.
3. The Protective geotextile is tack coated after placement to limit future surface water infiltration.
   a. A cationic or anionic water based asphalt emulsion may be used as approved by the Engineer.
   b. Minimum air temperature shall be at least $50^{o}F$ and rising for placement of the tack coat.
   c. The temperature of the tack coat shall be sufficiently high to permit a uniform spray pattern. To avoid damage to the geotextile, the maximum temperature shall not exceed $325^{o}F$.
   d. The application rate shall not be less than 0.20 gallons per square yard.

3.02 CQC TESTING

A. The CQC Consultant shall confirm that the identification, storage, and handling of geotextiles is in accordance with ASTM D4873. Any deviation from this requirement will be reported to the Engineer.

B. The CQC Consultant will examine all manufacturer's certifications to ensure that the property values listed on the certifications meet or exceed these specifications. Any deviations will be reported to the Engineer.

C. Conformance Testing: The CQC Consultant shall sample the geotextiles in accordance with ASTM D4354. Sample will be sent to the CQC Geosynthetics Laboratory for the following conformance testing. Any deviations will be reported to the Engineer.

1. Cushion Geotextile
   Unit Weight (ASTM D3776)
   Grab Tensile Strength (ASTM D4632)
2. Separator Geotextile

Unit Weight (ASTM D3776)
Grab Tensile Strength (ASTM D4632)
Elongation (ASTM D4632)
Puncture Strength (ASTM D4833)
Apparent Opening Size (ASTM D4751)
Permittivity (ASTM D4491)

3. Protective Geotextile
   Unit Weight (ASTM D3776)
   Grab Tensile Strength (ASTM D4632)
   Elongation (ASTM D4632)
   Puncture Strength (ASTM D4833)

D. The CQC Consultant will observe placement of the geotextiles to confirm that the panel overlaps and seams are in accordance with these specifications. Any deviations will be reported to the Engineer.

END OF SECTION

SECTION 02999

GEOCOMPOSITE DRAINAGE LAYER

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:
   1. Geocomposite drain for all uses as shown in drawings including but not limited to:
      a. Overlying textured geomembrane liner to form the leachate collection system on the side slopes of the liner.

B. Related Sections include but are not necessarily limited to:
   1. Division 0 - Bidding Requirements, Contract Forms, and Conditions of the Contract.
   2. Division 1 - General Requirements.
   3. Section 02220 - Earthwork.
   4. Section 02775 - HDPE Geomembrane Liner.
   5. Section 02900 - Geotextile Fabric.
   6. CQA Plan.

1.02 QUALITY STANDARDS

A. Reference Standards:
   1. American Society for Testing and Materials (ASTM):
      a. ASTM D1505, Standard Test Method for Density of Plastics by the Density-Gradient Technique.
      b. ASTM D792, Standard Test Methods for Density and Specific Gravity of Plastic by Displacement.
      c. ASTM D4716, Standard Test Method for Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextiles Related Products.
      d. ASTM D1777, Standard Method for Measuring Thickness of Textile Materials.

1.03 SUBMITTALS

A. Shop Drawings:
   1. See Section 01300.
   2. Product technical data.
   3. Manufacturer's delivery, storage, handling, and installation instructions.

PART 2 - PRODUCTS

2.01 FABRICATION

A. The geocomposite drainage layer shall be formed by thermally bonding a nonwoven geotextile to both faces of a geonet. Heat boding shall

be performed by the Manufacturer prior to shipping to the site.

B. The geonet shall be manufactured by extruding multiple sets of polyethylene strands to form a three-dimension structure to provide planer water flow.

C. Both geotextiles shall be 6 oz/sq.yd. nonwoven that meet the GT-S requirements of Section 02900 of these Specifications.

D. The geonet shall be manufactured by extruding two sets of polyethylene strands to form a three-dimensional structure that provides for planer flow.

E. The geonet shall have the following minimum properties:

Property	Test Method	Minimum Value
Thickness	ASTM D1777	0.200 inch
Resin Density	ASTM D1501	0.92 g/cc
Transmissivity	ASTM D4716	2.0 gal/min./ft*

* Conduct transmissivity test at a normal compressive load of 10,000 psf and a hydraulic gradient of 0.3. Boundary conditions are soil interface on the upper geotextile and HDPE geomembrane against the lower geotextile. Allow a seating period of 24 hours.

F. Each roll of geocomposite drainage media shall have the following identification information attached:
1. Manufacturer's name.
2. Product identification.
3. Thickness (geonet only).
4. Roll number.
5. Lot number.
6. Roll dimensions.

G. The manufactured rolls of geocomposite drain shall be wrapped or otherwise protected against moisture, dust, and dirt during shipping and storage. Geocomposite drainage media damaged during shipping or storage shall be replaced at Contractor's expense.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install geocomposite drain in accordance with manufacturer's written recommendations.

B. Geocomposite drainage media shall be placed to the lines and grades shown on the contract drawings.

C. The geocomponent drainage media shall be placed only on geomembrane that has been approved by the Geomembrane Installer and accepted by the CQC Consultant.

D. The Contractor shall provide temporary anchorage of the geocomposite drainage media at the top of berms during installation to prevent movement during construction. Permanent bonding to the geomembrane is prohibited.

E. Adjacent rolls of geonet shall be overlapped at a distance of at least 3 IN and secured using polyethylene ties placed every 5 FT.

F. Any geocomposite drainage media that is torn, crushed, or punctured shall be repaired or replaced by the Contractor at no additional cost to the Owner. The repair shall consist of a patch of the same geocomposite drainage media placed over the damaged are and overlapped a minimum of 12 IN from any point of damage. The patch shall be attached to the geonet using polyethylene ties placed at least every 5 FT.

G. All soils placed over the composite drainage manner shall be placed in such a manner as to ensure:
   1. The geocomposite drainage media and the underlying geomembranes are not damaged in anyway.
   2. Minimal slippage of the geocomposite drainage media on the underlying geomembrane occurs; and
   3. No excess tensile stresses occur in the geocomposite drainage media.

2.02 QUALITY CONTROL

A. Prior to installation to the geocomposite drainage media, the CQC Consultant shall provide quality control certificates signed by the Manufacturer's quality assurance manager for every 50,000 ft2 of geocomposite drainage media to be installed.

B. The Contractor shall submit to the CQC Consultant for approval two full sets of field erection drawings showing panel layout for the geocomposite drainage media. The erection drawings shall show panel lengths, locations, overlaps, method of securing joints, jointing to penetrations as shown on the contract drawings.

END OF SECTION

SECTION 03002

CONCRETE

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:
   1. Cast-in-place concrete and grout.
   2. Concrete mixes, proportioning, and source quality control for precast concrete.

B. Related Sections include but are not necessarily limited to:
   1. Division 0 - Bidding Requirements, Contract Forms, and Conditions of the Contract.
   2. Division 1 - General Requirements.
   3. Section 03431 - Precast Concrete.

1.02 QUALITY STANDARDS

A. Referenced Standards:
   1. American Concrete Institute (ACI):
      a. SP-19, Cement and Concrete Terminology.
      b. 211.1, Standard Practice for Selecting Proportions for Normal and Heavyweight Concrete.
      c. 212.1R, Admixtures for Concrete.
      d. 212.2R, Guide for Use of Admixtures in Concrete.
      e. 214, Recommended Practice for Evaluation of Compression Test Results of Field Concrete.
      f. 304, Recommended Practice for Measuring, Mixing, Transporting, and Placing Concrete.
      g. 305R, Hot Weather Concreting.
      h. 306R, Cold Weather Concreting.
      i. 318, Building Code Requirements for Reinforced Concrete.
      j. 347, Recommended Practice for Concrete Formwork.
   2. American Society for Testing and Materials (ASTM):
      a. A82, Standard Specifications for Cold Drawn Steel Wire for Concrete Reinforcement.
      b. A185, Standard Specification for Welded Steel Wire Fabric for Concrete Reinforcement.
      c. A615, Standard Specification for Deformed and Plain Billet Steel Bars for Concrete Reinforcement Including Supplementary Requirements S1.
      d. C31, Standard Method of Making and Curing Concrete Test Specimens in the Field.
      e. C33, Standard Specification for Concrete Aggregates.
      f. C39, Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens.
      g. C94, Standard Specification for Ready Mixed Concrete.
      h. C138, Standard Method of Test for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete.
      i. C143, Standard Method of Test for Slump of Portland Cement

Concrete.

j. C150, Standard Specification for Portland Cement.

k. C157, Test Method for Length Change of Hardened Hydraulic Cement Mortar and Concrete.

l. C171, Standard Specification for Sheet Materials for Curing Concrete.

m. C172, Standard Method of Sampling Fresh Concrete.

n. C173, Standard Method of Test for Air Content of Freshly Mixed Concrete by the Volumetric Method.

o. C192, Standard Method of Making and Curing Concrete Test Specimens in the Laboratory.

p. C231, Standard Method of Test for Air Content of Freshly Mixed Concrete by the Pressure Method.

q. C260, Standard Specification for Air Entraining Admixtures for Concrete.

r. C289, Test Method for Potential Reactivity of Aggregates (Chemical Method).

s. C309, Standard Specification for Liquid Membrane Forming Compounds for Curing Concrete.

t. C494, Standard Specification for Chemical Admixtures for Concrete.

v. C496, Standard Method of Test for Splitting Tensile Strength of Cylindrical Concrete Specimens.

w. C595, Specification for Blended Hydraulic Cements.

x. C618, Standard Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete.

y. E329, Standard Recommended Practice for Inspection and Testing Agencies for Concrete, Steel, and Bituminous Materials as Used in Construction.

