2-203.24
20100-CA-0001

739

FINAL DESIGN
CALCULATION PACKAGE
ON-SITE DISPOSAL FACILITY

REVISION 0
VOLUME III OF IV
MAY 1997

United States Department of Energy
Fernald Environmental Management Project
Fernald, Ohio

prepared by

GeoSyntec Consultants
1100 Lake Hearn Drive, NE, Suite 200
Atlanta, Georgia 30342

under

Fluor Daniel Fernald
Subcontract 95PS005028

000001

739 No. 02

FINAL DESIGN CALCULATION PACKAGE ON-SITE DISPOSAL FACILITY

Volume III

May 1997
Revision 0

United States Department of Energy

Fernald Environmental Management Project
Fernald, Ohio

Prepared by

GeoSyntec Consultants
1100 Lake Hearn Drive, NE, Suite 200
Atlanta, Georgia 30342

Under

Fluor Daniel Fernald
Subcontract 95PS005028

FINAL DESIGN PACKAGE
LIST OF CALCULATIONS
On-Site Disposal Facility
Fernald Environmental Management Project

VOLUME I

1. INTRODUCTION

1.1 Design Parameter Summary
1.2 Computer Program Validation

1.2.1 Autodesk® and SOFTDESK®
1.2.2 HydroCAD™
1.2.3 USDA-SCS TR-55
1.2.4 USEPA HELP Model
1.2.5 XSTABL - Version 5
1.2.6 SHAKE91
1.2.7 YSLIP_C
1.2.8 Landfill Air Emissions Estimation Model
1.2.9 RAECOM

1.3 Select Technical References
1.4 Geotechnical Data Points

2. OSDF LAYOUT

2.1 Required Volume
2.2 Capacity Verification
2.3 Earthwork Required Volume

3. GEOTECHNICAL - STATIC SLOPE STABILITY

3.1 OSDF Foundation
3.2 Liner System

LIST OF CALCULATIONS (continued)

3.3 Impacted Material Configurations

- Interim
- Final

3.4 Intercell Berm
3.5 Final Cover System
3.6 Access Corridor
3.7 Borrow Area Cut Slopes

4. GEOTECHNICAL - SEISMIC SLOPE STABILITY

4.1 Seismic Hazard Assessment
4.2 Seismic Site Response Analysis
4.3 Seismic Performance Evaluation

- Pseudo-Static Stability
- Deformation Analysis

5. GEOTECHNICAL - SETTLEMENT

5.1 Foundation Settlement
5.2 Localized Impacted Material Settlement
5.3 Overall Impacted Material Settlement

VOLUME II

6. LINER SYSTEM

6.1 Hydrostatic Uplift
6.2 Liner Geosynthetics Selection

- Geosynthetic Clay Liner
- Geomembrane Liner

LIST OF CALCULATIONS (continued)

- Geotextile Cushion
- Geosynthetic Selection to Preclude Tension

6.3 Liner Frost Protection

7. LEACHATE MANAGEMENT - LEACHATE GENERATION

7.1 Leachate Generation Rates

- During Filling
- After Closure

7.2 Required Cell Leachate Storage

8. LEACHATE MANAGEMENT - LEACHATE COLLECTION SYSTEM

8.1 Maximum Head in LCS

- Maximum Head in LCS Drainage Layer
- Maximum Head in LCS Drainage Corridor

8.2 Geotextile Filter Design

- Geotextile Filtration
- Geotextile Biological Clogging Potential

8.3 LCS Pipe Design

- LCS Pipe Flow Capacity
- LCS Pipe Perforation Sizing
- LCS Pipe Structural Stability

LIST OF CALCULATIONS (continued)

9. LEACHATE MANAGEMENT - LEAK DETECTION SYSTEM

9.1 Migration through Primary Liner
9.2 Maximum Head in LDS

- Maximum Head in LDS Drainage Layer
- Maximum Head in LDS Drainage Corridor

9.3 Time of Travel in LDS
9.4 LDS Pipe Design

- LDS Pipe Flow Capacity
- LDS Pipe Perforation Sizing
- LDS Pipe Structural Stability

9.5 Action Leakage Rate

10. LEACHATE MANAGEMENT - LEACHATE TRANSMISSION SYSTEM

10.1 LTS Gravity Line Design

- LTS Gravity Line Flow Capacity
- LTS Gravity Line Structural Stability
- LTS Gravity Line Frost Protection

10.2 LTS Temporary Gravity Line Design

- LTS Temporary Gravity Line Hydraulic Pressure
- LTS Temporary Gravity Line Structural Stability
- LTS Temporary Gravity Line Frost Protection

LIST OF CALCULATIONS (continued)

10.3 LDS and LCS Manhole Design

- LCS and LCS Manhole Hydrostatic Uplift
- LCS and LCS Manhole Structural Design
- Structural Concrete Design for the Cover and Floatation Anchor

10.4 LTS Permanent Lift Station Design

- LTS Permanent Lift Station Storage Volume
- LTS Permanent Lift Station Manhole Uplift
- LTS Permanent Lift Station Structural Design

10.5 LTS Pipe Hydrograph

VOLUME III

11. FINAL COVER SYSTEM

11.1 Final Cover System Temporary Erosion Mat Design
11.2 Final Cover System Vegetation Design
11.3 Final Cover System Erosion Resistance
11.4 Final Cover System Frost Penetration Depth
11.5 Final Cover System Granular Filter Layer Design
11.6 Final Cover System Biointrusion Barrier Design
11.7 Final Cover System Drainage Layer Design

- Cover System Water Balance
- Cover Drainage Layer Maximum Head

11.8 Final Cover System Geosynthetics Selection

- Geotextile Cushion
- Geomembrane Cap
- Geosynthetic Clay Cap

LIST OF CALCULATIONS (continued)

12. SURFACE-WATER MANAGEMENT
DURING OSDF CONSTRUCTION/FILLING/CLOSURE

12.1 Stormwater Runon/Runoff and Drainage Control Structures
12.2 OSDF Sediment Basins

13. SURFACE-WATER MANAGEMENT AFTER OSDF CLOSURE

13.1 Stormwater Runon/Runoff and Drainage Control Structures

- Northern Area Calculations
- Eastern Area Calculations
- Southern Area Calculations
- Western Area Calculations
- Addendum to Southern Area Calculations of 13.1

VOLUME IV

13.2 Drainage Control Structure Erosion Resistance

14. SUPPORT FACILITIES

14.1 Electrical Power Demand
14.2 Potable Water Demand
14.3 Sanitary Wastewater Discharge
14.4 Construction Water Demand
14.5 Decontamination Facility Water Demand
14.6 Decontamination Facility Pavement
14.7 Construction Administration Area Surfacing
14.8 Construction Haul Road
14.9 Leachate Transmission System Access Corridor

LIST OF CALCULATIONS (continued)

15. BORROW AREA

15.1 Borrow Area Required Volume
15.2 Borrow Area Capacity Verification
15.3 Borrow Area Water Demand
15.4 Stormwater Runoff Routing
15.5 Borrow Area Sediment Basin

16. IMPACTED MATERIALS MANAGEMENT

16.1 Impacted Material Haul Road
16.2 Impacted Runoff from Haul Road
16.3 OSDF Methane Generation
16.4 OSDF Radon 222 Release

17. HORIZONTAL MONITORING WELL

17.1 Differential Settlement and Tensile Strain
17.2 Structural Stability

11. FINAL COVER SYSTEM

11.1 Final Cover System Temporary Erosion Mat Design
11.2 Final Cover System Vegetation Design
11.3 Final Cover System Erosion Resistance
11.4 Final Cover System Frost Penetration Depth
11.5 Final Cover System Granular Filter Layer Design
11.6 Final Cover System Biointrusion Barrier Design
11.7 Final Cover System Drainage Layer Design
11.8 Final Cover System Geosynthetics Selection

SECTION 11

11.1 Final Cover System Temporary Erosion Mat Design

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: FINAL COVER EROSION MAT

Computations By: (Cognizant Engineer)
Signature: Daniel G. Pass — Date: 3 APRIL 96
Printed Name and Title: DANIEL G. PASS, STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature: Kara Olen — Date: 4 April 96
Printed Name and Title: Kara L. Olen, Asst. Proj Engr.

Computations Checked by:
Signature: Kara Olen — Date: 4 April 96
Printed Name and Title: Kara L Olen, Asst. Proj. Engr.

Computations Backchecked by: (Cognizant Engineer)
Signature: Daniel G. Pass — Date: 4 APRIL 96
Printed Name and Title: DANIEL G. PASS, STAFF ENGINEER

Approved by: (PDP)
Signature: Kara Olen — Date: 4 April 96
Printed Name and Title: Kara L. Olen, Asst. Proj. Engr.

Approved by: (DTL and TETL)
Signature: [illegible] — Date: 5 Ap 96
Printed Name and Title: Kenneth W Cargill, Associte

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
D	INTERMEDIATE DESIGN EPA SUBMITTAL	4 APRIL 96	DGP	—	—
G	Final Design Package	4 Oct 96	—	—	[illegible]
O	Response to Final Design Cmts.	9 May 97	—	—	[illegible]

Written by: Daniel Pass DSP Date: 3 April 1996 Reviewed by: K. Olen Date: 4 April 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.2

FINAL COVER EROSION MAT

EXECUTIVE SUMMARY

Purpose:

The purpose of this calculation is to estimate the requirements for erosion mat on recently seeded final cover.

Calculation Method:

Analysis is performed using an allowable shear stress criteria [Temple et. al., 1987] and estimating the slope distance from the top of the final cover beyond which erosion mat will be required. The Rational method is used to calculate the runoff rate for the design storm. The return period for the design storm is 2 years.

Conclusions:

Erosion mat will be required from the toe of the 20H:1V slope to the limits of the final cover at the base of the OSDF.

Written by: DaP Date: 4 April 1996 Reviewed by: K Oler Date: 4 Apr 1996

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE-3900 Task No.: 8.2

FINAL COVER EROSION MAT

TABLE OF CONTENTS

Calculation Procedures	1/7
Data Verification	1/5
Calculations	1/5

Written by: Daniel Pass DGP Date: 3 April 1996 Reviewed by: K Olen Date: 4 Apr 1996

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.2

FINAL COVER EROSION MAT

CALCULATION PROCEDURES

Introduction:

Portions of the OSDF will be brought under final closure (i.e., installation of final cover) periodically during the active life of the OSDF and shortly thereafter seeded. The seeded OSDF slopes may be suseptible to erosion during low intensity storms prior to the establishment of good vegetation. Erosion mat will be used in that portion of the final cover for which erosion is likely. The requirements for erosion will be specified in terms of a slope distance from the top of the OSDF and will continue to the limits of the final cover.

The distance down the OSDF cover beyond which the erosion mat would need to be installed is estimated by comparing an allowable shear stress [Temple et. al., 1987] with actual shear stresses exerted on the bare soil from runoff from the design storm at various locations on the final cover. The design storm is the 2-year 24 hour event..

Procedure:

The following iterative procedure is used.

Step 1: Select a critical cross-section through the final cover and measure the slope lengths for each segment. (i. e., 20H:1V, 10H:1V and 6H:1V)

Step 2: Assume a trial location on the final cover for calculation of the shear stress exerted on the soil and seeding by stormwater runoff from the design storm. The

location is defined as a slope length, L_s from the top of the OSDF final cover. For analysis, assume a 1 ft wide representative strip extending from the top of the final cover to the limits of the final cover at the base of the OSDF.

Step 3: Estimate the flow rate, Q at the trial location using the Rational method.

$$Q = Ci\left(\frac{1ft}{12in.} \bullet \frac{1hr}{3600\,\text{min}}\right)A$$

where,

C = runoff coefficient for the final cover;
i = rainfall intensity (in/hr); and
A = Drainage area (SF); A = (L_s)(1 ft wide strip)

- Select a value for C from Figure 1 [Goldman et. al., 1986]
- The calculation of i is performed in an iterative process using Figure 2 [USDOC, 1955] for a 2 year return period and a time of concentration, T_c, calculated using the following equation [USDOE, 1989]:

$$T_c = C_t\left(\frac{L_s}{Si^2}\right)^{1/3}$$

where,

T_c= time of concentration (minutes)
C_t= a coefficient equal to 1.0 for bare soil
S = a weighted slope for the final cover at trial location.
i = rainfall intensity for a given value of T_c (in/hr)

Step 4: The allowable shear stress, τ_a, for bare soil on the final cover is obtained from the calculation "Final Cover Erosion Resistance

Step 5: Calculate the actual shear stress, τ_0, at a distance L_s down the final cover using the following equation:

$$\tau_0 = \gamma_w dS$$

where,

γ_w = unit weight of water (pcf);
d = depth of flow (ft) calculated using Manning's equation; and
S = Slope of final cover at L_s.(ft).

Step 6: Calculate the safety factor, SF, against erosion using the following equation:

$$SF = \frac{\tau_a}{\tau_0}$$

If the value of SF is equal to 1.0 then erosion mat will be required beginning at a distance L_s down the final cover, otherwise select a new value of L_s. and repeat steps 2 through 6.

References:

1. Chow, Ven Te, "*Open Channel Hydraulics*", McGraw-Hill, Inc., New York, NY, 1959, 680 p.

2. Goldman, S., Jackson, K., and Bursztynsky, T., "*Erosion and Sediment Control Handbook*", McGraw-Hill Book Co., New York, NY, 1986.

3. Temple, D., Robinson, K., Ahring, R., and Davis, A. "*Stability Design of Grass-Lined Open Channels*", Agriculture Handbook Number 667, PB88-116629, U. S. Department of Agriculture, Agriculture Research Service, Beltsville, MD, Sep 1987, 167 p.

4. U.S. Department of Commerce [USDOC], "Rainfall Intensity-Duration-Frequency Curves", *USDOC Technical Paper No. 25*, Washington, DC, 1955.

5. U.S. Department of Energy [USDOE], "*Technical Approach Document, Revision II*", (Uranium Mill Tailings Remedial Action Project), UMTRA-DOE/AL 050425.0002, Dec 1989, 290 p. (plus attachment)

DGP FERMCO/OSDF GE 3900 3 APRIL 96 TASK 8.2 Rolen 4/4/96 Ck'd KS Olen 4 April 96

5/7 739

TABLE FOR SELECTION OF RUNOFF COEFFICIENT, C

Rational Method *C* Values (13)

Land use	C	Land use	C
Business		Lawns	
Downtown areas	0.70–0.95	Sandy soil, flat, 2%	0.05–0.10
Neighborhood areas	0.50–0.70	Sandy soil, average, 2–7%	0.10–0.15
Residential		Sandy soil, steep, 7%	0.15–0.20
Single-family areas	0.30–0.50	Heavy soil, flat, 2%	0.13–0.17
Multi units, detached	0.40–0.60	Heavy soil, average, 2–7%	0.18–0.22
Multi units, attached	0.60–0.75	Heavy soil, steep, 7%	0.25–0.35
Suburban	0.25–0.40	Agricultural land, 0–30%	
Industrial		Bare packed soil	
Light areas	0.50–0.80	Smooth	0.30–0.60
Heavy areas	0.60–0.90	Rough	0.20–0.50
Parks, cemeteries	0.10–0.25	Cultivated rows	
Playgrounds	0.20–0.35	Heavy, soil, no crop	0.30–0.60
Railroad yard areas	0.20–0.40	Heavy soil with crop	0.20–0.50
Unimproved areas	0.10–0.30	Sandy soil, no crop	0.20–0.40
Streets		Sandy soil with crop	0.10–0.25
Asphaltic	0.70–0.95	Pasture	
Concrete	0.80–0.95	Heavy soil	0.15–0.45
Brick	0.70–0.85	Sandy soil	0.05–0.25
Drives and walks	0.75–0.85	Woodlands	0.05–0.25
Roofs	0.75–0.95	Barren slopes, >30%*	
		Smooth, impervious	0.70–0.90
		Rough	0.50–0.70

Note: The designer must use judgment to select the appropriate *C* value within the range. Generally, larger areas with permeable soils, flat slopes, and dense vegetation should have lowest *C* values. Smaller areas with dense soils, moderate to steep slopes, and sparse vegetation should be assigned highest *C* values.

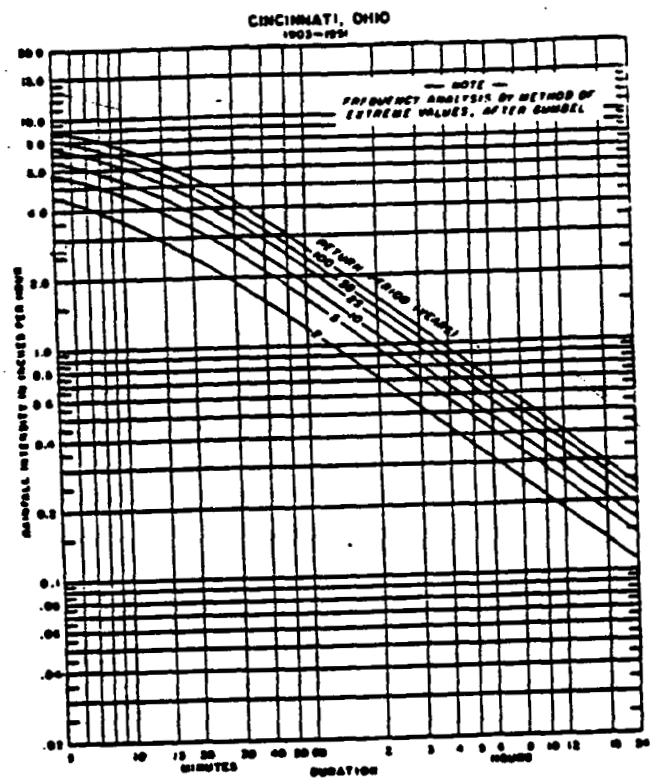
*From Portland Cement Association, *Handbook of Concrete Culvert Pipe Hydraulics*, 1964, p. 45.

[GOLDMAN, 1986] FIGURE 1

Written by: DGP Date: 96 / 4 / 3 (YY MM DD) Reviewed by: K Olen Date: 96 / 4 / 4 (YY MM DD)

Client: FECMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.2

FIGURE FOR SECECTION OF RAINFALL INTENSITY, i



[USDOC, 1955] FIGURE 2

Written by: DGP Date: 96/4/3 (YY MM DD) Reviewed by: K. Olen Date: 96/4/4 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.2

TABLE FOR SELECTION OF MANNING'S COEFFICIENT, n

TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT *n* (*continued*)

Type of channel and description	Minimum	Normal	Maximum
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
D-2. Flood plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
D-3. Major streams (top width at flood stage >100 ft). The *n* value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	.....	0.060
b. Irregular and rough section	0.035	.....	0.100

[CHOW, 1959] FIGURE 3

Written by: Daniel Pass DGP Date: 3 April 1996 Reviewed by: K Olen Date: 4 April 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.2

FINAL COVER EROSION MATT

DATA VERIFICATION

The following data was used in the calculation section:

- Slope distances and lengths from figure 1.

  20H:1V slope, 78.1 ft

  10H:1V slope, 54.2 ft

  6H:1V slope, 283.9 ft

- Runoff Coefficient, C = 0.6 (Figure 2) which is the also the average value for rough barren slopes above 30% [Goldman et. al., 1986] The value of C chosen is conservative for the OSDF final cover slopes below 30%. ✓

- Manning's coefficient for sheet flow, n_s = 0.025 (Figure 3; [Chow, 1959]); average of the minimum and normal values for a cultivated area with no crop. ✓

- Maximum sheet flow length = 100 ft. ✓

- Return Period for the design storm = 2 years. ✓

- The allowable shear stress for bare soil, τ_a = 0.029 as obtained from the calculation titled "Erosin Resistance of the Final Cover" ✓

- Unit weight of water, γ_w = 62.4 pcf. ✓

References:

1. Chow, Ven Te, "*Open Channel Hydraulics*", Mc Graw-Hill, Inc., New York, NY, 1959, 680 p.

2. Goldman, S., Jackson, K., and Bursztynsky, T., "*Erosion and Sediment Control Handbook*", McGraw-Hill Book Co., New York, NY, 1986.

3. U.S. Department of Commerce [USDOC], "Rainfall Intensity-Duration-Frequency Curves", *USDOC Technical Paper No. 25*, Washington, DC, 1955.

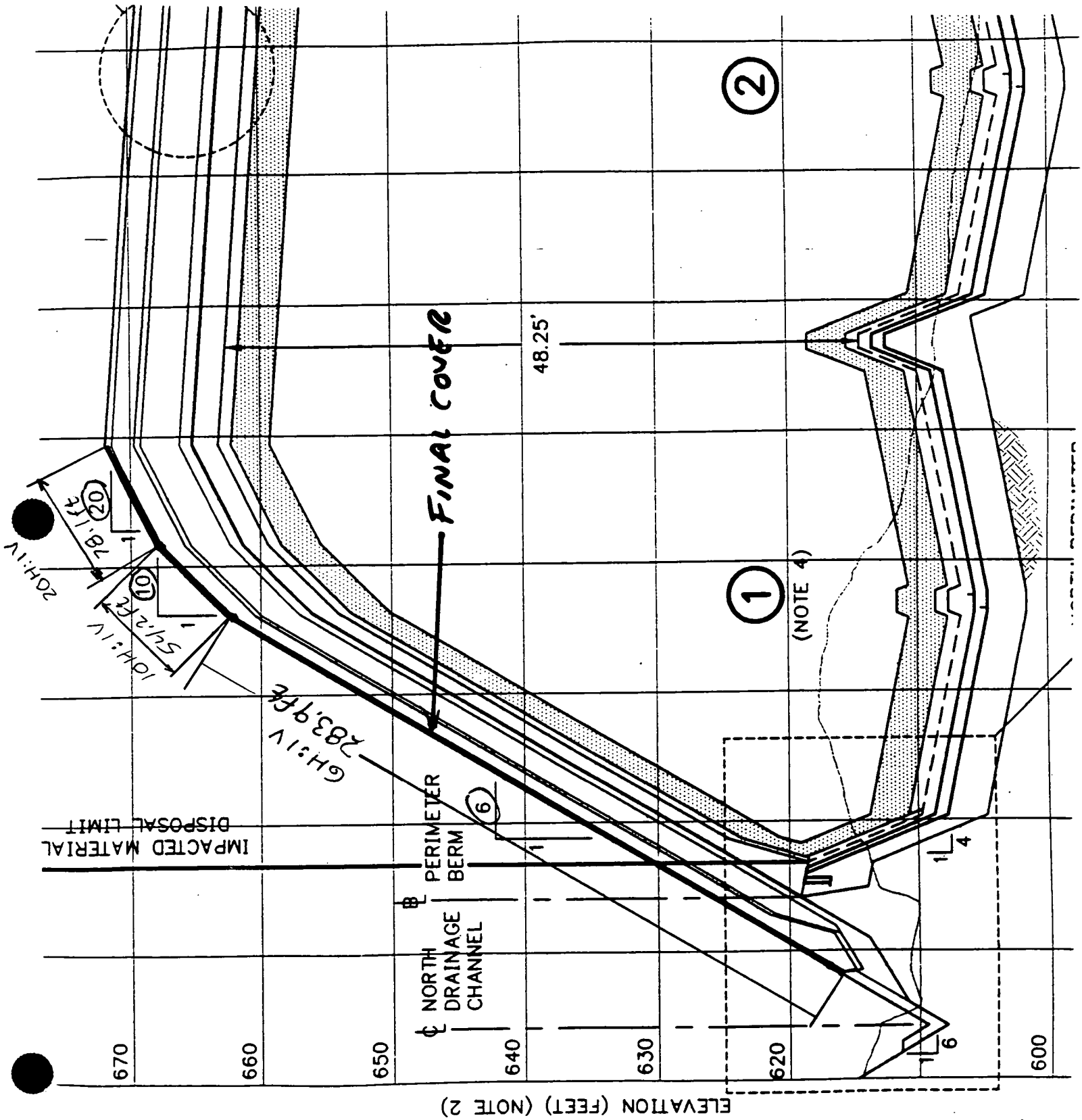
4. U.S. Department of Energy [USDOE], "*Technical Approach Document, Revision II*", (Uranium Mill Tailings Remedial Action Project), UMTRA-DOE/AL 050425.0002, Dec 1989, 290 p. (plus attachment)

739 K Olen 4/4/96

GeoSyntec Consultants

Written by: DaP Date: 96/4/3 (YY MM DD) Reviewed by: K Olen Date: 96/4/4 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.2



000024

FROM DESIGN DRAWING - "NORTH-SOUTH SECTION" FIGURE 1

Written by: DGP Date: 96/4/3 (YY MM DD) Reviewed by: K. Olen Date: 96/4/4 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 8.2

TABLE FOR SELECTION OF RUNOFF COEFFICIENT, C

Rational Method C Values (13)

Land use	C	Land use	C
Business		**Lawns**	
Downtown areas	0.70–0.95	Sandy soil, flat, 2%	0.05–0.10
Neighborhood areas	0.50–0.70	Sandy soil, average, 2–7%	0.10–0.15
Residential		Sandy soil, steep, 7%	0.15–0.20
Single-family areas	0.30–0.50	Heavy soil, flat, 2%	0.13–0.17
Multi units, detached	0.40–0.60	Heavy soil, average, 2–7%	0.18–0.22
Multi units, attached	0.60–0.75	Heavy soil, steep, 7%	0.25–0.35
Suburban	0.25–0.40	**Agricultural land, 0–30%**	
Industrial		Bare packed soil	
Light areas	0.50–0.80	Smooth	0.30–0.60
Heavy areas	0.60–0.90	Rough	0.20–0.50
Parks, cemeteries	0.10–0.25	Cultivated rows	
Playgrounds	0.20–0.35	Heavy, soil, no crop	0.30–0.60
Railroad yard areas	0.20–0.40	Heavy soil with crop	0.20–0.50
Unimproved areas	0.10–0.30	Sandy soil, no crop	0.20–0.40
Streets		Sandy soil with crop	0.10–0.25
Asphaltic	0.70–0.95	Pasture	
Concrete	0.80–0.95	Heavy soil	0.15–0.45
Brick	0.70–0.85	Sandy soil	0.05–0.25
Drives and walks	0.75–0.85	Woodlands	0.05–0.25
Roofs	0.75–0.95	**Barren slopes, >30%***	
		Smooth, impervious	0.70–0.90
		Rough	0.50–0.70

C = 0.6

Note: The designer must use judgment to select the appropriate C value within the range. Generally, larger areas with permeable soils, flat slopes, and dense vegetation should have lowest C values. Smaller areas with dense soils, moderate to steep slopes, and sparse vegetation should be assigned highest C values.

*From Portland Cement Association, *Handbook of Concrete Culvert Pipe Hydraulics*, 1964, p. 45.

FIGURE 2

[GOLDMAN, 1986]

Written by: DGP Date: 96/4/3 (YY MM DD) Reviewed by: K. Oler Date: 96/4/4 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.2

SELECTION OF MANNING'S COEFFICIENT, n

TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT n (*continued*)

Type of channel and description	Minimum	Normal	Maximum
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
D-2. Flood plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
D-3. Major streams (top width at flood stage >100 ft). The n value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	.....	0.060
b. Irregular and rough section	0.035	.....	0.100

AVG = 0.025

n = 0.025

[CHOW, 1959]

FIGURE 3

Written by: DGP Date: 96/4/3 (YY/MM/DD) Reviewed by: K Olen Date: 96/4/4 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.2

FINAL COVER EROSION MAT

CALCULATIONS

STEP 1: THE CRITICAL CROSS-SECTION IS SHOWN IN FIGURE 1. THE SECTION OF THE DATA VERIFICATION FOLLOWING ARE SLOPE LENGTHS FOR EACH SECTION.

20H:1V SLOPE	78.1 ft
10H:1V SLOPE	54.2 ft
6H:1V SLOPE	283.9 ft

STEP 2: THE TRIAL LOCATION FOR ANALYSIS OF SHEAR STRESS EXERTED BY RUNOFF TO THE SURFACE OF THE FINAL COVER SYSTEM IS AT THE TOE OF THE 20H:1V SLOPE. THUS $L_s = 78.1$ ft

TRIAL LOCATION AT $L = 78.1$ ft

STEP 3: ESTIMATE THE THE FLOW RATE, Q USING THE RATIONAL EQUATION:

$$Q = CiA$$

WHERE:

$C_1 = 0.6$

$A = L \times 1$ ft WIDE STRIP $= 78.1 \times 1 = 78.1$ ft^2

CALCULATE TIME OF CONCENTRATION, T_c, ASSUMING A TRIAL VALUE OF $i = 4.5$ IN/HR WHICH CORRESPONDS TO $T_c < 5$ MINUTES

$$T_c = C_1 \left(\frac{L_s}{S^{1/2}} \right)^{1/3}$$

Written by: DGP Date: 96/4/3 (YY/MM/DD) Reviewed by: K Olen Date: 96/4/4 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3906 Task No.: 8.2

WHERE,

$C_1 = 1.0$
$L_s = 78.1$ ft
$S = 1/20 = 0.05$

$$T_c = 1.0 \left(\frac{78.1 \text{ ft}}{0.05 \times (4.5 \text{ IN/HR})^2} \right)^{1/3}$$

$$= 4.26 \text{ MINUTES}$$

T_c (4.26 MIN) < 5 MIN. THUS i IS CORRECT AS CHOSEN (SEE FIGURE 1)

$i = 4.5$ IN/HR

NOTE: A MINIMUM OF 5 MINUTES IS RECOMENDED WHEN USING THE RAINFALL-INTENSITY CURVES [FIGURE 1] FOR THE RATIONAL METHOD.

- THUS,

$$Q = 0.6 \times 4.5 \text{ IN/HR} \times 78.1 \text{ ft}^2 \times 1 \text{ ft}/12 \text{ IN} \times 1 \text{ HR}/3600 \text{ MIN}$$

$$= 0.004881 \text{ CFS}$$

STEP 4: THE ALLOWABLE SHEAR STRESS IS 0.029. (SEE THE DATA VERIFICATION SECTION OF THIS CALCULATION)

Written by: DGP Date: 96/4/3 (YY/MM/DD) Reviewed by: K Olen Date: 96/4/4 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.2

STEP 5: CALCULATE THE SHEAR STRESS, τ_o AT THE TRIAL LOCATION.

$$\tau_o = \gamma_w d S$$

WHERE $\gamma_w = 62.4$ pcf
$S = 0.05$
$d = 0.0087$ Ft ← (BACK CALCULATED USING MANNINGS EQUATION)

$$\tau_o = 62.4 \text{ pcf} \times 0.0087 \text{ Ft} \times 0.05$$

$$= 0.0271 \text{ psf}$$ ✓

STEP 6: CALCULATE THE SAFETY FACTOR, SF AGAINST EROSION.

$$SF = \frac{\tau_a}{\tau_o}$$

FROM STEP 4 $\tau_a = 0.029$ psf
FROM STEP 5 $\tau_a = 0.0271$ psf

$$SF = \frac{0.029 \text{ psf}}{0.0271 \text{ psf}} \quad 1.07$$ ✓

THUS, NO SIGNIFICANT AMOUNT OF EROSION IS ANTICIPATED AT THE END OF THE 20H:1V SLOPE (i.e., $L_s = 78.1$ Ft)

STEPS 2 THROUGH 6 WERE REPEATED FOR THE START OF THE 10H:1V SLOPE ($L_s = 78.1$ Ft, $S = 0.1$) AND RESULTED IN A τ_o OF 0.0443 AND A SF OF 0.65. ✓

STEPS 2 THROUGH 6 WERE REPEATED FOR THE EAST AND WEST FACING SLOPES WHERE THE LENGTH OF THE 20H:1V SLOPE IS 90 ft AND RESULTED IN A $\tau_o = 0.0296$ AND A SF $= 0.98 \approx 1.0$ ✓

GEOSYNTEC CONSULTANTS

Written by: DGP Date: 96 / 4 / 3 (YY MM DD) Reviewed by: K Olem Date: 96 / 4 / 4 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.2

BASED ON THE ABOVE CALCULATIONS EROSION MATT WILL BE REQUIRED BEGGINING AT THE TOE OF THE 20H:1V SLOPE AND CONTINUING TO THE END OF THE FINAL COVER SYSTEM AT THE BASE OF THE OSDF. ✓

Written by: DGD Date: 96/4/3 (YY MM DD) Reviewed by: K Olen Date: 96/4/4 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.2

SELECTION OF RAINFALL INTENSITY, i

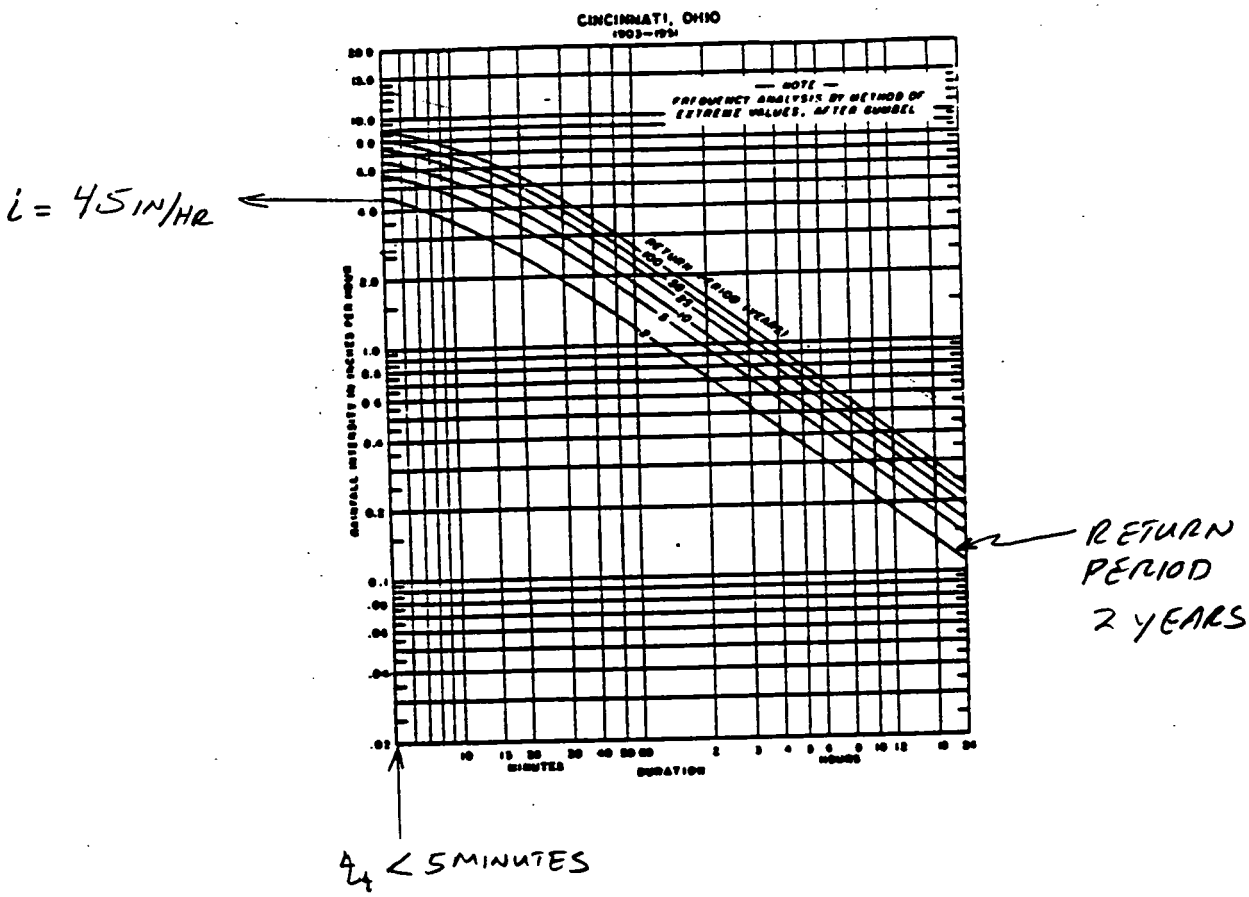


FIGURE 2

[USDOC, 1955]

11.2 Final Cover System Vegetation Design

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: VEGETATION DESIGN

Computations By: (Cognizant Engineer)
Signature: Philip D. Freshley — Date: 2/6/96
Printed Name and Title: Philip D. Freshley, CPSS Project Scientist

Assumptions and Procedures Checked by: (Checker)
Signature: Barbara-Ann G. Lewis — Date: 2/23/96
Printed Name and Title: Barbara-Ann G. Lewis, Assoc. Professor Environmental Engineering, Northwestern Universit

Computations Checked by:
Checked by:
Signature: — Date:
Printed Name and Title:

Computations Backchecked by: (Cognizant Engineer)
Signature: Philip D. Freshley — Date: 2/23/96
Printed Name and Title: Philip D. Freshley, CPSS Project Scientist

Approved by: (PDP)
Signature: David J. Bonnett — Date: 1 April 1996
Printed Name and Title: David J. Bonnett, Regional Manager - Field Services

Approved by: (DTL and TETL)
Signature: [illegible] — Date: 25 Feb 96
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
A					
~~B~~ D	Intermediate Design Submittal to EPA	29 May 96	[illegible]	—	—
G	Final Design Package	4 Oct 96	—	—	[illegible]
O	Response to Final Design Comments	9 May 97	—	—	[illegible]

EARTH SYSTEMS ASSOCIATES, LTD.

1073 S. Milledge Avenue
Athens, GA. 30605

Phone (706) 354-7925
FAX (706) 354-7928

February 23, 1996

David Bonnett, P.E.
GeoSyntec Consultants
1100 Lake Hearn Drive
Atlanta, GA 30342-1523

Subject: Preliminary Response to Review Comments on FEMP Site Vegetation Cover Plan. ESA Project No. 9603.

Today we received the comments of Dr. Barbara-Ann G. Lewis on the FERMC site vegetation cover plan. We found the comments to be constructive and beneficial. Our preliminary response and plan to address them follows.

Comment 1. Testing of the cover material and specification of amendments required for successful vegetation establishment has been provided for in Earth System's proposal for Phase II testing (not yet complete). We will review the proposed list of analytical parameters with respect to those suggested by Dr. Lewis and revise the Phase II scope of work as needed.

Comment 2. We agree that "low maintenance" may be a misnomer if taken in this context, and that burrowing animals are a major concern. We will revise pertinent sections to better address these issues.

Comment 3. Integrity of the cap with respect to the rate of diffusion of Radon-222 is an issue which is beyond the scope of our contract. Containment of radioactive material is beyond our area of expertise. However, we will be glad to discuss a proposal to address the consequences of cap leakage on the soil/plant system under a separate contract if needed.

We will forward any further comments to GeoSyntec within one week and revisions to the report and Phase II scope of work within three weeks. If you have any questions or comments, please do not hesitate to call.

Sincerely,

EARTH SYSTEMS ASSOCIATES, LTD.

Philip D. Freshley, CPSS
Project Manager

DATE: February 23, 1996

TO: David Bonnett and Mary Redican
GeoSyntec Consultants
1100 Lake Hearn Drive, N.E., Suite 200
Atlanta, Georgia 30342-1523
FAX (404)705-9400

FROM: Barbara-Ann G. Lewis, Ph.D.
[redacted]

SUBJECT: Review of Vegetation Cover Plan

I have reviewed the vegetation cover recommendations made by Earth Systems Associates, Ltd., for the On-Site Disposal Facility at the Fernald Environmental Management Project Site. In my opinion, the recommendations appear well-thought out and the plan is reasonable. The plan is consistent with the goals of the project, and with the climate and general ecology of the region. Sufficient detail is provided to implement the plan after closure of the site. However, a number of uncertainties exist that need to be considered before one can predict the overall success of the plan. These include, but may not be limited to, the following:

1. There is no information on the physical, chemical, or biological nature of the material to be used as cover over the disposal site, and that will serve as the medium for vegetative growth. The site soils described in the Earth Systems plan are the soils that now exist on the site. However, it is my understanding that much of these site soils have been contaminated, and will actually be removed and disposed of in the constructed cells. The cover that will then be vegetated will consist primarily of what is now subsoil, i.e., glacial till that may be primarily silty clay. If so, there is no evidence that the vegetation proposed for the site cover will thrive in this material without further treatment or amendments. I recommend that composite samples be taken of this proposed cover material and the following parameters (as a minimum) measured:

a. Physical: particle size analysis (as is, and after pulverization to pass a 2-mm sieve), water-stable aggregates, moisture-holding capacity, available water percentage.

b. Chemical: pH, cation exchange capacity, exchangeable sodium percentage, electrical conductance of saturation extracts, exchangeable bases, plant-available nutrients (macro- and micro-nutrients), total and soluble trace metals and non-metals that have potential for adverse effects on vegetation or herbivores (for example, boron, arsenic, and selenium).

c. Microbiological: Presence of *Rhizobium* or other genera of organisms that allow nitrogen fixation. If numbers of such populations are low or absent, the legume seeds that are planted should first be inoculated. Pretreatment of the site cover material by incorporation of organic matter will enhance physical and drainage characteristics.

I further recommend that prior to full-scale implementation of the vegetative plan, that a small area of the project site be used as an experimental site, to test the feasibility and potential for success of the vegetation plan. The plan can then be modified accordingly. Although such experiments are more expensive than office-chair speculation, I believe it would be far more cost-effective in the long run than going ahead full-scale without some preliminary trials. Those trials should cover at least three growing seasons.

2. The goals of the project are laudible, but may be contradictory in some cases. For example, "low maintenance" is desired, together with "limited root systems". As was pointed out in the Earth Systems plan, the climax vegetation for that region will include trees, whose roots may reach (if not penetrate) the underlying clay cap. Preventing such root growth will require periodic maintenance for the the life of the project, i.e., thousands of years if radioactive material is included in the disposal cells. This is not "low maintenance", in my opinion, nor is there any guarantee that such maintenance will be provided for the thousands of years. The report also acknowledges that wildlife will eventually inhabit the area. In my opinion, this is a benefit that will accrue from the disposal site plan, but there is not enough experience with such disposal sites to determine whether burrowing animals will penetrate the clay cap. Excluding wildlife will not be possible without constant vigilance. This, too, is not "low maintenance."

3. My final comment is a repetition of one of my comments to you in a previous communication: the figure in the report (Figure 2) that describes the disposal cell shows a compacted clay cap of 2 feet, overlain by a 6+ foot layer of additional barriers and soil. I understand that the material to be disposed of in the cells will contain uranium, and its daughter Ra-226. Depending on the composition and degree of compaction of the clay cap, the 2-foot thickness may be insufficient to allow decay of Radon-222 to background concentrations as it diffuses through the cap. The additional 6+ feet of cover above the clay cap will likely have little retardation effect on diffusion of this radioactive gas due to the relatively open structure of the overlying material compared to the compacted clay. Penetration by roots of grass and other species into the overlaying material (deep-rooted grasses can penetrate to 6 feet or more, tree tap roots sometimes deeper), can serve as conduits for radon gas transport above the ground surface. Such transport and release by the leaves of vegetation tend to increase with leaf area index [Lewis, B.G. and Macdonell, M.M., "Release of Radon-222 by Vascular Plants: Effect of Transpiration and Leaf Area", J. Environmental Quality :19 (1):93-97].

Barbara-Ann H. Lewis

P- 739

esa

VEGETATION COVER RECOMMENDATIONS

for the

On-Site Disposal Facility

at the

Fernald Environmental Management Project Site

Fernald, Ohio

FEBRUARY 1996

EARTH SYSTEMS ASSOCIATES, LTD.

Soil, Water and Waste Management Consultants

000037

VEGETATION COVER RECOMMENDATIONS

for the

On-Site Disposal Facility

at the

Fernald Environmental Management Project Site

Fernald, Ohio

Prepared for

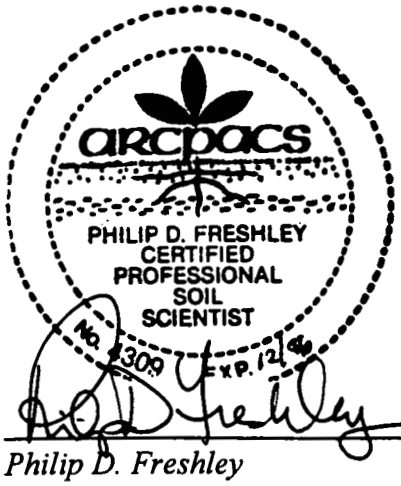
GeoSyntec Consultants
Atlanta, Georgia

Prepared by

Earth Systems Associates, Ltd
Athens, Georgia

February 1996

SIGNATURE PAGE



Philip D. Freshley
Certified Professional Soil Scientist No. 4309
Certified Professional in Erosion and Sediment Control No. 1197

TABLE OF CONTENTS

SIGNATURE PAGE ..... *ii*

TABLE OF CONTENTS ..... *iii*

LIST OF TABLES v

1. INTRODUCTION 1
- *1.1 Project Overview* 1
- *1.2 Project Location and Physiography* 2

2. ENVIRONMENTAL FACTORS 3
- *2.1 Climate* 3
- *2.2 Soil* 3
- *2.3 Disturbance Regime* 4

3. PROJECT VEGETATION GOALS 5
- *3.1 Site Stabilization* 5
- *3.2 Limited Root Systems* 5
- *3.3 Maintenance Requirements* 6
- *3.4 Wildlife Impacts* 6
- *3.5 Aesthetics* 6
- *3.6 Commercially Available Seed* 7
- *3.7 Compatible Short- and Long-Term Cover* 7

4. REGIONAL PLANT COMMUNITIES AND SUCCESSIONAL PATTERN 8
- *4.1 North-Central Hardwood Forest* 8
- *4.2 Tall Grass Grassland* 9
- *4.3 Forage Associations* 9
- 4.4 Successional Pattern 9
- 4.5 Disturbance Methods 10

5. POTENTIAL COVER SPECIES 11

6. RECOMMENDED SEED MIXES 16
- *6.1 Seasonal Cover* 16
- *6.2 Permanent Cover* 17

7. PLANTING METHODS 19
- *7.1 Seedbed Preparation* 19

7.2 Liming and Fertilization 19
7.3 Seeding 19
7.4 Mulching and Irrigation 20
7.5 Non-Vegetative Stabilization 20
7.6 Repair of Failed Areas 21

8. SUMMARY 22

9. REFERENCES 23

APPENDIX A Schematic of Cell Cover
APPENDIX B Regional Seed Suppliers and Sample Price Lists

LIST OF TABLES

Table 1. Annual plants for temporary cover. 12

Table 2. Perennial grasses for permanent cover. 13

Table 3. Legumes for permanent and temporary cover. 15

Table 4. Recommended seed mixes for seasonal cover. 16

Table 5. Recommended seed mixes for permanent cover. 17

1. INTRODUCTION

The following report recommends vegetation cover alternatives for various site conditions at the U.S. Department of Energy (DOE) On-Site Disposal Facility (OSDF) at the Fernald Environmental Management Project Site. A rationale for vegetation selection and background data is also included. The OSDF is operated by the Fernald Environmental Restoration Management Corporation. Earth Systems Associates, Ltd prepared these recommendations under subcontract to GeoSyntec Consultants of Atlanta, GA.

1.1 Project Overview

The OSDF site consists of a 65-acre area within the DOE's Fernald, Ohio reservation to be used for disposal of soils contaminated by low-level radioactive material (uranium mine tailings). This material is referred to as "impacted material"and will be disposed of in one of nine subterranean cells to be constructed on the site. Following cell construction and filling with impacted material, the cells will be capped with impermeable, drainage, and biointrusion barrier layers, with a vegetated soil surface as final cover. Schematics of the liner and cover system designed by GeoSyntec Consultants are included as Appendix A

Cell construction and filling will occur over a seven to ten year period with one cell completed before the next cell is opened. Seasonal vegetation cover will be required for temporary cover during periods when the cell is neither full or being operated. Typically, this will occur in October-November at the end of the fall construction period. Final cover is installed when the cell is full and the cap system completed. Final cover vegetation is to provide a permanent stable cover requiring minimal management within ten years.

Vegetation cover recommendations were developed as follows:

1. Identify site environmental factors affecting plant growth.

2. Identify vegetation characteristics required to maintain cell integrity and meet project environmental and aesthetic goals.

3. Identify regional plant communities, successional patterns, and cultural practices to serve as a model for selection of species and cultural and management practices.

4. Determine commercial availability of plant materials.

5. Select seed mixes, and cultural and management practices suitable for site conditions and project goals.

These analyses are presented in the following sections.

1.2 Project Location and Physiography

The Fernald site is located in Hamilton and Butler counties in the southwest corner of Ohio, approximately six miles east of the Indiana state line and ten miles north of the Ohio River and Kentucky state line. The site lies in the Till Plains section of the Central Lowland physiographic province, on Wisconsian era till plains. Most of the site is flat to gently sloping upland till plain (Lerch, et al., 1992).

2. ENVIRONMENTAL FACTORS

Environmental factors include the climate, soil characteristics, and the disturbance regime from construction operations.

2.1 Climate

Site climate is generally characterized by hot summers and cold winters with moderate, well distributed rainfall. Total annual precipitation is approximately 40 inches, of which 50% occurs during the April through September growing season. Average monthly temperature ranges from 32 degrees F in the winter to 71 degrees F in the summer for a yearly average temperature of 52 degrees. Annual minimum and maximum daily temperatures are approximately -8 and 96 degrees F respectively.

Thunderstorms occur on 30-40 days of the summer and must be considered when planning disturbed area erosion control and planting. The first freeze date typically occurs in mid-October with freezing weather ending by mid- to late-April. Snowfall averages approximately 17 inches per year. The wettest soil conditions of the year typically occur following the spring thaw. Most years have a growing season of at least 165 days.

2.2 Soil

Site soils and surrounding area consist mainly of the Fincastle, Henshaw, Martinsville and Xenia series located on flat to gently rolling till plains. The land slope of most of the site is less than 5%. These soils are characterized by a silt loam surface layer eight to ten inches thick underlain by a finer-textured (silty clay loam or clay loam) subsoil 30 to 40 inches thick (Lerch, et al., 1992). The subsoil is underlain by an unstructured silt loam to clay loam textured till with few fragments greater than three inches.

Soil drainage ranges from moderately well drained to somewhat poorly drained. Permeability is moderate in the surface soil and low in the subsoil. Soil pH is moderately acid in the surface soil, moderately acid to neutral in the subsoil and neutral to alkaline in the underlying till.

Current construction plans indicate the cover material will consist of stockpiled subsoil (8 to 36 inch depth) removed during the initial excavation. Based on construction plans and soil survey data for the site (Lerch, et al., 1992) the soil used for the seasonal and final cover will:

- have slopes less than 3:1 (33%) for seasonal cover and 6:1 (17%) for final cover;
- be well drained to somewhat poorly drained;
- be moderately acid to neutral in reaction with a pH of 5.1 to 7 S.U.;
- have a USDA texture of silt loam to clay loam (18%-35% clay);
- have moderately slow soil permeability of 0.1 to 0.6 inch/hr where cultivated and less than 0.1 in/hr where compacted; and
- have low organic matter content (less than 0.5%).

Drainage will vary by slope with low slope (<3%) and flat areas expected to be moderately well drained, and minor areas of somewhat poorly drained soils where runoff water collects. Sloping areas are expected to be moderately well to well drained. Artificial subsurface drainage is planned for the cell cover. Drainage characteristics of the final cover will be improved over that of the natural soil of the site which is moist to wet. Thus, a dry to moist soil moisture condition is expected. Vegetation recommendations are based on these characteristics.

2.3 Disturbance Regime

Construction activities, including excavation and cover, are planned for late spring to early fall. Cell closure due to full capacity may occur at any time during this period. Cover plantings may be required following cell closure. Closure is required in October-November each year, thus, planting of temporary and final covers will occur most frequently in this time frame. Once closure is complete and the site is stabilized, no activity is planned for the cell surface other than essential vegetation management.

3. PROJECT VEGETATION GOALS

Vegetation cover type and management regime is selected to achieve the following project goals:

- site stabilization;
- limited root systems;
- low maintenance;
- low wildlife impact;
- pleasing aesthetics;
- commercially available plant materials; and
- compatibility between cover types.

A discussion of each goal follows.

3.1 Site Stabilization

Both temporary and permanent cover species should provide rapid stabilization of cell cap soil and complete vegetative coverage for the project term to limit erosion and off-site sedimentation, and maintain the integrity of the cell cap.

3.2 Limited Root Systems

The root system of the vegetation complex should be limited to the 2.25-foot vegetative soil layer as much as possible. Below this soil layer is a 0.5-foot granular filter and a 3.0-foot rock biointrusion layer.

Most species of perennial grasses root to depths of two to six feet (this provides drought resistance), however, 80% of the root mass occurs in the top foot of soil (Gist and Smith, 1948). Rooting depth is limited by physical impedance and root aeration. Tree roots are larger than grass roots and may extend to great depth (30-40 feet) where surface soils are droughty, particularly species with large tap roots like pine (Pritchett and Fisher, 1987).

Like grasses, most of the tree root mass is in the tap root. Grass roots may extend to the geomembrane, but are judged to have the least potential to breech the geomembrane cap of any perennial vegetation type. The goal of limiting root systems is accommodated in the cover recommendations by excluding shrubs and trees from the site, particularly those with top roots.

3.3 Maintenance Requirements

Unmanaged vegetaive succession in the region inevitably terminates in forest species. Thus, exclusion of deep-rooted tree species from the site will require periodic site maintenence over the life of the project. The selected vegetation cover should be capable of progression to maturity with the least management input practical. Ideally, vegetative maintenance should be limited to vegetation repair for erosion control and control of deep-rooted (tree and shrub) invaders.

3.4 Wildlife Impacts

The cover should have as little impact on wildlife as possible, either positive or negative. It is recognized that in many ways, this goal is in conflict with the goal of providing a low-maintenance grassland environment. Grasslands tend to naturally succeed to species that provide cover and food sources for wildlife adapted to edges and openings, regardless of the initial seeding mix.

To accommodate this goal, plant species will be selected that have similar or less attraction for wildlife than vegetation in the surrounding landscape. This should limit the potential for drawing wildlife onto the site from surrounding areas. Also, wildlife will not be excluded from the site, thus, plant species known to be injurious to wildlife should not be used.

Regardless of the vegetation selected, habitat suitable for burrowing animals such as groundhogs and other rodents will be created. Periodic surveillance of the site for burrowing animal activity should be included in the site management plan. Burrowing animal control measures are species specific. Appropriate measures are best determined at such time as project impact and target species are identified.

3.5 Aesthetics

The selected vegetative cover should blend into the landscape and be aesthetically pleasing. Typical pastureland and old-field successional species will emulate farm land in the vicinity of the project site. Native grassland species will provide a taller grassland that will emulate tall grass prairie found farther west in Illinois and Kansas. Both of these cover options meet aesthetic goals.

3.6 Commercially Available Seed

The selected species must have commercially available seed to accommodate site operations.

3.7 Compatible Short- and Long-Term Cover

Seasonal cover species will be compatible with the final cover species.

4. REGIONAL PLANT COMMUNITIES AND SUCCESSIONAL PATTERN

Southwest Ohio, like much of the eastern U.S., has a fragmented landscape dominated by human disturbance. Rural areas are typically made up of permanent pasture and row crop lands on gentle to moderate slopes with forest on steep slopes and in riparian areas. In the vicinity of urban centers, much of the gently sloping land is used for suburban housing and associated commercial developments. If undisturbed, the ecological succession for the region will result in a climax vegetation of north-central hardwood forest (Lerch, et al., 1992). The species composition of this forest reflects the intermingling of the oak-hickory and beech-maple hardwood forest types (Kricher and Morrison, 1988).

Long-term vegetation management for the project site is determined by identifying the best practices for managing successional patterns to conform with project goals (Section 3). A discussion of regional plant communities and succession patterns follow. Eastern forests give way to the Tall Grass grasslands region of the Great Plains along a line from northeast Indiana to central Missouri (Voigt and MacLauchlan, 1985). In the past, these grasslands were more extensive. The tall grass vegetation type intermingles with hardwood forest in areas where disturbance prevents succession to tree species. Due to the proximity of the Tall Grass region, many native grassland species are well adapted to southwest Ohio (Van Keuren and George, 1985). North-central hardwood forest, tall grass grassland, and the forage plant associations developed for local agriculture and erosion control are considered the primary vegetative material pool to be considered for the project.

4.1 North-Central Hardwood Forest

This upland forest is characterized by black oak, northern red oak, pin oak, white oak, ash, beech, sugar maple, black cherry, yellow poplar, sweetgum, and black walnut. Understory species include dogwoood, sassafras, hawthorn, and hophornbeam. Forest nut production is essential to several wildlife species including blue jay, wild turkey, summer tanager, rose-breasted grosbeak, gray and fox squirrels, flying squirrel and eastern chipmunk.

4.2 Tall Grass Grassland

The tall grass community is dominated by tall (4-8 foot) warm-season bunchgrasses. Several species of this region have been found to thrive on sites as far east as West Virginia. Species found to be well adapted to southwest Ohio include big bluestem, Indiangrass, switchgrass, and eastern gamagrass. Canada wildrye is a fast sprouting native annual that has also been found to be well adapted to the region. The eastern edge of the tall grass region was protected from advancing woody vegetation by fire and bison grazing until control measures were instituted by European settlers. Most of the original tall grass region has been converted to agriculture due to adequate rainfall and an inherent high fertility. Grassland wildlife includes horned lark, meadowlark, mourning dove, pheasant, barn swallow, red-tailed hawk, ground squirrel, prairie dog, and bison (formerly). Whitetail deer are an edge species which are adapted to most vegetation types, hardwood forest and grassland included.

4.3 Forage Associations

Much of the original forest area has been converted and maintained in forage production as either permanent pasture or hayland. Due to large-scale beef and dairy production which began in the late 1930's and 1940's, many areas of southwest Ohio were transformed into grasslands consisting of cool-season perennial grasses introduced from Europe (Ball, et al., 1991). Widely used species are tall fescue, Kentucky bluegrass, orchardgrass and reed canarygrass. These grasses are typically seeded with an annual or perennial legume such as alfalfa, red clover, white clover, alsike clover, birdsfoot trefoil, crown vetch, and Korean lespedeza. All of the major grass and legume species used for commercial hay production are exotics. The cool-season grasses are from Europe, and the legumes are from the Mediterranean, Europe, and Korea.

4.4 Successional Pattern

The process of vegetation development expected to occur at the project site is old field succession, the most common successional pattern in Eastern North America (Kricher and Morrison, 1988). Old field succession begins at any disturbance event which eliminates vegetation. Typically, the successional pattern begins with annual weeds like horseweed, ragweed and crabgrass in the first year followed by asters, goldenrods, broomsedge, various grasses, and other herbaceous plants in years two and three. Woody species such as red maple, sweetgum, black cherry, eastern red cedar, black locust, and pine are first seen in the third and fourth years as seedlings and saplings and become a major component of the landscape by year ten. From age 10 years to approximately 60

years, the forest of light seeded tree species and shrubs evolves into a closed canopy deciduous forest dominated by heavier seeded tree species such as white oak , northern red oak, mockernut hickory and beech. This climax forest may persist for hundreds of years, depending on disturbance.

Based on the above scenario, management to arrest succession at the grassland stage will require disturbance every four to six years, depending on how aggressive woody invasion is. On sites that have not been forested for many years, and are not in close proximity to a forest area (seed source), the appearance of woody vegetation may be delayed by a year or two.

4.5 Disturbance Methods

Woody reproduction can be eliminated mechanically, chemically or by fire. Many woody species maintain the root system when cut and rapidly resprout. The root system continues to grow through repeated cuttings and can become quite extensive. For this reason, chemical herbicides (spraying of individual trees and shrubs) or fire are preferred for woody control where eradication of the whole plant including the root system is the goal. A combination of mechanical and chemical treatment where cut stumps are treated with herbicide to prevent resprouting is also effective. The most effective method should be determined by condition of site vegetation, available equipment and expertise, and cost. Selective herbicide applications will cost from $75 to $150 per acre. Controlled burning can be done for as little as $25 per acre once fire breaks are established. Combination cut and spray options will be in the range of $200 to $300 per acre.

5. POTENTIAL COVER SPECIES

Plant species that are considered potentially suitable for use on the project site and have a readily available seed source are presented in Tables 1, 2, and 3. Characteristics important to suitability are also presented to provide a basis for modification of seeding mixes if soil or operating conditions/assumptions change.

Both native and exotic species are included. Table 1 includes annuals and short-lived perennials that are suitable for temporary cover. These are principally small grains and ryegrass that are to be planted for erosion control during the operating season (warm season), or on temporary cover at the end of the operating season (October). Table 2 includes perennial grasses for permanent cover. The cool season grasses listed are the exotic varieties typically planted for local pastures. The warm season bunchgrasses are all native species and can be used to emulate a native grassland. Table 3 includes legumes that are suitable as companion crops to the perennial grasses. Legumes increase the fertility of soil by accumulating nitrogen from the atmosphere, and thus improving growth, survival, and reducing the need for supplemental fertilization for the grass stand as a whole. Inclusion of a legume in the grass mix is highly recommended.

Earth Systems evaluated a mix of fine fescues proposed for final cover by Prairie Nursery of West Field, WI. The mix is designed to provide a low growing lawn turf that has reduced mowing requirements. The mix consists of six varieties of fine fescues and, a cool season perennial bunchgrass. These species do not tolerate shade or poor drainage and require annual mowing to maintain uniform stocking. We concur with the suitability of fine fescues for the site, but recommend the use of these species with a sodgrass, annuals, and legumes to provide a more diverse plant community which should have greater long-term stability.

Based on the characteristics of available species listed in Tables 1, 2 and 3, seed mixes were developed to achieve project goals over the expected range of site conditions.

Table 1. Annual plants for temporary cover.

Species	Description	Height (ft)	Seed Rate (lb/ac)	Seeding Period	Site Moisture	Nutrients Required	pH Range	Other Considerations
Warm Season								
Oats (Avena sativa)	bunchgrass	2-4	128	June-Aug	WD-MWD	P,K	6-8	intolerant of low pH
Sudangrass (Sorghum bicolor)	erect-leafy	4-8	80	June-Aug	WD-ED	N,lime	6-8	Very drought tolerant
Foxtail Millet (Setavia italica)	erect-leafy	3-4	40	June-Aug	WD-ED	N	5.5-7.5	Infrequently planted for wildlife
Cool Season								
Rye (Secale cereale)	bunchgrass	2-4	120	Aug-Nov. 1	MWD-WD	P,K	5.5-7.5	More tolerant of low pH than wheat or oats
Ryegrass (Lolium sp.)	multi-season annual or perennial bunchgrass	2-3	40	Mar-Nov	PD-WD	N	5.0-7.5	High moisture, Sept.-Oct. planting best. Rapid coverage
Wheat (Triticum aestivum)	bunchgrass	2-4	120	Aug-Nov 1	MWD-WD	P,K	6-8	Marginal for erosion control

Key to Moisture Classes	ED = Excessivley drained (Droughty)	WD = Well Drained	MWD = Moderatley Well Drained (Moist)	PD = Poorly drained (Wet)

Table 2. Perennial grasses for permanent cover.

Species	Description	Height (ft)	Seed Rate (lb/ac)	Seeding Period	Site Moisture	Nutrients Required	pH Range	Other Considerations
Warm Season								
Big bluestem (Andropogon gerardii)	Native bunchgrass	3-6	10	April-May	WD-ED	N	5.5-7.5	More palatable than Panicum
E.Gamagrass (Tripscacum daetgloides)	Native bunchgrass	3-8	6	April-May	WD-ED	N,P,K	6-8	Establishment difficult
Indiangrass (Sorghastrum nutans)	Native bunchgrass	3-6	10	April-May	WD-ED	N	6-8	High forage quality
Switchgrass (Panicum virgatum)	Native bunchgrass	3-7	6	April-May	PD-ED	N	5.5-7.5	Aggressive, drought tolerant
Cool Season								
Kentucky bluegrass (Poa pratensis)	Sodgrass	1-3	15	Aug-Sept	WD-PD	P,N	4.5-7.5	Intolerant of drought, thrives under low fertility
Orchardgrass (Dactylis glomerata)	Bunchgrass	2-3	20	Sept	WD-MWD	N	5.5-7.5	Needs legume, used on flat areas
Reed Canarygrass (Phalan's arundiacea)	Sodgrass	2-6	8	Mar 15 - May Aug-Sept	ED-PD	N	5-8	Extremely flood tolerant

Key to Moisture Classes	ED = Excessively drained (Droughty)	WD = Well Drained	MWD = Moderately Well Drained (Moist)	PD = Poorly drained (Wet)

239

35 000075

Table 2. (Continued) Perennial grasses for permanent cover.

Species	Description	Height (ft)	Seed Rate (lb/ac)	Seeding Period	Site Moisture	Nutrients Required	pH Range	Other Considerations
Warm Season								
Red Top (Agrostis gigantea)	Creeping, upright course, perennial	1-3	6	Aug - Sept	ED-PD	Low	4.5-7.5	Less palatable than bluegrass to grazers
Tall Fescue (Festuca arundiacea)	Bunchgrass	2-4	20	Mar 15 - May Aug-Sept	WD-PD	Low	4.5-8	Fungal endophyte infection reduces performance of grazers
Creeping Red Fescue (Festuca rubra)	Fine leafed, spreading bunchgrass	1-2		Mar 15 - May Aug-Sept	WD-PD	Low	5.5-7.5	Growth habit more like sodgrass. Endophyte free
Timothy (Phleum pratense)	Bunchgrass	2-4	8	Mar 15 - May Aug-Sept	MWD-WD	Low	5.5-7.5	Needs legume, intolerant of heat
Canada Wildrye (Elymus canadensis)	Coarse native bunchgrass	1-3	5	Apr - May	MWD-ED	Low	5-8	Provides rapid establishment then fades out

Key to Moisture Classes	ED = Excessively drained (Droughty)	WD = Well Drained	MWD = Moderately Well Drained (Moist)	PD = Poorly drained (Wet)

95 00055

232

Table 3. Legumes for permanent and tempory cover.

Species	Description	Height (ft)	Seed Rate (lb/ac)	Seeding Period	Site Moisture	Nutrients Required	pH Range	Other Considerations
Warm Season								
Korean lespedeza (Lespedeza stipulacan)	Fine-stem, leafy, erect, annual	2-3	8	Mar 15-May Aug-Sept	WD-ED	Low	4.5-7.5	Good on poor droughty sites
Sericea lespedeza (Lespedeza caneata)	Fine-stem, erect, perennial	1.5-3	30	Mar 15-May	MWD-ED	Low	4.5 7.0	Not good on basic sites
Cool Season								
Alsike Clover (Trifolium hybridum)	Semi-erect, short lived perennial	1-3	10	Mar 15-May Aug-Sept	WD-PD	P,K	5.5-7.5	Tolerates flooding better than most clovers
Birdsfoot Trefoil (Lotus corniculatus)	Semi-erect, short lived perennial	1-1.5	10	Mar 15-May Aug-Sept	ED-PD	P,K	5.0-7.5	Works well with cool season grasses
Red Clover (Trifolium pratense)	Erect, short lived perennial	2-3	8	Mar 15-May Aug-Sept	WD	P,K	5.5-7.5	Best yielding clover
Vetches (Vica SPP)	Viney, winter annual	1-2	10	Mar 15-May Aug-Sept	WD	P	5.5-7.5	Crown vetch planted with fescue for bank stabilization
White Clover (Trifolium prepens)	Long lived leafy perennial	0.5-1	3	Mar 15-May Aug-Sept	WD-PD	P,K	5.5-7.5	Sensitive to grass competition
Flatpea (Luthyrus sylvestris)	Long-lived viny perennial	2-3	20	Mar 15-May Aug-Sept	MWD-ED	P,K	5.0-9.0	Excellent for restricting growth of woody plants

Key to Moisture Classes	ED = Excessively drained (Droughty)	WD = Well Drained	MWD = Moderately Well Drained (Moist)	PD = Poorly drained (Wet)

6. RECOMMENDED SEED MIXES

Recommended seed mixes for the project are presented in Tables 4 and 5. Table 4 presents the recommendations for seasonal cover. Table 5 presents the recommendations for permanent cover. Regional suppliers of grass seed are listed in Appendix B.

Table 4. Recommended seed mixes for seasonal cover.

Slope - Moisture Class	Planting Period			
	Warm Season (Jun. - Aug.)		Cool Season (Aug. -Nov.)	
	Species	lb/ac	Species	lb/ac
Wet Swales - Waterways	Annual Ryegrass	40	Annual Ryegrass	40
Moist Slopes of 1% - 9%	Oats Sudangrass	64 80	Rye Perennial Ryegrass	80 20
Dry Slopes of 10% - 33%	Oats Sudangrass	64 80	Rye Perennial Ryegrass	80 20
Drought Slopes > 33%	Korean lespedeza Sudangrass	8 80	No Slopes < 33% planned for this period	

6.1 Seasonal Cover

The primary considerations for seasonal seed mixes are suitability for the site, rapid stabilization, and planting season. These plants are annuals and short-lived perennials that will die-out or be replaced by the permanent cover. Table 4 presents seeding options based on anticipated site moisture conditions and expected planting season. Moisture conditions are expected to more or less conform to site slopes. Swales, waterways, and depressions are expected to be wet, slopes from 1% to 9% are expected to be moist, and slopes from 10% to 33% are expected to be dry to droughty. The maximum slope allowed in the construction plan is 33%.

Table 5. Recommended seed mixes for permanent cover.

	Species/Planting Period Class			
Slope - MoistureClass	Native Species / Apr. - May[1]		Pasture Species / Mar. 15 - May or Aug. - Sep.	
	Species[2]	lb/ac	Species	lb/ac
Wet Swales - Waterways	Big Bluestem Switchgrass	10 5	Reed Canarygrass Kentucky Bluegrass[3] Alsike Clover	8 10 5
Moist Slopes of 1% - 9%	Big Bluestem Indiangrass Canada Wildrye Switchgrass	5 5 1 3	Creeping Red Fescue Annual Ryegrass Kentucky Bluegrass[3] Alsike Clover	20 10 15 5
Dry Slopes of 10% - 17%	Big Bluestem Indiangrass Canada Wildrye Switchgrass	5 5 3 5	Creeping Red Fescue Annual Ryegrass Kentucky Bluegrass[3] Flatpea	20 10 10 5

[1]Switchgrass should be frost seeded (Jan. - Feb.) by broadcasting into wintercover.
[2]"Cave-in-rock" switchgrass variety recommended. Species other than switchgrass planted by drilling during April - May.
[3]Substitute Red Top on strongly acid sites.

Rye was selected as the primary annual cover due to its adaptability to a variety of soil conditions including low fertility and acidity. Ryegrass was added to the mix for rapid stabilization and a longer growing season. Sudangrass, lespedeza and oats were selected for temporary cover in the summer due to their adaptability to the region and site conditions. Seasonal seed mix costs for the mixes shown in Table 4 are estimated at $35 to $50 per acre. Cost of site preparation., fertilizer and seeding are additional.

6.2 Permanent Cover

In addition to site and planting considerations cited for seasonal cover, a native species mix is also included as an option for permanent cover (Table 5). The native mix will provide effective erosion control and a different look than the pasture grasses. In general, native grasses are taller, more aggressive on dry sites, and require a spring or dormant season planting regime. The seed is substantially more expensive than commonly grown pasture grasses. The cost of native mixes ranges from $53 to $125 per acre while pasture mixes range from $45 to $50 per acre. Growth of native grasses occurs mainly in the summer and they are dormant in the winter.

Pasture grasses have a longer growing season than native species with most growth occurring in the spring and fall. Tall fescue is the most widespread grass planted in the Eastern U.S., but is not recommended for the project due to potential toxicity problems for wildlife caused by a fungal endophyte infection common in this species. Wildlife agencies in several states have encouraged the use of alternative grass species due to observation of adverse effects of wildlife grazing on infected tall fescue stands.

The decision to select native or exotic vegetation depends on aesthetics and environmental goals. Pasture grasses will conform with the adjacent rural landscape which uses similar pasture species. The taller native grasses will give the site a "wilder" look and should provide better competition to prevent invading trees and shrubs due to increased height and shading. Both mixes will provide wildlife habitat under a low-intensity management regime, however, more cover will be provided by the native mix. Mixes for both native and pasture mixes are presented in Table 5.

The pasture grass seedings were designed around low growing and sod forming grasses best suited to site soils and climate. Kentucky bluegrass is the best adapted perennial sod-forming grass and is combined with a fine fescue bunchgrass for diversity. Reed canarygrass is added for wet sites due to its adaptability on saturated soils. Annual ryegrass is included in the mix to provide immediate stabilization (quick coverage). A perennial legume is included in each mix for building soil fertility. Alsike clover was selected for its adaptability to moist sites. Flatpea was selected for the sloping cell perimeter due to its tolerance for poor dry soils and its aggressive competition with woody invaders.

The native mixes include Canada wildrye for rapid establishment and stabilization. The remaining species provide a diverse tall grass community. Only switchgrass and big bluestem are recommended for wet sites.

7. PLANTING METHODS

Planting methods include site preparation, liming, fertilization, mulching and repair. The rate and type of liming and fertilization will be based on soil test results and will be specified in the Phase II Supplemental Report. These recommendations are based on USDA Technical Standards for Critical Area Planting (USDA, 1989; Dean, 1995).

7.1 Seedbed Preparation

All areas to be planted will be tilled to loosen the soil to a depth of four to six inches. All debris greater than six inches in diameter should be removed from the soil. All tillage operations will be conducted along the contour of the land.

In typical erosion control practice, hydroseeding is required in areas with slopes of 40% or more. Hydroseeding may be used on any sloping areas of the site which cannot be operated with conventional equipment. These areas do not require tilling, but should be scarified to improve seed retention. The soil surface will be pitted or trenched across the slope with hand tools to provide furrows 6-8 inches apart where seed will lodge and germinate.

7.2 Liming and Fertilization

Lime and fertilizer should be broadcast before land preparation and mixed with the soil during seedbed preparation. The seed bed must be prepared within 48 hours of amendment application.

For hydroseeding, these amendments are mixed with seed in a slurry and broadcast together. The mixing must be done within one hour of application. Rates and types of fertilizer will be addressed in the Phase II report following evaluation of site soil analyses.

7.3 Seeding

The primary seeding periods for permanent cover are March 15 through May 31 and August 1 to September 30. Planting outside of these dates has a significant risk of failure. Seasonal plantings are more flexible as indicated in Table 1.

Seeding may be done by drilling to a depth of 0.25 inch and cultipacking or use of a cultipack -type seeder operated along the contour. Alternatively, the seed may be broadcast and then covered with approximately 0.25 inch of soil with a light harrow or similar equipment. Hydroseeding will be done at the same rate (Table 4, 5) as broadcasting.

No-till seeding is planting in an existing crop which is dead or dormant. No-till seeding of permanent vegetation is desirable in temporary cover crops when planting is done following maturity of the cover crop. No-till seeding equipment is required for uniform seed distribution and proper planting depth. Mulch is not required on no-till areas.

7.4 Mulching and Irrigation

Mulch must be applied to all slopes greater than 3%, and to all areas when seeding is done near the end or after the specified planting period. Mulch must also be applied in all grassed waterways and swales regardless of slope. For hydroseeding, the mulch can be applied in the seed mix (hydromulching), or blown on with a tackifier following hydroseeding.

Mulch material should be cereal grain straw or good quality hay and applied by blower or hand at a rate of 2.5 air-dried tons per acre within 24 hours of seeding. The mulch must be spread uniformly such that 75% or more of the soil surface is covered.

On unstable slopes, mulch may be anchored with emulsified asphalt or synthetic tackifiers sprayed on the hay as it is blown, or by pressing into the soil with a packer disc or straight disc harrow. Soil retention blankets, erosion control netting, or block sod may be required in concentrated flow areas or severe slopes. Plastic mesh or netting should be no larger than one inch by one inch.

Rainfall is usually adequate for establishment during the planting periods cited. However, irrigation may be required if drought conditions occur soon after germination and before an adequate root system is developed. If these conditions occur, the plantings should be irrigated as needed with portable equipment. Irrigation water should be applied at a slow rate (less than 0.15 inch/hr) to prevent runoff.

7.5 Non-Vegetative Stabilization

For all areas with slopes greater than 3% requiring stabilization after the fall planting season, soil retention blankets made of geotextiles, natural fiber (coconut, jute) or some combination should be used as erosion control cover until the following planting season.

All blankets must be secured and buried at the top of the slope to prevent erosion underneath the blanket. For areas with slopes less than 3%, heavy straw mulch will be applied such that 100% of the ground is covered.

Dormant season planting is an alternative that is sometimes used in areas stabilized after the fall planting season. This practice is not recommended for the project site due to expected wet soil conditions in winter and early spring and associated seed rot.

7.6 Repair of Failed Areas

Failed areas fall into two categories, soil erosion and seed failures. Erosion failures are typically caused by concentrated flow washing away soil and seed. These repairs are conducted by first diverting the erosive flow to a suitable vegetated area or drainage structure to dissipate the energy (a dirt berm, staked haybales, or erosion fencing can be used), and then reshaping and reseeding the area. Where concentrated flow cannot be completely diverted, sodding is required.

Failed seed areas are due to improper planting time, poor seed, etc. These areas should be reseeded as prescribed with species identified in Table 4 and 5 at the soonest planting period for either seasonal or permanent cover.

8. SUMMARY

A grass cover was selected for the Fernald OSDF to limit root penetration of the final cover and provide uniform soil stabilization. Perennial grasses are expected to have root systems extending to a depth of six feet except where barriers are encountered. Approximately 80% of the root mass is expected to be in the top foot of soil cover.

Twelve seed mixes were developed to cover a range of site and environmental considerations for the OSDF. For permanent cover, both native and exotic mixes were developed. Native mixes will climax in a taller grassland than pasture type mixes and should provide greater competition for woody invaders and lower maintenance costs. The exotic mixes will emulate the permanent pasture common in the site vicinity, and are expected to require more frequent disturbance to maintain a grass community. Cultural practices for all mixes and sites are specified.

Based on professional experience and review of pertinent literature, the site vegetation will climax in hardwood forest over an approximately 60-year period if undisturbed. Based on regional successional patterns, disturbance is required every four to six years to control woody invasion and arrest succession at the grassland stage. Provisions for repair of failed plantings, irrigation specifications, and non vegetative stabilization methods are included.

9. REFERENCES

Ball, D.M. C. S. Hoveland, and G.D. Lacefield. 1991. Southern Forages. Potash and Phosphate Institute and Foundation for Agronomic Research. Atlanta, GA.

Dean, J.E. 1995. Vegetative practices. Structural and Vegetative Design Workshop. USDA - NRCS, Ga. SWCC, and Southern College of Technology. Marietta, GA.

Gist, G.R. and R.M. Smith. 1948. J. American Society of Agronomy. 40:1036-46.

Gould, F.W. 1968. Grass Systematics. McGraw Hill Co. New York, N.Y. p. 382.

Kricher, J.C. and G. Morrison. 1988. A field guide to eastern forests of North America. Peterson Field Guide Series. Houghton Mifflin Co. Boston, MA.

Lerch, N.K., W. F. Hale, and D.D. Lemaster. 1992. Soil survey of Hamilton County, Ohio. USDA Soil Conservation Service and Ohio Department of Natural Resources.

Pritchett, W.L. and R.F. Fisher. 1987. Properties and management of forest soils. p494. John Wiley & Sons. New York, NY.

USDA Natural Resources Conservation Service. 1989. Ohio technical standards and specifications; critical area planting (342). Technical Guide. Section IV. USDA-NRCS. Columbus, Ohio.

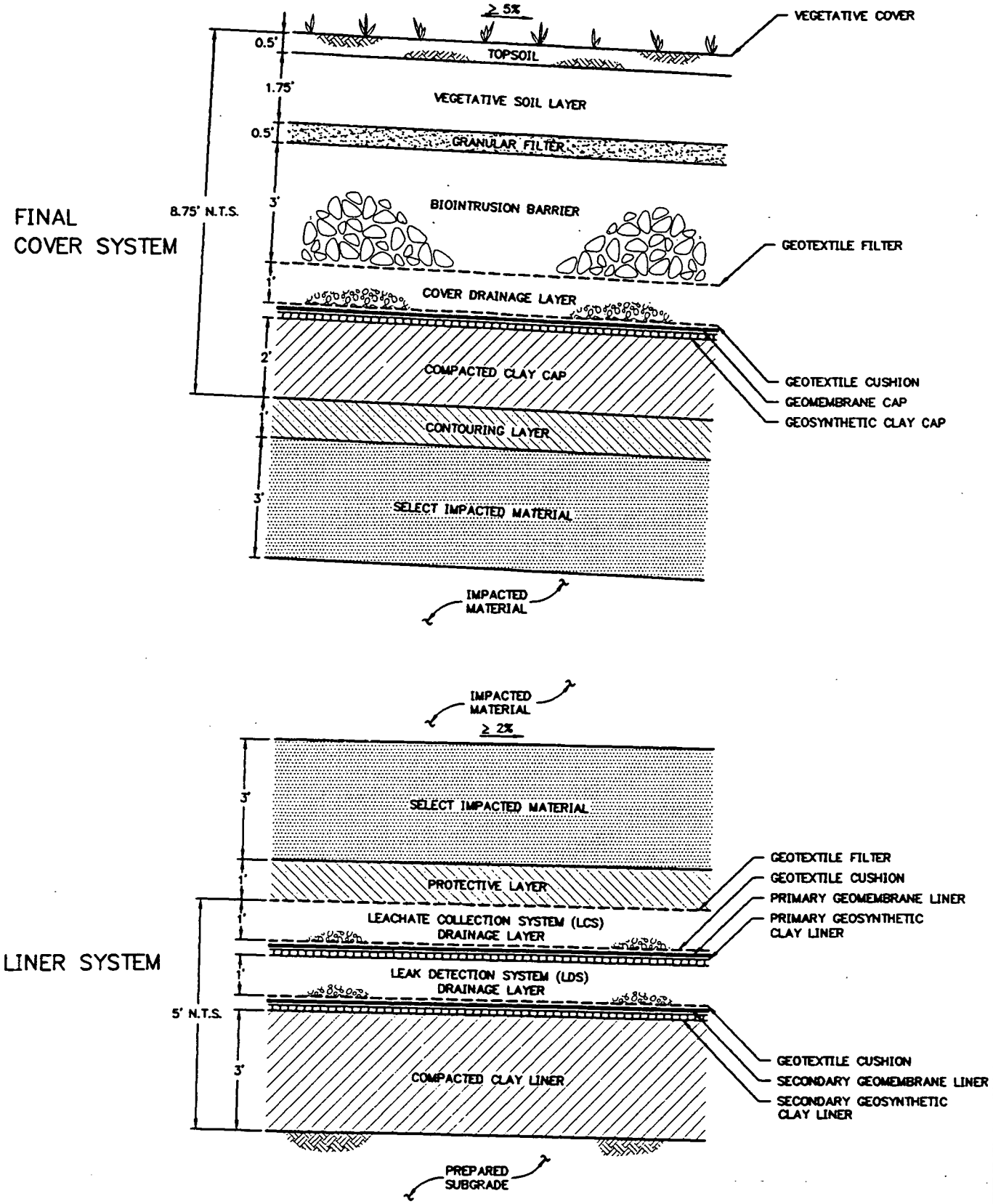
Van Keuren, R.W. and J.R. George. 1985. Hay and pasture seedings for the Central and Lake states. In: Heath, Barnes and Metcalfe (eds.), Forages; The science of grasslands agriculture. pp. 348-358. Iowa State Univ. Press. Ames, Iowa.

Voigt, P.W. and R.S. MacLauchlan. 1985. Native and other western grasses. In: Heath, Barnes and Metcalfe (eds.), Forages; The science of grassland agriculture. pp. 177-187. Iowa State Univ. Press. Ames, Iowa.

APPENDIX A

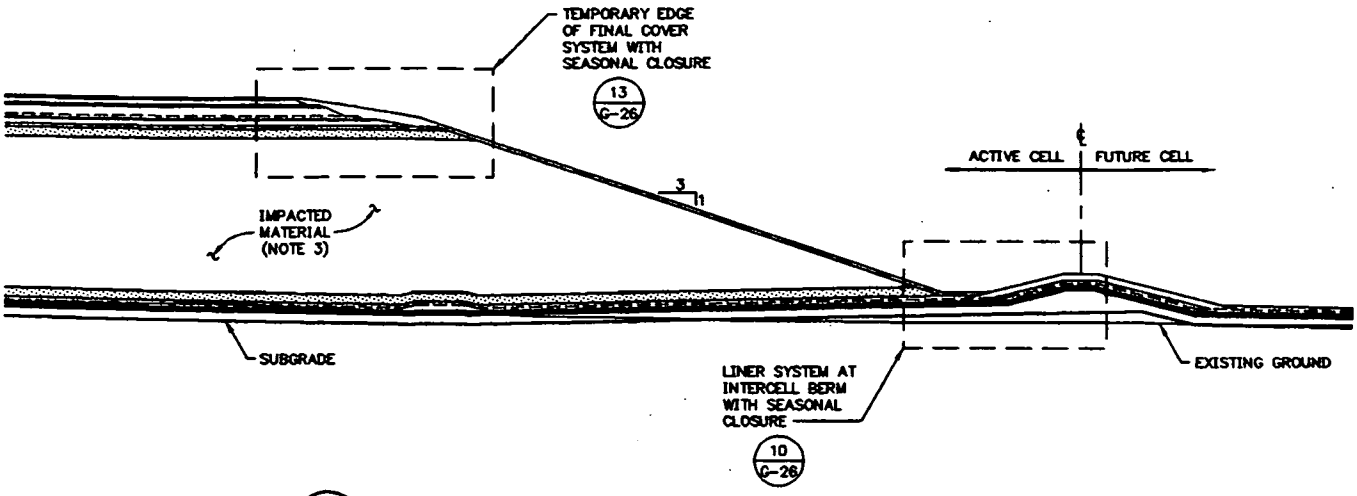
Schematic of Cell Cover

PRELIMINARY LINER AND COVER SYSTEM DESIGN
ON-SITE DISPOSAL FACILTY

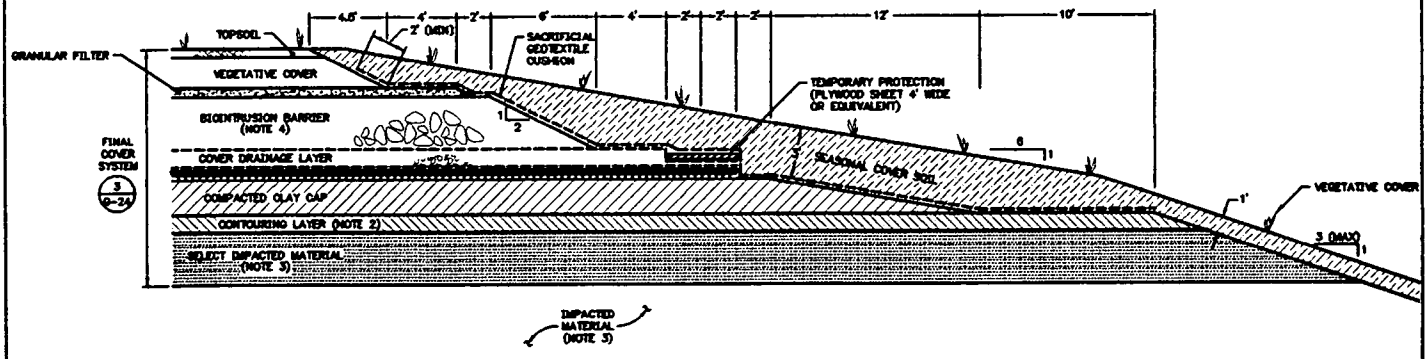


GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.	
PROJECT NO.	GE3900
DOCUMENT NO.	F9630010
FILE NO.	F95a001.DWG



11 G-20 DETAIL
SEASONAL CLOSURE COVER SYSTEM NORTH-SOUTH
SCALE: 1" = 30'



13 G-26 DETAIL
TEMPORARY EDGE OF FINAL COVER SYSTEM WITH SEASONAL CLOSURE
SCALE: 1" = 4' (NOTE 1)

GEOSYNTEC CONSULTANTS
ATLANTA, GEORGIA

FIGURE NO.	
PROJECT NO.	GE3900
DOCUMENT NO.	F9630010
FILE NO.	

