DESIGN, CONSTRUCTION

AND

OPERATING PROVISIONS

FOR

Carmen Johnson

Fac/Permit/Co ID #	Date	Doc ID#
34-06	8/8/13	DIN

Piedmont Sanitary Landfill

Forsyth County, North Carolina

Presented By Waste Management of Carolinas, Inc.

August 1988

Contract File

Waste Management of North America, Inc.
Carolinas/Tennessee District
110 Berry Shoals Road • P.O. Box 338
Duncan, South Carolina 29334
803/439-8426

SOLID WASTE
DATE APPROVED 2/23/89

August 29, 1988

Mr. Gordon Layton, Head
Solid Waste Branch
Solid Waste Management Section
North Carolina Department of Human Resources
P.O. Box 2091
Raleigh, NC 27602-2091

RE: Construction Plan Application for the Proposed Kernersville Sanitary Landfill Site

Dear Gordon:

Please consider this and the enclosed information as the Construction Plan Application for the above referenced site, as required by 10 NCAC 10G, Section .0503 (2) and .0504 (2). Also, this submittal addresses those items requested in your July 12, 1988 letter. The following Index/Cross Reference directs you to the correct location within the Application.

As you know we are anxious to begin operation of this landfill which will be an asset to both ourselves and the State of North Carolina. Your department's expedient review is appreciated and should you have any questions, please feel free to contact Mike Adams or myself.

Sincerely,

Edward L. Gibson, P.E.
District Environmental Engineer

/ELG:adb 174

Enclosure

cc: Mark Stendahl (w/o enclosure)
Mike Adams " "
John Stitt " "
Hank Ludwig " "

Facility/Permit/Co ID #: 34-06
Date: 8/8/13
Doc ID#
DIN

INDEX/CROSS REFERENCE

FOR THE

PROPOSED PIEDMONT SANITARY LANDFILL

CONSTRUCTION PLAN APPLICATION

LEGEND:

"PLANS" refer to the "Site Development Plans for Piedmont Sanitary Landfill, Forsyth County, North Carolina" prepared by Waste Management, Inc. May, 1988.

"GOLDER" refers to "A Phase II Hydrogeologic Investigation at the Proposed Kernersville, N.C. Sanitary Landfill Site." Prepared by Golder Associates, Inc. for Waste Management of the Carolinas, Inc., August 1987, 2 Volumes. Submitted to NCDHR and approved in a letter dated July 12, 1988.

"OP Report" refers to "Design, Construction, and Operating Provisions for Piedmont Sanitary Landfill, Forsyth County, North Carolina. Prepared by Environmental Engineering Group, Waste Management, Inc. 3003 Butterfield Rd., Oak Brook, Illinois 60521.

ITEM, July 12, 1988 Letter	WMCI Submittal
(1) (a), "100 ft. buffer..."	Plans, Sheet 2
(b), "Flood plain buffer..."	Plans, Sheet 2 OP Report, Appendix H
(c), "Surface, ground water discharge area buffers..."	Plans, Sheet 2 Golder, Figure 18
(2) "Liner/leachate Collection System"	Plans, Sheets 3, 10
(3) "Final Cover..."	Plans, Sheets 4, 10 OP Report, Section 3.5.3

ITEM, July 12, 1988 Letter (cont'd)	WMCI Submittal
(4) Leachate Management Plan	OP Report, Appendix E
(5) Groundwater Monitoring Plan	OP Report, Section 5.2
(6) Closure, Post Closure Plan	OP Report, Section 6
(7) "Procedure for acceptance of Out-of-State Waste..."	Exhibit 7

ITEM 10 NCAC 10G Rules Section		WMCI Submittal
.0503(2)		
	a	OP Report, Section 5.4
	b	OP Report, Section 4.8
	c	OP Report, Section 5.3
	d(i)	Golder, Section 6.3 OP Report, Section 5.2
	(ii)	Golder, Section 6.3 OP Report, Section 3.4 Plans, Sheet 2
	e	OP Report, Section 4.4.7
	f(i,iii) ii	Plans, Sheet 2 Golder, Section 4.2.2
	g	Plans, Sheet 5 OP Report, Section 2.7 Appendix B
.0504(2)		
	(a)	Plans, Sheet 1
	(b)	Plans, Sheet 2
	(c)	Plans, Sheet 4
	(d)	Plans, Sheets 5, 11

ITEMS, Rules Section (cont'd)	WMCI Submittal
.0504(2)	
(e)	Plans, Sheets 6,7
(f)	Plans, Sheets 6,7
(g)	Plans, Sheets 8,9
(h)i	Golder, Appendix G
ii	OP Report, Section 4.5
iii	OP Report, Section 6.2.1
iv	OP Report, Section 2.2
v	OP Report, Section 4.0
vi	OP Report, Section 2.3
vii	OP Report, Appendix C
viii	OP Report, Appendix B
ix	OP Report, Section 2.7
x	OP Report, Sections 4.4, 4.8, 5.0
xi	OP Report, Section 7.0

EXHIBIT 7

RESERVED. TO BE FORTHCOMING

OP Report

DESIGN, CONSTRUCTION, AND OPERATING PROVISIONS FOR PIEDMONT SANITARY LANDFILL FORSYTH COUNTY, NORTH CAROLINA

Waste Management of Carolinas, Inc.
110 Berry Shoals Road
Duncan, South Carolina 29334

AUGUST 1988

TABLE OF CONTENTS

	PAGE
1.0 INTRODUCTION	1
1.1 Background	1
1.2 Scope and Objectives	1
1.3 Supplemental Documents	2
2.0 DESIGN PROVISIONS	4
2.1 Types and Volume of Wastes Accepted	4
2.2 Landfill Service Life	4
2.3 Earthwork Calculations and Soil Balance	5
2.4 Liner Design	5
2.5 Leachate Collection System	6
2.5.1 Water Balance	6
2.5.2 Leachate Collection System Details	7
2.6 Final Cover/Grading	8
2.7 Sediment and Erosion Control	9
2.7.1 Perimeter Ditches	10
2.7.2 Sedimentation Ponds	10
2.7.3 Landfill Terrace Ditches	11
2.7.4 Landfill Vegetation	12

TABLE OF CONTENTS

(continued)

		PAGE
3.0	CONSTRUCTION PROVISIONS	13
3.1	Construction Sequence	13
3.2	Access and Haul Roads	14
3.2.1	Freeman Road Relocation	14
3.2.2	Site Haul Roads	14
3.3	Building Removal	15
3.4	Excavation	15
3.5	Quality Control/Assurance	15
3.5.1	Liner Construction	16
3.5.2	Leachate Collection System	17
3.5.3	Final Cover	17
4.0	OPERATING PROVISIONS	18
4.1	Site Preparation	18
4.2	General Landfilling Procedures	18
4.3	Progression of Landfill Operations	19
4.4	Control of Nuisance and Health Factors	20
4.4.1	Odor Control	20
4.4.2	Dust Control	20
4.4.3	Site Appearance	21
4.4.4	Noise Control	21
4.4.5	Litter Control	21
4.4.6	Vector Control	22

TABLE OF CONTENTS

(continued)

	PAGE
4.4.7 Police and Fire Protection	22
4.5 Site Personnel and Operating Schedule	23
4.6 Operating Equipment	25
4.7 Signs	25
4.8 Fencing and Access Control	26
5.0 ENVIRONMENTAL MONITORING PLAN	27
5.1 Leachate Monitoring	27
5.2 Ground-Water Monitoring	27
5.3 Surface-Water Monitoring	28
5.4 Landfill Gas Monitoring	29
5.5 Record Keeping	29
6.0 CLOSURE AND POST CLOSURE PROVISIONS	30
6.1 Closure	30
6.1.1 Notification	30
6.2 Post Closure	30
6.2.1 Projected Site End Use	30
6.2.2 Post-Closure Inspections	30
7.0 APPENDICES	

1.0 INTRODUCTION

1.1 Background

The proposed Piedmont Sanitary Landfill is located in Forsyth County, North Carolina, approximately 10 miles north of the city of Kernersville. The proposed 71 acre site is located on an approximately 100 acre parcel of land which is immediately adjacent to the current Kernersville Municipal Landfill. A legal description and survey plat of this property is included in Volume II, Appendix G of the site hydrogeologic study done by Golder Associates (Section 1.3, reference 2).

The Piedmont Sanitary Landfill will be owned and operated by Waste Management of Carolinas, Inc. (WMCI). Once opened, the site will accept those wastes noted in the "Site Plan Application". [10 NCAC 10G .0504 (1)].

1.2 Scope and Objectives

This report is intended, along with the supplemental documents, to:

A. Serve as a supporting document in response to the specific requirement of the North Carolina Department of Human Resources (NCDHR) "North Carolina Solid Waste Management Rules" [10 NCAC 10G .0504 (2), .0503 (2)].

B. Provide a written plan for use in conjunction with the design plans.

This report describes design, construction and operating provisions including the method of landfill operation and management; site preparations and construction required; stormwater, erosion, and sediment control plans; service life; and proposed groundwater and surface water monitoring programs.

1.3 Supplemental Documents and Information

In addition to this report, several other documents have been prepared for the design and construction of the Piedmont Sanitary Landfill. These additional documents include:

(1) "Site Development Plans for Piedmont Sanitary Landfill, Forsyth County, North Carolina." prepared by Waste Management, Inc. May 1988.

(2) "A Phase II Hydrogeologic Investigation at the Proposed Kernersville, N.C. Sanitary Landfill Site." prepared by Golder Associates, Inc. for Waste Management of the Carolinas, Inc., August 1987, 2 Volumes.

(3) "Quality Assurance Manual for the Installation of Geosynthetic Lining System". Prepared by Waste Management, Inc. June 1986. See Appendix F of this report.

(4) "Specification Guidelines for the Procurement and Installation of Geosynthetic Lining Systems". Prepared by Waste Management, Inc. June 1986. See Appendix G of this report.

2.0 DESIGN PROVISIONS

This section provides a discussion of the design provisions and considerations used to prepare the site development plans. Supporting design calculations are referenced and included in the appendices.

2.1 Types and Volume of Wastes Accepted

This information is included within the "Site Plan Application" submitted per 10 NCAC 10G .0504.

2.2 Landfill Service Life

The design proposes a fill volume (gross airspace) of approximately 6.5 million cubic yards after subtraction of volume requirements for the final soil cover. (Refer to Appendix A for service life and volume calculations). Based on a compacted refuse to daily and intermediate cover volume ration of 4:1, the total refuse airspace available at the site is approximately 5.2 million cubic yards. Using a gate refuse to compacted refuse ratio of 2:1, the site life is estimated to be approximately 23 years.

2.3 Earthwork Calculations and Soil Balance

Calculations of earthwork quantities and a soil balance for the site are contained in the calculations presented in Appendix A. It was determined that landfilling operations during the life of the site would require approximately 1.6 million cubic yards of soil. Since on-site soils available were determined to be approximately 2.5 million cubic yards, no material for daily operations will have to be obtained off-site.

In addition, approximately 530,000 cubic yards of suitable cohesive soils will be required for liner and final cover construction. If possible, suitable on-site soils will be used. If an insufficient quantity of suitable soils exist on-site, suitable material will be obtained from off-site sources, or soil admixtures utilized to attain the quality of soil material desired.

2.4 Liner Design

To insure adequate protection of the groundwater underlying the site, a composite liner system will be used at the base of the landfill. As shown in the design plan cross-sections (sheet nos. 6 & 7), this liner will be constructed so the base grades of refuse at the site are at least four feet above the projected seasonal high water table elevation. Once the landfill is excavated to the required subbase grade, a cohesive soil layer will be placed and compacted. This cohesive soil layer will have a maximum hydraulic conductivity of 1×10^{-7} cm/sec or less and be a minimum of 18" thick.

A 60-mil thick High Density Polyethylene (HDPE) synthetic liner will then be installed over the compacted soil layer. To protect the sythetic liner and promote drainage of any leachate, a 12-inch layer of sandy soil will be placed over the liner. This drainage layer will have minimum permeability of 1×10^{-3} cm/sec or greater. Finally, a 12-inch layer of sandy soil will be placed over the drainage layer so that a total of 24 inches of soil is provided to protect the liner system. A typical cross-section of the liner construction is shown on the "Miscellaneous Details" (sheet no. 10) sheet of the site design plans.

2.5 Leachate Collection System

2.5.1 Water Balance

To estimate the rate of leachate production at the landfill after the site is closed and final cover has been applied, a water balance anaylsis was performed. The leachate production rate was estimated by considering landfill topographic and climatic conditions. The water balance equation (excluding groundwater infiltration which will not be a factor at this site) is:

Precipitation - Run-off - Soil Moisture Storage
- Evapotranspiration = Leachate Production

This equation assumes that leachate production begins immediately. In actuality, the refuse and daily cover soil will absorb water

infiltration. The entire thickness of refuse and daily cover must reach field capacity (a condition near saturation) to yield leachate at the bottom of the landfill.

The type of water balance model used for the Piedmont Landfill was the Hydrologic Evaluation of Landfill Performance (HELP) computer model as released by the USEPA. This model simulates the field conditions encountered at the Piedmont site by using site specific design parameters (i.e., final cover thickness and permeability) in addition to available local climatological data.

The HELP Model simulation that was conducted for the Piedmont landfill indicated an average annual water infiltration of 7.9 inches or 17.4 percent of the average annual precipitation. This figure was used as a criteria in the design of the site's leachate collection system.

2.5.2 Leachate Collection System Details

To collect any leachate that infiltrates through the landfill and thus to preclude any build up of a hydrostatic head, a leachate collection system has been designed for the Piedmont site. This system is shown in detail in the Leachate Collection System Plan (sheet no. 3) and detail sheets (sheet nos. 10-11) of the site design plans. The system consists of a network of 6" diameter, Schedule 80, perforated PVC plastic pipes in stone-filled trenches within the base drainage layer of the landfill.

These pipes drain at a minimum 0.5% grade toward one of 6 leachate collection sumps.

Additional leachate collection pipes are located around the perimeter of the landfill base. The base of the landfill is designed to slope at a minimum 2% grade.

The leachate collection sumps are designed to accumulate any collected leachate and provide for removal of the leachate by pumping when a pumpable level of leachate is reached. Each sump consists of a minimum 3' deep trough with an 6' X 10' base and 3H:1V side slopes (see the detail of the collection sump in the design plans). The sump is lined with an 18" layer of compacted clay and 2 layers of 60 mil HDPE synthetic geomembrane liner. Access to the sump for leachate monitoring and removal is provided by an 18 inch diameter HDPE riser pipe.

2.6 Final Cover/Grading

The design of the final grades was based on a buffer between disposal areas and property lines/wetlands/flood-plain, 4 horizontal to 1 vertical sideslopes, and minimum 7 percent grades in the uppermost, central portion of the landfill. Final grades on the sideslopes were designed at 4:1 to minimize erosion and maintenance. In addition, erosion control drainage terraces have been designed to be placed at intervals along the landfill sideslopes to further limit erosion of the landfill cover (see section 2.7). Final grades on top of the landfill

were designed to ensure sufficient slope for surface water runoff after anticipated settlement of the underlying refuse fill.

The final cover will consist of a minimum 3 feet of compacted cohesive soil with a maximum hydraulic conductivity of 1×10^{-6} cm/sec and an additional six inches of topsoil capable of supporting vegetative cover. Final cover alternatives utilizing low permeability admixtures or synthetic liners may also be used if they have hydraulic transmissivities less than or equal to that of three feet of 1×10^{-6} cm/sec material. The leachate generation rate will be reduced by providing this low hydraulic conductivity final cover.

2.7 Sediment and Erosion Control

In order to comply with North Carolina Solid Waste Management rules addressing sedimentation and erosion control at sanitary landfills (10 NCAC 10.0503 through 10.0505), an erosion control plan has been developed for the Piedmont site. This plan is illustrated on sheet no. 5 of the design plans and meets all requirements the North Carolina Sedimentation Pollution Control Law (15 NCAC 4).

Several measures have been designed for the Piedmont Sanitary Landfill in order to control erosion and prevent eroded silt from leaving the site. These measures include:

(1) Perimeter diversion ditches to prevent surface water from entering the site or coming in contact with active fill areas.

(2) Three sedimentation ponds are provided to prevent eroded silt from leaving the site.

(3) Erosion control terrace ditches keyed into the final cover of the landfill to prevent stormwater from eroding the landfill cover.

2.7.1 Perimeter Ditches

To size the drainage structures, peak runoff rates have been calculated using the Soil Conservation Service (SCS) method TR-55. The perimeter ditches were designed based on the 25 year, 24 hour rainfall event of approximately 6 inches. Using a calculated runoff curve number (CN) of 79 for the site, a direct runoff of 3.7 inches has been determined. This value has been used to calculate the unit peak discharges in each particular drainage area. Detailed calculations of peak runoff rates are included in Appendix B of this report.

2.7.2 Sedimentation Ponds

The three permanent sedimentation ponds were designed based on peak runoff calculations from the 25 year, 24 hour storm event. Sediment storage required was based on soil loss calculated by the universal

soil loss equation and the drainage area of each pond. Each pond provides at least one year of calculated sediment storage before cleanout of accumulated sediment is required.

The design depth of sedimentation pond no. 1 (the southwest pond) is 4 feet. Sediment will be removed when sediment accumulates above a depth of 1.5 feet. The design depth of sedimentation pond no. 2 (the north pond) is 5 feet, with a sediment maintenance level of 2 feet. The design depth of sediment pond no. 3 (the northeast pond) is 5 feet with a sediment maintenance level of 2 feet. All calculations for the sedimentation pond designs are included in Appendix B of this report.

2.7.3 Landfill Terrace Ditches

Terrace ditches have been designed for the 4H:1V sideslopes of the landfill to help prevent erosion of the final landfill cover soil. These terraces intercept sheet flow along the slopes of the landfill and transport it to the perimeter ditches. These terraces are approximately 2.5 feet deep and 15 feet wide at the crest and have 2:1 and 4:1 interior slopes. The centerline of each terrace is sloped at a 1% grade towards the perimeter ditch.

Design calculations for the terrace ditches are located in Appendix B of this report. They are designed to carry runoff from a 25 year, 24 hour storm event.

2.7.4 Landfill Vegetation

The most important method of erosion and sediment control is establishment of a good vegetative cover. This will be done by seeding and mulching all final covered fill areas and all interim covered slopes that will not be active for over one year.

Seeding mixtures will be selected from the list of grass species listed in the seeding schedule in Appendix C. These species were selected for their hardiness in previous landfill applications and suitability for the climate of central North Carolina.

Before seeding of the final cover areas of the landfill, testing of the topsoil will be done to determine what types of fertilization are necessary. The appropriate fertilizers will be applied before or during seeding. Seeded areas will be mulched to protect the seedbed and prevent erosion.

3.0 CONSTRUCTION PROVISIONS

3.1 Construction Sequence

Landfill construction will involve a systematic usage of area on a module-by-module basis. The individual modules each provide approximately 6 months or more of refuse fill capacity. Clearing and grubbing will be done only as necessary as construction proceeds. After clearing each module will be constructed individually to planned base grades. The designed liner and leachate collection system will be installed, and temporary berms will be placed around each module. The module will then be filled up to an elevation based on the module's size and 3H:1V intermediate slopes. As the final plan elevation is reached, final cover will be applied to meet design grades.

The orientation and designation of landfill modules is shown on the "Base Grade Construction Sequence" sheet in the site design plans (sheet no. 8). The first module to be constructed will be Phase I Module I located at the southwest corner of the site. Operations will then proceed east to Modules 2, 3 and 4. Construction of Modules 5 and 6 will complete Phase I. The landfill will then proceed to Phase II, III and IV. Modules will be constructed in sequential order within the phases.

3.2 Access and Haul Roads

3.2.1 Freeman Road Relocation

As shown on the design plans, Freeman Road will be rerouted to the southern portion of the site property. The design and construction of the Freeman Road relocation shall meet all North Carolina Department of Transportation specifications. Detailed road plans and profiles will be submitted to NCDOT and written approval obtained from that agency.

3.2.2 Site Haul Roads

The existing portion of Freeman Road will be maintained within the site and used as the initial refuse haul road. As the construction of the landfill progresses eastward, a new refuse haul road will be constructed to reach the northern portions of the site. Haul roads for landfill construction vehicles will be constructed as needed to provide access to active fill and borrow areas.

3.3 Building Removal

The existing buildings on the landfill site will be demolished or relocated as necessary as landfill operations progress across the site property. Existing on-site drinking water wells will be abandoned per North Carolina Regulations.

3.4 Excavation

The landfill will be excavated on a module-by-module basis. In each module, excavation will be made to 3.5 feet below the plan base grades (See Sheet No. 2). This will allow for construction of the liner and drainage system. The horizontal limits of excavation will extend approximately 25 feet beyond the limits of each module interface as shown in the "Temporary Interface Between Modules" detail (See sheet No. 12).

Excavated materials will be separated and stockpiled according to their intended use as a base liner, daily and intermediate cover, final cover and soil capable of supporting vegetative cover. These materials will be stockpiled at locations determined by the site manager.

3.5 Quality Control/Assurance

A quality assurance/quality control (QA/QC) program will be implemented during all phases of liner, leachate collection system, and final cover

construction to assure that the intended design plans are followed and specifications are met.

3.5.1 Liner Construction

QA/QC will be maintained during the liner construction by supervision and inspection of the liner installation by a qualified engineer. The clay liner will be compacted in maximum 9 inch loose lifts. An independent engineering consultant will be retained to complete a laboratory testing program. The program will utilize strength and moisture/density relationships to verify that the soil layer's in-situ hydraulic conductivity meets the required 1×10^{-7} cm/sec minimum standard.

QA/QC procedures for the 60 mil HDPE synthetic geomembrane liner are described in the "Quality Assurance Manual for the Installation of Geosynthetic Lining Systems", a manual prepared by Waste Management, Inc. (see section 1.3). This manual describes quality assurance testing procedures and specifications that will be used by the Geosynthetic Quality Assurance Consultant to monitor the liner installation.

The synthetic geomembrane liner installation contractor will install the liner subject to the "Specification Guidelines for the Procurement and Installation of Geosynthetic Lining Systems" prepared by Waste Management, Inc.

3.5.2 Leachate Collection System

QA/AC will be maintained during the leachate collection system installation by observation of construction by a qualified engineer. Surveying of pipe locations and grades will be done by a qualified land surveyor. Landfill base grade elevations as well as piping locations and elevations will be recorded on an as-built plan using the information obtained from the surveys.

3.5.3 Final Cover

The integrity of the final cover will be verified by laboratory hydraulic conductivity tests conducted on soil samples obtained from in-situ final cover soil. The samples will be obtained by qualified personnel from an independent engineering consultant. All final cover areas that do not meet design requirements will be recompacted and retested.

4.0 OPERATING PROVISIONS

4.1 Site Preparation

Prior to disposal of waste in Module 1 of Phase I, the following site preparation must be completed.

A. Relocate Freeman Road as discussed in section 3.2.

B. Remove or relocate existing buildings and properly abandon existing drinking water wells on or near Module 1.

C. Construct haul roads for landfill equipment.

D. Construct the perimeter runoff control ditches around Module 1 and sedimentation pond at the southwest corner of the site.

E. Prepare the initial excavation and liner.

F. Install the leachate collection system and protective soil cover.

4.2 General Landfilling Procedures

The landfill will be filled using the area method. Compacted refuse will be placed in lifts approximately 15 to 20 feet thick. Interim slopes will typically be constructed at 3 horizontal to 1 vertical.

Refuse will be spread and compacted in thin layers on a working face approximately 50 feet to 100 feet wide. Landfill compaction equipment will make three to five passes over each layer. This will ensure adequate compaction and reduce long-term settlement of the landfill.

Large or bulky objects will be separated from refuse at the working face. These objects will be placed in the upper portion of the advancing refuse layer and thoroughly crushed by compaction equipment to prevent bridging and localized subsidence at a later time.

The advancing layer of compacted refuse will be covered daily. Initially, daily cover will consist of 6 inches of soil but as new daily cover alternatives become available, the Piedmont Landfill would propose to utilize these methods under the examination of the NCDHR. When additional refuse will not be placed over a landfill surface within one month, the surface will be covered with 12 inches of intermediate soil cover. Landfilling will proceed in this manner until final elevations as shown on the "Final Development Plan sheet" (sheet no. 4) are achieved.

4.3 Progression of Landfill Operations

Landfill activities will proceed on a module-by-module basis as discussed in section 3.1. As landfilling activities proceed within one module, the next module to be filled will be prepared to accept refuse. The first operation will take place in Phase I Module 1, located near the southwest corner of the site.

4.4 Control of Nuisance and Health Factors

Site operating procedures will include actions to control nuisance and health factors. The nuisance and health factors that affect operations are odors, dust, litter, noise, sight appearance, fire prevention and control of vectors.

4.4.1 Odor Control

Odor control will be achieved by taking the following measures:

(1) Apply daily cover.

(2) Grade the site to eliminate surface ponding.

(3) Maintain leachate control facilities in proper operating condition.

4.4.2 Dust Control

Dust generation at the landfill and borrow areas can occur from operations such as cover material stripping and placement, refuse compaction and vehicular travel on access roads.

Dust control will limit excessive wear of equipment. Dust raised from vehicular movement will be controlled by wetting roads with water available onsite.

4.4.3 Site Appearance

Waste Management of Carolinas will take several measures to make the Piedmont Sanitary Landfill aesthetically pleasing and minimize impacts on the surrounding environment. This will be accomplished by focusing on litter control and vegetative cover. Litter will be controlled by perimeter fencing, utilizing a small working face and policing the site and surrounding roadways. Landfilling will use the modular method, operating in only one module of the site at a time, and re-establishing vegetative cover on filled areas to minimize the amount of disturbed earth at the site.

4.4.4 Noise Control

Noise from on-site equipment will be controlled by equipment maintenance, particularly equipment mufflers. Additionally, the disposal areas will be isolated from property boundaries by maintaining perimeter buffer zones.

4.4.5 Litter Control

One of the most important aspects of periodic landfill maintenance is litter control. Litter will be minimized by:

(1) Maintaining a small working face.

(2) Covering portions of the face as they are constructed.

(3) Temporarily fencing the limits of the working face with litter control fencing in addition to six-foot high chain-link fencing plus three strand overhang around the site perimeter to minimize litter offsite.

(4) Taking advantage of prevailing wind directions and orienting daily landfill operations accordingly.

(5) Temporary laborers will be employed to cleanup any litter that is not controlled by operational measures.

(6) Policing weekly along Freeman Road.

4.4.6 Vector Control

Insects and rodents will be controlled by placing daily cover to deny them food and harborage. A commercial vector control company will be retained if necessary. Positive drainage will be maintained to eliminate mosquito breeding in ponded surface water areas.

4.4.7 Police and Fire Protection

Fire protection of landfill equipment and vehicles will be provided by portable fire extinguishers. The gatehouse and maintenance facility will be equipped with suitable fire extinguishers for suppression of any minor fires and for safety of personnel. Additional fire protection coverage of these facilities will be contracted with the fire district. Any fire that occurs on the landfill will be extinguished by landfill personnel using soil cover

stockpiled to smother the fire. No burning of waste will be practiced at the landfill.

In addition to fire protection, a burglar and fire alarm systems will be installed in all on-site buildings.

4.5 Site Personnel and Operating Schedule

Waste Management of Carolinas, Inc. (WMCI), a division of Waste Management of North America, Inc., will be the sole operator of the Piedmont Sanitary Landfill. Mr. Mike Adams, District Landfill Manager, will be the primary contact for the Piedmont Sanitary Landfill. Mr. Adams can be reached at the following address:

WMNA Carolinas/TN District
P.O. Box 338, 110 Berry Shoals Road
Duncan, South Carolina 29334
(803) 439-8426

Waste Management of Carolinas anticipates operating the facility Monday through Friday from 6:00 a.m. to 5:00 p.m. and Saturdays from 6:00 a.m. to 12:00 noon. The hours of operation may be adjusted on an as-needed basis.

The following personnel are projected to be employed at the facility:

Position	No.
Landfill Manager	1
Operators	2
Mechanics	1
Weigh Master	1
Laborers	1
TOTAL	6

These personnel will be trained in safe and proper landfill operating procedures. Changes will be made to this roster as need dictates.

The following programs will minimize possible health hazards to the site operating personnel:

1) Identification of Special Wastes prior to acceptance and minimizing the exposure time of any waste that may present health hazards to operating personnel.

2) Onsite first aid supplies, hygienic facilities and training of site personnel in safe operating procedures and compliance with operating provisions.

4.6 Operating Equipment

Equipment to be utilized initially at the facility is projected to be:

Excavation Equipment:

Description	No.
Scraper (Cat 627 or equivalent)	1
Dozer (Cat D7 or equivalent)	1

Other Equipment:

Description	No.
Compactor (Rex 355 or equivalent)	1
Motor Grader	1
Water Truck	1

4.7 Signs

Signs providing information on dumping procedures, the hours during which the site is open for public use, the permit number and other pertinent information will be posted at the site entrance.

A sign indicating that no liquids or hazardous wastes will be accepted at the landfill will be clearly posted at the site entrance. The sign will be similar to that shown in Appendix D.

4.8 Fencing and Access Control

In order to control security at the site and to prevent unknowing entry by the public, perimeter fencing will be installed around the site using the following guidelines:

1. Access at the site will be limited to entrances that have gates which are locked when the site is unsupervised.

2. The entire site perimeter shall be enclosed by six-foot high chain link fence plus barbed wired security top.

3. No trespassing signs shall be posted at a minimum of 250 foot intervals.

5.0 ENVIRONMENTAL MONITORING PLAN

5.1 Leachate Monitoring Plan

See Appendix E

5.2 Groundwater Monitoring Plan

Groundwater monitoring will be conducted at the site using the proposed groundwater monitoring wells. The locations of these wells are illustrated on sheets nos. 1 and 4 of the site plans. A monitoring well schedule indicating depths and screened intervals of these wells is shown on sheet no. 1. All monitoring wells will be constructed as shown on the monitoring well construction detail on sheet no. 11 of the site plans.

The proposed groundwater monitoring plan at the Piedmont site includes one upgradient well (MW1) and three downgradient wells (MW2, MW3 and MW4). The placement of these wells is based on findings and recommendations of a Phase II hydrogeologic study of the Piedmont site prepared by Golder Associates, Inc. in August of 1987 (see section 1.3 for reference.) This report determined that the groundwater at the site flows away from a groundwater mound located near the southeast corner of the site. The upgradient well (MW1) will be located in such a location to adequately monitor upgradient groundwater quality.

The remaining three downgradient wells, MW2, MW3, and MW4, are located around the perimeter of the site.

In monitoring groundwater quality to document compliance with 15 NCAC 2L, groundwater monitoring wells will be sampled annually and tested for a parameter list developed in coordination with the North Carolina Department of Human Resources. Sampling and analysis of the monitoring wells will be conducted in accordance with the procedures outlined in the "North Carolina Water Quality Monitoring Guidance Document For Solid Waste Facilities", with approved changes. Well Completion Reports for the groundwater monitoring wells will be submitted to the NCDHR.

Presently, all wells will be monitored in accordance with the following:

Frequency	Parameter
Annually	As, Ba, Cd, Cl, Cr, Cu, Fl, Fe, Pb, Mn, Hg, Nitrate, Se, Ag, Zn, Sulfate, TOX, TOC, TDS, BOD, COD, Spec Cond, pH and water level elevation

5.3 Surface-Water Monitoring

Surface-water monitoring will be performed to determine any impacts on the surrounding surface waters. The surface water monitoring program should indicate whether the discharge of run-off from the site is in violation with the National Pollution Discharge Elimination System (NPDES), under section 402 of the Clean Water Act and section 404 of the Clean Water Act.

In review of site hydrogeology as discussed in the site hydrogeologic investigation prepared by Golder Associates (see section 1.3), all surface water from the site area must discharge into two streams.

One stream borders the northern margin of the site, and the other traverses the southern portion of the site. It is proposed that monitoring stations be established both up and downgradient of the site for both streams to properly monitor the impacts that landfill operations would have on surface-water quality.

Five proposed surface water monitoring locations are illustrated on Figure 20 of the Golder hydrogeologic report. These locations, once approved, will be surveyed and recorded on a site topographic map. The frequency of monitoring and test parameters will be in accordance with the "North Carolina Water Quality Monitoring Guidance Document for Solid Waste Facilities". Specifically all surface water points will be monitored as per the groundwater program above.

5.4 Landfill Gas Monitoring

Landfill gas is not expected to be generated at the Piedmont site until after several years of filling have occurred. The low permeability of the bottom and sidewall liner system will preclude horizontal migration of landfill gas into the surrounding subsoils. If gas odors or problems with cover maintenance occur due to passive gas venting, then corrective measures will be proposed.

5.5 Record Keeping

Site records will be maintained at the landfill office during the life of the landfill. These records will include incoming waste volumes, water quality monitoring results, as-built construction details, and approved variations from operating procedures.

6.0 CLOSURE AND POST CLOSURE PROVISIONS

6.1 Closure

6.1.1 Notification

At least 60 days prior to final closure of the site, the site manager will notify the North Carolina Department of Human Resources - Solid Waste Branch and the Forsyth County Commissioners in writing of the proposed closure date. In addition, signs of suitable size will be placed at the site entrance facility to notify the general public of the proposed closure date.

6.2 Post Closure Plan

6.2.1 Projected Site End Use

A recreational end use is planned for the Piedmont Landfill. Facilities for public use that could be constructed at the site include baseball diamonds, tennis courts or practice fields. Creation of these facilities will be coordinated with the Forsyth County Recreation Department and/or the Town of Kernersville Recreation Department.

6.2.2 Post-Closure Inspections

During the post-closure monitoring period of the landfill, the site will be inspected on a semi-annual basis to identify and correct any problems associated with security, erosion, vegetative growth, leachate or methane migration, and surface subsidence. As site conditions merit, remedial action will take place for those deficiencies noted during these inspections. Leachate will continue to be disposed of in accordance with the site's Leachate Management Plan.

Appendix A

APPENDIX A

LANDFILL SERVICE LIFE

AND

VOLUME CALCULATIONS

TABLE A-1

PIEDMONT SANITARY LANDFILL

FINAL QUANTITY SUMMARY

Gross Airspace	6,514,400 cy
Excavation Volume	2,503,800 cy
Refuse Capacity	5,211,500 cy
Daily and Intermediate Cover	1,302,900 cy
18" Compacted Cohesive Soil Liner	186,400 cy
60 Mil HDPE Liner	3,355,200 sf
2' Protective Soil Cover (over HDPE)	248,500 cy
Final Cover	343,600 cy
Topsoil	57,300 cy
Berms	22,800 cy
On-Site Soil Balance	Excess 342,300 cy
Site Life	23.2 years

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 1 OF 1	PAGE
SUBJECT: Site Life Calculations	PREPARED BY aem 1/18/88	CHECKED BY / /	REVISED BY / /

Refuse Airspace Available (from volume calcs)

5,211,500 cy

Assumptions:

Daily Disposal Rate = 1250 gate cu yds / day

Disposal Operation = 5.5 days per week - 52 weeks / year

% Growth Rate = 2% per year in intake

Compaction Rate (Gate c.y. : In-place c.y)

= 2:1

$$* F/A = \frac{5,211,500 \text{ c.y.}}{\frac{1}{2}(1250 \text{ cy/day})(5.5 \text{ day/wk})(52 \frac{\text{wk}}{\text{yr}})} = 29.2$$

FROM TABLE ATTACHED, WITH F/A = 29.2, i = 2%

n = 23 years @ F/A = 28.845

n = 24 years @ F/A = 30.422

interpolating,

$$\frac{1}{1.58} = \frac{24-x}{1.22}$$

$$37.85 - 1.58x = 1.22$$

$$23.18 = x \approx 23.2 \text{ years}$$

Site Life at 2%/year growth in intake

23.2 years

F = future amount or worth (ultimate landfill capacity)

A = Annual amount or annuity (1250 cy/day)

n = number of years to reach ultimate capacity at 2% growth

i = % growth in refuse intake per year

CCMPOUND INTEREST TABLE FOR I=2.000PERCENT

N	F/P	P/F	F/A	A/F	P/A	A/P	N
1	1.020	.9804	1.00000	1.0000	.98039	1.0200	1
2	1.040	.9612	2.02000	.4950	1.94156	.5150	2
3	1.061	.9423	3.06040	.3268	2.88388	.3468	3
4	1.082	.9238	4.12161	.2426	3.80773	.2626	4
5	1.104	.9057	5.20404	.1922	4.71346	.2122	5
6	1.126	.8880	6.30812	.1585	5.60143	.1785	6
7	1.149	.8706	7.43428	.1345	6.47199	.1545	7
8	1.172	.8535	8.58297	.1165	7.32548	.1365	8
9	1.195	.8368	9.75463	.1025	8.16224	.1225	9
10	1.219	.8203	10.94972	.0913	8.98259	.1113	10
11	1.243	.8043	12.16872	.0822	9.78685	.1022	11
12	1.268	.7885	13.41209	.0746	10.57534	.0946	12
13	1.294	.7730	14.68033	.0681	11.34837	.0881	13
14	1.319	.7579	15.97394	.0626	12.10625	.0826	14
15	1.346	.7430	17.29342	.0578	12.84926	.0778	15
16	1.373	.7284	18.63929	.0537	13.57771	.0737	16
17	1.400	.7142	20.01207	.0500	14.29187	.0700	17
18	1.428	.7002	21.41231	.0467	14.99203	.0667	18
19	1.457	.6864	22.84056	.0438	15.67846	.0638	19
20	1.486	.6730	24.29737	.0412	16.35143	.0612	20
21	1.516	.6598	25.78332	.0388	17.01121	.0588	21
22	1.546	.6468	27.29898	.0366	17.65805	.0566	22
23	1.577	.6342	28.84496	.0347	18.29220	.0547	23
24	1.608	.6217	30.42186	.0329	18.91393	.0529	24
25	1.641	.6095	32.03030	.0312	19.52346	.0512	25
26	1.673	.5976	33.67091	.0297	20.12104	.0497	26
27	1.707	.5859	35.34432	.0283	20.70690	.0483	27
28	1.741	.5744	37.05121	.0270	21.28127	.0470	28
29	1.776	.5631	38.79223	.0258	21.84438	.0458	29
30	1.811	.5521	40.56808	.0246	22.39646	.0446	30
31	1.848	.5412	42.37944	.0236	22.93770	.0436	31
32	1.885	.5306	44.22703	.0226	23.46833	.0426	32
33	1.922	.5202	46.11157	.0217	23.98856	.0417	33
34	1.961	.5100	48.03380	.0208	24.49859	.0408	34
35	2.000	.5000	49.99448	.0200	24.99862	.0400	35
36	2.040	.4902	51.99437	.0192	25.48884	.0392	36
37	2.081	.4806	54.03425	.0185	25.96945	.0385	37
38	2.122	.4712	56.11494	.0178	26.44064	.0378	38
39	2.165	.4619	58.23724	.0172	26.90259	.0372	39
40	2.208	.4529	60.40198	.0166	27.35548	.0366	40
41	2.252	.4440	62.61002	.0160	27.79949	.0360	41
42	2.297	.4353	64.86222	.0154	28.23479	.0354	42
43	2.343	.4268	67.15947	.0149	28.66156	.0349	43
44	2.390	.4184	69.50266	.0144	29.07996	.0344	44
45	2.438	.4102	71.89271	.0139	29.49016	.0339	45
46	2.487	.4022	74.33056	.0135	29.89231	.0335	46
47	2.536	.3943	76.81718	.0130	30.28658	.0330	47
48	2.587	.3865	79.35352	.0126	30.67312	.0326	48
49	2.639	.3790	81.94059	.0122	31.05203	.0322	49
50	2.692	.3715	84.57940	.0118	31.42361	.0318	50
51	2.745	.3642	87.27099	.0115	31.78785	.0315	51
52	2.800	.3571	90.01641	.0111	32.14495	.0311	52
53	2.856	.3501	92.81674	.0108	32.49505	.0308	53
54	2.913	.3432	95.67307	.0105	32.83828	.0305	54

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont L.F. No. D-014	SHEET 1 OF 3	PAGE
SUBJECT: Final Landfill Volumes & Soil Balance	PREPARED BY AEM 1/18/88	CHECKED BY / /	REVISED BY / /

Calculations

Area of Landfill: 3,092,100 ft^2 = 71 acres

Area of Base: 2,879,900 ft^2

Area of Slope: 2.24 (212,200 ft^2) = 475,300 ft^2

Volumes:

18" clay layer

$1.5\,(2{,}879{,}900 + 475{,}300)\,\frac{1}{27}$ = 186,400 cy

2' protective soil cover

$2\,(2{,}879{,}900 + 475{,}300)\,\frac{1}{27}$ = 248,500 cy

Excavation Volume:

2,068,900 + 186,400 + 248,500 = 2,503,800 cy

Final Cover:

$3\,(3{,}092{,}100)\,\frac{1}{27}$ = 343,600 cy

Gross Airspace (assume 10% overfill):

(4,196,900 + 2,068,900 − 343,600) 1.1 = 6,514,400 cy

Topsoil:

$\frac{1}{2}\,(3{,}092{,}100)\,\frac{1}{27}$ = 57,300 cy

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont L.F. No. D-014	SHEET 2 OF 3	PAGE
SUBJECT: Final Land fill Volumes & Soil Balance	PREPARED BY a&m 1/18/88	CHECKED BY / /	REVISED BY / /

Daily & Intermediate Cover:

Assume – Refuse : D & I Cover Ratio = 4:1

1/5 (6,514,400) = 1,302,900 cy

Refuse Airspace:

6,514,400 cy − 1,302,900 cy = 5,211,500 cy

Berms:

Landfill 3000' long, avg. height 5', 15' crest

$\frac{3000}{27}[(15)(5) + (10)(5)] = 13,900$ cy

Sed. Ponds 2400' long, avg. height 5', 10' crest

$\frac{2400}{27}[10(5) + 10(5)] = 8,900$ cy

Soil Balance:

On-site soil required:

248,500 + 1,302,900 + 22,800 + 57,300 = 1,631,500 cy.

On-site soil available: 2,503,800 cy

Excess: 872,300 cy

Required Clay: 186,400 + 343,600 = 530,000 cy

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 3 OF 3	PAGE
SUBJECT: Preliminary Volumes Ground surface to base grades	PREPARED BY 12/4/87	CHECKED BY 1/18/88	REVISED BY / /

ELEVATION (FT)	AREA (FT²)	AVERAGE AREA (FT²)	Δ (FT)	VOLUME (FT³)
840	39,220			
		79,130	10	791,300
830	119,040			
		179,040	10	1,790,400
820	239,040			
		385,190	10	3,851,900
810	531,340			
		688,645	10	6,886,450
800	845,950			
		997,020	10	9,970,200
790	1,148,090			
		1,212,025	10	12,120,250
780	1,275,960			
		1,277,435	10	12,774,350
770	1,278,910			
		703,555	10	7,035,550
760	128,200			
		64,100	10	641,000
750	0			
				55,861,400

= 2,068,900 CY

Waste Management, Inc. Environmental Engineering Group	PROJECT PIEDMONT No. D-014	SHEET 1 OF 1	PAGE
SUBJECT: Phase 1 Life Calculations Modules A1, A2, A3, B1, C1, D1	PREPARED BY CEM 1/18/88	CHECKED BY / /	REVISED BY / /

Total Airspace from Volume Calc Sheet 1,754,100

Refuse D&I cover = 4:1 $-\frac{1}{5}(1,754,100) =$ 1,403,280

2:1 Compaction Ratio $\times 2$

2,806,560

$$\text{Phase 1 Life} = \frac{2,806,560}{(1250\ cy/day)(5.5\ day/wk)(52\ wk/year)}$$

= 7.85 years (at constant 1250 cy/day intake)

With 2%/year growth of intake:

F/A = 7.85

From table attached, with F/A = 7.85 & i = 2%

n = 7 @ F/A = 7.43

n = 8 @ F/A = 8.58

interpolating,

$$\frac{1}{1.15} = \frac{8-x}{8.58-7.85}$$

$$9.2 - 1.15x = .73$$

$$1.15x = 8.47$$

$$x = 7.37 \approx \underline{\underline{7.4 \text{ years}}}$$

Phase 1 Life = 7.4 years at 2% annual growth

Waste Management, Inc.
Environmental Engineering Group

VOLUME COMPUTATIONS

PREPARED BY A. Maxson DATE 1/18/88 SHEET 1 OF 1
CHECKED BY DATE PROJECT NO.