3. Federal Specification (FS):
   a. TT-S-227b, Sealer Compound; Rubber Base, Two Component.
   b. LLL-B-810B, Building Board, (Hardboard) Hard Pressed, Vegetable Fiber.

4. Corps of Engineers: Specification CRD-C572 Polyvinyl Waterstops.

B. Quality Control:

1. Concrete testing agency.
   a. Contractor to employ and pay for services of a testing laboratory to:
      1) Perform materials evaluation.
      2) Design concrete mixes.
   b. Concrete testing agency to meet requirements of ASTM E329.

2. Do not begin concrete production until proposed concrete mix design has been approved by Engineer.
   a. Approval of concrete mix design by Engineer does not relieve Contractor of his responsibility to provide concrete that meets the requirements of this Specification.

3. Adjust concrete mix designs when material characteristics, job conditions, weather, strength test results or other circumstances warrant.

a. Do not use revised concrete mixes until submitted to and approved by Engineer.

C. Qualifications: Ready mixed concrete batch plant certified by National Ready Mixed Concrete Association (NRMCA).

1.03 DEFINITIONS

A. Per ACI SP-19 except as modified herein:
1. Concrete fill: Non-structural concrete.
2. Concrete Testing Agency: Testing agency employed to perform materials evaluation, design of concrete mixes or testing of concrete placed during construction.
3. Exposed concrete: Exposed to view after construction is complete.
4. Indicated: Indicated by Contract Documents.
5. Lean concrete: Concrete with low cement content.
6. Nonexposed concrete: Not exposed to view after construction is complete.
7. Required: Required by Contract Documents.
8 Specified strength: Specified compressive strength at 28 days.
9. Submitted: Submitted to Engineer.

1.04 SUBMITTALS

A. Shop Drawings:
1. See Section 01300.
2. Concrete mix designs proposed for use. Concrete mix design submittal to include the following information:
a. Sieve analysis and source of fine and coarse aggregates.
b. Test for aggregate organic impurities.
c. Test for deleterious aggregate per ASTM C289.
d. Proportioning of all materials.
e. Type of cement with mill certificate for cement.
f. Type of fly ash with certificate of conformance to specification requirements.
g. Slump.
h. Air content.
i. Brand, type, ASTM designation, and quantity of each admixture proposed for use.
j. 28-day cylinder compressive test results of trial mixes per ACI 318 and as indicated herein.
k. Shrinkage test results.
l. Standard deviation value for concrete production facility.
3. Manufacturer and type of joint filler, joint sealant, curing agent and chemical floor hardener.
4. Manufacturer and type of bonding and patching mortar and bonding adhesive used at construction joints.
5. Manufacturer and type of nonshrink grout and the cure/seal compound required for the nonshrink grout.
6. Reinforcing steel: Show grade, sizes, number, configuration, spacing, location and all fabrication and placement details.

a. In sufficient detail to permit installation of reinforcing without having to make reference to Contract Drawings.
b. Obtain approval of shop drawings by Engineer before fabrication.
c. Mill certificates.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Delivery:
1. Concrete:
a. Prepare a delivery ticket for each load for ready-mixed concrete.
b. Truck operator shall hand ticket to Contractor at the time of delivery. All tickets should be available for review by Engineer.
c. Ticket to show:
1) Mix identification mark.
2) Quantity delivered.
3) Amount of each material in batch.
4) Outdoor temp in the shade.
5) Time at which cement was added.
6) Numerical sequence of the delivery.
7) Amount of water added.
2. Reinforcing steel: Ship to jobsite with attached plastic or metal tags with permanent mark numbers.
a. Mark numbers to match shop drawing mark number.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following manufacturers are acceptable:
1. Nonshrink, nonmetallic grout:
a. Sika "SikaGrout 212."
b. Gifford Hill "Supreme Grout."
c. Master Builders "Masterflow 713."
d. Or equal.
2. Expansion joint fillers:
a. Permaglaze Co.
b. Rubatex Corp.
c. Williams Products, Inc.
d. Or equal.
3. Form coating:
a. Richmond "Rich Cote."
b. Industrial Lubricants "Nox-Crete Form Coating."
c. Protex "Pro-Cote."
d. Or equal.
4. Prefabricated forms:
a. Simplex "Industrial Steel Frame Forms."
b. Symons "Steel Ply."
c. Universal "Uniform."

d. Or equal.

2.02 MATERIALS

A. Portland Cement: Conform to ASTM C150 Type II

B. Fly Ash:
1. ASTM C618, Class F.
2. Nonstaining.
a. Hardened concrete containing fly ash to be uniform light gray color.
3. Maximum loss on ignition: 6 percent.
4. Compatible with other concrete ingredients.
5. Obtain proposed fly ash from a source approved by the State Highway Department in the state where the Project is located for use in concrete for bridges.
6. Do not use for precast concrete.

C. Admixtures:
1. Air entraining admixtures: ASTM C260.
2. Water reducing, retarding, and accelerating admixtures:
a. ASTM C494 Type A through E.
b. Conform to provisions of ACI 212.1R and ACI 212.2R.
c. Do not use retarding or accelerating admixtures unless specifically approved in writing by Engineer and at no cost to Owner.
d. Follow manufacturer's instructions.
e. Use chloride free admixtures only.
3. Maximum total water soluble chloride ion content contributed from all ingredients of concrete including water, aggregates, cementitious materials and admixtures by weight percent of cement:
a. 0.06 prestressed concrete.
b. 0.10 all other concrete.
4. Do not use calcium chloride.
5. Pozzolanic admixtures: ASTM C618.
6. Provide admixtures of same type, manufacturer and quantity as used in establishing required concrete proportions in the mix design.

D. Water: Potable, clean, free of oils, acids and organic matter.

E. Aggregates:
1. Normal weight concrete: ASTM C33, except as modified below.
2. Fine aggregate: Clean natural sand.
a. No manufactured or artificial sand.
3. Coarse aggregate: Crushed rock, natural gravel, or other inert granular material.
a. Maximum amount of clay or shale particles: 1 percent.
4. Gradation of coarse aggregate:
a. Lean concrete and concrete topping: Size #7.
b. All other concrete: Size #57 or #67.
5. Coarse aggregate for lightweight concrete: ASTM C330.

a. Maximum size: 3/4 IN.

F. Concrete Grout:
1. Nonshrink nonmetallic grout:
a. Nonmetallic, noncorrosive, nonstaining, premixed with only water to be added.
b. Grout to produce a positive but controlled expansion.
c. Mass expansion not to be created by gas liberation.
d. Minimum compressive strength of nonshrink grout at 28 days: 6500 psi.

G. Reinforcing Steel:
1. Reinforcing bars: ASTM A615, Grade 60.
a. Provide with epoxy coating per ASTM A775.
2. Welded wire fabric: ASTM A185.
a. Minimum yield strength: 60,000 psi.
3. Column spirals: ASTM A82.

H. Forms:
1. Prefabricated or job built.
2. Plywood: PS1, waterproof, resin bonded, exterior-type Douglas Fir.
a. Face adjacent to concrete Grade B or better.
3. Fiberboard: Fed Spec LLL-B-810, Type IX, tempered, waterproof, screen back, concrete form hardboard.
4. Lumber: Straight; uniform width and thickness; and free from knots, offsets, holes, dents, and other surface defects.
5. Chamfer strips: Clear white pine, surface against concrete planed.
6. Form ties: Removable end, permanently embedded body type with cones on outer ends not requiring auxiliary spreaders.
a. Cone diameter: 3/4 IN minimum to 1 IN maximum.
b. Embedded portion 1 IN minimum back from concrete face.
c. If not provided with threaded ends, constructed for breaking off ends without damage to concrete.
7. Form release: Nonstaining and shall not prevent bonding of future finishes to concrete surface.
a. Nontoxic 30 days after application.

I. Chairs, Runners, Bolsters, Spacers, and Hangers:
1. Stainless steel, epoxy coated, or plastic coated metal.
a. Plastic coated: Rebar support tips in contact with the forms only.

J. Expansion Joint Filler:
1. Asphalt impregnated fiber type.

2.03 CONCRETE MIXES

A. General:
1. All concrete to be ready mixed concrete conforming to ASTM C94.
2. Provide concrete of specified quality capable of being placed

without segregation and, when cured, of developing all properties required.

3. All concrete to be normal weight concrete.

B. Strength:

1. Provide specified strength and type of concrete for each use in structure(s) as follows:

TYPE	WEIGHT	SPECIFIED STRENGTH*
Precast Concrete	Normal weight	5000 psi
All other Concrete	Normal weight	4000 psi

*Minimum 28-day compressive strength.

C. Air Entrainment: Provide air entrainment in all concrete resulting in a total air content percent by volume as follows:

MAX AGGREGATE SIZE	TOTAL AIR CONTENT PERCENT
1 IN or 3/4 IN	5 to 7
1/2 IN	6 to 8

1. Air content to be measured in accordance with ASTM C231, ASTM C173, or ASTM C138.

D. Slump: 4 IN maximum, 1 IN minimum.

1. Measured at point of discharge of the concrete into the concrete construction member.
2. Pumped concrete: Provide concrete with appropriate mix design so that slump of concrete at discharge end of pump hose does not exceed maximum slump specified above.
3. Determine slump per ASTM C143.