APPENDIX B

Regional Seed Suppliers and Sample Price Lists

Arrow Seed Co., Inc.
P.O. Box 722
Broken Bow, NE 68822
(800)622-4727

Booming Native Plants
2323 Co. Rd. 6
Barnum, MN 55707-8748
(218)389-3220

Caudill Seed Company
1201 Story Ave.
Louisville, KY 40206
(502)583-4402

CRM Ecosystems/Prairie Ridge Nursery
9738 Overland Road
Mount Horeb, WI 53572
(608)437-5245

Ernst Crownvetch Farms
Rd #5, Box 806
Meadville, PA 16335
(800)873-3321

F.W. Schumacher Co., Inc.
36 Spring Hill Road
Sandwich, MA 02563
(508)888-0659

Hybritech Seed International, Inc.
5912 N. Meridian
Wichita, KS 67204
(800)346-2256

Ion Exchange
1878 Old Mission Drive
Harpers Ferry, IA 52146-7533
(800)291-2143

McGinnis Tree and Seed
309 E. Florence
Glenwood, IA 51534
(712)527-4308

Osenbaugh Grass Seeds
R.R. 1, Box 44
Lucas, IA 50151
(515)766-6476

Prairie Nursery
P.O. Box 306
Westfield,WI 53964
(608)296-3679

Prairie Moon Nursery
Rt. 3, Box 163
Winona, MN 55987
(507)452-1362

Stock Seed Farms, Inc.
28008 Mill Road
Murdock, NE 68407
(402)867-3771

Sylva Native Nursery & Seed Co., Inc.
RD #2, Box 1033
New Freedom, PA 17349
(No Phone)

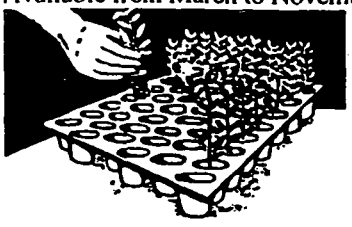
Taylor Creek Restoration Nurseries
17921 Smith Road
P.O. Box 256
Brodhead, WI 53520
(608)897-8641

ERNST Crownvetch Farms

R.D. 5, Box 806, Meadville, PA 16335
(800) 873-3321 (814) 425-7276 FAX (814) 425-2228

WHOLESALE PRICE LIST - 11/1/95

PENNGIFT CROWNVETCH (CORONILLA VARIA) PLANTS are well established plants growing in trays (72 plants per tray) ready for display or field planting, requiring a minimum of care and attention. We ship them guaranteed to arrive in good condition. Available from March to November.



Quantity	Price per plant
72 - 504	$0.28
576 - 1,368	0.26
1,440 - 2,376	0.25
2,448 - 9,576	0.24
9,648 and up	0.22

	Recommended Spacings: Minimum	Maximum
Distance on center:	18 inches	2 feet
Coverage per plant:	2.25 sq. ft.	4 sq. ft.
Plants per 1,000 sq. ft.:	445 plants	250 plants

PENNGIFT CROWNVETCH CROWNS (bare root) are one year old field grown seedlings with a sufficient root growth to insure rapid recovery. They are packaged (25 to a bundle) in moisture retaining bags for easy handling. Available from October to May.

Quantity	Price per crown
25 - 975	$0.17
1,000 - 2,475	0.15
2,500 - 4.975	0.14
5,000 - 9,975	0.13
10,000 and up	0.12

	Recommended Spacings: Minimum	Maximum
Distance on center:	18 inches	2 feet
Coverage per plant:	2.25 sq. ft.	4 sq. ft.
Plants per 1,000 sq. ft.:	445 plants	250 plants

PENNGIFT CROWNVETCH SEED

(with inoculant)

Coverage - One pound per 1,000 square feet

1 - 9 pounds	$11.50 per pound
10 - 19 pounds	10.50 per pound
20 - 49 pounds	9.50 per pound
50 - 99 pounds	8.50 per pound
100 or more pounds	8.00 per pound

CROWNVETCH SEEDING MIX

(50% Crownvetch, 40% Annual Ryegrass and 10% Alsike Clover)

Coverage - Two pounds per 1,000 square feet

10 - 18 pounds seeding mix	$6.15 per pound
20 - 38 pounds seeding mix	5.62 per pound
40 - 98 pounds seeding mix	5.10 per pound
100 - 198 pounds seeding mix	4.57 per pound
200 or more pounds seeding mix	4.30 per pound

COMBO PACK: two pounds of Crownvetch Seeding Mix (described above) in an attractive convenience package with directions and brochure for display and resale.
One pack will cover approximately 1,000 square feet.

One to nine	$12.50 each
Ten or more	11.50 each

Free delivery on all items listed above within a 500 mile radius of Meadville, PA.

We also have seed of the following soil conserving species available, each suitable for a specific purpose.

LATHCO FLATPEA (certified) - a long-lived, perennial legume excellent for stabilizing disturbed and bare areas, controlling erosion, and reducing water runoff. It provides effective cover on road banks, dams, borrow areas, gravel pits, logging roads and mine spoil. Flatpea suppresses the invasion of woody plants making it a valuable plant to use on road banks, logging roads and utility rights-of-way where it is desirable to retain open areas for wildlife, aesthetic considerations or access to utilities. It is used for food and cover by some species of wildlife ..... 3.90 per pound

TIOGA DEERTONGUE (certifed and treated) - useful for revegetating acid coal and other surface mine spoil and sandy infertile disturbed areas such as highway slopes and gravel pits. It is tolerant of sites with a pH as low as 3.8, aluminum concentration which limits growth of other species and light textured soil which is droughty and infertile. Deertongue has considerable merit for food and cover for wildlife ..... 2.25 per pound

Prices subject to change without notice. *We accept VISA and MASTERCARD!*

PLANTS AND SEED FOR CONSERVATION

[redacted]

LEGUMES	PRICE/LB
Vernal Alfalfa	1.30
Alsike Clover	0.65
Medium Red Clover	1.50
Mammoth Red Clover	0.90
New Zealand White Clover	2.20
White Dutch Clover	2.20
Ladino Clover	2.60
Trophy Blend Deer Clover Mix	4.50
Crimson Clover	1.20
Yellow Blossom Sweetclover	0.40
White Blossom Sweetclover	1.35
Birdsfoot Trefoil, V.N.S.	2.50
Empire Birdsfoot Trefoil	2.75
Empire Birdsfoot Trefoil, Certified	3.00
Leo Birdsfoot Trefoil, Certified	3.00
Norcen Birdsfoot Trefoil	3.00
Norcen Birdsfoot Trefoil, Certified	3.10
Appalow Lespedeza	3.50
Bicolor Lespedeza	3.40
Korean Lespedeza	0.90
Serecia Lespedeza	2.25
VA70 Shrub Lespedeza	4.50
Perennial Sweetpea	30.00
Crownvetch, *100 lbs. or more*	7.75
Crownvetch, Certified, *100 lbs. or more*	8.25
Black Locust	3.00
Bristly Locust	35.00

NATIVE GRASSES	PRICE/LB
Blackwell Switchgrass	3.00 PLS
Cave-in-Rock Switchgrass, Certified	3.50 PLS
NE28 Switchgrass, Certified	2.50 PLS
Shelter Switchgrass, Certified	3.50 PLS
Sunburst Switchgrass, Certified	2.50 PLS
Kaw Big Bluestem	5.25 PLS
Niagara Big Bluestem, Certified	5.00 PLS
Aldous Little Bluestem	12.00 PLS
Camper Little Bluestem, Certified	10.00 PLS
Goldstrike Sand Bluestem	6.00 PLS
Garrison Creeping Foxtail	4.75
Meadow Foxtail	4.30
Side Oats Grama	7.15 PLS
Indiangrass	6.00 PLS
NE27 Sand Lovegrass	5.10 PLS
Atlantic Coastal Panicgrass	8.50 PLS
The Intermediate Wheatgrass	1.00

SPECIAL MIXES	PRICE/LB
Wildlife Food Plot Seed Mixture (Dwarf Sorghum, Proso Millet, Buckwheat and Dwarf Sunflower)	0.45
Wildflower Mixes (area specific)	25.00/lb.

GRASSES	PRICE/LB
Kentucky Bluegrass	1.50
Kenblue Kentucky Bluegrass	1.70
Merit Kentucky Bluegrass	2.20
Newport Kentucky Bluegrass	1.70
Park Kentucky Bluegrass, Certified	2.10
Washington Kentucky Bluegrass	2.80
Canada Bluegrass	3.00
Poa Trivialis	2.10
Kentucky 31 Tall Fescue	0.80
Fawn Tall Fescue - *Endophyte Free*	0.80
Johnstone Tall Fescue	1.10
Turf-Type Tall Fescue	1.00
Creeping Red Fescue	0.70
Pennlawn Red Fescue	0.95
Chewings Fescue	1.00
Capitol Chewings Fescue	1.20
Reliant, Scaldis or Serra Hard Fescue	2.00
Sheep Fescue	2.00
Annual Ryegrass	0.44
Tetraploid Annual Ryegrass	0.46
Linn Perennial Ryegrass	0.85
Turf Type Perennial Ryegrass	1.05
Tetraploid (Pasture) Perennial Ryegrass	0.95
Distans Alkali Grass	2.80
Highland/Colonial Bentgrass	1.45
Creeping Bentgrass	4.00
Smooth Bromegrass	1.50
Reed Canarygrass	3.50
Palaton Reed Canarygrass	4.00
Weeping Lovegrass	2.50
Foxtail Millet	0.80
Japanese Millet	0.70
Potomac Orchardgrass	1.10
Axiom Orchardgrass	1.30
Red Top	2.75
Timothy	0.50
Climax Timothy	0.60

COVER CROPS	PRICE
Buckwheat	11.00/bu.
Oats, cleaned & tested	3.84/bu.
Ogle Oats, Certified	4.50/bu.
Grain Rye	6.16/bu.
Aroostook Rye	7.84/bu.
Wheat	6.00/bu.
Hairy Vetch	0.70/lb.
Austrian Winter Pea	0.40/lb.

HAND SEEDERS	PRICE
Spyker Canvas Model 126	25.00 ea.
Spyker Bucket Model 74	70.00 ea.
Even Spread Canvas	40.00 ea.

Plant A

Ordering Information

Plant Shipping Seasons:

Spring: Early April to mid-June.

Fall: Early September to mid-November.

Seed Shipping Season:

Seed is shipped throughout the year. Place your order in winter for the best selection. You can choose the shipping date and we will reserve and ship your seed when you want it. *(Please see Reserval policy below for additional information)*

Reservals:

If you wish to reserve plants or seed for later shipment, we require either a valid credit card, signed government purchase order or a 50% cash deposit. Plants and seed will be subject to sale until your deposit is received. Credit card reservals are charged when shipped, for cash reservals outstanding balance is due prior to shipment. **Cancelled reservals are subject to restocking fees.**

Delivery:

Prairie Nursery will ship your order as quickly as possible. Please allow a minimum of one week for processing. Due to the spring rush, orders placed in April and May occasionally take longer to process.

PLANTS are shipped UPS or RPS unless other arrangements are requested. Normal delivery time in the continental United States is 2–4 days. Shipments to the coasts may take as long as 5 days. UPS/RPS Blue Label (2nd Day Air) service is available (See Shipping & Handling fees).

If you wish to use UPS/RPS Red Label (Next Day Air) service, please contact our office for details on shipping charges.

New York City residents: To ensure timely delivery, please use UPS/RPS Blue Label service for plant shipments.

If you wish to receive your order on a particular day, please indicate this in the appropriate space on the order form. We will do our very best to get your order to you on or near the day you request. Please keep in mind that we have no control over UPS/RPS schedules. For minimum time in transit, we recommend scheduling delivery on Wednesdays through Fridays.

SEEDS are shipped via UPS/RPS or first class mail.

Terms:

Full payment must accompany all orders, unless credit has been approved prior to ordering. For your convenience, we accept MasterCard/VISA and Discover. Prairie Nursery does not charge prior to shipping your order.

In the event we cannot supply a species ordered, and no substitution has been indicated, we will issue a one year Credit Slip. You may apply the Credit Slip towards your next order, or a cash refund.

Credit Terms:

Credit is available to established accounts only. To establish an account please contact our office one week in advance of ordering. It takes time to check credit references, so if you need immediate shipment, we suggest you send payment with your first order, or use a credit card.

Payment on credit orders is due 30 days from date of invoice. Over-due accounts are subject to a 1.5% monthly (18% annual) finance charge.

Restocking Fee:

ALL CANCELLED ORDERS are subject to a 25% restocking fee.

Plant Shipments to Canada:

We ship plants to Canada. Please add an additional 5% Shipping and allow an additional 15 days for Department of Agriculture Phyto Sanitation Certification. Minimum plant order to Canada $250.

PLEASE REMIT PAYMENTS IN U.S. FUNDS.

Sales Tax:

Wisconsin residents must add 5% state sales tax and a 0.5% county sales tax, EXCEPT for residents of the following counties: Brown, Calumet, Clark, Eau Claire, Florence, Fond du Lac, Forest, Grant, Green, Green Lake, Lafayette, Manitowoc, Marinette, Outagamie, Racine, Rock, Sheboygan, Taylor, Vernon, Washington, Waukesha, Winnebago and Wood. **Also, Wisconsin residents of Milwaukee, Ozaukee, Racine, Washington and Waukesha must add 0.1% Stadium Tax.** PLEASE INDICATE YOUR COUNTY OF RESIDENCE ON THE ORDER FORM.

All pick up orders must add the 5% state sales tax **PLUS** an additional ½% Marquette County Sales Tax.

Wisconsin statutes state that all shipping charges are subject to state and county sales tax. Please include shipping and handling charges when computing sales tax.

If you intend to resell plants or seeds purchased from Prairie Nursery, enclose a completed Wisconsin Resale Certificate with your order to avoid being charged sales tax. You will be responsible for any sales tax until we have a completed Resale Certificate on file.

Prairie Nursery

Need Help? Call Us! 608-296-3679

Plant Prices 1996

Price Per Plant

Plants are extra-large, 1 year old, bare-root transplants unless listed otherwise.

Species are alphabetically listed according to their Latin Name.

ITEM #	SPECIES	Page No.	1-2	3-9	10-25	26-50	51-100	101-500
Wildflowers								
35660	Great Blue Lobelia *Lobelia siphilitica* ***2 yr.***	27	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
35750	Lupine *Lupinus perennis*	27	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
35943	Bergamot *Monarda fistulosa* ***3" pot***	27	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
36550	Wild Quinine *Parthenium integrifolium*	28	$4.50	$3.50	$2.75	$2.50	$2.25	$1.95
36720	Smooth Penstemon *Penstemon digitalis*	28	$4.00	$2.95	$2.25	$1.95	$1.75	$1.45
36730	Slender Penstemon *Penstemon gracilis*	28	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
36740	Beardtongue *Penstemon grandiflorus*	28	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
36860	Purple Prairie Clover *Petalostemum purpureum*	28	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
37080	False Dragonhead *Physostegia virginiana*	29	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
77053	Jacob's Ladder *Polemonium reptans* ***3" pot***	29	$4.50	$3.50	$2.75	$2.50	$2.25	$1.95
37850	Yellow Coneflower *Ratibida pinnata*	29	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
38040	Black-Eyed Susan *Rudbeckia hirta*	30	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
38060	Sweet Black-Eyed Susan *Rudbeckia subtomentosa*	30	$4.00	$2.95	$2.25	$1.95	$1.75	$1.45
38070	Branched Coneflower *Rudbeckia triloba*	30	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
38440	Compassplant *Silphium laciniatum*	30	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
38460	Cupplant *Silphium perfoliatum*	31	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
38480	Prairie Dock *Silphium terebinthinaceum*	31	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
38723	Zigzag Goldenrod *Solidago flexicaulus* ***3" pot***	31	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
38743	Ohio Goldenrod *Solidago ohioensis* ***3" pot***	32	$4.50	$3.50	$2.75	$2.50	$2.25	$1.95
38763	Riddell's Goldenrod *Solidago riddellii* ***3" pot***	-	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
38770	Stiff Goldenrod *Solidago rigida*	32	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
38780	Showy Goldenrod *Solidago speciosa*	32	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
39250	Meadowrue *Thalictrum dasycarpum*	32	$3.50	$2.50	AVAILABLE FALL 1996		$1.50	$1.25
39350	Spiderwort *Tradescantia ohiensis*	32	$4.00	$2.95	$2.25	$1.95	$1.75	$1.45
39350	White Spiderwort *Tradescantia ohiensis alba*	33	$4.00	$2.95	$2.25	$1.95	$1.75	$1.45
39650	Ironweed *Vernonia fasciculata*	33	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
39770	Culver's Root *Veronicastrum virginicum* ***2 yr.***	33	$4.00	$2.95	$2.25	$1.95	$1.75	$1.45
39860	Birdsfoot Violet *Viola pedata*	33	$4.50	$3.50	AVAILABLE FALL 1996		$2.25	$1.95
39920	Heartleaf Golden Alexanders *Zizia aptera*	33	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
Grasses & Sedges								
40530	Big Bluestem *Andropogon gerardi*	34	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
41523	Sideoats Grama *Bouteloua curtipendula* ***3" pot***	35	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
44463	Sweet Grass *Hierochloe odorata* ***3" pot***		$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
45523	Junegrass *Koeleria cristata* ***3" pot***	35	$3.50	$2.50	AVAILABLE FALL 1996		$1.50	$1.25
47570	Switchgrass *Panicum virgatum*	35	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
40560	Little Bluestem *Schizachyrium scoparium*	36	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
48550	Indiangrass *Sorghastrum nutans*	36	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
48880	Prairie Cordgrass *Spartina pectinata*	36	$3.50	$2.50	$1.95	$1.75	$1.50	$1.25
49052	Prairie Dropseed *Sporobolus heterolepis* ***2 yr. BR***	37	$5.00	$3.95	$3.25	$2.95	$2.75	$2.50
49053	Prairie Dropseed *Sporobolus heterolepis* ***3" pot***	37	$4.00	$2.95	$2.25	$1.95	$1.75	$1.45
43142	Pennsylvania Sedge *Carex pensylvanica* ***3" pot***	37	$3.50	$2.50	AVAILABLE FALL 1996		$1.50	$1.25

Retail Nurseries, Landscape Architects and Contractors:
Save money on large plant orders!
Call for details & prices (608) 296-3679.

Seed Prices 1996

Species are alphabetically listed according to their Latin Name.

ITEM #	SPECIES	Page No.	Seeds/oz	1/8 oz	1/4 oz	1/2 oz	1 oz	1 lb
Wildflowers								
10220	Lavender Hyssop *Agastache foeniculum*	14	65,000	$9.00	$12.00	$18.00	$30.00	$450.00
10350	Nodding Pink Onion *Allium cernuum*	14	7,700	$9.00	$12.00	$18.00	$30.00	$450.00
10430	Leadplant *Amorpha canescens*	15	17,000	$6.00	$8.00	$12.00	$20.00	$300.00
10690	Virginia Anemone *Anemone virginiana*	–	20,000	$9.00	$12.00	$18.00	$30.00	$450.00
10710	Angelica *Angelica atropurpurea*	15	6,600	$4.50	$6.00	$9.00	$15.00	$225.00
11030	Columbine *Aquilegia canadensis*	45	25,000	$9.00	$12.00	$18.00	$30.00	$450.00
60970	Rock Sandwort *Arenaria stricta*	–	250,000			$10/gram		
61170	Jack in the Pulpit *Arisaema triphyllum*	45	440			AVAILABLE FALL 1996		
11230	Red Milkweed *Asclepias incarnata*	15	4,500	$6.00	$8.00	$12.00	$20.00	$300.00
11260	Prairie Milkweed *Asclepias sullivantii*	–	5300	$18.00	$24.00	$36.00	$60.00	$900.00
11270	Common Milkweed *Asclepias syriaca*	15	4,000	$4.50	$6.00	$9.00	$15.00	$225.00
11280	Butterflyweed *Asclepias tuberosa*	16	3,500	$18.00	$24.00	$36.00	$60.00	$900.00
11310	Sky Blue Aster *Aster azureus*	16	82,000	$18.00	$24.00	$36.00	$60.00	$900.00
11320	Heath Aster *Aster ericoides*	16	140,000	$18.00	$24.00	$36.00	$60.00	$900.00
11340	Smooth Aster *Aster laevis*	16	48,000	$18.00	$24.00	$36.00	$60.00	$900.00
11350	New England Aster *Aster novae-angliae*	17	70,000	$15.00	$20.00	$30.00	$50.00	$750.00
11370	White Aster *Aster ptarmicoides*	17	70,000	$18.00	$24.00	$36.00	$60.00	$900.00
11450	Canada Milk Vetch *Astragalus canadensis*	17	16,000	$4.50	$6.00	$9.00	$15.00	$225.00
11520	Blue False Indigo *Baptisia australis*	17	1,600	$6.00	$8.00	$12.00	$20.00	$300.00
11550	White False Indigo *Baptisia leucantha*	17	1,600	$7.50	$10.00	$15.00	$25.00	$375.00
11560	Cream False Indigo *Baptisia leucophaea*	17	1,700	$18.00	$24.00	$36.00	$60.00	$900.00
11610	Pale Indian Plantain *Cacalia atriplicifolia*	17	6,500	$6.00	$8.00	$12.00	$20.00	$300.00
11660	Sweet Indian Plantain *Cacalia suaveolens*	18	12,000	$4.50	$6.00	$9.00	$15.00	$225.00
11750	Poppy Mallow *Callirhoe triangulata*	18	6,000	$24.00	$32.00	$48.00	$80.00	NA
61650	Marsh Marigold *Caltha palustris*	18	50,000			AVAILABLE FALL 1996		
11950	Harebell *Campanula rotundifolia*	18	800,000	$36.00	$48.00	$72.00	$120.00	NA
12040	Partridge Pea *Cassia fasciculata*	-	-	$1.50	$2.00	$3.00	$5.00	$75.00
12050	Wild Senna *Cassia hebecarpa*	18	1,400	$6.00	$8.00	$12.00	$20.00	$300.00
61970	Blue Cohosh *Caulophyllum thalictroides*	45	120			AVAILABLE FALL 1996		
12150	New Jersey Tea *Ceanothus americanus*	19	7,000	$36.00	$48.00	$72.00	$120.00	NA
12340	Lanceleaf Coreopsis *Coreopsis lanceolata*	19	12,500	$1.50	$2.00	$3.00	$5.00	$75.00
12750	Canada Tick-Trefoil *Desmodium canadense*	19	4,500	$4.50	$6.00	$9.00	$15.00	$225.00
12850	Shooting Star *Dodecatheon meadia*	19	75,000	$15.00	$20.00	$30.00	$50.00	$750.00
12920	Narrow-leaf Purple Coneflower *Echinacea angustifolia*	20	6,800	$6.00	$8.00	$12.00	$20.00	$300.00
12950	Pale Purple Coneflower *Echinacea pallida*	20	5,000	$4.50	$6.00	$9.00	$15.00	$225.00
12960	Purple Coneflower *Echinacea purpurea*	20	6,600	$3.00	$4.00	$6.00	$10.00	$150.00
13050	Fireweed *Epilobium angustifolium*	20	620,000			$10/gram		
13150	Rattlesnake Master *Eryngium yuccifolium*	20	8,000	$6.00	$8.00	$12.00	$20.00	$300.00
13240	Joe Pye Weed *Eupatorium maculatum*	21	85,000	$9.00	$12.00	$18.00	$30.00	$450.00
13260	Boneset *Eupatorium perfoliatum*	21	200,000	$6.00	$8.00	$12.00	$20.00	$300.00
13350	Flowering Spurge *Euphorbia corollata*	21	10,000	$6.00	$8.00	$12.00	$20.00	$300.00
13720	Bottle Gentian *Gentiania andrewsii*	21	800,000	$15.00	$20.00	$30.00	$50.00	$750.00
13950	Prairie Smoke *Geum triflorum*	22	34,000	$18.00	$24.00	$36.00	$60.00	$900.00
14230	Sawtooth Sunflower *Helianthus grosseserratus*	22	12,500	$7.50	$10.00	$15.00	$25.00	$375.00
14260	Downy Sunflower *Helianthus mollis*	22	7,700	$4.50	$6.00	$9.00	$15.00	$225.00
14270	Western Sunflower *Helianthus occidentalis*	22	13,000	$12.00	$16.00	$24.00	$40.00	$600.00
14280	Woodland Sunflower *Helianthus strumosus*	45	4,500	$12.00	$16.00	$24.00	$40.00	NA
14350	Ox-Eye Sunflower *Heliopsis helianthoides*	23	6,500	$3.00	$4.00	$6.00	$10.00	$150.00
14550	Alum Root *Heuchera richardsonii*	23	800,000	$22.50	$30.00	$45.00	$75.00	NA
14760	Great St. Johnswort *Hypericum pyramidatum*	23	220,000	$3.50	$5.00	$7.00	$12.00	$180.00
14950	Wild Iris *Iris shrevei*	23	1,400	$3.00	$4.00	$6.00	$10.00	$150.00
14960	Blue Flag Iris *Iris versicolor*	23	1,500	$4.50	$6.00	$9.00	$15.00	$225.00
15240	Roundheaded Bushclover *Lespedeza capitata*	23	10,000	$4.50	$6.00	$9.00	$15.00	$225.00

Seed Prices 1996

739

Species are alphabetically listed according to their Latin Name.

Wildflowers

ITEM #	SPECIES	Page No.	Seeds/oz	1/8 oz	1/4 oz	1/2 oz	1 oz	1 lb
15310	Rough Blazingstar *Liatris aspera*	26	13,500	$15.00	$20.00	$30.00	$50.00	$750.00
15340	Meadow Blazingstar *Liatris ligulistylus*	26	13,000	$18.00	$24.00	$36.00	$60.00	$900.00
15350	Dotted Blazingstar *Liatris punctata*	26	8,000	$7.50	$10.00	$15.00	$25.00	$375.00
15360	Prairie Blazingstar *Liatris pycnostachya*	26	12,000	$7.50	$10.00	$15.00	$25.00	$375.00
15370	Dense Blazingstar *Liatris spicata*	26	12,000	$6.00	$8.00	$12.00	$20.00	$300.00
15640	Cardinal Flower *Lobelia cardinalis*	27	300,000	$30.00	$40.00	$60.00	$100.00	$1,500.00
15660	Great Blue Lobelia *Lobelia siphilitica*	27	470,000	$6.00	$8.00	$12.00	$20.00	$300.00
15750	Lupine *Lupinus perennis*	27	1,000	$3.00	$4.00	$6.00	$10.00	$150.00
15870	Prairie Loosestrife *Lysimachia quadriflora*	27	88,000			$10/gram		
15960	Bergamot *Monarda fistulosa*	27	78,000	$7.50	$10.00	$15.00	$25.00	$375.00
15980	Dotted Mint *Monarda punctata*	27	94,000	$4.50	$6.00	$9.00	$15.00	$225.00
16010	Glade Mallow *Napea dioica*	28	5,300	$6.00	$8.00	$12.00	$20.00	$300.00
16110	Evening Primrose *Oenothera biennis*	28	550,000	$2.50	$3.50	$5.00	$8.00	$120.00
16220	Prickly Pear Cactus *Opuntia compressa*	–	1,800	$6.00	$8.00	$12.00	$20.00	$300.00
16550 •	Wild Quinine *Parthenium integrifolium*	28	6,800	$12.00	$16.00	$24.00	$40.00	$600.00
16720	Smooth Penstemon *Penstemon digitalis*	28	100,000	$7.50	$10.00	$15.00	$25.00	$375.00
16730	Slender Penstemon *Penstemon gracilis*	28	208,000	$22.50	$30.00	$45.00	$75.00	$1,125.00
16740	Beardtongue *Penstemon grandiflorus*	28	11,000	$6.00	$8.00	$12.00	$20.00	$300.00
16820	White Prairie Clover *Petalostemum candidum*	–	15,900	$4.50	$6.00	$9.00	$15.00	$225.00
16860	Purple Prairie Clover *Petalostemum purpureum*	28	20,000	$3.00	$4.00	$6.00	$10.00	$150.00
67050	Jacob's Ladder *Polemonium reptans*	29	22,000			AVAILABLE FALL 1996		
17220	Great Solomon's Seal *Polygonatum canaliculatum*	29	1,200	$7.50	$10.00	$15.00	$25.00	$375.00
17760	Prairie Buttercup *Ranunculus rhomboideus*	29	28,000	$15.00	$20.00	$30.00	$50.00	$750.00
17850	Yellow Coneflower *Ratibida pinnata*	29	27,000	$2.50	$3.50	$5.00	$8.00	$120.00
17920	Meadow Rose *Rosa blanda*	29	—	$6.00	$8.00	$12.00	$20.00	$300.00
17930	Pasture Rose *Rosa carolina*	29	2,900	$6.00	$8.00	$12.00	$20.00	$300.00
18040	Black-Eyed Susan *Rudbeckia hirta*	30	100,000	$1.50	$2.00	$3.00	$5.00	$75.00
18050	Green-headed Coneflower *Rudbeckia laciniata*	29	15,000	$7.50	$10.00	$15.00	$25.00	$375.00
18060	Sweet Black-Eyed Susan *Rudbeckia subtomentosa*	30	46,000	$6.00	$8.00	$12.00	$20.00	$300.00
18070	Branched Coneflower *Rudbeckia triloba*	30	33,000	$9.00	$12.00	$18.00	$30.00	$450.00
18360	Royal Catchfly *Silene regia*	30	23,000	$24.00	$32.00	$48.00	$80.00	NA
18420	Rosinweed *Silphium integrifolium*	30	4,000	$12.00	$16.00	$24.00	$40.00	$600.00
18440	Compassplant *Silphium laciniatum*	30	650	$7.50	$10.00	$15.00	$25.00	$375.00
18460	Cupplant *Silphium perfoliatum*	31	1,400	$7.50	$10.00	$15.00	$25.00	$375.00
18480	Prairie Dock *Silphium terebinthinaceum*	31	1,100			AVAILABLE FALL 1996		
18530	Blue Eyed Grass *Sisyrinchium campestre*	–	39,000			$5/gram		
18560	Mountain Blue Eyed Grass *Sisyrinch. montanum*	31	29,000			$5/gram		
18670	Solomon's Plume *Smilacina racemosa*	45	900	$7.50	$10.00	$15.00	$25.00	$375.00
18730	Sweet-Scented Goldenrod *Solidago jejunifolia*	31	130,000	$24.00	$32.00	$48.00	$80.00	NA
18750	Grey Goldenrod *Solidago nemoralis*	31	240,000	$12.00	$16.00	$24.00	$40.00	$600.00
18740	Ohio Goldenrod *Solidago ohioensis*	32	90,000	$18.00	$24.00	$36.00	$60.00	NA
18770	Stiff Goldenrod *Solidago rigida*	32	46,000	$9.00	$12.00	$18.00	$30.00	$450.00
18780	Showy Goldenrod *Solidago speciosa*	32	105,000	$24.00	$32.00	$48.00	$80.00	$1,200.00
19070	Fame Flower *Talinum rugospermum*	32	71,000			$25/gram		
19250	Meadowrue *Thalictrum dasycarpum*	32	13,900			AVAILABLE FALL 1996		
19350	Spiderwort *Tradescantia ohiensis*	32	8,000	$12.00	$16.00	$24.00	$40.00	$600.00
19540	Blue Vervain *Verbena hastata*	33	100,000	$3.00	$4.00	$6.00	$10.00	$150.00
19560	Hoary Vervain *Verbena stricta*	33	32,000	$1.50	$2.00	$3.00	$5.00	$75.00
19650	Ironweed *Vernonia fasciculata*	33	20,000	$9.00	$12.00	$18.00	$30.00	$450.00
19770	Culver's Root *Veronicastrum virginicum*	33	750,000	$30.00	$40.00	$60.00	$100.00	$1,500.00
19920	Heartleaf Golden Alexanders *Zizia aptera*	33	9,000	$12.00	$16.00	$24.00	$40.00	$600.00
19930	Golden Alexanders *Zizia aurea*	33	12,000	$4.50	$6.00	$9.00	$15.00	$225.00

Seed Prices 1996

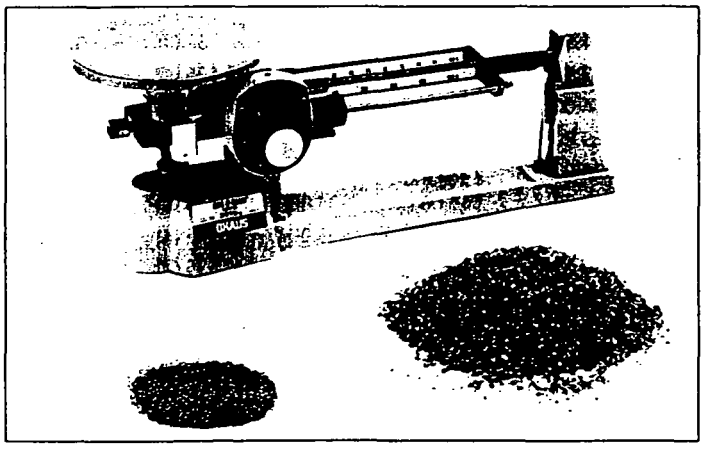
Species are alphabetically listed according to their Latin Name.

ITEM #	SPECIES	Page No.	Seeds/oz	1/2 oz	1 oz	1/4 lb.	1/2 lb.	1 lb
Grasses								
20530	Big Bluestem *Andropogon gerardi*	34	8,200	$2.00	$3.00	$10.00	$18.00	$30.00
21520	Sideoats Grama *Bouteloua curtipendula*	35	8,000	$2.50	$3.50	$12.00	$20.00	$32.00
23520	Canada Wild Rye *Elymus canadensis*	35	4,200	$1.00	$1.50	$5.00	$9.00	$14.00
23528	Virginia Wild Rye *Elymus virginicus*	35	3,900	$5.00	$7.50	$25.00	$45.00	$75.00
23470	Purple Lovegrass *Eragrostis spectabilis*	-	-	$9.00	$15.00	$55.00	$105.00	$200.00
24020	Rattlesnake Grass *Glyceria canadensis*	–	130,000	$15.00	$25.00	$95.00	$175.00	NA
24070	Fowl Manna Grass *Glyceria striata*	–	180,000	$15.00	$25.00	$95.00	$175.00	$300.00
25520	Junegrass *Koeleria cristata*	35	150,000	$9.00	$15.00	$55.00	$105.00	$200.00
27570	Switchgrass *Panicum virgatum*	35	18,000	$1.00	$1.50	$5.00	$9.50	$15.00
20560	Little Bluestem *Schizachyrium scoparium*	36	8,800	$2.00	$3.00	$10.00	$18.00	$30.00
28550	Indiangrass *Sorghastrum nutans*	36	8,300	$1.50	$2.00	$7.00	$12.00	$20.00
29050	Prairie Dropseed *Sporobolus heterolepis*	37	14,000	$6.00	$10.00	$35.00	$65.00	$120.00

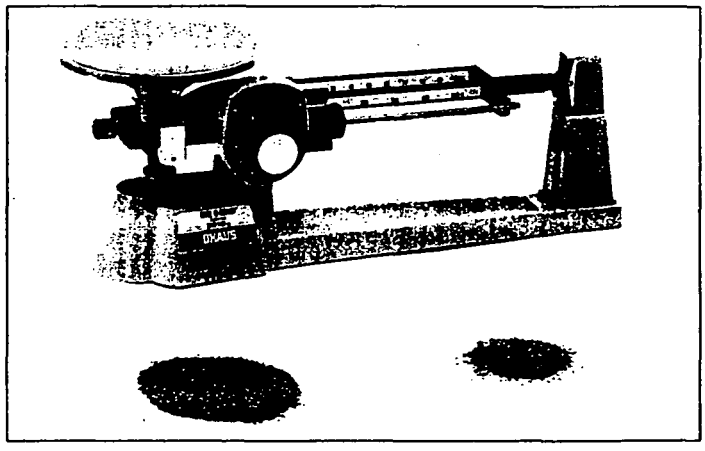
Sedges		Page No.	Seeds/oz	1/8 oz	1/4 oz	1/2 oz	1 oz	1lb
23017	Bebb's Sedge *Carex bebbii*	37	100,000	$9.00	$12.00	$18.00	$30.00	$450.00
23094	Porcupine Sedge *Carex hystericina*	37	36,000	$9.00	$12.00	$18.00	$30.00	NA
23197	Fox Sedge *Carex vulpinoidea*	37	90,000	$6.00	$8.00	$12.00	$20.00	$300.00

Seed Quality: Price versus Value

Cheap Price may be a Poor Value



One ounce of Prairie Nursery's Grey Goldenrod (Solidago nemoralis) seed (on the left), compared to 1 ounce of seed material purchased from another major wildflower seed retailer (on the right).



The same seed compared after cleaning. The ounce of the other retailer's seed material (on the right) reduced to barely a tenth of an ounce of clean seed.

Prairie Nursery Seed

Purchased Weight: 1.00 ounce (28.35 gm)
Purchase Price $40.00
Actual Clean Seed Weight: *1.00 ounce (28.35 gm)*

You will spend $40.00 to get 1 oz. of seed

Another Wildflower Producer's Seed

Purchased Weight: 1.00 ounce (28.35 gm)
Purchase Price $10.00
Actual Clean Seed Weight: *0.11 ounce (3.2 gm)*

You must spend $88.60 to get 1 oz. of seed

Grey Goldenrod seed was used in this comparison. Similar results were obtained with many other seed species purchased.

[redacted] 77

11.3 Final Cover System Erosion Resistance

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: FINAL COVER SYSTEM EROSION RESISTANCE

Computations By: (Cognizant Engineer)
Signature [signature] Date 21 FEB 96
Printed Name and Title DAVID W WARREN, STAFF ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature [signature] Date 22 Feb 96
Printed Name and Title Kenneth W Cargill, Associate

Computations Checked by:
Signature [signature] Date 22 FEB 96
Printed Name and Title DANIEL B. WISNIALOWSKI, ASSISTANT PROJECT ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 22 FEB 96
Printed Name and Title DAVID W WARREN, STAFF ENGINEER

Approved by: (PDP)
Signature [signature] Date 23 Feb 96
Printed Name and Title Kara L. Olen, Asst. Proj. Engr.

Approved by: (DTL and TETL)
Signature [signature] Date 23 Feb 96
Printed Name and Title Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	Intermediate Design				
D	Intermediate Design - EPA Submittal	4 Apr 96	[initials]		
O	Response to Final Design Comts	9 May 97	[initials]		[initials]

Written by: DAVE WARREN Date: 20-Feb-96 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

23 Feb 96
KO 23 Feb 96

COVER SYSTEM EROSION RESISTANCE

EXECUTIVE SUMMARY

Purpose

To demonstrate that the erosion resistance of the OSDF final cover system will satisfy the following design criteria:

- Topsoil shall have a maximum projected erosion rate of 5 tons/acre/year (11 tonnes/ha/year).
- Properties of the topsoil and underlying layers should be adequate to result in a cumulative projected volume of eroded material over the design life of the facility that results in sufficient remaining soil thickness to provide freeze-thaw protection of the compacted clay component of the final cover system.
- Topsoil and vegetation should resist gully initiation under the tractive forces of surface-water runoff from the cover.
- Properties of the biointrusion barrier shall be adequate to resist erosion in the 2000-year storm, should the biointrusion barrier be exposed by erosion gullies that have breached the overlying layers.

Contents

- Executive Summary
- Calculation Procedure
- Collection and Verification of Data
- Calculations and Results

Results

A well-established grass cover on the proposed clay loam topsoil should not exceed the maximum allowable rate of soil loss due to sheet and rill erosion. A less dense grass cover may be adequate if a

gravelly topsoil is used, but a gravelly topsoil will prohibit grass growth and encourage the growth of weeds, and is therefore not recommended.

At the calculated soil loss rate of 4.35 tons/acre/year, the topsoil and vegetative soil layers of the OSDF final cover will have a thickness of 22 inches after 200 years and a thickness of 3.5 inches after 1000 years. The results of the calculations indicate that a well-established native-grass cover should preclude formation of erosion gullies in the OSDF final cover during the 2000-year storm. However, circumstances may arise which cannot be accounted for through calculations; such as exposed soil due to burrowing animals, poor vegetation conditions due to severe drought, etc. For this reason, the resistance of the biointrusion barrier to erosion in the 2000-year storm and probable maximum precipitation (PMP) was calculated, assuming a gully has penetrated the overlying final cover system layers (gravel choke, vegetative soil, and topsoil). The results of these calculations indicate that the biointrusion barrier will stop the advancement of any gullies which penetrate the overlying layers, even in the PMP.

Recommendations

Use a native-grass vegetative cover on the OSDF final cover system. Calculations indicate that erosion gullies should not form in this vegetative cover in the 2000-year storm. Furthermore, in the event that gullies develop due to circumstances that cannot be accounted for through calculations, gullies should not penetrate the biointrusion barrier, and thus not breach final cover integrity.

GEOSYNTEC CONSULTANTS

Written by: _____ Date: _____ Reviewed

Client: FERMCO Project: OSDF P

THIS PAGE IS INSERTED ONLY FOR CLARITY AND DOES NOT AFFECT THE NUMBERING SYSTEM OF THE REST OF THE PACKAGE

COVER SYSTEM EROSION RESISTANCE

TABLE OF CONTENTS

		Page
1.	Calculation Procedures	3/76
2.	Collection and Verification of Data	4/76
	• Modified Universal Soil Loss Equation	5/76
	• Thickness of Topsoil and Vegetative Soil Layer at End of OSDF Design Life	14/76
	• Design Flow	17/76
	• Temple Method	25/76
	• Horton/NRC Method	34/76
	• Permissible Velocity Method	36/76
	• Design Flow Per Unit Width in a Gully Penetrating to the Biointrusion Barrier	39/76
	• Stephenson Method	42/76
	• Hartung and Scheuerlein Method	45/76
3.	Calculations	51/76

Written by: DAVE WARREN Date: 20-Feb-96 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

KC 22 Feb 96
KO 23 Feb 96

COVER SYSTEM EROSION RESISTANCE

CALCULATION PROCEDURE

1. Evaluate the ability of the planned native-grass cover and topsoil to satisfy the required soil loss rate to sheet and rill erosion (≤ 5 tons/acre/year). Use the Modified Universal Soil Loss Equation (MUSLE), [Nelson et al., 1986].

2. Accounting for soil loss to sheet and rill erosion a rate of 5 tons/acre/year, determine the thickness of the topsoil and vegetative soil layers at the end of the design life of the OSDF (200 years, up to 1000 years to the extent practicable and achievable).

3. Evaluate the resistance of the planned native-grass cover to gully formation in the topsoil layer of the OSDF final cover. The design storm is the 2000-year storm. Use the following methods:

   - Temple Method [Temple et al., 1987]
   - Horton/NRC Method [NRC, 1990]
   - Permissible Velocity Method [NRC, 1990 and USDA-SCS, 1986]

4. Evaluate the ability of the riprap in the biointrusion barrier to resist erosion, should the biointrusion barrier be exposed by erosion gullies that have breached the overlying OSDF final cover layers. The design storm is the 2000-year storm (resistance in the probable maximum precipitation is also checked for information). Use the following methods:

   - Stephenson Method [Abt et al., 1988]
   - Hartung and Scheuerlein Method [Hartung and Scheuerlein, 1970]

Written by: DAVE WARREN Date: 20-Feb-96 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

KC 22 Feb 96
KO 23 Feb 96

COVER SYSTEM EROSION RESISTANCE

COLLECTION AND VERIFICATION OF DATA (CVD)

OUTLINE

SOIL LOSS RATE TO SHEET AND RILL EROSION

1. **Modified Universal Soil Loss Equation**
2. **Thickness Of Topsoil And Vegetative Soil Layer At End Of OSDF Design Life**

POTENTIAL FOR GULLIES FORMING IN OSDF COVER

3. **Design Flow**
4. **Temple Method**
5. **Horton/NRC Method**
6. **Permissible Velocity Method**

ABILITY OF BIOINTRUSION BARRIER TO STOP GULLY ADVANCEMENT

7. **Design Flow Per Unit Width In A Gully Penetrating To The Biointrusion Barrier**
8. **Stepehenson Method**
9. **Hartung And Scheuerlein Method**

Written by: DAVE WARREN Date: 20-Feb-96 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

22 Feb 96
KO 23 Feb 96

1. MODIFIED UNIVERSAL SOIL LOSS EQUATION

The Modified Universal Soil Loss Equation (MUSLE) [Nelson et al., 1986] is:

$$A = R \times K \times LS \times VM$$

Where: A = rate of soil loss to sheet and rill erosion by water in tons/acre/year
R = rainfall energy factor K = soil erodability factor
LS = length and slope factor VM = vegetative measures factor

1.1 Rainfall Energy Factor (R)

R = 175 See Figure 1.

1.2 Soil Erodibility Factor (K)

See Table 1. On-site materials from the East Field borrow area will probably be used as topsoil in the OSDF final cover. The soils in the OSDF area and the East Field borrow area are glacial till, with the majority classifying as USCS *Lean Clay* (CL) or *Sandy Lean Clay* (CL), as shown in Table 2. CL generally corresponds to USDA *Clay Loam*, as can be seen in Table 3. Therefore, a soil erodability factor corresponding to clay loam will be used.

K = 0.32

***Table 1** - "K" Factor Values For Different Topsoil Textures, From USDA-SCS [1987]*

Topsoil Texture	Soil Erodability Factor Value
Silt Loam	0.37
Clay Loam	0.32
Loam	0.32
Sandy Loam	0.24
Loamy Sand	0.17
Sand	0.15

GEOSYNTEC CONSULTANTS

Written by: DAVE WARREN Date: 20 FEB 96 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

22 Feb 96
KO 23 Feb 96

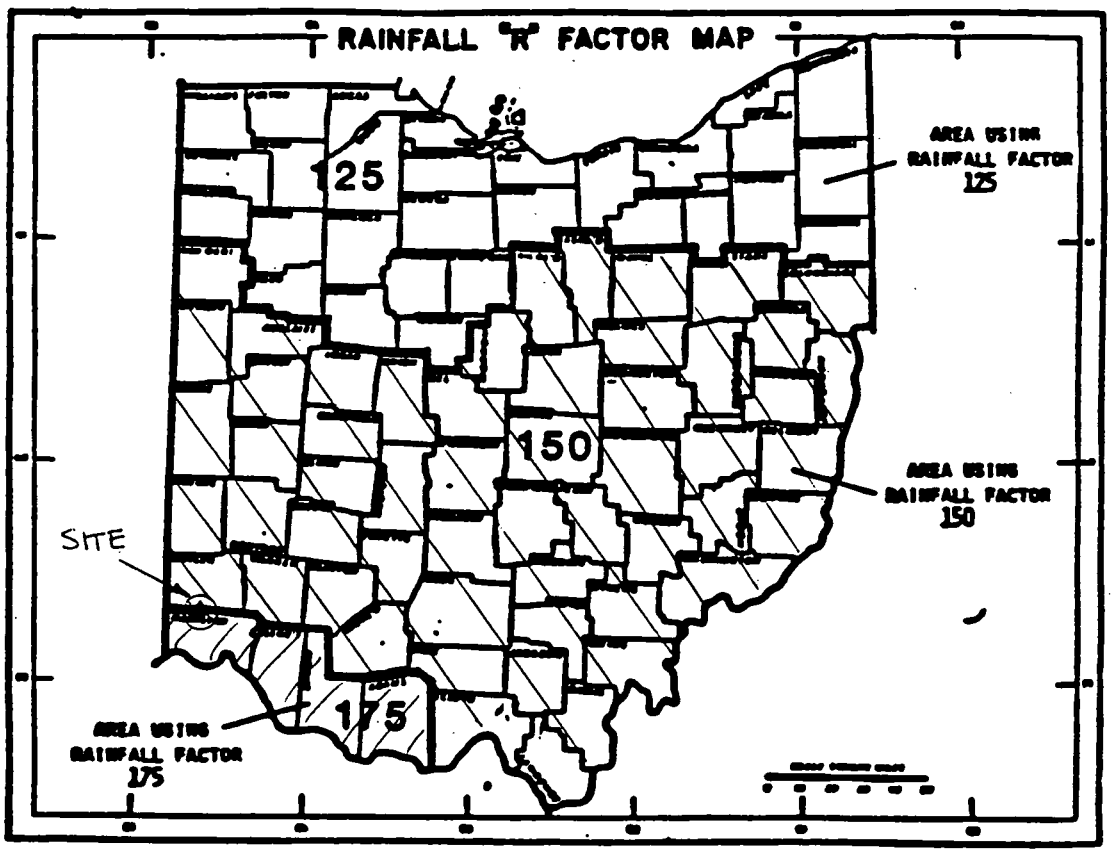


Figure 1 - Rainfall Energy Factor Map For Ohio. From USDA- SCS [1987]

[redacted]

Written by: DAVE WARREN Date: 19-Feb-96 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

Table 2 - Index Properties of Soils in the OSDF Area and North Borrow Area. Modified from Parsons [1995b]

General Stratum	USCS Group Symbol	Dry Density (pcf)	Liquid Limit	Plasticity Index	Percent Gravel	Percent Sand	Percent Silt	Percent Clay	Specific Gravity (avg)
Brown Till (0-5 ft)	CL	95-125	21-50	7-32	0-12	1-43	35-63	18-48	2.72
Brown Till (5-10 ft)	CL	91-130	22-49	7-28	0-23	1-33	30-64	21-59	2.75
Brown Till (10-15 ft)	CL	107-131	19-43	4-23	0-25	1-41	2-65	18-58	2.78
Gray Till	CL	113-139	19-33	5-17	0-31	1-39	28-79	18-38	2.74
Brown or Gray Till	CL-ML	113-130	17-23	4-7	0-16	15-42	36-55	18-30	2.78
Brown Till	CH	102-105	50-57	23-38	0-2	3-14	38-61	34-48	2.70
Brown or Gray Till	GC	114-135	28	13	26	25	27	22	2.73
Gray Till	GM				40	38	17	5	2.80
Brown or Gray Till	ML	100-135	16-23	0-4	0-7	3-38	41-84	10-18	2.75
Brown or Gray Till	SM	113	NP-13	NP-1	0-15	43-71	13-42	4-20	2.73
Brown or Gray Till	SC	131	19-25	8-12	18-26	29-55	13-27	8-18	2.72
Brown or Gray Till	SC-SM	98-135	18-24	5-8	0-25	37-56	26-35	12-18	2.74
Brown Till	GC-GM	85-124	24	7	43	22	23	12	2.79
Great Miami Aquifer	SM				0-32	53-84	10-36	1-5	2.75
Great Miami Aquifer	SW-SM				16-37	54-76	4-10	1-3	2.74
Great Miami Aquifer	SP-SM				0-35	57-91	4-10	0-3	2.73

Notes: 1. Percent clay defined as those particles finer than 0.005mm (Reference ASTM D 422)
2. Density shown is for in-situ soils
3. NP is non-plastic

22 Feb 96
KO 23 Feb 96

87

Written by: DAVE WARREN Date: 19-Feb-96 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

Table 3 - Typical Porosities and USCS Classifications for Different USDA Soil Textures. From Schroeder et al. [1994]

22 Feb 96
23 Feb 96

LOOSE SOILS

Classification			Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	USDA	USCS	vol/vol	vol/vol	vol/vol	cm/sec
1	CoS	SP	0.417	0.045	0.018	1.0×10^{-2}
2	S	SW	0.437	0.062	0.024	5.8×10^{-3}
3	FS	SW	0.457	0.083	0.033	3.1×10^{-3}
4	LS	SM	0.437	0.105	0.047	1.7×10^{-3}
5	LFS	SM	0.457	0.131	0.058	1.0×10^{-3}
6	SL	SM	0.453	0.190	0.085	7.2×10^{-4}
7	FSL	SM	0.473	0.222	0.104	5.2×10^{-4}
8	L	ML	0.463	0.232	0.116	3.7×10^{-4}
9	SiL	ML	0.501	0.284	0.135	1.9×10^{-4}
10	SCL	SC	0.398	0.244	0.136	1.2×10^{-4}
11	CL	CL	0.464	0.310	0.187	6.4×10^{-5}
12	SiCL	CL	0.471	0.342	0.210	4.2×10^{-5}
13	SC	SC	0.430	0.321	0.221	3.3×10^{-5}
14	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}
15	C	CH	0.475	0.378	0.265	1.7×10^{-5}
16	Barrier Soil		0.427	0.418	0.367	1.0×10^{-7}
17	Bentonite Mat (0.6 cm)		0.750	0.747	0.400	3.0×10^{-9}
18	Municipal Waste (900 lb/yd³ or 312 kg/m³)		0.671	0.292	0.077	1.0×10^{-3}
19	Municipal Waste (channeling and dead zones)		0.168	0.073	0.019	1.0×10^{-3}
20	Drainage Net (0.5 cm)		0.850	0.010	0.005	1.0×10^{-1}
21	Gravel		0.397	0.032	0.013	3.0×10^{-1}
22	L*	ML	0.419	0.307	0.180	1.9×10^{-5}
23	SiL*	ML	0.461	0.360	0.203	9.0×10^{-6}
24	SCL*	SC	0.365	0.305	0.202	2.7×10^{-6}
25	CL*	CL	0.437	0.373	0.266	3.6×10^{-6}
26	SiCL*	CL	0.445	0.393	0.277	1.9×10^{-6}
27	SC*	SC	0.400	0.366	0.288	7.8×10^{-7}
28	SiC*	CH	0.452	0.411	0.311	1.2×10^{-6}
29	C*	CH	0.451	0.419	0.332	6.8×10^{-7}
30	Coal-Burning Electric Plant Fly Ash*		0.541	0.187	0.047	5.0×10^{-5}
31	Coal-Burning Electric Plant Bottom Ash*		0.578	0.076	0.025	4.1×10^{-3}
32	Municipal Incinerator Fly Ash*		0.450	0.116	0.049	1.0×10^{-2}
33	Fine Copper Slag*		0.375	0.055	0.020	4.1×10^{-2}
34	Drainage Net (0.6 cm)		0.850	0.010	0.005	3.3×10^{-1}

* Moderately Compacted

22 Feb 96
23 Feb 96

1.3 Length and Slope Factor (LS)

The "LS" factor is calculated using the following equation [Foster and Wischmeier, 1974]:

$$LS = \frac{1}{\lambda_e}\sum_{j=1}^{n}\frac{S_j\lambda_j^{m+1} - S_j\lambda_{j-1}^{m+1}}{72.6^m} \qquad \text{For:} \quad S_j = (0.043s_j^2 + 0.30s_j + 0.43)/6.613$$

Where:
- λ_e = Total length (slope includes n segments)
- n = number of segments in slope
- S_j = slope factor for segment j
- s_j = slope for segment j (percent)
- λ_j = Length from top of entire slope to bottom of segment j
- λ_{j-1} = Length from top of entire slope to bottom of segment j-1
- m = slope-length exponent (Section 1.3.1)

Geometry of the OSDF is shown in Figures 2 through 4. The worst-case slope for erosion on the OSDF final cover will be the west-side slope, which at its longest, consists of the three segments below (see Figure 4):

- 90 ft long top segment at 20 Horizontal to 1 Vertical (20H:1V) (0.05 ft/ft);
- 60 ft long middle segment at 10H:1V (0.10 ft/ft); and
- 370 ft long bottom segment at 6H:1V (0.167 ft/ft).

Values of LS are presented in the calculations section.

1.3.1 Slope-length exponent (m)

'm' is taken from the table below [Nelson et al., 1986]:

Slope (%)	m
$s \le 1.0$	0.2
$1.0 < s \le 3.0$	0.3
$3.0 < s \le 5.0$	0.4
$5.0 < s \le 10.0$	0.5
$s > 10.0$	0.6

1.4 Vegetative Measures Factor (VM)

The VM factor is estimated from Table 4. From Table 4, VM = 0.01 for "permanent seedings after 12 months" (i.e., good grass cover). Also, VM = 0.01 can be achieved during vegetative cover establishment by using adequate mulching [Caltrans,1992].

Written By: D. WARREN Date: 20 FEB 96 Reviewed by: DBN Date: 22 FEB 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

KO 22 Feb 96
KO 23 Feb 96

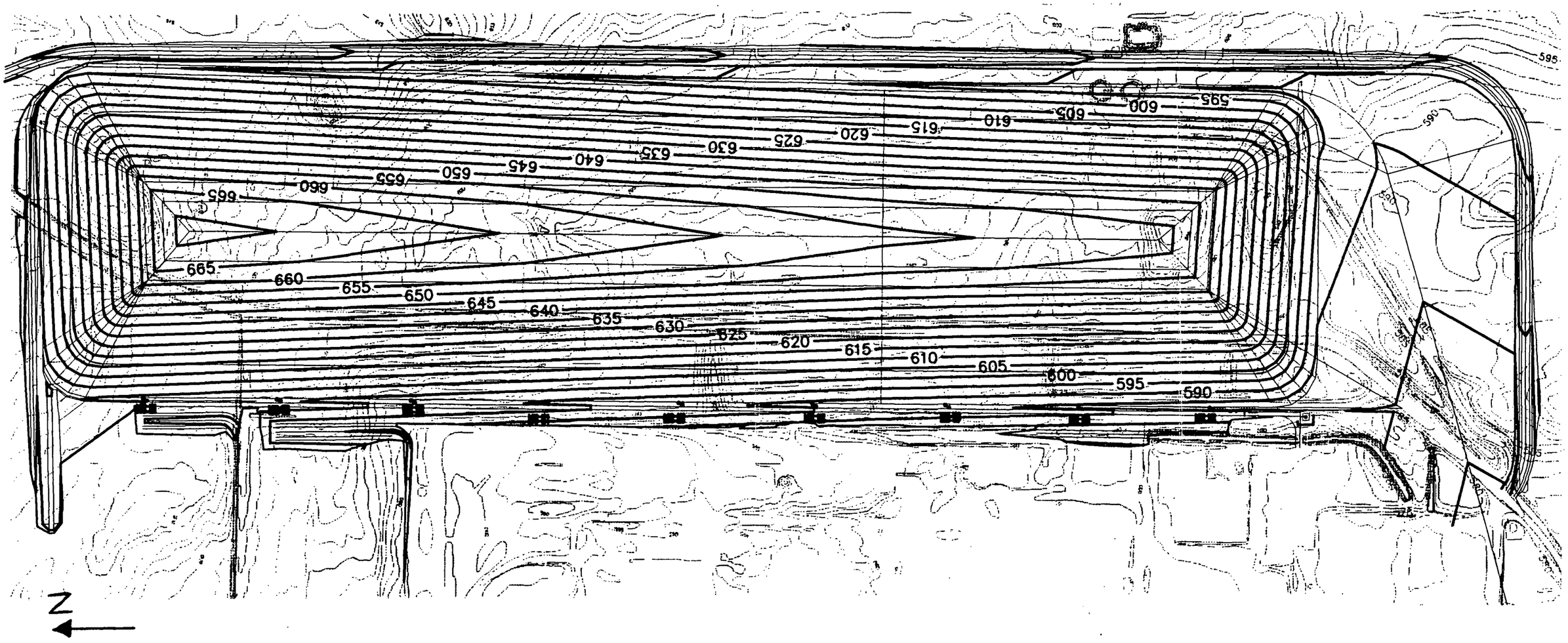


Figure 2 - Plan of OSDF Final Cover. From GeoSyntec [1996]

Written By: D. WARREN Date: 20FEB96 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

739 11/76

22 Feb 96
KO 23 Feb 96

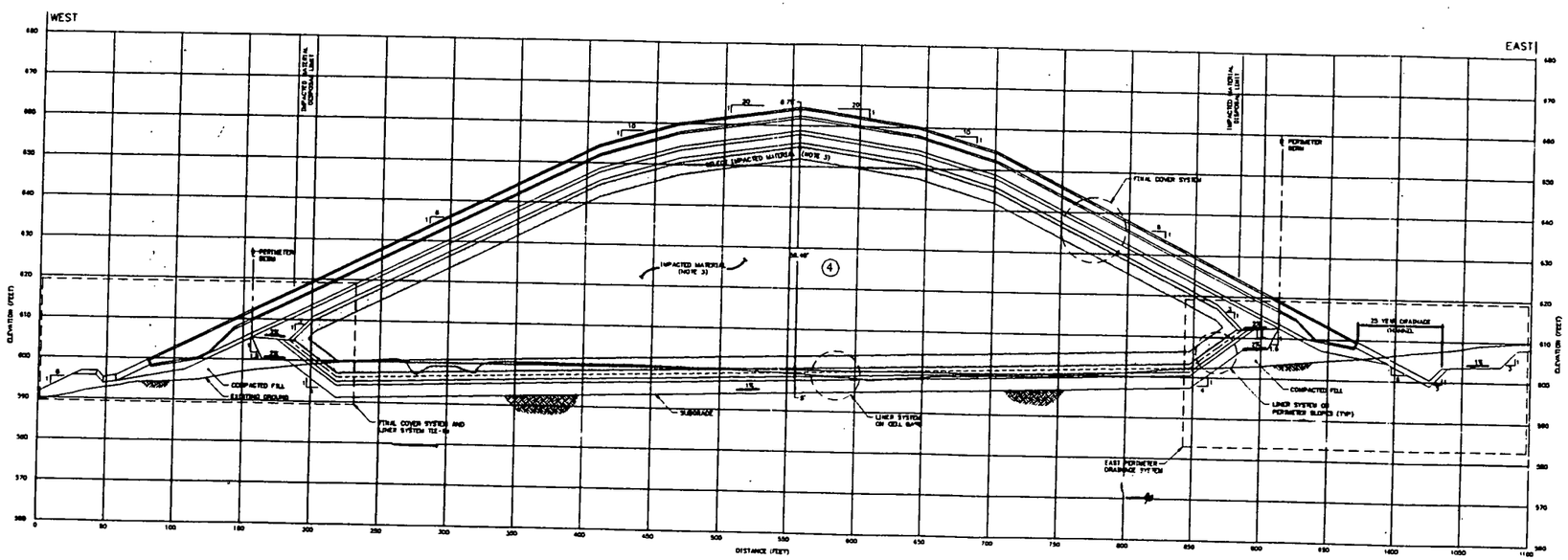
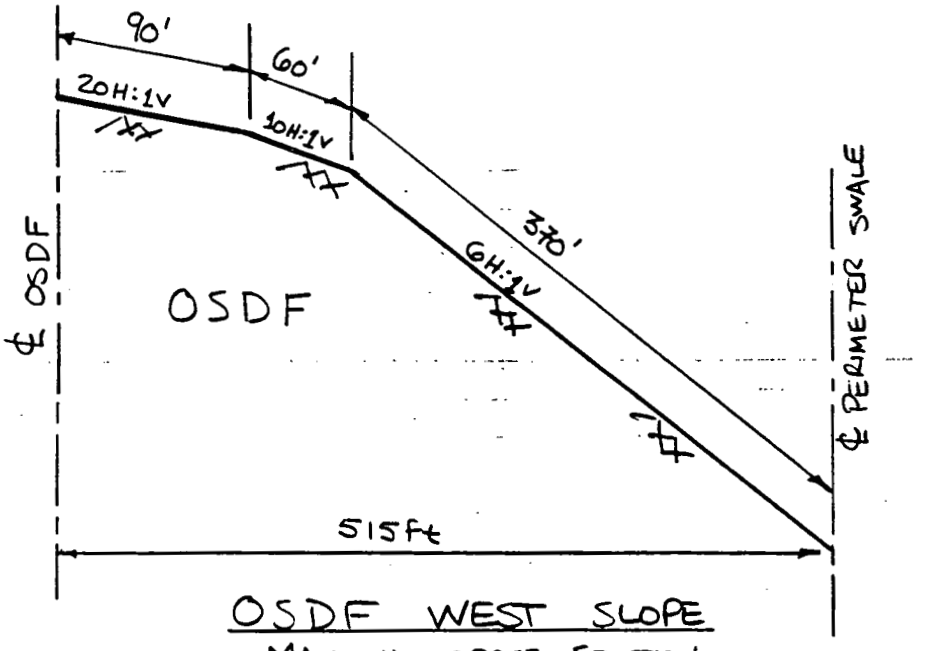


Figure 3 - West-East Cross Section of OSDF. From GeoSyntec [1996]

Written by: D. WARREN Date: 96/02/20 (YY MM DD) Reviewed by: DBW Date: 96/02/20 (YY MM DD)

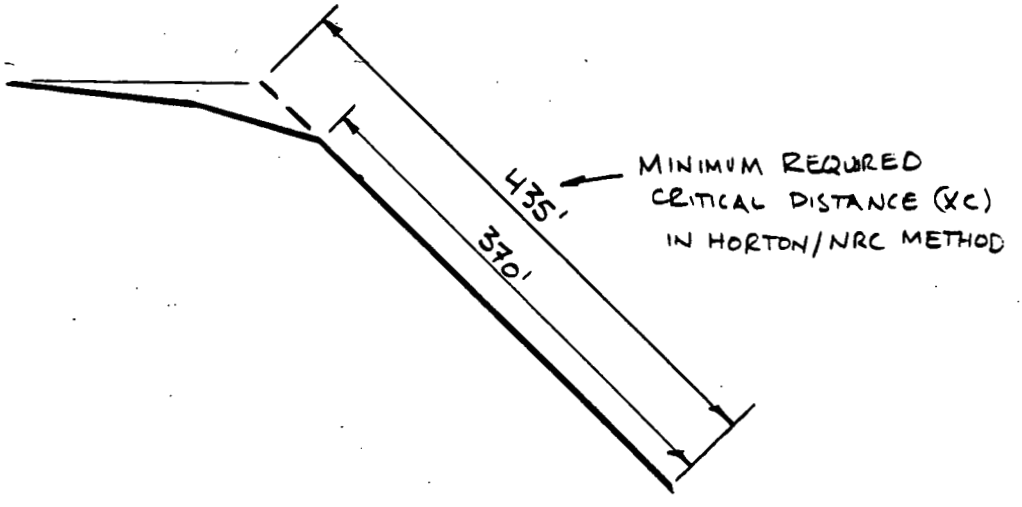
Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

KC 22Feb96
KO 23Feb96



20H:1V = 5%
10H:1V = 10%
6H:1V = 16.7%

OSDF WEST SLOPE
MAXIMUM CROSS-SECTION



PROCEDURE FOR ESTIMATING MINIMUM REQUIRED CRITICAL DISTANCE FOR HORTON/NRC METHOD

Figure 4 - West-Side Slope of OSDF Final Cover, and Estimate of Minimum Required Critical Distance for the Horton/NRC Method. Modified from GeoSyntec [1996]

[redacted]

Written by: DAVE WARREN Date: 19-Feb-96 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

Table 4 - Values for "VM" Factor in MUSLE. Modified from Caltrans [1992]

22 Feb 96
KO 23 Feb 96

CONDITION	VM FACTOR
1. Bare Soil Conditions	
freshly disked to 6-8 inches	1.00
after one rain	0.89
loose to 12 inches smooth	0.90
loose to 12 inches rough	0.80
compacted bulldozer scraped up and down	1.30
same except root raked	1.20
compacted bulldozer scraped across slope	1.20
same except root raked across	0.90
rough irregular tracked all directions	0.90
seed and fertilize, fresh	0.64
same after six months	0.54
seed, fertilizer, and 12 months chemical	0.38
not tilled algae crusted	0.01
tilled algae crusted	0.02
compacted fill	1.24-1.71
undisturbed except scraped	0.66-1.30
scarified only	0.76-1.31
sawdust 2 inches deep, disked in	0.61
4. Seedings	
temporary, 0 to 60 days	0.40
temporary, after 60 days	0.05
permanent, 0 to 60 days	0.40
permanent, 2 to 12 months	0.05
permanent, after 12 months	0.01
5. Brush	0.35
6. Excelsior blanket with plastic net	0.04-0.10
PVA	0.71-0.90
Terra-Tack	0.66
Wood fiber slurry, 1000 lb/acre fresh	0.05-0.73
Wood fiber slurry, 1400 lb/acre fresh	0.01-0.36
Wood fiber slurry, 3500 lb/acre fresh	0.009-0.1

[redacted]

2. THICKNESS OF TOPSOIL AND VEGETATIVE SOIL LAYER AT END OF OSDF DESIGN LIFE

The thickness is calculated by the following equation: $T_t = T_o - t(A / \gamma)$

Where:
- T = thickness of topsoil and vegetative support layers at time t
- T_o = initial thickness of topsoil and vegetative support layers
- t = time after construction of final cover
- A = soil loss rate to sheet and rill erosion
- γ = soil unit weight

2.1 Initial Thickness of Topsoil and Vegetative Soil Layers (T_o)

See Figure 5. T_o = 27 inches

2.2 Time After Construction of OSDF Final Cover (t)

OSDF design life is 200 years up to 1000 years (to the extent practical and achievable)

2.3 Soil Loss Rate to Sheet and Rill Erosion (A)

Determined in MUSLE (Section 1)

2.4 Soil Unit Weight (γ)

Unit weight can be conservatively estimated as: $\gamma \sim G_s\gamma_w(1-n) + \gamma_w(wp)$

Where:
- G_s = specific gravity of soil
- γ_w = unit weight of water
- n = porosity of soil
- wp = wilting point of soil (see below)

The wilting point is the volumetric moisture content at which the soil will no longer give up any moisture to plants. The soil, on average, should have a moisture content higher than the wilting point.

2.4.1 Specific gravity of soil (G_s)

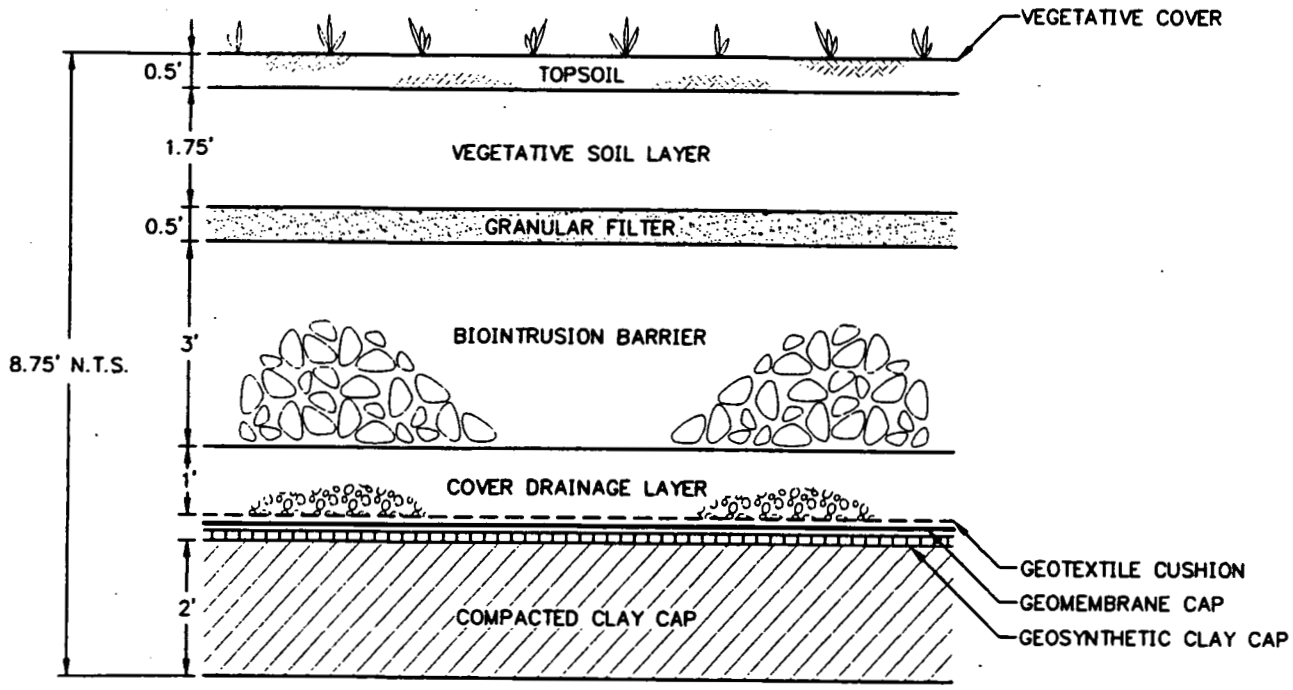
Specific gravity values for soil sampled from the OSDF area and East field borrow area are shown in Table 2. From the table, it can be seen that a low but accurate estimate of G_s is 2.70.

[redacted]

Written By: D. WARREN Date: 96/02/20 Reviewed by: DBW Date: 22 FEB 96

Client: FERMILO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

22 Feb 96
KO 23 Feb 96



FINAL COVER SYSTEM

Figure 5 - Detail of OSDF Final Cover System Components. From GeoSyntec [1996]

[redacted]

22 Feb 96
KO 23 Feb 96

2.4.2 Unit weight of water (γ_w)

Unit weight of water = 62.4 lbs/ft^3 [Daugherty et al, 1985].

2.4.3 Void ratio of soil (n)

See Table 3. The soil textures on lines 1-15 correspond to loose soils, as would be the condition of the topsoil. Both the topsoil and vegetative soil layers are assumed to be loose, to be conservative. The porosity for clay loam or CL (line 11) is: n = 0.464

2.4.4 Wilting point of soil (wp)

See Table 3. For clay loam or CL (line 11) the wilting point is: wp = 0.187

Written by: DAVE WARREN Date: 20-Feb-96 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

22 Feb 96
KO 23 Feb 96
30 Oct 96

3. DESIGN FLOW

Flow is calculated using the rational method: $q = c \cdot i \cdot A \cdot F$ as recommended in USDOE [1989].

Where:
- q = flow (cfs/ft)
- c = runoff coefficient (%)
- i = rainfall intensity for period of interest (in/hr) $\times \frac{1}{3600} \times \frac{1}{12}$
- A = drainage area (longest flow path, ft²)
- F = flow concentration factor (%)

3.1 Runoff Coefficient (c)

When the most intense period of a very large storm (i.e., larger return period than 100-years) hits the OSDF, the final cover topsoil will likely be saturated from rain falling before this time, causing all rain in this period to run off the OSDF. Therefore, use c = 1.0 for storms with return periods larger than 100 years, as recommended by USDOE [1989].

3.2 Rainfall Intensity (i)

The rainfall intensity is calculated by: $i = d / t_c$

Where:
- d = depth of rainfall in the time of concentration
- t_c = time of concentration

3.2.1 Time of concentration (t_c)

3.2.1.1 Flow on vegetative or soil cover

Time of concentration for flow on a soil or vegetated cover is calculated using the method of Brant and Oberman as presented in USDOE [1989]. The equation used is:

$$t_c = C\left(\frac{L}{S \cdot i^2}\right)^{1/3}$$

Where:
- C = coefficient (0.5 for paved areas, 1.0 for bare earth, 2.5 for turf)
- L = distance of overland flow (ft)
- S = slope of land (ft/ft)
- i = rainfall intensity (in/hr)

22 Feb 96 KO 23 Feb 96

Calculating time of concentration with this equation is an iterative procedure, since rainfall intensity has to be assumed for the calculation. Rainfall intensity is assumed, time of concentration calculated, the corresponding rainfall depth is taken from Figure 10 and the rainfall intensity calculated. This procedure is repeated until the assumed rainfall intensity matches that calculated from Figure 10.

3.2.1.2 Flow on a riprap cover (i.e., biointrusion barrier)

Time of concentration for flow on a riprap cover is calculated using the method of Kirpich as presented in NRC [1990]. The equation used is:

$$t_c = \left(\frac{11.5L^3}{H}\right)^{0.385}$$

Where: L = drainage length (miles)
H = elevation difference (ft)

3.2.1.3 Minimum time of concentration

According to USDOE [1989] the time of concentration used to calculate precipitation runoff flow should be no less than 2.5 minutes. This is because for very small values of t_c, small decreases in t_c will cause large increases in rainfall intensity, resulting in very over-conservative estimations of runoff flow.

3.2.2 Depth of rainfall in time of concentration (d)

Figure 9 is a plot of rainfall depth vs. return period. Specific durations of interest ranging from 5 minutes to 24 hours are shown (ex. the 5-minute *duration of interest* is the most intense 5 minutes of the storm in question). Data points are shown for return periods of 2, 5, 10, 25, 50, 100, and 100,000 years (100,000 years is the return period for the probable maximum precipitation, or PMP). PMP data points shown for 1-hour and shorter durations of interest were estimated from Figures 6-8. PMP data points shown for 6-hour and longer durations of interest, and all data points shown for storms with return periods of 100 years or less were taken from Parsons [1995a]. Rainfall depths for the 2000-year storm were estimated by interpolating between 100-year storm and PMP values, as shown on Figure 9.

Figure 10 is a plot of rainfall depth vs. duration of interest. Rainfall depths for durations of interest other than those shown in Figure 9 were estimated from Figure 10. As can be seen in Figure 10, rainfall depths for durations of interest less than 5 minutes were extrapolated from the data.