SUBJECT TITLE 5-year volumes - modules A1, B1, C1, D1, A2, A3

STATION	END AREA (ft.²)	AVERAGE END AREA (ft.²)	STATION INTERVAL (ft.)	VOLUME (yd.³)	ACCUMULATED TOTAL VOLUME (yd.³)
752	0	1050	2	78	
754	2100	180,050	6	40,011	40,089
760	358,000	737,750	10	273,240	313,330
770	1,117,500	1,038,250	10	384,537	697,867
780	959,000	870,000	10	322,222	1,020,089
790	781,000	690,500	10	255,741	1,275,830
800	600,000	511,350	10	189,389	1,465,219
810	422,700	379,950	10	140,722	1,605,941
820	337,200	243,350	10	90,130	1,696,071
830	149,500	105,300	10	39,000	1,735,071
840	61,100	45,450	10	16,833	1,751,904
850	29,800	14,900	4	2,207	1,754,112
854	0				

COMMENTS:

Appendix B

APPENDIX B

STORMWATER RUNOFF

AND

SEDIMENTATION CONTROL CALCULATIONS

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 1 OF 35	PAGE
SUBJECT: Stormwater runoff calculations Peak flows	PREPARED BY CMO 11/9/87	CHECKED BY dem 1/21/88	REVISED BY / /

Assumptions:

Use SCS TR-55 Chart method
Ref: "A Guide to Hydrologic Analysis Using SCS Methods" by McCuen

Calculation:

① Estimate CN for final landfill grades:
Antecedent soil Moisture condition II
Soils are SCS Group C (Cover must be equivalent to 3' of 10^{-6} cm/sec
Land description: Pasture or range, fair condition

CN = 79

② Estimate CN for natural areas outside of landfill:
Antecedent soil moisture condition II
Soils are SCS Group B
Land description: Forest land, fair

CN = 60

$EA = 1.36 \times 10^{-4} (HL)^{1.67}$

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (A-1) Computed By CMR Date 11/9/87
Checked By GEM Date 1/21/88

1. Required Input

A = 3.6 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6 Inches: Rainfall depth for 24-hour, T-year event
Y = 13 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 300 feet : Hydraulic Length
EA = 1.9 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 1.9 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 4.8 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 0.97 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 4.8 x 3.7 x 1.9 x 0.97 x _____
= 32.7 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (A-2) Computed By CMX Date 11/9/87
Checked By GPM Date 1/21/88

1. Required Input

A = 3.7 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 16 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 250 feet : Hydraulic Length
EA = 1.4 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 2.7 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 3.6 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.0 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 3.6 x 3.7 x 2.7 x 1 x _____
= 36.0 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (A-3) Computed By CMD Date 11/9/87
Checked By _____ Date _____

1. Required Input

A = 3.3 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 13 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 300 feet : Hydraulic Length
EA = 1.9 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 1.8 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 4.8 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 0.97 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 4.8 x 3.7 x 1.8 x 0.97 x _____
= 31.0 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (A-4) Computed By CMC Date 11/9/87
Checked By CEM Date 11/22/88

1. Required Input

A = 3.3 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 13 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 300 feet : Hydraulic Length
EA = 1.9 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 1.8 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 4.8 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 0.97 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 4.8 x 3.7 x 1.8 x 0.97 x _____
= 31.0 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (A-5) Computed By CMC Date 11/9/87
Checked By WPM Date 1/22/88

1. Required Input

A = 3.6 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 13 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 300 feet : Hydraulic Length
EA = 1.9 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 1.9 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 4.8 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 0.97 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 4.8 x 3.7 x 1.9 x 0.97 x _____
= 32.7 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (A-6) Computed By CMD Date 11/9/87
Checked By [illegible] Date 1/22/88

1. Required Input

A = 3.7 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 11 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 450 feet : Hydraulic Length
EA = 3.7 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 1 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 7.5 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 0.96 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 7.5 x 3.7 x 1 x 0.96 x _____
= 26.6 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (A-7) Computed By CMA Date 11/9/87
Checked By [illegible] Date 1/27/88

1. Required Input

A = 4.3 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 11 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 450 feet : Hydraulic Length
EA = 3.7 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 1.2 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 8.0 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 0.96 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 8.0 x 3.7 x 1.2 x 0.96 x _____
= 34.1 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (A-8) Computed By CMR Date 11/9/87
Checked By [illegible] Date 11/22/88

1. Required Input

A = 4.8 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 10 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 550 feet : Hydraulic Length
EA = 5.1 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 0.9 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 10.0 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 0.96 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 10.0 x 3.7 x 0.9 x 0.96 x _____
= 32.0 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (A-9) Computed By CMR Date 11/9/87
Checked By [illegible] Date 1/22/88

1. Required Input

A = 5.9 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 10 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 550 feet : Hydraulic Length
EA = 5.1 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 1.2 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 10.0 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 0.96 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 10.0 x 3.7 x 1.2 x 0.96 x _____
= 42.6 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (A-10) Computed By CMA Date 11/9/87
Checked By [illegible] Date 11/22/88

1. Required Input

A = 4.9 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 12 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 450 feet : Hydraulic Length
EA = 3.7 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 1.3 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 8.0 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 0.97 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 8.0 x 3.7 x 1.3 x 0.97 x _____
= 37.3 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (B-1) Computed By GMS Date 11/9/87
Checked By [illegible] Date 11/22/88

1. Required Input

A = 2.5 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 120 feet : Hydraulic Length
EA = 0.4 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 6.2 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.5 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.5 x 3.7 x 6.2 x 1.06 x _____
= 36.5 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (B-2) Computed By CMA Date 11/9/87
Checked By [illegible] Date 1/22/88

1. Required Input

A = 2.0 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 120 feet : Hydraulic Length
EA = 0.4 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 5.0 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.5 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a) ___; Center or Spread out (6-b) ___; Upper Reaches (6-c) ___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.5 x 3.7 x 5.0 x 1.06 x _____
= 29.5 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (B-3) Computed By GMX Date 11/9/87
Checked By GEM Date 1/22/88

1. Required Input

A = 1.5 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 120 feet : Hydraulic Length
EA = 0.4 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 3.8 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.5 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.5 x 3.7 x 3.8 x 1.06 x _____
= 22.4 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (B-4) Computed By GMX Date 11/9/87
Checked By [illegible] Date 1/24/88

1. Required Input

A = 1.3 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 120 feet : Hydraulic Length
EA = 0.4 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 3.3 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.5 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.5 x 3.7 x 3.3 x 1.06 x _____
= 19.4 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (B-5) Computed By CMX Date 11/9/87
Checked By [illegible] Date 11/22/88

1. Required Input

A = 1.2 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 100 feet : Hydraulic Length
EA = 0.3 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 4.0 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.3 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.3 x 3.7 x 4.0 x 1.06 x _____
= 20.4 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (B-6) Computed By CMD Date 11/9/87
Checked By [illegible] Date 11/22/87

1. Required Input

A = 1.8 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 120 feet : Hydraulic Length
EA = 0.4 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 4.5 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.5 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.5 x 3.7 x 4.5 x 1.06 x _____
= 26.5 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (B-7) Computed By CMO Date 11/9/87
Checked By DMM Date 11/24/88

1. Required Input

A = 0.3 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 50 feet : Hydraulic Length
EA = 0.1 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 3 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.0 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a) ✓; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.0 x 3.7 x 3 x 1.06 x _____
= 11.8 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (B-8) Computed By CMA Date 11/9/87
Checked By CPM Date 11/22/88

1. Required Input

A = 0.1 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 30 feet : Hydraulic Length
EA = 0.1 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 1 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.0 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.0 x 3.7 x 1 x 1.06 x _____
= 4.0 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (B-9) Computed By CMR Date 11/9/87
Checked By LJM Date 7/22/88

1. Required Input

A = 1.9 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 120 feet : Hydraulic Length
EA = 0.4 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 4.8 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.5 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.5 x 3.7 x 4.8 x 1.06 x _____
= 28.2 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (G-10) Computed By CMO Date 11/9/87
Checked By DBM Date 1/22/88

1. Required Input

A = 1.0 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 120 feet : Hydraulic Length
EA = 0.4 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 2.5 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.5 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.5 x 3.7 x 2.5 x 1.06 x _____
= 14.7 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (B-11) Computed By CMX Date 11/9/87
Checked By DPM Date 1/22/88

1. Required Input

A = 1.2 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 120 feet : Hydraulic Length
EA = 0.4 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 3 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.5 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.5 x 3.7 x 3 x 1.06 x _____
= 17.6 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (B-12) Computed By CMX Date 11/9/87
Checked By DBM Date 1/22/88

1. Required Input

A = 1.8 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 120 feet : Hydraulic Length
EA = 0.4 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 4.5 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.5 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.5 x 3.7 x 4.5 x 1.06 x _____
= 26.5 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (C-1) Computed By CMD Date 11/9/87
Checked By [illegible] Date 7/22/88

1. Required Input

A = 2.6 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 150 feet : Hydraulic Length
EA = 0.6 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 4.3 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.8 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.8 x 3.7 x 4.3 x 1.06 x _____
= 30.3 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (C-2) Computed By CMX Date 11/9/87
Checked By [illegible] Date 11/22/88

1. Required Input

A = 2.9 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 150 feet : Hydraulic Length
EA = 0.6 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 4.8 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.8 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.8 x 3.7 x 4.8 x 1.06 x _____
= 33.9 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (C-3) Computed By CMA Date 11/9/87
Checked By [illegible] Date 1/22/88

1. Required Input

A = 1.6 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 130 feet : Hydraulic Length
EA = 0.5 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 3.2 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.7 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.7 x 3.7 x 3.2 x 1.06 x _____
= 21.3 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (C-4) Computed By CMR Date 11/9/87
Checked By [illegible] Date 1/22/88

1. Required Input

A = 0.8 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 100 feet : Hydraulic Length
EA = 0.3 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 2.7 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.3 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.3 x 3.7 x 2.7 x 1.06 x _____
= 13.8 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (C-5) Computed By CMR Date 11/9/87
Checked By DEM Date 1/22/88

1. Required Input

A = 1.5 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 100 feet : Hydraulic Length
EA = 0.3 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 5 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.3 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.3 x 3.7 x 5 x 1.06 x _____
= 25.5 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (C-6) Computed By CMC Date 11/9/87
Checked By [illegible] Date 1/22/88

1. Required Input

A = 1.6 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 100 feet : Hydraulic Length
EA = 0.3 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 5.3 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.3 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.3 x 3.7 x 5.3 x 1.06 x _____
= 27.0 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (C-7) Computed By CMP Date 11/9/87
Checked By DEM Date 11/22/88

1. Required Input

A = 0.5 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 50 feet : Hydraulic Length
EA = 0.1 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 5 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.0 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.0 x 3.7 x 5 x 1.06 x _____
= 19.7 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (C-8) Computed By CMX Date 11/9/87
Checked By RFM Date 1/22/88

1. Required Input

A = 0.6 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 60 feet : Hydraulic Length
EA = 0.1 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 6 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.0 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.0 x 3.7 x 6 x 1.06 x _____
= 23.5 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (C-9) Computed By CWC Date 11/9/87
Checked By [illegible] Date 7/22/88

1. Required Input

A = 0.9 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 25 % : Average watershed slope
CN = 79 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 3.7 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 100 feet : Hydraulic Length
EA = 0.3 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 3 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 1.3 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.06 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 1.3 x 3.7 x 3 x 1.06 x _____
= 15.3 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (O-1) Computed By [illegible] Date 11/9/87
Checked By [illegible] Date 11/22/87

1. Required Input

A = 1.8 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 10 % : Average watershed slope
CN = 60 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 1.9 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 500 feet : Hydraulic Length
EA = 4.4 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 0.4 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 7.5 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 0.96 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 7.5 x 1.9 x 0.4 x 0.96 x _____
= 5.5 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (O-2) Computed By CMO Date 11/9/87
Checked By DEM Date 11/22/88

1. Required Input

A = 3.9 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 10 % : Average watershed slope
CN = 60 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 1.9 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 250 feet : Hydraulic Length
EA = 1.4 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 2.8 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 3.2 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 0.96 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 3.2 x 1.9 x 2.8 x 0.96 x _____
= 16.4 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (0-3) Computed By CMP Date 11/9/87
Checked By DEM Date 1/22/88

1. Required Input

A = 4.4 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 7 % : Average watershed slope
CN = 60 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 1.9 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 400 feet : Hydraulic Length
EA = 3.0 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 1.5 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 3.9 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.09 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a) ___; Center or Spread out (6-b) ___; Upper Reaches (6-c) ___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 3.9 x 1.9 x 1.5 x 1.09 x _____
= 12.1 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

TABLE 5. COMPUTATION SHEET FOR CHART METHOD

PROJECT Piedmont (O-4) Computed By CMK Date 11/9/87
Checked By LEM Date 1/22/88

1. Required Input

A = 19.2 Acres : Drainage Area
T = 25 Years : Design Frequency (return period)
P = 6.0 Inches: Rainfall depth for 24-hour, T-year event
Y = 7 % : Average watershed slope
CN = 60 : Runoff Curve Number

2. Compute Volume of Runoff, Q

Q = 1.9 Inches: Use CN and P as input to Fig. 5

3. Watershed Shape Adjustment (Optional: if adjustment is not made, set EA = A)

HL = 1000 feet : Hydraulic Length
EA = 14.0 Acres : Equivalent Drainage Area (use Fig. 10)
HF = 1.4 : HF = A/EA

4. Obtain Unit Peak Discharge, QU

QU = 11.0 cfs/inch Q : Use EA with Fig. 11 (Sheet 1, 2, and 3 for flat, moderate, and steep slopes, respectively)

5. Watershed Slope Interpolation Factor, SF (Optional: if adjustment is not made, set SF = 1.0)

SF = 1.09 : Use Y and EA with Table 7

6. Ponding and Swamp Storage Adjustment Factor, PF (Optional: if adjustment is not made, set PF = 1.0)

PPS = _____ % : % of Ponds and Swampy Area (Based on actual drainage area A)

Location in watershed (check one):
Design Point (6-a)___; Center or Spread out (6-b)___; Upper Reaches (6-c)___

PF = _____ : Use PPS and T with Table 6-a, 6-b, or 6-c.

7. Peak Discharge QP, Calculation with Adjustments

QP = QU x Q x HF x SF x PF
= 11.0 x 1.9 x 1.4 x 1.09 x _____
= 31.9 cfs

8. Modifications for Urbanization

IMP = _____ % : Percentage of Impervious Area (based on actual drainage area A)
IMPF = _____ : Impervious Area Adjustment Factor (Fig. 12)
HLM = _____ % : Percentage of Hydraulic Length Modified
HLMF = _____ : Hydraulic Length Modified Factor (Fig. 13)

QPU = QP x IMPF x HLMF
= _____ x _____ x _____
= _____ cfs

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 1 OF 13	PAGE
SUBJECT: Size perimeter ditches	PREPARED BY MO 11/25/87	CHECKED BY GEM 1/22/88	REVISED BY / /

Refine ditch sizes taking into account flow velocities and design linings as necessary. Riprap linings are designed using the "Tentative Design Procedure for Riprap lined channels" from National Cooperative Highway Research Program Report No 108 and presented in "Erosion and Sediment Control Handbook" by Goldman, et. al.

Resize ditches as necessary:

1A $Q = 92.4$ cfs

$S = 0.037$

use $b = 6'$ $D = 1.5'$ $b/D = 4$ $P/R = 12$

$$d_{50} = 12\left(118\,(92.4)(0.037)^{13/6}\,\tfrac{1}{12}\right)^{2/5} = 10.5''$$

$n = 0.039$

$$Q = \frac{0.176}{0.039}(6)^{2.67}(0.037)^{1/2} = 103.8 \text{ cfs} \checkmark$$

1B $Q = 112.8$

$S = 0.108$

use $b = 6'$ $D = 1.5'$ $b/D = 4$ $P/R = 12$

$$d_{50} = 12\left(118(112.8)(0.108)^{13/6}\,\tfrac{1}{12}\right)^{2/5} = 28.8 \quad \text{too large}$$

$$K' = \frac{112.8\,(0.03)}{6^{2.67}\,(0.108)^{1/2}} = 0.086 \qquad D = 0.17\,(6) = 1'$$

$$V = \frac{112.8}{1(6+2(1))} = 14 \text{ fps}$$

Use 12" thick gabion lining

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 2 OF 13	PAGE
SUBJECT: Size perimeter ditches	PREPARED BY CMO 11/25/87	CHECKED BY GEM 1/22/88	REVISED BY / /

1C $Q = 169.4$

$S = 0.045$

use $b = 8'$ $D = 2'$ $b/D = 4$ $P/R = 12$

$d_{50} = 12\left(118(169.4)(0.045)^{13/6}\frac{1}{12}\right)^{2/5} = 15.8''$

$n = 0.042$

$Q = \frac{0.176}{0.042}(8)^{2.67}(0.045)^{1/2} = 229$ cfs ✓

1D $Q = 183.2$

$S = 0.031$

use $b = 8'$ $D = 2'$ $b/D = 4$ $P/R = 12$

$d_{50} = 12\left(118(183.2)(0.031)^{13/6}\frac{1}{12}\right)^{2/5} = 11.8''$

$n = 0.04$

$Q = \frac{0.176}{0.04}(8)^{2.67}(0.031)^{1/2} = 199$ cfs ✓

1E $Q = 238.4$ cfs

$S = 0.008$

use $b = 8'$ $D = 3'$ $b/D = 2.7$ $P/R = 11$

$d_{50} = 12\left(118(238.4)(0.008)^{13/6}\frac{1}{11}\right)^{2/5} = 4.2''$

$n = 0.034$

$Q = \frac{0.372}{0.034}(8)^{2.67}(0.008)^{1/2} = 252$ cfs ✓

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 3 OF 13	PAGE
SUBJECT: Size perimeter ditches	PREPARED BY CMO 11/25/87	CHECKED BY ACM 1/22/88	REVISED BY / /

2A $Q = 10$ cfs

$S = 0.023$

$b = 6'$ $D = 1.5'$

$K' = \frac{10\,(0.03)}{6^{2.67}\,(0.023)^{1/2}} = 0.0165$ $D = 0.07(6) = 0.42'$

$V = \frac{10}{0.42(6+2(0.42))} = 3.5$ fps grass only

2B $Q = 165.4$ cfs

$S = 0.111$

$b = 6'$ $D = 1.5'$ $b/D = 4$ $P/12 = 12$

$d_{50} = 12\left(118\,(165.4)(0.111)^{13/6}\ \frac{1}{12}\right)^{2/5} = 34''$ • too large

$K' = \frac{165.4\,(0.03)}{6^{2.67}\,(0.111)^{1/2}} = 0.125$ $D = 0.20(6) = 1.2$

$V = \frac{165.4}{1.2(6+2(1.2))} = 16.4$ fps use 12" gabion lining

2C $Q = 190.9$ cfs

$S = 0.042$

$b = 8'$ $D = 2'$ $b/D = 4$ $P/12 = 12$

$d_{50} = 12\left(118\,(190.9)(0.042)^{13/6}\ \frac{1}{12}\right)^{2/5} = 15.7''$

$n = 0.042$

$Q = \frac{0.176}{0.042}(8)^{2.67}(0.042)^{1/2} = 221$ cfs ✓

3A $Q = 46.7$ cfs

$S = 0.017$

$b = 8'$ $D = 1.5'$

$K' = \frac{46.7\,(0.03)}{8^{2.67}\,(0.017)^{1/2}} = 0.042$ $D = 0.12(8) = 1'$

$V = \frac{46.7}{1(8+2(1))} = 4.7$ fps grass only

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 5 OF 13	PAGE
SUBJECT: Size perimeter ditches	PREPARED BY CMO 11/25/87	CHECKED BY GEM 1/22/88	REVISED BY / /

6A $Q = 80.1$ cfs

$S = 0.060$

$b = 6'$ $D = 1.5'$ $b/D = 4$ $P/R = 12$

$d_{50} = 12\left(118(80.1)(0.06)^{13/6}\frac{1}{12}\right)^{2/5} = 15''$

$n = 0.042$

$Q = \frac{0.176}{0.042}(6)^{2.67}(0.06)^{1/2} = 122$ cfs ✓

6B $Q = 131.3$ cfs

$S = 0.129$

$b = 6'$ $D = 1.5'$

$K' = \frac{131.3\ (0.03)}{6^{2.67}(0.129)^{1/2}} = 0.088$ $D = 0.17(6) = 1'$

$V = \frac{131.3}{1(6+2(1))} = 16.4$

use 12" thick gabion liner

6C $Q = 161.6$ cfs

$S = 0.040$

$b = 6'$ $D = 2'$ $b/D = 3$ $P/R = 11$

$d_{50} = 12\left(118(161.6)(0.04)^{13/6}\frac{1}{11}\right)^{2/5} = 14.5''$

$n = 0.042$

$Q = \frac{0.298}{0.042}(6)^{2.67}(0.04)^{1/2} = 169$ cfs ✓

6D $Q = 161.6$

$S = 0.067$

$b = 6'$ $D = 2'$ $b/D = 3$ $P/R = 11$

$d_{50} = 12\left(118(161.6)(0.067)^{13/6}\frac{1}{11}\right)^{2/5} = 22.8''$ too large

use 12" thick gabion liner

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 6 OF 13	PAGE
SUBJECT: Size perimeter ditches	PREPARED BY CMA 11/25/87	CHECKED BY aym 1/22/88	REVISED BY / /

6E $Q = 161.6$ cfs

$S = 0.014$

$b = 10'$ $D = 2'$ $b/D = 5$ $P/R = 13$

$d_{50} = 12\left(118(161.6)(0.014)^{13/6}\frac{1}{13}\right)^{2/5} = 5.5''$

7A & 8A $Q = 8.5$ cfs

$S = 0.017$

$b = 6'$ $D = 1.5'$

$k' = \frac{8.5(0.03)}{6^{2.67}(0.017)^{1/2}} = 0.016$ $D = 0.07(6) = 0.4$

$V = \frac{8.5}{0.4(6+0.8)} = 3.1$ fps grass only

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 4 OF 13	PAGE
SUBJECT: Size perimeter ditches	PREPARED BY CMA 11/25/87	CHECKED BY DEM 1/22/88	REVISED BY / /

4A $Q = 38.8$

$s = 0.024$

$b = 8'$ $D = 1.5'$

$$K' = \frac{38.8(0.03)}{8^{2.67}(0.024)^{1/2}} = 0.029 \qquad D = 0.09(8) = 0.7'$$

$$V = \frac{38.8}{0.7(8+2(0.7))} = 5.9 \text{ fps}$$

$b = 10'$ $D = 1.5'$

$$K' = \frac{38.8(0.03)}{10^{2.67}(0.024)^{1/2}} = 0.0161 \qquad D = 0.07(10) = 0.7'$$

$$V = \frac{38.8}{0.7(10+2(0.7))} = 4.9 \text{ fps}$$ grass only

5A $Q = 71.7$ cfs

$s = 0.090$

$b = 6$ $D = 1.5$ $b/D = 4$ $P/R = 12$

$$d_{50} = 12\left(118(71.7)(0.090)^{13/6}\tfrac{1}{12}\right)^{2/5} = 20.5'' \text{ too large}$$

$$K' = \frac{71.7(0.03)}{6^{2.67}(0.09)^{1/2}} = 0.060 \qquad D = 0.14(6) = 0.84'$$

$$V = \frac{71.7}{0.84(6+2(0.84))} = 11.1 \text{ fps}$$

use 12" thick gabion lining

5B $Q = 170.5$

$s = 0.185$

$b = 6'$ $D = 1.5'$

$$K' = \frac{170.5(0.03)}{6^{2.67}(0.185)^{1/2}} = 0.099 \qquad D = 0.19(6) = 1.1'$$

$$V = \frac{170.5}{1.1(6+(1.1)2)} = 18.9 \text{ fps}$$

use 12" thick gabion lining

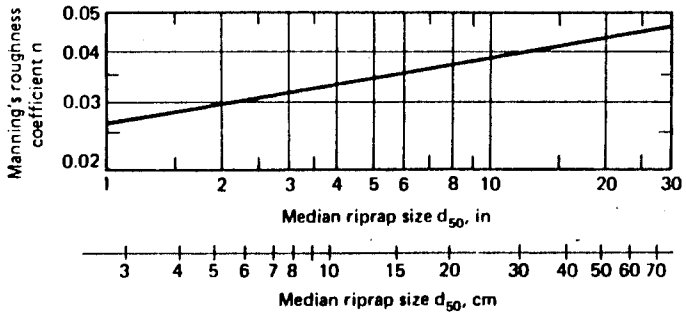


Fig. 7.29 Manning's n value for riprap-lined channels. (14)

4. For channels with bends, calculate the ratio B_s/R_o, where B_s is the channel surface width and R_o is the radius of the bend. Enter Fig. 7.32 and find the bend factor F_B. Multiply the d_{50} for straight channels by the bend factor to determine the riprap size to be used in bends. If the d_{50} for the bend is less than 1.1 times the d_{50} for the straight channel, then the size for the straight channel may be used in the bend. Otherwise, the larger stone size calculated for the bend should be used. The riprap should extend across the full channel section and extend upstream and downstream from the ends of the bend a distance equal to 5 times the bottom width.
5. Enter Fig. 7.33 to determine the maximum stable side slope of the riprap surface.

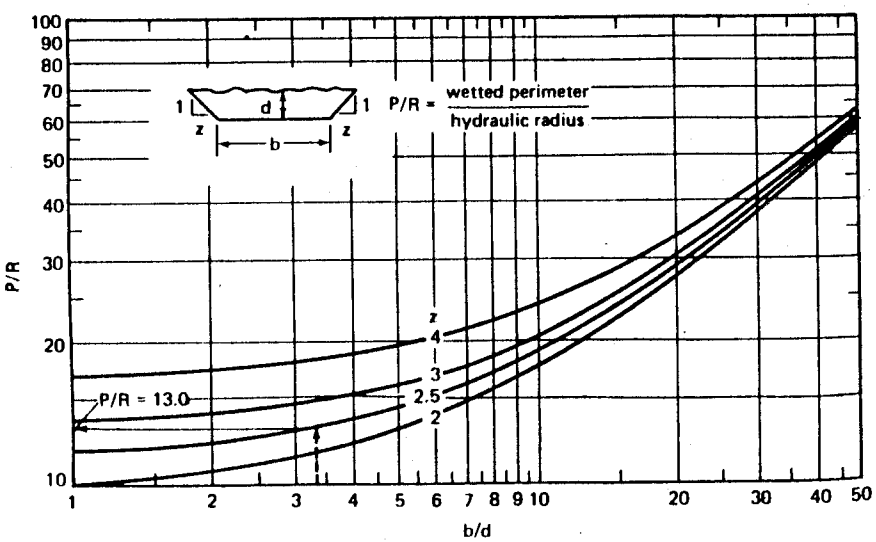


Fig. 7.30 Relation of P/R to B/D in trapezoidal channels. (14)

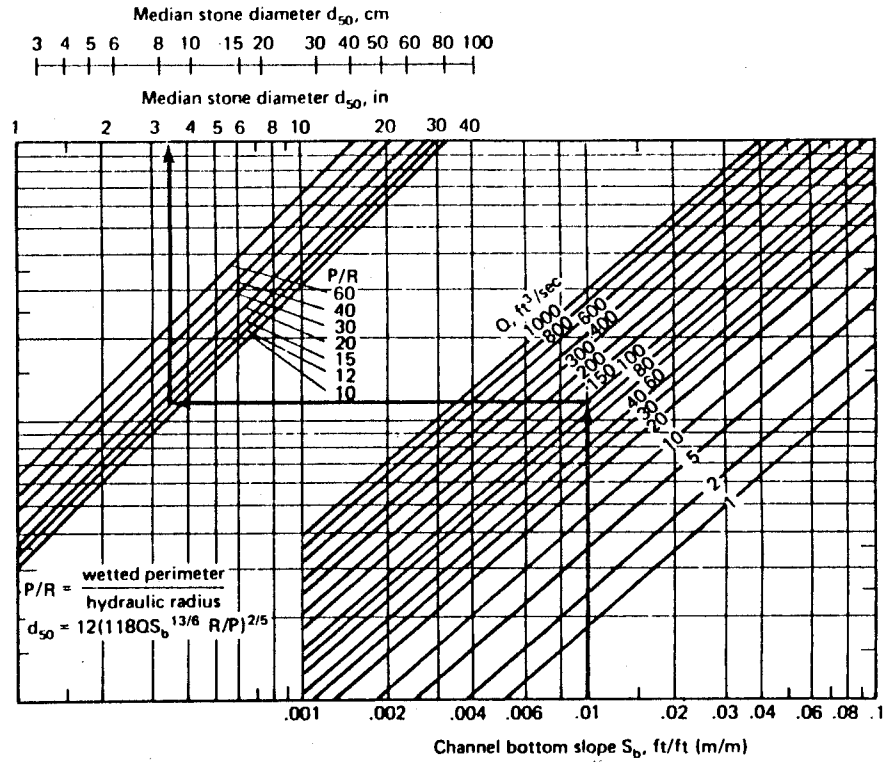


Fig. 7.31 Median riprap diameter for straight trapezoidal channels. (14)

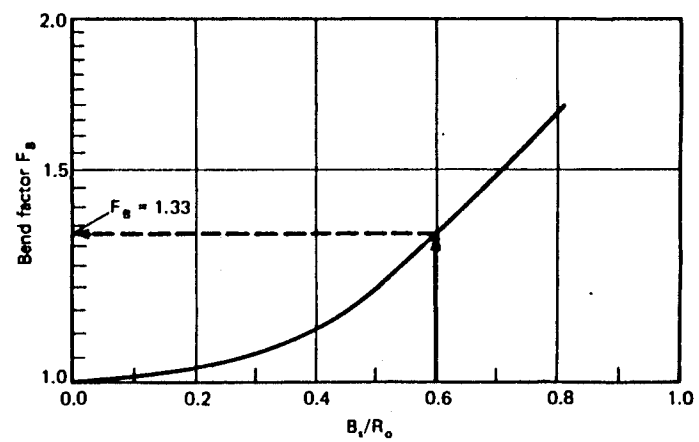


Fig. 7.32 Riprap size correction factor for flow in channel bends.
d_{50} (for bend) = d_{50} (for straight) × F_B
B_s = channel surface width
R_o = mean radius of bend

Table 7-10. Values of K in Formula $Q = \frac{K}{n} D^{5/3} s^{1/2}$ for Trapezoidal Channels

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼–1	½–1	¾–1	1–1	1½–1	2–1	2½–1	3–1	4–1
.01	146.7	147.2	147.6	148.0	148.3	148.8	149.2	149.5	149.9	150.5
.02	72.4	72.9	73.4	73.7	74.0	74.5	74.9	75.3	75.6	76.3
.03	47.6	48.2	48.6	49.0	49.3	49.8	50.2	50.6	50.9	51.6
.04	35.3	35.8	36.3	36.6	36.9	37.4	37.8	38.2	38.6	39.3
.05	27.9	28.4	28.9	29.2	29.5	30.0	30.5	30.9	31.2	32.0
.06	23.0	23.5	23.9	24.3	24.6	25.1	25.5	26.0	26.3	27.1
.07	19.5	20.0	20.4	20.8	21.1	21.6	22.0	22.4	22.8	23.6
.08	16.8	17.3	17.8	18.1	18.4	18.9	19.4	19.8	20.2	21.0
.09	14.8	15.3	15.7	16.1	16.4	16.9	17.4	17.8	18.2	19.0
.10	13.2	13.7	14.1	14.4	14.8	15.3	15.7	16.2	16.6	17.4
.11	11.83	12.33	12.76	13.11	13.42	13.9	14.4	14.9	15.3	16.1
.12	10.73	11.23	11.65	12.00	12.31	12.8	13.3	13.8	14.2	15.0
.13	9.80	10.29	10.71	11.06	11.37	11.9	12.4	12.8	13.3	14.1
.14	9.00	9.49	9.91	10.26	10.57	11.1	11.6	12.0	12.5	13.4
.15	8.32	8.80	9.22	9.57	9.88	10.4	10.9	11.4	11.8	12.7
.16	7.72	8.20	8.61	8.96	9.27	9.81	10.29	10.75	11.20	12.1
.17	7.19	7.67	8.08	8.43	8.74	9.28	9.77	10.23	10.68	11.6
.18	6.74	7.20	7.61	7.96	8.27	8.81	9.30	9.76	10.21	11.1
.19	6.31	6.78	7.19	7.54	7.85	8.39	8.88	9.34	9.80	10.7
.20	5.94	6.40	6.81	7.16	7.47	8.01	8.50	8.97	9.43	10.3
.21	5.60	6.06	6.47	6.82	7.12	7.67	8.16	8.63	9.09	10.00
.22	5.30	5.76	6.16	6.51	6.82	7.36	7.86	8.33	8.79	9.70
.23	5.02	5.48	5.87	6.22	6.53	7.08	7.58	8.05	8.51	9.43
.24	4.77	5.22	5.62	5.96	6.27	6.82	7.32	7.79	8.26	9.18
.25	4.54	4.98	5.38	5.73	6.04	6.58	7.08	7.56	8.03	8.95
.26	4.32	4.77	5.16	5.51	5.82	6.37	6.87	7.35	7.81	8.74
.27	4.13	4.57	4.96	5.31	5.62	6.17	6.67	7.15	7.62	8.54
.28	3.95	4.38	4.77	5.12	5.43	5.98	6.48	6.96	7.43	8.36
.29	3.78	4.21	4.60	4.95	5.25	5.81	6.31	6.79	7.26	8.19
.30	3.62	4.05	4.44	4.78	5.09	5.64	6.15	6.63	7.10	8.04
.31	3.48	3.90	4.29	4.63	4.94	5.49	6.00	6.48	6.96	7.89
.32	3.34	3.77	4.15	4.49	4.80	5.35	5.86	6.34	6.82	7.75
.33	3.21	3.64	4.02	4.36	4.67	5.22	5.73	6.21	6.69	7.62
.34	3.09	3.51	3.89	4.23	4.54	5.10	5.60	6.09	6.56	7.50
.35	2.98	3.40	3.78	4.12	4.43	4.98	5.49	5.97	6.45	7.39
.36	2.88	3.29	3.67	4.01	4.31	4.87	5.38	5.86	6.34	7.28
.37	2.78	3.19	3.57	3.90	4.21	4.76	5.27	5.76	6.24	7.18
.38	2.68	3.09	3.47	3.81	4.11	4.67	5.17	5.66	6.14	7.09
.39	2.59	3.00	3.38	3.71	4.02	4.57	5.08	5.57	6.05	6.99
.40	2.51	2.92	3.29	3.62	3.93	4.48	4.99	5.48	5.96	6.91
.41	2.43	2.83	3.20	3.54	3.85	4.40	4.91	5.40	5.88	6.83
.42	2.36	2.76	3.13	3.46	3.77	4.32	4.83	5.32	5.80	6.75
.43	2.29	2.68	3.05	3.38	3.69	4.24	4.76	5.25	5.73	6.67
.44	2.22	2.61	2.98	3.31	3.62	4.17	4.68	5.17	5.66	6.60
.45	2.15	2.55	2.91	3.24	3.55	4.10	4.61	5.11	5.59	6.54

Table 7-10. Values of K in Formula $Q = \frac{K}{n} D^{5/3} s^{1/2}$ for Trapezoidal Channels (*Continued*)

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼–1	½–1	¾–1	1–1	1½–1	2–1	2½–1	3–1	4–1
.46	2.09	2.48	2.85	3.18	3.48	4.04	4.55	5.04	5.52	6.47
.47	2.03	2.42	2.78	3.12	3.42	3.97	4.49	4.98	5.46	6.41
.48	1.98	2.36	2.72	3.06	3.36	3.91	4.43	4.92	5.40	6.35
.49	1.92	2.31	2.67	3.00	3.30	3.85	4.37	4.86	5.34	6.29
.50	1.87	2.26	2.61	2.94	3.25	3.80	4.31	4.81	5.29	6.24
.51	1.82	2.20	2.56	2.89	3.19	3.75	4.26	4.75	5.24	6.19
.52	1.78	2.16	2.51	2.84	3.14	3.70	4.21	4.70	5.19	6.14
.53	1.73	2.11	2.46	2.79	3.09	3.65	4.16	4.65	5.14	6.09
.54	1.69	2.06	2.42	2.74	3.05	3.60	4.11	4.61	5.09	6.04
.55	1.65	2.02	2.37	2.70	3.00	3.55	4.07	4.56	5.05	6.00
.56	1.61	1.98	2.33	2.66	2.96	3.51	4.02	4.52	5.00	5.96
.57	1.57	1.94	2.29	2.61	2.92	3.47	3.98	4.48	4.96	5.92
.58	1.53	1.90	2.25	2.57	2.87	3.43	3.94	4.44	4.92	5.88
.59	1.50	1.86	2.21	2.53	2.84	3.39	3.90	4.40	4.88	5.84
.60	1.46	1.83	2.17	2.50	2.80	3.35	3.86	4.36	4.84	5.80
.61	1.43	1.79	2.14	2.46	2.76	3.31	3.83	4.32	4.81	5.76
.62	1.40	1.76	2.10	2.43	2.73	3.28	3.79	4.29	4.77	5.73
.63	1.37	1.73	2.07	2.39	2.69	3.24	3.76	4.25	4.74	5.70
.64	1.34	1.70	2.04	2.36	2.66	3.21	3.73	4.22	4.71	5.66
.65	1.31	1.67	2.01	2.33	2.63	3.18	3.69	4.19	4.68	5.63
.66	1.28	1.64	1.98	2.30	2.60	3.15	3.66	4.16	4.64	5.60
.67	1.26	1.61	1.95	2.27	2.57	3.12	3.63	4.13	4.61	5.57
.68	1.23	1.58	1.92	2.24	2.54	3.09	3.60	4.10	4.59	5.54
.69	1.21	1.56	1.89	2.21	2.51	3.06	3.58	4.07	4.56	5.51
.70	1.18	1.53	1.87	2.19	2.48	3.03	3.55	4.04	4.53	5.49
.71	1.16	1.51	1.84	2.16	2.46	3.01	3.52	4.02	4.50	5.46
.72	1.14	1.48	1.82	2.13	2.43	2.98	3.50	3.99	4.48	5.44
.73	1.12	1.46	1.79	2.11	2.41	2.96	3.47	3.97	4.45	5.41
.74	1.10	1.44	1.77	2.09	2.38	2.93	3.45	3.94	4.43	5.39
.75	1.08	1.41	1.75	2.06	2.36	2.91	3.42	3.92	4.41	5.36
.76	1.056	1.39	1.73	2.04	2.33	2.88	3.40	3.90	4.38	5.34
.77	1.037	1.37	1.70	2.02	2.31	2.86	3.38	3.87	4.36	5.32
.78	1.018	1.35	1.68	2.00	2.29	2.84	3.35	3.85	4.34	5.30
.79	1.000	1.33	1.66	1.97	2.27	2.82	3.33	3.83	4.32	5.28
.80	.982	1.31	1.64	1.95	2.25	2.80	3.31	3.81	4.30	5.26
.81	.965	1.30	1.62	1.93	2.23	2.78	3.29	3.79	4.28	5.24
.82	.949	1.28	1.60	1.92	2.21	2.76	3.27	3.77	4.26	5.22
.83	.933	1.26	1.59	1.90	2.19	2.74	3.25	3.75	4.24	5.20
.84	.917	1.24	1.57	1.88	2.17	2.72	3.23	3.73	4.22	5.18
.85	.902	1.23	1.55	1.86	2.15	2.70	3.22	3.71	4.20	5.16
.86	.887	1.21	1.53	1.84	2.14	2.68	3.20	3.70	4.18	5.14
.87	.872	1.20	1.52	1.83	2.12	2.67	3.18	3.68	4.17	5.12
.88	.858	1.18	1.50	1.81	2.10	2.65	3.16	3.66	4.15	5.11
.89	.844	1.17	1.49	1.79	2.09	2.63	3.15	3.64	4.13	5.09
.90	.831	1.15	1.47	1.78	2.07	2.62	3.13	3.63	4.12	5.08

8/13

Table 7-10. Values of K in Formula $Q = \frac{K}{n} D^{5/3} S^{1/2}$ for Trapezoidal Channels (*Continued*)

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼-1	½-1	¾-1	1-1	1½-1	2-1	2½-1	3-1	4-1
.91	.818	1.14	1.46	1.76	2.05	2.60	3.11	3.61	4.10	5.06
.92	.805	1.12	1.44	1.75	2.04	2.58	3.10	3.60	4.08	5.04
.93	.793	1.11	1.43	1.73	2.02	2.57	3.08	3.58	4.07	5.03
.94	.781	1.10	1.41	1.72	2.01	2.55	3.07	3.57	4.05	5.01
.95	.769	1.08	1.40	1.70	1.99	2.54	3.05	3.55	4.04	5.00
.96	.758	1.07	1.39	1.69	1.98	2.53	3.04	3.54	4.03	4.99
.97	.746	1.06	1.37	1.68	1.97	2.51	3.03	3.52	4.01	4.97
.98	.736	1.05	1.36	1.66	1.95	2.50	3.01	3.51	4.00	4.96
.99	.725	1.04	1.35	1.65	1.94	2.48	3.00	3.50	3.98	4.94
1.00	.714	1.02	1.33	1.64	1.93	2.47	2.99	3.48	3.97	4.93
1.01	.704	1.011	1.32	1.63	1.92	2.46	2.97	3.47	3.96	4.92
1.02	.694	1.000	1.31	1.61	1.90	2.45	2.96	3.46	3.95	4.91
1.03	.684	.989	1.30	1.60	1.89	2.43	2.95	3.45	3.93	4.89
1.04	.675	.979	1.29	1.59	1.88	2.42	2.94	3.43	3.92	4.88
1.05	.666	.968	1.28	1.58	1.87	2.41	2.92	3.42	3.91	4.87
1.06	.657	.958	1.27	1.57	1.86	2.40	2.91	3.41	3.90	4.86
1.07	.648	.948	1.26	1.56	1.84	2.39	2.90	3.40	3.89	4.85
1.08	.639	.939	1.25	1.55	1.83	2.38	2.89	3.39	3.88	4.84
1.09	.630	.929	1.24	1.54	1.82	2.37	2.88	3.38	3.86	4.83
1.10	.622	.920	1.23	1.53	1.81	2.36	2.87	3.37	3.85	4.81
1.11	.614	.911	1.22	1.52	1.80	2.34	2.86	3.36	3.84	4.80
1.12	.606	.902	1.21	1.51	1.79	2.33	2.85	3.35	3.83	4.79
1.13	.598	.893	1.20	1.50	1.78	2.32	2.84	3.34	3.82	4.78
1.14	.590	.884	1.19	1.49	1.77	2.31	2.83	3.33	3.81	4.77
1.15	.583	.876	1.18	1.48	1.76	2.30	2.82	3.32	3.80	4.76
1.16	.576	.868	1.17	1.47	1.75	2.30	2.81	3.31	3.79	4.75
1.17	.568	.859	1.16	1.46	1.74	2.29	2.80	3.30	3.78	4.74
1.18	.561	.851	1.15	1.45	1.74	2.28	2.79	3.29	3.77	4.74
1.19	.554	.844	1.14	1.44	1.73	2.27	2.78	3.28	3.77	4.73
1.20	.548	.836	1.14	1.43	1.72	2.26	2.77	3.27	3.76	4.72
1.21	.541	.828	1.13	1.42	1.71	2.25	2.76	3.26	3.75	4.71
1.22	.535	.821	1.12	1.42	1.70	2.24	2.75	3.25	3.74	4.70
1.23	.528	.814	1.11	1.41	1.69	2.23	2.75	3.24	3.73	4.69
1.24	.522	.807	1.10	1.40	1.68	2.22	2.74	3.23	3.72	4.68
1.25	.516	.800	1.10	1.39	1.68	2.22	2.73	3.23	3.71	4.67
1.26	.510	.793	1.09	1.38	1.67	2.21	2.72	3.22	3.71	4.67
1.27	.504	.786	1.08	1.38	1.66	2.20	2.71	3.21	3.70	4.66
1.28	.498	.779	1.08	1.37	1.65	2.19	2.70	3.20	3.69	4.65
1.29	.492	.773	1.07	1.36	1.65	2.18	2.70	3.19	3.68	4.64
1.30	.487	.767	1.06	1.35	1.64	2.18	2.69	3.19	3.67	4.64
1.31	.481	.760	1.05	1.35	1.63	2.17	2.68	3.18	3.67	4.63
1.32	.476	.754	1.05	1.34	1.62	2.16	2.67	3.17	3.66	4.62
1.33	.470	.748	1.04	1.33	1.62	2.15	2.67	3.16	3.65	4.61
1.34	.465	.742	1.04	1.33	1.61	2.15	2.66	3.16	3.65	4.61
1.35	.460	.736	1.03	1.32	1.60	2.14	2.65	3.15	3.64	4.60

Table 7-10. Values of K in Formula $Q = \frac{K}{n} D^{5/3} S^{1/2}$ for Trapezoidal Channels (*Continued*)

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼-1	½-1	¾-1	1-1	1½-1	2-1	2½-1	3-1	4-1
1.36	.455	.730	1.023	1.31	1.60	2.13	2.65	3.14	3.63	4.59
1.37	.450	.725	1.016	1.31	1.59	2.13	2.64	3.14	3.62	4.59
1.38	.445	.719	1.010	1.30	1.58	2.12	2.63	3.13	3.62	4.58
1.39	.441	.714	1.004	1.29	1.58	2.11	2.63	3.12	3.61	4.57
1.40	.436	.708	.998	1.29	1.57	2.11	2.62	3.12	3.60	4.57
1.41	.431	.703	.993	1.28	1.56	2.10	2.61	3.11	3.60	4.56
1.42	.427	.698	.987	1.28	1.56	2.09	2.61	3.10	3.59	4.55
1.43	.422	.692	.981	1.27	1.55	2.09	2.60	3.10	3.58	4.55
1.44	.418	.687	.976	1.26	1.55	2.08	2.59	3.09	3.58	4.54
1.45	.414	.682	.970	1.26	1.54	2.08	2.59	3.08	3.57	4.53
1.46	.409	.677	.965	1.25	1.53	2.07	2.58	3.08	3.57	4.53
1.47	.405	.672	.960	1.25	1.53	2.06	2.58	3.07	3.56	4.52
1.48	.401	.668	.954	1.24	1.52	2.06	2.57	3.07	3.56	4.52
1.49	.397	.663	.949	1.24	1.52	2.05	2.56	3.06	3.55	4.51
1.50	.393	.658	.944	1.23	1.51	2.05	2.56	3.06	3.54	4.50
1.51	.389	.654	.939	1.23	1.51	2.04	2.55	3.05	3.54	4.50
1.52	.385	.649	.934	1.22	1.50	2.04	2.55	3.04	3.53	4.49
1.53	.382	.645	.929	1.22	1.50	2.03	2.54	3.04	3.53	4.49
1.54	.378	.640	.925	1.21	1.49	2.03	2.54	3.03	3.52	4.48
1.55	.374	.636	.920	1.21	1.49	2.02	2.53	3.03	3.52	4.48
1.56	.371	.632	.915	1.20	1.48	2.02	2.53	3.02	3.51	4.47
1.57	.367	.628	.911	1.20	1.48	2.01	2.52	3.02	3.51	4.47
1.58	.364	.624	.906	1.19	1.47	2.01	2.52	3.01	3.50	4.46
1.59	.360	.620	.902	1.19	1.47	2.00	2.51	3.01	3.50	4.46
1.60	.357	.616	.897	1.18	1.46	2.00	2.51	3.00	3.49	4.45
1.61	.353	.612	.893	1.18	1.46	1.99	2.50	3.00	3.49	4.45
1.62	.350	.608	.889	1.17	1.45	1.99	2.50	2.99	3.48	4.44
1.63	.347	.604	.884	1.17	1.45	1.98	2.49	2.99	3.48	4.44
1.64	.344	.600	.880	1.16	1.44	1.98	2.49	2.98	3.47	4.43
1.65	.341	.596	.876	1.16	1.44	1.97	2.48	2.98	3.47	4.43
1.66	.337	.593	.872	1.16	1.43	1.97	2.48	2.97	3.46	4.42
1.67	.334	.589	.868	1.15	1.43	1.96	2.47	2.97	3.46	4.42
1.68	.331	.585	.864	1.15	1.42	1.96	2.47	2.96	3.45	4.41
1.69	.328	.582	.860	1.14	1.42	1.95	2.46	2.96	3.45	4.41
1.70	.326	.578	.856	1.14	1.42	1.95	2.46	2.96	3.44	4.41
1.71	.323	.575	.852	1.13	1.41	1.95	2.46	2.95	3.44	4.40
1.72	.320	.571	.849	1.13	1.41	1.94	2.45	2.95	3.44	4.40
1.73	.317	.568	.846	1.13	1.40	1.94	2.45	2.94	3.43	4.39
1.74	.314	.565	.841	1.12	1.40	1.93	2.44	2.94	3.43	4.39
1.75	.312	.561	.838	1.12	1.40	1.93	2.44	2.93	3.42	4.38
1.76	.309	.558	.834	1.12	1.39	1.92	2.43	2.93	3.42	4.38
1.77	.306	.555	.831	1.11	1.39	1.92	2.43	2.93	3.41	4.38
1.78	.304	.552	.827	1.11	1.38	1.92	2.43	2.92	3.41	4.37
1.79	.301	.549	.824	1.10	1.38	1.91	2.42	2.92	3.41	4.37
1.80	.298	.546	.820	1.10	1.38	1.91	2.42	2.91	3.40	4.36

9/13

Table 7-10. Values of K in Formula $Q = \frac{K}{n} D^{5/8} s^{1/2}$ for Trapezoidal Channels (*Concluded*)

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼-1	½-1	¾-1	1-1	1½-1	2-1	2½-1	3-1	4-1
1.81	.296	.543	.817	1.10	1.37	1.90	2.41	2.91	3.40	4.36
1.82	.293	.540	.813	1.09	1.37	1.90	2.41	2.91	3.39	4.36
1.83	.291	.537	.810	1.09	1.37	1.90	2.41	2.90	3.39	4.35
1.84	.289	.534	.807	1.09	1.36	1.89	2.40	2.90	3.39	4.35
1.85	.286	.531	.804	1.08	1.36	1.89	2.40	2.90	3.38	4.34
1.86	.284	.528	.801	1.08	1.36	1.89	2.40	2.89	3.38	4.34
1.87	.282	.525	.797	1.08	1.35	1.88	2.39	2.89	3.38	4.34
1.88	.279	.522	.794	1.07	1.35	1.88	2.39	2.88	3.37	4.33
1.89	.277	.520	.791	1.07	1.35	1.88	2.39	2.88	3.37	4.33
1.90	.275	.517	.788	1.07	1.34	1.87	2.38	2.88	3.37	4.33
1.91	.273	.514	.785	1.06	1.34	1.87	2.38	2.87	3.36	4.32
1.92	.270	.512	.782	1.06	1.34	1.87	2.38	2.87	3.36	4.32
1.93	.268	.509	.779	1.06	1.33	1.86	2.37	2.87	3.36	4.32
1.94	.266	.506	.776	1.05	1.33	1.86	2.37	2.86	3.35	4.31
1.95	.264	.504	.774	1.05	1.33	1.86	2.37	2.86	3.35	4.31
1.96	.262	.501	.771	1.05	1.32	1.85	2.36	2.86	3.35	4.31
1.97	.260	.499	.768	1.04	1.32	1.85	2.36	2.85	3.34	4.30
1.98	.258	.496	.765	1.04	1.32	1.85	2.36	2.85	3.34	4.30
1.99	.256	.494	.762	1.04	1.31	1.84	2.35	2.85	3.34	4.30
2.00	.254	.491	.760	1.04	1.31	1.84	2.35	2.84	3.33	4.29
2.01	.252	.489	.757	1.03	1.31	1.84	2.35	2.84	3.33	4.29
2.02	.250	.487	.754	1.03	1.30	1.83	2.34	2.84	3.33	4.29
2.03	.248	.484	.752	1.03	1.30	1.83	2.34	2.84	3.32	4.28
2.04	.247	.482	.749	1.02	1.30	1.83	2.34	2.83	3.32	4.28
2.05	.245	.480	.746	1.02	1.30	1.82	2.33	2.83	3.32	4.28
2.06	.243	.477	.744	1.02	1.29	1.82	2.33	2.83	3.31	4.28
2.07	.241	.475	.741	1.02	1.29	1.82	2.33	2.82	3.31	4.27
2.08	.239	.473	.739	1.01	1.29	1.82	2.33	2.82	3.31	4.27
2.09	.237	.471	.736	1.01	1.28	1.81	2.32	2.82	3.31	4.27
2.10	.236	.469	.734	1.01	1.28	1.81	2.32	2.81	3.30	4.26
2.11	.234	.466	.722	1.006	1.28	1.81	2.32	2.81	3.30	4.26
2.12	.232	.464	.729	1.004	1.28	1.81	2.31	2.81	3.30	4.26
2.13	.231	.462	.727	1.001	1.27	1.80	2.31	2.81	3.29	4.26
2.14	.229	.460	.724	.999	1.27	1.80	2.31	2.80	3.29	4.25
2.15	.227	.458	.722	.996	1.27	1.80	2.31	2.80	3.29	4.25
2.16	.226	.456	.720	.994	1.27	1.79	2.30	2.80	3.29	4.25
2.17	.224	.454	.718	.991	1.26	1.79	2.30	2.80	3.28	4.24
2.18	.223	.452	.715	.989	1.26	1.79	2.30	2.79	3.28	4.24
2.19	.221	.450	.713	.987	1.26	1.79	2.29	2.79	3.28	4.24
2.20	.219	.448	.711	.984	1.26	1.78	2.29	2.79	3.28	4.24
2.21	.218	.446	.709	.982	1.25	1.78	2.29	2.78	3.27	4.23
2.22	.216	.444	.706	.980	1.25	1.78	2.29	2.78	3.27	4.23
2.23	.215	.442	.704	.977	1.25	1.78	2.28	2.78	3.27	4.23
2.24	.213	.440	.702	.975	1.25	1.77	2.28	2.78	3.26	4.23
2.25	.212	.439	.700	.973	1.24	1.77	2.28	2.77	3.26	4.22
∞	.000	.091	.274	.500	.743	1.24	1.74	2.23	2.71	3.67