E. Selection of Proportions:

1. General - Proportion ingredients to:
   a. Produce proper workability, durability, strength, and other required properties.
   b. Prevent segregation and collection of excessive free water on surface.
2. Minimum cement contents and maximum water cement ratios for concrete to be as follows:

	MINIMUM CEMENT, LB/CY			
SPECIFIED STRENGTH	MAXIMUM AGGREGATE SIZE, IN 1/2	3/4	1	MAXIMUM WATER CEMENT RATIO BY WEIGHT
3000	---	517	517	0.45
4000	611	611	611	0.45
5000	---	686	665	0.40

3. Substitution of fly ash:
   a. Maximum of 15 percent by weight of cement at rate of 1 LB fly ash for 1 LB of cement.
4. Submit mix design data as required by this specification section.
5. Normal weight concrete: Proportion mixture to provide desired characteristics using one of methods described below:
   a. Method 1 (Trial Mix): Per ACI 318, Chapter 5, except as modified herein.
      1) Air content within range specified above.
      2) Record and report temperature of trial mixes.
      3) Proportion trial mixes per ACI 211.1.
   b. Method 2 (Field Experience): Per ACI 318, Chapter 5, except as modified herein:
      1) Field test records must be acceptable to Engineer to use this method.
      2) Test records shall represent materials, proportions and conditions similar to those specified.
6. Required average strength to exceed the specified 28-day compressive strength by the amount determined or calculated in accordance with the requirements of paragraph 5.3 of ACI 318 using the standard deviation of the proposed concrete production facility as described in paragraph 5.3.1 of ACI 318.

PART 3 - EXECUTION

3.01 FORMING AND PLACING CONCRETE

A. General:
   1. Contractor is responsible for design and erection of formwork.
   2. Construct formwork so that concrete members and structures are of correct size, shape, alignment, elevation and position.
      a. Allowable tolerances: As recommended in ACI 347.

B. Openings: Provide openings in formwork to accommodate work of other trades.
   1. Accurately place and securely support items built into forms.

C. Chamfer Strips: Place 3/4 IN chamfer strips in forms to produce 3/4 IN wide beveled edges on permanently exposed corners of members.

D. Reinforcement:
   1. Position, support and secure reinforcement against displacement.
   2. Locate and support with chairs, runners, bolsters, spacers and hangers, as required.
   3. Set wire ties so ends do not touch forms and are directed into concrete, not toward exposed concrete surfaces.
   4. Lap splice lengths: ACI 318 Class B top bar tension splices unless indicated otherwise on the Drawings.
   5. Extend reinforcement to within 2 IN of concrete perimeter

edges.
a. If perimeter edge is earth formed, extend reinforcement to within 3 IN of the edge.

6. Unless otherwise indicated, provide minimum concrete cover as follows:
a. Concrete deposited against earth: 3 IN.
b. Formed surfaces exposed to weather or in contact with earth: 2 IN for reinforcing bars #6 or larger; 1-1/2 IN for reinforcing bars less than #6.
c. Formed surfaces exposed to or located above any liquid: 2 IN.
d. Interior surfaces: 1-1/2 IN for beams, girders and columns; 3/4 IN or bar diameter, whichever is greater, for slabs, walls and joists.

7. Do not weld reinforcing bars.

8. Welded wire fabric:
a. Install welded wire fabric in maximum practical sizes.
b. Splice sides and ends with a splice lap length measured between outermost cross wires of each fabric sheet not less than:
1) One spacing of cross wires plus 2 IN.
2) 1.5 x development length.
3) 6 IN.
c. Development length: ACI 318 basic development length for the specified fabric yield strength.

E. Construction, Expansion, and Contraction Joints:
1. Provide at locations approved by the Engineer.
2. At least 48 HRS shall elapse between placing of adjoining concrete construction.
3. Thoroughly clean and remove all laitance and loose and foreign particles from construction joints.
4. Before new concrete is placed, coat all construction joints with an approved bonding adhesive used and applied in accordance with manufacturer's instructions.

F. Embedments:
1. Set and build in anchorage devices and other embedded items required for other work that is attached to, or supported by concrete.
2. Use setting diagrams, templates and instructions for locating and setting.

G. Preparation:
1. Clean and adjust forms prior to concrete placement.
2. Tighten forms to prevent mortar leakage.
3. Coat form surfaces with form release agents prior to placing reinforcing bars in forms.

H. Placing Concrete:
1. Place concrete in compliance with ACI 304 and 304.2R.
2. Place in a continuous operation within planned joints or sections.

3. Begin placement when work of other trades affecting concrete is completed.
4. Place concrete by methods which prevent aggregate segregation.
5. Do not allow concrete to free fall more than 4 FT.
6. Where free fall of concrete will exceed 4 FT, place concrete by means of tremie pipe or chute.

I. Consolidation:
1. Consolidate all concrete using mechanical vibrators supplemented with hand rodding and tamping, so that concrete is worked around reinforcement and embedded items into all parts of forms.

J. Protection:
1. Protect concrete from physical damage or reduced strength due to weather extremes.
2. In cold weather comply with ACI 306R except as modified herein.
   a. Do not place concrete on frozen ground or in contact with forms or reinforcing bars coated with frost, ice or snow.
   b. Minimum concrete temperature at the time of mixing:

OUTDOOR TEMPERATURE AT PLACEMENT (IN SHADE)	CONCRETE TEMPERATURE AT MIXING
Below 30 DegF	70 DegF
Between 30-45 DegF	60 DegF
Above 45 DegF	50 DegF

   c. Do not place heated concrete that is warmer than 80 DegF.
   d. If freezing temperatures are expected during curing, maintain the concrete temperature at or above 50 DegF for 7 days or 70 DegF for 3 days.
   e. Do not allow concrete to cool suddenly.
3. In hot weather comply with ACI 305R except as modified herein.
   a. At air temperature of 90 DegF and above, keep concrete as cool as possible during placement and curing.
   b. Do not allow concrete temperature to exceed 70 DegF at placement.
   c. Prevent plastic shrinkage cracking due to rapid evaporation of moisture.
   d. Do not place concrete when the actual or anticipated evaporation rate equals or exceeds 0.2 LBS/SF/HR as determined from ACI 305R, Figure 2.1.5.

K. Curing:
1. Begin curing concrete as soon as free water has disappeared from exposed surfaces.
2. Cure concrete by use of moisture retaining cover, burlap kept continuously wet or by membrane curing compound.
3. Provide protection as required to prevent damage to concrete and to prevent moisture loss from concrete during curing period.
4. Provide curing for minimum of 7 days.

5. Form materials left in place may be considered as curing materials for surfaces in contact with the form materials except in periods of hot weather.
6. In hot weather follow curing procedures outlined in ACI 305R.
7. In cold weather follow curing procedures outlined in ACI 306R.
8. If forms are removed before 7 days have elapsed, finish curing of formed surfaces by one of above methods for the remainder of the curing period.
9. Curing vertical surfaces with a curing compound: Cover vertical surfaces with a minimum of two coats of the curing compound.
   a. Allow the preceding coat to completely dry prior to applying the next coat.
   b. Apply the first coat of curing compound immediately after form removal.
   c. Vertical surface at the time of receiving the first coat shall be damp with no free water on the surface.
   d. A vertical surface is defined as any surface steeper than 1 vertical to 4 horizontal.

3.02 CONCRETE FINISHES

A. Tolerances:
   1. Class A: 1/8 IN in 10 FT.
   2. Class B: 1/4 IN in 10 FT.

B. Surfaces Exposed to View:
   1. Remove fins and projections, and patch voids, air pockets, and honeycomb areas with cement grout.
   2. Fill tie holes with nonshrink nonmetallic grout.

C. Surfaces Not Exposed to View:
   1. Patch voids, air pockets and honeycomb areas with cement grout.
   2. Fill tie holes with nonshrink nonmetallic grout.

D. Slab Float Finish:
   1. After concrete has been placed, consolidated, struck off, and leveled, do no further work until ready for floating.
   2. Begin floating when water sheen has disappeared and surface has stiffened sufficiently to permit operation.
   3. During or after first floating, check planeness of entire surface with a 10 FT straightedge applied at not less than two different angles.
   4. Cut down all high spots and fill all low spots during this procedure to produce a surface within Class B tolerance throughout.
   5. Refloat slab immediately to a uniform sandy texture.

E. Troweled Finish:
   1. Float finish surface.
   2. Next power trowel, and finally hand trowel.
   3. Produce a smooth surface which is relatively free of defects

with first hand troweling.

4. Perform additional trowelings by hand after surface has hardened sufficiently.
5. Final trowel when a ringing sound is produced as trowel is moved over surface.
6. Thoroughly consolidate surface by hand troweling.
7. Leave finished surface essentially free of trowel marks, uniform in texture and appearance and plane to a Class A tolerance.
8. On surfaces intended to support floor coverings remove any defects of sufficient magnitude that would show through floor covering by grinding.

F. Broom Finish: Immediately after concrete has received a float finish as specified, give it a transverse scored texture by drawing a broom across surface.

3.03 GROUT

A. Preparation:
   1. Nonshrinking nonmetallic grout:
      a. Clean concrete surface to receive grout.
      b. Saturate concrete with water for 24 HRS prior to grouting.

B. Application:
   1. Nonshrinking nonmetallic grout:
      a. Mix in a mechanical mixer.
      b. Use no more water than necessary to produce flowable grout.
      c. Place in accordance with manufacturer's instructions.
      d. Completely fill all spaces and cavities below the bottom of baseplates.
      e. Provide forms where baseplates and bedplates do not confine grout.
      f. Where exposed to view, finish grout edges smooth.
      g. Except where a slope is indicated on Drawings, finish edges flush at the baseplate, bedplate, member, or piece of equipment.
      h. Protect against rapid moisture loss by covering with wet rags or polyethylene sheets.
      i. Wet cure grout for 7 days, minimum.