Written by: DAVE WARREN Date: 96/02/20 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

22 Feb 96
KO 23 Feb 96

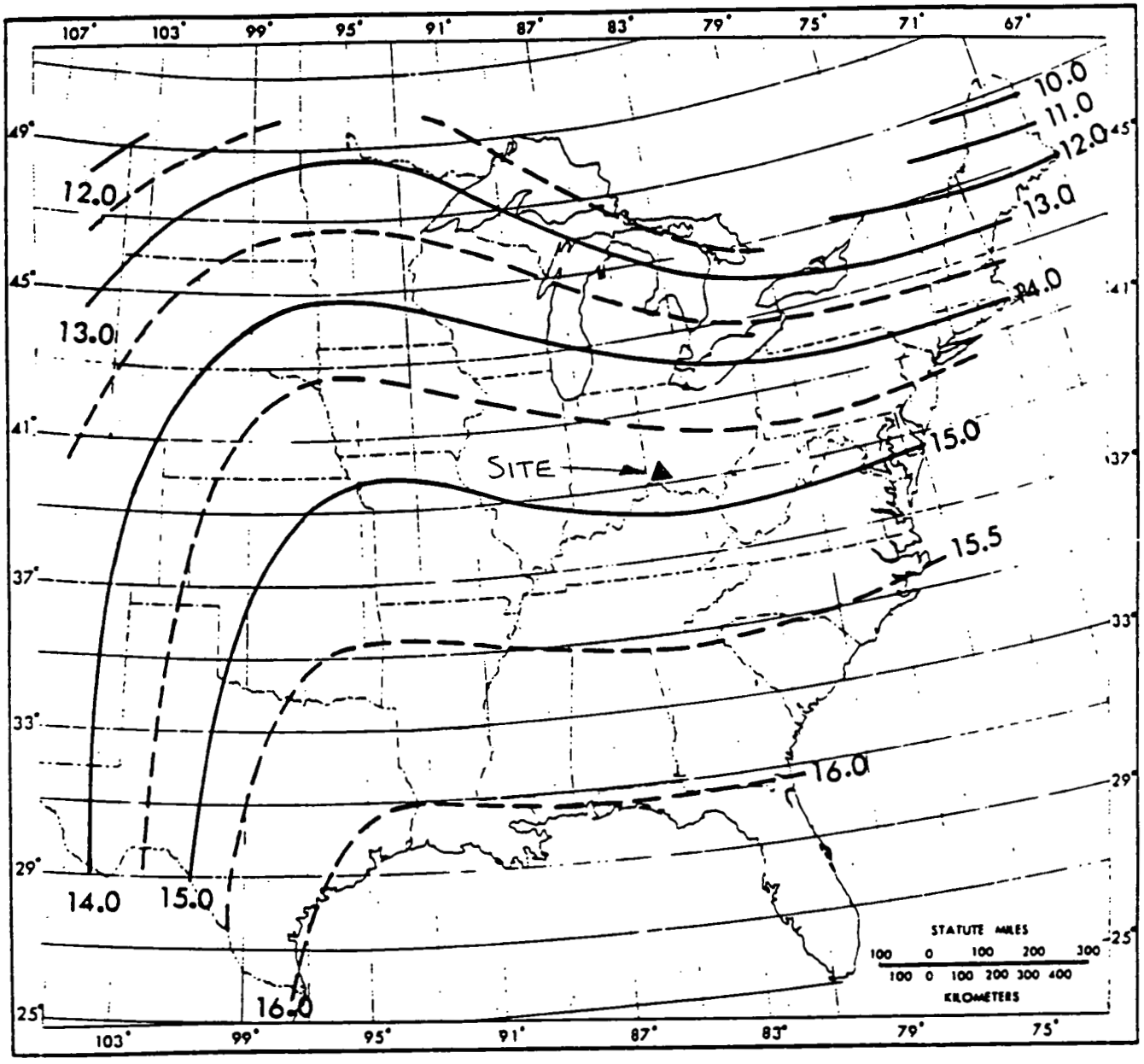


Figure 6 - 1-hour 10-mi^2 PMP Rainfall Depth for the Eastern United States. From Hansen et al., [1982]

[redacted]

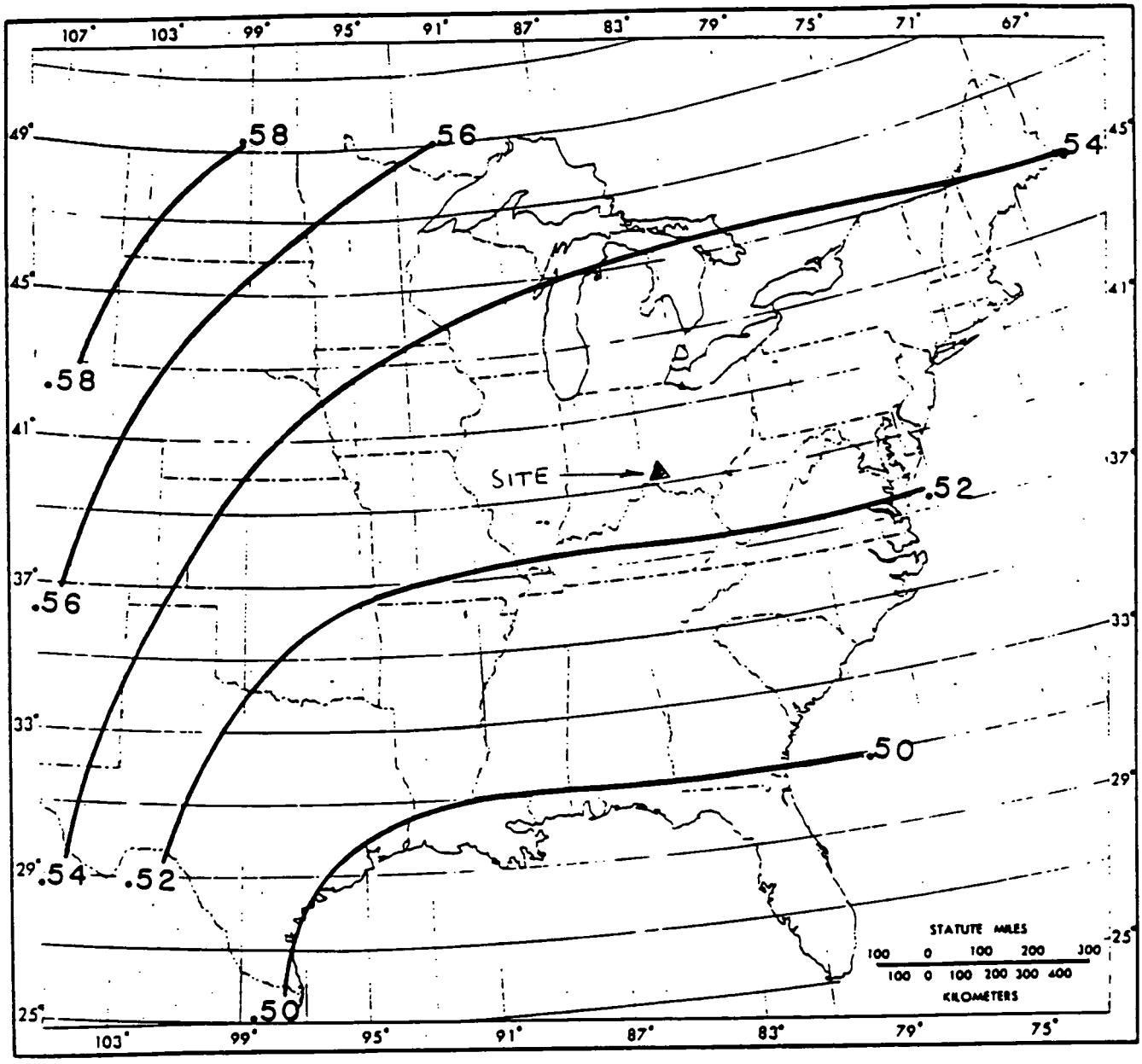


Figure 7 - Ratio of 15- to 60-minute PMP Rainfall Depth (for Areas < 200 mi^2) for Eastern United States. From Hansen et al., [1982]

Written by: DAVE WARREN Date: 96/02/20 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

22 Feb 96
KO 23 Feb 96

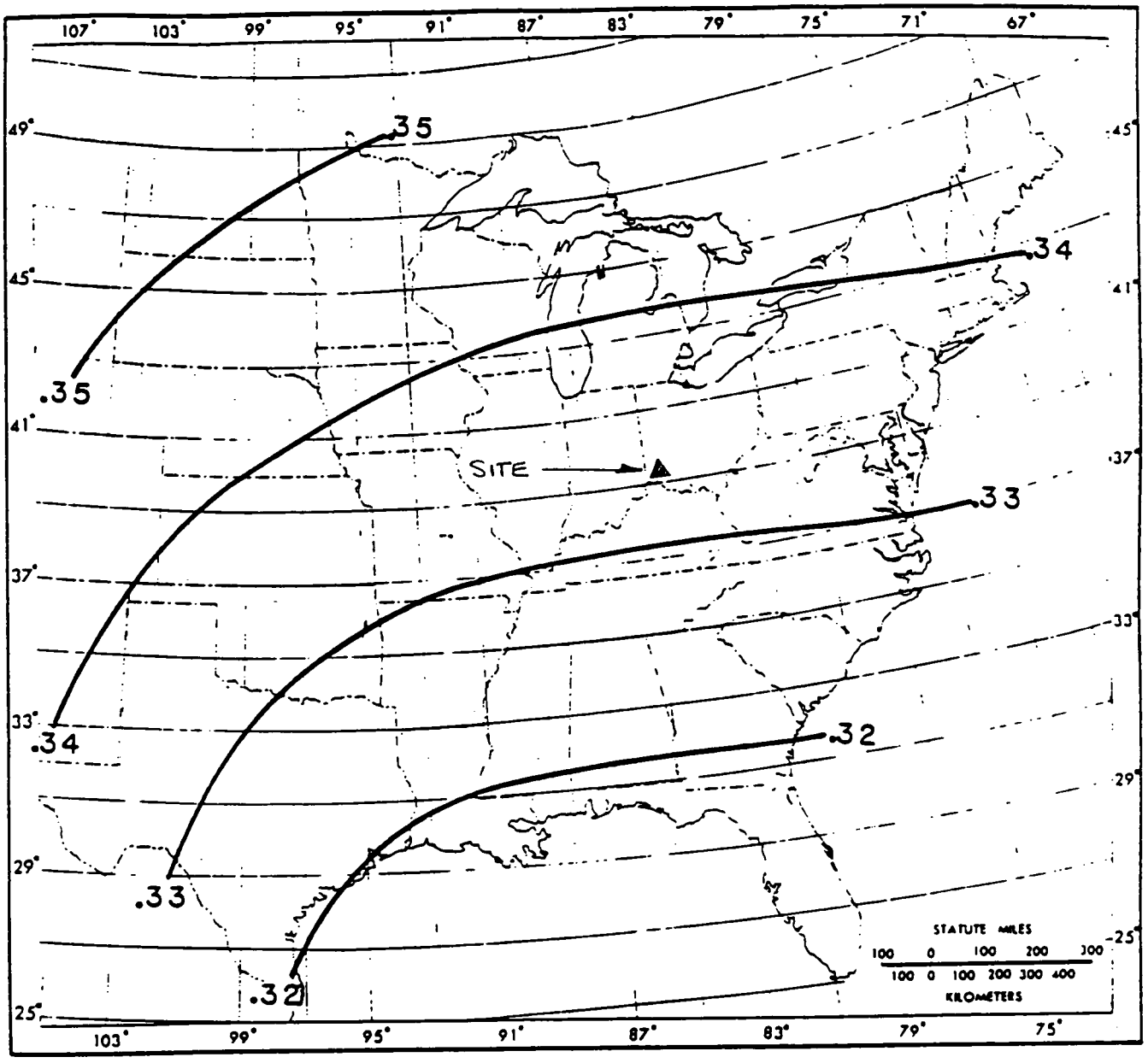


Figure 8 - Ratio of 5- to 60-minute PMP Rainfall Depth (for Areas < 200 mi^2) for Eastern United States. From Hansen et al., [1982]

[redacted]

Written by: DAVE WARREN Date: 96/02/20 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

KL 22Feb96
KO 23Feb96

Rainfall Return Period vs . Depth

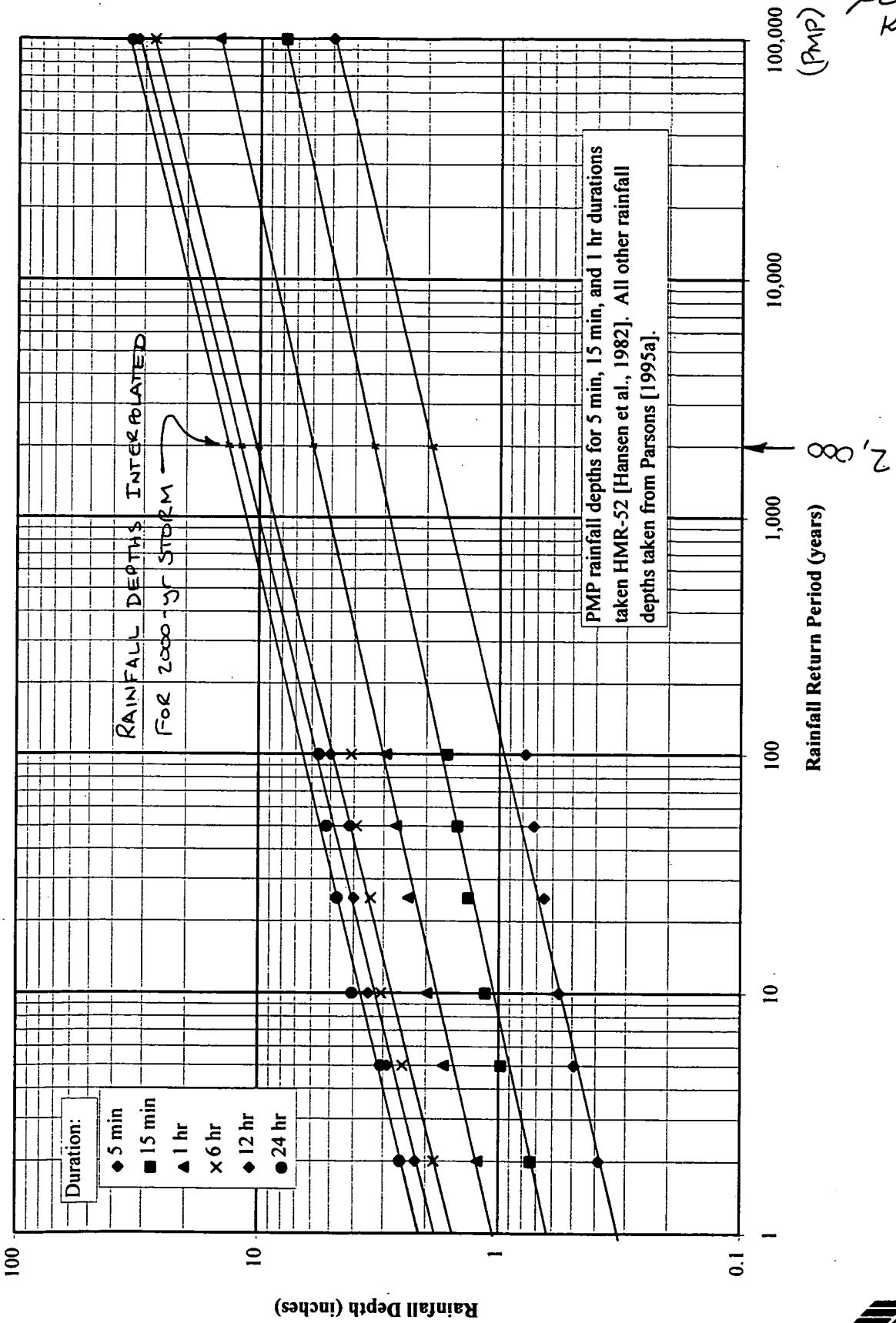


Figure 9 - Plot of Rainfall Return Period vs. Rainfall Depth

Written by: DAVE WARREN Date: 96/02/20 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

22Feb96
KO 23Feb96

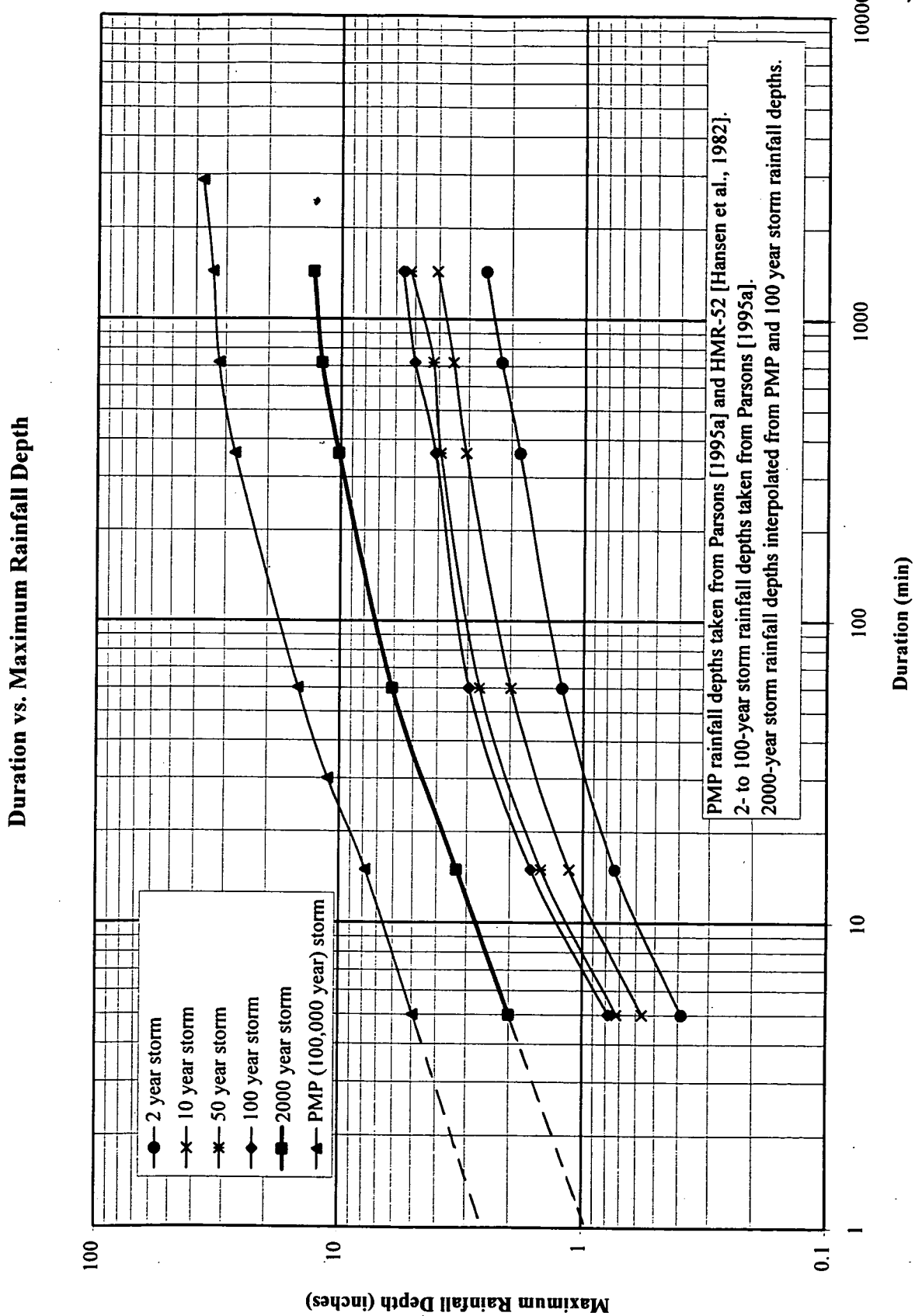


Figure 10 - Plot of Duration vs. Maximum Rainfall Depth

FC 22 Feb 96
KO 23 Feb 96

3.3 Drainage Area (A)

The drainage area used is a one-foot wide strip on the OSDF Final Cover. Geometry of the OSDF is shown in Figures 2 through 4. The critical point will be at the bottom of the west side slope (see Section 1.3), which has a drainage area of 520 ft^2/ft width [90ft (20H:1V) + 60ft (10H:1V) + 370 ft (6H:1V)].

3.4 Flow Concentration Factor (F)

NRC [1990] recommends using a flow concentration factor to account for flow possibly concentrating in rills and gullies. NRC recommends F = 3 for flow on a bare-soil or vegetative cover. The recommendations are based on work by Abt et al. [1987, 1988] who studied flow characteristics and erosion resistance of riprap slopes using flumes. Abt et al. [1988] recommend the following values of F for evaluating erosion resistance of riprap on slopes:

- F = 1.0 for overland sheet flow
- F = 2.0 for a high probability of shallow concentrated flow
- F = 3.0 for a high probability of channelized flow

Caldwell and Reith [1993] recommend using F between 2 and 3 when designing vegetative covers.

Based on Abt et al.'s recommendations, F = 2 should be achievable, as only shallow concentrated flow should occur down the final cover, (channelized flow will only occur in a gully). However, since these recommendations were developed for riprap, and since NRC and Caldwell and Reith recommend using F=3, a flow concentration factor of 3 will be used.

4. TEMPLE METHOD

The Temple Method (more formally the Temple/USDA Method) is used to evaluate the potential for gullies to form in the vegetated cover in the 2000-year storm, and is also used to calculate the allowable shear stress and Manning's roughness coefficient used in the Horton/NRC Method.

4.1 Allowable Shear Stress For Bare Soil (τ_a)

τ_a is calculated from the following equation [Temple et al., 1987]:

$$\tau_a = \tau_{ab}\, C_e^{\,2} \geq 0.02 \text{ lb/ft}^2$$

Where: τ_{ab} = basic allowable shear stress for bare soil (estimated from Figure 11)
C_e = void ratio correction factor (estimated from Figure 12)

4.2 Vegetal Parameters (C_I and C_F)

The Retardence Curve Index, C_I, can be calculated with the following equation [Temple et al., 1987]:

$$C_I = 2.5(h\sqrt{M})^{1/3}$$

Where: h = representative stem length
M = stems per area

C_I can also be taken from Table 5 for good uniform stands of grass. Values for the Vegetal Cover Factor (C_F) for good uniform stands of grass also appear in Table 5. Values of C_I and C_F for good uniform stands of grass in each SCS vegetal retardance class are inferred from Table 5.

For uniform stands of grass other than "good" quality, C_F is changed following the guidance in Table 5, and C_I is changed by adjusting the stem density per the guidance in Table 5 and figuring the corresponding change in C_I from the equation above. For going from "good" to "fair" quality uniform grass , C_F changes by a factor of 0.8, and the stem density changes by a factor of 2/3, which means C_I changes by a factor of $[(2/3)^{1/2}]^{1/3} = 0.9347$.

Further description of grasses corresponding to SCS retardance classes is given in Table 6. Preliminary recommended grasses for the OSDF final cover are shown in Table 7. According to Freshley [1996], SCS vegetal retardance class B should be attainable with native grasses on the OSDF final cover. Nevertheless, all vegetal retardance classes are analyzed to estimate the effect of less strong vegetation on erosion resistance.

4.3 Design Flow Per Unit Width (q)

See Section 3.

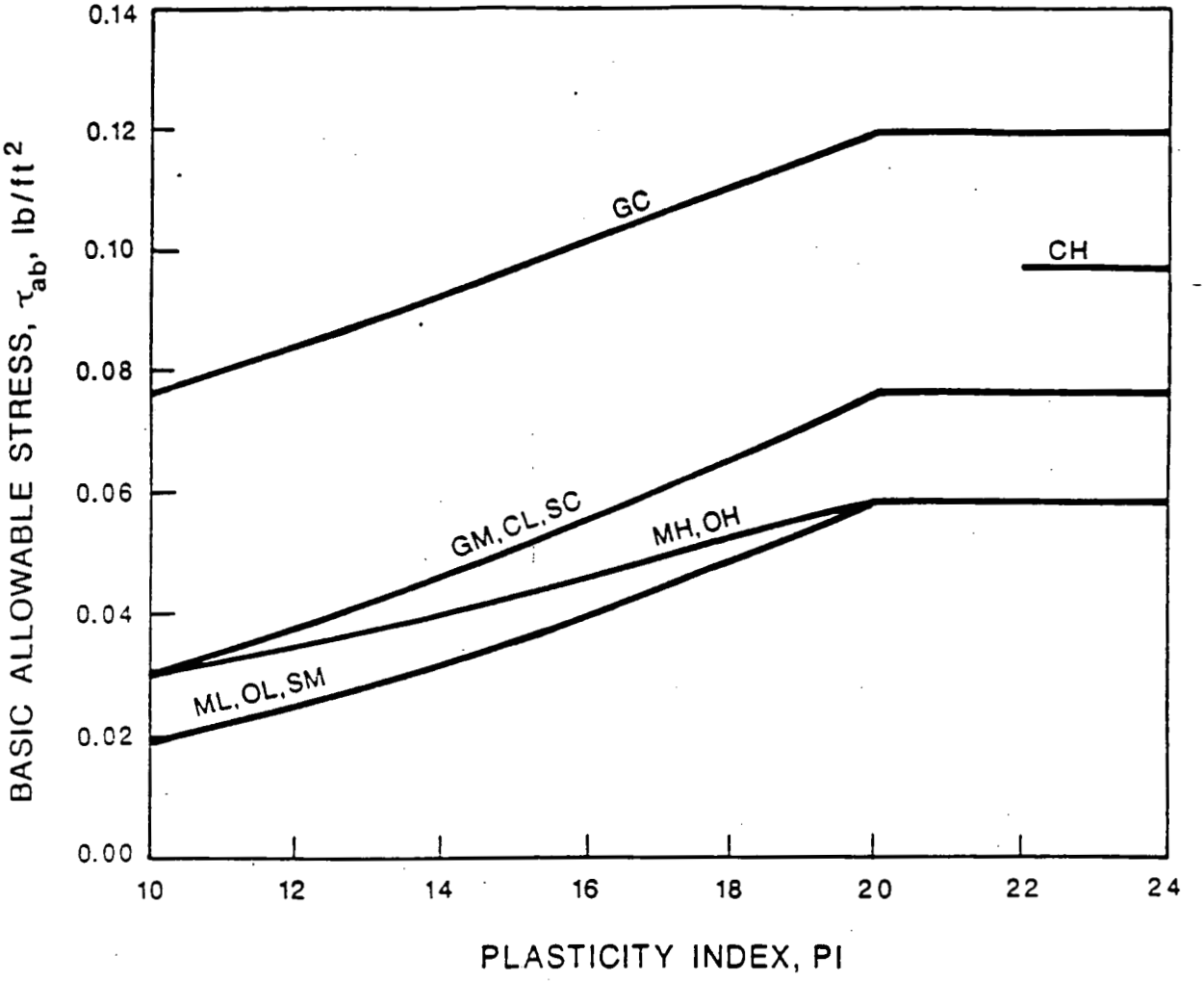
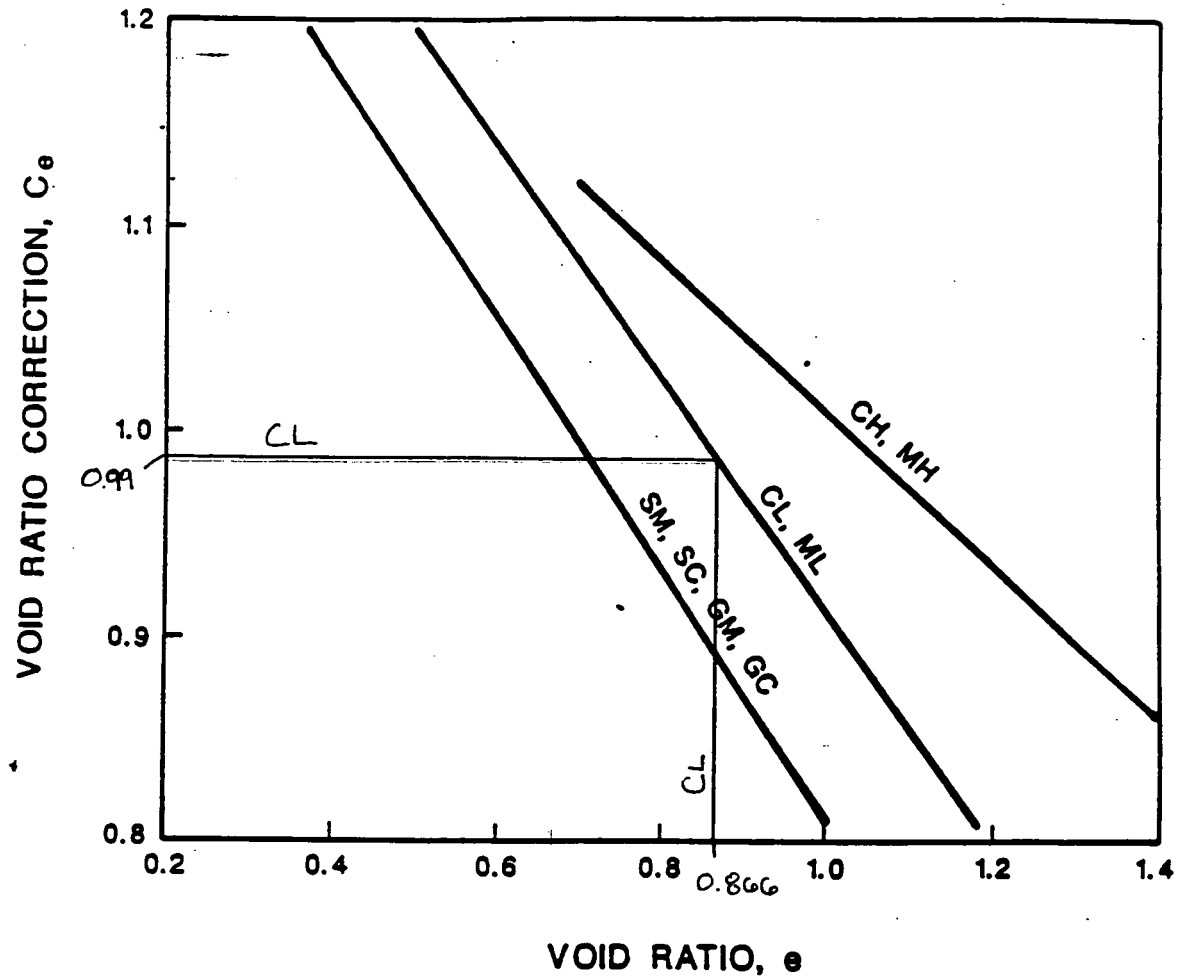


Figure 11 - Graph for Estimating τ_{ab} From USDOE [1989]

Written by: DAVE WARREN Date: 96/02/20 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

KC 22 Feb 96
KO 23 Feb 96



$n = 0.464$ (TABLE 3 LINE 11) (Clay Loam or CL)

$$e = \frac{n}{1-n} = \frac{0.464}{1-0.464} = 0.866 \checkmark$$

Figure 12 - Graph for Estimating C_e From USDOE [1989]

[redacted]

Written by: DAVE WARREN Date: 19-Feb-96 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

FC 22 Feb 96
KO 23 Feb 96

Table 5 - *Values of C_I and C_f for Good Uniform Stands of Grass. Modified from USDOE [1989]*

SCS RETARDANCE CLASS	Cover	C_f	C_I[a]	Reference stem density (stems/square foot)[b]
A	Burmuda grass, 12-inch height	0.9	10.00	500
	Weeping lovegrass			500
B	Buffalo grass			400
	Kentucky bluegrass	0.87	7.64	350
	Blue gramma			350
C	Grass-legume mixture	0.75	5.60	200
	Weeping lovegrass	0.75	5.60	350
	Burmuda grass, 6-inch height	0.75	5.60	350
	Yellow bluestem	0.75	5.60	350
D	Alfalfa[c]	0.5	4.44	350
	Lespedeza sericea, 2-inch height[c]	0.5	4.44	300
	Common lespedeza	0.5	4.44	150
E	Sudan grass	0.5	2.88	50
	Bermuda grass, burned stubble	0.5	2.88	50

[a]If vegetation is not uniformly distributed over the areas present, C_I and C_f will be set equal to zero. In other words, the cover will be designed as if it were bare soil only.

[b]Multiply the stem densities given by 1/3, 2/3, 1, 4/3, and 5/3, for poor, fair, good, very good, and excellent covers, respectively. The equivalent adjustment to C_f remains a matter of engineering judgment until more data are obtained or a more analytical model is developed. A reasonable, but arbitrary, approach is to reduce the cover factor by 20 percent for fair stands and 50 percent for poor stands. Values of C_f for untested covers may be estimated by recognizing that the cover factor is dominated by density and uniformity of cover near the soils surface. Thus, the sod-forming grasses near the top of the table exhibit higher C_f values than the bunch grasses and annuals near the bottom.

[c]For the legumes tested, the effective stem count for resistance (given) is approximately five times the actual stem count very close to the bed. Similar adjustment may be needed for other unusually large-stemmed, branching, and/or woody vegetation.

Table 6 - Examples of Vegetal Cover in Each Retardance Class. From USDA-SCS [1986]

Retar-dance	Cover	Condition
A	Reed canarygrass	Excellent stand, tall (average 36 inches)
	Yellow bluestem Ischaemum	Excellent stand, tall (average 36 inches)
B	Smooth bromegrass	Good stand, mowed (average 12 to 15 inches)
	Bermudagrass	Good stand, tall (average 12 inches)
	Native grass mixture (little bluestem, blue grama, and other long and short midwest grasses)	Good stand, unmowed
	Tall fescue	Good stand, unmowed (average 18 inches)
	Lespedeza sericea	Good stand, not woody, tall (average 19 inches)
	Grass-legume mixture--Timothy, smooth bromegrass, or orchard grass	Good stand, uncut (average 20 inches)
	Reed canarygrass	Good stand, mowed (average 12 to 15 inches)
	Tall fescue, with bird's foot trefoil or lodino	Good stand, uncut (average 18 inches)
	Blue grama	Good stand, uncut (average 13 inches)
C	Bahia	Good stand, uncut (6 to 8 inches)
	Bermudagrass	Good stand, mowed (average 6 inches)
	Redtop	Good stand, headed (15 to 20 inches)
	Grass-legume mixture--summer (Orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6 to 8 inches)
	Centipedegrass	Very dense cover (average 6 inches)
	Kentucky bluegrass	Good stand, headed (6 to 12 inches)
D	Bermudagrass	Good stand, cut to 2.5-inch height
	Red fescue	Good stand, headed (12 to 18 inches)
	Buffalograss	Good stand, uncut (3 to 6 inches)
	Grass-legume mixture--fall, spring (Orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (4 to 5 inches)
	Lespedeza sericea	After cutting to 2-inch height. Very good stand before cutting
E	Bermudagrass	Good stand, cut to 1.5-inch height.
	Bermudagrass	Burned stubble.

22 Feb 96
KO 23 Feb 96

Written by: DAVE WARREN Date: 19-Feb-96 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

Table 7 - Prelimininary Recommended Grass Seed Mixes for Planting on the OSDF Final Cover. From Earth Systems Associates [1996]

22 Feb 96
KO 23 Feb 96

Slope - Moisture Class	Species/Planting Period Class			
	Native Species / Apr. - May[1]		Pasture Species / Mar. 15 - May or Aug. - Sep.	
	Species[2]	lb/ac	Species	lb/ac
Wet Swales - Waterways	Big Bluestem Switchgrass	10 5	Reed Canary Grass Kentucky Bluegrass[3] Alsike Clover	8 10 5
Moist Slopes of 1% - 9%	Big Bluestem Indian grass Canada Wild Rye Switchgrass	5 5 1 3	Creeping Red Fescue Annual Ryegrass Kentucky Bluegrass[3] Alsike Clover	20 10 15 5
Dry Slopes of 10% - 17%	Big Bluestem Indian grass Canada Wild Rye Switchgrass	5 5 3 5	Creeping Red Fescue Annual Ryegrass Kentucky Bluegrass[3] Flat pea	20 10 10 5

[1] - Switchgrass should be frost seeded (Jan. - Feb.) by broadcasting into wintercover.
[2] - Species other than switchgrass planted by drilling during April - May.
[3] - Substitute Red Top on strongly acid sites.

4.4 Manning's Roughness Coefficient for Vegetated Cover (n)

KC 22 Feb 96
KD 23 Feb 96

Manning's n is calculated from the equation shown below [Temple et al., 1987], which was developed as a curve-fitting equation to the SCS vegetal retardance curves, shown in Figure 13. Manning's n calculated below is also used in the Horton/NRC Method (Section 5).

$$n = e^{0.01329C_I(\ln q)^2 - 0.09543C_I(\ln q) + 0.2971C_I - 4.16} \quad \text{for } 0.0025C_I \le q \le 36 \text{ cfs/ft}$$

If $q < 0.0025C_I$, replace q with $0.0025C_I$ in the above equation. $q \le 36$ cfs/ft in all cases considered in these calculations

4.5 Flow Depth (D)

Flow depth can be calculated from Manning's equation [USDOE, 1989]:

$$D = \left(\frac{qn}{1.49S^{1/2}}\right)^{3/5} \quad \text{Where:} \quad S = \text{slope (Section 4.5.1)}$$

4.5.1 Slope to use (S)

See Section 1.3. The steepest and most critical segment of the OSDF side slopes is at 6H:1V, or 16.7%. This value is used as the slope in the Temple Method.

4.6 Shear Stress Applied By Flow (τ_o)

The shear stress applied by flowing water is calculated by the Duboys formula [Temple, 1987]:

$$\tau_o = \gamma_w DS$$

Where: γ_w = unit weight of fluid (water), 62.4 lb/ft^3

GEOSYNTEC CONSULTANTS

Written by: DAVE WARREN Date: 96/02/20 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

22Feb96
KO 23 Feb 96

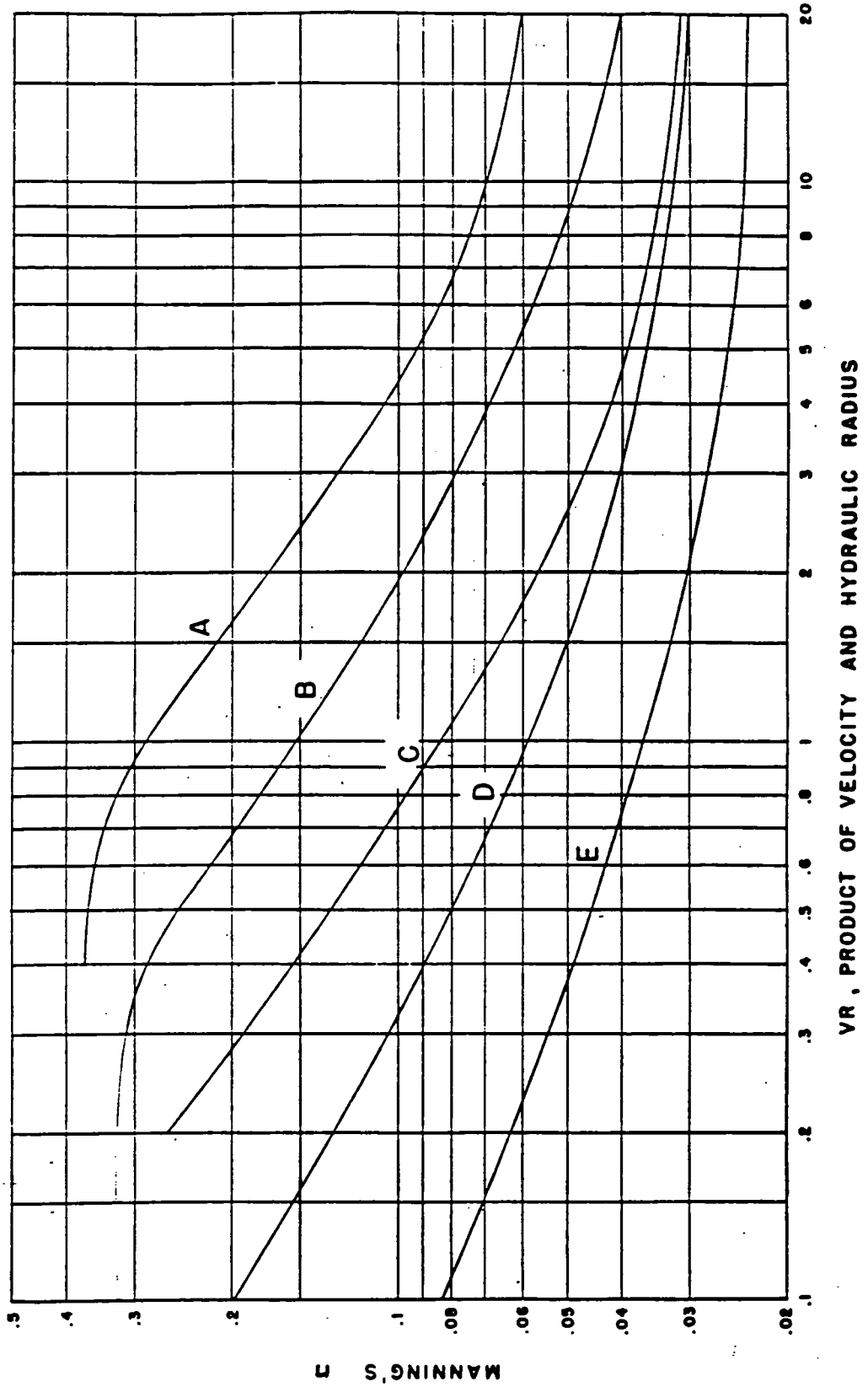


Figure 13 - Curves of Manning's n vs. VR for "Average Uniform Stands" of Grasses in Each SCS Vegetal Retardance Class. From USDA-SCS [1986]

See Table 6 for more information on SCS vegetal retardance classes A - E

4.7 "Effective" Shear Stress Applied to Soil (τ_e)

FC 22 Feb 96
KO 23 Feb 96

The "effective" shear stress applied to the soil (τ_e) is compared to the allowable shear stress for bare soil (τ_a). If $\tau_e \leq \tau_a$ gullies should not form in the soil. τ_e is calculated with the following equation [Temple et al., 1987]:

$$\tau_e = \gamma_w DS(1 - C_F)\left(\frac{n_s}{n}\right)^2$$

Where: γ_w = unit weight of fluid (water), 62.4 lb/ft^3
n_s = Manning's roughness coefficient for bare soil (Section 4.7.1)

4.7.1 Manning's roughness coefficient for bare soil (n_s)

According to Temple et al. [1987], $n_s = 0.0156$ for soils with $d_{75} < 0.05$ in (d_{75} is the diameter which 75% of the soil particles are smaller than). Most USCS fine-grained soils will have $d_{75} < 0.05$ in, and the final cover topsoil is assumed to have $d_{75} < 0.05$ in.

Therefore, $n_s = 0.0156$

5. HORTON/NRC METHOD

The Horton/NRC Method is also used to evaluate the potential for gullies to form in the vegetated cover during the 2000-year storm. The method can be used to estimate the critical distance on a slope before gully formation begins (xc). The equation used is [NRC, 1990]:

$$xc = \frac{65R^{5/3}}{F \cdot qs \cdot n \cdot f(S)^{5/3}}$$

Where: R = allowable shear stress (psf) F = flow concentration factor
qs = rainfall intensity (in/hr) n = Manning's roughness coefficient
f(S) = slope function

Both R and n are calculated using the Temple Method.

The minimum required critical distance is 435 feet, shown in Figure 4.

5.1 Allowable Shear Stress (R)

The allowable shear stress is calculated from the Temple Method, using the minimum result of the two equations shown below. Equation 1 is based on allowable soil stress. Equation 2 is based on allowable vegetal stress.

$$R = \frac{\tau_a}{(1 - C_F)\left(\frac{n_s}{n}\right)^2} \quad (1) \qquad R = \tau_{va} = 0.75\, C_I \quad (2)$$

Where: τ_a = allowable shear stress on bare soil
C_F = vegetal cover factor
n_s = Manning roughness coefficient for bare soil
n = Manning roughness coefficient for grass cover
τ_{va} = limiting vegetal stress (stress at which vegetation will break)
C_I = vegetal retardance curve index

5.2 Flow Concentration Factor (F)

See Section 3.4

5.3 Rainfall Intensity (qs)

Same as "i" - see Section 3.2

KC 22 Feb 96
KO 23 Feb 96

5.4 Manning Roughness Coefficient (n)

See Section 4.4

5.5 Slope Function, f(S)

The slope function is calculated by the equation below [NRC, 1990]:

$$f(S) = \frac{\sin\theta}{(\tan\theta)^{0.3}}$$

Where θ = slope angle = 9.46 deg for a 6H:1V slope

6. PERMISSIBLE VELOCITY METHOD

The Permissible Velocity Method is also used to evaluate the potential for gullies to form in the vegetated cover during the 2000-year storm. NRC [1990] recommends checking results of the Horton/NRC Method against those of the Permissible Velocity Method.

6.1 Flow Velocity (V)

The flow velocity is calculated from the following equation: $V = q / D$

Where: q = flow per unit width (Section 3)
D = flow depth (Section 5.5)

6.2 Permissible Velocity (V_{per})

Recommended permissible velocities for different vegetated channel linings are shown in Table 8. Permissible velocities corresponding to different SCS vegetal retardance classes are interpreted from this table using judgement, as shown below:

Grass Cover Retardance Class	Grass Cover Stand Quality	Permissible Velocity
A	Good	6.0 ft/sec
	Fair	5.5 ft/sec
B	Good	5.0 ft/sec
	Fair	4.5 ft/sec
C	Good	4.0 ft/sec
	Fair	3.75 ft/sec
D	Good	3.5 ft/sec
	Fair	3.25 ft/sec
E	Good	3.5 ft/sec
	Fair	3.0 ft/sec

Furthermore, as interpreted from the notes in Table 8, grass covers of retardance class C are not recommended for (lining grass channels) on slopes greater than 10%, and those of class D and E are not recommended (for lining grass channels) on slopes greater than 5%.

These permissible velocities shown above are further reduced by a reduction factor (R) when the flow depth is less than 3 feet [NRC, 1990].

Table 8 - Recommended Permissible Velocities for Different Vegetated Channel Linings. From USDA-SCS [1986]

Cover	Slope range 2/ (percent)	Permissible velocity 1/	
		Erosion resistant soils (ft.per sec.)	Easily eroded soils (ft.per sec.)
Bermudagrass	0-5 5-10 over 10	8 7 6	6 5 4
Bahia Buffalograss Kentucky bluegrass Smooth brome Blue grama Tall fescue	0-5 5-10 over 10	7 6 5	5 4 3
Grass mixtures Reed canarygrass	2/ 0-5 5-10	5 4	4 3
Lespedeza sericea Weeping lovegrass Yellow bluestem Redtop Alfalfa Red fescue	3/ 0-5	3.5	2.5
Common lespedeza 4/ Sudangrass 4/	5/ 0-5	3.5	2.5

1/ Use velocities exceeding 5 feet per second only where good covers and proper maintenance can be obtained.

2/ Do not use on slopes steeper than 10 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.

3/ Do not use on slopes steeper than 5 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.

4/ Annuals--use on mild slopes or as temporary protection until permanent covers are established.

5/ Use on slopes steeper than 5 percent is not recommended.

6.2.1 Reduction factor (R)

22 Feb 96
KO
23 Feb 96

R is calculated by the following equation :

$$R = 0.46 \log(D) + 0.78 \qquad (0.5 \leq R \leq 1.0)$$

This equation is interpreted from the following data given by NRC [1990]:

Flow Depth	Reduction Factor
3.0 ft or greater	1.0
1.9 ft	0.9
1.0 ft	0.8
0.65 ft	0.7
0.40 ft	0.6
0.25 ft or less	0.5

7. DESIGN FLOW PER UNIT WIDTH IN A GULLY PENETRATING TO THE BIOINTRUSION BARRIER

The flow per unit width for sheet flow down the OSDF cover is given in Section 3. However, if the biointrusion barrier is exposed, it will be at the bottom of a gully, and therefore the flow per unit width over the biointrusion barrier riprap will be larger than that for sheet flow.

7.1 Assumed Gully Geometry

To calculate flow over the biointrusion barrier, a trapezoidal gully with a one-foot bottom width and side slopes of 2H:1V is assumed to occur. A narrow gully like this will be more critical than a wider gully, because as a gully widens, conditions in the gully will move closer to sheet flow, and the maximum flow per unit width in the gully will decrease. The side slopes of the gully will be at least as steep as the angles of repose of the materials (the topsoil, vegetative support, and gravel choke layers), which should all be > 2H:1V, making 2H:1V side slope a conservative assumption (the flatter the side slopes, the larger the flow per unit width in the gully center). The geometry is shown in Figure 14.

7.2 Total Flow in Gully (Q)

Total flow in a gully is calculated by: $Q = qW$

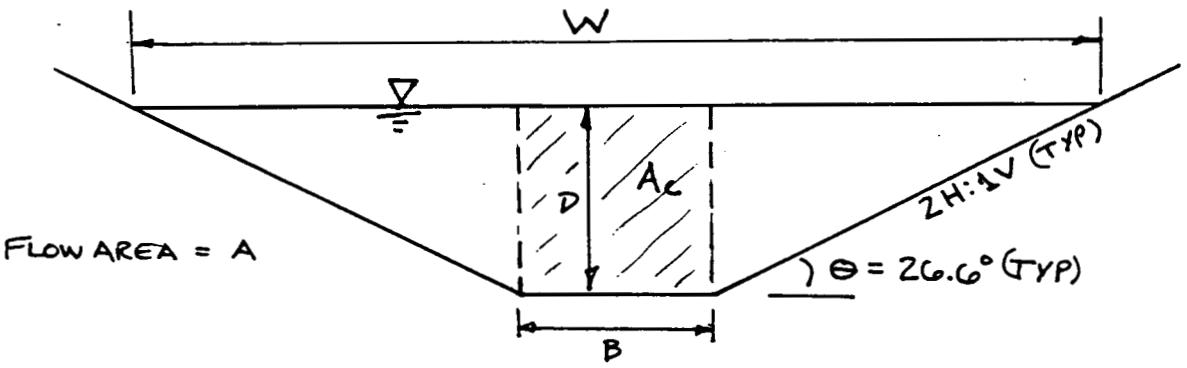
Where; q = flow per unit width for sheet flow (Section 3)
W = top width of gully (Figure 14)

Note that this will give the flow in a gully that extends all the way up the OSDF final cover. This is conservative, since most gullies probably will not extend all the way up the final cover.

Written by: D. WARREN Date: 96 / 02 / 20 (YY MM DD) Reviewed by: DBW Date: 96 / 02 / 22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

22 Feb96
23 Feb96



$$W = B + 2(D \cot\theta) \qquad A_c = BD$$

$$A = \frac{(B+W)}{2} D = \frac{2B + 2D\cot\theta}{2} D = BD + D^2 \cot\theta$$

MAX FLOW PER UNIT WIDTH = q_{MAX}
TOTAL FLOW IN CHANNEL = Q

$$q_{MAX} = Q \frac{A_c}{A} = Q \frac{BD}{BD + D^2 \cot\theta}$$

Figure 14 *- Assumed Cross-Section of Gully Penetrating the OSDF Final Cover to the Biointrusion Barrier, and Method for Calculating Maximum Flow Per Unit Width*

[redacted]

22 Feb 96
KO 23 Feb 96

7.3 Maximum Flow Depth in Gully (D)

The maximum flow depth (D) in a gully (Figure 14) is found by trial and error by estimating D, calculating the corresponding flow with Manning's equation, and comparing that flow to the flow from Section 7.2. D is iterated until the two flows are equal. Manning's equation for open-channel flow is [Daugherty et al., 1985]:

$$Q = \frac{1.49}{n} A R_h^{2/3} S^{1/2}$$

Where: n = Manning's roughness coefficient (Section 7.2.1)
A = flow area (Figure 14)
R_h = hydraulic radius = area / wetted perimeter
S = slope = 6H:1V (Section 1.3)

Equations relating D to A and R_h are shown in Figure 14.

Note that for flow down steep riprap slopes, Manning's equation may not be valid (Section 9.1)

7.3.1 Manning's roughness coefficient (n)

Manning's n is calculated using the method recommended by NRC [1990] for sheet flow over riprap slopes.

$n = 0.0456 (D_{50} \times S)^{0.159}$ Where: D_{50} = mean riprap size (inches)
S = slope

Riprap with D_{50} = 12 inches will be placed in the biointrusion barrier

7.4 Maximum Flow Per Unit Width (q_{max})

The maximum flow per unit width is calculated by assuming the flow per unit area is constant over an entire flow cross-section and taking the flow in the center 1-foot strip of the cross section (see Figure 14). The equation used is:

$q_{max} = Q (A_c / A)$ Where: A_c = flow area in center 1-foot of channel

q_{max} is the design flow rate used to evaluate the erosion resistance of the biointrusion barrier riprap.

8. STEPEHENSON METHOD

The Stephenson Method [Abt et al., 1988] is used to evaluate the resistance of the biointrusion barrier against gully advancement, should a gully erode through the overlying topsoil, vegetative support, and gravel choke layers. This method is based on work by Olivier [1967] who studied flow over riprap on slopes, for the purpose of designing rockfill dams to be overtopped. This method is recommended by NRC [1990] for evaluating the erosion resistance of slopes greater than 10%.

The acceptable riprap mean particle diameter (D_{50}) to survive the design flow is calculated with the following equation [Abt et al., 1988]:

$$D_{50} = \left[\frac{q(\tan\theta)^{7/6} n_p^{\ 1/6}}{Cg^{1/2}\left[(1-n_p)(G_s-1)\cos\theta(\tan\phi-\tan\theta)\right]^{5/3}} \right]^{2/3}$$

Where:
- q = design flow per unit width
- θ = slope = 0.167 ft/ft (Section 5.)
- n_p = porosity of riprap
- C = empirical factor
- g = acceleration of gravity (32.2 ft/s^2)
- G_s = specific gravity of riprap
- ϕ = angle of repose of riprap

Riprap with a D_{50} calculated by the above equation will be on the threshold of movement at the flow value (q) used. The riprap layer will completely collapse at a flow varying from 120% (gravel) to 180% (crushed granite) of q [Stephenson, 1979].

8.1 Design Flow Per Unit Width (q)

$q = q_{max}$ See Section 7

8.2 Porosity of Riprap (n_p)

Porosities for different soil textures are shown in Table 3, where it can be seen that porosity decreases with increasing particle size, and for the coarsest soil listed (gravel), n_p = 0.397.

8.3 Empirical Factor (C)

C varies from 0.22 for gravel to 0.27 for crushed granite [Stephenson, 1979]. Using a low value of C (0.22) is conservative

22 Feb 96
KO 23 Feb 96

8.4 Specific Gravity of Riprap, G_s

Where G_s is not specifically known, $G_s = 2.65$ is recommended [USDOE, 1989]

8.5 Angle of Repose of Riprap (ϕ)

See Figure 15. From Figure 15, a conservative estimate of ϕ for crushed stone riprap with D_{50} of 12 inches is 41 degrees.

Written by: DAVE WARREN Date: 4-Feb-96 Reviewed by: DBW Date: 22 FEB 96

Client: FERMCO Project: ON-SITE DISPOSAL FACILITY Project/Proposal No.: GE3900 Task No.: 08.2

KL 22 Feb 96
KO 23 Feb 96

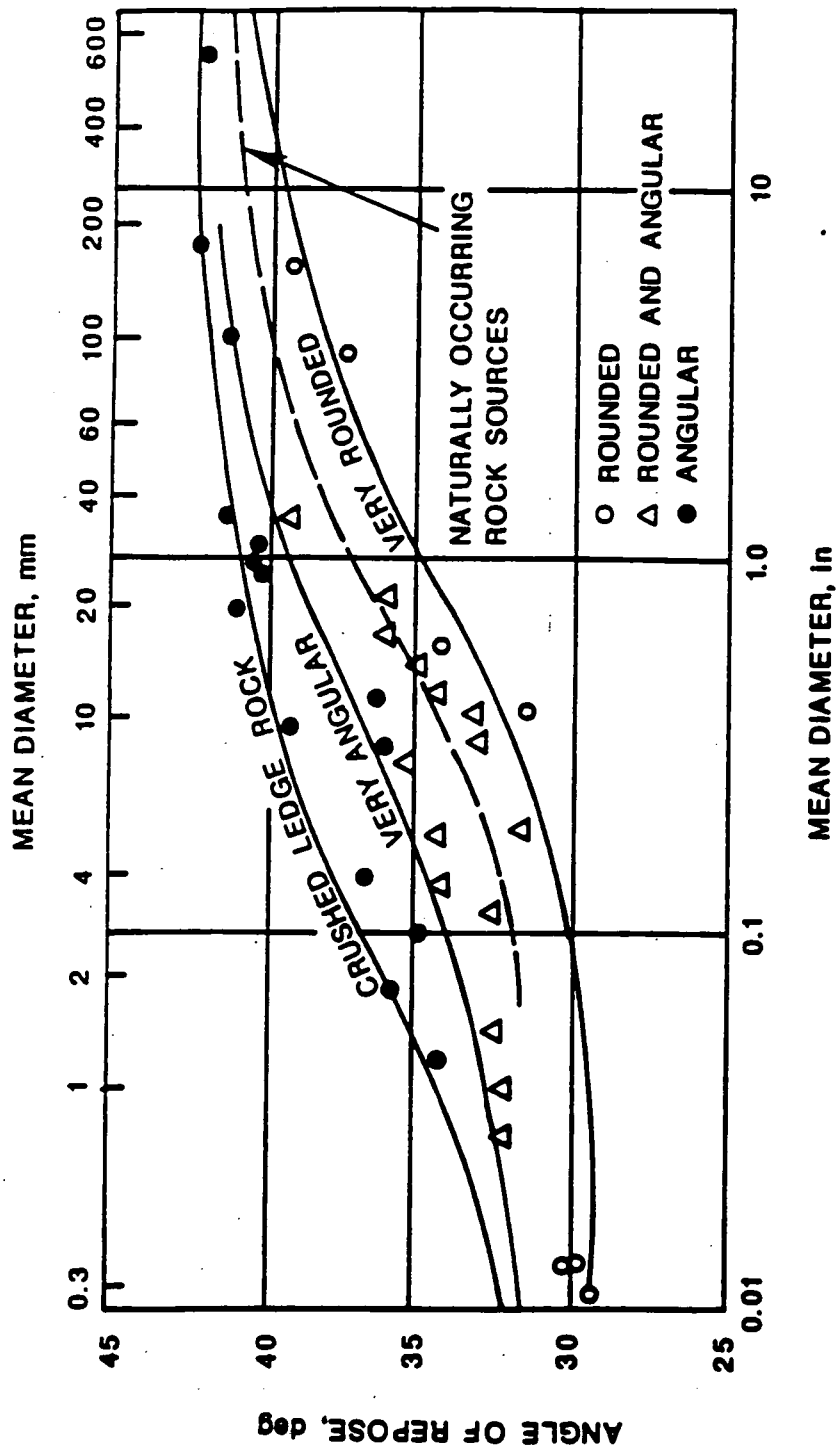


Figure 15 - Angle of Repose for Rock of Various Mean Diameters. From Abt et al. [1987]

9. HARTUNG AND SCHEUERLEIN METHOD

The Hartung and Scheuerlein Method (H&S Method) [Hartung and Scheuerlein, 1970] is used to evaluate the resistance of the biointrusion barrier against gully advancement, should a gully erode through the overlying topsoil, vegetative support, and gravel choke layers. Hartung and Scheuerlein studied flow over riprap on steep slopes (10H:1V to 1.5H:1V), and developed their method for the purpose of designing rockfill dams to be overtopped. Knauss [1979] compared the H&S Method to Olivier's Method (the Stepehenson Method is based on Olivier's Method). Knauss found both to be in general agreement for slopes flatter than 5H:1V, but found the H&S Method to be reasonable and Olivier's Method over-conservative for steeper slopes. Based on this, Knauss recommended using the H&S Method on slopes of 5H:1V or steeper. Though the steepest slope on the OSDF final cover is 6H:1V (within the range Knauss found both methods to agree), the Hartung and Scheuerlein Method is used for comparison with the results of the Stephenson Method.

The steps for the Hartung and Scheuerlein Method are presented below:

9.1 Maximum Flow Depth in Gully, D

The maximum flow depth is an iterated variable. D is selected until the average flow velocity (v_{avg}) equals the critical velocity (v_{crit}). Both velocities are calculated in the steps that follow.

9.2 Aeration Factor (σ)

The aeration factor is calculated from the equation shown below[Hartung and Scheuerlein, 1970]:

$$\sigma = 1 - 1.3\sin\varphi + 0.08\frac{y_m}{\theta_m} \leq 1$$

Where: φ = slope (6H:1V, Section 1.3)
y_m = mean flow depth
θ_m = mean roughness height

If σ = 1, there is no aeration in the flow and flow can be calculated with Manning's equation. Otherwise, Manning's equation is not valid [Hartung and Scheuerlein, 1970].

9.1.1 Mean flow depth (y_m)

See Figure 16

9.1.2 Mean roughness height (θ_m)

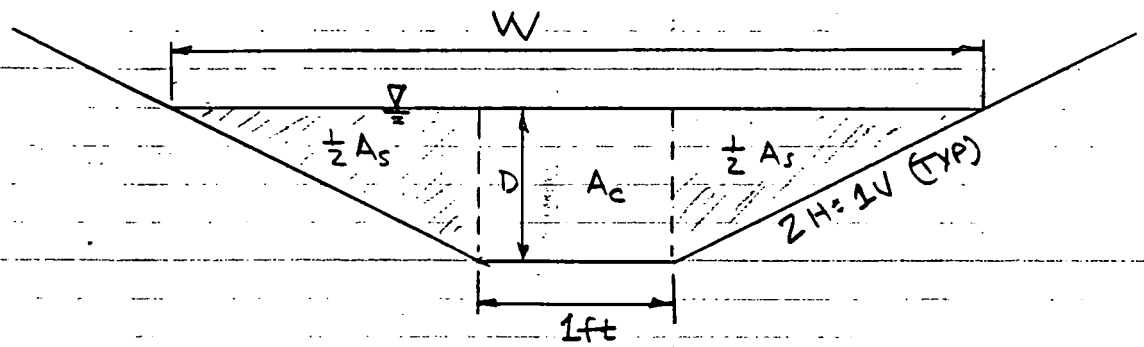
$\theta_m \sim D_{50}/3$ [Hartung and Scheuerlein, 1970] Where: D_{50} = mean diameter of riprap (= 0.305 m)

GEOSYNTEC CONSULTANTS

Written by: D. WARREN Date: 96/02/20 (YY MM DD) Reviewed by: DBW Date: 96/02/22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

KL 22 Feb 96
KO 23 Feb 96



$W = 1ft + 2D(2) \longrightarrow W - 1 = 4D$

$A_c = D \qquad A_s = \frac{1}{2}[(W-1)D] = 2D^2$

$$y_m = \frac{D A_c + \frac{D}{2} A_s}{A_c + A_s} = \frac{D^2 + D^3}{D + 2D^2} = \frac{D + D^2}{1 + 2D}$$

y_m = MEAN FLOW DEPTH

Figure 16 - Procedure For Calculating Mean Flow Depth, y_m, in a Trapezoidal Channel With a 1-foot Wide Base

[redacted]

KL 22Feb96
KO 23Feb96

9.2 Flow Coefficient, c

$c = \sigma(1.7 + 8.1\Phi\sin\varphi)$ Where: Φ = packing factor

9.2.1 Packing factor (Φ)

The packing factor varies from 0.625 for "dumped" or "natural" packing to 1.125 for "manual" packing "with flat stones placed on edge" [Knauss, 1979]

9.3 Resistance Factor (λ)

The equation for the resistance factor is [Hartung and Scheuerlein, 1970]:

$$\frac{1}{\sqrt{\lambda}} = -3.2\log\left(c\frac{\theta_m}{4y_m}\right)$$

9.4 Average Velocity (v_{avg})

The equation for average flow velocity is [Hartung and Scheuerlein, 1970]:

$$v_{avg} = \sqrt{\frac{8g}{\lambda}}\sqrt{y_m \sin\varphi}$$

Where: g = acceleration of gravity (9.81 m/s^2)

9.5 Critical Velocity (v_{crit})

The equation for critical velocity (the velocity at which riprap stones will begin to move) is [Hartung and Scheuerlein, 1970]:

$$v_{crit} = 1.2\sqrt{\frac{2g(G_s - 1)\gamma_w}{\sigma\gamma_w}}\sqrt{d_s \cos\varphi}$$

Where: G_s = specific gravity of riprap (assume G_S = 2.65 per USDOE [1989])
γ_w = unit weight of water = 1 g/cm^3

If $v_{crit} \geq v_{avg}$, the riprap should not erode (gullies should not penetrate the biointrusion barrier)

9.6 Allowable Flow Per Unit Width (q_{all})

The equation for allowable flow per unit width is [Hartung and Scheuerlein, 1970]:

$$q_{all} = \sigma y_m v_{crit}$$

If $q_{all} \geq q_{max}$, the riprap should not erode (gullies should not penetrate the biointrusion barrier). q_{max} is calculated in Section 7.

REFERENCES

Abt, S.R., Khattak, M.S., Nelson, J.D., Ruff, J.F., Shaikh, A., Wittler, R.J., Lee, D.W., and Hinkle, N.E., "*Development of Riprap Design Criteria By Riprap Testing In Flumes: Phase I*", NUREG/CR-4651 ORNL/TM-10100, U.S. Nuclear Regulatory Commission,May 1987, 111 p.

Abt, S.R. Wittler, R.J., Ruff, J.F., LaGrone, D.L., Khattak, M.S., Nelson, J.D., Hinkle, N.E., and Lee, D.W., "*Development of Riprap Design Criteria By Riprap Testing In Flumes: Phase II - Followup Investigations*", NUREG/CR-4651-V2 ORNL/TM-10100/V2, U.S. Nuclear Regulatory Commission, Washington, D.C., Sep 1988, 84 p. (plus appendices).

California Department of Transportation (Caltrans), "*Stormwater Pollution Prevention Handbook*", 1st ed., California Department of Transportation, Sacremento, CA, Oct 1992, 58 p.

Caldwell, J.A. and Reith, C.C., "*Principles and Practice of Waste Encapsulation*", Lewis Publishers, Chelsea, MI, 1993, 414 p.

Earth Systems Associates, "*Vegetation Cover Recommendations for the On-Site Disposal Facility at the Fernald Environmental Management Project Site*", (Draft), Earth Systems Associates, Ltd., Athens, GA, 1996, 16 p.

Foster, G.R., and Wischmeier, W.H., "Evaluating Irregular Slopes for Soil Loss Prediction", *Transactions of the American Society of Agricultural Engineers*, vol. 17, 1974, pp. 305-309.

Freshly, Phil, *Telephone conversation between Mr. Phil Freshly of Earth Systems Associates, Ltd and Messrs. David Bonnett and Dave Warren of GeoSyntec Consultants*, Athens, GA and Atlanta, GA, Feb 5, 1996.

GeoSyntec Consultants, "*On-Site Disposal Facility - Intermediate Design Package*", (Design Drawings), GeoSyntec Consultants, Atlanta, GA, Feb 1996.

Hansen, E.M., Schreiner, L.C., and Miller, J.F., "*Application of Probable Maximum Precipitation Estimates - United States East of the 105th Meridian*", Hydrometeorological Report No. 52 (HMR-52), PB83-118166, National Oceanic and Atmospheric Administration, National Weather Service, Silver Spring, MD, Aug 1982, 168 p.

Hartung, F. and Scheuerlein, H., "Design of Overflow Rockfill Dams", *Proceedings of the Tenth International Conference on Large Dams*, Montreal, Canada, Jun 1970, pp. 587-598.

Knauss, J., "Computation of Maximum Discharge at Overflow Rockfill Dams (A Comparison of Different Model Test Results)", *Proceedings of the Thirteenth International Conference on Large Dams*, New Dehli, India, Oct - Nov 1979, pp. 143-160.

NRC - See U.S. Nuclear Regulatory Commission

Nelson, J.D. Abt, S.R., Volpe, R.L., VanZyl, D., Hinkle, N.E., and Staub, W.P., "*Methodologies for Evaluating Long-Term Stabilization Designs of Uranium Mill Tailings Impoundments*", NUREG/CR-4620 ORNL/TM-10067, U.S. Nuclear Regulatory Commission, Washington, D.C., Jun 1986, 144 p.

Olivier, H., "Through and Overflow Rockfill Dams - New Design Techniques", *Proceedings of the ICE*, Mar 1967, pp. 433-471.

Parsons, "*2000-Year Flood and Probable Maximum Flood - Sitewide Floodplain Determination*", (Calculations), CERCLA/RCRA Unit 2, Project Order 148, Fernald Environmental Management Project, Rev. 0, Fairfield, OH, November 1995 (1995a), 7 p. (plus appendices).

Parsons, "*Geotechnical Investigation Report - On-Site Disposal Facility*", CERCLA/RCRA Unit 2, Project Order 140, Fernald Environmental Management Project, Rev. 0, Fairfield, OH, Dec 1995 (1995b).

Schroeder, P. R., Aziz, N.M., Lloyd, C.M., and Zappi, P.A., "*The Hydrologic Evaluation of Landfill Performance (HELP) Model: User's Guide for Version 3*", EPA/600/R-94/168a, U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., 1994, 83 p. (plus appendices).

Stephenson, D., "*Rockfill In Hydraulic Engineering*", Elsevier Scientific Publishing Company, New York, NY, 1979.

Temple, D.M., Robinson, K.M., Ahring, R.M., and Davis, A.G., "*Stability Design of Grass-Lined Open Channels*", Agriculture Handbook Number 667, PB88-116629, U. S. Department of Agriculture, Agriculture Research Service, Beltsville, MD, Sep 1987, 167p.

KC 22 Feb 96
KO 23 Feb 96

U. S. Department of Agriculture-Soil Conservation Service (USDA-SCS), "*Engineering Manual for Field Conservation Practices*", PB85-175164, U. S. Department of Agriculture, Soil Conservation Service, Washington D.C. November 1986,.

U. S. Department of Agriculture-Soil Conservation Service (USDA-SCS), "*Water Management and Sediment Control For Urbanizing Areas*", U. S. Department of Agriculture, Soil Conservation Service, Washington D.C., Mar 1987.

U.S. Department of Energy (USDOE), "*Technical Approach Document, Revision II*", (Uranium Mill Tailings Remedial Action Project), UMTRA-DOE/AL 050425.0002, December 1989, 290p (plus attachment).

U.S. Nuclear Regulatory Commission (NRC), "*Staff Technical Position: Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites*", NRC/UMT/1003-0064, Aug 1990, 23p (plus appendices).

GEOSYNTEC CONSULTANTS

Written by: D. WARREN Date: 96/02/20 (YY/MM/DD) Reviewed by: DBW Date: 96/02/22 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

EROSION RESISTANCE - OSDF FINAL COVER SYSTEM CALCULATIONS

SECTIONS:

- ESTIMATE SOIL LOSS RATE TO SHEET AND RILL EROSION
- EVALUATE THICKNESS OF TOPSOIL AND VEGETATIVE SUPPORT LAYER AT END OF OSDF DESIGN LIFE
- EVALUATE POTENTIAL FOR GULLIES TO FORM
- EVALUATE ABILITY OF BIOINTRUSION BARRIER TO IMPEDE GULLY ADVANCEMENT

[redacted]

Written by: D. WARREN Date: 96 / 02 / 20 (YY MM DD) Reviewed by: DBW Date: 96 / 02 / 22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

ESTIMATE SOIL LOSS DUE TO SHEET AND RILL EROSION

(SEE SECTION 1 IN CVD)

USE MUSLE:

$$A = RK(LS)(VM)$$

R = 175 (Figure 1)
K = 0.32 (Clay Loam in Table 1)
LS = 7.76 (SEE NEXT PAGE)
VM = 0.01 (Section 1.4 of CVD)

$$A = (175)(0.32)(7.76)(0.01)$$

$$= \underline{\underline{4.35 \text{ tons/Acre/year}}} < 5 \text{ tons/acre/year} \quad \underline{\underline{\text{OK}}} \checkmark$$

[redacted]

CALCULATIONS FOR DETERMINING 'LS' FACTOR IN MUSLE

Equations and procedures taken from Foster and Wischmeier [1974], except where noted

$$LS = \frac{1}{\lambda_e}\sum_{j=1}^{n}\frac{S_j\lambda_j^{m+1} - S_j\lambda_{j-1}^{m+1}}{72.6^m} = \frac{1}{\lambda_e}\sum_{j=1}^{n} u_{2j} - u_{1j}$$

$$u_{2j} = \frac{S_j\lambda_j^{m+1}}{72.6^m}$$

$$u_{1j} = \frac{S_j\lambda_{j-1}^{m+1}}{72.6^m}$$

Slope Segment	Length (ft)	Slope, s (%)	S	λ_j (ft)	λ_{j-1} (ft)	m	u_2	u_1	$u_2 - u_1$	LS*	Fraction of Total Sediment
OSDF West-Side Final Cover:											
Top	90	5.0	0.454	90	0	0.4	45	0	45	0.50	1.1%
Middle	60	10.0	1.169	150	90	0.5	252	117	135	2.25	3.3%
Bottom	370	16.7	2.636	520	150	0.6	4467	611	3856	10.42	95.6%
λ_e =	520								4035	7.76 (see below)	100.0%

S = slope function for segment = $(0.043s^2 + 0.30s + 0.43)/6.613$, where s = slope in percent

λ_j = length from top of total slope to bottom of jth segment

λ_{j-1} = length from top of total slope to bottom of (j-1)th segment

λ_e = total slope length

m = slope-length exponent, taken from Table 5.2 in Nelson et al. [1986]

Fraction of Total Sediment = $(u_{2j} - u_{1j}) / \Sigma(u_{2j} - u_{1j})$

*(for segment j): LS = $(u_{2j} - u_{1j})$ / segment length

*(for total slope): LS = $\Sigma(u_{2j} - u_{1j}) / \lambda_e$

DWJ 20 Feb 96

DBW 22FEB96 53/76

Written by: D. WARREN Date: 96/02/20 (YY MM DD) Reviewed by: DBW Date: 96/02/22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

THICKNESS OF TOPSOIL AND VEGETATIVE SOIL LAYERS AT END OF OSDF DESIGN LIFE

SEE SECTION 2 OF CVD

THICKNESS AT TIME t, T_t: $T_t = T_o - t\,(A/\gamma)$

T_o = Initial Thickness = 2.25 ft = 27 inches

t = 200 years to 1000 years

A = Soil Loss Rate = 4.35 tons/acre/year

γ = Soil Unit Weight (See Section 2.4 of CVD)

$$\gamma \sim G_s \gamma_w (1-n) + \gamma_w (wP)$$

$$= (2.7)(62.4\,pcf)(1-0.464) + (62.4\,pcf)(0.187)$$

$$= 102\,pcf \checkmark$$

AFTER 200 years:

$$T_{200} = 2.25\,ft - 200\,yr \left(\frac{4.35\,tons/acre/yr}{102\,pcf}\right)\left(\frac{2000\,lb/ton}{43560\,ft^2/acre}\right)$$

$$= 2.25\,ft - 200\,yr\,(0.0020\,ft/yr)$$

$$T_{200} = 1.86\,ft = \underline{\underline{22.3\ inches}} \checkmark$$

AFTER 1000 years:

$$T_{1000} = 2.25\,ft - (1000\,yr)(0.0020\,ft/yr)$$

$$T_{1000} = 0.29\,ft = \underline{3.5\ inches} \checkmark$$

NOTE ON FROST PENETRATION - SEE NEXT PAGE →

GEOSYNTEC CONSULTANTS

Written by: D. WARREN Date: 96/02/20 (YY MM DD) Reviewed by: DBW Date: 96/02/22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

NOTE: The frost penetration depth in the OSDF final cover, assuming no topsoil, vegetative soil, or gravel choke layers present, is calculated in the following Calculation Package:

"Final Cover System Frost Penetration Depth"

The calculated frost penetration depth is 3.1 ft.

This is LESS than the thickness of the biointrusion barrier and underlying drainage layer (4 ft).

[redacted]

Written by: D. WARREN Date: 96/02/20 (YY MM DD) Reviewed by: DBW Date: 96/02/22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

EVALUATE POTENTIAL FOR GULLIES TO FORM IN OSDF COVER

- DETERMINE DESIGN FLOW
- TEMPLE METHOD (USDA METHOD)
- HORTON / NRC METHOD
- PERMISSIBLE VELOCITY METHOD
- RESULTS SUMMARY
- DISCUSSION

[redacted]

Written by: D. WARREN Date: 96/02/20 (YY MM DD) Reviewed by: DBIN Date: 96/02/22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

DETERMINE DESIGN FLOW

SEE SECTION 3 OF CVD
USE RATIONAL METHOD: $q = c\,i\,A\,F$

RUNOFF COEFFICIENT, c:

c = 1.0 for ~~storms~~ > 100-year storm
(Section 3.1 of CVD)

RAINFALL INTENSITY, i:

$i = \frac{d}{t_c}$ WHERE: d = rainfall depth
t_c = time of concentration

(Section 3.2 of CVD)

NEED TIME OF CONCENTRATION, t_c:

$$t_c = C\left(\frac{L}{S\,i^2}\right)^{1/3}$$ (Section 3.2.1 of CVD)

C = 2.5 (turf)
L = 520 ft (FIG. 4)
S = 0.14 ft/ft WEIGHTED AVERAGE SLOPE (FIG. 4)

NEED TO ASSUME i

FOR 2000-yr STORM, ASSUME i = 25 inches/hour

$$t_c = 2.5\left(\frac{520}{(0.14)(25)^2}\right)^{1/3} = 4.5 \text{ minutes} \checkmark$$

FROM FIGURE 10 → d ~ 1.9 inches for 2000-yr storm with t_c = 4.5 minutes

$$i = \frac{d}{t_c} = \frac{1.9 \text{ inches}}{4.5 \text{ min}}(60 \text{ min/hr}) = 25.3 \text{ in} \sim 25 \text{ in} \checkmark$$

SO, SAY i = 25.5 in for 2000-yr storm

[redacted]

Written by: D. WARREN Date: 96/02/20 (YY MM DD) Reviewed by: DBW Date: 96/02/22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

DRAINAGE AREA, A

SLOPE	LENGTH
TOP	90 ft
MIDDLE	60
BOTTOM	370
TOTAL	520 ft

$A = (520\ ft)(1\ ft\ width) = 520\ ft^2$ (Section 3.3 of CVD)

FLOW CONCENTRATION FACTOR, F

$F = 3$ (Section 3.4 of CVD)

RESULTS

$$q = (1.0)\left[25.5\ in/hr \times \frac{1\ ft}{12\ in} \times \frac{1\ hr}{3600\ sec}\right](520\ ft^2)(3)$$

$$= \boxed{0.92\ cfs/ft}$$ ✓

Written by: D. WARREN Date: 96 / 02 / 20 (YY MM DD) Reviewed by: DBW Date: 96 / 02 / 22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

TEMPLE METHOD (USDA METHOD)

THIS METHOD ANALYZES TRACTIVE FORCE ON SOIL
SEE SECTION 4. OF CVD.

ALLOWABLE SHEAR STRESS (TRACTIVE STRESS) ON BARE SOIL, τ_a

FROM FIGURE 11 → $\tau_{ab} = 0.03$ psf (CL) (PI ≤ 10)

FROM FIGURE 12 → $C_e = 0.99$ (CL)

$$\tau_a = \tau_{ab} C_e^2 \geq 0.02 \text{ psf}$$

$$\tau_a = (0.03)(0.99)^2 = 0.029 \text{ psf} \checkmark$$

VEGETAL PARAMETERS (C_I & C_F)

SEE TABLE 5:

RETARDANCE CLASS	STAND QUALITY	C_I	C_F
A	GOOD	10.0	0.90
	FAIR	9.35	0.72
B	GOOD	7.64	0.87
	FAIR	7.14	0.70
C	GOOD	5.60	0.75
	FAIR	5.23	0.60
D	GOOD	4.44	0.50
	FAIR	4.15	0.40
E	GOOD	2.88	0.50
	FAIR	2.69	0.40

(1) $C_I(\text{FAIR}) = \left(\sqrt{2/3}\right)^{1/3} C_I(\text{GOOD}) = 0.9347\, C_I(\text{GOOD})$ FAIR HAS 2/3 STEM DENSITY OF GOOD → TABLE 5

(2) $C_F(\text{FAIR}) = 0.8\, C_F(\text{GOOD})$ (TABLE 5)

[redacted]

Written by: D. WARREN Date: 96 / 02 / 20 (YY MM DD) Reviewed by: DBW Date: 96 / 02 / 22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

DESIGN FLOW PER UNIT WIDTH, q

$q = 0.92$ cfs/ft for 2000-year storm

MANNING'S ROUGHNESS COEFFICIENT, n

$$n = e^{\{0.01329\, C_I \ln(x)^2 - 0.09543\, C_I \ln(x) + 0.2971\, C_I - 4.16\}}$$

WHERE $x = \text{MAX}\{q,\ 0.0025\, C_I^{2.5}\}$ (Section 4.4 of CVD)

EX. CLASS B VEGETATION, 2000-yr STORM

$q = 0.92$ cfs/ft

$C_I = 7.64$ $\quad 0.0025\, C_I^{2.5} = 0.403 < q$

$$n = e^{0.01329\, 7.64 \ln(0.92)^2 - 0.09543(7.64)\ln(0.92) + 0.2971(7.64) - 4.16}$$

$= 0.1606$ ✓

FLOW DEPTH, D

$$D = \left(\frac{q\,n}{1.49\, s^{1/2}}\right)^{0.6}$$

EX. CON'T:

$$D = \left(\frac{(0.92)(0.1606)}{1.49\,(0.167)^{1/2}}\right)^{0.6} = 0.43 \text{ ft} \checkmark$$

Written by: D. WARREN Date: 96 / 02 / 20 (YY MM DD) Reviewed by: DBW Date: 96 / 02 / 22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

SHEAR STRESS (i.e. TRACTIVE FORCE) APPLIED BY FLOW, τ_o

$\tau_o = \gamma_w D S$ (Section 4.6 of CVD)

EX. CON'T $\tau_o = (62.4\ pcf)(0.43\ ft)(0.167) = 4.5\ psf$ ✓

"EFFECTIVE" SHEAR STRESS APPLIED TO SOIL, τ_e

$\tau_e := (1 - C_F)\left(\frac{n_s}{n}\right)^2 \tau_o$ (Section 4.7 of CVD)

$n_s = 0.0156$ (Section 4.7.1 of CVD)

EX. CON'T: ASSUME "GOOD" STAND (CLASS B):

$\tau_e = (1 - 0.87)\left(\frac{0.0156}{0.16006}\right)^2 (4.5\ psf)$

$= 0.0055\ psf$ ✓

COMPARE τ_e TO τ_a:

$\tau_e = 0.0055\ psf < \tau_a = 0.029\ psf$ → OK, GULLIES WILL NOT FORM ✓

THE ABOVE CALCULATIONS FOR THE TEMPLE METHOD USING THE 2000-yr STORM ARE MADE FOR ALL VEGETAL RETARDANCE CLASSES. THE RESULTS ARE SHOWN ON PAGE 66.

[redacted]

Written by: D. WARREN Date: 96/02/20 (YY MM DD) Reviewed by: DRW Date: 96/02/22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

HORTON/NRC METHOD

THIS METHOD EVALUATES THE DISTANCE ALONG A SLOPE BEFORE GULLIES WILL FORM.

SEE SECTION 5. OF CVD.

CRITICAL DISTANCE, XC IS: $XC = \dfrac{65\ R^{5/3}}{F \cdot q_s \cdot n \cdot f(s)^{5/3}}$

ALLOWABLE SHEAR STRESS, R

GET FROM TEMPLE METHOD

$$R = \text{MIN}\left[\frac{\tau_a}{(1-C_F)\left(\frac{n_s}{n}\right)^2},\ \tau_a = 0.75\ C_I\right]$$ (Section 5.1 of CVD)

CONTINUE EX. FROM TEMPLE METHOD:
CLASS E VEGETATION, GOOD STAND QUALITY, 2000-yr STORM, ML TOPSOIL

$$R = \text{MIN}\left[\frac{0.029\ \text{psf}}{(1-0.97)\left(\frac{0.0156}{0.1606}\right)^2},\ 0.75(7.64)\right]$$

$$R = \text{MIN}\left[23.6\ \text{psf},\ 5.73\ \text{psf}\right] = 5.73\ \text{psf}$$ ✓

FLOW CONCENTRATION FACTOR, F

F = 3 (Section 3.4 of CVD)

PRECIPITATION INTENSITY, qs

$q_s = i = 25.5$ in/hr (page 57)

[redacted]

Written by: D. WARREN Date: 96 / 02 / 20 (YY MM DD) Reviewed by: DBW Date: 96 / 02 / 22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

SLOPE FUNCTION, f(S) (Section 5.5 of CVD)

$$f(S) = \frac{\sin\theta}{\tan\theta^{0.3}}$$ θ = SLOPE ANGLE = 9.56° FOR 6H:1V

EX. CON'T: $f(S) = \frac{\sin 9.56}{[\tan(9.56)]^{0.3}} = 0.283$ ✓

MANNING'S ROUGHNESS COEFFICIENT, n

GET FROM TEMPLE METHOD

EX. CON'T: → $n = 0.1606$ (SEE TEMPLE METHOD CALCS)

RESULTS

EX. CON'T:

$$XC = \frac{65\,(5.73)^{5/3}}{(3)(25.5)(0.1606)(0.283)^{5/3}} = 796 \text{ ft}$$ ✓

$XC = 796$ ft $> X = 435$ ft (See Figure 4)

→ OK, GULLIES WILL NOT FORM ✓

RESULTS OF HORTON/NRC METHOD CALCULATIONS FOR ALL VEGETAL RETARDANCE CLASSES ARE SHOWN ON PAGE 66.

[redacted]

GEOSYNTEC CONSULTANTS

Written by: D. WARREN Date: 96 / 02 / 20 (YY MM DD) Reviewed by: DBW Date: 96 / 02 / 22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 08.2

PERMISSIBLE VELOCITY METHOD

THIS METHOD COMPARES VELOCITY OF FLOW TO PERMISSIBLE VELOCITY.

SEE SECTION 6 OF CVD.

FLOW VELOCITY, V (Section 6.1 of CVD)

$V = q/D$

q = DESIGN FLOW
D = FLOW DEPTH FROM MANNING EQN
SEE TEMPLE METHOD

CONTINUE EXAMPLE FROM HORTON METHOD:
CLASS B VEGETATION, GOOD STAND, 2000-year STORM

$$V = \frac{0.92 \text{ cfs}}{0.43 \text{ ft}} = 2.14 \text{ ft/sec} \checkmark$$

PERMISSIBLE VELOCITY, V_{per} (Section 6.2 of CVD)

V_{per} = (BASE V_{per}) R

EX. CON'T: CLASS B, GOOD STAND → BASE V_{per} = 5.0 ft/sec

$$R = 0.46 \log(D) + 0.78$$
$$= 0.46 \log(0.43) + 0.78 = 0.61$$

$$V_{per} = (5.0)(0.61) = 3.05 \text{ ft/sec} \checkmark$$

[redacted]

Written by: D. WARREN Date: 96/02/20 (YY MM DD) Reviewed by: DBW Date: 96/02/22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

RESULTS

OK IF $V_{per} > V$

EX. CON'T: $V_{per} = 3.05$ ft/sec $> V = 2.14$ ft/sec ✓

→ OK, GULLIES WILL NOT FORM IN 2000-YR STORM ✓

PERMISSIBLE VELOCITY METHOD CALCULATIONS FOR ALL VEGETAL RETARDANCE CLASSES ARE SHOWN ON PAGE 66.

[redacted]

DWW 21 Feb 96
DBW 22 FEB96

[redacted]/76 73

02/21/96

EVALUATION OF POTENTIAL FOR GULLIES TO FORM IN OSDF FINAL COVER 2000-YEAR STORM

Geometry	
Slope =	16.7%
Slope Length =	435 ft

Design Flow	
Runoff Coeff., c =	1
Rainfall Intensity, i =	25.5 in/hr
Area, A =	520 ft^2
Flow Per Unit Width, q =	0.307 cfs/ft
Flow Concentration Factor, F =	3
With Flow Conc. Factor, q =	0.921 cfs/ft

RESULTS OF TEMPLE METHOD AND HORTON/NRC METHOD (using allowable shear and Manning n from Temple Method)

Grass Cover		Input from Temple Method: Vegetal Parameters		Calculations for Temple Method (τ_a = 0.029 psf)					Calculations for Horton/NRC Method	
Retardance Class	Stand Quality	C_I	C_f	Max. of q and $0.0025C_I^{2.5}$	Manning n	τ_e (psf)	OK?	Allow. Shear, R (psf)	Critical Dist., xc (ft)	OK?
A	Good	10.00	0.90	0.921	0.3298	0.0015	OK	7.50	611	OK
	Fair	9.35	0.72	0.921	0.2702	0.0057	OK	7.01	667	OK
B	Good	7.64	0.87	0.921	0.1605	0.0055	OK	5.73	802	OK
	Fair	7.14	0.70	0.921	0.1378	0.0156	OK	5.36	834	OK
C	Good	5.60	0.75	0.921	0.0862	0.0251	OK	3.54	669	OK
	Fair	5.23	0.60	0.921	0.0771	0.0470	No	1.77	236	No
D	Good	4.44	0.50	0.921	0.0605	0.0825	No	0.87	92	No
	Fair	4.15	0.40	0.921	0.0554	0.1121	No	0.61	55	No
E	Good	2.88	0.50	0.921	0.0376	0.1607	No	0.34	30	No
	Fair	2.69	0.40	0.921	0.0355	0.2090	No	0.25	20	No

RESULTS OF PERMISSIBLE VELOCITY METHOD

Grass Cover		Flow Depth (ft)	Flow Velocity (ft/sec)	Calculations for Perm. Velocity Method: Permissible Velocity (ft/sec)			OK?
Retardance Class	Stand Quality			Base	Reduct. Factor	Final	
A	Good	0.659	1.398	6.0	0.70	4.18	OK
	Fair	0.584	1.576	5.5	0.67	3.70	OK
B	Good	0.428	2.153	5.0	0.61	3.05	OK
	Fair	0.390	2.359	4.5	0.59	2.66	OK
C	Good	0.294	3.128	4.0	0.54	2.14	No
	Fair	0.275	3.345	3.75	0.52	1.96	No
D	Good	0.238	3.868	3.5	0.50	1.75	No
	Fair	0.226	4.079	3.25	0.50	1.63	No
E	Good	0.179	5.146	3.5	0.50	1.75	No
	Fair	0.173	5.326	3.0	0.50	1.50	No

EVALUATION OF POTENTIAL FOR GULLIES TO FORM IN OSDF FINAL COVER

DISCUSSION OF RESULTS

The potential for erosion gullies to form in the OSDF Final Cover during the 2000-year storm was evaluated using the Temple Method (or Temple/USDA Method), the Horton/NRC Method (recommended by NRC [1990]), and the Permissible Velocity Method (further recommended by NRC [1990] as a check to the Horton/NRC Method). The results of these calculations are shown on the previous page.

Note that the Horton/NRC method results show a longer allowable slope length for Class B and "Good" Class C, than for Class A vegetation. For high retardance vegetation in the case, the allowable shear stress (R) is controlled by allowable vegetal stress (see Section 5.1 of the Collection and Verification of Data). Where this occurs, R does not increase much with vegetal retardance. However, Manning's n also increases with vegetal retardance. From the equation for critical distance (xc) in Section 5 of the Collection and Verification of Data, increasing R causes xc to increase, and increasing Manning's n causes xc to decrease. In this case, the effect from increasing R between retardance classes is more than offset by the corresponding effect of increasing Manning's n. This shows that the OSDF final cover is near the edge of, or outside the range of, conditions for which the Horton/NRC Method is applicable (at least for high retardance vegetation). Furthermore, since R and Manning's n are calculated from the Temple Method, the OSDF final cover is also near or outside the range of conditions where the Temple Method is applicable.

As recommended by NRC [1990], the permissible velocity method is used to check the results of the Temple and Horton/NRC Methods. The permissible velocity method should be applicable where Manning's equation is applicable, and this is the case on the OSDF final cover. Hence, the permissible velocity method may be the only method of the three that is applicable to the conditions analyzed.

As can be seen, regardless of whether the Temple and Horton/NRC Methods are applicable to this case, the results of all three methods generally agree. The permissible velocity method results are slightly more conservative than those of the other two methods. All results show that Class B native-grass vegetation, currently planned for the OSDF final cover, should resist the formation of erosion gullies in the 2000-year storm.

