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CONSTRUCTION PLAN APPLICATION

DUKE ENERGY CORP.
MARSHALL STEAM STATION
FLUE GAS DESULFURIZATION (FGD)
GYPSUM LANDFILL, PHASE 1
CATAWBA COUNTY, NC

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TABLE OF CONTENTS

LIST OF DRAWINGS

REGULATION-CONSTRUCTION PLAN APPLICATION
CROSS REFERENCE
Duke Power Marshall Steam Station
FGD Gypsum Landfill, Phase 1
Catawba County, NC

The proposed FGD Gypsum landfill meets the design criteria requirements of Section .0504 (2) of the Solid Waste Management Rules. The construction plan application requirements are outlined below in bold text. The text that follows each criterion describes where the information is presented.

Section .0504 (2)(a) – A map showing existing features to include: (i) existing topography of the site...;(ii) bench marks; (iii) springs; (iv) streams; (v) potential ground-water monitoring sites; (vi) pertinent geological features; and (vii) soil boring locations.

The above information is presented on Sheet 1 of 7 of S&ME's Hydrogeologic Study, Volume 2, dated August 20, 2003.

Section .0504 (2)(b) – A grading plan that provides: (i) proposed excavation contours; (ii) soil boring locations; (iii) locations and elevations of dikes or trenches; (iv) designated buffer zones; (v) diversion and controlled removal of surface water from the work areas; and (vi) proposed utilities and structures.

The above information is presented on the Cell 1 Excavation, Dwg. No. M-6024-02 and the Cell 2 Excavation, Dwg. No. M-6024-05.

Section .0504 (2)(c) – A construction plan that provides; (i) engineering design for liners, leachate collections systems; (ii) proposed final contours showing removal of surface water runoff; and (iii) locations of slope drains or other drop structures.

The above information is presented on the Cell 1 Final Configuration, Dwg. No. M-

6024-01 and Cell 1 and Cell 2 Final Configuration, Dwg. No. M-6024-06. Details of the final cover system are presented on the Final Closure Details, Dwg. No. MM 6451.00-0001.001.

Section .0504 (2)(d) – An erosion control plan that identifies the following: (i) locations of temporary erosion control measures (sediment basins, stone filters, terraces, silt fences, etc.); (ii) locations of permanent erosion control measures...; and (iii) seeding specifications and schedules.

The erosion control plans are presented on the Cell 1 Erosion & Sediment Control Plan, Cell 2 Erosion & Sediment Control Plan, Final Closure Erosion & Sediment Control Plan, and Erosion Control Details, Dwg. Nos. MM 6451.01-0001.001 through MM 6451.01-0004.001.

Section .0504 (2)(e) – Detailed diagrams showing typical sections of: (i) dikes, (ii) trenches, (iii) diversions, (iv) sediment basins, and (v) other pertinent details.

The above information is presented on the Erosion Control Details, Dwg. No. MM 6451.01-0004.001 and the Final Closure Details, Dwg. No. MM 6451.00-0001.001.

Section .0504 (2)(f) – A minimum of two cross sections per operational area showing: (i) original elevations, (ii) proposed excavated depths, (iii) proposed final elevations, (iv) ground-water elevations, and (v) soil borings.

The cross sections are presented on the Cell 1 Profile and Sections, Dwg. No. M-6024-03 and Cell 1 and Cell 2 Gypsum Fill Sections, Dwg. No. M-6024.07. The soil borings are presented on the Cross Sections, Sheet Nos. 5, 6, and 7 in S&ME's Hydrogeologic Study, Volume 2, dated August 20, 2003.

Section .0504 (2)(g) – Site development showing phases or progression of operation.

Operational phasing diagrams are presented at the end of Section 2, Operations and Maintenance Plan.

Section .0504 (2)(h)- A written report that contains the following:

(i) A copy of the deed or other legal description of the landfill site that would be sufficient as a description in an instrument of conveyance and property owner's name;

A copy of the deed for the landfill property is submitted by Duke Energy under separate cover.

(ii) Name of individual responsible for operation and maintenance of the site;

Site operations and maintenance is the responsibility of the plant supervisor, Mr. Monte Neill as presented in Section 2, Operations and Maintenance Plan, Section 2.0.

(iii) Projected use of land after completion of the sanitary landfill;

The land will be maintained as a grassed area as presented in Section 3, Closure/Post-Closure Plan, Section 1.0.

(iv) Anticipated lifetime of the project;

Phase 1 has been designed for a capacity of 5 years as presented in Section 1, Construction Plan Application Report, Section 4.2.

(v) Description of systematic usage of area, operation, orderly development and completion of the sanitary landfill;

A detailed description of the landfill operation, development, and completion are presented in Section 2, Operations and Maintenance Plan.

(vi) Earthwork calculations;

Earthwork calculations are provided in the Appendix, Calculations.

(vii) Seeding specifications and schedules;

Seeding specifications and schedules are provided on the Erosion Control Details, Dwg. No. MM 6451.01-0004.001.

(viii) Calculations for temporary and permanent erosion control measures;

Erosion control calculations are provided in the Appendix, Calculations.

(ix) Any narrative necessary to describe compliance with the Sedimentation Pollution Control Act of 1973 (15A NCAC 4);

Information regarding the Sedimentation Pollution Control Act is presented in Section 1, Construction Plan Application Report, Section 2.1 and 5.3 and in Section 2, Operations and Maintenance Plan, Section 2.2.

(x) A discussion of compliance with design requirements in Rule .0503(2) of this Section;

Section .0503(2)(a) – The concentration of explosive gases generated by the site shall not exceed; (i) twenty-five percent of the limit for the gases in site structures…; and (ii) the lower explosive limit for the gases at the property boundary;

As provided in Section 2, Operations and Maintenance Plan, Section 2.5, there are no explosive gas concerns with the gypsum waste. A passive gas venting system is designed for the final cover in order to alleviate air pressure beneath the geomembrane cap. Additional information regarding the gas venting system is presented in Section 3, Closure/Post-Closure Plan, Section 2.5 and on the Gas Venting System Plan, Dwg. No. MM 6451.00-0002.001.

Section .0503(2)(b)- A site shall not allow uncontrolled public access so as to expose the public to potential health and safety hazards at the disposal site;

Access and security requirements are presented in Section 2, Operations and Maintenance Plan, Section 2.1.

Section .0503(2)(c) – A site shall meet the following surface water requirements: (i) A site shall not cause a discharge of pollutants into waters of the state that is in violation of the requirements of the National Pollutant Discharge Elimination System (NPDES), under Section 402 of the Clean Water Act, as amended, or that is in violation of standards promulgated under G.S. 143-214.1 and G.S. 143-215; (ii) A site shall not cause a discharge of dredged material or fill material into waters of the state that is in violation of the requirements under Section 404 of the Clean Water Act, as amended, or that is in violation of any state requirements regulating the discharge of dredged or fill material into waters of the state, including wetlands; and (iii) A site shall not cause non-point source pollution of waters of the state that violates assigned water quality standards.

Information regarding surface water requirements is presented in Section 1, Construction Plan Application Report, Section 5.2, 5.3 and 5.4.

Section .0503(2)(d) – A site shall meet the following ground water requirements: (i) A site ...shall be designed so that the bottom elevation of solid waste will be a minimum of four feet above the seasonal high water table.

The separation from bottom of waste to seasonal high water table is shown on the Cell 1 Profile and Sections, Dwg. No. M-6024-03 and Cell 1 and Cell 2 Gypsum Fill Sections, Dwg. No. M-6024.07.

(ii) Operators of new industrial solid waste landfills ... shall submit to the Division a design which satisfies one of the following criteria: (A) a design that will ensure that the ground water standards established under 15A NCAC 2L will not be exceeded in the uppermost aquifer at the compliance boundary established by the Division in accordance with 15A NCAC 2L. The design shall be based upon modeling methods acceptable to the Division, which shall include, at a minimum , the following factors: (I) the hydrogeologic characteristics of the facility and surrounding lands; (II) the climatic factors of the area; and (III) the volume and physical and chemical characteristics of the leachate;

In addition to the separation from the bottom of the waste to the estimated seasonal high ground water level, a geomembrane cap is incorporated into the design of the landfill. Detailed information for the final cover design is presented in Section 3, Closure/Post-Closure Plan and Section 4, Technical Specifications for Closure.

In order to demonstrate compliance with the 2L standards, ground water modeling was performed by Duke Energy and presented under separate cover.

1

CONSTRUCTION PLAN APPLICATION

DUKE POWER

MARSHALL STEAM STATION

FLUE GAS DESULFURIZATION (FGD) GYPSUM LANDFILL, PHASE 1

CATAWBA COUNTY, NC

Prepared for:

NCDENR
Solid Waste Section
Raleigh, North Carolina

Prepared by:

Chas. H. Sells, Inc.
128 Overhill Drive, Suite 105
Mooresville, NC 28117

March 2004

NORTH CAROLINA PROFESSIONAL SEAL 17582 ENGINEER DAN E. BREWER

3/26/04

1.0 INTRODUCTION

1.1 Project Description

The Clean Smokestacks Act passed in 2002 requires significant reductions in emissions from coal-fired power plants operating in North Carolina. NC utilities must reduce the actual emissions of nitrous oxides (NO_x) by 77% by the year 2009 and must reduce actual sulfur dioxide (SO_2) emissions by 49% by the year 2009 and by 73% by 2013. As part of Duke Power's effort to meet the SO_2 reduction requirements, a Flue Gas Desulfurization (FGD) system will be installed at the Marshall Steam Station in Catawba County, NC. Duke's intent is that a large portion of the residue from this process will be utilized in beneficial products and the remainder will be placed in the proposed FGD gypsum landfill.

The FGD gypsum landfill will be located on Duke Power property, northwest of the Marshall plant and to the west of the Marshall Ash Basin. The Phase 1 landfill footprint contains approximately 33 acres. The FGD residue will be conveyed to the landfill site by truck, where the material will be spread and compacted. The landfill will begin receiving FGD residue in the summer of 2006. The volumetric capacity of the landfill is 2.19 million cubic yards.

The FGD gypsum landfill at Marshall will receive residue generated at Marshall and potentially from other Duke plants located within NC. The residue placed in the landfill will be:

1. FGD residue material that is not needed to meet the production needs of any beneficial use options.

2. FGD residue material that does not meet the specifications required for beneficial use.

3. FGD residue material that is removed from settling or clarifier stages of the associated waste water treatment facility.

1.2 Site Conditions

Marshall Steam Station is located in the Piedmont physiographic region. The footprint for the landfill contains an area of approximately 33 acres.

The FGD gypsum landfill will be located on Duke Power property, northwest of the Marshall plant and to the west of the Marshall Ash Basin. The landfill is located to the east of a railroad line, running north to south. Located to the west of this railroad line is Sherrill's Ford Road, which runs north-south along a surface water divide. Located within the landfill footprint and the railroad line is a surface water drainage feature. This feature drains to the south, to an intermittent stream that drains to Beaverdam Creek, which drains to Lake Norman. There is a topographic divide running north-northwest through the landfill footprint, along Steam Plant Road. Surface drainage to the west of Steam Plant Road drains to the drainage feature, and surface drainage to the east of Steam Plant Road drains to the Marshall Ash Basin.

2.0 LANDFILL DESIGN

2.1 Site Development

The FGD gypsum landfill consists of one five year phase containing two cells. Cell 1 and Cell 2 will have an exterior perimeter berm ranging from 10 to 32 feet in height. The exterior perimeter berms are located along the outside edge of each cell. The perimeter berms will prevent run-on from entering the landfill during development. All fill placement for the berms will be compacted to a minimum of 95 percent of the standard Proctor maximum dry density. The berms will be constructed with on-site borrow material.

A 200-foot buffer will be maintained around the entire perimeter. A 500-foot buffer will be maintained from existing residences and water supply wells. The majority of the area within the buffer will remain in its current condition.

Each cell will be constructed with a minimum 1.5 percent base grade. The subgrade, as shown on the Site Grading Plan, will be a minimum of four feet above the estimated seasonal high groundwater level and four feet above bedrock. Based on the Site Plan Application Report, excavation will be allowed within all of Cell 1 and a majority of Cell 2. Sufficient quantities of borrow material for construction is available from excavation within the landfill. Excavated material will be stockpiled for future use as intermediate and final cover.

Surface water control structures are to be sized in accordance with the North Carolina Erosion and Sedimentation Pollution Control Act. Surface water control structures located downgradient of the landfill are designed to handle a 25 year, 24-hour maximum storm event.

Access roads will be provided around the landfill perimeter for maintenance. Temporary access roads will be constructed throughout the operation of the landfill. The roads will be approximately 24 feet wide with side ditches to prevent erosion of the roadway surface. The main haul road that extends north to south will be surfaced with ABC stone to provide all weather access and limit dust.

Final cover elevations, as shown on the Final Closure Plan will be sloped no steeper than 6H:1V (horizontal to vertical) with erosion control benches. The final cover will include a 24-inch thick vegetative soil layer, a geocomposite drainage layer, a 40 mil textured LLDPE geomembrane, and an 18-inch compacted soil layer on top of the waste.

2.2 Landfill Operation

The landfill will be operated from the upgradient end to the downgradient end so that stormwater that falls into an active area will be routed to the erosion and sediment control structures.

Waste acceptance and operational procedures are presented in the FGD Gypsum Landfill Operations and Maintenance Plan, Section 2.

Closure of cells will commence once final elevations are reached. Partial closure of cells may be implemented during landfill operations. Site phasing diagrams are presented in the FGD Gypsum Landfill Operations and Maintenance Plan, Section 2.

2.3 Intermediate Cover

An 8-inch thick intermediate layer of soil will be placed on top of the waste for each ten-foot waste height. The intermediate soil layer will divert surface water from the waste.

2.4 Closure Design

The primary purpose of a landfill cap is to minimize infiltration of water into the waste.

The typical cap cross section is presented on the Final Closure Plan. As depicted on the cross section, the final closure includes a 24-inch thick vegetative cover soil layer, a geocomposite drainage layer, a 40 mil textured LLDPE geomembrane, and an 18-inch thick compacted soil layer on top of the waste. Specifics regarding the closure and post-closure activities are included in the Closure/Post-Closure Plan, Section 3.

3.0 WASTE STREAM

3.1 Types of Waste

The type of waste specified for disposal in the landfill area is FGD residue, made up primarily of gypsum (93% to 95%). Typical parameters for the residue materials to be produced at Marshall Steam Station are:

Gypsum	93% to 95%
Sulfite	0.35%
CO3	1.3%
CaF2	0.2%
Inerts	2.5% to 3.5%
Fly Ash Content	0.5% to 0.8%
pH	6.0 to 8.3
Unit Weight	76 lb/ft^3 to 97 lb/ft^3
Specific Gravity	2.35
Moisture	10% to 12%

3.2 Disposal Rates

The FGD residue generation rate projected for this facility will be on the order of 350,000 dry tons (438,000 wet weight) per year. In place density is estimated to be 1.2 tons per cubic yard (89 lbs/ft^3).

Future disposal rates may vary due to beneficial reuse or recycling efforts.

Disposal tons shall be tracked with a certified scale.

3.3 Service Area

The FGD gypsum landfill at Marshall will receive FGD residue generated at Marshall and potentially from other Duke Power plants located within North Carolina.

3.4 Equipment Requirements

The equipment used to operate the landfill include tandem and tri-axle dump trucks, D65 Komatsu dozer and/or CAT D7 dozer, watering trucks and maintenance trucks.

4.0 LANDFILL CAPACITY AND BORROW SOIL

4.1 Design Parameters

Landfill capacity calculations were performed for Phase 1 from proposed grading and closure plans using anticipated monthly disposal rate data presented previously. The calculations account for intermediate cover and the final cover. The calculations presented in the Appendix assume the waste generation rate of 350,000 dry tons (438,000 wet weight) per year.

4.2 Operating Capacity

The gross capacity for the proposed landfill will be on the order approximately 2.19 million cubic yards. Based on the anticipated waste generation rates at a density of 2400 pounds per cubic yard, the operating capacity for Phase 1 will be on the order of 5 years.

4.3 Borrow Soil Quantities

Based on the borrow soil quantity calculations presented in the Appendix, about 525,800 cubic yards of soil will be required for construction, operation and closure of Phase 1. Borrow soil from excavation within the landfill footprint will provide approximately 669,400 cubic yards of borrow soil. Excess soil will be stockpiled south of the Phase 1 footprint.

5.0 CONTAINMENT AND ENVIRONMENTAL CONTROL SYSTEMS

5.1 Groundwater Considerations

The maximum seasonal high groundwater levels and top of bedrock at the project site were used to select the maximum depth/excavation of each cell. As indicated on the Cell 1 and Cell 2 Gypsum Fill Sections, a minimum four feet separation has been maintained from the landfill subgrade elevation to the estimated seasonal high groundwater level or top of bedrock (whichever is shallower).

5.2 Nuisance and Vectors

Potential nuisances to the areas surrounding the landfill include dust and sedimentation. Dust will be minimized by use of road surfaces with aggregate and regular spraying with water. Sedimentation will be controlled with appropriate erosion and sedimentation control devices. Potential vectors are not typically a problem with FGD gypsum landfills.

5.3 Surface Water and Sedimentation Control

Surface water will be diverted from the gypsum by installing diversion channels, intermediate cover and final cover. The perimeter berms and ditches will divert overland runoff from intercepting the proposed landfill. Intermediate cover will be used to shed precipitation during development of the landfill. Positive drainage will be maintained on the soil cover surfaces. The surface will be graded to drain toward ditches and berms and routed to the erosion and sediment control structures. Surface water flowing from disturbed areas will be routed into ditches that lead to the sediment basins. The sediment basins will be designed to remove the majority of the sediment from the surface water prior to discharge into the ash basin.

5.4 Wetlands and Waters of the US

An intermittent stream and wetland area of 0.56 acres are located within the landfill footprint for Cell 2. The stream and wetland were investigated by a qualified wetlands specialist. The preliminary determination from this investigation is that the stream is classified as an unimportant intermittent stream and therefore, does not require mitigation for disturbance. The intermittent stream will be re-routed south of the future Cell 2 area as shown on the Cell 2 Grading Plan.

The preliminary determination for the wetland area was that the area does meet all the criteria to classify the area as a jurisdictional wetland. Wetland disturbance permitting for the Cell 2 area is currently being applied for through the US Army Crops of Engineers (USACOE).

According to the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map there is no 100-year floodplain within 1000 feet of the landfill footprint.

OPERATIONS AND MAINTENANCE PLAN

DUKE ENERGY

MARSHALL STEAM STATION

FLUE GAS DESULFURIZATION (FGD) GYPSUM LANDFILL PHASE 1

CATAWBA COUNTY, NC

Prepared by:

Chas. H. Sells, Inc.
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Mooresville, NC 28117

March 2004

NORTH CAROLINA
PROFESSIONAL
SEAL
17582
ENGINEER
DAN E. BREWER

3/26/04

TABLE OF CONTENTS

1.0 LANDFILL OPERATIONS AND MAINTENANCE

1.1 Introduction

The Marshall Steam Station Flue Gas Desulfurization (FGD) system will create a residue generally comprising of gypsum. Residue that cannot meet beneficial use will be landfilled in the proposed FGD Gypsum Landfill located just west of the Marshall Steam Station Plant. The landfill footprint encompasses approximately 33 acres. Phase 1 will be developed in two cells with a minimum capacity of five years.

This Operations and Maintenance Plan has been prepared in accordance with Section 0.0505 of the North Carolina Solid Waste Management Rules.

1.2 Hours of Operation

The FGD landfill will be open seven days a week, as required.

1.3 Landfill Development

The landfill will be developed within the areas shown on the Grading Plan. A 200-foot buffer will be maintained around the entire perimeter. A 500-foot buffer will be maintained from existing residences and water supply wells. The majority of the areas within the buffer will remain in its current condition.

The FGD gypsum landfill will be constructed so that excavated soil can be used for intermediate and final cover. The landfill will be developed in one 5-year phase with two cells. The site will be graded in accordance with the Grading Plan which will provide a minimum of four foot separation from waste to the estimated seasonal high groundwater level or top of bedrock (whichever is shallower). The erosion control devices for each cell as shown on the Erosion and Sediment Control Plan will be constructed prior to excavation within each cell.

Waste will be placed initially from the upgradient to the downgradient end of each cell. An initial 10-foot thickness of waste, placed in 1-foot lifts, will be placed across half the landfill cell floor working from upgradient to downgradient areas. After the initial 10 foot thickness of waste has been placed and intermediate cover installed, subsequent lifts will also proceed from the upgradient end toward the downgradient end. This procedure will continue within a permitted cell until proposed final contours are reached. The downgradient half of the cell will be placed in the same manner as the first half, using ten foot layers in 1 foot lifts from upgradient to downgradient. The final cover will consist of a minimum of 2 feet of vegetative cover soil, a geocomposite drainage layer, a 40 mil textured LLDPE geomembrane, and 18-inch thick compacted soil layer on top of the waste. The final cover will be vegetated with native grasses within six months following closure. Operational phasing diagrams for each phase of development are presented in the appendix of this Plan.

1.4 Training of Facility Personnel

Due to the diversity of job tasks required at landfills and the critical nature of the landfill components, personnel are properly trained to handle the operation and maintenance of the facility. Some of the critical tasks include:

- Equipment operations;
- Inspection and maintenance of storm water and erosion control devices;
- Accurate records of waste loading (quantitative and qualitative);
- Identification of hazardous and liquid wastes;
- Control of accidental fires; and
- Control of dust.

The proposed staff for this facility is properly trained for operation and maintenance of this type of landfill.

1.5 Waste Placement

The gypsum residue will initially be loaded at the plant onto dump trucks. Alternatively, a conveyor system will transport the waste and stockpile it adjacent to the landfill. The waste will then be loaded onto dump trucks and hauled to the landfill active face. As waste is dumped from trucks, the waste shall be spread with a dozer in lifts no greater than 12 inches. Landfilling shall proceed until half of a cell is filled to the proposed final cover elevation for that cell. The downgradient end of each cell will then be landfilled in the same manner. Soil berms will be constructed as necessary to divert run-on from entering the working face or allowing runoff to drain from active areas.

Waste shall be compacted in thin lifts with a dozer and placed on the smallest active face as feasible. The FGD waste shall be covered with a compacted layer of eight inches of intermediate cover soil at the completion of each ten feet in vertical thickness, or as specified by the Division of Waste Management.

Loads of waste that exhibit higher moisture content than anticipated shall be placed no closer than 50 feet from the active face in thin lifts and dozed into place. No waste shall be placed in areas of accumulated water.

Areas that will not have waste placed for 30 days or more shall be covered with a minimum of eight inches of intermediate soil cover, placed and compacted by a dozer. Areas not filled for 12 months or more shall be seeded with temporary seeding in accordance with the seeding specifications presented in the Erosion and Sediment Control Plan. The seeding will be provided as necessary to stabilize the cover.

1.6 Waste Acceptance

The permit requirements for the FGD gypsum landfill will allow the facility to accept the following waste types:

1. FGD residue material that is not needed to meet the production needs of any beneficial use options.
2. FGD residue material that does not meet the specifications required for beneficial use.
3. FGD residue material that is removed from settling or clarifier stages of the associated waste water treatment facility.

The Operations Manager shall notify the Division within 24 hours of attempt to dispose of any other waste products. No hazardous, liquid, or infectious waste shall be accepted or disposed of in the FGD residue landfill.

2.0 SITE OPERATIONS AND MAINTENANCE

The Duke Energy Marshall Steam Station FGD Gypsum Landfill is owned and operated by Duke Energy Corporation. Operation and maintenance of the landfill will be the responsibility of the Plant Supervisor, Mr. Monte Neill.

2.1 Access and Security Requirements

The site lies entirely within Duke Energy property. Security is currently in place that includes fencing, wooded buffers and security check stations.

Access roads to the site shall be of all weather construction and maintained in good condition.

Directional signs shall be placed along the access road to the landfill. A sign shall also be posted at the landfill that includes the permit number, hours of operation, and a statement reading, "NO HAZARDOUS OR LIQUID WASTE PERMITTED."

2.2 Erosion/Sedimentation Control Maintenance

The site is designed with erosion and sedimentation control in accordance with the requirements of the Sedimentation Pollution Control Law (15A NCAC4). Erosion/sedimentation control structures include sediment basins, outlet protection aprons and diversion ditches. Sediment basins shall be checked after periods of significant runoff and as specified in the Technical Specifications and Erosion and Sedimentation Control Plans. Sediment shall be removed to its original dimensions when the sediment accumulates to one half of the design depth. Excavated sediment shall be transported to the soil stockpile area. The sediment basins, embankments, and outlets shall also be inspected for erosion damage after each significant rainfall event. All necessary repairs shall be made immediately.

Diversion ditches shall be inspected for damage after each significant rainfall event, as specified on the Erosion and Sediment Control Plan. Riprap channels and outlet protection aprons shall be inspected for wash outs. Riprap shall be added to these areas as needed.

Embankment slopes shall be periodically inspected for erosion. These areas shall be mowed at least twice a year. The embankment slopes shall be refertilized in the second year unless vegetation growth is fully adequate. Reseed, fertilize, and mulch damaged areas immediately. Seeding, fertilizing and mulching shall be in accordance with the seeding specifications in the Erosion and Sediment Control Plan.

2.3 Stormwater Structures

All culverts and inlets shall be inspected quarterly for signs of damage, settlement, clogging, siltation build-up or washouts. Repairs to the stormwater structures shall be made as soon as possible.

2.4 Dust, Litter, Odors and Vectors

Dust generated due to landfill activities will be controlled through the application of water by truck or other approved dust control products, if necessary. Additionally, final cover will be vegetated as soon as is practical in order to minimize the blowing of dust on-site. Odors and vectors are typically not a problem at FGD gypsum landfills.

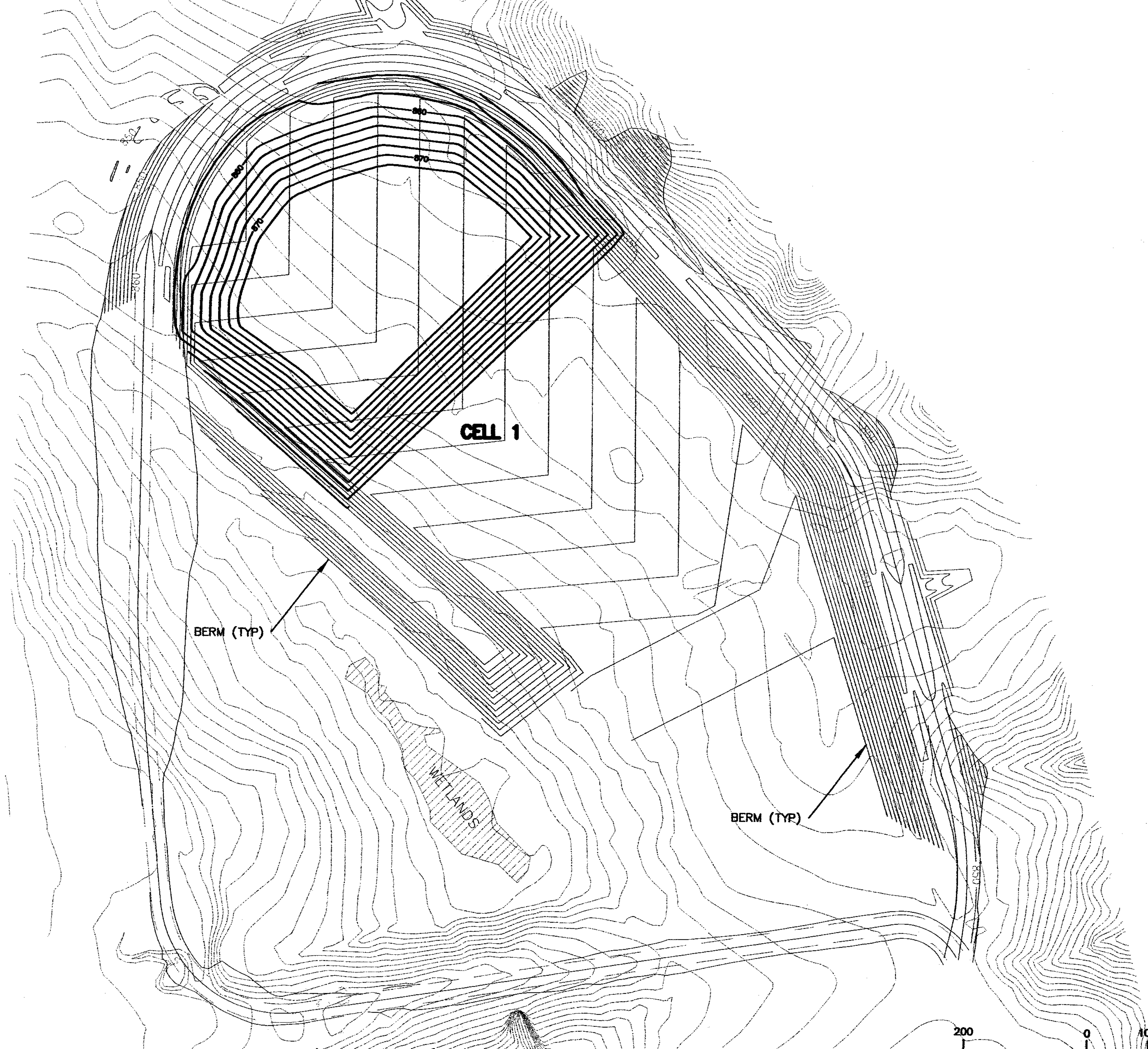
2.5 Fire Control

There are no explosive gas concerns with the gypsum waste.

The Marshall Steam Station has employees trained in fire control at the plant. In the event of fire to equipment at the landfill site, Duke's fire control personnel will be immediately dispatched.

2.6 Groundwater Monitoring Wells

Groundwater monitoring wells will be located around the landfill perimeter. Care must be taken around the wells to prevent any damage to the wells. The proposed groundwater monitoring plan including well locations, screened intervals, depths and construction details is included in the Groundwater Monitoring Plan.



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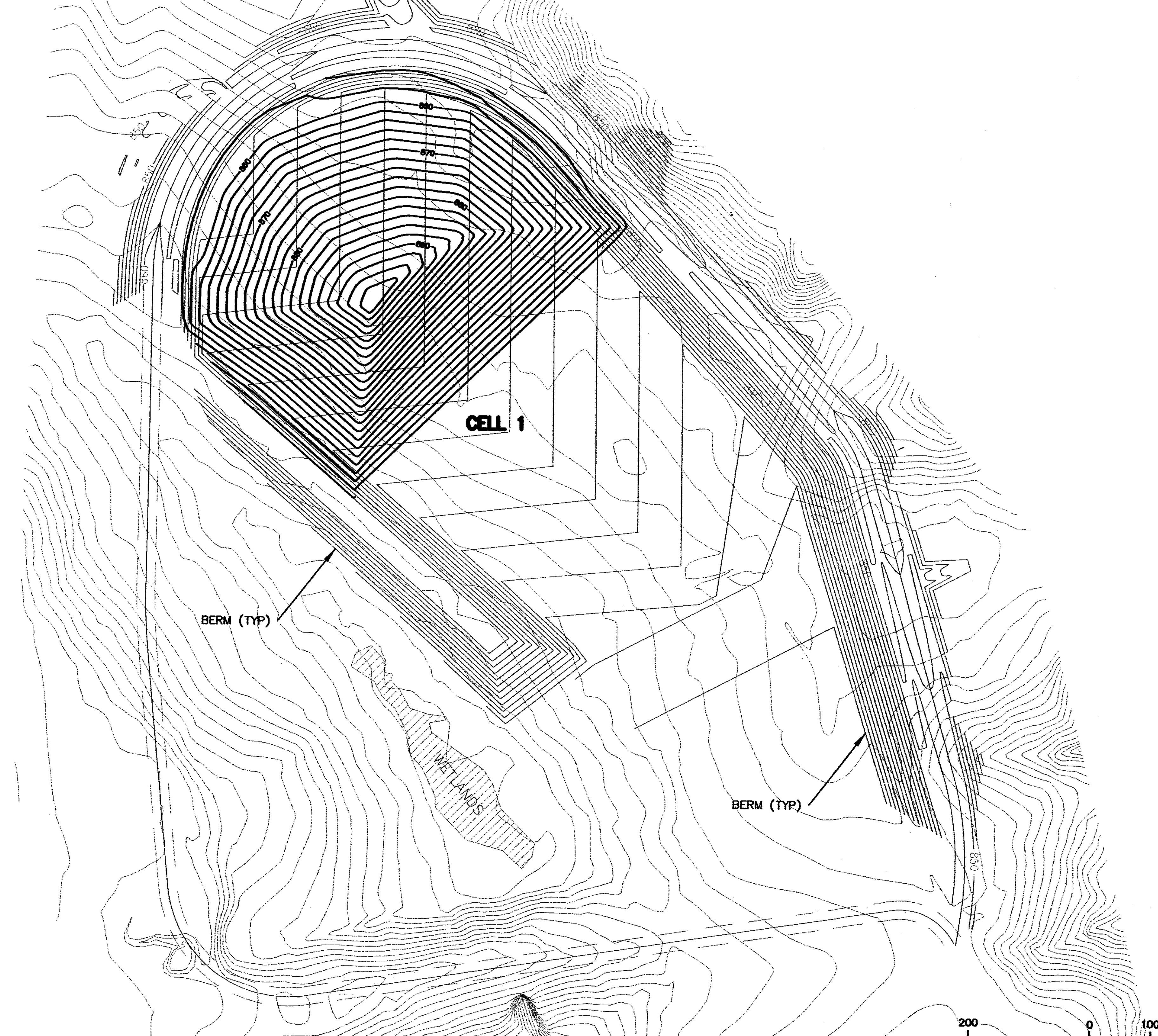
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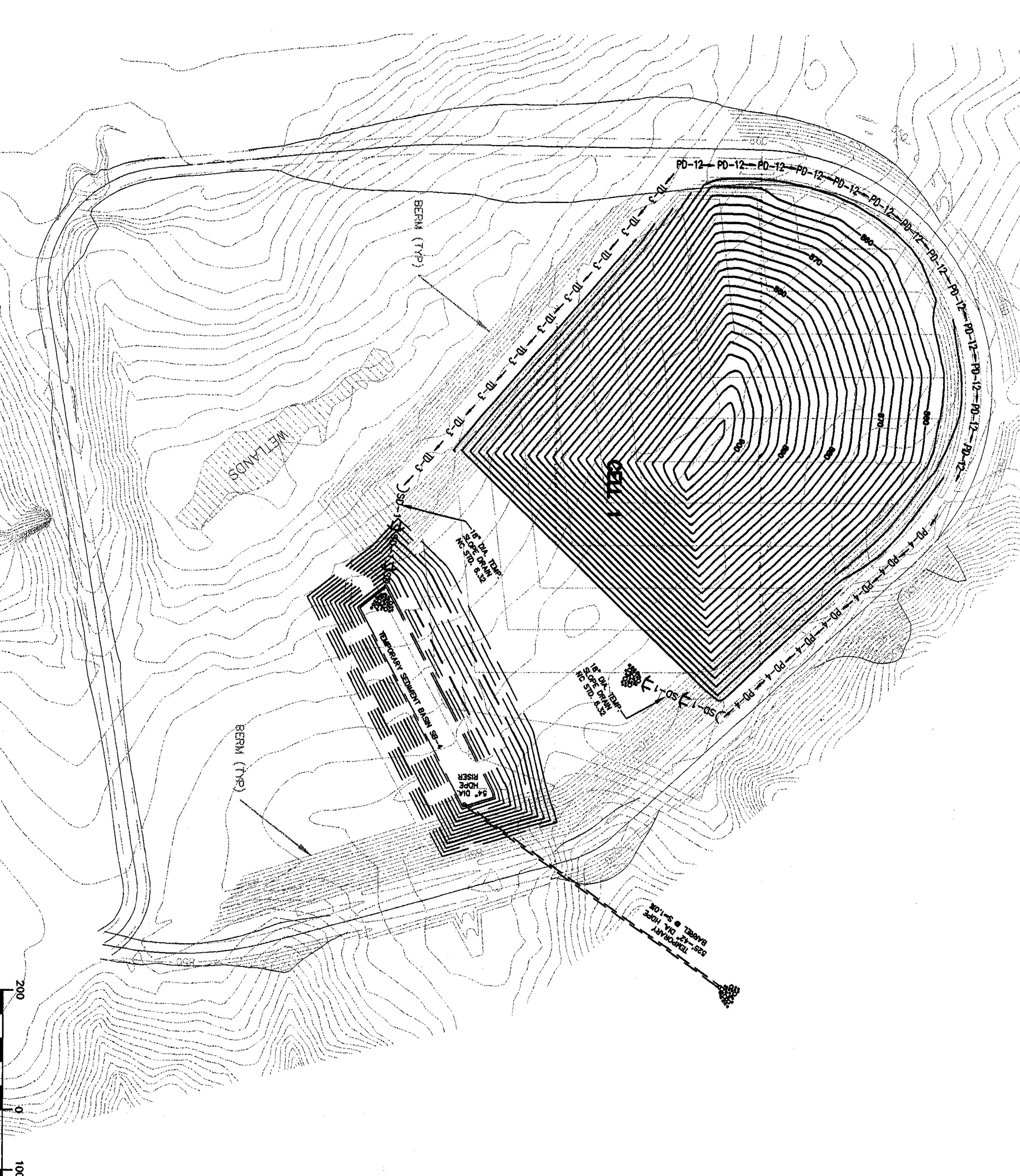

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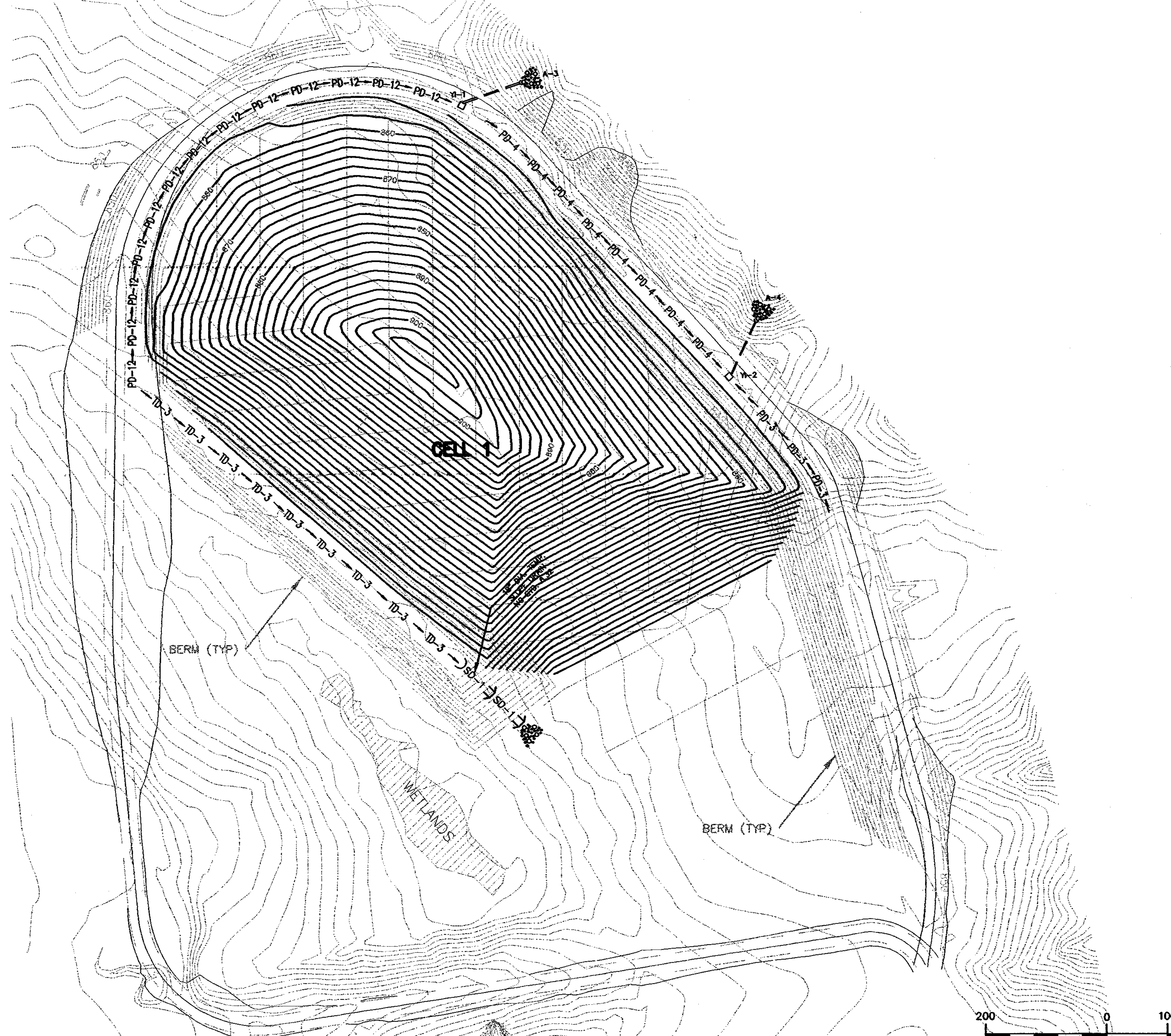
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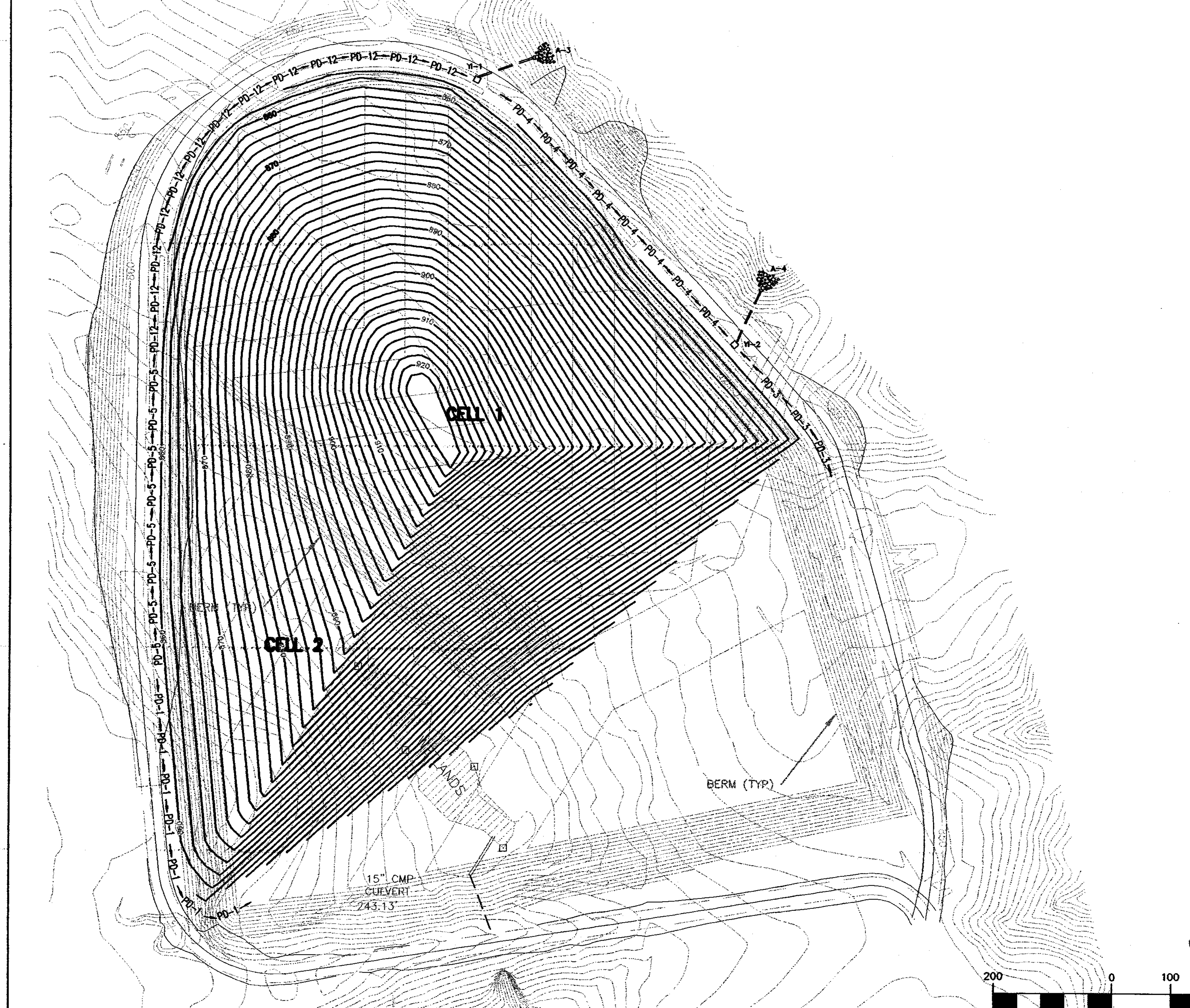
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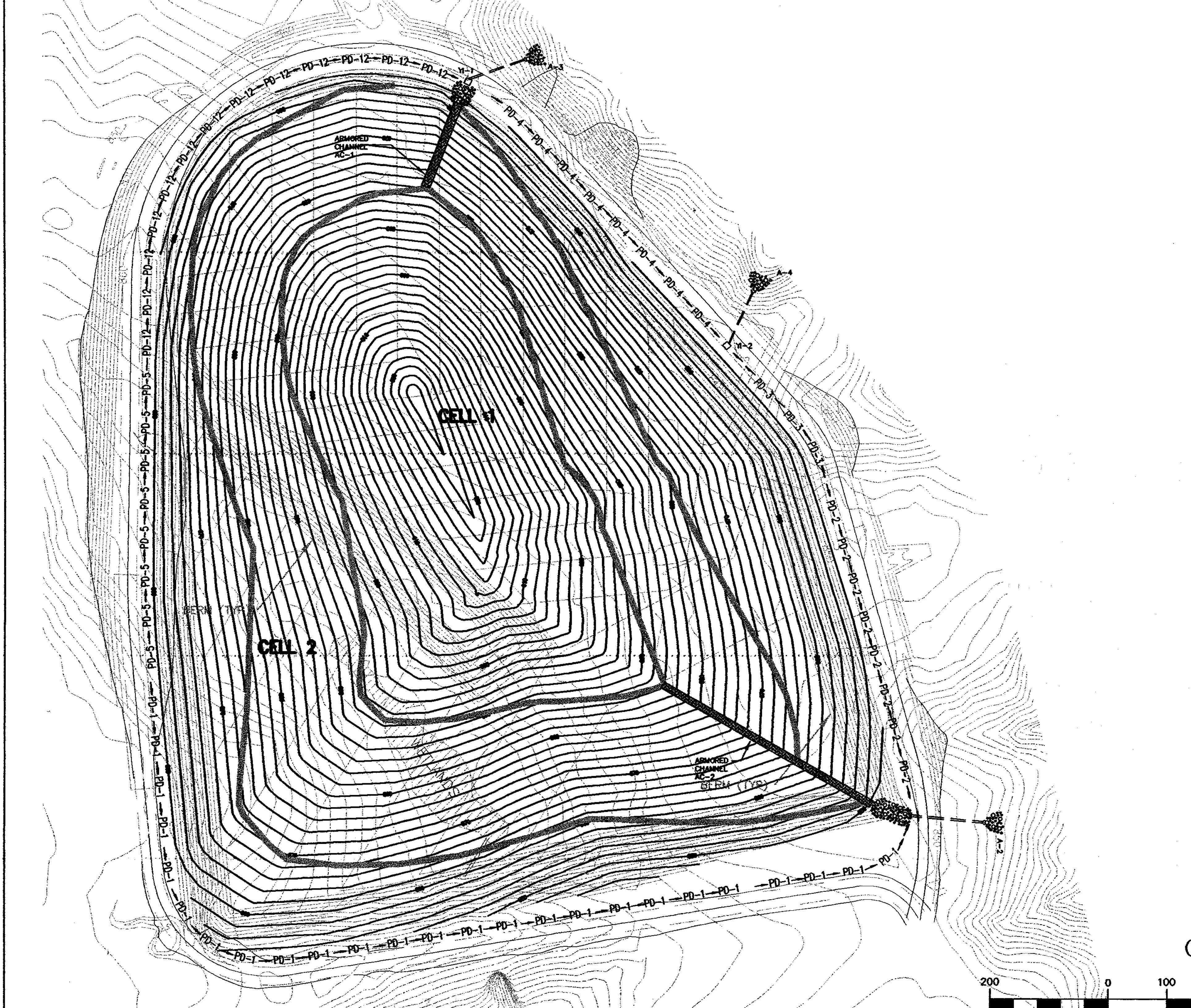
CELL 2
BERM (TYP)
15" CMP
CULVERT
243.13'
PD-1
PD-5
PD-12
PD-4
PD-3
200
0
100


CELL 1
CELL 2
ARMORED CHANNEL AC-1
ARMORED CHANNEL AC-2
BERM (TYP)
PD-1
PD-2
PD-3
PD-4
PD-5
PD-12
A-2
A-3
A-4
200
0
100

CLOSURE/POST CLOSURE PLAN

DUKE ENERGY

MARSHALL STEAM STATION

FLUE GAS DESULFURIZATION (FGD) GYPSUM LANDFILL, PHASE 1

CATAWBA COUNTY, NC

Prepared by:

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March 2004

NORTH CAROLINA PROFESSIONAL SEAL 17582 ENGINEER DAN E. BREWER

3/26/04

TABLE OF CONTENTS

1.0 INTRODUCTION

The purpose of the Closure/Post-Closure Plan is to outline the sequence for closing the landfill phase and the post-closure maintenance activities for each phase. Closure is designed to minimize the need for long term maintenance and to control the post-closure release of contaminants. Closure activities may be revised as appropriate for materials, specifications, technology advances or changes in regulations at that time.