3.04 FIELD QUALITY CONTROL

A. Contractor will employ and pay for services of a concrete testing laboratory to perform testing of concrete placed during construction.

B. Tests During Construction:
   1. Strength test - procedure:
      a. Four cylinders, 6 IN DIA x 12 IN high, will be taken from each sample per ASTM C172 and C31.
      b. Cylinders will be tested per ASTM C39:

1) One at 7 days.
2) Two at 28 days.
3) One spare for 56 day break if requested by Engineer.

2. Strength test - frequency:
   a. Not less than one test each day concrete placed.
   b. Not less than one test for each 50 CY or major fraction thereof placed in one day.
   c. Not less than one test for each type of concrete poured.
   d. Not less than one test for each concrete structure exceeding 2 CY volume.
3. Slump test: Per ASTM C143.
   a. Determined for each strength test sample.
   b. Additional slump tests may be taken.
4. Air content: Per ASTM C231, C173, and C138.
   a. Determined for each strength test sample.
5. Temperature: Determined for each strength test sample.
6. Unit weight of lightweight concrete.
   a. Determined for each strength test sample.
   b. Sample taken at point of discharge of fresh concrete.

C. Evaluation of Tests:
1. Strength test results: Average of 28-day strength of two cylinders from each sample.
   a. If one cylinder manifests evidence of improper sampling, molding, handling, curing or testings, strength of remaining cylinder will be test result.
   b. If both cylinders show any of above defects, test will be discarded.

D. Acceptance of Concrete:
1. Strength level of each type of concrete shall be considered satisfactory if both of the following requirements are met:
   a. Average of all sets of three consecutive strength tests equals or exceeds the required specified 28-day compressive strength.
   b. No individual strength test falls below the required specified 28-day compressive strength by more than 500 psi.

3.05 SCHEDULES

A. Form Types:
1. Surfaces exposed to view:
   a. Prefabricated plywood panel forms, job-built plywood forms, or forms lined with plywood or fiberboard.
   b. Laid out in a regular and uniform pattern with long dimensions vertical and joints aligned.
   c. Produce finished surfaces free from offsets, ridges, waves, and concave or convex areas.
   d. Construct forms sufficiently tight to prevent leakage of mortar.
2. Surfaces normally submerged or not normally exposed to view:
   a. Wood or steel forms sufficiently tight to prevent leakage of mortar.

3. Other types of forms may be used:
   a. For surfaces not restricted to plywood or lined forms.
   b. As backing for form lining.

B. Grout:
   1. Nonshrinking nonmetallic grout: General use.

C. Concrete:
   1. Precast concrete: Where indicated on Drawings.
   2. Normal weight concrete: All other locations.

D. Concrete Finishes:
   1. Grout cleaned finish: Where indicated on Drawings.
   2. Slab finishes:
      a. Use following finishes as applicable, unless otherwise indicated:
         1) Troweled finish: Base slabs of structures, and equipment bases.
         2) Broom finish: Sidewalks, docks, concrete stairs, and ramps.

END OF SECTION

SECTION 03431

PRECAST CONCRETE

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:
   1. Precast concrete structures.

B. Related Sections include:
   1. Section 03002 - Concrete.

1.02 QUALITY STANDARDS

A. Referenced Standards:
   1. American Association of State Highway and Transportation Officials (AASHTO):
      a. Standard Specifications for Highway Bridges.
   2. American Concrete Institute (ACI):
      a. 315, Manual of Standard Practice for Detailing Reinforced Concrete Structures.
      b. 318, Building Code Requirements for Reinforced Concrete.
   3. American Society for Testing and Materials (ASTM):
      a. A36, Standard Specification for Structural Steel.
      b. A108, Standard Specification for Steel Bars, Carbon, Cold Finished, Standard Quality.
      c. A185, Steel Welded Wire Fabric, Plain, for Concrete Reinforcement.
      d. A496, Standard Specification for Steel Wire, Deformed, for Concrete Reinforcement.
      e. C33, Standard Specification for Concrete Aggregates.
      f. C150, Standard Specification for Portland Cement.
      g. E329, Standard Recommended Practice for Inspection and Testing Agencies for Concrete, Steel, and Bituminous Materials as Used in Construction.
   4. American Welding Society (AWS):
      a. A5.1, Standard Specification for Mild Steel Covered Arc-Welding Electrodes.
      b. A5.5, Standard Specification for Low-Alloy Steel Covered Arc-Welding Electrodes.
      c. D1.1, Structural Welding Code, Steel.
      d. D1.4, Structural Welding Code, Reinforcing Steel.
   5. Prestressed Concrete Institute (PCI):
      a. MNL-116, Manual for Quality Control for Plants and Production of Precast Prestressed Concrete Products.
      b. PCI Design Handbook Precast and Prestressed Concrete.

B. Qualifications:
   1. Provide units manufactured by plant which has regularly and continuously engaged in manufacture of units of same type as

those required for a minimum of 3 years.

2. Assure manufacturer's testing facilities meet requirements of ASTM E329.
3. Welding operators and processes to be qualified in accordance with:
   a. AWS D1.1 for welding steel shapes and plates.
   b. AWS D1.4 for welding reinforcing bars.
4. Welding operators to have passed qualification tests for type of welding required during the previous 12 months prior to commencement of welding.

1.03 DEFINITIONS

A. Installer or Applicator: Installer or applicator is the person actually installing or applying the product in the field at the Project site.

1.04 SUBMITTALS

A. Shop Drawings:
   1. See Section 01300.
   2. Product technical data including:
      a. Acknowledgement that products submitted meet requirements of standards referenced.
      b. Manufacturer's installation instructions.
      c. Sizes, types and manufacturer of neoprene bearing pads.
      d. Hardware to be utilized to support suspended appurtenances.
   3. Shop drawings and erection plans for precast units, their connections and supports showing:
      a. Member size and location.
      b. Size, configuration, location and quantity of reinforcing bars.
      c. Size and location of openings verified by Contractor.
      d. Size, number, and locations of embedded metal items and connections.
      e. Required concrete strengths.
      f. Identification of each unit using same standard marking numbers as used to mark actual units.
   4. Concrete mix design(s) including submittal information defined in Sections 03002.
   5. Copies of source quality control tests.
   6. Certification of manufacturer's testing facility qualifications.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Transport and handle units with appropriate equipment to protect from dirt, chipping and damage.

B. Do not place units in positions which will cause overstress, warp or twist.

C. Utilize lifting inserts.

D. Store off ground.

E. Place stored units so that identification marks are visible.

F. Separate stacked members by wood battens across full width of each bearing point.

G. Stack so that lifting devices are accessible and undamaged.

H. Do not use upper member of stacked tier as storage area.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Concrete:
1. Minimum 28-day compressive strength of 5000 psi.
2 Provide concrete materials and proportions as required in Section 03002.
3. Concrete color to be gray.
4. Cement: Conform to ASTM C150 Type I or III.

B. Aggregates:
1. Crushed rock indigenous to area.
2. ASTM C33, Table 2, size number 67.
3. Aggregate quality per Section 03002.

C. Water:
1. Potable, clean.
2. Free of oils, acids, and organic matter.

D. Maximum total chloride ion content contributed from all ingredients of concrete including water, aggregates, cement and admixtures measured as a weight percent of cement to not exceed 0.06 for prestressed concrete and 0.10 for all other precast concrete.

E. Reinforcing Steel and Welded Wire Fabric: See Section 03002.

F. Electrodes:
1. E70 series conforming to AWS A5.1 or A5.5 for welding steel shapes and plates.
2. E90 series conforming to AWS A5.5 for welding rebar.

G. Metal Anchors, Inserts and Anchorages: Galvanized.

2.02 ACCESSORIES

A. Provide all connection items, lifting devices, anchors, and other

items secured to or embedded in units or other work as necessary to erect, support and anchor units.

B. Provide all accessories necessary for inter-locking units.

2.03 MIXES

A. See Sections 03002.

B. Do not begin fabrication of units until concrete mix design(s) have been approved by Engineer.

2.04 DESIGN

A. General Design Requirements:
1. Design units and connections in strict accordance with ACI 318 and the PCI Design Handbook Precast and Prestressed Concrete.
2. Design units for spans, dead load of members, dead and live loads indicated on the Drawings with concentrated loads placed in their actual locations. Verify weights and locations of concentrated loads.
3. Design units taking into account reduced cross section at openings and penetrations.
4. Provide all reinforcing in units as indicated. Where not indicated, design and provide all reinforcing subject to approval of Engineer.

2.05 FABRICATION

A. Do not fabricate units until shop drawings have been approved by Engineer and returned to Contractor and support locations have been field verified by Contractor.

B. Manufacture, quality, dimensional and erection tolerances of all units to be in accordance with both PCI MNL-116 and PCI Design Handbook Precast and Prestressed Concrete.

C. Cast all members in smooth rigid forms which will provide straight, true members of uniform thickness and uniform color and finish.

D. Use sand cement grout mixture to fill all air pockets and voids, and to repair chipped edges.

E. Finish all repairs smooth and to match adjacent surface texture and color.

F. Finish all horizontal surfaces subject to foot traffic with a broom finish.

G. Incorporate embedded plates, angles, lifting hardware, and flange welding strips into members at time of manufacture.

1. Provide manufacturer's standard flange welding strips provided such welding strips are approved by Engineer and are required by the Drawings.