Written by: D. WARREN Date: 96/02/20 (YY MM DD) Reviewed by: DBW Date: 96/02/22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

EVALUATE ABILITY OF BIOINTRUSION BARRIER TO IMPEDE GULLY ADVANCEMENT

- DETERMINE DESIGN FLOW
- STEPHENSON METHOD
- HARTUNG AND SCHEUERLEIN METHOD
- DISCUSSION OF RESULTS

[redacted]

Written by: D. WARREN Date: 96/02/20 (YY MM DD) Reviewed by: DBW Date: 96/02/22 (YY MM DD)

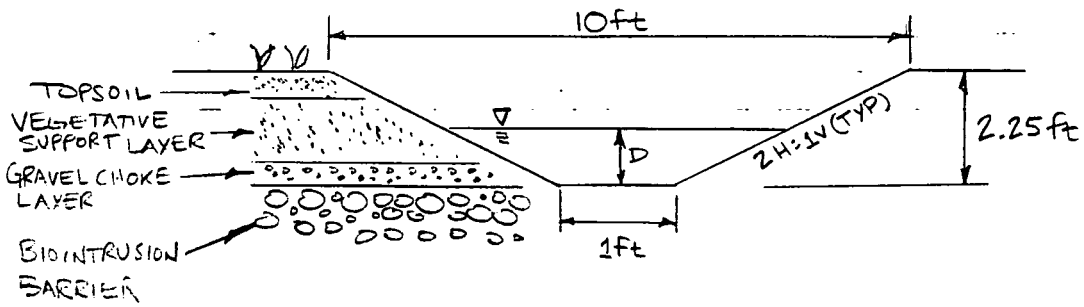
Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

DETERMINE DESIGN FLOW

SEE SECTION 7.1 of CVD and Figure 18

MAX. FLOW PER UNIT WIDTH AT BOTTOM OF GULLY WILL BE MUCH LARGER THAN AVERAGE FLOW PER UNIT WIDTH DOWN THE OSDF FINAL COVER

ASSUMED GULLY CROSS-SECTION:



FLOW IN GULLY, Q

$$Q = qW = q(10ft)$$

FLOW PER UNIT WIDTH, q

$$q = c\,i\,A$$

$c = 1.0$

i = CALCULATED ON FOLLOWING PAGE

$A = 520 ft^2$ (SEE PAGE 58)

[redacted]

Written by: D. WARREN Date: 96/02/20 (YY MM DD) Reviewed by: DBW Date: 96/02/22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

RAINFALL INTENSITY, i

$$i = \frac{d}{t_c}$$

d = Rainfall Depth - Estimated from Figure 10
t_c = time of concentration, calculated below

TIME OF CONCENTRATION, t_c

$$t_c = \left(\frac{11.9\,L^3}{H}\right)^{0.385}$$

$L = 520\text{ft} / 5280\text{ ft/mile} = 0.0985$ miles

$H = 90'\{\sin[\tan^{-1}(\frac{1}{20})]\} + 60'\{\sin[\tan^{-1}(\frac{1}{10})]\} + 370'\{\sin[\tan^{-1}(\frac{1}{6})]\}$

$= 71.3$ ft ✓

$$t_c = \left[\frac{11.9\,(0.0985\text{ mi})^3}{71.3\text{ ft}}\right]^{0.385} = 0.0345\text{ hr} = 2.07\text{ min} ✓$$

$t_c < 2.5$ min ⟶ USE $t_c = \underline{2.5\text{ min}}$

FROM FIGURE 10 WITH $t_c = 2.5$ min:

2000-yr STORM: $d \sim 1.5$ in $\quad i = \frac{1.5\text{ in}}{2.5\text{min}}\left(60\,\frac{\text{min}}{\text{hr}}\right) = \underline{36\text{ in/hr}}$ ✓

PMP: $d \sim 3.7$ in $\quad i = \frac{3.7\text{ in}}{2.5\text{min}}\left(60\,\frac{\text{min}}{\text{hr}}\right) = \underline{89\text{ in/hr}}$ ✓

CALCULATE q:

2000-yr STORM: $q = (1.0)\left[36\text{ in/hr} \times \frac{1}{12}\text{ ft/in} \times \frac{1}{3600}\text{ hr/sec}\right](520\text{ ft}^2) = \underline{\underline{0.433}}$ cfs/ft ✓

PMP: $q = (1.0)\left[89\text{ in/hr} \times \frac{1}{12} \times \frac{1}{3600}\right](520\text{ ft}^2) = \underline{\underline{1.07}}$ cfs/ft ✓

[redacted]

GEOSYNTEC CONSULTANTS

Written by: D. WARREN Date: 96 / 02 / 20 (YY MM DD) Reviewed by: DBN Date: 96 / 02 / 22 (YY MM DD)

Client: FERMCO Project: DSDF Project/Proposal No.: GE3900 Task No.: 08.2

CALCULATE FLOW IN GULLY:

2000-yr STORM: $Q = (0.433\ cfs/ft)(10ft) = \underline{\underline{4.33}}\ cfs$ ✓

PMP: $Q = (1.07\ cfs/ft)(10ft) = \underline{\underline{10.7}}\ cfs$ ✓

[redacted]

Written by: D. WARREN Date: 96/02/20 (YY MM DD) Reviewed by: DBW Date: 96/02/22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 08.2

MAXIMUM FLOW DEPTH IN GULLY, D (Section 7.3 of CVD)

ITERATE FOR D → CHOOSE D
SOLVE MANNING'S EQN FOR Q
IF Q = Q FROM LAST STEP, OK
OTHERWISE, CHOOSE ANOTHER D

MANNING'S EQN:

$$Q = \frac{1.49}{n} A R_h^{2/3} S^{1/2}$$

n: $n = 0.0456 (D_{50} \times S)^{0.159}$

$D_{50} = 12$ in $S = 0.167$

$n = 0.0456((12)(0.167))^{0.159} = 0.051$ ✓

A: $A = BD + D^2 \cot\theta$

$B = 1$ ft $\cot\theta = 2$

SAY $D = 0.69$ ft

$A = (1)(0.69) + (0.69)^2(2) = 1.64$ ft^2 ✓

R_h: $R_h = \frac{A}{W_p}$

$W_p = B + \frac{2D}{\sin\theta} = 1 + \frac{2(0.69)}{\sin(26.6°)} = 4.09$ ft

$R_h = \frac{1.64}{4.09} = 0.40$ ft ✓

S: $S = 16.7\%$

$Q = \frac{1.49}{0.051}(1.64)(0.40)^{2/3}(0.167)^{1/2} = 10.7$ cfs ✓

= FLOW FOR PMP

D = 0.69 ft FOR PMP

[redacted]

Written by: D. WARREN Date: 96 / 02 / 20 (YY MM DD) Reviewed by: DBW Date: 96 / 02 / 22 (YY MM DD)

Client: FERMCO Project: DSDF Project/Proposal No.: GE3900 Task No.: 08.2

MAXIMUM FLOW PER UNIT WIDTH, q_{MAX} (Section 7.4 of CVD)

q_{MAX} WILL OCCUR IN CENTER OF CHANNEL

$$q_{MAX} \sim \frac{A_c}{A} Q$$

A_c = Area of center 1-foot of flow
A = Total flow area

q_{MAX} WILL BE SLIGHTLY GREATER THAN THIS, BECAUSE DRAG OF SIDES ON FLOW WILL BE LESS IN CENTER OF CHANNEL THAN FOR ALL OF CHANNEL.

A_c: FOR TRAPEZOIDAL CHANNEL, $A_c = D\,(1\,ft) = D$

FOR PMP $\rightarrow A_c = 0.69\ ft^2$

A: FOR PMP $\rightarrow A = 1.64\ ft^2$

$$q_{MAX} = \frac{0.69}{1.64}(10.7) = 4.5\ cfs/ft \quad \text{(FOR PMP)}$$

NOTE: FLOW CONCENTRATION FACTOR $= \dfrac{4.5\ cfs/ft}{1.07\ cfs/ft} = 4.2$ ✓

RESULTS FOR q_{MAX} ARE SHOWN ON THE NEXT PAGE.

[redacted]

DBW 22FEB96

CALCULATION OF MAX. FLOW / UNIT WIDTH IN TRAPEZOIDAL CHANNEL

PMP

Channel Geometry

Slope, S	Depth (ft)	Side Angle	Width (ft) Top	Width (ft) Base
16.7%	2.25	2H:1V	10	1

Riprap Properties

D_{50} (in)	
12	0.0509

Flow Properties

Input Flow: Design flow / width, q (cfs/ft)	Total Flow Q (cfs)	Iterate for Flow Depth With Manning's Equation: Depth, D (ft)	Area, A (ft^2)	Wetted Perim. (ft)	Hydraulic Radius (ft)	Manning Q (cfs)
1.07	10.7	0.69	1.64	4.09	0.40	10.69

Flow in Center of Channel

A_c /A	q_{max} (cfs/ft)
0.42	**4.49**

✓

q_{max} = maximum flow per unit width

2000-YEAR STORM

Channel Geometry

Slope, S	Depth (ft)	Side Angle	Width (ft) Top	Width (ft) Base
16.7%	2.25	2H:1V	10	1

Riprap Properties

D_{50} (in)	n
12	0.0509

Flow Properties

Input Flow: Design flow / width, q (cfs/ft)	Total Flow Q (cfs)	Iterate for Flow Depth With Manning's Equation: Depth, D (ft)	Area, A (ft^2)	Wetted Perim. (ft)	Hydraulic Radius (ft)	Manning Q (cfs)
0.433	4.33	0.45	0.86	3.01	0.28	4.41

Flow in Center of Channel

A_c /A	q_{max} (cfs/ft)
0.53	**2.32**

✓

q_{max} = maximum flow per unit width

[redacted]

EVALUATION OF RESISTANCE OF BIOINTRUSION BARRIER TO GULLY ADVANCEMENT USING THE STEPHENSON METHOD

$$D_{50} = \left[\frac{q(\tan\theta)^{7/6} n_p^{1/6}}{Cg^{1/2}\left[(1-n_p)(G_s-1)\cos\theta(\tan\phi - \tan\theta)\right]^{5/3}} \right]^{2/3}$$

(Section 8 of CVD)

D_{50} = Minimum required rock diameter (ft)
q = allowable flow per unit width (flow at which movement of riprap will commence)
Riprap will fail at a flow of 1.2 q (gravel) to 1.8 q (cruhsed stone)
Failure means entire thickness of riprap layer washing away
θ = slope angle
n_p = porosity of rock
C = empirical constant (0.22 for gravel to 0.28 for crushed granite)
g = acceleration of gravity
G_s = specific gravity of rock
ϕ = angle of repose of rock

θ =	9.46 deg	6H:1V
n_p =	0.397	Value for gravel (Line 21 in Table 4)
C =	0.22	Conservative
g =	32.2 ft/sec^2	
G_s =	2.65	NRC recommended value to assume when G_s is unknown
ϕ =	41 deg	Conservative value taken from Figure 18

PMP

q_{max} = 4.5 cfs/ft Max flow per unit width for PMP

(D_{50})req'd = 0.80 ft ✓

Actual D_{50} = 1 ft **OK**

2000-YEAR STORM

q_{max} = 2.4 cfs/ft Max flow per unit width for PMP

(D_{50})req'd = 0.52 ft ✓

Actual D_{50} = 1 ft **OK**

DBW 22FEB96

EVALUATION OF RESISTANCE OF BIOINTRUSION BARRIER TO GULLY ADVANCEMENT USING THE HARTUNG AND SCHEUERLEIN METHOD

(Section 9 of CVD)

Input Parameters

Slope (φ) = 6H:1V 9.46deg 0.165rad

Flow Depth (D) = 0.88 ft 0.268 m Iterate flow depth until $v_{avg} \sim v_{crit}$

Riprap D_{50} = 0.67 ft 0.204 m

1. Calculate aeration factor, σ

φ = 9.46deg
y_m = 0.183 m
θ_m = 0.068 m
σ = **1.000** ✓

$$\sigma = 1 - 1.3\sin\varphi + 0.08\frac{y_m}{\theta_m} \le 1$$

2. Calculate flow coefficient, c

Φ = 0.625
c = 2.53 ✓

$$c = \sigma(1.7 + 8.1\Phi\sin\varphi)$$

3. Calculate resistance function, $1/(\lambda)^{0.5}$

$1/(\lambda)^{0.5}$ = 2.01 ✓

$$\frac{1}{\sqrt{\lambda}} = -3.2\log\left(c\frac{\theta_m}{4y_m}\right)$$

4. Calculate average velocity, v_{avg}

g = 9.81 m/s^2
v_{avg} = **3.08 m/s** ✓

$$v_{avg} = \sqrt{\frac{8g}{\lambda}}\sqrt{y_m\sin\varphi}$$

5. Calculate critical velocity, v_{crit}

G_s = 2.65
d_s = 0.204 m
γ_w = 1 g/cm^3
v_{crit} = **3.06 m/s** ✓

$$v_{crit} = 1.2\sqrt{\frac{2g(G_s-1)\gamma_w}{\sigma\gamma_w}}\sqrt{d_s\cos\varphi}$$

6. $v_{avg} \sim v_{crit}$? Yes

7. Calculate allowable flow per unit width, q_{all}

$$q_{all} = \sigma y_m v_{crit}$$

q_{all} = **0.560 m^3/s/m** ✓ **6.0 ft^3/s/ft**

q_{max} = **4.5 ft^3/s/ft** **For PMP**

OK ✓

11.4 Final Cover System Frost Penetration Depth

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: FINAL COVER SYSTEM FROST PENETRATION DEPTH

Computations By: (Cognizant Engineer)
Signature: Majdy Ahmed Othman — Date: 9 Feb 96
Printed Name and Title: MAJDI A. OTHMAN, PROJECT ENGINEER

Assumptions and Procedures Checked by: (Checker)
Signature: Paul J. Sabatini — Date: 9 Feb 96
Printed Name and Title: PAUL J. SABATINI, SENIOR STAFF ENGINEER

Computations Checked by:
Signature: Paul J. Sabatini — Date: 9 Feb 96
Printed Name and Title: PAUL J. SABATINI, SENIOR STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Majdy Ahmed Othman — Date: 10 Feb 96
Printed Name and Title: MAJDI A. OTHMAN, PROJECT ENGINEER

Approved by: (PDP)
Signature: Majdy Ahmed Othman — Date: 10 Feb 96
Printed Name and Title: MAJDI A. OTHMAN, PROJECT ENGINEER

Approved by: (DTL and TETL)
Signature: Rudolph Bonaparte — Date: 16 Feb 96
Printed Name and Title: Rudolph Bonaparte, Principal (DTL)

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	Modified weather input parameters and added case B of analysis	9 Feb 96	MAO	PJS	RB
D	Intermediate Design - EPA Submittal	4 Apr 96	[illegible]	—	—
G	Final Design Package	4 Oct 96	—	—	[illegible]
O	Response to Final Design Comts	9 May 97	—	—	[illegible]

Written By: MAO Date: 96/2/9 Reviewed by: PJS Date: 96-2-9

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3906 Task No.: 08.8

FINAL COVER SYSTEM FROST PENETRATION DEPTH

EXECUTIVE SUMMARY

PURPOSE OF ANALYSIS

The purpose of this package is to estimate the frost penetration depth for the final cover system to ensure that the compacted clay layer of the system is not subject to frost. Two cases are analyzed as described below.

- Case A: The final cover system is intact (i.e., erosion has not decreased the thickness of the final cover system).
- Case B: All layers above the biointrusion barrier have eroded.

METHODS OF ANALYSIS

The frost penetration depth into the final cover system was calculated using the modified Berggren method.

CONCLUSIONS

- Case A: Maximum frost penetration depth was estimated to be 2.25 ft. Therefore, the compacted clay layer of the final cover system should not be subject to frost under the conditions analyzed.
- Case B: Maximum frost penetration depth was estimated to be 3.1 ft. Therefore, the compacted clay layer of the final cover system should not be subject to frost under the conditions analyzed.

[redacted]

COVER FROST PENETRATION DEPTH

TABLE OF CONTENTS

		Page
1.	Calculation Procedures	1/8
2.	Data Verification	1/17
	• Weather Data	2/17
	• Soil Thermal Properties	14/17
3.	Calculations	1/9

Written by: MAO Date: 96/2/5 (YY/MM/DD) Reviewed by: DJS Date: 96/2/9 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 08.8

RB(DTL) 6 Feb 96

FROST PENETRATION DEPTH CALCULATION PROCEDURES

The depth of frost penetration into the final-closure cover system will be calculated using the modified Berggren method [Aldrich and Paynter, 1953] as specified in Section 2.6.3 of the Design Criteria Package (DCP). The modified Berggren method is described below.

The temperature distribution in a soil with an initial temperature (T_i) when its surface is subjected to a temperature (T_s) which is less than the freezing temperature (T_f) is shown in Figure 1. Based on the modified Berggren method, the depth of frost penetration (X) can be calculated from the following equation:

$$X = \lambda \sqrt{\frac{(K_f + K_t)(T_f - T_s)\, t}{L}} \qquad (1)$$

where: K_f = thermal conductivity of frozen soil;
K_t = thermal conductivity of thawed soil;

[redacted]

GEOSYNTEC CONSULTANTS

Written by: MAO Date: 96/2/5 (YY MM DD) Reviewed by: PJS Date: 96/2/9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: Ø8.8

RB(DTL) 6 Feb 96

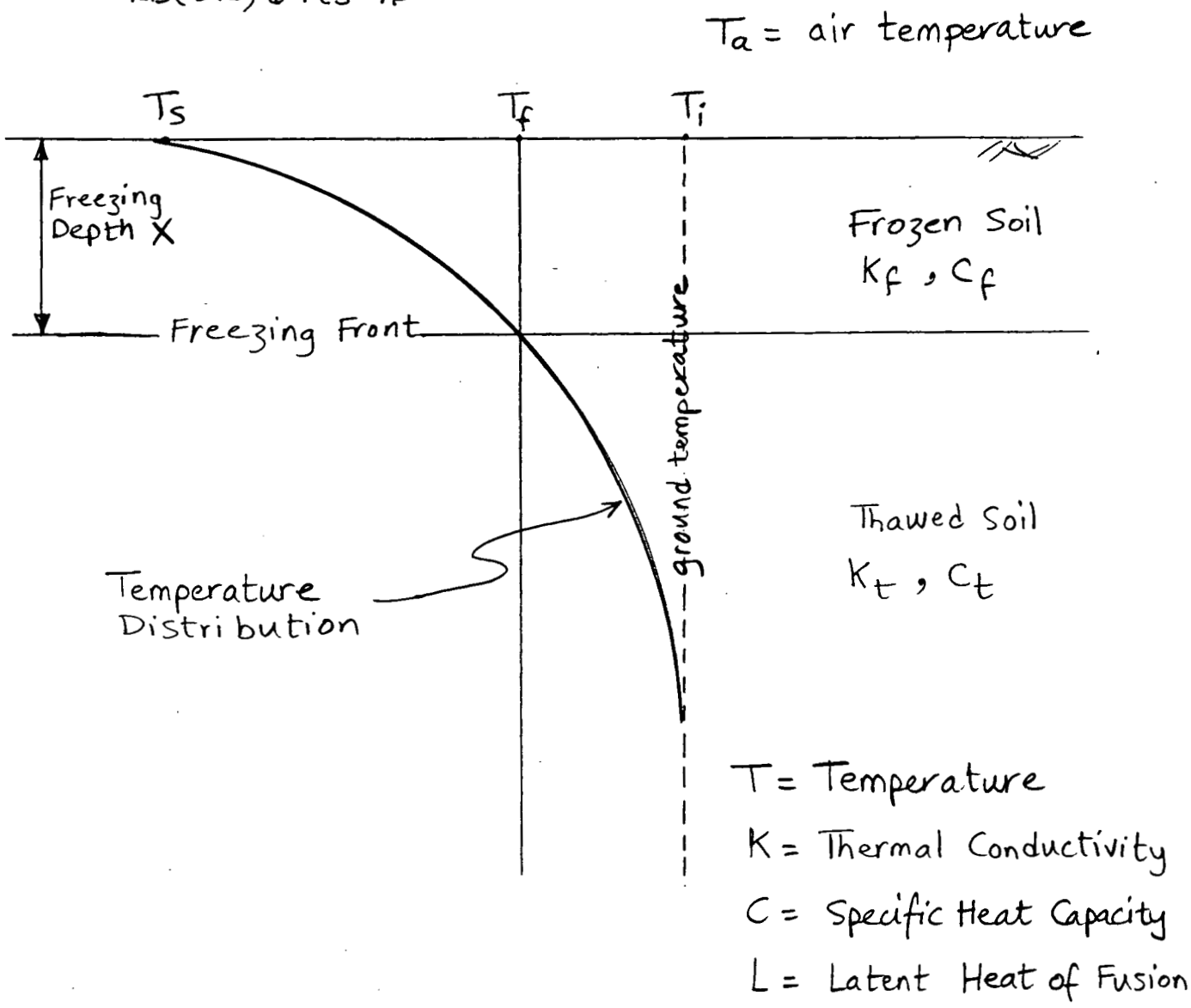


Figure 1. Temperature distribution in the ground under freezing conditions.

[redacted]

Written by: MAO Date: 96/2/5 (YY/MM/DD) Reviewed by: PJS Date: 96/2/9 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: Ø8.8

RB(DTL) 6 Feb 96

T_f = freezing temperature = 32°F = 0°C;

T_s = ground-surface temperature;

t = time period soil surface is subject to temperature T_s;

L = latent heat of fusion of soil;

λ = parameter which is a function of the fusion parameter (μ) and the thermal ratio (α) as given in Figure 2;

μ = fusion parameter = $\frac{C_f + C_t}{2} \frac{T_f - T_s}{L}$;

α = thermal ratio = $\frac{T_i - T_f}{T_f - T_s}$;

C_f = specific heat capacity of frozen soil; and

C_t = specific heat capacity of thawed soil.

[redacted]

GEOSYNTEC CONSULTANTS

Written by: MAO Date: 96/2/5 (YY MM DD) Reviewed by: PJS Date: 96/2/9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.8

RB(DTL) 6 Feb 96

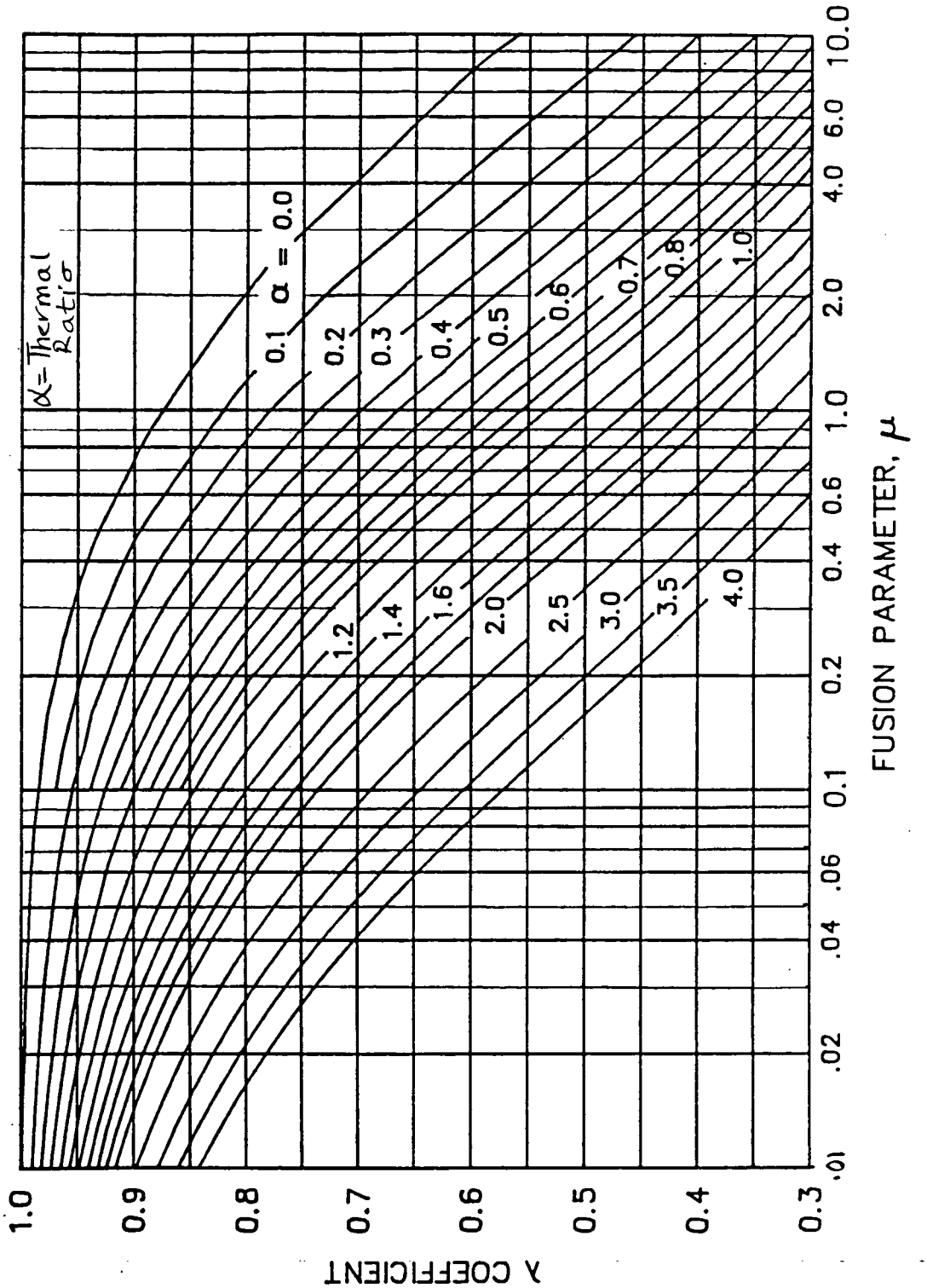


Figure 2. Coefficient λ as a function of fusion parameter (μ) and thermal ration (α) [Aldrich and Paynter, 1953]

[redacted]

Written by: MAO Date: 96/2/5 (YY/MM/DD) Reviewed by: PJS Date: 96/2/9 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.8

RB(DTL) 6 Feb 96

To apply equation (1) to field cases where the surface temperature varies, the average surface temperature for the freezing season is used for T_s and T_i is taken as the mean annual air or ground temperature. The average surface temperature is estimated from the air temperature freezing index using a correction factor (n), refered to as the n-factor, to account for differences between the air temperature and the ground surface temperature. The air freezing index (FI_{air}) is defined as the sum of the deviations of mean daily air temperatures (T_a) from the freezing temperature calculated over the freezing season as follows:

$$FI_{air} = \sum_{i=1}^{t} (T_f - T_{a_i}) \qquad (2)$$

where: t = the number of freezing season days.

The soil surface freezing index is corrected using the n-factor which depends on the soil type and ground surface cover type as follows:

$$FI_{surface} = FI_{air} \times n \qquad (3)$$

[redacted]

Written by: MAO Date: 96/2/5 Reviewed by: PJS Date: 96/2/9

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.8

RB(DTL) 6 Feb 96

Equation (1) can be rewritten as follows:

$$X = \lambda \sqrt{\frac{(K_f + K_t)\ FI_{surface}}{L}} \qquad (4)$$

λ is a function of μ and α which are also rewritten as:

$$\mu = \frac{C_f + C_t}{2} \frac{FI_{surface}}{L\ t}$$

$$\alpha = \frac{(T_i - T_f)\ t}{FI_{surface}}$$

For a layered soil system, the modified Berggren method uses depth weighted thermal properties. The solution begins by determining the number of surface freezing degree days needed to freeze the first layer as follows:

$$FI_{①} = \frac{d_{①}^2\ L_{①}}{\lambda_{①}^2\ (K_{f①} + K_{t①})} \qquad (5)$$

where $\lambda_{①}$ is a function of $\mu_{①}$ and α;

$$\mu_{①} = \frac{C_{f①} + C_{t①}}{2} \frac{FI_{surface}}{L_{①}\ t}\ ; \text{ and}$$

$d_{①}$ = depth of soil layer ①.

[redacted]

Written by: MAO Date: 96/2/5 Reviewed by: PJS Date: 96/2/9

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: Ø8.8

RB (ØTL) 6 Feb 96

- If $FI_{①} > FI_{surface} \Rightarrow X < d_{①}$; calculate X using Equation (4)

- If $FI_{①} < FI_{surface} \Rightarrow$ frost penetration depth (X) will exceed $d_{①}$; calculate the freezing index for layer ② and so on. For all layers except layer ①, the freezing index is calculated as follows:

$$FI_{ⓝ} = \frac{d_{ⓝ}\,\bar{L}_{ⓝ}}{\lambda^2_{ⓝ}} \left[\frac{d_{ⓝ}}{K_{f_{ⓝ}} + K_{t_{ⓝ}}} + \sum_{i=1}^{n-1} \frac{d_i}{(K_{f_i} + K_{t_i})/2} \right] \quad (6)$$

where: $\lambda_{ⓝ} = \text{function}\,(\mu_{ⓝ}, \alpha)$

$$\mu_{ⓝ} = \frac{\bar{C}_{ⓝ}}{\bar{L}_{ⓝ}} \frac{FI_{surface}}{t} \quad (7)$$

$$\bar{C}_{ⓝ} = \frac{1}{2} \frac{\sum_{i=1}^{n} (C_{f_i} + C_{t_i})\, d_i}{\sum_{i=1}^{n} d_i} \quad (8)$$

$$\bar{L}_{ⓝ} = \frac{\sum_{i=1}^{n} L_i d_i}{\sum_{i=1}^{n} d_i} \quad (9)$$

- If $\sum_{i=1}^{n} FI_i > FI_{surface}$, the nth layer will partialy freeze → Calculate thickness of layer n which will freeze

Written by: MAO Date: 96/2/5 Reviewed by: PJS Date: 96/2/9

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.8

RB(DTL) 6 Feb 96

using an iterative solution where $d_{(n)}$ in Equation (6) is varied and corresponding $FI_{(n)}$ is calculated. The solution converges when $FI_{(n)} = FI_{surface} - \sum_{i=1}^{n-1} FI_i$.

Then, the thickness of layer (n) which will freeze (Y) is known. The total frost penetration depth $= \left(\sum_{i=1}^{n-1} d_i\right) + Y$

References:

Aldrich, H.P., and Paynter, H.M., "Frost Investigations, Fiscal Year 1953, First Interim Report", Analytical Studies of Freezing and Thawing Soils, Arctic Construction and Frost Effects Laboratory, New England Division, U.S. Army Corps of Engineers, Boston, MA, 1953.

Written by: MAO Date: 96/2/7 (YY/MM/DD) Reviewed by: RJS Date: 96/2/9 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 08.8

RB (DTL) 8 Feb 96

FROST PENETRATION DEPTH DATA VERIFICATION

Data required to calculate frost penetration depth includes the following:

- Weather Data:
  - mean annual ground temperature, T_i
  - number of days in the freezing season, t
  - air freezing index, FI_{air}
  - the n-factor relating ground surface freezing index ($FI_{surface}$) to FI_{air}
- Soil Thermal Properties (for each soil layer):
  - frozen and thawed thermal conductivities, K_f and K_t.
  - frozen and thawed specific heat capacities, C_f and C_t.
  - latent heat of fusion, L.

Written by: MAO Date: 96/2/7 (YY MM DD) Reviewed by: PJS Date: 96/2/9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: Ø8.8

RB (DTL) (8 Feb 96)

- Weather Data:

Daily minimum and maximum air temperatures were obtained from the National Climatic Data Center for Fairfield, Ohio, for years 1936 to 1995. Fairfield is located approximately 8 miles east to northeast of the OSDF site. This temperature data was analyzed to obtain parameters required for frost penetration depth calculations. The minimum and maximum temperatures were averaged to obtain average daily temperatures. The mean air temperature for the entire 1936 to 1995 temperature record was calculated to be 54.2 °F. For the purpose of frost penetration depth calculations, it is assumed that the mean annual ground temperature (T_i) is equal to the mean annual air temperature $\simeq$ 54 °F.

The temperature data was examined to estimate the number of days in the freezing season (t) and the air freezing index (FI_{air}). For this purpose, plots were produced which present the difference

RB(DTL) 8 Feb 96

between average daily temperature and freezing temperature (i.e., 32°F) as a function of time for each year from 1936 to 1995. Examples of these plots are included herein as Figures 1, 2, and 3. Due to the scatter in the temperature data, a curve is fitted through the data which represents median values for the entire year. The length of the freezing season (t) is estimated as the number of days for which the curve plots below zero. The air freezing index is calculated by summing the difference between 32°F and the average daily temperature for all days within the freezing season, as follows:

$$FI_{air} = \sum_{i=1}^{t} (32°F - Ta_i)$$

The length of the freezing season (t) and the air freezing index (FI_{air}) for years 1936 through 1995 are summarized in Table 1. The mean and standard deviation for the air freezing index (FI_{air}) were also calculated. The mean air freezing index was calculated to

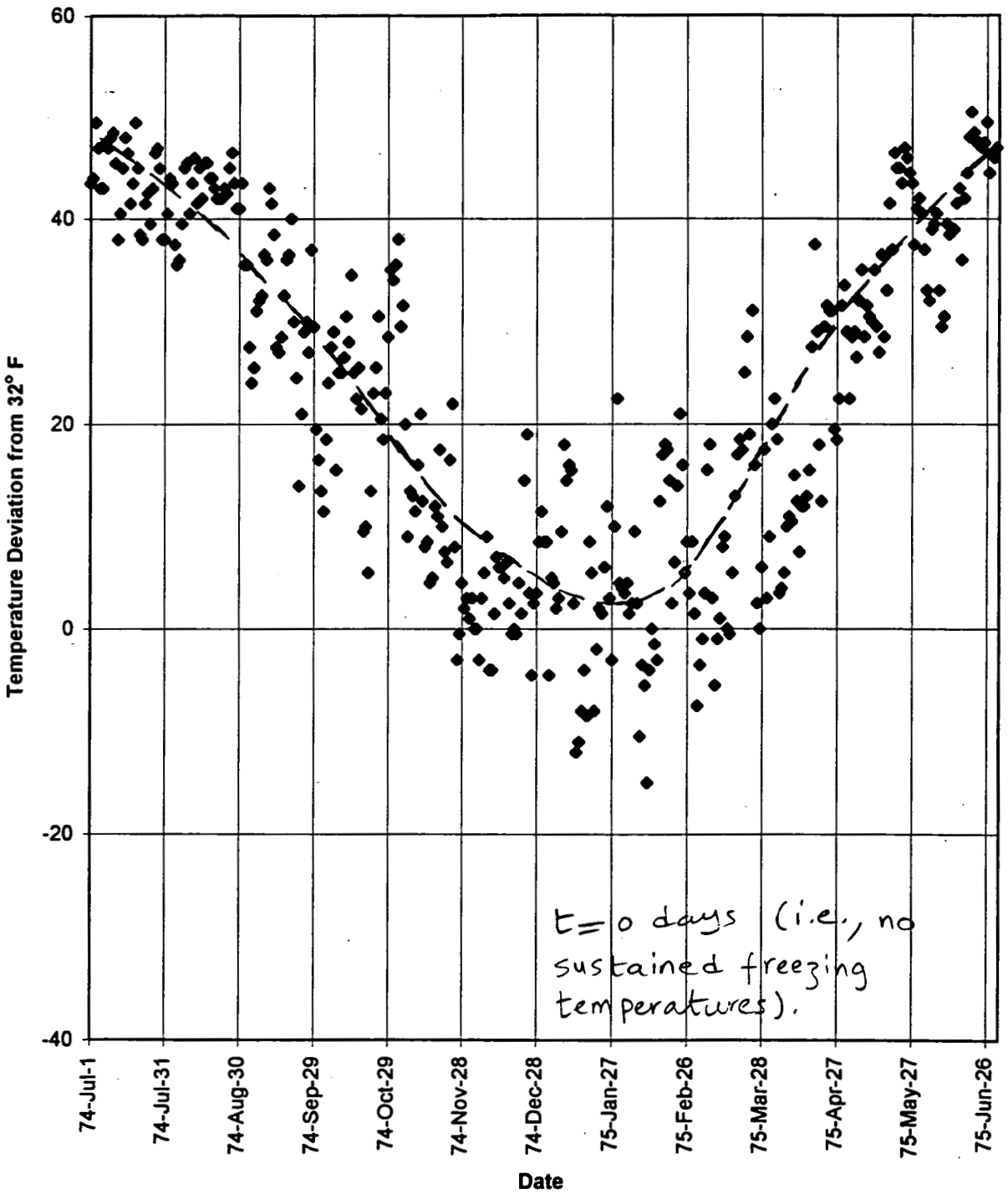
GEOSYNTEC CONSULTANTS

Written by: MAO Date: 96/2/7 (YY MM DD) Reviewed by: PJS Date: 96/2/9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: Φ8.8

RB (DTL) 8 Feb 96

Figure 1. Temperature Data for Fairfield, Ohio for year 1974 to 1975.



[redacted]

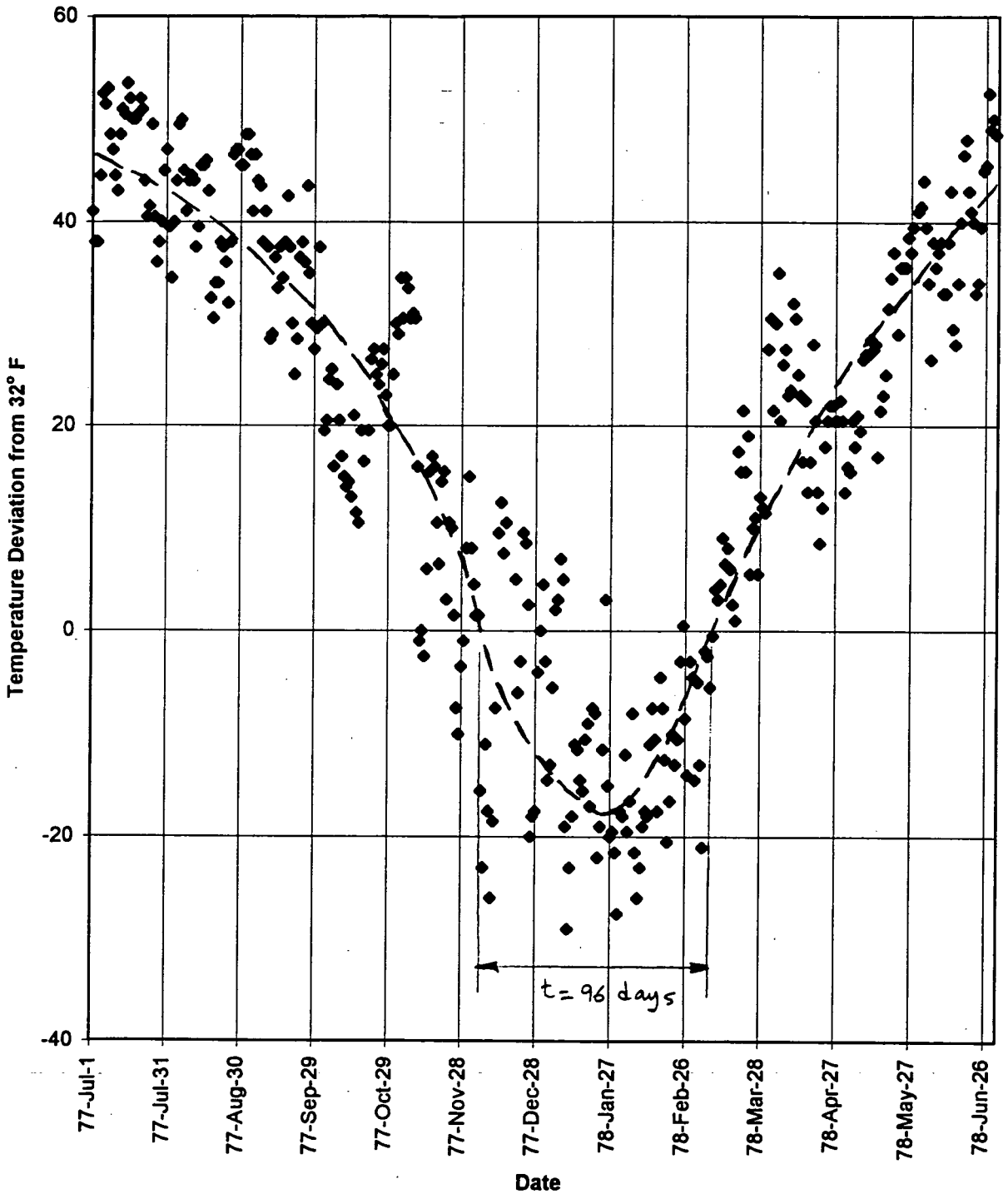
GEOSYNTEC CONSULTANTS

Written by: MAO Date: 96/2/7 (YY MM DD) Reviewed by: PJS Date: 96/2/9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: Ø 8.8

RB (DTL) 8 Feb 96

Figure 2. Temperature Data for Fairfield, Ohio for year 1977 to 1978.



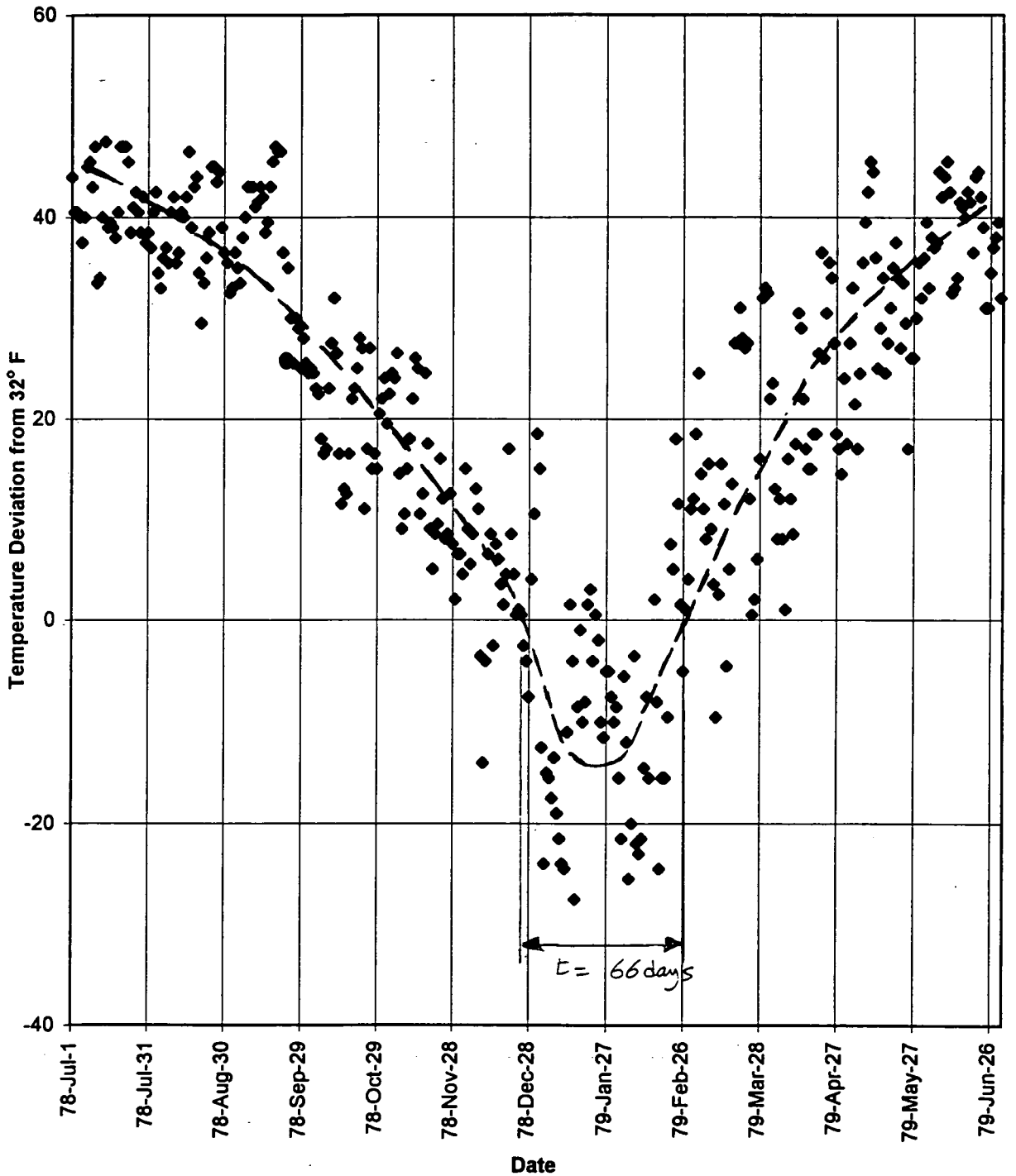
GEOSYNTEC CONSULTANTS

Written by: MAO Date: 96/2/7 (YY MM DD) Reviewed by: PJS Date: 96/2/9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.8

RB (DTL) 8 Feb 96

Figure 3. Temperature Data for Fairfield, Ohio for year 1978 to 1979.



[redacted]

Written by: MAO Date: 96/2/7 (YY/MM/DD) Reviewed by: PJS Date: 96/2/9 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: Ø8.8

RB(DTL) 8 Feb 96

Table 1. Summary of Freezing Season Days and Freezing Index Data for Fairfield, Ohio.

Year	Number of Freezing Season Days	Freezing Index (°F.days)
1936-1937	0	0
1937-1938	26	45.5
1938-1939	0	0
1939-1940	55	466
1940-1941	44	36
1941-1942	60	115
1942-1943	19	102
1943-1944	33	218.5
1944-1945	78	364.5
1945-1946	22	206
1946-1947	36	243.5
1947-1948	32	396.5
1948-1949	0	0
1949-1950	0	0
1950-1951	77	271.5
1951-1952	16	142
1952-1953	0	0
1953-1954	0	0
1954-1995	32	183.5
1955-1956	65	121.5
1956-1957	30	109.5
1957-1958	23	221
1958-1959	65	349
1959-1960	40	277
1960-1961	62	420
1961-1962	75	168
1962-1963	86	532.5
1963-1964	39	331
1964-1965	22	207
1965-1966	45	234
1966-1967	31	58.5
1967-1968	65	317
1968-1969	32	214.5
1969-1970	73	325
1970-1971	48	293
1971-1972	34	128.5
1972-1973	0	0
1973-1974	27	118
1974-1975	0	0
1975-1976	48	106
1976-1977	82	726.5
1977-1978	96	930
1978-1979	66	513.5
1979-1980	54	206.5
1980-1981	55	348.5
1981-1982	57	350
1982-1983	5	52.5
1983-1984	45	450
1984-1985	41	414.5
1986-1987	9	112
1987-1988	47	203
1988-1989	27	95
1989-1990	29	381.5
1990-1991	55	45
1991-1992	26	45.5
1992-1993	61	83.5
1993-1994	50	480
1994-1995	40	208

[redacted]

RB(DTL)(8 Feb 96)

be 224° F. days and the standard deviation to be 191°F. days. A histogram of the air freezing index values is shown in Figure 4. The probability of occurance decreases significantly with the increase of the air freezing index, as shown in Figure 4 and Table 1. For example, an air freezing index of 300°F. days has a higher probability of being exceeded than an air freezing index of 500°F. days in any particular year. The data suggests that an air freezing index greater than approximately 500°F. days has very low probability of occurence. The air freezing indices for the 1976-77 and 1977-78 winters appear to be extremely high in comparison to the indices for all other years since 1936. In fact the air freezing index for the 1977-1978 winter (FI_{air} = 930 °F. days) is almost five standard deviations higher than the mean freezing index (i.e., 224°F. days). Therefore, it appears that a design air freezing index of approximately 500°F. days may be reasonable for most

[redacted]

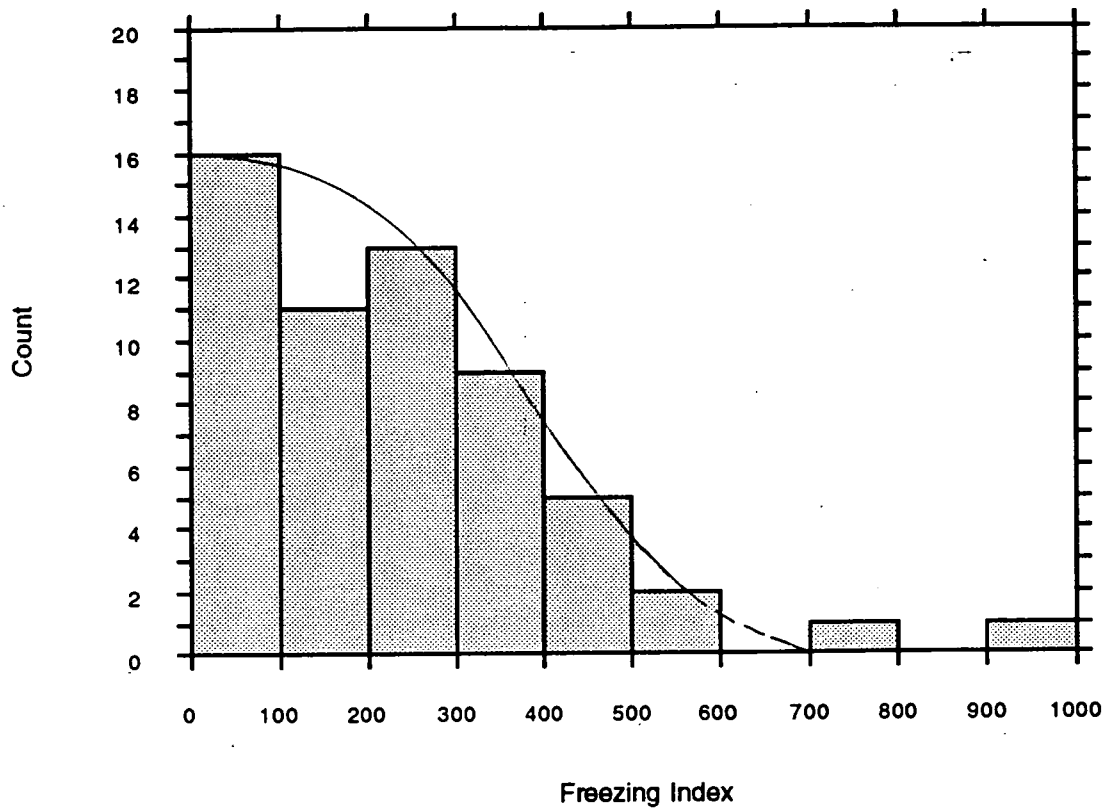
GEOSYNTEC CONSULTANTS

Written by: MAO Date: 96 / 2 / 7 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.3

RB (DTL) 8 Feb 96

Figure 4. Histogram of Freezing Index for Fairfield, Ohio for 1936 to 1995.



RB (DTL) 8 Feb 96

applications. In fact, the design air freezing index recommended by the U.S. Army Corps of Engineers is approximately 500°F. days, as shown in Figure 5. However, because the design life of the final cover system is expected to be on the order of 200 to 1000 years, which is much greater than the design life of most engineering structures, a design air freezing index greater than 500°F. days may be warranted. For the analysis of the final cover system, the highest air freezing index calculated from the available temperature records for Fairfield, Ohio, will be used. This freezing index equals 930°F. days (calculated for the winter of 1977-1978). The number of days in this freezing season (t) was calculated to be 96 days.

Table 2 (from Lunardini, 1978) gives values of n-factors for different surfaces. For soil surfaces covered with vegetation n-factors listed range from 0.25 to 0.29. Guidance

GEOSYNTEC CONSULTANTS

Written by: MAO Date: 96/2/7 (YY MM DD) Reviewed by: PJS Date: 96/2/9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: Ø8.8

RB (DTL) 8 Feb 96

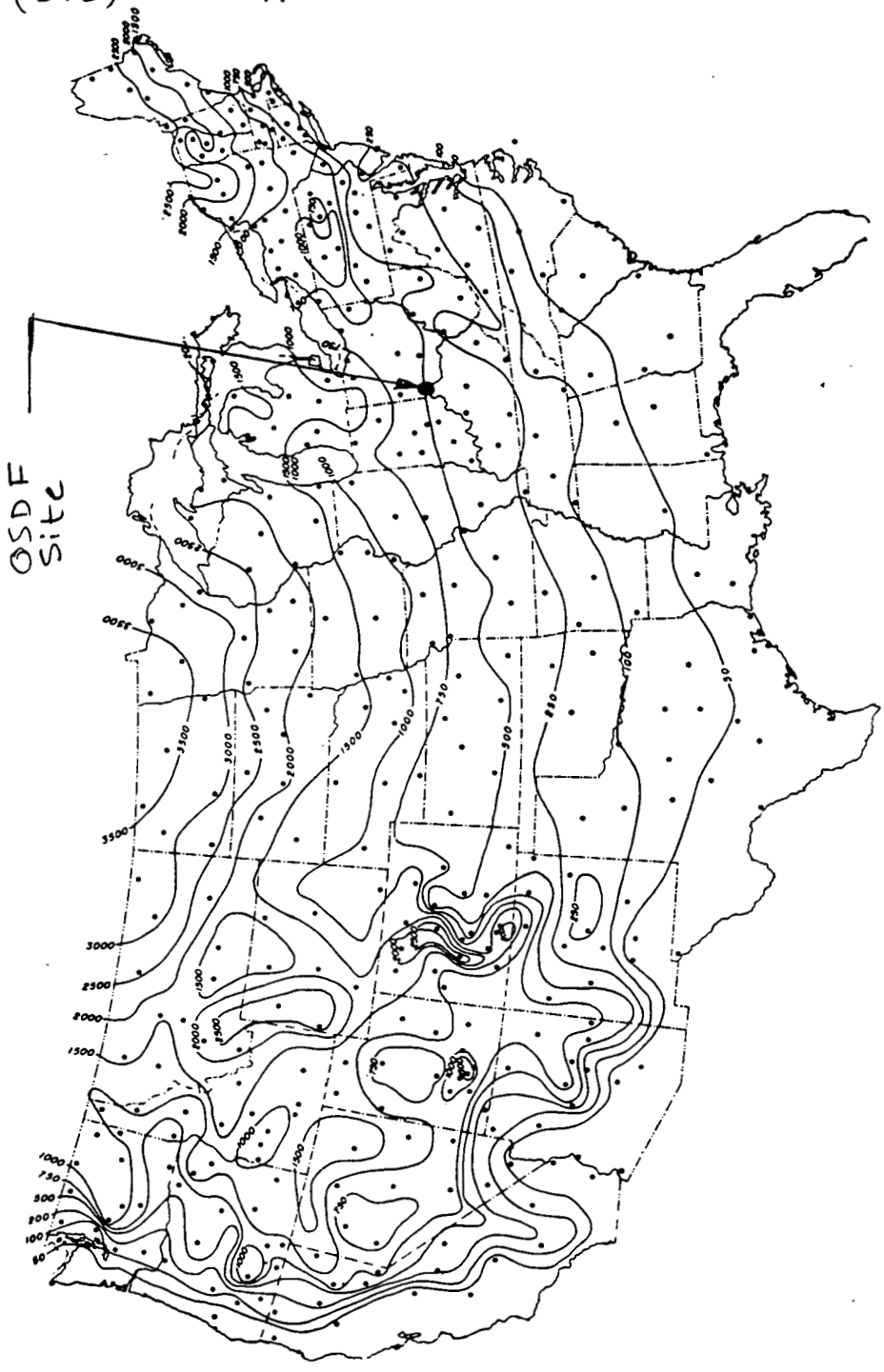


Figure 5. Design Freezing Index Values for the United States [from U.S. Army Corps of Engineers, 1962].

GEOSYNTEC CONSULTANTS

Written by: MAO Date: 96/2/7 (YY MM DD) Reviewed by: PJS Date: 96/2/9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.8

RB (DTL) 8 Feb 96

Table 2. Values of n-factors for Different Surfaces [After Lunardini, 1978].

Surface Type	Freezing-n_f	Thawing-n_t
Spruce trees, brush, moss over peat—soil surface	0.29 (under snow)	0.37
As above with trees cleared—soil surface	0.25 (under snow)	0.73
Turf	0.5 (under snow)	1.0
Snow	1.0	—
Gravel	0.6 – 1.0	1.3 – 2
(probable range for northern conditions)	(0.9 – 0.95)	
Asphalt pavement	0.29 – 1.0 or greater	1.4 – 2.3
(probable range for northern conditions)	(0.9 – 0.95)	
Concrete pavement	0.25 – 0.95	1.3 – 2.1
(probable range for northern conditions)	(0.7 – 0.9)	

[redacted]

Written by: MAO Date: 96/2/7 (YY MM DD) Reviewed by: PJS Date: 96/2/9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.8

RB (DTL) 8 Feb 96

provided in the UMTRA Technical Approach Document produced by the U.S. Department of Energy (USDOE) suggests using a factor of 0.60 to 0.70 for UMTRA projects. For this analysis, an n-factor of 0.70 will be used to be conservative.

[redacted]

Written by: MAO Date: 96/2/7 (YY/MM/DD) Reviewed by: PJS Date: 96/2/9 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: Ø8.8

RB(DTL) 8 Feb 96

- Soil Thermal Properties

Frozen and Thawed thermal conductivities (K_f and K_t) for all final cover system layers will be estimated based on the equations derived by Kersten [1949]. For coarse-grained soils (i.e., sands and gravels):

$$K_f = \frac{0.076\,(10)^{0.013\gamma_d} + \omega\,(0.032)\,(10)^{0.0146\gamma_d}}{12} \qquad (1)$$

$$K_t = \frac{(0.7\log\omega + 0.4)\,(10)^{0.01\gamma_d}}{12} \qquad (2)$$

For fine-grained soils (i.e., silts and clays):

$$K_f = \frac{0.01\,(10)^{0.022\gamma_d} + \omega\,(0.085)\,(10)^{0.008\gamma_d}}{12} \qquad (3)$$

$$K_t = \frac{(0.9\log\omega - 0.2)\,(10)^{0.01\gamma_d}}{12} \qquad (4)$$

where: ω = moisture content of soil by weight (%); and

γ_d = dry unit weight (pcf). [redacted]

Written by: MAO Date: 96/2/7 (YY/MM/DD) Reviewed by: RJS Date: 96/2/9 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSF Project/Proposal No.: GE3900 Task No.: 08.8

RB(DTL) 8 Feb 96

K_f and K_t are expressed in units of $\frac{Btu}{ft \cdot hr \cdot {}^oF}$

The following table summarizes K_f and K_t values calculated from Equations 1 through 4 for all of the final cover system layers.

Table 1. Summary of K_f and K_t data.

Layer	moisture content by volume, $\omega_{vol.}$ (%) (1)	total unit weight γ (pcf) (2)	moisture content by weight $\omega_{wt.}$ (%) (3)	dry unit weight γ_d (pcf) (4)	K_f $\frac{Btu}{ft \cdot hr \cdot {}^oF}$ (5)	K_t $\frac{Btu}{ft \cdot hr \cdot {}^oF}$ (5)
① Topsoil (6")	19.7	125	10.9	113	0.87	0.82
② Vegetative soil (21")	28.2	125	16.4	107	1.02	0.87
③ Granular filter (6")	17.3	125	9.5	114	1.36	1.25
④ Biointrusion barrier (36")	3.0	125	1.5	123	0.50	0.74
⑤ Drainage Layer (12")	4.2	125	2.1	122	0.58	0.87
⑥ GCL/compacted Clay (24.25")	43.0	130	26	103	1.38	0.96

Notes: (1) volumetric moisture content values are as used in leachate generation calculations performed using the USEPA HELP model.

(2) Assumed values based on expected material properties

(3) $\omega_{wt.} = \frac{\omega_{vol.}\ \gamma_w}{\gamma - \omega_{vol.}\ \gamma_w}$, where γ_w = unit weight of water, $\omega_{wt.} = \omega$ in Equations 1–4.

(4) $\gamma_d = \frac{\gamma}{1+\omega_{wt.}}$

(5) Equations 1 and 2 were used for layers ③, ④, and ⑤
Equations 3 and 4 were used for layers ①, ②, and ⑥

Written by: MAO Date: 96/2/7 (YY MM DD) Reviewed by: PJS Date: 96/2/9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 2900 Task No.: 3.3

RB(DTL) 8 Feb 96

Frozen and thawed specific heat capacities (C_f and C_t) for all layers will be estimated as follows:

$$C_f = \gamma_d \left(0.17 + \frac{0.5\omega}{100}\right) \quad (5)$$

$$C_t = \gamma_d \left(0.17 + \frac{\omega}{100}\right) \quad (6)$$

where: γ_d = dry unit weight (pcf)

ω = moisture content by weight (%)

C_f and C_t are in $\frac{Btu}{ft^3 \cdot {}^\circ F}$

Latent heat of fusion is calculated from the following equation:

$$L = \left(\gamma_d \frac{\omega}{100}\right) \times 144 \quad (7)$$

where: L = Latent heat of fusion $\left(\frac{Btu}{ft^3}\right)$

γ_d = dry unit weight (pcf)

ω = moisture content by weight (%)

Table 2 summarizes C_f, C_t, and L values for all of the final cover system components.

[redacted]

Written by: MAO Date: 96/2/7 (YY/MM/DD) Reviewed by: PJS Date: 96/2/9 (YY/MM/DD)

Client: FERMCO Project: FERNALD OU5DF Project/Proposal No.: GE3900 Task No.: 08.8

RB (DTL) 8 Feb 96

Table 2. Summary of C_f, C_t, and L data.

Layer	ω (%)	γ_d (%)	C_f $\left(\frac{Btu}{ft^3 \cdot °F}\right)$	C_t $\left(\frac{Btu}{ft^3 \cdot °F}\right)$	L $\left(\frac{Btu}{ft^3}\right)$
① Topsoil (6")	10.9	113	25.4	31.5	1,774
② Vegetative soil (21")	16.4	107	27.0	35.7	2,527
③ Granular Filter (6")	9.5	114	24.8	30.2	1,560
④ Biointrusion Barrier (36")	1.5	123	21.8	22.8	266
⑤ Drainage Layer (12")	2.1	122	22.0	23.3	369
⑥ GCL/Compacted Clay (24.25")	26	103	30.9	44.3	3,856

References:

Kersten, M.S., "Thermal Properties of Soils," Bulletin 28, Engineering Experimental Station, University of Minnesota, 1949.

Lunardini, V.J., "Theory of N-factors and Correlation of Data," Proceedings of the Third International Permafrost Conference, National Research Council of Canada, Vol. 1, 1978, pp. 41-46.

U.S. Army Corps of Engineers, "Pavement Design for Frost Conditions," Engineer Manual 1110-1-306, Washington, D.C., 1962, 33 p.

[redacted]

Written by: MAO Date: 96/2/9 (YY MM DD) Reviewed by: PJS Date: 96/2/9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.8

FROST PENETRATION DEPTH CALCULATIONS

The frost penetration depth into the final cover system is calculated herein based on the procedures and data summarized in the earlier parts of this package. The freezing indices required to freeze the final cover system layers are calculated. The design freezing index at the ground surface is compared to the sum of calculated freezing indices of the final cover system layers from top to bottom to estimate the location of the freezing front and hence frost penetration depth. Two cases will be analyzed: (i) the final cover system is intact (case A); and (ii) all layers above the biointrusion barrier have eroded (case B).

*CASE A:

Step 1 (calculate the thermal ratio, α):

$$\alpha = \frac{(T_i - T_f)\,t}{FI_{surface}}$$

$$FI_{surface} = n \times FI_{air} = 0.7 \times 930\,°F\cdot days$$
$$= 651\,°F\cdot days$$

$T_i = 54\,°F$, $T_f = 32\,°F$, $t = 96$ days.

Written by: MAO Date: 96/2/9 (YY/MM/DD) Reviewed by: PJS Date: 96/2/9 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.8

$$\rightarrow \alpha = \frac{(54\,^\circ F - 32\,^\circ F) \times 96 \text{ days}}{651\,^\circ F.\text{ days}} = 3.24$$

Step 2 (calculate the freezing index, FI, for the final cover system layers from top to bottom until Σ FI exceeds $FI_{surface}$):

$$FI_{①} = \frac{d_{①}^2 \, L_{①}}{\lambda_{①}^2 \left(K_{f①} + K_{t①}\right)}$$

$\lambda_{①}$ = function of $\mu_{①}$ and α as shown in Figure 1.

$$\mu_{①} = \frac{C_{f①} + C_{t①}}{2} \cdot \frac{FI_{surface}}{L_{①}\, t}$$

$$= \frac{(25.4 + 31.5)\frac{Btu}{ft^3 \cdot {}^\circ F}}{2} \; \frac{651\,^\circ F.\text{ days}}{1{,}774 \frac{Btu}{ft^3} \cdot 96 \text{ days}}$$

$$= 0.109$$

For $\alpha = 3.24$ and $\mu_{①} = 0.109 \longrightarrow \lambda_{①} = 0.62$

$$\rightarrow FI_{①} = \frac{(0.5\,ft)^2 \left(1{,}774 \frac{Btu}{ft^3}\right)}{(0.62)^2 \; (0.87 + 0.82)\frac{Btu}{ft.hr.^\circ F}} = 683\,^\circ F.\text{ hrs}$$

$$= 28\,^\circ F.\text{ days} \quad < \left(FI_{surface} = 651\,^\circ F.\text{days}\right)$$

$\longrightarrow$ Layer ① will freeze entirely and the freezing front will advance into layer ②.

Written by: MAO Date: 96/2/9 (YY/MM/DD) Reviewed by: PJS Date: 96/2/9 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.8

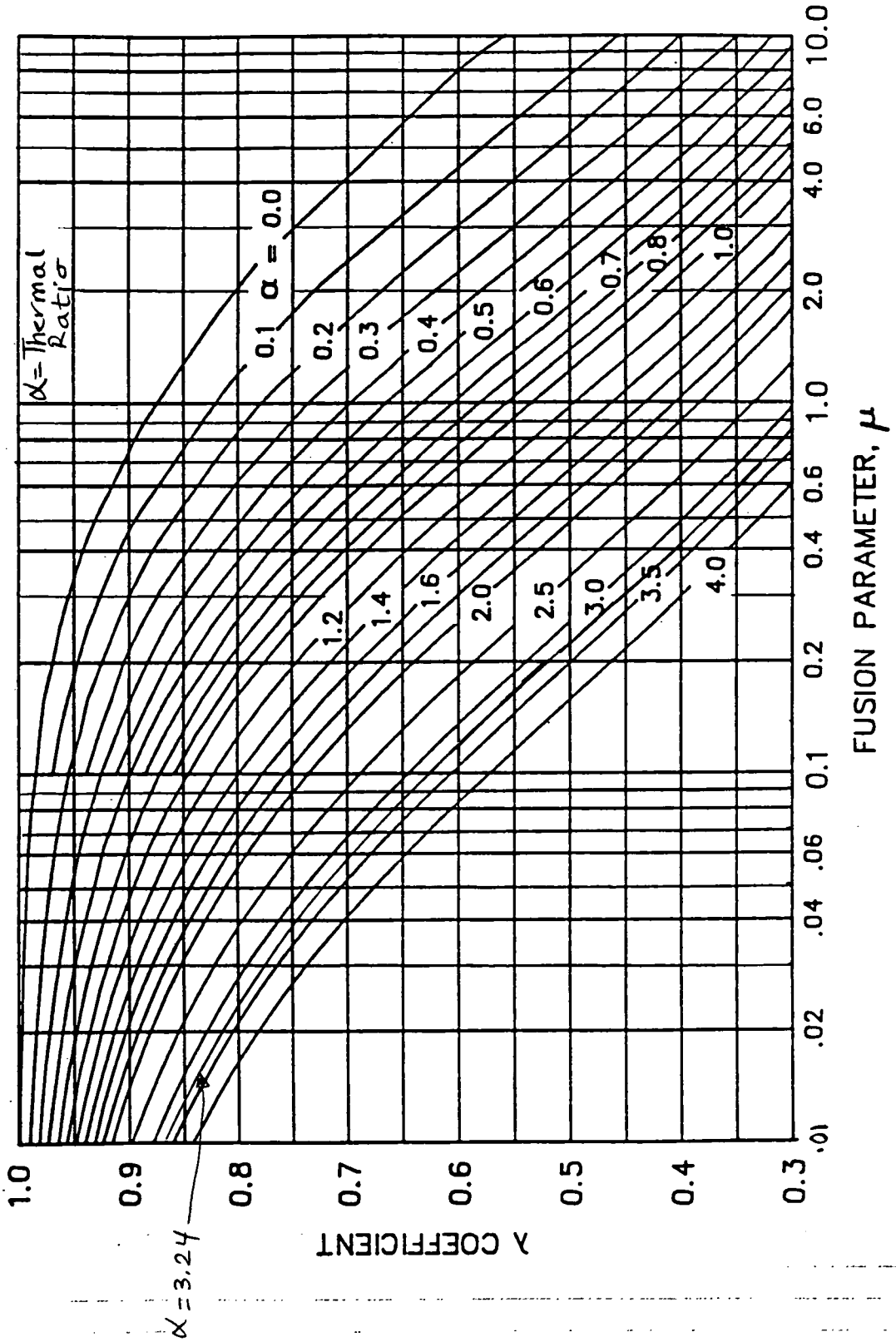


Figure 1. Coefficient λ as a function of fusion parameter (μ) and thermal ration (α) [Aldrich and Paynter, 1953]

Written by: MAO Date: 96/2/9 (YY MM DD) Reviewed by: PJS Date: 96/2/9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.8

Calculate $FI_{②}$

$$\bar{C}_{②} = \frac{1}{2} \sum_{i=1}^{2} (C_{fi} + C_{ti})\, d_i \Big/ \sum_{i=1}^{2} d_i$$

$$= \frac{1}{2} \frac{(25.4 + 31.5)\frac{Btu}{ft^3 \cdot {}^\circ F}(0.5\,ft) + (27.0 + 35.7)\frac{Btu}{ft^3 \cdot {}^\circ F}(1.75\,ft)}{0.5\,ft + 1.75\,ft}$$

$$= 30.7 \frac{Btu}{ft^3 \cdot {}^\circ F}$$

$$\bar{L}_{②} = \sum_{i=1}^{2} L_i\, d_i \Big/ \sum_{i=1}^{2} d_i$$

$$= \frac{(1{,}774 \frac{Btu}{ft^3})(0.5\,ft) + (2{,}527 \frac{Btu}{ft^3})(1.75\,ft)}{0.5\,ft + 1.75\,ft}$$

$$= 2{,}360 \frac{Btu}{ft^3}$$

$$\mu_{②} = \frac{\bar{C}_{②}}{\bar{L}_{②}} \frac{FI_{surface}}{t}$$

$$= \frac{30.7 \frac{Btu}{ft^3 \cdot {}^\circ F}}{2{,}360 \frac{Btu}{ft^3}} \frac{651\,{}^\circ F \cdot days}{96\,days}$$

$$= 0.088$$

for $\alpha = 3.24$ and $\mu_{②} = 0.088 \rightarrow \lambda_{②} = 0.645$

[redacted]

Written by: MAO Date: 96 / 2 / 9 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: Ø8.8

$$FI_{②} = \frac{d_{②}\,\bar{L}_{②}}{\lambda_{②}^2}\left[\frac{d_{②}}{K_{f_{②}} + K_{t_{②}}} + \frac{d_{①}}{(K_{f_{①}} + K_{t_{①}})/2}\right]$$

$$= \frac{(1.75\,ft)\left(2{,}360\,\frac{Btu}{ft^3}\right)}{(0.645)^2}\left[\frac{1.75\,ft}{(1.02+0.87)\frac{Btu}{ft\cdot hr\cdot °F}} + \frac{0.5\,ft}{\left(\frac{0.87+0.82}{2}\right)\frac{Btu}{ft\cdot hr\cdot °F}}\right]$$

$$= 15{,}066\ °F.hrs = 628\ °F.days$$

$$FI_{①} + FI_{②} = 28 + 628 = 656\ °F.days$$

$$\approx \left(FI_{surface} = 651\,°F.days\right)$$

Therefore, almost all of layer ② will freeze (i.e., the freezing front is at the bottom of layer ②).

Step 3 (Calculate Frost Penetration Depth):

$$\text{Frost penetration depth} = d_{①} + d_{②}$$

$$= 0.5\,ft + 1.75\,ft$$

$$= \underline{2.25\ ft}$$

Therefore, the compacted clay is protected from freezing under the conditions analyzed.

[redacted] 190

Written by: MAO Date: 96/2/9 (YY/MM/DD) Reviewed by: PJS Date: 96/2/9 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.8

* CASE B:

Step 1. (Calculate α):

As from before, $\alpha = 3.24$ ✓

Step 2 (Calculate FI for each layer and compare ΣFI to $FI_{surface}$ going from top to bottom starting from the biointrusion barrier)

$$\mu_{①} = \frac{C_{f①} + C_{t①}}{2} \quad \frac{FI_{surface}}{L_{①}\, t}$$

$$= \frac{(21.8 + 22.8)\frac{Btu}{ft^3\,°F}}{2} \frac{(651\,°F.\,days)}{\left(266\,\frac{Btu}{ft^3}\right)(96\,days)} = 0.57 \checkmark$$

For $\alpha = 3.24$ and $\mu_{①} = 0.57 \rightarrow \lambda_{①} = 0.355$

$$FI_{①} = \frac{d_{①}^2\, L_{①}}{\lambda_{①}^2 \left(K_{f①} + K_{t①}\right)}$$

$$= \frac{(3\,ft)^2 \left(266\,\frac{Btu}{ft^3}\right)}{(0.355)^2 \left(0.5 + 0.74\right)\frac{Btu}{ft.hr.°F}} = 15{,}320\,°F.\,hrs$$

$$= 638\,°F.\,days < FI_{surface} = 651\,°F.\,days \checkmark$$

Therefore, the entire biointrusion barrier will freeze and the freezing front will extend slightly into the drainage layer.

GEOSYNTEC CONSULTANTS

Written by: MAO Date: 96/2/9 (YY/MM/DD) Reviewed by: PJS Date: 96/2/9 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE 3900 Task No.: 08.8

calculate $FI_{②}$ =

$$\overline{C}_{②} = \frac{1}{2} \sum_{i=1}^{2} (C_{fi} + C_{ti})\, d_i \Big/ \sum_{i=1}^{2} d_i$$

$$= \frac{1}{2} \frac{(21.8 + 22.8)\frac{Btu}{ft^3 \cdot {}^\circ F}(3\,ft) + (22.0 + 23.3)\frac{Btu}{ft^3 \cdot {}^\circ F}(1\,ft)}{3\,ft + 1\,ft}$$

$$= 22.4 \frac{Btu}{ft^3 \cdot {}^\circ F} \checkmark$$

$$\overline{L}_{②} = \sum_{i=1}^{2} L_i d_i \Big/ \sum_{i=1}^{2} d_i$$

$$= \frac{\left(266 \frac{Btu}{ft^3}\right)(3\,ft) + \left(369 \frac{Btu}{ft^3}\right)(1\,ft)}{3\,ft + 1\,ft}$$

$$= 292 \frac{Btu}{ft^3} \checkmark$$

$$\mu_{②} = \frac{\overline{C}_{②}}{\overline{L}_{②}} \frac{FI_{surface}}{t}$$

$$= \frac{22.4 \frac{Btu}{ft^3 \cdot {}^\circ F}}{292 \frac{Btu}{ft^3}} \frac{651\,{}^\circ F \cdot days}{96\,days} = 0.52. \checkmark$$

For $\alpha = 3.24$ and $\mu_{②} = 0.52 \rightarrow \lambda_{②} = 0.37 \checkmark$

[redacted]

Written by: MAO Date: 96 / 2 / 9 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.3

$$FI_{②} = \frac{d_{②}\,\overline{L}_{②}}{\lambda_{②}^2}\left[\frac{d_{②}}{K_{f②}+K_{t②}} + \frac{d_{①}}{(K_{f①}+K_{t①})/2}\right]$$

$$= \frac{(1\,ft)(292\,\frac{Btu}{ft^3})}{(0.37)^2}\left[\frac{1\,ft}{(0.58+0.87)\frac{Btu}{ft.hr.^\circ F}} + \frac{3\,ft}{\frac{(0.5+0.74)}{2}\frac{Btu}{ft.hr.^\circ F}}\right]$$

$$= 11{,}792\ ^\circ F.\,hrs = 491\ ^\circ F.\,days$$

$$FI_{①} + FI_{②} = 638\ ^\circ F.\,days + 491\ ^\circ F.\,days$$
$$= 1129\ ^\circ F.\,days$$

Therefore, only a portion of the drainage layer will freeze. Assume 0.1 ft of drainage layer freezes. Recalculate $FI_{②}$.

$$\overline{C}_{②} = \frac{1}{2}\,\frac{(21.8+22.8)\frac{Btu}{ft^3\,^\circ F}(0.1\,ft) + (22.0+23.3)\frac{Btu}{ft^3\,^\circ F}(3\,ft)}{0.1\,ft + 3\,ft}$$

$$= 22.6\ \frac{Btu}{ft^3\,^\circ F}$$

$$\overline{L}_{②} = \frac{(266\,\frac{Btu}{ft^3})(3\,ft) + (369\,\frac{Btu}{ft^3})(0.1\,ft)}{3\,ft + 0.1\,ft} = 269.3\,\frac{Btu}{ft^3}$$

$$\bar{\mu}_{②} = \frac{22.6\,\frac{Btu}{ft^3\,^\circ F}}{269.3\,\frac{Btu}{ft^3}}\ \frac{651\ ^\circ F.\,days}{96\ days} = 0.57.$$

For $\alpha = 3.24$ and $\bar{\mu}_{②} = 0.57 \rightarrow \lambda_{②} = 0.355$

Written by: MAC Date: 96 / 2 / 9 (YY MM DD) Reviewed by: Date: 96 / 2 / 9 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 08.8

$$FI_{②} = \frac{(0.1\ ft)\left(269.3\ \frac{Btu}{ft^3}\right)}{(0.355)^2}\left[\frac{0.1\ ft}{(0.58+0.87)\frac{Btu}{ft \cdot hr \cdot °F}} + \frac{3\ ft}{\left(\frac{0.5+0.74}{2}\right)\frac{Btu}{ft \cdot hr \cdot °F}}\right]$$

$$= 1{,}049\ °F.hrs = 44\ °F.days$$

$$FI_{①} + FI_{②} = 638\ °F.days + 44\ °F.days$$
$$= 682\ °F.days > FI_{surface} = 651\ °F.days$$

Therefore, a thickness greater than 0 and less than 0.1 ft of the biointrusion layer will freeze. Say 0.1 ft.

Step 3 (calculate frost depth):

$$\text{frost depth} \approx 3\ ft + 0.1\ ft = \underline{3.1\ ft}$$

Therefore, the compacted clay layer of the final cover system is protected from frost even if all layers above the biointrusion layer erode.

[redacted]

11.5 Final Cover System Granular Filter Layer Design

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: FINAL COVER SYSTEM GRANULAR FILTER LAYER DESIGN

Computations By: (Cognizant Engineer)
Signature: Peter J. Prommer — Date: 16 Feb 1996
Printed Name and Title: Peter J. Prommer, Senior Staff Engineer

Assumptions and Procedures Checked by: (Checker)
Signature: Paul J. Sabatini — Date: 17 Feb 96
Printed Name and Title: PAUL J. SABATINI, SENIOR STAFF ENGINEER

Computations Checked by:
Signature: Paul J. Sabatini — Date: 17 Feb 96
Printed Name and Title: SENIOR STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Peter J. Prommer — Date: 18 Feb 1996
Printed Name and Title: Peter J. Prommer, Senior Staff Engineer

Approved by: (PDP)
Signature: Majdy Ahmed Othman — Date: 19 Feb 1996
Printed Name and Title: MAJDI A. OTHMAN, PROJECT ENGINEER

Approved by: (DTL and TETL)
Signature: Rudolph Bonaparte — Date: 20 Feb 1996
Printed Name and Title: Rudolph Bonaparte, Principal (DTL)

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	60% Submittal	16 Feb 1996	PJP	RJS	RB
D	Intermediate Design - EPA Submitted	4 Apr 96	—	—	—
G	Final Design Package	4 Oct 96	—	—	—
O	Response to Final Design Cmts	9 May 97	—	—	—

Written By: PJP Date: 16 Feb 1996 Reviewed by: PJS Date: 96 2-17

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

FINAL COVER SYSTEM GRANULAR FILTER LAYER DESIGN

EXECUTIVE SUMMARY

PURPOSE OF ANALYSIS

The purpose of this package is to evaluate the performance of the final cover system granular filter layer. This consists of determining an appropriate soil that will provide soil filtration between the vegetative soil layer and the biointrusion barrier choke stone.

METHODS OF ANALYSIS

A range of grain-size distribution curves for the on-site brown till was obtained from a previous site investigation report and is anticipated to represent the range of grain-size distributions of the vegetative soil layer. A range of allowable grain size distributions was established for the granular filter layer such that the granular filter would provide adequate filtration of the vegetative soil layer and be compatible with (i.e., retained by) the biointrusion barrier choke stone.

CONCLUSIONS

- the following grain-size distibution is required for the granular filter layer

Sieve	% Passing Sieve by Weight
2"	100
3/4"	80 to 100
1/2"	70 to 85
#4	55 to 70
#8	50 to 65
#50	15 to 35
#60	0 to 30
#200	0 to 5

[redacted]

GEOSYNTEC CONSULTANTS

Written by: _____ Date: _____ Reviewed

Client: FERMCO Project: OSDF P

THIS PAGE IS INSERTED ONLY FOR CLARITY AND DOES NOT AFFECT THE NUMBERING SYSTEM OF THE REST OF THE PACKAGE

GRANULAR FILTER LAYER DESIGN

TABLE OF CONTENTS

		Page
1.	Calculation Procedures	1/3
2.	Data Verification	1/4
3.	Calculation Results	1/3

Written By: PJP Date: 16 Feb 1996 Reviewed by: PJS Date: 96 2-17

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB(DTL)16 FEB 96

FINAL COVER SYSTEM GRANULAR FILTER LAYER DESIGN

CALCULATION PROCEDURES

INTRODUCTION

The purpose of this package is to present the calculation procedures for evaluation of the performance of the FEMP On-Site Disposal Facility (OSDF) final cover system granular filter layer. This package addresses the following issues:

- establishing a range of allowable grain-size distributions for the granular filter layer to provide adequate soil filtration of the vegetative soil layer; and
- checking the compatibility of the granular filter with the biointrusion barrier choke stone.

The final cover system configuration is shown in Figure 1.

METHODS OF ANALYSIS

The final cover system contains a granular filter which separates the vegetative soil layer and the biointrusion barrier. Analyses will be performed to establish a range of allowable grain-size distributions for the granular filter layer such that the granular filter layer adequately filters the vegetative soil layer. The following criterion from Cedergren [1989] will be used:

1. (d_{15} of filter soil / d_{85} of soil being filtered) $\leq$ 4 to 5 (5 or 10 if protected soil is plastic clay)
   - the ratio will be checked against $\leq$10 when the protected soil is the vegetative soil layer and $\leq$5 for all other conditions

[redacted]

Written By : PJP Date: 16 Feb 1996 Reviewed by: RJS Date: 96 2-17

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB(DTL)16 FEB 96

2. (d_{15} of filter soil / d_{15} of soil being filtered) $\geq$ 4 to 5
   - the ratio will be checked against ≥4 for all conditions

where d_{15} corresponds to the material particle size for which 15% by weight of the particles are finer and d_{85} corresponds to the material particle size for which 85% by weight of the particles is finer.

The intent of criterion 1 is to prevent piping of the retained soil by the filter soil. The intent of criterion 2 is to obtain a filter soil with a sufficiently larger permeability than the retained soil to prevent the build-up of large seepage forces and hydrostatic pressures in the filter. For the final cover system, relatively small seepage forces and hydrostatic pressures exist; thus, criterion 2 is not critical, but it is still verified. In addition to the foregoing criteria, UMTRA [1989] suggests the fines content of a filter should be limited to less than 5% by weight passing the #200 sieve to prevent excessive movement of fines in the filter. Additionally, to limit segregation and bridging of particles during placement and aid in constructibility, the filter should not contain any materials larger than 3 inches.

REFERENCES

Cedergren, H.R. (1989). *Seepage, Drainage, and Flow Nets*. John Wiley and Sons, New York, 465 p.

U.S. Department of Energy (1989). "Technical Approach Document," UMTRA-DOE/AL 050425.0002, Uranium Mill Tailings Remedial Action Project, Revision 2, December.

[redacted]

GEOSYNTEC CONSULTANTS

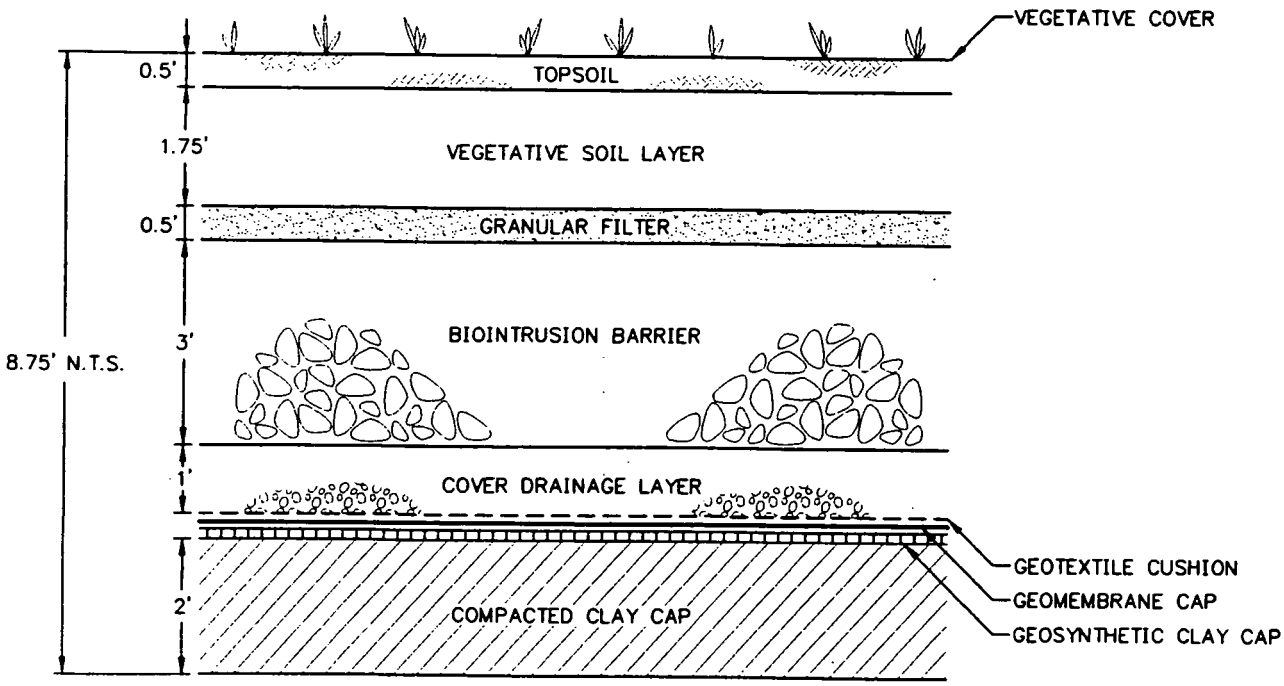
MAD 96/2/16

Written By: PJP Date: 16 Feb 1996 Reviewed by: PJS Date: 96-2-17

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB(DTL) 16 FEB 96

Figure 1. Final Cover System



FINAL COVER SYSTEM

[redacted]

Written By: PJP Date: 16 Feb 1996 Reviewed by: RJS Date: 96 2-17

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB(DTL) 16 FEB 96

FINAL COVER SYSTEM GRANULAR FILTER LAYER DESIGN

DATA VERIFICATION

INTRODUCTION

The purpose of this package is to verify the data required for the calculation procedures described in the previous section to perform the following analyses:

- establishing a range of allowable grain-size distributions for the granular filter layer to provide adequate soil filtration of the vegetative soil layer; and
- checking the compatibility of the granular filter with the biointrusion barrier choke stone.