Phasing of landfill development is designed so that final cover can be established as soon as possible. The final cover will be constructed in stages as cells of the landfill reach final grade, at the end of the cell's life. Intermediate grading, that indicate the contours prior to development of adjacent cells, is shown on the Phasing Diagrams in the Operations and Maintenance Plan. The final landfill contours will have erosion control benches and side slopes at a maximum 6H:1V. The central portion of the landfill will have a minimum 10% slope. Complete closure of Phase 1 will encompass a gross waste volume (including cover soils) of approximately 2.19 million cubic yards. Final closure of the FGD residue landfill will commence when Duke Energy declares that no more waste will be accepted or as directed by NCDENR, Division of Waste Management, Solid Waste Section.

The owner or operator shall notify the Division that a notice of intent to close the FGD gypsum landfill has been placed in the operating record. Closure activities for the FGD gypsum landfill shall begin no later than 30 days after final receipt of waste unless otherwise approved by NCDENR.

The final cover system for a completed phase will be completed within 180 days following the beginning of closure activities unless otherwise approved by NCDENR. The final cover system for the closed phase will be certified by a professional engineer as being completed in accordance with the Closure Plan. Duke Energy shall record a notation on the deed to the landfill property stating that the property has been used as a landfill and its use is restricted under the Closure Plan approved by the NCDENR Division of Waste Management. NCDENR will be notified by Duke Energy of the closure completion, certification, deed notation and placement in the operating record.

Following closure operations, the landfill will be developed as a grassed area. If the landfill must be closed prior to reaching the final contours, the surface of the landfill will be sloped to a minimum grade of 5 percent and a maximum grade of 17 percent. A final cover will be established over the landfill in accordance with the Technical Specifications for Closure, Section 4.

2.0 FINAL COVER SYSTEM

2.1 Compacted Soil Layer

The compacted soil layer will consist of an 18-inch thick compacted soil layer directly above the gypsum waste. The compacted soil layer provides a smooth surface for the geomembrane and reduces the infiltration of water into the waste.

2.2 Geomembrane

The geomembrane is a 40-mil thick, textured linear low density polyethylene (LLDPE) material. The geomembrane provides a barrier layer that reduces leachate generation.

2.3 Geocomposite

The geocomposite is a non-woven geotextile/ HDPE geonet/ non-woven geotextile composite. The geocomposite provides a drainage layer for water that percolates through the vegetative soil layer. The geocomposite also reduces the build-up of water directly on top of the geomembrane. A perimeter toe drain is provided at the toe of the landfill slope to drain out water flowing through the geocomposite.

2.4 Vegetative Soil Layer

The vegetative layer will consist of 18 inches of general fill with a 6-inch thick topsoil layer suitable for establishing a grass cover. The soil will be spread in two lifts and lightly compacted with a dozer. This layer will protect the geomembrane from damage due to ultraviolet degradation, desiccation (drying), freeze-thaw, erosion and vectors. A mixture of fertilizer and seed will be applied to the surface which will rapidly establish a continuous dense cover of grass.

2.5 Gas Venting System

A gas venting system will be incorporated into the final cap configuration. A passive gas venting system will be required to remove gas that collects beneath the geomembrane cap. The gas venting system will consist of screened pipes encased in a gravel trench. The vents will be connected to the upper geomembrane cap by means of a geomembrane boot to retard surface water infiltration into the landfilled waste. The locations and quantity of vents are shown on the Gas Venting System Plan.

3.0 POST-CLOSURE MAINTENANCE

3.1 Post-Closure Period

Post closure maintenance of the facility after closure will be conducted for 30 years and consist of the following elements:

- Inspection and maintenance of final cover,
- Control of access, and
- Operation, inspection and maintenance of surface water and erosion/sedimentation control systems.

The post-closure care period may be decreased by the NCDENR Division of Waste Management if the owner or operator demonstrates that the decreased period is sufficient to protect human health and the environment. However, the post-closure care period may also be increased by the NCDENR Division of Waste Management if the Division determines that an increased period is required to protect human health and the environment.

Following completion of the post-closure care period of the FGD residue landfill, the owner or operator shall notify the NCDENR Division of Waste Management that a certification, by a registered professional engineer, verifying that post-closure care has been completed in accordance with the post-closure plan and has been placed in the operating record.

3.2 Erosion and Sediment Control

Surface water running off the landfill during and after a rainfall event will be collected and routed off the cover by erosion control benches. Surface water that flows towards the landfill from off-site uphill areas (run-on) will be intercepted and channeled away from the landfill and final cover surface by diversion ditches and perimeter berms.

Erosion will be controlled by vegetation, erosion control benches and run-on diversion. Vegetation will aid in reducing soil erosion. Benches break the velocity of sheet flow, control development of erosion features before they damage the final cover, and divert runoff into manageable flow volumes. Run-on diversion helps eliminate the source of erosion. Sediment laden runoff will be collected in the sediment basins.

All diversion ditches and erosion control benches shall be inspected quarterly for signs of wash-outs or siltation. Riprap channels and outlet protection aprons shall be inspected for wash-outs. Damaged areas shall be repaired as soon as possible.

The sediment basins shall be inspected after significant rainfall events. Sediment shall be removed when the sediment accumulates to one half the design depth.

Culverts and inlets shall be inspected quarterly for signs of damage, siltation buildup, settlement or clogging. Repairs shall be made as soon as possible.

3.3 Final Cover

The final cover shall be inspected quarterly for signs of settlement, erosion, vector damage and bare spots. The grass cover shall be mowed at least twice a year. Bare spots shall be re-vegetated with grass seed. Any deep-rooted or woody vegetation that may have established itself on the cover soil shall be removed so that the deep root growth will not penetrate the geomembrane. Areas exhibiting settlement shall be filled to provide positive drainage. Eroded areas shall be filled and reseeded as needed.

3.4 Gas Venting System

The gas venting system shall be inspected quarterly for signs of damage. Geomembrane connections to each vent shall also be inspected. Any damaged vents shall be repaired.

3.5 Groundwater Monitoring Wells

All groundwater monitoring wells shall be inspected during groundwater sampling events. Any damaged wells shall be repaired immediately. Access to the wells shall be maintained to provide all-weather access.

4.0 POST-CLOSURE MONITORING

Following closure of the landfill, a monitoring program will be implemented to monitor the quality of groundwater and surface water in the areas surrounding the landfill. The monitoring program will be in accordance with the State approved monitoring plan and will continue for a period of 30 years after final closure. The length of the post-closure care period may be decreased or increased by the NCDENR Division of Waste Management if the reduced period is sufficient or the lengthened period is necessary to protect human health and the environment. Following completion of the post-closure period, the owner or operator shall notify the Division that a certification signed by a registered professional engineer, verifying that the post-closure care has been completed in accordance with the post-closure plan, has been placed in the operating record.

4.1 Groundwater

The Groundwater Monitoring Plan will be continued semi-annually (or as required) after final closure. The results of the analytical testing will be submitted to NCDENR as directed in the Groundwater Monitoring Plan.

4.2 Surface Water

Surface water monitoring of the downgradient tributaries to Lake Norman will be continued after closure as required by the NCDENR Division of Waste Management. Surface water discharged from the sediment basins will be sampled and analyzed if required by the NPDES stormwater permit.

4

TECHNICAL SPECIFICATIONS FOR CLOSURE

DUKE ENERGY

MARSHALL STEAM STATION

FLUE GAS DESULFURIZATION (FGD) GYPSUM LANDFILL, PHASE 1

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TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Scope of Work

The Work consist of furnishing all labor, materials, supervision, equipment and services necessary to complete the closure of the Duke Energy Marshall Steam Station Flue Gas Desulfurization (FGD) Gypsum Landfill, as presented within these Technical Specifications and Closure Plan.

1.2 Definitions

The following list of definitions is provided for reference.

- Gas Vent: shall mean a vertically installed slotted, perforated, or porous pipe with a solid riser pipe surrounded by a gravel-packed zone over the perforated pipe section to allow removal of landfill gas and any intercepted leachate.

- Geomembrane: an impermeable membrane liner or barrier used for waste and wastewater containment.

- Geonet: a geosynthetic net consisting of two or more traverse strands of synthetic fiber used to convey fluids and facilitate drainage.

- Geotextile: fabric used for filtration, drainage or reinforcement. The fabric structure may be knit, woven or nonwoven. Filter geotextile is a material which provides separation of materials with different pore size openings to prevent clogging. Drainage geotextiles are materials with adequate transmissivity to provide planar flow of fluid. Reinforcing geotextile is a material with sufficient strength to support some or all of the load applied to a composite system.

- Extrusion Weld: a bond between two polyethylene materials that is achieved by extruding a bead of polyethylene material over the overlap area or between the overlapped sheets followed by pressure to create a water tight, homogenous bond.

- In-Situ: "As is", or as it exists in-place natural.

- Double or Single Fusion Weld: a bond between two flexible polyethylene materials that is achieved by heating both surfaces to the melting point followed by pressure in order to fuse the two surfaces together in a homogeneous bond. The welding method must use a power-driven system for heating and pressurizing with temperature control.

- Moisture Content: ratio of quantity of water in the soil (by weight) to the weight of the soil solids (dry soil), expressed in percentage; also referred to as water content (ASTM D2216).

- Optimum Moisture Content (OMC): moisture content corresponding to maximum dry density as determined in the Standard Proctor Test (ASTM D1557)

- Permeability: ability of pore fluid to travel through a soil mass via interconnected voids. "Low" permeability indicates relatively slow flow of pore fluid through a media. Coefficients of permeability are generally reported in centimeters per second (cm/sec) and are determined by a laboratory test using a flexible wall permeameter test (ASTM D5084-90).

- Plasticity: ability of a soil mass to be remolded without raveling or breaking apart. The plasticity index, numerically equal to the difference between the liquid and plastic limit, is a comparative number which describes the range of moisture contents over which a soil behavior is plastic.

2.0 EARTHWORK

2.1 Site Preparation

2.1.1 Scope of Work

The EARTHWORK CONTRACTOR shall furnish all labor, materials, supervision and equipment to complete the site preparation for closure of Phase 1, Cells 1 and 2.

Site preparation includes the stripping of temporarily vegetated areas designated for compacted soil cover. Site preparation also includes the installation of gas venting system, stormwater management structures and erosion/sediment control outside the landfill cells as designated on the Closure Plan.

2.1.2 Specification

2.1.2.1 Stripping

In areas to be stripped, all materials shall be removed to a depth necessary to eliminate topsoil and other soils containing more than 5 percent by weight fibrous organic matter, rubbish, vegetable matter, roots, small stones, and all other perishable or objectionable matter. The minimum stripping depth shall be determined by the ENGINEER. Stripped material shall be stockpiled on-site in areas for spoil materials as designated by the ENGINEER.

2.1.2.2 Stormwater Management Structures and Erosion/Sediment Control

Stormwater management structures shall include but not be limited to diversion benches, diversion ditches and drainage culverts. Diversion benches and ditches (permanent, temporary or along access roads) shall be constructed to divert run-on or route run-off to the erosion/sediment control structures as specified on the Closure Plan.

Drainage culverts shall consist of galvanized corrugated metal pipe with bituminous coating, HDPE or reinforced concrete pipe as shown on the Closure Plan. The culverts shall be placed in an excavated trench and covered with compacted earth backfill. Earth backfill shall be placed in accordance with Section 2.2 of the Specifications.

Erosion/sediment control shall include but not be limited to check dams, outlet protection aprons, and grassing as specified on the Closure Plan.

2.1.3 Measurement and Payment (left blank intentionally)

2.2 Compacted Soil Layer

2.2.1 Scope of Work

The landfill cells shall include an 18-inch compacted soil layer. The EARTHWORK CONTRACTOR shall furnish all labor, material, supervision and equipment to complete the Compacted Soil Layer for the cells, including hauling, sieving, raking, discing, compacting, drying, wetting, removal of rainwater and removal of all previously placed material rendered unsuitable due to weather conditions or construction operations, final grading and sealing and all necessary and incidental items as detailed or required to complete the compacted soil layer, all in accordance with the Closure Plan.

2.2.2 Materials

Stockpiled soils that meet all of the following requirements shall be classified as compacted soil layer material for use in construction of the compacted soil layer.

Compacted soil layer materials are available in the on-site borrow stockpile area. Compacted soil layer materials shall be classified according to the Unified Soil Classification System as SC, CL, CH, ML or MH (ASTM D2487-83). Liquid limit, plasticity index and percent passing the No. 200 sieve will be considered for proper classification. The soil cover material shall have a Plasticity Index (PI) greater than 5 or as subsequently specified based on laboratory testing.

Compacted soil layer materials shall be reasonably free of gypsum, ferrous, and/or calcareous concretions and nodules or other deleterious substances. Compacted soil layer material shall have a maximum aggregate size of 1 inch. The compacted soil layer material shall be raked or sieved by the EARTHWORK CONTRACTOR, if necessary, to remove all aggregate greater than 2 inches in diameter. No more than 5 percent of the soil cover material should be retained on the No. 4 sieve.

Continuous and repeated visual inspection of the materials will be performed by the EARTHWORK CONTRACTOR to ensure proper soils are being used. In addition, the Owner or Owner's representative will make frequent inspections of the soil cover placement operations and materials and will consult with the site personnel on suitable fill and locations of such. All soil cover fill proposed shall be inspected by the Engineer prior to actual use.

2.2.3 Construction

2.2.3.1 Soil cover fill lift thickness, after compaction, shall be 9 inches +\- 1 inch. Thinner lifts are permissible to achieve design grade.

2.2.3.2 If required, the compacted soil layer should be sprinkled or sprayed with water, utilizing equipment creating a uniform application and dozed, wind-rowed, and/or disc-plowed to uniformly increase the moisture content of the compacted soil layer if the material moisture content is too low. The compacted soil layer fill shall be dozed, wind-rowed, and/or disc-plowed to help air dry the soil if the moisture content is too high.

2.2.3.3 Each lift shall be thoroughly compacted and satisfy moisture and density controls through field testing before a subsequent lift is placed.

2.2.3.4 Compaction of lifts shall be as follows:

Compaction of lifts shall be performed with adequate equipment and shall be subject to approval by the Owner or Owner's representative.

The daily work area shall extend a distance so as to maintain moist soil conditions (facilitate bonding) and continuous operations. Desiccation, crusting, or cracking of the lift surface shall be avoided as much as possible. Each lift shall be protected, at all times after placement, from desiccation and crusting.

If desiccation, crusting or cracking of the lift surface occurs before placement of the next lift, this area shall be scarified to a sufficient depth to mix with moist materials, or sprinkled with water and then scarified at the direction of the Owner or Owner's representative.

The surface of the underlying lift shall be scarified a minimum of 2 inches prior to compaction of each subsequent lift (i.e.: Lift 2 to Lift 3) to facilitate bonding of lifts.

2.2.3.5 During compaction of the Compacted Soil Layer material, the soil moisture content and dry density shall be maintained within the limits specified below.

To determine the moisture content and dry density requirements of the compacted soils are being satisfied, field and compaction tests shall be made at least two density tests per acre. Laboratory tests should be made at least once per 2,000 cubic yards of compacted soil layer material placed.

Compaction moisture content shall be between 0 and 6 percent wet of optimum moisture content.

The Compacted Soil Layer shall be compacted to a minimum dry density of 92 percent of the maximum dry density determined by the standard Proctor test (ASTM D-698). Where densities less than the specified compaction of the maximum dry density as determined from the standard Proctor test are measured, the soil layer shall be recompacted and/or removed and reworked to meet density objectives.

2.2.3.6 The Compacted Soil Layer shall not be placed or compacted during sustained periods with air temperature below 32°F. Soil cover fill may be placed and compacted during periods of early morning and early evening freezing temperatures with warming trends above 45°F during the day. No fill shall be placed on frozen subgrade. If the soil cover freezes or ices, the fill section shall be rescarified and recompacted, at the discretion of the ENGINEER.

2.2.3.7 During construction, finished lifts or sections of compacted soil layer shall be sprinkled with water twice a day if needed.

At the end of each day's activities, completed lifts or sections of Compacted Soil Layer shall be sealed by rolling with a rubber tired or smooth drum roller and sprinkled with water as needed to avoid excessive cracking.

2.2.3.8 The surface of the Compacted Soil Layer shall be smooth drum rolled and maintained free of rocks, organics, voids and sharp edges.

2.2.3.9 The Compacted Soil Layer shall be a minimum of 18 inches thick. Thickness of the Compacted Soil Layer on the side slopes shall be measured perpendicular to the slope face.

2.2.3.10 The as-built thickness of the Compacted Soil Layer shall be determined by auger probes. Thickness testing shall be performed twice per acre. All test locations shall be surveyed and recorded on a copy of the Closure Plan. Any areas less than the specified 18 inches shall have additional material placed. The resulting penetration shall be promptly backfilled by the EARTHWORK CONTRACTOR with hand tamped clayey soil

2.2.4 Measurement and Payment (left blank intentionally)

2.3 Gas Venting System

2.3.1 Scope of Work

The EARTHWORK CONTRACTOR shall furnish all labor, materials and equipment necessary to complete the installation of the Gas Venting System for Phase 1, Cells 1 and 2. The work includes trenching, installation of nonwoven geotextile, placement of pipe and stone, and installation of riser vent pipes.

2.3.2 Materials

The gas venting system shall include lining of trenches with 4 oz. /sy nonwoven geotextile equivalent to Mirafi 140N.

Piping in the trenches shall be 4 inch diameter perforated corrugated HDPE pipe and fittings meeting the requirements of AASHTO M-252, Type S.

Piping for the riser stems shall be 4 inch diameter smooth-walled HDPE pipe.

Stone backfill for the trenches shall be NCDOT No. 57 washed stone.

2.3.3 Construction

Once the compacted soil cover is placed, a network of 12-inch wide trenches shall be excavated to the top of the gypsum. Trenches shall be spaced as shown on the Gas Venting System Plan.

Each trench shall be lined with 4oz/sy nonwoven geotextile with a minimum 12 inch overlap on top.

A minimum 4 inch thick layer of washed stone shall be placed prior to placement of the perforated pipe. The perforated pipe shall be placed in the center of the trench and backfilled with No. 57 stone to the top of the compacted soil layer level. The geotextile shall be overlapped and heat tacked to prevent unraveling.

A minimum 36 inch high riser stub (36 inches above compacted soil layer) shall be provided at each vent location prior to installation of the geomembrane. The geomembrane shall provide a boot fitting for each riser vent as shown on the Gas Venting System Plan. An additional 4 ft. riser section with turn-down elbow shall be installed once the final cover is placed.

2.3.4 Measurement and Payment (left blank intentionally)

2.4 Final Cover

2.4.1 Scope of Work

The EARTHWORK CONTRACTOR shall furnish all labor, materials, supervision and equipment to complete the final cover for Phase 1, Cells 1 and 2, but not limited to excavation, hauling, scraping, stockpiling, seeding and removing accumulated rainwater during construction.

2.4.2 Materials

Final Cover material shall consist of 18 inches of soil and 6 inches of topsoil. The 18 inches of soil will be on site or borrow area natural soils free of all topsoil, roots, stumps, brush, vegetation and other deleterious material. Structural fill shall have a minimum size aggregate of 4 inches with no more than 15% retained on the No. 4 sieve.

The ENGINEER will assist the EARTHWORK CONTRACTOR in the determination of final cover, and non-select material. The EARTHWORK CONTRACTOR will be responsible for excavation, transporting, stockpiling, placing and compacting the final cover.

The erosion control mat for the diversion benches/ditches on the side slopes shall be North American Green P300P or equivalent.

2.4.3 Construction

The 18 inches of final soil cover placed directly on top of the geocomposite and shall be compacted with a low pressure CAT D-6 dozer or equivalent. The use of penetrating foot compactors immediately above the cap geomembrane, or other sensitive element is not permissible.

Topsoil shall be placed above the soil cover for the cap, to a minimum thickness of 6 inches. Topsoil should be left loose, to allow seeding and fertilizer to produce adequate vegetative cover (shallow rooted) to retard cap erosion. Moderate compaction by dozing the topsoil in place should be sufficient. The types and application amounts of fertilizer and native grass seed will be as indicated in the Closure Plan and Erosion and Sediment Control Plan.

The erosion control mat shall be placed in accordance with the manufacturer's specifications and recommendations.

2.4.4 Measurement and Payment (left blank intentionally)

3.0 Geomembrane Cap

3.1 Scope of Work

The GEOSYNTHETIC CONTRACTOR shall furnish all labor, materials, supervision and equipment to complete the Geomembrane Cap for the Duke Energy Marshall Steam Station FGD Gypsum Landfill including, but not limited to, anchor trench excavation and backfill, liner layout, seaming, patching and all necessary and incidental items required to complete the work, in accordance with the Closure Plan and these Specifications.

3.2 Materials

The geomembrane cap shall be textured, very flexible polyethylene 40 mil nominal thickness. The geomembrane used shall meet, at a minimum, the specifications included in Table 1.

The chemical resistance of the geomembrane cap shall be in keeping with typical properties of high quality polyethylene products currently available through commercial sources.

Geomembrane cap shall be shipped rolled with a protective wrap around each roll, labeled with roll number and manufacturer's batch number. Manufacturer's quality control documentation shall be included with each roll.

The geomembrane shall be free of holes, blisters, undispersed raw materials or any sign of contamination by foreign matter. Any such defect shall be repaired in accordance with the geomembrane manufacturer's recommendations. The ENGINEER may reject all or portions of units (or rolls) of the geomembrane if in his opinion significant quantities of production flaws are observed.

The GEOSYNTHETIC CONTACTOR shall submit proposed geomembrane panel layouts to the ENGINEER at least 14 days prior to mobilization of crews (2 copies). Once the panel layout is approved, the GEOSYNTHETIC CONTRACTOR may not change the layout without permission from the ENGINEER.

3.3 Construction

The geomembrane cap shall be constructed as soon as practical after completion and approval of the Compacted Soil Layer (or substantial portion thereof). The geomembrane is to cover the top of the cells and the side slopes in accordance with the Closure Plan.

3.3.1 Areas to receive cap installation should be relatively smooth and even, free of ruts, voids, etc., to the extent required by the Engineer. This shall be accomplished by final dressing of the compacted cover with smooth drum roller. No vehicles are permitted on the final dressed surfaces unless authorized by the ENGINEER.

3.3.2 An anchor trench will be required to secure the geomembrane. No loose soil will be allowed to underlie the geomembrane in the anchor trenches. The time schedule for excavation and backfilling of the anchor trenches is to be approved by the ENGINEER so that desiccation of trench soils does not occur prior to backfilling (See Section 3.3.10).

3.3.3 Installation of the geomembrane shall be as follows:

Unroll only those sections that are to be seamed together in one day. Panels should be positioned with the overlap recommended by the manufacturer, but not less than 4 inches. For stormwater drainage purposes, the upstream panel should be overlapped on top of the downstream panel. The side slope geomembrane will be placed in an anchor trench that is then backfilled with soil and compacted as shown on the Closure Plan.

After panels are initially in place, remove wrinkles as directed by the ENGINEER. Unroll several panels and allow the cap to "relax" before beginning field seaming. The purpose of this is to make the edges that are to be bonded as smooth and free of wrinkles as possible.

Once panels are in place and smooth, commence field seaming operations.

The GEONSYNTHETIC CONTRACOTR'S Field Superintendent will complete the Daily Report form at the end of each day and submit the form daily to the ENGINEER.

3.3.4 Field seaming shall be in accordance with the EPA Technical Guidance document; "The Fabrication of Polyethylene FML Field Seams" EPA/530/SW-89/069 or as follows. Where conflicts exist between the two guidance specifications, the most stringent specification prevails unless otherwise directed by the ENGINEER.

All foreign matter (dirt, water, oil, etc.) shall be removed from the edges to be bonded. For extrusion welds, the bonding surfaces must be thoroughly cleaned by mechanical abrasion or alternate methods approved by the ENGINEER to remove surface cure and prepare the surfaces for bonding. All abrasive buffing shall be performed using No. 80 grit or finer sandpaper. The grinding shall be performed so that any and all grind marks are perpendicular to the edge of the sheet. No grinding greater than

¼ inch outside the welds is permitted or the ENGINEER can require patching. No solvents shall be used to clean the geomembrane cap.

As much as practical, field seaming shall start form the top of the slope down. This will minimize large wrinkles from becoming trapped that require cutting and patching. Tack welds (if used) shall use heat only; no double sided tape or glue or other method will be permitted. The geomembrane should be seamed completely to the ends of all panels to minimize the potential of tear propagation along the seam.

The completed cap shall not exhibit any "trampolining" during any daylight hours (sunrise to sunset). All areas exhibiting trampolining must be repaired as directed by the ENGINEER. Additional slack (i.e.: 1-3%) shall be allowed on the side slopes to reduce the potential for trampolining.

Seaming of the cell top membrane to the sidewall membrane (crest seam) shall be conducted hen conditions minimize thermal expansion effects. All crest seams must me a minimum of 50 feet horizontally from the crest of the slope. Horizontal seams will not be allowed on the side slopes steeper than 10H:1V unless approved by the ENGINEER. However, 45 degree seams will be permitted.

At the end of each day or installation segment, all unseamed edges shall be anchored by sand bags or other approved device. Sand bags securing the geomembrane on the side slopes should be connected by a rope fastened at the top of the slope by a temporary anchor. If high winds are expected, boards along the edge of the unseamed panels, with weighted sand bags on top, may be used to anchor the geomembrane. Sand bags fastened by rope should be used to secure unseamed edges on the side slopes. Staples, U-shaped rods or other penetrating anchors shall not be used to secure the geomembrane on the side slopes. Any damage to the cap or soil cover including damage due to construction activities or wind, rain, hail or other weather shall be the sole responsibility of the GEOSYNTHETIC CONTRACTOR.

3.3.5 Field seaming may be fusion or extrusion welding or a combination of these methods. Solvent welding is not acceptable. The ENGINEER reserves the right to reject any proposed seaming method it believes unacceptable. Double hot wedge fusion welding shall be the predominant seaming method. Additional concepts and requirements of proper field seaming include the following:

Extrusion welding applies a molten bead of material to preheated sheets of geomembrane. The sheets are then joined by pressure.

The fusion welding process heats the area to be joined to the melting point and then applies pressure to join the melted surfaces.

The sheets to be joined shall be overlapped at least 4 inches after the necessary cleaning, aligning and cutting.

The seams should be oriented parallel to the line of maximum slope, i.e., oriented up and down, not across, the slope. In corners and odd shaped geometric locations, the number of field seams should be minimized.

No seaming should be attempted above 40°C (104°F) ambient air temperature. Below 5°C (41°F) ambient air temperature, preheating of the geomembrane will be required, unless it is demonstrated that this is not necessary (i.e. acceptable test (start-up) seams that duplicate, as closely as possible, actual field conditions can be achieved). Preheating may be achieved by natural and/or artificial means (shelters and heating devices). Ambient temperature is measured 18 inches above the cap surface. The GEOSYNTHETIC CONTRACTOR shall supply instrumentation for measurement of ambient temperature.

A moveable protective layer of plastic or approved material may be placed directly below each overlap of geomembrane that is to be seamed. This is to prevent any moisture build-up between the sheets to be welded. The protective layer must be removed after welding.

Seaming will extend to the outside edge of panels to be placed in anchor trenches.

If required, firm substrata should be provided by using a flat board, or similar hard surface directly under the seam overlap to achieve proper support across the anchor trench.

Grinding prior to welding shall be done perpendicular to the sheet edge. Over grind greater than ¼ inch beyond the welded seam or improperly ground areas shall be replaced at the GEOSYNTHETIC CONTRACTOR'S expense.

Seams at the panel corners of 3 or 4 sheets shall be completed with a circular patch approximately 12 inches in diameter, extrusion welded to the parent sheets, or with a "T" weld at suitable locations.

3.3.6 Quality Control

All geomembrane sheet, seams and patches will be tested and evaluated prior to acceptance. In general, testing of the sheet will be conducted by the manufacturer. Testing of the seams will be conducted by the GEOSYNTHETIC CONTRACTOR under observation by the ENGINEER or a designated, independent geosynthetics laboratory may perform additional testing, as required by these Technical Specifications or as required in the judgment of the ENGINEER to verify that the very flexible cap sheet and seams meet the specifications. Testing requirements are detailed in the following subsections:

3.3.6.1 Pre-shipping Sheet Tests – The GEOSYNTHETIC CONTRACTOR or supplier (manufacturer) will be required to submit his Quality Control program to the ENGINEER prior to initiating field work. At a minimum, the Manufacturer will perform the tests at the frequencies given in Table 2 on the very flexible liner sheet prior to shipping material to the site.

3.3.6.2 Test Seams (Destructive Tests) – The Installer shall maintain and use equipment and personnel at the site to perform testing of test seams. Test seams will be made of at least twice each day prior to commencing field seaming. These seams will be made on fragment pieces of geomembrane cap to verify that seaming conditions are adequate. Such test seams will be made at the beginning of each seaming periods, when changes in storing equipment occur, at the ENGINEER'S discretion, and at least once every four hours during continuous operation of each welding machine. The ENGINEER shall complete the Test Seam Form immediately after each test. Requirements for test seams are as follows:

The test seam samples will be at least 1.8 m (6 ft) long by 0.3 m (1 ft) wide with the seam centered lengthwise. Six adjoining specimens 25 mm (1 in) wide each will be cut from the test seam sample. At the ENGINEER'S option the shear test may be eliminated for test seams. These specimens will be tested in the field with a tensiometer and/or manual seam tester for both shear (3 specimens) and peel (3 specimens). For dual wedge both inside and outside welds should be tested in peel. Test seams will be tested by the GEOSYNTHETIC CONTRACTOR under observation of the ENGINEER. The specimens should not fail in the weld. The GEOSYNTHETIC CONTRACTOR shall supply all necessary knowledgeable personnel and all necessary testing equipment. Quantitative strength measurements from a calibrated field tensiometer, supplied by the Installer, need only be obtained for one specimen in shear and peel for the test seams. A passing test seam will be achieved when the criteria described below are satisfied. If a test seam fails, the entire operation will be repeated. If the additional test seam fails, the seaming apparatus or welding technician will not be accepted and will not be used for seaming until the deficiencies are corrected and two consecutive successful test seams are achieved. Test seam failure is defined as failure of any one of the specimens tested in shear or peel.

The ENGINEER will approve all test seams procedures and results. The remainder of the successful test seam sample and the tested specimens will be assigned a number and marked accordingly by the ENGINEER, who will also log the date, hour, ambient temperature, number of seaming unit, name of seamer, and pass or fail description. The sample itself should be retained in the ENGINEER'S archives. The ENGINEER will transmit these specimens to the OWNER following acceptance of the geomembrane materials and installation by the ENGINEER.

3.3.6.3 Production Seams – 100% of the production seams will be tested by the GEOSYNTHETIC CONTRACTOR continuously using non-destructive techniques and at specified intervals using destructive tests.

All areas failing nondestructive test procedures described below shall be clearly marked both on the cap itself and on the Seam Inspection Quality Control Form included at the end of this Section.

3.3.6.4 Non-Destructive Testing

Single Weld Seams – the GEOSYNTHETIC CONTRACTOR shall maintain and use equipment and personnel at the site to perform continuous vacuum box testing under the observation of the ENGINEER on all single weld production seams except those corner seams where vacuum box testing is impossible. The system shall be capable of applying a vacuum of at least 3 psi. The vacuum shall be held for a minimum of 15 seconds for each section of seam. Where vacuum box testing is not possible, spark testing or an approved alternative will be used.

Double Weld Seams – the GEOSYNTHETIC CONTRACTOR shall maintain and use equipment and personnel to perform air pressure testing under the observation of the ENGINEER of all double weld seams greater than 20 feet (double weld seams less than 20 feet may be vacuum box tested as specified above). The system shall be capable of applying pressure of at least 30 psi for not less than 5 minutes. After the 5 minute testing period, the end of the seam shall be cut open and pressure loss monitored to verify the entire length of the seam channel is open. If no pressure loss is realized, the location of the blocked channel must be found and the remainder of the seam tested separately. The air pressure test results shall be documented. Pressure loss tests shall be conducted in accordance with the procedures outlined in "Pressurized Air Channel Test for Dual Seamed

Geomembranes", Geosynthetic Research Institute Test Method GM-6. As outlined by the test method, following a 2 minute pressurized stabilization period, pressure losses over a measurement period of 5 minutes shall not exceed 3 psi.

Double weld seams will also be visually inspected on 100% of the seam. If necessary the outside flap can be pulled back to aid in the visual inspection.

3.3.6.5 Destructive Testing

Laboratory destructive testing (LDT) is defined as 18"x36" samples cut on 500' centers for both extrusion and double welded seams. Field destructive testing (FDT) is defined as 3"x6" samples cut at the end of each seamed area exceeding 200 feet. Both are described below:

Laboratory destructive testing will be performed on an average of every 500 linear feet of production seam. The locations will be selected by the ENGINEER. Samples will be 18"x36" in order to provide one sample to the archive, one sample to the ENGINEER for potential laboratory testing and one sample to be retained by the GEOSYNTHETIC CONTRACTOR for possible field and/or additional laboratory testing at the option of the ENGINEER or GEOSYNTHETIC CONTRACTOR.

Before the sample is sent to the laboratory, two specimens, one from each end of the specimen will be tested in peel in a calibrated field tensiometer, supplied by the GEOSYNTHETIC CONTRACTOR. Both specimens must meet the qualitative and quantitative criteria listed below. Testing requirements are as follows: Each sample shall be large enough to test five specimens in peel and five specimens in shear. The average values of each set of five specimens must meet the specification, and four of the five specimens tests must meet the specifications for the seam to be considered a passing seam. If the average of the five specimens is adequate, but one of the specimens is failing, values for the failing specimen must be at least 80 percent of the values required for the seam for the sample to pass. All samples must fail in film tear bond (FTB). Tests shall be conducted using a calibrated tensiometer and must meet the criteria outlined below. Samples which do not pass the shear and peel tests will be re-sampled from locations at least 10 feet on each side of the original locations. These two re-test samples must pass both shear and peel testing. If these two samples do not pass, then additional samples will continue to be obtained until the questionable seam area is defined. If the length of the questionable seam area is defined to be excessive by the

ENGINEER, a cap pad may be required over the entire seam with nondestructive testing prior to acceptance of the seam.

Field Destructive Testing (FDT) shall be 3"x6" samples cut out at the beginning and end of each seam exceeding 200 feet in length. Three 1'x6' specimens will be tested in peel from each sample using the GEOSYNTHETIC CONTRACTOR'S Field Tensiometer or qualitative peel tester at the option of the GEOSYNTHETIC CONTRACTOR. No qualitative peel strength values need to be determined with the Field Destructive test, but each specimen must meet all the qualitative criteria listed below.

The ENGINEER will approve all seam field and laboratory test procedures and results. All laboratory destructive test specimens will be marked with the seam number and letters then bound together for a particular seam and stored in the OWNER'S archives. The specimens for FDT need not be retained.

Each sample area will be clearly marked both on the cap itself (LDT or FDT) using the procedures outlined in the marking section and on the "as-built" record drawing prepared by the GEOSYNTHEICS CONTRACTOR. Destructive test forms will be retested and completed by the ENGINEER.

All areas cut out for testing should be immediately patched by the GEOSYNTHEICS CONTRACTOR and the patches should be tested and approved by the ENGINEER.

A passing double seam weld will be achieved in peel (ASTM D413 modified) when (1) failure is by Film Tear Bond (FTB), National Sanitation Foundation (NSF), Standard 54, definition 2.16 and (2) yield strength for the seam is not less than 62 percent of the minimum tensile strength at yield as specified in Table 1, and (3) no greater than 10 percent of the seam width peels (separates) at any point, and (4) the failed sheet exhibits elongation, prior to failure. Both sides of the double welded seam must be tested and must meet all of the criteria listed above. A passing double welded seam will be achieved in shear (ASTM D3083 modified) when (1) failure is by FTB, and (2) yield strength for the seam is not less than 95 percent of the minimum tensile strength at yield specified in Table 1, and (3) yield strain for the seam is at least 10 percent, and (4) break strain for the seam is at least 50 percent.

A passing extrusion welded seam will be achieved in peel (ASTM D413 modified) when (1) failure is by FTB, and (2) yield strength for the seam is not less than 62 percent of the minimum tensile strength at yield specified in Table 1, and (3) no greater than 1/8 inch separation occurs from the edge of the sheet at any point, and (4) the failed sheet exhibits ductility prior to failure. A passing extrusion welded seam will be achieved in shear (ASTM D3083 modified) when (1) failure is by FTB, and (2) yield strength for the seam is not less than 95 percent of the minimum tensile strength at yield specified in Table 1, and (3) yield strain for the seam is at least 10 percent, and (4) break strain for the seam is at least 50 percent.

3.3.7 Repair of Damaged and Sampled Areas

Damaged and sample coupon areas of geomembrane shall be repaired by the GEOSYNTHEICS CONTRACTOR by construction of an extrusion welded cap. No repairs shall be made to seams by application of an extrusion bead to a seam edge previously welded by fusion r extrusion methods. Repaired areas will be tested for seam integrity as outlined in Section 3.3.6.4. Damaged materials are the property of the GEOSYNTHEICS CONTRACTOR and will be removed from the site at the GEOSYNTHEICS CONTRACTOR'S expense. The GEOSYNTHEICS CONTRACTOR will retain all ownership and responsibility for the geomembrane until acceptance by the ENGINEER. The geomembrane shall be accepted by the ENGINEER after the installation and repair are complete, and after the ENGINEER has received all necessary documentation for the installation in accordance with these Specifications.

3.3.8 Seams at Panel Corners

Seams at panel corners of 3 or 4 sheets shall be completed with a circular patch approximately 12 inches in diameter, extrusion welded to the parent sheet, or with a "T" weld at suitable locations. If the GEOSYNTHEICS CONTRACTOR wishes to use a different method, samples must be submitted to the ENGINEER and tested accordingly.

3.3.9 Potentially Damaging Activities

No support equipment shall be allowed on the geomembrane unless approved by the ENGINEER. Personnel working on the geomembrane shall not smoke, wear damaging shoes, or engage in any activity that could damage the geomembrane.

3.3.10 Anchor Trench Backfilling

The anchor trench will be backfilled and compacted by the GEOSYNTHEICS CONTRACTOR to a dry density not less than 90 percent of the maximum dry density determined by the standard Proctor

(ASTM D-698). Care should be taken when backfilling the trench to prevent any damage to the geomembrane. Anchor trench soil shall be used as backfill material, wherever acceptable by the ENGINEER. The time schedule for excavation and backfilling of the anchor trench is to be approved by the ENGINEER so that desiccation of the trench soils does not occur prior to backfilling.

The geomembrane shall be anchored with continuous sand bags immediately after installation of the geomembrane. The anchor trench shall be backfilled a minimum of 12 inches as specified above. The GEOSYNTHEICS CONTRACTOR shall be responsible for keeping the anchor trenches from accumulating ponding surface water. This may be accomplished by supplying temporary drainage outlets along the outside edge of the anchor trench.

3.3.11 Protection of Leading Edges

Between construction of partial sections of the geomembrane cap, leading edges of the geomembrane may be exposed or buried for extended periods of time prior to their joining adjacent, subsequent membrane sections. The combined action of abrasive soil and equipment impact stresses may "etch" unprotected membrane surfaces sufficiently to affect seam strengths. Therefore, it is necessary to protect leading edges in high activity areas with sacrificial layers of geotextile and liner sheet until they are ready for final seaming. As a minimum, each leading edge to be seamed that must be buried or which must be exposed for periods of one month or longer shall be continuously covered by a layer of liner. The geotextile shall be non-woven and have a minimum weight of 8 oz. per square yard. The sacrificial sheet shall have a minimum thickness equal to that of the geomembrane cap to be protected. Both protective layers shall have a minimum width of 2 feet. The protective cover sheets shall be either covered with soil or weighted with sand bags to prevent displacement by the wind. The edge of the sheet to be protected shall be approximately centered beneath the overlying protective layers prior to burial or weighing with sandbags. Leading edges located in areas expected to receive direct traffic from construction equipment shall be buried under a minimum thickness of one foot of buffer soil.

3.3.12 Warranty

The GEOSYNTHEICS CONTRACTOR and MANUFACTURER (where applicable) shall provide a one year non pro-rated warranty on materials and installation workmanship including all joints, penetrations, seams and connections, whether prefabricated or constructed in the field for the following geosynthetic materials: geomembrane cap, geonet, and geotextiles. The warranty shall cover damage due to the following occurrences:

- Stress cracking, weathering, and ultraviolet degradation.
- Excessive wrinkling or trampolining due to the effects of thermal expansion/contraction.
- Ruts in the soil liner from erosion or construction vehicles.
- Any activity from the GEOSYNTHEICS CONTRACTOR such as backfilling and soil placement on top of the liner.
- Over heating, over grinding, or improper or inadequate quality control by the GEOSYNTHEICS CONTRACTOR of any joint, seam, penetration or connection, whether prefabricated or field installed.
- Any other cause or Contractor-related activity no herein mentioned excluding non-compatibility between the geosynthetic materials and the leachate; vandalism; or natural and unnatural occurrences including but not limited to tornadoes, hurricanes flooding, etc.

If it is determined by the procedures described herein that the damage is the fault of the GEOSYNTHEICS CONTRACTOR, the GEOSYNTHEICS CONTRACTOR will, at no cost to the OWNER, expose the damaged area as needed to replace and/or repair the damaged material at the discretion of the ENGINEER, perform the necessary quality control testing and rebackfill or restore the area as required.

If it is determined that the damage is the fault of the OWNER or MANUFACTURER, the GEOSYNTHEICS CONTRACTOR will be reimbursed at a mutually agreed price for the services rendered. Within the warranty period at the request of the OWNER, regardless of which party is ultimately responsible, the GEOSYNTHEICS CONTRACTOR will send a representative to the site within five days of the request to assist in the assessment and evaluation of the problem. The GEOSYNTHEICS CONTRACTOR will then agree to send a crew to repair and/or replace as agreed within ten days from the date of evaluation.

3.3.13 Marking on Cap by the Geosynthetics Contractor

The GEOSYNTHEICS CONTRACTOR will mark directly on the cap as described herein for the purpose of readily identifying panels, seams, repairs and destructive testing locations.

Panel Identification

Each panel indicated in the pre-construction panel layout drawings will be numbered sequentially using the format P1, P2, etc. Panels in the field must be numbered in the order in which the panels are actually laid regardless of preconstruction numbering. The panels will be permanently marked in white with letters approximately 12 inches high (and 1/3 the way down the slope for liners on slope). In addition, each panel will be marked with the Manufacturer's roll number.

Seam Identification

Each seam will be assigned a sequential number. Documentation will be completed for each seam showing panels that are joined by the seam.

Quality Control Marking

Following the completion of each seam, patch or repair the welding technician will write, at the end of the seam or in the middle of the patch or repair, the following: the initials of the technician date welded, time welded, and welder unit number. The markings will be done clearly with a white or yellow permanent marking pen or pencil.

Similarly, after each quality control test, the QA Technician or a representative will record the following immediately adjacent to the area tested: initials of the QA Technician performing the test, date of the test, type of test (i.e. VB, SP AP for vacuum box, spark test and air pressure test respectively) and the words "pass" or "fail". For the air pressure test, the QA Technician must also define the limits or zone of the test as well as the amount of pressure loss observed. Again, a permanent white or yellow marking pen is required. If the test fails and the necessary repair is made, the technician will cross out the previous markings and mark appropriately for the new test results.

Destructive test samples will be clearly circled with white permanent pen or pencil and the words "FDT" or "LDT" as defined in the Specifications and marked in white (red for white surfaced geomembrane). The QA Technician will mark the works "pass" or "fail" as appropriate. Similarly, any other area needing repair will be clearly marked in white permanent pen or pencil to identify where the repair is required to be made.

The QA Technician will also mark areas in need of repair using white (red for white surfaced geomembrane) marking pens.

Graffiti, offensive marking or any marking not necessary to the project will not be permitted.

3.3.14 Documentation

The GEOSYNTHEICS CONTRACTOR shall document subgrade acceptance, seam test welds, pre-construction shop drawings and post construction as-built record drawings.

The QA Technician shall document seam inspections, LDT testing, and repairs.

3.3.15 Daily Meetings

At the beginning of each work day the EARTHWORK CONTRACTOR'S superintendent, the GEOSYNTHEICS CONTRACTOR'S superintendent, and the QA Technician will meet to discuss the upcoming work plan for all parties to ensure cooperation, communication and understanding.

3.4 Measurement and Payment (left blank intentionally)

TABLE 1
REQUIRED PHYSICAL PROPERTIES OF TEXTURED GEOMEMBRANE

Property	Test Method	Required Values 40 Mil LLDPE
Thickness	ASTM D-751	36/40*
Sheet Density	ASTM D-1505	0.915 g/cm^3 min.
% Elongation at Break	ASTM D-638	300
Tensile Strength at Break	ASTM D-638	150 lb/in. min.
Carbon Black Content	ASTM D-1603	2% min. – 3% max.
Carbon Black Dispersion	ASTM D-3015	A1, A2 or B1
Environmental Stress-Crack Resistance	ASTM D-1693 (as modified in NSF54 Appendix A)	1800 hours min.
Dimensional Stability	ASTM D-1204 (as modified in NSF54 appendix A)	+/- 3.0% max.
Puncture Resistance	FTMS 101C Method 2065	40 lb. min.
Tear Resistance	ASTM D-1004 Die C	26 lb. average min.
Seam Strengths		
1. Shear Strength	ASTM D-3038 (as modified in NSF54 Appendix A)	FTB, 95% of Parent Material (min.)
2. Peel Strength	ASTM D-413 (as modified in NSF54 Appendix A)	FTB, 62% of Parent Material (min.)
Non-Destructive Testing		
1. Single Weld	Continuous Vacuum Box; Impact	Maintain vacuum of 3 psi, hold vacuum for 15 seconds.
2. Double Weld	Air Testing	Maintain 30 psi for not less than 5 min., pressure loss not greater than 3 psi for last 3 minutes.

*Thickness - first value represents lowest individual value
- second value represents average across roll.

TABLE 2
REQUIRED PRE-SHIPPING SHEET TESTING OF TEXTURED GEOMEMBRANE

Property	Test Method	Frequency
Thickness	ASTM D-751	Each Roll
Sheet Density	ASTM D-792 Method A	Every Other Roll
Tensile Properties	ASTM D-638 (as modified In NSF54)	Each Roll
Tear Resistance	ASTM D-1004 Die C	Every Fifth Roll
Environmental Stress-Crack	ASTM D-1693 Appendix A (as modified in NSF541)	One Per Batch
Puncture Resistance	FTMS 101C Method 2065	Every Fifth Roll
Carbon Black Content	ASTM D-1603	Every Other Roll
Carbon Black Dispersion	ASTM D-3015 (as modified In NSF54)	Every Other Roll
Melt Index	ASTM D-1238 Condition 190/2.16	Every 180,000 lbs.
Dimensional Stability	ASTM D-1204 (as modified In NSF54)	Every Tenth Roll

4.0 STORMWATER COLLECTION AND REMOVAL (SWCR) SYSTEM

4.1 Scope of Work

The EARTHWORK CONTRACTOR shall furnish all labor, materials, supervision and equipment necessary to complete the construction of the SWCR system for the Duke Energy Marshall Steam Station FGD Residue Landfill, including but not limited to trench excavation, hauling, spreading, grading and all other necessary and incidental items required to complete the work, all in accordance with the Closure Plan and these Specifications.

4.2 Materials

4.2.1 Pipe, Drop Inlets and Edgedrain

Pipe, drop inlets and edgedrains shall have nominal diameters and dimensions as noted on the Contract Drawings.

Pipe and fittings shall be HDPE corrugated high density polyethylene meeting the requirements of AASSHTO M-252, Type S. Edgedrains shall be ADS AdvanEDGE or equivalent corrugated high density polyethylene having a minimum width of 12 inches. The edgedrains shall be wrapped with a nonwoven geotextile.

Drop inlets shall be NCDOT Standard No. 840.14 with grates Standard No. 840.16.

All pipe and fitting connections shall be demonstrated to be watertight.

4.2.2 Gravel surrounding the edgedrain shall be of sub angular, sub rounded, rounded or well rounded particle shape, and shall meet NC DOT No. 57 aggregate.