Table 7-11. Values of K' in Formula $Q = \frac{K'}{n} b^{5/8} s^{1/2}$ for Trapezoidal Channels

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼-1	½-1	¾-1	1-1	1½-1	2-1	2½-1	3-1	4-1
.01	.00068	.00068	.00069	.00069	.00069	.00069	.00069	.00069	.00070	.00070
.02	.00213	.00215	.00216	.00217	.00218	.00220	.00221	.00222	.00223	.00225
.03	.00414	.00419	.00423	.00426	.00428	.00433	.00436	.00439	.00443	.00449
.04	.00660	.00670	.00679	.00685	.00691	.00700	.00708	.00716	.00723	.00736
.05	.00946	.00964	.00979	.00991	.01002	.01019	.01033	.01047	.01060	.01086
.06	.0127	.0130	.0132	.0134	.0136	.0138	.0141	.0143	.0145	.0150
.07	.0162	.0166	.0170	.0173	.0175	.0180	.0183	.0187	.0190	.0197
.08	.0200	.0206	.0211	.0215	.0219	.0225	.0231	.0236	.0240	.0250
.09	.0241	.0249	.0256	.0262	.0267	.0275	.0282	.0289	.0296	.0310
.10	.0284	.0294	.0304	.0311	.0318	.0329	.0339	.0348	.0358	.0376
.11	.0329	.0343	.0354	.0364	.0373	.0387	.0400	.0413	.0424	.0448
.12	.0376	.0393	.0408	.0420	.0431	.0450	.0466	.0482	.0497	.0527
.13	.0425	.0446	.0464	.0480	.0493	.0516	.0537	.0556	.0575	.0613
.14	.0476	.0502	.0524	.0542	.0559	.0587	.0612	.0636	.0659	.0706
.15	.0528	.0559	.0585	.0608	.0627	.0662	.0692	.0721	.0749	.0805
.16	.0582	.0619	.0650	.0676	.0700	.0740	.0777	.0811	.0845	.0912
.17	.0638	.0680	.0716	.0748	.0775	.0823	.0866	.0907	.0947	.1026
.18	.0695	.0744	.0786	.0822	.0854	.0910	.0960	.1008	.1055	.1148
.19	.0753	.0809	.0857	.0899	.0936	.1001	.1059	.1115	.1169	.1277
.20	.0812	.0876	.0931	.0979	.1021	.1096	.1163	.1227	.1290	.1414
.21	.0873	.0945	.101	.106	.111	.120	.127	.135	.142	.156
.22	.0934	.1015	.109	.115	.120	.130	.139	.147	.155	.171
.23	.0997	.1087	.117	.124	.130	.141	.150	.160	.169	.187
.24	.1061	.1161	.125	.133	.140	.152	.163	.173	.184	.204
.25	.1125	.1236	.133	.142	.150	.163	.176	.188	.199	.222
.26	.119	.131	.142	.152	.160	.175	.189	.202	.215	.241
.27	.126	.139	.151	.162	.171	.188	.203	.218	.232	.260
.28	.132	.147	.160	.172	.182	.201	.217	.234	.249	.281
.29	.139	.155	.170	.182	.194	.214	.232	.250	.268	.302
.30	.146	.163	.179	.193	.205	.228	.248	.267	.287	.324
.31	.153	.172	.189	.204	.218	.242	.264	.285	.306	.347
.32	.160	.180	.199	.215	.230	.256	.281	.304	.327	.371
.33	.167	.189	.209	.227	.243	.271	.298	.323	.348	.396
.34	.174	.198	.219	.238	.256	.287	.316	.343	.370	.423
.35	.181	.207	.230	.251	.269	.303	.334	.363	.392	.450
.36	.189	.216	.241	.263	.283	.319	.353	.385	.416	.478
.37	.196	.225	.252	.275	.297	.336	.372	.406	.440	.507
.38	.203	.234	.263	.288	.312	.353	.392	.429	.465	.537
.39	.211	.244	.274	.301	.326	.371	.413	.452	.491	.568
.40	.218	.253	.286	.315	.341	.389	.434	.476	.518	.600
.41	.226	.263	.297	.328	.357	.408	.456	.501	.546	.633
.42	.233	.273	.309	.342	.373	.427	.478	.526	.574	.668
.43	.241	.283	.321	.357	.389	.447	.501	.553	.603	.703
.44	.248	.293	.334	.371	.405	.467	.525	.580	.633	.740
.45	.256	.303	.346	.386	.422	.488	.549	.607	.664	.777

10/13

Table 7-11. Values of K' in Formula $Q = \frac{K'}{n} b^{5/3} s^{1/2}$ for Trapezoidal Channels (*Continued*)

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼-1	½-1	¾-1	1-1	1½-1	2-1	2½-1	3-1	4-1
.46	.264	.313	.359	.401	.439	.509	.574	.636	.696	.816
.47	.271	.323	.372	.416	.457	.531	.599	.665	.729	.856
.48	.279	.334	.385	.432	.474	.553	.625	.695	.763	.897
.49	.287	.344	.398	.447	.493	.575	.652	.725	.797	.939
.50	.295	.355	.412	.463	.511	.598	.679	.757	.833	.983
.51	.303	.366	.425	.480	.530	.622	.707	.789	.869	1.03
.52	.311	.377	.439	.496	.549	.646	.736	.822	.907	1.07
.53	.319	.388	.453	.513	.569	.671	.765	.856	.945	1.12
.54	.327	.399	.467	.531	.589	.696	.795	.891	.984	1.17
.55	.335	.410	.482	.548	.609	.722	.826	.926	1.025	1.22
.56	.343	.422	.497	.566	.630	.748	.857	.963	1.07	1.27
.57	.351	.433	.511	.584	.651	.775	.889	1.000	1.11	1.32
.58	.359	.445	.526	.602	.673	.802	.922	1.038	1.15	1.37
.59	.367	.456	.542	.621	.694	.830	.956	1.077	1.20	1.43
.60	.375	.468	.557	.640	.717	.858	.990	1.117	1.24	1.49
.61	.383	.480	.573	.659	.739	.887	1.02	1.16	1.29	1.54
.62	.391	.492	.588	.678	.762	.916	1.06	1.20	1.33	1.60
.63	.399	.504	.604	.698	.785	.946	1.10	1.24	1.38	1.66
.64	.408	.516	.620	.718	.809	.977	1.13	1.28	1.43	1.72
.65	.416	.529	.637	.738	.833	1.008	1.17	1.33	1.48	1.79
.66	.424	.541	.653	.759	.857	1.04	1.21	1.37	1.53	1.85
.67	.433	.553	.670	.780	.882	1.07	1.25	1.42	1.59	1.91
.68	.441	.566	.687	.801	.907	1.10	1.29	1.47	1.64	1.98
.69	.449	.579	.704	.822	.933	1.14	1.33	1.51	1.69	2.05
.70	.457	.592	.722	.844	.959	1.17	1.37	1.56	1.75	2.12
.71	.466	.604	.739	.866	.985	1.21	1.41	1.61	1.81	2.19
.72	.474	.617	.757	.889	1.012	1.24	1.46	1.66	1.86	2.26
.73	.483	.631	.775	.911	1.039	1.28	1.50	1.71	1.92	2.34
.74	.491	.644	.793	.934	1.067	1.31	1.54	1.77	1.98	2.41
.75	.499	.657	.811	.957	1.095	1.35	1.59	1.82	2.05	2.49
.76	.508	.670	.830	.981	1.12	1.39	1.63	1.87	2.11	2.57
.77	.516	.684	.849	1.005	1.15	1.43	1.68	1.93	2.17	2.65
.78	.525	.698	.868	1.029	1.18	1.46	1.73	1.99	2.24	2.73
.79	.533	.711	.887	1.053	1.21	1.50	1.78	2.04	2.30	2.81
.80	.542	.725	.906	1.078	1.24	1.54	1.83	2.10	2.37	2.90
.81	.550	.739	.925	1.10	1.27	1.58	1.88	2.16	2.44	2.98
.82	.559	.753	.945	1.13	1.30	1.62	1.93	2.22	2.51	3.07
.83	.567	.767	.965	1.15	1.33	1.67	1.98	2.28	2.58	3.16
.84	.576	.781	.985	1.18	1.36	1.71	2.03	2.34	2.65	3.25
.85	.585	.796	1.006	1.21	1.40	1.75	2.08	2.41	2.72	3.35
.86	.593	.810	1.03	1.23	1.43	1.79	2.14	2.47	2.80	3.44
.87	.602	.825	1.05	1.26	1.46	1.84	2.19	2.54	2.87	3.54
.88	.610	.839	1.07	1.29	1.49	1.88	2.25	2.60	2.95	3.63
.89	.619	.854	1.09	1.31	1.53	1.93	2.31	2.67	3.03	3.73
.90	.628	.869	1.11	1.34	1.56	1.98	2.36	2.74	3.11	3.83

Table 7-11. Values of K' in Formula $Q = \frac{K'}{n} b^{5/3} s^{1/2}$ for Trapezoidal Channels (*Continued*)

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼-1	½-1	¾-1	1-1	1½-1	2-1	2½-1	3-1	4-1
.91	.636	.884	1.13	1.37	1.60	2.02	2.42	2.81	3.19	3.93
.92	.645	.899	1.15	1.40	1.63	2.07	2.48	2.88	3.27	4.04
.93	.653	.914	1.18	1.43	1.67	2.12	2.54	2.95	3.35	4.14
.94	.662	.929	1.20	1.46	1.70	2.17	2.60	3.02	3.44	4.25
.95	.671	.944	1.22	1.49	1.74	2.22	2.66	3.10	3.52	4.36
.96	.680	.960	1.24	1.52	1.78	2.27	2.73	3.17	3.61	4.47
.97	.688	.975	1.27	1.55	1.81	2.32	2.79	3.25	3.70	4.58
.98	.697	.991	1.29	1.58	1.85	2.37	2.85	3.33	3.79	4.70
.99	.706	1.006	1.31	1.61	1.89	2.42	2.92	3.40	3.88	4.81
1.00	.714	1.022	1.33	1.64	1.93	2.47	2.99	3.48	3.97	4.93
1.01	.723	1.04	1.36	1.67	1.97	2.53	3.05	3.56	4.06	5.05
1.02	.732	1.05	1.38	1.70	2.01	2.58	3.12	3.65	4.16	5.17
1.03	.741	1.07	1.41	1.73	2.05	2.63	3.19	3.73	4.26	5.30
1.04	.749	1.09	1.43	1.77	2.09	2.69	3.26	3.81	4.35	5.42
1.05	.758	1.10	1.46	1.80	2.13	2.75	3.33	3.90	4.45	5.55
1.06	.767	1.12	1.48	1.83	2.17	2.80	3.40	3.98	4.55	5.68
1.07	.776	1.14	1.50	1.86	2.21	2.86	3.48	4.07	4.66	5.81
1.08	.784	1.15	1.53	1.90	2.25	2.92	3.55	4.16	4.76	5.94
1.09	.793	1.17	1.56	1.93	2.29	2.98	3.62	4.25	4.86	6.07
1.10	.802	1.19	1.58	1.97	2.34	3.04	3.70	4.34	4.97	6.21
1.11	.811	1.20	1.61	2.00	2.38	3.10	3.78	4.43	5.08	6.35
1.12	.820	1.22	1.63	2.04	2.42	3.16	3.85	4.53	5.19	6.49
1.13	.829	1.24	1.66	2.07	2.47	3.22	3.93	4.62	5.30	6.63
1.14	.837	1.25	1.69	2.11	2.51	3.28	4.01	4.72	5.41	6.77
1.15	.846	1.27	1.71	2.14	2.56	3.35	4.09	4.81	5.52	6.92
1.16	.855	1.29	1.74	2.18	2.61	3.41	4.17	4.91	5.63	7.06
1.17	.864	1.31	1.77	2.22	2.65	3.47	4.25	5.01	5.75	7.21
1.18	.873	1.32	1.79	2.25	2.70	3.54	4.34	5.11	5.87	7.36
1.19	.882	1.34	1.82	2.29	2.75	3.61	4.42	5.21	5.99	7.52
1.20	.891	1.36	1.85	2.33	2.79	3.67	4.51	5.32	6.11	7.67
1.21	.899	1.38	1.88	2.37	2.84	3.74	4.59	5.42	6.23	7.83
1.22	.908	1.40	1.90	2.41	2.89	3.81	4.68	5.52	6.35	7.99
1.23	.917	1.41	1.93	2.44	2.94	3.88	4.77	5.63	6.48	8.15
1.24	.926	1.43	1.96	2.48	2.99	3.95	4.86	5.74	6.61	8.31
1.25	.935	1.45	1.99	2.52	3.04	4.02	4.95	5.85	6.73	8.48
1.26	.944	1.47	2.02	2.56	3.09	4.09	5.04	5.96	6.86	8.64
1.27	.953	1.49	2.05	2.60	3.14	4.16	5.13	6.07	6.99	8.81
1.28	.962	1.51	2.08	2.64	3.19	4.23	5.22	6.18	7.13	8.98
1.29	.971	1.52	2.11	2.69	3.24	4.31	5.32	6.30	7.26	9.16
1.30	.980	1.54	2.14	2.73	3.30	4.38	5.41	6.41	7.40	9.33
1.31	.989	1.56	2.17	2.77	3.35	4.46	5.51	6.53	7.53	9.51
1.32	.997	1.58	2.20	2.81	3.40	4.53	5.61	6.65	7.67	9.69
1.33	1.006	1.60	2.23	2.85	3.46	4.61	5.71	6.77	7.81	9.87
1.34	1.015	1.62	2.26	2.90	3.51	4.69	5.81	6.89	7.96	10.05
1.35	1.024	1.64	2.29	2.94	3.57	4.77	5.91	7.01	8.10	10.24

11/13

Table 7-11. Values of K' in Formula $Q = \frac{K'}{n} b^{5/3} s^{1/2}$ for Trapezoidal Channels (*Continued*)

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼-1	½-1	¾-1	1-1	1½-1	2-1	2½-1	3-1	4-1
1.36	1.03	1.66	2.32	2.98	3.62	4.85	6.01	7.14	8.24	10.4
1.37	1.04	1.68	2.35	3.03	3.68	4.93	6.11	7.26	8.39	10.6
1.38	1.05	1.70	2.38	3.07	3.74	5.01	6.21	7.39	8.54	10.8
1.39	1.06	1.72	2.42	3.11	3.79	5.09	6.32	7.51	8.69	11.0
1.40	1.07	1.74	2.45	3.16	3.85	5.17	6.42	7.64	8.84	11.2
1.41	1.08	1.76	2.48	3.21	3.91	5.25	6.53	7.77	8.99	11.4
1.42	1.09	1.78	2.51	3.25	3.97	5.34	6.64	7.91	9.15	11.6
1.43	1.10	1.80	2.55	3.30	4.03	5.42	6.75	8.04	9.31	11.8
1.44	1.11	1.82	2.58	3.34	4.09	5.51	6.86	8.17	9.46	12.0
1.45	1.11	1.84	2.61	3.39	4.15	5.59	6.97	8.31	9.62	12.2
1.46	1.12	1.86	2.65	3.44	4.21	5.68	7.08	8.45	9.78	12.4
1.47	1.13	1.88	2.68	3.49	4.27	5.77	7.20	8.59	9.95	12.6
1.48	1.14	1.90	2.71	3.53	4.33	5.86	7.31	8.73	10.11	12.8
1.49	1.15	1.92	2.75	3.58	4.39	5.95	7.43	8.87	10.28	13.1
1.50	1.16	1.94	2.78	3.63	4.46	6.04	7.54	9.01	10.45	13.3
1.51	1.17	1.96	2.82	3.68	4.52	6.13	7.66	9.15	10.6	13.5
1.52	1.18	1.98	2.85	3.73	4.58	6.22	7.78	9.30	10.8	13.7
1.53	1.19	2.00	2.89	3.78	4.65	6.31	7.90	9.45	11.0	14.0
1.54	1.20	2.03	2.92	3.83	4.71	6.41	8.02	9.59	11.1	14.2
1.55	1.20	2.05	2.96	3.88	4.78	6.50	8.15	9.74	11.3	14.4
1.56	1.21	2.07	3.00	3.93	4.85	6.60	8.27	9.90	11.5	14.6
1.57	1.22	2.09	3.03	3.98	4.91	6.69	8.40	10.05	11.7	14.9
1.58	1.23	2.11	3.07	4.03	4.98	6.79	8.52	10.20	11.9	15.1
1.59	1.24	2.13	3.11	4.09	5.05	6.89	8.65	10.36	12.0	15.3
1.60	1.25	2.16	3.14	4.14	5.12	6.99	8.78	10.52	12.2	15.6
1.61	1.26	2.18	3.18	4.19	5.18	7.09	8.91	10.7	12.4	15.8
1.62	1.27	2.20	3.22	4.25	5.25	7.19	9.04	10.8	12.6	16.1
1.63	1.28	2.22	3.25	4.30	5.32	7.29	9.17	11.0	12.8	16.3
1.64	1.29	2.24	3.29	4.35	5.40	7.39	9.30	11.2	13.0	16.6
1.65	1.29	2.27	3.33	4.41	5.47	7.50	9.44	11.3	13.2	16.8
1.66	1.30	2.29	3.37	4.46	5.54	7.60	9.57	11.5	13.4	17.1
1.67	1.31	2.31	3.41	4.52	5.61	7.70	9.71	11.7	13.6	17.3
1.68	1.32	2.33	3.45	4.57	5.68	7.81	9.85	11.8	13.8	17.6
1.69	1.33	2.36	3.49	4.63	5.76	7.92	9.99	12.0	14.0	17.9
1.70	1.34	2.38	3.52	4.69	5.83	8.02	10.13	12.2	14.2	18.1
1.71	1.35	2.40	3.56	4.74	5.90	8.13	10.3	12.3	14.4	18.4
1.72	1.36	2.43	3.60	4.80	5.98	8.24	10.4	12.5	14.6	18.7
1.73	1.37	2.45	3.64	4.86	6.06	8.35	10.6	12.7	14.8	18.9
1.74	1.38	2.47	3.68	4.92	6.13	8.46	10.7	12.9	15.0	19.2
1.75	1.39	2.50	3.73	4.98	6.21	8.58	10.8	13.1	15.2	19.5
1.76	1.39	2.52	3.77	5.04	6.29	8.69	11.0	13.2	15.4	19.8
1.77	1.40	2.54	3.81	5.10	6.36	8.80	11.1	13.4	15.7	20.1
1.78	1.41	2.57	3.85	5.16	6.44	8.92	11.3	13.6	15.9	20.3
1.79	1.42	2.59	3.89	5.22	6.52	9.03	11.4	13.8	16.1	20.6
1.80	1.43	2.62	3.93	5.28	6.60	9.15	11.6	14.0	16.3	20.9

Table 7-11. Values of K' in Formula $Q = \frac{K'}{n} b^{5/3} s^{1/2}$ for Trapezoidal Channels (*Concluded*)

D = depth of water b = bottom width of channel

$\frac{D}{b}$	Side slopes of channel, ratio of horizontal to vertical									
	Vertical	¼-1	½-1	¾-1	1-1	1½-1	2-1	2½-1	3-1	4-1
1.81	1.44	2.64	3.97	5.34	6.68	9.27	11.7	14.2	16.5	21.2
1.82	1.45	2.66	4.02	5.40	6.76	9.39	11.9	14.4	16.8	21.5
1.83	1.46	2.69	4.06	5.46	6.84	9.51	12.1	14.5	17.0	21.8
1.84	1.47	2.71	4.10	5.52	6.93	9.63	12.2	14.7	17.2	22.1
1.85	1.48	2.74	4.15	5.59	7.01	9.75	12.4	14.9	17.5	22.4
1.86	1.49	2.76	4.19	5.65	7.09	9.87	12.5	15.1	17.7	22.7
1.87	1.49	2.79	4.23	5.71	7.18	9.99	12.7	15.3	17.9	23.0
1.88	1.50	2.81	4.28	5.78	7.26	10.12	12.9	15.5	18.2	23.3
1.89	1.51	2.84	4.32	5.84	7.34	10.24	13.0	15.7	18.4	23.6
1.90	1.52	2.86	4.36	5.91	7.43	10.37	13.2	15.9	18.6	24.0
1.91	1.53	2.89	4.41	5.97	7.52	10.5	13.4	16.1	18.9	24.3
1.92	1.54	2.91	4.45	6.04	7.60	10.6	13.5	16.3	19.1	24.6
1.93	1.55	2.94	4.50	6.10	7.69	10.8	13.7	16.6	19.4	24.9
1.94	1.56	2.96	4.55	6.17	7.78	10.9	13.9	16.8	19.6	25.3
1.95	1.57	2.99	4.59	6.24	7.87	11.0	14.0	17.0	19.9	25.6
1.96	1.58	3.02	4.64	6.31	7.96	11.1	14.2	17.2	20.1	25.9
1.97	1.59	3.04	4.68	6.37	8.05	11.3	14.4	17.4	20.4	26.2
1.98	1.60	3.07	4.73	6.44	8.14	11.4	14.6	17.6	20.6	26.6
1.99	1.60	3.09	4.78	6.51	8.23	11.5	14.7	17.8	20.9	26.9
2.00	1.61	3.12	4.82	6.58	8.32	11.7	14.9	18.1	21.2	27.3
2.01	1.62	3.15	4.87	6.65	8.41	11.8	15.1	18.3	21.4	27.6
2.02	1.63	3.17	4.92	6.72	8.50	12.0	15.3	18.5	21.7	28.0
2.03	1.64	3.20	4.97	6.79	8.60	12.1	15.5	18.7	22.0	28.3
2.04	1.65	3.23	5.01	6.86	8.69	12.2	15.6	19.0	22.2	28.7
2.05	1.66	3.25	5.06	6.93	8.79	12.4	15.8	19.2	22.5	29.0
2.06	1.67	3.28	5.11	7.00	8.88	12.5	16.0	19.4	22.8	29.4
2.07	1.68	3.31	5.16	7.08	8.98	12.7	16.2	19.7	23.0	29.7
2.08	1.69	3.33	5.21	7.15	9.08	12.8	16.4	19.9	23.3	30.1
2.09	1.70	3.36	5.26	7.22	9.17	12.9	16.6	20.1	23.6	30.5
2.10	1.70	3.39	5.31	7.30	9.27	13.1	16.8	20.4	23.9	30.8
2.11	1.71	3.42	5.36	7.37	9.37	13.2	17.0	20.6	24.2	31.2
2.12	1.72	3.44	5.41	7.44	9.47	13.4	17.2	20.8	24.5	31.6
2.13	1.73	3.47	5.46	7.52	9.57	13.5	17.4	21.1	24.7	32.0
2.14	1.74	3.50	5.51	7.60	9.67	13.7	17.6	21.3	25.0	32.3
2.15	1.75	3.53	5.56	7.67	9.77	13.8	17.8	21.6	25.3	32.7
2.16	1.76	3.56	5.61	7.75	9.87	14.0	18.0	21.8	25.6	33.1
2.17	1.77	3.58	5.66	7.82	9.97	14.1	18.2	22.1	25.9	33.5
2.18	1.78	3.61	5.72	7.90	10.08	14.3	18.4	22.3	26.2	33.9
2.19	1.79	3.64	5.77	7.98	10.18	14.5	18.6	22.6	26.5	34.3
2.20	1.80	3.67	5.82	8.06	10.28	14.6	18.8	22.8	26.8	34.7
2.21	1.81	3.70	5.87	8.14	10.4	14.8	19.0	23.1	27.1	35.1
2.22	1.81	3.73	5.93	8.22	10.5	14.9	19.2	23.3	27.4	35.5
2.23	1.82	3.75	5.98	8.29	10.6	15.1	19.4	23.6	27.7	35.9
2.24	1.83	3.78	6.03	8.37	10.7	15.2	19.6	23.9	28.0	36.3
2.25	1.84	3.81	6.09	8.46	10.8	15.4	19.8	24.1	28.4	36.7

12/13

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 13 OF 13	PAGE
SUBJECT: Size perimeter ditches	PREPARED BY CMO 11/25/87	CHECKED BY / /	REVISED BY / /

DRAINAGE DITCH SCHEDULE

Ditch	b_{MIN} (ft)	D_{MIN} (ft)	Approx Length (ft)	Ave. Slope (ft/ft)	Lining
1A	6	1.5	350	0.037	Riprap $d_{50} = 10''$
1B	6	1.5	200	0.108	12" thick gabions
1C	8	2	500	0.045	12" thick gabions
1D	8	2	375	0.031	Riprap $d_{50} = 10''$
1E	8	3	900	0.008	Riprap $d_{50} = 6''$
2A	6	1.5	130	0.023	Grass
2B	6	1.5	375	0.111	12" thick gabions
2C	8	2	500	0.042	12" thick gabions
3A	8	1.5	1125	0.017	Grass
4A	8	1.5	700	0.024	Grass
5A	6	1.5	500	0.090	12" thick gabions
5B	6	1.5	100	0.185	12" thick gabions
6A	6	1.5	100	0.060	12" thick gabions
6B	6	1.5	275	0.129	12" thick gabions
6C	6	2	500	0.040	12" thick gabions
6D	6	2	150	0.067	12" thick gabions
6E	10	2	350	0.014	Riprap $d_{50} = 6''$
7A	6	1.5	175	0.020	Grass
8A	6	1.5	150	0.017	Grass

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 1 OF 5	PAGE
SUBJECT: Size drainage benches	PREPARED BY TMZ 11/9/87	CHECKED BY acm 1/22/88	REVISED BY / /

Assumptions:

Use results of stormwater runoff calcs.
Use tables in "Handbook of Hydraulics" by Brater & King

Calculation:

Max flow through B-1 is:

A-1 + A-3 + ⅓ A-5

32.7 cfs + 31.0 cfs + ⅓ (32.7 cfs) = 74.6 cfs

Max flow through B-2 is:

⅔ A-5 + A-7 + 6/7 A-9

⅔ (32.7 cfs) + 34.1 cfs + 6/7 (42.6 cfs) = 92.4 cfs

Max flow through B-3 is:

B-1 + ½ B-2

36.5 + ½ (29.5) = 51.2 cfs

Max flow through B-4 is:

½ B-2 + B-3 + B-4

½ (29.5 cfs) + 22.4 cfs + 19.4 cfs = 56.6 cfs

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 2 OF 5	PAGE
SUBJECT: Size drainage benches	PREPARED BY CMB 11/9/87	CHECKED BY AEM 1/22/88	REVISED BY / /

Max flow through B-5 is:

$6/7(A-2) + A-4 + 1/4(A-6) + 1/10(A-8)$

$6/7(36.0) + 31.0 + 1/4(26.6) + 1/10(32.0) = 71.7$ cfs

Max flow through B-6 is:

B-12 + B-11 + B-10 + B-9 + B-7

26.5 cfs + 17.6 cfs + 14.7 cfs + 28.2 cfs + 11.8 cfs = 98.8 cfs

Max flow through B-7 is:

$9/10(A-8) + A-10 + 3/4\ A-6$

$9/10(32.0) + 37.3 + 3/4(26.6) = 86.1$ cfs

Max flow through R-1 is:

$3/4(A-6) + 9/10(A-8)$

$3/4(26.6) + 9/10(32.0) = 48.8$ cfs

Max flow through R-2 is:

R-1 + B-8 + B-6

48.8 cfs + 4.0 cfs + 26.5 cfs = 79.3 cfs

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 3 OF 5	PAGE
SUBJECT: Size drainage benches	PREPARED BY CMX 11/9/87	CHECKED BY aem 1/22/88	REVISED BY / /

Size drainage benches to carry 100 cfs

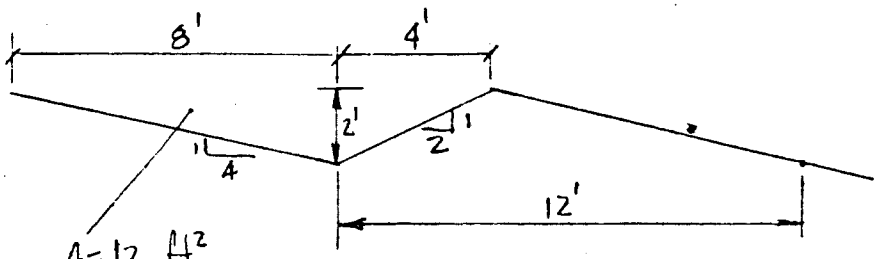
Size inside access road ditch to carry 80 cfs

Design drainage bench:

$Q = 100 cfs$

Assume $S = 0.01$

$n = 0.03$



$A = 12 \ ft^2$

$WP = 12.7 \ ft$

$R = \frac{12}{12.7} = 0.95 \ ft$

$$Q = \frac{1.486}{0.03}(0.95)^{2/3}(0.01)^{1/2}(12) = 57 \ cfs$$

Not sufficient

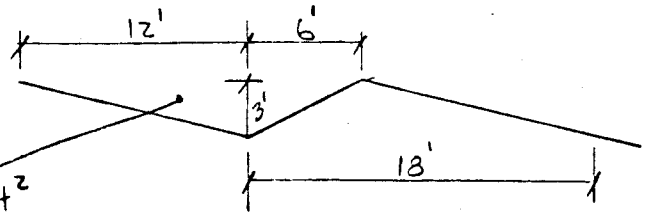
if $S = 0.05$:

$$Q = \frac{1.486}{0.03}(0.95)^{2/3}(0.05)^{1/2}(12) = 128 \ cfs$$ ok for road ditch

$$V = \frac{128}{12} = 10.7 \ fps$$

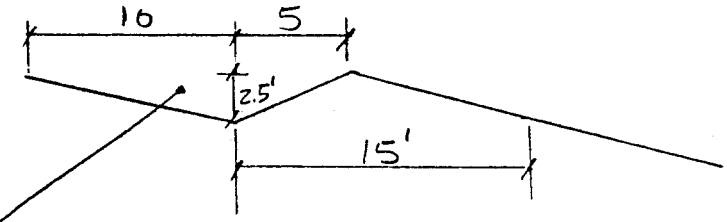
Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 4 OF 5	PAGE
SUBJECT: Size drainage benches	PREPARED BY CMA 11/9/87	CHECKED BY aem 1/22/88	REVISED BY / /

$S = 0.01$
$n = 0.03$



$A = 27\ ft^2$
$WP = 19.1\ ft$
$R = \frac{27}{19.1} = 1.42\ ft$

$$Q = \frac{1.486}{0.03}(1.42)^{2/3}(0.01)^{1/2}(27) = 170\ cfs$$



$S = 0.01$
$n = 0.03$

$A = 18.75\ ft^2$
$WP = 15.9$
$R = \frac{18.75}{15.9} = 1.18\ ft$

$$Q = \frac{1.486}{0.03}(1.18)^{2/3}(0.01)^{1/2}(18.75) = \underline{\underline{103.8\ cfs}}$$

$$V = \frac{103.8}{18.75} = 5.5\ fps$$

velocity too high, riprap req'd

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 5 OF 5	PAGE
SUBJECT: Size drainage benches	PREPARED BY CMG 11/9/87	CHECKED BY DEM 1/22/88	REVISED BY / /

Use method of sizing riprap as presented in the "Erosion and Sediment Control Handbook" by Goldman, et. al. (pg 7.40)

$$\frac{P}{R} = \frac{15.9}{1.18} = 13.5$$

$$d_{50} = 12\left(118\, Q\, S^{13/6}\, R/P\right)^{2/5}$$

$$d_{50} = 12\left(118\,(100\text{ cfs})(0.01)^{13/6}\ \frac{1}{13.5}\right)^{2/5} = 3.3''$$

use $d_{50} = 4''$ $\quad n = 0.033$ $\quad$ (fig 7.29)

$$Q = \frac{1.486}{0.033}(1.18)^{2/3}(0.01)^{1/2}(18.75) = 94 \text{ cfs}$$

Since minor overtopping of these drainage benches would not be a problem, this design is acceptable.

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 1 OF 1	PAGE
SUBJECT: Estimate soil loss	PREPARED BY CMO 11/12/87	CHECKED BY GCM 1/22/88	REVISED BY / /

Estimate soil loss with the Universal Soil Loss Equation:

$A = R \times K \times LS \times C \times P$

R = 250 (100 ft. tons/acre x in/hr)

Assume typical soils have a gradation of:

50% sand
30% silt
20% clay

K = 0.28

For a slope of 25% and length of 125'

LS = 6.55

Assume 90% cover, annual grass, no mulch

C = 0.1

Assume slopes are trackwalked parallel to contours

P = 0.9

$A = 250(0.28)(6.55)(0.1)(0.9) = 41$ tons/ac·year

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 1 OF 9	PAGE
SUBJECT: Size perimeter drainage ditches	PREPARED BY CMO 11/10/87	CHECKED BY DCM 1/22/88	REVISED BY / /

Assumptions

Flows into ditch segments are shown on the attached drawing

Use tables from "Handbook of Hydraulics" by Brater & King
Design trapezoidal sections with 2:1 side slopes

Size Ditches:

Preliminary sizes

1A

$Q = 92.4$ cfs
$S = 0.037$
$n = 0.03$

$A = Db + 2D^2 = D(b+2D)$

$K = \frac{Qn}{D^{8/3} S^{1/2}}$

$V = Q/A$

D	K	D/b	b
1.5	4.88	0.41	3.7
2	2.26	2.25	0.9
2.5	1.25	∞	0
3	0.78	∞	0

use $b = 4'$ $D = 1.5'$ $V \cong 8.8$ fps

1B

$Q = 112.8$ cfs
$S = 0.111$
$n = 0.03$

$K = \frac{112.8(0.03)}{D^{2.67}(0.111)^{1/2}}$

D	K	D/b	b
1	10.15	0.16	6.25
1.5	3.44	0.74	2.0
2	1.60	∞	0

use $b = 4'$ $D = 1.5'$ $V \cong 10.7$ fps

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 2 OF 9	PAGE
SUBJECT: Size perimeter ditches	PREPARED BY CMR 11/11/87	CHECKED BY GEM 1/22/88	REVISED BY / /

1C

$Q = 169.4$ cfs
$S = 0.024$
$n = 0.03$

$$K = \frac{169.4\,(0.03)}{D^{2.67}\,(0.024)^{1/2}}$$

D	K	D/b	b
1	32.8	0.05	20
1.5	11.11	0.14	10.7
2	5.15	0.38	5.3
2.5	2.84	1.13	2.2

Use $b = 6'$ $D = 2'$ $V \cong 8.5$ fps

1D

$Q = 183.2$
$S = 0.133$
$n = 0.03$

$$K = \frac{183.2\,(0.03)}{D^{2.67}\,(0.133)^{1/2}}$$

not required

D	K	D/b	b
1	15.07	0.10	10
1.5	5.1	0.39	3.8
2	2.36	1.96	1.0

Use $b = 6'$ $D = 2'$ $V \cong 16$ fps

1D
~~1E~~

$Q = 183.2$
$S = 0.029$
$n = 0.03$

$$K = \frac{183.2\,(0.03)}{D^{2.67}\,(0.029)^{1/2}}$$

D	K	D/b	b
1	32.27	0.05	20
1.5	10.93	0.15	10
2	5.07	0.39	5.1
2.5	2.80	1.17	2.1

use $b = 6'$ $D = 2'$ $V \sim 10$ fps

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 3 OF 9	PAGE
SUBJECT: Size Perimeter ditches	PREPARED BY CMA 11/12/87	CHECKED BY aem 1/22/88	REVISED BY / /

1E

$Q = 238.4$
$S = 0.010$
$n = 0.03$

$$k = \frac{238.4\,(0.03)}{D^{2.67}\,(0.010)^{1/2}}$$

D	k	D/b	b
1	71.5	0.02	50
1.5	24.2	0.06	25
2	11.2	0.14	14
2.5	6.2	0.30	8.3
3	3.8	0.61	4.9

Use $b = 6'$ $D = 3'$ $V \sim 7$ fps

2A

$Q \sim 10$ cfs
$S = 0.030$
$n = 0.03$

$$k = \frac{10\,(0.03)}{D^{2.67}\,(0.03)^{1/2}}$$

D	k	D/b	b
1	1.74	∞	0

use $b = 4'$ $D = 1.5'$ $V \sim 5$ fps
(same as 2B)

2B

$Q = 165.4$ cfs
$S = 0.100$
$n = 0.03$

$$k = \frac{165.4\,(0.03)}{D^{2.67}\,(0.100)^{1/2}}$$

D	k	D/b	b
1	15.7	0.10	10
1.5	5.31	0.36	4.2
2	2.46	1.69	1.2

use $b = 4'$ $D = 1.5'$ $V \sim 15$ fps

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 4 OF 9	PAGE
SUBJECT: Size perimeter ditches	PREPARED BY CMA 11/12/87	CHECKED BY GEM 1/22/88	REVISED BY / /

2C

$Q = 190.9$ cfs
$S = 0.042$
$n = 0.03$

$$K = \frac{190.9\,(0.03)}{D^{2.67}\,(0.042)^{1/2}}$$

D	K	D/b	b
1	27.9	0.05	20
1.5	9.47	0.16	9.4
2	4.39	0.41	4.9
2.5	2.42	1.79	1.4

Use $b = 6'$ $D = 2'$ $V \sim 11$ fps

3A

$Q = 46.7$ cfs
$S = 0.010$
$n = 0.03$

$$K = \frac{46.7\,(0.03)}{D^{2.67}\,(0.010)^{1/2}}$$

D	K	D/b	b
1	14.0	0.11	9.1
1.5	4.75	0.43	3.5
2	2.20	2.25	0.9

Use $b = 4$ $D = 1.5'$ $V \sim 4.8$ fps

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 5 OF 9	PAGE
SUBJECT: Size perimeter ditches	PREPARED BY CMD 11/12/87	CHECKED BY GEM 1/22/88	REVISED BY / /

4A

$Q = 38.8$ cfs
$S = 0.02$
$n = 0.03$

$$K = \frac{38.8\,(0.03)}{D^{2.67}\,(0.02)^{1/2}}$$

D	K	D/b	b
1	8.23	0.20	5
1.5	2.78	2.21	0.67
2	1.29	∞	0

use $b = 4$ $D = 1.5$ $V \sim 5$ fps

~~4B~~

not req'd

$Q = 38.8$ cfs
$S = 0.050$
$n = 0.03$

$$K = \frac{38.8\,(0.03)}{D^{2.67}\,(0.05)^{1/2}}$$

Same as 4A

D	K	D/b	b
1	5.20	0.37	2.7
1.5	1.76	∞	0

use $b = 4'$ $D = 1.5'$ $V \sim 10$ fps

5A

$Q = 71.7$ cfs
$S = 0.050$
$n = 0.03$

$$K = \frac{71.7\,(0.03)}{D^{2.67}\,(0.05)^{1/2}}$$

D	K	D/b	b
1	9.62	0.17	5.88
1.5	3.25	0.83	1.8
2	1.51	∞	0

use $b = 4'$ $D = 1.5'$ $V \sim 10$ fps

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 6 OF 9	PAGE
SUBJECT: Size perimeter ditches	PREPARED BY CMX 11/12/87	CHECKED BY AEM 1/22/88	REVISED BY / /

~~5B~~

$Q = 71.7$ cfs
$S = 0.050$
$n = 0.140$

use $b = 4'$ $D = 1.5'$

$$K' = \frac{71.7(0.03)}{(4)^{2.67}(0.05)^{1/2}} = 0.24$$

$D/b = 0.3$ $D = 1.2$ $V \sim 9$ fps

5B
~~5C~~

$Q = 170.5$ cfs
$S = 0.100$
$n = 0.03$

$$K = \frac{170.5(0.03)}{D^{2.67}(0.10)^{1/2}}$$

D	k	D/b	b
1	16.2	0.09	11.1
1.5	5.48	0.35	4.3
2	2.54	1.53	1.3

use $b = 6'$ $D = 1.5'$ $V \sim 16$ fps

6A

$Q = 80.1$ cfs
$S = 0.065$
$n = 0.03$

$$K = \frac{80.1(0.03)}{D^{2.67}(0.065)^{1/2}}$$

D	k	D/b	b
1.	9.43	0.17	5.9
1.5	3.19	0.86	1.7
2	1.48	∞	0

Use $b = 4'$ $D = 1.5'$ $V \sim 8$ fps

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 7 OF 9	PAGE
SUBJECT: Size perimeter Ditches	PREPARED BY CMJ 11/14/87	CHECKED BY AEM 1/22/88	REVISED BY / /

6B

$Q = 131.3$ cfs
$S = 0.140$
$n = 0.03$

$$K = \frac{131.3\,(0.03)}{D^{2.67}\,(0.140)^{1/2}}$$

D	K	D/b	b
1	10.53	0.15	6.7
1.5	3.57	0.69	2.2
2	1.65	∞	0

Use $b = 4'$ $D = 1.5'$ $V \sim 12.5$ fps

6C

$Q = 161.6$ cfs
$S = 0.040$
$n = 0.03$

$$K = \frac{161.6\,(0.03)}{D^{2.67}\,(0.040)^{1/2}}$$

D	K	D/b	b
1	24.24	0.06	16.7
1.5	8.21	0.20	7.5
2	3.81	0.61	3.3

Use $b = 6'$ $D = 2'$ $V \cong 8$ fps

6D

$Q = 161.6$
$S = 0.067$
$n = 0.03$

Use $b = 6'$ $D = 2'$ (same as 6C)

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 8 OF 9	PAGE
SUBJECT: Size Perimeter Ditches	PREPARED BY CMR 11/14/87	CHECKED BY DEM 1/22/88	REVISED BY / /

6E $Q = 161.6$ cfs

$S = 0.014$

$n = 0.03$

$$K = \frac{161.6\,(0.03)}{D^{2.67}\,(0.014)^{1/2}}$$

D	K	D/b	b
1	41.0	0.03	33
1.5	13.9	0.11	13.6
2	6.4	0.28	7.1
2.5	3.55	0.70	3.6

Use $b = 8'$ $D = 2'$ $V \sim 7$ fps

7A – 8A $Q = \frac{1}{4}(33.9) = 8.5$ cfs

$S = 0.017$

$n = 0.03$

$$K = \frac{8.5\,(0.03)}{D^{2.67}\,(0.017)^{1/2}}$$

D	K	D/b	b
1	1.95	2.25	0.4
1.5	0.67	∞	0

Use $b = 4'$ $D = 1.5'$ $V \sim 1$ fps

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 9 OF 9	PAGE
SUBJECT: Size perimeter ditches	PREPARED BY CMO 11/14/87	CHECKED BY DEM 1/18/88	REVISED BY / /

Preliminary sizes

Ditch	b	D	APPROX LENGTH	AVE S
1A	4	1.5	350	0.037
1B	4	1.5	200	0.108
1C	6	2	500	0.045
1D	6	2	375	0.031
1E	6	3	900	0.008
2A	4	1.5	130	0.023
2B	4	1.5	375	0.111
2C	6	2	500	0.042
3A	4	1.5	1125	0.017
4A	4	1.5	700	0.024
5A	6	1.5	500	0.090
5B	6	1.5	100	0.185
6A	4	1.5	100	0.060
6B	4	1.5	275	0.129
6C	6	2	500	0.040
6D	6	2	150	0.067
6E	8	2	350	0.014
7A	4	1.5	175	0.020
8A	4	1.5	150	0.017

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 1 OF 7	PAGE
SUBJECT: Size Sedimentation Ponds	PREPARED BY CMO 11/12/87	CHECKED BY WM 1/22/88	REVISED BY / /

Assumptions:

Flows into sedimentation ponds were calculated previously
Use design methods presented in "Erosion and Sediment Control Handbook" by Goldman, et. al.

?. → 25 year 6 hr storm is 4.5"

Sedimentation Pond 1: (south west pond)

Peak flow into pond = 161.6 + 238.4 = 400 cfs

Total flow into pond (25 year 24 hour)

A-1 + A-3 + A-5 + A-7 + A-9 + B-1 + B-2 + B-3 + B-4 + B-5 + C-1 + C-2 + C-3 + C-4 + O-1

$$3.7 \text{ inches} \left(\frac{1 \text{ foot}}{12 \text{ inches}}\right)(158{,}900 \text{ ft}^2 + 142{,}100 + 155{,}500 + 189{,}400 + 256{,}400 + 111{,}000 + 88{,}500 + 64{,}000 + 58{,}300 + 54{,}300 + 114{,}000 + 126{,}800 + 68400 + 36{,}900) + 1.9 \text{ inch} \left(\frac{1}{12}\right)(81{,}000)$$

$$= 500{,}888 \text{ ft}^3 + 12{,}825 \text{ ft}^3 = 513{,}713 \text{ ft}^3$$

$$i_{Ave} = \frac{4.5''}{6} = 0.75 \text{ in/hr}$$

$$Q_{ave} = 0.25\,(0.75 \text{ in/hr})(39.2 \text{ ac}) = 7.4 \text{ cfs}$$

Retain 0.01 mm size particles

$$A_s = \frac{1.2\,Q}{V_s} = \frac{1.2(7.4)}{0.00024} = 37{,}000 \text{ ft}^2$$

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 2 OF 7	PAGE
SUBJECT: Size sedimentation Pond	PREPARED BY CMD 11/13/87	CHECKED BY AEM 1/22/88	REVISED BY / /

Sediment storage required:

$$41 \text{ tons/ac}\cdot\text{year } (39.2 \text{ ac}) = 1607 \text{ tons/year}$$

assume $\gamma = 100$ pcf

$$1607 \text{ tons/year } \left(\frac{2000 \text{ lbs}}{\text{ton}}\right)\left(\frac{1}{100 \text{ pcf}}\right) = 32{,}140 \text{ ft}^3$$

If flow enters the pond at 2 locations, and is divided into 161.6 cfs and 238.4 cfs:

$$\text{Contributing acreage} \sim \frac{238.4}{400}(39.2) = 23.4 \text{ ac}$$

$$Q_{ave} = 0.25\,(0.75 \text{ in/hr})(23.4 \text{ ac}) = 4.4 \text{ cfs}$$

$$A_s = \frac{1.2(4.4)}{0.00024} = 22{,}000 \text{ ft}^2$$

$\therefore$ required lengths are:

$w_s = 50'$	$l_s = 440'$
$w_s = 75'$	$l_s = 300'$
$w_s = 100'$	$l_s = 220'$

$$\frac{\text{settling length}}{\text{settling depth}} < 200$$

The maximum settling length of pond 1 is ~400'

$\therefore$ $d_{settling} \geq 2'$

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 3 OF 7	PAGE
SUBJECT: Sump Sedimentation Pond	PREPARED BY CMX 11/13/87	CHECKED BY GEM 1/22/88	REVISED BY / /

Min. required area of pond is 37,000 ft^2

To store 1 years sediment: $\frac{32,140\ ft^3}{37,000\ ft^2} = 0.9'$ is required

Design pond with a depth of 4'
Remove sediment which accumulates above 1.5' deep.