H. Cast openings larger than 6 IN SQ or 6 IN DIA in units at time of manufacture. Make smaller openings by neat cutting or neat drilling by trades requiring them. Coordinate sizes and locations of all openings before fabrication of units.

I. Weld steel shapes and plates per AWS D1.1 and reinforcing steel per AWS D1.4.

J. Minimum concrete compressive strength at 28 days: All precast - 5000 psi.

K. Mark each unit as indicated on the erection plans. Place mark on non-exposed-to-view surface.

L. Curing: See Section 03002.

M. Design Criteria:
1. Provide engineering design performed by a registered professional Structural Engineer, licensed in the State and bearing their seal, as a part of this work.
2. Design and provide internal reinforcing and all embedded lifting device connections to withstand all erection forces.
3. Reinforce panels with reinforcing bars according to design criteria.

2.06 SOURCE QUALITY CONTROL

A. During production of precast concrete units, conduct strength tests of concrete placed in units as required in Specification Section 03002 for concrete placed during fabrication. Results of strength tests to be sent immediately to Engineer, Contractor and Owner. Test reports to indicate units they represent.

B. When approved by Engineer, strength tests may be made by precast manufacturer after he has submitted certification that his testing facilities meet the requirements of ASTM E329.

PART 3 - EXECUTION

3.01 PREPARATION

A. Verify acceptability and location of supports to receive units. Check bearing surfaces to determine that they are level and uniform.

B. Verify compressive strengths of concrete and masonry supports. Do not start erection of units until supports have reached their 28-day required compressive strengths.

3.02 ERECTION, INSTALLATION, APPLICATION

A. Contractor is responsible for all dewatering measures required for base soil preparation and for the correct bearing conditions needed for each precast structure.

B. Give consideration to possible lack of stability or capacity of partially completed frame or structure.

C. Contractor to be responsible for guying, shoring, and bracing of frame, walls and individual members as necessary to resist forces due to wind, erection, or any other source that may occur before a structure is completed.

D. Use only erection equipment adequate for placing units at lines and elevations indicated on Drawings. Do not damage units or existing construction during erection. Erect units using lifting handles or inserts cast into the units.

E. Weld steel shapes and plates per AWS D1.1 and reinforcing steel per AWS D1.4.

F. Patch defective concrete surfaces in accordance with method approved by Engineer.

3.03 FIELD QUALITY CONTROL

A. Causes for rejection of units include, but are not necessarily limited to the following:
   1. Cracked units.
   2. Chipped, broken, or spalled edges.
   3. Units not within allowable casting tolerances.
   4. Voids or air pockets which, in opinion of Engineer, are too numerous or too large.
   5. Non-uniform finish or appearance.
   6. Low concrete strength.
   7. Improperly placed embedded items and/or openings.
   8. Exposed wire mesh or reinforcing.

B. Do not stack sections concrete-to-concrete, but use wood separator strips or pads to prevent damage.

C. On initial delivery of all precast units, the Contractor shall inspect each, and accept or reject each, and shall call upon the Engineer for opinion if he deems it necessary to do so. A written record of acceptance or rejection of delivered precast parts shall always be entered into the daily construction log.

D. Replace any unit which exhibits damage to surfaces, finish, corners or edges which will be exposed to view after setting in place, or which is broken or cracked due to shrinkage, temperature, transportation, handling or erection, except, that when approved

in writing by Engineer unit may be repaired in place. Perform such work at no additional expense to Owner.

E. Acceptance of repaired unit, repaired pursuant to written approval, is contingent upon repairs being skillfully done so as to be sound, permanent, flush with adjacent surfaces and of color and texture matching similar adjoining surfaces and showing no apparent line of demarcation between original and repaired work. Remove and replace other work damaged by removal of defective panel members at no additional cost to Owner.

3.04 CLEANING

A. Leave units clean, free of traces of cleaning compound.

END OF SECTION

SECTION 15060

PIPE AND PIPE FITTINGS: GENERAL

PART 1 - GENERAL

1.01 DESCRIPTION

A. General:
1. Furnish all labor, materials, tools, equipment and services for all pipe and pipe fittings as indicated, in accordance with provisions of Contract Documents.
2. Completely coordinate with work of all other trades.
3. Although such work is not specifically indicated, furnish and install all supplementary or miscellaneous items, appurtenances and devices incidental to or necessary for a sound, secure and complete installation.

B. Work required within the project consists of, but is not necessarily limited to the following piping systems:
1. Leachate collection and header piping systems (within lined areas).
2. Leachate gravity header piping (outside lined areas).
3. Culverts.

1.02 QUALITY STANDARDS

A. Related requirements:
1. Section 01300: Submittals
2. Section 02221: Trenching, Backfilling and Compacting
3. Section 03431: Precast Concrete
4. Section 15064: Pipe: Plastic

B. Refer to accompanying CQA/CQC Plan.

1.03 SUBMITTALS

A. See Section 01300.

B. Verify on shop drawings dimensions, schedule of pipe, fittings, hangers, supports and miscellaneous appurtenances. When special fittings are necessary, verify locations of items and include complete details.

C. As work progresses and again when work is complete, submit "As-Recorded" drawings of piping systems including project items and pre-existing items. Identify complete location, elevation, description of piping systems. Relate piping systems to identified structures and appurtenances.

D. Submit written verification of required quality control testing.

PART 2 - PRODUCTS

2.01 GENERAL PIPING SCHEDULE

A. Unless otherwise shown on drawings, piping system materials, fittings and appurtenances are subject to requirements of specific technical specifications and shall be as follows:

Service Category	Size Range	Piping System
Leachate Collection	all sizes	HDPE
Leachate Gravity Header Piping	all sizes	HDPE
Culverts	all sizes	RCP or CMP

PART 3 - EXECUTION

3.01 DELIVERY, INSPECTION AND STORAGE

A. Inspect materials thoroughly upon arrival. Remove damaged or rejected materials from site.

B. Observe manufacturer's directions for delivery and storage of materials and accessories.

C. Store materials on site in enclosures or under protective coverings above ground to keep clean and dry.

3.02 HANDLING OF PIPE

A. Protect pipe coating during handling using methods recommended by manufacturer. Use of bare cables, chains, hooks, metal bars or narrow skids in contact with coated pipe is not permitted.

B. Prevent damage to pipe during transit. Repair abrasions, scars, and blemishes. If repair of satisfactory quality cannot be achieved, replace damaged material immediately.

C. Install piping to accurate lines and grades and support as required on drawings or described in specifications. When temporary supports are used, insure that sufficient rigidity is provided to prevent shifting or distortion of pipe. Install expansion devises as necessary to allow expansion and contraction movements.

3.03 PIPING - GENERAL

A. Minimum bury. Unless otherwise shown on the drawings, provide a

minimum of three (3) FT earth cover over exterior buried piping systems and appurtenances conveying water, fluids, or solutions subject to freezing.

3.04 PIPING WITHIN BUILDINGS, STRUCTURES AND UNITS

A. Install piping in vertical and horizontal alignment as shown on drawings.

B. Use methods of piping support as shown on drawings.

C. Locate and size sleeves required for piping system. Arrange insert or anchors at proper elevation and location.

3.05 PIPING OUTSIDE STRUCTURES

A. Install piping as shown on drawings with ample clearance and allowance for expansion or contraction.

B. Install flexible joint within two (2) FT of point where pipe enters or leaves structure. Install second flexible joint not more than six (6) FT nor less than four (4) FT from first joint. Provide balance of piping with standard laying lengths and in accordance with drawings.

3.06 PIPE INTERSECTIONS WITH STRUCTURES AND UNITS

A. Enter and exit through structure walls by using wall seals specified or as shown on drawings.

3.07 EQUIPMENT PIPE CONNECTIONS

A. Exercise care in bolting flanged joints so that there is no restraint on the opposite end of pipe or fitting which would prevent uniform gasket pressure at connection or would cause unnecessary stresses to be transmitted to equipment flanges. Where push-on joints are used in conjunction with flanged joints, final positioning of push-on joints shall not be made until flange joints have been tightened without strain.

B. Tighten flange bolts at uniform rate which will result in uniform gasket compression over entire area of joint. Provide tightening torque in accordance with manufacturer's recommendations.

C. Support and match flange faces to uniform contact over their entire face area prior to installation of any bolt between the piping flange and equipment connecting flange.

D. Permit piping connecting to equipment to freely move in directions parallel to longitudinal centerline when and while bolts in connection flange are tightened. Align, level, and wedge equipment into place during fitting and alignment of connecting piping. Grout equipment into place prior to final

bolting of piping but not before initial fitting and alignment. To provide maximum flexibility and ease of alignment, assemble connecting piping with gaskets in place and minimum of four (4) bolts per joint installed and tightened. Test alignment by loosening flange bolts to see if there is any change relationship of piping flange with equipment connecting flange. Realign as necessary to performance of alignment test, install flange bolts and make equipment connection.

E. Provide utility connections to equipment shown on drawings, scheduled or specified.

F. Obtain rough-in data from approved shop drawings on equipment.

G. Unless otherwise specified, make piping connections to equipment, including but not limited to installation of fittings, flow control valves and relief valves provided with or as integral part of equipment.

H. Provide gaskets of rubber or Teflon impregnated asbestos for flanged pipe joints not otherwise specified.

3.08 BUTT FUSION PROCEDURES

A. All perforated leachate collection piping and solid wall cleanouts and gravity header piping shall be joined using manufacturer's recommended butt-fusion procedures.