4.2.3 Nonwoven Filter Geotextile for the cell shall be as indicated below:

The geotextile used shall be ultraviolet stabilized 1) nonwoven, needle punched, continuous filament polyester material or 2) nonwoven, needle punched continuous filament polypropylene material or, 3) nonwoven, needle punched staple fiber polypropylene material.

The nonwoven material shall meet or exceed the following criteria using Minimum Average Values:

Property	ASTM Test Method	8 oz. Geotextile Required Value
Fabric Weight	D3776	7.5 oz/yd^3
Grab Strength	D4632	200 lbs.
Wide Width Tensile Strength (M.D.)	D4595	50 lbs/inch
Grab/Tensile Elongation	D4632	50%
Puncture Strength	D4833	95 lbs.
Apparent Opening Size (AOS)	D4751	.210 mm (70 sieve max)

4.2.4 The geonet drainage blanket for the geotextile/geonet composite shall consist of solid rib extruded high to medium density polyethylene. A sample of the geonet shall be submitted to the Owner or Owner's representative for approval prior to acceptance.

The geonet shall have an 8 oz. filter geotextile above and below the geonet. Bonding is required between the filter geotextile and the geonet.

The geonet shall have carbon black for ultraviolet stabilization and meet or exceed the following:

Density	.92 g/cm^3
Nominal Opening Size	0.3 in (7 mm =/- 1)
Wide Width Tensile Strength (M.D.)	25 lb/in.

The geonet and the filter geotextile shall have a minimum transmissivity of 1x10^{-4} m^2/sec. at a hydraulic gradient of 0.25 and a normal load of 1,000 psf at a time of 100 hours when tested with compacted soil against the filter geotextile and 40 mil textured liner against the geocomposite. Transmissivity curves with the specified conditions must be submitted to the Owner or Owner's representative before the geonet and geotextile materials will be accepted.

The chemical resistance of the geonet shall be in keeping with typical properties of high quality polyethylene products currently available through commercial sources.

4.3 Construction

4.3.1 Geocomposite

The geotextile/geonet/geotextile composite for the slopes of the cell shall be installed with rows or panels with the geonet tied at least once every 5 feet. The geonet should be installed with the machine direction running up and down the slope. Panel ends shall be tied every foot. No horizontal seams will be permitted on the side slopes unless demonstrated to the Owner or Owner's representative to exhibit seam strengths equal to or greater than the parent material.

The geotextile of the composite shall be placed over the adjacent composite panel. A minimum 4 inch overlap shall be maintained on adjacent panels and ends. The geotextile shall be immediately continuously heat tacked by a methodology approved by the ENGINEER. No horizontal seams will be permitted on the side slope unless sewn by a method approved by the Owner or Owner's representative.

4.3.2 Drop Inlets, Pipe and Edgedrain

The drop inlets, slope drain pipes and edgedrain shall be placed to the lines and grades shown on the Closure Plan or as determined in the field by the ENGINEER.

4.4 Measurement and Payment (left blank intentionally)

Shaw® Stone & Webster, Inc. PROJECT SPECIFICATION				
	J.O./W.O. NO.	101540	SPEC. NO.:	MS-6451.00-00-0001
	PAGE	Cover	REVISION	B
	CLIENT	Duke Energy		
	PROJECT	Flue Gas Desulfurization Retrofit Program		
	TITLE	Site Preparation Gypsum Landfill Cell 1		

SITE PREPARATION FOR GYPSUM LANDFILL CELL 1

NORTH CAROLINA
PROFESSIONAL
SEAL
029024
ENGINEER
JOHN A. LAPERRIERE-HUNT

REVISION	A	B	0	1	2	3
REV. DATE	March 1, 2004	March 29, 2004				
REV. DESC.	IFA	IF-Permitting				
PREPARER	J.LaPerriere Hunt					
LEAD ENGINEER	D.Jordan					
PROJECT ENGINEER	C.Bussell					

TABLE OF CONTENTS

1.0 PART 1 – GENERAL

1.1 SCOPE

The work to be performed under this scope of work is located in the town of Terrell, Catawba County, North Carolina. The site is on land which is part of the existing Marshall Steam Station. The area is generally wooded and the terrain varies from flat to steep hills. The site is adjacent to Lake Norman and North Carolina State Route 150.

This specification covers the technical requirements for performing all site preparation work to grade the site to the planned rough grades, shown on the drawings and to install underground storm drainage system as indicated on the drawings. The Subcontractor shall be responsible for performing all in accordance with the Project Specifications and the Codes and Standards listed herein. The work consists of furnishing of all labor, materials and equipment to perform the following:

a. Provide all surveying and engineering services to establish reference points, lines and grades to control the work, and to measure excavation and fill quantities. The Owner will provide coordinates and elevations of control points at existing plant site for the Subcontractor's use.

b. Install and maintain erosion control measures in the Gypsum Landfill including sediment ponds and underground piping shown on Drawings Cell 1, Erosion and Sediment Control Plan and Erosion Control Detail. Note: proposed contours shall be as the shown on Drawing M-6024-02.00.

c. Protect land, water and air resources affected by construction.

d. Clear and grub, including removal of trees, the area within the limits shown on Drawing M-6024-02.00, Gypsum Landfill, Cell 1 Excavation.

e. Demolish existing facilities where required or called for on the drawings.

f. Strip topsoil from designated area and stockpile it on site.

g. Excavations and fill placement to grade the site to proposed contours indicated on Drawing M-6024-02.00, Gypsum Landfill, Cell 1 Excavation.

h. Areas to be designated as parking and laydown shall be determined by the Engineer in the field.

i. Place topsoil from stockpile on slopes and designated areas after completion of grading.

j. Hydroseed or seed or establish by other means, including mulching, a permanent grass surface on slopes and areas designated on the Drawing MM6451.01-0001.001.

k. Develop and maintain a temporary surface drainage system during the course of site preparation.

l. Construct sediment ponds and drainage systems as shown on the drawing MM6451.01-0001.001.

m. Conform to N.C. Landfill Permit Regulations.

1.2 REFERENCED CODES AND STANDARDS

The codes and standards referenced below shall be the issues in effect on the date of Invitation to Bid. If there is, or appears to be, a conflict between this specification and a referenced document, the matter shall be referred to the Engineer.

a. American Society for Testing and Materials (ASTM)

1) D 422, Particle-Size Analysis of Soils

2) D1557, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort

3) D 2487, Classification of Soils for Engineering Purposes (Unified Soil Classification System)

4) D 2488, Description and Identification of Soils (Visual-Manual Procedure)

5) D 4318, Liquid Limit, Plastic Limit, and Plasticity Index of Soils

b. Occupational Safety and Health Administration (OSHA)

29 CFR 1926/1910, Safety Standards for the Construction Industry

c. North Carolina Department of Transportation Standard Specifications for Roads and Structures, most current version

d. Project Specifications

1) MS-6168.00-00-0000, Underground Storm Piping Materials

2) MS-6168.00-00-0001, Installation of Storm Drainage System

e. North Carolina Solid Waste Management Rules sections .055 and .1600

1.3 DEFINITION OF TERMS

The meaning of the following terms, or pronouns used in place of them, whenever used in these specifications, or instruments of construction which these specifications govern, shall be interpreted as follows:

Owner: Duke Energy.

Company: Shaw Stone and Webster, Inc.

Subcontractor: The company accepting overall responsibility for fulfilling the requirements of this specification.

Engineer: Authorized Engineer of the Company.

1.4 SUBSURFACE INVESTIGATION

The Company will provide the Subcontractor with a copy of the subsurface investigation program report, which includes boring and soils data. The Company does not represent that the information in the report, including the boring logs, represent actual conditions that will be found throughout the site. The boring logs only indicate the conditions at the particular locations of the borings. The Subcontractor shall assume full responsibility for any interpretation and conclusions which he may make as to the nature of subsurface materials and conditions to be found and the difficulty of performing the work.

1.5 COMPANY QUALITY ASSURANCE ACTIVITIES

The Company shall have the right, at all reasonable times, to inspect the Subcontractor's work, material, equipment or inspection program, as applicable to the work covered by this specification, to confirm that specification requirements are being fulfilled.

The Company and/or an independent testing agency hired by the Company may perform materials testing and inspections of the Subcontractor's work. The Company's surveyor may also periodically verify the Subcontractor's locations and elevations. The Subcontractor shall provide reasonable assistance so the Engineer, the independent testing agency and surveyor can perform the tests, inspections and surveys.

Test and survey results shall not be the sole basis the Company will use to evaluate Subcontractor compliance with Specification requirements. The test and survey results shall not relieve the Subcontractor of the sole responsibility of performing all work to conform to specification requirements.

It is not intended that the presence or activity of the Company shall relieve the Subcontractor in any way of his obligation under this Specification. Furthermore, the fact that the Company may inadvertently overlook a deviation from some requirement of this specification shall not constitute a waiver of that requirement, nor the Subcontractor's obligation to correct the condition when it is discovered, nor of any other obligation of this specification.

1.6 BENCHMARKS AND REFERENCE BASE LINES

The Subcontractor shall satisfy himself that any benchmarks or reference lines provided by the Owner or Company are correct. The Subcontractor shall furnish all equipment and tools and shall be responsible for accurately locating and staking out the work. Benchmarks and reference lines shall be carefully maintained and, if disturbed or destroyed, shall be replaced by the Subcontractor at no cost to the Company or Owner.

1.7 PROTECTION OF EXISTING SERVICES

Existing utility lines and underground facilities, where known, are indicated on the drawings. The Subcontractor shall be responsible for locating and identifying in the field all existing underground utilities, pipelines and other installations prior to executing any earthworks or excavations. The Subcontractor shall notify the Company of any additional obstructions encountered and shall provide support, protection or removal of such obstructions as directed by the Company.

The existing structures and utilities which are adjacent to the site and those to remain within the limits of the work shall be protected against damage. The Subcontractor shall be fully responsible to the Company or Owner in the event of removal of or damage to any existing objects by Subcontractor personnel, which are intended by the Owner to remain in place.

1.8 TOPSOIL

Topsoil (see Part 2 for definition) shall be considered to be the property of the Owner and shall be stockpiled for future use at the locations designated by the Company.

1.9 WEATHER

No excavation, grading or other work shall be performed in wet, cold or other adverse weather conditions which, in the opinion of the Company, will prevent attaining satisfactory construction.

1.10 ENVIRONMENTAL PROTECTION

1.10.1 General

a. The control of environmental pollution which could result from construction operations under this contract requires consideration of land, water and air quality at the site.

b. The Subcontractor and his subcontractors shall comply with all applicable federal, state and local laws and regulations concerning environmental pollution control or Landfill Construction Permit abatement. The Subcontractor shall make sure that necessary permits have been obtained and that his work is in compliance with such permits concerning environmental protection.

c. The Company and the Subcontractor shall establish the criteria for compliance and administration of the environmental pollution control program prior to commencement of work.

d. The Company will notify the Subcontractor in writing of any noncompliance with this specification and the action to be taken. The Subcontractor shall immediately take corrective action.

1.10.2 Protection of Land Resources

a. Land resources adjacent to the project boundaries shall be preserved in their present condition or restored to a natural appearance.

b. The Subcontractor shall not injure or destroy trees or shrubs adjacent to the project site. Construction activities shall be confined within the construction limits shown on the plans.

c. Temporary roads, embankments or excavations shall be restored to natural grade and seeded prior to completion of construction.

1.10.3 Protection of Water Resources

a. The Subcontractor shall not adversely affect the existing water quality within or adjacent to the project site. No construction wastes or other harmful materials shall be permitted to enter these water resources.

b. Surface drainage from cuts and fills shall be protected by an effective erosion and sediment control plan or shall be graded to control erosion within acceptable limits. These measures shall be maintained until permanent drainage and erosion control facilities are completed.

1.10.4 Control of Air Pollutants

a. The Subcontractor shall ensure that fires which are permitted are kept small in size and that no heavy oils, asphaltic materials or anything other than wood or natural plant growth are burned.

b. The Subcontractor shall maintain the project site and access roads free from dust, which would cause a hazard or nuisance to others.

2.0 PART 2 – PRODUCTS

2.1 EARTH MATERIALS

Earth materials used as fill shall contain no topsoil; pieces of roots, grass, weeds, other vegetation; organic materials; snow, ice or frozen materials; debris or other foreign material; or chemical contamination (oil, grease, solvents, dissolved metals, etc). The material shall not be excessively dry or moist (i.e. shall be near the optimum moisture content for compaction per ASTM D 1557).

2.2 TOPSOIL

Unless otherwise directed by the Company and/or indicated on the drawings, topsoil shall be defined as the top six (6) inches of surface soil measured from the existing grade. The Subcontractor shall remove roots larger than one (1) inch in diameter, and any debris prior to stockpiling of the topsoil as determined by the Company.

2.3 COMMON FILL

Common Fill shall consist of sands or gravels, classified in accordance with the Unified Soil Classification System (ASTM D 2487, ASTM D 2488), or mixtures thereof, containing no individual particles larger than 3 inches in size. The plasticity index (ASTM D 4318) of the material shall not exceed 10. In areas approved by the Company, such as deep embankments, rocks up to 12 inches in size may be incorporated into the fill material provided such rocks are widely separated in the fill so that compaction of the fill, as determined by the Company, is not affected.

2.4 GRAVEL SURFACING

Gravel shall consist of durable angular gravels conforming to the Class IV classification for Select Material of Section 1016 of the North Carolina Department of Transportation Standard Specifications.

2.5 PIPE EMBEDMENT

Pipe embedment shall refer to pipe bedding, haunching, and initial backfill as indicated on the design drawings.

Pipe embedment where indicated by this specification or on the Engineer's drawings, shall conform to Section 1044-1, "Subdrain Fine Aggregate", of the North Carolina Department of Transportation Standard Specifications.

2.6 GEOTEXTILES

Geotextiles shall be as shown on the drawings. Unless indicated otherwise these shall be woven geotextiles, such as Mirafi 700X or approved equal. Equivalent fabrics shall meet the strength and filtration characteristics of the specified products.

Geotextile rolls shall be furnished with suitable wrapping for protection against moisture, and extended ultraviolet exposure prior to placement. Each roll shall be labeled or tagged to provide product identification sufficient for inventory and quality control purposes. Rolls shall be stored in a manner which protects them from the elements. If stored outdoors, they shall be elevated and protected with a waterproof cover.

2.7 RIP RAP

Rip rap materials shall conform to Section 1042, "Rip Rap", Class 1 of North Carolina Department of Transportation Standard Specifications.

3.0 PART 3 - EXECUTION

3.1 EROSION AND SEDIMENT CONTROL MEASURES

Prior to beginning work at the site, and during the course of the work, the Subcontractor shall install erosion and sediment control measures, as indicated by the drawings and in the Owner's permits and plans. The Subcontractor shall maintain those measures, and install additional measures, as necessary, during the course of the Subcontractor's work, and shall comply to all requirements of the permits.

The Subcontractor shall design, provide, operate and maintain all temporary and permanent ditches, culverts, berms, site grading and pumps to divert, collect and remove all ground and surface water from the work area. The Subcontractor shall ensure that such water removal is in compliance with the erosion and sediment control measures shown on the drawings and described in this specification.

3.2 DEMOLITION

3.2.1 Scope of Work

The work includes demolition and removal of all facilities indicated on the drawings. The Subcontractor shall provide adequate safety precautions. The use of explosives will not be permitted without written authorization from the Owner and the Company.

3.2.2 General

3.2.2.1 The Subcontractor shall be solely responsible for securing all necessary permits, and for performing the work in compliance with all applicable federal, state, and local requirements.

3.2.2.2 The Subcontractor shall take every possible precaution against damage or injury to other properties and workers. Demolition shall conform to requirements as set forth in the latest issue of OSHA requirements for the construction industry (29 CFR 1926). Any damage or injury that may result from the Subcontractor's operations shall be the Subcontractor's responsibility.

3.2.2.3 The Subcontractor shall not start demolition of any facility or obstruction until he submits to the Company a written demolition plan or drawing for approval and receives his authorization, from the Company, to proceed with the work.

3.2.2.4 All materials, fixtures and equipment in, attached, or belonging to a facility at the time it is released for demolition shall become the property of the Subcontractor unless stated otherwise in writing.

3.2.3 Disposal

All demolished material shall be removed from the site daily as demolition work progresses unless otherwise approved by the Company. Salvage materials shall be stored as approved by the Company but shall be removed before completion of the demolition portion of the contract.

3.3 CLEARING AND GRUBBING

3.3.1 General

3.3.1.1 Clearing shall consist of removal of all trees, brush, grasses, trash, rubbish and debris from within the clearing limits shown on the drawings. All overhanging trees shall be trimmed to the line of clearing. All trimmed surfaces over ¾ inch in diameter shall be treated with bitumastic paint.

3.3.1.2 No trees shall be cut outside the areas shown on the drawings.

3.3.1.3 Grubbing shall consist of removal and disposal of all stumps and roots greater than 1 inch in diameter.

3.3.1.4 Trees and vegetation indicated on the drawings to remain shall be protected from damage incident to clearing, grubbing and construction operations by the erection of appropriate barriers.

3.3.2 Disposal of Materials

3.3.2.1 Trees, brush, stumps, roots, and debris shall be disposed of by burning, or by removal from the site.

3.3.2.2 Burning operations if approved by the Company shall be conducted in accordance with federal, state, and local regulations. The Subcontractor shall be responsible for obtaining all permits for burning. Fires shall be located and supervised to prevent spreading or scorching of remaining vegetation. The Subcontractor shall be responsible for any damage resulting from such fires.

3.3.2.3 The Subcontractor shall seek the directions of the Company for the disposal of any material suspected to be contaminated with substances considered harmful to human health.

3.4 STRIPPING

3.4.1 General

Stripping shall consist of excavation and removal of all topsoil and organic material within the clearing limits shown on the drawings. Stumps, roots, and other organic material larger than 1 inch in size shall be separated from the topsoil.

3.4.2 Stockpiling Topsoil

Material suitable for use as topsoil shall be stockpiled in areas shown on the drawings or as indicated by the Company during the course of the work. Stockpile slopes shall be maintained in a stable condition. Rubbish and debris shall not be intermixed with stockpiled topsoil materials. Unsuitable material shall be removed from site.

Materials shall be deposited in lifts by dumping and spreading with a bulldozer.

Lift thickness shall be a maximum of 3 feet.

Stockpile slopes shall not be steeper than 3 horizontal to 1 vertical.

Topsoil shall not be stockpiled within the drip line of remaining trees.

Stockpiles shall be graded to facilitate runoff.

3.5 EXCAVATION

3.5.1 General

The Subcontractor shall take every possible precaution against damage or injury to other properties and workers during excavation. Excavation methods shall conform to requirements as set forth in the latest issue of OSHA requirements for the construction industry (29 CFR 1926). Any damage or injury that may result from the Subcontractor's operations shall be the Subcontractor's responsibility.

After clearing, grubbing and stripping operations have been completed, excavations to grade the site to planned grades shall be at the locations and to the lines and elevations shown on the drawings. If loose or unsuitable earth materials, as determined by the Company, are found in excavation bottoms or slopes, the Company will require the excavations to be deepened to remove the loose or unsuitable material.

Should the Subcontractor excavate below the planned permanent lines and grades indicated on the drawings, or below depths directed by the Company, the Company shall be notified immediately. In the event of over excavation, work in the area in question shall cease until further notice. Earth shall be placed to return unauthorized over excavation to the lines and grades indicated on the construction plans, as directed by the Company.

Temporary excavations to prepare areas to receive fill or for culverts, pipes, and appurtenances shall be to the depths shown on the drawings. The Subcontractor shall shore, brace or otherwise support such excavations, flatten excavation slopes and/or increase excavation dimensions as necessary to provide for worker safety. Such shoring, bracing, supports, and increased excavation dimensions shall be provided by the Subcontractor and shall be in accordance with applicable local, state and federal laws and regulations.

Excavations will be by hand if and where required by the Company.

The bottom of all excavations shall be inspected and approved by the Company immediately prior to any subsequent construction.

Excavation shall be to the lines and grades indicated on the drawings.

3.5.2 Common Excavation

Common excavation shall include all excavation except that of rock (defined in Section 3.5.3). All soils from common excavation that conform to requirements of Common Fill shall be temporarily stockpiled, at locations indicated by the Company, or transported to and placed in common fill areas. Materials unsuitable for fill shall be hauled to other locations within the Marshall Steam Station site for disposal, or stockpiled at on-site locations, as designated by the Company.

3.5.3 Rock Excavation

Beds, ledges, masses and deposits of rock material occupying a volume in excess of one cubic yard that are located in excavation areas above the planned final site grades shown on the drawings (non-trench areas) shall be considered rock excavation if they cannot be loosened for excavation with a single tooth ripper drawn by a crawler tractor having a minimum fly wheel power not less than 285 horsepower (Caterpiller D-8N, or equivalent). Such materials located in small areas below planned site grades (in trenches) and in areas not accessible to large tractors, shall be considered rock excavation if they occupy a volume of at least ½ cubic yard, and cannot be loosened for excavation with a Caterpiller 325, or equivalent, excavator equipped with a rock bucket.

Rock materials that, in the opinion of the Company, can be considered Rock Excavation, that are located within the lines of required excavation, shall be loosened for excavation using hydraulic breakers, jack hammers or other similar method proposed by the Subcontractor and authorized by the Company. The use of explosives shall not be permitted without the Subcontractor developing a written site specific plan for the use of explosives for submittal to and approval by the Company. The Subcontractor shall obtain all necessary permits from authorities having jurisdiction. No explosives shall be used until written authorization of the Owner and Company has been provided.

All material exceeding 12 inches in size from rock excavations and from common excavation areas shall be transported by the Subcontractor to a rock disposal area for disposal. The material shall be placed in the disposal area using methods approved by the Company that result in a stable mass with a relatively level surface and uniform slopes, and that prevents rock pieces from rolling down slopes during and after placement. Dumping and dozing of the excavated materials over exterior slopes of the disposal area will not be allowed.

3.6 FILL

3.6.1 General

The Subcontractor shall provide all fill material in the quantities required to the lines and grades indicated on the drawings. Material from onsite excavations may be used for common fill, if appropriate, as determined by the Company. The Subcontractor shall submit test reports of material at the proposed source of borrow showing conformance to the requirements of this specification for gravel surfacing, rip rap, structural fill, road base, and pipe bedding prior to use on the project and as specified herein. Materials brought to the site that do not, in the opinion of the Company, conform to specification requirements shall be removed from the site by the Subcontractor, at no cost to the Company

3.6.2 Fill Material Delivery and Unloading

3.6.2.1 Fill material shall be delivered to the site in trucks (dump trucks) that can unload the materials without the use of other equipment. The beds of all trucks used to transport earth materials shall have solid walls and floors, and a tailgate that will prevent the enclosed materials from spilling, falling or blowing from the beds during transport. The top of the truck beds and the enclosed materials shall be covered with a tarp or similar cover that is securely fastened to the bed walls and tailgate prior to and during transport. The tarp or cover, in conjunction with the bed, walls and tailgate, shall completely encapsulate the materials during transport.

3.6.2.2 All equipment and vehicles used for the work shall be maintained in good operating condition. The Subcontractor shall be responsible for maintenance of all vehicles and equipment, and for the fueling of the hauling vehicles used for the work at off-site facilities.

3.6.2.3 The Subcontractor shall provide sufficient vehicles, equipment, labor and supervision to transport the fill materials to conform to project schedules.

3.6.3 Unloading Fill Materials

3.6.3.1 All vehicles shall enter and leave the site at construction vehicle access entrances designated by the Engineer. All vehicles shall remove all dirt or mud from the vehicles' wheels prior to leaving the site to minimize tracking such materials off the site. The Subcontractor shall provide a wheel wash and/or tire bath near the construction entrance for that purpose. The Subcontractor shall also provide a sweeper, as necessary, to clean the public roads and streets adjacent to the designated entrances, to remove soils tracked from the site onto those roads and streets.

3.6.3.2 Fill materials shall be unloaded at the site at locations indicated by the Company. Truck routes across the site shall be as indicated by the Company. In general, the trucks hauling the materials to the site shall unload the fill material as close as practical to the location where the fill material is being spread, and in a manner that will facilitate the spreading of the materials.

3.6.3.3 Each lift of fill shall be spread, mixed and compacted using suitable equipment approved by the Company.

3.6.4 Common Fill Placement

Common fill shall be placed in horizontal loose lifts of no more than 12 inches in thickness. Prior to compaction, the moisture content of the fill shall be conditioned (moistened or dried), as necessary, to be within 3 percent of the optimum moisture content for compaction. Each lift of fill shall be compacted to at least 90 percent of maximum density (ASTM D 1557).

3.6.4.1 Gravel Surfacing Placement

Gravel surfacing shall be placed in horizontal loose lifts of no more than 8 inches in thickness. Prior to compaction, the moisture content of the material shall be conditioned (moistened or dried), as necessary, to be within 3 percent of the optimum moisture content for compaction. Each lift of gravel surfacing shall be compacted to at least 95 percent of maximum density (ASTM D 1557).

3.6.4.2 Pipe Bedding Placement

Pipe bedding shall be placed in horizontal loose lifts of no more than 8 inches in thickness. Prior to compaction, the moisture content of the material shall be conditioned (moistened or dried), as necessary, to be within 3 percent of the optimum moisture content for compaction. Each lift of base course shall be compacted to at least 90 percent of maximum density (ASTM D 1557).

3.7 TOLERANCES

Excavations and fills shall be in accordance with the lines, grades, and dimensions shown on the Company's drawings or as directed by the Company. The surfaces of the completed excavations upon which fill is to be placed shall be reasonably smooth, compacted, and free from irregular surface changes that will pond water. Ditches shall be finished to permit effective drainage. The surfaces of all excavations and fills shall not vary by more than 0.1 feet from the lines and grades shown on the drawings.

Newly graded areas shall be protected from traffic and from erosion and any settlement or erosion that may occur from any cause, prior to acceptance, shall be repaired and grades reestablished to the required elevations and slopes.

3.8 TOPSOIL AND SEEDING

3.8.1 General

3.8.1.1 The Subcontractor shall distribute the stockpiled topsoil over those areas indicated on the drawings or as directed by the Company. Topsoil shall be uniformly deposited to a minimum thickness of 4 inches in loose depth, unless more is indicated on the drawings.

3.8.1.2 The Subcontractor shall fertilize and seed those areas indicated on the drawings, or as directed by the Company.

3.8.1.3 Before fertilizing, the surface shall be trimmed and raked to true lines free from unsightly variations, humps, ridges or depressions. The surface material shall be free from clods of soil, matted roots, roots greater than 1 inch in diameter, and any other objectionable material which might hinder subsequent grassing and mowing operations.

3.8.1.4 Prior to fertilizing or seeding, the Subcontractor shall analyze top soil samples to determine the nutrient deficiencies and pH adjustment required for establishing and maintaining a thriving grass growth. Soil samples shall be taken at random, but as a minimum at each area where the topsoil varies in color, texture or organic content. Provide and apply fertilizer and lime in accordance with the requirements for soil amendments on the erosion control drawings.

3.8.2 Fertilizer And Lime

The Subcontractor shall select the equipment to uniformly blend these ingredients with the topsoil to encourage a deep root system for the new grass. The Company shall approve all soil amendments.

3.8.3 Seed

The Subcontractor shall provide perennial grass seed mixtures in accordance with the seeding specifications shown on MM6451.01-0004.001, Erosion Control Details, Details #2 and #3. Detail #3 applies to all areas except grass-lined ditches. Seed shall have minimum 85 percent germination.

3.8.4 Application

Application rates shall be as shown on MM6451.01-0004.001, Erosion Control Details, Details #2 and #3.

3.8.4.1 Seed shall be applied to the topsoil bed by mechanical, hydroseeding or any other method that will produce a uniform distribution.

3.8.4.2 Within 24 hours after seeding, apply mulch in accordance the requirements of MM6451.01-0004.001, Erosion Control Details.

3.8.4.3 During progress of the work, the Company reserves the right to reject any and all materials, which in its opinion appears unsatisfactory for the intended use.

3.8.4.4 The Subcontractor shall maintain seeded areas in accordance with the requirements of MM6451.01-0004.001, Erosion Control Details, until the work under this contract has been completed.

3.9 FINAL CLEANUP

3.9.1 Acceptance

Before final acceptance of the project, the Subcontractor shall remove all equipment, temporary work, unused and/or useless material, rubbish and temporary buildings, shall repair or replace, in a manner acceptable to the Company, fences and other private or public property which may have been damaged on account of execution of the work, shall fill all depressions and water pockets caused by his operations, shall remove all obstructions from waterways caused by his work, shall clean all drains and ditches within and adjacent to the site which have been obstructed by his operations, and shall leave the site of the project in a neat and presentable condition wherever his operations have disturbed conditions existing at the time of starting his work.

Shaw® Stone & Webster, Inc. PROJECT SPECIFICATION	J.O./W.O. NO.	101540	SPEC. NO.:	MS-6451.00-00-0002
	PAGE	Cover	REVISION	B
	CLIENT	Duke Energy		
	PROJECT	Flue Gas Desulfurization Retrofit Program		
	TITLE	Site Preparation Gypsum Landfill Cell 2		

SITE PREPARATION FOR GYPSUM LANDFILL CELL 2

NORTH CAROLINA PROFESSIONAL SEAL 029024 ENGINEER JOHN A. LAPERRIERE-HUNT 3-29-04

REVISION	A	B	0	1	2	3
REV. DATE	March 1, 2004	March 29, 2004				
REV. DESC.	IFA	IF-Permitting				
PREPARER	J.LaPerriere-Hunt	[signature]				
LEAD ENGINEER	D.Jordan	[signature]				
PROJECT ENGINEER	C.Bussell	[signature]				

TABLE OF CONTENTS

1.0 PART 1 – GENERAL

1.1 SCOPE

The work to be performed under this scope of work is located in the town of Terrell, Catawba County, North Carolina. The site is on land which is part of the existing Marshall Steam Station. The area is generally wooded and the terrain varies from flat to steep hills. The site is adjacent to Lake Norman and North Carolina State Route 150.

This specification covers the technical requirements for performing all site preparation work to grade the site to the planned rough grades, shown on the drawings and to install underground storm drainage system as indicated on the drawings. The Subcontractor shall be responsible for performing all in accordance with the Project Specifications and the Codes and Standards listed herein. The work consists of furnishing of all labor, materials and equipment to perform the following:

a. Provide all surveying and engineering services to establish reference points, lines and grades to control the work, and to measure excavation and fill quantities. The Owner will provide coordinates and elevations of control points at existing plant site for the Subcontractor's use.

b. Install and maintain erosion control measures in the Gypsum Landfill including sediment ponds and underground piping shown on Drawings, Cell 2, Erosion and Sediment Control Plan and Erosion Control Detail. Note: proposed contours shall be as the shown on Drawing M-6024-05.00.

c. Protect land, water and air resources affected by construction.

d. Clear and grub, including removal of trees, the area within the limits shown on Drawing M-6024-05.00, Gypsum Landfill, Cell 2 Excavation.

e. Demolish existing facilities where required or called for on the drawings.

f. Strip topsoil from designated area and stockpile it on site.

g. Excavations and fill placement to grade the site to proposed contours indicated on Drawing M-6024-05.00, Gypsum Landfill, Cell 2 Excavation.

h. Areas to be designated as parking and laydown shall be determined by the Engineer in the field.

i. Place topsoil from stockpile on slopes and designated areas after completion of grading.

j. Hydroseed or seed or establish by other means, including mulching, a permanent grass surface on slopes and areas designated on the Drawing MM6451.01-0002.001.

k. Develop and maintain a temporary surface drainage system during the course of site preparation.

l. Construct sediment ponds and drainage systems as shown on the drawing MM6451.01-0002.001.

m. Conform to N.C. Landfill Permit Regulations.

1.2 REFERENCED CODES AND STANDARDS

The codes and standards referenced below shall be the issues in effect on the date of Invitation to Bid. If there is, or appears to be, a conflict between this specification and a referenced document, the matter shall be referred to the Engineer.

a. American Society for Testing and Materials (ASTM)

1) D 422, Particle-Size Analysis of Soils
2) D1557, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort
3) D 2487, Classification of Soils for Engineering Purposes (Unified Soil Classification System)
4) D 2488, Description and Identification of Soils (Visual-Manual Procedure)
5) D 4318, Liquid Limit, Plastic Limit, and Plasticity Index of Soils

b. Occupational Safety and Health Administration (OSHA)

29 CFR 1926/1910, Safety Standards for the Construction Industry

c. North Carolina Department of Transportation Standard Specifications for Roads and Structures, most current version

d. Project Specifications

1) MS-6168.00-00-0000, Underground Storm Piping Materials
2) MS-6168.00-00-0001, Installation of Storm Drainage System

e. North Carolina Solid Waste Management Rules sections .055 and .1600

1.3 DEFINITION OF TERMS

The meaning of the following terms, or pronouns used in place of them, whenever used in these specifications, or instruments of construction which these specifications govern, shall be interpreted as follows:

Owner: Duke Energy.

Company: Shaw Stone and Webster, Inc.

Subcontractor: The company accepting overall responsibility for fulfilling the requirements of this specification.

Engineer: Authorized Engineer of the Company.

1.4 SUBSURFACE INVESTIGATION

The Company will provide the Subcontractor with a copy of the subsurface investigation program report, which includes boring and soils data. The Company does not represent that the information in the report, including the boring logs, represent actual conditions that will be found throughout the site. The boring logs only indicate the conditions at the particular locations of the borings. The Subcontractor shall assume full responsibility for any interpretation and conclusions which he may make as to the nature of subsurface materials and conditions to be found and the difficulty of performing the work.

1.5 COMPANY QUALITY ASSURANCE ACTIVITIES

The Company shall have the right, at all reasonable times, to inspect the Subcontractor's work, material, equipment or inspection program, as applicable to the work covered by this specification, to confirm that specification requirements are being fulfilled.

The Company and/or an independent testing agency hired by the Company may perform materials testing and inspections of the Subcontractor's work. The Company's surveyor may also periodically verify the Subcontractor's locations and elevations. The Subcontractor shall provide reasonable assistance so the Engineer, the independent testing agency and surveyor can perform the tests, inspections and surveys.

Test and survey results shall not be the sole basis the Company will use to evaluate Subcontractor compliance with Specification requirements. The test and survey results shall not relieve the Subcontractor of the sole responsibility of performing all work to conform to specification requirements.

It is not intended that the presence or activity of the Company shall relieve the Subcontractor in any way of his obligation under this Specification. Furthermore, the fact that the Company may inadvertently overlook a deviation from some requirement of this specification shall not constitute a waiver of that requirement, nor the Subcontractor's obligation to correct the condition when it is discovered, nor of any other obligation of this specification.

1.6 BENCHMARKS AND REFERENCE BASE LINES

The Subcontractor shall satisfy himself that any benchmarks or reference lines provided by the Owner or Company are correct. The Subcontractor shall furnish all equipment and tools and shall be responsible for accurately locating and staking out the work. Benchmarks and reference lines shall be carefully maintained and, if disturbed or destroyed, shall be replaced by the Subcontractor at no cost to the Company or Owner.

1.7 PROTECTION OF EXISTING SERVICES

Existing utility lines and underground facilities, where known, are indicated on the drawings. The Subcontractor shall be responsible for locating and identifying in the field all existing underground utilities, pipelines and other installations prior to executing any earthworks or excavations. The Subcontractor shall notify the Company of any additional obstructions encountered and shall provide support, protection or removal of such obstructions as directed by the Company.

The existing structures and utilities which are adjacent to the site and those to remain within the limits of the work shall be protected against damage. The Subcontractor shall be fully responsible to the Company or Owner in the event of removal of or damage to any existing objects by Subcontractor personnel, which are intended by the Owner to remain in place.

1.8 TOPSOIL

Topsoil (see Part 2 for definition) shall be considered to be the property of the Owner and shall be stockpiled for future use at the locations designated by the Company.

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No excavation, grading or other work shall be performed in wet, cold or other adverse weather conditions which, in the opinion of the Company, will prevent attaining satisfactory construction.

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1.10.1 General

a. The control of environmental pollution which could result from construction operations under this contract requires consideration of land, water and air quality at the site.

b. The Subcontractor and his subcontractors shall comply with all applicable federal, state and local laws and regulations concerning environmental pollution control or Landfill Construction Permit abatement. The Subcontractor shall make sure that necessary permits have been obtained and that his work is in compliance with such permits concerning environmental protection.

c. The Company and the Subcontractor shall establish the criteria for compliance and administration of the environmental pollution control program prior to commencement of work.

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a. Land resources adjacent to the project boundaries shall be preserved in their present condition or restored to a natural appearance.

b. The Subcontractor shall not injure or destroy trees or shrubs adjacent to the project site. Construction activities shall be confined within the construction limits shown on the plans.

c. Temporary roads, embankments or excavations shall be restored to natural grade and seeded prior to completion of construction.

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a. The Subcontractor shall not adversely affect the existing water quality within or adjacent to the project site. No construction wastes or other harmful materials shall be permitted to enter these water resources.

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a. The Subcontractor shall ensure that fires which are permitted are kept small in size and that no heavy oils, asphaltic materials or anything other than wood or natural plant growth are burned.

b. The Subcontractor shall maintain the project site and access roads free from dust, which would cause a hazard or nuisance to others.

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Earth materials used as fill shall contain no topsoil; pieces of roots, grass, weeds, other vegetation; organic materials; snow, ice or frozen materials; debris or other foreign material; or chemical contamination (oil, grease, solvents, dissolved metals, etc). The material shall not be excessively dry or moist (i.e. shall be near the optimum moisture content for compaction per ASTM D 1557).

2.2 TOPSOIL

Unless otherwise directed by the Company and/or indicated on the drawings, topsoil shall be defined as the top six (6) inches of surface soil measured from the existing grade. The Subcontractor shall remove roots larger than one (1) inch in diameter, and any debris prior to stockpiling of the topsoil as determined by the Company.

2.3 COMMON FILL

Common Fill shall consist of sands or gravels, classified in accordance with the Unified Soil Classification System (ASTM D 2487, ASTM D 2488), or mixtures thereof, containing no individual particles larger than 3 inches in size. The plasticity index (ASTM D 4318) of the material shall not exceed 10. In areas approved by the Company, such as deep embankments, rocks up to 12 inches in size may be incorporated into the fill material provided such rocks are widely separated in the fill so that compaction of the fill, as determined by the Company, is not affected.

2.4 GRAVEL SURFACING

Gravel shall consist of durable angular gravels conforming to the Class IV classification for Select Material of Section 1016 of the North Carolina Department of Transportation Standard Specifications.

2.5 PIPE EMBEDMENT

Pipe embedment shall refer to pipe bedding, haunching, and initial backfill as indicated on the design drawings.

Pipe embedment where indicated by this specification or on the Engineer's drawings, shall conform to Section 1044-1, "Subdrain Fine Aggregate", of the North Carolina Department of Transportation Standard Specifications.

2.6 GEOTEXTILES

Geotextiles shall be as shown on the drawings. Unless indicated otherwise these shall be woven geotextiles, such as Mirafi 700X or approved equal. Equivalent fabrics shall meet the strength and filtration characteristics of the specified products.

Geotextile rolls shall be furnished with suitable wrapping for protection against moisture, and extended ultraviolet exposure prior to placement. Each roll shall be labeled or tagged to provide product identification sufficient for inventory and quality control purposes. Rolls shall be stored in a manner which protects them from the elements. If stored outdoors, they shall be elevated and protected with a waterproof cover.

2.7 RIP RAP

Rip rap materials shall conform to Section 1042, "Rip Rap", Class 1 of North Carolina Department of Transportation Standard Specifications.

3.0 PART 3 - EXECUTION

3.1 EROSION AND SEDIMENT CONTROL MEASURES

Prior to beginning work at the site, and during the course of the work, the Subcontractor shall install erosion and sediment control measures, as indicated by the drawings and in the Owner's permits and plans. The Subcontractor shall maintain those measures, and install additional measures, as necessary, during the course of the Subcontractor's work, and shall comply to all requirements of the permits.

The Subcontractor shall design, provide, operate and maintain all temporary and permanent ditches, culverts, berms, site grading and pumps to divert, collect and remove all ground and surface water from the work area. The Subcontractor shall ensure that such water removal is in compliance with the erosion and sediment control measures shown on the drawings and described in this specification.

3.2 DEMOLITION

3.2.1 Scope of Work

The work includes demolition and removal of all facilities indicated on the drawings. The Subcontractor shall provide adequate safety precautions. The use of explosives will not be permitted without written authorization from the Owner and the Company.

3.2.2 General

3.2.2.1 The Subcontractor shall be solely responsible for securing all necessary permits, and for performing the work in compliance with all applicable federal, state, and local requirements.

3.2.2.2 The Subcontractor shall take every possible precaution against damage or injury to other properties and workers. Demolition shall conform to requirements as set forth in the latest issue of OSHA requirements for the construction industry (29 CFR 1926). Any damage or injury that may result from the Subcontractor's operations shall be the Subcontractor's responsibility.

3.2.2.3 The Subcontractor shall not start demolition of any facility or obstruction until he submits to the Company a written demolition plan or drawing for approval and receives his authorization, from the Company, to proceed with the work.

3.2.2.4 All materials, fixtures and equipment in, attached, or belonging to a facility at the time it is released for demolition shall become the property of the Subcontractor unless stated otherwise in writing.

3.2.3 Disposal

All demolished material shall be removed from the site daily as demolition work progresses unless otherwise approved by the Company. Salvage materials shall be stored as approved by the Company but shall be removed before completion of the demolition portion of the contract.

3.3 CLEARING AND GRUBBING

3.3.1 General

3.3.1.1 Clearing shall consist of removal of all trees, brush, grasses, trash, rubbish and debris from within the clearing limits shown on the drawings. All overhanging trees shall be trimmed to the line of clearing. All trimmed surfaces over ¾ inch in diameter shall be treated with bitumastic paint.

3.3.1.2 No trees shall be cut outside the areas shown on the drawings.

3.3.1.3 Grubbing shall consist of removal and disposal of all stumps and roots greater than 1 inch in diameter.

3.3.1.4 Trees and vegetation indicated on the drawings to remain shall be protected from damage incident to clearing, grubbing and construction operations by the erection of appropriate barriers.

3.3.2 Disposal of Materials

3.3.2.1 Trees, brush, stumps, roots, and debris shall be disposed of by burning, or by removal from the site.

3.3.2.2 Burning operations if approved by the Company shall be conducted in accordance with federal, state, and local regulations. The Subcontractor shall be responsible for obtaining all permits for burning. Fires shall be located and supervised to prevent spreading or scorching of remaining vegetation. The Subcontractor shall be responsible for any damage resulting from such fires.

3.3.2.3 The Subcontractor shall seek the directions of the Company for the disposal of any material suspected to be contaminated with substances considered harmful to human health.

3.4 STRIPPING

3.4.1 General

Stripping shall consist of excavation and removal of all topsoil and organic material within the clearing limits shown on the drawings. Stumps, roots, and other organic material larger than 1 inch in size shall be separated from the topsoil.

3.4.2 Stockpiling Topsoil

Material suitable for use as topsoil shall be stockpiled in areas shown on the drawings or as indicated by the Company during the course of the work. Stockpile slopes shall be maintained in a stable condition. Rubbish and debris shall not be intermixed with stockpiled topsoil materials. Unsuitable material shall be removed from site.

Materials shall be deposited in lifts by dumping and spreading with a bulldozer.

Lift thickness shall be a maximum of 3 feet.

Stockpile slopes shall not be steeper than 3 horizontal to 1 vertical.

Topsoil shall not be stockpiled within the drip line of remaining trees.

Stockpiles shall be graded to facilitate runoff.

3.5 EXCAVATION

3.5.1 General

The Subcontractor shall take every possible precaution against damage or injury to other properties and workers during excavation. Excavation methods shall conform to requirements as set forth in the latest issue of OSHA requirements for the construction industry (29 CFR 1926). Any damage or injury that may result from the Subcontractor's operations shall be the Subcontractor's responsibility.

After clearing, grubbing and stripping operations have been completed, excavations to grade the site to planned grades shall be at the locations and to the lines and elevations shown on the drawings. If loose or unsuitable earth materials, as determined by the Company, are found in excavation bottoms or slopes, the Company will require the excavations to be deepened to remove the loose or unsuitable material.

Should the Subcontractor excavate below the planned permanent lines and grades indicated on the drawings, or below depths directed by the Company, the Company shall be notified immediately. In the event of over excavation, work in the area in question shall cease until further notice. Earth shall be placed to return unauthorized over excavation to the lines and grades indicated on the construction plans, as directed by the Company.

Temporary excavations to prepare areas to receive fill or for culverts, pipes, and appurtenances shall be to the depths shown on the drawings. The Subcontractor shall shore, brace or otherwise support such excavations, flatten excavation slopes and/or increase excavation dimensions as necessary to provide for worker safety. Such shoring, bracing, supports, and increased excavation dimensions shall be provided by the Subcontractor and shall be in accordance with applicable local, state and federal laws and regulations.

Excavations will be by hand if and where required by the Company.

The bottom of all excavations shall be inspected and approved by the Company immediately prior to any subsequent construction.

Excavation shall be to the lines and grades indicated on the drawings.

3.5.2 Common Excavation

Common excavation shall include all excavation except that of rock (defined in Section 3.5.3). All soils from common excavation that conform to requirements of Common Fill shall be temporarily stockpiled, at locations indicated by the Company, or transported to and placed in common fill areas. Materials unsuitable for fill shall be hauled to other locations within the Marshall Steam Station site for disposal, or stockpiled at on-site locations, as designated by the Company.

3.5.3 Rock Excavation

Beds, ledges, masses and deposits of rock material occupying a volume in excess of one cubic yard that are located in excavation areas above the planned final site grades shown on the drawings (non-trench areas) shall be considered rock excavation if they cannot be loosened for excavation with a single tooth ripper drawn by a crawler tractor having a minimum fly wheel power not less than 285 horsepower (Caterpiller D-8N, or equivalent). Such materials located in small areas below planned site grades (in trenches) and in areas not accessible to large tractors, shall be considered rock excavation if they occupy a volume of at least ½ cubic yard, and cannot be loosened for excavation with a Caterpiller 325, or equivalent, excavator equipped with a rock bucket.

Rock materials that, in the opinion of the Company, can be considered Rock Excavation, that are located within the lines of required excavation, shall be loosened for excavation using hydraulic breakers, jack hammers or other similar method proposed by the Subcontractor and authorized by the Company. The use of explosives shall not be permitted without the Subcontractor developing a written site specific plan for the use of explosives for submittal to and approval by the Company. The Subcontractor shall obtain all necessary permits from authorities having jurisdiction. No explosives shall be used until written authorization of the Owner and Company has been provided.

All material exceeding 12 inches in size from rock excavations and from common excavation areas shall be transported by the Subcontractor to a rock disposal area for disposal. The material shall be placed in the disposal area using methods approved by the Company that result in a stable mass with a relatively level surface and uniform slopes, and that prevents rock pieces from rolling down slopes during and after placement. Dumping and dozing of the excavated materials over exterior slopes of the disposal area will not be allowed.

3.6 FILL

3.6.1 General

The Subcontractor shall provide all fill material in the quantities required to the lines and grades indicated on the drawings. Material from onsite excavations may be used for common fill, if appropriate, as determined by the Company. The Subcontractor shall submit test reports of material at the proposed source of borrow showing conformance to the requirements of this specification for gravel surfacing, rip rap, structural fill, road base, and pipe bedding prior to use on the project and as specified herein. Materials brought to the site that do not, in the opinion of the Company, conform to specification requirements shall be removed from the site by the Subcontractor, at no cost to the Company

3.6.2 Fill Material Delivery and Unloading

3.6.2.1 Fill material shall be delivered to the site in trucks (dump trucks) that can unload the materials without the use of other equipment. The beds of all trucks used to transport earth materials shall have solid walls and floors, and a tailgate that will prevent the enclosed materials from spilling, falling or blowing from the beds during transport. The top of the truck beds and the enclosed materials shall be covered with a tarp or similar cover that is securely fastened to the bed walls and tailgate prior to and during transport. The tarp or cover, in conjunction with the bed, walls and tailgate, shall completely encapsulate the materials during transport.

3.6.2.2 All equipment and vehicles used for the work shall be maintained in good operating condition. The Subcontractor shall be responsible for maintenance of all vehicles and equipment, and for the fueling of the hauling vehicles used for the work at off-site facilities.

3.6.2.3 The Subcontractor shall provide sufficient vehicles, equipment, labor and supervision to transport the fill materials to conform to project schedules.

3.6.3 Unloading Fill Materials

3.6.3.1 All vehicles shall enter and leave the site at construction vehicle access entrances designated by the Engineer. All vehicles shall remove all dirt or mud from the vehicles' wheels prior to leaving the site to minimize tracking such materials off the site. The Subcontractor shall provide a wheel wash and/or tire bath near the construction entrance for that purpose. The Subcontractor shall also provide a sweeper, as necessary, to clean the public roads and streets adjacent to the designated entrances, to remove soils tracked from the site onto those roads and streets.