Check design with USDA-SCS method:

Required vol = 67 CY/ac (39.2ac) (27) = 70,913 CF

70,913 < 37,000 (4) ✓

Min vol before cleanout = 27 (39.2)(27) = 28,577 CF

28,577 < 2.5 (37,000) ✓

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 4 OF 7	PAGE
SUBJECT: Size Sedimentation Ponds	PREPARED BY CMA 11/13/87	CHECKED BY GEM 1/22/88	REVISED BY / /

Sedimentation Pond 2 : (North pond)

Peak flow into pond is 38.8 cfs + 170.5 cfs = 209.3 cfs

Contributing area is:

A-2 + A-4 + 1/4 A-6 + 1/10 A-8 + B-7 + B-9 + B-10 + B-11 + B-12 + C-8 + C-9

159,200 + 144,600 + 1/4 (158,400) + 1/10 (207,300) + 15,200 + 82,000 + 42,600 + 52,500 + 77,200 + 26,200 + 37,100

= 696,930 ft^2 = 16 acres

i_{ave} = 0.75 in/hr

Q_{ave} = 0.25 (0.75)(16) = 3.0 cfs

$$A_s = \frac{1.2(3.0)}{0.00024} = 15{,}000\ ft^2$$

required settling lengths : $w_s = 50'$ $l_s = 300'$

$w_s = 75'$ $l_s = 200'$

$$\frac{l_s}{d_s} < 200$$

max l_s = 200'

$\therefore d_s \geq 1'$

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 5 OF 7	PAGE
SUBJECT: Size Sedimentation Pond	PREPARED BY CMO 11/13/87	CHECKED BY AEM 1/22/88	REVISED BY / /

Sediment storage required:

41 tons/ac·year (16 ac) = 656 tons/year

$\gamma = 100$ pcf

$$656 \left(\frac{2000}{1}\right)\left(\frac{1}{100}\right) = 13{,}120 \text{ ft}^3$$

$$\frac{13{,}120 \text{ ft}^3}{15{,}000 \text{ ft}} = 0.9' \quad \text{required storage}$$

Design pond w/ min. depth of 5' and max. 2' of storage.

Check with USDA-SCS method

$67(16)(27) = 28{,}944$ CF $< 15{,}000(5)$ ✓

$27(16)(27) = 11{,}664$ CF $< 15{,}000(5-2)$ ✓

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 6 OF 7	PAGE
SUBJECT: Size Sedimentation Pond	PREPARED BY CMG 11/13/87	CHECKED BY / /	REVISED BY / /

Sedimentation Pond 3: (North east pond)

Peak flow into pond is 190.9 + 46.7 = 237.6 cfs

Contributing area is:

$\frac{3}{4}$A-6 + $\frac{9}{10}$ A-8 + A-10 + B-6 + B-8 + C-5 + C-6 + C-7

$\frac{3}{4}(158,400) + \frac{9}{10}(207,300) + 211,900 + 80,300 + 5000 + 63,400 + 70,200 + 20,500$

$= 756,670 \text{ ft}^2 \quad = 17.4 \text{ ac}$

$i_{AVE} = 0.75 \text{ in/hr}$

$Q_{ave} = 0.25(0.75)(17.4) = 3.3 \text{ cfs}$

$A_s = \frac{1.2(3.3)}{0.00024} = 16,500 \text{ ft}^2$

Flow enters from two locations. Approx. ave. flows are:

① $\frac{190.9}{237.6}(3.3) = 2.7 \text{ cfs}$

② $\frac{46.7}{237.6}(3.3) = 0.6 \text{ cfs}$

$A_{s①} = \frac{1.2(2.7)}{0.00024} = 13,500 \text{ ft}^2$ $\quad w_s = 50' \quad l_s = 270'$ $\quad w_s = 75' \quad l_s = 180'$

$A_{s②} = \frac{1.2(0.6)}{0.00024} = 3000 \text{ ft}^2$ $\quad w_s = 50' \quad l_s = 60'$

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 7 OF 7	PAGE
SUBJECT: Size Sedimentation Ponds	PREPARED BY CMR 11/13/87	CHECKED BY / /	REVISED BY / /

$\frac{l_s}{d_s} < 200$ max $l_s = 400'$

$\therefore d_s \geq 2'$

Sediment storage required:

41 tons/ac·year (17.4) = 713 tons/year

$\gamma = 100$ pcf

$713(2000)\left(\frac{1}{100}\right) = 14{,}270\ ft^3$

$\frac{14{,}270}{16{,}500} = 0.9'$ required storage

Design pond w/ min depth of 5' and max. 2' of storage

Check w/ USDA-SCS method

$67(17.4)(27) = 31{,}477 < 5(16{,}500)$ ✓

$27(17.4)(27) = 12{,}684 < (5-2)(16{,}500)$ ✓

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 1 OF 4	PAGE
SUBJECT: Size culverts under Freeman Road	PREPARED BY CMO 12/28/87	CHECKED BY aEM 1/22/88	REVISED BY / /

Assumptions:

Use Mannings equation for pipes flowing full.
Size for 100 year - 24 hr storm. (7.5 in)

Calculations:

Culvert #1 (western culvert)

total peak flow from 25 year - 24 hr storm is 170 cfs
peak flow from 100 year storm is $\frac{5.1}{3.7}(170) = 235$ cfs

$$Q = \frac{0.463}{n} d^{8/3} s^{1/2}$$

$n = 0.016$ for concrete pipe
$s = 0.015$

Try 48" pipe

$$Q = \frac{0.463}{0.016}(4)^{8/3}(0.015)^{1/2} = 143 \text{ cfs}$$

use 2 48" ϕ concrete pipes

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 2 OF 4	PAGE
SUBJECT: Size culverts under Freeman Road	PREPARED BY CMO 12/28/87	CHECKED BY DEM 1/22/88	REVISED BY / /

Culvert #2 (eastern culvert)

total peak flow from 25 year storm is 247 cfs

peak flow from 100 year storm is $\frac{5.1}{3.7}(247) = 340$ cfs

$S = 0.023$

Try 48" pipe

$$Q = \frac{0.463}{0.016}(4)^{8/3}(0.023)^{1/2} = 177 \text{ cfs}$$

Use 2 48" ϕ concrete pipes

Values of f for fire hose, computed from test data of the Underwriters' Laboratories, Inc., are shown in Table 6-1.

The Chezy Formula. This formula [Eq. (6-22)] was the earliest attempt to express energy loss in conduits algebraically.

$$V = c\sqrt{rs} \tag{6-22}$$

If in this formula r is replaced by $d/4$ and s by h/l, the value of h is given by the expression

$$h = \frac{4}{c^2}\frac{l}{d}V^2 \tag{6-23}$$

from which it can be seen that the Darcy-Weisbach formula [Eq. (6-19)] is a rearrangement of the Chezy formula, the roughness coefficients being related as follows:

$$f = \frac{8g}{c^2} \tag{6-24}$$

From the previous discussion concerning Fig. 6-4 it may be concluded that the Chezy formula would give excellent results for flow in rough conduits at large Reynolds numbers, where the exponent of V is approximately 2. When later investigators found that this formula did not adhere to test results for smooth pipe with low velocities, other empirical formulas were devised to satisfy each particular group of tests. Only in recent years has it become generally recognized that all such tests can be unified by means of Reynolds number.

A dimensional investigation of the Chezy formula will show that the left term has the dimension L/T whereas the right side is simply $L^{1/2}$. The expression is therefore not dimensionally homogeneous and can be used in the above form only in the foot-pound-second system.

The Manning[1] *Formula.* Manning concluded that C in Chezy should vary with $r^{1/6}$ as follows:

$$C = \frac{1.486}{n}r^{1/6} \tag{6-25}$$

where n is the roughness coefficient. Substitution of Eq. (6-25) in the Chezy formula [Eq. (6-22)] yields the following equation, which is in the form usually referred to as the Manning formula:

$$V = \frac{1.486}{n}r^{2/3}s^{1/2} \tag{6-26}$$

[1] Robert Manning, Flow of Water in Open Channels and Pipes, *Trans. Inst. Civil Engrs. (Ireland)*, vol. 20, 1890.

It is obvious from the variation in values of n derived from various tests that the constant 1.486 could be written 1.49 or 1.5 with no sacrifice in accuracy. It may be noted that the exact value of the constant in the Manning equation was chosen because it is the cube root of the number of feet in one meter (3.281) and is therefore the factor required to convert to the foot-pound-second system from the metric form of the Manning formula.

For round pipes flowing full, $d/4$ may be substituted for r and the Manning formula becomes

$$V = \frac{0.590}{n}d^{2/3}s^{1/2} \tag{6-26a}$$

A comparison of the Manning equation [Eq. (6-26)] with the Darcy-Weisbach equation [Eq. (6-19)] reveals the following relationship between n and f:

$$f = \frac{185n^2}{d^{1/3}} \tag{6-27}$$

It is convenient to express the Manning formula, when used for pipes, in one of the following forms:

$$V = \frac{0.590}{n}d^{2/3}s^{1/2} \tag{6-26a}$$

$$Q = \frac{0.463}{n}d^{8/3}s^{1/2} \tag{6-26b}$$

$$h = 2.87n^2\frac{lV^2}{d^{5/3}} \tag{6-26c}$$

$$h = 4.66n^2\frac{lQ^2}{d^{16/3}} \tag{6-26d}$$

$$d = \left(\frac{2.159Qn}{s^{1/2}}\right)^{3/8} \tag{6-26e}$$

$$d_i = \left(\frac{1,630Qn}{s^{1/2}}\right)^{3/8} \tag{6-26f}$$

The solution of the Manning formula expressed in terms of the diameter in inches d_i, s, and the discharge Q [formula (6-26*f*)] is given in Table 6-2. It is assumed that the length of pipe is known and that the value of n has been selected. The use of this table in solving three types of problems is described:

1. *To determine d_i, s and Q being given:* Table 6-2 gives directly the diameters of pipes in inches.

2. *To determine s, d_i and Q being given:* On the page having the proper n, in the same row with the given discharge, find the diameter nearest to the given diameter. At the top of the

column will be the approximate values of s. Closer values can be obtained by interpolation.

3. *To determine Q, s and d, being given:* On the page having the proper n, in the same column with the given s, find the diameter nearest to the given diameter. At the left end of this row will be the approximate discharge. Closer values can be obtained by interpolation.

Inasmuch as hydraulic formulas are never accurate enough to justify very close adherence to them, great exactness in interpolation is not desirable.

The values of n contained in the following table are recommended. Practically all the experimental results that have been published lie between the extremes of these values.

Values of n for Pipes, To Be Used with the Manning Formula

Kind of pipe	Variation		Use in designing	
	From	To	From	To
Clean uncoated cast-iron pipe	0.011	0.015	0.013	0.015
Clean coated cast-iron pipe	0.010	0.014	0.012	0.014
Dirty or tuberculated cast-iron pipe	0.015	0.035		
Riveted steel pipe	0.013	0.017	0.015	0.017
Lock-bar and welded pipe	0.010	0.013	0.012	0.013
Galvanized-iron pipe	0.012	0.017	0.015	0.017
Brass and glass pipe	0.009	0.013		
Wood-stave pipe	0.010	0.014		
Wood-stave pipe, small diameter	.....	.....	0.011	0.012
Wood-stave pipe, large diameter	.....	.....	0.012	0.013
Concrete pipe	0.010	0.017		
Concrete pipe with rough joints	.....	.....	0.016	0.017
Concrete pipe, "dry mix," rough forms	.....	.....	0.015	0.016
Concrete pipe, "wet mix," steel forms	.....	.....	0.012	0.014
Concrete pipe, very smooth	.....	.....	0.011	0.012
Vitrified sewer pipe	0.010	0.017	0.013	0.015
Common clay drainage tile	0.011	0.017	0.012	0.014
Corrugated metal (2⅔ × ½)	0.023	0.026		
Corrugated metal (3 × 1 and 6 × 1)	0.026	0.029		
Corrugated metal (6 × 2 structural plate)	0.030	0.033		
Rock, unlined	0.038	0.041		
Enameled steel	0.009	0.010		

The following tables will be found helpful in various solutions of the Manning formula: square roots of decimal numbers,

Table 7-17; two-thirds powers of numbers, Table 7-18; three-eighths powers of numbers, Table 7-20; areas of circles by hundredths, Table 6-4; diameters of circles in feet and inches with areas in square feet, Table 6-3. Table 6-5 gives circumferences of circles.

The Hazen-Williams Formula[1]. This formula is widely used in waterworks design. It is an empirical equation based on laboratory and field observation.

$$V = 1.318 C_H r^{0.63} s^{0.54} \tag{6-28}$$

Typical values of the Hazen-Williams discharge coefficient, C_H, are given in the following table:

Type of pipe	*C_H Value*
Extremely smooth and straight	140
Very smooth	130
New riveted steel	110
Old riveted steel	100
Old cast iron	95
Old pipes in poor condition	60 to 80

The equation has the advantage that the coefficient C_H is not a function of Reynolds number, but has the disadvantage that it is valid only for water and is not able to account for temperature or viscosity variations.

Selection of Energy-loss Equation and Friction Factor. Only two energy-loss equations have been presented in detail, the Darcy-Weisbach equation [Eq. (6-19)] and the Manning equation [Eq. (6-26)]. Many other formulas have been used for this purpose, notably those of Hazen-Williams,[1] Tutton,[2] Unwin,[3] Scobey,[4-6] Barnes,[7] and Lea.[8] A detailed discussion of these may be found in the third edition of this Handbook.

[1] G. S. Williams and A. Hazen, Hydraulic Tables, 3d ed., rev., John Wiley & Sons, Inc., New York, 1933.

[2] C. H. Tutton, The Flow of Water in Pipes, *J. Assoc. Eng. Soc.*, vol. 23, p. 151, 1899.

[3] W. C. Unwin, "A Treatise on Hydraulics," p. 217, A. & C. Black, Ltd., London, 1907.

[4] Fred C. Scobey, The Flow of Water in Concrete Pipe, *U.S. Dept. Agr. Bull.* 852, 1920.

[5] Fred C. Scobey, The Flow of Water in Wood Stave Pipe, *U.S. Dept. Agr. Bull.* 376, 1916, rev. 1926.

[6] Fred C. Scobey, The Flow of Water in Riveted Steel and Analogous Pipe, *U.S. Dept. Agr. Bull.* 15C, 1930.

[7] A. & A. Barnes, "Hydraulic Flow Reviewed," Spon and Chamberlain, New York, 1916.

[8] F. C. Lea, "Hydraulics," Edward Arnold (Publishers) Ltd., London, 1909.

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 1 OF 3	PAGE
SUBJECT: Size sed. pond structures	PREPARED BY CMO 12/28/87	CHECKED BY AZM 1/22/88	REVISED BY / /

Assumptions:

Use design aids presented in USDA-SCS manual.

Calculations

Sedimentation Pond 1:

Peak flow into pond is 400 cfs

Try a 72" riser with 2x36" outlet CMP's.

Allow for 1' of freeboard over top of riser to bottom of overflow spillway. Overflow spillway to be 3' deep.

If spillway is flowing 2' deep

inflow into riser is 230 cfs

Head on outlet pipes is $(3' + 4' - 1.5') = 5.5'$

Q out ~ 145 cfs

Flow over spill way must be 400 - 145 = 255 cfs

a 36' wide spillway is req'd.

downstream slope of embankment must be riprapped

Waste Management, Inc. Environmental Engineering Group	PROJECT Piedmont No. D-014	SHEET 2 OF 3	PAGE
SUBJECT: Size sed pond structures	PREPARED BY CMO 12/28/87	CHECKED BY ATM 1/22/88	REVISED BY / /

Sedimentation ponds 2 & 3 have similar depths and peak inflows. Use same design for both.

Max inflow ≅ 240 cfs

Bottom of spillway will be 1' above top of riser
Overflow spillway will be 3' deep, at max. flow the depth of flow over spillway will not exceed 2'

Use 1 36" CMP outlet

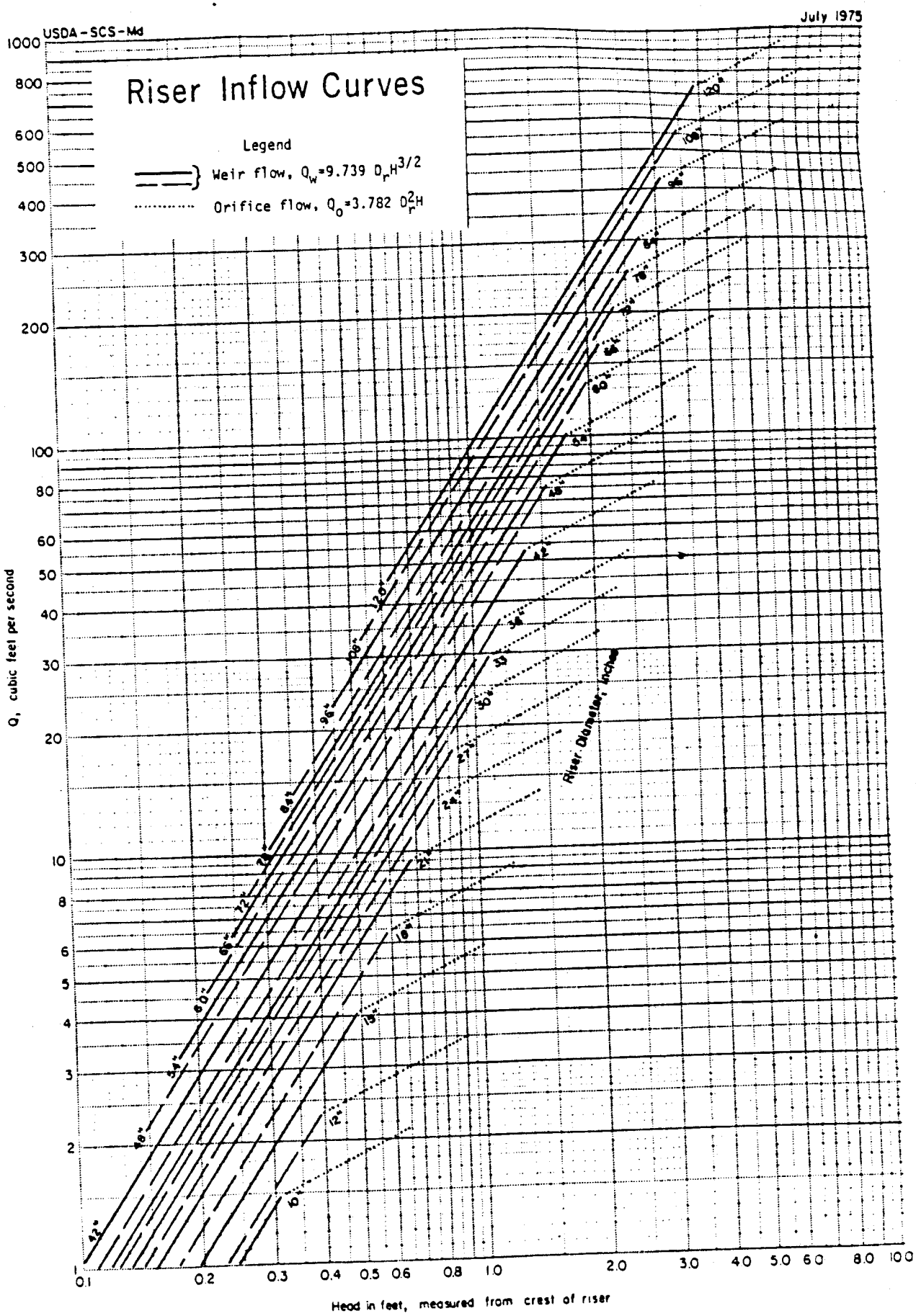
Max H = 5' + 3' - 1.5' = 6.5'

Qmax ~ 73 cfs

Min riser req'd ~42" use 48" ϕ riser

Flow over spillway 240 - 73 = 167 cfs

24' wide spillway req'd


USDA-SCS-Md
July 1975
Riser Inflow Curves
Legend
Weir flow, $Q_w = 9.739\ D_r H^{3/2}$
Orifice flow, $Q_o = 3.782\ D_r^2 H$
Q, cubic feet per second
Head in feet, measured from crest of riser
Riser Diameter, inches
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1
0.1
0.2
0.3
0.4
0.5
0.6
0.8
1.0
2.0
3.0
4.0
5.0
6.0
8.0
10.0
42"
36"
30"
27"
24"
21"
18"
15"
12"
10"
48"
54"
60"
66"
72"
78"
84"
96"
108"
120"

Appendix C

APPENDIX C

RECOMMENDED GRASS SPECIES AND SEEDING SCHEDULE FOR PERMANENT VEGETATIVE COVER

TABLE C-1

RECOMMENDED GRASS SPECIES AND

SEEDING SCHEDULE FOR PERMANENT VEGETATIVE COVER

PIEDMONT SANITARY LANDFILL

RECOMMENDED SPECIES	SEEDING[a] TIME	SEEDING[b] RATE, lb/A	COMMENTS
Tall fescue (Festuca Arundinacea Screb.)	Spring & Fall	40	Use K-31 or Alta varieties.
Perennial ryegrass (Lolium perenne L.)	Spring & Fall	40	Do not use named varieties. Quick germination.
Smooth bromegrass (Bromus inermis Leyss.)	Spring & Fall	20	Use southern type
Red top (Agrostis alba L.)	Spring & Fall	15	Not very tolerant of mowing. Good for wet conditions.
Weeping lovegrass (Eragrostis curvula Schrad.)	Spring & Early summer	5	Adaptable to sandy soil.

---

a For species that can be seeded spring and fall, fall seedings are almost always more successful.

b Seeding rates assume single species. Reduce rates by the number of components in mixtures. Minimum % pure live seed of 70% is assumed (% pure live seed = % germination x purity). If the % pure live seed is less than 70, increase seeding rate accordingly.

Appendix D

APPENDIX D

LANDFILL ENTRANCE SIGN:

"NO HAZARDOUS WASTES ACCEPTED"

SECTION IV FIGURE 1

Appendix E

APPENDIX E

LEACHATE MANAGEMENT PLAN

A Waste Management Company

LEACHATE MANAGEMENT PLAN

FOR THE PROPOSED PIEDMONT LANDFILL

KERNERSVILLE, NC

This plan has been developed to provide for the proper management of landfill leachate. Specifically, this plan provides for the reduction of leachate generation and to make provisions for leachate disposal.

1. **Diversion of Run-on.** Run-on from all areas adjoining the landfill is diverted around the landfill by perimeter ditching.

2. **Management of Run-off.** On-site drainage during development will be controlled by temporary drainage diversion berms. Clean stormwater will be diverted by these berms around the active fill area into existing natural drainageways. Drainage from the completed portions of the landfill will be collected and transported by terraces, ditches, and pipes into existing silt and proposed sedimentation ponds. The sedimentation ponds serve to reduce sediments from site runoff prior to being discharged into natural drainageways. Potential contamination of surface water can be limited by several methods. In the active fill area, temporary drainage swales and berms will be utilized to divert clean stormwater around the working face.

3. **Liquid Special Waste.** Bulk liquids will not be landfilled at this facility.

4. **Cover Design.** The final cover for this site will require clay soils and topsoil and/or other soils capable of sustaining vegetation. The proposed final grades and vegetative cover will promote sheet flow runoff of stormwater and thereby minimizing infiltration. Consequently, the leachate generation rate at the site should be reduced.

   Final cover will consist of materials whose hydraulic transmissivity is less than or equal to that of 3 feet of 1 x 10 cm/sec. Six inches of a mixture of topsoil and other soils capable of sustaining vegetation will then be placed atop this final cover. Soils available on the proposed site and other borrow sources will be evaluated for their capacity to meet this criteria.

5. **Landfill Staging.** Landfill construction is being phased to promote proper drainage, followed by placement of 12 inches intermediate cover. The working face is kept as small as possible. Intermediate slopes are constructed at 4H to 1V (approximately) and are vegetated if the slope will be exposed for a full growing season or longer.

6. **Leachate Collection and Analysis.** The leachate collection system, including collection lines, risers, and manholes, is being constructed as the landfill progresses in accordance with the approved design. Fluid levels in the leachate collection installed during landfill operations will be monitored on a monthly basis for leachate buildup. Records of

monitored liquid levels will be maintained and reviewed monthly for indications of leachate buildup which may require removal. A leachate level will be maintained in order to allow adequate flow into the collection sump from the leachate collection pipe. For the landfill collection system, the leachate will be removed as fluid levels necessitate.

Leachate will be removed from the riser by pumping. On an annual basis, a representative sample will be analyzed for the following parameters:

A. EP Toxicity or Toxicity Characteristic Leaching Procedure (TCLP) (as per NC Hazardous Waste Regulations).

B. Those parameters required by the treatment plant where disposal will take place, should it be considered non-hazardous.

7. **Leachate Disposal.** The above techniques will serve (1) to minimize leachate generation and (2) to provide for the management of any leachate generated. At this time there are no sanitary sewers within reasonable proximity to the landfill and as such, any leachate which is withdrawn will be trucked to an approved treatment plant operator. The operator's approval will be obtained prior to withdrawing any leachate.

Appendix F

APPENDIX F

QUALITY ASSURANCE MANUAL FOR

THE INSTALLATION OF GEOSYNTHETIC

LINING SYSTEM

Waste Management, Inc.

QUALITY ASSURANCE MANUAL FOR THE INSTALLATION OF HIGH DENSITY POLYETHYLENE GEOMEMBRANES

MAY 1985

TABLE OF CONTENTS

		Page
1.	INTRODUCTION	1
2.	DEFINITION OF OPERATIONS AND RESPONSIBILITIES	2
	2.1 Scope	2
	2.2 Parties	3
	2.3 Meetings	4
	2.3.1 Initial Meeting	4
	2.3.2 Pre-Construction Meeting	5
3.	QUALIFICATIONS OF PARTIES	7
	3.1 Manufacturer	7
	3.2 Fabricator	7
	3.3 Installer	9
	3.4 Inspector	10
4.	GEOMEMBRANE MANUFACTURING, FABRICATION AND DELIVERY	12
	4.1 Manufacturing	12
	4.1.1 Raw Materials	12
	4.1.2 Geomembrane Production	12
	4.1.3 Rolls	13
	4.1.4 Manufacturing Plant Visit	14
	4.2 Blanket Fabrication	14
	4.2.1 Definition of Blanket	14
	4.2.2 Blanket Geometry	15
	4.2.3 Requirements of Personnel	15
	4.2.4 Seaming Equipment and Products	15
	4.2.4.1 Extrusion Process	15
	4.2.4.2 Fusion Process	16
	4.2.5 Weather Conditions for Seaming	16
	4.2.6 Test Seams	16
	4.2.7 Overlapping and Temporary Bonding	17
	4.2.8 Non-destructive Seam Continuity Testing	17
	4.2.8.1 Vacuum Testing	17
	4.2.8.2 Air Pressure Testing (For double Fusion Seam Only)	18
	4.2.9 Destructive Seam Strength Testing	19

4.2.10 Repairs 19
4.2.11 Blanket Certification 20
4.2.12 Fabrication Factory Visit 20

4.3 Transportation, Handling and Storage 21

5. GEOMEMBRANE INSTALLATION 23

5.1 Earthwork 23

5.1.1 Surface Preparation 23
5.1.2 Crest Anchorage System 24

5.2 Geomembrane Placement 25

5.2.1 Panel Identification 25
5.2.2 Panel Placement 25

5.2.2.1 Location 25
5.2.2.2 Installation Schedule 26
5.2.2.3 Weather Conditions 26
5.2.2.4 Method of Placement 27
5.2.2.5 Damage 27

5.3 Field Seaming 27

5.3.1 Seam Layout 27
5.3.2 Requirements of Personnel 28
5.3.3 Overlapping and Temporary Bonding 28
5.3.4 Seam Preparation 29
5.3.5 Seaming Equipment and Products 29

5.3.5.1 Extrusion Process 29
5.3.5.2 Fusion Process 30

5.3.6 Weather Conditions for Seaming 31
5.3.7 Test Seams 31
5.3.8 General Seaming Procedure 32
5.3.9 Non-destructive Seam Continuity Testing 33

5.3.9.1 Vacuum Testing 34
5.3.9.2 Air Pressure Testing (For Double Fusion Seam Only) 34

5.3.10 Destructive Seam Strength Testing 35

5.3.10.1 Location and Frequency 35
5.3.10.2 Sampling Procedure 36
5.3.10.3 Size of Samples 36
5.3.10.4 Laboratory Testing 37
5.3.10.5 Installer's Laboratory Testing 37

5.3.10.6 Procedures for Destructive Test Failure 37
5.4 Defects and Repairs 38

5.4.1 Identification 38
5.4.2 Evaluation 38
5.4.3 Repair Procedures 39
5.4.4 Seam Reconstruction Procedures 39
5.4.5 Verification of Repairs 39

5.5 Backfilling of Anchor Trench 40
5.6 Geomembrane Acceptance 40
5.7 Geomembrane Certification 40
5.8 Materials in Contact with the Geomembrane 41

5.8.1 Granular Materials 41
5.8.2 Concrete 42
5.8.3 Sumps and Appurtenances 42

6. GEOTEXTILES 44

6.1 Design 44
6.2 Manufacturing 44
6.3 Packaging 45
6.4 Shipment and Storage 45
6.5 Conformance Testing 45

6.5.1 Sampling Procedures 46
6.5.2 Test Results 46

6.6 Handling and Placement 46
6.7 Seams and Overlaps 47
6.8 Geotextile Repair 47
6.9 Placement of Cover Materials 48

7. GEONETS 49

7.1 Design 49
7.2 Manufacturing 49
7.3 Packaging 49
7.4 Shipment and Storage 49
7.5 Conformance Testing 50

7.5.1 Sampling Procedures 50
7.5.2 Test Results 50

7.6 Handling and Placement 50
7.7 Stacking and Joining 51
7.8 Geonet Repair 52
7.9 Placement of Cover Materials 52

Table 1 - HDPE Geomembrane Properties 54

Table 2 - HDPE Seam Properties 55

Appendix A - Examples of Q.A. Documentation

1 INTRODUCTION

This manual primarily addresses quality assurance of High Density Polyethylene (HDPE) geomembranes used by Waste Management, Inc. in landfills and/or surface impoundments. The term "quality assurance" is used in its broadest sense, as defined in Section 2.1. Although this manual does not address "quality control" (also defined in Section 2.1), such procedures should be included, along with this manual, as integral portions of a comprehensive quality assurance plan. Similarly, this manual does not address design guidelines, geomembrane selection (which includes compatibility between geomembrane and waste), and installation specifications.

This manual stresses careful documentation during the entire quality assurance process from the certification of raw materials through manufacture, to fabrication and installation of the geomembrane.

The manual includes references to test procedures of the American Society for Testing and Materials (ASTM) and the "Standards for Flexible Membrane Liners" of the National Sanitation Foundation (NSF). Recognizing the changing nature of the above standards and the geosynthetic industry at large, this manual is subject to revision.

In addition to the installation of the geomembrane, this manual addresses quality assurance procedures for the placement of materials associated with the geomembrane. Some of these materials, such as geotextiles and geonets, are used as, or in conjunction with, leachate collection systems adjacent to the geomembrane.

2 DEFINITION OF OPERATIONS AND RESPONSIBILITIES

2.1 Scope

This manual is applicable to only those geomembranes manufactured of polyethylene resins having a specific gravity greater than 0.93 and is intended to cover the manufacturing, handling, and installation of these geomembranes. It is also intended to cover the quality assurance of related materials, such as geotextiles, geonets, and granular materials as they are used in conjuction with geomembrane to comprise primary and secondary leachate collection systems. All geomembrane considerations in this manual are equally applicable to the primary liner and the geomembrane portion of the composite liner as described in Hazardous and Solid Waste Amendments of 1984 guidelines.

This manual is devoted to quality assurance, not to quality control. Quality assurance and quality control are defined as follows:

Quality Assurance: - A planned and systematic pattern of all means and actions designed to provide adequate confidence that items or services meet contractual and jurisdictional requirements and will perform satisfactorily in service. Quality Assurance includes Quality Control.

Quality Control: - Those actions which provide a means to measure and regulate the characteristics of an item or service to contractual and jurisdictional requirements.

In the context of liner installation:

- Quality Assurance refers to means and actions employed by the Inspector to assure conformity of the liner installation with the Quality Assurance Manual, drawings and specifications.

- Quality Control refers to those actions taken by the Manufacturer, the Fabricator and Installer to ensure that material and the workmanship meet the requirements of plans and specifications.

2.2 Parties

The parties who may be involved with the geomembrane production, delivery, installation and utilization are listed and defined below.

Designer	- Responsible for the design, drawings plans and specifications of the lining system and the supporting soil.
Earthwork Contractor	- Responsible for the preparation of the supporting soil on which the geomembrane is to be installed; may also be the party responsible for placing earth and granular materials (if any) over the installed geomembrane.
Resin Supplier	- Produces and delivers HDPE resin to the Manufacturer.
Manufacturer	- Responsible for production of geomembrane rolls from resin.
Fabricator	- Responsible for the fabrication of geomembrane blankets from geomembrane rolls.
Installer	- Responsible for field handling, storing, placing, seaming and other site aspects of the geomembrane panels; may also be responsible for transportation to the site; responsible for anchor trenches and all temporary anchoring or loading required to support the liner during installation.
Transporter	- Transports geomembrane rolls or blankets between the Manufacturer, Fabricator, and/or the site, as appropriate.
Inspector	- Party independent from the Manufacturer, Fabricator and Installer that is responsible for observing and documenting activities related to the quality assurance of the geomembrane from manufacturing to installation, as well as the installation of geotextiles, geonets and other components related to the geomembrane. Also, responsible for issuing a certification report, sealed by a registered Professional Engineer.

Owner	- Owns and/or is responsible for the lined facility; in this manual, the term "Owner" shall apply equally to "Operator", i.e., the party responsible for operating the lined facility.
Project Manager	- The official representative of the owner; in this manual, the term "Project Manager" shall apply equally to "Construction Coordinator", i.e., the individual in charge of coordinating field activities.

All parties, as they become involved in a lining system project, should receive from the Owner or Project Manager this Quality Assurance Manual, and/or any quality assurance documents specially prepared for the project.

2.3 Meetings

2.3.1 Initial Meeting

Following the completion of the design, plans and specifications for the project, an Initial Meeting shall be held with the assigned quality assurance Inspector. This meeting shall include all parties then involved. The purpose of this meeting is to:

- communicate to all parties any relevant documents;
- review critical design details of the project;
- review the seam layout drawing provided by the Designer, the Fabricator or the Installer;
- make any appropriate modification to the quality assurance plan, i.e., ensure that site-specific considerations are added to the plan;
- reach a consensus on the quality assurance plan and quality control procedures, especially on methods of determining acceptability of the liner;
- assign responsibilities of each party;
- decide the number of spare seaming units to be maintained on site by the Installer (this number depends on the number of seaming crews and on the type of seaming equipment);

- establish methods for documenting and reporting, and for distributing documents and reports;

- establish rules for writing on the geomembrane, i.e., who is authorized to write, what can be written and in which color;

- outline procedures for packaging and storing archive samples;

- establish lines of authority and communication; and

- prepare a time schedule for all operations (see Section 5.2.2.2).

The meeting shall be documented by a person designated at the beginning of the meeting, and minutes shall be transmitted to all parties.

2.3.2 Pre-Construction Meeting

If possible, the Pre-Construction Meeting shall be held at the site. As a minimum, the meeting shall be attended by the Installer, the Inspector and the Project Manager. The Initial Meeting and the Pre-Construction Meeting may be held concurrently in special cases. The purpose of the Pre-Construction Meeting is to:

- make any appropriate modification to the quality assurance plan, i.e., ensure that site-specific considerations are added;

- review the responsibilities of each party;

- review lines of authority and communication;

- review methods for documenting and reporting, and for distributing documents and reports;

- review rules for writing on the geomembrane, i.e., who is authorized to write, what can be written and in which color;

- review the time schedule for all operations;

- conduct a site walk-around to verify that the designed plans and specifications are reasonable, that earthwork construction is proceeding on schedule, and to review material storage location;

- review panel layout and numbering systems for panels and seams;

- establish procedures for use of the extrusion welding apparatus, if applicable;

- establish procedures for use of the fusion welding apparatus, if applicable;
- review seam testing procedures;
- review repair procedures;
- review seam and sheet inspection procedure; and
- review schedule for all operations.

The meeting shall be documented by a person designated at the beginning of the meeting, and minutes shall be transmitted to all parties.

3 QUALIFICATIONS OF PARTIES

3.1 Manufacturer

Prior to confirmation of any contractual agreements, the Manufacturer shall provide the Project Manager with the following written information:

- Corporate background and information.

- Manufacturing capabilities:

  .. information on plant size, equipment, personnel, number of shifts per day and capacity per shift;

  .. daily production quantity available for this contract;

  .. quality control manual for manufacturing; and

  .. list of material properties including certified test results, to which are attached geomembrane samples.

- A list of at least ten completed facilities totaling a minimum of 200,000 m^2 (2,000,000 $ft.^2$), for which the Manufacturer has manufactured an HDPE geomembrane. For each facility, the following information shall be provided:

  .. name and purpose of facility, its location and date of installation;

  .. name of owner, project manager, designer, fabricator (if any), and installer;

  .. thickness of HDPE geomembrane, surface area of geomembrane manufactured; and

  .. available information on the performance of the lining system and the facility.

3.2 Fabricator

Section 3.2 is not applicable if the rolls are not fabricated into blankets in a factory. (The term blanket is defined in Section 4.2.1.)

The Fabricator shall be trained and qualified to fabricate HDPE blankets from HDPE rolls. The Fabricator shall be a well established firm able to provide sufficient fabrication capacity and qualified personnel to meet the demands of the project. The Fabricator shall be approved and/or licensed by the Manufacturer. A copy of the approval letter(s) or license(s) shall be submitted by the Fabricator to the Project Manager.

Prior to the confirmation of any contractual agreements, the Fabricator shall provide the Project Manager with the following written information:

- Corporate background and information.

- Fabrication capabilities:

  .. information on factory size, equipment, personnel, number of shifts per day and capacity per shift;

  .. daily fabrication quantity available for this contract;

  .. quality control manual for fabrication; and

  .. certified test results and samples of fabricated seams.

- A list of at least ten completed facilities for which the Fabricator has fabricated HDPE geomembrane blankets, totaling a minimum of 200,000 m^2 (2,000,000 $ft.^2$). For each fabrication, the following information shall be provided:

  .. name and purpose of facility, its location, and date of installation;

  .. name of owner, project manager, designer, manufacturer, and installer;

  .. thickness of HDPE geomembrane, surface area of geomembrane fabricated;

  .. type of seaming and type of seaming apparatus used; and

  .. available information on the performance of the lining system and the facility.

3.3 Installer

The Installer shall be trained and qualified to install HDPE geomembranes. The Installer shall be approved and/or licensed by the Manufacturer and/or Fabricator. A copy of the approval letter(s) or license(s) shall be submitted by the Installer to the Project Manager.

Prior to confirmation of any contractual agreements, the Installer shall provide the Project Manager with the following written information:

- Corporate background and information.

- Installation capabilities:

  .. information on equipment and personnel;

  .. daily anticipated production;

  .. quality control manual for installation; and

  .. samples of field seams and certified test results.

- A list of at least ten completed facilities, totaling a minimum of 200,000 m^2 (2,000,000 $ft.^2$) for which the Installer has installed an HDPE geomembrane. For each installation, the following information shall be provided:

  .. name and purpose of facility, its location, and date of installation;

  .. name of owner, project manager, designer, manufacturer, and fabricator (if any);

  .. name and qualifications of the supervisor(s) of the Installer's crew(s);

  .. thickness of geomembrane, surface area of the installed geomembrane;

  .. type of seaming and type of seaming apparatus used;

  .. duration of installation; and

  .. available information on the performance of the lining system and the facility.

3.4 Inspector

The Inspector shall be the company which furnishes Quality Assurance personnel, and shall be a well-established engineering firm incorporated (or otherwise registered) in the United States for more than one year. Prior to confirmation of any contractual agreements, the Inspector shall provide the Project Manager with the following written information:

- Corporate background and information.
  - .. proof of insurance:
    - ... professional liability in the amount of $1,000,000 or more;
    - ... "umbrella" coverage in the amount of $1,000,000 or more; and
    - ... other coverage as required by statute and/or proposed contractual agreement.
- Inspection capabilities:
  - .. a summary of the firm's experience with geosynthetics, including HDPE geomembranes, geonets, and geotextiles;
  - .. a summary of the firm's experience in Quality Assurance, including installation Quality Assurance of HDPE geomembranes, geonets, and geotextiles; and
  - .. a summary of Quality Assurance documentation and methods used by the firm, including sample Quality Assurance forms, reports, certifications, and manuals prepared by the firm.
- Personnel:
  - .. resumes of personnel to be involved in the project including supervising engineers, resident engineers, and inspectors;
  - .. proof of Professional Engineering registration (or ability to be registered) in the project state of the engineer to be designated the Quality Assurance officer, as well as proof of B.S, M.S or Ph.D. engineering degree; and

.. proof of Quality Assurance experience of Quality Assurance officer, resident engineer(s) and inspector(s), with emphasis on HDPE geomembranes, geonets, and geotextiles.

4 GEOMEMBRANE MANUFACTURING, FABRICATION AND DELIVERY

4.1 Manufacturing

4.1.1 Raw Materials

Prior to the installation of any geomembrane material, the Manufacturer shall provide the Project Manager with the following information:

- origin (Resin Supplier's name, resin production plant), identification (brand name, number) and production date of the HDPE resin;
- copy of quality control certificates issued by the HDPE Resin Supplier;
- reports on the tests conducted by the Manufacturer to verify the quality of the HDPE resin used to manufacture the geomembrane rolls assigned to the considered facility [these tests should include specific gravity (ASTM* D792 Method A or ASTM D1505) and melt index (ASTM D1238 condition E)]; and
- statement that no reclaimed polymer is added to the resin (however, the use of polymer recycled during the manufacturing process may be permitted if done with appropriate cleanliness and if recycled polymer does not exceed 2% by weight).

4.1.2 Geomembrane Production

The Project Manager shall provide to the Inspector the plans, specifications and drawings for the geomembrane prepared by the Designer. The Inspector shall verify that these:

- include at least all properties listed in Table 1, measured with the same methods or equivalent; and
- are consistent with the values indicated in Table 1.

If the above conditions are not fulfilled, the required alterations of the specifications prepared by the Designer shall be completed by a Designer.

*ASTM: The American Society for Testing and Materials

The Manufacturer shall provide the Project Manager with the following:

- a properties sheet including at least all specified properties, measured using test methods indicated in the specifications, or equivalent;
- the sampling procedure and results of testing; and
- a statement that property values given in the properties sheet are guaranteed by the Manufacturer.

The Project Manager will provide the Inspector with all information on the geomembrane provided by the Manufacturer. The Inspector shall verify that:

- properties guaranteed by the Manufacturer meet all the specifications; and
- the measurements of properties by the Manufacturer are properly documented and test methods used are acceptable.

4.1.3 Rolls

Prior to shipment, the Manufacturer shall provide the Project Manager with a quality control certificate for each shift's production of geomembrane. The quality control certificate shall be signed by a responsible party employed by the Manufacturer, such as the production manager. The quality control certificate shall include:

- roll numbers and identification; and
- sampling procedures and results of quality control tests; as a minimum, thickness, tensile strength, and tear resistance, conducted with the methods indicated in the specifications or equivalent methods, approved by the Inspector.

The Project Manager shall provide the Inspector with the information on rolls provided by the Manufacturer. The Inspector shall:

- verify that the quality control certificates have been provided for all rolls; and

- review the quality control certificates, and verify that the test methods used are acceptable and the measured roll properties meet the specifications.

4.1.4 Manufacturing Plant Visit

The Manufacturer shall agree to allow CWMI or its representatives to visit the manufacturing plant. Such a visit shall be prior to or during the manufacturing of the geomembrane rolls for the specific project. CWMI shall visit the Manufacturer's plant to review the manufacturing process, quality control, laboratory facilities and testing procedures.

During the plant visit, those inspecting shall also:

- verify that properties guaranteed by the Manufacturer meet all specifications;
- verify that the measurements of properties by the Manufacturer are properly documented and test methods used are acceptable;
- spot inspect the rolls and verify that they are free of holes, blisters, or any sign of contamination by foreign matter;
- review packaging and transportation procedures to verify that these procedures are not damaging the geomembrane;
- verify that roll packages have a label indicating the name of the manufacturer, type of geomembrane, its thickness and roll number; and
- verify that extrusion rods and/or beads are derived from the same base resin type as the geomembrane.

An inspection report shall be retained by CWMI.

4.2 Blanket Fabrication

Section 4.2 shall be deleted if the rolls are not fabricated into blankets in a factory.

4.2.1 Definition of Blanket

A blanket is a combination of rolls welded together by the Fabricator.

4.2.2 Blanket Geometry

If the Designer has prepared a layout requiring fabrication of rolls into a blanket prior to site delivery, it shall be given by the Project Manager to the Inspector for review. The Inspector shall indicate to the Project Manager any aspect of the geomembrane layout likely to be detrimental to the project.

The Fabricator must concur with the designed geomembrane layout or propose a new layout.

4.2.3 Requirements of Personnel

All personnel performing seaming operations shall be qualified by experience or by successfully passing seaming tests similar to those described in Section 4.2.6. At least one seamer shall have experience seaming a minimum of 100,000 m^2 (1,000,000 $ft.^2$) of HDPE geomembrane using the same type of seaming apparatus to be used to fabricate the site-specific geomembrane. The most experienced seamer, the "master seamer", shall provide direct supervision over less experienced seamers.

The Fabricator shall provide the Project Manager with a list of proposed seaming personnel and their professional records. This document shall be reviewed by the Project Manager and the Inspector.

4.2.4 Seaming Equipment and Products

Approved seaming processes for fabrication are extrusion welding and fusion welding. Proposed alternate processes shall be documented and submitted to the Project Manager for approval. The Project Manager shall forward all material to the Inspector for his concurrence.

4.2.4.1 Extrusion Process

The welding apparatus shall be equipped with gauges giving the extrudate temperature in the apparatus and at the nozzle.

The Fabricator shall provide documentation regarding the HDPE extrudate to the Project Manager and shall certify that the extrudate is compatible with the specifications.

Prior to the installation of any geomembrane material, the Fabricator shall submit quality control records, including apparatus temperatures, extrudate temperatures and ambient temperatures to the Project Manager. The Project Manager shall forward this data to the Inspector for review and verification of acceptability.

4.2.4.2 Fusion Process

Fusion-welding apparatus must be automated vehicular-mounted devices which produce a double seam with an enclosed space.

The welding apparatus shall be equipped with gauges giving the applicable temperatures and pressures.

Prior to the installation of any geomembrane material, the Fabricator shall submit seaming quality control records, including ambient temperatures and applicable apparatus temperatures and pressures, to the Project Manager. The Project Manager shall forward this data to the Inspector for review and verification of acceptability.

4.2.5 Weather Conditions for Seaming

The normally required weather conditions for seaming are as follows:

- Unless authorized in writing by the Project Manager, no seaming shall be attempted below 5°C (40°F) nor above 40°C (104°F).
- Between 5°C (40°F) and 10°C (50°F), seaming is possible if the geomembrane is preheated by either sun or hot air device, and if there is no excessive cooling.
- Above 10°C (50°F), no preheating is required.
- In all cases, the geomembrane shall be dry and protected from wind damage.

If the Fabricator wishes to use methods which may allow seaming below 5°C, then the Fabricator shall demonstrate and certify that such methods produce seams which are entirely equivalent to seams produced above 5°C.

4.2.6 Test Seams

Test seams shall be made on fragment pieces of geomembrane liner to verify that seaming conditions are adequate. Such test seams shall be made at the beginning of each seaming period, and at least once each four hours, for each seaming apparatus used that day. Also, each seamer shall make at least one test seam each day. Test seams shall be made under the same conditions as fabrication seams. The test seam sample shall be at least 0.6m (2 ft.) long by 0.3m (1 ft.) wide with the seam centered lengthwise.

Two adjoining specimens 25mm each (1 in.) wide shall be cut from the test seam sample by the Fabricator. The specimens shall be tested respectively in shear and peel and should not fail in the seam. If a specimen fails, the entire operation shall be repeated. If the additional specimen fails, the seaming apparatus or seamer shall not be accepted and shall not be used for fabrication seaming until the deficiencies are corrected and two consecutive successful full test seams are achieved.