3.09 LINING-UP PUSH-ON JOINT PIPING

A. Lay piping on route lines shown. Deflect from straight alignments or grades by vertical or horizontal curves or offsets. Maximum offset between extended centerlines of any two (2) adjacent pipe lengths is as follows:

Size of Pipe	Offset Allowance
All sizes	4/D

1. Where D is diameter of pipe in inches. Offset distance is expressed as inches per lineal foot of pipe.

B. Provide special bends when specified or where required alignment exceeds allowable deflections stipulated. Install shorter lengths of pipe in such length and number that angular deflection of any joint, as represented by specified maximum deflection, is not exceeded.

3.10 LAYING PIPE IN TRENCH

A. Excavate and backfill trench in accordance with Section 02221.

B. Clean each pipe length thoroughly and inspect for compliance to

specifications. Grade trench bottom and excavate for pipe bell (as applicable) and lay pipe on trench bottom. Install gasket or joint material (as applicable) according to manufacturer's directions after joints have been thoroughly cleaned, examined, and approved by the CQA Consultant.

C. Except for first two joints, before making final connections of joints, two (2) full sections of pipe shall have been previously installed with earth tamped along side of pipe or final bedding material placed.

D. Lay pipe in only suitable weather with good trench conditions. Never lay pipe in water except where approved by the Project Manager or CQA Consultant or where intended for water crossing.

3.11 EMBEDMENT REQUIREMENTS

A. Insure that piping is adequately supported. Provide pipe bedding incorporated in Section 02221 and in accordance with drawings.

3.12 ANCHORAGE AND BLOCKING

A. Block, anchor, or harness exposed piping subjected to internal pressure, in internal pressure, in which mechanical, push-on, flexible, or similar joints are installed, to prevent separation of joints.

B. Provide reaction blocking, anchors, joint harnesses, or other acceptable means for preventing movement of piping caused by internal pressure in buried piping tees, wye branches, plugs, or bends.

C. Place concrete blocking so that it extends from fitting into solid undisturbed earth wall. Concrete blocks shall not cover pipe joints. Provide bearing area of concrete in accordance with drawings. In event that adequate support cannot be achieved against undisturbed soil, install restrained piping joints.

D. Provide reaction blocking, anchorages, or other supports for fittings as shown on drawings for piping installed in fills, unstable ground, above grade, or exposed within structures.

3.13 CLEANING

A. General:
1. Clean interior of piping systems thoroughly before installing. Maintain pipe in clean condition during installation.
2. Before jointing pipe, thoroughly clean and wipe joint contact surfaces and they properly dress and make joint.
3. Immediately prior to pressure testing, clean and remove grease, metal cuttings, dirt, or other foreign materials which may have entered the system.
4. At completion of work and prior to final acceptance,

thoroughly clean work installed under these specifications. Clean equipment,fixtures, pipe, valves, and fittings of grease, metal cuttings, and sludge which may have accumulated by operation of system, from testing or from other causes.

3.14 TESTING AND INSPECTION

A. Perform testing and inspection prior to cleaning and final acceptance. Acknowledge satisfactory performance of tests and inspections in writing to the Project Manager or CQA Consultant prior to final acceptance.

B. Types of testing and inspection to be employed for the piping systems include:
   1. Hydrostatic pressure testing.
   2. Low pressure air test.

C. Test and inspect all pipes and joints in designated sections. Provide all necessary equipment and perform all work required in connection with the tests and inspections.

D. The Contractor shall bear the cost of all testing and inspecting, locating and remedying of leaks and any necessary retesting and re-examination.

E. Hydrostatic pressure testing.
   1. Provide temporary restraints for expansion joints for additional pressure load under test. Equipment in piping system with rated pressure lower than pipe test pressure, shall be isolated by valves or blind flanges.
   2. Test piping to hydrostatic test pressure scheduled on drawings or otherwise indicated in the CQA/CQC Plan.

F. Low pressure test.
   1. For gravity piping where low pressure testing is required or noted on schedules, comply with Testing Methods outlined in these paragraph specifications for test performance unless otherwise specified in the CQA/CQC Plan. Insure all gravity sewers comply with Infiltration - Exfiltration Testing criteria after backfill and compaction are satisfied.
   2. Infiltration. Perform and observe following testing criteria and procedures. Maximum infiltration allowance is 100 gpd/IN diameter/mile.
      a. Infiltration test procedure:
         1) Plug upper section of line.
         2) Install suitable measuring device at lower end.
         3) Measure amount of water flowing through outlet over a specified period of time.
   3. Exfiltration. Perform and observe following testing criteria and procedures. Maximum exfiltration allowance is 100 gpd/IN diameter/mile.
      a. Exfiltration air test procedure:
         1) Check pneumatic plugs for proper sealing.

2) Place plugs in line at each manhole and inflate to 25 psig.
3) Introduce low pressure air into sealed line until air pressure reaches 4 psig greater than average back pressure of any ground water that may be over the pipe. Use test gage conforming to ANSI B40.1 with 0 to 15 psi scale and an accuracy of 1 percent of full range.
4) Allow two (2) minutes for air pressure to stabilize.
5) After stabilization period (3.5 psig minimum pressure in pipe) discontinue air supply to line segment.
6) Acceptable time for loss of one (1) psig of air pressure shall be:

Pipe Size (IN)	Time, Minutes/100 FT
6	0.7
8	1.2
10	1.5
12	1.8

G. Repair or replace defective joints, pieces of pipe, jointing materials, and related work and repeat pressure testing until piping in each system meets the test criteria. Additional costs to be paid by the Contractor. Caulking of screwed joints or holes will not be acceptable.

3.15 LOCATION OF BURIED OBSTACLES

A. Furnish exact location of buried utilities encountered and any below grade structures. Reference items to definitive reference point locations such as found property corners, existing structure lines and related fixed structures. Include such information as location, elevation, coverage, supports and additional pertinent information which will be required by future contractors for replacement servicing, or adjacent construction around any buried facility.

B. Incorporate information to "As-Recorded" drawings.

3.15 SPECIAL REQUIREMENTS AND PIPING SPECIALTIES

A. Heat tracing.
1. Provide electric heat tracing on pipe systems for freeze protection to locations shown on the drawings. Ensure heat tape is self-limiting, parallel circuit construction consisting of an inner core of conductive material between parallel copper bus wires, with inverse temperature-conductivity characteristics. Provide heat tracing as manufactured by Chemelex or equal.
2. Provide all necessary components such as end seals, straps, tape and fitting brackets.

3. Provide components and installations approved for Class I, Division I explosion proof service (as applicable).
4. Install each system in strict accordance with manufacturer's instructions and recommendations.
5. Provide and connect thermostats.

END OF SECTION

SECTION 15064

PIPE: PLASTIC

PART 1 - GENERAL

1.01 DESCRIPTION

A. General:

1. Work items in project include, but are not necessarily limited to the following:
   a. HDPE Leachate Collection and Header Piping.
   b. HDPE Gravity Header Piping.
   c. HDPE Force Main Piping.
   d. HDPE Cleanout Risers.
2. Furnish all labor, materials, tools, equipment, and perform all work and services necessary for or incidental to the furnishing and installation, complete, of plastic pipe, as shown on drawings and specified in accordance with provisions of the Contract Documents.
3. Completely coordinate work with that of all other trades.
4. Although such work is not specifically shown or specified, all supplementary or miscellaneous items, appurtenances, and devices incidental to or necessary for a sound, secure, complete, and compatible installation shall be furnished and installed as part of this work.

1.02 QUALITY STANDARDS

A. Refer to the following standards and include as part of these specifications:

1. PVC Materials:

ASTM D1785	Schedule 40, 80 and 120 PVC Plastic Pipe
ASTM D2412	External Loading Properties of Plastic Pipe by Parallel - Plate Loading
ASTM D2564	Solvent Cements for (PVC) Plastic Pipe, Tubing and Fittings
ASTM D2729	(PVC) Sewer Pipe and Fittings
ASTM D3034	Type PSM - PVC Sewer Pipe and Fittings
ASTM D3212	Joints

2. (HD) Polyethylene Materials:
   1) D-1505, Density
   2) D-1238, Melt Index
   3) D-790, Flexural Modulus
   4) D-638, Tensile Strength
   5) D-1693, Environmental Stress Crack
   6) D-2513, D-3261, D-2683, Molded Fittings

7) D-3350, Materials
8) F-714, Dimensions and Workmanship

C. CQA/CQC Plan (Attached to Technical Specifications).

1.03 SUBMITTALS

A. See Section 01300.

B. Verify on shop drawings dimensions, schedule of pipe, fittings, and miscellaneous appurtenances. When special fittings are necessary, verify locations of items and include complete details.

C. Render copies of any manufacturer's written instructions regarding material handling, delivery, storage, and installation.

D. As work progresses and again when work is complete, submit "As Recorded" drawings of piping systems in project including project items and pre-existing items. Identify complete location, elevation, and description of piping systems. Relate piping systems to identified structures and appurtenances.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Polyvinyl Chloride Piping (PVC)
1. Materials. Furnish materials in full compliance to the following material specification: PVC pipe shall be rigid, unplasticized polyvinyl chloride (PVC) made of PVC plastic having a cell classification of 12454-B or 12454-C as described in specification ASTM D1784.
2. Provide Schedule 80 pipe and fittings meeting or exceeding all requirements of ASTM D1785 and ASTM 2467. All joints to be socket-type.
3. Solvent cement weld joints in accordance with ASTM D2564.