3.6.3.2 Fill materials shall be unloaded at the site at locations indicated by the Company. Truck routes across the site shall be as indicated by the Company. In general, the trucks hauling the materials to the site shall unload the fill material as close as practical to the location where the fill material is being spread, and in a manner that will facilitate the spreading of the materials.

3.6.3.3 Each lift of fill shall be spread, mixed and compacted using suitable equipment approved by the Company.

3.6.4 Common Fill Placement

Common fill shall be placed in horizontal loose lifts of no more than 12 inches in thickness. Prior to compaction, the moisture content of the fill shall be conditioned (moistened or dried), as necessary, to be within 3 percent of the optimum moisture content for compaction. Each lift of fill shall be compacted to at least 90 percent of maximum density (ASTM D 1557).

3.6.4.1 Gravel Surfacing Placement

Gravel surfacing shall be placed in horizontal loose lifts of no more than 8 inches in thickness. Prior to compaction, the moisture content of the material shall be conditioned (moistened or dried), as necessary, to be within 3 percent of the optimum moisture content for compaction. Each lift of gravel surfacing shall be compacted to at least 95 percent of maximum density (ASTM D 1557).

3.6.4.2 Pipe Bedding Placement

Pipe bedding shall be placed in horizontal loose lifts of no more than 8 inches in thickness. Prior to compaction, the moisture content of the material shall be conditioned (moistened or dried), as necessary, to be within 3 percent of the optimum moisture content for compaction. Each lift of base course shall be compacted to at least 90 percent of maximum density (ASTM D 1557).

3.7 TOLERANCES

Excavations and fills shall be in accordance with the lines, grades, and dimensions shown on the Company's drawings or as directed by the Company. The surfaces of the completed excavations upon which fill is to be placed shall be reasonably smooth, compacted, and free from irregular surface changes that will pond water. Ditches shall be finished to permit effective drainage. The surfaces of all excavations and fills shall not vary by more than 0.1 feet from the lines and grades shown on the drawings.

Newly graded areas shall be protected from traffic and from erosion and any settlement or erosion that may occur from any cause, prior to acceptance, shall be repaired and grades reestablished to the required elevations and slopes.

3.8 TOPSOIL AND SEEDING

3.8.1 General

3.8.1.1 The Subcontractor shall distribute the stockpiled topsoil over those areas indicated on the drawings or as directed by the Company. Topsoil shall be uniformly deposited to a minimum thickness of 4 inches in loose depth, unless more is indicated on the drawings.

3.8.1.2 The Subcontractor shall fertilize and seed those areas indicated on the drawings, or as directed by the Company.

3.8.1.3 Before fertilizing, the surface shall be trimmed and raked to true lines free from unsightly variations, humps, ridges or depressions. The surface material shall be free from clods of soil, matted roots, roots greater than 1 inch in diameter, and any other objectionable material which might hinder subsequent grassing and mowing operations.

3.8.1.4 Prior to fertilizing or seeding, the Subcontractor shall analyze top soil samples to determine the nutrient deficiencies and pH adjustment required for establishing and maintaining a thriving grass growth. Soil samples shall be taken at random, but as a minimum at each area where the topsoil varies in color, texture or organic content. Provide and apply fertilizer and lime in accordance with the requirements for soil amendments on the erosion control drawings.

3.8.2 Fertilizer And Lime

The Subcontractor shall select the equipment to uniformly blend these ingredients with the topsoil to encourage a deep root system for the new grass. The Company shall approve all soil amendments.

3.8.3 Seed

The Subcontractor shall provide perennial grass seed mixtures in accordance with the seeding specifications shown on MM6451.01-0004.001, Erosion Control Details, Details #2 and #3. Detail #3 applies to all areas except grass-lined ditches. Seed shall have minimum 85 percent germination.

3.8.4 Application

Application rates shall be as shown on MM6451.01-0004.001, Erosion Control Details, Details #2 and #3.

3.8.4.1 Seed shall be applied to the topsoil bed by mechanical, hydroseeding or any other method that will produce a uniform distribution.

3.8.4.2 Within 24 hours after seeding, apply mulch in accordance the requirements of MM6451.01-0004.001, Erosion Control Details.

3.8.4.3 During progress of the work, the Company reserves the right to reject any and all materials, which in its opinion appears unsatisfactory for the intended use.

3.8.4.4 The Subcontractor shall maintain seeded areas in accordance with the requirements of MM6451.01-0004.001, Erosion Control Details, until the work under this contract has been completed.

3.9 FINAL CLEANUP

3.9.1 Acceptance

Before final acceptance of the project, the Subcontractor shall remove all equipment, temporary work, unused and/or useless material, rubbish and temporary buildings, shall repair or replace, in a manner acceptable to the Company, fences and other private or public property which may have been damaged on account of execution of the work, shall fill all depressions and water pockets caused by his operations, shall remove all obstructions from waterways caused by his work, shall clean all drains and ditches within and adjacent to the site which have been obstructed by his operations, and shall leave the site of the project in a neat and presentable condition wherever his operations have disturbed conditions existing at the time of starting his work.

Appendix

APPENDIX

CALCULATIONS

LANDFILL CAPACITY

BORROW SOIL AVAILABILITY

NORTH CAROLINA
PROFESSIONAL
SEAL
17582
ENGINEER
DAN E. BREWER

3/26/04

CHAS. H. SELLS, INC.
Consulting Engineers, Surveyors & Photogrammetrists

Comp. By DEB Date 2/16/04 Project Marshall FGD Landfill Sheet No. 1 of 1
Chkd. By acm Date 2/17/04 Subject Landfill Capacity Job No. 046003

OBJECTIVE : Determine 5 Year Phase

PARAMETERS : Conditioned Annual Tonnage = 438,000 Tons

Volume for 438,000 Tons = 365,000 Cubic Yards

Reference : Duke Energy

Required Volume

365,000 CY (5 years) = 1,825,000 CY

Volume Provided (Gross)

Cell 1 = 751,200 CY
Cell 2 = 1,436,600 CY } Ref : LDD Software and Terramodel Verification

2,187,800 CY Gross Volume

Subtract Final Cover

$33 \text{ ac} (43,560 \text{ ft}^2/\text{ac})(3.5 \text{ ft})(1 \text{ cy}/27 \text{ ft}^3) = 186,340 \text{ CY}$

Subtract Intermediate Cover (8-inch thick layers)

Average 5 lifts = 3.33 ft total intermediate cover

$33 \text{ ac} (43,560 \text{ ft}^2/\text{ac})(3.33 \text{ ft})(1 \text{ cy}/27 \text{ ft}^3) = 177,300 \text{ CY}$

Net Volume = 2,187,800
− 186,340
− 177,300

1,824,160 CY Net OK

CHAS. H. SELLS, INC.
Consulting Engineers, Surveyors & Photogrammetrists

Comp. By DEB Date 2/16/04 | Project Marshall FGD Landfill | Sheet No. 1 of 1
Chkd. By Oen Date 2/17/04 | Subject Borrow Soil Availability | Job No. 046003

OBJECTIVE : Evaluate Borrow Soil Availability

PARMETERS : From LDD Software and Terramodel Verification

Cell 1 Fill = 47,200 CY

Cell 2 Fill = 46,370 CY

Intermediate Cover = 177,300 CY } From Landfill Capacity Calcs.

Final Cover = 186,340 CY

Cell 1 Cut = 414,900 CY

Cell 2 Cut = 254,500 CY

Compare Total Cut to Total Fill

Total Cut = 414,900 + 254,500 = 669,400 CY

Total Fill = 47,200 + 46,370 + 177,300 + 186,340 = 457,210 CY

Apply 15% Shrinkage Factor = 525,800 CY

Excess Soil = 669,400
− 525,800

143,600 CY Excess OK

SETTLEMENT/STABILITY

NORTH CAROLINA
PROFESSIONAL
SEAL
17582
ENGINEER
DAN E. BREWER

3/26/04

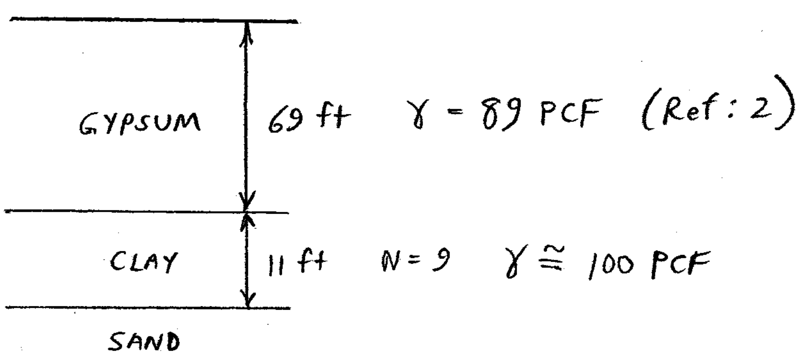
OBJECTIVE : EVALUATE SUBGRADE SETTLEMENT DUE TO WASTE

PARAMETERS : S&ME BORING LOGS B-2, B-3, B-6, OW-1, OW-2, MS-7, MS-8 (Reference #1)

	Ground EL	Proposed Subgrade EL	Proposed Final EL	ΔH (ft)
B-2	858	834	868	34
B-3	856	828	870	42
B-6	852	823	863	40
OW-1	840	850	892	52
CONTROLS → OW-2	833	831	900	69
MS-7	833	828	894	66
MS-8	848	842	907	65

REFERENCES:
1) S&ME, Inc., "Site Suitability Information for Marshall Steam Station FGD Residue Landfill", 8/20/0
2) S&ME, Inc., "FGD Scrubber Sludge Testing", Duke Power Coal Fired Steam Stations in NC", 2/04
3) FHWA Settlement Analysis Method by US Dept. of Transportation, publication No. FHWA-HI-88-00?

Determine Maximum Settlement at OW-2



Effective Vertical Stress at Mid Depth of Clay Layer

$$P_o = \gamma d = 100 \text{ PCF} (5.5 \text{ ft}) = 550 \text{ PSF}$$

Pressure Distribution

Due to size of landfill, assume Influence Value = 1

$$\Delta P = \gamma H = 89 \text{ PCF} (69 \text{ ft}) = 6{,}141 \text{ PSF}$$

Corrected N-value, N'

for $P_o = 550$ PSF, $\frac{N'}{N} = 1.85$ from Chart $\frac{N'}{N}$ vs P_o (Ref: 3, attached)

$$N' = 1.85(9) = 16.7$$

Bearing Capacity Index, C'

for $N' = 16.7$, $C' = 45$ for Sandy Clay

from Chart N' vs. C' (Ref: 3, attached)

Calculate Settlement

$$\Delta H = H\left(\frac{1}{C'}\right) \log \frac{P_o + \Delta P}{P_o}$$

$$= 11 \text{ ft}\left(\frac{1}{45}\right) \log \frac{550 + 6141}{550} = 0.27 \text{ ft}$$

Correction Factor = 2/3 (Ref 3)

$$\Delta H_{COR} = \frac{2}{3}(0.27) \text{ ft} = 0.18 \text{ ft} = \underline{2 \text{ inches}} \quad \text{OK}$$

∴ **Differential Settlement < 2 inches Does Not Affect Subgrade Slope**

BORING LOG OW-2

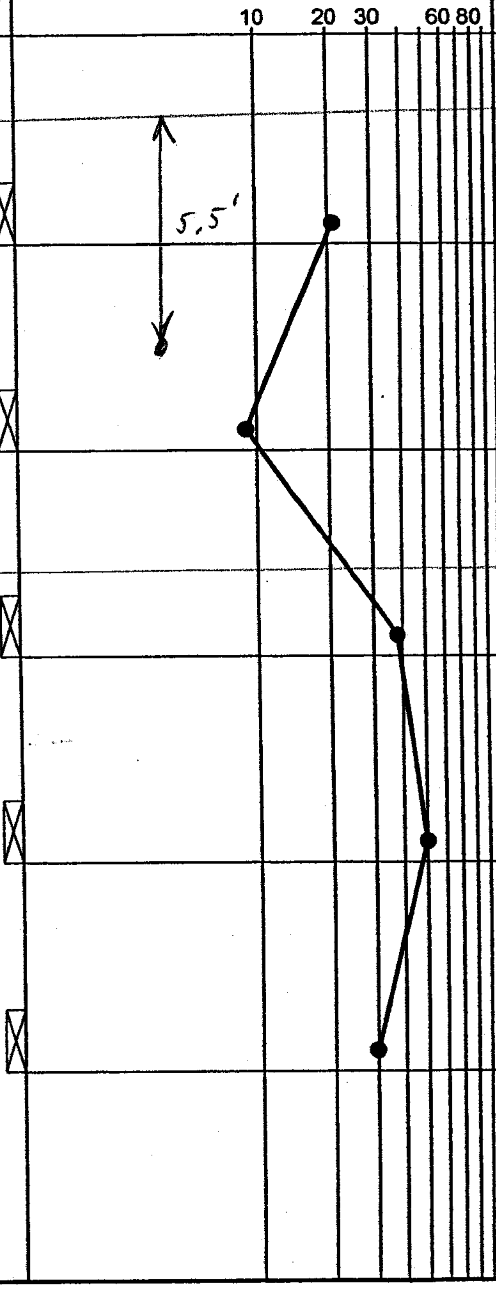
PROJECT: Marshall Steam Station, Terrell, North Carolina, 1264-02-578

DATE DRILLED: 2/12/03	ELEVATION:
DRILLING METHOD: 4¼" H.S.A.	BORING DEPTH: 26.0
LOGGED BY: Julie Petersen	WATER LEVEL: 17.56 ft bls at 24 hrs.
DRILLER: Brian Wilson, NC Cert No. 2718	DRILL RIG: Mobile B-57

NOTES:

DEPTH (feet)	GRAPHIC LOG	MATERIAL DESCRIPTION	WATER LEVEL	ELEVATION (feet-MSL)	SAMPLE NO/TYPE	N VALUE
0–3		RESIDUUM: Red Slightly Sandy Silty **CLAY**				
3–11		RESIDUUM: Tan to Reddish Tan Slightly Sandy Silty **CLAY** with Grey High Plasticity Clay Mottles			1 (at 5 ft); 2 (at 10 ft)	21; 9
11–13		RESIDUUM: Grey Fine Sandy **CLAY** (high plasticity)				
13–22		SAPROLITE: Red and Grey to White and Grey Very Micaceous Silty Fine **SAND**	▼ (approx. 17.5 ft); ▽ (approx. 21 ft)		3 (at 15 ft); 4 (at 20 ft)	38; 50
22–26		SAPROLITE: Grey and White Very Micaceous Coarse to Fine **SAND**			5 (at 25 ft)	30

STANDARD PENETRATION TEST DATA (blows/ft)



1. BORING AND SAMPLING IS IN ACCORDANCE WITH ASTM D-1586.
2. PENETRATION (N-VALUE) IS THE NUMBER OF BLOWS OF 140 LB. HAMMER FALLING 30 IN. REQUIRED TO DRIVE 1.4 IN. I.D. SAMPLER 1 FT.

BORING LOG WELLLOGS.GPJ S&ME.GDT 3/13/03

S&ME ENGINEERING • TESTING ENVIRONMENTAL SERVICES
9751 Southern Pine Blvd.
Charlotte, NC 28273

METHODOLOGY

In 1967, Bazaraa proposed the attached correlation between the standard penetration test N-value correction factor and the effective overburden pressure at the depth of testing in a paper entitled "The Use of Standard Penetration Test for Estimating Settlement of Shallow Foundations on Sand". As indicated by the attached relationship between correction factor (N'/N) and effective overburden pressure (P_o), the correction factor is greater than one for effective overburden pressures less than about 1500 pounds per square foot where the available confinement results in reduced standard penetration test N-values. Above about 1500 pounds per square foot up to about 6000 pounds per square foot, the standard penetration resistance correction factor decreases from about 1.0 to about 0.67 which is an approximate minimum correction factor value.

In 1959, Hough developed a correlation between what he termed the "Bearing Capacity Index" and a corrected standard penetration test N-Value in a paper entitled "Compressibility as a Basis for Soil Bearing Value". The so-called Bearing Capacity Index (C') is the reciprocal of the Compressibility Index used in calculation of settlements by one-dimensional consolidation theory. The attached correlation between Bearing Capacity Index (C') and corrected standard penetration test resistance value (N'-value) presents six curves for materials varying from a clean uniform medium sand to an inorganic silt. As indicated by the provided curves, the FHWA Settlement Analysis Method is best utilized for cohesionless soils and/or very low plasticity clayey sands, sandy clays, and inorganic silts. The relationships for sandy clay and inorganic silts should only be utilized for low-plasticity materials (PI less than about ten). Furthermore, the curve for inorganic silt should only be utilized for true silts and not sandy silts. An example of the use of this inorganic silt curve would be residual silts chemically weathered from limestone bedrock in the Ridge and Valley Provinces of Tennessee and Virginia.

APPLICATION

Application of the FHWA Settlement Analysis Method involves the following steps which are illustrated by the enclosed example problem.

1. Develop a subsurface profile representative of subsurface conditions for which settlement is to be calculated.

2. Stratify subsurface soils according to typical standard penetration resistance values (N-values), the existing groundwater level, soil types, and foundation dimensions. The author recommends use of a stratification of the upper layer at about the depth of the maximum width of footing but not greater than about ten feet. Individual layer thicknesses should be approximately

equal to that of the upper layer to slightly greater than the upper layer with increased depth below the footing.

3. Calculate the effective overburden pressure at the mid-depth of each stratification layer.

4. Calculate the foundation pressure influence at the mid-depth of each stratification layer. The approximation method (2:1 stress distribution), Westergaard stress distribution, or other suitable methods of stress distribution may be utilized to determine foundation pressure influence.

5. Correct the average standard penetration resistance values in each stratification layer using the calculated effective overburden pressure at the mid-depth of each layer.

6. Determine the appropriate Bearing Capacity Index for each stratification layer. Note: Use the curve for Well Graded Fine to Medium Silty SAND for non-plastic residual sandy silts.

7. Calculate the settlement of each stratification layer by the following equation:

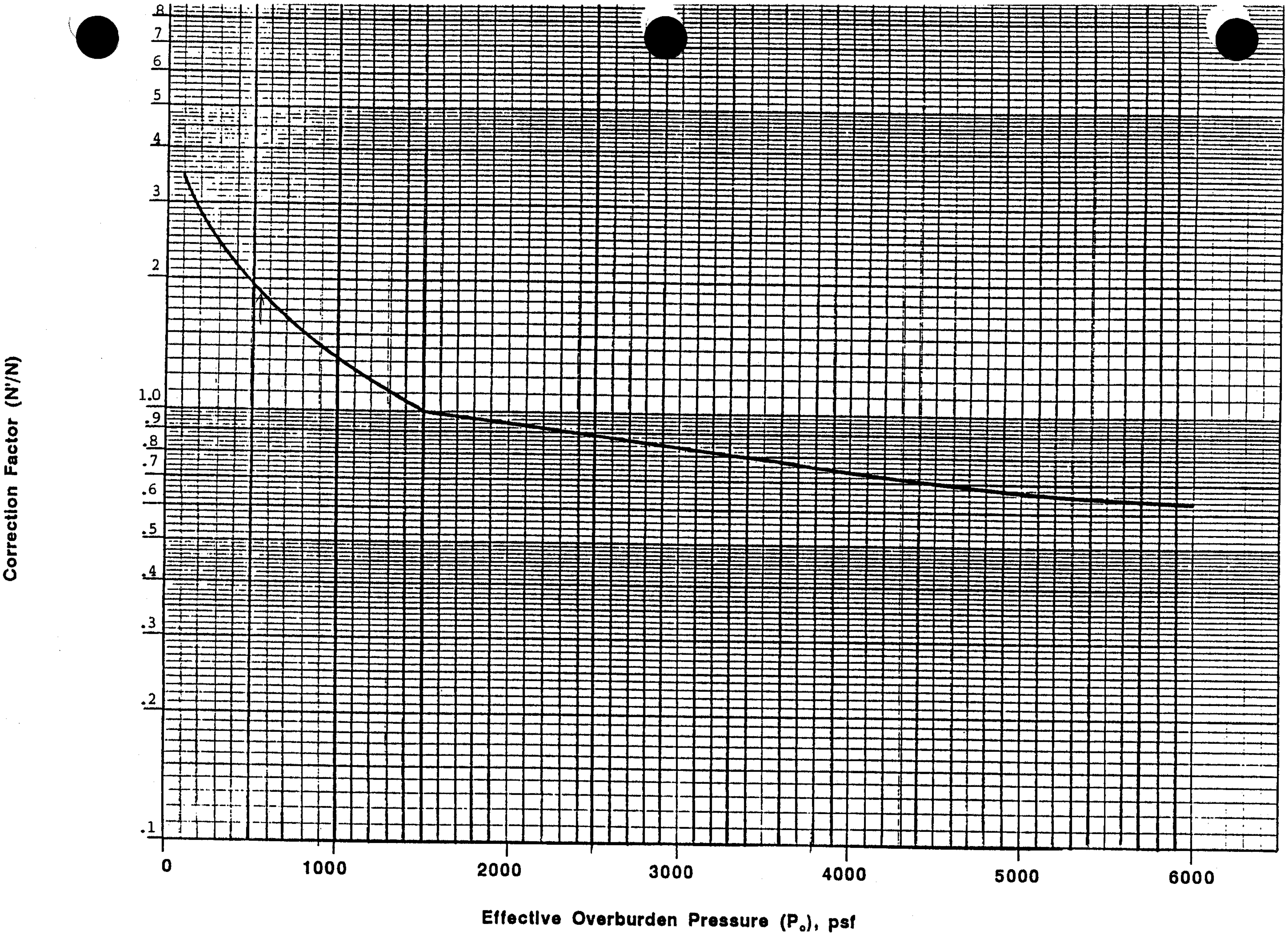
$$\Delta H = H \cdot {}^{1}/C' \cdot \text{Log} \frac{P_o + \Delta P}{P_o}$$

8. Reduce the calculated settlement by factors of 0.6 to 0.7. The author recommends the use of a reduction factor of two-thirds (0.67).

CORRELATIONS

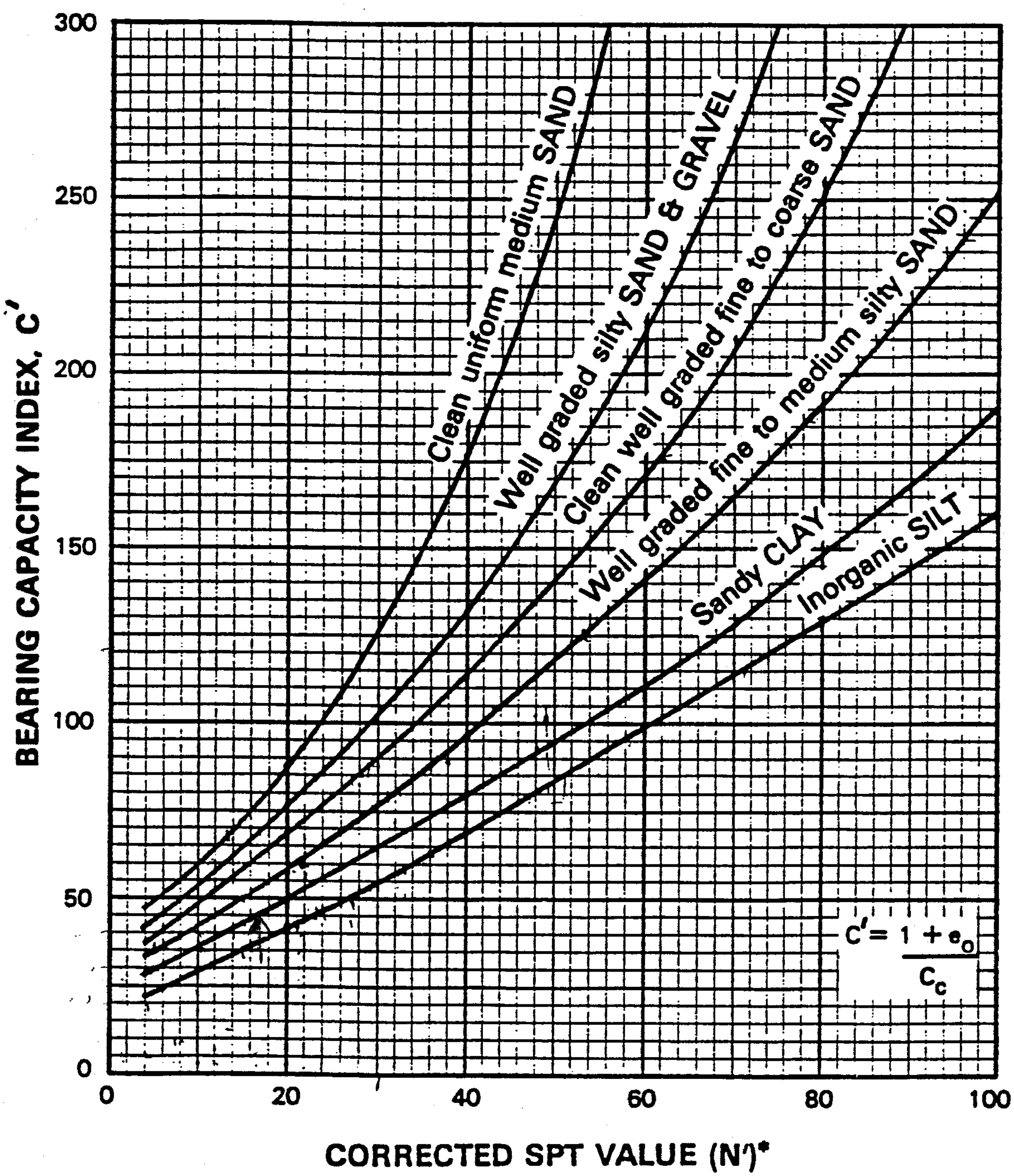
Settlement predictions conducted for the example problem utilizing the FHWA Settlement Analysis Method resulted in an estimated settlement of about seven-tenths (0.7) inch. This predicted settlement compares very closely to estimated settlements of one-half to three-quarters (0.5 to 0.75) inch utilizing the pressuremeter settlement analyses methods previously reported by Brad McLester at this seminar.

The FHWA Settlement Analysis Method was utilized to predict settlements of a 500,000 gallon water tank constructed at Emerald Isle, North Carolina in 1994. This water tank was supported on an approximately 44-foot diameter circular mat foundation that produced contact pressures of about 300 pounds per square foot for the dead load of the tank and about 2750 pounds per square foot for live load with a total of about 3050 pounds per square foot for the total dead load plus live load. The generalized subsurface profile consisted of clean to very slightly fine to medium sands. The stratification of the subsurface profile for the tank site is presented in the attached figure. The FHWA Settlement Analysis Method with applied correction factor (0.67) predicted a settlement



N' = Corrected SPT Resistance Value
N = Recorded SPT Resistance Value

SOURCE: U.S. Department of Transportation
Federal Highway Administration
Soils and Foundation Workshop Manual.



*N'—*SPT (N) Value Corrected for Overburden Pressure.*

Reference: Hough, "Compressibility as a Basis for Soil Bearing Value" ASCE 1959

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Comp. By DEB	Date 2/16/04	Project Marshall FGD Landfill		Sheet No. 1	of 1
Chkd. By aem	Date 2/17/04	Subject Gypsum Settlement for Closure		Job No. 046003	

OBJECTIVE: EVALUATE GYPSUM SETTLEMENT AFTER CLOSURE

PARAMETERS: CONSOLIDATION TEST DATA BY S&ME (Attached)

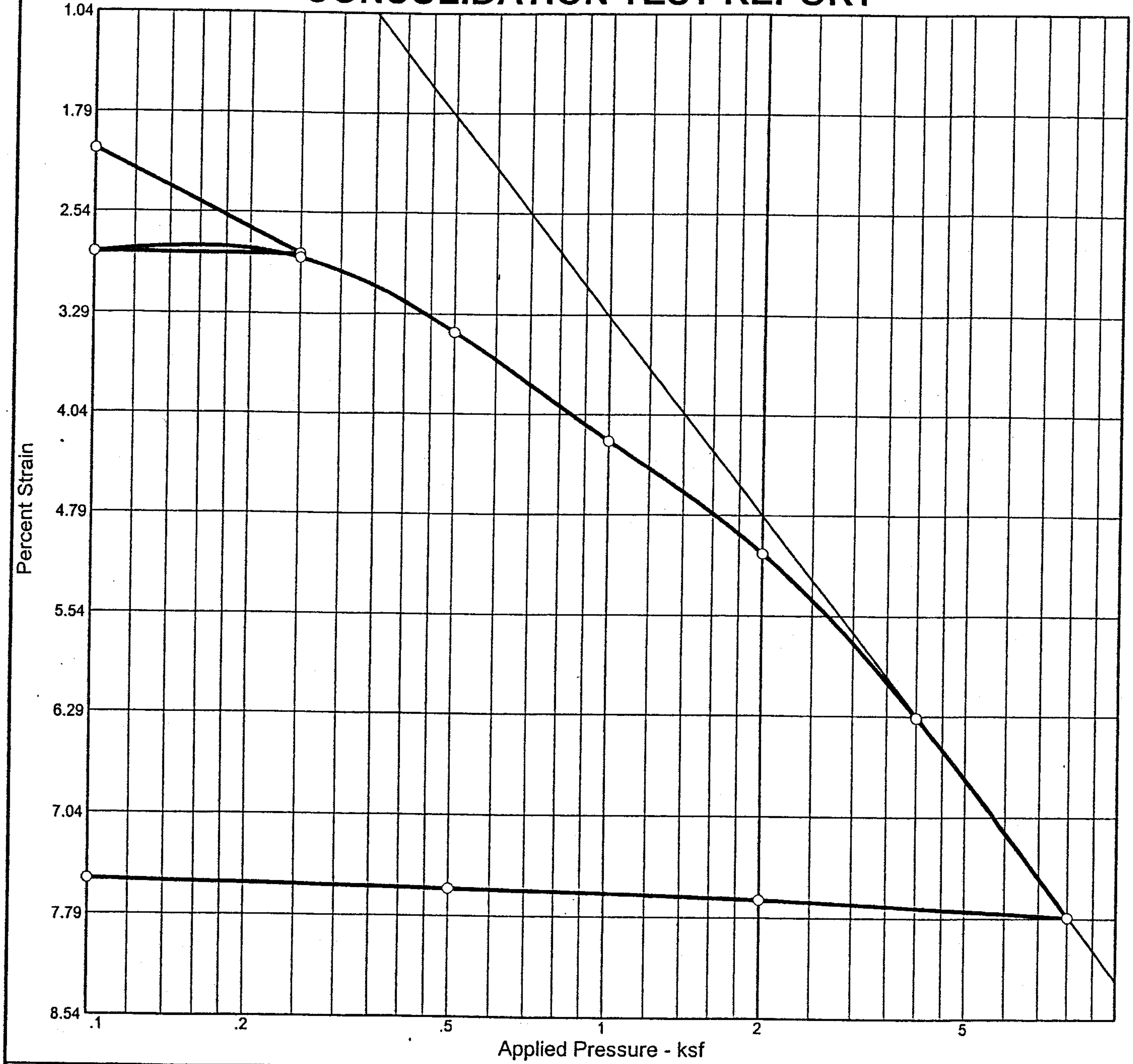
Based Upon Consolidation Test Data:

Compression Index, C_c Range 0.03 to 0.12

Void Ratio, e_o Range 0.783 to 0.885

∴ By Inspection, Total Settlement of Gypsum Compacted to 90% Std. Proctor Max. Dry Density Is Negligible (< 6") and Will Not Affect Final Cover System. Also, Moisture Contents of Gypsum is Expected to be Less Than Samples Tested by S&ME.

CONSOLIDATION TEST REPORT



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	P_c (ksf)	C_c	Initial Void Ratio
Saturation	Moisture							
32.2 %	12.1 %	79.1	27	1	2.35	2.43	0.09	0.885

MATERIAL DESCRIPTION	USCS	AASHTO
FGD SCRUBBER SLUDGE	ML	

Project No. 1264-03-057 **Client:** DUKE ENERGY

Project: FGD SCRUBBER WASTE TESTING

Location: CONFIDENTIAL POWERPLANT

Remarks:

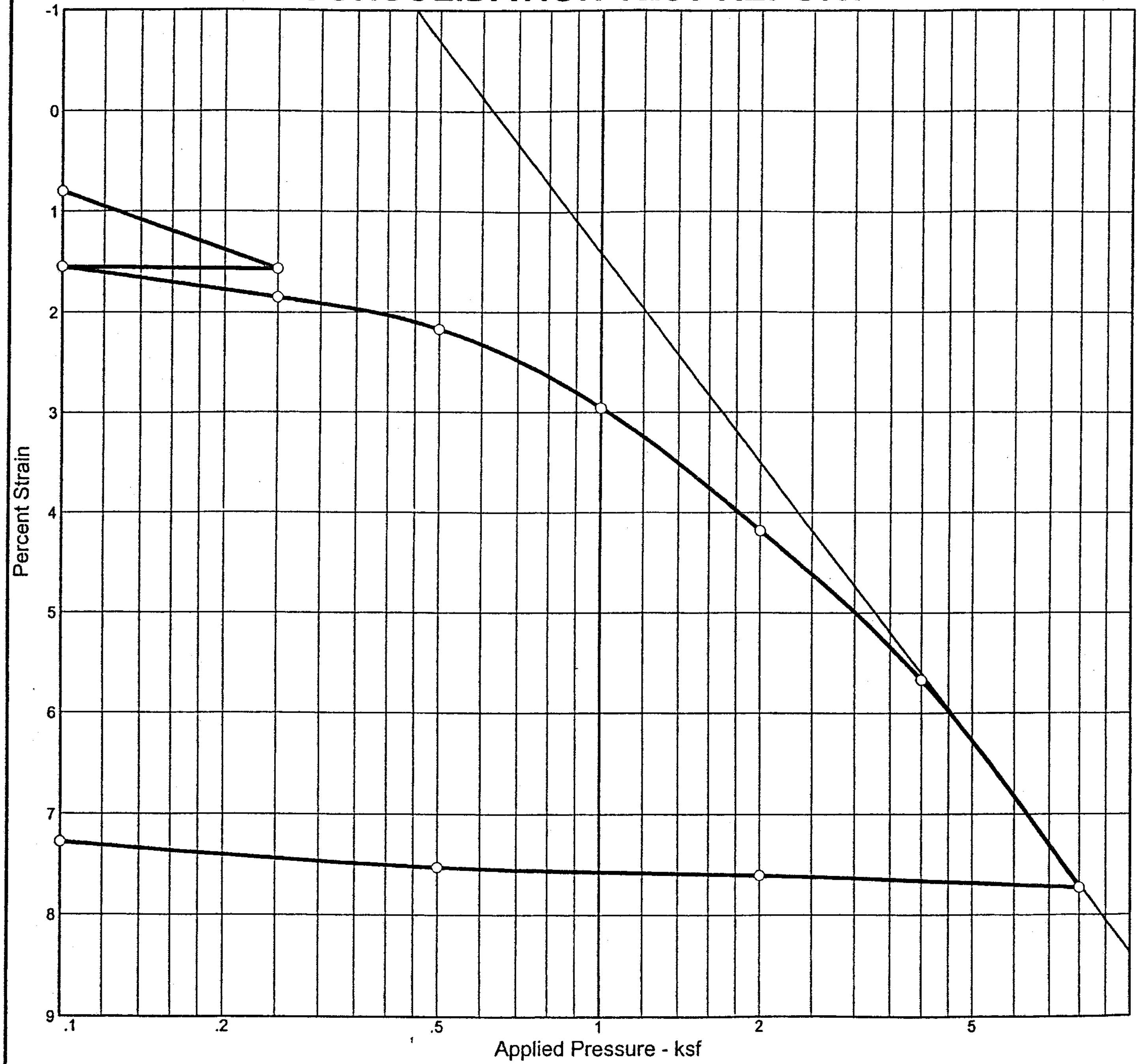
SATURATED/REMOLDED

CONSOLIDATION TEST REPORT

S & ME, INC.

SAMPLE S-1,(90%)

CONSOLIDATION TEST REPORT



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	P_c (ksf)	C_c	Initial Void Ratio
Saturation	Moisture							
57.5 %	19.4 %	83.3	27	1	2.35	1.96	0.12	0.791

MATERIAL DESCRIPTION	USCS	AASHTO
FGD SCRUBBER SLUDGE	ML	

Project No. 1264-03-057 **Client:** DUKE ENERGY

Project: FGD SCRUBBER WASTE TESTING

Location: CONFIDENTIAL POWERPLANT

CONSOLIDATION TEST REPORT

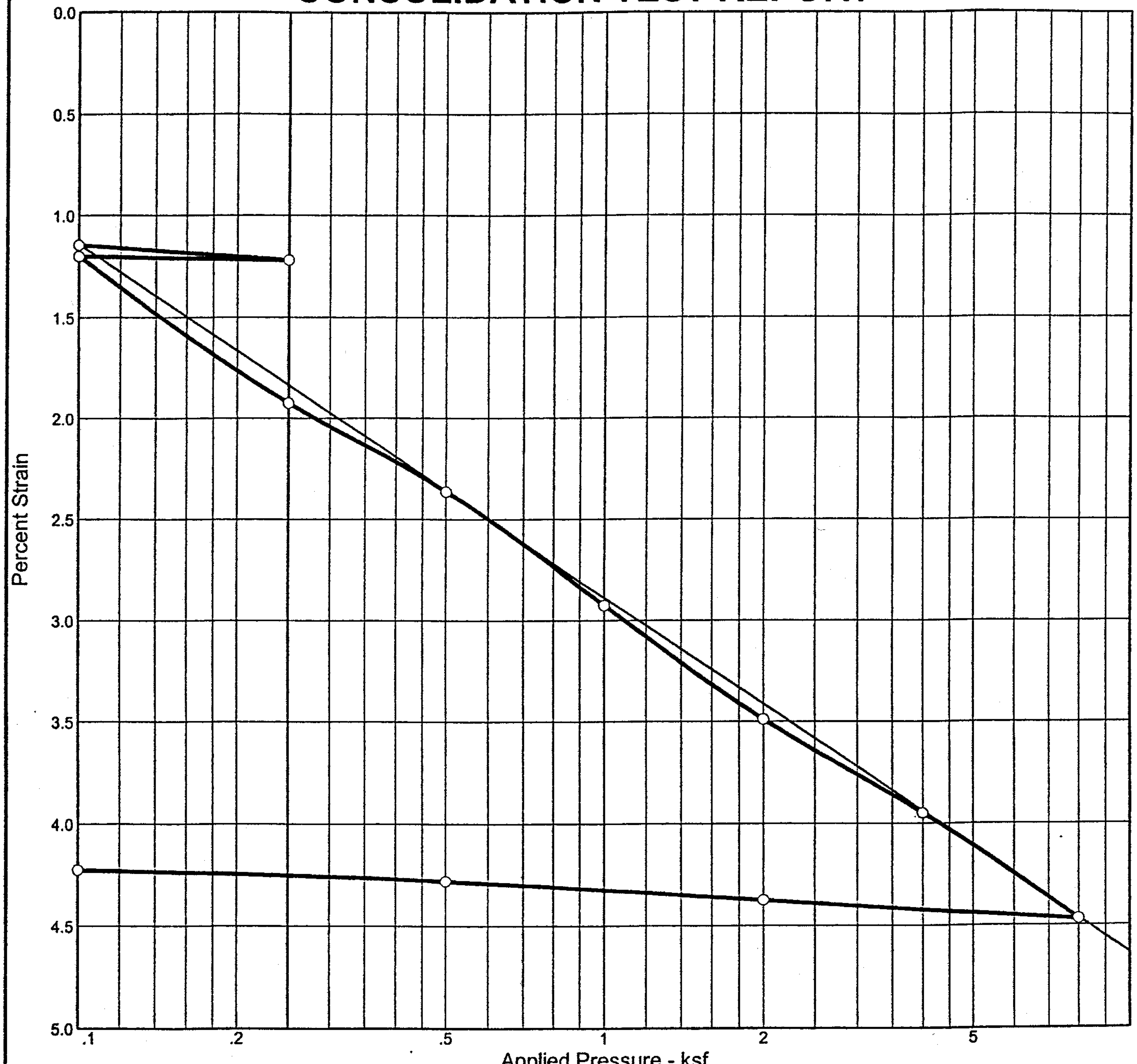
S & ME, INC.

Remarks:

SATURATED/REMOLDED

SAMPLE S-2,(95%)

CONSOLIDATION TEST REPORT



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	P_c (ksf)	C_c	Initial Void Ratio
Saturation	Moisture							
74.5 %	24.8 %	81.7	27	1	2.35	0.01	0.03	0.783

MATERIAL DESCRIPTION	USCS	AASHTO
FGD SCRUBBER SLUDGE	ML	

Project No. 1264-03-057 **Client:** DUKE ENERGY

Project: FGD SCRUBBER WASTE TESTING

Location: CONFIDENTIAL POWERPLANT

CONSOLIDATION TEST REPORT

S & ME, INC.

Remarks:
UNSATURATED/REMOLDED

SAMPLE S-3,(92%)

OBJECTIVE : DETERMINE FINAL COVER STABILITY

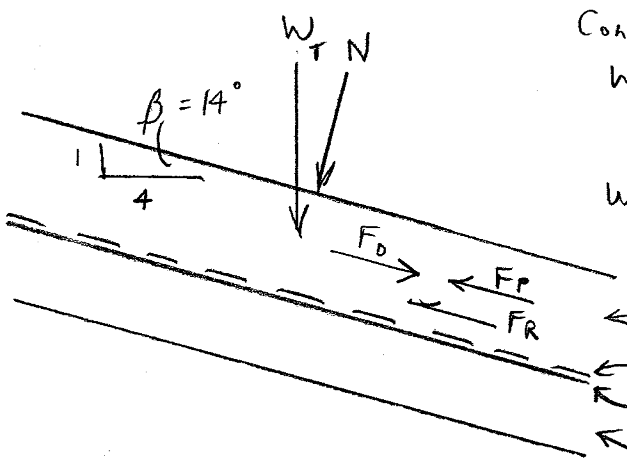
PARAMETERS : FRICTION ANGLES (References attached)

Cover Soil → Geocomposite $\delta_1 = 25°$

Geocomposite → Textured Geomembrane $\delta_2 = 23°$

Textured Geomembrane → Cover Soil $\delta_3 = 32°$

Check Cover Soil



Consider a CAT D5 dozer on cover

$$W_D = \frac{20,000 \text{ lbs}}{2 \text{ Tracks}} \left(\frac{1 \text{ Track}}{2 \text{ ft wide}} \right) = 5^k/ft$$

$$W_{soil} = 500 \text{ ft} (2 \text{ ft})(100 \text{ PCF}) = 100^k/ft$$

↑ Slope Length

$$N = W_T \cos \beta_1$$

$$= 105^k/ft \cos 14° = 102^k/ft$$

$$F_D = W_T \sin \beta_1$$

$$= 105^k/ft \sin 14° = 25.4^k/ft$$

$$F_P = \tfrac{1}{2} \gamma H^2 \tan^2 (45 + \phi/2)$$

$$= \tfrac{1}{2}(100 \text{ PCF})(2 \text{ ft})^2 \tan^2 \left(45 + \tfrac{30}{2}\right) = 600 \text{ lb/ft} = 0.6^k/ft$$

$$F_R = F_D - F_P = 25.4 - 0.6 = 24.8^k/ft$$

$$FS = \frac{N \tan \delta_1}{F_R} = \frac{105^k/ft \tan 25°}{24.8^k/ft} \approx \underline{2.0} \quad \text{OK}$$

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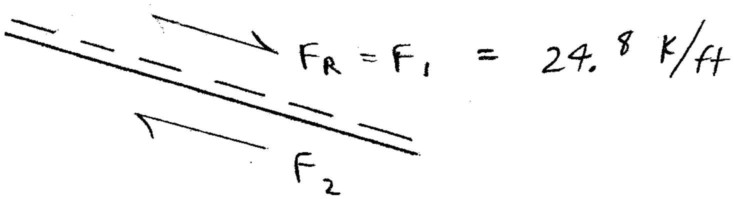
Comp. By DEB Date 2/16/04 Project Marshall FGD Landfill Sheet No. 2 of 2
Chkd. By [illegible] Date 2/17/04 Subject Final Cover Stability Job No. 046003

Check Geocomposite

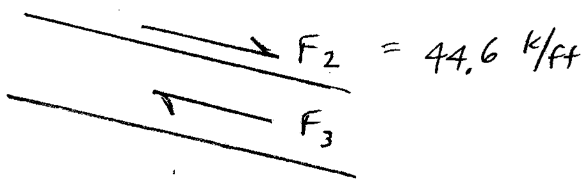


$$F_2 = N \tan \delta_2$$

$$= 105 \text{ k/ft} \tan 23^\circ = 44.6 \text{ k/ft}$$

$$FS = \frac{F_2}{F_1} = \frac{44.6}{24.8} = \underline{\underline{1.8}} \quad \text{OK}$$

Check Geomembrane



$$F_3 = N \tan \delta_3$$

$$= 105 \text{ k/ft} \tan 32^\circ = 65.6 \text{ k/ft}$$

$$FS = \frac{F_3}{F_2} = \frac{65.6}{44.6} = \underline{\underline{1.5}} \quad \text{OK}$$

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& LEWIS

nthetics. This may occur

rally has a high efficiency
s generally higher for wo-
nded nonwovens. This is
of soil-to-fabric interaction
factors or trends observed
tiles include:

xtiles decreases the shear
ri et al., 1986).
ctions produce different in-
ypically being lower (Ei-

ect on the interface friction
geotextiles (Eigenbrod and

t due to the interlocking of
nwoven geotextiles (Eigen-

e and high confining
d the adhesion decrease
textile (Williams and Houli-

ent on the soil and type of
sts using the actual materials
preliminary designs. Table
sts reported in the literature
986: Eigenbrod and Locker,
.. 1990; Koutsourais et al.,
Table 3.13 are due to varia-
l geotextiles. The range also

ntain openings or pores, the
largely dependent on whether
ough to push the failure plane
d into the adjacent soils, the

WASTE CONTAINMENT SYSTEMS, WASTE STABILIZATION, AND LANDFILLS

TABLE 3.13 Typical Range of Reported Soil Geotextile Friction Angles

Geotextile	Sand Friction Angle (deg) (Efficiency)	Clay Friction Angle (deg) (Efficiency)
Woven	23–42 (0.68–1.0)	16–26 (0.61–0.93)
* Nonwoven, Needle-punched	25–44 (0.67–1.0)	15–28 (0.62–0.99)
Nonwoven, resin or heat bonded	22–40 (0.56–0.91)	17–33 (0.60–0.85)

interface friction strength is generally similar to the soil strength. Factors that affect the soil strength include items such as the soil type, density, moisture content, and confining stress. For clays, the loading and shearing conditions, such as consolidated drained (CD), consolidated undrained (CU), or unconsolidated undrained (UU), also have significant influence.

If the failure plane is not pushed into the adjacent soils, low interface friction values may result. For example, the interface strength between smooth HDPE geomembranes and clay can be less than 10°. This low interface friction strength can lead to significant stability problems. Also, if the interface between the clay and geomembrane is wetted (i.e., due to condensation of water under the geomembrane, clay swelling, or excess moisture during construction), the interface strength can be further reduced (VonPein and Prasad, 1990; Mitchell et al., 1990). It is therefore critical that interface friction tests accurately model potential field conditions.

Table 3.14 summarizes soil geomembrane interface strengths based on the results reported by several researchers (Martin et al., 1984; Williams and Houlihan,

TABLE 3.14 Typical Range of Reported and Recommended Soil Geomembrane Friction Angles

Geomembrane	Reported Sand Friction Angles (deg) (Efficiency)	Recommended Sand Friction Angles, δ (deg)	Reported Clay Friction Angles (deg) (Efficiency)	Recommended Clay Friction Angles, δ (deg)
PVC	21–33 (0.62–0.93)	20–30	6–39 (0.53–1.0)	6–15
HDPE	17–28 (0.45–0.81)	17–25	5–29 (0.47–0.88)	5–10 *
Textured HDPE	30–45 (0.86–1.0)	30–40	7–35 (0.70–1.0)	9–15 *
VLDPE[a]	21–28 (0.62–0.67)	—	—	—

[a] Since VLDPE is a relatively new product, limited results were reported in the literature. It is anticipated that the range of efficiencies for VLDPE to sand interfaces is broader than shown. Blank (—) means insufficient data at this time.