GRANULAR FILTER LAYER ANALYSIS

It is anticipated that brown till from on-site borrow sources will be used for the vegetative soil layer. Figure 1 (from Parsons, 1995) presents summary information on the grain-size distribution characteristics of 27 samples of brown till. It is assumed that the range of grain-size distributions shown in Figure 1 encompasses the range of grain-size distributions for the vegetative soil layer. Figure 1 primarily represents soils within the OSDF foot-print. Additional grain-size information is being processed from samples obtained from the brown till in the Borrow Area which will likely be used for the vegetative soil layer. As this information is obtained, the grain-size distibution used to represent the vegetative soil layer will be verified.

From the "Final Cover System Biointrusion Barrier Design" Calculation Package, the upper portion (approximately the upper 6 inches) of the biointrusion barrier will be "choked off." An Ohio DOT #1 stone will be used for the choke stone.

The grain-size distribution curves for the vegetative cover (brown till) layer and the biointrusion barrier choke stone are shown in Figure 2. Based on these curves, d_{15} and d_{85} for these layers are summarized below:

[redacted]

- d_{15} of the vegetative soil layer = <0.001 to 0.0028 mm
- d_{85} of the vegetative soil layer = 0.035 to 3.0 mm
- d_{15} of the biointrusion choke stone = 37.5 to 58 mm
- d_{85} of the biointrusion choke stone = 70 to 90 mm

REFERENCES

Parsons. (1995). *Disposal Facility Predesign Geotechnical Investigation, Soil Investigation Data Report, Summary Document*,Operable Unit 2, Project Order 132, Revision 0 (Final Document), prepared for FERMCO for the Fernald Environmental Management Project, Subcontract No. 2-21487, July.

[redacted]

GEOSYNTEC CONSULTANTS

MAO 96/2/16

Written By: PJP Date: 16 Feb 1996 Reviewed by: PJS Date: 96 2-17

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB(DTL) 16 FEB 96

FIGURE 1

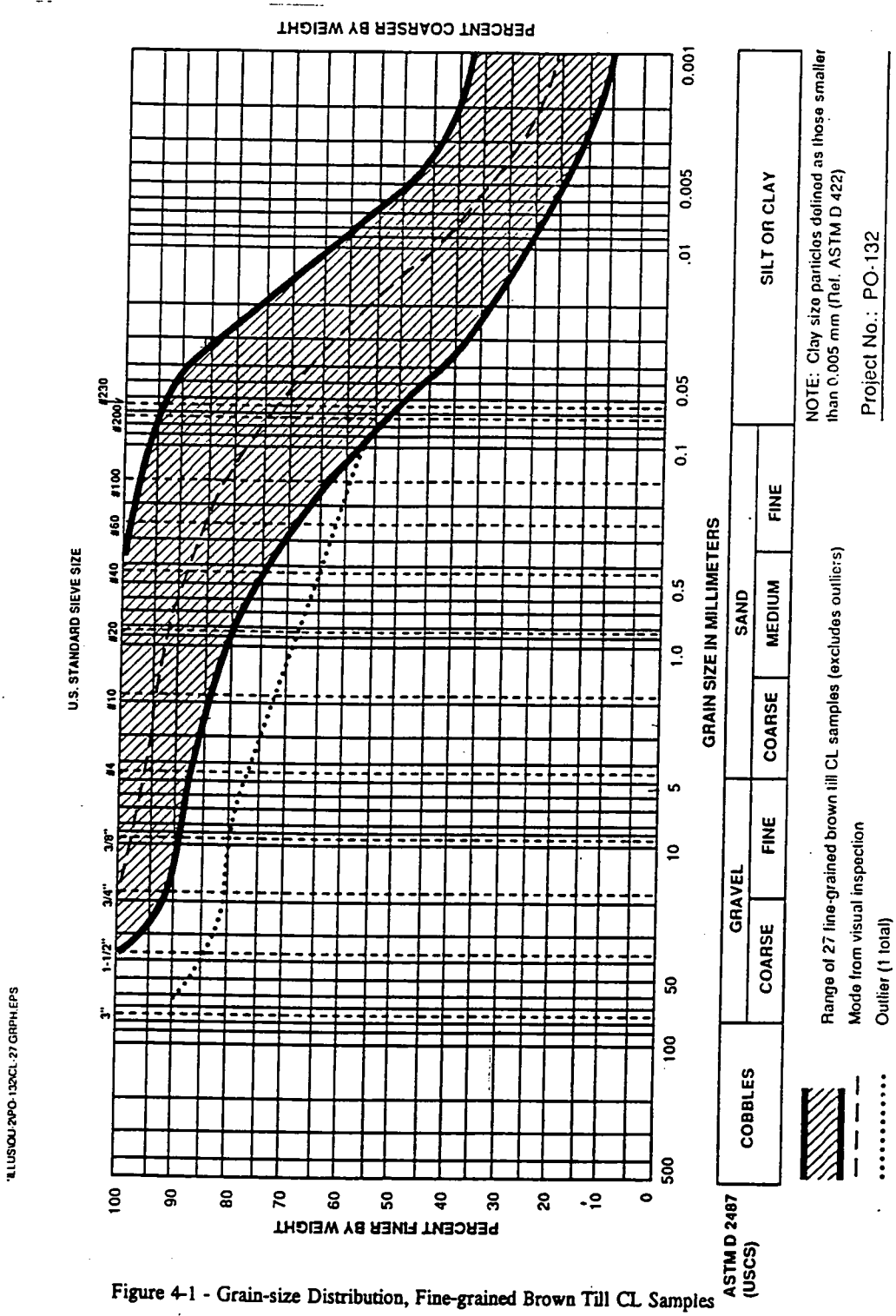


Figure 4-1 - Grain-size Distribution, Fine-grained Brown Till CL Samples

from Parsons [1995]

[redacted]

GEOSYNTEC CONSULTANTS

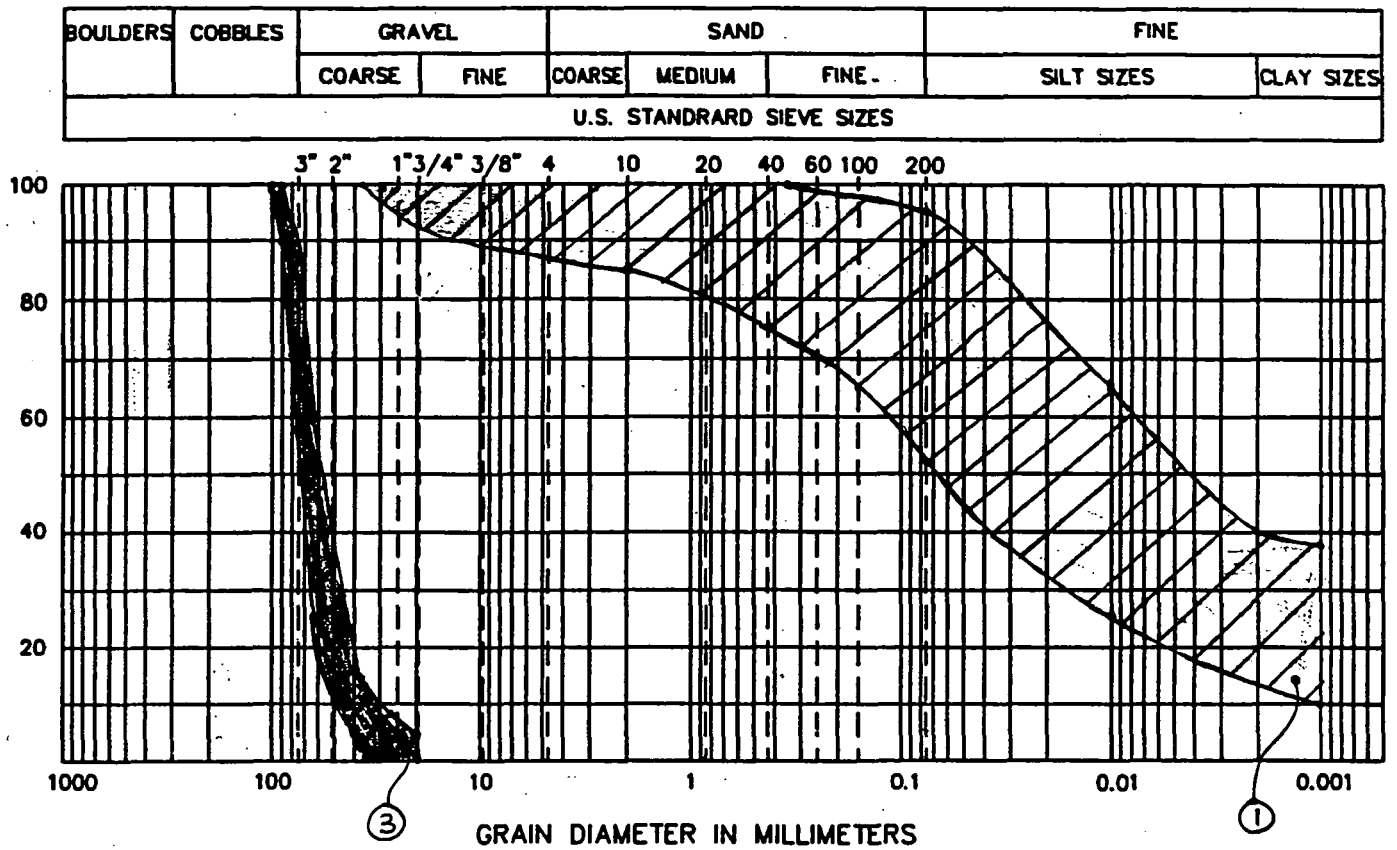
MAO 96/2/16

Written By: PJP Date: 16 Feb 1996 Reviewed by: PJS Date: 96 2-17

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB (DTL) 16 FEB 96

FIGURE 2. GRAIN-SIZE DISTRIBUTION OF THE VEGETATIVE SOIL LAYER AND BIOINTRUSION BARRIER CHOKE STONE



1 -- Vegetative Soil Layer (brown till from Parsons, 1995)

3 -- Biointrusion Barrier Choke Stone (Ohio DOT #1)

[redacted]

GEOSYNTEC CONSULTANTS

MAO 96/2/19

Written by: PJP Date: 96/02/16 (YY/MM/DD) Reviewed by: PJS Date: 96/2/17 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

FINAL COVER SYSTEM GRANULAR FILTER DESIGN

CALCULATION RESULTS

		d_{15}	d_{85}
Vegetative Soil	①	<0.0010 to 0.0028 mm	0.035 to 3.0 mm
Granular Filter	②	to be determined	to be determind
Biointrusion Barrier Choke Stone	③	37.5 to 58 mm	70 to 90 mm
Biointrusion Barrier			

Piping (Layer ① → ②)

$$\frac{d_{15_{②}}}{d_{85_{①}}} \leq 5 \text{ to } 10 \rightarrow \text{use ratio of } 10$$

$$\frac{d_{15_{②}}}{0.035 \text{ to } 3.0 \text{ mm}} \leq 10 \rightarrow$$ check versus 0.035 since this will give upper limit of $d_{15_{②}}$

$$d_{15_{②}} \leq 0.35 \text{ mm}$$

Permeability (Layer ① → ②)

$$\frac{d_{15_{②}}}{d_{15_{①}}} \geq 4 \text{ to } 5 \rightarrow \text{use ratio of } 4$$

[redacted]

$$\frac{d_{15_{②}}}{<0.0010 \text{ to } 0.0028} \geq 4 \rightarrow$$ check versus 0.0028 to get lower limit of $d_{15_{②}}$

$\therefore$ $d_{15_{②}} \geq 0.011$, but the fines content must also be limited to less than 5% passing #200 sieve

MAO 96/2/19

Written by: PJP Date: 96 / 02 / 16 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 17 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

Piping (Layer ② → ③)

$$\frac{d_{15③}}{d_{85②}} \leq 4 \text{ to } 5 \rightarrow \text{use ratio of } 5$$

$$\frac{37.5 \text{ to } 58}{d_{85②}} \leq 5 \rightarrow \text{check versus 58 to get lower limit of } d_{85②}$$

$$d_{85②} \geq 12\text{mm}$$

Permeability (Layer ② → ③)

$$\frac{d_{15③}}{d_{15②}} \geq 4 \text{ to } 5$$

$$\frac{37.5 \text{ to } 58}{0.011 \text{ to } 0.35} \geq 4 \text{ to } 5$$

$$107 \text{ to } 5272 > 4 \text{ to } 5 \checkmark$$

$\boxed{\text{Granular Filter Criteria}}$

- $0.011\text{mm} < d_{15②} < 0.35\text{mm}$
  ↓
  with limit of <5% passing #200

- $d_{85②} \geq 12\text{mm}$, but should be <3 in. to limit segregation (use <2 in. to be conservative and because layer is only 6 in. thick)
- want a well-graded material

* See curve on the following page

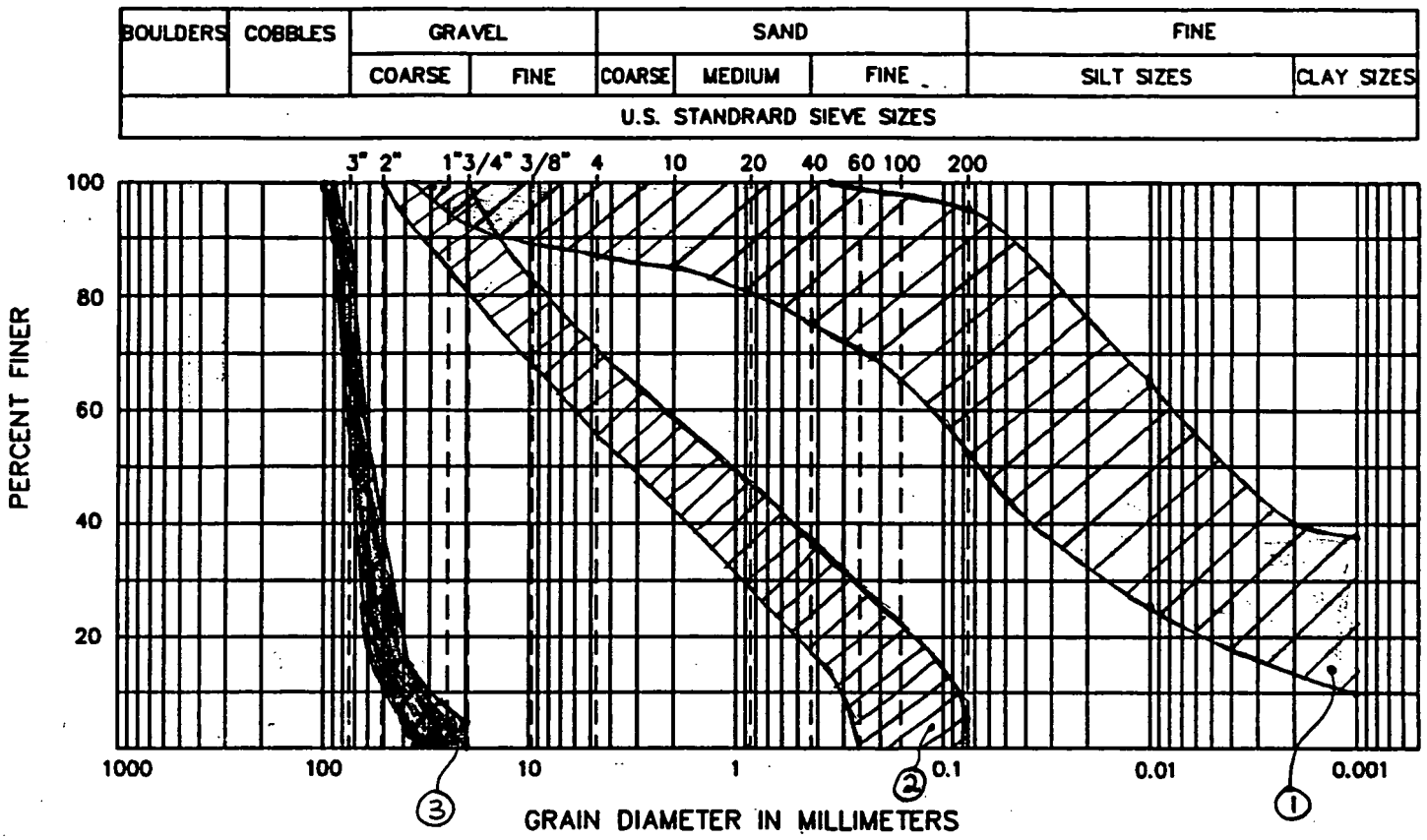
[redacted]

GeoSyntec Consultants

MAO 96/2/19

Written by: PJP Date: 96 / 02 / 16 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 17 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8



1. Vegetative Soil Layer (brown till CL)
2. Granular Filter Layer
3. Biointrusion Barrier Choke Stone

Granular Filter Grain-Size Distribution:

Sieve	% Passing by Weight
2"	100
3/4"	80 to 100
1/2"	70 to 85
#4	55 to 70
#8	50 to 65
#50	15 to 35
#60	0 to 30
#200	0 to 5

[redacted]

11.6 Final Cover System Biointrusion Barrier Design

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: FINAL COVER SYSTEM BIOINTRUSION BARRIER DESIGN

Computations By: (Cognizant Engineer)
Signature [signature] Date 17 Feb 1996
Printed Name and Title Peter J. Prommer, Senior Staff Engineer

Assumptions and Procedures Checked by: (Checker)
Signature Paul J. Sabatini Date 17 Feb 1996
Printed Name and Title PAUL J. SABATINI, SR. STAFF ENGINEER

Computations Checked by:
Signature Paul J. Sabatini Date 17 Feb 1996
Printed Name and Title SR. STAFF ENGINEER, PAUL J. SABATINI

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 19 Feb 1996
Printed Name and Title Peter J. Prommer, Senior Staff Engineer

Approved by: (PDP)
Signature Magdy Ahmed Othman Date 19 Feb 1996
Printed Name and Title MAJDI A. OTHMAN, PROJECT ENGINEER

Approved by: (DTL and TETL)
Signature Rudolph Bonaparte Date 20 Feb 96
Printed Name and Title Rudolph Bonaparte, Principal (DTL)

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	~~60% Submitted~~ Intermediate Design 19 Feb 96 MAJ	17 Feb 1996	[illegible]	RJS	RB
D	Intermediate Design - EPA Submittal	4 Apr 96	[illegible]	—	—
G	Final Design Package	4 Oct 96	—	—	[illegible]
O	Response to Final Design Cmts	9 May 97	—	—	[illegible]

Written By : PJP Date: 17 Feb 1996 Reviewed by: PJS Date: 17 Feb 1996

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

FINAL COVER SYSTEM BIOINTRUSION BARRIER DESIGN

EXECUTIVE SUMMARY

PURPOSE OF ANALYSIS

The purpose of this package is to evaluate the performance of the final cover system biointrusion barrier. This consists of establishing the characteristics of an appropriate material that will limit intrusion of plant roots and burrowing animals and have filtration characteristics compatible with the granular filter layer.

METHODS OF ANALYSIS

The biointrusion barrier is designed to limit intrusion of plant roots and burrowing animals. In addition, the barrier design includes a choke stone in the upper surface of the layer to provide retention of the overlying granular filter layer.

CONCLUSIONS

The biointrusion barrier should be at least 3 ft thick and consist of Ohio DOT 601.07 Type C Dumped Rock Fill with the following modifications:

- all material should consist of sound and durable rock or stone and be free of soil
- the maximum acceptable rock dimension is 18 inches
- the fraction of material smaller than a 6-inch square opening should consist of rocks no smaller than a 1-inch square opening with the exception of a small percentage (<5% by total weight) of rock spalls (<1-inch square opening) and rock fines
- the material should have a d_{15} = 150 to 350 mm

[redacted]

Written By : PJP Date: 17 Feb 1996 Reviewed by: PJS Date: 17 Feb 1996

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

Ohio DOT #1 coarse aggregate will be compacted into approximately the upper 0.5 ft of the biointrusion barrier to "choke" it off.

An evaluation is currently underway of the material selection and relative durability of locally available biointrusion barrier materials (this study is not complete).

Special care must be taken during placement of the biointrusion barrier and choke stone to limit segregation and bridging of particles.

[redacted]

BIOINTRUSION BARRIER DESIGN

TABLE OF CONTENTS

		Page
1.	Calculation Procedures	1/4
2.	Data Verification	1/1
3.	Calculation Results	1/6

Written By : PJP Date: 17 Feb 1996 Reviewed by: PJS Date: 17 Feb 1996

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB (DTL) 17 FEB 96

FINAL COVER SYSTEM BIOINTRUSION BARRIER DESIGN

CALCULATION PROCEDURES

INTRODUCTION

The purpose of this package is to present the calculation procedures for evaluation of the performance of the FEMP On-Site Disposal Facility (OSDF) final cover system biointrusion barrier. This package addresses the following issues:

- limit intrusion of plant roots and burrowing animals; and
- provide retention of the overlying granular filter layer through the choke stone and, in turn, retention of the choke stone by the biointrusion barrier.

The final cover system configuration is shown in Figure 1.

METHODS OF ANALYSIS

The purpose of the biointrusion barrier is to deter and inhibit downward advancement of roots and burrowing animals. However, all of the final cover system components must be adequately designed to prevent biointrusion. The biointrusion barrier will be designed to meet the requirements described below:

- The biointrusion barrier layer should be of high hydraulic conductivity (i.e., large voids) to prevent water or soil particles from filling the voids and therefore deter plant root penetration [Hakonson, 1986].
- The gradation of the biointrusion barrier layer material should be such that at least two voids exist along the depth of the biointrusion layer such that roots are obstructed from penetrating

the biointrusion layer by at least two voids. This can be achieved by making the maximum particle size less than or equal to half of the layer thickness.

- Based on UMTRA [1989], the biointrusion barrier material selection and relative durability (ability of the material to withstand physical and chemical forces) needs to be evaluated. The selection and durability will need to be evaluated by the following procedure:

  - identify several rock sources within a reasonable distance of the site;
  - determine suitability of rocks by evaluating physical rock characteristics through laboratory testing;
  - use results to classify rocks as poor, fair or good quality;
  - if good quality rock is reasonably available, it should be used for the biointrusion barrier ; and
  - if only rock of poor or fair quality is reasonably available, increase the average rock size and biointrusion barrier thickness.

  It is noted that a study is currently underway to evaluate potential sources of biointrusion barrier rock. The selection procedure of UMTRA [1989] will be used to evaluate the rock sources as data and information about the sources becomes available. The study results will then be incorporated into a later OSDF design package.

- Appropriate materials will be selected to prevent migration of fines from the choke stone into the biointrusion layer. Additionally, the choke stone will be selected to allow a reasonable design of the granular filter layer. The following criterion from Cedergren [1989] will be used:

  1. (d_{15} of filter soil / d_{85} of soil being filtered) $\leq$ 4 to 5
     - the ratio will be checked against ≤ 5

[redacted]

where d_{15} corresponds to the material particle size for which 15% by weight of the particles are finer and d_{85} corresponds to the material particle size for which 85% by weight of the particles is finer.

The intent of criterion 1 is to prevent piping of the retained soil by the filter soil. Cedergren [1989] also suggests checking a permeability criteria of (d_{15} filter/d_{15} soil) ≥ 4 to 5 to obtain a filter soil with a sufficiently larger permeability than the retained soil to prevent the build-up of large seepage forces and hydrostatic pressures in the filter. For the final cover system, relatively small seepage forces and hydrostatic pressures exist. In addition, the biointrusion barrier material will have a very high hydraulic conductivity due to the large void spaces in the material. Thus, the permeability criterion is not critical for the biointrusion barrier and is therefore not checked.

To limit segregation and bridging of particles during placement and aid in constructibility, the filter should not contain any materials larger than 3 inches.

REFERENCES

Hakonson, T.H. (1986). "Evaluation of Geologic Materials to Limit Biological Intrusion into Low-Level Radioactive Waste Disposal Sites," LA-10286-MS/UC-70B, Los Alamos National Laboratories, Los Alamos, New Mexico.

U.S. Department of Energy (1989). "Technical Approach Document," UMTRA-DOE/AL 050425.0002, Uranium Mill Tailings Remedial Action Project, Revision 2, December.

Cedergren, H.R. (1989). *Seepage, Drainage, and Flow Nets*. John Wiley and Sons, New York, 465 p.

GEOSYNTEC CONSULTANTS

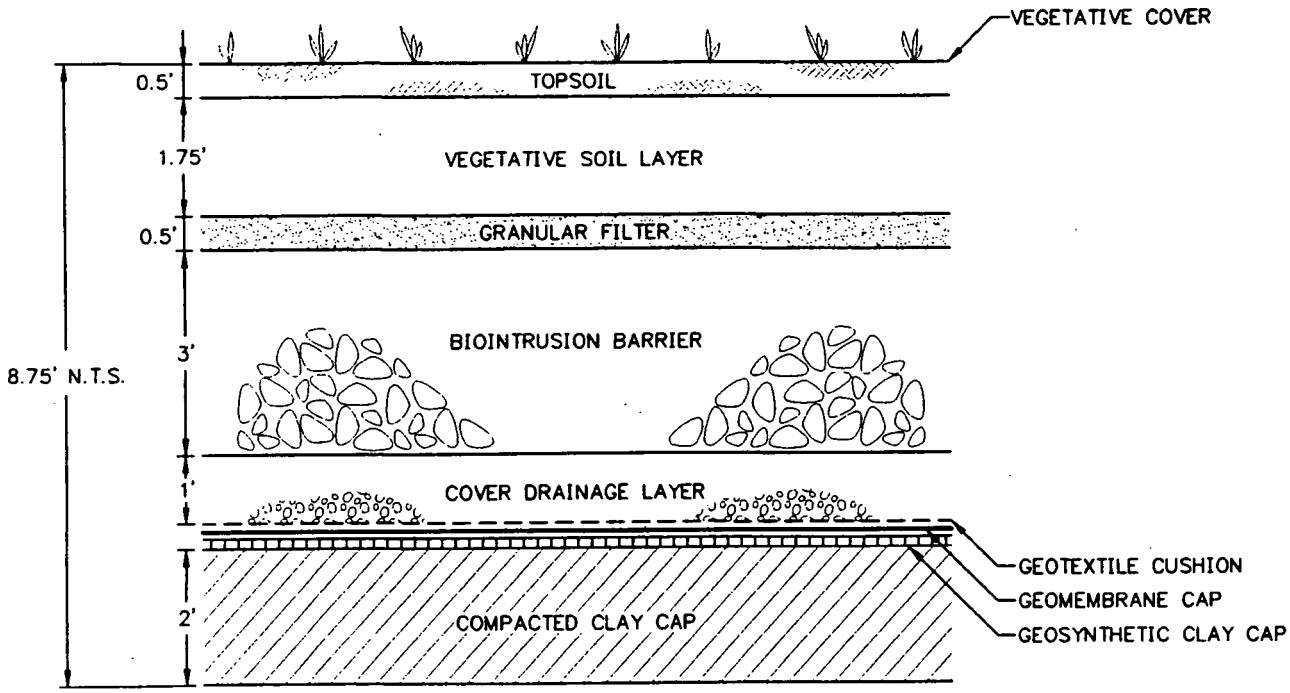
MAO 96/2/17

Written By : PJP Date: 17 Feb 1996 Reviewed by: PJS Date: 96 Feb 17

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB (DTL) 17 FEB 96

Figure 1: Final Cover System



FINAL COVER SYSTEM

[redacted]

Written By : PJP Date: 17 Feb 1996 Reviewed by: PJS Date: 96-2-17

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB(DTL) 17 FEB 96

FINAL COVER SYSTEM BIOINTRUSION BARRIER DESIGN

DATA VERIFICATION

INTRODUCTION

The purpose of this package is to verify the data required for the calculation procedures described in the previous section to perform the following analyses:

- establishing a material specification to limit intrusion of plant roots and burrowing animals; and
- establishing a range of allowable grain-size distributions of the biointrusion barrier and choke stone to provide adequate retention.

BIOINTRUSION BARRIER ANALYSIS

The biointrusion barrier is selected to be 3 ft thick. The upper portion (approximately the upper 6 inches) of the biointrusion barrier will be "choked off." Ohio DOT coarse aggregate and dumped rock fill specifications will be used for the biointrusion barrier and choke stone if they are found to be suitable.

[redacted]

GEOSYNTEC CONSULTANTS

MAO 96/2/19

Written by: PJP Date: 96 / 02 / 17 (YY MM DD) Reviewed by: DJS Date: 96 / 2 / 17 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

FINAL COVER SYSTEM BIOINTRUSION BARRIER DESIGN

CALCULATION RESULTS

- The biointrusion barrier is selected to be 3 ft thick ∴ the maximum particle size must be less than or equal to:

$$\frac{(3\text{ ft})(12\text{ in/ft})}{2} = 18 \text{ inches} = \text{half the layer thickness}$$

- To maintain a high hydraulic conductivity, a minimum particle size of 1 inch is selected with exceptions to allow for rock spalls and rock fines
- Based on the above selections and on other requirements from the calculation procedures, the biointrusion barrier will have relatively large voids and will require a choke stone to limit the migration of fines from the granular filter.
- In an attempt to use Ohio DOT specification materials, Type C Dumped Rock Fill (biointrusion barrier) and Ohio DOT #1 coarse aggregate (choke stone) are evaluated

[redacted]

GEOSYNTEC CONSULTANTS

MAO 96/2/19

Written by: PJP Date: 96/02/17 (YY MM DD) Reviewed by: PJS Date: 96/2/17 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

- Ohio DOT specification 601.07 Dumped Rock Fill, Type C should be modified as follows:
  - only sound and durable rock or stone, free of soil will be allowed (i.e., no broken concrete)
  - limit the maximum particle size to 18-inches
    - according to Type C spec., up to 15% of the rock fill could range from 18- to 36-inch size which is not acceptable for the 3 ft thick biointrusion barrier
  - to limit the amount of fines in the rock fill the material smaller than a 6-inch square opening will consist of no rocks smaller than a 1-inch square opening with the exception of a small percentage (< 5%) by weight of rock spalls (< 1-inch square opening) and rock fines (free of soil)
  - a filtration check needs to be completed to see if there is a d_{15} limitation

[redacted]

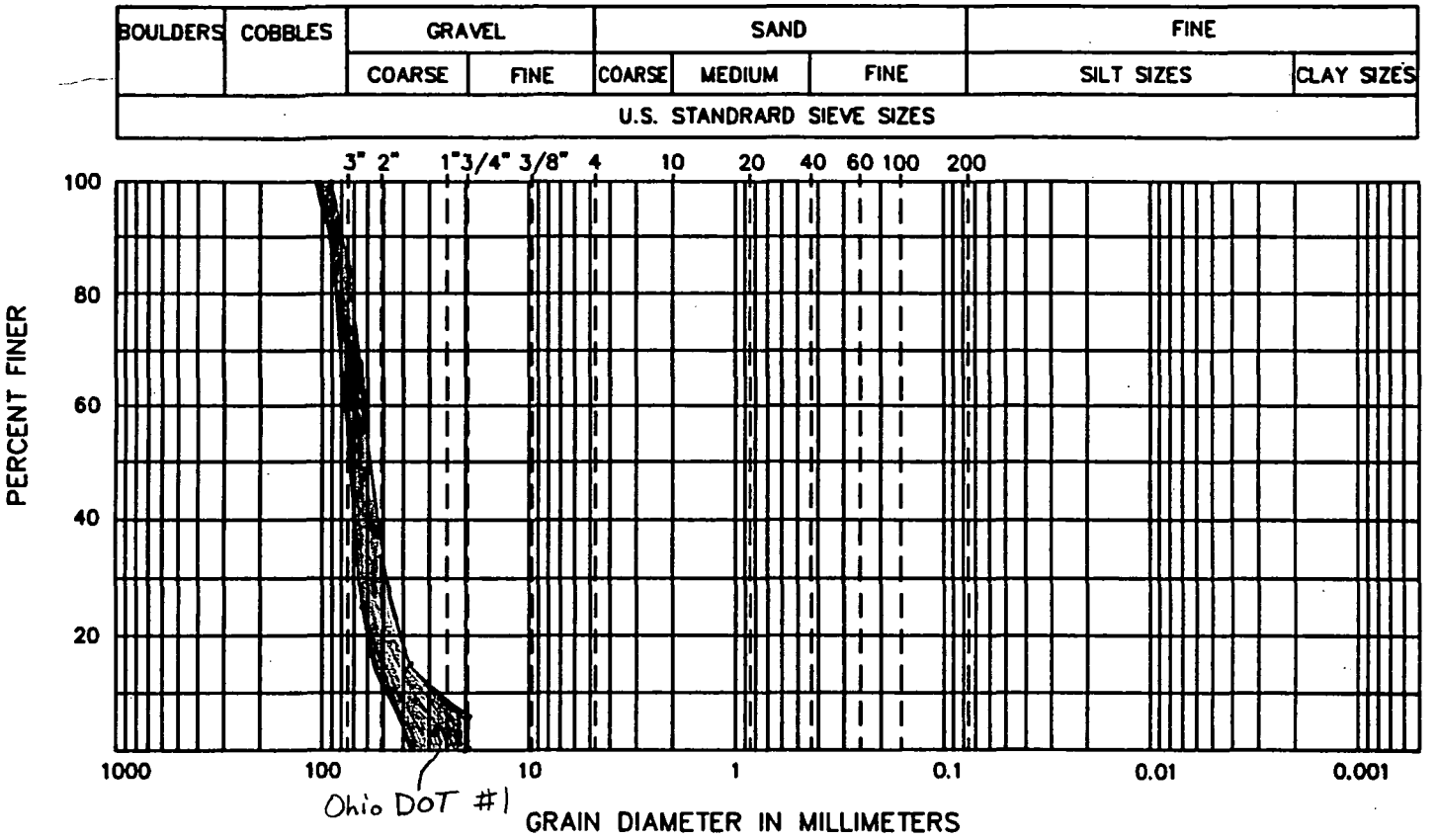
GEOSYNTEC CONSULTANTS

MAO 96/2/19

Written by: PJP Date: 96 / 02 / 17 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 17 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

Ohio DOT #1 stone has the following approximate grain-size curve:



This gives a d_{15} = 37.5 to 58 mm and a d_{85} = 70 to 90 mm

[redacted]

MAJ 96/2/19

Written by: PJP Date: 96 / 02 / 17 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 17 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

$$\frac{d_{15_{biointrusion}}}{d_{85_{choke\ stone}}} \leq 4 \text{ to } \underset{\text{use ratio of 5}}{5}$$

$$\frac{d_{15_{biointrusion}}}{70 \text{ to } 90_{mm}} \leq 5 \rightarrow \text{check vs. 70 to get upper limit of } d_{15_{biointrusion}}$$

$$d_{15_{biointrusion}} \leq 350 \text{ mm}$$

- Since permeability is not critical and the biointrusion barrier has a hydraulic conductivity higher than the choke stone there is no need to check ($d_{15_{bio}} / d_{15_{choke}}$).

- the Type C spec. places a d_{15} lower limit of 6 in (150 mm)
∴ the d_{15} of the biointrusion layer should be limited to 150 to 350 mm

---

Vegetative Soil	
Granular Filter	
Choke Stone	3
Biointrusion	4

layer profile of final cover system

- Based on the modifications made to the Type C Dumped Rock Fill, The figure on the next page shows the grain-size curve for the biointrusion barrier. The Ohio DOT #1 grain-size curve is also drawn on the figure.

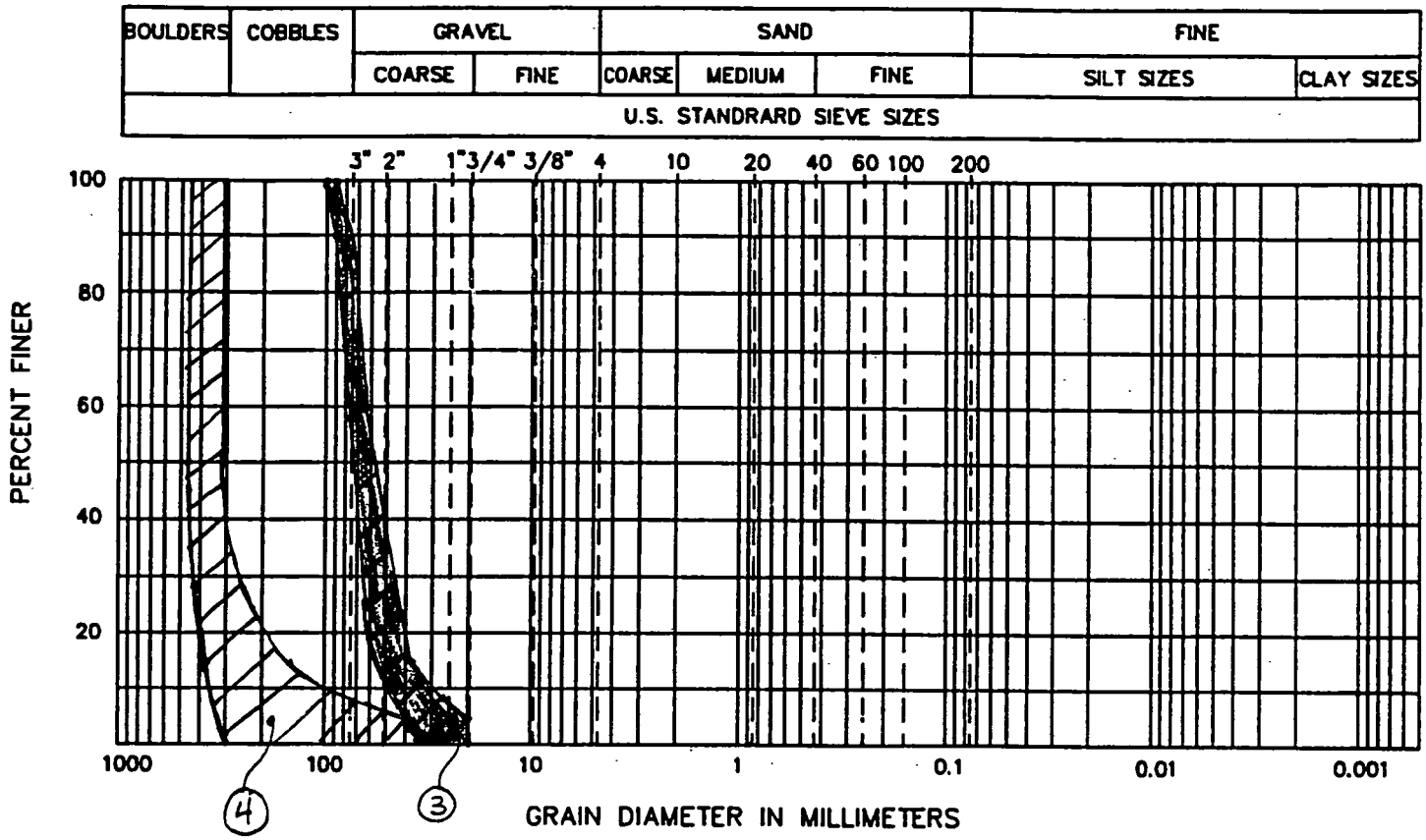
[redacted]

GeoSyntec Consultants

MAO 96/2/19

Written by: PJP Date: 96 / 02 / 17 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 19 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8



③ Choke Stone (Ohio DOT #1)

④ Biointrusion Barrier (Type C with modifications)

- The granular filter was designed as an artifical soil (non-Ohio DOT). The granular filter filtration design was thus based on the d_{15} of the choke stone (Ohio DOT #1) which is calculated in the Final Cover System Granular Filter Layer Design.

* Note that the choke stone and biotrusion barrier have particle sizes > 3 inches. Special care must be taken when placing these materials to minimize particle segregation.

[redacted]

GEOSYNTEC CONSULTANTS

MAO 96/2/19

Written by: PJP Date: 96 / 02 / 17 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 17 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

Additional Comments

- The hydraulic conductivity of the biotrusion barrier will be high ($k \approx 10$ to 100 cm/sec). With high hydraulic conductivity, water and soil particles will be prevented from filling the voids and therefore deter plant root penetration.

- With a maximum 18-inch particle size, at least two voids should exist along the depth of the biointrusion barrier to prevent root penetration.

- The gradation of the biointrusion barrier should prevent burrowing animals from advancing downward

- A material selection and relative durability analysis still needs to be completed

[redacted]

11.7 Final Cover System Drainage Layer Design

- Cover System Water Balance
- Cover Drainage Layer Maximum Head

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: FINAL COVER SYSTEM DRAINAGE LAYER DESIGN

Computations By: (Cognizant Engineer)
Signature: Peter J. Prommer — Date: 16 Feb 1996
Printed Name and Title: Peter J. Prommer, Senior Staff Engineer

Assumptions and Procedures Checked by: (Checker)
Signature: Paul J. Sabatini — Date: 16 Feb 1996
Printed Name and Title: PAUL J. SABATINI, SENIOR STAFF ENGINEER

Computations Checked by:
Signature: Paul J. Sabatini — Date: 16 Feb 1996
Printed Name and Title: PAUL J. SABATINI, SENIOR STAFF ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: Peter J. Prommer — Date: 18 Feb 1996
Printed Name and Title: Peter J. Prommer, Senior Staff Engineer

Approved by: (PDP)
Signature: Majdy Ahmed Othman — Date: 18 Feb 96
Printed Name and Title: MAJDI A. OTHMAN, PROJECT ENGINEER

Approved by: (DTL and TETL)
Signature: Rudolph Bonaparte — Date: 19 Feb 96
Printed Name and Title: Rudolph Bonaparte (Principal)

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	~~60% Submittal~~ Intermediate Design	16 Feb 1996	AP	PJS	RB
D	Intermediate Design - EPA Submittal	4 Apr 96	—	—	—
G	Final Design Package	4 Oct 96	—	—	—
O	Response to Final Design Cmts	9 May 97	—	—	—

MAS 18 Feb 96

Written By: PJP Date: 15 Feb 1996 Reviewed by: PJS Date: 96 Feb 16

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

FINAL COVER SYSTEM DRAINAGE LAYER DESIGN

EXECUTIVE SUMMARY

PURPOSE OF ANALYSIS

The purpose of this package is to evaluate the performance of the final cover system drainage layer. This consists of estimating cover system water balance (i.e., infiltration rate through composite cap) and drainage layer hydraulic head.

METHODS OF ANALYSIS

Infiltration through the cover system was estimated using the USEPA HELP model. The maximum and average thickness and hydraulic head of the drainage layer were also estimated using the HELP model, and a closed-form analytical solution was used as a check to the HELP model results.

CONCLUSIONS

- For the cover system water balance (i.e., infiltration rate through composite cap):
  - average daily percolation = 2.05×10^{-3} gpad; and
  - peak daily percolation = 6.33×10^{-2} gpad.

- For the cover drainage layer:
  - maximum liquid thickness = 8.5 in.;
  - average liquid thickness = 4.4 in.;
  - maximum liquid head = 8.4 in.; and
  - average liquid head = 4.4 in.

[redacted]

GEOSYNTEC CONSULTANTS

Written by: _____ Date: _____ Reviewe

Client: FERMCO Project: OSDF

THIS PAGE IS INSERTED ONLY FOR CLARITY AND DOES NOT AFFECT THE NUMBERING SYSTEM OF THE REST OF THE PACKAGE

DRAINAGE LAYER DESIGN

TABLE OF CONTENTS

		Page
1.	Calculation Procedures	1/6
2.	Data Verification	1/1
3.	Calculation Results	1/3

MAO 15 Feb 96

Written By: PJP Date: 15 Feb 1996 Reviewed by: RJS Date: 16 Feb 96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB (DTL) 16 FEB 96

FINAL COVER SYSTEM DRAINAGE LAYER DESIGN

CALCULATION PROCEDURES

INTRODUCTION

The purpose of this package is to present the calculation procedures for evaluation of the performance of the FERNALD On-Site Disposal Facility (OSDF) final cover system drainage layer design. This package addresses the following issues:

- final cover system water balance (i.e., infiltration rate through composite cap); and
- final cover system drainage layer analysis (i.e., hydraulic head).

The final cover system configuration is shown in Figure 1.

METHODS OF ANALYSIS

FINAL COVER SYSTEM WATER BALANCE (INFILTRATION ANALYSIS)

The final cover system infiltration analysis will be performed as part of the leachate generation rate analysis using the United States Environmental Protection Agency (USEPA) Hydrologic Evaluation of Landfill Performance (HELP) model [Shroeder et al., 1994a, 1994b].

FINAL COVER SYSTEM DRAINAGE LAYER ANALYSIS

Hydraulic Head: As part of the leachate generation rate calculations to be performed elsewhere, the HELP model will be used to estimate the hydraulic head in the final cover system drainage layer.

[redacted]

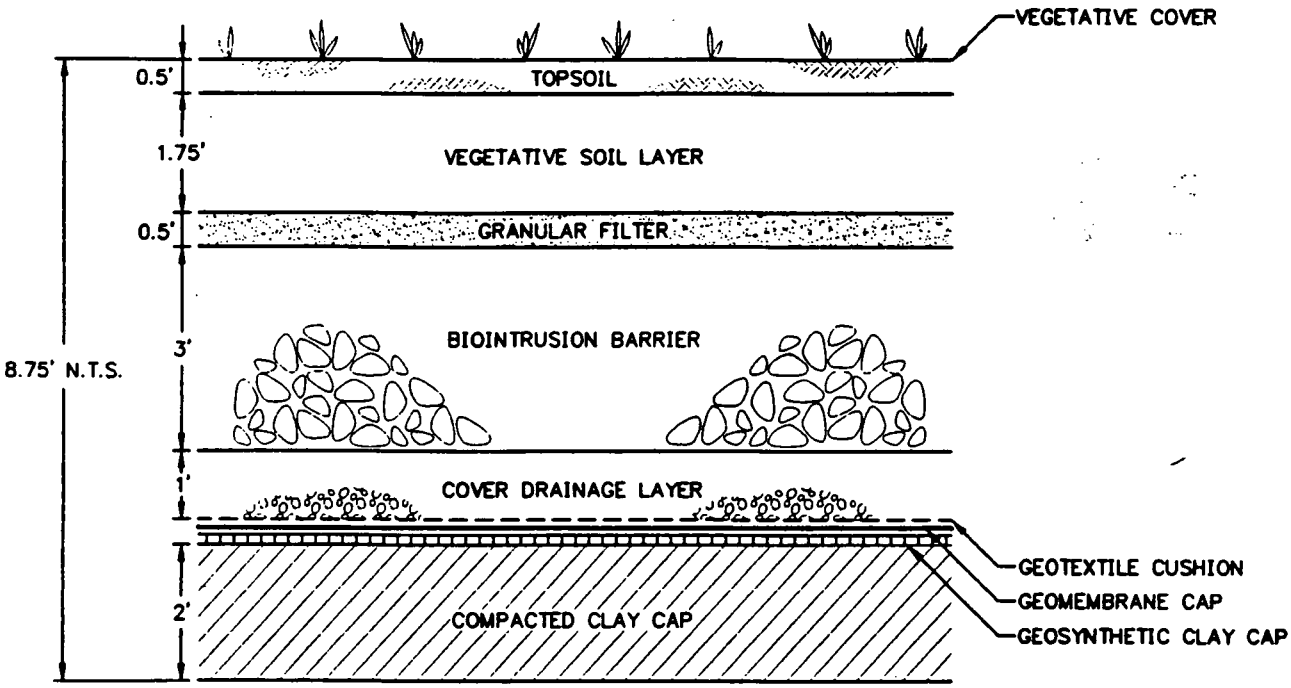
MAO 96/2/15

Written By : PJP Date: 15 Feb 96 Reviewed by: PJS Date: 16 Feb 96

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB(DTL) 16 FEB 96

Figure 1: Final-Closure Cover System



FINAL COVER SYSTEM

[redacted]

As a check, the closed-form analytical solution described by Giroud and Houlihan [1995] will be used to estimate hydraulic head. For the analytical solution, the impingement rate of flow into the cover drainage layer estimated using HELP and assumed characteristics of the drainage layer will be used to estimate the average and maximum hydraulic head and thickness in the drainage layer.

The following six-step approach based on Giroud and Houlihan [1995] will be used to calculate the maximum and average liquid thickness, T_{max} and T_{avg}, and the maximum and average hydraulic heads, h_{max} and h_{avg} :

- *Step 1.* Calculate the dimensionless parameter λ using the following equation:

$$\lambda = \frac{q_i}{k \tan^2 \beta} \tag{1}$$

where: q_i = the impingement rate of flow into the drainage layer; k = hydraulic conductivity of the drainage layer material; and β = angle between the horizontal and slope.

- *Step 2.* Use Equations 2 and 3 to calculate T_{max}.

$$T_{max} = j\left[\frac{\sqrt{1+4\lambda}-1}{2}\frac{\tan\beta}{\cos\beta}\right](L) \tag{2}$$

$$j = 1 - 0.12\exp\left[-\left[\log(8\lambda/5)^{5/8}\right]^2\right] \tag{3}$$

where: T_{max} = maximum liquid thickness; L = length of the slope; j = corrective coefficient; λ = parameter defined by Equation (1); and β = angle between the horizontal and slope.

- *Step 3.* Calculate the maximum hydraulic head, h_{max}, from Equation 4.

$$h_{max} = T_{max}\cos\beta \tag{4}$$

- *Step 4.* Use Table 1 or Figure 2 to obtain T_{avg}/T_{max}.
- *Step 5.* From T_{max} obtained in Step 2 and T_{avg}/T_{max} obtained in Step 4, calculate T_{avg}.
- *Step 6.* Calculate the average hydraulic head, h_{avg}, from Equation 5.

$$h_{avg} = T_{avg}\cos\beta \tag{5}$$

[redacted]

MAO 96/2/15

Written By: PJP Date: 15 Feb 96 Reviewed by: PJS Date: 96 Feb 16

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB(DTL) 16 FEB 96

Table 1: Values of T_{avg}/T_{max} and x_m/L

$\lambda = \frac{q_i/k}{\tan^2\beta}$	$\frac{T_{ave}}{T_{max}}$	$\frac{x_m}{L}$	$\lambda = \frac{q_i/k}{\tan^2\beta}$	$\frac{T_{ave}}{T_{max}}$	$\frac{x_m}{L}$
0.00	0.500	1.000	0.50	0.73	0.68 - 0.68 - 0.67
0.002	0.50	0.99	0.53	0.74	0.68 - 0.68 - 0.66
0.005	0.51	0.98	0.57	0.75	0.67 - 0.67 - 0.65
0.01	0.52	0.97	0.62	0.76	0.66 - 0.66 - 0.64
0.02	0.53	0.94	0.67	0.77	0.66 - 0.66 - 0.63
0.03	0.54	0.92	0.73	0.78	0.65 - 0.65 - 0.61
0.04	0.55	0.90	0.80	0.79	0.64 - 0.63 - 0.59
0.05	0.56	0.89	0.87	0.80	0.63 - 0.62 - 0.57
0.07	0.57	0.86	0.95	0.81	0.62 - 0.61 - 0.55
0.08	0.58	0.85	1.05	0.82	0.60 - 0.60 - 0.53
0.09	0.59	0.84	1.16	0.83	0.59 - 0.58 - 0.51
0.10	0.60	0.83	1.32	0.84	0.57 - 0.56 - 0.47
0.12	0.61	0.82	1.58	0.85	0.57 - 0.53 - 0.43
0.14	0.62	0.80	2.0	0.86	0.51 - 0.49 - 0.37
0.15	0.63	0.79	3.2	0.87	0.44 - 0.41 - 0.26
0.16	0.64	0.78	5.5	0.86	0.36 - 0.31 - 0.16
0.17	0.65	0.77	8.5	0.85	0.30 - 0.23 - 0.11
0.18	0.66	0.76	13	0.84	0.25 - 0.17 - 0.07
0.20	0.67	0.75	19	0.83	0.21 - 0.13 - 0.05
0.23	0.68	0.73	30	0.82	0.17 - 0.09 - 0.03
0.25	0.69	0.71	55	0.81	0.13 - 0.05 - 0.02
0.35	0.70	0.70	135	0.80	0.08 - 0.02 - 0.01
0.40	0.71	0.70	1000	0.79	0.03 - 0.00 - 0.00
0.45	0.72	0.69	∞	0.785	0 - 0 - 0

Note: This table was established using Equations 46, 50 and 51 for values of $\lambda \geq 0.25$, and using charts, published by McEnroe and Schroeder (1988), for $\lambda < 0.25$. The ratio T_{avg}/T_{max} varies very little with the slope angle, β; when β varies between 0 and 45°, the change in T_{avg}/T_{max} is typically less than 0.03. Therefore, the tabulated values of T_{avg}/T_{max} (which are average values) are either unaffected or affected by $\pm$ 0.01. The two limit values for T_{avg}/T_{max}, i.e. 1/2 (for $\lambda = 0$) and $\pi/4$ (for $\lambda = \infty$), are accurate. For $\lambda < 0.5$, the values of x_m/L also vary very little with β; in this case, when β varies between 0 and 45°, the tabluated values of x_m/L are either unaffected or affected by $\pm$ 0.01. For $\lambda > 0.5$, the influence of β on x_m/L is significant. To illustrate the influence of β in this case, three values of x_m/L are tabulated in the last column: the value on the left is for $0 < \tan\beta < 10\%$, the middle value is for $\tan\beta = 1/3$ (i.e. a 1V:3H slope) and the value on the right is for $\tan\beta = 1$ (i.e. a 1V:1H slope) (see Figure 11). It should be noted that, in the charts by McEnroe and Schroeder (1988), the parameter λ is not used. Therefore, it does not appear in those charts that T_{avg}/T_{max} and, to a certain extent, x_m/L are independent of β.

[redacted]

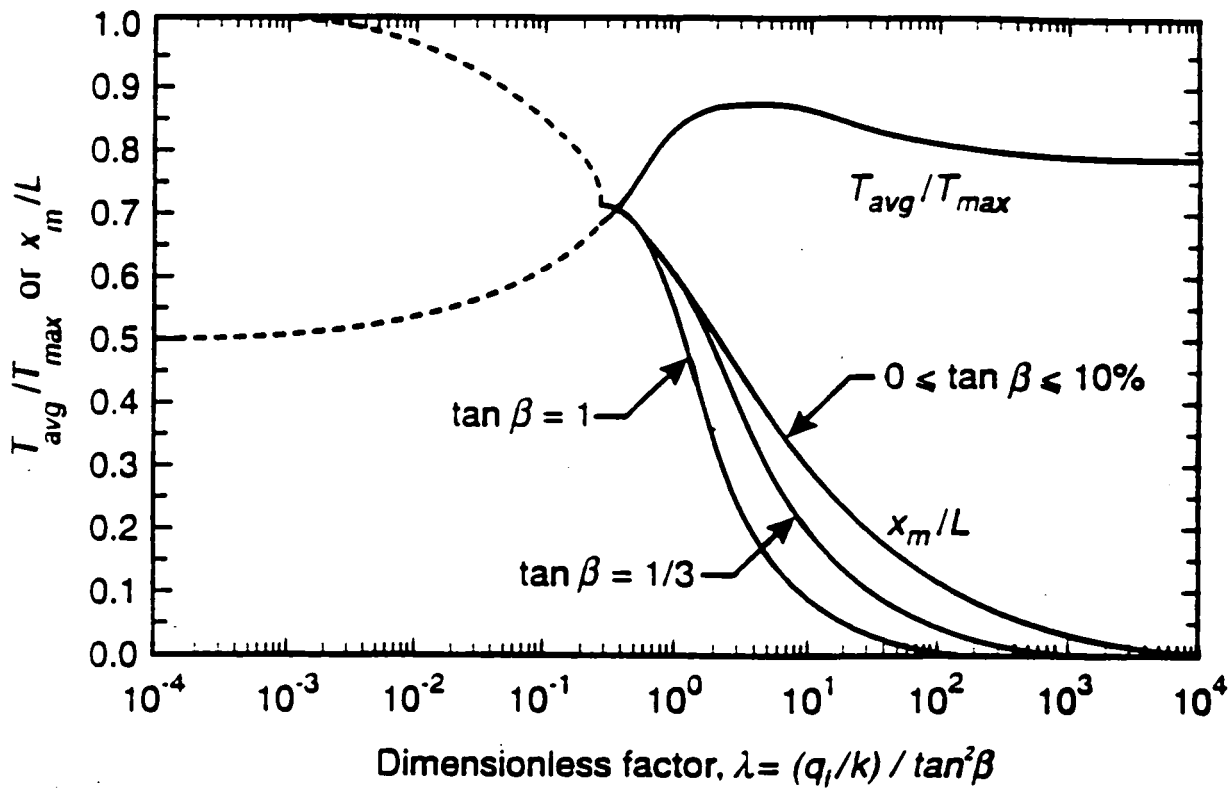
MAO 96/2/15

Written By: PJP Date: 15 Feb 96 Reviewed by: RJS Date: 96 Feb 16

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB (DTL) 16 FEB 96

Figure 2: Values of T_{avg}/T_{max} and x_m/L



X_m = Abscissa of the maximum of the liquid phreatic surface (from crest of slope).

[redacted]

MAJ 96/2/15

Written By : PJP Date: 15 Feb 1996 Reviewed by: PJS Date: 96 Feb 16

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB (DTL) 16 FEB 96

REFERENCES

Giroud, J.P. and Houlihan, M.F. (1995). "Design of Leachate Collection Layers", *Proceedings of the Fifth International Landfill Symposium*, Sardinia, Italy, vol. 2, October, pp. 613-640.

Schroeder, P.R., Lloyd, C.M. and Zappi, P.A. (1994a). *The Hydrologic Evaluation of Landfill Performance (HELP) Model, User's Guide for Version 3.* U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., Report No. EPA/600/R-94/168a, September.

Schroeder, P.R., Dozier, T.S., Zappi, P.A., McEnroe, B.M., Sjostrom, J.W. and Peyton, R.L. (1994b). *The Hydrologic Evaluation of Landfill Performance (HELP) Model Engineering Documentation for Version 3.* U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., Report No. EPA/600/R-94/168b, September, 116 p.

MAO 96/2/15

Written By: PJP Date: 15 Feb 1996 Reviewed by: PJS Date: 96 Feb 16

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB(DTL) 16 FEB 96

DRAINAGE LAYER DESIGN

DATA VERIFICATION

INTRODUCTION

The purpose of this package is to verify the data required for the calculation procedures described in the previous section to perform the following analyses:

- final cover system water balance (i.e., infiltration rate through composite cap);
- final cover system drainage layer analysis (i.e., hydraulic head)

FINAL COVER SYSTEM WATER BALANCE (INFILTRATION ANALYSIS)

The final cover system infiltration analysis will be performed as part of the leachate generation analysis package using the HELP model. All input parameters are included in that package.

FINAL COVER SYSTEM DRAINAGE LAYER ANALYSIS

Hydraulic Head:

q_i = the maximum impingement rate of flow into the drainage layer = 0.7809 in./day
(peak daily value from the HELP model results; Cases 3C and 3D) = 2.3×10^{-5} cm/sec

k = hydraulic conductivity of the drainage layer material = 0.1 cm/sec

β = average angle between the horizontal and slope = 7.63° (13.4%)

L = the length of the slope = 430 ft (5160 in.)

Values of k, β and L were verified in the leachate generation rate calculation package.

[redacted]

GEOSYNTEC CONSULTANTS

~~MAO~~ 96/2/18

Written by: PJP Date: 96 / 02 / 15 (YY MM DD) Reviewed by: PJS Date: 96 / 2 / 16 (YY MM DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

DRAINAGE LAYER DESIGN CALCULATION RESULTS

Cover System Water Balance (Infiltration Analysis)

Based on HELP model analysis (completed in leachate generation section):

Cases 3C and 3D have the annual percolation and peak daily percolation maximum values

- Average Daily Percolation:

$$2.75 \times 10^{-5}\ \text{in/year}$$

$$= \left(2.75 \times 10^{-5}\ \text{in/year}\right)\left(\frac{1\ \text{ft}}{12\ \text{in}}\right)\left(\frac{1\ \text{year}}{365\ \text{days}}\right)\left(\frac{43560\ \text{ft}^2}{1\ \text{acre}}\right)\left(7.48\ \frac{\text{gal}}{\text{ft}^3}\right)$$

$$= \underline{2.05 \times 10^{-3}\ \text{gpad}}$$

- Peak Daily Percolation:

$$2.33 \times 10^{-6}\ \text{in/day}$$

$$= \left(2.33 \times 10^{-6}\ \text{in/day}\right)\left(\frac{1\ \text{ft}}{12\ \text{in}}\right)\left(\frac{43560\ \text{ft}^2}{1\ \text{acre}}\right)\left(7.48\ \text{gal/ft}^3\right)$$

$$= \underline{6.33 \times 10^{-2}\ \text{gpad}}$$

[redacted]

Written by: PJP Date: 96 / 02 / 15 (MAY 96/2/18) Reviewed by: RSS Date: 96 / 2 / 16

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

Cover Drainage Layer Analysis

- Hydraulic Head

From HELP model analysis:

q_i = maximum impingement rate of flow into the cover drainage layer

$= 0.7809 \text{ in/day} = 2.30 \times 10^{-5} \text{ cm/sec}$

$$\lambda = \frac{q_i}{k \tan^2 \beta} \quad \text{where} \quad k = 0.1 \text{ cm/sec}, \quad \beta = \tan^{-1}\frac{13.4}{100} = 7.63^\circ$$

$$\lambda = \frac{2.30 \times 10^{-5} \text{ cm/sec}}{(0.1 \text{ cm/sec})(\tan^2 7.63^\circ)} = \underline{0.01282}$$

$$j = 1 - 0.12\, e^{\left[-\left[\log(8\lambda/5)^{5/8}\right]^2\right]} = \underline{0.961}$$

$$T_{max} = j\left[\frac{\sqrt{1+4\lambda}-1}{2} \cdot \frac{\tan\beta}{\cos\beta}\right](L) \quad \text{where } L = 430 \text{ ft} = 5160 \text{ in}$$

$$= 0.961\left[\frac{\sqrt{1+4\cdot 0.01282}-1}{2} \cdot \frac{\tan 7.63^\circ}{\cos 7.63^\circ}\right](5160)$$

$$= \underline{8.48 \text{ in}}$$

$$h_{max} = T_{max} \cos\beta = (8.48 \text{ in})(\cos 7.63^\circ)$$

$$= \underline{8.40 \text{ in}}$$

[redacted]

GEOSYNTEC CONSULTANTS

MAY 96/2/18

Written by: PJP Date: 96/02/15 (YY/MM/DD) Reviewed by: PJS Date: 96/2/16 (YY/MM/DD)

Client: FERMCO Project: FERNALD OSDF Project/Proposal No.: GE3900 Task No.: 8.8

- for $\lambda = 0.01282$, $T_{avg}/T_{max} = 0.52$ ✓ from Table 1 of the calculation procedures package reproduced from Giroud and Houlihan [1995]

$$T_{avg} = 0.52\ T_{max} = 0.52\,(8.48\,in) = \underline{4.41\ in}\ ✓$$

$$h_{avg} = T_{avg}\ \cos\beta = (4.41\,in)(\cos 7.63^\circ) = \underline{4.37\,in}\ ✓$$

- it is noted that the average head, T_{avg}, in the cover drainage layer calculated using the HELP model for the peak daily was 4.5 in. This is close to the value of 4.4 in calculated above.

- based on these results, it is concluded that the calculated maximum liquid thickness (i.e., 8.5 inches) is less than the cover drainage layer thickness (i.e., 12 inches) ✓

[redacted]

11.8 Final Cover System Geosynthetics Selection

- Geotextile Cushion
- Geomembrane Cap
- Geosynthetic Clay Cap

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: COVER GEOSYNTHETICS SELECTION

Computations By: (Cognizant Engineer)
Signature [signature] Date 16 Feb 96
Printed Name and Title Gary R. Schmertmann, Sr. Project Engineer

Assumptions and Procedures Checked by: (Checker)
Signature Majdy Ahmed Othman Date 17 Feb 96
Printed Name and Title MAJDI A. OTHMAN, PROJECT ENGINEER

Computations Checked by:
Signature Majdy Ahmed Othman Date 17 Feb 96
Checked by:
Printed Name and Title MAJDI A. OTHMAN, PROJECT ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 17 Feb 96
Printed Name and Title Gary R. Schmertmann, Sr. Project Engineer

Approved by: (PDP)
Signature [signature] Date 17 Feb 96
Printed Name and Title Gary R. Schmertmann, Sr. Project Engineer

Approved by: (DTL and TETL)
Signature Rudolph Bonaparte Date 19 Feb 96
Printed Name and Title Rudolph Bonaparte, Principal (DTL)

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	~~60% Submittal~~ MAO intermediate design	16 Feb 96	GPS	MAO	RB
D	Intermediate Design - EPA Submittal	4 Apr 96	[illegible]	—	—
G	Final Design Package	4 Oct 96	—	—	[illegible]
O	Response to Final Design Cmts	9 May 97	—	—	[illegible]

Written by: GRS Date (Y/M/D): 96/2/16 Reviewed by: MAO Date: 96/2/17

Client.: FERMCO Project: GSDF Project No.: GE3900 Task No.: 8.8

COVER GEOSYNTHETICS SELECTION

EXECUTIVE SUMMARY

Purpose of Calculations:

- Select key characteristics of the low-permeability geosynthetic components of the final cover system. These components are the geomembrane cap and the geosynthetic clay liner (GCL) cap.

- Select key characteristics of the geotextile cushion in the final cover system.

Methodology:

- Selection of key characteristics of low-permeability final cover system geosynthetics is made from the range of commercially-available geosynthetic products. The selection accounts for the intended function of the component as well as material durability, resistance to anticipated loads, and constructability.

- Selection of key characteristics of the geotextile cushion is made from the range of commercially-available geotextile products. The method of Koerner et al. [1995] (Ref. 2 in Procedures/Methods package) is used to evaluate the ability of the geotextile to provide puncture protection for the liner system geomembranes. The method presented by Koerner [1994] (ref. 3 in Procedures / Methods package) is used to evaluate the ability of the geotextile to survive construction stresses.

Conclusions:

- The calculated factor of safety (FS) against geomembrane puncture is 10.2 . This FS, which accounts for the effect of the geotextile cushion, exceeds the minimum required value of 3.0. Although this FS is significantly larger than the required value, a geotextile cushion with a mass density of at least 270 g/m^2 (8 oz/yd^2) will be required because this is the minimum mass density recommended for cushioning applications by Koerner et al. [1995] (Ref. 2 in Procedures/Methods package).

- The selected key characteristics are presented in the following table:

Characteristic	Geomembrane Cap	GCL Cap	Geotextile Cushion
polymer type	HDPE(1)	NA	PP(2) or PET(3)
thickness (mils)	60	NA	NA
mass density (g/m^2) [oz/yd^2]	NA	NA	270 [8]
clay mineral	NA	sodium bentonite	NA
clay mineral mass density (lb/ft^2) [kg/m^2]	NA	1.0 [5.0]	NA
method of manufacture	NA	Option 1: internally reinforced with geotextile backings (one woven and one nonwoven)(4) Option 2: unreinforced with HDPE geomembrane backing(5)	nonwoven needlepunched
surface texture	textured	Option 1: NA Option 2: textured HDPE backing	NA
grab strength (ASTM D 4632)	NA	NA	200 lb
trapezoidal tear strength (D 4533)	NA	NA	75 lb
puncture resistance (D 4833)	NA	NA	90 lb

Notes:
(1) HDPE= high density polyethylene
(2) PP= polypropylene
(3) PET= polyester
(4) GCL cap orientation: woven geotextile backing in contact with overlying geomembrane cap and nonwoven geotextile backing in contact with underlying compacted clay cap
(5) GCL cap orientation: unreinforced bentonite component in contact with overlying geomembrane cap and HDPE geomembrane backing in contact with underlying compacted clay cap

End of Executive Summary

COVER GEOSYNTHETICS SELECTION

TABLE OF CONTENTS

		Page
1.	Procedures/Methods	1/13
	• Geotextile Cushion	3/13
	• Geomembrane Cap	11/13
	• Geosynthetic Clay Liner Cap	12/13
2.	Data Verification	1/7
	• Geotextile Cushion	1/7
	• Geomembrane Cap	7/7
	• Geosynthetic Clay Liner Cap	7/7
3.	Calculations	1/14
	• Geotextile Cushion	2/14
	• Geomembrane Cap	8/14
	• Geosynthetic Clay Liner Cap	11/14

Written by: GRS Date (Y/M/D): 96/2/10 Reviewed by: MAD Date: 96/2/17

Client.: FERMCO Project: OSDF Project No.: GE3900 Task No.: 8.8

RB(DTL) 12 FEB 96

COVER GEOSYNTHETICS SELECTION:

GEOTEXTILE CUSHION
GEOMEMBRANE CAP
GEOSYNTHETIC CLAY CAP

PROCEDURES/METHODS

Purpose:

Present procedures and methods for selection of the low-permeability geosynthetic components of the final cover system (i.e., geomembrane cap and geosynthetic clay liner cap (GCL)). Present procedures and methods for selection of the geotextile cushion component of the final cover system.

Scope:

- Selection of key characteristics of the geotextile cushion.
- Selection of key characteristics of the geomembrane cap.
- Selection of key characteristics of the GCL cap.

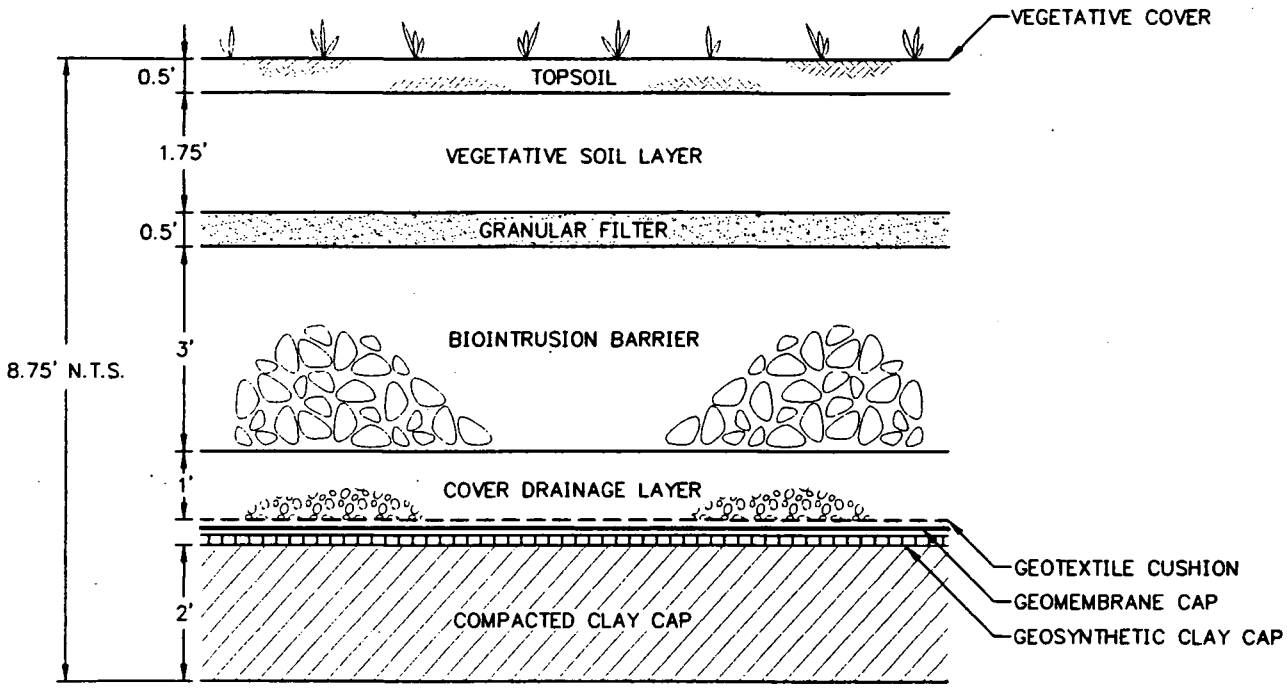
Statement of Design Problem:

Design of the final cover system includes selection of the key characteristics of the geosynthetic components. Key characteristics considered in this calculation package are polymer type, method of manufacture, surface texture, thickness or mass density, and construction survivability. Selection of key characteristics is made from the range of commercially-available geosynthetic products. The selection accounts for geosynthetic durability, constructability, and resistance to anticipated loads. The components of the final cover system are illustrated in the figure on the following page.

Written By : GBS Date: 10 Feb 96 Reviewed by: MAO Date: 96/2/17

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB (DTL) 12 FEB 96



FINAL COVER SYSTEM

[redacted]

Written by: GRS Date (Y/M/D): 961 2 / 10 Reviewed by: MAO Date: 96/2/17

Client.: FERMCO Project: OSDF Project No.: GE3900 Task No.: 8.8

RB (DTL) 12 FEB 96

GEOTEXTILE CUSHION

Approach for Selection of Key Characteristics of Geotextile Cushions:

Key characteristics for the geotextile cushions are polymer type, mass density, method of manufacture, and construction survivability. The factors to be considered in specifying these characteristics are mechanical properties and demonstrated cushioning capability. The selection process involves the following three evaluations: (i) selection of polymer type and method of manufacture; (ii) evaluation of capacity to provide puncture protection for the geomembrane cap under construction and post-closure conditions; and (ii) evaluation of construction survivability. Detailed procedures/methods for conducting these evaluations are described below.

Procedures/Methods for Selection of Polymer Type and Method of Manufacture

The factors to be considered in selecting polymer type and method of manufacture are the range of commercially-available geotextile products and demonstrated cushioning capability. The selection process will consider the available information on cushioning performance of different types of geotextiles.

Procedures/Methods for Evaluation of Puncture Protection Capacity:

Introduction

Design of the final cover system includes addressing the potential for the granular material in the cover drainage layer to puncture the geomembrane cap during OSDF construction and in the post-closure period. Puncture protection is provided by a geotextile cushion which prevents direct contact between the cover drainage material and geomembrane cap. Adequate puncture protection is achieved by appropriate selection of the mass density of the geotextile cushion.

Procedure

The following step-by-step calculation procedure will be used.

1. Evaluate maximum vertical stress on geomembrane cap for post-closure conditions. Maximum vertical stress on the geomembrane for post-closure conditions will be evaluated using the following equation:

$$\sigma_{v,max} = T_{max}\,\gamma_{ave}$$

where, T_{max} = maximum thickness of material to be placed above geomembrane cap in the final landfill configuration

γ_{ave} = average unit weight of material placed above geomembrane cap

2. Evaluate maximum vertical stresses on geomembrane cap for construction conditions. Maximum stresses will be induced by construction equipment, both wheeled and tracked, operating above the geomembrane cap. The maximum stresses will be calculated using the following equation:

$$\sigma_{v,max} = t\,\gamma + q\,A$$

where, t = thickness of material overlying geomembrane cap on which equipment is operating

γ = unit weight of overlying material

q = equipment ground pressure

A = pressure reduction factor; depends on size and configuration of pressure loading area and value of thickness, t

For this calculation, several sets of values for the parameters t and q will be obtained for tracked equipment from the restrictions on equipment operation above the geomembrane cap that are given in the project specification 02770, *Geomembrane Liner and Cover*. Values for t and q for wheeled equipment will be selected to represent a truck with a loaded weight of 35 tons and a tire pressure of 90 psi. This loaded weight is the same used in the evaluation of pipe crushing under equipment loads found in the "LCS pipe design" portion of the "leachate management - leachate collection system" calculation package. This tire pressure is representative of off-road trucks. Loaded weight distribution between axles will be assumed to be 30:70 (front:rear).

The parameter A will be obtained using published elastic theory solutions from Reference 1 for vertical stress distributions below loaded areas, as shown on the following page. The pressure loading area for tracked equipment will be assumed to be an infinite strip with a width of 2 ft. The pressure loading area for wheeled equipment will be assumed to be a circular area with a radius determined by tire pressure and wheel loading.

Written by: GRS Date: 96/2/10 (YY MM DD) Reviewed by: MAO Date: 96/2/17 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB (DTL) 12 FEB 96

3.1 Loading on an Infinite Strip

3.1.1 UNIFORM VERTICAL LOADING (Fig.3.1)

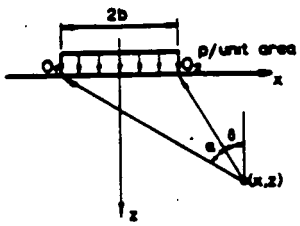


FIG.3.1

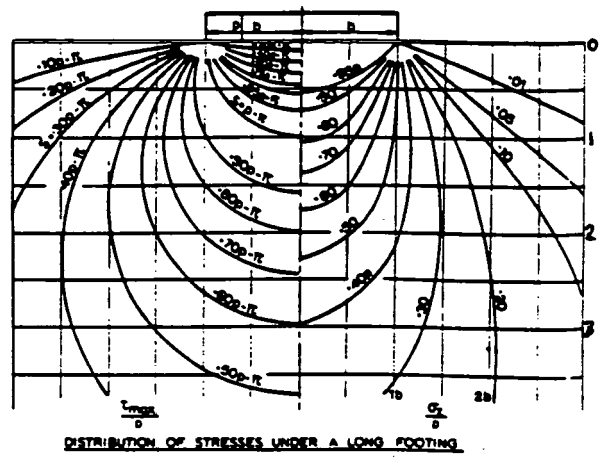


FIG.3.2 Stresses beneath a strip (Jurgenson,1934

3.3 Loading on a Circular Area

3.3.1 UNIFORM VERTICAL LOADING (Fig.3.13)

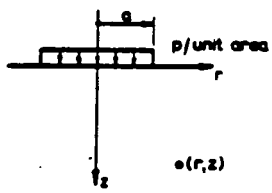


FIG.3.13

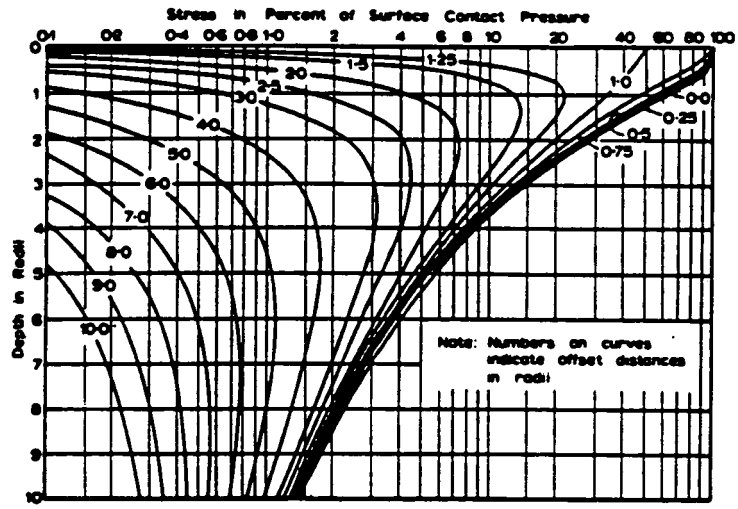


FIG.3.14 Vertical stress σ_z beneath uniform c load (Foster and Ahlvin, 1954).

SOURCE: Reference 1

[redacted]

Written by: GRS Date (Y/M/D): 96 / 2 / 10 Reviewed by: MAD Date: 96/2/17

Client.: FERMCO Project: OSDF Project No.: GE3900 Task No.: 8.8
RB(DTL) 12 FEB 96

It is noted that this calculation for the stresses induced by construction equipment does not account for potential dynamic loading effects from equipment operation. Such potential effects are neglected because the project specification for granular drainage layer placement specifically prohibits equipment maneuvers (i.e., hard braking and sharp turning) that have the potential to induce dynamic loading effects (project specification 02710, *Granular Drainage Layer)*.

3. Obtain vert. stress on geomembrane cap for evaluation of puncture protection.
The vertical stress, p_{actual}, will be taken as the largest value calculated from steps 1 and 2.

4. Evaluate allowable vertical stress on geomembrane cap.
The allowable vertical stress on the geomembrane cap, p_{allow}, will be evaluated using the procedure presented by Koerner et al. [1995] (Reference 2). This procedure is based on theoretical considerations along with puncture testing of HDPE geomembranes protected by needle-punched, nonwoven geotextiles. The allowable vertical stress depends on the mass density of the cushion geotextile.

The procedure uses the following equations:

$$p_{allow} = (p_{lab}) \div [\, MF_s \;\; MF_{pd} \;\; MF_a \;\; FS_{cr} \;\; FS_{cbd} \,]$$

where,
MF_s = modification factor for protrusion shape
MF_{pd} = modification factor for packing density
MF_a = modification factor for arching
FS_{cr} = factor of safety for creep
FS_{cbd} = factor of safety for chemical/biological degradation
p_{lab} = allowable vertical stress from controlled lab tests

Guidelines for selection of modification factors and factors of safety are provided in Reference 2.

Written by: GRS Date (Y/M/D): 96 / 2 / 10 Reviewed by: MAJ Date: 96/2/17

Client.: FERMCO Project: OSDF Project No.: GE3900 Task No.: 8.8

RB(DTL) 12 FEB 96

Reference 2 provides the following empirical formula for p_{lab} for 60-mil HDPE geomembranes:

$$p_{lab,60} = 450\ M / H^2 \quad \text{(kPa)}$$

where, M = mass density of cushion geotextile (g/m^2)
H = effective protrusion height (mm), depends on maximum particle size of drainage gravel

For these calculations, a value of p_{lab} is needed for geomembranes with thicknesses other than 60-mil. Based on the statement in part I of Reference 2 that "the [theoretical] analysis shows that the puncture resistance of the geomembrane is linearly related to its thickness," the value for p_{lab} will be assumed to be proportional to the geomembrane thickness (for example, $p_{lab,80} = 1.33\ p_{lab,60}$).

5. Compare the actual maximum vertical stress to allowable value.
The ratio of the allowable value to the actual value is taken as a global factor of safety against geomembrane puncture. Reference 2 recommends a minimum value of 3.0 for this ratio. This recommendation will be used for these calculations, as expressed by the following:

$$FS_{global} = p_{allow} / p_{actual} > 3.0$$

Written by: GRS Date (Y/M/D): 96 / 2 / 10 Reviewed by: MAO Date: 96/2/17

Client.: FERMCO Project: OSDF Project No.: GE3900 Task No.: 8.8

RB (DTL) 12 FEB 96

Procedures/Methods for Evaluation of Construction Survivability

Introduction

During final cover system construction, handling and installation stresses will be imposed on the cushion geotextile. The cushion geotextile must have the capacity to survive these stresses with negligible damage in order to provide continuing puncture protection for the geomembrane cap. Construction survivability is provided for by appropriate selection of certain mechanical strength properties of the geotextile cushions.

Procedure

The evaluation will be performed using the procedure outlined by Koerner [1994] (Reference 3). The procedure involves the following two steps: (i) establish the required degree of survivability as a function of subgrade conditions and type of construction equipment operating above the geotextile cushion using the table presented on the upper portion of the following page; and (ii) establish the recommended minimum values of certain mechanical strength properties (i.e., grab strength, puncture resistance, and trapezoidal tear strength) using the table presented on the lower portion of the following page.

Written by: GRS Date (Y/M/D): 96/2/10 Reviewed by: MAO Date: 96/2/17

Client.: FERMCO Project: OSDF Project No.: GE3900 Task No.: 8.8

RB (DTL) 12 FEB 96

Source: Koerner [1994] (Reference 3)

Table 2.20 Required degree of survivability as a function of subgrade conditions and construction equipment[a]

Subgrade conditions	*Construction equipment and 6 to 12 in. of cover material: initial lift thickness*		
	Low ground-pressure equipment (≤4 lb./in.)	*Medium ground-pressure equipment (>4 lb./in.², ≤8 lb./in.²)*	*High ground-pressure equipment (>8 lb./in.²)*
Subgrade has been cleared of all obstacles except grass, weeds, leaves, and fine wood debris. Surface is smooth and level such that any shallow depressions and humps do not exceed 6 in. in depth or height. All larger depressions are filled. Alternatively a smooth working table may be placed.	Low	Moderate	High
Subgrade has been cleared of obstacles larger than small to moderate-sized tree limbs and rocks. Tree trunks and stumps should be removed or covered with a partial working table. Depressions and humps should not exceed 1 in. in depth or height. Larger depressions should be filled.	Moderate	High	Very high
Minimal site preparation is required. Trees may be felled, delimbed, and left in place. Stumps should be cut to project not more than 6 in. ± above subgrade. Fabric may be draped directly over the tree trunks, stumps, large depressions and humps, holes, stream channels, and large boulders. Items should be removed only if placing the fabric and cover material over them will distort the finished road surface.	High	Very high	Not recommended

Recommendations are for 6 to 12 in. initial lift thickness. For other initial lift thicknesses:
12 to 18 in.: reduce survivability requirement one level;
18 to 24 in.: reduce survivability requirement two levels;
>24 in.: reduce survivability requirement three levels.
Survivability levels are in increasing order: low, moderate, high, and very high.
For special construction techniques such as prerutting, increase fabric survivability requirement one level.
Placement of excessive initial cover material thickness may cause bearing failure of soft subgrade.

Source: After Christopher and Holtz [146].

Table 2.21 AASHTO-AGC-ARBTA Joint Committee minimum geotextile properties recommended for survivability (reference 4)

	Physical Property Requirements[a] Geotextiles < 50% Elongation/Geotextiles > 50% Elongation[b,c]		
Survivability Level	*Grab Strength ASTM D4632 (lb.)*	*Puncture Resistance ASTM D4833 (lb.)*	*Trapezoid Tear Strength ASTM D4533 (lb.)*
Medium	180/115	70/40	70/40
High	270/180	100/75	100/75

[a]Values shown are minimum average roll values. Strength values are in the weaker principal direction.

[b]Elongation (strain) at failure as determined by ASTM D4632, Grab Tensile.

[c]The values of geotextile elongation do not imply the allowable consolidation properties of the subgrade soil. These must be determined by a separate investigation.