B. HDPE LEACHATE PIPING (HDPE)
1. General: Provide pipe and appurtenances including perforations as shown on the Drawings.
2. Pipe: High density, high molecular weight polyethylene piping having a classification of PE 345434C.
3. Installation: All joints shall be butt fusion welds as recommended by the manufacturer and approved by the Project Manager.
4. Pipe type and sizing per drawings.

PART 3 - EXECUTION

3.01 DELIVERY AND STORAGE

A. Inspect materials thoroughly upon arrival. Examine materials for damage. Remove damaged or rejected materials from site.

B. Observe manufacturer's instructions for delivery and storage of materials and accessories.

3.02 HANDLING OF PIPE

A. Protect pipe during handling using methods recommended by manufacturer.

B. Prevent damage to pipe during transit. Replace damaged material immediately.

C. Install piping to accurate lines and grades and support as required on drawings or described in specifications. When temporary supports are used, ensure that sufficient rigidity is provided to prevent shifting or distortion of pipe.

3.03 PIPE INSTALLATION

A. Piping Outside Structures:
1. Install piping as shown on drawings with ample clearance and allowance for expansion or contraction.

B. Pipe Intersections with Structures and Units:
1. Install piping as shown on drawings and enter and exit through structure walls in accordance with penetration requirements specified on the Plans.

C. Laying Pipe in Trench:
1. Excavate and backfill trench as shown on Drawings and Technical Specifications.
2. Clean each pipe length thoroughly and inspect for compliance to specifications. Grade trench bottom and excavate for pipe bell (as applicable) and lay pipe on trench bottom. Install gasket or joint material (as applicable) according to manufacturer's directions after joints have been thoroughly cleaned and examined.
3. Lay pipe only in suitable weather with good trench conditions. Never lay pipe in water except where approved by CQA Consultant or Project Manager or intended for water crossing.
4. The Contractor shall be responsible for protection of the synthetic liner during installation of the leachate collection system piping.
5. Install pipe and fittings in accordance with ASTM D2321 or as recommended by the manufacturer for the intended application. See Drawings for bedding and backfilling conditions.

D. Bedding Requirements:
1. Ensure that piping is adequately supported. Provide pipe

bedding in accordance with Drawings and Specification Section 02221.

3.04 CLEANING

A. General Cleaning:
1. Clean interior of piping systems thoroughly of foreign matter before installing. Maintain pipe in clean condition during installation.
2. Before jointing pipe, thoroughly clean and wipe joint contact surfaces and then properly dress and make joint.
3. Immediately prior to pressure testing of PVC piping systems, clean and remove grease, dirt or other foreign materials which may have entered the system.
4. Upon completion of work and prior to final acceptance, thoroughly clean work installed under these specifications. Clean pipe, valves and fittings of debris which may have accumulated by operation of system, from testing or from other causes.

3.05 TESTING AND INSPECTION

A. Perform testing and inspection prior to cleaning and final acceptance. Acknowledge satisfactory performance of tests and inspections in writing to CQA Consultant prior to final acceptance.

B. Types of testing and inspection to be employed for the piping systems include: Low Pressure Air Test unless otherwise approved by the Project Manager and CQA Consultant.

C. Test and inspect all pipes, fittings and joints. Provide all necessary equipment and perform all work required in connection with the tests and inspections.

D. Bear the cost of all testing and inspecting, locating and remedying of Leaks, and any necessary retesting and re-examination.

E. Refer to Section 15060, Paragraph 3.13-F for low pressure test requirements.

END OF SECTION

SECTION 15066

PIPE: STAINLESS STEEL

PART 1 - GENERAL

1.01 SUMMARY

A. General work included in this Section:
   1. Stainless steel piping, fittings and appurtenances, as required to protect the cleanout riser piping.

B. Related Sections include but are not necessarily limited to:
   1. Division 0 - Bidding Requirements, Contract Forms, and Conditions of the Contract.
   2. Division 1 - General Requirements.
   3. Section 15060 - Pipe and Pipe Fittings: General.

1.02 QUALITY STANDARDS

A. Referenced Standards:
   1. American National Standards Institute (ANSI):
      a. B16.5, Pipe Flanges and Flanged Fittings.
   2. American Society for Testing and Materials (ASTM):
      a. A182, Standard Specification for Forged or Rolled Alloy Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service.
      b. A269, Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service.
      c. A312, Seamless and Welded Austenitic Stainless Steel Pipe.
      d. A320, Standard Specification for Alloy Steel Bolting Materials for Low Temperature Service.
      e. A351, Steel Castings, Austenitic, for High Temperature Service.
      f. A530, Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe.
      g. A774, As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperatures.
      h. A778, Welded Unannealed Austenitic Stainless Steel Tubular Products.
   3. American Water Works Association (AWWA).
      a. M11, Steel Pipe - A Guide for Design and Installation

1.03 SUBMITTALS

A. Shop Drawings consistent with Section 01300.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Tubing: ASTM A269.
   1. Filler material: Extra low carbon (ELC) with 0.03 percent maximum carbon.

B. Pipe:
   1. ASTM A778.
   2. ASTM A351.

C. Pipe Fittings:
   1. ASTM A774.
   2. ASTM A351

D. Nuts, Bolts and Washers:
   1. ASTM A320, Type 316.
   2. Two nuts provided for 1 IN DIA bolt applications and larger.

E. Gasket Material:
   1. Rubber or neoprene.
   2. Temperature rating of 250 DegF.

2.02 FABRICATION

A. All tube, piping, fitting product to be immersion pickled subsequent to manufacturing and fabrication operations and prior to shipping.
   1. Pickling solution of 6-10 percent nitric acid and 3-4 percent hydrofluoric acid.
   2. Temperature and exact concentrations to be such only a modest etch is produced but all oxidation and ferrous contamination is removed from metal surface.
   3. All pickling solution residues are to be neutralized after pickling.

B. Diameter tolerance and wall thickness tolerance are to conform to ASTM A530.

C. Joints.
   1. Shop welded circumferential buttweld joints.
   2. Van Stone joints using angle face rings with backing flanges.
   3. ANSI B16.1, Class 150

PART 3 - EXECUTION

3.01 EXAMINATION

A. Prior to installation, inspect and verify condition of piping and appurtenances. Installation constitutes installer's acceptance of condition for satisfactory installation.

3.02 PREPARATION

A. Correct defects or conditions which may interfere with or prevent a satisfactory installation.

B. Ensure ends of pipe to be fitted with flanges have all protrusions ground flush.

3.03 INSTALLATION

A. Install stainless steel pipe as protective casing for 6" (Nom.) Dia. HDPE cleanout riser, as shown on the drawings.

B. Embed the steel pipe within the concrete collar as shown on the drawings.

C. Provide tamper resistant locking cap pipe end, as shown on the drawings.

3.04 FIELD QUALITY CONTROL

A. Test piping systems in accordance with Section 15060.

3.05 CLEANING

A. Clean in accordance with Section 15060.

END OF SECTION

SECTION 15069

PIPE: REINFORCED CONCRETE

PART 1 - GENERAL

1.01 SUMMARY

A. Work covered by this section includes supplying and installing RCP culverts and drop inlet RCPs as shown on the Plans.

B. Related Sections include but are not necessarily limited to:
   1. Division 0 - Bidding Requirements, Contract Forms, and Conditions of the Contract.
   2. Division 1 - General Requirements.
   3. Section 02221 - Trenching, Backfilling, and Compacting.
   4. Section 03002 - Concrete.
   5. Section 03431 - Precast Concrete.
   3. Section 15060 - Pipe and Pipe Fittings: General.

1.02 QUALITY STANDARDS

A. Referenced Standards:
   1. Reinforced concrete pipe (RCP):
      a. American Society for Testing and Materials (ASTM):
         1) C76, Reinforced Concrete Culvert, Storm Drain and Sewer Pipe.
         2) C361, Reinforced Concrete Low-Head Pressure Pipe.
         3) C443, Joints for Circular Concrete Sewer and Culvert Pipe Using Flexible, Watertight, Rubber Gaskets.
      b. American Water Works Association (AWWA):
         1) C302, Reinforced Concrete Pressure Pipe, Non-Cylinder Water and Other Liquids.

   2. Installation and testing:
      a. American Water Works Association (AWWA):
         1) M9, Installation of Concrete Pipe.

B. Conduct testing methods to evaluate physical properties of pipe in full compliance with ASTM C497 "Determining Physical Properties of Concrete Pipe or Tile." Report full results test showing compliance with referenced standard.

C. Determine acceptability of RCP in all diameters and classes by appropriate ASTM plant tests, including such test to indicate specified design strengths have been met prior to shipment.
   1. Conduct three-edged bearing test as specified in AASHTO T280, or by the testing of cores in accordance with AASHTO T24. Complete bearing test prior to shipment date of lot tested.
   2. Conduct crushing test, as specified on cured concrete cylinders. Achieve specified 28-day design compressive strength prior to shipment date of lot tested.

D. Provide each pipe, fitting, special appurtenance with a plainly and permanently waterproofed, marked identification. Include but not necessarily limit markings to the following:
   1. Size and class of pipe, pressure rating in compliance with referenced standards.
   2. Date of manufacture.
   3. Manufacturer's trademark.
   4. Manufacturer's name.
   5. Full details on fittings and pipe schedule regarding angles of change, reduction.
   6. Special notations and tagging of special items in regard to line location.