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'STEMS

lual strength (clay/
embrane interface)
84 + .022 σ_n (psf)

strength (clay/
embrane interface)
30 psf

7000 8000 9000

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1987; Koutsourais et al.,
:l et al., 1990; Ojeshina,
Khilnani, 1991; Sharma
to the large range of soil
:s are included within the
soil geomembrane inter-

y–geomembrane exhibits
p at lower normal
.14 represent this be-
:le becomes very low and
f σ_n. The authors' experi-
CH) clays tested against
this τ–σ_n behavior. Rec-
l only as a guide in feasi-
geomembranes should be

ngth

o-geosynthetic interfaces
urais et al., 1990; Mitch-
1990; Somasundaram and
rized in Table 3.15. The
le layers of geosynthetics
ic surface (Williams and

WASTE CONTAINMENT SYSTEMS, WASTE STABILIZATION, AND LANDFILLS

TABLE 3.15 Typical Range of Reported Geosynthetic to Geosynthetic Friction Angles (Degrees)

	PVC	HDPE Smooth	HDPE Textured	Geonet
Woven Geotextile	10–28	7–11	9–17	9–18
Nonwoven, needle-punched Geotextile	16–26	8–12	15–33	10–27
Nonwoven, resin/heat-bonded Geotextile	18–21	9–11	15–16	17–21
Geonet	11–24	5–19	7–25	—

Try 23°

The testing conditions may also have a significant effect on results. Mitchell et al. (1990) noted that polishing of geomembrane surfaces by geotextiles reduced interface friction. Also, the orientation of geonet strands can affect the interface strength between geonets and geomembranes (Geotek, 1987; Mitchell et al., 1990). Site-specific tests should therefore be performed using the actual materials and anticipated shear conditions.

3.6.4 Geosynthetic Clay Liner Shear Strength

Limited information is currently available on the internal shear strength of GCLs, due primarily to their relatively short history. The tests that have been performed are also difficult to compare, due to the numerous variations in test conditions. Many of these variations, such as strain rate, normal load, sample size, and consolidation conditions, are similar to the variations experienced when comparing shear strength testing of other geosynthetics. An additional variation of GCLs, however, is the hydrating conditions, including the hydrating liquid. Hydration can occur under free swell, constrained swell, or partially constrained swell, or the sample may be tested unhydrated. Even if hydrated under free-swell conditions, it may be difficult to assess whether full hydration has occurred since the bentonite may be restricted from free swell by the bonded geotextiles. Also, due to the large water absorption of bentonite, most shear strength test results will incorporate some immeasurable pore pressure effects unless the test is performed at extremely low displacement rates.

Table 3.16 presents the results of direct shear testing performed under various hydration conditions. The tests were performed at a strain rate of 9 mm/min and at normal stresses up to 60 kPa. Although these test results provide some information on the internal shear strength of GCLs, it is highly recommended that project specific testing be performed.

GSE™

FrictionFlex® Application Data

GSE's FrictionFlex®process provided the industry's first textured liner. It is the only geomembrane texturing process ever to be granted a U.S. Patent. In fact, it has been awarded two (U.S. Patent numbers 4,885,201 and 5,075,135). The FrictionFlex process begins with 24-foot wide **GSE HyperFlex®** or **UltraFlex®** sheet manufactured to stringent industry standards. After the smooth sheet passes all QA testing, texturing is added to one or both sides as required. The patented manufacturing process enables **GSE** to produce a textured liner exhibiting outstanding mechanical and chemical properties demanded of **GSE's** premium grades of smooth geomembrane liners – **HyperFlex** and **UltraFlex.**

An engineer can utilize **GSE** geomembranes textured by the **FrictionFlex** process to improve the factor of safety and steepness of slopes. This increases facility design capacity, service life, and ultimately total revenue potential. GSE's textured geomembranes can be used to improve the factors in a number of applications.

An added feature of the **GSE** FF process is that an edge, approximately six inches wide, remains smooth. This smooth edge means that GSE's seaming procedures are the same for FrictionFlex textured geomembranes and smooth geomembranes and requires no change in field quality control.

The following summarizes reference data regarding FrictionFlex liner performance in contact with soils and synthetics:

* High coefficient of friction with soils
* High coefficient of friction with synthetics
* Premium grade mechanical and chemical properties
* Excellent strength elongation

Material	GSE FrictionFlex Textured Liner Materials Adhesion (lb/ft^2)	Friction Angle (deg.)	Smooth HDPE Friction Angle (deg.)
Sandy Glacial Till	27	36	20
Sandy Clay	65	35	18
Smooth Clay	39	32	16 *
Ottawa Sand	21	30	19
Non-woven Polyester Geotextile	116	28	11
Non-woven Polypropylene Geotextile	133	33	12

NOTE: The above values are appoximate. Testing performed according to ASTM D 5321. GSE recommends that specific data be developed for all application designs. Shearbox testing of the specific geosynthetic and natural components of the composite is necessary to establish an appropriate design basis. GSE will be pleased to provide any necessary material samples for such purposes.

This information is provided for reference purposes only and is not intended as a warranty or guarantee. GSE assumes no liability in connection with the use of this information. Check with GSE for current, standard minimum quality assurance procedures.

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3/26/04

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Comp. By DHB Date 2-3-04 Project MARSHALL FGD RESIDUE LANDFILL Sheet No. ...... of ......
Chkd. By DEB Date 2/24/04 Subject TEMP. SED. Job No. 046003.001

ST-2

D.A. = 4.8 Ac.
I_{10} = 6.8 in/hr
C = .60
Q_{10} = .60 (6.8) (4.8) = 19.58 cfs

REQ'D VOL = 1800 ft^3/ac (4.8 ac.) = 8,640 ft^3
REQ'D S.A. FOR EFF. = .01 (19.58)(43,560) = 8,530 ft²
PROVIDE S.A. = 50 X 175 = 8,750 ft² , D = 3 ft.
VOL. PROVIDED = 0.4 (8750)(3) = 10,500 ft^3

TOP OF DAM EL. = 834.0
SPILLWAY EL. = 832.5
BTM BASIN EL. = 829.5
CLEANOUT EL = 831.0
LENGTH OF SPILLWAY = 12 ft.
TOP OF DAM WIDTH = 5 ft.

ST-3

Clay Stockpile Area
Req'd 100,000 yd³
Disturbed Area
Σ Area 100,212 sf

North Area = 50,522 sf = 1.16 ac
(basin 153,374 sf = 3.52 ac)
South Area = 49,690 sf = 1.14 ac
(basin 197,987 sf = 4.55 ac)

North Area
1.16 Ac disturbed ; 3.52 basin
Req'd Volume (1800)(1.16) = 2,088 ft³
$Q_{10} = ciA$
$= (.6)(6.8)(3.52)$
$= 14.36$ cfs
Effective area = $.01(Q_{10}) = (.01)(14.36)(43,560)$
= 6,255 sf
h = 3' from spillway
try 56×112 = 6272 sf
@ elev. 820.0

Top of Dam 820.0 width = 5'
Spillway 818.5 length = 6'
Bottom Elev. 815.5
Cleanout Elev 817.0

Vol. provided = (.4)(6272)(3)
= 7,526 ft³
OK

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Comp. By ACN Date 2/25/04 Project Marshall FGD Landfill Sheet No. ...... of ......
Chkd. By DEB Date 2/29/04 Subject Clay Stockpile Area Job No. 04003.001

ST-4

South Area

1.14 ac disturbed ; 4.55 ac basin

Req'd volume (1800)(1.14) = 2,052 sf

$Q_{10} = ciA$

$= (.6)(6.8)(4.55) = 18.56$ cfs

effective area $= .01 (Q_{10})$

$= .01 (18.56)(43,560)$

$= 8,085$ sf

h=3' from spillway

try 64×128 = 8,192 sf
@ elev. 830.0

Top of Dam 830.0 width = 5'
Spillway 828.5 length = 6'
Bottom Elev. 825.5
Cleanout Elev. 827.0

Vol. provided
$= (.4)(8192)(3)$
$= 9,830$ ft³
OK

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Comp. By DHB Date 2-6-04 Project MARSHALL LANDFILL Sheet No. ... of ...
Chkd. By DEB Date 2/24/04 Subject TEMP. SED. BASIN SB-4 Job No. 046003.001

SB-4 D.A. = 23 Ac.
$C = .60$
$I_{10} = 6.8$ IN/HR.

$Q_{10} = .6(6.8)(23) = 94$ cfs.

REQ'D VOL = 1800 (23) = 41,400 ft^3
S.A. FOR EFFICIENCY = .01 (94)(43,560) = 40,946 ⊄
S.A. @ ELEV. 830 = 43,059 ⊄
FROM TABLE 8.07a; CHOOSE 42" ϕ BARREL
Q = 100.65 cfs @ H = 6 ft.
RISER ϕ = 54"
REQ'D HEAD ABOVE CREST OF RISER = 1.65 ft.
CREST OF RISER ELEV. = 829.0
BOTTOM BASIN ELEV. = 823.0
CLEANOUT ELEV. = 826.0
TOP OF DAM ELEV. = 850.0

VOLUME PROVIDED = $\left(\frac{21,051 ⊄ + 43,059 ⊄}{2}\right) \times 7' = 224,385\ ft^3$
to ELEV. 830.

ANTI-FLOTATION BLOCK:
DISPLACED WEIGHT OF WATER = $\frac{\pi(4.5)^2}{4}(6)(62.4) = 5955$ lb ↑
VOLUME CONC. REQ'D = $\frac{5955}{150}(1.2) = 48\ ft^3$
PROVIDE CONC. FTG. 6' × 6' × 1.5' DEEP = 54 ft^3
WEIGHT ↓ = 54(150) = 8,100 lb↓

$F.S. = \frac{8,100}{5955} = 1.36$ OK.

SB-4

AREA OF DEWATERING HOLES:

CIRCUMFERENCE OF RISER = $\pi(54)$ = 169.6 in.

$$A_0 = \frac{43{,}059\sqrt{2(7.0)}}{8(.6)(20{,}428)} \qquad h = 830 - 823 = 7.0 \text{ ft.}$$

$$A_0 = 1.64 \text{ ft}^2 = 236.6 \text{ in}^2$$

HOLES PER ROW @ 4" c/c = 42
AREA 1" ø HOLES = 0.785 in^2/HOLE
HOLES REQ'D = 301
PROVIDE 8 ROWS 1" ø HOLES SPACED 4" c/c E.W. = 264 in^2
OK.

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Comp. By ACN Date 2/23/04 Project Marshall FGD Landfill Sheet No. 1 of
Chkd. By DEB Date 2/25/04 Subject Sediment pond for Stockpile Job No. 046003.001

SB-5

Drainage Area 706,730 ft² = 16.22 Ac

$C = .60$
$I_{10} = 6.8$ in/hr
$Q = ciA$
$Q = (.60)(6.8)(16.22) = 66.18$ cfs

Vol Req'd = 1800(16.22) = 29,196 ft³
A_{reqd} for efficiency = .01 qr
= (.01)(66.18)(43,560)
= 28,828 sf

say 120 x 245 = 29,400 sf

Barrel
table 807.a
cmp H = 6'
Dia = 36"
Q = 70.60 cfs

$h_{req'd}$ @ crest of riser 1.5'
(8.07b) (48"Ø riser)

Top of Dam 830.0
Top of Spillway 828.5
Riser 827.0
Bottom 821.0
Cleanout 824.0

Vol = (29,400)(6.5)(.4) = 76,440 ft³ ok

cmp barrel $S = \frac{821.0 - 820.5}{95'} = 0.5\%$

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Comp. By ACN Date 2/25/04	Project Marshall FGD Landfill	Sheet No. 2 of
Chkd. By DEB Date 2/25/04	Subject Sediment Pond for Stockpile	Job No. 046003.001

SB-5

Area of dewatering holes

circumference of riser $= \pi(48) = 150.8$ in

$$A_o = \frac{A_s \sqrt{2h}}{T\, C_d\, 20{,}428}$$

h = spillway − bottom
= 7.5'

$$A_o = \frac{(29{,}400)\sqrt{2(7.5)}}{(8)(.6)(20{,}428)}$$

$$A_o = 1.16\ ft^2 = 167.22\ in^2$$

try 1" ø holes spaced 4" o.c. $A = .785\ in^2/ft$

$$\frac{150.8}{4} = 37/\text{row}$$

$167.22/.785 = 213$ holes req'd

6 rows of holes @ 4" o.c. (each way)

Anti-flotation block

wt. of water displaced

$$\frac{\pi(4)^2}{4}(6)(62.4) = 4{,}705\ lb.$$

Vol. concrete req'd

$$\frac{4{,}705\,(1.2)}{150\ lb/ft^3} = 37.64\ ft^3$$

say 1'3" deep 6x6
$= 45\ ft^3$

$= 6{,}750\ lb.$

$/4705 = 1.43$
F.S.

OK

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Consulting Engineers, Surveyors & Photogrammetrists

Comp. By DHB Date 2-24-04 Project MARSHALL LANDFILL Sheet No. ..... of .....
Chkd. By DEB Date 2/24/04 Subject SB-6 Job No. 46003.001

TEMP. SED. BASIN SB-6

D.A. = 23 Ac.
C = .60
I_{10} = 6.8
Q_{10} = .60(6.8)(23) = 93.84

REQ'D VOL = 1800(23) = 41,400 ft^3
S.A. FOR EFFICIENCY = .01(94)(43,560) = 40,946 ft^2
S.A. PROVIDED @ CREST OF RISER ELEV = 43,355 ft^2

FROM TABLE 8.07a, CHOOSE 42" ϕ CMP BARREL W/ Q_{CAP} = 100.65 cfs.
42" ϕ BARREL REQ. 54" ϕ CMP RISER.
REQ'D HEAD ABOVE CREST OF RISER = 1.65 ft.

TOP OF DAM ELEV. = 812.0
SPILLWAY ELEV = 810.5
CREST OF RISER ELEV. = 808.5
BOTTOM BASIN ELEV. = 802.5
CLEANOUT ELEV. = 805.5
TOP OF DAM WIDTH = 8 ft.
LENGTH OF SPILLWAY = 20 ft.
VOLUME PROVIDED = 0.4(43,355)(6) = 104,052 ft^3

SB-6

ANTI-FLOTATION BLOCK:

DISPLACED WEIGHT OF WATER: $\frac{\pi (4.5)^2}{4}(6)(62.4) = 5{,}955$ lb

VOLUME CONC. REQ'D = $\frac{5{,}955}{150}(1.2) = 48$ ft^3

PROVIDE CONC. FTG. $6' \times 6' \times 1.5'$ DEEP $= 54$ ft^3

WEIGHT ↓ = $54(150) = 8{,}100$ lb ↓

$F.S. = \frac{8{,}100}{5{,}955} = 1.36$ OK.

AREA OF DEWATERING HOLES:

CIRCUMFERENCE OF RISER = $\pi(54) = 169.6$ in

$$A_o = \frac{43{,}355\sqrt{2(6)}}{8(.6)(20{,}428)} = 1.53 \text{ ft}^2 = 220.6 \text{ in}^2$$

\# HOLES PER ROW = 42 SPACED 4" c/c
AREA 1" ø HOLES = 0.785 in^2/HOLE
\# HOLES REQ'D = 281
PROVIDE 7 ROWS 1" ø HOLES SPACED 4" c/c E.W. = 231 in^2
OK.

CHAS. H. SELLS, INC.
Consulting Engineers, Surveyors & Photogrammetrists

Comp. By DHB Date 2-24-04 Project MARSHALL LANDFILL Sheet No. .... of ....
Chkd. By DEB Date 2/24/04 Subject SB-7 Job No. 46003.001

TEMP. SED. BASIN SB-7

D.A. = 26.3 Ac.
$C = .60$
$I_{10} = 6.8$
$Q_{10} = .60(6.8)(26.3) = 107.3$ cfs.

REQ'D VOLUME = 1800 (26.3) = 47,340 ft^3
S.A. REQ'D FOR EFFICIENCY = .01 (107.3)(43,560) = 46,741 ⌖
S.A. PROVIDED @ CREST OF RISER ELEV. = 33,818 ⌖ = 72.4%

BASIN TO BE PROVIDED W/ BAFFLES.

FROM TABLE 8.07a, CHOOSE 42" ø CMP BARREL W/ Q_{CAP} = 108.75 cfs.
42" ø BARREL REQ. 54" ø CMP RISER.
REQ'D HEAD ABOVE CREST OF RISER = 1.80 ft.

TOP OF DAM ELEV. = 814.50
SPILLWAY ELEV = 813.0
CREST OF RISER ELEV. = 811.20
BOTTOM BASIN ELEV = 804.2
CLEANOUT ELEV. = 807.7
TOP OF DAM WIDTH = 8 ft.
LENGTH OF SPILLWAY = 20 ft.
VOLUME PROVIDED = 0.4 (33,818)(7.0) = 94,690 ft^3

SB-7

ANTI-FLOTATION BLOCK:

DISPLACED WEIGHT OF WATER = $\frac{\pi}{4}(4.5)^2(7)(62.4) = 6{,}947$ lb ↑

VOLUME CONC. REQ'D = $\frac{6{,}947}{150}(1.2) = 55.6$ ft³

PROVIDE CONC FTG. 6' × 6' × 1.75' DEEP = 63 ft³

WEIGHT ↓ = 63 (150) = 9,450 lb ↓

$F.S. = \frac{9{,}450}{6{,}947} = 1.36$ OK.

AREA OF DEWATERING HOLES:

CIRCUMFERENCE OF RISER = $\pi(54") = 169.6$ in.

$A_0 = \frac{33{,}818\sqrt{2(7)}}{8(.6)(20{,}428)} = 1.29$ ft² = 185.8 in²

\# HOLES PER ROW = 42 SPACED 4" c/c
AREA 1" ⌀ HOLES = 0.785 in²/HOLE
\# HOLES REQ'D = 237
PROVIDE 6 ROWS 1" ⌀ HOLES SPACED 4" c/c E.W. = 198 in²
OK.

CHAS. H. SELLS, INC.
Consulting Engineers, Surveyors & Photogrammetrists

Comp. By DHB Date 2-9-04 Project MARSHALL LANDFILL Sheet No. ...... of ......
Chkd. By DEB Date ...... Subject TEMP. DIVERSION CHANNELS Job No. 046003.001

TD-1
CELL 1

D.A. = 19 Ac.
$C = .60$
$I_2 = 4.8$ in/hr.
$I_{10} = 6.8$ in/hr
$S = 0.5\%$ +/-
$Q_2 = .60(4.8)(19) = 54.72$
$Q_{10} = .60(6.8)(19) = 77.52$

TD-2
CELL 1

D.A. = 4 Ac.
$C = .60$
$S = 0.5\%$ +/-
$Q_2 = .60(4.8)(4) = 11.52$
$Q_{10} = .60(6.8)(4) = 16.32$

TD-3
CELL 2

D.A. = 3.9 Ac.
$C = .60$
$S = 0.5\%$
$Q_2 = .6(4.8)(3.9) = 11.2$ cfs.
$Q_{10} = .6(6.8)(3.9) = 15.9$ cfs.

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	TD-1
Flow Element	Trapezoidal Cha
Method	Manning's Form
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.033	
Slope	005000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	6.00	ft
Discharge	54.72	cfs

Results		
Depth	1.56	ft
Flow Area	16.6	ft²
Wetted Perim	15.86	ft
Top Width	15.35	ft
Critical Depth	1.13	ft
Critical Slope	0.017539	ft/ft
Velocity	3.29	ft/s
Velocity Head	0.17	ft
Specific Energ	1.73	ft
Froude Numb	0.56	
Flow Type	Subcritical	

STRAW W/ NET TEMP. LINER

n = .033

$T_d = \gamma d s = 62.4(1.56)(.005)$

$= 0.49$ lb/ft OK.

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	TD-1
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.037	
Slope	005000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	6.00	ft
Discharge	77.52	cfs

Results		
Depth	1.96	ft
Flow Area	23.3	ft²
Wetted Perim	18.41	ft
Top Width	17.77	ft
Critical Depth	1.37	ft
Critical Slope	0.020969	ft/ft
Velocity	3.32	ft/s
Velocity Head	0.17	ft
Specific Enerç	2.13	ft
Froude Numb	0.51	
Flow Type	Subcritical	

TALL FESCUE GRASS

$n = .037$

$V_A = 3.32$ ft/sec.

$R_h = \frac{23.3}{18.41} = 1.265$ ft.

$V_A * R_h = 4.20$

$n = .037$ OK.

GEOMETRY: $B = 6$ ft.

$D = 2.5$ ft

$z = 3$

$T = 21$ ft.

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	TD-2
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.033	
Slope	005000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	3.00	ft
Discharge	11.52	cfs

Results		
Depth	0.90	ft
Flow Area	5.1	ft²
Wetted Perim	8.70	ft
Top Width	8.41	ft
Critical Depth	0.62	ft
Critical Slope	0.021544	ft/ft
Velocity	2.24	ft/s
Velocity Head	0.08	ft
Specific Energ	0.98	ft
Froude Numb	0.51	
Flow Type	Subcritical	

STRAW W/ NET

$n = .033$

$T_d = 62.4(.90)(.005) = .28 \text{ lb}/\text{ft}$

OK

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	TD-2
Flow Element	Trapezoidal Cha
Method	Manning's Form
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.050	
Slope	005000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	3.00	ft
Discharge	16.32	cfs

Results		
Depth	1.30	ft
Flow Area	9.0	ft²
Wetted Perim	11.24	ft
Top Width	10.82	ft
Critical Depth	0.75	ft
Critical Slope	0.047067	ft/ft
Velocity	1.81	ft/s
Velocity Head	0.05	ft
Specific Energ	1.35	ft
Froude Numb	0.35	
Flow Type	Subcritical	

TALL FESCUE GRASS

$n = .050$

$V_A = 1.81$ ft/sec.

$R_h = \frac{9.0}{11.24} = 0.80$

$V_A * R_h = 1.45$

$n = .05$ OK.

GEOMETRY: $B = 3'$

$Z = 3'$

$D = 2$ ft.

$T = 15$ ft.

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	~~PD 12~~ TD-3
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Q2

Straw w/Net

$T_d = (62.4)(.005)(.99)$

$= .31 < 1.45$ OK

Input Data		
Mannings Coeffic	0.033	
Slope	005000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	11.20	cfs

Results		
Depth	0.99	ft
Flow Area	5.0	ft²
Wetted Perim	8.29	ft
Top Width	7.97	ft
Critical Depth	0.70	ft
Critical Slope	0.021489	ft/ft
Velocity	2.26	ft/s
Velocity Head	0.08	ft
Specific Energ	1.07	ft
Froude Numb	0.51	
Flow Type	Subcritical	

Chas H. Sells
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Project Engineer: Donna Barbour

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	~~PD-12~~ TD-3
Flow Element	Trapezoidal Cha
Method	Manning's Formi
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.053	
Slope	005000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	15.90	cfs

Results		
Depth	1.44	ft
Flow Area	9.1	ft²
Wetted Perim	11.13	ft
Top Width	10.66	ft
Critical Depth	0.84	ft
Critical Slope	0.052862	ft/ft
Velocity	1.74	ft/s
Velocity Head	0.05	ft
Specific Enerç	1.49	ft
Froude Numb	0.33	
Flow Type	Subcritical	

Q_{10}

Tall Fescue

$n = .053$

$V_A = 1.74$

$R_h = \frac{9.1}{11.13} = .82$

$V_A R_h = 1.42$

$n = .053$ OK

Geometry

B = 2'

D = 2'

Z = 3

T = 14'

CHAS. H. SELLS, INC.
Consulting Engineers, Surveyors & Photogrammetrists

Comp. By DHB Date 2-23-04 | Project MARSHALL LANDFILL | Sheet No. 1 of 4
Chkd. By DEB Date 2/25/04 | Subject PERM. DIVERSION CHANNELS | Job No. 046003.001

PD-1

D.A = 5.9 Ac.
C = .60
I_2 = 4.8 IN/HR
I_{10} = 6.8 IN/HR.
S = $\frac{862 - 850}{1720'}$ = 0.7% +/- FROM ROADGRADES.
Q_2 = .60 (4.8)(5.9) = 17 cfs.
Q_{10} = .60 (6.8)(5.9) = 24 cfs.

PD-2

D.A. = 2.5 Ac.
C = .60
S = $\frac{854 - 850}{570'}$ = 0.7% +/-
Q_2 = 0.6 (4.8)(2.5) = 7.2 cfs.
Q_{10} = 0.6 (6.8)(2.5) = 10.2 cfs.

PD-3

D.A. = 1.4 Ac.
C = .60
S = 2/280' = 0.7% +/-
Q_2 = .6 (4.8)(1.4) = 4 cfs
Q_{10} = .6 (6.8)(1.4) = 5.7 cfs

* PD-4

D.A. = 4.2 Ac.
C = .60
S = $\frac{854 - 852}{550'}$ = 0.4%. FROM ROADGRADES, DESIGN CHANNEL @ 0.5%.
Q_2 = 0.6 (4.8)(4.2) = 12.1 cfs.
Q_{10} = 0.6 (6.8)(4.2) = 17.1 cfs

CHAS. H. SELLS, INC.
Consulting Engineers, Surveyors & Photogrammetrists

Comp. By DHB Date 2-24-04 Project MARSHALL LANDFILL Sheet No. 2 of 4
Chkd. By DEB Date 2/25/04 Subject DIVERSION CHANNELS Job No. 46003.001

PD-5

D.A. = 3.8 Ac.
C = .60
$S = \frac{862 - 854}{1500} = 0.5\% \pm$
$Q_2 = 0.6(4.8)(3.8) = 11$ cfs.
$Q_{10} = 0.6(6.8)(3.8) = 15.5$ cfs.

ARMORED CHANNEL AC-1 :

D.A. = 9.3 Ac.
C = .60
$S = \frac{880 - 854}{190} = 13.6\% \pm$
$Q_{10} = 0.6(6.8)(9.3) = 38$ cfs.

ARMORED CHANNEL AC-2 :

D.A. = 12.4 Ac.
C = .60
$S = \frac{886 - 848}{470'} = 8.1\% \pm$
$Q_{10} = .6(6.8)(12.4) = 50.6$ cfs.

CULVERT @ STA. 1+75±: $Q_{10} = .6(6.8)(20.8) = 85$ CFS. (@ ENDWALL)
CULVERT @ STA. 10+65±: $Q_{10} = .6(6.8)(5.10) = 20.8$ cfs. (@ YI-2
CULVERT @ STA. 17+00±: $Q_{10} = .6(6.8)(13.10) = 53.5$ cfs. (@ YI-1)

CHAS. H. SELLS, INC.
Consulting Engineers, Surveyors & Photogrammetrists

Comp. By ACN Date 2/24/04 Project Marshal FGD Landfill Sheet No. 3 of 4
Chkd. By DEB Date 2/25/04 Subject Sediment Pond for Stockpile Job No. 04003.001

PD-6

L = 1306'

Slope $\frac{850 - 834}{1306'} = 1.23\%$

DA = 200,134 sf = 4.6 Ac.

$Q_2 = .6(4.8)(4.6) = 13.3$ cfs

$Q_{10} = .6(6.8)(4.6) = 18.8$ cfs

PD-7

L = 1125'

Slope $\frac{850 - 834}{1125} = 1.42\%$

DA = 200,133 sf = 4.6 Ac.

$Q_2 = .6(4.8)(4.6) = 13.3$ cfs

$Q_{10} = .6(6.8)(4.6) = 18.8$ cfs

CHAS. H. SELLS, INC.
Consulting Engineers, Surveyors & Photogrammetrists

Comp. By ACN Date 4/25/04 Project Marshall FGD Landfill Sheet No. 4 of 4
Chkd. By .... Date .... Subject Sediment Control Structures Job No. 046003.001

@ST-1

PD-8

L = 363'

Slope $\frac{858-824}{363} = 9.3\%$

DA = 57,321 sf = 1.32 Ac

$Q_2 = (.6)(4.8)(1.32) = 3.80$ cfs

$Q_{10} = (.6)(6.8)(1.32) = 5.39$ cfs

PD-9

L = 275'

Slope $\frac{853-824}{275} = 10.5\%$

DA = 31,683 sf = 0.73 Ac

$Q_2 = (.6)(4.8)(.73) = 2.10$ cfs

$Q_{10} = (.6)(6.8)(.73) = 2.98$ cfs

PD-10

L = 354'

Slope $\frac{858-834}{354} = 6.8\%$

DA = 35,661 sf = 0.82 Ac

$Q_2 = (.6)(4.8)(.82) = 2.36$ cfs

$Q_{10} = (.6)(6.8)(.82) = 3.35$ cfs

PD-11

L = 230'

Slope $\frac{853-834}{230} = 8.3\%$

DA = 36,625 sf = 0.84 Ac

$Q_2 = (.6)(4.8)(.84) = 2.42$ cfs

$Q_{10} = (.6)(6.8)(.84) = 3.43$ cfs

CHAS. H. SELLS, INC.
Consulting Engineers, Surveyors & Photogrammetrists

Comp. By DHB Date 2-24-04 Project MARSHALL LANDFILL Sheet No. ...... of ......
Chkd. By ...... Date ...... Subject PERM. DIVERSION CHANNELS. Job No. ......

~~PD-12 D.A. = 3.9 Ac.~~
~~C = .60~~
~~S = 0.5 %~~
~~Q_2 = .6(4.8)(3.9) = 11.2 cfs~~
~~Q_{10} = .6(6.8)(3.9) = 15.9 cfs~~

PD-12 D.A. = 4.8 Ac.
C = .60
S = 0.5 %
Q_2 = .6(4.8)(4.8) = 13.8 cfs
Q_{10} = .6(6.8)(4.8) = 19.6 cfs.

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-1
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.033	
Slope	007000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	3.00	ft
Discharge	17.00	cfs

Results		
Depth	1.00	ft
Flow Area	6.0	ft²
Wetted Perim	9.35	ft
Top Width	9.03	ft
Critical Depth	0.77	ft
Critical Slope	0.020385	ft/ft
Velocity	2.81	ft/s
Velocity Head	0.12	ft
Specific Energ	1.13	ft
Froude Numb	0.61	
Flow Type	Subcritical	

STRAW W/ NET.

n = .033

$T_d = 62.4(1.00)(.007)$

$= 0.44$ lb/ft OK.

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-1
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.046	
Slope	007000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	3.00	ft
Discharge	24.00	cfs

Results		
Depth	1.39	ft
Flow Area	9.9	ft²
Wetted Perim	11.78	ft
Top Width	11.33	ft
Critical Depth	0.93	ft
Critical Slope	0.037756	ft/ft
Velocity	2.41	ft/s
Velocity Head	0.09	ft
Specific Enerç	1.48	ft
Froude Numbı	0.45	
Flow Type	Subcritical	

TALL FESCUE GRASS

$n = .046$

$V_A = 2.41$ ft/sec.

$R_h = \frac{9.9}{11.78} = 0.84$ ft.

$V_A * R_h = 2.02$

$n = .046$ OK.

GEOMETRY: $B = 3'$

$D = 2'$

$z = 3$

$T = 15'$

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-2
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.033	
Slope	007000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	7.20	cfs

Results		
Depth	0.75	ft
Flow Area	3.2	ft²
Wetted Perim	6.72	ft
Top Width	6.47	ft
Critical Depth	0.56	ft
Critical Slope	0.022837	ft/ft
Velocity	2.28	ft/s
Velocity Head	0.08	ft
Specific Energ	0.83	ft
Froude Numb	0.58	
Flow Type	Subcritical	

STRAW W/ NET.

n= .033

$T_d = 62.4(.75)(.007) = 0.33$ lb/ft

OK.

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Project Engineer: Donna Barbour

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-2
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.058	
Slope	007000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	10.20	cfs

Results		
Depth	1.14	ft
Flow Area	6.2	ft²
Wetted Perim	9.23	ft
Top Width	8.86	ft
Critical Depth	0.67	ft
Critical Slope	0.067236	ft/ft
Velocity	1.64	ft/s
Velocity Head	0.04	ft
Specific Enerç	1.18	ft
Froude Numb	0.35	
Flow Type	Subcritical	

TALL FESCUE GRASS

n=.058

V_A = 1.64 ft/sec.

$R_h = \frac{6.2}{9.23} = 0.67$ ft.

$V_A * R_h = 1.10$

n= .058 OK.

GEOMETRY: B= 2'
D= 2'
z= 3
T= 14 ft.

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-3
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.033	
Slope	007000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	4.00	cfs

Results		
Depth	0.56	ft
Flow Area	2.1	ft²
Wetted Perim	5.54	ft
Top Width	5.35	ft
Critical Depth	0.40	ft
Critical Slope	0.024820	ft/ft
Velocity	1.95	ft/s
Velocity Head	0.06	ft
Specific Energ	0.62	ft
Froude Numb	0.55	
Flow Type	Subcritical	

STRAW W/ NET

n= .033

Td= 62.4 (.56)(.007) = 0.24 lb/ft

OK.

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-3
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.068	
Slope	007000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	5.70	cfs

Results		
Depth	0.94	ft
Flow Area	4.5	ft²
Wetted Perim	7.95	ft
Top Width	7.64	ft
Critical Depth	0.49	ft
Critical Slope	0.100191	ft/ft
Velocity	1.26	ft/s
Velocity Head	0.02	ft
Specific Enerç	0.96	ft
Froude Numb	0.29	
Flow Type	Subcritical	

TALL FESCUE GRASS

$n = .068$

$V_A = 1.26$ ft/sec

$R_h = \frac{4.5}{7.95} = 0.57$ ft.

$V_A * R_h = 0.71$

$n = .068$ OK.

GEOMETRY: $B = 2'$

~~1.5~~ $D = 2'$

$z = 3$

$T = 11$ ft

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-4
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.033	
Slope	004000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	12.10	cfs

Results		
Depth	1.08	ft
Flow Area	5.7	ft²
Wetted Perim	8.86	ft
Top Width	8.51	ft
Critical Depth	0.73	ft
Critical Slope	0.021265	ft/ft
Velocity	2.12	ft/s
Velocity Head	0.07	ft
Specific Enerç	1.15	ft
Froude Numb	0.46	
Flow Type	Subcritical	

Q_2

Straw w/Net

n= .033

$T_d = (62.4)(.004)(1.08)$

$= .27 < 1.45$ OK

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-4
Flow Element	Trapezoidal Cha
Method	Manning's Form
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.052	
Slope	004000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	17.10	cfs

Results		
Depth	1.55	ft
Flow Area	10.3	ft²
Wetted Perim	11.82	ft
Top Width	11.32	ft
Critical Depth	0.87	ft
Critical Slope	0.050390	ft/ft
Velocity	1.65	ft/s
Velocity Head	0.04	ft
Specific Energ	1.60	ft
Froude Numb	0.30	
Flow Type	Subcritical	

Q_{10}

Tall Fescue

n=.052

$V_A = 1.65$

$R_h = \frac{10.3}{11.82} = .87$

$V_A R_h = 1.44$

n=.052

ok

Geometry

B=2'

D=2'

Z=3

T=14'

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-5
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.033	
Slope	005000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	11.00	cfs

Results		
Depth	0.99	ft
Flow Area	4.9	ft²
Wetted Perim	8.24	ft
Top Width	7.92	ft
Critical Depth	0.70	ft
Critical Slope	0.021542	ft/ft
Velocity	2.25	ft/s
Velocity Head	0.08	ft
Specific Enerç	1.06	ft
Froude Numb	0.50	
Flow Type	Subcritical	

STRAW W/ NET

$n = .033$

$T_d = 62.4(.99)(.005)$

$= 0.31$ lb/ft² ok.

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-5
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.052	
Slope	005000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	15.50	cfs

Results		
Depth	1.42	ft
Flow Area	8.8	ft²
Wetted Perim	10.96	ft
Top Width	10.50	ft
Critical Depth	0.83	ft
Critical Slope	0.051061	ft/ft
Velocity	1.75	ft/s
Velocity Head	0.05	ft
Specific Enerç	1.46	ft
Froude Numb	0.34	
Flow Type	Subcritical	

TALL FESCUE GRASS

$n = .052$

$V_A = 1.75$ ft/sec.

$R_h = \frac{8.8}{10.96} = 0.80$ ft.

$V_A * R_h = 1.41$

$n = .052$ ok.

GEOMETRY: $b = 2'$

$D = 2'$

$z = 3$

$T = 14'$

Chas. H. Sells, Inc.
Project Engineer: Donna Barbour

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-6
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.033	
Slope	012500	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	13.30	cfs

Results		
Depth	0.87	ft
Flow Area	4.0	ft²
Wetted Perim	7.50	ft
Top Width	7.22	ft
Critical Depth	0.77	ft
Critical Slope	0.020994	ft/ft
Velocity	3.32	ft/s
Velocity Head	0.17	ft
Specific Enerç	1.04	ft
Froude Numbı	0.78	
Flow Type	Subcritical	

STRAW W/ NET

$n = .033$

$\tau = 62.4(.87)(.0125)$

$= 0.68$ lb/ft OK.

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-6
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.046	
Slope	012500	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	18.80	cfs

Results		
Depth	1.19	ft
Flow Area	6.6	ft²
Wetted Perim	9.53	ft
Top Width	9.14	ft
Critical Depth	0.92	ft
Critical Slope	0.038934	ft/ft
Velocity	2.84	ft/s
Velocity Head	0.12	ft
Specific Enerç	1.32	ft
Froude Numb	0.59	
Flow Type	Subcritical	

TALL FESCUE GRASS

$n = .046$

$V_A = 2.84$ ft/sec.

$R_h = \frac{6.6}{9.53} = 0.69$ ft.

$V_A * R_h = 1.97$

$n = .046$ OK.

GEOMETRY: $B = 2'$

$D = 2'$

$Z = 3$

$T = 14'$

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-7
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.033	
Slope	015000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	13.30	cfs

Results		
Depth	0.83	ft
Flow Area	3.7	ft²
Wetted Perim	7.27	ft
Top Width	7.00	ft
Critical Depth	0.77	ft
Critical Slope	0.020994	ft/ft
Velocity	3.55	ft/s
Velocity Head	0.20	ft
Specific Enerç	1.03	ft
Froude Numb	0.85	
Flow Type	Subcritical	

STRAW W/ NET.

n = .033

Td = 62.4 (.83)(.015)

= 0.78 lb/# OK.

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-7
Flow Element	Trapezoidal Cha
Method	Manning's Form
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.046	
Slope	015000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	18.80	cfs

Results		
Depth	1.14	ft
Flow Area	6.2	ft²
Wetted Perim	9.22	ft
Top Width	8.85	ft
Critical Depth	0.92	ft
Critical Slope	0.038935	ft/ft
Velocity	3.03	ft/s
Velocity Head	0.14	ft
Specific Energ	1.28	ft
Froude Numb	0.64	
Flow Type	Subcritical	

TALL FESCUE GRASS

$n = .046$

$V_A = 3.03$ ft/sec.

$R_h = \frac{6.2}{9.22} = 0.67$ ft.

$V_A * R_h = 2.04$

$n = .046$ OK.

GEOMETRY: B = 2'

D = 2'

Z = 3

T = 14'

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-8
Flow Element	Trapezoidal Cha
Method	Manning's Form
Solve For	Channel Depth

Q2

Synthetic net
n = .036

$T_d = (62.4)(.29)(.093) = 1.68$
< 2.0

OK

Input Data		
Mannings Coeffic	0.036	
Slope	093000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	3.80	cfs

Results		
Depth	0.29	ft
Flow Area	0.8	ft²
Wetted Perim	3.84	ft
Top Width	3.74	ft
Critical Depth	0.39	ft
Critical Slope	0.029758	ft/ft
Velocity	4.55	ft/s
Velocity Head	0.32	ft
Specific Enerc	0.61	ft
Froude Numb	1.70	
Flow Type	Supercritical	

Worksheet
Worksheet for Trapezoidal Channel

Q10

Project Description	
Worksheet	PD-8
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.057	
Slope	093000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	5.39	cfs

Results		
Depth	0.45	ft
Flow Area	1.5	ft²
Wetted Perimı	4.82	ft
Top Width	4.67	ft
Critical Depth	0.48	ft
Critical Slope	0.070957	ft/ft
Velocity	3.63	ft/s
Velocity Head	0.20	ft
Specific Enerç	0.65	ft
Froude Numbı	1.13	
Flow Type	Supercritical	

Tall Fescue

$n = .057$

$V_A = 3.63$ ft/sec

$R_h = \frac{1.5}{4.82} = .31$ ft

$V_A R_h = 1.13$

$n = .057$ ok

Geometry

$B = 2'$

$D = 1'$

$z = 3'$

$T = 8'$

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-9
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.036	
Slope	105000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	2.10	cfs

Results		
Depth	0.20	ft
Flow Area	0.5	ft²
Wetted Perim	3.28	ft
Top Width	3.22	ft
Critical Depth	0.28	ft
Critical Slope	0.032504	ft/ft
Velocity	3.96	ft/s
Velocity Head	0.24	ft
Specific Energ	0.45	ft
Froude Numb	1.72	
Flow Type	Supercritical	

Q_2

Synthetic net

$n = .036$

$T_d = (62.4)(.20)(.105)$

$= 1.31 < 2.0$ OK

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-9
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.067	
Slope	105000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	2.98	cfs

Results		
Depth	0.34	ft
Flow Area	1.0	ft²
Wetted Perim	4.18	ft
Top Width	4.07	ft
Critical Depth	0.34	ft
Critical Slope	0.106811	ft/ft
Velocity	2.85	ft/s
Velocity Head	0.13	ft
Specific Energ	0.47	ft
Froude Numb	0.99	
Flow Type	Subcritical	

Q_{10}

Tall Fescue

$n = .067$

$V_A = 2.85$ ft/sec

$R_h = \frac{1.0}{4.18} = .24$

$V_A R_h = .68$

$n = .067$ ok

Geometry

$B = 2'$

$D = 1'$

$Z = 3$

$T = 8'$

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-10
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.065	
Slope	068000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	2.36	cfs

Results		
Depth	0.34	ft
Flow Area	1.0	ft²
Wetted Perim	4.13	ft
Top Width	4.02	ft
Critical Depth	0.30	ft
Critical Slope	0.104100	ft/ft
Velocity	2.33	ft/s
Velocity Head	0.08	ft
Specific Enerç	0.42	ft
Froude Numb	0.82	
Flow Type	Subcritical	

Q_2

Straw with net

n = .065

$T_d = (62.4)(.34)(.068)$

$= 1.44$

< 1.45

OK

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-10
Flow Element	Trapezoidal Cha
Method	Manning's Formu
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.065	
Slope	068000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	3.35	cfs

Results		
Depth	0.40	ft
Flow Area	1.3	ft²
Wetted Perim	4.56	ft
Top Width	4.42	ft
Critical Depth	0.37	ft
Critical Slope	0.098811	ft/ft
Velocity	2.58	ft/s
Velocity Head	0.10	ft
Specific Energ	0.51	ft
Froude Numb	0.84	
Flow Type	Subcritical	

Q_{10}

Tall Fescue

n = .065

$V_A = 2.58$ ft/sec

$R_h = \frac{1.3}{4.56} = .285$

$V_A R_h = .74$

n = .065

OK

Geometry

B = 2'

D = 1'

Z = 3'

T = 8'

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-11
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.036	
Slope	083000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	2.42	cfs

Results		
Depth	0.23	ft
Flow Area	0.6	ft²
Wetted Perimı	3.48	ft
Top Width	3.41	ft
Critical Depth	0.30	ft
Critical Slope	0.031812	ft/ft
Velocity	3.82	ft/s
Velocity Head	0.23	ft
Specific Energ	0.46	ft
Froude Numbı	1.56	
Flow Type	Supercritical	

Q_2

synthetic net

$n = .036$

$T_d = (62.4)(.23)(.083) = 1.19 < 2.0$ ok

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	PD-11
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.065	
Slope	083000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	3.43	cfs

Results		
Depth	0.39	ft
Flow Area	1.2	ft²
Wetted Perim	4.46	ft
Top Width	4.33	ft
Critical Depth	0.37	ft
Critical Slope	0.098471	ft/ft
Velocity	2.79	ft/s
Velocity Head	0.12	ft
Specific Enerç	0.51	ft
Froude Numb	0.92	
Flow Type	Subcritical	

Q_{10}

Tall Fescue
n = .065

$V_A = 2.79$ ft/sec

$R_h = \frac{1.2}{4.46} = .27$

$V_A R_h = .75$
n = .065

OK

Geometry
B = 2'
D = 1'
Z = 3'
T = 8'

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	~~PD-13~~ PD-12
Flow Element	Trapezoidal Cha
Method	Manning's Form
Solve For	Channel Depth

Q2

Straw w/Net

$T_d = (62.4)(.005)(1.09)$
$= .34 < 1.45$ OK

Input Data		
Mannings Coeffic	0.033	
Slope	005000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	13.80	cfs

Results		
Depth	1.09	ft
Flow Area	5.8	ft²
Wetted Perim	8.92	ft
Top Width	8.57	ft
Critical Depth	0.78	ft
Critical Slope	0.020889	ft/ft
Velocity	2.39	ft/s
Velocity Head	0.09	ft
Specific Energ	1.18	ft
Froude Numb	0.51	
Flow Type	Subcritical	

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	~~PD-13~~ PD-12
Flow Element	Trapezoidal Cha
Method	Manning's Form
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.048	
Slope	005000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	2.00	ft
Discharge	19.60	cfs

Results		
Depth	1.52	ft
Flow Area	9.9	ft²
Wetted Perim	11.59	ft
Top Width	11.10	ft
Critical Depth	0.94	ft
Critical Slope	0.042157	ft/ft
Velocity	1.97	ft/s
Velocity Head	0.06	ft
Specific Energ	1.58	ft
Froude Numb	0.37	
Flow Type	Subcritical	

Q_{10}

Tall Fescue

$n = .048$

$V_A = 1.97$

$R_h = \frac{9.9}{11.59} = .854$

$V_A R_h = 1.68$

$n = .048$

OK

Geometry

$B = 2'$

$D = 2'$

$z = 3$

$T = 14'$

CHAS. H. SELLS, INC.
Consulting Engineers, Surveyors & Photogrammetrists

Comp. By DHB Date 3-26-04 Project MARSHALL LANDFILL Sheet No. ...... of ......
Chkd. By ...... Date ...... Subject RIPRAP FLUMES TO SB-4 Job No. ......

CELL 1 RIPRAP FLUMES

$A = 10.1$ Ac.
$C = 0.6$
$I_{10} = 6.8$ IN/HR.
$Q_{10} = .6(6.8)(10.1) = 41.2$ cfs.

$S = 25\%$
REF. FIGURE 8.05l, $B = 6$, $Z = 3$
$d_n = 0.6$ ft +/-
$d = \frac{A_3}{A_z} \cdot d_n = 0.6$ WHERE $\frac{A_3}{A_z} = 1.0$ (8.05h)
$d_{50c} = 1.5$ ft.
$d_{50} = \frac{d}{d_n} \cdot d_{50c} = 1.5$ ft. ⇒ USE 18" RIPRAP.

$d_{max} = 27''$
$t = 40.5''$

USE CHANNEL DEPTH = 1.5 ft.
$Z = 3$
$T = 15$ ft.

Worksheet
Worksheet for Circular Channel

SLOPE DRAIN SD-1 FROM TD-3

Project Description	
Worksheet	SD-1
Flow Element	Circular Chann
Method	Manning's Forr
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.024	
Slope	170000	ft/ft
Diameter	18	in
Discharge	16.00	cfs

Results		
Depth	0.91	ft
Flow Area	1.1	ft²
Wetted Perime	2.68	ft
Top Width	1.47	ft
Critical Depth	1.42	ft
Percent Full	60.6	%
Critical Slope	0.068493	ft/ft
Velocity	14.28	ft/s
Velocity Head	3.17	ft
Specific Energ:	4.08	ft
Froude Numbe	2.88	
Maximum Disc	25.23	cfs
Discharge Full	23.46	cfs
Slope Full	0.079083	ft/ft
Flow Type	Supercritical	

Worksheet
Worksheet for Circular Channel

STA 1+75
@ ENDWALL

D.A. = 20.8 Ac.

Project Description	
Worksheet	Culvert Sta. 1+7
Flow Element	Circular Channe
Method	Manning's Forr
Solve For	Full Flow Diame

Input Data		
Mannings Coeffic	0.013	
Slope	025000	ft/ft
Discharge	85.00	cfs

Results		
Depth	2.77	ft
Diameter	33	in
Flow Area	6.0	ft²
Wetted Perime	0.00	ft
Top Width	0.00	ft
Critical Depth	2.68	ft
Percent Full	100.0	%
Critical Slope	022011	ft/ft
Velocity	14.14	ft/s
Velocity Head	3.11	ft
Specific Energ	5.87	ft
Froude Numbe	0.00	
Maximum Disc	91.44	cfs
Discharge Full	85.00	cfs
Slope Full	025000	ft/ft
Flow Type	N/A	

Worksheet
Worksheet for Circular Channel

STA: 17+00
@ YI-1

D.A. = 13.10 Ac.