[redacted]

Written by: GBS Date (Y/M/D): 96 / 2 / 10 Reviewed by: MAO Date: 96/2/17

Client.: FERMCO Project: OSDF Project No.: GE3966 Task No.: 8.8

RB (DTL) 12 FEB 96

GEOMEMBRANE CAP

Procedures/Methods for Selection of Key Characteristics of Geomembrane Cap:

Key characteristics for the geomembrane cap in the final cover system are polymer type, geomembrane thickness, and surface texture. The factors to be considered in specifying these characteristics are hydraulic properties, mechanical properties, installation considerations, long-term behavior, and resistance to concentrated stresses and abrasion. The selection process will consider the anticipated final cover system service conditions.

Written by: GBS Date (Y/M/D): 96 / 2 / 10 Reviewed by: MAO Date: 96/2/17

Client.: FERMCO Project: OSDF Project No.: GE3900 Task No.: 8.8

RB(DTL) 12 FEB 96

GEOSYNTHETIC CLAY LINER CAP

Procedures/Methods for Selection of Key Characteristics of GCL Cap:

Key characteristics for the GCL cap in the final cover system are the clay mineral type, method of manufacture, and mass density of clay mineral. The factors to be considered in specifying these characteristics are hydraulic properties, plasticity of the clay component, and internal shear strength. The selection process will consider the anticipated final cover system service conditions.

Written by: GRS Date (Y/M/D): 961 2 1 10 Reviewed by: MAO Date: 96/2/17

Client.: FERMCO Project: OSDF Project No.: GE3900 Task No.: 8.8

RB(DTL)12 FEB 96

References

1. Poulos, H.G. and Davis, E.H., *Elastic Solutions for Soil and Rock Mechanics*, John Wiley & Sons, New York, 1974, Sections 3.1 and 3.4.

2. Koerner, R.M., Wilson-Fahmy, R., and Narejo, D., "Puncture Protection of Geomembranes, Part I: Theory, Part II: Experimental , and Part III: Examples," Geosynthetic Research Institute, 1995.

3. Koerner, R.M., *Designing with Geosynthetics*, Third Edition, Prentice Hall, 1994, pp. 302-304.

GEOSYNTEC CONSULTANTS

Written by: GRS Date: 96/2/12 (YY/MM/DD) Reviewed by: MAD Date: 96/2/17 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB (DTL) 12 FEB 96

COVER GEOSYNTHETICS SELECTION

GEOTEXTILE CUSHION
GEOMEMBRANE CAP
GEOSYNTHETIC CLAY CAP

DATA VERIFICATION PACKAGE

PURPOSE: Establish data and parameters required to perform calculations and evaluations for the "Cover Geosynthetics Selection"

SCOPE: Includes all data and parameters presented in the "Procedures/Methods" package

GEOTEXTILE CUSHION

* Selection of Polymer Type and Method of Manufacture

No data or parameters required

* Evaluation of Puncture Protection Capacity

This section refers to the calculation step numbers in the "Procedures/Methods" package

[redacted]

GEOSYNTEC CONSULTANTS

Written by: GBS Date: 96/2/12 (YY MM DD) Reviewed by: MAO Date: 96/2/17 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB(DTL)12 FEB 96

① Evaluate max. vert. stress on geomembrane cap for post-closure condition:

Need two parameters, γ_{ave} and T_{max}

A. γ_{ave} represents the average unit weight of the drainage layer and the other final cover system components to be placed above the geomembrane cap. A reasonable value for this parameter is 125 pcf. This value is conservative as it represents a near upper-bound value for the type of soil materials considered. It is conservative to use a near upper-bound value because the higher the unit weight the greater the calculated stress on the geomembrane. Therefore, use

$\gamma_{ave} = 125$ pcf ✓

B. T_{max} represents the maximum thickness of material which will overlie the geomembrane cap. This thickness is obtained from the final cover system design (see p. 2 of the "Procedures/Methods" package) as the combined thickness of the cover drainage layer [1.0 ft], biointrusion barrier [3.0 ft], [redacted]

Written by: GRS Date: 96/2/12 Reviewed by: MAO Date: 96/2/17

Client: FERMCO Project: OSDF Project/Proposal No.: GE3906 Task No.: 8.8

RB(DTL) 12 FEB 96

granular filter [0.5 ft], vegetative soil layer [1.75 ft] and topsoil [0.5 ft]. The combined value is

$T_{max} = 6.75$ ft ✓

(2) Evaluate max. vert. stress on geomembrane cap for construction conditions:

Need 4 parameters t, q, γ and A

The same values obtained for the liner system geomembranes will be used. These values are presented in the "geotextile cushion" portion of the "liner geosynthetics selection" calculation package. It is appropriate to use the same values because assumed limitations on equipment operation above the geomembrane, as reflected in project specification no. 02770 "Geomembrane Liner and Cover", apply to both the liner and final cover system.

(3) Obtain vertical stress on geomembrane cap for evaluation of puncture protection:

No data needed

[redacted]

GEOSYNTEC CONSULTANTS

Written by: GES Date: 96/2/12 (YY MM DD) Reviewed by: MAO Date: 96/2/17 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB(DTL) 12 FEB 96

④ Evaluate allowable vert. stress on geomembrane cap:

Five modification factors and factors of safety are needed. The same values obtained for the liner system geomembranes will be used. These values are presented in the "geotextile cushion" portion of the "liner geosynthetics selection" calculation package. It is appropriate to use the same values because the angularity and gradation of the cover drainage material, as specified in project specification no. 02710 "Granular Drainage Layer", is the same as for the LCS and LDS drainage layers in the liner system. The values are as follows: $MF_s = \underline{1.0}$ $MF_{pd} = \underline{0.5}$

$MF_a = \underline{1.0}$ $FS_{cbd} = 1.5$ (short-term conditions)
$= \underline{2.0}$ (long-term conditions) ✓

A value of FS_{cr} will be established using the following table from ref. 2 in "Procedures/Methods" package:

Mass per unit area, M g/m²	Effective Protrusion Height, H (mm) 38	25	12	6
0	N/R	N/R	N/R	>>1.5
270	N/R	N/R	>1.5*	1.5
550	N/R	1.5	1.3	1.2
1100	1.3	1.2	1.1	1.0
>1100	~1.2	~1.1	~1.0	1.0

* Assume this value is 2.5 for calculation purposes

use value in between 6 and 12 to represent H=9.5mm

[redacted]

Written by: GRS Date: 96/2/12 (YY MM DD) Reviewed by: MAO Date: 96/2/17 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB (DTL) 12 FEB 96

To use the above table for FS_{cr}, a value of effective protrusion height, H, is needed. As in the "geotextile cushion" portion of the "liner geosynthetics selection" calculation package this value is taken as ½ of the maximum drainage layer particle size, H = 9.5 mm

The calculation also requires a value for P_{lab}, the allowable vertical stress for controlled laboratory conditions. The value of P_{lab} will be obtained from the following equation, after the value of geomembrane cap thickness, G, is obtained in the "Calculations" package:

$$P_{lab} = \left(\frac{G}{60\ mil}\right)(450)\ M/H^2$$

units G: mil M = g/m²
P_{lab} = kPa H = mm (value established as 9.5 mm)

(5) Compare actual max. vert. stress to allowable value:

No data needed

Written by: GRS Date: 96/2/12 (YY MM DD) Reviewed by: MAO Date: 96/2/17 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.8

RB (DTL) 12 FEB 96

GEOTEXTILE CUSHION SELECTION (Continued)

* Evaluation of Construction Survivability

To establish required degree of survivability, three pieces of information are needed:

(i) Condition of subgrade on which geotextile will be placed

(ii) Thickness of initial lift of material overlying the geotextile

(iii) Highest ground pressure of construction equipment which will operate on the initial lift

The needed information is obtained as follows:

(i) Subgrade condition – The cushion geotextile will be placed on top of the cover system geomembrane, an extremely smooth and ~~level~~ regular surface.

(ii) Initial lift thickness – Based on the project specification 02710 "Granular Drainage Layer" the initial lift thickness is a minimum of 12 inches.

(iii) Max ground pressure on initial lift – Based on same spec. cited above maximum allowable ground pressure on initial lift is 5 psi.

GEOSYNTEC CONSULTANTS

Written by: GRS Date: 96/2/12 (YY MM DD) Reviewed by: MAO Date: 96/2/17 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3966 Task No.: 8.8

RB(DTL) 12 FEB 96

GEOMEMBRANE CAP

No data or parameters required

GEOSYNTHETIC CLAY CAP

No data or parameters required

[redacted]

Written by: GRS Date (Y/M/D): 96/2/16 Reviewed by: MAO Date: 96/2/17

Client.: FERMCO Project: OSDF Project No.: GE3900 Task No.: 8.8

COVER GEOSYNTHETICS SELECTION:

GEOTEXTILE CUSHION
GEOMEMBRANE CAP
GEOSYNTHETIC CLAY CAP

CALCULATIONS

Purpose:

Present selection processes and calculations for selection and evaluation of the low-permeability geosynthetic components of the final cover system and for the geotextile cushion component of the final cover system.

Scope:

Presents selection processes and calculations as described in the "Procedures/Methods" package.

GEOTEXTILE CUSHION

Selection of Polymer Type and Method of Manufacture:

Polymer Type - Virtually all commercially available geotextiles are composed of either polypropylene (PP) or polyester (PET). Both polymers are suitable for cushioning applications (Reference 1). Therefore, either PP or PET is selected for the cushion geotextile.

Method of Manufacture - The three primary manufacturing methods used to produce geotextiles are summarized below.

- Woven: Orthogonal polymer fibers or filaments are woven together in a flat sheet-like structure. The product is relatively thin and incompressible.

- Nonwoven Needlepunched: A mat of randomly oriented polymer fibers is formed. Arrays of closely-spaced needles are punched through the mat to entangle the random fibers. The product is relatively thick and compressible.

- Nonwoven Heatbonded: A mat of randomly oriented polymer fibers is formed. The mat is heated and passed through rollers to melt the random fibers together at their points of contact. The product is relatively thin and incompressible.

For the geotextile cushion, the key performance factors related to method of manufacture are shear strength and cushioning ability. With respect to cushioning ability, Reference 1 indicates that method of manufacture is not a major factor. However, nonwoven needlepunched geotextiles have typically been used as cushions and available cushion design methods are based on these materials. Therefore, use of a nonwoven needlepunched product is desirable. In addition, use of a nonwoven needlepunched product is desirable because these products generally exhibit higher interface shear strengths with soils and textured geomembranes than other products. Considering these factors, a nonwoven needlepunched product is selected for the geotextile cushion.

Written by: GRS Date: 96/2/16 (YY MM DD) Reviewed by: MAU Date: 96/2/17 (YY MM DD)

Client: FERMCO Project: GSDF Project/Proposal No.: GE3966 Task No.: 8.8

* Evaluation of Puncture Protection Capacity

This section uses the calculation step numbers given in the "Procedures/Methods" package.

For this calculation, check adequacy of geotextile mass density of 8 oz/yd² (270 g/m²). This is min. value recommended for cushion in Koerner et al., 1995.*

① Evaluate max. vertical stress on geomembrane cap for post-closure conditions:

$$\sigma_{v,max} = T_{max}\,\gamma_{ave} = 6.75\text{ ft}\,(125\text{ pcf}) = \underline{845\text{ psf}}$$ ✓

② Evaluate max. vert. stress on geomembrane cap for construction conditions:

The maximum vert. stress for construction conditions for the liner system geomembranes will be used. This value is presented in the "geotextile cushion" portion of the "liner geosynthetics selection" calculation package. It is appropriate to use the same value because the parameters used for the calculation are the same for the liner and final cover systems, as explained in the "Data Verification" package.

Therefore, $\sigma_{v,max} = \underline{1835\text{ psf}}$ ✓

* Koerner et al. [1995] (Reference no. 2 in 'Procedures/Methods' package)

Written by: GRS Date: 96/2/16 (YY MM DD) Reviewed by: MAO Date: 96/2/17 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.8

(3) Obtain vertical stress on geomembrane for evaluation of puncture protection:

value from step (1) = 845 psf (long-term)

value from step (2) = 1,835 psf (construction)

P_{actual} is taken as largest value from steps (1) and (2)

P_{actual} = 1,835 psf (construction)

(4) Evaluate allowable vertical stress on geomembrane

$P_{allow} = P_{lab} / [MF_s \; MF_{pd} \; MF_a \; FS_{cr} \; FS_{cbd}]$

where $MF_s = 1.0$ $MF_{pd} = 0.5$ $MF_a = 1.0$

FS_{cr}: $H = 9.5$ mm

$M = 270$ g/m² (8 oz/yd²)

(value assumed for this evaluation)

$FS_{cr} = 2.0$ interpolated from table using values of H and M

$FS_{cbd} = 1.5$ (for short-term condition)

P_{lab}: $H = 9.5$ mm $M = 270$ g/m²

$G = 60$ mil from "Selection of Geomembrane Cap Characteristics"

$P_{lab} = \frac{60 \text{ mil}}{60 \text{ mil}} (450)\left(\frac{270}{9.5^2}\right) = 1350 \text{ kPa} = 28{,}100 \text{ psf}$

GEOSYNTEC CONSULTANTS

Written by: GRS Date: 96 / 2 / 16 (YY MM DD) Reviewed by: MAo Date: 96 / 2 / 17 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3900 Task No.: 8.8

Therefore,

$$P_{allow} = \frac{28{,}100 \text{ psf}}{(1.0)(0.5)(1.0)(2.0)(1.5)} = 18{,}750 \text{ psf}$$

(5) Compare actual maximum vert. stress to allowable value

$$FS_{global} = \frac{P_{allow}}{P_{actual}} = \frac{18{,}750 \text{ psf}}{1{,}835 \text{ psf}}$$

$$= 10.2 > 3.0 \checkmark$$

The calculated value exceeds the target value.
Conclude that puncture protection is adequate. ✓
with a 8 oz/yd² [270 g/m²] cushion geotextile.

Written by: GRS Date (Y/M/D): 96 / 2 / 16 Reviewed by: MAO Date: 96/2/17

Client.: FERMCO Project: OSDF Project No.: GE3900 Task No.: 8.8

Evaluation of Construction Survivability:

The two-step method outlined by Koerner [1994] in Reference 3 of the "Procedures/Methods" package will be followed. For the first step, the required degree of survivability is established based on the following conditions: (i) smooth and regular subgrade condition; (ii) initial lift thickness of 12 inches; and (iii) maximum equipment ground pressure on initial lift of 5 psi. From the chart on the following page, these conditions indicate that the required degree of survivability is 'moderate'.

For the second step, minimum required values for mechanical properties of the geotextile are established from the chart on the following page based on the 'moderate', or medium survivability requirement. The chart provides minimum required values for two ranges of geotextile extensibility. Values were obtained for the more extensible range because this range is applicable to nonwoven materials. The required minimum average roll values from the chart are: (i) grab strength (ASTM D 4632) of 115 lb; (ii) puncture resistance (ASTM D 4833) of 40 lb; and (iii) trapezoidal tear strength (ASTM D 4533) of 40 lb. These required minimum values apply to both the machine and cross-machine directions of the geotextile.

Adequate construction survivability for the geotextile cushion can be achieved by including mechanical property requirements in the appropriate project specification (i.e., project spec. 02714, "*Geotextiles*") which exceed the required minimum values cited above. Inspection of the referenced specification indicates that this approach has been followed and that the construction survivability of the geotextile cushion is adequate. The specific values in the specification are as follows: (i) grab strength (ASTM D 4632) of 200 lb; (ii) puncture resistance (ASTM D 4833) of 90 lb; and (iii) trapezoidal tear strength (ASTM D 4533) of 75 lb.

Source: Koerner [1994] (Reference 3)

Table 2.20 Required degree of survivability as a function of subgrade conditions and construction equipment*

Subgrade conditions	Construction equipment and 6 to 12 in. of cover material: initial lift thickness		
	Low ground-pressure equipment (≤4 lb./in.)	*Medium ground-pressure equipment (>4 lb./in.², ≤8 lb./in.²)*	*High ground-pressure equipment (>8 lb./in.²)*
Subgrade has been cleared of all obstacles except grass, weeds, leaves, and fine wood debris. Surface is smooth and level such that any shallow depressions and humps do not exceed 6 in. in depth or height. All larger depressions are filled. Alternatively a smooth working table may be placed.	Low	Moderate	High
Subgrade has been cleared of obstacles larger than small to moderate-sized tree limbs and rocks. Tree trunks and stumps should be removed or covered with a partial working table. Depressions and humps should not exceed 1 in. in depth or height. Larger depressions should be filled.	Moderate	High	Very high
Minimal site preparation is required. Trees may be felled, delimbed, and left in place. Stumps should be cut to project not more than 6 in. ± above subgrade. Fabric may be draped directly over the tree trunks, stumps, large depressions and humps, holes, stream channels, and large boulders. Items should be removed only if placing the fabric and cover material over them will distort the finished road surface.	High	Very high	Not recommended

*Recommendations are for 6 to 12 in. initial lift thickness. For other initial lift thicknesses:
12 to 18 in.: reduce survivability requirement one level;
18 to 24 in.: reduce survivability requirement two levels;
>24 in.: reduce survivability requirement three levels.
Survivability levels are in increasing order: low, moderate, high, and very high.
For special construction techniques such as prerutting, increase fabric survivability requirement one level.
Placement of excessive initial cover material thickness may cause bearing failure of soft subgrade.

Source: After Christopher and Holtz [146].

Table 2.21 AASHTO-AGC-ARBTA Joint Committee minimum geotextile properties recommended for survivability (reference 4)

	Physical Property Requirements[a] Geotextiles < 50% Elongation/Geotextiles > 50% Elongation[b,c]		
Survivability Level	*Grab Strength ASTM D4632 (lb.)*	*Puncture Resistance ASTM D4833 (lb.)*	*Trapezoid Tear Strength ASTM D4533 (lb.)*
Medium	180/115	70/40	70/40
High	270/180	100/75	100/75

[a]Values shown are minimum average roll values. Strength values are in the weaker principal direction.

[b]Elongation (strain) at failure as determined by ASTM D4632, Grab Tensile.

[c]The values of geotextile elongation do not imply the allowable consolidation properties of the subgrade soil. These must be determined by a separate investigation.

[redacted]

GEOMEMBRANE CAP

Selection of Key Characteristics of the Geomembrane Cap:

Polymer Type - Polymer types considered for the geomembrane cap in the final cover system are high density polyethylene (HDPE), polyvinyl chloride (PVC), and chlorosulfonated polyethylene (CSPE). Geomembranes composed of these polymers are available from a number of manufacturers. The following narrative points address the key performance factors related to polymer type.

- The three identified polymers all have acceptable characteristics as liquid barriers, although HDPE geomembranes have the best characteristics. All three have extremely low permeability and are impermeable for practical purposes.

- The most significant mechanical properties of the geomembrane cap are tensile stiffness and yield strain. Although these properties vary somewhat with geomembrane thickness, HDPE is in general relatively stiff and has relatively small yield strain. PVC, in contrast, is relatively extensible and does not exhibit yield. The tensile properties of CSPE often fall between those of HDPE and PVC but are difficult to generalize because CSPE is often made with embedded reinforcing fabrics, or scrims, which affect tensile response.

- Geomembranes composed of all three of the identified polymers have acceptable ability to maintain integrity when subjected to concentrated stresses. The best performance is obtained with more extensible geomembranes. Therefore, based on the relative extensibilities discussed above, PVC offers the most favorable performance.

- Key considerations with respect to geomembrane installation include ease of placement and seaming. PVC and CSPE are easier to place than HDPE because their greater flexibility makes them conform more easily to certain shapes and makes them less prone to develop large thermal expansion wrinkles.

Acceptable placement and wrinkle control, can, however, be achieved with all three polymers if appropriate installation procedures are used. All three polymers are easily seamed, with HDPE usually achieving the highest seam strength and quality.

- With respect to chemical resistance, it has been found that HDPE has the highest degree of compatibility with a wide variety of chemicals encountered in wastes (References 2 and 3). CSPE has good resistance to many chemicals, but is attacked by some which are relatively common, namely chlorinated solvents and hydrocarbons. PVC typically is the least chemically resistant of the three polymers.

- With respect to long-term durability, HDPE offers the best performance. HDPE is a highly inert and durable material that is not susceptible to chemical degradation (i.e., oxidation) under conditions expected to exist in the OSDF final cover. In addition, HDPE is not susceptible to physical degradation (i.e., extraction or solvation) under conditions expected to exist in the OSDF final cover. The durability of PVC geomembranes is significantly less favorable than that of HDPE. This is because PVC geomembranes are composed of approximately two-thirds PVC resin and one-third plasticizers. Over time, physical degradation (i.e., extraction) may cause plasticizer loss which results in reduced geomembrane flexibility and dimensional stability. The durability of CSPE geomembranes is typically between that of HDPE and PVC.

Based on these performance factors, HDPE is selected for the geomembrane cap. This selection is based primarily on its superior chemical resistance and durability. The less favorable aspects of HDPE performance, related to response to concentrated stresses and installation, will be addressed through appropriate design, specification and construction quality assurance practices.

Geomembrane Thickness - A wide range of HDPE geomembrane thicknesses are available. The following narrative points address the key performance factors related to geomembrane thickness.

- The abrasion resistance of HDPE geomembranes increases with geomembrane thickness. Experience indicates that geomembranes with thickness less than 40 mils may not have acceptable abrasion resistance in some situations.

- The thicker the HDPE geomembrane, the higher its stiffness and the more prominent are the material's less favorable performance aspects (i.e., response to concentrated stresses and ease of installation issues). This issue is more significant for the geomembrane cap in the final cover system than for the liner system geomembranes because the geomembrane cap must be flexible enough to accommodate differential settlements resulting from the settlement of the impacted material within the OSDF. From this viewpoint, a thickness of not more than 80 mils is desirable.

- The thinner the HDPE geomembrane, the more difficult it is to weld adjacent panels. For most effective welding, thicknesses of at least 40 mils are desirable, with 60 to 80 mils perhaps being best.

Based on these performance factors, a thickness of 60 mil is selected for the HDPE geomembrane cap. This selection balances the performance factors described above and meets the ARAR requirement in OAC 3745-27-08(C)(2) that HDPE geomembranes have a minimum thickness of 60 mils.

Surface Texture - Two surface textures are widely available for HDPE geomembranes, smooth and textured. The primary performance factor affected by surface texture is the shear strength of the interface between the geomembrane and adjacent materials. The adjacent materials in the final cover system are the geotextile cushion and the GCL, both of which are known to form relatively weak interfaces with smooth HDPE geomembranes. Therefore, in order to provide higher interface shear strengths and thereby increase final cover system stability, a textured surface is selected for the geomembrane cap.

Written by: GRS Date (Y/M/D): 96 / 2 / 16 Reviewed by: MAJ Date: 96/2/17

Client.: FERMCO Project: OSDF Project No.: GE3900 Task No.: 8.8

GEOSYNTHETIC CLAY LINER CAP

Selection of Key Characteristics of the GCL Cap:

Clay Mineral Type - GCLs are commercially produced using sodium bentonite clay or calcium bentonite clay. The sodium bentonite is a more active clay mineral with greater plasticity and swell potential, properties which are needed for effective GCL hydraulic performance. In addition, the greater the clay plasticity and swell potential the more effective the GCL will be in sealing around any final cover system defects. The calcium bentonite, however, generally has a higher internal shear strength due to its lower plasticity.

Based on these factors, sodium bentonite is selected as the GCL cap clay mineral because of its better hydraulic performance capability. The less favorable aspect of sodium bentonite, i.e., low shear strength, will be addressed through appropriate cover system design and stability analysis.

Method of Manufacture - GCLs are commercially produced using one of the three manufacturing methods summarized below.

- Unreinforced with Geotextile Backing: A layer of dry, granular bentonite is placed between two geotextiles. Both woven and nonwoven geotextiles are sometimes used. A bentonite-based adhesive is used to adhere the geotextiles to the granular bentonite core.

- Unreinforced with HDPE Geomembrane Backing: A layer of bentonite is glued to one side of a HDPE geomembrane. Both textured and smooth geomembranes are sometimes used.

- Internally Reinforced with Geotextile Backing: a layer of dry, granular bentonite is placed between two geotextiles. Both woven and nonwoven geotextiles are sometimes used. The two geotextiles are joined by needlepunching or stitching. The needlepunched fibers or stitches serve to confine the bentonite and increase the in-plane shear strength of the GCL.

Written by: GRS Date (Y/M/D): 961 2 / 16 Reviewed by: MAO Date: 96/2/17

Client.: FERMIO Project: OSDF Project No.: GE3900 Task No.: 8.8

The key performance factors related to method of manufacture are as follows: (i) ability to form a composite hydraulic barrier with the overlying geomembrane cap; (ii) internal shear strength; and (iii) shear strength of interfaces with adjacent materials. These factors are discussed below.

- Composite hydraulic barrier - A composite barrier is best achieved with GCL products that allow close contact between the bentonite component and the overlying geomembrane. For GCLs with geotextile backings, those with woven backings can generally provide for closer contact with an overlying geomembrane than can those with nonwoven backings. This statement is based on observations which indicate that bentonite particles will more readily pass through a woven geotextile backing than through a nonwoven backing. For unreinforced GCLs with HDPE geomembrane backings, close contact is achieved if the bentonite component is placed directly in contact with the geomembrane.

- Internal shear strength - For GCLs with geotextile backings, a relatively high internal shear strength can be obtained by using an internally reinforced product. Relatively high internal shear strengths can also be achieved with unreinforced GCLs with HDPE geomembrane backings if the bentonite component is prevented from hydrating. This may be achieved if hydration is prevented during construction and if the bentonite component is placed directly in contact with the overlying geomembrane. This orientation serves to minimize hydration because the bentonite is confined between two geomembranes, i.e. the geomembrane cap in the final cover system and the geomembrane backing of the GCL.

- Interface shear strength - For GCLs with geotextile backings, it is observed that nonwoven backings generally produce higher interface shear strengths with adjacent materials than do woven backings. For unreinforced GCLs with HDPE geomembrane backings, higher interface shear strengths are generally achieved when the HDPE backing has a textured outer surface.

Based on these factors, both GCLs with geotextile backings and unreinforced GCLs with HDPE geomembrane backings can provide adequate performance as the GCL cap. Specific requirements for GCLs with geotextile backings are given in the following list.

- GCL will have one nonwoven backing and one woven backing.
- GCL will be oriented with the nonwoven backing against the underlying compacted clay cap and the woven backing against the overlying geomembrane cap in order to achieve as close contact as possible between the bentonite component and the overlying geomembrane cap.
- GCL will be internally reinforced to achieve a relatively high internal shear strength.

Specific requirements for unreinforced GCLs with HDPE geomembrane backings are given in the following list.

- GCL will be oriented with the HDPE geomembrane backing against the underlying compacted clay cap and the bentonite component against the overlying geomembrane cap. This orientation is intended to achieve as close contact as possible between the bentonite component and the overlying geomembrane cap and to minimize bentonite hydration.
- The geomembrane backing will have a textured surface to achieve a relatively high interface shear strength with the underlying compacted clay cap.

Clay Mineral Mass Density - A certain minimum mass density of clay mineral in the GCL cap is required for development of a continuous hydraulic barrier. In addition, the ability of the GCL to swell and seal around any final cover system defects is likely greater with greater clay mineral mass density. Most commercially produced GCLs have a clay mineral mass density of at least one pound per square foot, a value which is considered to provide for reasonable GCL performance. Therefore, a clay mineral mass density of at least one pound per square foot is selected for the GCL cap. This value meets the ARAR requirement in OAC 3745-27-08(C)(3) that GCLs have a minimum bentonite mass density of one pound per square foot.

References

1. Hullings, D. and Koerner, R., "Puncture Resistance of Geomembranes Using a Truncated Cone Test," *Proc. of Geosynthetics '91*, Vol. 1, Atlanta, February 1991, pp. 273-285.

2. Haxo, H.E., White, R.M., Haxo, P.D. and Fong, M.A., "Liner Materials Exposed to Municipal Solid Waste Leachate", U.S. Environmental Protection Agency, December 1982, 169 p.

3. Schwope, A.D., Costas, P.F. and Lyman, W.J., "Resistance of Flexible Membrane Liners to Chemicals and Wastes", U.S. Environmental Protection Agency, September 1985, 217 p.

SECTION 12

12. SURFACE-WATER MANAGEMENT DURING OSDF CONSTRUCTION/ FILLING/CLOSURE

12.1 Stormwater Runon/Runoff and Drainage Control Structures
12.2 OSDF Sediment Basins

12.1 Stormwater Runon/Runoff and Drainage Control Structures

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: SURFACE-WATER MANAGEMENT DURING OSDF CONSTRUCTION/ FILLING/CLOSURE STORMWATER RUNON/RUNOFF AND DRAINAGE CONTROL STRUCTURES — Early Stage

Computations By: (Cognizant Engineer)
Signature [signature] Date 21 Feb 96
Printed Name and Title: Robert S Cobb II, Senior Staff Engineer

Assumptions and Procedures Checked by: (Checker)
Signature [signature] Date 21 Feb 96
Printed Name and Title: Eric S. Steinhauser, Senior Project Engineer

Computations Checked by:
Signature [signature] Date 21 Feb 96
Checked by:
Printed Name and Title: Eric S. Steinhauser, Senior Project Engineer

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 21 Feb 96
Printed Name and Title: Robert S Cobb II, Senior Staff Engineer

Approved by: (PDP)
Signature [signature] Date 21 Feb 96
Printed Name and Title: Eric S. Steinhauser, Senior Project Engineer

Approved by: (DTL and TETL)
Signature [signature] Date 22 Feb 96
Printed Name and Title: Kenneth W Cargill

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	Intermediate Design				
	~~Drainage Areas and Routing to Be Updated in Pre-Final Design~~			KK 9 May 97	
D	Intermediate Design - EPA Submittal	4 Apr 96	KK		
G	Final Design Package	4 Oct 96			KK
O	Response to Final Design Cmts	9 May 97			KK

GE3900-08.1/F9630077

Written by: Ganesh Gopalakrishnan GG 5May97 Date: 5/5/97 Reviewed by: Ken W. Cargill Date:

Client: FDF Project: OSDF Project/Proposal No.: GQ 0131 Task No.: 12.1

ADDENDUM

(Added to the Revision 0 Package)

Surface-water management calculations performed in this package are based on assumed drainage areas during the initial stripping and early construction stages of the OSDF. These calculations will be treated as an example for future calculations that will be performed to design the surface-water management features based on clearly defined drainage areas and other site conditions.

GEOSYNTEC CONSULTANTS

Written by: Asc Date: 21/Feb/96 Reviewed by: SSS Date: 21/Feb/96

lient: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

SURFACE-WATER MANAGEMENT DURING OSDF CONSTRUCTION/FILLING/CLOSURE

STORMWATER RUNON/RUNOFF AND DRAINAGE CONTROL STRUCTURES

EXECUTIVE SUMMARY

Purpose of Analysis

The purpose of this analysis is to evaluate the surface-water management system during the early stages of on site disposal facility construction. This system is designed to direct stormwater runoff to an existing sediment basin. This system consists of drainage channels and culverts.

Method of Analysis

Stormwater Runoff: The amount of stormwater runoff was calculated using the computer program "HydroCAD™ Stormwater Modeling System" (HydroCAD™). This program uses the hydraulic modeling methods presented in USDA-SCS Technical Releases 20 and 55.

Drainage Control Structures: The performance of the drainage channels was evaluated using HydroCAD™. The performance of culverts was evaluated using methods presented in USDOT FHWA technical report entitled "Hydraulic Design of Highway Culverts" and the "Concrete Pipe Design Manual", by the American Concrete Pipe Association.

Conclusions

Runon/Runoff from the 25-year, 24-hour design storm event can be controlled with 4.5 ft. deep drainage channels with 3H:1V sides.

GeoSyntec Consultants

Written by: _____ Date: ___/___/___ Reviewed by: _____ Date: ___/___/___

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.2

TABLE OF CONTENTS

SURFACE-WATER MANAGEMENT DURING OSDF CONSTRUCTION/FILLING/CLOSURE
Stormwater Runon/Runoff and Drainage Control Structures

Calculation Procedures

Purpose	1 of 9
Scope	1 of 9
Calculation Procedures	2 of 9
General	2 of 9
Storm Runon and Runoff Quantities	2 of 9
Peak Flow velocities and Maximum Depth of Flow in Drainage Channels	5 of 9
Flow Capacity of Culverts	7 of 9
Structural capacity of Culverts	7 of 9
Culvert Outlet Protection	8 of 9
References	9 of 9

Data Verification

Purpose	1 of 26
Scope	1 of 26
Parameters for Design	2 of 26
General	2 of 26
Rainfall Information	2 of 26
Rainfall Quantities and Durations	2 of 26
Rainfall Distribution	2 of 26
Drainage Area Data	3 of 26
Drainage Areas	2 of 26
Drainage Flow Types	3 of 26
Hydrology Soil Group (HSG)	3 of 26
Vegetative Cover Type	4 of 26
Runoff Curve Numbers	4 of 26
Summary	4 of 26
Culverts	4 of 26
References	5 of 26

Tables

1	Rainfall Depth for a given duration	6 of 26
2	Roughness coefficients (Manning's n) for sheet flow	7 of 26
3	Manning's coefficients	8 of 26
4	Hydrologic soil group for United States soils	9 of 26

5	Runoff curve numbers for urban areas	12 of 26
6	Initial stripping drainage areas	13 of 26
7	Early construction drainage areas	13 of 26
8	Highways loads	14 of 26
9	Backfill loads on circular pipe in trench installation	15 of 26

Figures

1	Approximate geographic boundaries for SCS rainfall distributions	16 of 26
2	SCS 24-hour rainfall distributions	17 of 26
3	Initial stripping drainage areas	18 of 26
4	Early construction drainage areas	19 of 26
5	Ditch cross section	20 of 26
6	Hydrologic soil groups	21 of 26
7	Manning's n related to velocity, hydraulic radius and vegetable retardance	22 of 26
8	Headwater depth for concrete pipe culverts with inlet control	23 of 26
9	Head for concrete pipe culverts flowing full (n=0.012)	24 of 26
10	Trench bedding circular pipe	25 of 26
11	Water management and sediment control for urbanizing areas	26 of 26

Calculation

Purpose	1 of 44
Scope	1 of 44
Initial Stripping	1 of 44
Summary of Input Data	1 of 44
Summary of Calculation Results	1 of 44
Early Construction	3 of 44
Summary of Input Data	3 of 44
Summary of Calculation Results	3 of 44
Drainage Area Maps	5 of 44
Worksheets for weighted runoff curve numbers	10 of 44
HydroCAD Runs Runoff	14 of 44
Culvert Calculations	34 of 44

Tables

1	Initial stripping drainage areas	2 of 44
2	Summary of HydroCAD results- Initial stripping	3 of 44
3	Initial stripping drainage areas	4 of 44
4	Summary of HydroCAD results- Early construction	5 of 44
5	Summary of culvert design results	5 of 44

Appendix A - HydroCAD Stormwater modeling System (Manual) 1 of 26

Written by: RSC Date: 16/Feb/96 Reviewed by: ASS Date: 20/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

SURFACE-WATER MANAGEMENT DURING OSDF CONSTRUCTION/FILLING/CLOSURE

22 Feb 96

STORMWATER RUNON/RUNOFF AND DRAINAGE CONTROL STRUCTURES

CALCULATION PROCEDURES

Purpose

The purpose of this document is to present the calculation procedures used to analyze the drainage control features that will collect the OSDF stormwater runoff during the early construction stages. The drainage control features include:

- drainage channels that will carry stormwater runoff to a sediment basin; and
- culverts constructed in conjunction with the drainage channels to carry stormwater runoff to the sediment basin.

The calculations are performed in accordance with, and to verify compliance with, the DCP. The DCP requirements relevant to these calculations are:

- the drainage channels must accommodate peak precipitation runoff flows;
- the peak flow velocity in the drainage channels should not initiate scour in the channels; and
- the freeboard in the drainage channels should be at least 6 in. during the design storm event.

Scope

The procedures presented in this document will be used to perform the following calculations for each drainage area and for each design storm event:

- runoff quantities;

- peak flow velocities and maximum depth of flow in drainage channels; and

- flow capacity of the culverts.

In addition, the structural capacity of the culverts will be analyzed.

Calculation Procedures

General

The computer program "HydroCAD™ Stormwater Modeling System" [Applied Microcomputer Systems, 1993] (HydroCAD™), will be used to calculate runoff quantities, the peak flow velocities, and maximum depth of flow in the drainage channels. HydroCAD™ uses the hydrologic modeling methods presented in Technical Release 20 (TR20) [USDA-SCS, 1975] and TR55 [USDA-SCS, 1986a]. (See Appendix A for information related to HydroCAD™.) The flow capacity of the culverts will be analyzed using the methods presented in the document entitled *"Hydraulic Design of Highway Culverts"* [USDOT-FHWA, 1985]. The structural capacity of the culverts will be analyzed using the "Concrete Design Manual" [American Concrete Pipe Association, 1970].

Stormwater Runon and Runoff Quantities

The procedure for calculating stormwater runoff quantities consists of the following steps.

1. Define the drainage area to be analyzed. These data are presented in the design verification document.

2. Calculate the weighted CN using the runoff curve number worksheet [USDA-SCS, 1986a], except for the OSDF cover slopes. A weighted CN of 98 is assigned for the OSDF final cover slopes.

3. Define the parameters associated with the surface-water flow segments for each drainage area. The flow segments consist of sheet flow, shallow concentrated flow, and open channel flow. The engineering parameters needed to define these flow segments are listed below:

22 Feb 96

- for sheet flow:

  - surface type which yields a Manning's coefficient for sheet flow;
  - the flow length (ft);
  - slope of land (ft/ft);

- for shallow concentrated flow:

  - flow length (ft);
  - surface type (paved or unpaved); and
  - average slope of land (ft/ft); are

- for open channel flow:

  - Manning's coefficient for open channel flow;
  - channel length (ft);
  - channel slope (ft/ft); and
  - pertinent channel geometry (e.g., side slopes (H:V) and depth (ft) or cross-sectional area (ft^2), and wetted perimeter (ft)).

These data are also presented in the data verification document.

4. Calculate the amount of runoff for a drainage area, a design storm event, and a vegetative cover type. The data defined in Steps 1 through 3 are used as input to HydroCAD™. HydroCAD™ uses the data to develop a "runoff hydrograph" as described below.

   a. Calculate the Time of Concentration (T_c) for a drainage area. The Tc represents the time required for stormwater to travel from the most hydrologically distance point of a drainage area to the point of interest. Tc is calculated by summing the individual travel times (T_t) for each flow segment define in a drainage area.

Written by: Asc Date: 26/Feb/96 Reviewed by: SSS Date: 20/Feb/96

lient: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

22Feb96

Travel time for each flow segment is calculated as follows:

for sheet flow:

$$T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5} S^{0.4}}$$

where: T_c = Travel time for sleet flow (hours);
n = Manning's coefficient for sheet flow, based on surface types;
L = flow length (ft);
P_2 = amount of rainfall from a 2-year, 24-hour design storm event (in.); and
S = slope of land (ft/ft).

for shallow concentrated flow:

$$T_t = \frac{L}{3600V}$$

where: T_t = Travel time for shallow concentrated flow (hours);
L = Flow length (ft);
V = average flow velocity (ft/s).

for open channel flow:

$$T_t = \frac{nL}{(3600)(1.486)r^{0.67}S^{0.5}}$$

where: T_t = Travel time for open channel flow (hours);
n = Manning's coefficient for open channel flow;
L = channel length (ft)
r = hydraulic radius (ft) = a/Pw;
a = cross-sectional area of flow (ft^2);
P_w = wetted perimeter (ft);
S = channel slope (ft).

b. Develop a unit hydrograph for the project site. The unit hydrograph is a dimensionless curve that represent the runoff distribution resulting from 1 in. of rainfall excess over the drainage area. To develop a unit hydrograph, HydroCAD™ uses the CN value and the anticipated rainfall distribution. HydroCAD™ then develops a runoff hydrograph for the design storm event. HydroCAD™ develops the runoff hydrograph by summing the amount of runoff calculated over a series of discrete time intervals during the storm event. The amount of runoff is calculated as follows:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad (Q = \text{zero if } P < 0.2S)$$

where: Q = amount of runoff (in.);
P = cumulative rainfall (in.);
S = potential maximum retention after runoff begins (in.);
S = 1000/CN - 10
CN = runoff curve number.

The discrete time interval or rainfall burst duration for which runoff calculations are performed is calculated as follows:

$$D = \frac{2}{15} Tc$$

where: D = duration (hours); and
T_c = time of concentration (hours).

5. The resulting runoff hydrograph provides the runoff quantities for the storm event as well as the peak runon/runoff quantity.

Peak Flow Velocities and Maximum Depth of Flow in Drainage Channels

The procedures for calculating the peak flow velocity and the maximum depth of flow in a drainage channel consists of the following steps.

1. Define points of interest along the drainage channel. These points are at culvert entrances. These locations are presented in the data verification document.

22 Feb 96

2. Define the dimensions and geometry of the drainage channel at each point of interest. This information is also presented in the data verification document.

3. Develop a discharge versus depth curve for the drainage channel by calculating the flow rate for various flow depths in the drainage channel based on the channel geometry. Flow rate is calculated as follows:

$$Q = \frac{1.486 a r^{0.67} s^{0.5}}{n}$$

where: Q = flow rate (cfs);
a = cross-section area of flow (ft^2);
r = hydraulic radius (ft) = a/P_w;
P_w = wetted perimeter (ft);
s = channel slope (ft/ft); and
n = Manning's coefficient for open channel flow.

4. Calculate the peak flow velocity and the maximum depth of flow in a drainage channel at the point of interest. The runoff hydrograph previously calculated, the data defined in Steps 1 and 2, and the data calculated in Step 3 are used as input to HydroCAD™ to route a design storm through the drainage channel. The routing calculation uses the runoff hydrograph as an inflow hydrograph to the point of interest. The result of this routing is an outflow hydrograph from which the peak flow is obtained. HydroCAD™ simultaneously solves for the peak flow velocity and the maximum depth of flow by comparing the discharge versus depth curve and the following equation:

$$V_p = \frac{Q_p}{A_p}$$

where: V_p = peak flow velocity (ft/s);
Q_p = peak flow (cfs);
A_p = cross-sectional area of flow a peak flow (ft^2)

5. Verify that the drainage channel satisfies the design criteria.

Written by: Asc Date: 16/Feb/96 Reviewed by: GSS Date: 20/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

22Feb96

Flow Capacity of Culverts

The procedure for calculating the flow capacity of culverts consists of the following steps.

1. Define the peak flow to be carried by the culvert and maximum design water depth at the culvert entrance. These data were previously calculated.

2. Define the size type, and length of the culvert. These data are presented in the design verification document.

3. Verify that the culvert headwater meets design criteria. The data defined in Steps 1 and 2 are used as input to USDOT-FHWA [1985] culvert design charts. The headwater depth is evaluated by checking both inlet and outlet control.

Structural Capacity of Culverts

The procedure for calculating the structural capacity of the culverts consists of the following steps.

1. Define the loading (i.e., dead load and live load) to be exerted on the culvert. These data are presented in the data verification document.

2. Define the pipe bedding and loading factors. These data are also presented in the data verification document.

3. Define the factor of safety.

4. Calculate pipe strength (D-load) using the following equation:

$$\text{D-load} = \left[\left(\frac{W_L}{L_f}\right) + \left(\frac{W_E}{L_f}\right)\right]\frac{F_s}{D} \text{ for } L_f \leq 1.5$$

or

Written by: Asc Date: 16/Feb/96 Reviewed by: SSS Date: 20/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

KC 22 Feb 96

$$\text{D-load} = \left[\left(\frac{W_L}{1.5}\right) + \left(\frac{W_L}{L_f}\right)\right]\frac{F_s}{D} \text{ for } L_f > 1.5$$

where: D-load = pipe strength
D = inside diameter (ft);
F_s = factor of safety;
W_L = live load (kips);
W_E = earth load (kips); and
L_f = loading factor.

Culvert Outlet Protection

The procedure for calculating the riprap culvert outlet consists of the following steps.

1. Define culvert discharge. These data were previously calculated.

2. Use the USDA-SCS [1987] design chart to select a D_{50} for the riprap and the length of the outlet apron.

3. Calculate the apron size using the relationships shown on the design chart [USDA-SCS, 1987].

4. Calculate the D_{max} and D_{15} of the riprap as follows:

$$D_{max} = 1.5 \times D_{50}$$
$$D_{15} = 0.5 \text{ to } 0.75 \times D_{50}$$

where: D_{50} = theoretical spherical diameter of average stone size;
D_{max} = theoretical spherical diameter of largest stone size; and
D_{15} = theoretical spherical diameter of the stone size for which 15 percent of the material is smaller.

5. Calculate the minimum thickness of the riprap, which should be two times the D_{50}, but not less than 6 in.

Written by: RSC Date: 16/Feb/96 Reviewed by: RSS Date: 20/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

22 Feb96

References

American Concrete Pipe Association, "*Concrete Pipe Design Manual*", Arlington, VA, 1970.

Applied Microcomputer Systems, "HydroCAD™ Stormwater Modeling System," version 3.10, Chocorna, NH, 1993.

Chow, "Open Channel Hydraulics," 1959

USDA-SCS, "Computer Program for Project Formulation, Hydrology", Technical Release 10 (TR20), U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., 1975.

USDA - SCS "National Engineering Handbook, Section 4 - Hydrology," Washington, DC, Mar 1985.

USDA-SCS, *"Urban Hydrology for Small Watersheds"*, Technical Release 55 (TR55), U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., 2nd Edition, 1986a.

USDA-SCS, *"Engineering Field Manual for Conservation Practices"*, U.S. Department of Agriculture, Soil conservation Service, Washington, D.C., 1986b.

USDA-SCS, *"Water Management and Sediment Control for Urbanizing Areas"*, U.S. Department of Agriculture, Soil Conservation Services, Washington, D.C., 1987.

USDOT-FHWA, *"Hydraulic Design of Highway Culverts"*, Hydraulic Design Series No.5, Report No. FHWA-1P-85-15, U.S. Department of Transportation, Federal Highway Administration, McLean, VA, 1985.

Written by: RSC Date: 16/Feb/96 Reviewed by: SSS Date: 20/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

FC 22Feb96

SURFACE-WATER MANAGEMENT DURING CONSTRUCTION/FILLING/CLOSURE

STORMWATER RUNON/RUNOFF AND DRAINAGE CONTROL STRUCTURES

DATA VERIFICATION

PURPOSE

The purpose of this document is to present the engineering data used to design the drainage control features that will collect the stormwater runoff during the early construction stage of the On-Site Disposal Facility (OSDF). The calculations are subdivided into two categories that represent the site conditions when the stormwater runoff will be greatest: (i) initial stripping; and (ii) early construction. The drainage control features that will be in place to handle the stormwater include:

- drainage channels that will carry stormwater runoff to a sediment basin; and
- culverts constructed in conjunction with the drainage channels.

The data presented in this document are used to satisfy the requirements presented in the DCP. The DCP requirements relevant to the data verification are:

- the drainage control structures shall be designed to carry the runoff from the 25-year, 24-hour design storm event;
- the slope of the drainage channels shall be no less than 0.5 percent;
- the channel sideslopes should be no steeper than 3 horizontal to 1 vertical; and
- the channel bottom may be zero.

SCOPE

The data presented in this document will be used to perform the following calculations:

- runoff quantities;
- peak flow velocities and maximum depth of flow in the drainage channels;
- flow capacity of culverts; and
- structural capacity of culverts.

Written by: RSC Date: 16 / Feb / 96 Reviewed by: SSS Date: 20 / Feb / 96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

PARAMETERS FOR DESIGN

22 Feb 96

General

Data required to perform the calculations include: (i) rainfall information (i.e., quantities, durations, distribution); (ii) drainage area information (i.e., drainage channel dimensions and geometries, Manning's coefficients for sheet flow and open channel flow, soil and vegetative cover types); and (iii) culvert information (i.e., size, type, cover, loadings). Engineering data will be obtained from site-specific studies and published engineering texts.

Rainfall Information

Rainfall Quantities and Durations

Rainfall quantities for specific design storm events were summarized by Parsons [1995] and are presented in Table 1. Rainfall for the design storm required by the DCP or by the calculation method include:

Storm Event	Rainfall (in.)
2-Year, 24-Hour	2.55
25-Year, 24-Hour	4.7

Rainfall Distribution

According to USDA-SCS [1986a], storm events that occur in the area of the OSDF site will have a Type II storm distribution, see Figure 1. Rainfall intensities for a Type II, 24-hour storm are shown on Figure 2.

Drainage Area Data

Drainage Areas

The drainage areas containing the initial stripping stage and early construction stage of the OSDF are subdivided into drainage subareas (e.g., E, W) to accurately model the hydrologic and soil conditions of the drainage area. The drainage areas and their subareas are shown on Figures 3 and 4.

Drainage Flow Types

KM 22-Feb96

Surface water flow within a drainage area is characterized as a series of flow segments. The flow segments will consist of sheet flow, shallow concentrated flow, and open channel flow. The engineering parameters needed to define these flow segments, along with the reference source for the data, is listed below:

- for sheet flow:
  - surface type which yields a Manning's coefficient for sheet flow, Table 2 [USDA-SCS, 1986a];
  - flow length (ft), Figures 3 and 4;
  - slope of land (ft/ft), Figures 3 and 4;
- for shallow concentrated flow:
  - flow length (ft), Figures 3 and 4;
  - surface type (paved or unpaved);
  - average slope of land (ft/ft), Figures 3 and 4; and
- for open channel flow:
  - Manning's coefficient for open channel flow, Table 3 [Chow, 1959] and Figure 7 [USDA-SCS, 1986b];
  - channel length (ft), Figures 3 and 4;
  - channel slope (ft/ft), Figures 3 and 4;
  - pertinent channel geometry (e.g., side slopes (H:V) and depth (ft) or cross-sectional area (ft^2), and wetted perimeter (ft)), Figure 5.

Hydrologic Soil Group (HSG)

The soil types found within the OSDF watershed are illustrated in Figure 6 [USDA-SCS, 1992]. The HSG classification for each soil type identified were obtained from Table 4 [USDA-SCS, 1986a]. Soils found within the OSDF watershed and their associated HSG are:

SCS Map Designator	Soil Name	HSG Group
FcA	Fincastle	C
FdA	Fincastle	C
RwB2	Russell-Miamian	B
XeB	Xenia	B

22 Feb 96

Vegetative Cover Type

The HSGs identified within the drainage are subdivided by vegetative cover type. There will be no vegetative cover after stripping. Vegetative cover types (including bare soil) recognized by Technical Release 55 [USDA-SCS, 1986a] (i.e., the hydrology model used in these calculations) are presented in Table 5 [USDA-SCS, 1986a].

Runoff Curve Numbers

Runoff Curve Numbers (CN) are factors used to account for the influence that each of the HSG and vegetative cover type have on the amount of runoff. CN values may be obtained from Table 5 [USDA-SCS, 1986a].

The Manning's coefficient (n) for grass-lined open channels is dependent on the three factors: (i) vegetation type; (ii) flow velocity; and (iii) hydraulic radius. Manning's n for various vegetative retardance groups may be obtained from Figure 7 [USDA-1986b]. Because the vegetation in the drainage channel will vary over time, an average Manning's n of 0.050 was selected. This Manning's n value falls within the range presented in Chow [1959], see Table 3.

Summary

A summary of the drainage area data is presented in Tables 6 and 7.

Culverts

Culverts will be used to carry the stormwater runoff from a 25-year, 24-hour design storm event. The culverts will be concrete pipes placed in a Class B type trench with a granular foundation. Culvert design charts [USDOT-FHWA, 1985] are presented as Figures 8 and 9. These culverts must function with a factor of safety between 1.25 and 1.5 under an AASHTO H-20 live load (i.e., maximum axle load of 32 kips) and applicable dead loads, see Tables 8 and 9 [American Concrete Pipe Association, 1970]. For cover thickness less than 3 ft, increase the live load by an impact factor I_F as follows:

- 0 - 1 ft, I_F = 1.3;
- 1 - 2 ft, I_F = 1.2; and
- 2 - 3 ft, I_F = 1.1.

Pipe bedding and loading factors are presented in Figure 10. Riprap for the culvert outlet will be size using the USDA-SCS [1982] design chart presented in Figure 11.

Written by: RJC Date: 16 / Feb / 96 Reviewed by: JSS Date: 20 / Feb / 96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

REFERENCES

22 Feb 96

American Concrete Pipe Association, *"Concrete Pipe Design Manual"*, Arlington, VA, 1970.

Chow, *"Open Channel Hydraulics"*, 1959.

Earth Systems Associates, *"Vegetation Cover Recommendations for the On-Site Disposal Facility at the Fernald Environmental Management Project Site"*, February 1996.

GeoSyntec Consultants, *"Design Criteria Package"*, document in preparation.

Parsons Engineering, *"2000-Year Flood and Probable Maximum Flood, Sitewide Flood Plain Determination"*, Revision A, Aug 1995.

USDA-SCS, *"National Engineering Handbook, Section 4 - Hydrology"*, U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., Mar 1985.

USDA-SCS, *"Urban Hydrology for Small Watersheds"*, Technical Release 55 (TR-55), U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., Jun 1986a.

USDA-SCS, *"Engineering Field manual for Conservation Practices"*, U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., Nov 1986b.

USDA-SCS, *"Water Management and Sediment Control for Urbanizing Areas'*, U.S. Department of Agriculture, Soil Conservation Services, Washington, D.C., 1987.

USDOT-FHWA, *"Hydraulic Design of Highway Culverts"*, Hydraulic Design Series No. 5, Report No. FHWA-IP-85-15, U.S. Department of Transportation, Federal Highway Administration, McLean, Virginia, 1985.

739 RSC 2/13/96

6/26

20Feb96

KL 22Feb96

TABLE 1 - RAINFALL DEPTH FOR A GIVEN DURATION (INCHES)

DURATION (YEARS)	TIME							
	HYDRO-35			TP-40				
	5 MIN	15 MIN	60 MIN	2 HOURS	3 HOURS	6 HOURS	12 HOURS	24 HOURS
2	0.387	0.739	1.223	1.408	1.54	1.848	2.2	2.552
5	0.49	0.979	1.69	2.016	2.112	2.496	2.88	3.072
10	0.564	1.139	1.99	2.277	2.475	3.069	3.465	4.059
25	0.65	1.34	2.38	2.6	3.0	3.4	4.0	4.7
50	0.72	1.49	2.67	3.0	3.25	3.9	4.2	5.2
* 100	0.78	1.64	2.95	3.3	3.6	4.1	5.0	5.6
* 500	0.93	2.1	4.3	5.2	5.9	7.3	8.5	9.4
2000	1.2	2.6	5.8	7.2	8.2	10.2	12.0	13.0
10,000	1.4	3.4	8.2	10.5	12.0	15.5	18.0	19.2
100,000	1.9	5.0	13.3	17.7	20.8	27.4	31.8	33.4
	DESIGN OF SMALL DAMS					HMR-51		

NOTE: Rainfall Points For 2, 5, and 10 year rainfall events were adjusted per TP-40. Values for the 500, 2000, and 10,000 Year Events were interpolated from Figure 3 (Appendix E)

* These values are used on PH Records for HEC-1.

REF: PARSONS, "2,000-YEAR FLOOD AND PROBABLE MAXIMUM FLOOD, SITEWIDE FLOOD PLAIN DETERMINATION", AUG 1995.

[redacted]

299

739 asc 2/13/85
7 / 26

SSS 20feb96 KL 22Feb96

Table 2 .—Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1]The n values are a composite of information compiled by Engman (1986).
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3]When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

(210-VI-TR-55, Second Ed., June 1986)

[redacted]

300

TABLE 3. MANNING'S COEFFICIENTS

VALUES OF THE ROUGHNESS COEFFICIENT n
(Boldface figures are values generally recommended in design)

Type of channel and description	Minimum	Normal	Maximum
A. CLOSED CONDUITS FLOWING PARTLY FULL			
A-1. Metal			
a. Brass, smooth	0.009	0.010	0.013
b. Steel			
1. Lockbar and welded	0.010	0.012	0.014
2. Riveted and spiral	0.013	0.016	0.017
c. Cast iron			
1. Coated	0.010	0.013	0.014
2. Uncoated	0.011	0.014	0.016
d. Wrought iron			
1. Black	0.012	0.014	0.015
2. Galvanized	0.013	0.016	0.017
e. Corrugated metal			
1. Subdrain	0.017	0.019	0.021
2. Storm drain	0.021	0.024	0.030
A-2. Nonmetal			
a. Lucite	0.008	0.009	0.010
b. Glass	0.009	0.010	0.013
c. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
d. Concrete			
1. Culvert, straight and free of debris	0.010	0.011	0.013
2. Culvert with bends, connections, and some debris	0.011	0.013	0.014
3. Finished	0.011	0.012	0.014
4. Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
5. Unfinished, steel form	0.012	0.013	0.014
6. Unfinished, smooth wood form	0.012	0.014	0.016
7. Unfinished, rough wood form	0.015	0.017	0.020
e. Wood			
1. Stave	0.010	0.012	0.014
2. Laminated, treated	0.015	0.017	0.020
f. Clay			
1. Common drainage tile	0.011	0.013	0.017
2. Vitrified sewer	0.011	0.014	0.017
3. Vitrified sewer with manholes, inlet, etc.	0.013	0.015	0.017
4. Vitrified subdrain with open joint	0.014	0.016	0.018
g. Brickwork			
1. Glazed	0.011	0.013	0.015
2. Lined with cement mortar	0.012	0.015	0.017
h. Sanitary sewers coated with sewage slimes, with bends and connections	0.012	0.013	0.016
i. Paved invert, sewer, smooth bottom	0.016	0.019	0.020
j. Rubble masonry, cemented	0.018	0.025	0.030

VALUES OF THE ROUGHNESS COEFFICIENT n (*continued*)

Type of channel and description	Minimum	Normal	Maximum
B. LINED OR BUILT-UP CHANNELS			
B-1. Metal			
a. Smooth steel surface			
1. Unpainted	0.011	0.012	0.014
2. Painted	0.012	0.013	0.017
b. Corrugated	0.021	0.025	0.030
B-2. Nonmetal			
a. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
b. Wood			
1. Planed, untreated	0.010	0.012	0.014
2. Planed, creosoted	0.011	0.012	0.015
3. Unplaned	0.011	0.013	0.015
4. Plank with battens	0.012	0.015	0.018
5. Lined with roofing paper	0.010	0.014	0.017
c. Concrete			
1. Trowel finish	0.011	0.013	0.015
2. Float finish	0.013	0.015	0.016
3. Finished, with gravel on bottom	0.015	0.017	0.020
4. Unfinished	0.014	0.017	0.020
5. Gunite, good section	0.016	0.019	0.023
6. Gunite, wavy section	0.018	0.022	0.025
7. On good excavated rock	0.017	0.020	
8. On irregular excavated rock	0.022	0.027	
d. Concrete bottom float finished with sides of			
1. Dressed stone in mortar	0.015	0.017	0.020
2. Random stone in mortar	0.017	0.020	0.024
3. Cement rubble masonry, plastered	0.016	0.020	0.024
4. Cement rubble masonry	0.020	0.025	0.030
5. Dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0.023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. Glazed	0.011	0.013	0.015
2. In cement mortar	0.012	0.015	0.018
g. Masonry			
1. Cemented rubble	0.017	0.025	0.030
2. Dry rubble	0.023	0.032	0.035
h. Dressed ashlar	0.013	0.015	0.017
i. Asphalt			
1. Smooth	0.013	0.013	
2. Rough	0.016	0.016	
j. Vegetal lining	0.030	.....	0.500

This table reprinted from OPEN CHANNEL HYDRAULICS by Ven Te Chow, Copyright 1959 by McGraw-Hill, with the permission of the publisher.

739 ASC 2/13/96

9/26

RSS 20Feb96

KC 22Feb96

TABLE 4, continued: Hydrologic soil groups for United States soils

EYOTA	A	FARRAGUT	C	FETTIC	D	FLATIRON	D	FORKWOOD	B
EYRE	D	FARRAR	B	FETZER	C	FLATTOP	D	FORMADER	C
EZBIN	B	FARRELL	B	FEZ	C	FLAXTON	B	FORMAN	B
FABIUS	B	FARRENBURG	B	FIANCER	D	FLEAK	D	FORMDALE	B
FACEVILLE	B	FARROT	C	FIANDER, DRAINED	C	FLEER	A/D	FORNEY	D
FACEY	B	FARSON	B	FIAT	C	FLEISCHMANN	D	FORNOR	B
FACTORY	C	FARSON, WET	C	FIDALGO	C	FLEMING	C	FORREST	C
FACTORY, MOIST	B	FARVA	C	FIDDLER	C	FLEMINGTON	D	FORSEER	C
FADDIN	D	FARVANT	D	FIDDLETOWN	B	FLETCHER	B	FORSEY	B
FADOLL	B	FASHING	D	FIDDYMENT	D	FLEWSIE	B	FORSGREN	C
FAGAN	C	FASKIN	B	FIELD	C	FLEX	D	FORSYTH	A
FAGASA	C	FATHOM	A	FIELDCREEK	B	FLO	A	FORT COLLINS	B
FAHEY	B	FATIMA	B	FIELDING	B	FLOER	D	FORT MEADE	A
FAIM	C	FATTIG	C	FIELDON	B/D	FLOKE	D	FORT MOTT	A
FAIM, MOIST	B	FAUNCE	A	FIFER	D	FLOM	B/D	FORT ROCK	C
FAIRBANKS	B	FAUNSDALE	D	FIFIELD	C	FLOMATON	A	FORTANK	C
FAIRBURN	D	FAUQUIER	C	FILION	D	FLOMOT	B	FORTESCUE	C/D
FAIRCHILD	C	FAUSSE	D	FILIRAN	D	FLOODWOOD	B	FORTUNA	D
FAIRDALE	B	FAVRET	C	FILLMORE	D	FLORAHOME	A	FORTWINGATE	C
FAIRFAX	B	FAWIN	B	FINCASTLE	C	FLORALA	C	FORTYFOUR	C
FAIRFIELD	B	FAX	C	FINCH	C	FLORENCE	C	FORVIC	C
FAIRHAVEN	B	FAXON	B/D	FINCHFORD	A	FLORESVILLE	C	FORWARD	B
FAIRLIE	D	FAYETTE	B	FINDOUT	D	FLORIDANA	B/D	FOSS	B
FAIRLO	B	FAYETTEVILLE	B	FINGAL	C	FLORIDANA,	D	FOSSILON	D
FAIRMOUNT	D	FAYWOOD	C	FINGEROCK	D	DEPRESSIONAL		FOSSUM	A/D
FAIRPLAY	B	FE	D	FINLAND	C	FLORIDANA, FLOODED	D	FOSTER	C
FAIRPOINT	C	FEARS	B	FINLEY	B	FLORIN	C	FOSTORIA	B
FAIRPORT	C	FEATHERLEGS	B	FINLEYPOINT	B	FLORISSANT	C	FOUNTAIN	C
FAIRWAY	C	FEATHERSTONE	D	FINNERTY	C	FLORITA	B	FOUR STAR	C
FAIRYDELL	C	FEDJI	A	FINO	B	FLOTAG	B	FOUR STAR, DRAINED	B
FAIRYLAWN	D	FEDORA	B/D	FINOL	C	FLOWELL	C	FOURCHE	B
FAJARDO	C	FEDSCREEK	B	FIONE	B	FLOWEREE	B	FOURLOG	C
FALAYA	D	FELAN	B	FIFADA	C	FLOYD	B	FOURME	B
FALBA	D	FELCHER	B	FIREBALL	B	FLUETSCH	B	FOURMILE	B
FALCON	D	FELDA	B/D	FIREBOX	B	FLUGLE	B	FOX	B
FALFA	C	FELDA,	D	FIRESTEEL	B	FLUKER	C	FOXCREEK	D
FALFURRIAS	A	DEPRESSIONAL		FIRESTONE	C	FLUVANNA	C	FOXCREEK, DRAINED	C
FALK	C	FELICITY	A	FIRMAGE	B	FLYBOW	D	FOXHOME	B
FALKIRK	B	FELIPE	D	FIRO	D	FLYGARE	B	FOXMOUNT	C
FALKNER	C	FELIZ	B	FIROKE	B	FLYNN	B	FOXOL	D
FALLBROOK	B	FELKER	B	FIRSTVIEW	C	FLYNNCOVE	B	FOXTON	C
FALLCREEK	C	FELLOWSHIP	D	FIRTH	C	FOAD	C	FOXWORTH	A
FALLERT	B	FELOR	B	FIRTH, DRAINED	B	FOARD	D	FRADDLE	B
FALLON	C	FELT	B	FISHERMAN	D	FOEHLIN	B	FRAILEY	B
FALLON, NONFLOODED	B	FELTA	C	FISHERS	B	FOIDEL	B	FRAILTON	C
FALLSAM	D	FELTMAN	B	FISHFIN	D	FOLA	B	FRAM	B
FALLSINGTON	B/D	FELTNER	D	FISHHOOK	C	FOLDAHL	B	FRANCIS	A
FALOMA	D	FELTON	B	FISHLAKE	D	FOLEY	D	FRANCISCAN	C
FALSEN	A	FELTONIA	B	FISHPOT	C	FOLLET	D	FRANCISQUITO	C
FALULA	D	FENCE	B	FISHRUCK	D	FOMSENG	C	FRANCITAS	C
FAMAL	C	FENDALL	C	FISHTRAP	D	FONDA	D	FRANDSEN	B
FANCHER	C	FENELON	C	FISK	B	FONDIS	C	FRANKFORT	C
FANDANGLE	C	FENN	D	FITCHVILLE	C	FONNER	B	FRANKIRK	C
FANDOW	D	FENSTER	B	FITZGERALD	B	FONS	B	FRANKLIN	B
FANG	B	FENWICK	C	FITZHUGH	B	FONTANA	B	FRANKSTOWN	B
FANNIN	D	FENWOOD	B	FIVEBLOCK	C	FONTREEN	B	FRANETOWN	C
FANNO	C	FERA	C	FIVEMILE	B	FOPIANO	D	FRANKVILLE	B
FANSHAW	B	FERDELFORD	C	FIVEMILE, SALINE	C	FORADA	B/D	FRATERNIDAD	C
FANTZ	C	FERDINAND	C	FIVEOM	B	FORAKER	D	FRAVAL	C
FANU	B	FEREBEE	D	FIVEPINE	D	FORBAR	D	FRAVAL, GRAVELLY	B
FAPS	C	FERGUS	B	FIVES	B	FORBES	C	FRAZER	C
FARAWAY	D	FERN CLIFF	B	FIVESPRINGS	C	FORBESVILLE	C	FRAZERTON	B
FARB	D	FERNANDO	B	FLACO	C	FORBING	D	FRED	C
FARBER	D	FERNCREEK	D	FLAGG	B	FORD	D	FREDENSBORG	C
FARGO	D	FERNDALE	B	FLAGLER	B	FORDICE	B	FREDERICK	
FARISITA	D	FERNEY	D	FLAGSTAFF	D	FORDNEY	A	FREDON	C
FARLAND	D	FERNHAVEN	B	FLAK	C	FORDNEY, WET	C	FREDONIA	C
FARLOW	B	FERNLEY	C	FLAMBEAU	B	FORDIRAN	C	FREDONYER	C
FARLOW, HIGH	C	FERNOW	B	FLAMING	A	FORDUM	D	FREE	B/D
RAINFALL		FERNPOINT	B	FLANAGAN	B	FORDYILLE	B	FREEBURG	C
FARMELL	B	FERNWOOD	B	FLANDREAU	B	FORELAND	D	FREECE	D
FARMINGTON	C	FERRELO	B	FLANE	C	FORELLE	B	FREEDOM	C
FARNSWORTH	D	FERRIS	D	FLANLY	B	FORESMAN	B	FREEDOM, SALINE	B
FARNTON	D	FERROBURRO	D	FLASHER	D	FORESTBURG	A	FREEHOLD	B
FARNHAM	B	FERRON	D	FLAT HORN	B	FORESTDALE	D	FREELAND	C
FARNHAMTON	C	FERTALINE	D	FLATHEAD	B	FORESTER	C	FREEMAN	C
FARNUF	B	FERTEG	C	FLATIRONS	C	FORESTON	C	FREEMANVILLE	B
FARNUF, WET	C	FESTINA	B	FLATNOSE	B	FORGAY	B	FREEON	B
FARNUM	B	FETT	D	FLATONIA	D	FORK	C	FREER	C

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

[redacted]

302

73y RJC 2/13/96

10/26

20Feb96 KC 22Feb96

TABLE 4, continued: Hydrologic soil groups for United States soils

RODIE	A	ROSENDALE	C	RUBY	A	SABENYO	B	SAMINIEGO	C
RODMAN	A	ROSENWALL	D	RUBYHILL	C	SABINA	C	SAMISH	D
RODROF	D	ROSEVILLE	A	RUCH	B	SABINE	A	SAMMAMISH	D
ROEBUCK	D	ROSEWOOD	A/D	RUCKER	A	SABLE	B/D	SAMOIST	D
ROELLEN	D	ROSEWOOD, WET	D	RUCKLES	D	SAC	B	SAMOR	D
ROEMER	C	ROSEWORTH	D	RUCLICK	C	SACHEEN	A	SAMPSEL	D
ROETEX	D	ROSHE SPRINGS	D	RUDD	D	SACHETT	C	SAMPSON	B
ROFISS	B	ROSHE SPRINGS,	C	RUDDLEY	D	SACO	D	SAMSIL	D
ROGAN	A	DRAINED		RUDEEN	C	SACRAMENTO	D	SAMSULA	B/D
ROGERSON	D	ROSHOLT	B	RUDYARD	C	SACTUS	D	SAN ANDREAS	D
ROGERT	D	ROSINE	B	RUEDLOFF	B	SACUL	C	SAN ANTON	B
ROGRUBE	B	ROSITAS	A	RUELLA	A	SADDLE	C	SAN ANTONIO	C
ROGUE	B	ROSITAS, CLAYEY	C	RUFUS	D	SADDLEBACK	C/D	SAN ARCACIO	C
ROHAN	D	SUBSTRATUM		RUGAR	C	SADDLEGAP	B	SAN BENITO	B
ROHNERVILLE	B	ROSITAS, LOAMY,	C	RUGG	B	SADDLEROCK	D	SAN EMIGDIO	B
ROHONDA	C	WET		RUGLES	A	SADER	D	SAN GERMAN	D
ROHRERSVILLE	D	ROSITAS, WET	C	RUHI	D	SADIE	C	SAN ISABEL	A
ROIC	D	ROSLYN	B	RUIDOSO	C	SADLER	C	SAN JOAQUIN	D
ROJO	C	ROSMAN	B	RUINPOINT	A	SAFFELL	B	SAN JON	C
ROLETTE	C	ROSNEY	B	RUIZ	A	SAG	B	SAN JOSE	B
ROLFE	C	ROSS	B	RUKO	D	SAGANING	A/D	SAN JUAN	A
ROLIE	D	ROSSBURG	B	RULE	B	SAGASER	A	SAN LUIS	C
ROLISS	B/D	ROSSFIELD	B	RUMBLECREEK	B	SAGE	D	SAN MATEO	B
ROLLA	C	ROSSMOOR	B	RUMDO	C	SAGECREEK	A	SAN MIGUEL	D
ROLLINGSTONE	C	ROSSMOYNE	C	RUMFORD	A	SAGEDALE	C	SAN SABA	D
ROLOC	D	ROSWELL	A	RUNLEY	D	SAGEHILL	B	SAN SEBASTIAN	B
ROLOFF	C	ROSY	B	RUNNEY	C	SAGEMOOR	B	SAN SIMEON	D
ROMBERG	B	ROTAMER	B	RUNPAH	D	SAGERS	A	SAN TIMOTEO	C
ROMBO	C	ROTAN	C	RUPPLE	C	SAGERION	C	SAN YSIDRO	D
ROME	B	ROTHICAN	B	RURUNG	C	SAGLE	C	SANCHEZ	D
ROMEO	D	ROTHIEMAY	C	RUNE	C	SAGO	D	SANCLEMENTE	D
ROMERO	D	ROTHSAY	B	RUNEBERG	C/D	SAGOUSPE	C	SANDALL	C
ONGAN	C	ROTINOM	A	RUNGE	A	SAGOUSPE, DRAINED	B	SANDBRANCH	D
MIA	B	ROTO	C	RUNN	D	SAGUACHE	B	SANDCREEK	D
OMINE	B	ROTTULSE	C	RUPLE	C	SAHALIE	B	SANDERSON	B
OMINELL	C	ROUBIDEAU	C	RUPLEY	A	SAHUARITA	B	SANDHILL	B
ONNELL	B/D	ROUEN	C	RUSCO	C	SAID	B	SANDIA	B
ONSTOCK	B	ROUGHCREEK	D	RUSCO, PONDED	D	SAIDO	A	SANDOSE	A
ONULUS	D	ROUGHLOCK	A	RUSE	D	SAILBOAT	C	SANDOVAL	D
ONAN	D	ROUGHMOUNT	C	RUSH	D	SAILBOAT, DRAINED	B	SANDRIDGE	A
OND	C	ROUND BUTTE	D	RUSHMORE	B/D	SAIPAN	B	SANDSPRING	B
ONDEAU	A/D	ROUNDABOUT	C	RUSHTOWN	A	SAL	D	SANDUN	B
ONDELL	B	ROUNDPAWN	B	RUSHVILLE	D	SALADAR	D	SANDUSKY	D
ONDONA	B	ROUNDHEAD	B/D	RUSO	B	SALADON	D	SANDVIEW	A
ONNEBY	C	ROUNDOR	C	RUSON	C	SALAL	C	SANDWASH	C
ONSEL	B	ROUNDTOP	C	RUSS	A	SALAMATOF	D	SANDWICK	B
ONSON	B	ROUNDUP	C	RUSSELL	B	SALANDER	B	SANELI	D
OONEY	D	ROUNDY	C	RUSSIAN	B	SALAS	C	SANFORD	B
OOSET	C	ROUSSEAU	A	RUSSLER	C	SALCHAKET	B	SANGER	D
OOSEVELT	C	ROUTON	D	RUSTICO	A	SALCO	B	SANGO	C
OOT	B/D	ROUTT	C	RUSTIGATE	C	SALEM	B	SANHEDRIN	B
OOTEL	C	ROYAL	B	RUSTON	A	SALERATUS	C	SANIDEL	B/D
OPER	B/D	ROWDEN	C	RUSTY	B	SALERNO	B/D	SANILAC	B
OSALIE	B	ROWDY	B	RUTAB	B	SALGA	C	SANJE	D
OSAMOND	B	ROWE	C	RUTERSVILLE	C	SALIDA	A	SANLOREN	B
OSAMOND,	C	ROWEL	D	RUTHERFORD	C	SALINAS	B	SANPETE	B
SALINE-ALKALI,		ROWENA	C	RUTLAND	C	SALISBURY	C	SANPITCH	C
FLOODED		ROWLAND	C	RUTLEDGE	B/D	SALIX	B	SANPOIL	D
OSANE	D	ROWLEY	C	RYAN	D	SALKUM	D	SANSARC	D
OSANKY	C	ROXAL	D	RYAN PARK	B	SALLISAW	B	SANTA	D
OSARIO	C	ROXANA	B	RYARK	A	SALLYANN	C	SANTA CLARA	C
OSCOE	D	ROXBURY	B	RYCO	D	SALMO	C/D	SANTA FE	D
OSCOMMON	A/D	ROXER	B	RYDE	C	SALMON	B	SANTA ISABEL	D
OSE CREEK	C	ROXTON	D	RYDER	C	SALONIE	D	SANTA LUCIA	C
OSE CREEK,	B	ROY	B	RYDOLPH	C	SALT CHUCK	A	SANTA MARIA	C
DRAINED		ROYAL	D	RYEGATE	C	SALT LAKE	D	SANTA YNEZ	D
OSE VALLEY	D	ROYCE	C	RYELL	B	SALTAIR	D	SANTANA	D
OSEBERRY	D	ROYGORGE	D	RYELL, SALINE	D	SALTER	B	SANTANELA	D
OSEBLOOM	D	ROYOSA	A	RYEPATCH	C	SALTERY	D	SANTAQUIN	A
OSEBOROUGH	B	ROYST	C	RYER	C	SALTESE	D	SANTAROSA	B
OSEBUD	B	ROYSTONE	B	RYKER	B	SALTINE	C	SANTEE	D
OSEBURG	B	ROZA	C	RYMAN	C	SALTON	D	SANTIAGO	B
OSEDHU	D/D	ROZELLVILLE	B	RYORP	C	SALUDA	C	SANTIAM	C
OSEGLEN	B	ROZETTA	B	RYPOC	B	SALVISA	C	SANTO	B
OSEHAVEN	B	ROZLEE	C	RYUS	B	SALZER	D	SANTO TOMAS	B
OSEHILL	D	RUARK	A/D	SAAR	C	SALZER, PROTECTED	C	SANTONI	D
OSELAND	B	RUBICON	A	SABANA	D	SAMBA	D	SANWELL	B
OSELLA	D	RUBIO	C/D	SABANA SECA	C	SAMBRITO	B	SAPEHA	B
OSELMS	D	RUBSON	B	SABE	B	SAMDAY	D	SAPELO	D

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

[redacted]

303

739 RSC 2/13/96

11/26

TABLE 4., continued: Hydrologic soil groups for United States soils

WILSON	D	WISHARD	C	WOODS CROSS	D	WYNOOSE	D	YEGEN	D
WILSONGULCH	B	WISHBONE	B	WOODSEYE	D	WYOCENA	B	YEGUAS	C
WILSONVILLE	D	WISHEYLU	C	WOODSFIELD	C	WYOMING	A	YELJACK	B
WILSOR	B	WISHKAH	D	WOODSIDE	B	WYRENE	B	YELLOWDAY	B
WILST	C	WISHKAH, DRAINED	C	WOODSLAKE	D	WYSOCKING	C/D	YELLOWHOUND	B
WILTON	B	WISKAN	C	WOODSON	D	XANA	B	YELLOWROCK	A
WINADA	C	WISKIFLAT	B	WOODSTOCK	C/D	XANADU	B	YELLOWSTONE	D
WINDERRY	C	WISNER	B/D	WOODSTOWN	C	XAVIER	B	YELM	C
WINCHESTER	A	WISTER	C	WOODTELL	D	XENIA	B	YEMASSEE	C
WINCHUCK	C	WITBECK	B/D	WOODVILLE	D	XENO	B	YENCE	C
WIND RIVER	B	WITEFELS	B	WOODWARD	B	XERTA	C	YENLO	B
WINDCOAT	D	WITHAM	D	WOODWEST	D	XERXES	D	YENRAB	A
WINDER	B/D	WITHEE	C	WOOFUS	D	XICA	C	YEOMAN	B
WINDER, DEPRESSIONAL	D	WITHERBEE	A/D	WOOLPER	C	XINE	C	YEOPIM	B
		WITHERELL	D	WOOLSEY	B	XIPE	D	YERINGTON	A
WINDHAM	B	WITHERS	C	WOOLSTALF	B	XIPE, MODERATELY WET	C	YERMO	B
WINDICREEK	A	WITT	B	WOOLSTED	B			YESUM	B
WINDMILL	B	WITTEN	D	WOONSOCKET	B	XMAN	D	YETTEM	B
WINDSOR	A	WITTENBERG	B	WOOSLEY	C	YACOLT	B	YETULL	A
WINDTHORST	C	WITZEL	D	WOOSTER	C	YAGO	C	YIGO	B
WINDWHISTLE	C	WIX	C	WORCESTER	C	YAHANA	C	YIPOR	B
WINDWHISTLE, WARM	B	WIXOM	B	WORDEN	C	YAHARA	C	YLIG	C
WINDY	B	WOCKLEY	C	WORF	D	YAHNE	C	YOBE	C
WINDYPOINT	B	WODA	D	WORFKA	D	YAHOLA	B	YOCHUM	C
WINEG	B	WODEN	B	WORFMAN	D	YAHOO	D	YOCKEY	C
WINEMA	C	WODSKOW	C	WORFSTONE	C	YAINAX	B	YODER	B
WINETTI	B	WODSKOW, DRAINED	B	WORK	C	YAKI	D	YODY	C
WINEVADA	C	WOHLY	B	WORK, GRAVELLY	B	YAKIMA	B	YOHURT	D
WINFALL	B	WOLCO	C	WORLAND	C	YAKUS	D	YOKAYO	D
WINFIELD	B	WOLCOTT	B/D	WORLEY	D	YAKUTAT	A	YOKOHL	D
WING	D	WOLDALE	D	WORMSER	C	YALELAKE	B	YOKUT	B
WINGATE	B	WOLDALE, DRAINED	C	WOROCK	B	YALESVILLE	C	YOLLABOLLY	D
WINGER	B/D	WOLF	B	WORSHAM	D	YALLANI	B	YOLO	B
WINGINAW	D	WOLF POINT	C	WORTH	C	YALMER	B	YOLOGO	D
WINGVILLE	D	WOLFCREEK	B	WORTHEN	B	YAMAC	B	YOMBA	B
WINIFRED	C	WOLFESON	C	WORTHING	D	YAMHILL	C	YOMONT	B
WINK	B	WOLFESON, WET	D	WORTMAN	D	YAMO	B	YONGES	D
WINKEL	D	WOLFEY	C	WORTMAN, SANDY	A	YAMSAY	D	YONNA	D
WINKLEMAN	C	WOLFPEN	A	WOYOKA	D	YANA	B	YORDA	D
WINKLEMAN, WET	D	WOLFTEVER	C	WRANGELL	D	YANCY	D	YORK	C
WINKLER	B	WOLLARD	C	WRANGO	A	YANKEE	D	YORKTOWN	D
WINLER	D	WOLLENT	D	WRAYHA	D	YANKTON	B	YORKTREE	C
WINLO	D	WOLOT	B	WREDAH	B	YANUSH	B	YORKVILLE	D
WINN	C	WOLVERINE	A	WRENCOE	D	YAP	B	YOST	D
WINNEBAGO	B	WOMACK	C	WRENMAN	C	YAPOAH	B	YOST, DRAINED	C
WINNECONNE	C	WOO	B	WRENTHAM	C	YAQUI	B	YOUD	D
WINNECOOK	C	WOO, OVERWASH	C	WRIGHT	C	YAQUINA	D	YOUGA	B
WINNEMUCCA	B	WOO, WET	C	WRIGHTMAN	C	YAQUINA, DRAINED	C	YOUGA, SANDY SUBSTRATUM	D
WINNESHIEK	B	WOOD RIVER	D	WRIGHTSBORO	C	YARCO	D		
WINNETT	D	WOODBECK	B	WRIGHTSVILLE	D	YARDLEY	C	YOUJAY	D
WINNSBORO	D	WOODBINE	B	WRIGHTWOOD	B	YARTS	B	YOUMAN	C
WINOM	D	WOODBRIDGE	C	WUKOKI	B	YATAHONEY	C	YOUNGSTON	B
WINONA	D	WOODBURN	C	WUKSI	A	YATAHONEY, STONY	D	YOUNGSTON, WET	C
WINOOSKI	B	WOODBURY	D	WULFERT	D	YATES	D	YOURAME	B
WINOPEE	B	WOODCOCK	B	WUNJEY	B	YAUCO	C	YOUTLKUE	D
WINRIDGE	D	WOODFORD	D	WUPATKI	D	YAUHANNAH	B	YOVIMPA	D
WINSHIP	C	WOODGULCH	A	WURNO	C	YAUPON	D	YPSI	C
WINSPECT	B	WOODHALL	C	WURSTEN	B	YAWDIM	D	YRIBARREN	D
WINSTON	B	WOODHURST	C	WURTSBORO	C	YAWHEE	B	YSIDORA	C
WINT	D	WOODIN	C	WYALUSING	D	YAWKEY	B	YTURBIDE	A
WINTERFIELD	A/D	WOODINGTON	B/D	WYANDOTTE	D	YAXON	B	YTURRIA	A
WINTERHAVEN	B	WOODINVILLE	D	WYANT	C	YEAGER	A	YUBA	D
WINTERIDGE	B	WOODINVILLE, DRAINED	C	WYARD	B	YFARY	C	YUKO	D
WINTERS	C			WYARNO	B	YEATES HOLLOW	B	YUKON	D
WINTERSBURG	C	WOODLAWN	B	WYATT	C	YEATES HOLLOW, LOAMY SUBSTRATUM, STONY	C	YULEE	D
WINTERSET	C	WOODLEAF	C	WYCOLO	C			YUNES	D
WINTHROP	A	WOODLY	B	WYE	B			YUNQUE	C
WINTLEY	D	WOODLYN	D	WYEAST	D	YEATES HOLLOW, LOAMY SUBSTRATUM	C	YURM	D
WINTON	C	WOODMANSIE	B	WYETH	B			YUTRUE	D
WINTONER	B	WOODMERE	B	WYEVILLE	C	YEATES HOLLOW, STONY	C	YUVAS	D
WINU	C	WOODMONT	C	WYICK	D			ZAAR	D
WINZ	D	WOODPASS	B	WYKEHAM	B	YEATES HOLLOW, NONSTONY	C	ZABA	B
WIOTA	B	WOODROCK	C	WYKOFF	B			ZACA	D
WIPPLE	C	WOODROW	B	WYMAN	B	YEATES HOLLOW, DRY	C	ZACHARIAS	B
WIRT	B	WOODROW, SALINE-ALKALI	C	WYMORE	D	YEATES HOLLOW, COBBLY	C	ZACHARY	C
WISCON	D			WYNDMERE	B			ZACK	D
WISE	C	WOODROW, OCCASIONALLY FLOODED	C	WYNN	B	YEATON	C	ZADOG	A/D
WISEMAN	A			WYNNVILLE	C	YECROSS	A	ZADVAR	D
WISFLAT	D			WYNONA	C	YEDLICK	B	ZAFRA	B

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

[redacted]

304

739 RSC 2/13/96 SSS 20feb96 12/26 22feb96

Table 5 .—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2a).					