1.03 SUBMITTALS

A. Shop Drawings:
   1. See Section 03431, Part 1.04,A.

B. Furnish full details of reinforcement, concrete, and joints for the straight pipe, specials, and connections.

C. Detail special fittings and appurtenances showing reinforcement, concrete, and special requirements.

1.04 DELIVERY, STORAGE AND HANDLING

A. See Section 03431, Part 1.05.

PART 2 - PRODUCTS

2.01 FABRICATION

A. Provide non-pressure service or gravity drainage piping meeting or exceeding ASTM C76, Class IV (unless otherwise approved by the Engineer) with varying lengths a minimum of 7 FT long.
   1. Each lot shall consist of a single diameter and strength designation manufactured by essentially the same process.
      a. RCP manufactured with lifting holes shall not be furnished for installation below established water table.
   2. Provide RCP for non-pressure service or gravity drainage with sealed joints using continuous rubber gaskets conforming to the requirements of ASTM (C443 or C361).
   3. Type of joint shall be spigot groove type joint with O-ring gasket (R/C) equivalent to United States Bureau of Reclamation Type R/4. Ensure that the rubber gasket will perform as the sole element to make the joint watertight. Joint material and gaskets shall conform to NCDOT Standard Specifications for Highway Construction.
   4. An alternate type of joint may be used if approved by the Engineer.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Observe all recommendations in accordance with AWWA M9 for installation, delivery, and storage of pipe material.

3.02 CONNECTIONS WITH EXISTING WORK

A. All connections made shall be performed in the same manner as the connections of the existing pipes unless otherwise approved by the Engineer.

B. All existing pipe which has been damaged shall be replaced with the same pipe using the same installation method as the existing pipe unless otherwise approved by the Engineer.

END OF SECTION

SECTION 15103

BUTTERFLY VALVES

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:
   1. Butterfly valves as included in manholes and distribution box as shown on the plans.

B. Related Sections include but are not necessarily limited to:
   1. Division 0 - Bidding Requirements, Contract Forms, and Conditions of the Contract.
   2. Division 1 - General Requirements.
   3. Section 15060 - Pipe and Pipe Fittings: General.
   4. Section 15064 - Pipe: Plastic

1.02 QUALITY STANDARDS

A. Referenced Standards:
   1. American National Standards Institute (ANSI):
      a. B16.1, Pipe Flanges and Flanged Fittings.
   2. American Society for Testing and Materials (ASTM):
      a. D2241, Specification for PVC Pressure-Rated Pipe.
      b. D2464, Specification for Threaded PVC Plastic Pipe Fittings, Schedule 80.
      c. D2466, Specifications for PVC Pipe Fittings, Schedule 40.
   3. American Water Works Association (AWWA):
      a. C504, Rubber Seated Butterfly Valves.
   4. Manufacturers Standardization Society of the Valve and Fittings Industry (MSS):
      a. SP-67, Butterfly Valves.

1.03 SUBMITTALS

A. Shop Drawings:
   1. See Section 01300.
   2. For valves 8 IN and larger, furnish "Affidavit of Compliance" with Owner in accordance with AWWA C504.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Subject to compliance with the Contract Documents, the following Manufacturers are acceptable:
   1. ASAHI.
   2. Chemtrol.
   3. George Fischer.

4. Or approved equal.

B. Submit requests for substitution in accordance with Specification Section 01630.

2.02 BUTTERFLY VALVES

A. Materials:
1. Valve bodies:
a. ASTM A126, Class B, or ASTM A536, Grade 65-45-12 ductile iron.
b. Wafer valves may be constructed of ASTM A48, Class 40 cast iron.
2. Valve shafts:
a. Stainless steel, 18-8, Type 403 or 316.
3. Valve discs:
a. Potable and nonpotable water:
1) ASTM A48, Class 40 cast iron.
2) ASTM A536, Grade 65-45-12 ductile iron.
3) ASTM A436, Type 1 alloy cast iron.
4) Bronze in accordance with AWWA C504.
b. Wastewater and similar applications:
1) ASTM A436, Type 1 alloy cast iron.
2) ASTM A536, Grade 65-45-12 ductile iron.
3) ASTM A436, Type 1 alloy cast iron.
4) Bronze in accordance with AWWA C504.
c. Air and similar applications: ASTM A48, Class 40 cast iron:
4. Valve seats and seals:
a. Potable and nonpotable water below 150 DegF:
1) Natural rubber.
b. Potable and nonpotable water and wastewater and air below 180 DegF:
1) Buna-N.
c. Heating water and air 180 to 250 DegF.
1) EPDM.

C. Design Requirements:
1. Seat type: Resilient. Comply with AWWA C504.
2. Exposed and submerged valves 3 through 20 IN.
a. Body type: Wafer or short body flange (laying length may vary from AWWA C504).
b. Working pressure: Rated for 150 psi (Class 150B per AWWA C504).
c. Equip wafer type with fully tapped anchor lugs drilled per ANSI B16.5.
3. Exposed and submerged valves 24 IN and larger:
a. Body type: Short body flange.
b. Working pressure: Rated for 150 psi (Class 150B per AWWA C504).
4. Direct buried valves:
a. All valves: Working pressure rated for 150 psi (Class 150B per AWWA C504).

PART 3 - EXECUTION

3.01 INSTALLATION

A. Refer to the construction plans for additional information and coordination with the HDPE manhole fabrication.

B. Comply with the manufacturer's installation guidelines and appropriate application recommendations.

END OF SECTION

SECTION 15900

PIPE - CORRUGATED METAL

PART 1 - GENERAL

1.01 DESCRIPTION

A. This item shall consist of furnishing, fabricating, and installing corrugated steel pipe culvert or corrugated aluminum pipe culvert of the types, classes, sizes, gauges, and dimensions as shown on the plans, at such places as are designated on the plans and profiles, or by the Engineer, in accordance with these specifications and in conformity with the lines and grades given.

B. Piping locations include, but may not be limited to:
   1. CMP culverts, and
   2. CMP risers/conduits as principal spillways in sediment basins A and B.

PART 2 - MATERIALS

2.01 GENERAL

A. Corrugated Steel Culvert Pipe and Connections: This pipe and connections shall conform to the requirements of AASHTO M 36 and AASHTO M 218.

B. Corrugated Aluminum Culvert Pipe and Connections: This pipe and connections shall conform to the requirements of AASHTO M 196.

C. Equivalent Gauges for C.M.P.s:

Specified Alum. Gauge	Min. Allowable Steel Gauge	Specified Steel Gauge	Min. Allowable Aluminum Gauge
18	18	18	14
16	18	16	12
14	16	14	12
12	12	12	8
10	12	10	None
8	10	8	None

D. Perforations: The perforations shall be located and sized in accordance with the Plans.

E. Aluminum Pipe: This pipe shall not be used in direct contact with steel pipe or other metals. Where it is necessary to repair an aluminum with steel, a proper insulation of the 2 dissimilar metals will be affected by use of a rubber or neoprene sheeting,

special fabricated coupling, or concrete expansion block or other methods as approved by the Engineer.

F. Coupling Bands: Flexible pipe shall be firmly joined by coupling bands. These bands shall be not more than two nominal sheet thicknesses lighter than the thickness of the pipe to be connected and in no case lighter than 0.052 inches. Unless specified otherwise, the Contractor shall have the option of furnishing any one of the following types of coupling bands.

1. Corrugated bands furnished and installed such that the band corrugations match and conform to the corrugations of the pipe. The gap between the pipe being joined shall be in the center of the band and shall be no wider than one corrugation width. Bands for 12-inch thru 30-inch diameter pipe shall have a minimum width of 12 inches. Bands for pipe with diameters greater than 30 inches shall have a minimum width of 22 inches.
2. Deformed sheet bands (dimple bands) furnished and installed such that the projections match and are of the same depth as the pipe corrugations. These projections shall be formed in circumferential rows with one projection for each corrugation of the helical pipe. Bands for 12-inch diameter pipe shall have a minimum width of 12 inches and shall have one circumferential row of projections for each pipe end being joined. Bands for pipe with diameters greater than 12 inches shall have a minimum width of 24 inches and shall have two circumferential rows of projections for each pipe end being joined. These bands shall be furnished and installed with gasket to provide resistance to infiltration and leakage. The gap between the pipe being joined shall be in the center of the band and shall be no wider than two inches. All bolted connections on coupling bands shall be furnished with cutwashers placed between the nut and the angle bracket, or nuts with integral washers.

G. Asphaltic or bituminous coatings shall be applied in conformance with manufacturers' requirements and NCDOT Standard Specification, as applicable.

PART 3 - EXECUTION

3.01 GENERAL

A. Equipment: All equipment necessary and required for the proper construction of culverts shall be on the project, in first class working condition. The Contractor shall provide such mechanical tampers as required to obtain the compaction of the pipe bedding and backfill as specified.

B. Excavation: The Contractor shall perform all excavation to the depth shown on the plans. The bedding for the pipe shall be so shaped that at least the lower quarter of the pipe shall be in continuous contact with the bottom of the trench. Bedding shall

be as shown on the plans.

C. Placing Pipe: The pipe shall be laid with the separate sections joined firmly together with coupling bands with outside laps of circumferential joints pointing upgrade, and with longitudinal laps on the sides. The pipe shall be laid carefully and true to lines and grades on a bed which is uniformly firm throughout its entire length. Any pipe which is not in true alignment, or which shows any undue settlement after laid or or is damaged, shall be taken up and relaid or replaced without extra compensation. Pipe shall not be laid on frozen ground.

D. Connections: Contractor shall follow manufacturer's recommendations in installing pipe connections.

E. Backfill: The trench shall be backfilled with material as specified in Section 02221.

END OF SECTION