Project Description	
Worksheet	Culvert @ Sta. 17
Flow Element	Circular Channel
Method	Manning's Formu
Solve For	Full Flow Diamete

Input Data		
Mannings Coeffic	0.013	
Slope	030000	ft/ft
Discharge	53.50	cfs

Results		
Depth	2.25	ft
Diameter	27	in
Flow Area	4.0	ft²
Wetted Perime	0.00	ft
Top Width	0.00	ft
Critical Depth	2.19	ft
Percent Full	100.0	%
Critical Slope	026651	ft/ft
Velocity	13.48	ft/s
Velocity Head	2.82	ft
Specific Energy	5.07	ft
Froude Numbe	0.00	
Maximum Disc	57.55	cfs
Discharge Full	53.50	cfs
Slope Full	030000	ft/ft
Flow Type	N/A	

Worksheet
Worksheet for Circular Channel

STA. 10+65
@ Y-2

D.A. = 5.10

Project Description	
Worksheet	Culvert @ Sta. 1(
Flow Element	Circular Channel
Method	Manning's Formu
Solve For	Full Flow Diamete

Input Data		
Mannings Coeffic	0.013	
Slope	030000	ft/ft
Discharge	20.80	cfs

Results		
Depth	1.58	ft
Diameter	19	in
Flow Area	2.0	ft²
Wetted Perime	0.00	ft
Top Width	0.00	ft
Critical Depth	1.53	ft
Percent Full	100.0	%
Critical Slope	026405	ft/ft
Velocity	10.65	ft/s
Velocity Head	1.76	ft
Specific Energ	3.34	ft
Froude Numbe	0.00	
Maximum Disc	22.37	cfs
Discharge Full	20.80	cfs
Slope Full	030000	ft/ft
Flow Type	N/A	

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	AC-1
Flow Element	Trapezoidal Cha
Method	Manning's Formı
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.015	
Slope	136000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	8.00	ft
Discharge	38.00	cfs

Results		
Depth	0.29	ft
Flow Area	2.6	ft²
Wetted Perimı	9.82	ft
Top Width	9.73	ft
Critical Depth	0.80	ft
Critical Slope	0.003888	ft/ft
Velocity	14.88	ft/s
Velocity Head	3.44	ft
Specific Enerç	3.73	ft
Froude Numbı	5.12	
Flow Type	Supercritical	

GEOMETRY B = 8 ft
D = 1 ft
Z = 3
T = 14 ft

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	AC-2
Flow Element	Trapezoidal Cha
Method	Manning's Formι
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.015	
Slope	081000	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	6.00	ft
Discharge	50.60	cfs

Results		
Depth	0.46	ft
Flow Area	3.4	ft²
Wetted Perim	8.92	ft
Top Width	8.77	ft
Critical Depth	1.08	ft
Critical Slope	0.003665	ft/ft
Velocity	14.85	ft/s
Velocity Head	3.43	ft
Specific Enerc	3.89	ft
Froude Numb	4.20	
Flow Type	Supercritical	

GEOMETRY B = 6 ft

D = 1 ft

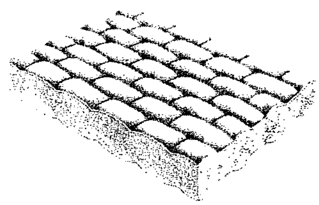
Z = 3

T = 12 ft.

ARMORFORM® UNIFORM SECTION MAT (USM)

TYPICAL DIMENSIONS, WEIGHTS AND VOLUMES

(Values shown are typical only, and will vary with field conditions.)



Uniform Section Size	Cord Spacing	Nominal Thickness	Weight/ Sq. Ft.	Coverage/ Cu. Yd. Concrete	Availability
3″ USM	3″ x 3″	3.0″	35 lbs.	97 ft.^{2}	Inventory
4″ USM	3″ x 3″	4.0″	47 lbs.	73 ft.^{2}	Inventory
6″ USM	3″ x 4″	6.0″	70 lbs.	49 ft.^{2}	Inventory
8″ USM	3″ x 5″	8.0″	93 lbs.	36 ft.^{2}	Special Order

PRODUCT DESCRIPTION

Uniform Section Mat (USM) is formed with a double-layer woven fabric, joined together by spacer cords and engineered exclusively to serve as a form for casting concrete erosion control linings. The fabric forms are positioned on the area to be protected, where they are filled with a pumpable fine aggregate concrete (structural grout).

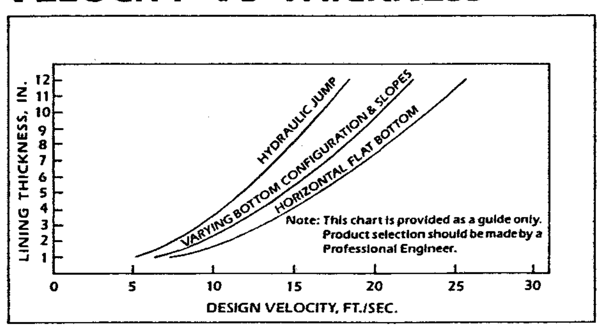
Uniform Section Mat fabric is woven from polypropylene slit film yarns, and designed with the required strength, stability, and filtration characteristics of a superior fabric form. The fabric forms are constructed with spacer cords on closely spaced centers to form a lining of required nominal thickness, bonded cobbled surface, and specified weight to provide strength and erosion protection. The design criterion for selection of lining thickness is the same as that used to determine the thickness of conventional concrete slope paving.

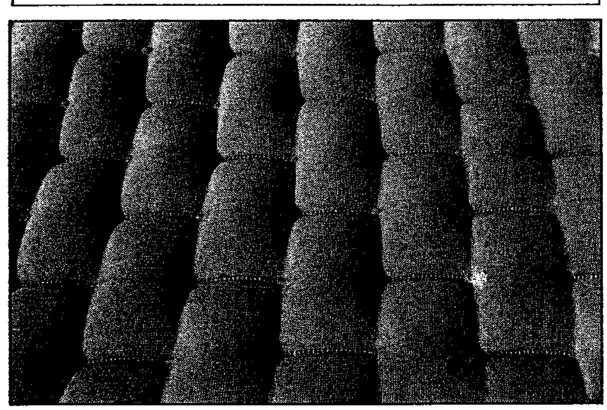
Relief of hydrostatic uplift pressure, caused by entrapped and ground water, may be provided by inserting plastic weep tubes through the mat at specified centers. When weep tubes are used, the lower end of the weep tube should be covered by filter fabric or the mat should be placed over filter fabric.

At Nicolon's fabrication facilities, Uniform Section Mat fabric in mill width rolls is factory fabricated into multiple mill width panels, designed to fit site dimensions and topography.

Panels are delivered to the job site where the installer assembles the panels into a continuous concrete forming system. Fabric forms contract as they are pumped with a structural grout. Allowance must be made for this contraction in estimating the quantity of fabric form required. Nicolon should be contacted to determine the appropriate contraction factors for your site conditions.

VELOCITY -VS- THICKNESS





ARMORFORM® GUIDE SPECIFICATION FOR UNIFORM SECTION MAT (USM)

1.0 GENERAL

1.1 SCOPE OF WORK
The Contractor shall furnish all labor, materials, equipment, and incidentals required to perform all operations in connection with the installation of the proposed Uniform Section Mat (USM) lining in accordance with the lines, grades, design and dimensions shown on the Contract Drawings and as specified herein.

1.2 DESCRIPTION
The work shall consist of installing an unreinforced concrete mat lining, by positioning a specially woven double-layer synthetic fabric form on the surface to be protected and filling it up with a pumpable fine aggregate concrete (structural grout) in such a way as to form a stable mat of required thickness, weight and configuration.

2.0 MATERIALS

2.1 FINE AGGREGATE CONCRETE
Fine aggregate concrete shall consist of a mixture of portland cement, fine aggregate (sand), and water so proportioned and mixed as to provide a pumpable grout. Pozzolan and grout fluidifier conforming to these Specifications may be used at the option of the Contractor. The mix shall exhibit a compressive strength of 2,000 psi at 28 days when made and tested in accordance with ASTM C-31 and C-39.

Note: The average compression strength of ARMORFORM cast fine aggregate concrete shall be at least 20% higher at 7 days than that of the companion test cylinders made in accordance with ASTM C-31, and not less than 2,500 psi at 28 days.

2.1.1 Portland cement shall conform to ASTM C-150, Type I or Type II.

2.1.2 Fine aggregate shall conform to ASTM C-33, except as to grading. Aggregate grading shall be reasonably consistent and shall be well graded from the maximum size which can be conveniently handled with available pumping equipment.

2.1.3 Water for mixing shall be clean and free from injurious amounts of oil, acid, salt, alkali, organic matter or other deleterious substances.

2.1.4 Pozzolan, if used, shall conform to ASTM C-350.

2.2 FABRIC FORM
The fabric forms shall be, as specified, ARMORFORM *note a* Uniform Section Mat as manufactured by Nicolon Corporation, or approved equal. Each layer of fabric shall meet the statistical mean (average) results as shown below.

Property	Test Method	Unit	Values USM
Physical:			
Composition			PP[1]
Weight (double-layer)	ASTM D-3776-79	oz/yd	10
Thickness	ASTM D-1777-75	mils	20
Mill Width		in	84/172
Mechanical:			
Grab Tensile Strength	ASTM D-1682-75	lbs	
Warp			200
Fill			200
Grab Tensile Elongation	ASTM D-1682-75	%	
Warp			20
Fill			20
Diaphragm Burst Strength	ASTM D-3786-80 a	psi	475
Trapezoid Tear Strength	ASTM D-1117-80	lbs	
Warp			65
Fill			75
Puncture Strength	ASTM D-3787-80	lbs	60
Hydraulic:			
Water Flow Rate	ASTM D-4491	gal/min/sf	80
Coefficient of Permeability (k)	ASTM D-4491	cm/sec	0.05
Permittivity (k/l)	ASTM D-4491	l/sec	1.0
Porosity	ASTM D-737-75	cf/min/sf	125
Spacer Cord:			
Break Strength	ASTM D-2256	lbs/cord	135 (2)

[1] PP - Polypropylene

The Contractor shall furnish the Engineer, in duplicate, manufacturer's certified test results showing actual test values obtained when the above physical properties were tested for compliance with the Specifications.

Note a: The Engineer shall indicate the Uniform Section Mat size required. Example: 4" USM.

2.2.1 Fabric form material shall consist of double-layer woven fabric joined together by spacer cords, of uniform length, to produce a mat with a finished nominal thickness of *note b* inches, and a nominal weight of *note b* lbs./ft.². Spacer cords shall connect two layers of fabric on *note c* centers. Points of connection shall be staggered to provide a bonded cobbled surface appearance.

Note b: The Engineer shall indicate the nominal mat thickness and weight/sq. ft. for the Uniform Section Mat required.

Note c: The Engineer shall indicate the cord spacing for the Uniform Section Mat required.

2.2.2 Individual mill width rolls of fabric form shall be a minimum width of 84 inches. Mill width rolls shall be cut to the length required, and the two layers of fabric separately joined bottom edge to bottom edge, and top edge to top edge by means of sewing thread, to form multiple mill width panels. All factory sewn seams shall be downward facing as shown on the Contract Drawing. The grab tensile strength of all sewn seams shall be not less than 100 lbs./in. when tested in accordance with ASTM D-1692-75.

2.2.3 Grout stops shall be installed at predetermined, mill width, intervals to regulate the flow of fine aggregate concrete.

2.2.4 Plastic weep tubes, for relief of hydrostatic uplift pressure, shall be inserted through the mat, at *note d* foot centers, at locations shown on the Contract Drawings. Where weep tubes are required, the lower end of the weep tube shall be covered by filter fabric held securely in place or the mat shall be placed over filter fabric as specified elsewhere in these Specifications.

Note d: Plastic weep tubes are normally inserted in Uniform Section Fabric on approximately 5' to 10' centers, or as specified by the Engineer.

2.2.5 Immediately following receipt of fabric forms to the job site, forms should be inspected and stored in a clean dry area where they will not be subject to mechanical damage, exposure to moisture or direct sunlight.

3.0 INSTALLATION

3.1 SITE PREPARATION

3.1.1 Areas on which fabric forms are to be placed shall be constructed to the lines and grades shown on the Contract Drawings. Where such areas are below the allowable grades they shall be brought to grade by placing compacted layers of selected material. The depth of layers and amount of compaction shall be as specified by the Engineer. All obstructions such as roots and projecting stones shall be removed.

3.1.2 Excavation and preparation of anchor trenches, terminal trenches, and toe trenches or aprons shall be done in accordance with the lines, grades and dimensions shown on the Contract Drawings.

3.1.3 Immediately prior to placing the fabric forms, the prepared area shall be inspected by the Engineer and no forms shall be placed thereon, until the area has been approved.

3.2 FABRIC FORM PLACEMENT

3.2.1 Fabric form panels, as specified in Section 2.2 of this Specification shall be placed within the limits shown on the Contract Drawings.

3.2.2 Adjacent fabric form panels shall be joined before fine aggregate concrete injection, by field sewing or zippering the two bottom layers of fabric together and the two top layers of fabric together. All sewn seams shall be downward facing as shown on the Contract Drawings except with the approval of the Engineer.

3.2.3 When conventional joining of panels is impractical, or where called for on Contract Drawings, adjacent panels may be overlapped a minimum of two feet pending approval by the Engineer. In no case shall simple butt joints between panels be permitted.

3.2.4 Lap joints and expansion joints shall be provided as shown on the Contract Drawing, or as specified by the Engineer. Filter fabric with a minimum width of six feet shall be placed under all lap joints and expansion joints and shall extend continuously along the length of the joint.

3.2.5 Immediately prior to injection of fine aggregate concrete, the assembled fabric form panels shall be inspected by the Engineer and no fine aggregate concrete shall be pumped therein until the fabric seams and panel connections have been approved.

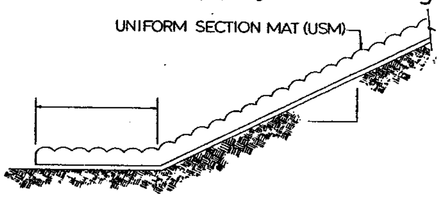
3.3 FINE AGGREGATE CONCRETE PLACEMENT

3.3.1 Following panel placement, small slits shall be cut in the top layer of the fabric form to allow for the insertion of the injection pipe. Fine aggregate concrete shall be injected between the top and bottom layers of fabric, filling the panel to the recommended thickness and configuration.

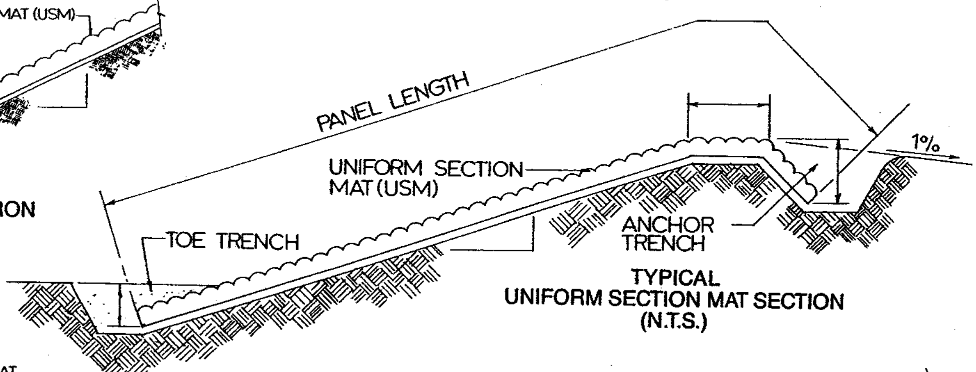
3.3.2 Fine aggregate concrete shall be injected in such a way that excessive pressure on the fabric form and cold joints are avoided.

3.3.3 Holes in the fabric left by the removal of the injection pipe shall be temporarily closed by inserting a piece of burlap or similar material. The burlap shall be removed when the concrete is no longer fluid and the concrete surface at the hole smoothed by hand. Foot traffic on the filled mat shall be restricted to an absolute minimum for one hour after pumping.

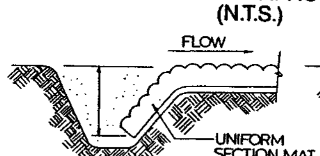
3.3.4 Upon completion of the fine aggregate concrete placement, all the anchor trenches, terminal trenches and toe trenches shall be backfilled and compacted, as specified by the Engineer.



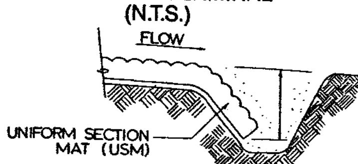
TYPICAL APRON
(N.T.S.)



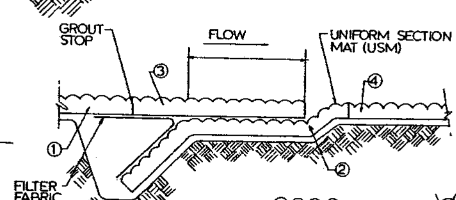
TYPICAL
UNIFORM SECTION MAT SECTION
(N.T.S.)



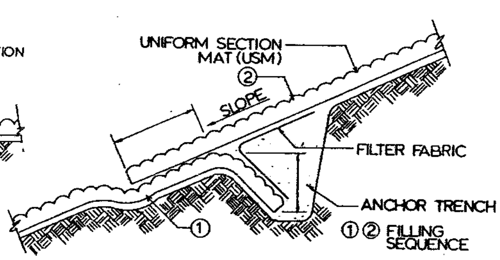
TYPICAL
UPSTREAM TERMINAL
(N.T.S.)



TYPICAL
DOWNSTREAM TERMINAL
(N.T.S.)



TYPICAL
LAP OR EXPANSION JOINT
WITH CUTOFF TRENCH
(N.T.S.)



TYPICAL
SIDE SLOPE LAP OR EXPANSION JOINT
WITH ANCHOR TRENCH
(N.T.S.)

LANDFILL ARMORED CHANNEL

CHAS. H. SELLS, INC.
Consulting Engineers, Surveyors & Photogrammetrists

Comp. By DHB Date 2-25-04 Project MARSHALL LANDFILL Sheet No. ...... of ......
Chkd. By ...... Date ...... Subject OUTLET PROT. APRONS Job No. ......

CELL 1
A-1
@ SB-4

$D_o = 42''$
$Q_{10} = 94$ cfs
$L_A = 26$ ft
$W = 29.5$ ft.
d_{50} RIPRAP = 12"
$d_{max} = 18''$
$t = 27''$
$H = 28''$

CLOSURE
A-2
CULVERT OUTLET
STA. 1+75

$D_o = 36''$
$Q_{10} = 85$ cfs
$L_A = 29$ ft
$W = 32$ ft
d_{50} RIPRAP = 12"
$d_{max} = 18''$
$t = 27''$
$H = 24''$

CELL 2
A-3
CULVERT OUTLET
STA. 17+00

$D_o = 30''$
$Q_{10} = 53.5$ cfs
$L_A = 24$ ft.
$W = 26.5$ ft.
d_{50} RIPRAP = 12"
$d_{max} = 18''$
$t = 27''$
$H = 20''$

CELL 2
A-4
CULVERT OUTLET
STA. 10+65

$D_o = 18''$
$Q_{10} = 12.65$ cfs
$L_A = 12$ ft.
$W = 13.5$ ft.
d_{50} RIPRAP = 6"
$d_{max} = 9''$
$t = 13.5''$
$H = 12''$

CELL 2
A-5
@ SB-7

D_o = 42"
Q_{10} = 107 cfs
L_A = 30 ft
W = 33.5 ft.
d_{50} RIPRAP = 12"
d_{max} = 18"
t = 27"
H = 28"

CELL 2
A-6
@ SB-6

D_o = 42"
Q_{10} = 94 cfs
L_A = 26 ft.
W = 29.5 ft
d_{50} RIPRAP = 12"
d_{max} = 18"
t = 27"
H = 28"

CELL 1
A-7
@ SB-5

D_o = 42"
Q_{10} = 66.2 cfs
L_A = 22 ft
W = 25.5 ft.
d_{50} RIPRAP = 12"
d_{max} = 18"
t = 27"
H = 28"

CHAS. H. SELLS, INC.
Consulting Engineers, Surveyors & Photogrammetrists

Comp. By DHB Date 2-25-04 | Project MARSHALL LANDFILL | Sheet No. .... of ....
Chkd. By .... Date .... | Subject OUTLET PROT. APRONS. | Job No. ....

A-8
@ ARMORED CHANNEL AC-1

$D_o = 30''$
$Q_{10} = 38$ cfs
$L_A = 17$ ft.
$W = 19.5$ ft.
d_{50} RIPRAP = 6″
$d_{max} = 9''$
$t = 13.5''$
$H = 20''$

A-12
@ SD-1 CELL 2

$D_o = 18''$
$Q_{10} = 16$ cfs
$L_A = 14$ ft
$W = 15.5$ ft.
d_{50} RIPRAP = 6″
$d_{max} = 9''$
$t = 13.5''$
$H = 12''$

A-9
@ ARMORED CHANNEL AC-2

$Q_{10} = 50.6$ cfs
$L_A = 20$ ft.
$W = 23$ ft.
d_{50} RIPRAP = 12″
$d_{max} = 18''$
$t = 27''$
$H = 24''$
$D_o = 36''$

A-10
@ CELL 2 42″ CULVERT TO SB-7

$Q_{10} = 107$ cfs.
$L_A = 30$ ft
$W = 33.5$ ft.
d_{50} RIPRAP = 12″
$d_{max} = 18''$
$t = 27''$
$H = 28''$
$D_o = 42''$

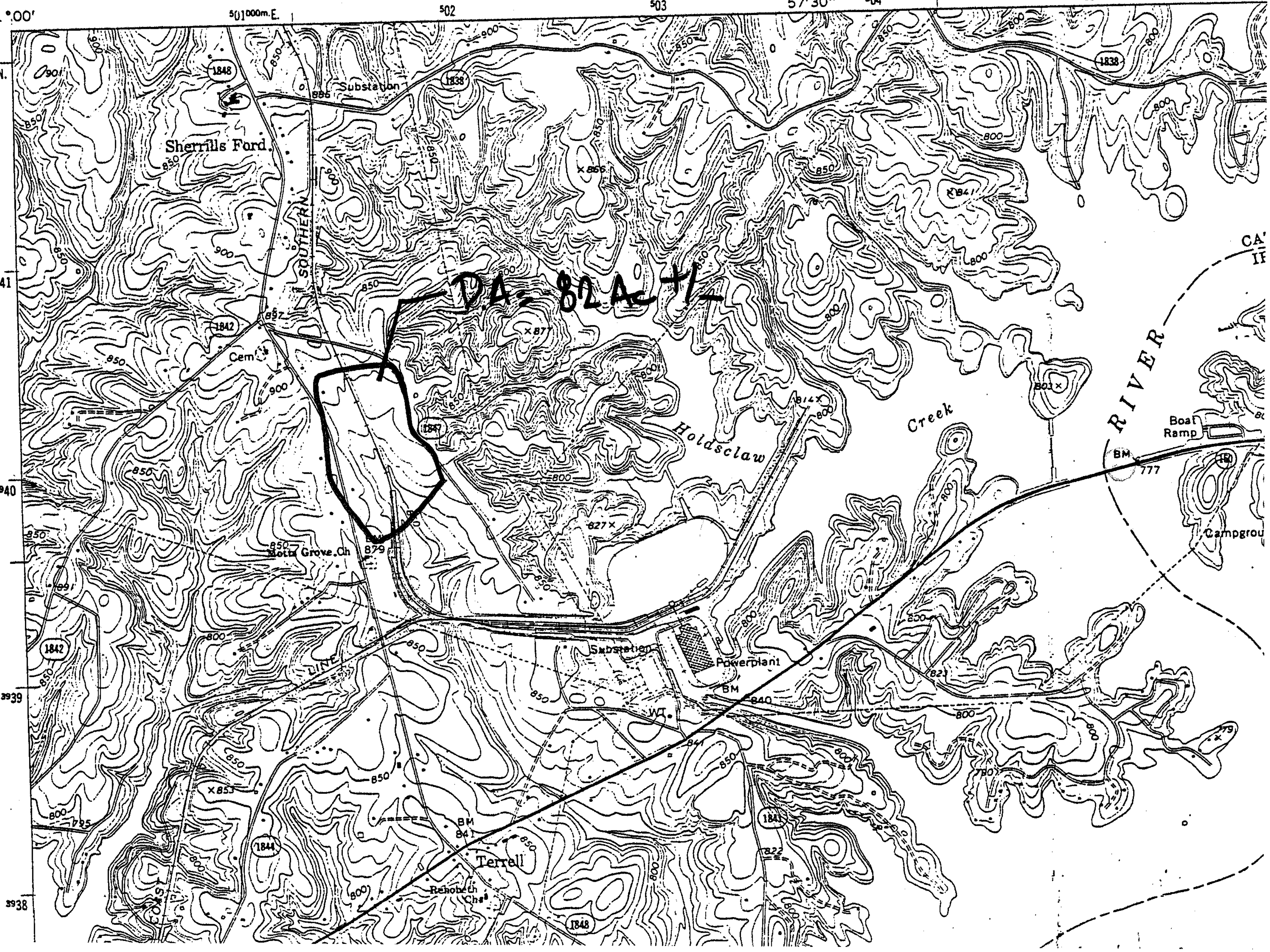
A-11
@ HW-2

$Q_{10} = 223$ cfs
$D_o = 60''$
$L_A = 36$ ft.
$W = 41$ ft.
d_{50} RIPRAP = 12″
$d_{max} = 18''$
$t = 27''$
$H = 40''$

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SCALE 1" = 2000'

STATE OF NORTH C
DEPARTMENT OF URAL AND E
RALEIGH, NORTH C



CHAS. H. SELLS, INC.
Consulting Engineers, Surveyors & Photogrammetrists

Comp. By DHB Date 2-4-04 Project MARSHALL GYPSUM LANDFILL Sheet No. ____ of ____
Chkd. By ____ Date ____ Subject ____ Job No. 046003

D.A. = 82 Ac +/-
I_{10} = 6.8 IN/HR.

If c = .40 Q_{10} = .40(6.8)(82) = 223 cfs.
If c = .35 Q_{10} = .35(6.8)(82) = 195 cfs.
If c = .30 Q_{10} = .30(6.8)(82) = 167 cfs.

RIPRAP OUTLET PROT. APRON @ HW-2:

A-10 Q_{10} = 223 cfs
D_o = 60"
L_A = 36 ft.
W = 41 ft.
d_{50} RIPRAP = 12"
d_{max} = 18"
t = 27"
H = 40"

Worksheet
Worksheet for Circular Channel

Project Description	
Worksheet	STREAM RCP
Flow Element	Circular Channe
Method	Manning's Forr
Solve For	Full Flow Diame

Input Data		
Mannings Coeffic	0.013	
Slope	009000	ft/ft
Discharge	167.00	cfs

Results		
Depth	4.32	ft
Diameter	52	in
Flow Area	14.6	ft²
Wetted Perime	0.00	ft
Top Width	0.00	ft
Critical Depth	3.77	ft
Percent Full	100.0	%
Critical Slope	008174	ft/ft
Velocity	11.41	ft/s
Velocity Head	2.02	ft
Specific Energ;	6.34	ft
Froude Numbe	0.00	
Maximum Disc	179.64	cfs
Discharge Full	167.00	cfs
Slope Full	009000	ft/ft
Flow Type	N/A	

⇒ 60" ϕ

Worksheet
Worksheet for Circular Channel

Project Description	
Worksheet	STREAM RCP
Flow Element	Circular Channe
Method	Manning's Forr
Solve For	Full Flow Diame

Input Data		
Mannings Coeffic	0.013	
Slope	009000	ft/ft
Discharge	195.00	cfs

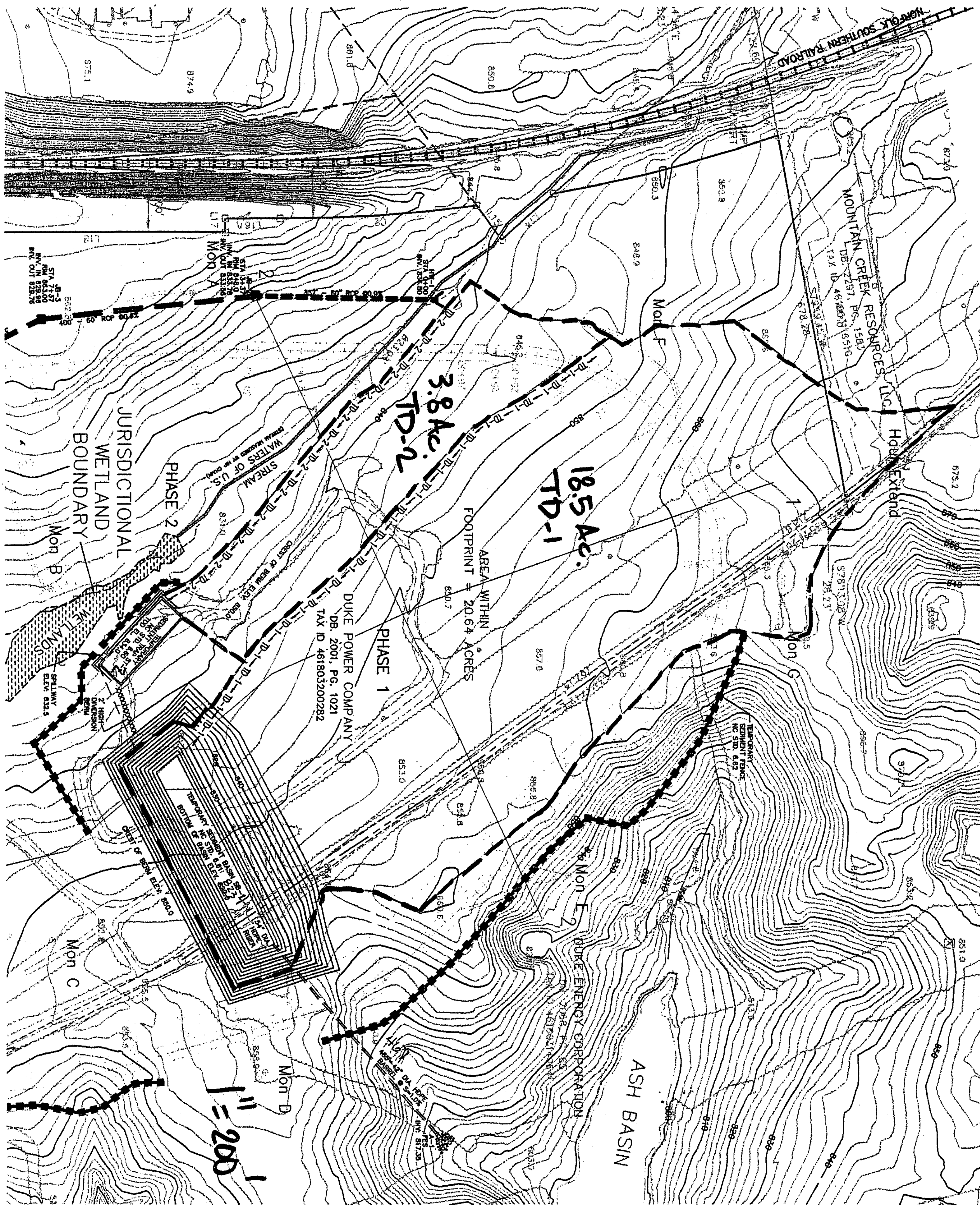
Results		
Depth	4.58	ft
Diameter	55	in ⇒ 60" ϕ
Flow Area	16.4	ft²
Wetted Perime	0.00	ft
Top Width	0.00	ft
Critical Depth	4.01	ft
Percent Full	100.0	%
Critical Slope	008138	ft/ft
Velocity	11.86	ft/s
Velocity Head	2.19	ft
Specific Energ	6.76	ft
Froude Numbe	0.00	
Maximum Disc	209.76	cfs
Discharge Full	195.00	cfs
Slope Full	009000	ft/ft
Flow Type	N/A	

Worksheet
Worksheet for Circular Channel

Project Description	
Worksheet	STREAM RCP
Flow Element	Circular Channe
Method	Manning's Forr
Solve For	Full Flow Diame

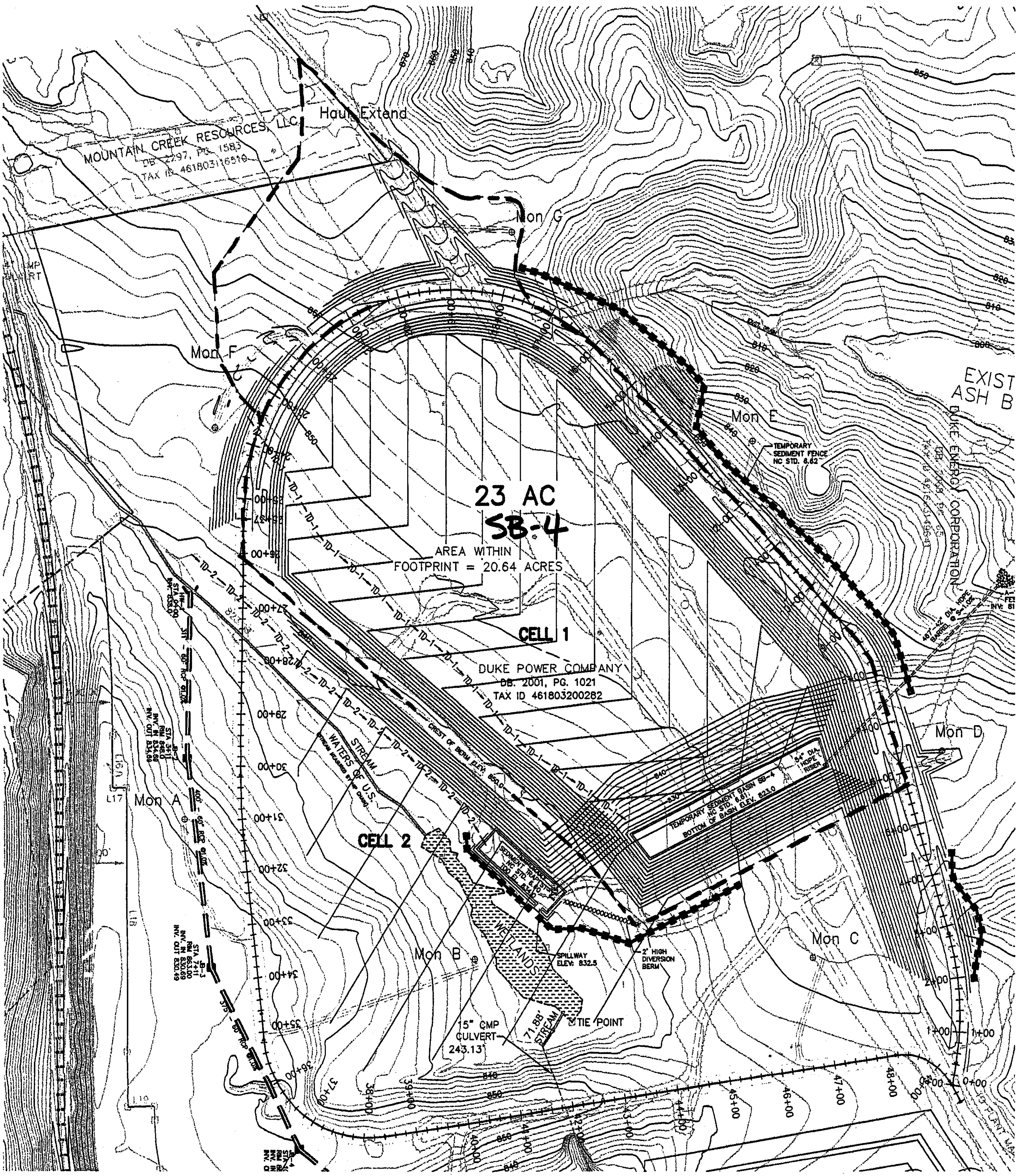
Input Data		
Mannings Coeffic	0.013	
Slope	009000	ft/ft
Discharge	223.00	cfs

Results		
Depth	4.81	ft
Diameter	58	in ⇒ 60" ϕ
Flow Area	18.2	ft²
Wetted Perime	0.00	ft
Top Width	0.00	ft
Critical Depth	4.23	ft
Percent Full	100.0	%
Critical Slope	008110	ft/ft
Velocity	12.26	ft/s
Velocity Head	2.34	ft
Specific Energ;	7.15	ft
Froude Numbe	0.00	
Maximum Disc	239.88	cfs
Discharge Full	223.00	cfs
Slope Full	009000	ft/ft
Flow Type	N/A	

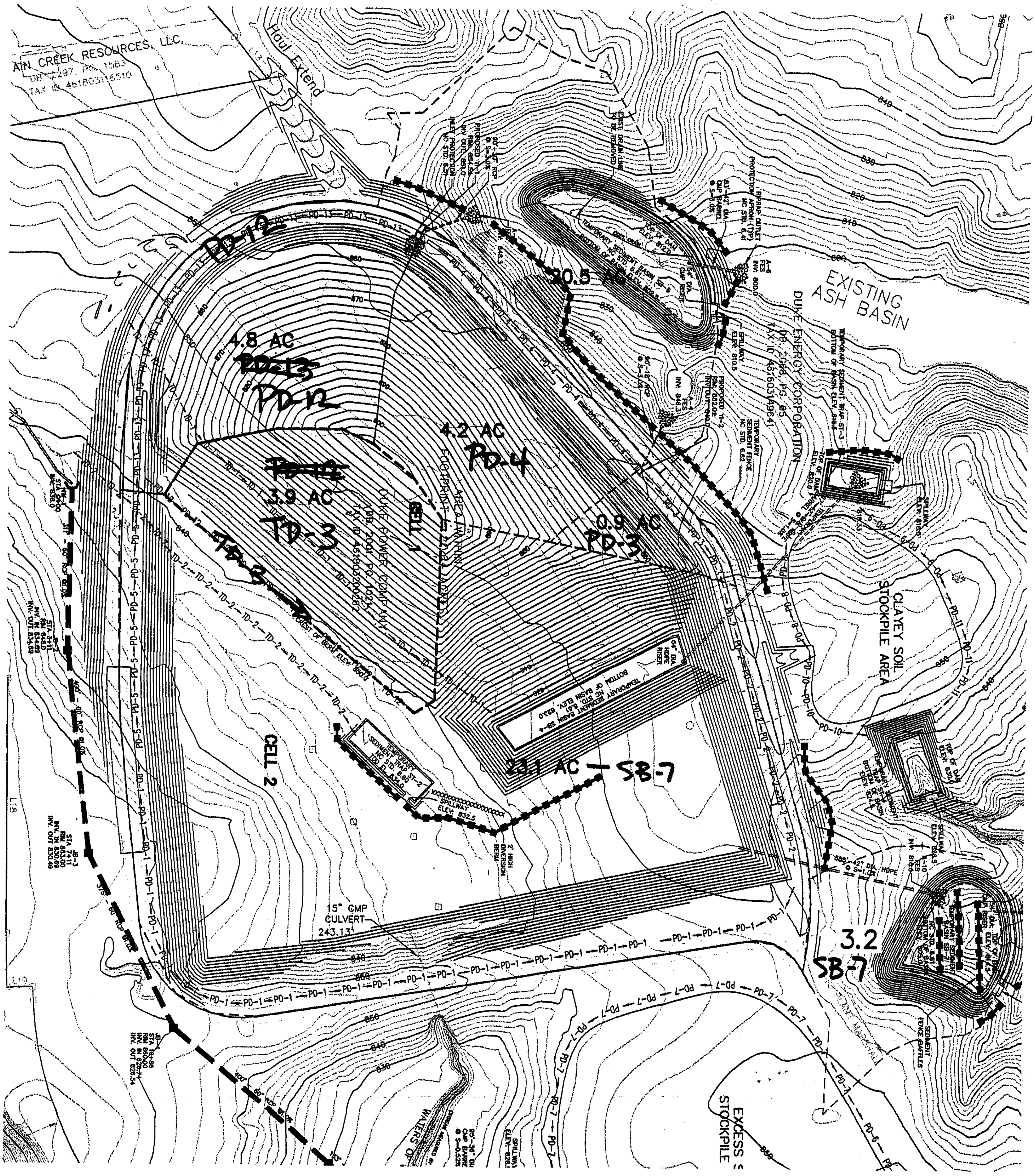


CELL 1 TEMPORARY DIVERSION CHANNEL DRAINAGE AREAS.

SCALE: 1" = 200'

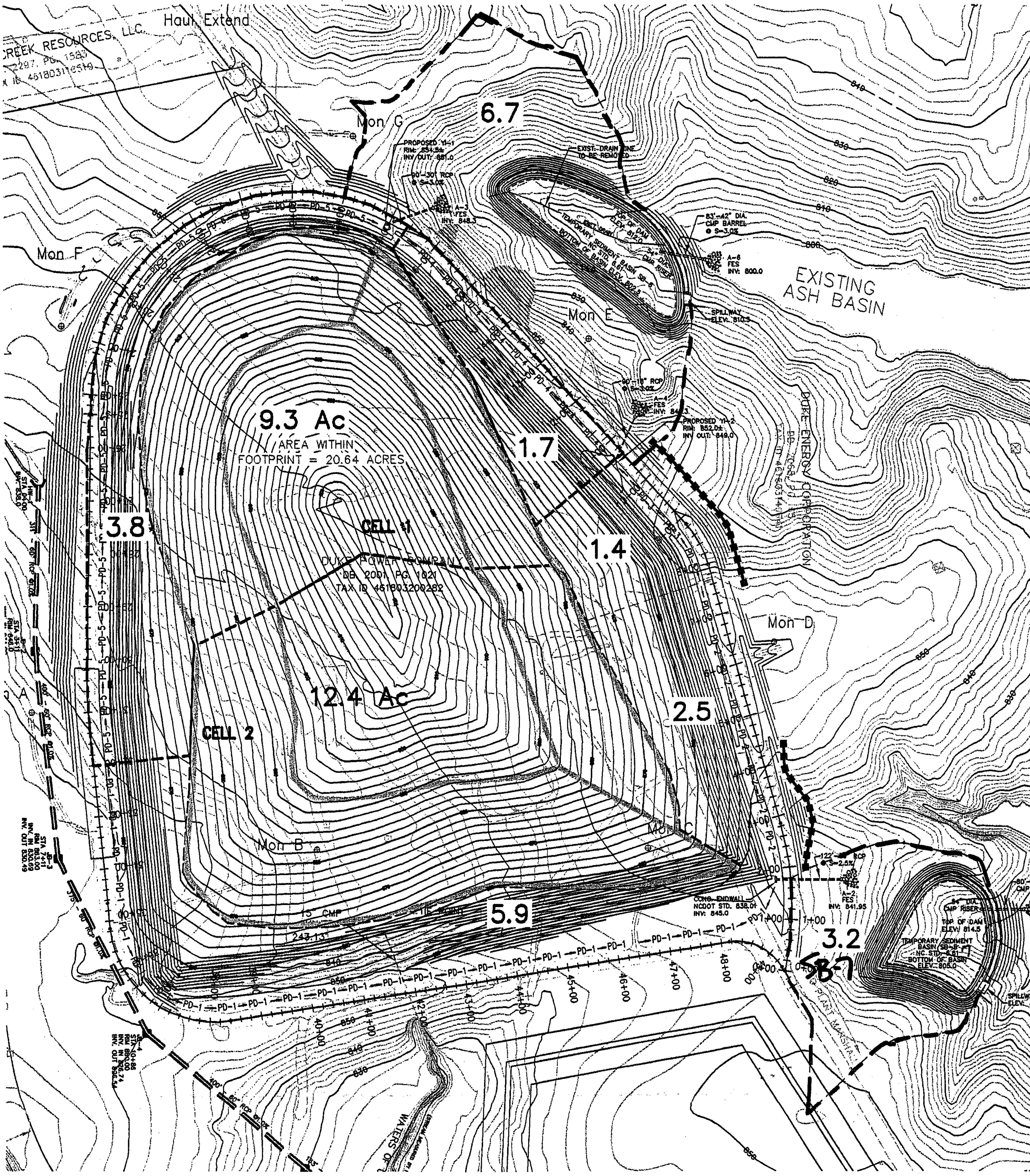


CELL 1 SED. BASIN SB-4 DRAINAGE AREA
SCALE: 1" = 200'



CELL 1 CLOSED EROSION CONTROL DRAINAGE AREAS.

SCALE: 1" = 200'



FINAL CLOSURE EROSION CONTROL DRAINAGE AREAS.
SCALE: 1" = 200'

Step 10. For grass-lined channels once the appropriate channel dimensions have been selected for low retardance conditions, repeat steps 6 through 8 using a higher retardance class, corresponding to tall grass. Adjust capacity of the channel by varying depth where site conditions permit.

NOTE 1: If design velocity is greater than 2.0 ft/sec may be required to stabilize the channel until vege The temporary liner may be designed for peak flow If a channel requires temporary lining, the designer stresses in the channel to select the liner that pro promotes establishment of vegetation. For the desig use tractive force procedure.

NOTE 2: Design Tables—Vegetated Channels and of this section may be used to design grass-lined ch cross-sections.

Step 11. Check outlet for carrying capacity and stability. I exceed allowable velocities for the receiving stream, an o ture will be required (Table 8.05d, pg. 8.05.9).

Sample Problem 8.05a illustrates the design of a grass-lin

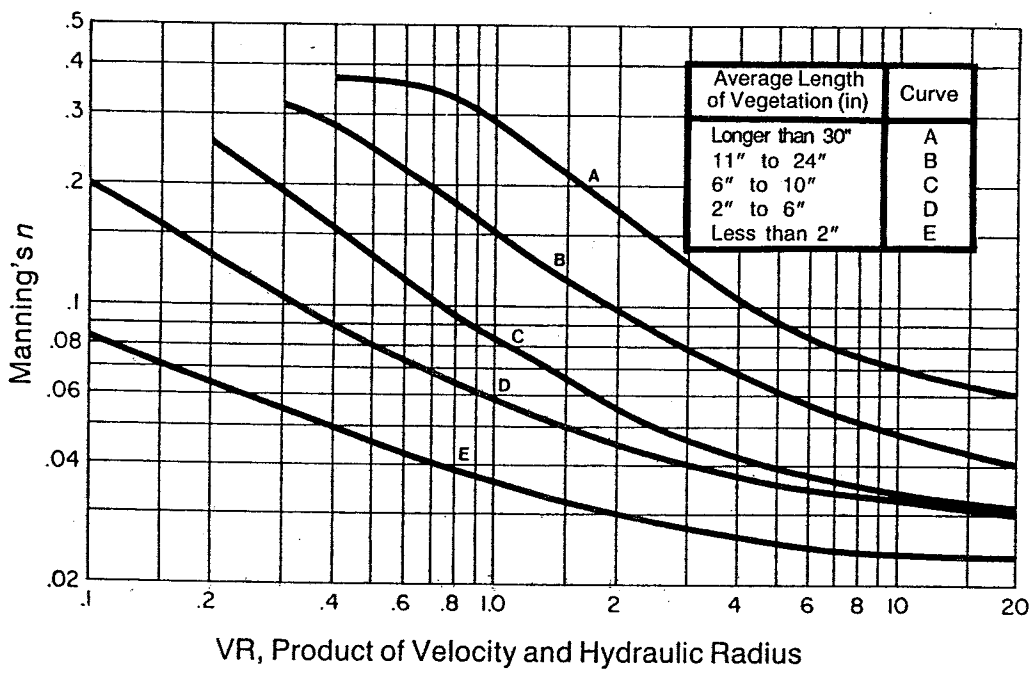


Figure 8.05c Manning's *n* related to velocity, hydraulic radius, and vegetal retardance.

Note: From Sample Problem 8.05a multiply Vp x Hydralulic Radius (4.5x0.54=2.43), then enter the product of VR and extend a straight line up to Retardance class "D", next project a straight line to the left to determine a trial manning's *n*.

(continued)
Sample Problem 8.05a
Design of a
grass-lined channel.

Channel summary:
Trapezoidal shape, Z=3, b=3 ft, d=1.5 ft, grade = 2%

Note: In Sample Problem 8.05a the "n-value" is first choosen based on a permissible velocity and not a design velocity criteria. Therefore the use of table 8.05c may not be as accurate as individual retardance class charts when a design velocity is the determining factor.

Tractive Force Procedure

The design of riprap-lined channels and temporary channel linings is based on analysis of tractive force.

NOTE: This procedure is for uniform flow in channels and is *not* to be used for design of deenergizing devices and may not be valid for larger channels

To calculate the required size of an open channel, assume the design flow is uniform and does not vary with time. Since actual flow conditions change through the length of a channel, subdivide the channel into design reaches as appropriate.

PERMISSIBLE SHEAR STRESS

The permissible shear stress, T_d, is the force required to initiate movement of the lining material. Permissible shear stress for the liner is not related to the erodibility of the underlying soil. However, if the lining is eroded or broken, the bed material will be exposed to the erosive force of the flow.

COMPUTING NORMAL DEPTH

The first step in selecting an appropriate lining is to compute the design flow depth (the normal depth) and determine the shear stress.

Normal depths can be calculated by Manning's equation as shown for trapezoidal channels in Figure 8.05d. Values of the Manning's roughness coefficient for different ranges of depth are provided in Table 8.05e for temporary linings and Table 8.05f for riprap. The coefficient of roughness generally decreases with increasing flow depth.