[1] Average runoff condition.
[2] The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition.
[3] CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4] Composite CN's for natural desert landscaping should be computed based on the impervious area (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

USDA-SCS, 1986 a

[redacted]

305

TABLE 6

INITIAL STRIPPING DRAINAGE AREAS

			Sheet Flow			Shallow Concentrated Flow			Open Channel Flow					
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	Total Length (ft)	Manning's n	Depth (ft)	Channel Slope (%)	Right Slope	Left Slope
E	29.0	90	100	0.02	fallow	240	0.02	unpaved	2,570	0.05	4.5	0.5	3:1	3:1
W	14.5	90	100	0.02	fallow	340	0.010	unpaved	2,120	0.05	4.5	0.5	3:1	3:1

TABLE 7

EARLY CONSTRUCTION DRAINAGE AREAS

			Sheet Flow			Shallow Concentrated Flow			Open Channel Flow					
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	Total Length (ft)	Manning's n	Depth (ft)	Channel Slope (%)	Right Slope	Left Slope
E	15.6	94	147	0.07	fallow	325	0.167	unpaved	2,150	0.05	4.5	0.5	3:1	3:1
W	20.6	94	147	0.07	fallow	325	0.167	unpaved	2,630	0.05	4.5	0.5	3:1	3:1

739

14/26

TABLE 8

HIGHWAY LOADS

POUNDS PER LINEAR FOOT

CIRCULAR PIPE

PIPE SIZE D IN INCHES	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET										PIPE SIZE D IN INCHES
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	
12	4849	2730	1524	954	574	361	316	237	168	46	12
15	5915	3322	1872	1163	700	441	358	289	205	56	15
18		3926	2196	1369	825	520	454	341	242	66	18
21		4498	2525	1580	950	599	522	392	279	77	21
24			2856	1788	1077	679	592	444	316	87	24
27			3096	1998	1201	757	660	496	353	97	27
30				2204	1328	837	731	548	390	107	30
33				2370	1452	915	798	599	426	117	33
36					1580	996	869	652	463	127	36
42					1679	1154	1007	755	537	147	42
48						1221	1146	859	611	168	48
54							1185	962	684	188	54
60								998	758	208	60
66									832	228	66
72									857	249	72
78										269	78
84										275	84

HORIZONTAL ELLIPTICAL PIPE

PIPE SIZE R × S IN INCHES	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET										PIPE SIZE R × S IN INCHES
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	
14×23	5915	4498	2716	1699	1022	644	561	422	300	82	14×23
19×30			3096	2177	1309	825	719	451	384	105	19×30
22×34				2370	1471	927	808	607	432	118	22×34
24×38					1631	1028	896	674	479	131	24×38
27×42					1679	1119	975	733	521	143	27×42
29×45						1221	1064	800	569	156	29×45
32×49							1152	866	616	169	32×49
34×53							1185	933	663	182	34×53
38×60								998	748	205	38×60
43×68									842	231	43×68
48×76									857	257	48×76
53×83										275	53×83

ARCH PIPE

PIPE SIZE R × S IN INCHES	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET										PIPE SIZE R × S IN INCHES
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	
11×18	5915	3840	2144	1342	807	509	443	333	237	65	11×18
13½×22		4498	2573	1610	968	520	532	400	284	78	13½×22
15½×26			3000	1879	1130	712	621	467	332	91	15½×26
18×28½			3096	2058	1238	780	680	511	363	100	18×28½
22½×36¼				2370	1533	966	842	633	450	124	22½×36¼
26 5/16×43¾					1679	1170	1019	766	545	150	26 5/16×43¾
31⅝×51⅛						1221	1185	981	633	174	31⅝×51⅛
36×58½								998	721	198	36×58½
40×65									800	220	40×65
45×73									857	246	45×73
54×88										275	54×88

Unsurfaced Roadway; 16,000-Pound Wheel Load; Dual Tires; 80 p.s.i. Tire Pressure; Impact Included. Last number in each column **(bold type)** *indicates maximum load for any given fill height. Interpolate for intermediate fill heights.*

[redacted]

[redacted]

739

TABLE 9

42" BACKFILL LOADS ON CIRCULAR PIPE IN TRENCH INSTALLATION 42"

*100 POUNDS PER CUBIC FOOT BACKFILL MATERIAL — LOADS IN POUNDS PER LINEAR FOOT

A — SAND AND GRAVEL Kμ'—0.165

Height of Backfill H above Top of Pipe, Feet	Trench Width at Top of Pipe: 6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	8'-6"	9'-0"	9'-6"	10'-0"	11'-0"	▲Transition Width
5	2622	**2671**									6'- 1"
6	3066	**3361**									6'- 6"
7	3485	3829	**4114**								6'-11"
8	3883	4273	4665	**4932**							7'- 4"
9	4259	4695	5134	**5582**							7'- 6"
10	4615	5097	5581	6067	**6227**						7'- 8"
11	4951	5478	6008	6540	**6869**						7'-10"
12	5270	5841	6415	6992	**7510**						7'-11"
13	5572	6185	6803	7425	8049	**8150**					8'- 1"
14	5858	6513	7174	7839	8508	**8789**					8'- 2"
15	6128	6824	7527	8235	8948	**9434**					8'- 4"
16	6384	7120	7864	8614	9370	**10070**					8'- 6"
17	6626	7401	8186	8977	9775	10580	**10710**				8'- 7"
18	6855	7669	8492	9324	10160	11010	**11350**				8'- 8"
19	7072	7923	8785	9657	10540	11420	**11980**				8'-10"
20	7277	8164	9064	9975	10890	11820	**12630**				8'-11"
21	7472	8394	9331	10280	11240	12200	13180	**13270**			9'- 1"
22	7656	8612	9585	10570	11570	12570	13590	**13900**			9'- 2"
23	7830	8820	9827	10850	11880	12930	13980	**14550**			9'- 3"
24	7994	9017	10060	11120	12190	13270	14360	**15190**			9'- 4"
25	8150	9204	10280	11370	12480	13600	14730	**15830**			9'- 6"
26	8298	9382	10490	11620	12760	13920	15080	16260	**16470**		9'- 7"
27	8438	9552	10690	11850	13030	14220	15420	16640	**17090**		9'- 8"
28	8570	9713	10880	12070	13280	14510	15750	17010	**17740**		9'- 9"
29	8695	9866	11060	12290	13530	14790	16070	17360	**18380**		9'-11"
30	8814	10010	11240	12490	13770	15060	16370	17700	**19000**		10'- 0"
31	8926	10150	11400	12690	13990	15320	16670	18030	19410	**19670**	10'- 1"
32	9032	10280	11560	12880	14210	15570	16950	18350	19760	**20280**	10'- 2"
33	9132	10400	11710	13060	14420	15810	17230	18660	20100	**20920**	10'- 3"
34	9227	10520	11860	13230	14620	16040	17490	18950	20440	**21540**	10'- 4"
35	9317	10640	12000	13390	14820	16270	17740	19240	20760	**22190**	10'- 5"
36	9402	10740	12130	13550	15000	16480	17990	19520	21060	**22830**	10'- 7"
37	9483	10850	12250	13700	15180	16690	18220	19780	21360	**23500**	10'- 8"
38	9559	10940	12370	13840	15350	16890	18450	20040	21660	**24110**	10'- 9"
39	9631	11040	12490	13980	15510	17080	18670	20290	21940	**24760**	10'-10"
40	9700	11120	12600	14110	15670	17260	18880	20530	22210	**25400**	10'-11"

B — SATURATED TOP SOIL Kμ'—0.150

Trench Width at Top of Pipe: 6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	8'-6"	9'-0"	9'-6"	10'-0"	11'-0"	▲Transition Width	Height of Backfill H above Top of Pipe, Feet
2671										6'- 0"	5
3110	**3361**									6'- 5"	6
3543	3888	**4114**								6'-10"	7
3956	4348	4740	**4932**							7'- 3"	8
4348	4787	5227	**5582**							7'- 5"	9
4721	5206	5693	6181	**6227**						7'- 7"	10
5076	5606	6139	6674	**6869**						7'- 8"	11
5414	5989	6567	7147	**7510**						7'-10"	12
5735	6354	6976	7602	**8150**						7'-11"	13
6040	6702	7369	8039	**8789**						8'- 0"	14
6331	7035	7745	8459	9177	**9434**					8'- 2"	15
6608	7353	8105	8863	9625	**10070**					8'- 3"	16
6871	7657	8450	9250	10060	**10710**					8'- 5"	17
7121	7947	8781	9623	10470	**11350**					8'- 6"	18
7359	8223	9098	9981	10870	11770	**11980**				8'- 8"	19
7585	8488	9401	10320	11260	12190	**12630**				8'- 9"	20
7800	8740	9692	10660	11630	12610	**13270**				8'-10"	21
8005	8981	9971	10970	11980	13000	**13900**				8'-11"	22
8200	9211	10240	11280	12330	13390	14460	**14550**			9'- 1"	23
8385	9431	10490	11570	12660	13760	14870	**15190**			9'- 2"	24
8561	9641	10740	11850	12980	14120	15260	**15830**			9'- 3"	25
8729	9841	10970	12120	13290	14460	15650	**16470**			9'- 4"	26
8889	10030	11200	12380	13580	14800	16020	**17090**			9'- 5"	27
9040	10220	11410	12630	13870	15120	16380	**17740**			9'- 6"	28
9185	10390	11620	12870	14140	15430	16730	18040	**18380**		9'- 8"	29
9322	10560	11820	13100	14410	15730	17070	18420	**19000**		9'- 9"	30
9453	10720	12010	13320	14660	16020	17390	18780	**19670**		9'-10"	31
9577	10870	12190	13540	14910	16300	17710	19130	**20280**		9'-11"	32
9695	11010	12360	13740	15140	16570	18010	19470	**20920**		10'- 0"	33
9807	11150	12530	13940	15370	16830	18310	19800	21310	**21540**	10'- 1"	34
9914	11280	12690	14130	15590	17080	18590	20120	21670	**22190**	10'- 2"	35
10020	11410	12840	14310	15800	17320	18870	20430	22010	**22830**	10'- 3"	36
10110	11530	12990	14480	16010	17560	19130	20730	22350	**23500**	10'- 4"	37
10200	11640	13130	14650	16200	17780	19390	21020	22670	**24110**	10'- 5"	38
10290	11760	13260	14810	16390	18000	19640	21300	22990	**24760**	10'- 6"	39
10360	11860	13390	14960	16570	18210	19880	21580	23290	**25400**	10'- 7"	40

C — ORDINARY CLAY Kμ'—0.130

Height of Backfill H above Top of Pipe, Feet	Trench Width at Top of Pipe: 6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	8'-6"	9'-0"	9'-6"	10'-0"	11'-0"	▲Transition Width
5	**2671**										5'-11"
6	3170	**3361**									6'- 4"
7	3622	3968	**4114**								6'- 8"
8	4056	4450	4844	**4932**							7'- 1"
9	4471	4912	5355	**5582**							7'- 3"
10	4869	5357	5847	**6227**							7'- 5"
11	5249	5784	6321	**6869**							7'- 6"
12	5614	6194	6777	7362	**7510**						7'- 7"
13	5963	6589	7217	7848	**8150**						7'- 9"
14	6297	6967	7641	8318	**8789**						7'-10"
15	6617	7331	8050	8772	**9434**						7'-11"
16	6924	7681	8443	9210	**10070**						8'- 0"
17	7217	8017	8823	9633	10450	**10710**					8'- 2"
18	7498	8340	9188	10040	10900	**11350**					8'- 3"
19	7768	8650	9540	10440	11340	**11980**					8'- 4"
20	8025	8948	9880	10820	11760	**12630**					8'- 5"
21	8272	9234	10210	11190	12180	13170	**13270**				8'- 7"
22	8509	9509	10520	11540	12570	13610	**13900**				8'- 8"
23	8735	9774	10820	11890	12960	14040	**14550**				8'- 9"
24	8952	10030	11120	12220	13330	14450	**15190**				8'-10"
25	9159	10270	11400	12540	13690	14850	**15830**				8'-11"
26	9358	10510	11670	12850	14040	15240	**16470**				9'- 0"
27	9548	10730	11930	13150	14380	15620	16870	**17090**			9'- 1"
28	9731	10950	12180	13440	14710	15990	17280	**17740**			9'- 2"
29	9905	11160	12430	13720	15020	16340	17670	**18380**			9'- 3"
30	10070	11360	12660	13990	15330	16690	18060	**19000**			9'- 4"
31	10230	11550	12890	14250	15630	17020	18430	**19670**			9'- 5"
32	10380	11730	13100	14500	15910	17350	18790	**20280**			9'- 6"
33	10530	11910	13310	14740	16190	17660	19140	20640	**20920**		9'- 7"
34	10670	12080	13520	14980	16460	17970	19490	21020	**21540**		9'- 8"
35	10810	12240	13710	15200	16720	18260	19820	21390	**22190**		9'- 9"
36	10940	12400	13900	15420	16980	18550	20140	21750	**22830**		9'-10"
37	11060	12550	14080	15640	17220	18830	20460	22100	**23500**		9'-11"
38	11180	12700	14250	15840	17460	19100	20760	22440	**24110**		10'- 0"
39	11290	12840	14420	16040	17680	19360	21060	22770	24510	**24760**	10'- 1"
40	11400	12970	14580	16230	17910	19610	21340	23100	24870	**25400**	10'- 2"

D — SATURATED CLAY Kμ'—0.110

Trench Width at Top of Pipe: 6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	8'-6"	9'-0"	9'-6"	10'-0"	11'-0"	▲Transition Width	Height of Backfill H above Top of Pipe, Feet
2671										5'-10"	5
3231	**3361**									6'- 3"	6
3704	4051	**4114**								6'- 7"	7
4160	4555	**4932**								7'- 0"	8
4599	5042	5467	**5582**							7'- 1"	9
5022	5514	6006	**6227**							7'- 3"	10
5431	5969	6509	**6869**							7'- 4"	11
5624	6410	6997	**7510**							7'- 5"	12
6204	6836	7470	**8150**							7'- 6"	13
6570	7247	7928	8611	**8789**						7'- 7"	14
6922	7645	8372	9101	**9434**						7'- 9"	15
7262	8030	8802	9577	**10070**						7'-10"	16
7590	8402	9218	10040	**10710**						7'-11"	17
7906	8761	9622	10490	**11350**						8'- 0"	18
8210	9109	10010	10920	11840	**11980**					8'- 1"	19
8504	9445	10390	11350	12310	**12630**					8'- 2"	20
8787	9770	10760	11760	12760	**13270**					8'- 3"	21
9059	10080	11120	12160	13200	**13900**					8'- 4"	22
9322	10390	11460	12540	13640	**14550**					8'- 5"	23
9576	10680	11800	12920	14060	**15190**					8'- 6"	24
9820	10960	12120	13290	14460	15640	**15830**				8'- 7"	25
10060	11240	12440	13640	14860	16080	**16470**				8'- 8"	26
10280	11500	12740	13990	15240	16510	**17090**				8'- 9"	27
10500	11760	13030	14320	15620	16930	**17740**				8'-10"	28
10710	12010	13320	14650	15990	17340	**18380**				8'-10"	29
10920	12250	13600	14960	16340	17730	**19000**				9'- 0"	30
11110	12480	13860	15270	16690	18120	**19670**				9'- 0"	31
11300	12700	14120	15570	17020	18500	19980	**20280**			9'- 1"	32
11480	12920	14380	15860	17350	18860	20380	**20920**			9'- 2"	33
11660	13130	14620	16140	17670	19220	20780	**21540**			9'- 3"	34
11830	13330	14860	16410	17980	19570	21170	**22190**			9'- 4"	35
11990	13530	15090	16670	18280	19910	21550	**22830**			9'- 5"	36
12150	13720	15310	16930	18570	20240	21920	**23500**			9'- 6"	37
12300	13900	15520	17180	18860	20560	22280	**24110**			9'- 6"	38
12450	14070	15730	17420	19140	20870	22630	24400	**24760**		9'- 7"	39
12590	14240	15940	17660	19410	21180	22970	24780	**25400**		9'- 8"	40

* *For backfill weighing 110 pounds per cubic foot, increase loads 10%; for 120 pounds per cubic foot, increase 20%; etc.*

▲*Transition loads (bold type) and widths based on Kμ=0.19, r_{sd}p=0.5 in the embankment equation.*

000308

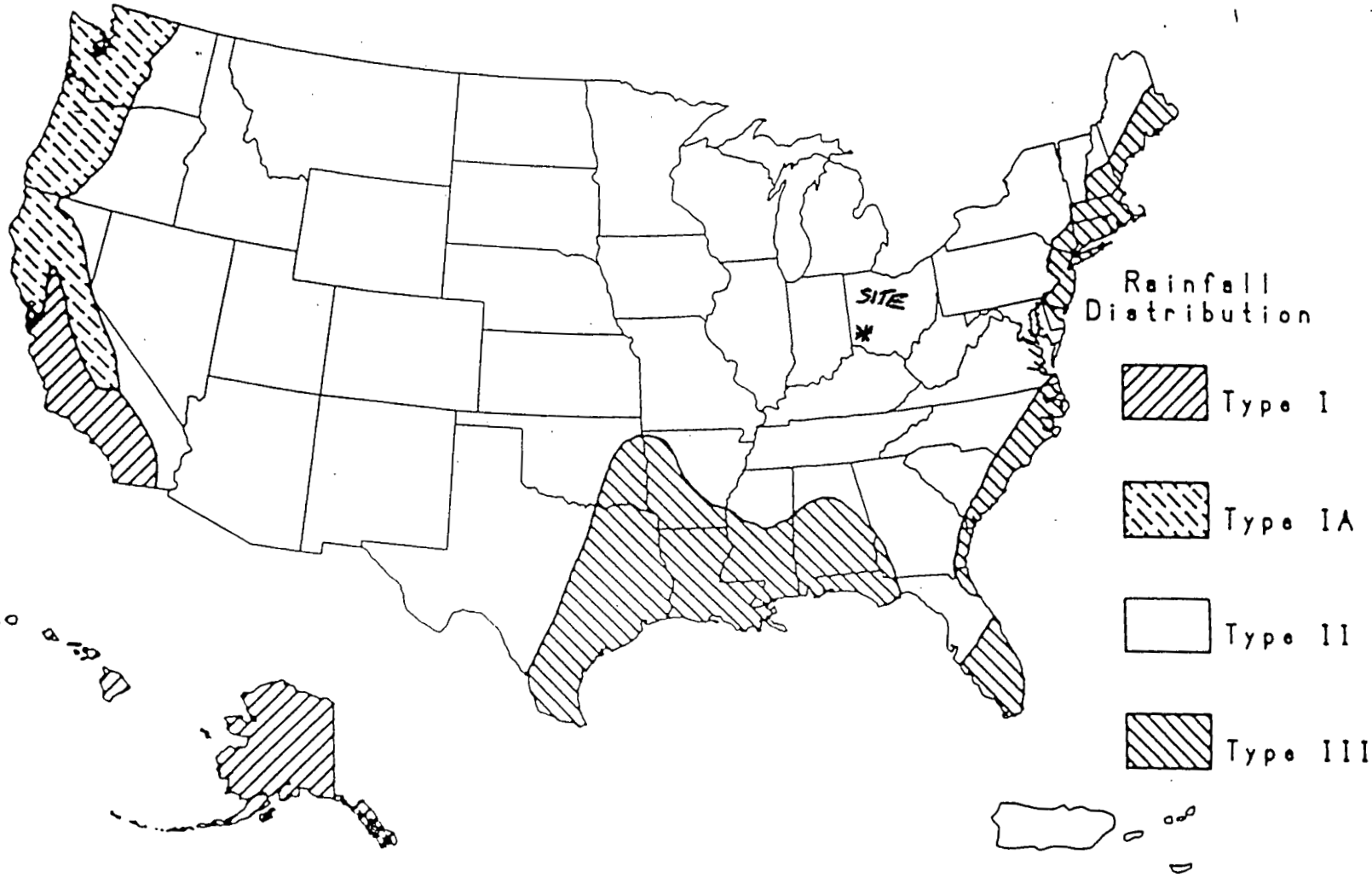


Figure 1 —Approximate geographic boundaries for SCS rainfall distributions.

239

309

739 2/13/96
17/26
20feb96
22feb96

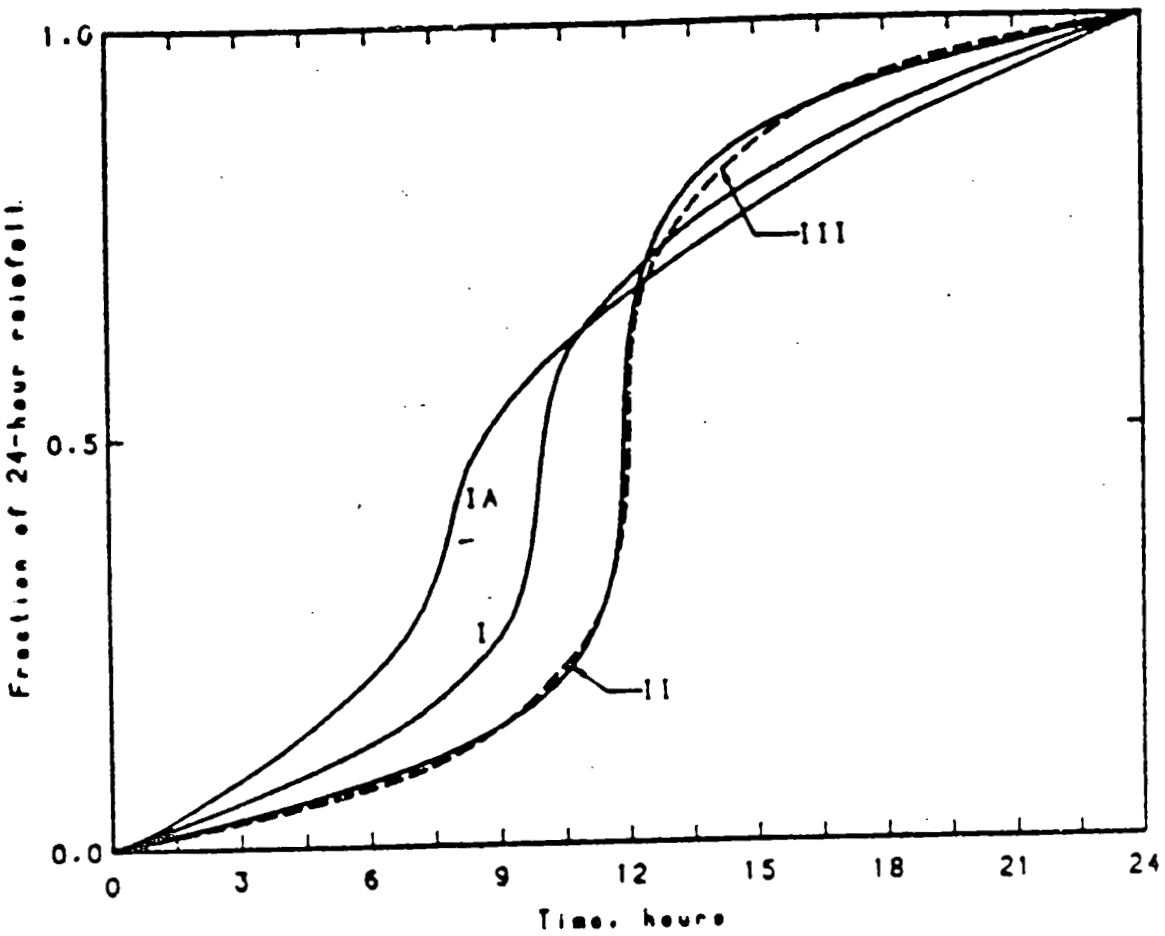


Figure 2 .—SCS 24-hour rainfall distributions.

[redacted] 310

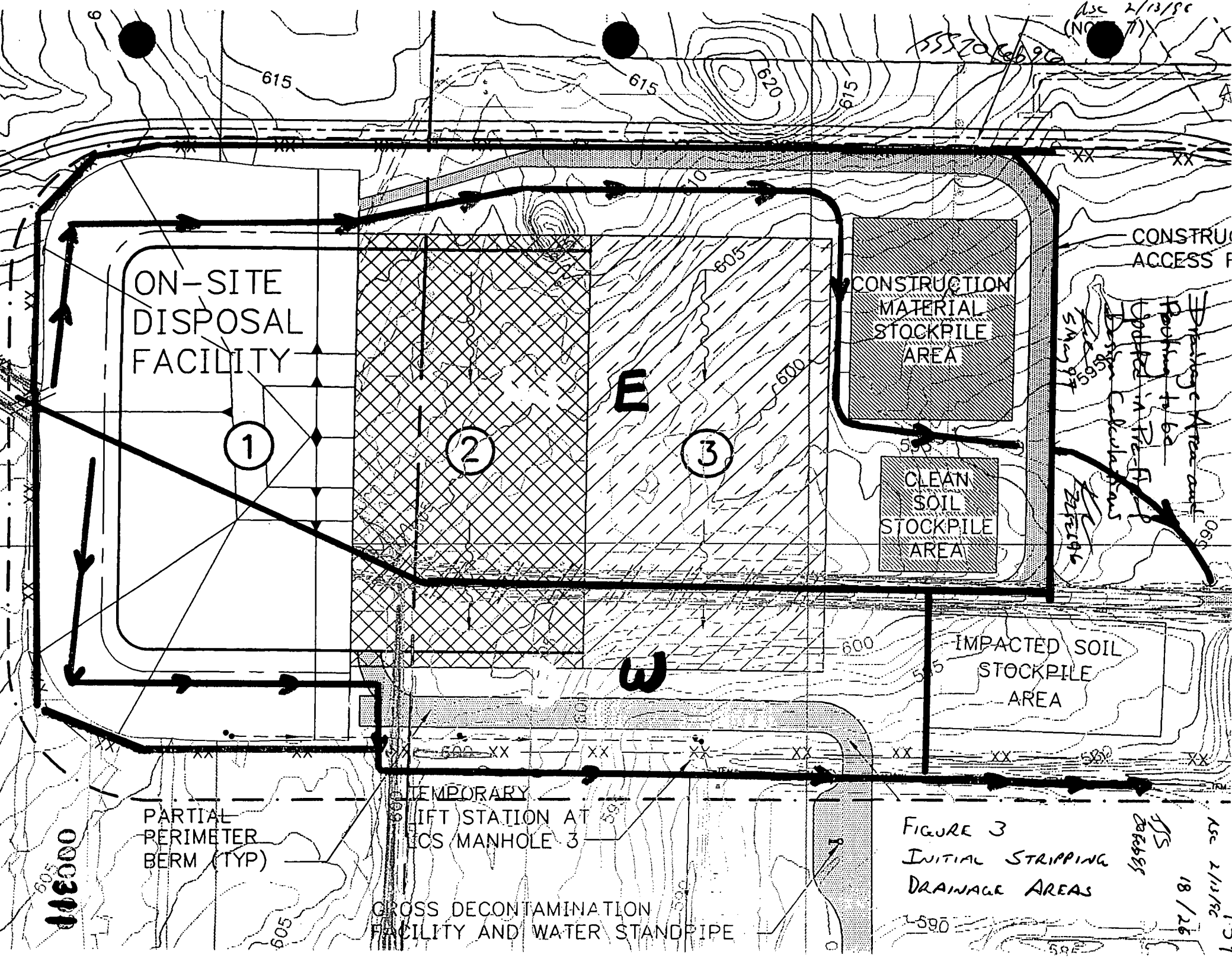


FIGURE 3
INITIAL STRIPPING
DRAINAGE AREAS

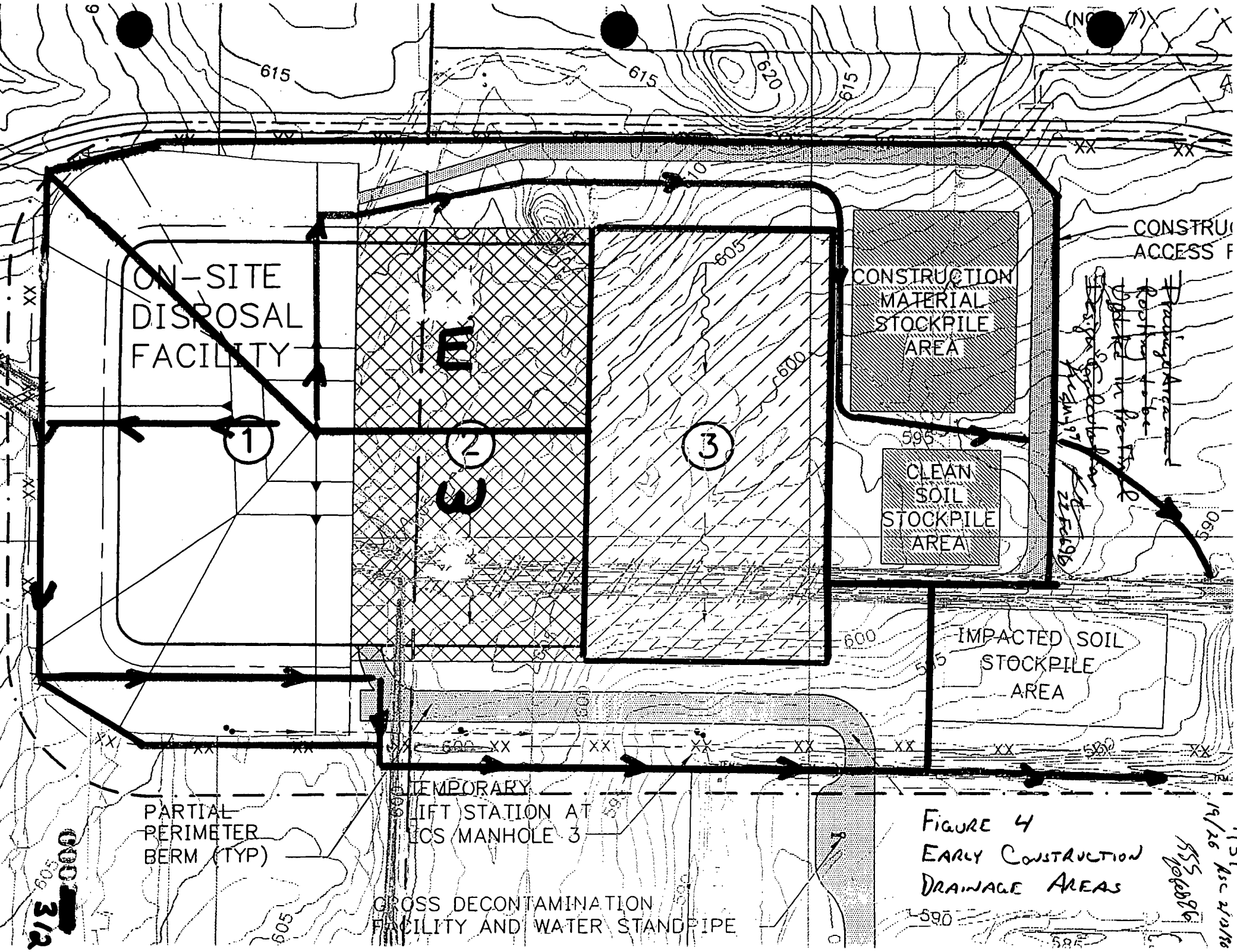


FIGURE 4
EARLY CONSTRUCTION
DRAINAGE AREAS

GEOSYNTEC CONSULTANTS

Written by: RSL Date: 96 / Feb / 13 (YY MM DD) Reviewed by: [illegible] Date: 20 / Feb / 96 (YY MM DD)

Client: Exxon Project: OSDF Project/Proposal No.: GL 3900 Task No.:

[illegible] 21 Feb 96

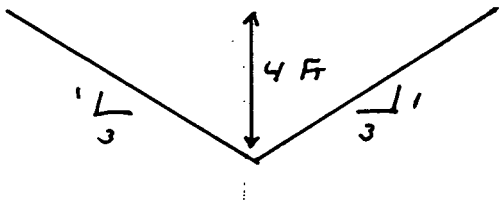


FIGURE 5. DITCH CROSS SECTION

[redacted]

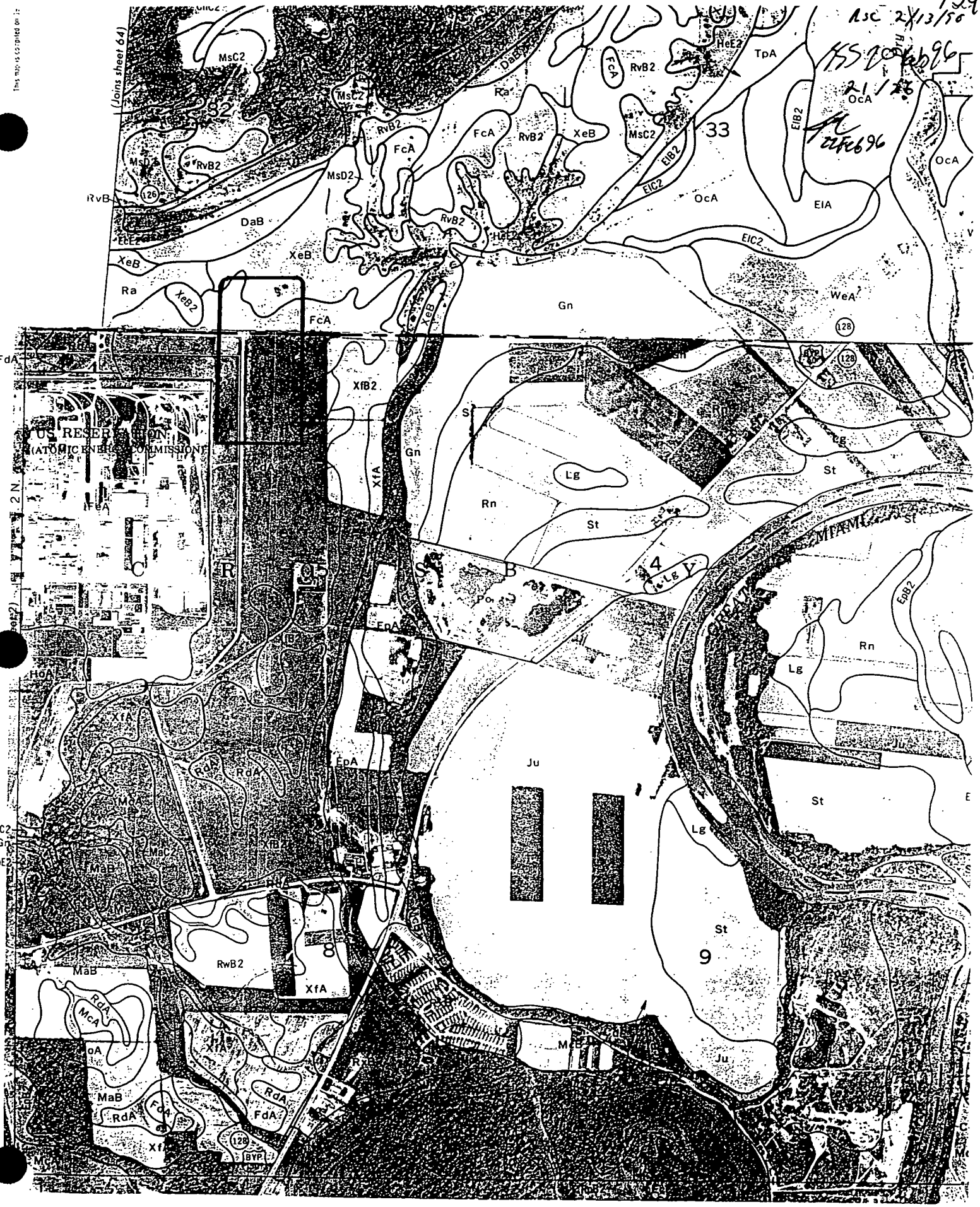


FIGURE 6. HYDROLOGIC SOILS GROUPS

USDA-SCS, 1992

[redacted]

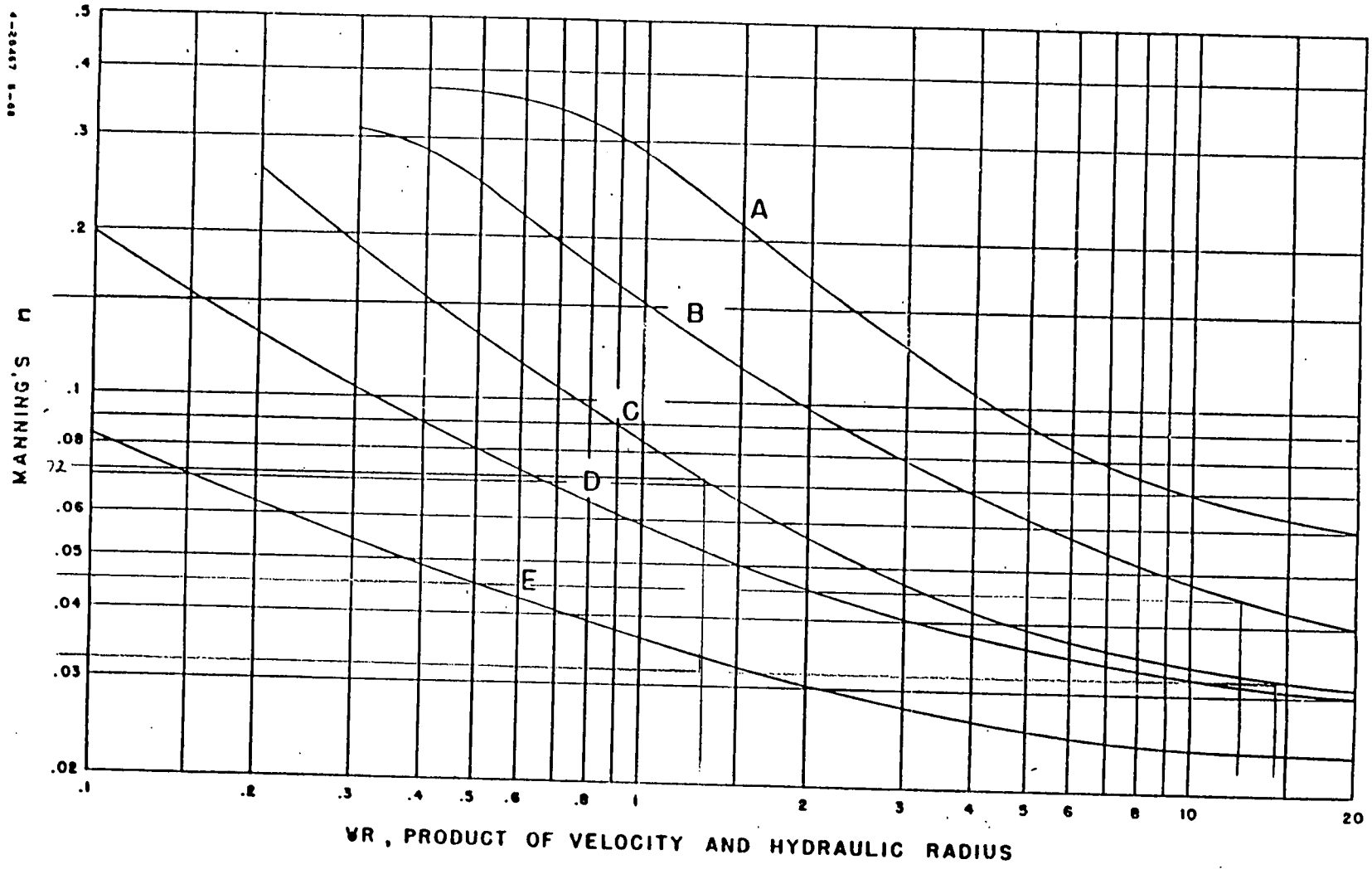


FIGURE 7. Manning's "n" related to velocity, hydraulic radius, and vegetal retardance.

239 LSC 2/13/96
22/26
NSS 20Feb96
FL 22Feb96
315

739

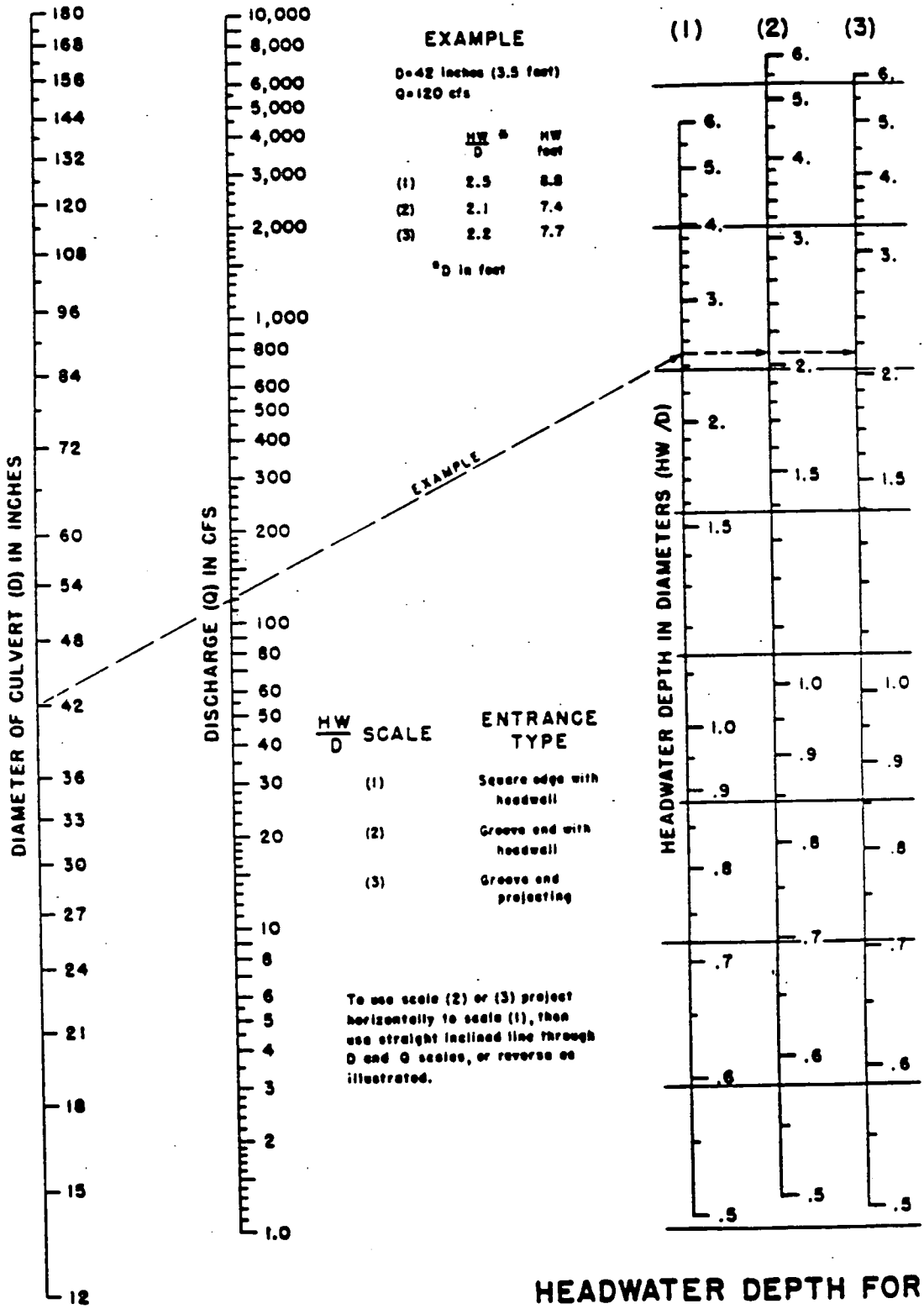
RSC 2/13/96

23/26

RSS 20feb96

22feb96

CHART 1



HEADWATER SCALES 2&3
REVISED MAY 1964

BUREAU OF PUBLIC ROADS JAN. 1963

HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

FIGURE 8.

FROM FHWA, 1982

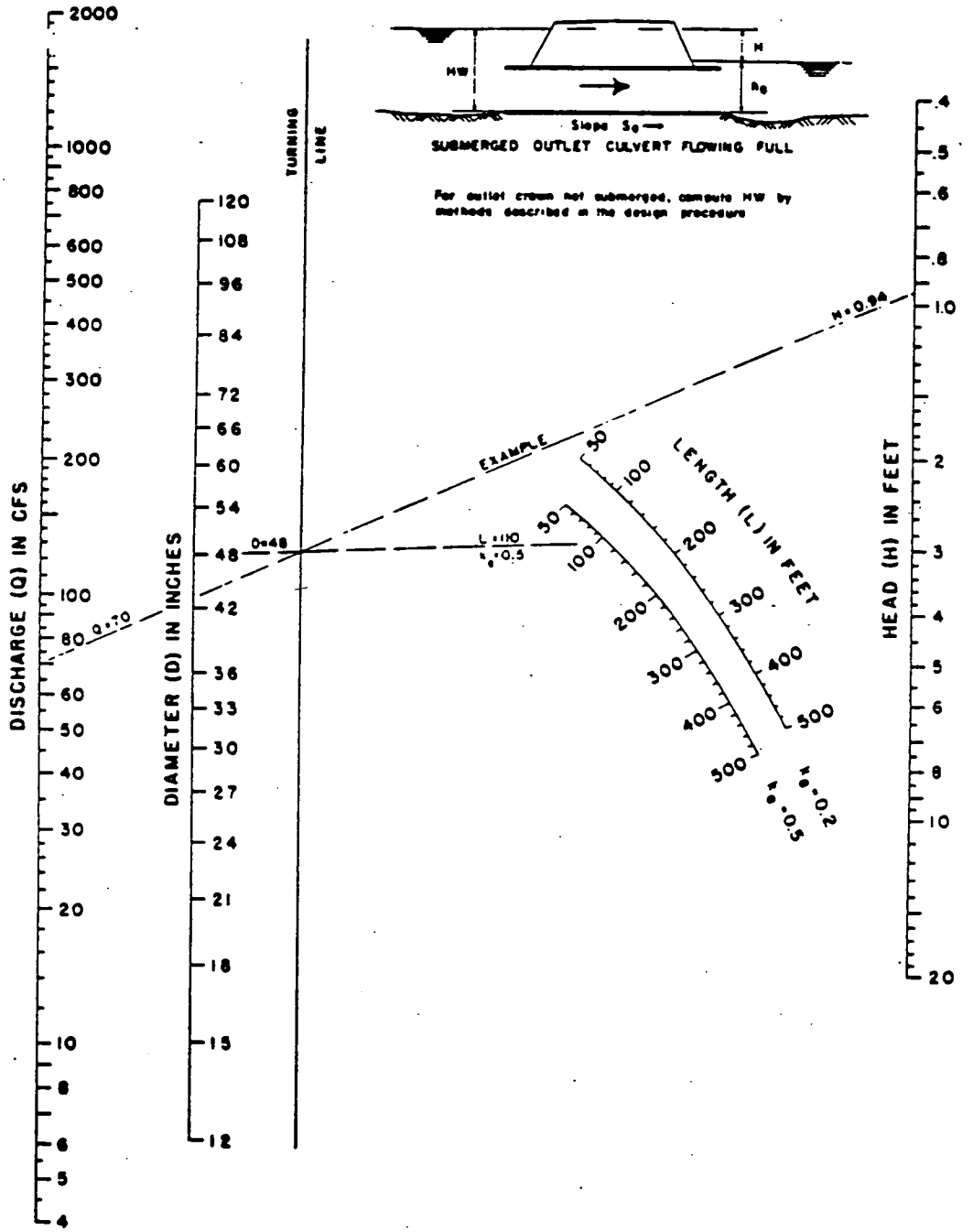
[redacted]

316

739 Asc 2/13/96

RSS 20Feb96 24/20

CHART 5 TK 22Feb96



HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

FIGURE 9.

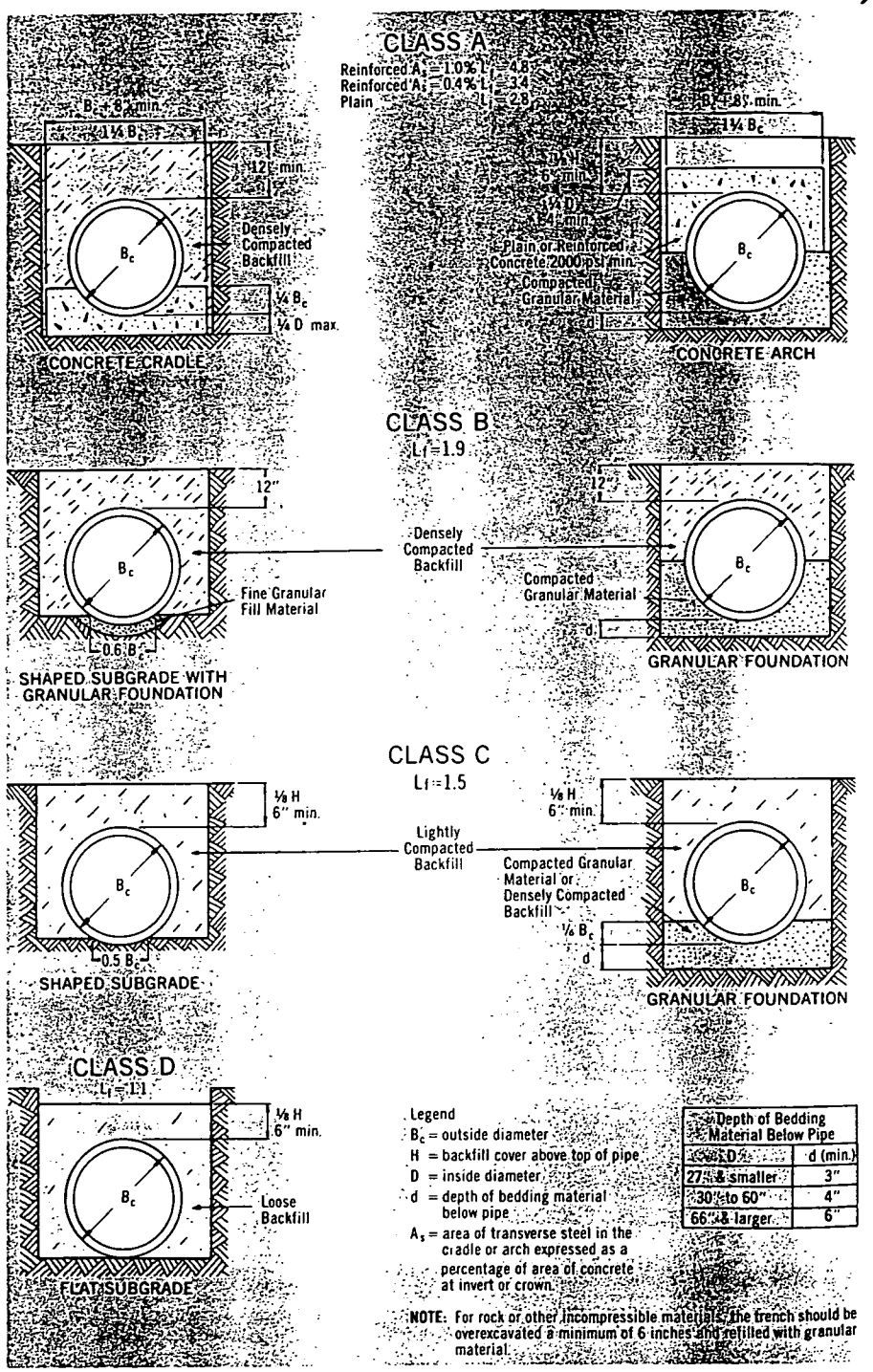
From FHWA, 1982

[redacted]

739 RSC 2/13/96
25/26
20Feb96
22Feb96

FIGURE 10

TRENCH BEDDINGS
CIRCULAR PIPE



[redacted]

318

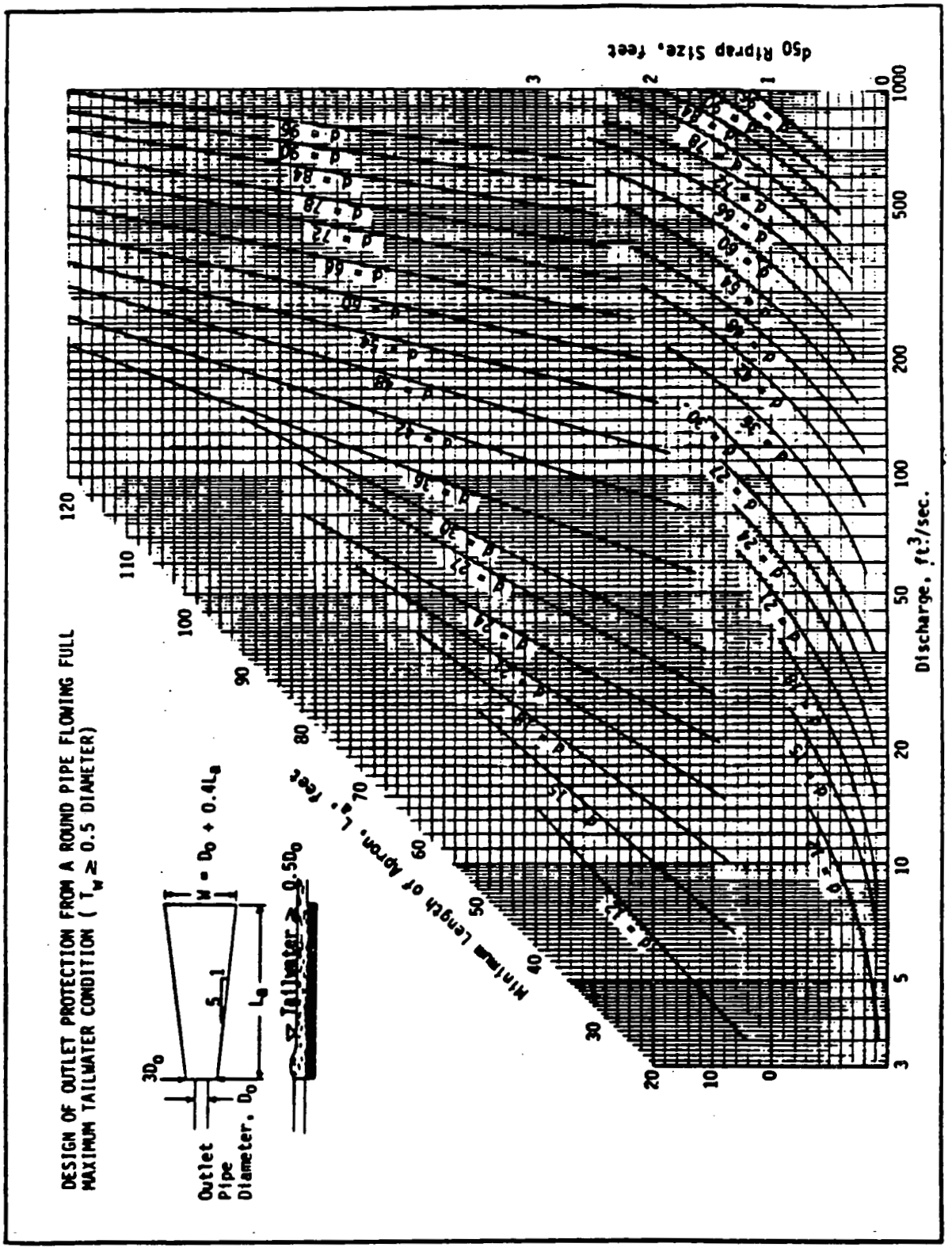


Figure 41

319

GeoSyntec Consultants

Written by: LSC Date: 21/Feb/95 Reviewed by: [illegible] Date: 21/Feb/95

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

SURFACE-WATER MANAGEMENT DURING OSDF CONSTRUCTION/FILLING/CLOSURE

STORMWATER RUNON/RUNOFF AND DRAINAGE CONTROL STRUCTURES

EARLY CONSTRUCTION STAGE

CALCULATIONS

Purpose

The purpose of this document is to provide the engineering calculations used in the design of the surface-water management system during the early construction stages.

Scope

The calculation procedures used in this document are presented in the calculations procedures document. The data used in the calculations is presented in the data verification document.

For clarity, these calculations are divided into 2 sections: (i) after initial stripping; and (ii) during early construction. In general, each set of calculations consists of: (i) a summary of the input data; (ii) a summary of the calculation results; and (iii) the calculations (i.e., worksheets, computer runs).

Initial Stripping

Summary of Input Data

A summary of the HydroCAD™ input data is presented in Table 1.

Summary of Calculation Results

A summary of the calculation results is presented in Table 2. Drainage Area maps, worksheets for calculations, weighted runoff curve numbers, and HydroCAD™ runs for runoff and drainage channel routing are attached.

[redacted]

Table 1. Initial Stripping Drainage Areas

			Sheet Flow			Shallow Concentrated Flow			Open Channel Flow					
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	Total Length (ft)	Manning's n	Depth (ft)	Channel Slope (%)	Right Slope	Left Slope
E	29.0	90	100	0.02	fallow	240	0.02	unpaved	2,570	0.05	4.5	0.5	3:1	3:1
W	14.5	90	100	0.02	fallow	340	0.010	unpaved	2,120	0.05	4.5	0.5	3:1	3:1

ASC 2/2/96

21 Feb 96

239
2/44

Table 2. Summary of HydroCAD™ Results - Initial Stripping

	Point of Interest Along Channel	Peak Flow Quantity (CFS)	Peak Flow Depth (Ft)	Peak Flow Velocity (FPS)
East Drainage Area	First Culvert Entrance	121.4	3.6	3.0
East Drainage Area	Second Culvert Entrance	121.0	3.6	3.0
West Drainage Area	Culvert Entrance	62.5	2.8	2.6

Early Construction

Summary of Input Data

A summary of the HydroCAD™ input data is presented in Table 3.

Summary of Calculation Results

A summary of the calculation results is presented in Table 4 and a summary of culvert results is presented in Table 5. Drainage area maps, worksheets for calculation weighted runoff curve members, and HydroCAD™ runs for runoff and drainage channel routing are attached.

Table 3. Initial Stripping Drainage Areas

			Sheet Flow			Shallow Concentrated Flow			Open Channel Flow					
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	Total Length (ft)	Manning's n	Depth (ft)	Channel Slope (%)	Right Slope	Left Slope
E	15.6	94	147	0.07	fallow	325	0.167	unpaved	2,150	0.05	4.5	0.5	3:1	3:1
W	20.6	97	147	0.07	fallow	325	0.167	unpaved	2,630	0.05	4.5	0.5	3:1	3:1

Table 4. Summary of HydroCAD™ Results - Early Construction

	Point of Interest Along Channel	Peak Flow Quantity (CFS)	Peak Flow Depth (Ft)	Peak Flow Velocity (FPS)
East Drainage Area	First Culvert Entrance	78.7	3.0	2.7
East Drainage Area	Second Culvert Entrance	78.6	3.0	2.7
West Drainage Area	Culvert Entrance	103.0	3.4	2.9

Table 5. Summary of Culvert Design Results

Culvert Diameter = two 42 in.

Culvert Pipe Strength = 1,128 lb./ft. per foot of inside diameter, with at least 3.0 ft. of soil cover

Maximum Headwater = 4.4 ft.

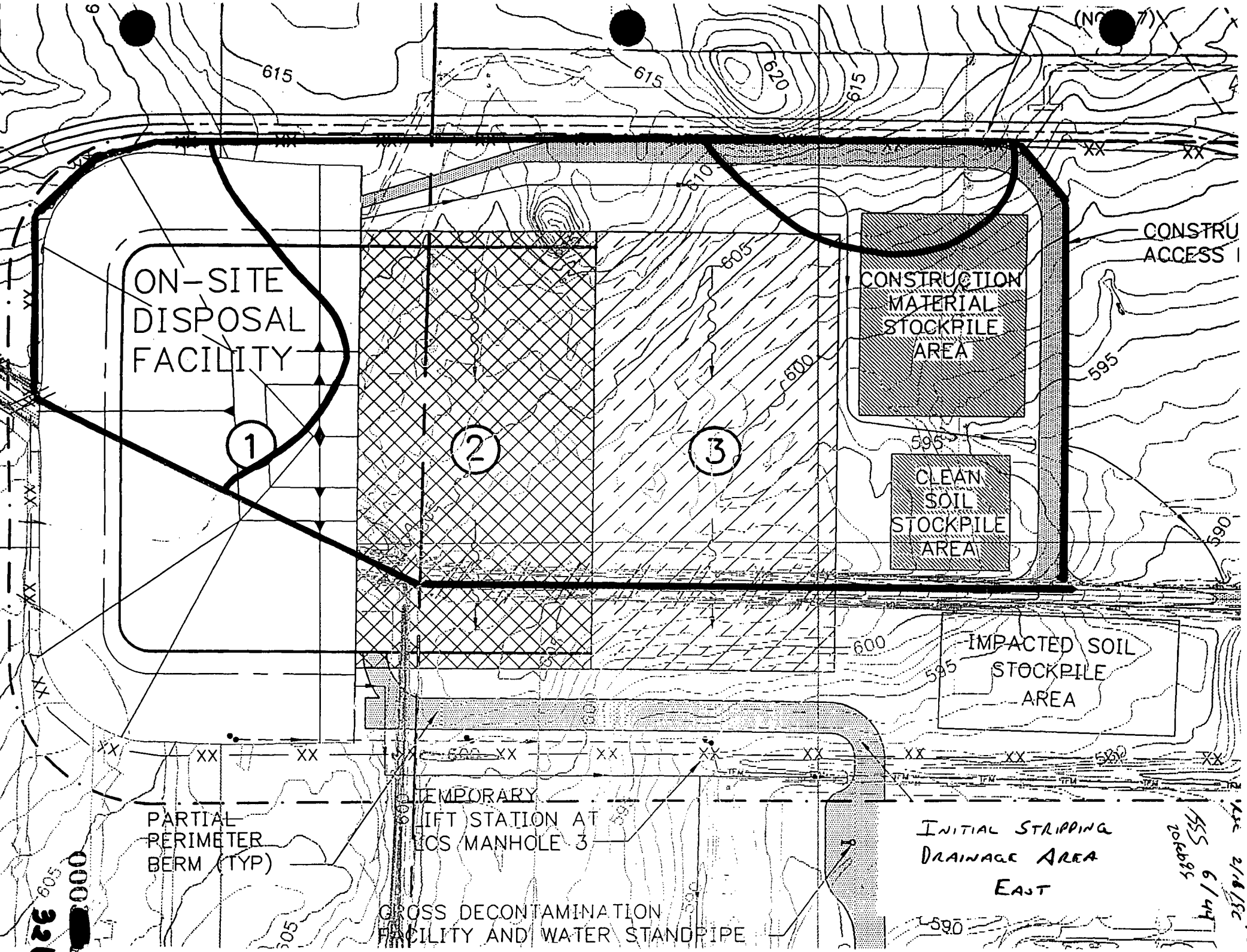
Riprap Size: D_{MAX} = 3.75 in.
D_{50} = 2.5 in.
D_{15} = 1.25 to 1.9 in.

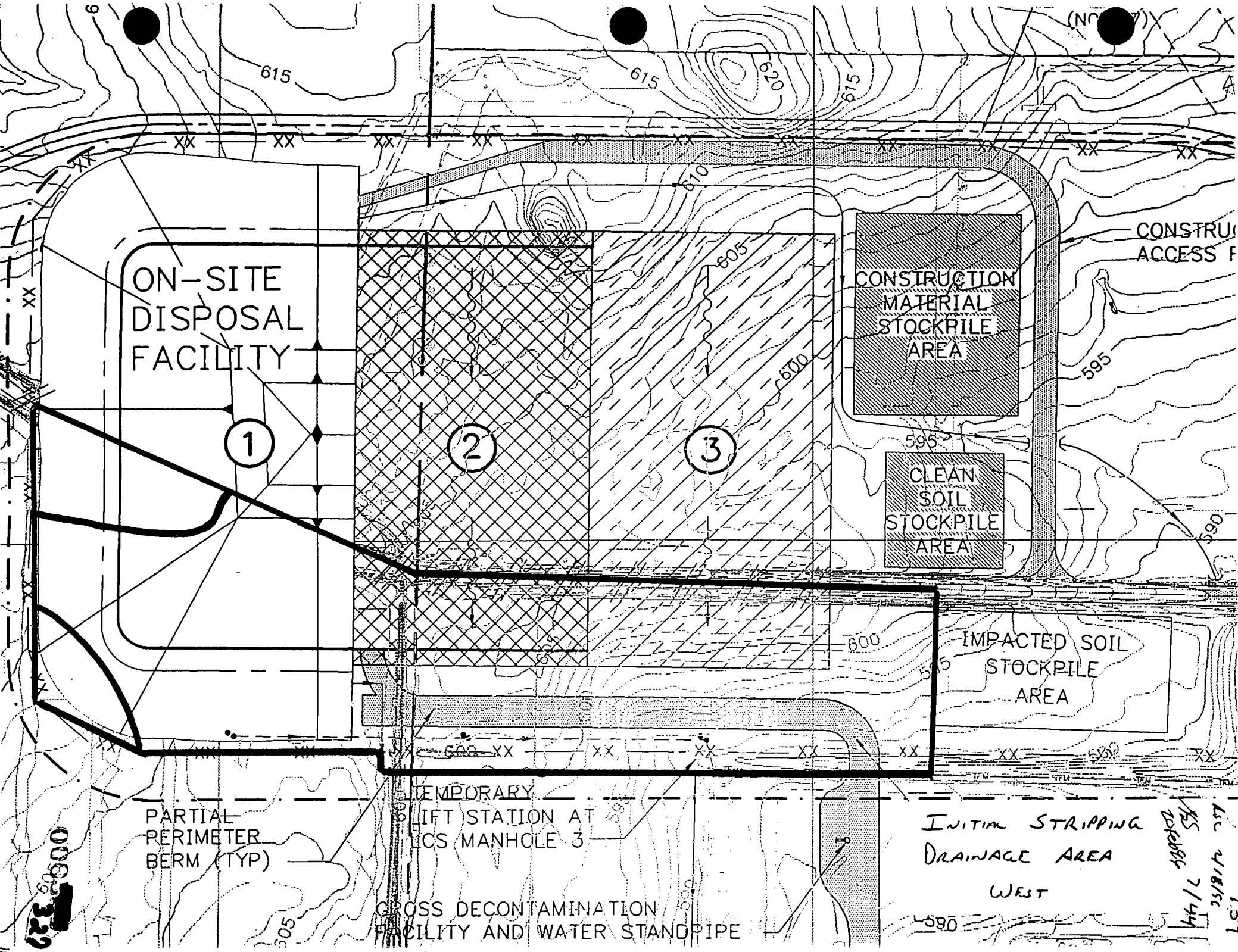
Riprap Thickness 6 in. (minimum)

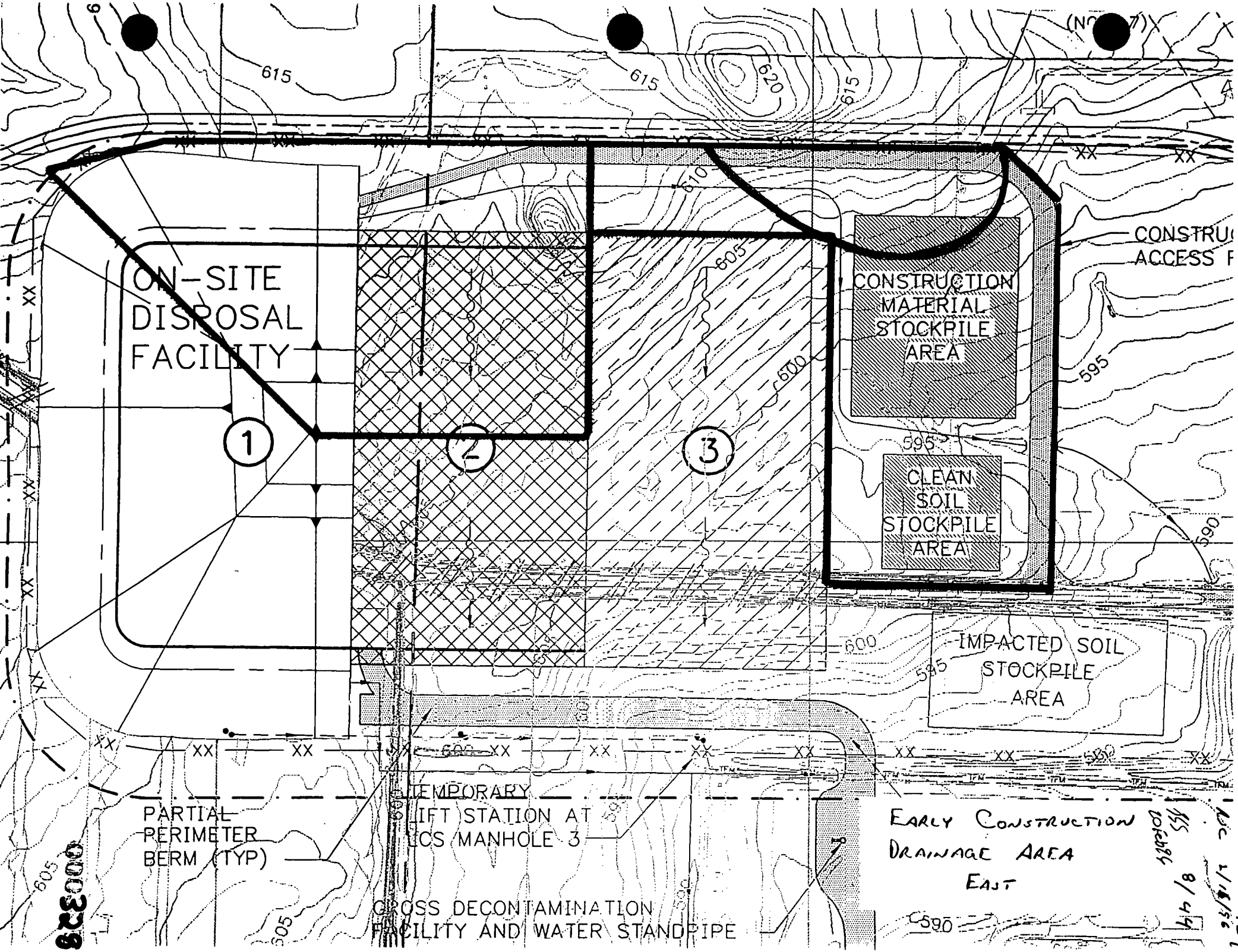
Length of Riprap Apron 15 ft.

Width of Riprap Apron 14 ft. at culvert, 20.0 at end of apron

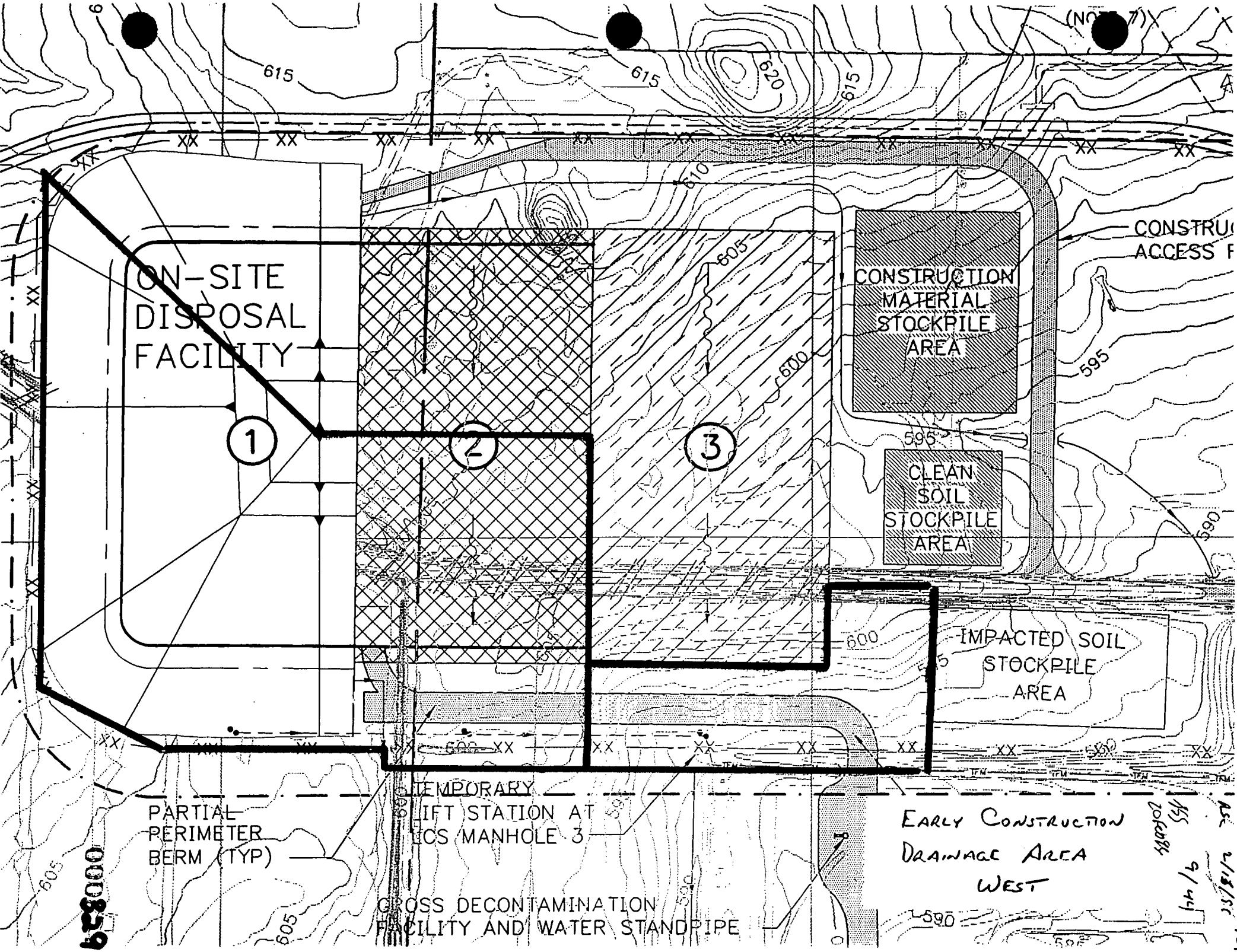
DRAINAGE AREA MAPS


ON-SITE DISPOSAL FACILITY
1
2
3
CONSTRUCTION MATERIAL STOCKPILE AREA
CLEAN SOIL STOCKPILE AREA
IMPACTED SOIL STOCKPILE AREA
CONSTRU
ACCESS
PARTIAL PERIMETER BERM (TYP)
TEMPORARY LIFT STATION AT CS MANHOLE 3
GROSS DECONTAMINATION FACILITY AND WATER STANDPIPE
INITIAL STRIPPING DRAINAGE AREA EAST
615
620
610
605
600
595
590


ON-SITE DISPOSAL FACILITY
1
2
3
CONSTRUCTION MATERIAL STOCKPILE AREA
CLEAN SOIL STOCKPILE AREA
IMPACTED SOIL STOCKPILE AREA
CONSTRU
ACCESS R
PARTIAL PERIMETER BERM (TYP)
TEMPORARY LIFT STATION AT ICS MANHOLE 3
CROSS DECONTAMINATION FACILITY AND WATER STANDPIPE
INITIAL STRIPPING DRAINAGE AREA WEST
615
620
610
605
600
595
590


ON-SITE DISPOSAL FACILITY
1
2
3
CONSTRUCTION MATERIAL STOCKPILE AREA
CLEAN SOIL STOCKPILE AREA
IMPACTED SOIL STOCKPILE AREA
CONSTRU
ACCESS R
PARTIAL PERIMETER BERM (TYP)
TEMPORARY LIFT STATION AT ICS MANHOLE 3
CROSS DECONTAMINATION FACILITY AND WATER STANDPIPE
EARLY CONSTRUCTION DRAINAGE AREA EAST
615
620
610
605
600
595
590

000328


ON-SITE DISPOSAL FACILITY
1
2
3
CONSTRUCTION MATERIAL STOCKPILE AREA
CLEAN SOIL STOCKPILE AREA
IMPACTED SOIL STOCKPILE AREA
CONSTRU
ACCESS R
PARTIAL PERIMETER BERM (TYP)
TEMPORARY LIFT STATION AT LCS MANHOLE 3
GROSS DECONTAMINATION FACILITY AND WATER STANDPIPE
EARLY CONSTRUCTION DRAINAGE AREA WEST
615
620
610
605
600
595
590

WORKSHEETS FOR

WEIGHTED RUNOFF CURVE NUMBERS

Worksheet 2: Runoff curve number and runoff

Project FERMCO - OSDF By RSC Date 16 Feb 96

Location INITIAL STRIPPING (E) Checked [illegible] Date 20 Feb 96

Circle one: Present Developed

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
RUSSELL - MIAMIAN B	BARE GROUND	86			1.8	154.8
FINCASTLE C	" "	91			21.6	1965.6
XENIA B	" "	86			5.6	481.6
					Totals = 29.0	2602.0

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{2602.0}{29.0} = 89.7$; Use CN = 90

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr			
Rainfall, P (24-hour)	in			
Runoff, Q	in			

(Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)

[redacted]

Worksheet 2: Runoff curve number and runoff

Project FERMCO - OSDF By RSC Date 16 FEB 96

Location INITIAL STRIPPING (W) Checked [illegible] Date 20Feb96

Circle one: Present (Developed)

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒acres ☐mi² ☐%	Product of CN x area
FINCASTLE C	BARE GROUND	91			13.0	1183.0
XENIA B	" "	86			1.5	129.0
					Totals =	14.5 / 1312.0

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{1312.0}{14.5} = 90.5$; Use CN = 90

~~2. Runoff~~

	Storm #1	~~Storm #2~~	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in			

~~(Use P~~ and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)

[redacted]

Worksheet 2: Runoff curve number and runoff

Project FERMCO - OSDF By RSC Date 16 FEB 96

Location EARLY CONSTRUCTION (E) Checked BS Date 20 Feb 96

Circle one: Present (Developed)

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒acres ☐mi² ☐%	Product of CN x area
COVER	BARE GROUND	98			8.2	803.6
RUSSELL-MIAMIAN B	" "	86			1.8	154.8
FINCASTLE C	" "	91			5.6	509.6
					Totals = 15.6	1468.0

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{1468.0}{15.6} = 94.1$; Use CN = 94

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr			
Rainfall, P (24-hour)	in			
Runoff, Q (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)	in			

Worksheet 2: Runoff curve number and runoff

Project FERMCO OSDF By RSC Date 16 Feb 96

Location EARLY CONSTRUCTION (W) Checked HSS Date 20 Feb 96

Circle one: Present Developed

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
COVER	BARE GROUND	98			16.3	1597.4
FINCASTLE C	" "	91			4.3	391.3
					Totals =	20.6 / 1988.7

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{1988.7}{20.6} = 96.5$; Use CN = 97

~~2. Runoff~~

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 21 Feb 96

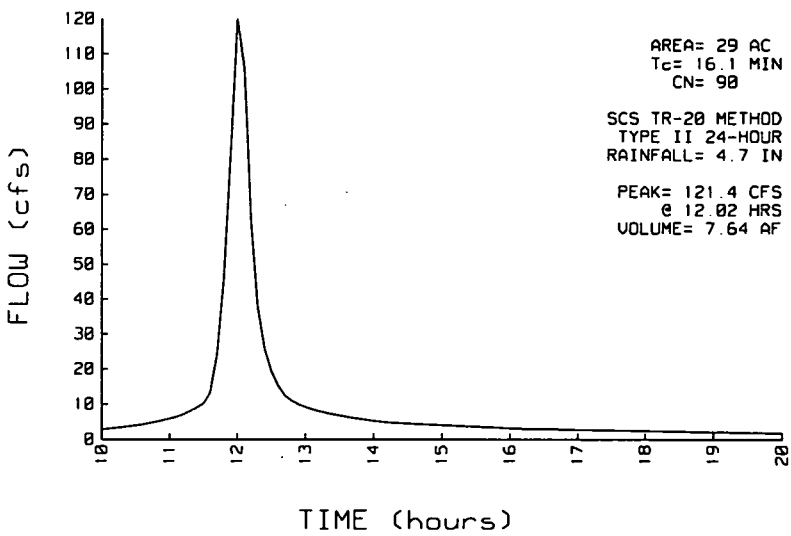
SUBCATCHMENT 1 **INITIAL STRIPPING - EAST**

ACRES	CN
29.00	90

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 121.4 CFS @ 12.02 HRS
VOLUME= 7.64 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	4.5
Fallow n=.05 L=100' P2=2.6 in s=.02 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	1.8
Unpaved Kv=16.1345 L=240' s=.02 '/' V=2.28 fps		
CHANNEL FLOW	**Segment ID:**	9.8
a=60.8 sq-ft Pw=28.5' r=2.133'		
s=.005 '/' n=.05 V=3.48 fps L=2050'	Capacity=211.7 cfs	
	Total Length= 2390 ft Total Tc=	16.1

SUBCATCHMENT 1 RUNOFF
INITIAL STRIPPING - EAST



[redacted]

P- 739 15/44

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

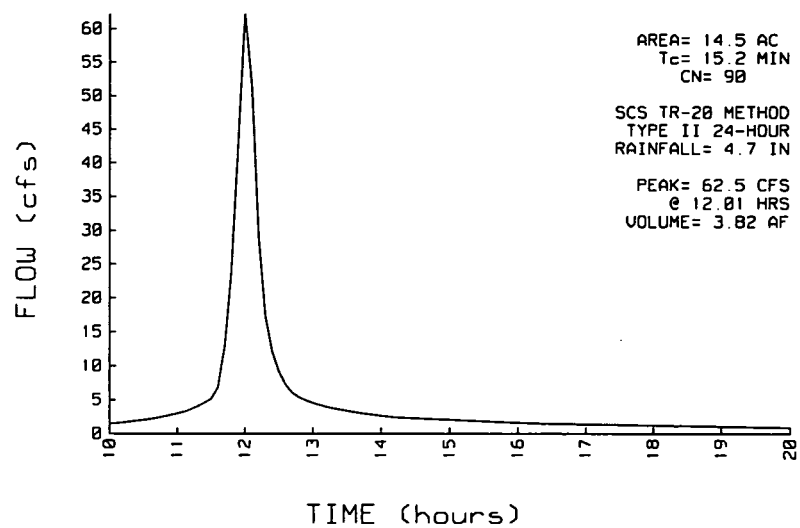
SUBCATCHMENT 2 **INITIAL STRIPPING AREA - WEST** SSS 21 Feb 96

ACRES	CN
14.50	90

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 62.5 CFS @ 12.01 HRS
VOLUME= 3.82 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	4.5
Fallow n=.05 L=100' P2=2.6 in s=.02 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	3.5
Unpaved Kv=16.1345 L=340' s=.01 '/' V=1.61 fps		
CHANNEL FLOW	**Segment ID:**	7.2
a=60.8 sq-ft Pw=28.5' r=2.133'		
s=.005 '/' n=.05 V=3.48 fps L=1500'	Capacity=211.7 cfs	
	Total Length= 1940 ft Total Tc=	15.2

SUBCATCHMENT 2 RUNOFF
INITIAL STRIPPING AREA - WEST



[redacted]

Data for **FERMCO, EARLY CONSTRUCTION DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

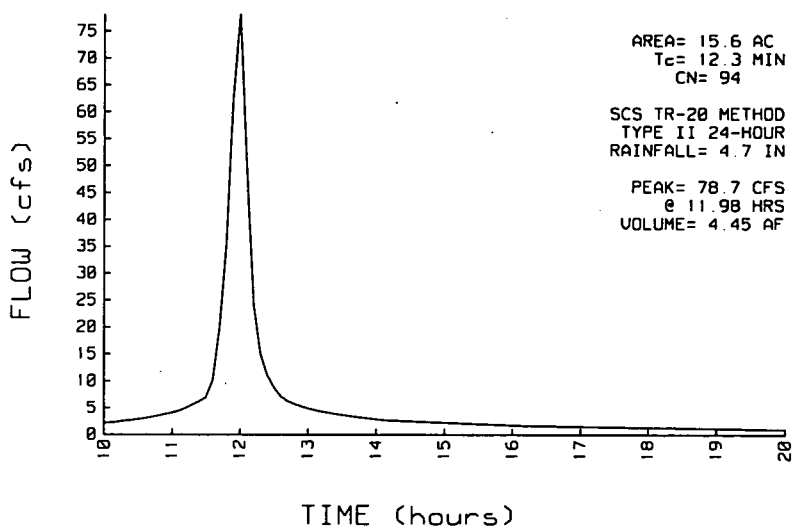
SUBCATCHMENT 1 **EARLY CONSTRUCTION - EAST**

ACRES	CN
15.60	94

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 78.7 CFS @ 11.98 HRS
VOLUME= 4.45 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	3.7
Fallow n=.05 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=325' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	7.8
a=60.8 sq-ft Pw=28.5' r=2.133'		
s=.005 '/' n=.05 V=3.48 fps L=1630'	Capacity=211.7 cfs	
	Total Length= 2102 ft Total Tc=	12.3

SUBCATCHMENT 1 RUNOFF
EARLY CONSTRUCTION - EAST



[redacted]

Data for **FERMCO, EARLY CONSTRUCTION DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

BSS 21 Feb 96

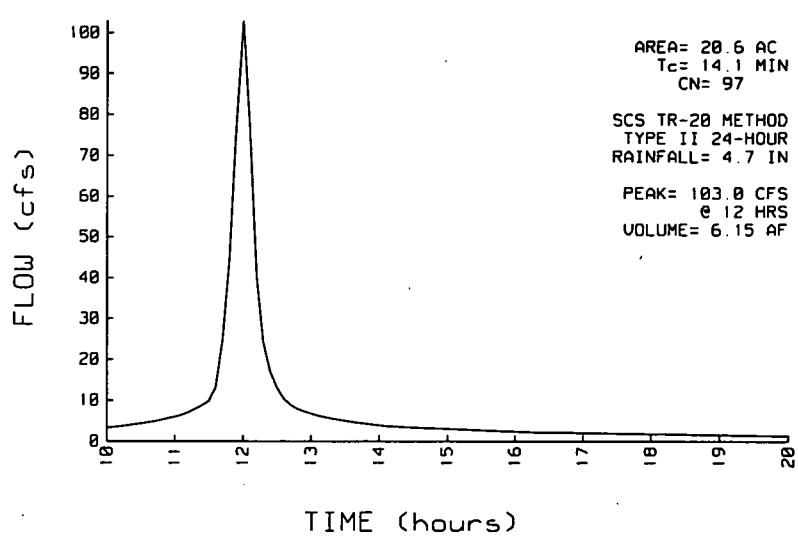
SUBCATCHMENT 2 **EARLY CONSTRUCTION AREA - WEST**

ACRES	CN
20.60	97

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 103.0 CFS @ 12.00 HRS
VOLUME= 6.15 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	3.7
Fallow n=.05 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=325' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	9.6
a=60.8 sq-ft Pw=28.5' r=2.133'		
s=.005 '/' n=.05 V=3.48 fps L=2010' Capacity=211.7 cfs		
	Total Length= 2482 ft Total Tc=	14.1