4.2.7 Overlapping and Temporary Bonding

The Fabricator shall certify that:

- the rolls of HDPE geomembrane are overlapped by a minimum of 75mm (3 in.) for extrusion welding and 125mm (5 in.) for fusion welding;
- the procedure used to temporarily bond adjacent rolls together does not damage the geomembrane; in particular, the temperature of hot air at the nozzle of any spot welding apparatus shall be controlled such that the geomembrane is not damaged; and
- no solvent or adhesive is used unless the product is approved by the Project Manager.

4.2.8 Non-destructive Seam Continuity Testing

The Fabricator shall non-destructively test all fabricated seams over their full length using a vacuum unit or air pressure test (for fusion process). Tests shall be fully documented by the Fabricator and a copy of the documentation shall be forwarded to the Project Manager.

Any seams which fail non-destructive testing shall be repaired in accordance with Section 5.4. Repairs shall be fully documented and the Fabricator shall submit such documents to the Project Manager.

4.2.8.1 Vacuum Testing

The equipment shall be comprised of the following:

- a vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly, and a vacuum gauge;
- a steel vacuum tank and pump assembly equipped with a pressure controller and pipe connections;

- a rubber pressure/vacuum hose with fittings and connections;
- a bucket and wide paint brush;
- a soapy solution.

The following procedures shall be followed:

- energize the vacuum pump and reduce the tank pressure to approximately 35 kPa (10 in. of mercury, i.e., 5 psi absolute);
- wet a strip of geomembrane approximately 0.3m by 1.2m (12 in. by 48 in.) with the soapy solution;
- place the box over the wetted area;
- close the bleed valve and open the vacuum valve;
- ensure that a leak tight seal is created;
- for a period of not less than 30 seconds, examine the geomembrane through the viewing window for the presence of soap bubbles;
- if no bubble(s) appear after 30 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 75mm (3 in.) overlap, and repeat the process;
- all areas where soap bubbles appear shall be marked and repaired in accordance with Section 5.4.

4.2.8.2 Air Pressure Testing (For Double Fusion Seam Only)

The equipment shall be comprised of the following:

- an air pump (manual or motor driven) equipped with pressure gauge capable of generating and sustaining a pressure between 160 and 200 kPa (25 and 30 psi);
- a rubber hose with fittings and connections;
- a sharp hollow needle, or other approved pressure feed device.

The following procedures shall be followed:

- seal both ends of the seam to be tested;
- insert needle or other approved pressure feed device into the tunnel created by the fusion weld;
- energize the air pump to a pressure between 160 and 200 kPa(25 and 30 psi), close valve, and sustain pressure for approximately 5 minutes;
- if loss of pressure exceed 15 kPa (2 psi), or does not satbilize, locate faulty area and repair in accordance with Section 5.4;
- remove needle or other approved pressure feed device and seal.

4.2.9 Destructive Seam Strength Testing

The Fabricator shall destructively test an average of two samples per blanket. These samples shall be taken from extra material at the beginning or end of blanket seams such that the blanket is not damaged and the blanket geometry is not altered. The location of these samples shall be chosen and documented by the Fabricator.

The samples shall be 0.3m (1 ft.) by 0.3m (1 ft.) with the seam centered lengthwise. The samples shall then be cut into two equal pieces with one piece used for testing by the Fabricator and one piece forwarded to the Owner (for archive storage) with appropriate documentation.

4.2.10 Repairs

All repairs shall be conducted in accordance with Section 5.4. Each patch or other type of repair shall be numbered and logged by the Fabricator.

All repairs shall be subjected to the non-destructive seam testing procedure described in Section 4.2.8.

All repair documentation shall be forwarded to the Project Manager by the Fabricator.

4.2.11 Blanket Certification

Prior to shipment of the blankets to the site, the Fabricator shall provide the Project Manager with a quality control certificate for each shift's production of blankets. The quality control certificate shall be signed by a responsible party employed by the Fabricator, such as the production manager. The quality control certificate should include:

- blanket numbers and identification;
- results of quality control tests including sampling procedures;
- documentation of repairs and non-destructive testing of the repairs; and
- in the event of seaming below 5°C (40°F), an addendum specifically stating that the low temperature seaming procedure does not cause any physical or chemical modification to the geomembrane that will generate any short or long term damage to the geomembrane.

The Project Manager shall provide the Inspector with the information on blankets provided by the Fabricator. The Inspector shall:

- verify that the quality control certificates have been provided for all blankets;
- review the quality control certificates and verify that:
  - the test methods used are acceptable;
  - the measured properties meet the specifications; and
  - repairs are well documented.

4.2.12 Fabrication Factory Visit

The Fabricator shall agree to allow CWMI or its representatives to visit the fabrication factory. Such visit shall be prior to or during the fabrication of the geomembrane blankets for the specific project. Those inspecting shall:

- review the fabrication process;
- verify all quality control procedures, such as non-destructive and destructive seam testing procedures, repair procedures, and documentation procedures for testing and repair;

- review testing facilities of the Fabricator;

- spot inspect the blankets and verify that they are free of holes, blisters, any sign of contamination by foreign matter, or improper patches or re-welds;

- review packaging and transportation procedures to verify that these procedures are not damaging the geomembrane; and

- verify that the blanket packages have a label indicating name of Fabricator, type of geomembrane, dimension and blanket number; and

- verify that extrusion rods and/or beads are derived from the same base resin type as the geomembrane.

An inspection report shall be retained by CWMI. Alternatively, CWMI may elect to have full time inspectors at the fabrication factory to observe all factory seaming.

4.3 Transportation, Handling and Storage

Transportation of the geomembrane is the responsibility of the Manufacturer, the Fabricator, the Installer, or other party as decided at the Initial Meeting or Pre-Construction Meeting. All handling on site is the responsibility of the Installer.

The Inspector shall verify the following:

- handling equipment used on the site is adequate and does not pose any risk of damage to the geomembrane; and

- the Installer's personnel handle the geomembrane with care.

Upon delivery at the site, the Installer and the Inspector shall conduct a surface inspection of all rolls or blankets for defects and for damage. This inspection shall be conducted without unrolling rolls or unfolding blankets unless defects or damages are found or suspected. The Inspector shall indicate to the Project Manager:

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

- rolls or blankets which include minor repairable flaws.

The geomembrane shall be stored under the responsibility of the Installer. The Project Manager shall provide storage space in a location (or several locations) such that on-site transportation and handling are optimized if possible. Storage space should be protected from theft, vandalism, passage of vehicles, etc. The Inspector shall verify that storage of the geomembrane ensures adequate protection against dirt, shock and other sources of damage.

5 GEOMEMBRANE INSTALLATION

5.1 Earthwork

5.1.1 Surface Preparation

The Earthwork Contractor shall be responsible for preparing the supporting soil according to the Designer's specifications.

The Inspector shall verify that:

- a qualified Land Surveyor has verified all lines and grades;
- a qualified Geotechnical Engineer has verified that the supporting soil meets the density specification and has a minimum unconfined compressive strength of 100 kPa (1 tsf);
- the surface to be lined has been rolled and compacted so as to be free of irregularities, protrusions, loose soil, and abrupt changes in grade;
- the surface of the supporting soil does not contain stones which may be damaging to the geomembrane; and
- there is no area excessively softened by high water content.

The Installer shall certify in writing that the surface on which the geomembrane will be installed is acceptable. This certificate of acceptance shall be given by the Installer to the Project Manager prior to commencement of geomembrane installation. The Inspector shall be given a copy of this certificate by the Project Manager.

After the supporting soil has been accepted by the Installer, it shall be the Installer's responsibility to indicate to the Project Manager any change in the supporting soil condition that may require repair work. If the Inspector concurs with the Installer, then the Project Manager shall ensure that the supporting soil is repaired by the Earthwork Contractor.

At any time before and during the geomembrane installation, the Inspector shall indicate to the Project Manager locations which may not provide adequate support to the liner.

If the soil surface supporting the geomembrane is a clay liner, special care shall be taken to avoid dessication cracking. To that end:

- The Designer shall write specifications regarding maximum allowable crack depth and width and should describe the procedure for repairing cracks.

- The Project Manager shall inform the Earthwork Contractor, the Installer and the Inspector of these specifications.

- The Earthwork Contractor, as directed by the Project Manager, shall be required to prevent dessication by using a temporary geomembrane (for example, 0.25mm (10 mil) thick polyethylene sheets with one-foot overlaps secured with sand bags or reclaimed tires) on the clay liner as soon as clay placement and compaction is completed in an area, or by other suitable means.

- The temporary geomembrane shall be removed by the Installer immediately before installation of the designed geomembrane.

- Immediately prior to installation of the designed geomembrane liner, the clay surface shall be observed by the Project Manager, the Installer and the Inspector: the decision to repair cracks, if any, or to commence placement of the designed geomembrane liner shall then be made.

5.1.2 Crest Anchorage System

The anchor trench (if any) shall be excavated by the Earthwork Contractor (unless otherwise specified) to the lines and width shown on the design drawings, prior to geomembrane placement. The Inspector shall verify that the anchor trench has been constructed according to design drawings.

If the anchor trench is excavated in a clay liner susceptible to dessication, no more than the amount of trench required for the geomembrane to be anchored in one day shall be excavated (unless otherwise specified) to minimize dessication potential of the anchor trench clay soils.

Slightly rounded corners shall be provided in the trench where the geomembrane adjoins the trench so as to avoid sharp bends in the geomembrane. No loose soil shall be allowed to underlie the geomembrane in the anchor trench.

Backfilling of the anchor trench shall be conducted in accordance with Section 5.5.

5.2 Geomembrane Placement

5.2.1 Panel Identification

A panel is the unit area of geomembrane which is to be seamed in the field. Two cases can be considered:

- If the geomembrane is not fabricated into blankets in a factory, a panel is a roll or a portion of roll cut in the field.

- If the geomembrane is fabricated into blankets in a factory, a panel is a blanket or a portion of blanket cut in the field.

Each panel shall be given an "identification code" (number or letter-number) consistent with the layout plan. This identification code shall be agreed upon by the Project Manager, Installer and Inspector. This identification code shall be as simple and logical as possible. (Note that roll numbers and blanket numbers established in the manufacturing plant and fabrication factory are usually cumbersome and are not related to location in the field.)

The Inspector shall establish a table or chart showing correspondence between roll numbers, blanket numbers (if any), and identification codes. The identification code shall be used for all quality assurance records.

The Inspector shall verify that geomembrane thickness is in conformance with the specifications. Thickness readings shall be taken at appropriate intervals across the panel width and periodically along the panel length. Readings shall be taken across the width at any point where the panel has been cut. Any non-conformance shall be reported to the Project Manager.

5.2.2 Panel Placement

5.2.2.1 Location

The Inspector shall verify that panels are installed at the location indicated in the Designer's layout plan, as approved or modified at the Initial Meeting and/or Pre-Construction Meeting.

5.2.2.2 Installation Schedule

Panels may be installed using any one of the following schedules:

- all panels are placed prior to field seaming;
- panels are placed one at a time and each panel is seamed immediately after its placement; and
- any combination of the above.

If a decision is reached to place all panels prior to field seaming, it is usually beneficial to begin in the sump area and proceed upward and outward with "shingle" overlaps to facilitate drainage in the event of precipitation. It is also usually beneficial to proceed in the direction of prevailing winds. Accordingly, a decision regarding installation scheduling should be made at the Initial Meeting or Pre-Construction Meeting if and only if weather conditions can be predicted with reasonable certainty. Otherwise, scheduling decisions must be made during installation, in accordance with varying conditions.

The Inspector shall evaluate every change in the schedule proposed by the Installer and advise the Project Manager on the acceptability of that change. The Inspector shall also verify that the condition of the supporting soil has not changed detrimentally during installation.

The Inspector shall record on a drawing the identification code, location and date of installation of each panel.

5.2.2.3 Weather Conditions

Geomembrane placement shall not proceed at an ambient temperature below 5°C (40°F) or above 40° C (105°F) unless otherwise specified. Geomembrane placement shall not be done during any precipitation, in the presence of excessive moisture (e.g., fog, dew),in an area of ponded water, or in the presence of excessive winds, as determined by the Inspector.

The Inspector shall verify that the above conditions are fulfilled. Additionally, the Inspector shall verify that the supporting soil has not been damaged by weather conditions.

The Inspector shall inform the Project Manager if the above conditions are not fulfilled.

5.2.2.4 Method of Placement

The Inspector shall verify the following:

- any equipment used does not damage the geomembrane by handling, trafficking, leakage of hydrocarbons or other means;
- all personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane;
- the method used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil;
- the method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels);
- adequate loading (e.g.,sand bags, tires), not likely to damage the geomembrane, has been placed to prevent uplift by wind (in case of high winds, continuous loading is recommended along edges of panels to minimize risk of wind flow under the panels);
- direct contact with the geomembrane is minimized; i.e., the geomembrane in traffic areas is protected by geotextiles, extra geomembrane, or other suitable materials.

The Inspector shall inform the Project Manager if the above conditions are not fulfilled.

5.2.2.5 Damage

The Inspector shall inspect each panel, after placement and prior to seaming, for damage. The Inspector shall advise the Project Manager which panels, or portions of panels, should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels which have been rejected shall be marked and their removal from the work area recorded by the Inspector. The damaged materials shall become the property of the Installer and shall be removed from the site at the expense of the Installer. Repairs shall be made according to procedures described in Section 5.4.

5.3 Field Seaming

5.3.1 Seam Layout

At, or prior to, the Initial Meeting, the Designer, the Fabricator or the Installer shall provide the Project Manager with a

drawing of the facility to be lined showing fabricated seams and field seams in a manner which differentiates the seam types. The Project Manager shall provide this seam layout to the Installer and the Inspector. The Inspector shall review the seam layout and verify that it is consistent with accepted state of practice.

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

No horizontal seam should be less than 1.5m (5 ft.) from the toe of the slope.

A seam numbering system compatible with the panel numbering system shall be agreed upon at the Initial and/or Pre-Construction Meeting.

5.3.2 Requirements of Personnel

All personnel performing seaming operations shall be qualified by experience or by successfully passing seaming tests. At least one seamer shall have experience seaming a minimum of 100,000 m^2 (1,000,000 $ft.^2$) of HDPE geomembrane using the same type of seaming apparatus in use at the site. The most experienced seamer, the "master seamer", shall provide direct supervision, as required, over less experienced seamers. No field seaming shall take place without the master seamer being present.

The Installer shall provide the Project Manager with a list of proposed seaming personnel and their professional records. This document shall be reviewed by the Project Manager and the Inspector. Any proposed seaming personnel deemed insufficiently experienced shall not be accepted by the Project Manager or shall be invited to pass a seaming test similar to the "test seams" described in Section 5.3.7.

5.3.3 Overlapping and Temporary Bonding

The Inspector shall verify that:

- the panels of HDPE geomembrane are overlapped by a minimum of 75mm (3 in.) for extrusion welding and 125mm (5 in.) for fusion welding;

- the procedure used to temporarily bond adjacent panels together does not damage the geomembrane; in particular, the temperature of hot air at the nozzle of any spot welding apparatus is controlled such that the geomembrane is not damaged; and

- no solvent or adhesive is used unless the product is approved in writing by the Owner (samples shall be submitted to the Owner for testing and evaluation).

The Inspector shall log all appropriate temperatures and conditions, and shall log and report to the Project Manager any non-compliance.

5.3.4 Seam Preparation

The Inspector shall verify that:

- prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris of any kind, and foreign material;
- if seam overlap grinding is required, the process is completed according to the Manufacturer's instructions and in a way that does not damage the geomembrane; and
- seams are aligned with the fewest possible number of wrinkles and "fishmouths".

5.3.5 Seaming Equipment and Products

Approved processes for field seaming are extrusion welding and fusion welding. Only apparatus which have been specifically approved by make and model shall be used. Proposed alternate processes shall be documented and submitted to the Owner or his representative for his approval. The Project Manager shall submit all material to the Inspector for his concurrence.

5.3.5.1 Extrusion Process

The welding apparatus shall be equipped with gauges giving the temperature in the apparatus and at the nozzle.

The Installer shall provide documentation regarding the HDPE extrudate to the Project Manager and shall certify that the extrudate is compatible with the specifications.

The Inspector shall log apparatus temperatures, extrudate temperatures, ambient temperatures, and geomembrane surface temperatures at appropriate intervals.

The Inspector shall verify that:

- the Installer maintains on-site the number of spare operable seaming apparatus decided at the Initial Meeting;

- equipment used for seaming is not likely to damage the geomembrane;
- the extruder is purged prior to beginning a seam until all heat degraded extrudate has been removed from the barrel;
- the electric generator is placed on a smooth base such that no damage occurs to the geomembrane;
- a smooth insulating plate or fabric is placed beneath the welding apparatus after usage; and
- the geomembrane is protected from damage in heavily trafficked areas.

5.3.5.2 Fusion Process

Fusion-welding apparatus must be automated vehicular-mounted devices which produce a double seam with an enclosed space.

The seaming apparatus shall be equipped with gauges giving the applicable temperatures and pressures.

The Inspector shall log ambient, seaming apparatus, and geomembrane surface temperatures as well as seaming apparatus pressures.

The Inspector shall also verify that:

- the Installer maintains on-site the number of spare operable seaming apparatus decided at the Initial Meeting;
- equipment used for seaming is not likely to damage the geomembrane;
- for cross seams, the edge of the cross seams is ground to a smooth incline (top and bottom) prior to welding;
- the electric generator is placed on a smooth base such that no damage occurs to the geomembrane;
- a smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage;
- the geomembrane is protected from damage in heavily trafficked areas; and

- a movable protective layer may be used as required by the Inspector directly below each overlap of geomembrane that is to be seamed to prevent buildup of moisture between the sheets.

5.3.6 Weather Conditions for Seaming

The normally required weather conditions for seaming are as follows:

- Unless authorized in writing by the Project Manager, no seaming shall be attempted below 5°C (40°F) nor above 40°C (104°F).
- Between 5°C (40°F) and 10°C (50°F), seaming is possible if the geomembrane is preheated by either sun or hot air device, and if there is not excessive cooling resulting from wind (as determined by the Inspector).
- Above 10°C (50°F), no preheating is required.
- In all cases, the geomembrane shall be dry and protected from wind damage.

If the Installer wishes to use methods which may allow seaming below 5°C (40°F), an addendum to the contract between the Owner and the Installer is required which specifically states that the low temperature seaming procedure does not cause any physical or chemical modification to the geomembrane that will generate any short or long term damage to the geomembrane. Then, the above quality assurance procedure shall be modified accordingly.

The Inspector shall verify that the above weather conditions are fulfilled and will advise the Project Manager if they are not. The Project Manager shall decide if the installation shall be stopped or postponed.

5.3.7 Test Seams

Test seams shall be made on fragment pieces of geomembrane liner to verify that seaming conditions are adequate. Such test seams shall be made at the beginning of each seaming period, at the Inspector's discretion, and at least once each four hours, for each seaming apparatus used that day. Also, each seamer shall make at least one test seam each day.

The test seam sample shall be at least 0.6m (2 ft.) long by 0.3m (1 ft.) wide with the seam centered lengthwise. Two adjoining specimens 25mm (1 in.) wide each shall be cut from the test seam sample by the Installer. These specimens shall be tested in the field respectively in shear and peel by the Installer or the Owner as decided at the Initial Meeting, by hand or tensometer, and shall not fail in the seam. [Note: if a tensometer is not available and if a 25mm (1 in.) wide specimen is too hard to test by hand, a 10mm (0.5 in.) specimen will be accepted.] If a test seam fails, the entire operation shall be repeated. If the additional test seam fails, the seaming apparatus or seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful full test seams are achieved.

The Inspector shall observe all test seam procedures. The remainder of the successful test seam sample shall be assigned a number and marked accordingly by the Inspector, who shall also log the date, hour, ambient temperature, number of seaming unit, name of seamer, and pass or fail description. The sample itself shall be retained in the Owner's archives.

5.3.8 General Seaming Procedure

Unless otherwise specified, the general seaming procedure used by the Installer shall be as follows:

- For fusion welding, a movable protective layer of plastic may be required, as recommended by the Inspector, to be placed directly below each overlap of geomembrane that is to be seamed. This is to prevent any moisture buildup between the sheets to be welded.

- Seaming shall extend to the outside edge of panels to be placed in the anchor trench.

- If required, a firm substrate shall be provided by using a flat board, a conveyor belt, or similar hard surface directly under the seam overlap to achieve proper support.

- Fishmouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut fishmouths or wrinkles shall be seamed and any portion where the overlap is inadequate shall then be patched with an oval or round patch of the same geomembrane extending a minimum of 150mm (6 in.) beyond the cut in all directions.

The Inspector shall verify that the above seaming procedures (or any other procedures agreed upon) are followed, and shall inform the Project Manager if they are not.

5.3.9 Non-destructive Seam Continuity Testing

The Installer shall non-destructively test all field seams over their full length using a vacuum test unit or air pressure (fusion process). The purpose of this test is to check the continuity of seams. It does not provide any information on seam strength. Continuity testing shall be done as the seaming work progresses, not at the completion of all field seaming.

The Inspector shall:

- observe all continuity testing;
- record location, date, test unit number, name of tester, and outcome of all testing; and
- inform the Installer and Project Manager of any required repairs.

The Installer shall complete any required repairs in accordance with Section 5.4.

The Inspector shall:

- observe the repair and re-testing of the repair;
- mark on the geomembrane that the repair has been made; and
- document the results.

The following procedures shall apply to locations where seams cannot be non-destructively tested:

- All such seams shall be cap-stripped with the same geomembrane.
- If the seam is accessible to testing equipment prior to final installation, the seam shall be non-destructively tested prior to final installation.
- If the seam cannot be tested prior to final installation, the seaming and cap-stripping operations shall be observed by the Inspector and Installer for uniformity and completeness.

The seam number, date of observation, name of tester, and outcome of the test or observation shall be recorded by the Inspector.

5.3.9.1 Vacuum Testing

The equipment shall be comprised of the following:

- a vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly, and a vacuum gauge;
- a steel vacuum tank and pump assembly equipped with a pressure controller and pipe connections;
- a rubber pressure/vacuum hose with fittings and connections;
- a bucket and wide paint brush;
- a soapy solution.

The following procedures shall be followed:

- energize the vacuum pump and reduce the tank pressure to approximately 35 kPa (10 in. of mercury, i.e., 5 psi absolute);
- wet a strip of geomembrane approximately 0.3m by 1.2m (12 in. by 48 in.) with the soapy solution;
- place the box over the wetted area;
- close the bleed valve and open the vacuum valve;
- ensure that a leak tight seal is created;
- for a period of not less than 30 seconds, examine the geomembrane through the viewing window for the presence of soap bubbles;
- if no bubble(s) appear after 30 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 75mm (3 in.) overlap, and repeat the process;
- all areas where soap bubbles appear shall be marked and repaired in accordance with Section 5.4.

5.3.9.2 Air Pressure Testing (For Double Fusion Seam Only)

The equipment shall be comprised of the following:

- an air pump (manual or motor driven) equipped with pressure gauge capable of generating and sustaining a pressure between 160 and 200 kPa (25 to 30 psi);

- a rubber hose with fittings and connections;

- a sharp hollow needle, or other approved pressure feed device.

The following procedures shall be followed:

- seal both ends of the seam to be tested;

- insert needle or other approved pressure feed device into the tunnel created by the fusion weld;

- energize the air pump to a pressure between 160 and 200 kPa (25 and 30 psi), close valve, and sustain pressure for approximately 5 minutes;

- if loss of pressure exceeds 30 kPa (4 psi) or does not stabilize, locate faulty area and repair in accordance with Section 5.4;

- remove needle or other approved pressure feed device and seal.

5.3.10 Destructive Seam Strength Testing

If the fusion process is used, the Installer shall be provided an opportunity to prove that air pressure test results are equivalent to destructive test results. The Project Manager shall submit all results of such testing to the Inspector and the Designer for their concurrence.

5.3.10.1 Location and Frequency

The Inspector shall submit to the Project Manager a list of locations where seam samples will be cut out for laboratory testing. This list shall be established as follows:

- A minimum frequency of one test location per 150m (500 ft.) of seam length.

- A maximum frequency shall be agreed upon by the Installer, Project Manager and Inspector at the Initial and/or Pre-Construction Meeting.

- Predetermined test locations shall be assigned by the Inspector prior to the commencement of seaming and submitted to the Project Manager.

- Additional test locations shall be determined during seaming at the Inspector's discretion. Selection of such locations may be prompted by suspicion of excess crystallinity, contamination, offset welds, or any other potential cause of imperfect welding.

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

5.3.10.2 Sampling Procedure

Samples shall be cut by the Installer as the seaming progresses in order to have laboratory test results before completion of liner installation. The Inspector shall:

- observe sample cutting;

- assign a number to each sample, and mark it accordingly;

- record sample location on layout drawing; and

- record reason for taking the sample at this location (e.g., statistical routine, suspicious feature of the geomembrane).

All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described in Section 5.4. The continuity of the new seams in the repaired area shall be tested according to Section 5.3.9.

5.3.10.3 Size of Samples

The samples shall be 0.3m (12 in.) wide by 1.1m (44 in.) long with the seam centered lengthwise. One 25mm (1 in.) wide strip shall be cut from each end of the sample and these shall be tested in the field, by hand or tensometer, for peel and shear respectively and shall not fail in the seam. [Note: if a tensometer is not available and if a 25mm (1 in.) wide specimen is too hard to test by hand, a 10mm (0.5 in.) wide specimen will be accepted.] The remaining sample shall be cut into three parts and distributed as follows:

- one portion to the Installer for laboratory testing , 0.3m x 0.38m (12 in. x 15 in.);

- one portion for independent laboratory testing, 0.3m x 0.38m (12 in. x 15 in.); and

- one portion to the Owner for archive storage, 0.3m x 0.30m (12 in. x 12 in.).

Samples shall be cut by the Installer at locations designated by the Inspector and under the observation of the Inspector as the seaming progresses in order to obtain laboratory test results prior to completion of liner installation.

The Inspector shall witness all field tests and mark all samples and portions with their number. The Inspector shall also log the date and time, ambient temperature, number of seaming unit, name of seamer, welding apparatus temperatures and pressures, and pass or fail description, and attach a copy to each sample portion.

5.3.10.4 Laboratory Testing

Destructive test samples shall be packaged and shipped under the responsibility of the Inspector in a manner which will not damage the test sample. The Project Manager will verify that packaging and shipping conditions are acceptable. The Project Manager will be responsible for packaging and storing the archive samples. This procedure shall be fully outlined at the initial meeting.

Each day, test samples shall be forwarded to an independent laboratory selected by the Project Manager with concurrence of the Inspector. Testing shall include "Seam Strength" [ASTM D3083 as modified in NSF Appendix A] and "Peel Adhesion" (ASTM D413 as modified in NSF Appendix A). The minimum acceptable values to be obtained in these tests are those indicated in Table 2.

The Inspector shall review independent laboratory test results as soon as they become available, and make appropriate recommendations to the Project Manager.

5.3.10.5 Installer's Laboratory Testing

All test results from the Installer's laboratory shall be submitted to the Project Manager as soon as they become available. The Project Manager shall immediately forward all such test results to the Inspector for his evaluation and recommendations.

5.3.10.6 Procedures for Destructive Test Failure

The following procedures shall apply whenever a sample fails the field destructive test. The Installer has two options:

- The Installer can reconstruct the seam between the failed location and any passed test location.

- The Installer can retrace the welding path to an intermediate location (at 3m (10 ft.) minimum from the location of the failed test) and take a small sample for an additional field test. If this additional sample passes the test, then the seam is reconstructed between that location and the original failed location. If this sample fails, then the process is repeated.

In any case, all acceptable seams must be bounded by two passed test locations (i.e., the above procedure shall be followed in both directions from the original failed location), and one test must be taken within the reconstructed area.

In the event that a sample fails a laboratory destructive test (whether it is conducted by the independent laboratory or by the Installer's laboratory), then the above procedures shall be followed, considering laboratory tests exclusively. Since the final seam must be bounded by two passed test locations, it may then be necessary to take one or more new samples for laboratory testing in addition to the one required in the reconstructed seam area.

The Inspector shall document all actions taken in conjunction with destructive test failures.

5.4 Defects and Repairs

5.4.1 Identification

All seams and non-seam areas of the geomembrane shall be inspected by the Inspector for identification of defects, holes, blisters, undispersed raw materials and any sign of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of inspection. The geomembrane surface shall be broomed or washed by the Installer if the amount of dust or mud inhibits inspection.

5.4.2 Evaluation

Each suspect location both in seam and non-seam areas shall be non-destructively tested using the methods described in Section 5.3.9 as appropriate. Each location which fails the non-destructive testing shall be marked by the Inspector and repaired by the Installer.

5.4.3 Repair Procedures

Repair procedures should be agreed upon between Project Manager, Installer and Inspector at the Pre-Construction Meeting. Unless otherwise agreed, the procedures shall be as follows:

- defective seams shall be repaired by reconstruction (as described in Section 5.4.4);
- tears or pinholes shall be repaired by seaming or patching;
- blisters, larger holes, undispersed raw materials, and contamination by foreign matter shall be repaired by patches;
- surfaces of HDPE geomembrane which are to be patched shall be abraded no more than one hour prior to the repair;
- all seams used in repairing procedures must be approved extrusion welded seams and shall be subjected to the same non-destructive test procedures as outlined for all other seams.

Each patch shall be numbered and logged. Patches shall be round or oval in shape, made of the same geomembrane, and extend a minimum of 150mm (6 in.) beyond the edge of defects.

Patches shall be applied using approved methods only.

Where excessive extrudate surface occurs, the affected seam length, as determined by the Inspector, shall be cap-stripped.

5.4.4 Seam Reconstruction Procedures

Seam reconstruction for the extrusion welding process shall be achieved by grinding the existing seam and rewelding a new seam.

Seam reconstruction for the fusion process shall be achieved by cutting out the existing seam and welding in a replacement strip.

5.4.5 Verification of Repairs

Each repair shall be non-destructively tested using the methods described in Section 5.3.9 as appropriate. Repairs which pass the non-destructive test shall be taken as an indication of an adequate repair. Failed tests indicate that the repair shall be redone and retested until a passing test results. The Inspector shall observe all non-destructive testing of repairs and shall record the number of each patch, date, name of patcher and test outcome.

5.5 Backfilling of Anchor Trench

The anchor trench, if any, shall be backfilled and compacted to specifications by the Earthwork Contractor or the Installer, as outlined in the specifications and bid documents and at the Initial Meeting.

Care shall be taken when backfilling the trenches to prevent any damage to the geomembrane.

The Inspector shall observe the backfilling operation and advise the Project Manager of any problems.

5.6 Geomembrane Acceptance

The Installer, Fabricator, and Manufacturer shall retain all ownership and responsibility for the geomembrane until acceptance by the Owner.

The geomembrane liner shall be accepted by the Owner when:

- the installation is finished;
- all documentation of installation is completed including the Inspector's final report;
- verification of the adequacy of all field seams and repairs, including associated testing, is complete; and
- certification, including "as built" drawing(s), sealed by a registered professional engineer has been received by the Project Manager.

The Inspector shall certify that installation has proceeded in accordance with the quality assurance plan for the project except as noted to the Project Manager.

5.7 Geomembrane Certification

The Inspector or inspector's firm shall, in addition to other duties assigned herein, issue at the completion of the project a report documenting all aspects of the quality assurance program performed under his contract, and a summary certification report, that shall include as a minimum the following information:

- personnel involved with the project;

- scope of inspector/firm work;
- outline of project (dates, meetings, etc.);
- inspection methods;
- test results (destructive and non-destructive, including laboratory tests);
- certification sealed and signed by a registered professional engineer; and
- "as-built" drawing, sealed and signed by a registered professional engineer.

5.8 Materials in Contact with the Geomembrane

Some of the materials discussed in this section (such as sand, gravel, geonets, and geotextiles) are used to construct leachate collection systems. The quality assurance procedures indicated hereafter are only intended to assure that the installation of these materials does not damage the geomembrane. Additional quality assurance procedures would be necessary to assure that leachate collection systems built with these materials would be constructed in such a way to enable proper performance.

5.8.1 Granular Materials

A copy of the specifications prepared by the Designer for placement of granular materials shall be given to the Inspector by the Project Manager. The Inspector shall verify that these specifications are consistent with the state of the art such as:

- Placement of granular materials on the geomembrane shall not proceed at an ambient temperature below 5°C (40°F) nor above 40°C (104°F) unless otherwise specified.
- A geotextile may be installed between angular aggregate and the geomembrane.
- Equipment used for placing granular material shall not be driven directly on the geomembrane.
- A minimum thickness of 0.3m (1 ft.) of granular material is specified between a light dozer (such as a D-6 or lighter) and the geomembrane.

- A minimum thickness of 0.9m (3 ft.) of granular material is specified between a rubber-tired vehicle and the geomembrane.

- In heavily trafficked areas such as access ramps, granular material thickness should be at least 0.9m (3 ft.).

The Inspector shall:

- measure granular material thickness and verify that the thicknesses required during construction are met;

- verify that final thicknesses are consistent with design; and

- verify that placement of granular material is done in such a manner that geomembrane damage is unlikely.

The Inspector shall inform the Project Manager if the above conditions are not fulfilled.

5.8.2 Concrete

A copy of the specifications prepared by the Designer for placement of concrete shall be given by the Project Manager to the Inspector. The Inspector shall verify that these specifications are consistent with the state of the art, including the use of geosynthetic layers between concrete and geomembrane.

The Inspector shall verify that geosynthetic layers are placed between the concrete and the geomembrane according to design specifications. He will also verify that construction methods used are not likely to damage the geomembrane.

5.8.3 Sumps and Appurtenances

A copy of the specifications prepared by the Designer for sumps and appurtenances shall be given by the Project Manager to the Inspector. The Inspector shall review these specifications and verify the use of geosynthetic layers between concrete and geomembranes.

The Inspector shall verify that:

- installation of the geomembrane in sump and appurtenance areas, and connection of geomembrane to sumps and appurtenances have been made according to specifications;

- extreme care is taken while welding around appurtenances since both non-destructive and destructive testing might not be feasible; and

- the geomembrane has not been visibly damaged while making connections to sumps and appurtenances.

The Inspector shall inform the Project Manager if the above conditions are not fulfilled.

6 GEOTEXTILES

6.1 Design

The designer may include geotextiles to perform any of the following functions:

- filtration - the geotextile acts as a filter between a drainage layer or medium and any soil or fill material;
- cushion - the geotextile acts to protect the geomembrane from abrasion, cutting or other damage;
- transmission - the geotextile acts as a drainage layer for liquids or gases (this function is usually better performed by geonets - see Section 7).

Minimum design considerations shall include:

- Filtration: soil retention, permeability, clogging, wide strip tensile modulus, stiffness, friction angle, dimensional stability, chemical resistance, color, ultraviolet resistance, survivability.
- Cushion: thickness, structure, abrasion resistance, burst strength, puncture resistance, wide strip tensile modulus, friction angle, chemical resistance, color, ultraviolet resistance.

A copy of the geotextile drawings and specifications prepared by the Designer shall be given to the Inspector. The Inspector shall review these and verify that they are conceptually consistent with the state of practice.

6.2 Manufacturing

The geotextile manufacturer will provide the Project Manager with a list of guaranteed "minimum average roll value" properties, as defined by the Federal Highway Administration, for the type of geotextile to be delivered. The geotextile manufacturer shall also provide the Project Manager with a written certification signed by a responsible party that the materials actually delivered have property "minimum average roll values" , as defined by the Federal Highway Administration, which meet or exceed all guaranteed property values listed for that type of geotextile.

The Inspector shall examine all the list of guaranteed properties to ensure compliance with design drawings and specifications. The Inspector shall examine manufacturer's specifications to ensure that the geotextile actually delivered is in compliance with the list of guaranteed properties. Any deviations shall be reported to the Project Manager.

6.3 Packaging

The geotextile manufacturer shall identify all rolls of geotextile with the following:

- manufacturer's name,
- product identification,
- lot number,
- roll number,
- roll dimensions.

Additionally, if any special handling is required, it shall be so marked on the top surface of the geotextile, e.g., "This Side Up" or "This Side Against Geonet".

The Inspector shall examine rolls upon delivery and any deviation from the above requirements shall be reported to the Project Manager.

6.4 Shipment and Storage

During shipment and storage, the geotextile shall be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions. To that effect, geotextile rolls shall be shipped and stored in relatively opaque and watertight wrappings.

The Inspector shall observe rolls upon delivery at the site and any deviation from the above requirements shall be reported to the Project Manager.

6.5 Conformance Testing

Upon delivery of the rolls of geotextiles, the Inspector shall ensure that samples are removed and forwarded to an independent laboratory for testing to ensure conformance to both the design specifications and the list of guaranteed properties.

6.5.1 Sampling Procedures

Samples shall be taken across the entire width of the roll and shall not include the first linear meter (three feet). Unless otherwise specified, samples shall be 1m (3 ft.) long by the roll width. The Inspector shall mark the machine direction on the samples with an arrow.

Unless otherwise specified, samples shall be taken at a rate of one per lot or one per 10,000 m^2 (10,000 yd^2), whichever is least.

6.5.2 Test Results

The Inspector shall examine all results from laboratory conformance testing and shall report any non-conformance to the Project Manager.

6.6 Handling and Placement

The Installer shall handle all geotextiles in such a manner as to ensure the geotextiles are not damaged in any way, and the following shall be complied with:

- On slopes, the geotextile shall be securely anchored in the anchor trench and then rolled down the slope in such a manner as to continually keep the geotextile sheet in tension.

- In the presence of wind, all geotextiles shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during placement and shall remain until replaced with cover material.

- If white colored geotextile is used, precautions shall be taken against "snowblindness" of personnel.

- The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geotextile.

- During placement of geotextiles, care shall be taken not to entrap in the geotextile stones, excessive dust, or moisture that could damage the geomembrane, generate clogging, or hamper subsequent seaming.

- Geotextiles shall not be exposed to precipitation prior to being installed, and shall not be exposed to direct sunlight for more than 15 days (unless otherwise specified).

The Inspector shall note any non-compliance and report it to the Project Manager.

6.7 Seams and Overlaps

On slopes steeper than 10 Horizontal/1 Vertical, all geotextiles shall be seamed. Seaming can be achieved by sewing, adhesives, fusion or other approved means. All seams shall be continuously seamed (i.e., spot seaming is not allowed). Geotextiles shall be overlapped 0.15m (6 in.) prior to seaming. No horizontal seams shall be allowed on slopes steeper than 10 Horizontal/1 Vertical (i.e., seams shall be along, not across, the slope).

On slopes less steep than 10 Horizontal/1 Vertical, geotextiles can be either seamed as indicated above, or overlapped 0.3m (12 in.). In the latter case, spot seaming may be considered as a measure against wind uplift. Overlaps shall be oriented in the direction of earth filling.

The Installer shall pay particular attention at seams and overlaps to ensure that no cover material is inavertently inserted beneath the geotextile.

Any sewing shall be done using polymeric thread with chemical properties equal to or exceeding those of the geotextile.

The Inspector shall note any non-compliance and report it to the Project Manager.

6.8 Geotextile Repair

Any holes or tears in the fabric shall be repaired as follows:

- On slopes: A fabric patch shall be sewn into place using a double sewn lock stitch (seams 5mm to 20mm (1/4 in. to 3/4 in.) apart and no closer than 25mm (1 in.) from any edge). Should any tear exceed 10% of the width of the roll, that roll shall be removed from the slope and replaced.

- Non-slopes: A fabric patch shall be spot-seamed in place with a minimum of 0.60m (24 in.) overlap in all directions.

Care shall be taken to remove any soil or other material which may have penetrated the torn geotextile.

The Inspector shall observe any repair, note any non-compliance with the above requirements and report them to the Project Manager.

6.9 Placement of Cover Materials

The Installer shall place all cover materials in such a manner to ensure:

- the geotextile is not damaged;
- minimal slippage of the geotextile on underlying layers;
- no excess tensile stresses in the geotextile.

No construction equipment with ground pressure greater than 60 kPa (8 psi) shall operate on slopes unless they are more than 3m (10 ft.) from exposed geosynthetics and are operating on 0.6m (2 ft.) or more of cover material.

Except where compacted clay is utilized as part of the double liner system, all lifts of cover material shall be in conformance with the following guidelines:

Equipment Ground Pressure		Minimum Lift Thickness	
kPa	(psi)	m	(in.)
<30	(<4)	0.30	(12)
30-60	(4-8)	0.45	(18)
>60	(>8)	0.60	(24)

Any non-compliance shall be noted by the Inspector and reported to the Project Manager.

The Inspector shall periodically place two (or more, at his discretion) marks on the geotextile 3m (10 ft.) apart along the slope and measure the elongation of the geotextile during the covering operation. This elongation shall be related by the Designer to the tensile stess in the geotextile.

7 GEONETS

7.1 Design

The Designer may include geonets to replace or complement traditional drainage systems such as granular layers or pipes.

A copy of the geonet drawings and specifications prepared by the Designer shall be given to the Inspector. The Inspector shall review these and verify that they are conceptually consistent with the state of practice.

7.2 Manufacturing

The geonet manufacturer shall provide the Project Manager with a list of guaranteed properties for the type of geonet to be supplied. The geonet manufacturer shall provide the Project Manager with a written certification signed by a responsible party that the geonets actually delivered have properties which meet or exceed the guaranteed properties.

The Inspector shall examine the list of guaranteed properties to ensure compliance with design drawings and specifications. The Inspector shall examine all manufacturer's certifications to ensure that the geonet actually delivered is in compliance with the list of guaranteed properties. Any deviations shall be reported to the Project Manager.

7.3 Packaging

The manufacturer shall identify all rolls of geonets with the following:

- manufacturer's name,
- product identification,
- lot number,
- roll number,
- roll dimensions.

The Inspector shall examine rolls upon delivery and any deviation from the above requirements shall be reported to the Project Manager.

7.4 Shipment and Storage

Unless otherwise specified by the Designer, geonets can be stored outdoors for one year without any protection against ultraviolet light.

Geonets shall be shipped and stored in such a manner that they are free of dirt and dust when they are installed. The Inspector shall verify that geonets are free of dirt and dust just before installation. The Inspector shall report the outcome of this verification to the Project Manager, and if the geonets are judged dirty or dusty, they shall be washed by the Installer prior to installation.

Washing operations shall be observed by the Inspector and improper washing operations shall be reported to the Project Manager.

7.5 Conformance Testing

Upon delivery of the rolls of geonets, the Inspector shall ensure that samples are removed and forwarded to an independent laboratory for testing to ensure conformance to both the design specifications and the list of guaranteed properties.

7.5.1 Sampling Procedures

Samples shall be taken across the entire width of the roll and shall not include the first linear meter (three feet). Unless otherwise specified, samples shall be 1m (3 ft.) long by the roll width. The Inspector shall mark the machine direction on the samples with an arrow.

Unless otherwise specified, samples shal be taken at a rate of one per lot or one per 10,000m^2 (10,000 yd^2), whichever is least.

7.5.2 Test Results

The Inspector shall examine all results from laboratory conformance testing and shall report any non-conformance to the Project Manager.

7.6 Handling and Placement

The Installer shall handle all geonets in such a manner as to ensure the geonets are not damaged in any way, and the following shall be complied with:

- On slopes, the geonets shall be secured in the anchor trench and then rolled down the slope in such a manner as to continually keep the geonet sheet in tension. If necessary, the geonet shall be stretched by hand after unrolled to minimize wrinkles. Geonets can be placed horizontally (i.e.,

across the slope) in some special locations (e.g., at the toe of a slope, if an extra layer of geonet is required, this extra layer of geonet can be placed horizontally). Such locations shall be identified by the Designer in design drawings.

- In the presence of wind, all geonets shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during placement and shall remain until replaced with cover material.

- Unless otherwise specified, nets shall not be welded to geomembranes.

- The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geonet.

- During placement of geonets, care shall be taken not to entrap in the geonet dirt or excessive dust that could cause clogging of the drainage system, and/or stones that could damage the adjacent geomembrane.

- Care should be taken not to leave tools in the geonet.

- Geonets shall be anchored at the top of the slope as indicated in the construction drawings.

The Inspector shall note any non-compliance and report it to the Project Manager.

7.7 Stacking and Joining

When several layers of geonets are stacked, care should be taken to prevent strands from one layer from penetrating the channels of the next layer, thereby significantly reducing the transmissivity. This cannot happen if stacked geonets are placed in the same direction. Therefore, stacked geonets shall always be laid in the same direction (i.e., stacked geonets shall never be laid in perpendicular directions, unless otherwise specified by the Designer). In the corners of side slopes of rectangular landfills, adjacent overlapping geonets are usually in perpendicular directions and special precautions shall be taken as discussed below.

Adjacent geonets shall be joined according to construction drawings and specifications. As a minimum, the following requirements shall be met:

- Adjacent rolls shall be overlapped by at least 100mm (4 in.).

- These overlaps shall be secured by gluing, spot welding, or tying.

- Tying can be achieved by strings, plastic fasteners, or polymer braid. Tying devices shall be white or yellow for easy inspection. Metallic devices are not allowed.

- Spot gluing, spot welding or tying shall be every 1.5m (5 ft.) along the slope, every 0.6m (2 ft.) across the slope, and every 0.15m (6 in.) in the anchor trench.

- In the corners of the side slopes of rectangular landfills, where overlaps between perpendicular geonet strips are required, an extra layer of geonet shall be unrolled along the slope, on top of the previously installed geonets, from top to bottom of the slope.

- When more than one layer of geonet is installed, joints shall be staggered.

The Inspector shall note any non-compliance and report it to the Project Manager.

7.8 Geonet Repair

Any holes or tears in the geonet shall be repaired by placing a patch extending 0.6m (2 ft.) beyond edges of the hole or tear. The patch shall be secured to the original geonet by spot gluing, spot welding or tying every 0.15m (6 in.). Tying devices shall be as indicated in Section 7.7. If the hole or tear width across the roll is more than 50% the width of the roll, the damaged area shall be cut out and the two portions of the geonet shall be joined as indicated in Section 7.7.

The Inspector shall observe any repair, note any non-compliance with the above requirements and report them to the Project Manager.

7.9 Placement of Cover Materials

The Installer shall place all cover materials in such a manner to ensure:

- the geonet and underlying lining materials are not damaged;

- minimal slippage of the geonet on underlying layers;

- no excess tensile stresses in the geonet.

Unless otherwise specified by the Designer, all lifts of cover material shall be in conformance with the following guidelines:

Equipment Ground Pressure		Minimum Lift Thickness	
kPa	(psi)	m	(in.)
<30	(<4)	0.30	(12)
30-60	(4-8)	0.45	(18)
>60	(>8)	0.60	(24)

Any non-compliance shall be noted by the Inspector and reported to the Project Manager.

If portions of the geonet are still exposed, the Inspector shall periodically place two (or more, at his discretion) marks on the geonet 3m (10ft.) apart along the slope and measure the elongation of the geonet during the covering operation. This elongation shall be related by the Designer to the tensile stress in the geonet.

TABLE 1

HDPE GEOMEMBRANE PROPERTIES

PROPERTY	QUALIFIER	UNIT	SPECIFIED VALUE[1]				TEST METHOD
Physical Properties							
Gauge	nominal	mils	40	60	80	100	-
Thickness	minimum	mils	36	54	72	90	ASTM D1593 Para. 8.1.3
Specific Gravity	minimum	N/A	0.93	0.93	0.93	0.93	ASTM D792 Method A or ASTM D1505
Mechanical Properties							
Tensile Properties (each direction)							ASTM D638
1. Force per unit width at yield	minimum	lb/in	80	120	160	200	
2. Tensile strength (force per unit width at break)	minimum	lb/in	150	225	300	375	
3. Elongation at yield	minimum	%	10	10	10	10	
4. Elongation at break	minimum	%	500	500	500	500	
5. Modulus of elasticity	minimum	psi	100,000	100,000	100,000	100,000	
Tear Resistance	minimum	lb	30	40	50	60	ASTM D1004 Die C
Puncture Resistance	minimum	lb	50	60	70	80	FTMS 101B/ 2065
Environmental Properties							
Low Temperature	maximum	°F	-40	-40	-40	-40	ASTM D746 Procedure B
Carbon Black Content	minimum/ maximum	%	2/3	2/3	2/3	2/3	ASTM D1603
Carbon Black Dispersion	N/A		A-1	A-1	A-1	A-1	ASTM D3015
Dimensional Stability (each direction)	max. change	%	3	3	3	3	ASTM D1204 212°F, 15 min.
Resistance to Soil Burial							ASTM D3083 (as modified in NSF Appendix A)
1. Tensile strength at yield	max. change	%	10	10	10	10	
2. Tensile strength at break	max. change	%	10	10	10	10	
3. Elongation at yield	max. change	%	10	10	10	10	
4. Elongation at break	max. change	%	10	10	10	10	
5. Modulus of elasticity	max. change	%	10	10	10	10	
Environmental Stress Crack	minimum	hrs.	2,000	2,000	2,000	2,000	ASTM D1693 (as modified in NSF Appendix A)

1. For a specific geomembrane, only the column of values corresponding to the selected nominal gauge thickness should appear under the heading "specified value".