Table 8.05e
Manning's Roughness Coefficients for Temporary Lining Materials

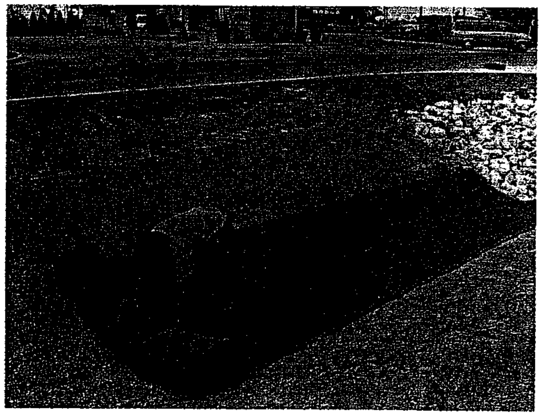
	n value for Depth Ranges*		
	0-0.5 ft	0.5-2.0 ft	>2.0 ft
Lining Type			
Woven Paper Net	0.016	0.015	0.015
Jute Net	0.028	0.022	0.019
Fiberglass Roving	0.028	0.021	0.019
Straw with Net	0.065	0.033✓	0.025
Curled Wood Mat	0.066	0.035	0.028
Synthetic Mat	0.036	0.025	0.021

* Adapted from: FHWA-HEC 15, Pg. 37 - April 1988

North American Green® Flexible Channel Liners

P300N/P300P

The P300 flexible channel liner is available with 100% recycled nylon fiber (P300N), or 100% UV stabilized polypropylene fiber matrix (P300P), sewn between an extra heavy duty UV stabilized top net and heavy UV stable bottom net. Both the P300N and P300P are non-degradable mattings designed to provide temporary protection of high-discharge channels and shorelines during vegetation establishment and permanent reinforcement of the vegetal stand after maturity.



P300N Specifications

Material Composition

Recycled Nylon

Fibers . . .	.8 lbs/sq yd (.43 kg/sq m)
Net	extra heavyweight UV stabilized top heavyweight UV stabilized bottom
Thread. . .	black polyester

P300N Roll Specifications

Width . . .	6.5 ft (2 m)
Length . .	83.5 ft (25.4 m)
Weight . .	48 lbs (21.8 kg) ±10%
Area	60 sq yd (50 sq m)

P300P Specifications

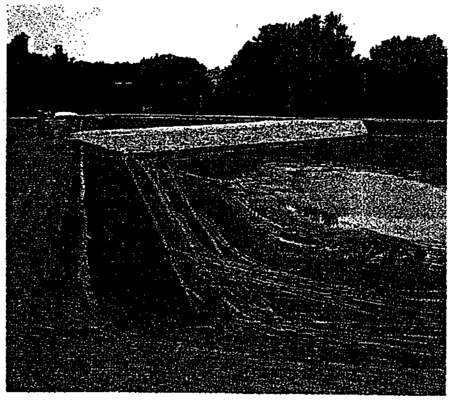
Material Composition

UV Stabilized 100% Polypropylene

Fibers . . .	.7 lbs/sq yd (.38 kg/sq m)
Net	extra heavyweight UV stabilized top heavyweight UV stabilized bottom
Thread. . .	black polyester

P300P Roll Specifications

Width . . .	6.5 ft (2 m)
Length . .	83.5 ft (25.4 m)
Weight . .	42 lbs (19.1 kg) ±10%
Area	60 sq yd (50 sq m)



North American Green® Straw Erosion Control Blankets

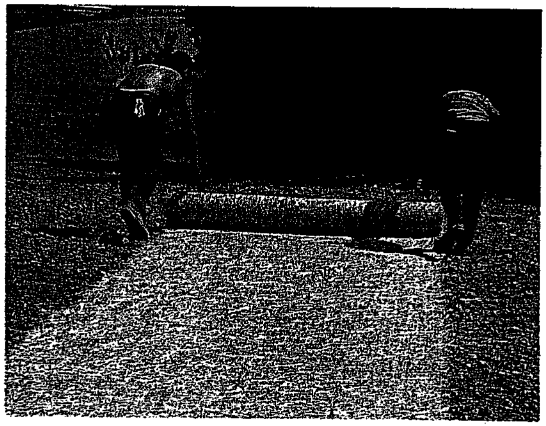
North American Green straw blankets were developed for moderate to steep slopes and low-flow swales where erosion protection is required for only a short period during vegetation establishment. The blankets combine lightweight photo-degradable netting with a uniform, high-quality straw matrix for excellent soil erosion control and seed bed mulching.

S75

The S75 blanket features a 100% straw matrix sewn into a lightweight, photo-degradable net. The S75 blanket offers effective erosion control on 4:1 - 3:1 slopes, and low-flow swales where conventional mulches fail.

DS75

The DS75 straw blanket is a quick-degrading version of the S75. An accelerated photo-degradable net assures blanket deterioration in 30 to 45 days. The DS75 is ideal for use in moderate landscape applications where close mowing will occur soon after grass establishment.



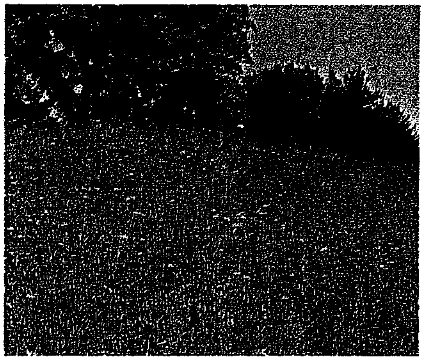
S75/DS75 Specifications

Material Composition

Straw	.5 lbs/sq yd (.27 kg/sq m)
Net	lightweight degradable top side only
Thread	cotton, bio-degradable

S75/DS75 Roll Specifications

Width	6.5 ft (2 m)
Length	83.5 ft (25.5 m)
Weight	30 lbs (13.6 kg)
Area	60 sq yd (51 sq m)



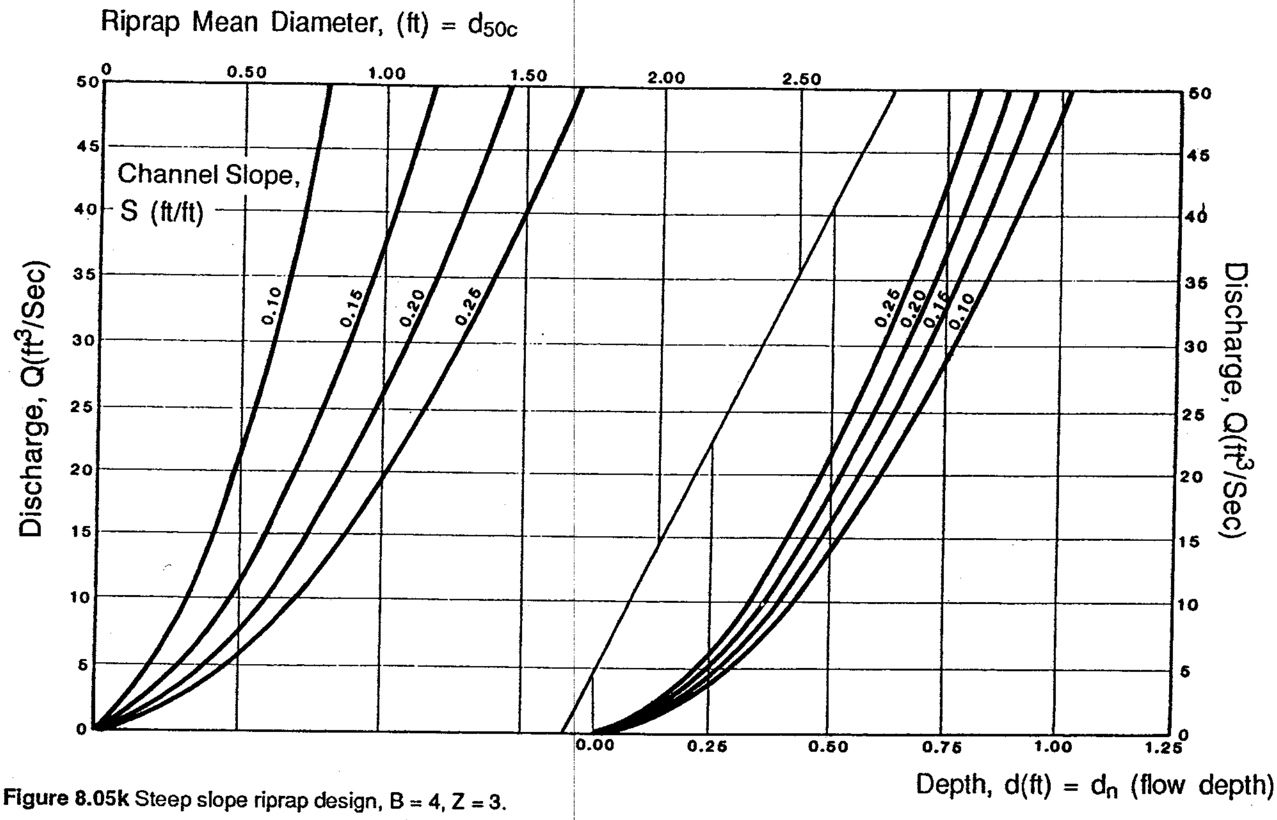


Figure 8.05k Steep slope riprap design, B = 4, Z = 3.

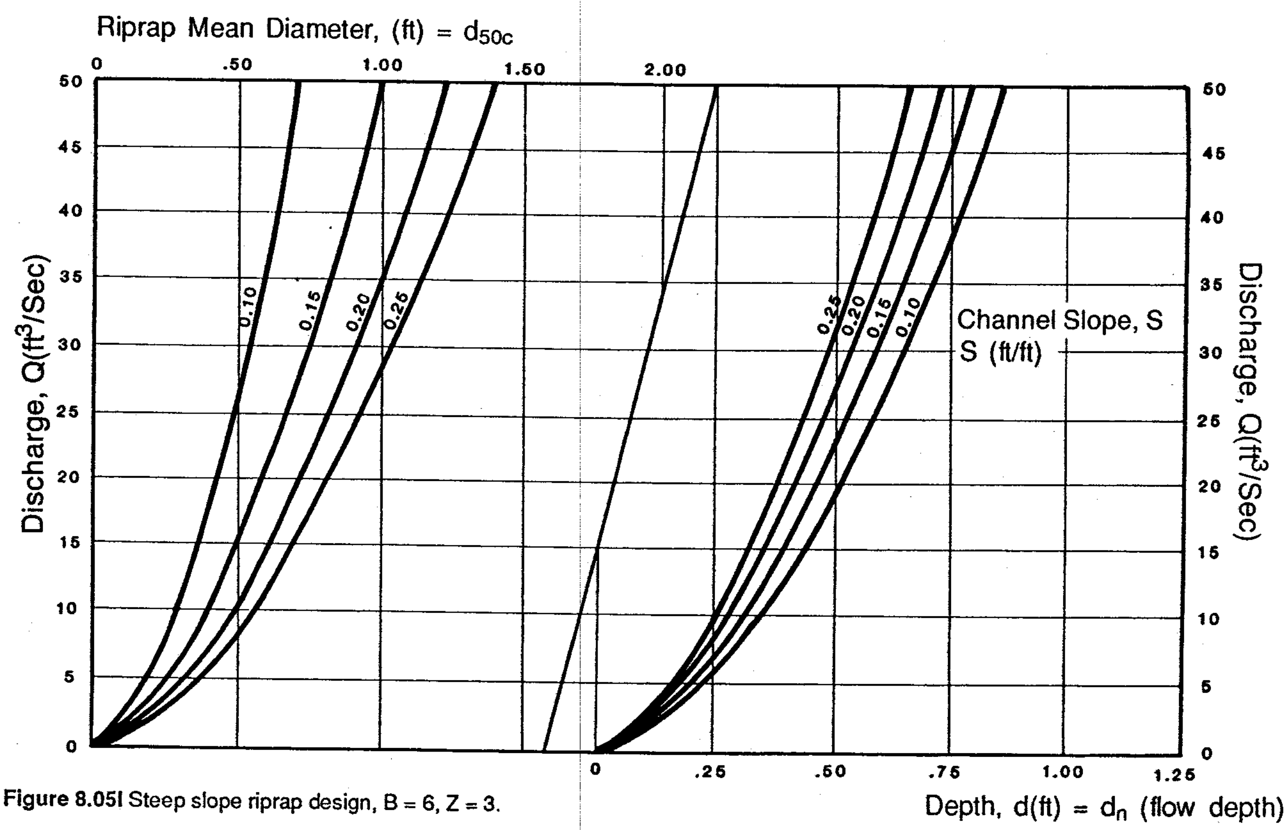


Figure 8.05l Steep slope riprap design, B = 6, Z = 3.

Table 8.05h
Values of A_3/A_z for Selected Side Slopes and Depth-to-Bottom Width Ratios[1]

	A_3/A_z				
d/b	2:1	3:1	4:1	5:1	6:1
0.10	1.083	1.000	0.928	0.866	0.812
0.20	1.142	1.000	0.888	0.800	0.727
0.30	1.187	1.000	0.853	0.760	0.678
0.40	1.222	1.000	0.846	0.733	0.647
0.50	1.250	1.000	0.833	0.714	0.625
0.60	1.272	1.000	0.823	0.700	0.608
0.70	1.291	1.000	0.815	0.688	0.596
0.80	1.307	1.000	0.809	0.680	0.586
0.90	1.321	1.000	0.804	0.672	0.578
1.00	1.333	1.000	0.800	0.666	0.571
1.10	1.343	1.000	0.796	0.661	0.565
1.20	1.352	1.000	0.793	0.657	0.561
1.30	1.361	1.000	0.790	0.653	0.556
1.40	1.368	1.000	0.787	0.650	0.553
1.50	1.378	1.000	0.785	0.647	0.550
1.60	1.381	1.000	0.783	0.644	0.547
1.70	1.386	1.000	0.782	0.642	0.544
1.80	1.391	1.000	0.780	0.640	0.542
1.90	1.395	1.000	0.779	0.638	0.540
2.00	1.400	1.000	0.777	0.636	0.538

[1] Based on the following equation:

$$A_3/A_Z = \frac{1 + 3(d/b)}{1 + Z(d/b)}$$

Adapted from: FHWA-HEC 15, pg. 59 - April 1988

b. Find the riprap size using the following equation:

$$d_{50} = \frac{d}{d_n} d_{50c}$$

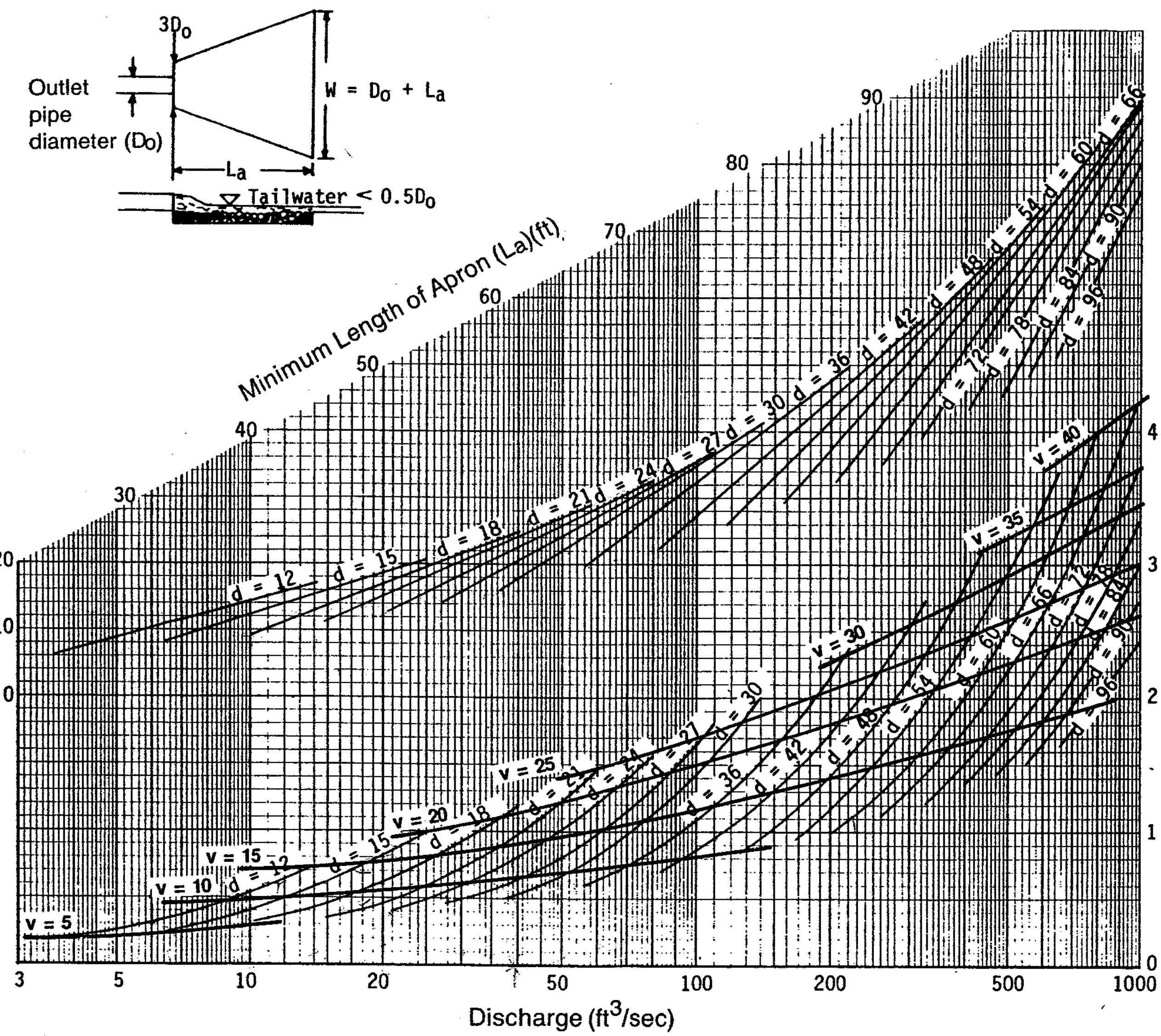
where d_n and d_{50c} are values from the design charts (Figures 8.05j, 8.05k, and 8.05l).

Sample Problem 8.05d demonstrates the tractive force procedure for design of riprap channels on steep grade.

Stability Evaluation for Natural Channels

Determining flow capacity and velocity in a natural channel involves detailed analysis and evaluation. Variations in channel cross section, alignment, grade and roughness, and often changing conditions of in-bank and out-of-bank flow make accurate determination of channel capacity and velocity difficult.

The following procedure uses Manning's equation and the continuity equation to estimate stream channel capacity and velocity. Flow constrictions caused by culverts or bridges must be evaluated separately.



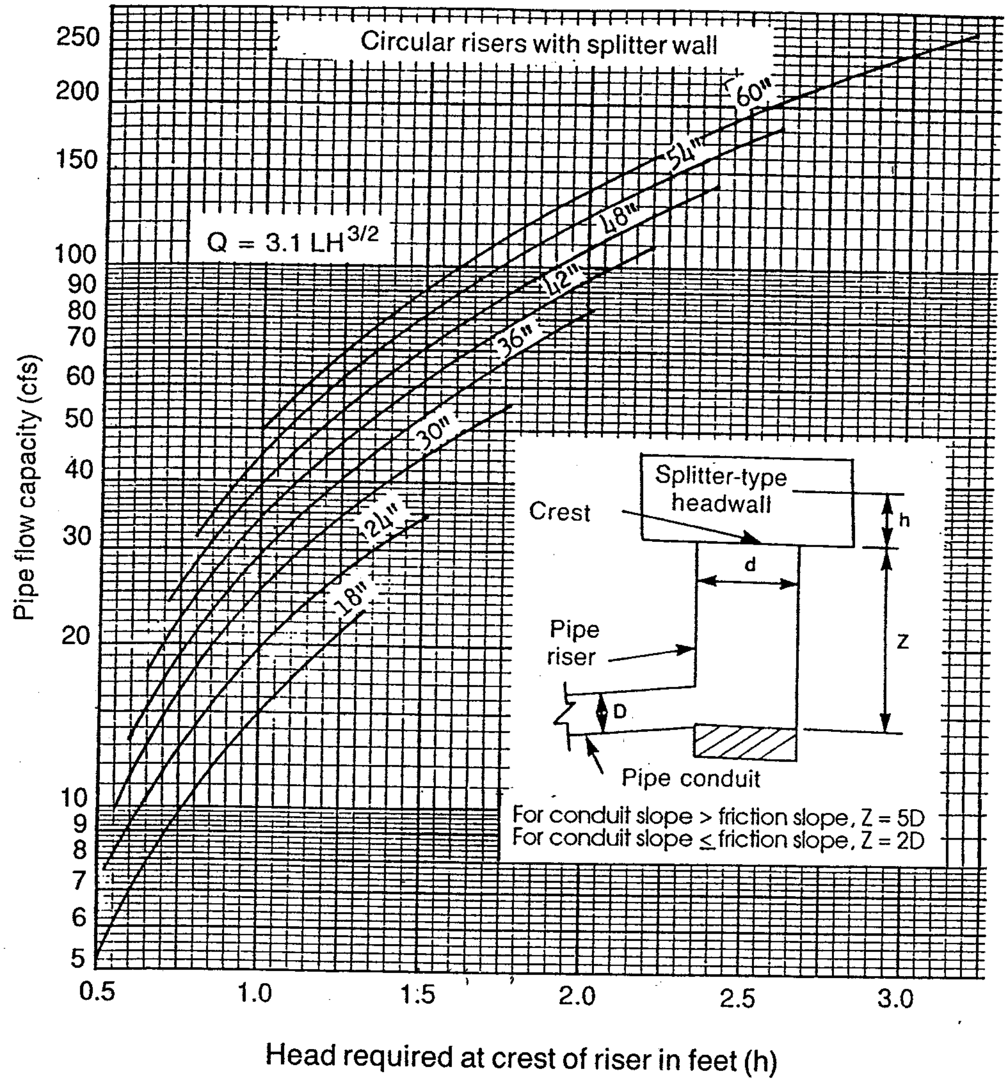
Curves may not be extrapolated.

Figure 8.06a Design of outlet protection protection from a round pipe flowing full, minimum tailwater condition (T_w < 0.5 diameter).

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.

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



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.

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CALCULATION COVER SHEET

J.O./W.O. No:	101540
CLIENT:	Duke Energy
PROJECT:	Marshall Steam Station
LOCATION:	Catawba County, North Carolina

TITLE: Gypsum Landfill Stability	EQUIP/DWG. No: NA	CALCULATION No: MC-6451.00-00-0001 ERN No: FHS00056

OBJECTIVE:
Evaluate the slope stability of landfilled flue gas desulfurization (FGD) gypsum.

NORTH CAROLINA PROFESSIONAL SEAL 029316 ENGINEER DARRELL C. JORDAN

3/29/04

INPUTS:
Inputs are identified for the landfill geometry, gypsum properties, soil properties, groundwater, and seismic parameters. Those inputs are identified in Sections 4.2 through 4.6 – Method of the calculation.

ASSUMPTIONS:
Specific assumptions made relative to the stability analysis are identified in Section 4 – Method of the calculation.

ASSUMPTIONS REQUIRING CONFIRMATION:
None

BASIS OF CALCULATION, METHOD, OR SOFTWARE TO BE USED:
The stability of the landfill slope was evaluated using Slope/W software licensed from Geo-Slope International.

CONCLUSION:
The stability analyses of the completed landfill slopes was performed using the planned landfill geometry and conservative properties for the gypsum (by-product) placed in the landfill. The analyses indicate there should be low risk of landfill slope instability.

DATA CONFIRMATION REQUIRED Y ☐ N ☐

REVISION	0	1	2	3	4	5	6
PREPARER/ DATE	Gary Parks 3/3/04	[signature] 3/25/04					
CHECKER/ DATE	William Zakely 3/3/04	[signature] 3/29/04					

TABLE OF CONTENTS

1.0 OBJECTIVE

Evaluate the slope stability of landfill slopes being planned for disposal of the Marshall Station flue gas desulfurization (FGD) by-product (gypsum).

2.0 BACKGROUND

At least part of the solid by-product from the FGD facilities being constructed at Marshall Station will be disposed of in a landfill to be constructed at the Marshall Station site. The landfill will be constructed in two cells (Alstom Shaw Stone & Webster, 2004a, 2004b). Cell 1 will be for disposal of the material during initial operation of the FGD facilities. Cell 2 will be used in the future if on-going disposal of the material is required. If the landfill in enlarged to include Cell 2, the Cell 2 landfill will be placed against and on the previously landfilled Cell 1 material to create a single, continuous landfill.

The completed landfill surface will be sloped to provide surface water runoff, and will be covered with a geomembrane-soil cover system to reduce infiltration of water into the landfilled material and for reclamation of the landfill surface. The design, including stability analysis of the landfill cover system, is being prepared by others (Chas. H. Sells, 2004).

3.0 ASSUMPTIONS

Specific assumptions made relative to the stability analysis are identified in Section 4 – Method of this calculation.

4.0 METHOD

4.1 General

The slope stability analysis has been made using the Simplied Bishop method and the computer program Slope/W (Geo-Slope, 1998). The analysis includes both static (non-earthquake) and dynamic (earthquake) conditions. Specific parameters and assumptions used to complete the analysis are discussed in this section of the calculation.

4.2 Landfill Geometry

The landfill is to be constructed at the northwest part of the Marshall Station site. Grading plans for the landfill (Alstom Shaw Stone & Webster, 2004a, 2004b), showing both the Cell 1 configuration and the potential configuration of the potential Cell 2 expansion, indicate the ground surface beneath the landfill will be excavated up to approximately 25 feet below the current ground surface. The top elevation of the completed landfill will be approximately 926 feet. The maximum total thickness of either Cell 1 or Cell 2 will be approximately 84 feet and the overall slopes of either Cell 1 or Cell 2 will be approximately 6:1 (horizontal:vertical). Short lengths of the completed slopes of the Cell 2 landfill will be as steep as approximately 4:1 (horizontal:vertical).

The typical section assumed for the stability analysis, shown as Figure 1, is based on the planned slopes of the east of west faces of the completed Cell 2 landfill (Alstom Shaw Stone & Webster, 2004a, 2004b). The section incorporates the following:

- An overall slope of 6:1 (horizontal:vertical) with some intermediate slopes of 4:1 (horizontal:vertical)
- A maximum thickness of approximately 84 feet

The Cell 2 landfill slope was selected for analysis as it will be the highest slope of either the Cell 1 or Cell 2 landfill and represents the steepest slope of either the Cell 1 or Cell 2 landfill. Therefore, its stability should be representative of either the Cell 1 or Cell 2 landfills.

4.3 By-Product (Gypsum) Properties

Limestone (calcium carbonate) feed into the planned FGD facilities will react with the plant exhaust gas to create gypsum (calcium sulfate) as a by-product. The results of laboratory tests (S&ME, 2004) on a sample of by-product from similar power plant that uses the FGD process are as follows:

Gradation 100 percent sizes smaller than the No. 200 sieve size

Atterberg Limits Liquid Limit = 27
Plasticity Index = 1

As-Sampled Moisture Content 11.8 %

Compaction (ASTM D 698) Maximum Dry Density = 88.5 pcf
Optimum Moisture Content = 19.5 %

Effective Strength Parameters (at 90 % ASTM D 698 Maximum Density and 12 % moisture content)

Cohesion 0 psf
Angle of Internal Friction (ϕ) 39.3°

The gradation and Atterberg Limit test results indicate the gypsum by-product would be a silt with Unified Soil Classification System (ASTM D 2487) Group Symbol of ML.

The laboratory test results are within the following range of values reported in the literature:

Gradation	Some sand sizes (larger than the No. 200 sieve) but predominately silt size particles (smaller than the No. 200 sieve)
Compaction (ASTM D 698)	Maximum Dry Density = 76 to 97 pcf Optimum Moisture Content = 13 to 32 %
Effective Strength Parameters	Cohesion 0 to 720 psf Angle of Internal Friction (ϕ) 31 to 39°

Based on the results of the laboratory tests and the reported values from the literature, the probable method of placement of the gypsum in the landfill, typical soil parameters for silt soils, and the requirements of the FGD by-product material to be produced, the following parameters have been assumed for the gypsum by-product for stability analysis:

Soil Type	Silt (ML)
In-Place Dry Density	80 pcf
In-Place Moisture Content	10 %
In-Place Moist Unit Weight (dry density x 1+moisture content)	88 pcf
Strength Parameters	Cohesion 0 psf Angle of Internal Friction (ϕ) 30°

The gypsum will likely be placed in the landfill by dozing the material into relatively thin loose lifts (of the order of 12 inches) and compacting the lifts using the spreading equipment and by routing trucks delivering additional gypsum to the landfill across the surface of the lifts. Additional moisture in excess of the "as-delivered" moisture contained in the gypsum will not be added to the gypsum during placement. Contract requirements (Duke Power Company, 2003) indicate gypsum with a maximum residual moisture content of 10 percent is to be produced from the FGD facilities. Any "off-spec" gypsum with a moisture content in excess of 10 percent will be also be placed in the landfill. However, it is unlikely that the moisture content of the "off-spec" material will be significantly larger than 10 percent as that would indicate the FGD facilities are not operating correctly, and adjustments would be made to correct their operation. Wetting of the gypsum as it is hauled to and stockpiled at the landfill prior to placement by precipitation should also not significantly increase the moisture content of the gypsum. Most precipitation moisture will runoff the fine grained, low permeability gypsum by-product, and any wetting should only be of materials exposed at the surface of the material in haul trucks or stockpiles. Those "wetted" materials will be mixed with the much larger volume of dryer gypsum underlying the wetted surfaces during placement, resulting in an overall moisture placement content near 10 percent. The intermediate (working) and final surfaces of the landfilled materials will be sloped to facilitate precipitation runoff, so the chance of additional moistening of the landfilled gypsum after placement should be low.

The in-place density and strength parameters assumed for the analysis are typical of the lower range of values indicated for "loose" silts and other similar non-cohesive granular soils (Figure 7, page 7.1-149, NAVFAC, 1982; Table 3-4, page 163, Bowles, 1996). Dry densities larger than 80 pcf may be achieved even if the gypsum is placed as described in the preceding paragraph, and will be achieved for at least the lower parts of the landfilled material as the landfill consolidates under the weight of subsequently placed material. Any dry densities larger than 80 pcf should result in larger strength parameters. Therefore, the assumed parameters should be conservative for use in the analysis.

4.4 Soil Properties

Several borings have been drilled at the Marshall Station site, including some at the proposed landfill site (S&ME, 2003a, 2003b). Soils found in those borings are residual soils and partially weathered bedrock of the Piedmont Geologic Province. The residual soils are reported to range from medum dense to dense sands and clayey silts to stiff silty clays. The weathered bedrock is reported to consist of dense sands or sandy silts. The following soil parameters, typical of medium dense sands and silts (Table 3-4, page 163, Bowles, 1996) and of laboratory strength test results on samples of the site sands (S&ME, 2003a) have been assumed for the analysis:

Moist Unit Weight	120 pcf
Strength Parameters	Cohesion 0 psf Angle of Internal Friction (ϕ) 32°

4.5 Groundwater

The bottom elevation of the landfill (Alstom Shaw Stone & Webster, 2004a, 2004b) has been selected to be a minimum of 4 feet above the seasonal high groundwater surface (Chas. H. Sells, 2004). A groundwater surface 4 feet below the bottom of the landfill, as shown in Figure 1, has been assumed for the analysis.

4.6 Seismic Parameters

The United States Geological Survey (USGS) indicates an earthquake at the Marshall Station site that has a probability of exceedence of 2 percent in 50 years should have a maximum horizontal ground acceleration of approximately 0.15g (S&ME, 2004). That value has been used for dynamic slope analysis. A vertical ground acceleration of 0.10g, which is two thirds of the horizontal acceleration, acting in an upward direction and simultaneously with the horizontal acceleration, has also been used.

4.7 Stability Analyses

The stability analyses were performed using the landfill, gypsum, soil and groundwater parameters discussed in Sections 4.2 through 4.6, which are summarized in Figure 1. A grid of potential centers of stability analysis slip circles was selected that should produce failure surfaces along the slope of the landfill model. That grid is also as shown in Figure 1. Three (3) lines labeled "Bottom of Slip Circles" in Figure 1 were also input into the model to control the depth of the potential failure surfaces. The positions of those lines were selected so that the analysis would be of potential failure surfaces that penetrated a minimum of 10 to 15 feet into the gypsum material. That was done to avoid potential failure surfaces that bottomed very close to the landfill surface. Erroneously low factors of safety against failure are predicted by the simplified Bishop Method when the strength of the near surface soils is represented only by an angle of internal friction (ϕ). The overall strength (resistance to sliding) calculated by the Bishop Method is a function of the moist density, depth below the surface and tangent of the friction angle. Therefore, failure surfaces near the surface which have a minimum depth and possibly a factor of safety less than one are predicted by the model, even though the overall factor of safety of the slope is greater than one.

The model was operated for the static (non-seismic) and dynamic (seismic) conditions shown in Figure 1. The angle of internal friction (ϕ) of the gypsum was also reduced to 25^{o} to parametrically evaluate that extremely low value on the model results.

5.0 RESULTS

Results of the analyses are shown on Figures 2 through 5. The failure surfaces along only a portion of the landfill slope and along most of the landfill slope that resulted in minimum factors of safety from the static analyses are shown in Figures 2 and 3, respectively. The failure surfaces for the same conditions with the seismic parameters included are shown in Figures 4 and 5.

Results of the parametric analyses using an angle of internal friction of 25^{o} for the gypsum are shown on Figures 6 through 9. The failure surfaces along only a portion of the landfill slope and along most of the landfill slope that resulted in minimum factors of safety from the static analyses are shown in Figures 6 and 7, respectively. The failure surfaces for the same conditions with the seismic parameters included are shown in Figures 8 and 9.

Each of the factors of safety predicted by the model and shown in Figures 2 through 9 are the minimum of approximately 390 failure surfaces. Those minimum factors of safety, summarized in the following table, are greater than 2.8 for the static analyses, and are greater than 1.5 for the seismic analyses. They are also based on conservative assumptions of the strength of the gypsum material placed in the landfill. That is particularly the case for the parametric analyses that were made using an angle of internal friction of 25° for the gypsum. The analyses indicate there should be low risk of overall failure of the completed landfill slopes.

Summary of Gypsum Landfill Stability Analysis

Analysis	Gypsum Angle of Internal Friction (ϕ)	Minimum Factory of Safety	Figure Number Reference
Static	30°	3.8	2
Static	30°	3.8	3
Seismic	30°	1.9	4
Seismic	30°	1.5	5
Static	25°	2.8	6
Static	25°	2.8	7
Seismic	25°	1.5	8
Seismic	25°	1.5	9

6.0 CONCLUSIONS

1. The stability analyses of the completed landfill slopes was performed using the planned landfill geometry and conservative properties for the gypsum (by-product) placed in the landfill.
2. The analyses indicate there should be low risk of landfill slope instability.

7.0 REFERENCES

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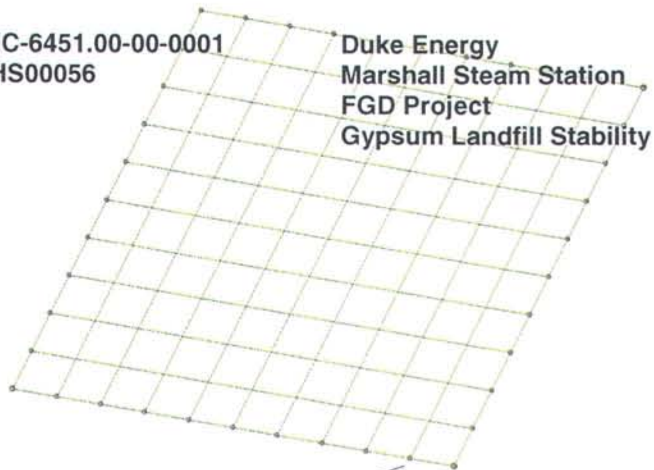
S&ME, "FGD Scrubber Sludge Testing (Revision 1), Duke Power, Coal Fired Steam Stations in North Carolina," S&ME Project 1264-03-057, February 2004.

Calc. No. MC-6451.00-00-0001
ERN No. FHS00056
Rev. 1

Duke Energy
Marshall Steam Station
FGD Project
Gypsum Landfill Stability

Figure 1. Landfill Model



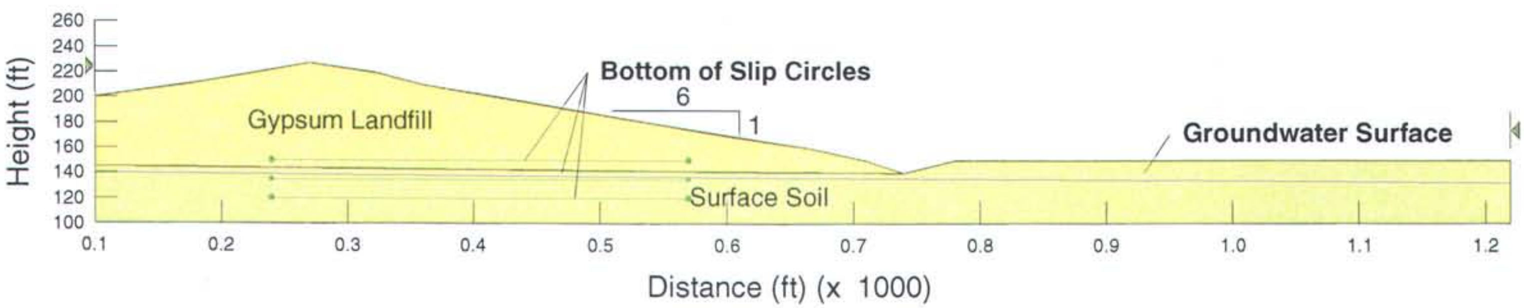
Soil Properties

Gypsum
friction angle (phi) = 30
moist density (gamma) = 88 lb/ft3
cohesion = 0

Surface Soil
friction angle (phi) = 32
moist density (gamma) = 120 lb/ft3
cohesion = 0

Seismic Properties

Horizontal Acceleration = 0.15g
Vertical Acceleration = 0.10g



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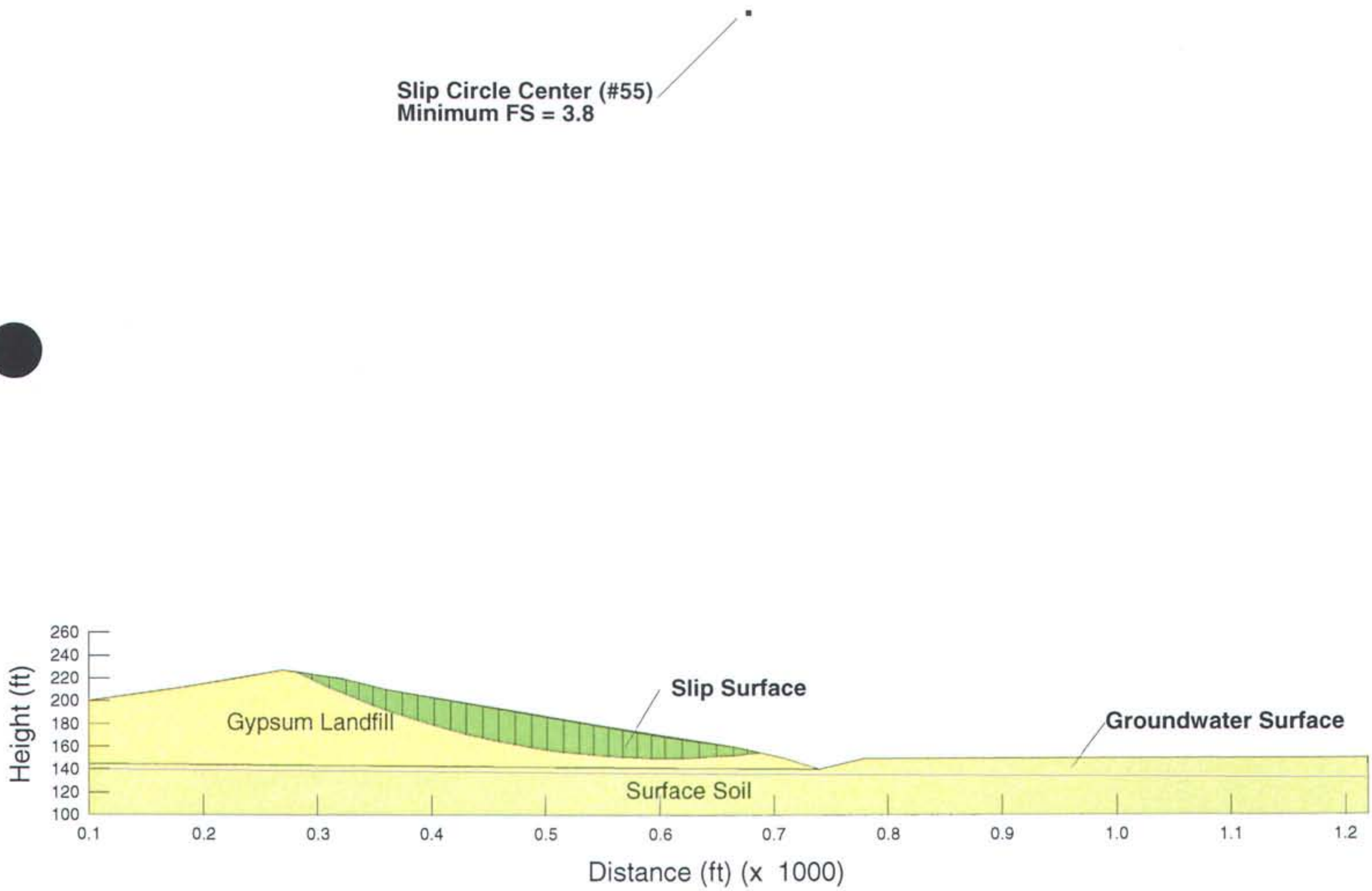
FGD Project
Gypsum Landfill Stability

Figure 2. Typical Failure Surface 1
Static Conditions



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ERN No. FHS00056
Rev. 1

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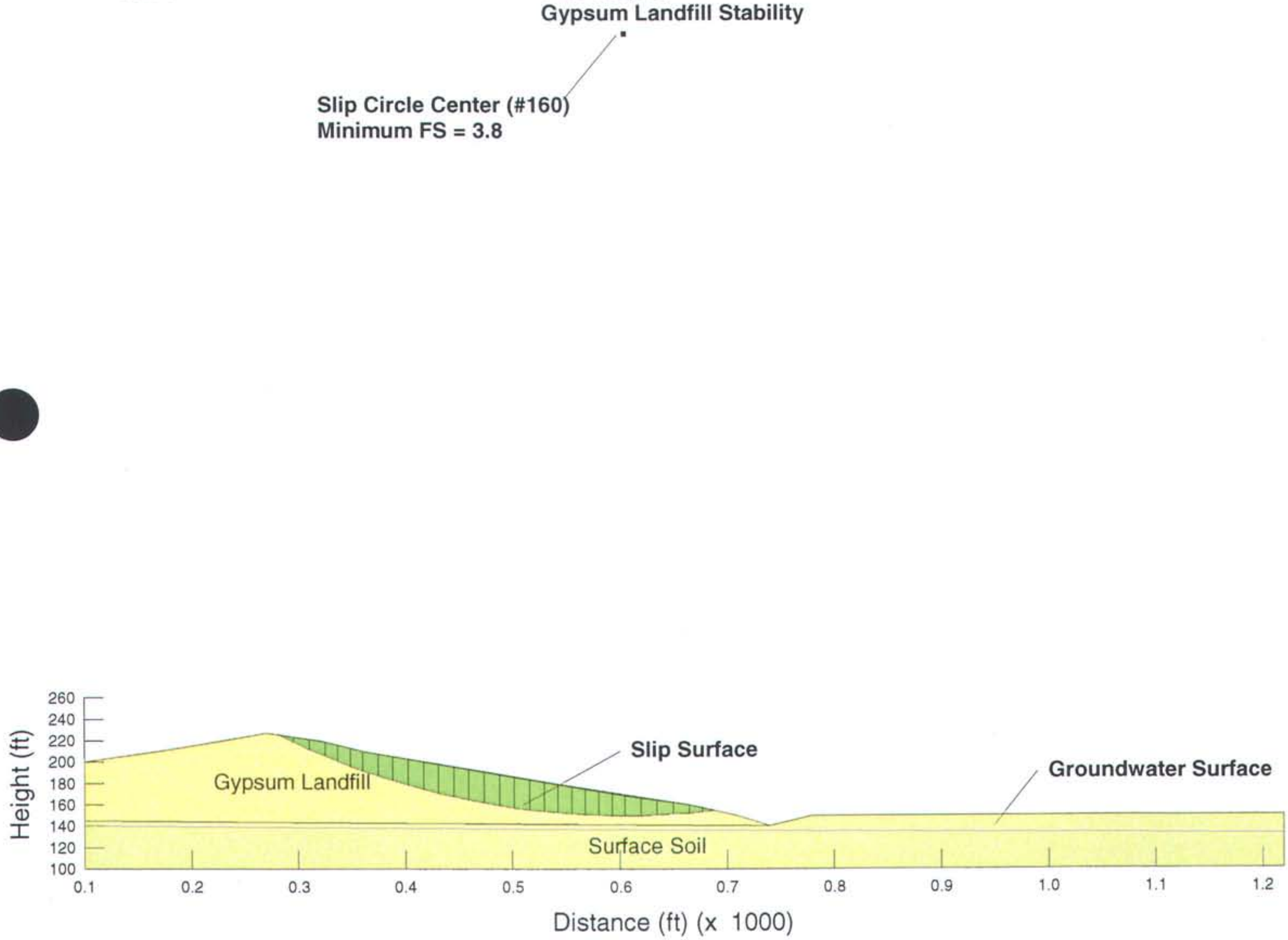
Marshall Steam Station
FGD Project
Gypsum Landfill Stability

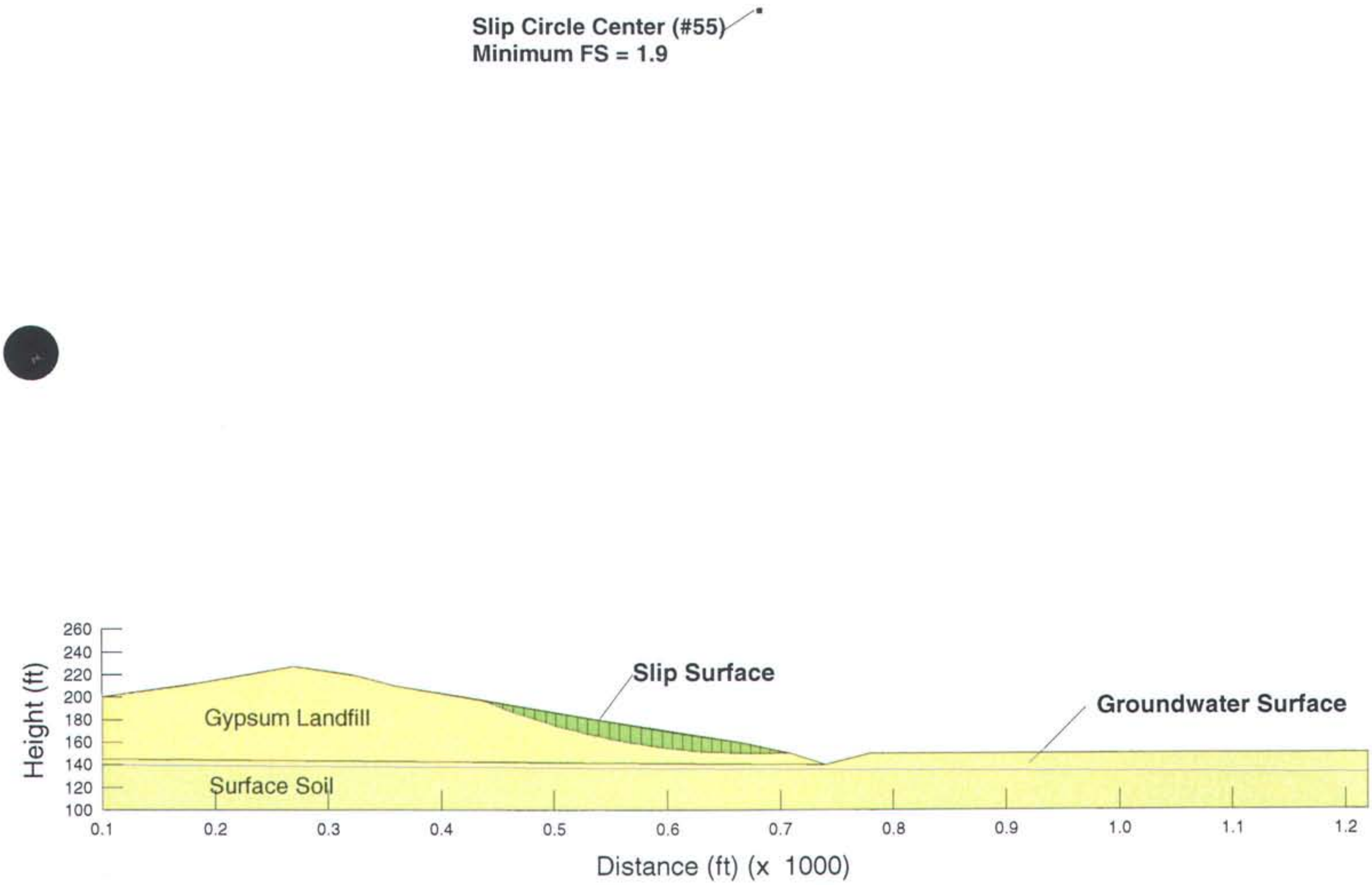
Figure 3. Typical Failure Surface 2
Static Conditions