TABLE 2

HDPE SEAM PROPERTIES

PROPERTY	QUALIFIER	UNIT	SPECIFIED VALUE[1]				TEST METHOD
Gauge	nominal	mils	40	60	80	100	-
Bonded Seam Strength (at yield point)	minimum	lb/in width	80 FTB[2]	120 FTB[2]	160 FTB[2]	200 FTB[2]	ASTM D3083 (as modified in NSF Appendix A)
Peel Adhesion			FTB[2]	FTB[2]	FTB[2]	FTB[2]	ASTM D413 or ASTM D638 (as modified in NSF Appendix A)
Dead Load							
1. Room temperature 73°F 50% bonded seam load	N/A		pass	pass	pass	pass	NSF Appendix A
2. Elevated temperature 158°F 25% bonded seam load	N/A		pass	pass	pass	pass	NSF Appendix A
Resistance to Soil Burial							ASTM D3083 (as modified in NSF Appendix A)
1. Peel adhesion			FTB[2]	FTB[2]	FTB[2]	FTB[2]	
2. Bonded seam strength	maximum change	%	-20	-20	-20	-20	

1. For a specific geomembrane, only the column of values corresponding to the selected nominal thickness should appear under the heading "specified value".

2. FTB = Film Tear Bond.

APPENDIX A

Examples of Q.A. Documentation

CARD NUMBER: 301

PANEL PLACEMENT CHECK-LIST

OWNER: _____

PROJECT: _____

DATE/TIME: _____

INSPECTOR: _____

PANEL NUMBER: _____

WEATHER CONDITIONS

TEMPERATURE: _____

WIND: _____

WEATHER: _____

SUBGRADE CONDITIONS

LINES AND GRADE: _____

SURFACE COMPACTION: _____

PROTRUSIONS: _____

PONDED WATER: _____

DESSICATION: _____

TRANSPORT EQUIPMENT: _____

VISUAL PANEL INSPECTION: _____

_____

TEMPORARY LOADING: _____

OVERLAPS: _____

SPOT WELDING: _____

SPOT WELD TEMPERATURE: _____

TEMPORARY BONDS: _____

DAMAGES: _____

_____

NOTES: _____

_____

CARD NUMBER: 301

PANEL SEAMING CHECK-LIST

OWNER: _____

PROJECT: _____

DATE/TIME: _____

INSPECTOR: _____

PANEL NUMBER: _____

WEATHER CONDITIONS

TEMPERATURE: _____

WIND: _____

WEATHER: _____

SEAM TYPE: _____

SEAM NUMBERS: _____

PANEL NUMBERS: _____

CLEANLINESS: _____

DRYNESS: _____

WRINKLES: _____

FISHMOUTHS: _____

SEAMING APPARATUS ID: _____

SEAMER ID: _____

FIRM SUBSTRATE: _____

PRE-HEATING TEMP.: _____

SEAMING APPARATUS TEMP.: _____

SEAMING APPARATUS PRES.: _____

EXTENSION TO OUTSIDE EDGE: _____

PATCHES: _____

NOTES: _____

CARD NUMBER: 301

SEAM TESTING CHECK-LIST

OWNER: _____

PROJECT: _____

DATE/TIME: _____

INSPECTOR: _____

PANEL NUMBER: _____

WEATHER CONDITIONS

TEMPERATURE: _____

WIND: _____

WEATHER: _____

NON-DESTRUCTIVE TESTING

PANEL NUMBERS: _____

SEAM NUMBERS: _____

TEST UNIT NUMBER: _____

TESTER ID: _____

100%: _____

REPAIRS: _____

VERIF. OF REPAIRS: _____

DESTRUCTIVE TESTING

PANEL NUMBERS: _____

SEAM NUMBERS: _____

SAMPLE ID: _____

LOCATION: _____

REASON: _____

FIELD TEST OUTCOME: _____

REPAIRS: _____

VERIF. OF REPAIRS: _____

NOTES: _____

SAMPLE TAG

Owner: _____

Project: _____

Date/Time: _____

Sample ID: _____

Sample Number: _____

Sample Location: _____

Ambient Temperature: _____

Seaming Apparatus ID: _____

Seaming Equip. Temp.: _____

Seamer ID: _____

Passed Field Test ☐ Failed Field Test ☐

Inspector ID: _____

Remarks: _____

_____

_____

_____

TEST AND INSPECTION REPORT

Project

Owner

Contractor

Seam #	Seam Length	Test Method	Pressure at Beginning Atmosphere	Pressure After 15 Minutes Atmos	Results and Judgments on Pressure Diff.	Air Temp.	Date	Visual Inspection	Person Doing Test
31									
32									
33									
34									
35									
36									
37									
38									
39									
40									
41									
42									
43									
44									
45									

SITE WELDING QUALITY CONTROL REPORT

PROJECT _____ CONTRACT # _____

SITE _____ DATE _____

MATERIAL _____ THICKNESS _____

Weld Reference _____

Weld Inspection _____ Observations _____

Weld Re-Inspection _____ Observations _____

Sample Weld Location _____

Sampled by _____

Sample Weld Test Results

Sample Weld #	Specimen	Peel Results
	1	
	2	
	1	
	2	
	1	
	2	

_____
Quality Control Inspector

1201.2/9

Appendix G

APPENDIX G

"Specification Guidelines for the Procurement

and Installation of Geosynthetic Lining

Systems"

Waste Management, Inc.

SPECIFICATION GUIDELINES FOR THE PROCUREMENT AND INSTALLATION OF GEOSYNTHETIC LINING SYSTEMS

JUNE 1986

FOREWORD

These specifications address the materials and services required for the procurement and installation of geosynthetic lining systems used by Waste Management, Inc. (the Owner) in solid waste landfills and/or surface impoundments. These lining systems often incorporate several geosynthetic elements, including geomembranes, geotextiles, geogrids, and geonets. For purposes of this document, the term "geomembrane(s)" refers to polyethylene geomembrane(s) made from polyethylene resins with a specific gravity greater than 0.93.

The bidder is cautioned that all information, data, certifications and other documentation specified herein are absolutely required. Accordingly, any bidder whose corporate structure does not include the manufacturing, fabrication and installation phases must secure binding agreements with other parties, as applicable, to ensure compliance with these specifications. The Owner will hold the bidder responsible for the gathering and submittal of all required information, data, certifications and other documentation, regardless of the specified originating source.

TABLE OF CONTENTS

	Page
FOREWORD	
1 GENERAL REQUIREMENTS	1
1.1 Scope	1
1.2 Units	1
1.3 References	2
1.4 Definition and Qualifications of Parties and Required Submittals	2
1.4.1 Designer	2
1.4.2 Earthwork Contractor	2
1.4.3 Resin Supplier	2
1.4.4 Manufacturers	3
1.4.4.1 Geomembrane Manufacturer	3
1.4.4.2 Manufacturers of Other Geosynthetics	4
1.4.5 Fabricator	5
1.4.5.1 Geomembrane Fabricator	5
1.4.5.2 Fabricators of Other Geosynthetics	6
1.4.6 Installer	7
1.4.7 Transporter	9
1.4.8 Geosynthetic Quality Assurance Consultant	9
1.4.9 Soils Quality Assurance Consultant	11
1.4.10 Geosynthetic Quality Assurance Laboratory	11
1.4.11 Owner	11
1.4.12 Project Manager	12
1.5 Warranty	12
1.6 Quality Assurance Program	12
2 MATERIAL SPECIFICATIONS	13
2.1 Geomembrane	13
2.1.1 General Requirements	13
2.1.2 Specified Geomembrane Properties	13
2.1.2.1 Geomembrane Resin	13
2.1.2.2 Geomembrane Rolls	13
Table 1	14
Table 2	15
2.1.3 Labelling	16
2.2 Geotextiles and Geogrids	17
2.2.1 General Requirements	17
2.2.2 Specified Geotextile Properties	17
2.2.2.1 Filtration Applications	17
Table 3	18
2.2.2.2 Cushion Applications	18
Table 4	19

Table 5 19
2.2.2.3 Reinforcement Applications 19
2.2.3 Labelling 20
2.3 Geosynthetic Transmission Media 20
2.3.1 General Requirements 20
2.3.2 Specified Geosynthetic Transmission Media Properties 21
2.3.3 Labelling 21
Table 6 22
2.4 Transportation, Handling and Storage 23

3 MANUFACTURING AND FABRICATION - QUALITY CONTROL 24

3.1 Geomembrane Manufacturing 24
3.1.1 Raw Material Quality Control 24
3.1.2 Roll Quality Control 24
3.1.3 Geomembrane Manufacturing Plant Visit 26

3.2 Geomembrane Fabrication 27
3.2.1 Requirements of Personnel 27
3.2.2 Seaming Equipment and Products 27
3.2.2.1 Extrusion Process 27
3.2.2.2 Fusion Process 28
3.2.3 Seam Preparation 28
3.2.4 Weather Conditions for Factory Seaming 28
3.2.5 Overlapping and Temporary Bonding 29
3.2.6 Trial Seams 29
3.2.7 Nondestructive Seam Continuity Testing 30
3.2.7.1 Concept 30
3.2.7.2 Vacuum Testing 30
3.2.7.3 Air Pressure Testing (For Double Fusion Seam Only) 31
3.2.8 Destructive Seam Strength Testing 32
3.2.8.1 Location and Frequency 32
3.2.8.2 Sampling Procedure 32
3.2.8.3 Size of Samples 33
3.2.8.4 Testing at the Fabrication Factory 33
3.2.8.5 Laboratory Testing 33
3.2.8.6 Fabricator's Laboratory Testing 34
3.2.8.7 Procedures for Destructive Test Failure 34
3.2.9 Repairs 35
3.2.10 Panel Certification 35
3.2.11 Fabrication Factory Visit 35

3.3 Manufacture of Other Geosynthetics 36
3.3.1 Roll Quality Control 36

4 GEOMEMBRANE INSTALLATION 38

4.1 Earthwork 38
4.1.1 Surface Preparation 38
4.1.2 Crest Anchorage System 38
4.2 Conformance Testing 39
4.3 Geomembrane Placement 39
4.3.1 Layout Drawings 39
4.3.2 Panel Identification 39
4.3.3 Field Panel Placement 40
4.3.3.1 Location 40
4.3.3.2 Installation Schedule 40
4.3.3.3 Weather Conditions 40
4.3.3.4 Method of Placement 40
4.3.3.5 Damage 41
4.4 Field Seaming 41
4.4.1 Seam Layout 41
4.4.2 Requirements of Personnel 41
4.4.3 Overlapping and Temporary Bonding 42
4.4.4 Seam Preparation 42
4.4.5 Seaming Equipment and Products 42
4.4.5.1 Extrusion Process 42
4.4.5.2 Fusion Process 43
4.4.6 Weather Conditions for Seaming 43
4.4.7 Trial Seams 44
4.4.8 General Seaming Procedures 45
4.4.9 Non-destructive Seam Continuity Testing 45
4.4.9.1 Concept 45
4.4.9.2 Vacuum Testing 46
4.4.9.3 Air Pressure Testing (For Double Fusion Seam Only) 47
4.4.10 Destructive Testing 47
4.4.10.1 Concept 47
4.4.10.2 Location and Frequency 48
4.4.10.3 Sampling Procedure 48
4.4.10.4 Size of Samples 48
4.4.10.5 Field Testing 49
4.4.10.6 Laboratory Testing 49
4.4.10.6.1 Installer's Laboratory 49
4.4.10.6.2 Geosynthetic Quality Assurance Laboratory 49
4.4.10.7 Procedures for Destructive Test Failure 49
4.4.11 Defects and Repairs 50
4.4.11.1 Identification 50
4.4.11.2 Evaluation 50
4.4.11.3 Repair Procedures 50

1 GENERAL REQUIREMENTS

1.1 Scope

The work includes the manufacture, fabrication (if needed), supply and installation of a geomembrane lining system, for the lining of a solid waste disposal facility. The system includes: granular soils (sand and gravel) and geosynthetic materials (geotextiles and geonets) used in primary and secondary leachate collection systems; geomembranes used as the primary liner and the geomembrane portion of the secondary liner; and compacted clay used as the clay portion of the secondary liner. Whenever it is used in this document, the term "geomembrane(s)" refers to polyethylene geomembrane(s) made from polyethylene resins with a specific gravity greater than 0.93. Among the polymers which may satisfy this definition are those known as high density polyethylene (HDPE) and linear low density polyethylene (LLDPE).

The work includes furnishing all labor, materials, transportation, supervision, tools, and construction machinery which may be necessary to construct and test the geosynthetic portions of the lining system including installation as described in these specifications and the associated plans and engineering drawings. Specifications for the cohesive and granular materials associated with the lining system are listed in a separate document.

All procedures, operations and methods shall be in strict accordance with the specifications, plans, and engineering drawings. The installed system shall conform exactly to the specifications, plans, and engineering drawings except where authorized in writing by the Owner, based on submitted changes and/or modifications.

All materials, procedures, operations, and methods shall be subjected to strict quality assurance monitoring as detailed in the Owner's Geosynthetic Quality Assurance Plan for this project. The project specific Geosynthetic Quality Assurance Plan is comprised of the Owner's Geosynthetic Quality Assurance Manual modified as required by site specific addenda.

1.2 Units

In these specifications, all properties and dimensions are expressed in U.S. units, with "equivalent" SI units in parentheses. It should be noted that the conversion is typically only accurate within ten per cent. In cases of conflict or clarification, the U.S. units shall be deemed to govern.

1.3 References

These specifications include references to test procedures of the American Society for Testing and Materials (ASTM), the Federal Test Method Standards (FTMS), and the "Standards for Flexible Membrane Liners" of the National Sanitation Foundation (NSF). Recognizing the changing nature of the above standards and of the geosynthetic industry at large, these specifications are subject to periodic revision.

1.4 Definition and Qualifications of Parties and Required Submittals

1.4.1 Designer

The Designer is responsible for performing the design and preparing the drawings, plans and specifications of the lining system.

The designer shall be a qualified, certified engineer. The designer shall have a history which demonstrates familiarity with the use of geosynthetics in landfills, including detailed geosynthetic design methods and procedures.

1.4.2 Earthwork Contractor

The Earthwork Contractor is responsible for the preparation of the supporting soil on which the lining system is to be installed, and may also be the party responsible for placing earth and granular materials (if any) over the installed lining system.

Qualifications of the Earthwork Contractor are specific to the construction contract, and independent of these specifications.

1.4.3 Resin Supplier

The Resin Supplier produces and delivers the resin to the Manufacturer.

Qualifications of the Resin Supplier are specific to the Manufacturer's requirements. The Resin Supplier should have a demonstrated history of providing consistent resin properties. The Manufacturer shall be held responsible for the quality of the resin.

1.4.4 Manufacturers

1.4.4.1 Geomembrane Manufacturer

The Geomembrane Manufacturer is responsible for the production of geomembrane rolls from resin.

The Geomembrane Manufacturer shall have sufficient production capacity and qualified personnel to meet the demands of the project. The Geomembrane Manufacturer shall be pre-qualified and approved by the Owner.

A geomembrane manufacturer shall submit the following information in order to be considered for pre-qualification:

- Corporate background and information.
- Manufacturer bid questionnaire (see Appendix A).
- Manufacturing capabilities:
  - information on plant size, equipment, personnel, number of shifts per day, and capacity per shift;
  - daily production quantity available for this contract;
  - quality control procedures for manufacturing; and
  - list of material properties including certified test results, to which are attached geomembrane samples.
- A list of at least ten completed facilities totalling a minimum of 2,000,000 ft^2 (200,000 m^2), for which the Manufacturer has manufactured a geomembrane. For each facility, the following information shall be provided:
  - name and purpose of facility, its location and date of installation;
  - name of owner, project manager, designer, fabricator (if any), and installer;
  - thickness of geomembrane, surface area of geomembrane manufactured; and
  - available information on the performance of the lining system and the facility.
- Statement that no reclaimed polymer is added to the resin (however, the use of polymer recycled during the manufacturing

process may be permitted if done with appropriate cleanliness and if recycled polymer does not exceed 2% by weight).

- Origin (Resin Supplier's name, resin production plant) and identification (brand name, number) of the polyethylene resin.

In addition, the following information must be submitted by the successful bidder prior to shipping any material:

- Manufacturer pre-delivery information questionnaire completed in full by the Manufacturer (form supplied in Appendix B).

- Documentation on Raw Materials:

  .. copy of quality control certificates issued by the Resin Supplier;

  .. production date(s) of the resin;

  .. reports on the tests conducted to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the considered facility; and

  .. statement that no reclaimed polymer is added to the resin during the manufacture of the actual geomembrane to be used in this project (however, the use of polymer recycled during the manufacturing process may be permitted if done with appropriate cleanliness and if recycled polymer does not exceed 2% by weight).

- Documentation on Geomembrane Roll Production:

  .. copy of quality control certificates; and

  .. certification that the geomembrane produced for this project has the same chemical compatibility properties as geomembrane previously tested by the Owner for chemical compatibility.

1.4.4.2 Manufacturers of Other Geosynthetics

The manufacturers of other geosynthetics (geotextiles, geonets, and geogrids) are responsible for the production and delivery of rolls of their respective products.

Manufacturers of geosynthetics other than geomembranes must be well-established firms with more than two years experience in the manufacture of geosynthetics. They shall submit a statement to the Project Manager listing:

- certified minimum property values of the proposed geosynthetics and the tests used to determine those properties; and,

- production capacity available and projected delivery dates for this project.

1.4.5 Fabricator

The Fabricator is responsible for the fabrication of factory panels of geosynthetics constructed from rolls received from the Manufacturer. He may also be responsible for delivery of the factory panels to the site.

The Fabricator shall be trained and qualified to fabricate factory panels from rolls of geosynthetics. The Fabricator shall be a well established firm able to provide sufficient fabrication capacity and qualified personnel to meet the demands of the project. The Fabricator shall be approved and/or licensed by the Manufacturer and prequalified by the Owner.

1.4.5.1 Geomembrane Fabricator

Prior to the confirmation of any contractual agreements, the Geomembrane Fabricator shall provide the Project Manager and Geosynthetic Quality Assurance Engineer with the following written information:

- Fabricator bid information questionnaire completed in full by the Fabricator (form supplied in Appendix A).

- Copy of Geomembrane Manufacturer's letter of approval or license.

- Corporate background and information.

- Fabrication capabilities:

  .. information on factory size, equipment, personnel, number of shifts per day and capacity per shift;

  .. daily fabrication quantity available for this contract;

  .. quality control procedures; and

  .. samples of fabricated seams and a certified list of seam properties minimum values and employed test methods;

- A list of at least ten completed facilities for which the Fabricator has fabricated geomembrane factory panels, totalling a minimum of 2,000,000 ft^2 (200,000 m^2); for each fabrication, the following information shall be provided:

  - name and purpose of facility, its location, and date of installation;

  - name of owner, project manager, designer, manufacturer, installer, and the name of the contact at the site who can discuss the project;

  - thickness of geomembrane and surface area of geomembrane fabricated;

  - type of seaming and type of seaming apparatus used; and,

  - available information on the performance of the lining system and the facility.

- Resume of the qualifications of the "master seamer" to be assigned to this project.

All personnel performing seaming operations shall be qualified by experience or by successfully passing seaming tests. At least one seamer shall have experience seaming a minimum of 1,000,000 ft^2 (100,000 m^2) of geomembrane using the same type of apparatus as used for this project. No seaming shall be carried out without this "master seamer" being present.

After award of the Contract but prior to any delivery of geomembrane panels, the following documentation is required:

- Geomembrane Fabricator pre-delivery information questionnaire completed in full by the Geomembrane Fabricator (form supplied in Appendix B).

- Copies of quality control certificates.

1.4.5.2 Fabricators of Other Geosynthetics

Prior to delivery of materials to the site, Fabricators of other geosynthetics shall submit:

- results of quality control tests on seams, and,

- certification that the minimum average roll values of seams comply with the specifications.

1.4.6 Installer

The Installer is responsible for field handling, storing, deploying, seaming, temporary restraining (against wind), and other site aspects of the geosynthetics, including the geomembranes, geotextiles, geogrids, and geonets. The Installer may also be responsible for transportation of these materials to the site, and for anchoring systems.

The Installer shall be trained and qualified to install geosynthetics. The Geomembrane Installer shall be approved and/or licensed by the Geomembrane Manufacturer and/or Geomembrane Fabricator. The Installer shall be prequalified by the Owner.

Prior to confirmation of any contractual agreements, the Installer shall provide the Project Manager and Geosynthetic Quality Assurance Engineer with the following written information:

- Installer bid information questionnaire completed in full by the Installer (form supplied in Appendix A).
- Corporate background and information.
- Description of installation capabilities, including:
  - information on equipment and personnel;
  - average daily production anticipated;
  - quality control procedures; and
  - samples of field seams and list of certified seam properties minimum values and employed test methods.
- A list of at least ten completed facilities, totalling a minimum of 2,000,000 ft^2 (200,000 m^2) for which the Installer has installed geomembrane. For each installation, the following information shall be provided:
  - name and purpose of facility, its location, and date of installation;
  - name of owner, project manager, designer, manufacturer, fabricator (if any), and name of contact at the facility who can discuss the project;
  - name and qualifications of the supervisor(s) of the Installer's crew(s);
  - thickness of geomembrane, surface area of the installed geomembrane;

.. type of seaming and type of seaming apparatus used;

.. duration of installation; and,

.. available information on the performance of the lining system and the facility.

- A copy of the approval letter(s) and/or license(s) by the Geomembrane Manufacturer and/or Geomembrane Fabricator.

- Resume of the "master seamer" to be assigned to this project, including dates and duration of employment.

- Resume of the field engineer or installation supervisor to be assigned to this project, including dates and duration of employment.

All personnel performing seaming operations shall be qualified by experience or by successfully passing seaming tests. At least one seamer shall have experience seaming a minimum of 1,000,000 ft^2 (100,000 m^2) of geomembrane using the same type of seaming apparatus in use at the site. The most experienced seamer, the "master seamer", shall provide direct supervision, as required, over less experienced seamers. No field seaming shall take place without the master seamer being present.

Prior to commencement of the installation, the Installer shall submit:

- Installer pre-installation information questionnaire completed in full by the Installer (form supplied in Appendix B).

- A drawing showing the installation layout identifying both fabricated (if applicable) and field seams as well as any variance or additional details which deviate from the engineering drawings. The layout shall be adequate for use as a construction plan and shall include dimensions, details, etc.

- Installation schedule.

- A list of personnel performing field seaming operation along with pertinent experience information.

- Initial subgrade acceptance certificates, signed by the Installer, as defined in the Quality Assurance Plan.

During the installation, the Installer shall be responsible for the timely submission of:

- Quality control documentation.

- Subgrade acceptance certificates for each area to be covered by the lining system, signed by the Installer.

Upon completion of the installation, the Installer shall submit:

- Geomembrane installation certification.

- The warranty obtained from the Manufacturer/Fabricator and the installation warranty.

1.4.7 Transporter

The Transporter transports the geosynthetics, including rolls or factory panels of geomembrane, geotextiles, geogrids and geonets, between: the various Manufacturers and the site; and/or between the Manufacturer(s) and the Fabricator(s); and/or between the Fabricator(s) and the site.

All personnel responsible for the loading, transport, and unloading of the geomembrane must be fully aware of the consequences of damage to the geomembrane, and familiar with handling and transport constraints required by the Manufacturer(s) and/or Fabricator(s). Any damage resulting from the handling and/or transport of the geosynthetics shall be repaired at no cost to the Owner. If irreparable, in the opinion of the Geosynthetic Quality Assurance Engineer, then the damaged materials shall be replaced at no cost to the Owner.

1.4.8 Geosynthetic Quality Assurance Consultant

The Geosynthetic Quality Assurance Consultant is a party, independent from the Owner, Manufacturer(s), Fabricator(s) and Installer, that is responsible for observing and documenting activities related to the quality assurance of the production and installation of the geosynthetic components of the lining system, i.e., the geomembranes, geotextiles, geogrids, and geonets. He is also responsible for issuing a certification report, including as-built drawings, and documentation sealed by a Registered Professional Engineer. He is also responsible for the laboratory testing of the geosynthetics.

The Geosynthetic Quality Assurance Consultant shall be a well-established engineering firm incorporated (or otherwise registered) in the United States. The Geosynthetic Quality Assurance Consultant shall hold: an "umbrella" coverage as required by statute and/or contractual agreement. The Geosynthetic Quality Assurance Consultant shall be experienced with geosynthetics, including geomembranes, geonets, geogrids and geotextiles. The Geosynthetic Quality Assurance Consultant shall be experienced in quality assurance including

installation quality assurance of geomembranes, geonets, geogrids and geotextiles. The Geosynthetic Quality Assurance Consultant shall be experienced in the preparation of quality assurance documentation, including quality assurance forms, reports, certifications, and manuals.

The Geosynthetic Quality Assurance Consultant shall provide the following, in writing, to the Owner:

- Corporate background and information.
- Proof of "umbrella" insurance coverage as required by statute and/or proposed contractual agreement.
- Quality assurance capabilities:
  - a summary of the firm's experience with geosynthetics, including geomembranes, geonets, geogrids and geotextiles;
  - a summary of the firm's experience in quality assurance, including installation quality assurance of geomembranes, geogrids, geonets, and geotextiles; and
  - a summary of quality assurance documentation and methods used by the firm, including sample quality assurance forms, reports, certifications, and manuals prepared by the firm.

The Geosynthetic Quality Assurance Engineer shall hold at least a B.S. engineering degree and be registered as a Professional Engineer in the state in question. He shall also comply with the experience requirements listed for the Geosynthetic Quality Assurance Consultant. The Geosynthetic Quality Assurance Engineer shall also be specifically experienced in the installation of geosynthetics and shall be trained and certified by the Geosynthetic Quality Assurance Consultant in the duties and responsibilities associated with geosynthetic quality assurance. Some of the duties of the Geosynthetic Quality Assurance Engineer may, in some cases, be assigned to another individual who is assigned as the full time on-site resident manager in charge of the Quality Assurance Monitors. In such cases, this on-site manager shall meet the installation-related experience requirements listed for the Geosynthetic Quality Assurance Engineer. Geosynthetic Quality Assurance Monitors shall be quality assurance personnel who have been specifically trained in quality assurance of geosynthetics.

The Geosynthetic Quality Assurance Consultant shall provide the following, in writing, to the Owner:

- Resumes of personnel to be involved in the project including the Geosynthetic Quality Assurance Engineer, the

on-site manager (if different from the Geosynthetic Quality Assurance Engineer), and the Geosynthetic Quality Assurance Monitors.

- Proof of Professional Engineering registration (or ability to be registered) in the project state of the engineer to be designated the Geosynthetic Quality Assurance Engineer, as well as proof of B.S, M.S or Ph.D. engineering degree.

- Proof of quality assurance experience of quality assurance personnel with emphasis on geomembranes, geonets, geotextiles and geogrids.

1.4.9 Soils Quality Assurance Consultant

The Soils Quality Assurance Consultant is a party, independent from the Owner, Manufacturer(s), Fabricator(s) and Installer that is responsible for observing, testing and documenting activities related to the quality assurance of the earthworks at the site. He is also responsible for issuing a certification report, sealed by a Registered Professional Engineer.

Qualifications of the Soils Quality Assurance Consultant relate specifically to the earthworks contract and are not addressed in these specifications.

1.4.10 Geosynthetic Quality Assurance Laboratory

The Geosynthetic Quality Assurance Laboratory is a party, independent from Owner, Manufacturer(s), Fabricator(s) and Installer, responsible for conducting tests on samples of geosynthetics taken from the site. The Geosynthetic Quality Assurance Laboratory service cannot be provided by any party involved with the manufacture, fabrication, or installation of any of the geosynthetic components.

The Geosynthetic Quality Assurance Laboratory shall have experience in testing geosynthetics and be familiar with ASTM, FTMS, NSF and other applicable test standards. The Geosynthetic Quality Assurance Laboratory shall be capable of providing test results within 48 hours of receipt of samples and shall maintain that standard throughout the installation.

1.4.11 Owner

The Owner owns, and/or is responsible for, the lined facility; in these specifications, the term "Owner" shall apply equally to "Operator", i.e., the party responsible for operating the lined facility.

1.4.12 Project Manager

The Project Manager is the official representative of the Owner; in these specifications, the term "Project Manager" shall apply equally to "Construction Coordinator", i.e., the individual in charge of coordinating field activities.

The selection of the Project Manager is the direct responsibility of the Owner. Qualifications for this position are therefore determined by the Owner independently of the program.

1.5 Warranty

A written warranty shall be obtained from the Manufacturer/Fabricator/Installer as part of the contract documents. This warranty shall address both the quality of the material and the workmanship. A minimum installation defects warranty period of two (2) years shall be acceptable. Warranty conditions proposed by the Manufacturer/ Fabricator/Installer concerning limits of liability shall be evaluated on a project-specific basis.

1.6 Quality Assurance Program

The Manufacturer(s)/Fabricator(s)/Installer shall all agree to participate in and conform with all items and requirements of the Owner's quality assurance program, as outlined in this specification and related documents.

2. MATERIAL SPECIFICATIONS

2.1 Geomembrane

2.1.1 General Requirements

The manufacturer shall deliver geomembranes which are in conformance with the specifications listed below.

2.1.2 Specified Geomembrane Properties

2.1.2.1 Geomembrane Resin

The geomembrane shall be manufactured from new, first-quality polyethylene resin, and shall be designed and manufactured specifically for use in geomembranes.

The polyethylene resin shall meet the following specifications:

Specific Gravity	(ASTM* D792 Method A, or ASTM D1505)	$\geq$ 0.93
Melt Index	(ASTM* D1238 Condition 190/216)	0.1 - 1.1 g/10 min.

* American Society for Testing and Materials

Reclaimed polymer shall not be added to the resin (however, the use of polymer recycled during the manufacturing process shall be permitted if done with appropriate cleanliness and if recycled polymer does not exceed 2% by weight).

2.1.2.2 Geomembrane Rolls

Unless otherwise noted on drawings and specifications, all geomembranes used as secondary or primary liners shall be at least 60 mils (1.5 mm) thick. All geomembranes used as caps for cover systems shall be at least 40 mils (1 mm) thick.

The geomembranes shall meet the specifications shown in Table 1.

TABLE 1

GEOMEMBRANE PROPERTIES

PROPERTY	QUALIFIER	UNIT	SPECIFIED VALUE[1]				TEST METHOD
Physical Properties							
Thickness	minimum	mils (mm)	40 (1.0)	60 (1.5)	80 (2.0)	100 (2.5)	ASTM D1593 Para. 8.1.3
Specific Gravity	minimum	N/A	0.93	0.93	0.93	0.93	ASTM D792 Method A or ASTM D1505
Mechanical Properties							
Tensile Properties (each direction)							ASTM D638
1. Force per unit width at yield[2]	minimum	lb/in (kN/m)	80 (14)	120 (21)	160 (28)	200 (35)	
2. Tensile strength[3] (force per unit width at break)	minimum	lb/in (kN/m)	150 (26)	225 (40)	300 (53)	375 (66)	
3. Elongation at yield	minimum	%	10	10	10	10	
4. Elongation at break	minimum	%	500	500	500	500	
5. Modulus of elasticity	minimum	ksi (MPa)	80 (550)	80 (550)	80 (550)	80 (550)	
Tear Resistance	minimum	lb (N)	30 (133)	40 (178)	50 (222)	60 (266)	ASTM D1004 Die C
Puncture Resistance	minimum	lb (N)	40 (178)	60 (266)	70 (311)	80 (356)	FTMS 101B/ 2065
Environmental Properties							
Low Temperature	maximum	°F (°C)	-40 (-40)	-40 (-40)	-40 (-40)	-40 (-40)	ASTM D746 Procedure B
Carbon Black Content	range	%	2 - 3	2 - 3	2 - 3	2 - 3	ASTM D1603
Carbon Black Dispersion	N/A		A-1	A-1	A-1	A-1	ASTM D3015
Dimensional Stability (each direction)	max. change	%	3	3	3	3	ASTM D1204 212°F, 15 min.
Resistance to Soil Burial							ASTM D3083 (as modified in NSF Appendix A)
1. Tensile strength at yield	max. change	%	10	10	10	10	
2. Tensile strength at break	max. change	%	10	10	10	10	
3. Elongation at yield	max. change	%	10	10	10	10	
4. Elongation at break	max. change	%	10	10	10	10	
5. Modulus of elasticity	max. change	%	10	10	10	10	
Environmental Stress Crack	mimimum	hrs.	2,000	2,000	2,000	2,000	ASTM D1693 (as modified in NSF Appendix A Condition C at 100°C)

1. For a specific geomembrane, only the column of values corresponding to the selected nominal thickness should appear under the heading "specified value".

2. The values given correspond to a stress of 2000 psi (14 MPa).

3. The values given correspond to a stress of 3750 psi (26 MPa).

TABLE 2

SEAM PROPERTIES

PROPERTY	QUALIFIER	UNIT	SPECIFIED VALUE[1]				TEST METHOD
Gauge	nominal	mils (mm)	40 (1.0)	60 (1.5)	80 (2.0)	100 (2.5)	-
Shear Strength[2] (at yield point)	minimum	lb/in (kN/m) width	80 (14)	120 (21)	160 (28)	200 (35)	ASTM D638 (type M-1 specimen 0.5 in (10 mm) wide tested at 2 in (50 mm) per minute.
			FTB[3]	FTB[3]	FTB[3]	FTB[3]	
Peel Adhesion			FTB[3]	FTB[3]	FTB[3]	FTB[3]	ASTM D638 (type M-1 specimen 0.5 in (10 mm) wide tested at 2 in (50 mm) per minute.
Dead Load							
1. Room temperature 73°F 50% bonded seam load	N/A		pass	pass	pass	pass	NSF Appendix A
2. Elevated temperature 158°F 25% bonded seam load	N/A		pass	pass	pass	pass	NSF Appendix A
Resistance to Soil Burial							ASTM D3083 (as modified in NSF Appendix A)
1. Peel adhesion			FTB[3]	FTB[3]	FTB[3]	FTB[3]	
2. Bonded seam strength	maximum change	%	-20	-20	-20	-20	

1. For a specific geomembrane, only the column of values corresponding to the selected nominal thickness should appear under the heading "specified value".
2. Also called "Bonded Seam Strength".
3. FTB = Film Tear Bond.

In addition, the geomembrane shall:

- contain a maximum of 1% by weight of additives, fillers or extenders (not including carbon black);
- contain 2% - 3% carbon black for ultra-violet light resistance;
- not have striations, roughness, pinholes or bubbles on the surface; and,
- be produced so as to be free of holes, blisters, undispersed raw materials, or any sign of contamination by foreign matter.

The geomembrane shall be supplied to the site as factory panels or in rolls. A factory panel is comprised of one or more rolls which have been seamed together in a factory. A field panel is the unit area of geomembrane which is to be seamed in the field. Two cases can be considered:

- if the geomembrane is not fabricated into factory panels, a field panel is a roll or a portion of roll cut in the field; or,
- if the geomembrane is fabricated into factory panels, a field panel is a factory panel or a portion of a factory panel cut in the field.

Field panel sizes shall be determined by approved plans showing the layout and dimensions of field panels in the structure.

During shipment and storage, the geomembrane shall be protected from excessive heat or cold, puncture, cutting, or other damaging or deleterious conditions.

2.1.3 Labelling

Labels on each roll or factory panel shall identify:

- the thickness of the material;
- the length and width of the roll or factory panel;
- the manufacturer;
- directions to unroll the material;
- product identification;
- lot number; and,
- roll or field panel number.

2.2 Geotextiles and Geogrids

2.2.1 General Requirements

Unless otherwise noted on the drawings, geotextile and geogrid suppliers shall furnish materials whose "Minimum Average Roll Values", as defined by the Federal Highway Administration (FHWA), meet or exceed the criteria listed below under "Specified Geotextile Properties". The Designer shall prepare generic property value specifications which are relevant to the physical, mechanical, hydraulic and environmental conditions expected at the specific site. A list of properties for which the Designer will prepare values is given in 2.2.2.1. The geotextiles and geogrids provided by the suppliers shall meet or exceed the property values specified by the Designer and shall be stock products; i.e., except when specifically authorized, the supplier shall not furnish products specifically manufactured to meet the specifications of this project.

The products shall be comprised of polymeric yarns, or fibers, or welded or drawn strands oriented into a stable network which retains its structure during handling, placement and long-term service. Unless a longer durability is specified by the Designer, geotextiles and geogrids shall be capable of withstanding direct exposure to sunlight for 30 days with no measurable deterioration. Products shall be chemically compatible with the expected site-specific leachate.

During shipment and storage, the geotextiles shall be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions. The geogrids shall be protected from damaging or deleterious conditions.

2.2.2 Specified Geotextile Properties

2.2.2.1 Filtration Applications

If one particular side of the geotextile filter is to be placed against the soil to be filtered, that side shall be so marked. The side of a geotextile filter to be placed in contact with a geonet shall present a relatively smooth surface (heatbonded or similar). This requirement shall in no way diminish responsibility for any of the property values which must be determined by the Designer. The geotextile properties whose values must be selected by the Designer are as follows:

Porosity (Nonwovens)	Thickness
Apparent Opening Size (AOS)	Roll Length and width
Permeability	Percent Open Area (Wovens)
Stiffness	Friction angle
Maximum necking at 5% elongation	

In addition to the designed properties values listed immediately above, the property values listed in Table 3 must be met.

PROPERTY	UNITS	VALUE	TEST
Grab Strength	lb (N)	180 (800)	ASTM D1682, Method 16 using CRE and 1 in. (25 mm)
Trapezoidal Tear	lb (N)	50 (220)	ASTM D1117, Method 14
Puncture Strength	lb (N)	80 (355)	ASTM D751, with flat tip 5/16 in. (8 mm) probe
Burst Strength	psi (kPa)	290 (2000)	ASTM D3736, Method 4

Table 3: Required survivability property values for geotextile filters.

2.2.2.2 Cushion Applications

The property values shown in Tables 4 and 5 must be met. In unusual or severe conditions, the Designer may be required to increase the values shown in these tables, in which case they shall be revised and the revised Tables 4 and 5 shall govern.

PROPERTY	UNITS	VALUE		TEST
Thickness	mils (mm)	200	(5)	D1777, 4 psf (0.2 kPa)
Mass/Unit Area	oz/yd^2 (g/m^2)	12	(400)	ASTM D1910
Apparent Opening Size	in (mm)	.04	(1)	ASTM D35 Proposed

Table 4: Required Index Property values for geotextile cushions.

PROPERTY	UNITS	VALUE		TEST
Grab Strength	lb (N)	270	(1200)	ASTM 1682, Method 16, using CRE and 1 in. (25 mm) jaws
Trapezoidal Tear	lb (N)	75	(330)	ASTM D117 Method 14
Puncture Strength	lb (N)	75	(330)	Modified ASTM 751, with flat tip 5/16 in. (8 mm) probe
Burst Strength	psi (kPa)	430	(3000)	ASTM D3736, Method 4
Trapezoidal Tear	lb (N)	75	(330)	ASTM D117 Method

Table 5: Required Survivability property values for geotextile cushions.

2.2.2.3 Reinforcement Applications

The following geogrid property values must be determined for each specific site by the Designer:

- Wide strip tensile secant modulus at 2, 5, and 10%;
- Ultimate tensile strength; and,
- Pull out resistance at the design normal load (soil-specific).

In addition, the geogrid must be chemically compatible, for a period of time to be determined by the Designer, with the waste products to which it will be exposed.

2.2.3 Labelling

Geotextiles shall be supplied in rolls wrapped in relatively impermeable and opaque protective covers. Geotextile and geogrid rolls shall be marked or tagged with the following information:

- manufacturer's name;
- product identification;
- lot number;
- roll number; and,
- roll dimensions.

Additionally, if any special handling is required, it shall be so marked on the geotextile or geogrid itself, e.g., "This Side Up" or "This Side Against Geonet".

2.3 Geosynthetic Transmission Media

Commonly used geosynthetic transmission media are geonets, thick geotextiles and geosynthetic composite drains.

2.3.1 General Requirements

Suppliers shall furnish geosynthetic transmission media whose properties meet or exceed the requirements in these specifications. The Designer shall prepare generic property value specifications which are relevant to the mechanical, hydraulic and environmental conditions expected at the specific site. A list of specific properties for which the Designer will prepare values is given in Section 2.3.2. The geosynthetic tranmission media provided by the suppliers shall meet or exceed the property values specified by the Designer and shall be stock products; i.e., except when specifically authorized, the supplier shall not furnish products specifically manufactured to meet the specifications of this project.

During shipment and storage, the geosynthetic transmission media shall be protected from mud, dirt, dust, puncture, cutting or other damaging or deleterious conditions.

2.3.2 Specified Geosynthetic Transmission Media Properties

The Designer shall specify values for the properties listed below. These values shall be based on the specific conditions at the site.

Roll length	Transmissivity
Roll width	Conductivity

In addition to the design property values listed immediately above, the specifications shown below in Table 6 must be met. The Manufacturer shall provide test results for these procedures, as well as a certification that the materials meet the specifications developed by the Designer.

In addition to the property values listed in Table 4 and 5, the geosynthetic transmission media shall:

- retain their structure during handling, placement, and long-term service;
- be capable of withstanding outdoor exposure for at least one year; and
- be chemically compatible with the expected site-specific leachate.

2.3.3 Labelling

Geosynthetic transmissions media shall be supplied in rolls wrapped in protective covers and marked or tagged with the following information.

- manufacturer's name;
- product identification;
- lot number;
- roll number; and,
- roll dimensions.

PROPERTY	UNITS	VALUE	TEST
Polymer composition	%	minimum 95% polyethylene	
Polymer specific gravity		0.93	ASTM D1505 Note (1)
Polymer melt index	g/min	1.1/10	ASTM D1238
Carbon black content	%	2 - 3	ASTM D4218
Thickness	mils (mm)	160 (4)	ASTM D35 Proposed
Nominal transmissivity	ft^2/s (m^2/s) x 10^{-5}	32 (3)	Notes (2) (4)
Nominal conductivity	ft^2/s (m^2/s) x 10^{-3}	23 (4)	Notes (3) (4)
Tensile strength	lb/in (kN/m)	23 (4)	Notes (4)

Notes:

(1) The specific gravity of the net polymer must not exceed that of the geomembrane.

(2) The nominal transmissivity is the transmissivity of a geosynthetic transmission media measured using water at 68°F (20°C) with a gradient of one, under a compressive stress of 200 psf (10 kPa), between two smooth steel plates.

(3) The nominal conductivity is obtained by dividing the nominal transmissivity by the nominal thickness (i.e., the thickness of the net measured between two steel plates under a compressive stress of 200 psf (10 kPa).

(4) Use tentative methods being prepared by ASTM Committee D35 on Geotextiles and Related Products.

Table 6: Required property values for geosynthetic transmission media.

2.4 Transportation, Handling and Storage

Transportation of the respective geosynthetic materials is the responsibility of the Manufacturer(s) and/or Fabricator(s). The Manufacturer(s) and/or Fabricator(s) shall be liable for all damages to the materials incurred prior to and during transportation to the site.

Handling, storage, and care of the geosynthetic materials prior to and following installation at the site, is the responsibility of the Installer. The owner shall provide adequate storage space at the site. The Installer shall be liable for all damages to the materials incurred prior to final acceptance of the lining system by the Owner, except for those due to negligent actions on the part of the Owner.

The Manufacturer(s) and/or Installer shall retain ownership of the geosynthetic materials until the lining system is fully certified and accepted by the Owner.

3. MANUFACTURING AND FABRICATION - QUALITY CONTROL

3.1 Geomembrane Manufacturing

3.1.1 Raw Material Quality Control

The resin specifications are listed in Section 2.1.1. Resins which do not meet all specifications shall not be accepted.

Testing shall be carried out by the Geomembrane Manufacturer to demonstrate that the resin meets the specification. The Geomembrane Manufacturer shall certify in writing that the resin does meet the specifications, and shall be held liable for any non-compliance. Any geomembrane manufactured from non-complying resin shall be rejected. At the Owner's discretion, additional conformance testing may be carried out by the Geosynthetic Quality Assurance Laboratory, and paid for by the Owner. If the results of the Geomembrane Manufacturer's and the Geosynthetic Quality Assurance Laboratory's testing differ, the testing shall be repeated by the Geosynthetic Quality Assurance Laboratory, and the Manufacturer shall be allowed to monitor this testing. The results of this latter series of tests will prevail, provided that the applicable test methods have been followed.

3.1.2 Roll Quality Control

The geomembrane specifications are listed in Section 2.1.2. Geomembranes which do not meet all specifications shall not be accepted.

The carbon black for ultra-violet protection shall be added to the otherwise pure polyethylene resin as part of the roll manufacturing process.

The geomembrane shall be continuously monitored during the manufacturing process for inclusions, bubbles, or other defects, and no geomembrane shall be accepted which exhibits any defects. Geomembrane thickness shall also be monitored continuously during the manufacturing process and no geomembrane shall be accepted which fails to meet the specified thickness.

The geomembrane shall be tested, at a minimum, once every 40,000 ft.^{2} (4,000 m^2) to evaluate its stress-deformation characteristics. This testing shall be performed by the Geomembrane Manufacturer. Samples not satisfying the specifications shall result in the rejection of the applicable rolls. In the case of a failure, subsequent testing shall be performed on geomembrane produced from the same resin batch to determine if rolls produced from the entire batch shall be regarded as unsatisfactory. At the Geomembrane Manufacturer's discretion and expense, additional testing of

individual rolls may be performed to more closely identify the non-complying rolls and/or to qualify individual rolls.

As a minimum, the following tests shall be performed:

Test	Procedure
density	ASTM D792 Method A or ASTM D1505
thickness	ASTM D1593 or ASTM D374 Method C
yield strength	ASTM D638
yield elongation	ASTM D638
tensile strength	ASTM D638
tensile elongation	ASTM D638
carbon black	ASTM D1603
carbon black dispersion	ASTM D3105

The following tests need not be run at the 1 per 40000 ft^2 (4000 m^2) frequency. The Manufacturer must certify for each project, however, that these tests have been run on geomembrane sheeting made from the particular resin (and provide the test results from this testing):

Test	Procedure
soil burial	ASTM D3083
environmental stress crack (2000 hrs.)	ASTM D1693
low temperature brittleness	ASTM D746

Samples shall be taken across the entire width of the roll and shall not include the first linear meter (three feet). Unless otherwise specified, samples shall be 1 m (3 ft.) long by the roll width. The Manufacturer shall mark the machine direction on the samples with an arrow.

The geomembrane conformance test samples shall meet or exceed the specified values.

The Manufacturer shall provide to the Owner certification of the test values obtained.

In addition, the Geomembrane Manufacturer shall certify the quality of the geomembrane rolls. As a minimum, the Geomembrane Manufacturer shall provide quality control certificates for each batch of resin and each shift's production of geomembrane. These quality control certificates shall be signed by responsible parties employed by the Geomembrane Manufacturer (such as the production manager), notarized, and supplied to the Project Manager.

The quality control certificate shall include:

- roll numbers and identification;
- sampling procedures; and,
- results of quality control tests, including a description of test methods used.

3.1.3 Geomembrane Manufacturing Plant Visit

The Geomembrane Manufacturer shall agree to allow the Owner to carry out an annual plant visit to the manufacturing plant. In addition, the Geomembrane Manufacturer shall agree to allow the Owner or his designated alternate to visit the manufacturing plant for a project specific visit. If possible, this latter visit shall be prior to or during the manufacturing of the geomembrane rolls for the specific project. The Owner or his designated alternate shall review the manufacturing process, quality control, laboratory facilities, and testing procedures.