Calc. No. MC-6451.00-00-0001
ERN No. FHS00056
Rev. 1

Duke Energy
Marshall Steam Station
FGD Project
Gypsum Landfill Stability

Figure 4. Typical Failure Surface 1
Seismic Loading Conditions



Calc. No. MC-6451.00-00-0001
ERN No. FHS00056
Rev. 1

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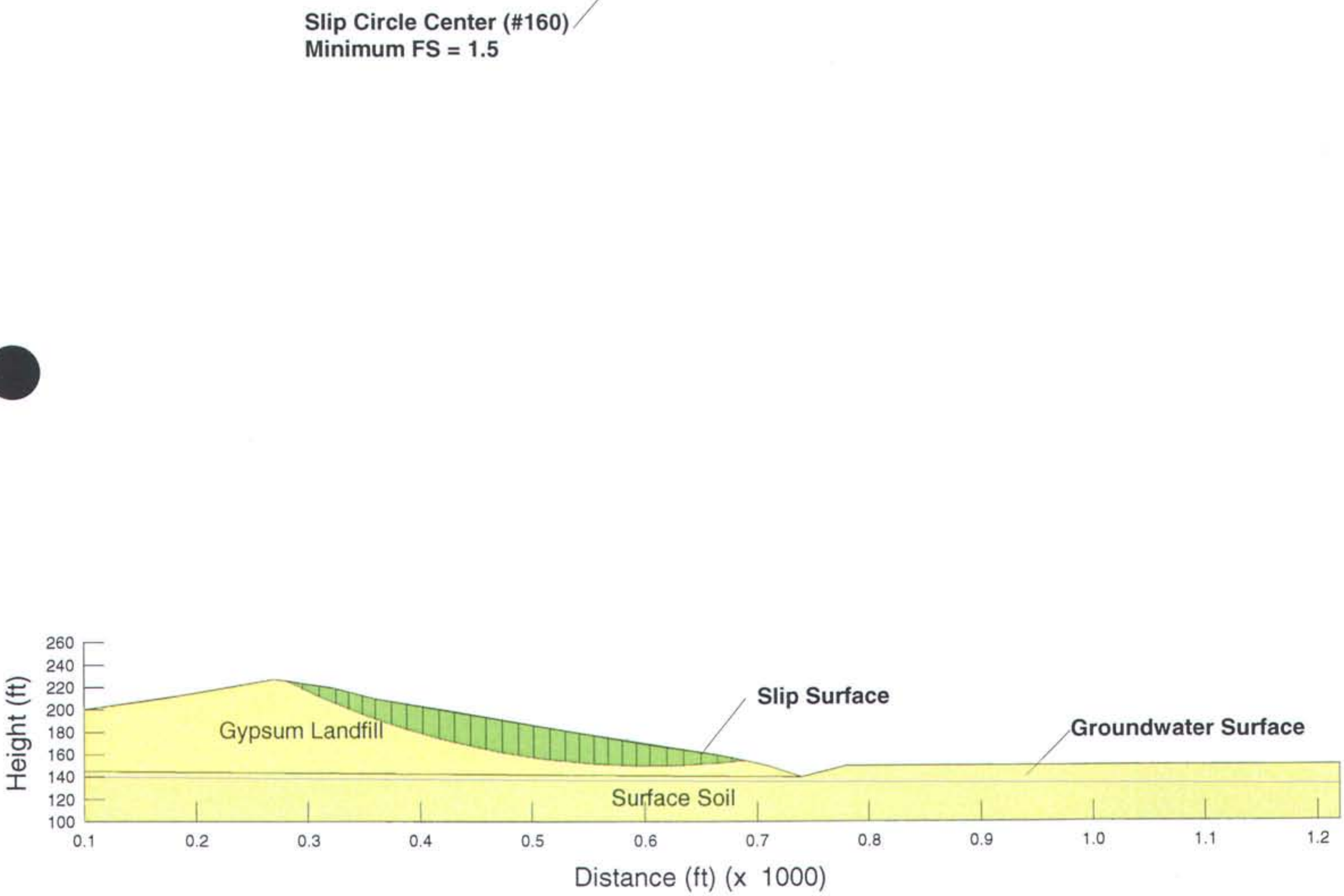
Marshall Steam Station
FGD Project
Gypsum Landfill Stability

Figure 5. Typical Failure Surface 2
Seismic Loading Conditions



Calc. No. MC-6451.00-00-0001
ERN No. FHS00056
Rev.1

Duke Energy
Marshall Steam Station
FGD Project
Gypsum Landfill Stability

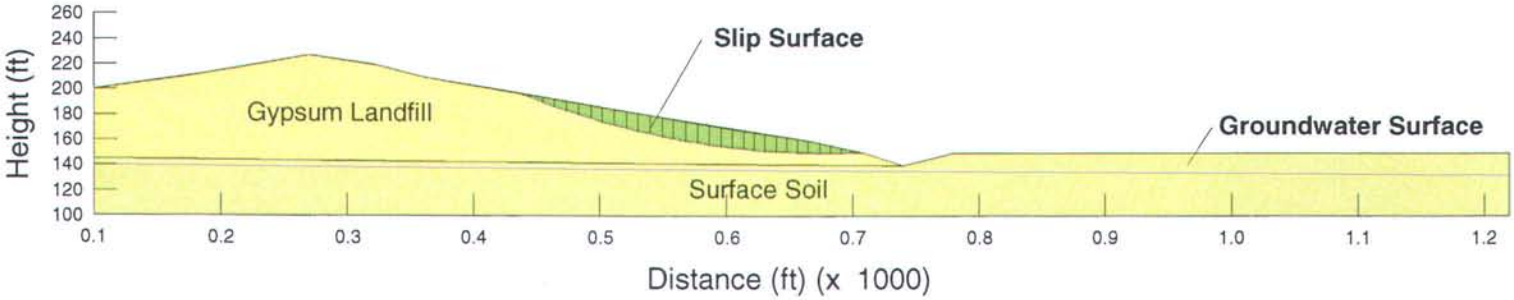
Figure 6. Typical Failure Surface 1
Parametric Analysis
Static Conditions

Slip Circle Center (#55)
Minimum FS = 2.8

Soil Properties

Gypsum
friction angle (phi) = 25
moist density (gamma) = 80 lb/ft3
cohesion = 0

Surface Soil
friction angle (phi) = 32
moist density (gamma) = 120 lb/ft3
cohesion = 0



Calc. No. MC-6451.00-00-0001
ERN No. FHS00056
Rev. 1

Duke Energy
Marshall Steam Station
FGD Project
Gypsum Landfill Stability

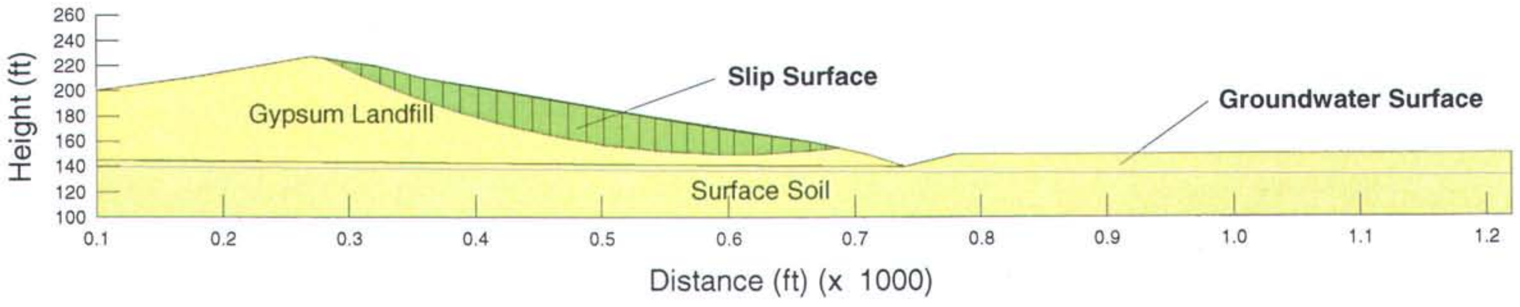
Figure 7. Typical Failure Surface 2
Parametric Analysis
Static Conditions

Slip Circle Center (#160)
Minimum FS = 2.8

Soil Properties

Gypsum
friction angle (phi) = 25
moist density (gamma) = 80 lb/ft3
cohesion = 0

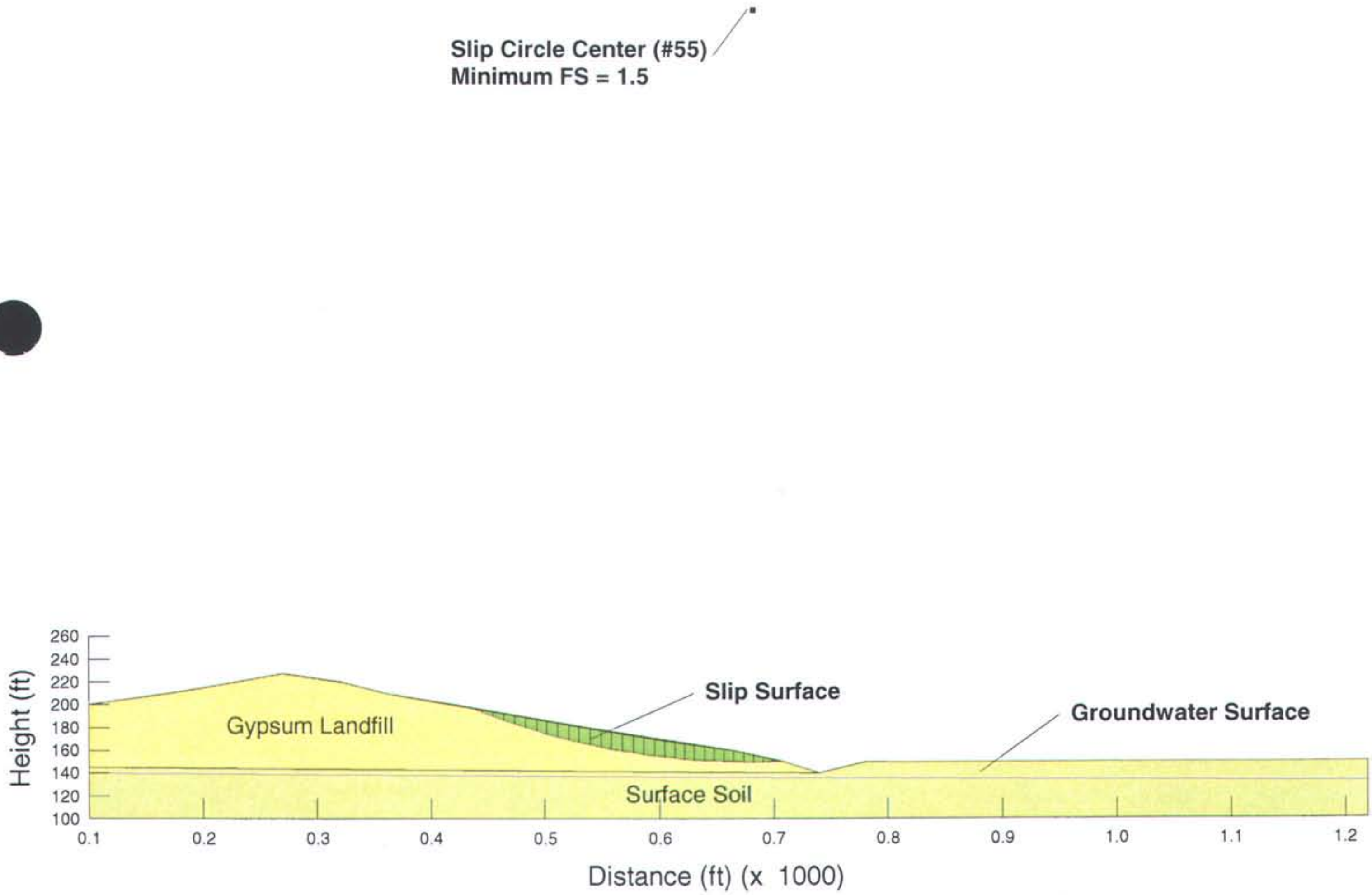
Surface Soil
friction angle (phi) = 32
moist density (gamma) = 120 lb/ft3
cohesion = 0



Calc. No. MC-6451.00-00-0001
ERN No. FHS00056
Rev. 1

Duke Energy
Marshall Steam Station
FGD Project
Gypsum Landfill Stability

Figure 8. Typical Failure Surface 1
Parametric Analysis
Seismic Loading

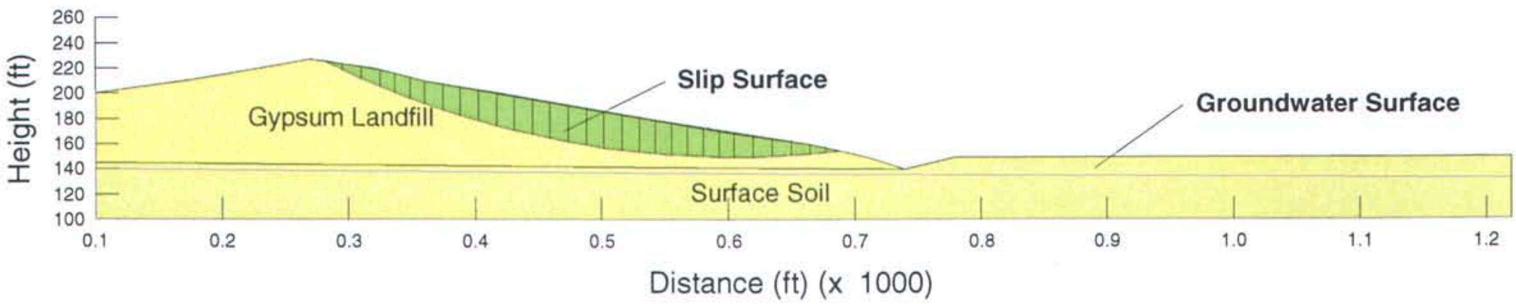


Calc. No. MC-6451.00-00-0001
ERN No. FHS00056
Rev. 1

Duke Energy
Marshall Steam Station
FGD Project
Gypsum Landfill Stability

Figure 9. Typical Failure Surface 2
Parametric Analysis
Seismic Loading

Slip Circle Center (#160)
Minimum FS = 1.5



18-09

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PROCUREMENT, CONSTRUCTION AND EH&S

Duke Power
EC11E / P.O. Box 1006
Charlotte, NC 28201-1006

Carmen Johnson
Fac/Perm/Co ID # 18-09 | Date 1/25/12 | Doc ID# | DIN

November 17, 2004

North Carolina Department of Environment
and Natural Resources
Division of Waste Management
Solid Waste Section
Mooresville Regional Office
610 East Center Avenue, Suite 301
Mooresville, NC 28115

RECEIVED
NOV 1 9 2004
NC DEPT OF ENVIRONMENT
AND NATURAL RESOURCES
MOORESVILLE REGIONAL OFFICE

ATTENTION: Mr. John Murray
Hydrogeologist
Solid Waste Permitting Branch

SUBJECT: Marshall Steam Station
FGD Industrial Landfill
Construction Plan Application

After review of your September 20, 2004 letter, we have hopefully included a response to the concerns you have cited. These concerns are cross referenced with the number sequence used in your letter. For each concern expressed, a Duke Power response is given below.

Need title sheet with location, legend, project name, owner, etc.

A title sheet has been prepared for the Construction Plan Application drawings.

Need info on ash ponds; permits etc.

Information on the ash ponds, permits, etc. is attached for reference.

Need a truck crossing at PD-7 to Excess Soil Area.

A construction entrance has been added to the drawings to access the excess soil stockpile.

Where are the scales? Need traffic pattern.

There are no scales for this project. The traffic pattern is shown on the drawings. In summary, the gypsum is conveyed from the plant to the gypsum stockpile. The gypsum is then hauled from the stockpile to the landfill along the perimeter haul road.

Are all trucks entering from SR150?

All trucks hauling gypsum from the stockpile to the landfill remain on the plant property. There will be no hauling off-site.

Explain TD-1's use and timing.

TD-1 is a temporary diversion channel to be constructed prior to construction of the western berm for Cell 1. This channel will be removed once the berm is constructed. Additional notes for TD-1 have been added to the construction sequence on the erosion and sediment control plan for Cell 1.

Note: Sed trap is within 50 feet of the wetland buffer.

The sediment trap ST-2 is within 50 feet of the wetland area. This sediment trap is provided to keep siltation out of the wetland area. The sediment trap location has been approved by NCDENR Land Quality Section. The wetland area is currently being permitted to fill prior to construction of Cell 2.

An operational dirt berm running east to west at station 12+00 w/ 2 openings at the low areas will reduce material into sed pond.

An operational berm is not needed at the down-gradient end of Cell 1. The proposed subgrades are designed to divert stormwater to the east and west ends of the Cell.

Six inches of gravel by itself does not seem to provide enough stability for heavy equipment and trucks. Please give calculations.

The proposed haul road will be constructed with 6-inches of compacted stone. A nomograph showing that this thickness is suitable for the haul road is attached for reference. The haul road will be maintained for all-weather access. Additional stone may be required as part of the plant's existing roadway maintenance operations.

Draining TD-3 into cell 2 is not acceptable if cell 2 is being landfilled. Also, during construction of cell 2 this will cause constructibility issue's. Drain TD-3 into flume or reverse grade to PD-12 by moving it up the slope.

The TD-3 drainage pattern has been reconfigured to drain into a riprap-lined channel into the Cell 1 Sediment Basin.

At the southeast corner of the wetlands there looks to be a pipe or ditch added to connect to the old culvert. What is this and what function does it serve? Water from this pipe does not go through a sed trap or pond.

The down-gradient end of the wetlands currently has a shallow channel from the end of the wetlands to the existing culvert. This channel has been labeled on the drawings.

The two pipes (one from sed basin at south end of cell one and the one draining cell 2 (SE corner) need to be removed.

The culverts draining the cells into the sediment basins shown on the drawings are temporary. These culverts are to be removed as noted on the drawings.

Note on section 1-1 that the pond needs to be excavated to stable conditions and backfilled and compacted with clayey soils. Some of this pond looks to be within the 4' groundwater buffer.

The Cell 1 Sediment Basin will be cleaned out and backfilled with clayey soil. This note has been added to the construction sequence on the Cell 1 Erosion and Sediment Control Plan. The bottom grades for sediment basin have been raised one foot along the western end of the basin to provide a minimum five foot separation from estimated seasonal high groundwater level.

Condensate can not be discharged as surface water. Gas will also be exiting from this pipe. Have you applied for an air permit for the passive system? Do you have data on the quantity and quality of this gas.

There is no gas generated from this type of gypsum. The passive gas system is only used as an air pressure relief for the geomembrane cap. The condensate drains are a precaution to reduce the possibility of water building up beneath the geomembrane. An air permit is not required for this system.

Miscellaneous.
Need gate shown on N. end of Steam Plant Rd.

As shown on the revised drawings, a lockable gate has been added to the north end of the landfill haul road.

Waste at final grade needs to be receive final cover within 180 days.

Waste at final grade needs to receive final cover within 180 days. This note has been added to the construction sequence of the Final Closure Erosion and Sediment Control Plan.

Intermediate cover is 12".

The intermediate cover is designed to be compacted at 8 inches thick.

Why was daily or weekly cover not mentioned.

The gypsum waste does not require daily or weekly cover. Once the surface of the gypsum accumulates moisture, a crust layer is created. The intermediate cover is designed for each 10 foot thick lift to reduce the erosion potential on inactive areas within the landfill cell.

The hours of operation is stated to be 7 days per week. Does this mean 24 hours per day or less.

The gypsum disposal operations will be conducted up to 24 hours per day, 7 days per week.

Section 1.5 of the operations plans discusses a conveyor system to dump waste near the landfill. This concept needs to be designed to make sure it meets our rules and regulations.

The FGD project has an extensive conveyor system design. The conveyor transports limestone from the railcar unloading area to the plant. A return conveyor system is designed to bring the gypsum byproduct from the plant to a stockpile near the landfill. The gypsum will be trucked from the stockpile to the landfill.

Permit Application's Attachment 1 by SM&E suggests three items to follow up on (testing with on site materials for stability, swelling. And liquefaction). Has this been done?

Samples of the gypsum have been obtained from the pilot study as well as from other plants of similar operations. Laboratory testing of the gypsum have been performed by S&ME to address compaction, moisture content, and triaxial shear testing.

Please contact me at (704) 382-4309 if additional information is needed to ensure that a Permit to Construct is issued by December 15, 2004.

Sincerely,

Allen Stowe

Allen Stowe, Scientist
Environmental Support

Attachments

cc: Ms. Ellen Lorscheider
Solid Waste Section
Raleigh Central Office

Division of Waste Management
Solid Waste Section
Morresville Office

To:Dan E. Brewer, P.E.
Chas. H. Sells, Inc.

As we discussed yesterday I am sending to you for your use a list of comments and questions on Duke's Marshall gypsum landfill.

Pg. 01.00

Need title sheet with location, legend, project name, owner, etc.
Need info on ash ponds; permits etc.
Need a truck crossing at PD-7 to Excess Soil Area.
Where are the scales? Need traffic pattern.
Are all trucks entering from SR150?
Pg. 02.00
Explain TD-1's use and timing.
Note: Sed trap is within 50 feet of the wetland buffer.
Pg. 03.00
An operational dirt berm running east to west at station 12+00 w/ 2 openings at the low areas will reduce material into sed pond.
Six inches of gravel by itself does not seem to provide enough stability for heavy equipment and trucks. Please give calculations.
Pg.05.00
Draining TD-3 into cell 2 is not acceptable if cell 2 is being landfilled. Also, during construction of cell 2 this will cause constructibility issue's. Drain TD-3 into flume or reverse grade to PD-12 by moving it up the slope.
At the southeast corner of the wetlands there looks to be a pipe or ditch added to connect to the old culvert. What is this and what function does it serve? Water from this pipe does not go through a sed trap or pond.
Pg. 06.00
The two pipes (one from sed basin at south end of cell one and the one draining cell 2 (SE corner) need to be removed.
Pg. 07.00
Note on section 1-1 that the pond needs to be excavated to stable conditions and backfilled and compacted with clayey soils. Some of this pond looks to be within the 4' groundwater buffer.
Pg. 02.001
Condensate can not be discharged as surface water. Gas will also be exiting from this pipe. Have you applied for an air permit for the passive system? Do you have data on the quantity and quality of this gas.
Misc.
Need gate shown on N. end of Steam Plant Rd.
Waste at final grade needs to be receive final cover within 180 days.
Intermediate cover is 12" .
Why was daily or weekly cover not mentioned.
The hours of operation is stated to be 7 days per week. Does this mean 24 hours per day or less.
Section 1.5 of the operations plans discusses a conveyor system to dump waste near the landfill. This concept needs to be designed to make sure

it meets our rules and regulations.
Permit Application's Attachment 1 by SM&E suggests three items to follow up on (testing with on site materials for stability, swelling. and liquefaction). Has this been done?

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John Murray - John.Murray@ncmail.net
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North Carolina Dept. of Environment & Natural Resources
Solid Waste Division
919 N. Main St.
Mooresville, NC 28115
Ph: (704) 663-1699 Fax: (704) 663-7579

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Central file

PROCUREMENT, CONSTRUCTION AND EH&S

Duke Power
EC11E / P.O. Box 1006
Charlotte, NC 28201-1006

18-09

November 17, 2004

Received
NOV 2004
Solid Waste Section

North Carolina Department of Environment
and Natural Resources
Division of Waste Management
Solid Waste Section
401 Oberlin Road, Suite 150
Raleigh, NC 27605-1350

ATTENTION: Ms. Ellen Lorscheider
Hydrogeologist
Solid Waste Permitting Branch

SUBJECT: Marshall Steam Station
FGD Industrial Landfill
Construction Plan Application

After review of your September 20, 2004 letter, we have hopefully included a response to the concerns you have cited. These concerns are cross referenced with the number sequence used in your letter. For each concern expressed, a Duke Power response is given below.

<u>Construction Plan Application</u>

1.0 Phase 1 is cited as 33 acres. The Site Suitability document only referenced 20.64 acres.

The Phase 1 footprint is 33 acres. An addendum to applicable portions of the Site Suitability document is included under separate cover.report have been revised to reflect the 33 acre landfill footprint for Phase 1. These revised portions are found in the Site Suitability Report, Addendum 1, dated November 12, 2004.

2.2 "Closure of cells will commence once final elevations are reached." This statement is contrary to the 5-year cap being placed regardless of the quantity of FGD material disposed of.

The closure of the landfill will commence following the 5-year permit period. An addendum to Section 2.2 is attached.

2.3 8" soil/10 feet. Compaction level and lift depth of FGD is not included. S&ME document cites that FGD will "typically" be compacted to 95%. Compaction as indicated in the modeling should also be reflected in the construction and operation plans.

The intermediate soil layer will be compacted to 92 percent of standard Proctor maximum dry density. The modeling has been revised to reflect the compaction criteria.

3.0 "The FGD gypsum landfill at Marshall will receive FGD residue generated at Marshall and potentially from other Duke Power plants located within North Carolina." This is contrary to the zoning letter from Catawba County.

The Catawba County Planning Department has approved a Duke Power request to receive FGD residue generated by other Duke Power facilities at Marshall Steam Station. Please refer to the attached letter.

5.4 The intermittent stream and wetland area of 0.56 acres that are located within the landfill footprint area for Cell 2 may need to be further evaluated. Is it possible to break this out into another phase? Further evaluation of the hydrogeology may be necessary after stream is relocated and wetland mitigation is complete.

The wetland area within the Cell 2 footprint is currently being permitted to be filled. The groundwater observation wells within the Cell 2 footprint will remain during operation of Cell 1 so that additional groundwater level data can be obtained prior to construction of Cell 2.

Landfill Operations and Maintenance

1.5 Areas not filled for 12 months or more shall be seeded with temporary seeding. Long period of infiltration with no evapotranspiration.

Temporary seeding of the FGD residue will not be done during operations. An addendum to Section 1.5 is attached. The HELP analyses used a LAI (Leaf Area Index) equal to zero for the upper layer in the model (this is the intermediate soil cover layer). This LAI is associated with bare ground and would provide no transpiration. Evaporation would still occur with the actual rate dependent on soil and evaporative conditions. These conditions are modeled in HELP.

1.6 "will allow the facility to accept...FGD residue that is removed from settling or clarifer stages of the associated waste treatment facility." What are the specific waste characteristics of this material? In particular the increased surface area of this waste due to it being a finer material than the FGD residue may cause the leaching of contaminants to be increased. The moisture level of the material may be greater than the FGD residue. Comment

FGD residue from utilities that utilize analogous scrubber technology and coal types was analyzed and characterized. Once the Marshall scrubber is operational, Duke Power will fully analyze the FGD residue.

2.1 Compaction levels are only indicated for the berms. Subgrades of landfills, even if insitu, are usually disked and recompacted to eliminate conduits for contamination to enter the groundwater. Subgrade preparation is not addressed. It looks from the cross sections that Silty Sand (SM) material will make up the (4 foot sepration to groundwater) subgrade material of the landfill. SM materials are not desirable materials for unlined landfills.

Compaction criteria for the FGD residue and intermediate cover has been added to the attached addendum to Sections 1.3 and 1.5.

Sign posted shall read "No Hazardous or Liquid Waste Permitted" it would be pertinent to limit the waste on this sign to FGD residue etc.

The sign information has been revised per the attached addendum .

Compliance Demonstration

5.1.1 The SPLP was run on FGD residue typical of the material produced by the scrubber system. The FGD residue material that does not meet specifications ($CaSO_4$ is generally >94% for use in wallboard) for the end use (probably wallboard) will be lower in the amount of gypsum, higher in the contaminant.

The material from the clarifier stage will be placed in the landfill. This material will be "the same composition as the FGD residue, but will consist of smaller particles." Due to the increased surface area would this not increase potential leachate from this material?

Once the wastewater treatment system becomes operational, samples of the clarifier stage material will be collected. The physical, chemical, and leaching characteristics of these samples will be determined and presented to NCDENR.

FGD residue from utilities that utilize analogous scrubber technology and coal types was analyzed and characterized. Once the Marshall scrubber is operational, Duke Power will fully analyze the FGD residue.

8.4 Two cases were modeled with HELP. Operational at 40 feet filled, and Closed with 80.5 feet of waste in the landfill. More runs of HELP are needed. At a minimum yearly runs are needed. Also runs of HELP are needed for smaller fill areas. For example what if only one lift of 10 feet was needed in a year due to reuse of material. A worst case scenario, generated by HELP, needs to be used in MYGRT. This may require a number of HELP runs evaluating various scenarios.

The comments appeared to be addressed to two areas; comments concerning the quantity of leachate and comments concerning the concentration of constituents in leachate. The responses are addressed to these two areas.

Quantity of Infiltration (Leachate)
Two periods were modeled with HELP. These periods are:

- *Operational Period – models the infiltration that occurs during the period of gypsum placement.*
- *Closed Period – models the infiltration that occurs after placement of the engineered cover.*

The landfill was modeled during the operational period (the 5 year period of gypsum placement) to determine the quantity of infiltration that would pass through the gypsum, becoming leachate. The properties described in the Compliance Demonstration Addendum, Section 8.3, were used, along with a 100 year period of simulated weather conditions to determine the amount of infiltration that would occur.

Since the thickness of the gypsum will increase during the operational period. Separate HELP runs were made to at the thicknesses listed below to evaluate the infiltration at different thicknesses of material. As described in the Construction Plan Application, after 10 feet of gypsum are placed, an 8" layer of site soil will be placed. The HELP runs for the Operational Period include an 8" layer of site soil placed over each 10' layer of gypsum. The thicknesses listed below are nominal thicknesses representing only the thickness of the gypsum layer. A nominal elevation of 740' was selected as the base grade for the landfill. Conservative assumptions were used to characterize conditions and properties of site soils and FGD residue.

The infiltration values calculated by HELP using these conservative conditions and properties should envelope worst case conditions for infiltration.

HELP Run Thickness	*Upper Elevation*	*HELP Calculated Infiltration During Operational Period (in/yr)*
10 feet	*750 feet*	*18.64*
20 feet	*760 feet*	*18.64*
40 feet	*780 feet*	*18.53*
60 feet	*800 feet*	*18.36*

The HELP model removes surface water run-off from further calculations for evapotranspiration and infiltration. In these analyses the entire landfill was considered to have a runoff characteristics based on a 2% slope, with soils having site properties for wilting point and field capacity, and having a good grass cover. These characteristics reduce run-off, increasing the *water available for infiltration. The value for LAI was chosen to be zero (0) for the entire landfill, reducing evapotranspiration. As the landfill height reaches and goes above the surrounding grade, the outer side slopes will receive grassing (increasing evapotranspiration) and will be sloped at the final side slope grade around 12%). These actual conditions will produce more run-off than the modeled conditions and therefore will generate less infiltration. Regular inspections and good surface water control practices will prevent the concerns noted about preferential pathways of flow developing.*

Concentration of Constituents in Leachate

Refer to the Figure on page 3 of 5 with pathways labeled as "A" and "B." There would be no significant difference in the concentrations of leachate at either point. The concentrations of the constituents in the infiltration are controlled more by solubility, and conditions expressed by eH and pH, than by the thickness or available mass of material.

If any difference were to be found, it likely would be that lower constituent concentrations would be found under the thinner material (pathway "B") since the infiltration might pass through the thinner material (depending on the thermodynamics of the reactions) before the reactions could occur.

8.4.2 The assumed number of holes in the LDPE cover used by HELP should be 8 per acre instead of 5.

The number of holes in the HELP analysis for the LDPE cover was increased to 8 per acre.

8.5 Properties for the Gypsum Layer from the S&ME FGD Scrubber Sludge Testing (Revision 1).

Total Porosity – value used is for 8 ksf loading at 92% compaction. This indicates moderately compacted FGD with close to optimum moisture. The field conditions of no compaction and 11.8% moisture should be used to determine porosity at least in the upper portion of a HELP run.

The value for porosity for the FGD material in the HELP analyses was changed to the porosity for 90% maximum dry density. The value for the porosity of the FGD residue used in the HELP analyses is 0.47.

Additional SPLP testing needs to be performed on FGD residue from the pilot plant.

Additional testing of the FGD residue will be performed once the Marshall scrubber is operational.

The material generated by the FGD system to be installed at Marshall will be washed with water to remove chlorides. In addition to the reduction of chlorides, we anticipate that the concentrations of other constituents will be reduced by removal or exchange of water from the pore spaces. The material generated by the pilot scrubber plant was not washed, so we do not believe that it represents the material that the actual FGD system will generate. Therefore, we *do not plan on using this material in an evaluation of the material to be produced by the actual FGD system at Marshall.*

8.5 Properties for Soil layer Beneath the Landfill

Cover material: An evaluation of the type of material used as cover is necessary. Because of the large quantity of sand that will be cut from the footprint of landfill, stockpiled and presumably used for cover, the 8 inches of cover per 10 feet may increase the infiltration during operation.

As described in the Compliance Demonstration Report – Addendum 1, the HELP model runs for the operational conditions model an 8" thick layer of soil placed after placement of 10 feet of gypsum. The properties used for these soil layers were determined by reviewing the soil boring information and by considering the range of soils that could be used. Section 8.0 of the Compliance Demonstration Report – Addendum 1 presents these values and the results of the HELP runs.

<u>Appendix B</u>
USGS Seismic Maps showing Peak Acceleration were updated in 2002. Map, if required, should be updated.

The USGS Seismic Maps referred to are contained in Appendix B of a document (S&ME Project 12264-03-057 - February 2004) prepared by S&ME on properties of FGD Scrubber Sludge testing. This document was included in the Compliance Demonstration Report since selected geotehcnical properties of FDG residue were used in the modeling.

As described on page 8 of this S&ME report, the stability analyses performed were on various conceptual designs for FGD residue landfills with final slopes (2:1, 3:1, 4:1) and a fill height (100 ft) selected to illustrate stability of slopes only at the conceptual level. Because these maps were used in analyses at the conceptual level, there is no need to update these maps.

<u>Other HELP questions</u>
It is necessary that the porosity and hydraulic conductivity which is used in HELP is the same as would occur during actual operation. For example a figure of 0.41 is currently used but if the material is compacted to only 90% this may produce a porosity of 0.47. It is our understanding that a new proctor test will be performed, which should stimulate operating conditions.

A second proctor test was performed on the gypsum material to verify that 90% maximum dry density could be achieved at 12% moisture conditions. This additional testing found that 90% maximum dry density could be achieved at 12% moisture conditions. The value for porosity of the FGD material in the HELP analyses was changed to the porosity for 90% maximum dry density. The value for porosity used in the HELP analyses is 0.47. A copy results of this proctor test is included.

Other MYGRT questions:
Are the Input values – Width of Source and Source Length, reversed in all analyses?

The values input for Width of Source and Source Length are correct as presented in the analyses. As the MYGRT manual states (page 7-10), the Source Length is the length of the source parallel to the direction of flow. The Width of Source is the width of the source perpendicular to the groundwater flow.

There are two cross sections used in the MYGRT analyses to represent the conditions at the landfill. These two cross sections represent the two major groundwater drainage areas. The dimensions used for width and length for both of these areas are larger than the actual dimensions for these two areas. This results in MYGRT providing constituent loading over a larger area than will actually occur.

Is the Input – Dispersion along the Y supposed to be 19.6 in the Sulfate analysis?

The definitions and methods for calculating the coefficients for dispersion in the saturated material are found on page 7-17 and 7-18 of the MYGRT manual. The user enters a value for the Scale Distance for Dispersion. This is normally taken to be the furthest down gradient distance of interest. In this case a distance of 250', was used. The values for horizontal, transverse, and vertical dispersion were calculated by the program using the horizontal seepage velocity and the factors presented in the definitions found on page 7-18 of the MYGRT manual.

Please include the soil type on the cross sections used for MYGRT.

The cross sections used for the MYGRT analyses are the same as two of the cross sections provided in the Hydrogeological report report. The soil boring information is provided on the cross sections in the Hydrogeological report. Please refer to the cross sections on the hydro-geological report.

An additional run of MYGRT analyzing a worst case scenario (0.018 mg/l) of Arsenic is needed.

As described in the Compliance Demonstration Report and the Addendum to the Compliance Demonstration Report, arsenic did not leach at concentrations greater than the 2L standard in the initial SPLP leaches. As described in Section 9.1 of the Addendum to the Compliance Demonstration Report, the period of time associated with these initial leaches is longer than the period of time that the landfill will be operational and exposed to infiltration. However, to address the issue, additional MYGRT analyses were performed for arsenic at a concentration of 0.018 mg/l.

Other questions:
The coal ash landfill at Belews showed that water tended to wick up in the waste. In the absence of a liner or a capillary break, how do we know a similar situation is not to occur here. The FHA recommends 5 feet separation of flyash structural fills from groundwater and a capillary break. Water has been proven to move up in the ash. FGD material because of its particle size and porosity would be expected to act similarly.

An investigation of the water levels near well OB-1 is being performed at the Belews Creek ash landfill. This investigation consists of field work installing piezometers, performing filed permeability's, and lab work. The field work is complete and the lab work will be completed in 1-2 weeks. The preliminary findings are that the water observed in the ash near and around well OB-1 is from a perched condition, where a clay-rich layer of soil exists under a portion of the landfill. Duke will submit a report on this matter at some future date. No evidence of capillary action causing water to be present in the ash was observed.

Please contact me at (704) 382-4309 if additional information is needed to ensure that a Permit to Construct is issued by December 15, 2004.

Sincerely,

Allen Stowe

Allen Stowe, Scientist
Environmental Support

Attachments

Addendum No. 1
Construction Plan Application
Duke Energy Marshall Steam Station
FGD Residue Landfill
Catawba County, NC

Construction Plan Application Report

Section 2.2, page 3- Replace "Closure of cells will commence once final elevations are reached." With "Closure of cells will commence at the 5-year permit period."

Section 2.3, page 3- Add the following sentence, "The intermediate soil layer shall be compacted with a dozer in one lift with a minimum compaction of 92 percent of standard Proctor maximum dry density."

Landfill Operations and Maintenance

Section 1.3, page 1- Add the following third paragraph, "Prior to waste placement, the top 8 inches of the landfill bottom subgrade shall be scarified, disced, and compacted to 95 percent of the standard Proctor maximum dry density. Initial compaction shall be achieved by a deep penetrating sheepsfoot roller. The final surface shall be rolled with a smooth drum roller."

Section 1.5, page 2- Replace the second paragraph with the following: "Waste shall be compacted in 8-inch thick lifts with a dozer and placed on the smallest active face as feasible. The waste shall be compacted to 90 percent of standard Proctor maximum dry density. Each 10-foot lift of FGD waste shall be covered with an 8-inch thick layer of intermediate cover soil compacted to 92 percent of standard Proctor maximum dry density."

Section 1.5, page 2- Delete the fourth paragraph in its entirety.

Section 2.1, page 3- Add the following sentence at the end of the first paragraph: "A lockable gate will be provided at the haul road at the north end of the landfill."

Section 2.1, page 3- Add "ONLY FGD RESIDUE WASTE IS ACCEPTED AT THIS LANDFILL" before "NO HAZARDOUS OR LIQUID WASTE PERMITTED".

Technical Specifications for Closure

Section 4.2.4, page 26- In the last paragraph, change "$5x10^{-5}$ m^2/sec" to "$5x10^{-4}$ m^2/sec".

Moisture - Density Relationship

S&ME

S&ME Project #:	**1261-03-051**	Test Date(s):	October 22, 2004
Project Name:	DUKE POWER FGD SCRUBBER WASTE	Report Date:	October 23, 2004
Client Name:	DUKE POWER		
Client Address:			

Boring #:	Sample #: S-1	Sample Date:	
Location:	Offset:	Depth:	BULK
Sample Description:	GYPSUM		

Liquid Limit: Specific Gravity: 2.360

Plastic Limit: Plastic Index:

Natural Moisture Content:

Moisture Content of the Oversize Fraction:

NOTES:

Sieve Size	% Passing
3/4"	
1/2"	
3/8"	
#4	100.0

MDD: **88.9** **Opt. MC %:** **22.0**

Water Content

Water Content requires GP 2 Balance (0.1 gram Readability).

ASTM D2216 ☒ AASHTO T265 ☐ ASTM D4959 ☐ ASTM D4643 ☐

Sample #:							
Water Added:							
Tare #:							
A. Tare Weight	A.						
B. Wet Wt + Tare Wt	B.	366	500	500	500	500	500
C. Dry Wt. + Tare Wt.	C.	328.7	440	426.7	416.5	408.5	400.9
D. Water Weight	B-C	37.3	60	73.3	83.5	91.5	99.1
E. Dry Weight	C-A	328.7	440	426.7	416.5	408.5	400.9
F. Moisture Content	100*D/E	**11.3%**	**13.6%**	**17.2%**	**20.0%**	**22.4%**	**24.7%**

Compaction Data

The Compaction Test requires a GP 5 Balance for ASTM (1 gram or .0022 Lb. readability)

G. Wt of Soil + Mold	G.	5710	5751	5813	5863	5901	5883
H. Wt. of Mold	H.	4263	4263	4263	4263	4263	4263
I. Wt. of Soil (g. or lbs.)	G-H	1447.000	1488.000	1550.000	1600.000	1638.000	1620.000
J. Wt of Soil (Lbs.)	I/453.6 or I	3.190	3.280	3.417	3.527	3.611	3.571
K. Mold Volume Factor	K.	30.14	30.14	30.14	30.14	30.14	30.14
L. Wet Density	J*K	96.1	98.9	103.0	106.3	108.8	107.6
M. Dry Density	L/(1+F)	**86.3**	**87.0**	**87.9**	**88.6**	**88.9**	**86.3**

ASTM D558 ☐ ASTM D 698 ☒ ASTM D1557 ☐ AASHTO T99 ☐ AASHTO T180 ☐

Method A ☒ Method B ☐ Method C ☐ Method D (ASTM 1978) ☐ AASHTO Method D ☐

Moisture-Density Relation of: Fine Fraction ☒ Corrected for Coarse Fraction (ASTM D 4718) ☐

Sieve Size used to separate the Oversize Fraction: #4 Sieve ☒ 3/8 inch Sieve ☐ 3/4 inch Sieve ☐

Mechanical Hammer ☒ Manual Hammer ☐ Moist Preparation ☒ Dry Preparation ☐

Soil Plasticity: ASTM D 4318 ☒ AASHTO T 89 ☐ AASHTO T 90 ☐

Sieve Analysis / Particle Size Analysis: ASTM C136 ☐ AASHTO T 27 ☐ ASTM D 422 ☒ AASHTO T 88 ☐

Specific Gravity of Soil: ASTM D 854 ☒ AASHTO T 100 ☐

Bulk Gravity of Oversize Fraction: ASTM C 127 ☐ AASHTO T 85 ☐

Moisture - Density Report

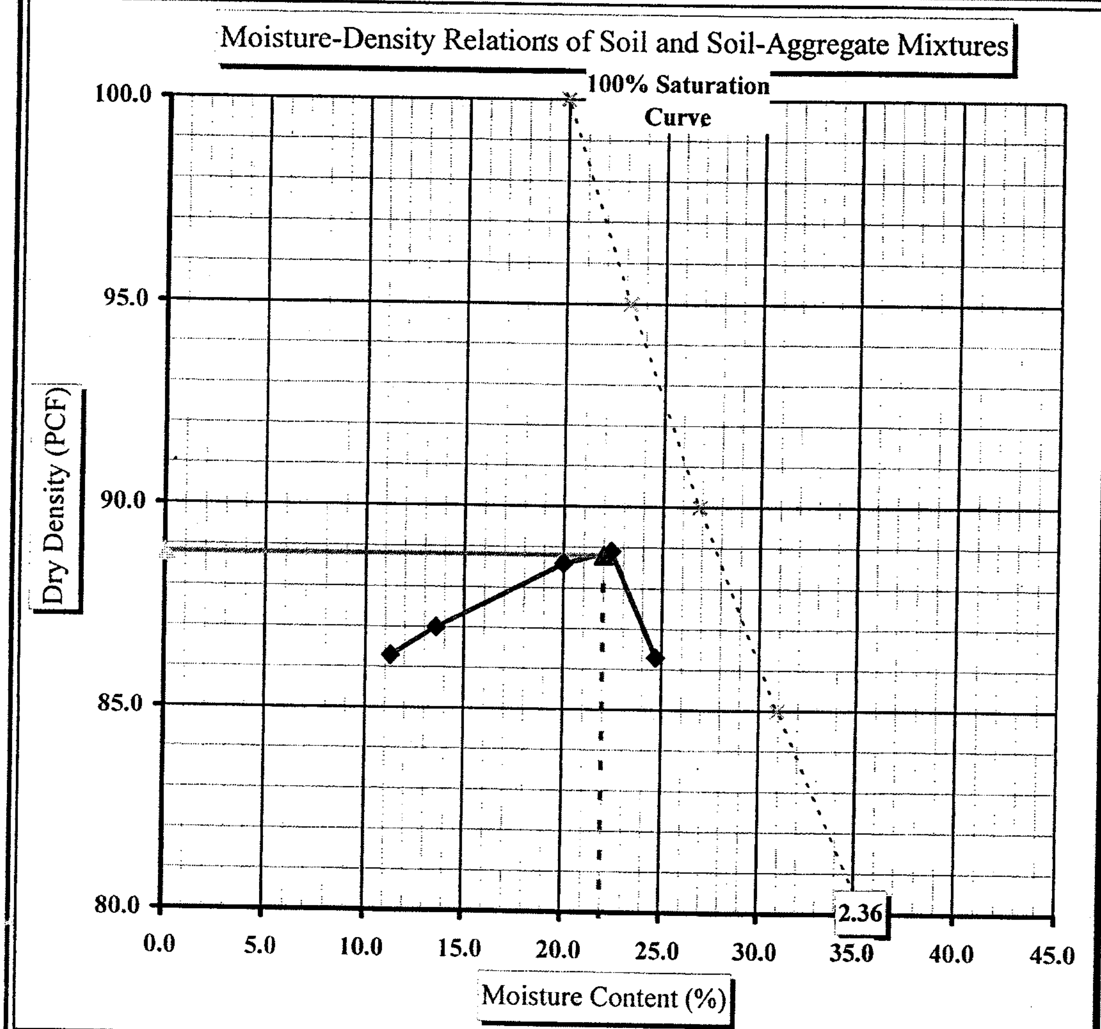
S&ME

S&ME Project #:	**1264-03-057**	Report Date:	October 23, 2004
Project Name:	**DUKE POWER FGD SCRUBBER WASTE**	Test Date(s):	October 22, 2004
Client Name:	DUKE POWER		
Client Address:			

Boring #: 0		Sample #:	S-1	Sample Date:	
Location:		Offset:		Depth:	BULK
Sample Description:	GYPSUM				

Maximum Dry Density 88.9 PCF. **Optimum Moisture Content** 22.0 %

ASTM D 698 Method A



Soil Properties	
Natural Moisture Content:	
Liquid Limit:	29
Plastic Limit:	29
Plastic Index:	
Specific Gravity:	2.360
% Passing	
3/4"	
1/2"	
3/8"	
#4	100

Oversize Fraction

Bulk Sp. Gravity
% Moisture
Oversize Fraction
MDD
Opt. MC

Moisture-Density Curve Displayed: Fine Fraction ☒ Corrected for Oversize Fraction (ASTM D 4718) ☐
Sieve Size used to separate the Oversize Fraction: #4 Sieve ☒ 3/8 inch Sieve ☐ 3/4 inch Sieve ☐
Mechanical Hammer ☒ Manual Hammer ☐ Moist Preparation ☒ Dry Preparation ☐

References: ASTM D 698: Laboratory Compaction Characteristics of Soil Using Standard Effort
ASTM D 2216: Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
ASTM D 422: Particle Size Analysis of Soils
ASTM D 854: Specific Gravity of Soils
ASTM D 4318: Liquid Limit, Plastic Limit, & Plastic Index of Soils

Technical Responsibility: Larry Armstrong ______________ Signature

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Shaw® Stone & Webster, Inc.

Carmen Johnson
Fac/Perm/Co ID # 18-09 | Date 1/25/12 | Doc ID# | DIN

CONSTRUCTION PLAN APPLICATION

DUKE ENERGY CORP.
MARSHALL STEAM STATION
FLUE GAS DESULFURIZATION (FGD)
GYPSUM LANDFILL, PHASE 1
CATAWBA COUNTY, NC

APPROVED
DIVISION OF WASTE MANAGEMENT
SOLID WASTE SECTION
DATE 1/14/05 BY [illegible]
Central Office
18-09

March 2004

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