During the project specific plant visit, those reviewing shall also:

- verify that properties guaranteed by the Geomembrane Manufacturer meet all specifications;
- verify that the measurements of properties by the Geomembrane Manufacturer are properly documented and test methods used are acceptable;
- spot inspect the rolls and verify that they are free of holes, blisters, or any sign of contamination by foreign matter;
- review packaging and transportation procedures to verify that these procedures are not damaging the geomembrane; and,
- verify that roll packages have a label indicating the name of the manufacturer, type of geomembrane, sheet thickness, and roll number.

3.2 Geomembrane Fabrication

This section shall be deleted if the manufactured geomembrane rolls are not fabricated into factory panels. Factory Panels are defined as combinations of rolls seamed together in a factory.

If the Designer, Manufacturer or Installer has proposed a field panel layout which requires specific factory panel layouts, and if this field panel layout has been accepted by the Owner, then the required factory panel layout shall be considered part of the specifications.

The approved seaming processes are extrusion welding and fusion welding. Proposed alternate processes shall be documented and submitted to the Project Manager for approval.

The factory seam specifications are listed in Table 2. No factory panels shall be accepted which do not meet all of the seam specifications. The Fabricator shall be required to certify in writing that the factory panels do meet the seam specifications and shall be held liable for any non-compliance.

3.2.1 Requirements of Personnel

All personnel performing factory seaming operations shall be qualified by experience or by successfully passing seaming tests. At least one seamer shall have experience seaming a minimum of 1,000,000 ft^2 (100,000 m^2) of geomembrane thicker than 24 mils (0.6 mm) using the same type of seaming apparatus to be used in fabricating this factory panel. The most experienced seamer, the "master seamer", shall provide direct supervision over less experienced seamers, and shall be present during all seaming operations.

3.2.2 Seaming Equipment and Products

Only apparatus which have been specifically approved in advance by the Owner (by make and model) shall be used.

3.2.2.1 Extrusion Process

The extrusion-welding apparatus shall be equipped with gauges giving the extrudate temperature in the apparatus and at the nozzle.

The Fabricator shall provide documentation regarding the extrudate to the Project Manager and shall certify that the extrudate is compatible with the specifications, and in any event is comprised of resins compatible with the geomembrane sheeting. Resin conformance testing shall be conducted on the extrudate rod/beads by the

Manufacturer and/or the Fabricator, and the Manufacturer (if involved) and Fabaricator shall certify that the extrudate meets all resin specifications as well as other applicable specifications.

Prior to the installation of any geomembrane material, the Fabricator shall submit quality control records, including apparatus temperatures, extrudate temperatures and ambient temperatures to the Project Manager.

3.2.2.2 Fusion Process

The fusion-welding apparatus must be automated vehicular-mounted devices. The fusion-welding apparatus shall be equipped with gauges giving the applicable temperatures and pressures.

Prior to the installation of any geomembrane material, the Fabricator shall submit seaming quality control records, including ambient temperatures and applicable apparatus temperatures and pressures, to the Project Manager.

3.2.3 Seam Preparation

Prior to seaming, the seam area shall be clean and free of moisture, dust, dirt, debris of any kind, and foreign material. If seam overlap grinding is required, the process shall be completed according to the Geomembrane Manufacturer's instructions, within one hour of the seaming operation and in a way that does not damage the geomembrane. Seams shall be aligned with the fewest possible number of wrinkles and "fishmouths".

3.2.4 Weather Conditions for Factory Seaming

Panel fabrication is usually done in factories with a controlled atmosphere. Therefore this section applies to the less frequent case of outdoor fabrication, or fabrication under a rudimentary shelter.

Allowable weather conditions for factory seaming are as follows:

- Unless authorized in writing by the Project Manager, no seaming shall be attempted at ambient temperatures below 40°F (5°C) or above 104°F (40°C).

- At ambient temperatures between 40°F (5°C) and 50°F (10°C), seaming shall be allowed if the geomembrane is preheated by either sun or hot air device, and if there is no excessive cooling.

- Above an ambient temperature of 50°F (10°C), no preheating shall be required.

- In all cases, the geomembrane shall be dry and protected from wind damage.

If the Fabricator wishes to use methods which may allow seaming at ambient temperatures below 40°F (5°C), then the Fabricator shall demonstrate and certify that such methods produce seams which are entirely equivalent to seams produced at ambient temperatures above 40°F (5°C).

3.2.5 Overlapping and Temporary Bonding

The Fabricator shall ensure and certify that:

- the rolls of geomembrane have a finished overlap of a minimum of 3 in. (75 mm) for extrusion welding and 5 in. (125 mm) for fusion welding;

- the procedure used to temporarily bond adjacent rolls together does not damage the geomembrane; in particular, the temperature of hot air at the nozzle of any spot welding apparatus shall be controlled such that the geomembrane is not damaged; and

- no solvent or adhesive is used unless the product is approved by the Project Manager.

The Fabricator shall provide the Project Manager and Geosynthetics Quality Assurance Engineer with a certificate indicating that the above conditions are met.

3.2.6 Trial Seams

Trial seams shall be made on fragment pieces of geomembrane liner to verify that seaming conditions are adequate. Such trial seams shall be made at the beginning of each seaming period, and at least once each four hours, for each seaming apparatus used that day. Also, each seamer shall make at least one trial seam each day. Trial seams shall be made under the same conditions as fabrication seams.

The trial seam sample shall be at least 2 ft. (0.6 m) long by 1 ft. (0.3 m) wide (after seaming) with the seam centered lengthwise. Seam overlap shall be as indicated in Section 3.2.5.

Two adjoining specimens each 1 in. (25 mm) wide shall be cut from the trial seam sample by the Fabricator. The specimens shall be tested

respectively in shear and peel at the factory and should not fail in the seam. If a specimen fails, the entire operation shall be repeated. If the additional specimen fails, the seaming apparatus or seamer shall not be accepted and shall not be used for fabrication seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved.

After completion of the above described tests, the remaining portion of the trial seam sample can be discarded. Alternatively, if agreed upon between the parties involved and indicated in the project specific Geosynthetic Quality Assurance Plan, the remaining portion of the trial seam sample can be subjected to destructive testing as indicated in Section 3.2.8. If a trial seam sample fails a test conducted by the Geosynthetic Quality Assurance Laboratory, then a destructive test seam sample shall be taken from the seams completed by the seamer during the shift related to the considered trial seam. These samples shall be forwarded to the Geosynthetics Quality Assurance Laboratory and, if they fail the tests, the procedure indicated in Section 3.2.8 shall apply. The conditions of this paragraph shall be considered as met for a given seam if a destructive seam test sample has already been taken from the considered seams.

Results of all factory test seams shall be forwarded to the Project Manager and Geosynthetics Quality Assurance Engineer.

3.2.7 Nondestructive Seam Continuity Testing

3.2.7.1 Concept

The Fabricator shall nondestructively test all fabricated seams over their full length using a vacuum unit, air pressure test, or other approved procedure. The purpose of this test is to check the continuity of seams. It does not provide any information on seam strength. Continuity testing shall be done as the seaming work progresses, not at the completion of all factory seaming.

Tests shall be fully documented by the Fabricator and reported to the Project Manager and Geosynthetics Quality Assurance Engineer.

Any seams which fail nondestructive testing shall be repaired in accordance with Section 3.2.8.7. Repairs shall be fully documented by the Fabricator and reported to the Project Manager.

3.2.7.2 Vacuum Testing

The equipment shall be comprised of the following:

- a vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly, and a vacuum gauge;

- a steel vacuum tank and pump assembly equipped with a pressure controller and pipe connections;

- a rubber pressure/vacuum hose with fittings and connections;

- a bucket and wide paint brush; and,

- a soapy solution.

The following procedures shall be followed:

- energize the vacuum pump and reduce the tank pressure to approximately 10 in. of mercury, i.e., 5 psi gauge (35 kPa);

- wet a strip of geomembrane approximately 12 in. by 48 in. (0.3 m by 1.2 m) with the soapy solution;

- place the box over the wetted area;

- close the bleed valve and open the vacuum valve;

- ensure that a leak tight seal is created;

- for a period of not less than 30 seconds, examine the geomembrane through the viewing window for the presence of soap bubbles;

- if no bubble(s) appear after 30 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 3 in. (75 mm) overlap and repeat the process; and,

- all areas where soap bubbles appear shall be marked and repaired in accordance with Section 3.2.8.7.

3.2.7.3 Air Pressure Testing (For Double Fusion Seam Only)

The equipment shall be comprised of the following:

- an air pump (manual or motor driven) equipped with pressure gauge capable of generating and sustaining a pressure between 25 and 30 psi (160 and 200 kPa);

- a rubber hose with fittings and connections; and,

- a sharp hollow needle, or other approved pressure feed device.

The following procedures shall be followed:

- seal both ends of the seam to be tested;
- insert needle or other approved pressure feed device into the tunnel created by the fusion weld;
- energize the air pump to a pressure between 25 and 30 psi (160 and 200 kPa), close valve, and sustain pressure for approximately 5 minutes;
- if loss of pressure exceeds 15 kPa (2 psi) or does not stabilize, locate faulty area and repair in accordance with Section 3.2.8.7; and,
- remove needle or other approved pressure feed device and seal.

3.2.8 Destructive Seam Strength Testing

Destructive seam samples are taken to test seam integrity, the measures of which are shear and peel strengths.

The Fabricator shall destructively test an average of two samples per factory panel. These samples shall be taken from extra material at the beginning or end of factory panel seams such that the factory panel is not damaged and the factory panel geometry is not altered. The location of these samples shall be documented by the Fabricator.

3.2.8.1 Location and Frequency

A minimum frequency of one test location per 500 ft. (150 m) of seam length shall be used. This minimum frequency is to be determined as an average taken from all the panels. A maximum frequency shall be agreed upon by the Fabricator and the Owner. Test locations shall be determined during seaming. Selection of such locations may be prompted by suspicion of excess crystallinity, contamination, offset welds, or any other potential cause of imperfect welding.

3.2.8.2 Sampling Procedure

Samples shall be cut by the Fabricator as the seaming progresses in order to have laboratory test results before completion of factory panel fabrication. The Fabricator shall:

- assign a number to each sample, and mark it accordingly;
- record sample location on layout drawing; and,
- record reason for taking the sample at this location (e.g., statistical routine, suspicious feature of the geomembrane).

In the event samples are taken from the usable area of the factory panel, all holes in the factory panel resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described in Section 3.2.8.7. The continuity of the new seams in the repaired area shall be tested according to Section 3.2.8.7.

3.2.8.3 Size of Samples

The samples shall be 12 in. (0.3 m) wide by 44 in. (1.1 m) long with the seam centered lengthwise. One 1 in. (25 mm) wide strip shall be cut from each end of the sample and these shall be tested at the fabrication plant. The remaining sample shall be cut into three parts and distributed as follows:

- one portion to the Fabricator for laboratory testing, 12 in. x 12 in. (0.3 m x 0.3 m);
- one portion for Geosynthetic Quality Assurance Laboratory testing, 12 in. x 18 in. (0.3 m x 0.5 m); and,
- one portion to the Owner for archive storage, 12 in. x 12 in. (0.3 m x 0.3 m).

3.2.8.4 Testing at the Fabrication Factory

The two 1 in. (25 mm) wide strips mentioned in Section 3.2.8.3 shall be tested at the fabrication factory by tensometer, for peel and shear respectively and shall not fail in the seam. If any test sample fails to pass, then the procedures outlined in 3.2.8.7 shall be followed. If it passes, the sample qualifies for testing in the laboratory.

3.2.8.5 Laboratory Testing

Destructive test samples shall be packaged and shipped, in a manner which will not damage the test sample. The Project Manager will be responsible for storing the archive samples. Test samples shall be tested by the Geosynthetic Quality Assurance Laboratory. The Geosynthetic Quality Assurance Laboratory shall be selected by the

Geosynthetic Quality Assurance Engineer with the concurrence of the Project Manager.

Testing shall include "Seam Strength" and "Peel Adhesion" [ASTM D638 with type M-1 specimen 0.5 in. (10 mm) wide, tested at 2 in. (50 mm) per minute]. These terms are defined in the specifications. The minimum acceptable values to be obtained in these tests are those indicated in Table 2. At least 5 specimens shall be tested for each test method. Specimens shall be selected alternately by test from the samples (i.e., peel, shear, peel, shear...).

The Geosynthetic Quality Assurance Laboratory shall provide test results no more than 48 hours after they receive the samples.

3.2.8.6 Fabricator's Laboratory Testing

The Fabricator's laboratory test results shall be presented, for information purposes, to the Geosynthetic Quality Assurance Manager for his comments.

3.2.8.7 Procedures for Destructive Test Failure

The following procedures shall apply whenever a sample fails a destructive test, whether that test is conducted by the Geosynthetic Quality Assurance Laboratory, the Fabricator's Laboratory, or by tensometer. The Fabricator has two options:

- The Fabricator can reconstruct the seam between any two passed test locations.

- The Fabricator can trace the welding path to an intermediate location (at 10 ft. (3 m) minimum from the point of the failed test in each direction) and take a small sample for an additional test at each location. If these additional samples pass the test, then full laboratory samples are taken. If these laboratory samples pass the tests, then the seam is reconstructed between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed.

All acceptable seams must be bounded by two locations from which samples passing laboratory destructive tests have been taken. In cases exceeding 150 ft. (50 m) of reconstructed seam, a sample taken from the zone in which the seam has been reconstructed must pass destructive testing.

3.2.9 Repairs

All repairs shall be conducted in accordance with Section 3.2.8.7. Each patch or other type of repair shall be numbered and logged by the Fabricator.

All repairs shall be subjected to the non-destructive seam testing procedure described in Section 3.2.7.

All repair documentation shall be provided by the Fabricator to the Project Manager.

3.2.10 Panel Certification

Prior to shipment of the factory panels to the site, the Fabricator shall provide the Owner with a quality control certification for each shift's production of factory panels. The quality control certification shall be signed by a responsible party employed by the Fabricator such as the production manager, and shall be notarized. The quality control certification shall include:

- factory panel numbers and identification;
- results of quality control tests including sampling procedures;
- documentation of repairs and non-destructive testing of repairs; and,
- in the event of seaming below 40°F (5°C), an addendum specifically stating that the low temperature seaming procedure does not cause any physical or chemical modification to the geomembrane that will generate any short or long term damage to the geomembrane.

3.2.11 Fabrication Factory Visit

The Fabricator shall agree to allow the Owner to carry out an annual factory visit to the fabrication factory. In addition, the Fabricator shall agree to allow the Owner or his designated alternate to visit the fabrication factory for a project specific visit. Such a visit shall be during the fabrication of the geomembrane panels for the specific project. Those conducting the visit shall:

- review the fabrication process;
- verify all quality control procedures, such as non-destructive and destructive seam testing procedures, repair procedures, and documentation procedures for testing and repair;

- review testing facilities of the Fabricator;
- spot inspect the factory panels and verify that they are free of holes, blisters, any sign of contamination by foreign matter, or improper patches or re-welds;
- review packaging and transportation procedures to verify that these procedures are not damaging the geomembrane;
- verify that the panel packages have a label indicating name of Fabricator, type of geomembrane, dimension and panel number; and,
- verify that extrusion rods and/or beads are derived from the same base resin type as the geomembrane.

A report describing the visit shall be retained by the Owner. Alternatively, the Owner may elect to have a full time Geosynthetic Quality Assurance Contractor at the fabrication factory to observe all factory seaming.

3.3 Manufacture of Other Geosynthetics

The other geosynthetic materials utilized in the geomembrane lining system (geotextiles, geonets, and geogrids) shall also be manufactured with a high degree of quality control. In most cases, however, sampling can be carried out on sacrificial portions of the material. Consequently, repair of sampled locations should not be required. The following criteria are necessary for these components.

3.3.1 Roll Quality Control

Specifications for geotextiles, geonets, and geogrids are contained in Section 2.2 and 2.3.

All materials shall be tested, at a minimum, once every 40,000 ft^2 (4,000 m^2) to evaluate the pertinent characteristics for quality control. This testing shall be performed by the respective Manufacturers. Samples not satisfying the specifications shall result in the rejection of the applicable rolls. At the Manufacturers' discretion and expense, additional testing of individual rolls may be performed to more closely identify the non-complying rolls and/or to qualify individual rolls.

The Manufacturers shall certify the quality of the rolls of geotextiles, geonets, or geogrids. As a minimum, the Manufacturers shall provide quality control certificates for each batch of resin and each shift's production. These quality control certificates shall be

signed by responsible parties employed by the Manufacturer(s) (such as the production manager), notarized, and supplied to the Project Manager.

The quality control certificate shall include:

- roll numbers and identification;
- sampling procedures; and,
- results of quality control tests, including a description of test methods used.

4. GEOMEMBRANE INSTALLATION

4.1 Earthwork

4.1.1 Surface Preparation

The Earthwork Contractor shall be responsible for preparing the supporting soil according to the Designer's specifications. These earthwork specifications are not included in this document.

The Installer shall certify in writing that the surface on which the geomembrane will be installed is acceptable. This certification of acceptance shall be given by the Installer to the Project Manager prior to commencement of geomembrane installation in the area under consideration.

After the supporting soil has been accepted by the Installer it shall be the Installer's responsibility to indicate to the Project Manager any change in the supporting soil condition that may require repair work. Special care must be taken to maintain the prepared soil surface. No geomembrane shall be placed onto an area which has become softened by precipitation or which has cracked due to desiccation. The soil surface shall be observed daily by the Installer to evaluate desiccation cracking. The daily observations shall ascertain the effects of surface desiccation cracking upon the integrity of the soil liner.

Any damage to the subgrade caused by installation activities shall be repaired at the Installer's expense.

4.1.2 Crest Anchorage System

The anchor trench (if any) shall be excavated by the Earthwork Contractor unless otherwise specified, to the lines and grades shown on the engineering drawings, prior to geomembrane placement. The trench shall use a "V" or "U" configuration and shall have rounded corners. No loose soil shall be allowed beneath the geomembrane or lowest geosynthetic layer.

Unless otherwise specified, if the anchor trench will be excavated in a clay liner susceptible to desiccation, no more than the amount of trench required for the geomembrane to be anchored in one day shall be excavated to minimize desiccation potential of the anchor trench clay soils.

The anchor trench, if any, shall be backfilled and compacted by the Installer to the specifications noted on the design drawings. Care shall be taken when backfilling the trenches to prevent any damage to the geomembrane.

4.2 Conformance Testing

The Geosynthetic Quality Assurance Manager shall collect samples of geomembrane from the materials delivered to the site, for conformance testing, as outlined in section 2.1.4, above, and section 2.1.5 of the "Quality Assurance Manual for the Installation of Geosynthetic Lining Systems".

4.3 Geomembrane Deployment

4.3.1 Layout Drawings

The Installer shall produce layout drawings prior to geomembrane deployment. The drawings shall indicate the panel configuration and location of seams. Field seams must be differentiated from factory seams (if any). The layout drawings must be approved by the Owner and the Designer prior to the installation of any geomembrane. The layout drawings shall be suitable for use as construction drawings and shall include dimensions, details, etc. The layout drawings, as modified and/or approved by the Designer, shall become part of these specifications.

4.3.2 Panel Identification

A field panel is the unit area of geomembrane which is to be seamed in the field, i.e., a field panel is a roll or a factory panel or a portion of roll or factory panel cut in the field. Two cases can be considered:

- If the geomembrane is fabricated into panels in a factory, a field panel is a factory panel or a portion of factory panel cut in the field.

- If the geomembrane is not fabricated into factory panels, a field panel is a roll or a portion of roll cut in the field.

Each field panel must be given an "identification code" (number or letter-number) consistent with the layout plan. This identification code shall be agreed upon by the Project Manager, Installer and Geosynthetic Quality Assurance Engineer. The field panel identification code shall be related, through a table or chart, to the original resin, and the constituent rolls and factory panels.

4.3.3 Field Panel Placement

4.3.3.1 Location

Field panels shall be installed at the location and positions indicated in the layout drawings, as approved or modified. Instructions on the boxes or wrapping containing the geomembrane materials shall be followed to assure that the rolls and/or factory panels are unrolled and/or unfolded in the proper direction for seaming.

4.3.3.2 Installation Schedule

Field panels may be installed using any one of the following schedules:

- all field panels are placed prior to field seaming (in order to protect the subgrade from erosion by rain);
- field panels are placed one at a time and each field panel is seamed immediately after its placement (in order to minimize the number of unseamed field panels exposed to wind); and
- any combination of the above.

4.3.3.3 Weather Conditions

Geomembrane placement shall not proceed at an ambient temperature below 40°F (5°C) unless otherwise authorized. Geomembrane placement shall not be done during any precipitation, in the presence of excessive moisture (e.g., fog, dew), in an area of ponded water, or in the presence of excessive winds.

4.3.3.4 Method of Placement

The installer shall ensure that:

- no equipment used shall damage the geomembrane by handling, trafficking, leakage of hydrocarbons or other means;
- no personnel working on the geomembrane shall smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane;
- the method used to unroll the panels shall not cause scratches or crimps in the geomembrane and shall not damage the supporting soil;

- the prepared surface underlying the geomembrane must not be allowed to deteriorate after acceptance, and must remain acceptable up to the time of geomembrane placement;

- all geosynthetic elements immediately underlying the geomembrane must be kept clean and free of debris;

- the method used to place the panels shall minimize wrinkles (especially differential wrinkles between adjacent panels);

- adequate temporary loading and/or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, shall be placed to prevent uplift by wind (in case of high winds, continuous loading is recommended along edges of panels to minimize risk of wind flow under the panels); and,

- direct contact with the geomembrane shall be minimized; i.e., the geomembrane in excessively high traffic areas shall be protected by geotextiles, extra geomembrane, or other suitable materials.

4.3.3.5 Damage

Any field panel or portion thereof which becomes seriously damaged (torn, twisted or crimped) shall be replaced at no cost to the Owner. Less serious damage should be repaired according to Section 4.5.11.

Damaged panels or portions of damaged panels which have been rejected shall be removed from the work area.

4.4 Field Seaming

4.4.1 Seam Layout

In general, seams shall be oriented parallel to the line of maximum slope, i.e., oriented along, not across, the slope. In corners and odd-shaped geometric locations, the number of field seams shall be minimized. If possible, no horizontal seam shall be less than 5 ft. (1.5 m) from the toe of the slope. No seams shall be located in areas of potential stress concentrations.

4.4.2 Requirements of Personnel

All personnel performing seaming operations shall be qualified as indicated in Section 1.4.4.1.

4.4.3 Overlapping and Temporary Bonding

The panels of HDPE geomembrane shall be overlapped by a minimum of 3 in. (75 mm) for extrusion welding and 5 in. (125 mm) for fusion welding, but in any event, sufficient overlap shall be provided to allow peel tests to be performed on the seam.

The procedure used to temporarily bond adjacent panels together shall not damage the geomembrane; in particular, the temperature of the air at the nozzle of any spot welding apparatus shall be controlled such that the geomembrane is not damaged.

No solvent or adhesive shall be used unless the product is approved in writing by the Owner (samples shall be submitted to the Owner for testing and evaluation).

4.4.4 Seam Preparation

Prior to seaming, the seam area shall be clean and free of moisture, dust, dirt, debris of any kind, and foreign material.

If seam overlap grinding is required, the process shall be completed according to the Manufacturer's instructions within one hour of the seaming operation and in a way that does not damage the geomembrane.

Seams shall be aligned with the fewest possible number of wrinkles and "fishmouths".

4.4.5 Seaming Equipment and Products

Approved processes for field seaming are extrusion welding and fusion welding. Only apparatus which have been specifically approved by make and model shall be used. Proposed alternate processes shall be documented and submitted for approval.

4.4.5.1 Extrusion Process

The extrusion welding apparatus shall be equipped with gauges giving the temperature in the apparatus and at the nozzle.

The Installer shall provide documentation regarding the extrudate to the Project Manager and shall certify that the extrudate is compatible with the specifications, and in any event is comprised of the same resins as the geomembrane sheeting.

The Installer shall maintain at least one spare operable seaming apparatus on site. Equipment used for seaming shall not damage the

geomembrane, and the geomembrane shall be especially protected from damage in heavily trafficked areas.

The extruder shall be purged prior to beginning a seam until all heat-degraded extrudate has been removed from the barrel. Whenever the extruder is stopped, the barrel shall be purged of all heat degraded extrudate. The electric generator shall be placed on a smooth base such that no damage occurs to the geomembrane. Similarly, a smooth insulationg plate or fabric shall be place beneath the hot welding apparatus after usage.

4.4.5.2 Fusion Process

The fusion-welding apparatus must be automated vehicular-mounted devices. The fusion-welding apparatus shall be equipped with gauges giving the applicable temperatures and pressures.

The Installer shall maintain at least one spare operable seaming apparatus on site. Equipment used for seaming shall not damage the geomembrane, and the geomembrane shall be protected from damage in heavily trafficked areas.

For cross seams associated with fusion welding, the edge of the cross seams shall be ground to a smooth incline (top and bottom) prior to welding. The electric generator shall be placed on a smooth base such that no damage occurs to the geomembrane. Similarly, a smooth insulating plate or fabric shall be place beneath the hot welding apparatus after usage.

A movable protective layer may be used directly below each overlap of geomembrane that is to be seamed to prevent buildup of moisture between the sheets.

4.4.6 Weather Conditions for Seaming

Unless authorized in writing by the Project Manager, no seaming shall be attempted at ambient temperatures below 40°F (5°C) or above 104°F (40°C).

At ambient temperatures between 40°F (5°C) and 50°F (10°C), seaming shall be allowed if the geomembrane is preheated by either sun or hot air device, and if there is no excessive cooling resulting from wind. At ambient temperatures above 50°F (10°C), no preheating shall be required.

In all cases, the geomembrane shall be dry and protected from wind damage.

If the Installer wishes to use methods which may allow seaming at ambient temperatures below 40°F (5°C) or above 104°F (40°C), he shall demonstrate that the seam so produced is equivalent to those produced under normally approved conditions, and that the overall quality of the geomembrane is not adversely affected. In addition, an addendum to the contract between the Owner and the Installer is required which specifically states that the seaming procedure does not cause any physical or chemical modification to the geomembrane that will generate any short or long term damage to the geomembrane.

4.4.7 Trial Seams

Trial seams shall be made on fragment pieces of geomembrane liner to verify that seaming conditions are adequate. Such trial seams shall be made at the beginning of each seaming period, and at least once each four hours, for each seaming apparatus used that day. Also, each seamer shall make at least one trial seam each day. Trial seams shall be made under the same conditions as actual seams.

The trial seam sample shall be at least 3 ft. (1.0 m) long by 1 ft. (0.3 m) wide (after seaming) with the seam centered lengthwise. Seam overlap shall be as indicated in Section 4.4.3.

Two adjoining specimens each 1.0 in. (25 mm) wide shall be cut from the trial seam sample by the Installer. The specimens shall be tested respectively in shear and peel using a field tensometer, and shall not fail in the seam. If a specimen fails, the entire operation shall be repeated. If the additional specimen fails, the seaming apparatus or seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial welds are achieved.

After completion of the above described tests, the remaining portion of the trial seam sample can be discarded. Alternatively, if agreed upon between the parties involved and indicated in the project specific Geosynthetic Quality Assurance Plan, the remaining portion of the trial seam sample can be subjected to destructive testing as indicated in Section 2.2.10. If a trial seam sample fails a test conducted by the Geosynthetic Quality Assurance Laboratory, then a destructive test seam sample shall be taken from the seams completed by the seamer during the shift related to the considered trial seam. These samples shall be forwarded to the Geosynthetics Quality Assurance Laboratory and, if they fail the tests, the procedure indicated in Section 4.3.10.7 shall apply. The conditions of this paragraph shall be considered as met for a given seam if a destructive seam test sample has already been taken from the considered seam(s).

4.4.8 General Seaming Procedures

The general seaming procedure used by the Installer shall be as follows:

- For fusion welding, a movable protective layer of plastic 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.

- Seaming shall extend to the outside edge of panels to be placed in the anchor trench.

- If required, a firm substrate shall be provided by using a flat board, a conveyor belt, or similar hard surface directly under the seam overlap to achieve proper support.

- If seaming operations are carried out at night, adequate illumination shall be provided.

- Fishmouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut fishmouths or wrinkles shall be seamed and any portion where the overlap is inadequate shall then be patched with an oval or round patch of the same geomembrane extending a minimum of 6 in. (150 mm) beyond the cut in all directions.

4.4.9 Nondestructive Seam Continuity Testing

4.4.9.1 Concept

The Installer shall nondestructively test all field seams over their full length using a vacuum test unit, air pressure (for double fusion seams only), or other approved method. Continuity testing shall be carried out as the seaming work progresses, not at the completion of all field seaming.

The Installer shall complete any required repairs in accordance with Section 4.4.11.

The following procedures shall apply to locations where seams cannot be nondestructively tested:

- All such seams shall be cap-stripped with the same geomembrane.

- If the seam is accessible to testing equipment prior to final installation, the seam shall be nondestructively tested prior to final installation.

- If the seam cannot be tested prior to final installation, the seaming and cap-stripping operations shall be observed by the Geosynthetic Quality Assurance Contractor and Installer for uniformity and completeness.

4.4.9.2 Vacuum Testing

The equipment shall be comprised of the following:

- a vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, port hole or valve assembly, and a vacuum gauge;
- a steel vacuum tank and pump assembly equipped with a pressure controller and pipe connections;
- a rubber pressure/vacuum hose with fittings and connections;
- a bucket and wide paint brush; and
- a soapy solution.

The following procedures shall be followed:

- energize the vacuum pump and reduce the tank pressure to approximately 10 in. of mercury, i.e., 5 psi gauge (35 kPa);
- wet a strip of geomembrane approximately 12 in. by 48 in. (0.3 m by 1.2 m) with the soapy solution;
- place the box over the wetted area;
- close the bleed valve and open the vacuum valve;
- ensure that a leak tight seal is created;
- for a period of not less than 30 seconds, examine the geomembrane through the viewing window for the presence of soap bubbles;
- if no bubble appears after 30 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 3 in. (75 mm) overlap, and repeat the process; and,
- all areas where soap bubbles appear shall be marked and repaired in accordance with Section 4.4.11.

4.4.9.3 Air Pressure Testing (For Double Fusion Seam Only)

The following procedures are applicable to those processes which produce a double seam with an enclosed space.

The equipment shall be comprised of the following:

- an air pump (manual or motor driven) equipped with a pressure gauge capable of generating and sustaining a pressure between 25 and 30 psi (160 and 200 kPa) and mounted on a cushion to protect the geomembrane;
- a rubber hose with fittings and connections;
- a sharp hollow needle, or other approved pressure feed device.

The following procedures shall be followed:

- seal both ends of the seam to be tested;
- insert needle or other approved pressure feed device into the tunnel created by the fusion weld;
- insert a protective cushion between the air pump and the geomembrane;
- energize the air pump to a pressure between 25 and 30 psi (160 and 200 kPa), close valve, and sustain pressure for approximately 5 minutes;
- if loss of pressure exceeds 2 psi or 10 mm mercury (15 kPa) or does not stabilize, locate faulty area and repair in accordance with Section 4.4.11;
- remove needle or other approved pressure feed device and seal.

4.4.10 Destructive Testing

4.4.10.1 Concept

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

4.4.10.2 Location and Frequency

Destructive test samples shall be collected at a minimum average frequency of one test location per 500 ft. (150 m) of seam length.

Samples, in addition to the minimum average frequency, shall be taken as required by the Geosynthetics Quality Assurance Consultant.

Test locations shall be determined during seaming, and may be prompted by suspicion of excess crystallinity, contamination, offset welds, or any other potential cause of imperfect welding. The Quality Assurance Manager shall be responsible for choosing the locations.

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

The Owner reserves the right to increase the frequency in accorance with actual performance results of samples taken.

4.4.10.3 Sampling Procedure

Samples shall be cut by the Installer at locations designated by the Geosynthetic Quality Assurance Manager as the seaming progresses in order to obtain laboratory test results before the geomembrane is covered by another material. Each sample shall be numbered and the sample number and location identified on the panel layout drawing.

All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described in Section 4.4.11. The continuity of the new seams in the repaired area shall be tested according to Section 4.4.9.

4.4.10.4 Size of Samples

The samples shall be 12 in. (0.3 m) wide by 44 in. (1.1 m) long with the seam centered lengthwise. One 1 in. (25 mm) wide strip shall be cut from each end of the sample and these shall be tested in the field. The remaining sample shall be cut into three equal parts and distributed as follows:

- one portion to the Installer for laboratory testing, 12 in. x 12 in. (0.3 m x 0.3 m);
- one portion for Geosynthetic Quality Assurance testing, 12 in. x 18 in. (0.3 m x 0.5 m); and,
- one portion to the Owner for archive storage, 12 in. x 12 in. (0.3 m x 0.3 m).

4.4.10.5 Field Testing

The two 1 in. (25 mm) wide strips mentioned in Section 4.4.10.4 shall be tested in the field, by hand or tensometer, for peel and shear respectively and shall not fail in the seam. If any field test sample fails to pass, then the procedures outlined in 4.4.10.7 shall be followed.

4.4.10.6 Laboratory Testing

4.4.10.6.1 Installer's Laboratory

As a courtesy, all test results from the Installer's laboratory may be submitted to the Owner as soon as they become available.

4.4.10.6.2 Geosynthetic Quality Assurance Laboratory

Testing shall include "Seam Strength" and "Peel Adhesion" [ASTM D638 with type M-1 specimen 0.5 in. (10 mm) wide, tested at 2 in. (50 mm) per minute]. These terms are defined in the specifications. The minimum acceptable values to be obtained in these tests are those indicated in Table 2, and the specifications. At least 5 specimens shall be tested for each test method. Specimens shall be selected alternately by test from the samples (i.e., peel, shear, peel, shear...). The geosynthetic quality assurance laboratory shall provide test results no more than 48 hours after they receive the samples.

4.4.10.7 Procedures for Destructive Test Failure

The following procedures shall apply whenever a sample fails the destructive test, whether the test conducted by the Geosynthetic Quality Assurance Laboratory, the Installer's laboratory, or by field tensometer. The Installer shall have two options:

- The Installer can reconstruct the seam between any two passed test locations.

- The Installer can trace the welding path to an intermediate location (at 10 ft. (3 m) minimum from the location of the failed test in each direction) and take a small sample for an additional field test at each location. If these additional samples pass the tests, then full laboratory samples shall be taken. If these laboratory samples pass the tests, then the seam shall be reconstructed between these locations. If either sample fails, then the process shall be repeated to establish the zone in which the seam should be reconstructed..

In any case, all acceptable seams must be bounded by two locations from which samples passing laboratory destructive tests have been taken. In cases exceeding 150 ft. (50 m) of reconstructed seam, a sample taken from within the reconstructed zone must pass destructive testing.

Whenever a sample fails, additional testing may be required for seams that were welded by the same welder and/or welding apparatus or welded during the same time shift.

4.4.11 Defects and Repairs

4.4.11.1 Identification

All seams and non-seam areas of the geomembrane will be examined for identification of defects, holes, blisters, undispersed raw materials and any sign of contamination by foreign matter. The surface of the geomembrane shall be clean at the time of examination. The geomembrane surface shall be broomed or washed by the Installer if the amount of dust or mud inhibits examination. The Installer shall ensure that this examination of the goemembrane precedes any seaming of that section.

4.4.11.2 Evaluation

Each suspect location both in seam and non-seam areas shall be nondestructively tested using the methods described in Section 4.4.9 as appropriate. Each location which fails the nondestructive testing shall be marked by the Geosynthetic Quality Assurance Contractor and repaired by the Installer. Work shall not proceed with any materials which will cover locations which have been repaired until laboratory test results with passing values are available.

4.4.11.3 Repair Procedures

Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, shall be repaired by the Installer. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be agreed upon between the Project Manager, and the Installer. The procedures available include:

- patching, used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter;
- grinding and rewelding, used to repair small sections of extruded seams;

wrinkles. The Installer shall cut and reseam all wrinkles so identified. The seam thus produced shall be tested like any other seam.

The same process will be repeated for the primary geomembrane liner.

4.5 Materials in Contact with the Geomembrane

The specifications indicated in this section are only intended to assure that the installation of these materials does not damage the geomembrane. Additional specifications are necessary to assure that systems built with these materials are constructed in such a way to enable proper performance.

Installation on rough surfaces such as concrete shall be carefully performed to minimize damage. If approved, additional loosely placed geotextile sections may be used by the Installer as protection for the geomembrane.

4.5.1 Granular Materials

Placement of granular materials on the geomembrane shall not proceed at an ambient temperature below 40°F (5°C) or above 104°F (40°C), unless otherwise specified. A geotextile or other cushion approved by the Designer may be installed between angular aggregate and the geomembrane. Equipment used for placing granular material shall not be driven directly on the geomembrane. A minimum thickness of 1 ft. (0.3 m) of granular material is specified between a light dozer (such as a wide pad caterpillar D-3 or lighter) and the geomembrane. A minimum thickness of 3 ft. (0.9 m) of granular material is specified between rubber-tired vehicles and the geomembrane. In heavily trafficked areas such as access ramps, granular material thickness should be at least 3 ft. (0.9 m).

4.5.2 Concrete

Geosynthetic layers shall be used between concrete and the geomembrane as required. Construction methods used shall not damage the geomembrane.

4.5.3 Sumps and Appurtenances

Installation of the geomembrane in sump and appurtenant areas, and connection of geomembrane to sumps and appurtenances shall be made according to specifications. Extreme care shall be taken while welding around appurtenances since neither non-destructive nor

wrinkles. The Installer shall cut and reseam all wrinkles so identified. The seam thus produced shall be tested like any other seam.

The same process will be repeated for the primary geomembrane liner.

4.5 Materials in Contact with the Geomembrane

The specifications indicated in this section are only intended to assure that the installation of these materials does not damage the geomembrane. Additional specifications are necessary to assure that systems built with these materials are constructed in such a way to enable proper performance.

Installation on rough surfaces such as concrete shall be carefully performed to minimize damage. If approved, additional loosely placed geotextile sections may be used by the Installer as protection for the geomembrane.

4.5.1 Granular Materials

Placement of granular materials on the geomembrane shall not proceed at an ambient temperature below 40°F (5°C) or above 104°F (40°C), unless otherwise specified. A geotextile or other cushion approved by the Designer may be installed between angular aggregate and the geomembrane. Equipment used for placing granular material shall not be driven directly on the geomembrane. A minimum thickness of 1 ft. (0.3 m) of granular material is specified between a light dozer (such as a wide pad caterpillar D-3 or lighter) and the geomembrane. A minimum thickness of 3 ft. (0.9 m) of granular material is specified between rubber-tired vehicles and the geomembrane. In heavily trafficked areas such as access ramps, granular material thickness should be at least 3 ft. (0.9 m).

4.5.2 Concrete

Geosynthetic layers shall be used between concrete and the geomembrane as required. Construction methods used shall not damage the geomembrane.

4.5.3 Sumps and Appurtenances

Installation of the geomembrane in sump and appurtenant areas, and connection of geomembrane to sumps and appurtenances shall be made according to specifications. Extreme care shall be taken while welding around appurtenances since neither non-destructive nor

destructive testing may be feasible in these areas. The Installer shall ensure that the geomembrane has not been visibly damaged while making connections to sumps and appurtenances.

All clamps, clips, bolts, nuts or other fasteners used to secure the geomembrane to each appurtenance shall have a life-span equal to or exceeding that of the geomembrane.

4.6 Lining System Acceptance

The Installer shall retain all ownership and responsibility for the geosynthetics in the lining system until acceptance by the Owner.

The geosynthetic lining system shall be accepted by the Owner when:

- the installation is finished;
- all documentation of installation is completed including the Geosynthetic Quality Assurance Contractor's final report;
- verification of the adequacy of all field seams and repairs, including associated testing, is complete; and,
- written certification documents, including "as built" drawings, sealed by a registered professional engineer have been received by the Owner.

5. GEOTEXTILES

The geotextile materials shall comply with the properties listed in Section 2.2.2 of these specifications.

5.1 Handling and Placement

The Installer shall handle all geotextiles in such a manner as to ensure they are not damaged in any way, and the following shall be complied with:

- On slopes, the geotextiles shall be securely anchored in the anchor trench and then rolled down the slope in such a manner as to continually keep the geotextile sheet in sufficient tension to preclude folds and wrinkles.

- In the presence of wind, all geotextiles shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during placement and shall remain until replaced with earth cover material.

- Geotextiles shall be cut using an approved geotextile cutter only. If in place, special care must be taken to protect other geosynthetic materials from damage which could be caused by the cutting of the geotextiles.

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

- An examination of the geotextile over the entire surface, after installation, shall be conducted to ensure that no potentially harmful foreign objects, such as needles, are present. Any foreign objects so encountered shall be removed by the Installer, or the geotextile shall be replaced.

- If white colored geotextile is used, precautions shall be taken against "snowblindness" of personnel.

5.2 Conformance Testing

The Geosynthetic Quality Assurance Manager shall collect samples of geotextile from the materials delivered to the site, for conformance testing, as outlined in section 4.5 of the "Quality Assurance Manual for the Installation of Geosynthetic Lining Systems".

5.3 Seams and Overlaps

On slopes steeper than 10 horizontal/1 vertical, all geotextiles shall be continuously sewn (i.e., spot sewing is not allowed). Geotextiles shall be overlapped 6 in. (0.15 m) prior to seaming. No horizontal seams shall be allowed on side slopes (i.e., seams shall be along, not across, the slope).

On bottoms and slopes shallower than 10 horizontal/1 vertical, geotextiles can be either sewn as indicated above, or thermally bonded.

The Installer shall pay particular attention at seams to ensure that no earth cover material could be inadvertently inserted beneath the geotextile.

Any sewing shall be done using polymeric thread with chemical resistance properties equal to or exceeding those of the geotextile.

5.4 Repair

Any holes or tears in the geotextile shall be repaired as follows:

- On slopes: A patch made from the same geotextile shall be double seamed into place [with each seam 1/4 in. to 3/4 in. (5 mm to 20 mm) apart and no closer than 1 in. (25 mm) from any edge]. Should any tear exceed 10% of the width of the roll, that roll shall be removed from the slope and replaced.

- Non-slopes: A patch made from the same geotextile shall be spot-seamed in place with a minimum of 24 in. (0.60 m) overlap in all directions.

Care shall be taken to remove any soil or other material which may have penetrated the torn geotextile.

5.5 Placement of Soil Materials

The Installer shall place all soil materials located on top of a geotextile, in such a manner as to ensure:

- no damage of the geotextile;
- minimal slippage of the geotextile on underlying layers;
- no excess tensile stresses in the geotextile.

6. GEOGRIDS

The geogrid materials shall comply with the properties listed in Section 2.2.2.3 of these specifications.

6.1 Handling and Placement

The Installer shall handle all geogrids in such a manner as to ensure they are not damaged in any way, and the following shall be complied with:

- On slopes, the geogrids shall be securely anchored in the anchor trench and then rolled down the slope in such a manner as to continually keep the geogrid sheet in tension.

- In many cases it is advisable to pre-fusion the geogrid by hand (or with equipment) and place the first lift of cover while the geogrid is in tension.

- In the presence of very strong wind, geogrids may have to be weighted with sandbags or the equivalent. Such sand bags must be removed prior to my pre-tensioning of the geogrid.

- Geogrids shall be cut using scissors only. If in place, special care must be taken to protect other materials from damage which could be caused by the cutting of the geogrids.

6.2 Conformance Testing

The Geosynthetic Quality Assurance Manager shall collect samples of geogrid from the materials delivered to the site, for conformance testing, as outlined in section 4.5 of the "Quality Assurance Manual for the Installation of Geosynthetic Lining Systems".

6.3 Seams and Overlaps

The geogrids, where used on slopes, shall be placed in continuous pieces downslope. No lateral joining is normally required, i.e., edge to edge placement will be sufficient.

In some special cases, geogrids may require edge to edge seaming. In such cases the Designer will prepare seaming specifications which will be added to these specifications. No horizontal seams shall be allowed on side slopes, i.e., seams shall be along, not across, slopes.

6.4 Repair

Any damaged roll of geogrid shall be discarded. No repairs will be allowed.

6.5 Placement of Soil Materials

The Installer shall place all soil materials located on top of a geogrid, in such a manner as to ensure:

- no damage of the geogrid; and
- minimal slippage of the geogrid on underlying layers.

7. GEONETS

The geonet materials shall comply with the properties listed in Section 2.3.2 of these specifications.

7.1 Handling and Placement

The Installer shall handle all geonets in such a manner as to ensure the geonets are not damaged in any way, and the following shall be complied with:

- On slopes, the geonets shall be secured in the anchor trench and then rolled down the slope in such a manner as to continually keep the geonet sheet in tension. If necessary, the geonet shall be positioned by hand after being unrolled to minimize wrinkles. Geonets can be placed in the horizontal direction (i.e., across the slope) in some special locations (e.g., at the toe of a slope, if an extra layer of geonet is required, this extra layer of geonet can be placed in the horizontal direction). Such locations shall be identified by the Designer in design drawings.

- In the presence of wind, all geonets shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during placement and shall remain until replaced with cover material.

- Unless otherwise specified, geonets shall not be welded to geomembranes.

- Geonets shall only be cut using scissors.

- The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geonet.

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

- Care should be taken not to leave tools in the geonet.

7.2 Conformance Testing

The Geosynthetic Quality Assurance Manager shall collect samples of geonet from the materials delivered to the site, for conformance testing, as outlined in section 5.5 of the "Quality Assurance Manual for the Installation of Geosynthetic Lining Systems".

7.3 Stacking and Joining

When several layers of geonets are stacked, care should be taken to prevent strands from one layer from penetrating the channels of the next layer, thereby significantly reducing the transmissivity. This cannot happen if stacked geonets are placed in the same direction. A stacked geonet shall never be laid in perpendicular directions to the underlying geonet (unless otherwise specified by the Designer). In the corners of side slopes of rectangular landfills, adjacent overlapping geonets are usually perpendicular and special precautions shall be taken as discussed below.

Adjacent geonets shall be joined according to construction drawings and specifications. As a minimum, the following requirements shall be met:

- Adjacent rolls shall be overlapped by at least 4 in. (100 mm).
- These overlaps shall be secured by spot welding or tying.
- Tying can be achieved by strings, plastic fasteners, or polymer braid. Tying devices shall be white or yellow for easy inspection. Metallic devices are not allowed.
- Spot welding or tying shall be every 5 ft. (1.5 m) along the slope, every 2 ft. (0.6 m) across the slope, and every 6 in. (0.15 m) in the anchor trench.
- In the corners of the side slopes of rectangular landfills, where overlaps between perpendicular geonet strips are required, an extra layer of geonet shall be unrolled along the slope, on top of the previously installed geonets, from top to bottom of the slope.
- When more than one layer of geonet is installed, joints shall be staggered.

7.4 Repair

Any holes or tears in the geonet shall be repaired by placing a patch extending 2 ft. (0.6 m) beyond edges of the hole or tear. The patch shall be secured to the original geonet by spot welding or tying

every 6 in. (0.15 m). Tying devices shall be as indicated in Section 7.6. If the hole or tear width across the roll is more than 50% the width of the roll, the damaged area shall be cut out and the two portions of the geonet shall be joined as indicated in Section 7.2.

7.5 Placement of Soil Materials

Although soil should never be placed in contact with geonets, the Installer shall ensure that all soil materials such as primary clay liner and earth cover, are placed in such a manner as to ensure:

- the geonet and underlying lining materials are not damaged;
- minimal slippage of the geonet on underlying layers occurs; and
- no excess tensile stresses occur in the geonet.

APPENDIX A

BID QUESTIONNAIRE

MANUFACTURER BID INFORMATION QUESTIONNAIRE

(Please submit with necessary attachments
along with your bid documents)

(Please Type or Print)

1. CORPORATE INFORMATION

COMPANY NAME: _____

ADDRESS: _____

TELEPHONE: (_____) _____ _____

MAIN OFFICERS:

PRESIDENT _____

SALES MANAGER _____

QUALITY CONTROL MANAGER _____

PLANT OPERATION HISTORY _____

_____

_____

_____

2. MANUFACTURING CAPABILITIES

BRIEF DESCRIPTION OF EQUIPMENT AND PERSONNEL: _____

_____

_____

_____

DAILY FABRICATION QUANTITY AVAILABLE: _____

(Please type or print)

	Project Name	Purpose of Facility	Location of Facility	Owner	Fabricator (if any)	Installer	Project Manager	Sheet Thickness (mils)	Covered Area (ft^2)
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									

TOTAL AREA (FT^2)

FABRICATOR PRE-DELIVERY INFORMATION QUESTIONNAIRE

(Please remit with necessary attachments prior to material delivery)

Please type
or print

Panel Number	Panel Area	Roll Numbers	Fabrication Date	Fabrication Panel Q.C. Certificate Number

FABRICATOR BID INFORMATION QUESTIONNAIRE

(Please submit with necessary attachments along with your bid documents)

(Please Type or Print)

1. CORPORATE INFORMATION

COMPANY NAME: _____

ADDRESS: _____

TELEPHONE: (_____) _____ _____

MAIN OFFICERS:

PRESIDENT _____

SALES MANAGER _____

QUALITY CONTROL MANAGER _____

PLANT OPERATION HISTORY _____

_____

_____

_____

2. FABRICATION CAPABILITIES

BRIEF DESCRIPTION OF EQUIPMENT AND PERSONNEL: _____

_____

_____

_____

DAILY FABRICATION QUANTITY AVAILABLE: _____

3. LIST OF TEN COMPLETED HDPE FACILITIES - FABRICATOR (IF APPLICABLE)

(Please type or print)

	Project Name	Purpose of Facility	Location of Facility	Owner	Manufacturer	Installer	Project Manager	Sheet Thickness (mils)	Covered Area (ft^2)	Type of Seaming
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										
10.										

INSTALLER PRE-INSTALLATION INFORMATION QUESTIONNAIRE

(Please remit with necessary attachments prior to the commencement of installation)

Please type or print.

Job Title	Personnel Name	Experience (Years)	Experience (ft^2)
Site Superintendent			
Assistant Site Superintendent			
Tack-Welder			
Tack-Welder			
Tack-Welder			
Tack-Welder			
Tack-Welder			
Welder			
Welder			
Welder			
Welder			
Welder			
Inspector			
Inspector			
Inspector			
Inspector			
Inspector			

INSTALLER BID INFORMATION QUESTIONNAIRE

(Please submit with necessary attachments
along with your bid documents)

(Please Type or Print)

1. CORPORATE INFORMATION

COMPANY NAME: _____

ADDRESS: _____

TELEPHONE: (_____) _____ _____

MAIN OFFICERS:

PRESIDENT _____

SALES MANAGER _____

QUALITY CONTROL MANAGER _____

FIELD EXPERIENCE HISTORY _____

_____

_____

_____

2. INSTALLATION CAPABILITIES

BRIEF DESCRIPTION OF EQUIPMENT AND PERSONNEL: _____

_____

_____

_____

DAILY INSTALLATION QUANTITY AVAILABLE: _____

3. LIST OF TEN COMPLETED HDPE FACILITIES - INSTALLER

(Please type or print)

	Project Name	Purpose of Facility	Location of Facility	Owner	Manufacturer	Fabricator (if any)	Project Manager	Sheet Thickness (mils)	Covered Area (ft^2)	Type of Seaming
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										
10.										

TOTAL AREA (ft^2)

APPENDIX B

PRE-DELIVERY INFORMATION

MANUFACTURER PRE-DELIVERY INFORMATION QUESTIONNAIRE

(Please remit with necessary attachments prior to material delivery)

(Please type or print)

Roll Number	Production Date	Roll Q.C. Certificate No.	HDPE Resin Batch Number	HDPE Resin Supplier	HDPE Resin Production Date	HDPE Resin Supplier Q.C. Certificate No.	Manufacturer Resin Q.C. Certificate No.

APPENDIX C

CERTIFICATE OF ACCEPTANCE

OF SOIL SUBGRADE

CERTIFICATE OF ACCEPTANCE

OF SOIL SUBGRADE BY INSTALLER

INSTALLER

NAME _____

ADDRESS _____

_____

_____

AUTHORIZED REPRESENTATIVE _____

PROJECT

LOCATION _____

PROJECT _____

OWNER _____

I the Undersigned, duly authorized representative of _____ do hereby accept the Soil Subgrade and shall be responsible for its integrity and suitability, in accordance with these specifications from this date to completion of the installation.

_____

NAME SIGNATURE TITLE DATE

_____

CERTIFICATION ACCEPTED BY INSPECTOR - COMPANY _____

_____

NAME SIGNATURE TITLE DATE

_____

Appendix H

APPENDIX H

US ARMY CORPS OF

ENGINEERS, WETLANDS

DETERMINATION

Waste Management of North America, Inc.
Carolinas Tennessee District
110 Berry Shoals Road • P.O. Box 338
Duncan, South Carolina 29334
803 439-8426

February 24, 1988

Mr. David Lekson
Mr. Ken Jolly
U.S. Army Corps of Engineers
11413 Falls of the Neuse Rd.
Wake Forest, NC 27857

Re: Proposed Sanitary Landfill near Kernersville, NC by Waste Management of Carolinas, Inc. (Piedmont Sanitary Landfill)

Dear Mr. Lekson & Mr. Jolly:

Please consider this letter and attachments as a follow-up to our meeting held on February 5, 1988 at the above referenced site.

As you remember, Waste Management requested in a letter dated June 27, 1987 that the COE make a wetlands determination of the 100 acre, proposed Piedmont Sanitary landfill (see attached copy). Subsequent meetings at the site revealed that the Freeman Road Relocation and the two small farm ponds did not impact wetlands area and thus did not require a permit. However, these meetings also revealed that our initial sedimentation pond locations impacted wetlands. Waste Management has reconsidered the locations of both the north central and southwest ponds and, as you can see from the attached, these ponds no longer impact wetlands. Both of these new pond locations are in accordance with the wetlands boundary determined on our February 5, 1988 meeting.

Understand that this design plan has yet to be approved by the NCDHR for a Solid Waste Disposal Permit, but if there are any changes that would impact wetland areas, we will certainly let you know.

We are awaiting your determination regarding this site and should you have any questions, please do not hesitate to call.

Sincerely,

Edward L. Gibson, P.E.
District Environmental Engineer

enclosure

cc: Mike Adams
Dan Sweeney

Waste Management of North America, Inc.
Eastern-South Central Region
2600 Delk Road • Marietta, Georgia 30067
Delk Place, Suite 200 • 404/859-0800

June 27, 1987

In reply, refer to EG-092

Mr. Hugh Heine
U. S. Army Corps of Engineers
P. O. Box 1890
Wilmington, NC 28402-1890

RE: WETLANDS DETERMINATION - FORSYTH COUNTY, NC

Dear Mr. Heine,

Waste Management, Inc. requests that the U. S. Corps of Engineers provide a wetlands determination of a 100 acre parcel of land located near Kernersville, NC (Forsyth County).

This parcel of land adjoins an existing sanitary landfill, namely, City of Kernersville Sanitary Landfill. Attached, please find maps showing the location of the site.

Also, if at all possible, Waste Management would like to accompany your staff during the field visit to the site. Therefore, please let me know when this visit will take place.

If you need further information, please do not hesitate to call me at 404/859-0800.

Eagerly awaiting your response, I am

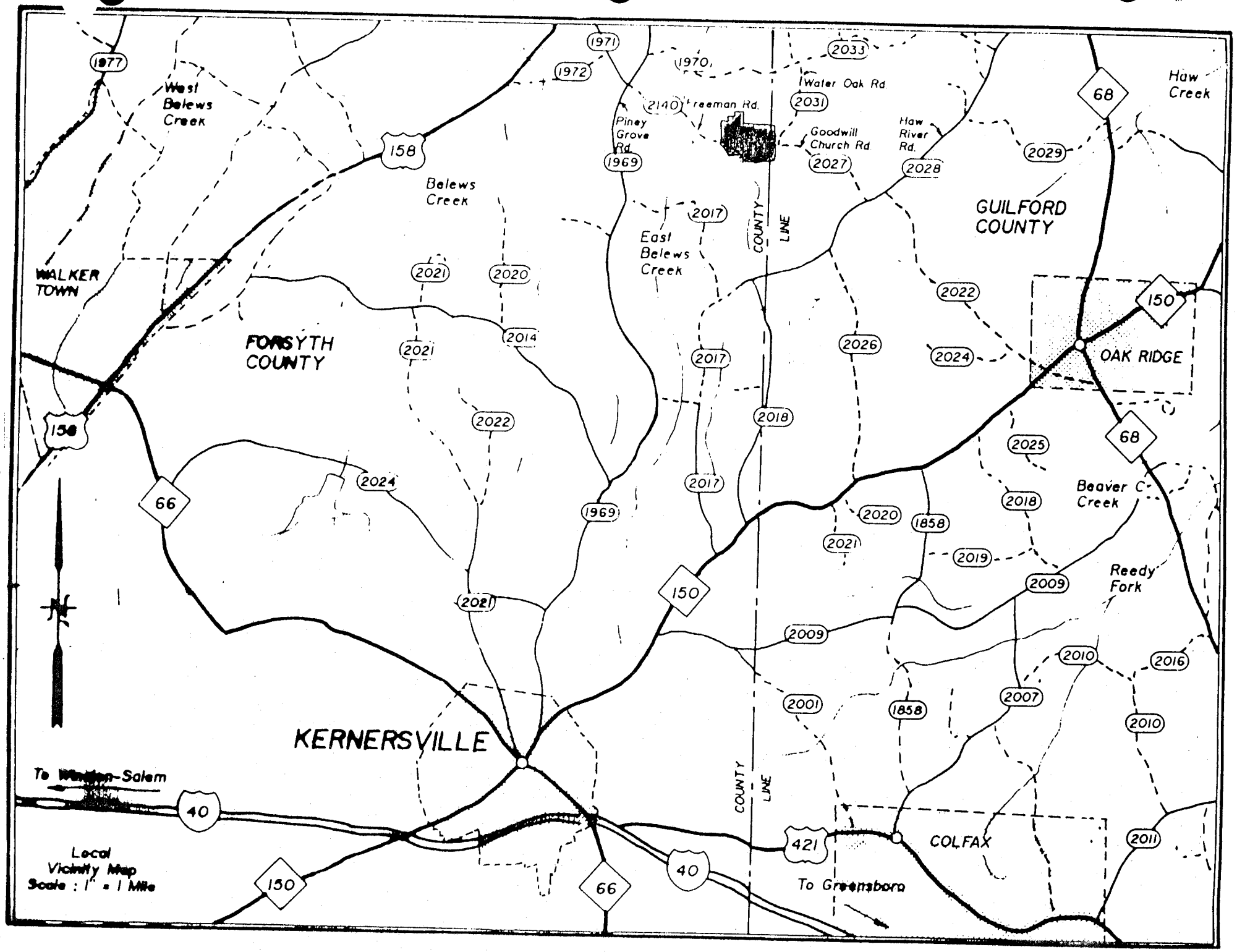
Sincerely,

Edward L. Gibson, P. E.
District Engineer

ELG/dnb

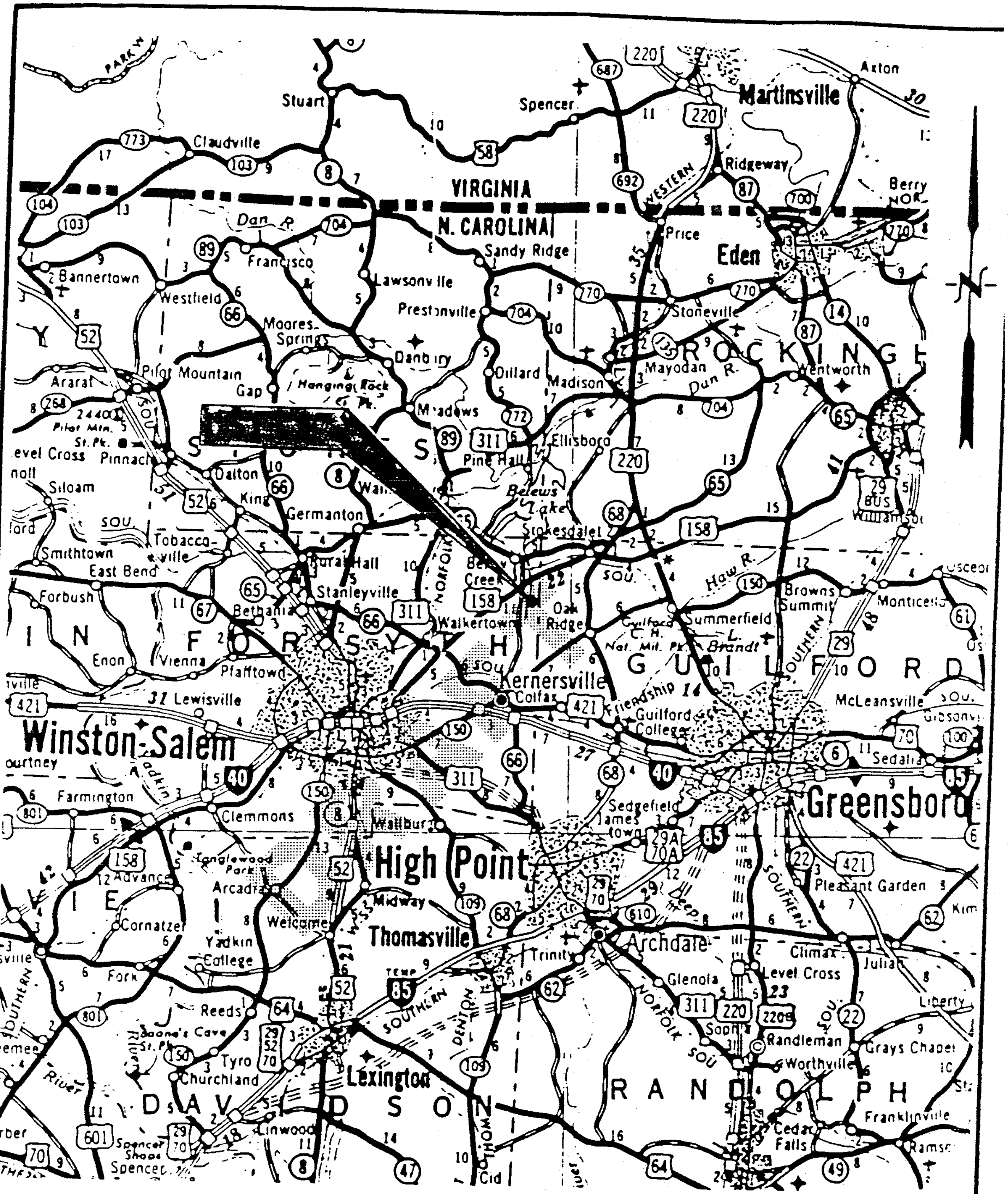
Attachment

cc: Mike Adams (w/out attachment)
Laura Liggett (w/out attachment)
Ed Parvin (w/out attachment)
John Stitt (w/out attachment)



Local Vicinity Map
Scale : 1" = 1 Mile

A< 20440A.8



JOB NO. 863-3407	SCALE N.T.S.	SITE LOCATION PLAN
DRAWN SKB	DATE 10/31/86	
CHECKED KES	DWG NO 1	
Golder Associates		WASTE MANAGEMENT, INC. — FIGURE 1

DEPARTMENT OF THE ARMY
WILMINGTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1890
WILMINGTON, NORTH CAROLINA 28402-1890

March 9, 1988

IN REPLY REFER TO
Regulatory Branch

SUBJECT: Nationwide Permit No. 26

Mr. Edward L. Gibson, P.E.
Waste Management of North America, Inc.
Post Office Box 338
Duncan, South Carolina 29334

Dear Mr. Gibson:

This letter is in reference to the February 5, 1988, meeting you had with Messrs. David Lekson and Ken Jolly of my staff at the proposed Forsyth County Landfill off of Goodwill Church and Freeman Roads, near the community of Oak Ridge, adjacent East Belews Creek, Forsyth County, North Carolina. This letter also confirms Mr. Lekson's receipt of your letter and plans, dated February 24, 1988.

Based upon the referenced meeting and review of the aforementioned plans dated February 1988, we have determined that the entire project is to be constructed on high ground with the exception of Sedimentation Pond No. 3, located in the northeast corner of the site. All work restricted to high ground will not require Department of the Army permit authorization.

Sedimentation Pond No. 3 will involve construction of an earthen dike across and above the headwaters of an unnamed tribuary to East Belews Creek. For the purposes of the Corps of Engineers' Regulatory Program, Title 33, Code of Federal Regulations (CFR), Part 330, published in the Federal Register on November 13, 1986, lists nationwide permits. Authorization was provided for discharges of dredged or fill material into non-tidal rivers, streams, and their lakes and impoundments, including adjacent wetlands, that are located above the headwaters and other non-tidal waters of the United States, including adjacent wetlands, that are not a part of a surface tributary system to interstate waters or navigable waters of the United States.

Construction of Sediment Pond No. 3, impacting less than 1 acre of "waters of the United States" above the headwaters of the tributary to East Belews Creek, is authorized by nationwide permit, provided it is accomplished in strict accordance with the enclosed conditions. Please be aware that this authorization does not relieve you of the responsibility to obtain any required State or local approval.

If you have questions, please contact Mr. Lekson, Regulatory Branch, telephone (919) 846-0648.

Sincerely,

Charles W. Hollis
Chief, Regulatory Branch

Enclosure

Copies Furnished (without enclosure):

Mr. John Parker
North Carolina Department of
Natural Resources and
Community Development
Post Office Box 27687
Raleigh, North Carolina 27611-7687

Mr. William Mills
Water Quality Section
Division of Environmental Management
North Carolina Department of Natural
Resources and Community Development
Post Office Box 27687
Raleigh, North Carolina 27611-7687

Mr. Samuel H. McDonald
City-County Planning Board
Post Office Box 2511
Winston-Salem, North Carolina 27102

CONDITIONS

a. Any discharge of dredged or fill material will not occur in the proximity of a public water supply.

b. The activity will not jeopardize a threatened or endangered species as identified under the Endangered Species Act, or destroy or adversely modify the critical habitat of such species.

c. The activity will not significantly disrupt the movement of those species of aquatic life indigenous to the waterbody (unless the primary purpose of the fill is to impound water).

d. Any discharge of dredged or fill material will consist of suitable material free from toxic pollutants.

e. Any structure or fill will be properly maintained.

f. If the activity may adversely affect historic properties which the National Park Service has listed on, or determined eligible for listing on, the National Register of Historic Places, or if significant historic properties are encountered before or during work, the permittee will notify the District Engineer.

g. An individual state water quality certification must be obtained or waived. Conditions of certification will be considered to be special conditions of the Federal nationwide permit.

h. The following management practices will be followed to the maximum extent:

(1) Discharges of dredged or fill material into waters of the United States will be avoided or minimized through the use of other practical alternatives.

(2) Discharges in spawning areas during spawning seasons will be avoided.

(3) Discharges will not restrict or impede the movement of aquatic species indigenous to the waters or the passage of normal or expected high flows or cause the relocation of the waters (unless the primary purpose of the fill is to impound water).

(4) If the discharge creates an impoundment of water, adverse impacts on the aquatic system caused by the accelerated passage of water and/or the restriction of its flow will be minimized.

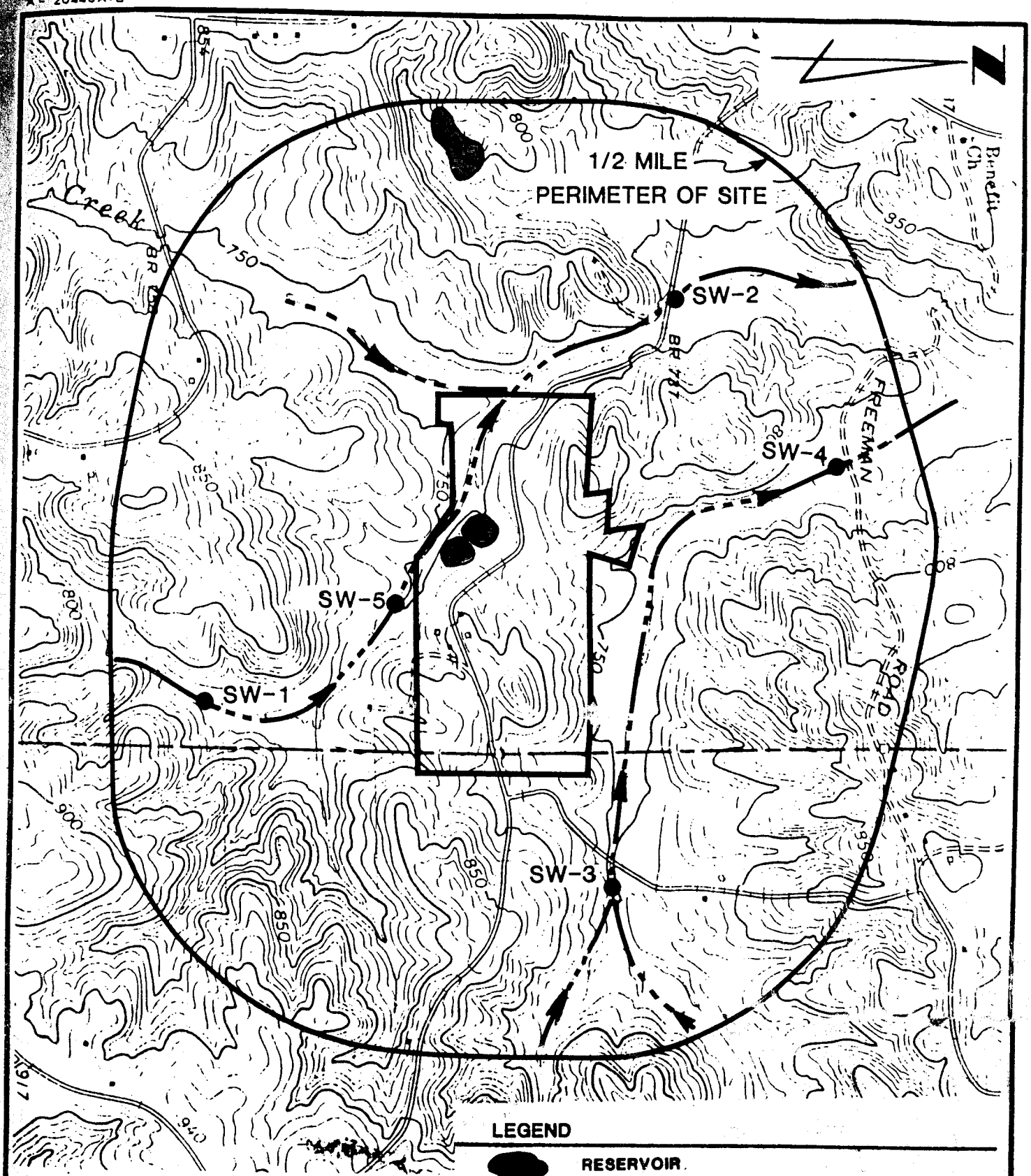
(5) Discharge in wetland areas will be avoided.

(6) Heavy equipment working in wetlands will be placed on mats.

(7) Discharges into breeding areas for migratory waterfowl will be avoided.

(8) All temporary fills will be removed in their entirety.

F 20440A-B



LEGEND

RESERVOIR

PERENNIAL STREAM, ARROW SHOWING FLOW DIRECTION

SW-1 ● PROPOSED SURFACE WATER SAMPLING LOCATION

SCALE IN FEET

0 500 1000 2000 3000

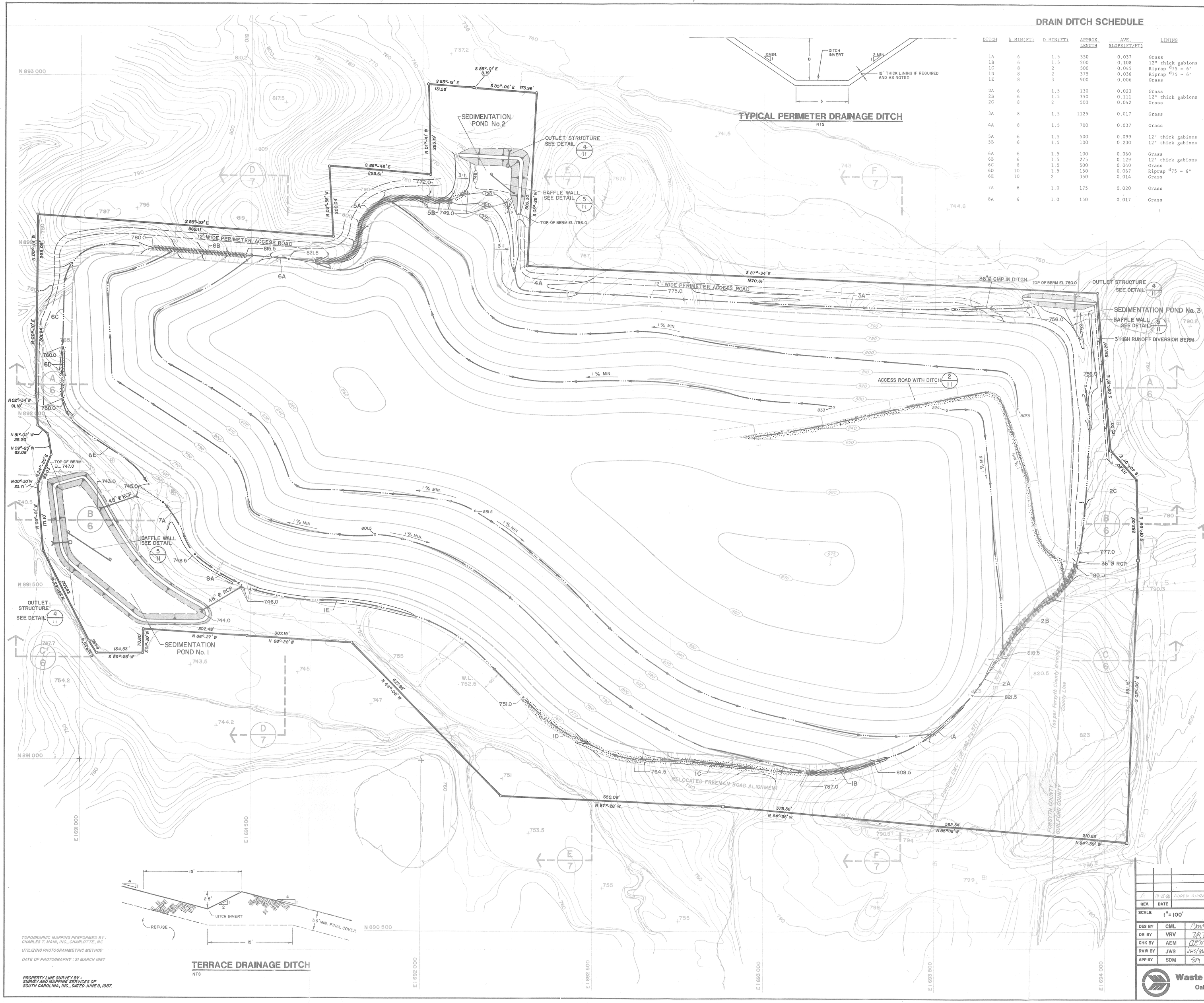
JOB NO. 863-3407	SCALE AS SHOWN	PROPOSED SURFACE WATER MONITORING STATIONS
DRAWN LJW	DATE 12/22/86	
CHECKED	DWG. NO. 52	
Golder Associates	WASTE MANAGEMENT, INC.	FIGURE 20

FILE NO. 863-3407

DRAIN DITCH SCHEDULE

DITCH	b MIN(FT)	D MIN(FT)	APPROX. LENGTH	AVE. SLOPE(FT/FT)	LINING
1A	6	1.5	350	0.037	Grass
1B	6	1.5	200	0.108	12" thick gabions
1C	8	2	500	0.045	Riprap d_{75} = 6"
1D	8	2	375	0.036	Riprap d_{75} = 6"
1E	8	3	900	0.006	Grass
2A	6	1.5	130	0.023	Grass
2B	6	1.5	350	0.111	12" thick gabions
2C	8	2	500	0.042	Grass
3A	8	1.5	1125	0.017	Grass
4A	8	1.5	700	0.037	Grass
5A	6	1.5	500	0.099	12" thick gabions
5B	6	1.5	100	0.230	12" thick gabions
6A	6	1.5	100	0.060	Grass
6B	6	1.5	275	0.129	12" thick gabions
6C	8	1.5	500	0.040	Grass
6D	10	1.5	150	0.067	Riprap d_{75} = 6"
6E	10	2	350	0.014	Grass
7A	6	1.0	175	0.020	Grass
8A	6	1.0	150	0.017	Grass

TYPICAL PERIMETER DRAINAGE DITCH
NTS



LEGEND

- 800 — EXISTING CONTOUR ELEVATION
- 820.5 — EXISTING SPOT ELEVATION
- N 24°-30' E 93.03' — PROPERTY LINE WITH BEARINGS
- 860 — PROPOSED FINAL GRADE ELEVATION
- x 875 — PROPOSED SPOT ELEVATION
- 745 — CULVERT WITH INVERT ELEVATIONS
- 777.0 — DRAINAGE DITCH FLOW WITH INVERT ELEVATIONS
- LIMIT OF LANDFILL
- A/6 — CROSS-SECTION INDICATOR
- RIPRAP DITCH LINING
- GABION DITCH LINING
- TOP OF SLOPE (TYP.) / TOE OF SLOPE (TYP.) — EXCAVATION SLOPE
- FILL SLOPE

NOTE

1. FOR SEEDING SCHEDULE SEE "DESIGN, CONSTRUCTION, AND OPERATING PROVISIONS FOR PIEDMONT SANITARY LANDFILL" PREPARED BY WASTE MANAGEMENT, INC.

TERRACE DRAINAGE DITCH
NTS

TOPOGRAPHIC MAPPING PERFORMED BY: CHARLES T. MAIN, INC., CHARLOTTE, NC
UTILIZING PHOTOGRAMMETRIC METHOD
DATE OF PHOTOGRAPHY : 21 MARCH 1987

PROPERTY LINE SURVEY BY: SURVEY AND MAPPING SERVICES OF SOUTH CAROLINA, INC., DATED JUNE 9, 1987.

34-06

RECEIVED NOV 07 1988 SOLID WASTE BRANCH

REV.	DATE	DESCRIPTION	DR BY	APP BY
1	10-11-88	ADDED RIPRAP SYMBOL FOR ACCESS ROAD DITCH	VRV	

SCALE: 1" = 100'	PROJECT NO 047C0	DATE MAY 1988
DES BY CML	PROJECT: PIEDMONT SANITARY LANDFILL, FORSYTH COUNTY, NORTH CAROLINA	
DR BY VRV	SHEET TITLE: SEDIMENT AND EROSION CONTROL PLAN	
CHK BY AEM		
RVW BY JWS		
APP BY SDM		

Waste Management, Inc.
Oak Brook, Illinois 60521

SHEET 5 OF 11
SHEET NO. 5

MODULE 5

MODULE 6

INITIAL FILLING AREA

MODULE 1

MODULE 2

MODULE 3

MODULE 4

SEDIMENTATION POND NO. 1

SEDIMENTATION POND NO. 2

BORROW AREA

STOCKPILE AREA

APPROXIMATE LIMIT OF CLEARING

GRADE TO DRAIN

TEMPORARY DRAINAGE DIVERSION BENCH SEE DETAIL BELOW

SCALE HOUSE AND OFFICE

MAINTENANCE AREA

ALL WEATHER SITE ACCESS ROAD

ACCESS RAMP, TYPICAL 7% SLOPE

PROVIDE RIPRAP CHECK DAMS, SILT FENCE OR OTHER SEDIMENT CONTROLS AS NECESSARY

RELOCATED FREEMAN ROAD ALIGNMENT

LCR-1 LCR-2 LCR-3 LCR-4 LCR-5 LCR-6 LCR-7 LCR-8 LCR-9 LCR-10 LCR-11 LCR-22 LCR-23 LCR-24 LCR-25

LCS-1 LCS-2

N 893 000

N 892 000

N 891 500

N 891 000

N 890 500

E 691 000

E 691 500

E 692 000

E 692 500

E 693 000

E 693 500

E 694 000

N

Scale : 1" = 100'

LEGEND

- EXISTING CONTOUR ELEVATION
- EXISTING SPOT ELEVATION
- PROPERTY LINE WITH COORDINATES & DISTANCE
- LEACHATE COLLECTION PIPE
- LEACHATE COLLECTION RISER
- LEACHATE COLLECTION SUMP AND RISER
- DRAINAGE FLOW
- PROPOSED BASE GRADE ELEVATION
- CULVERT
- EXCAVATION SLOPE
- FILL SLOPE

NOTES

1. SEE SHEET 3 FOR DETAILS OF LEACHATE COLLECTION SYSTEM.
2. LANDFILL LIFE FOR PHASE I IS APPROXIMATELY 7.4 YEARS.
3. PHASE I WILL BE CONSTRUCTED IN MODULES. SEE SHEET 8.
4. SEE SHEET 5 FOR DRAINAGE PLAN.

ACTIVE MODULE | MODULE TO BE EXCAVATED

EXCAVATION SIDE SLOPE

12' | 3' MIN. | 2 : 1

TEMPORARY DRAINAGE DIVERSION BENCH

NTS

TOPOGRAPHIC MAPPING PERFORMED BY: CHARLES T. MAIN, INC., CHARLOTTE, NC

UTILIZING PHOTOGRAMMETRIC METHOD

DATE OF PHOTOGRAPHY : 21 MARCH 1987

PROPERTY LINE SURVEY BY: SURVEY AND MAPPING SERVICES OF SOUTH CAROLINA, INC., DATED JUNE 9, 1987.

RECEIVED NOV 07 1988 SOLID WASTE BRANCH

34-06

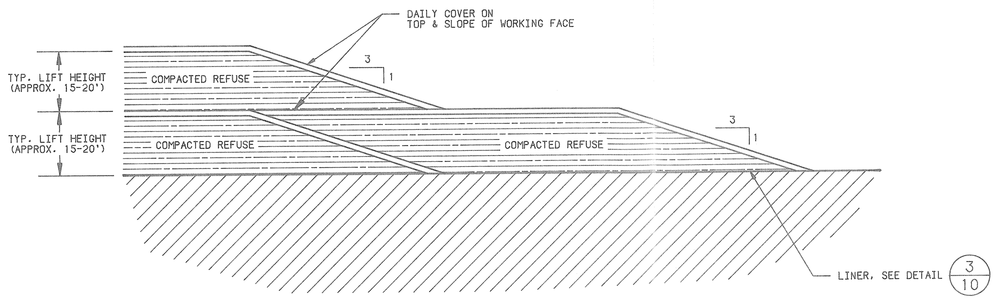
REV.	DATE	DESCRIPTION	DR BY	APP BY
		2.21 FOOTED INSTRUCTION NOTE	VRV	

SCALE: 1" = 100'	PROJECT NO. 047CO	DATE MAY 1998
DES BY CML	PROJECT: PIEDMONT SANITARY LANDFILL FORSYTH COUNTY, NORTH CAROLINA	
DR BY VRV		
CHK BY AEM	SHEET TITLE: PHASE I BASE PREPARATION PLAN	
RVW BY JWS		
APP BY SDM		

Waste Management, Inc.
Oak Brook, Illinois 60521

SHEET 9 OF 11

SHEET NO. 9

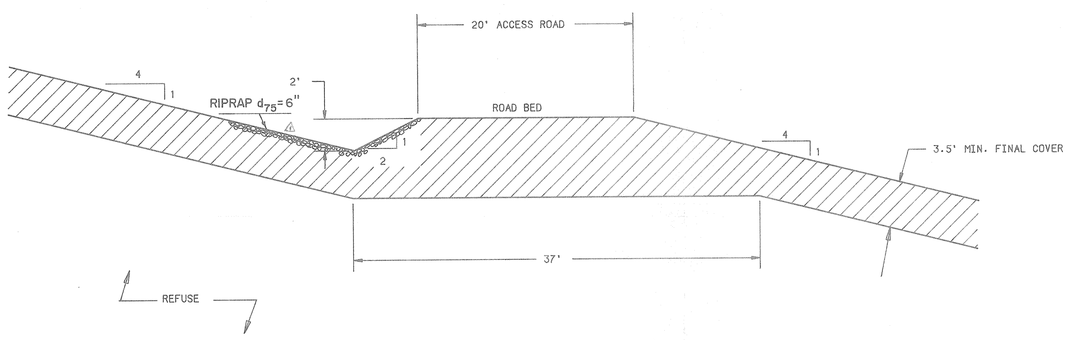


1/11 TYPICAL DAILY CELL CONSTRUCTION

NTS

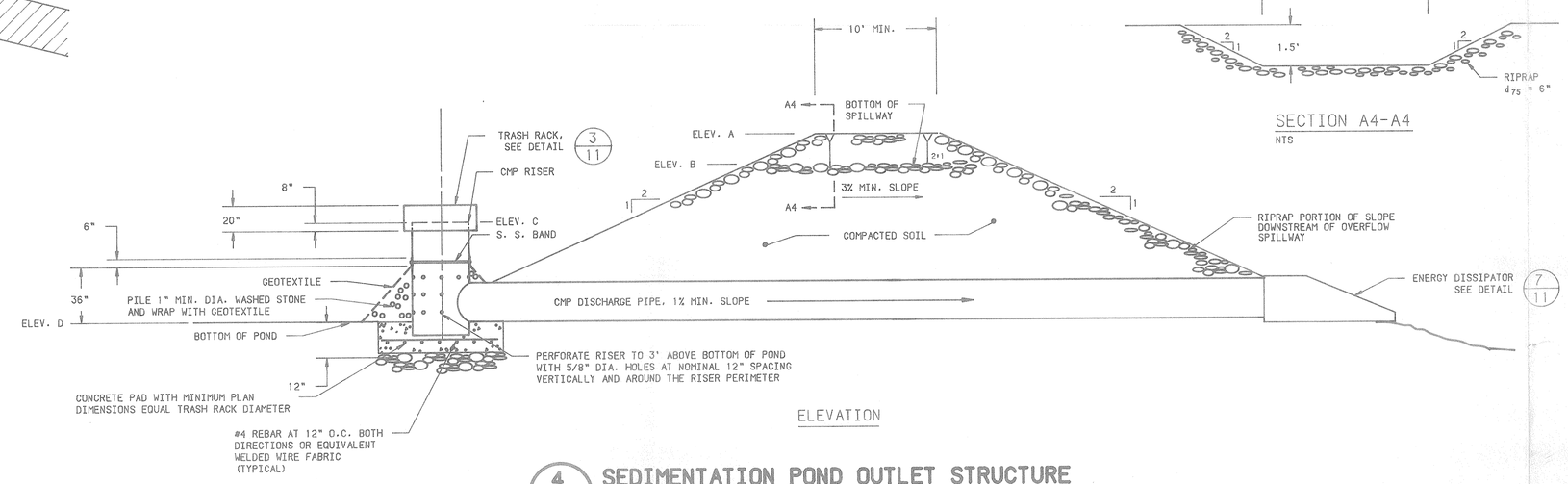
SEDIMENTATION POND SPECIFICATIONS

LOCATION	ELEV. A	ELEV. B	ELEV. C	ELEV. D	DISCHARGE PIPE DIA. (IN.)	RISER PIPE DIA. (IN.)	TRASH RACK DIA. (IN.)	SEDIMENT CLEANOUT ELEV.
POND 1	746.5	745.0	743.0	739.0	42"	54"	78"	740.5
POND 2	756.0	754.5	753.0	746.0	36"	48"	72"	748.0
POND 3	760.0	758.5	757.5	752.0	36"	48"	72"	754.0



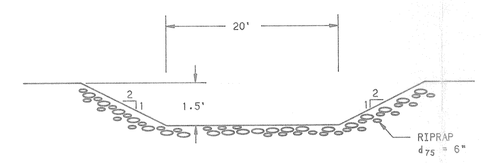
2/11 FINAL SITE ACCESS ROAD

NTS



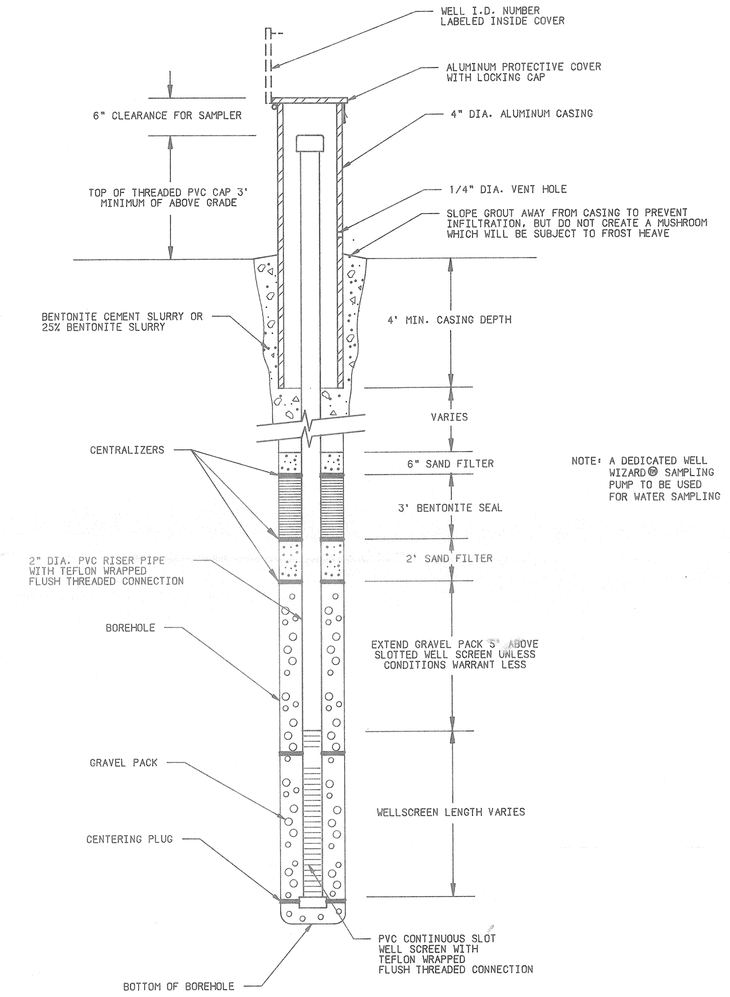
4/11 SEDIMENTATION POND OUTLET STRUCTURE

NTS



SECTION A4-A4

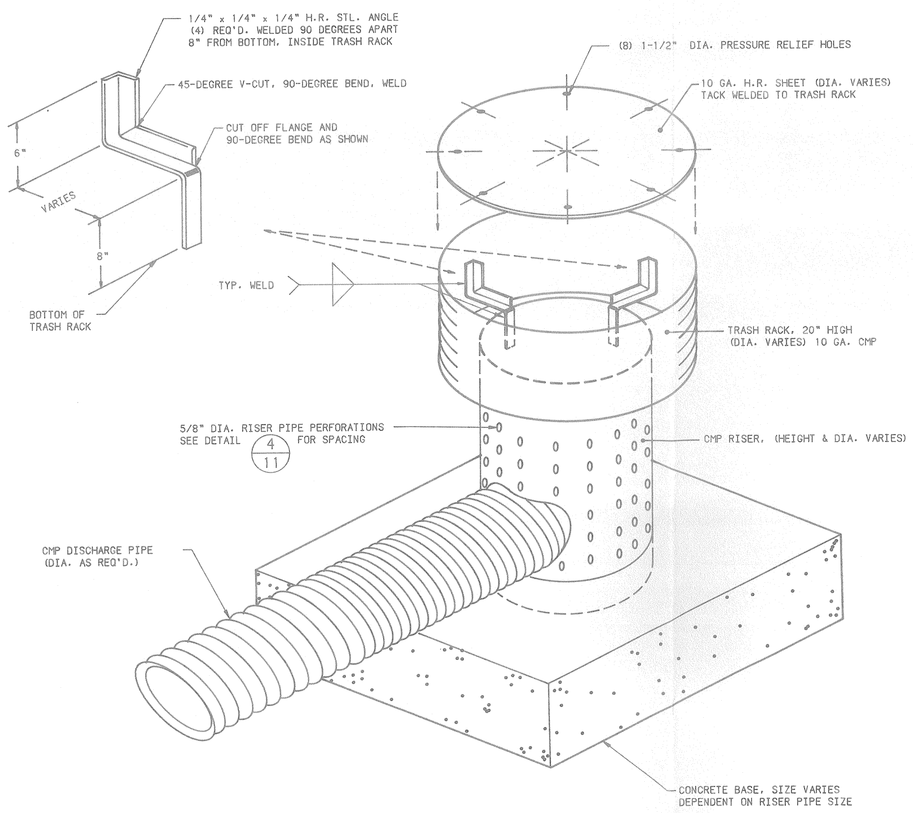
NTS



NOTE: A DEDICATED WELL WIZARD® SAMPLING PUMP TO BE USED FOR WATER SAMPLING

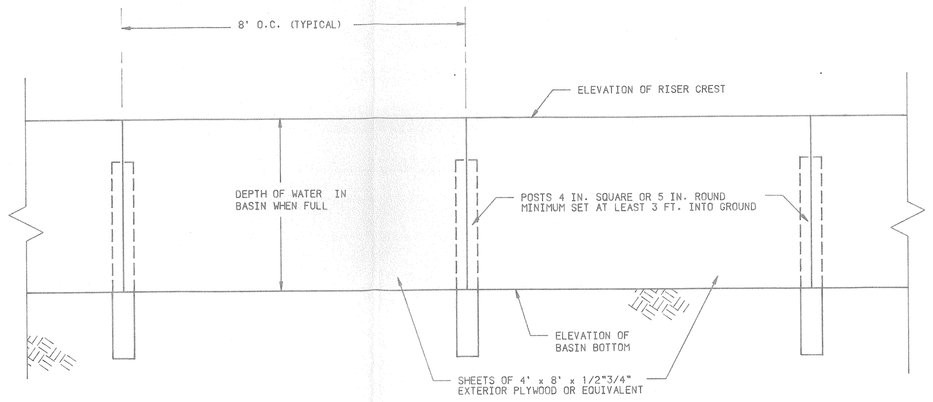
6/11 TYPICAL MONITORING WELL DETAIL

NTS



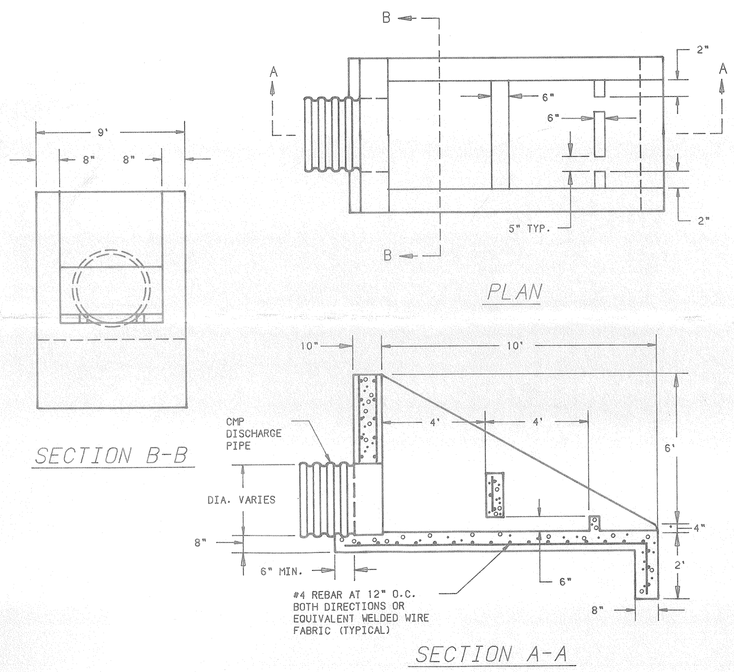
3/11 TRASH RACK

NTS



5/11 BAFFLE WALL

NTS



7/11 TYPICAL ENERGY DISSIPATOR

NTS

34-06

RECEIVED
NOV 07 1988
SOLID WASTE BRANCH

REV.	DATE	DESCRIPTION	DR BY	APP BY
1	11-21-91	ADDED RIPRAP SYMBOL DETAIL 2/11	VRV	

SCALE	NONE	PROJECT NO. 04700	DATE MAY 1988
DES BY	CML	PROJECT	PIEDMONT SANITARY LANDFILL FORSYTH COUNTY, NORTH CAROLINA
DR BY	VRV		
CHK BY	AEH	SHEET TITLE	MISCELLANEOUS DETAILS
RVW BY	JWS		
APP BY	SDM		

Waste Management, Inc.
Oak Brook, Illinois 60521

SHEET 11 OF 11
SHEET NO. 11

CADD PRODUCED DRAWING