SUBCATCHMENT 2 RUNOFF
EARLY CONSTRUCTION AREA - WEST



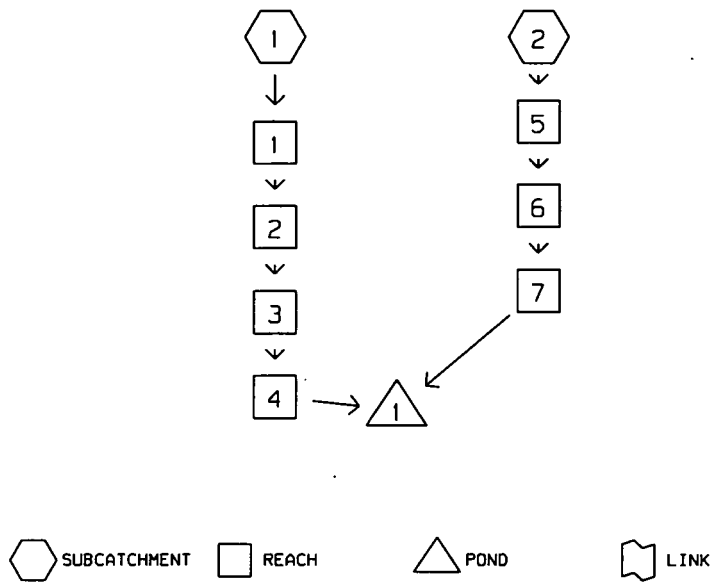
HYDROCAD™ RUNS

DRAINAGE CHANNEL ROUTING

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

WATERSHED ROUTING ==========

155
21 Feb 96



[redacted]

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 21 Feb 96

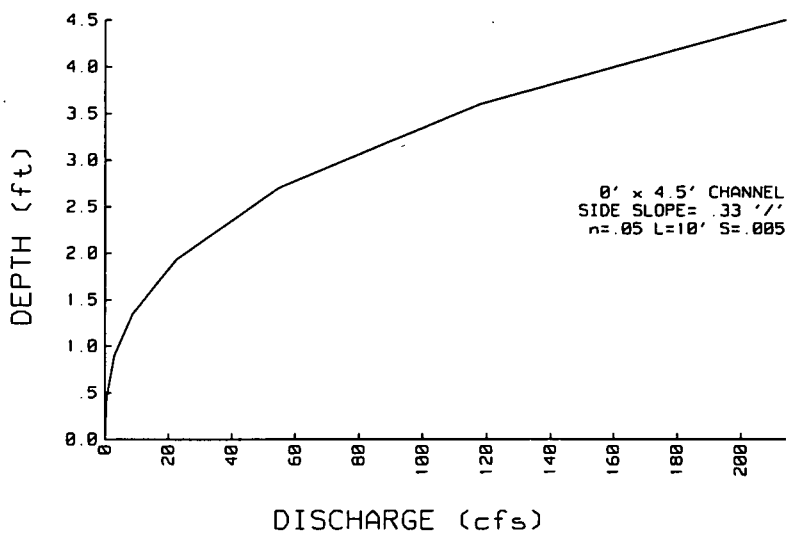
REACH 1 **EAST DITCH 1**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	.6	.5
.9	2.5	2.9
1.4	5.5	8.6
1.9	11.3	22.5
2.7	22.1	54.8
3.6	39.3	118.0
4.5	61.4	213.9

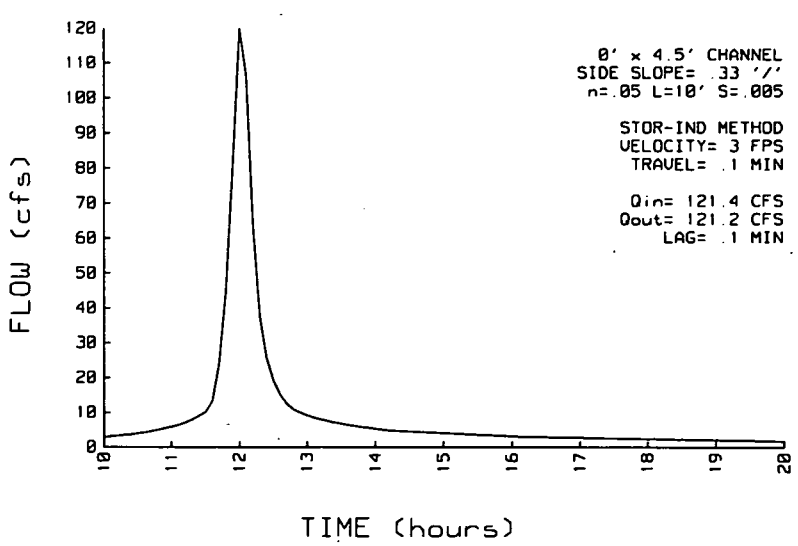
0' x 4.5' CHANNEL
SIDE SLOPE= .33 '/'
n= .05
LENGTH= 10 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 3.62 FT
PEAK VELOCITY= 3.0 FPS
TRAVEL TIME = .1 MIN
Qin = 121.4 CFS @ 12.02 HRS
Qout= 121.2 CFS @ 12.02 HRS
ATTEN= 0 % LAG= .1 MIN
IN/OUT= 7.64 / 7.64 AF

REACH 1 DISCHARGE
EAST DITCH 1



REACH 1 INFLOW & OUTFLOW
EAST DITCH 1



[redacted]

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

RSS 21 Feb 96

REACH 2 **EAST CULVERT 1**

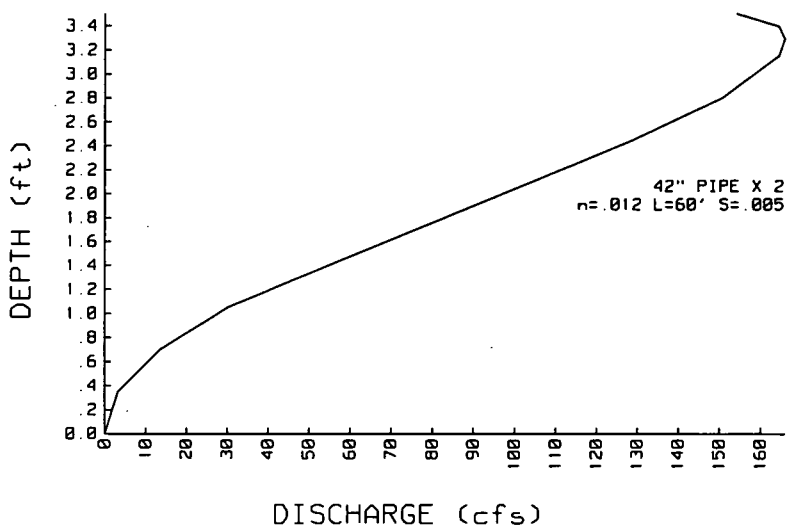
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	1.0	3.2
.7	2.7	13.5
1.1	4.9	30.2
2.5	14.4	129.1
2.8	16.5	150.7
3.2	18.2	164.3
3.3	18.8	165.8
3.4	19.1	164.3
3.5	19.2	154.1

42" PIPE X 2

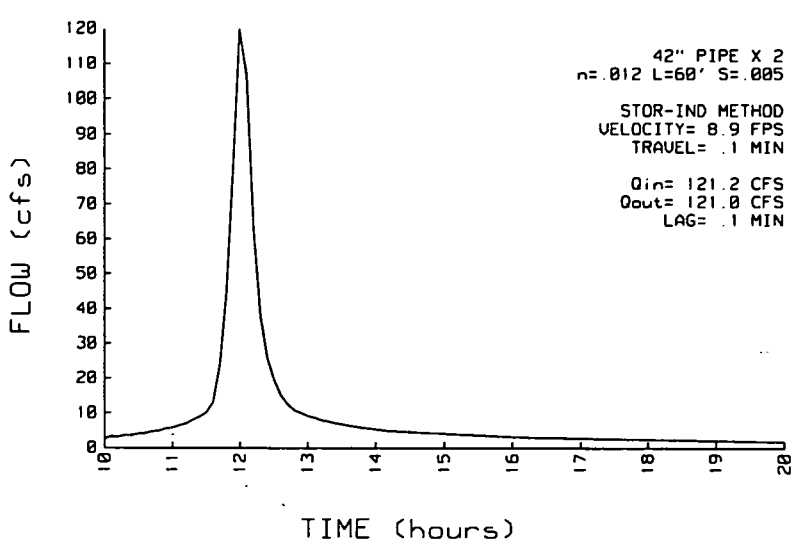
n= .012
LENGTH= 60 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.31 FT
PEAK VELOCITY= 8.9 FPS
TRAVEL TIME = .1 MIN
Qin = 121.2 CFS @ 12.02 HRS
Qout= 121.0 CFS @ 12.03 HRS
ATTEN= 0 % LAG= .1 MIN
IN/OUT= 7.64 / 7.64 AF

REACH 2 DISCHARGE
EAST CULVERT 1



REACH 2 INFLOW & OUTFLOW
EAST CULVERT 1



[redacted]

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

REACH 3 **EAST DITCH 2**

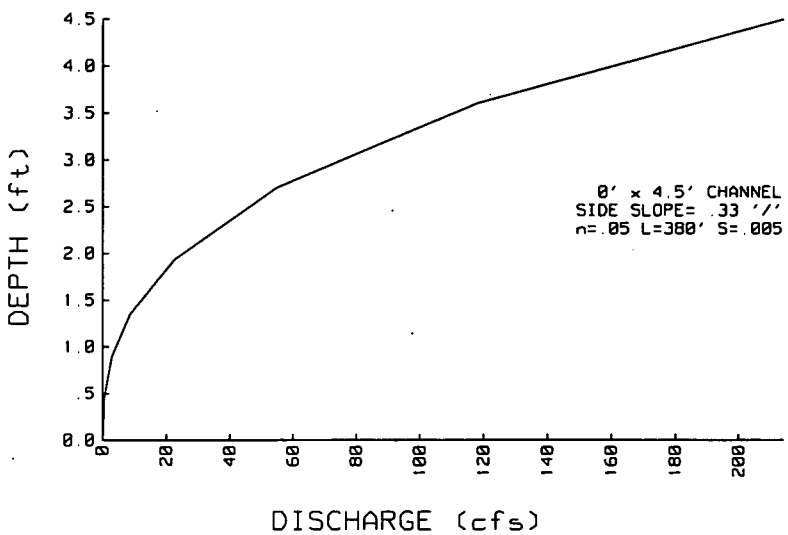
RSS 21Feb96

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	.6	.5
.9	2.5	2.9
1.4	5.5	8.6
1.9	11.3	22.5
2.7	22.1	54.8
3.6	39.3	118.0
4.5	61.4	213.9

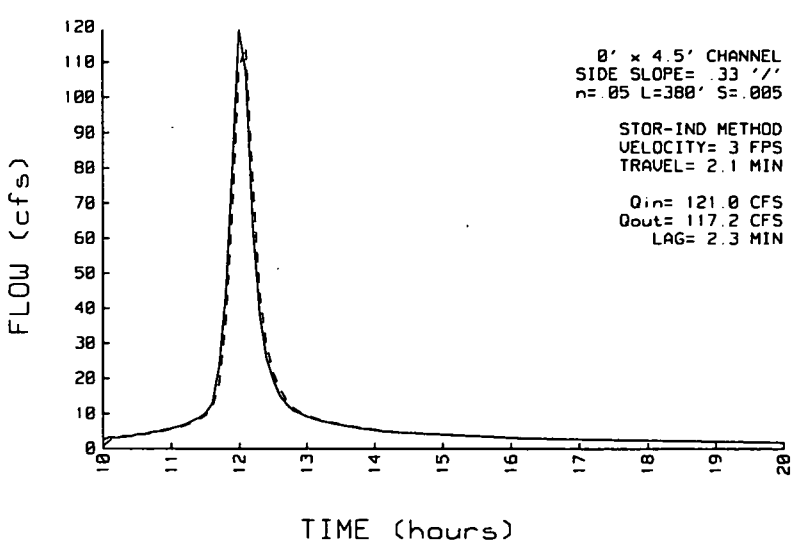
0' x 4.5' CHANNEL
SIDE SLOPE= .33 '/'
n= .05
LENGTH= 380 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 3.55 FT
PEAK VELOCITY= 3.0 FPS
TRAVEL TIME = 2.1 MIN
Qin = 121.0 CFS @ 12.03 HRS
Qout= 117.2 CFS @ 12.06 HRS
ATTEN= 3 % LAG= 2.3 MIN
IN/OUT= 7.64 / 7.62 AF

REACH 3 DISCHARGE
EAST DITCH 2



REACH 3 INFLOW & OUTFLOW
EAST DITCH 2



[redacted]

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 21Feb96

REACH 4 **EAST CULVERT 2**

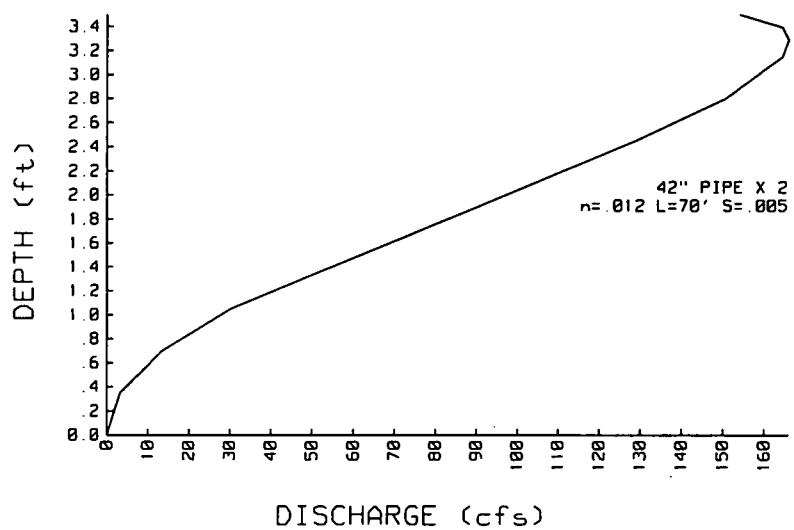
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	1.0	3.2
.7	2.7	13.5
1.1	4.9	30.2
2.5	14.4	129.1
2.8	16.5	150.7
3.2	18.2	164.3
3.3	18.8	165.8
3.4	19.1	164.3
3.5	19.2	154.1

42" PIPE X 2

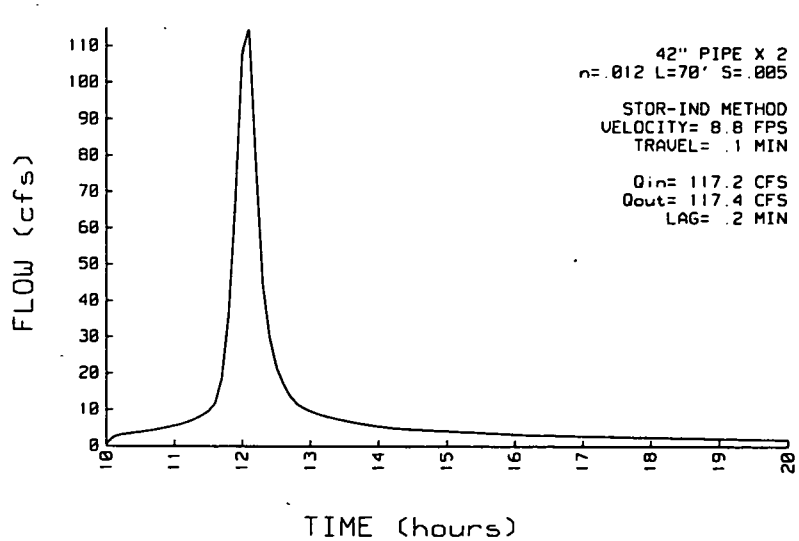
n= .012
LENGTH= 70 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.25 FT
PEAK VELOCITY= 8.8 FPS
TRAVEL TIME = .1 MIN
Qin = 117.2 CFS @ 12.06 HRS
Qout= 117.4 CFS @ 12.07 HRS
ATTEN= 0 % LAG= .2 MIN
IN/OUT= 7.62 / 7.62 AF

REACH 4 DISCHARGE
EAST CULVERT 2



REACH 4 INFLOW & OUTFLOW
EAST CULVERT 2



[redacted]

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

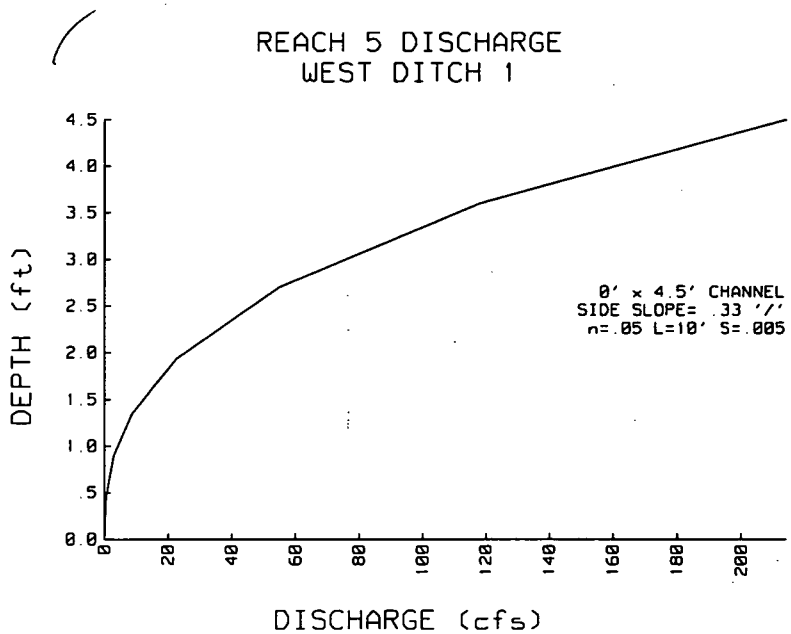
BSS 21Feb96

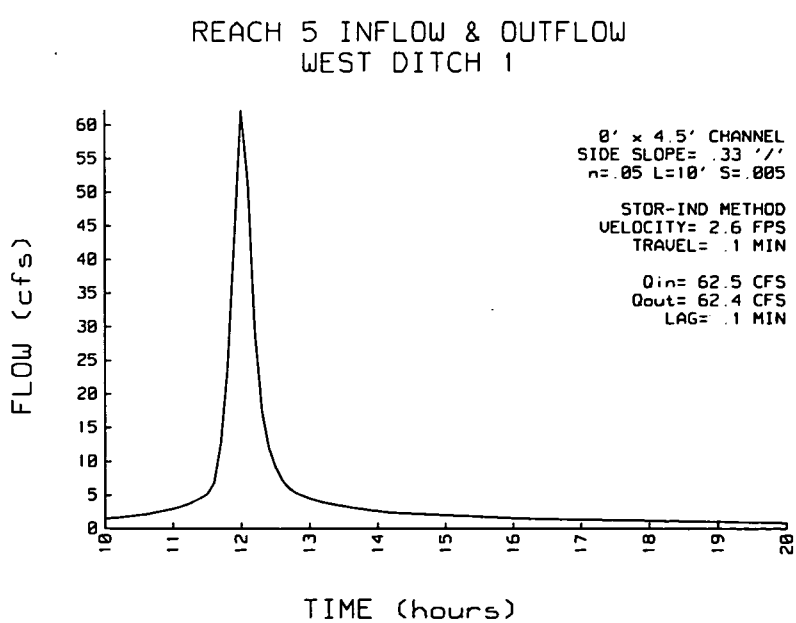
REACH 5 **WEST DITCH 1**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	.6	.5
.9	2.5	2.9
1.4	5.5	8.6
1.9	11.3	22.5
2.7	22.1	54.8
3.6	39.3	118.0
4.5	61.4	213.9

0' x 4.5' CHANNEL
SIDE SLOPE= .33 '/'
n= .05
LENGTH= 10 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.80 FT
PEAK VELOCITY= 2.6 FPS
TRAVEL TIME = .1 MIN
Qin = 62.5 CFS @ 12.01 HRS
Qout= 62.4 CFS @ 12.01 HRS
ATTEN= 0 % LAG= .1 MIN
IN/OUT= 3.82 / 3.82 AF





[redacted]

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

555
21Feb96

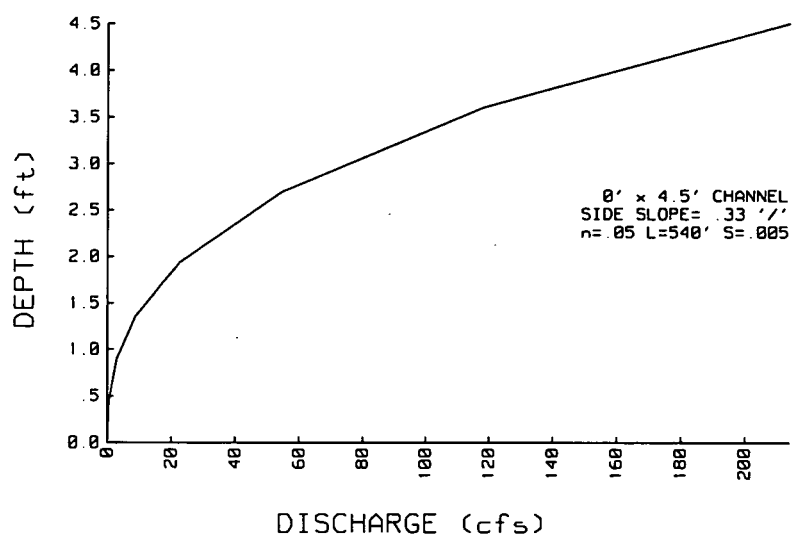
REACH 7 **WEST DITCH 2**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	.6	.5
.9	2.5	2.9
1.4	5.5	8.6
1.9	11.3	22.5
2.7	22.1	54.8
3.6	39.3	118.0
4.5	61.4	213.9

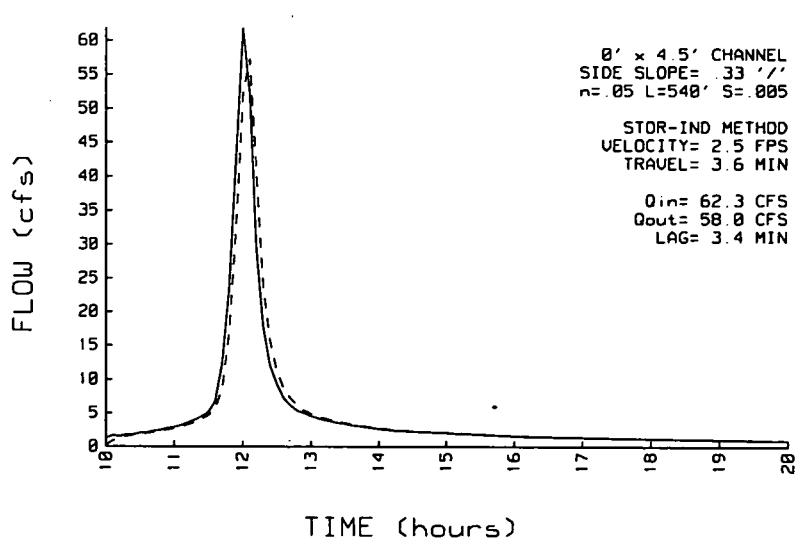
0' x 4.5' CHANNEL
SIDE SLOPE= .33 '/'
n= .05
LENGTH= 540 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.74 FT
PEAK VELOCITY= 2.5 FPS
TRAVEL TIME = 3.6 MIN
Qin = 62.3 CFS @ 12.02 HRS
Qout= 58.0 CFS @ 12.07 HRS
ATTEN= 7 % LAG= 3.4 MIN
IN/OUT= 3.82 / 3.81 AF

REACH 7 DISCHARGE
WEST DITCH 2



REACH 7 INFLOW & OUTFLOW
WEST DITCH 2



[redacted]

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

RSS 21Feb96

REACH 6 **WEST CULVERT 3**

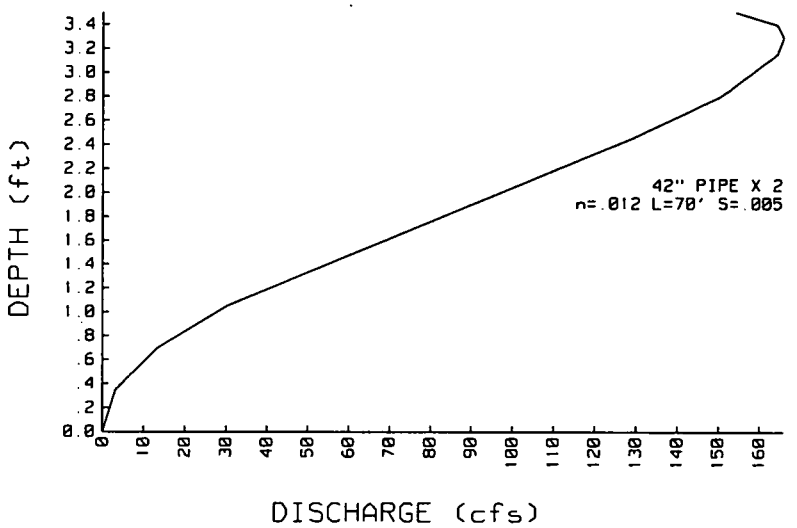
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	1.0	3.2
.7	2.7	13.5
1.1	4.9	30.2
2.5	14.4	129.1
2.8	16.5	150.7
3.2	18.2	164.3
3.3	18.8	165.8
3.4	19.1	164.3
3.5	19.2	154.1

42" PIPE X 2

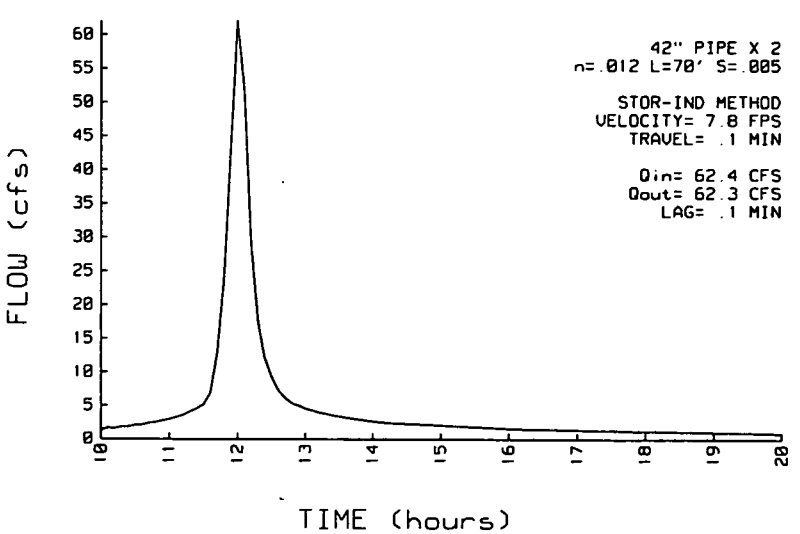
n= .012
LENGTH= 70 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.50 FT
PEAK VELOCITY= 7.8 FPS
TRAVEL TIME = .1 MIN
Qin = 62.4 CFS @ 12.01 HRS
Qout= 62.3 CFS @ 12.02 HRS
ATTEN= 0 % LAG= .1 MIN
IN/OUT= 3.82 / 3.82 AF

REACH 6 DISCHARGE
WEST CULVERT 3



REACH 6 INFLOW & OUTFLOW
WEST CULVERT 3

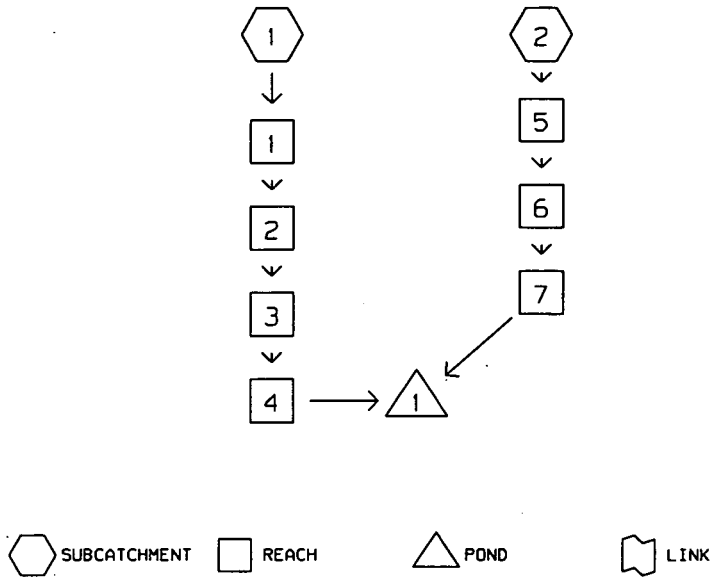


[redacted]

Data for **FERMCO, EARLY CONSTRUCTION DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

TSS 21Feb96

WATERSHED ROUTING ==========



[redacted]

739 ASC 27/44

Data for **FERMCO, EARLY CONSTRUCTION DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

855 21 Feb 96

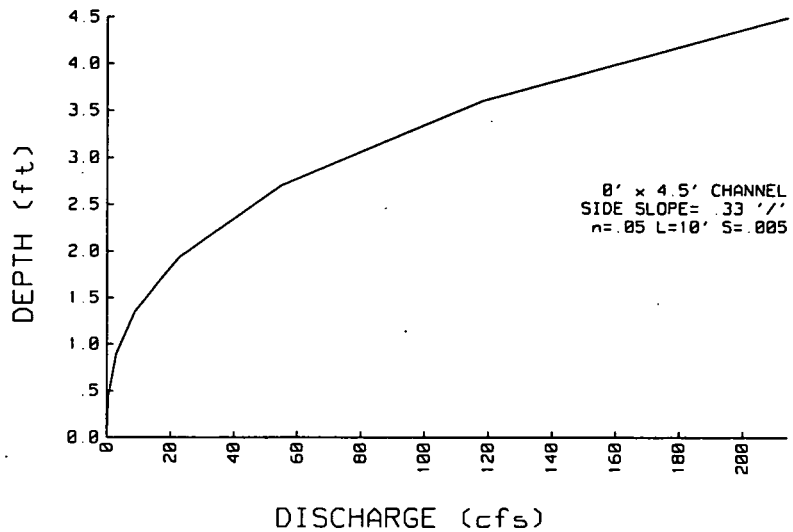
REACH 1 **EAST DITCH 1**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	.6	.5
.9	2.5	2.9
1.4	5.5	8.6
1.9	11.3	22.5
2.7	22.1	54.8
3.6	39.3	118.0
4.5	61.4	213.9

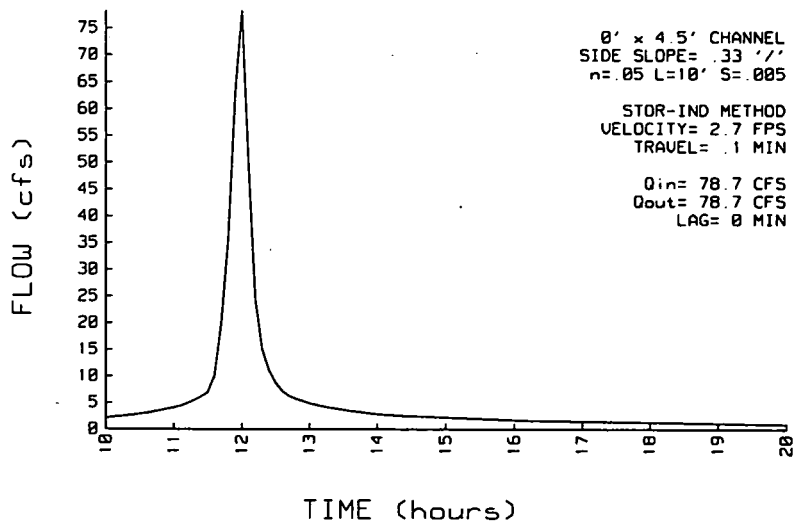
0' x 4.5' CHANNEL
SIDE SLOPE= .33 '/'
n= .05
LENGTH= 10 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 3.03 FT
PEAK VELOCITY= 2.7 FPS
TRAVEL TIME = .1 MIN
Qin = 78.7 CFS @ 11.98 HRS
Qout= 78.7 CFS @ 11.99 HRS
ATTEN= 0 % LAG= 0.0 MIN
IN/OUT= 4.45 / 4.45 AF

REACH 1 DISCHARGE
EAST DITCH 1



REACH 1 INFLOW & OUTFLOW
EAST DITCH 1



[redacted]

Data for **FERMCO, EARLY CONSTRUCTION DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

855
21 Feb 96

REACH 2 **EAST CULVERT 1**

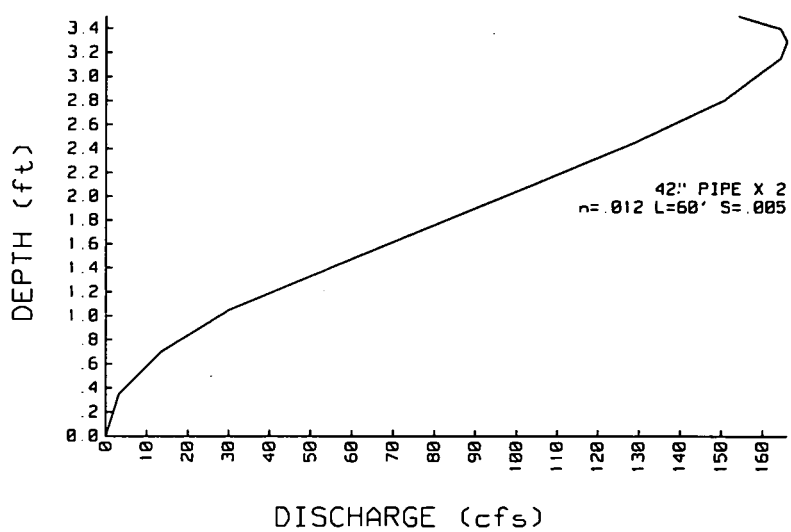
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	1.0	3.2
.7	2.7	13.5
1.1	4.9	30.2
2.5	14.4	129.1
2.8	16.5	150.7
3.2	18.2	164.3
3.3	18.8	165.8
3.4	19.1	164.3
3.5	19.2	154.1

42" PIPE X 2

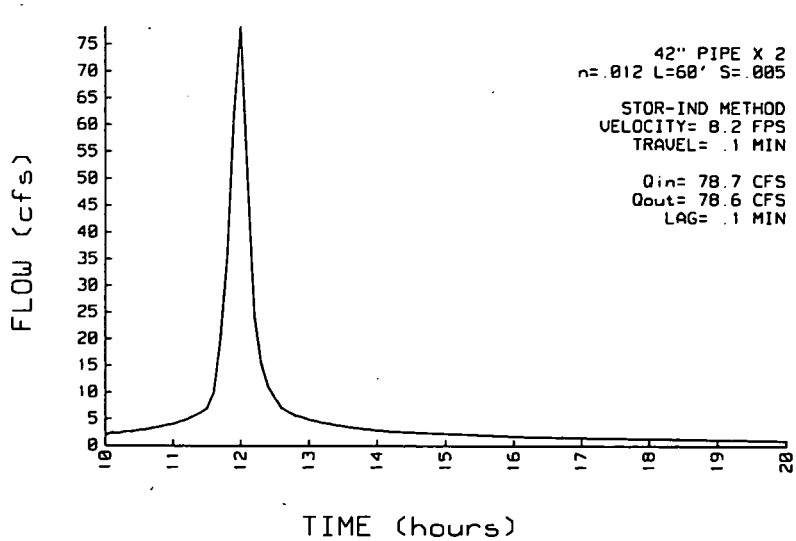
n= .012
LENGTH= 60 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.73 FT
PEAK VELOCITY= 8.2 FPS
TRAVEL TIME = .1 MIN
Qin = 78.7 CFS @ 11.99 HRS
Qout= 78.6 CFS @ 11.99 HRS
ATTEN= 0 % LAG= .1 MIN
IN/OUT= 4.45 / 4.45 AF

REACH 2 DISCHARGE
EAST CULVERT 1



REACH 2 INFLOW & OUTFLOW
EAST CULVERT 1



[redacted]

Data for **FERMCO, EARLY CONSTRUCTION DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

RSS 21Feb96

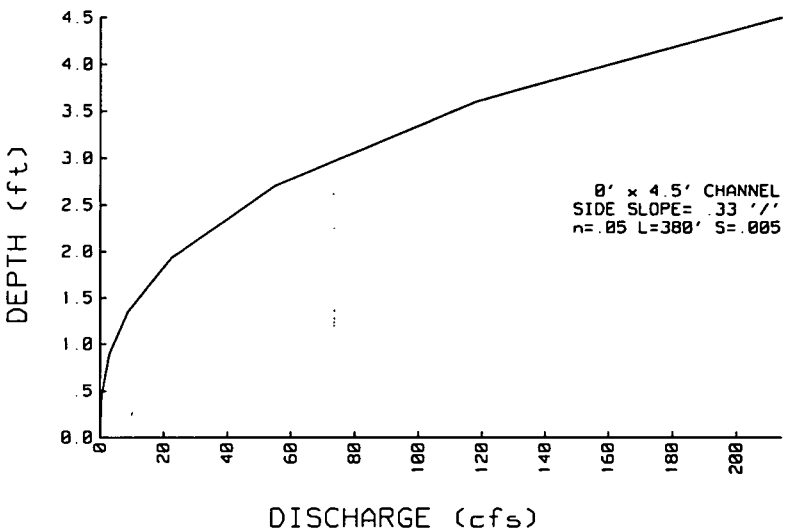
REACH 3 **EAST DITCH 2**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	.6	.5
.9	2.5	2.9
1.4	5.5	8.6
1.9	11.3	22.5
2.7	22.1	54.8
3.6	39.3	118.0
4.5	61.4	213.9

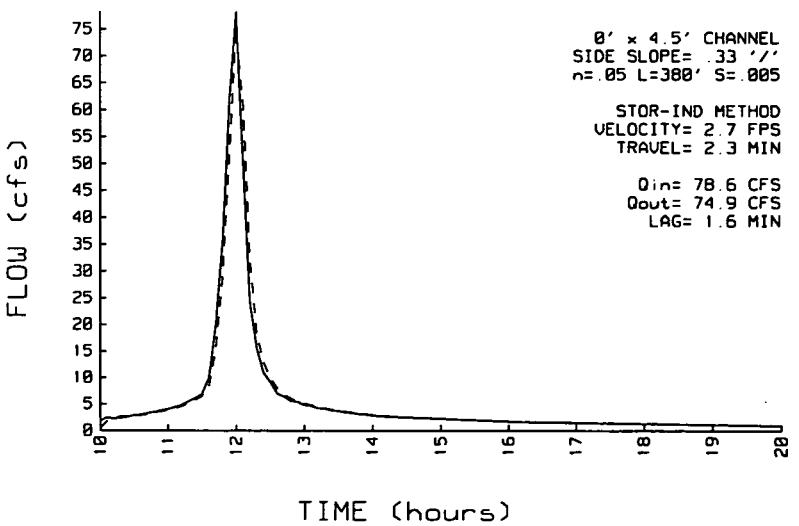
0' x 4.5' CHANNEL
SIDE SLOPE= .33 '/'
n= .05
LENGTH= 380 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.98 FT
PEAK VELOCITY= 2.7 FPS
TRAVEL TIME = 2.3 MIN
Qin = 78.6 CFS @ 11.99 HRS
Qout= 74.9 CFS @ 12.01 HRS
ATTEN= 5 % LAG= 1.6 MIN
IN/OUT= 4.45 / 4.45 AF

REACH 3 DISCHARGE
EAST DITCH 2



REACH 3 INFLOW & OUTFLOW
EAST DITCH 2



[redacted]

Data for **FERMCO, EARLY CONSTRUCTION DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

BSS 21Feb96

REACH 4 **EAST CULVERT 2**

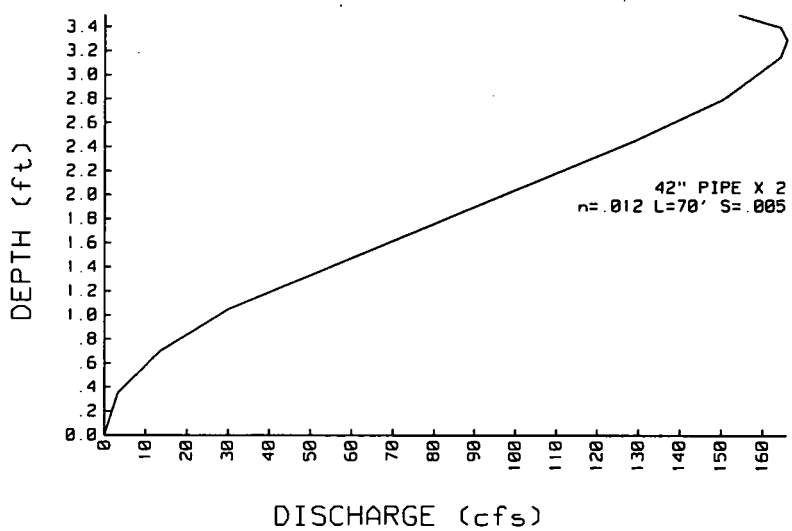
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	1.0	3.2
.7	2.7	13.5
1.1	4.9	30.2
2.5	14.4	129.1
2.8	16.5	150.7
3.2	18.2	164.3
3.3	18.8	165.8
3.4	19.1	164.3
3.5	19.2	154.1

42" PIPE X 2

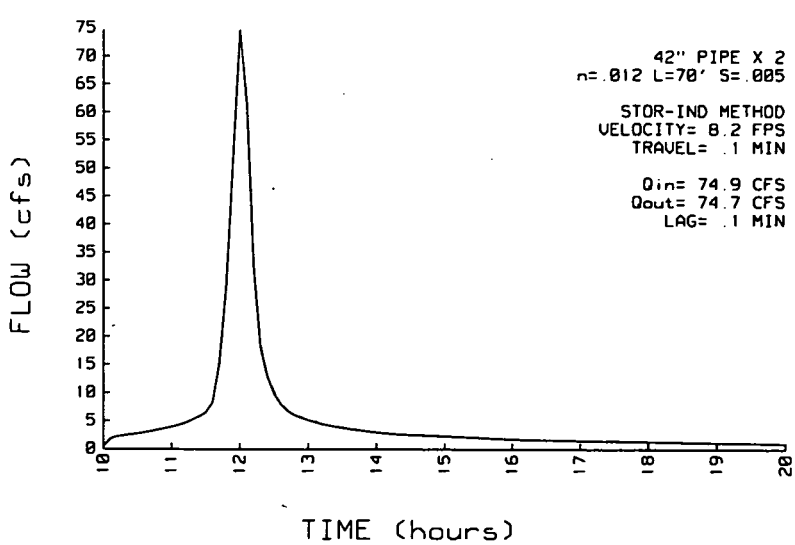
n= .012
LENGTH= 70 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.67 FT
PEAK VELOCITY= 8.2 FPS
TRAVEL TIME = .1 MIN
Qin = 74.9 CFS @ 12.01 HRS
Qout= 74.7 CFS @ 12.02 HRS
ATTEN= 0 % LAG= .1 MIN
IN/OUT= 4.45 / 4.45 AF

REACH 4 DISCHARGE
EAST CULVERT 2



REACH 4 INFLOW & OUTFLOW
EAST CULVERT 2



[redacted]

Data for **FERMCO, EARLY CONSTRUCTION DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

RSS 21Feb96

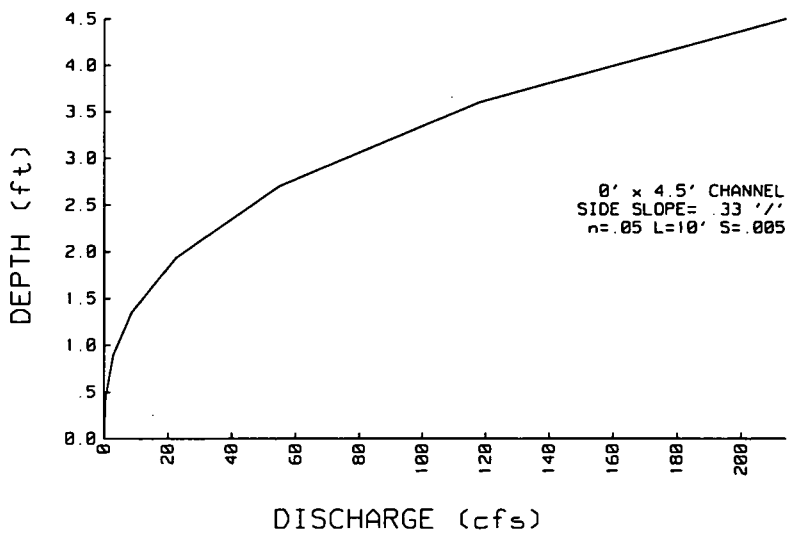
REACH 5 **WEST DITCH 1**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	.6	.5
.9	2.5	2.9
1.4	5.5	8.6
1.9	11.3	22.5
2.7	22.1	54.8
3.6	39.3	118.0
4.5	61.4	213.9

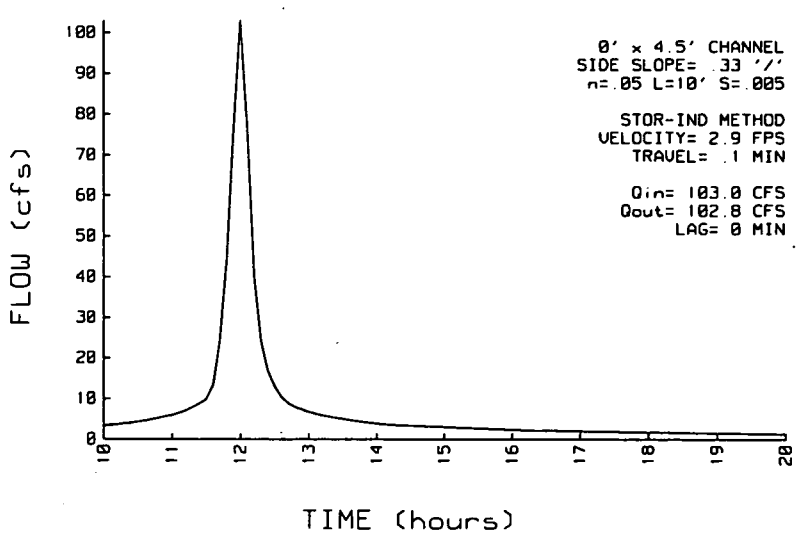
0' x 4.5' CHANNEL
SIDE SLOPE= .33 '/'
n= .05
LENGTH= 10 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 3.38 FT
PEAK VELOCITY= 2.9 FPS
TRAVEL TIME = .1 MIN
Qin = 103.0 CFS @ 12.00 HRS
Qout= 102.8 CFS @ 12.00 HRS
ATTEN= 0 % LAG= 0.0 MIN
IN/OUT= 6.15 / 6.15 AF

REACH 5 DISCHARGE
WEST DITCH 1



REACH 5 INFLOW & OUTFLOW
WEST DITCH 1



[redacted]

Data for **FERMCO, EARLY CONSTRUCTION DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

855 21Feb96

REACH 6 **WEST CULVERT 3**

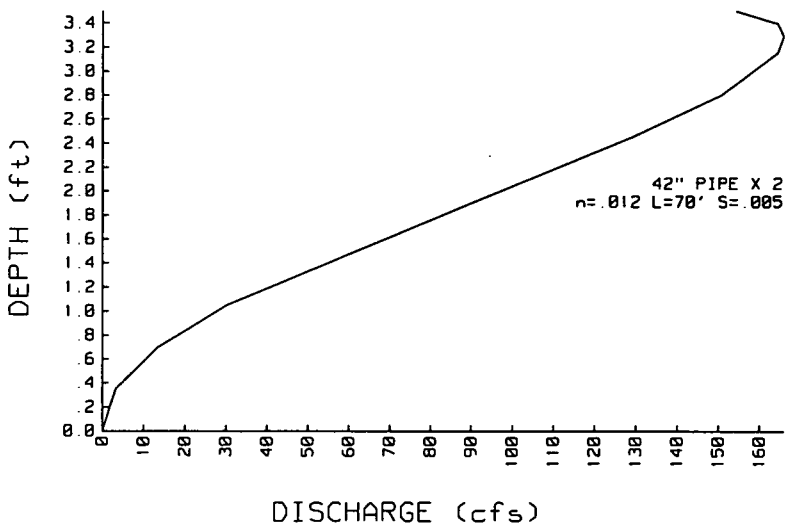
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	1.0	3.2
.7	2.7	13.5
1.1	4.9	30.2
2.5	14.4	129.1
2.8	16.5	150.7
3.2	18.2	164.3
3.3	18.8	165.8
3.4	19.1	164.3
3.5	19.2	154.1

42" PIPE X 2

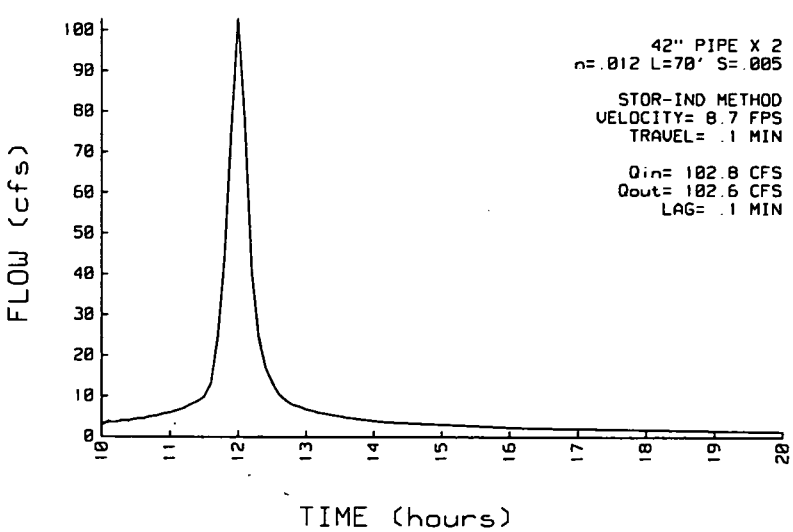
n= .012
LENGTH= 70 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.08 FT
PEAK VELOCITY= 8.7 FPS
TRAVEL TIME = .1 MIN
Qin = 102.8 CFS @ 12.00 HRS
Qout= 102.6 CFS @ 12.00 HRS
ATTEN= 0 % LAG= .1 MIN
IN/OUT= 6.15 / 6.15 AF

REACH 6 DISCHARGE
WEST CULVERT 3



REACH 6 INFLOW & OUTFLOW
WEST CULVERT 3



[redacted]

Data for **FERMCO, EARLY CONSTRUCTION DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

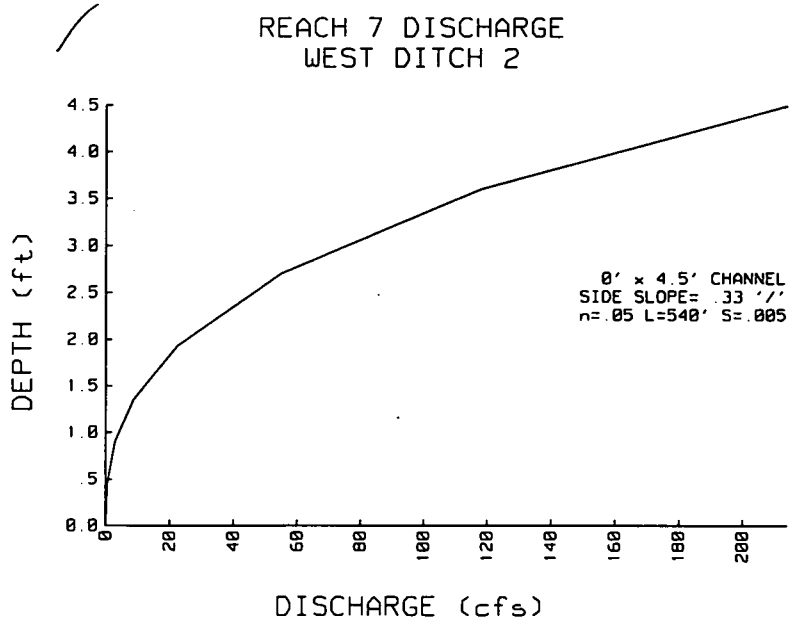
SSS 21 Feb 96

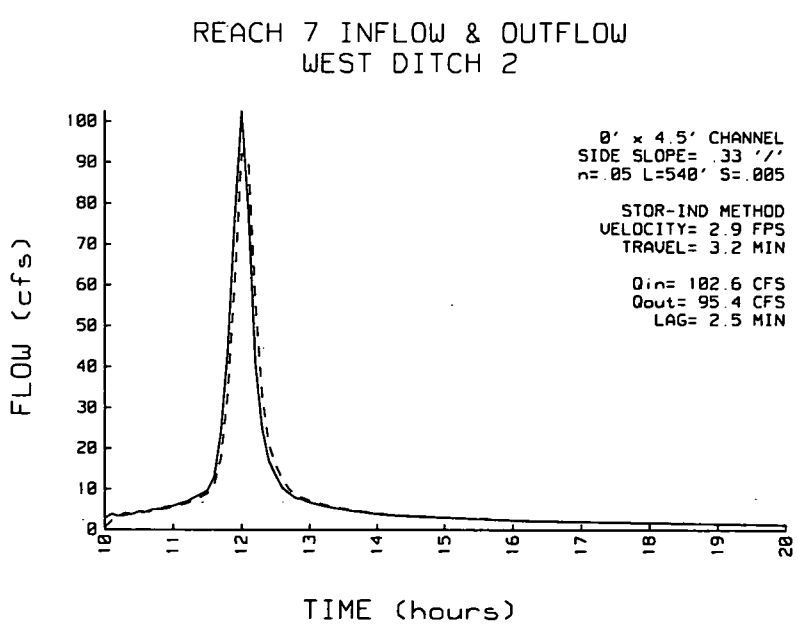
REACH 7 **WEST DITCH 2**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	.6	.5
.9	2.5	2.9
1.4	5.5	8.6
1.9	11.3	22.5
2.7	22.1	54.8
3.6	39.3	118.0
4.5	61.4	213.9

0' x 4.5' CHANNEL
SIDE SLOPE= .33 '/'
n= .05
LENGTH= 540 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 3.23 FT
PEAK VELOCITY= 2.9 FPS
TRAVEL TIME = 3.2 MIN
Qin = 102.6 CFS @ 12.00 HRS
Qout= 95.4 CFS @ 12.04 HRS
ATTEN= 7 % LAG= 2.5 MIN
IN/OUT= 6.15 / 6.14 AF



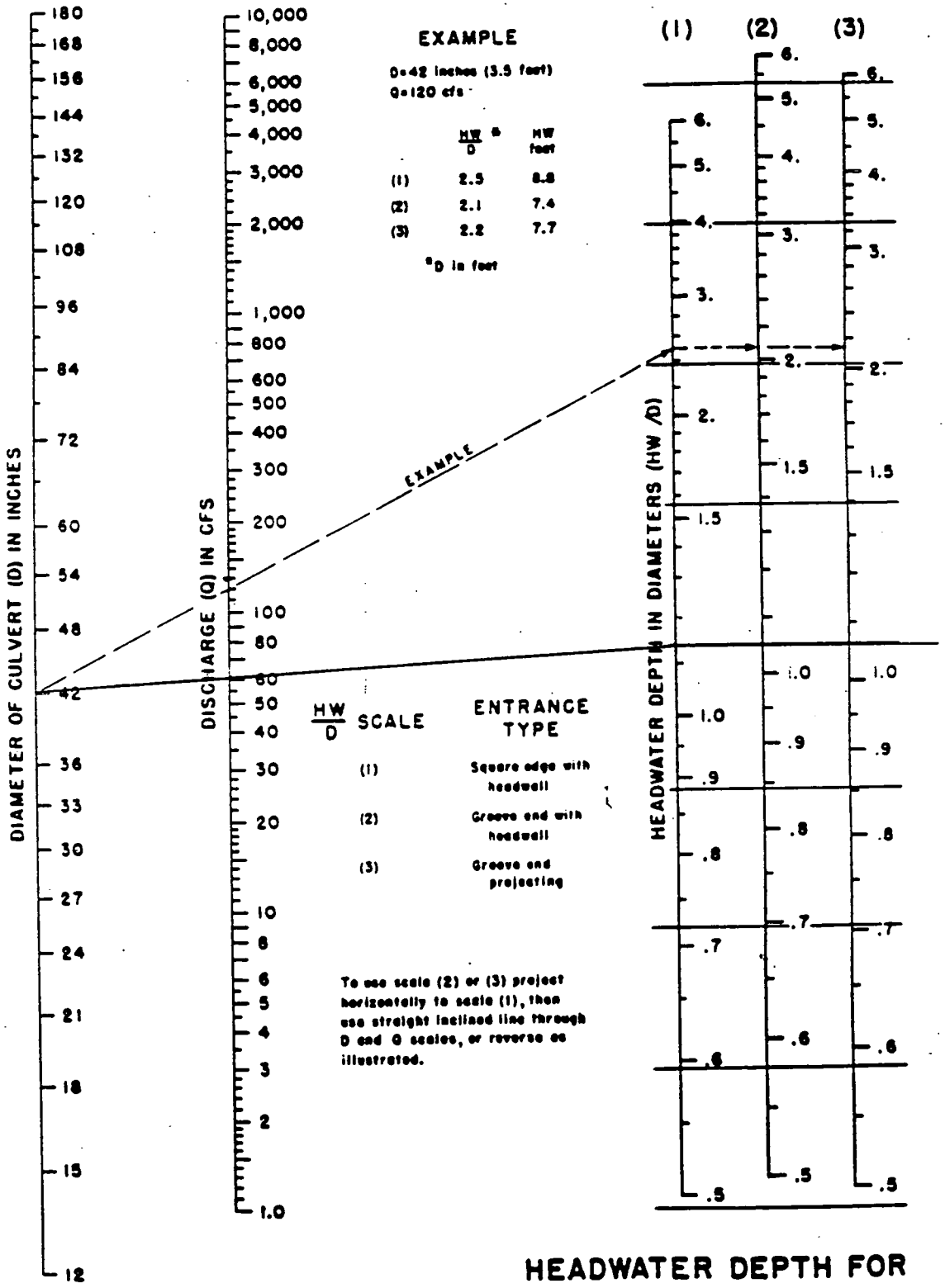


[redacted]

CULVERT CALCULATIONS

739 LSC 2/11/96 34/44
SSS 21 Feb 96

CHART 1



HEADWATER SCALES 2&3
REVISED MAY 1964

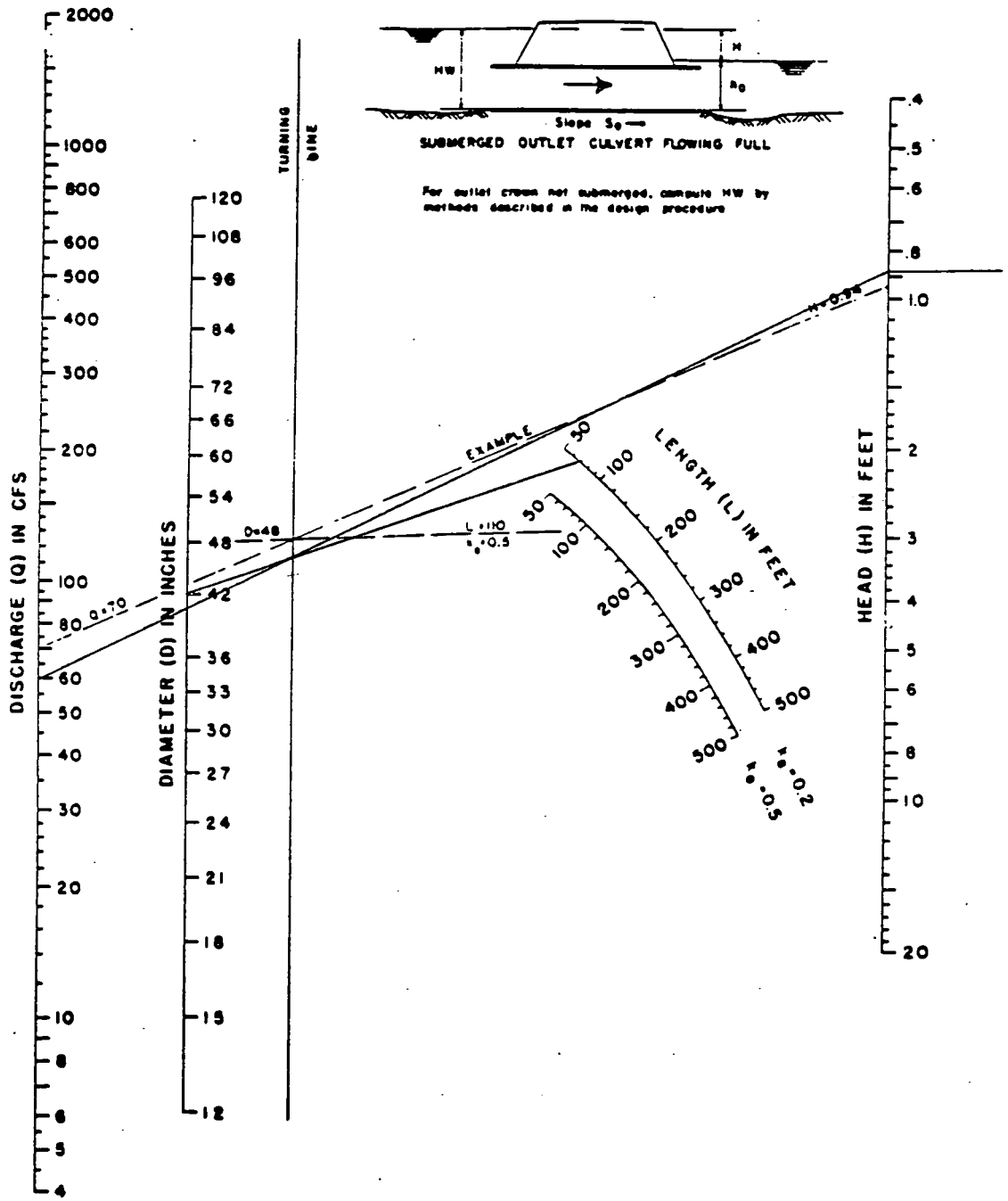
BUREAU OF PUBLIC ROADS JAN. 1963

HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

EAST DRAINAGE AREA CULVERTS
MAX. FLOW: ~~118 CFS~~ 121.4 cfs SSS
[redacted] 30 Oct 96
USE 2 - 42" CULVERTS MAX HW: 3.9 FT OK
357

739 ASC 2/16/96
35/44
SSS 21Feb96

CHART 5



HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

[redacted]

EAST DRAINAGE AREA CULVERTS
MAX FLOW: ~~48 CFS~~ 121.4 cfs
USE 2-42" CULVERTS MAX HW: 4.4 FT OK

SSS KL 3 Oct 96

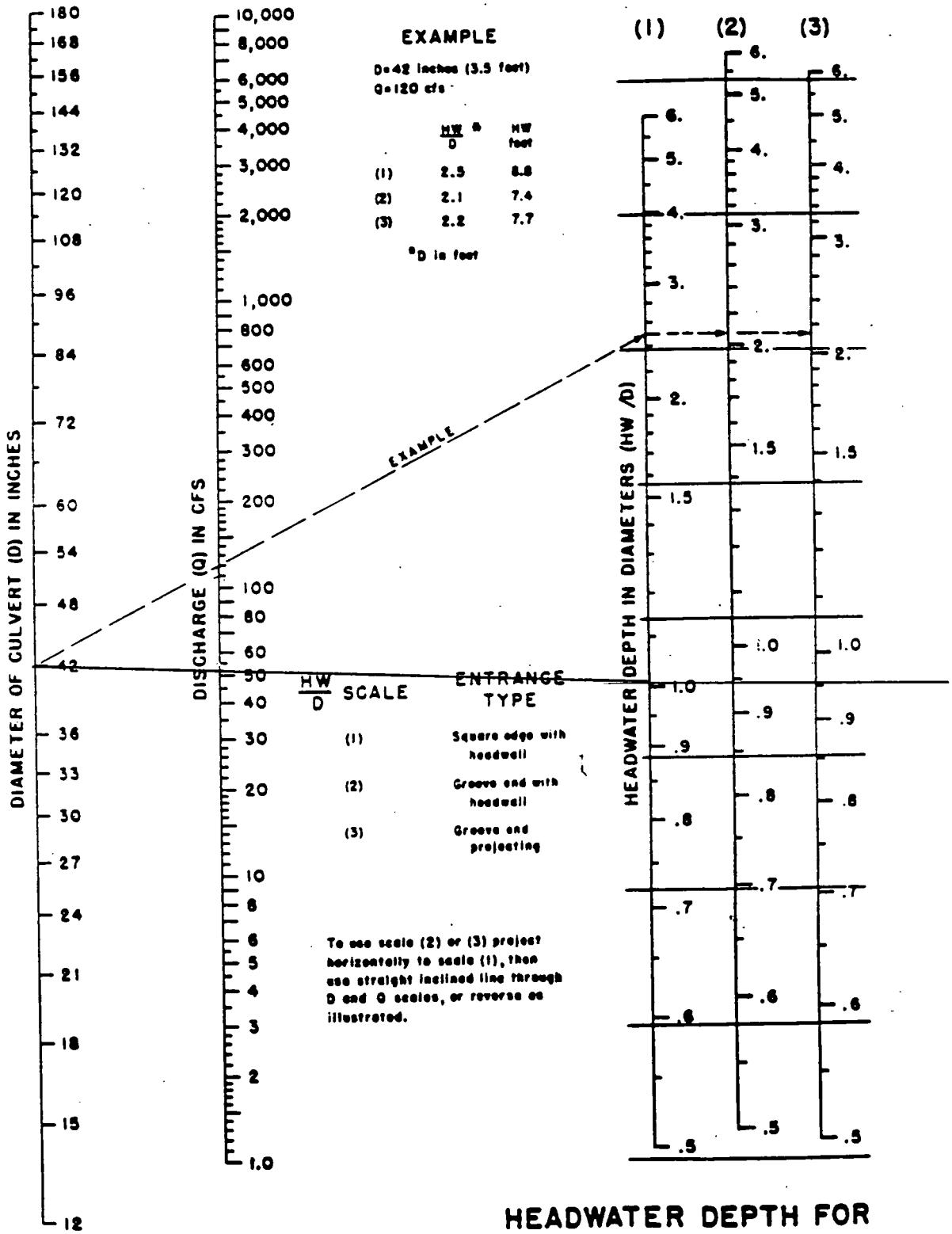
358

739 ASC 2/16/96

SSS 21 Feb 96

36/44

CHART 1



HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL [redacted]

HEADWATER SCALES 2&3
REVISED MAY 1964

BUREAU OF PUBLIC ROADS JAN. 1963

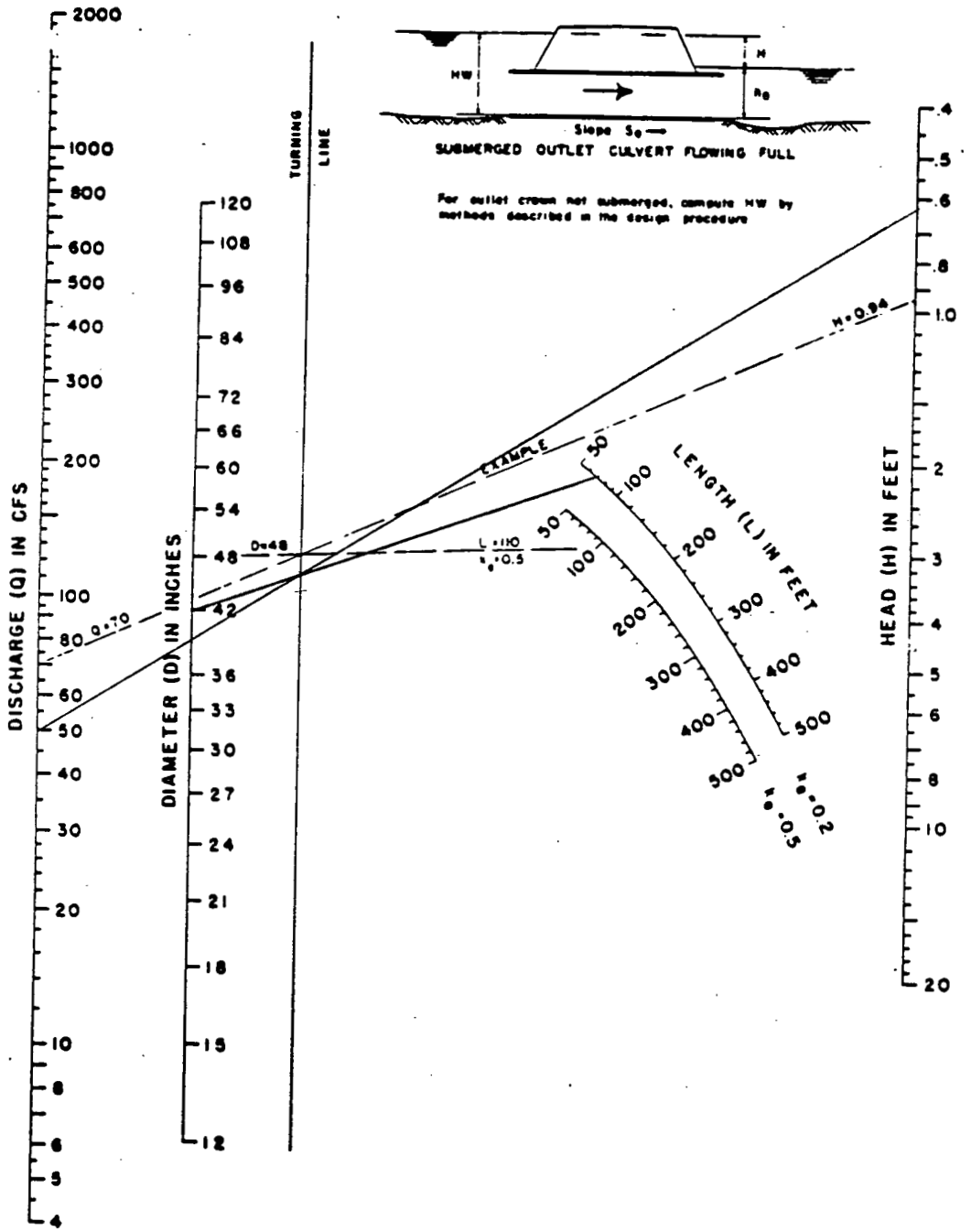
WEST DRAINAGE AREA CULVERTS
MAX FLOW: ~~100 CFS~~ 103 cfs SSS
USE 2-42" CULVERTS
MAX HW: 3.5 FT

OK 30 Oct 96

359

[redacted] - 739 AX 2/16/96
37/44
SSS
21Feb96

CHART 5



HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

WEST DRAINAGE AREA CULVERTS
• MAX FLOW : ~~100 CFS~~ 103 cfs SSS
USE 2-42" CULVERTS MAX HW: 4.1 FT

KL 30Oct96
OK

[redacted]

360

Outlet Protection (OP) (Cont'd)

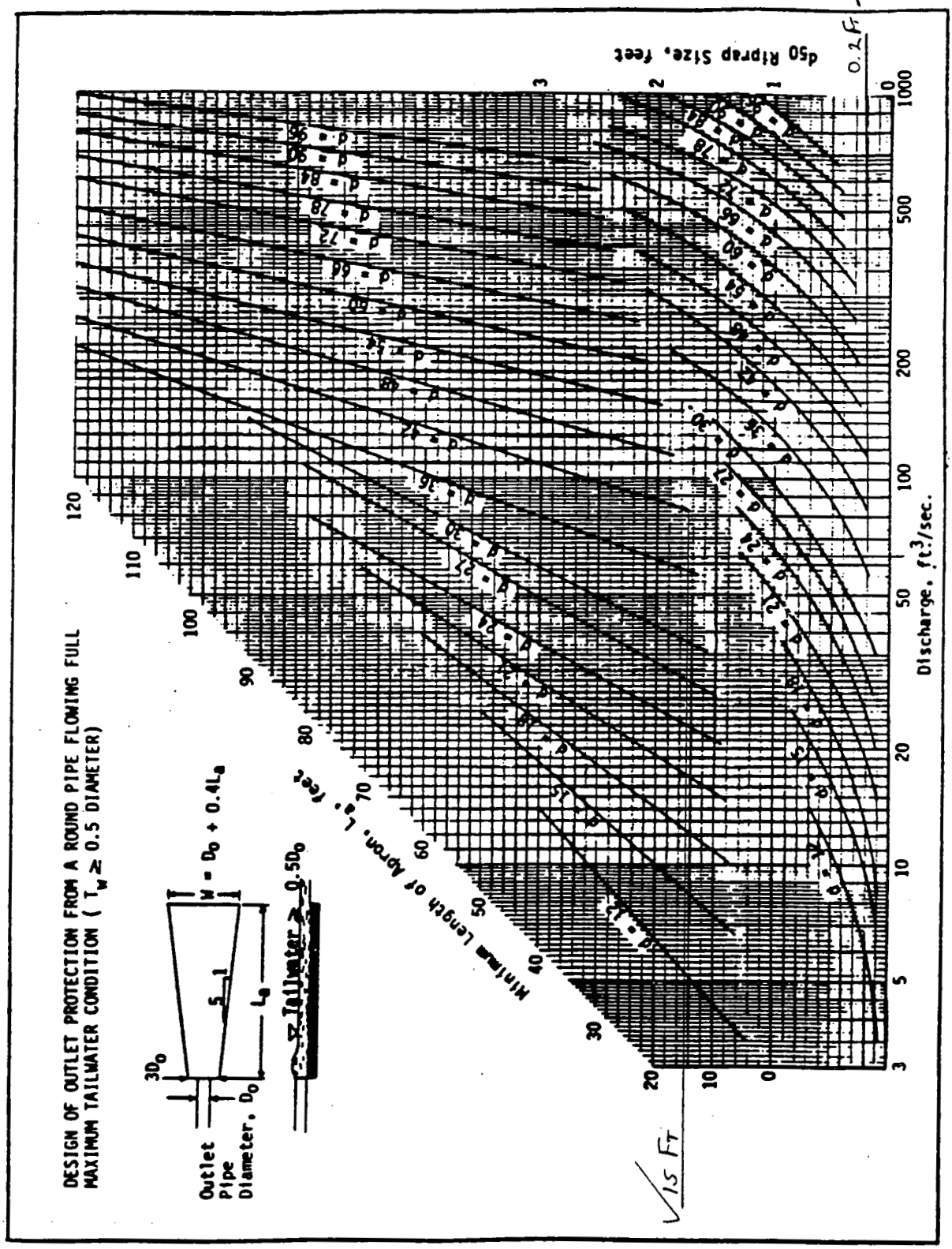


Figure 4

GEOSYNTEC CONSULTANTS

Written by: ASC Date: 21 / Feb / 96 (YY MM DD) Reviewed by: RSS Date: 96 / 02 / 21 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GL 3500 Task No.: 08.1

RIPRAP SIZE CALCULATIONS:

GIVEN: $D_{50} = 2.5$ IN

$D_{MAX} = 1.5 \times D_{50} = 3.75$ IN

$D_{15} = 0.5$ TO $0.25 \times D_{50}$

$= 1.25$ TO 1.9 IN

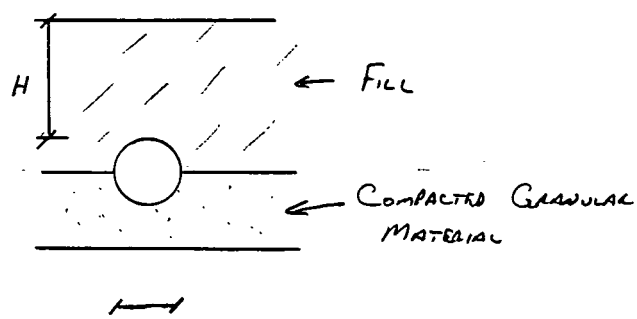
[redacted]

GEOSYNTEC CONSULTANTS

Written by: RSC Date: 96 / 02 / 16 (YY MM DD) Reviewed by: SSS Date: 96 / 02 / 21 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 08.1

CULVERT CAPACITY CALCULATION



$B \geq D + .75'$ (min)

1. ASSUMING THE FILL WILL BE SAND AND GRAVEL

FROM TABLE 9, THE EARTH LOAD e_s (BASED ON $\gamma = 100$ PCF)

$W_E = 2622$

CORRECTION DUE TO FILL WEIGHT ($\gamma = 135$ PCF)

$W_E = \frac{135}{100}(2622) = 3540$ lbs/FT

THE LIVE LOAD CAN BE EXTRACTED FROM TABLE 8

$W_L = 1154$ lbs/FT

2. THE BEDDING TYPE IS CLASSIFIED AS TYPE B WITH A LOADING FACTOR

$L_s = 1.9$

[redacted]

GEOSYNTEC CONSULTANTS

Written by: RSC Date: 96/02/16 (YY MM DD) Reviewed by: RSS Date: 96/02/21 (YY MM DD)

Client: Fermco Project: OSDF Project/Proposal No.: GE 3900 Task No.: 08.1

3. THE PIPE MAY BE UNREINFORCED. THE FACTOR OF SAFETY SUGGESTED FOR UNREINFORCED PIPE IS:

1.25 TO 1.5

4. THE REQUIRED PIPE STRENGTH IS:

$$D_{LOAD} = \left[\frac{W_L}{1.5} + \frac{W_E}{L_S}\right]\frac{F_S}{D}$$

$$D_{LOAD} = \left[\frac{1154}{1.5} + \frac{3540}{1.9}\right]\left(\frac{1.5}{3.5}\right)$$

$$= (2632.5)(.43)$$

$$= 1128.2$$

[redacted]

-739 KSC 2/13/96
42/44
JSS 28Feb96 ✓

TABLE ~~20~~ 9

42"

BACKFILL LOADS ON CIRCULAR PIPE IN TRENCH INSTALLATION

*100 POUNDS PER CUBIC FOOT BACKFILL MATERIAL — LOADS IN POUNDS PER LINEAR FOOT

42"

A — SAND AND GRAVEL Kμ'—0.165

HEIGHT OF BACKFILL H ABOVE TOP OF PIPE, FEET	TRENCH WIDTH AT TOP OF PIPE 6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	8'-6"	9'-0"	9'-6"	10'-0"	11'-0"	▲TRANSITION WIDTH
5	2622	**2671**									6'- 1"
6	3066	**3361**									6'- 6"
7	3485	3829	**4114**								6'-11"
8	3883	4273	4665	**4932**							7'- 4"
9	4259	4695	5134	**5582**							7'- 6"
10	4615	5097	5581	6067	**6227**						7'- 8"
11	4951	5478	6008	6540	**6869**						7'-10"
12	5270	5841	6415	6992	**7510**						7'-11"
13	5572	6185	6803	7425	8049	**8150**					8'- 1"
14	5858	6513	7174	7839	8508	**8789**					8'- 2"
15	6128	6824	7527	8235	8948	**9434**					8'- 4"
16	6384	7120	7864	8614	9370	**10070**					8'- 6"
17	6626	7401	8186	8977	9775	10580	**10710**				8'- 7"
18	6855	7669	8492	9324	10160	11010	**11350**				8'- 8"
19	7072	7923	8785	9657	10540	11420	**11980**				8'-10"
20	7277	8164	9064	9975	10890	11820	**12630**				8'-11"
21	7472	8394	9331	10280	11240	12200	13180	**13270**			9'- 1"
22	7656	8612	9585	10570	11570	12570	13590	**13900**			9'- 2"
23	7830	8820	9827	10850	11880	12930	13980	**14550**			9'- 3"
24	7994	9017	10060	11120	12190	13270	14360	**15190**			9'- 4"
25	8150	9204	10280	11370	12480	13600	14730	**15830**			9'- 6"
26	8298	9382	10490	11620	12760	13920	15080	16260	**16470**		9'- 7"
27	8438	9552	10690	11850	13030	14220	15420	16640	**17090**		9'- 8"
28	8570	9713	10880	12070	13280	14510	15750	17010	**17740**		9'- 9"
29	8695	9866	11060	12290	13530	14790	16070	17360	**18380**		9'-11"
30	8814	10010	11240	12490	13770	15060	16370	17700	**19000**		10'- 0"
31	8926	10150	11400	12690	13990	15320	16670	18030	19410	**19670**	10'- 1"
32	9032	10280	11560	12880	14210	15570	16950	18350	19760	**20280**	10'- 2"
33	9132	10400	11710	13060	14420	15810	17230	18660	20100	**20920**	10'- 3"
34	9227	10520	11860	13230	14620	16040	17490	18950	20440	**21540**	10'- 4"
35	9317	10640	12000	13390	14820	16270	17740	19240	20760	**22190**	10'- 5"
36	9402	10740	12130	13550	15000	16480	17990	19520	21060	**22830**	10'- 7"
37	9483	10850	12250	13700	15180	16690	18220	19780	21360	**23500**	10'- 8"
38	9559	10940	12370	13840	15350	16890	18450	20040	21660	**24110**	10'- 9"
39	9631	11040	12490	13980	15510	17080	18670	20290	21940	**24760**	10'-10"
40	9700	11120	12600	14110	15670	17260	18880	20530	22210	**25400**	10'-11"

B — SATURATED TOP SOIL Kμ'—0.150

TRENCH WIDTH AT TOP OF PIPE 6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	8'-6"	9'-0"	9'-6"	10'-0"	11'-0"	▲TRANSITION WIDTH	HEIGHT OF BACKFILL H ABOVE TOP OF PIPE, FEET
2671										6'- 0"	5
3110	**3361**									6'- 5"	6
3543	3888	**4114**								6'-10"	7
3956	4348	4740	**4932**							7'- 3"	8
4348	4787	5227	**5582**							7'- 5"	9
4721	5206	5693	6181	**6227**						7'- 7"	10
5076	5606	6139	6674	**6869**						7'- 8"	11
5414	5989	6567	7147	**7510**						7'-10"	12
5735	6354	6976	7602	**8150**						7'-11"	13
6040	6702	7369	8039	**8789**						8'- 0"	14
6331	7035	7745	8459	9177	**9434**					8'- 2"	15
6608	7353	8105	8863	9625	**10070**					8'- 3"	16
6871	7657	8450	9250	10060	**10710**					8'- 5"	17
7121	7947	8781	9623	10470	**11350**					8'- 6"	18
7359	8223	9098	9981	10870	11770	**11980**				8'- 8"	19
7585	8488	9401	10320	11260	12190	**12630**				8'- 9"	20
7800	8740	9692	10660	11630	12610	**13270**				8'-10"	21
8005	8981	9971	10970	11980	13000	**13900**				8'-11"	22
8200	9211	10240	11280	12330	13390	14460	**14550**			9'- 1"	23
8385	9431	10490	11570	12660	13760	14870	**15190**			9'- 2"	24
8561	9641	10740	11850	12980	14120	15260	**15830**			9'- 3"	25
8729	9841	10970	12120	13290	14460	15650	**16470**			9'- 4"	26
8869	10030	11200	12380	13580	14800	16020	**17090**			9'- 5"	27
9040	10220	11410	12630	13870	15120	16380	**17740**			9'- 6"	28
9185	10390	11620	12870	14140	15430	16730	18040	**18380**		9'- 8"	29
9322	10560	11820	13100	14410	15730	17070	18420	**19000**		9'- 9"	30
9453	10720	12010	13320	14660	16020	17390	18780	**19670**		9'-10"	31
9577	10870	12190	13540	14910	16300	17710	19130	**20280**		9'-11"	32
9695	11010	12360	13740	15140	16570	18010	19470	**20920**		10'- 0"	33
9807	11150	12530	13940	15370	16830	18310	19800	21310	**21540**	10'- 1"	34
9914	11280	12690	14130	15590	17080	18590	20120	21670	**22190**	10'- 2"	35
10020	11410	12840	14310	15800	17320	18870	20430	22010	**22830**	10'- 3"	36
10110	11530	12990	14480	16010	17560	19130	20730	22350	**23500**	10'- 4"	37
10200	11640	13130	14650	16200	17780	19390	21020	22670	**24110**	10'- 5"	38
10290	11760	13260	14810	16390	18000	19640	21300	22990	**24760**	10'- 6"	39
10350	11860	13390	14960	16570	18210	19880	21580	23290	**25400**	10'- 7"	40

C — ORDINARY CLAY Kμ'—0.130

HEIGHT OF BACKFILL H ABOVE TOP OF PIPE, FEET	TRENCH WIDTH AT TOP OF PIPE 6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	8'-6"	9'-0"	9'-6"	10'-0"	11'-0"	▲TRANSITION WIDTH
5	**2671**										5'-11"
6	3170	**3361**									6'- 4"
7	3622	3968	**4114**								6'- 8"
8	4056	4450	4844	**4932**							7'- 1"
9	4471	4912	5355	**5582**							7'- 3"
10	4869	5357	5847	**6227**							7'- 5"
11	5249	5784	6321	**6869**							7'- 6"
12	5614	6194	6777	7362	**7510**						7'- 7"
13	5963	6589	7217	7848	**8150**						7'- 9"
14	6297	6967	7641	8318	**8789**						7'-10"
15	6617	7331	8050	8772	**9434**						7'-11"
16	6924	7681	8443	9210	**10070**						8'- 0"
17	7217	8017	8823	9633	10450	**10710**					8'- 2"
18	7498	8340	9188	10040	10900	**11350**					8'- 3"
19	7768	8650	9540	10440	11340	**11980**					8'- 4"
20	8025	8948	9880	10820	11760	**12630**					8'- 5"
21	8272	9234	10210	11190	12180	13170	**13270**				8'- 7"
22	8509	9509	10520	11540	12570	13610	**13900**				8'- 8"
23	8735	9774	10820	11890	12960	14040	**14550**				8'- 9"
24	8952	10030	11120	12220	13330	14450	**15190**				8'-10"
25	9159	10270	11400	12540	13690	14850	**15830**				8'-11"
26	9358	10510	11670	12850	14040	15240	**16470**				9'- 0"
27	9548	10730	11930	13150	14380	15620	16870	**17090**			9'- 1"
28	9731	10950	12180	13440	14710	15990	17280	**17740**			9'- 2"
29	9905	11160	12430	13720	15020	16340	17670	**18380**			9'- 3"
30	10070	11360	12660	13990	15330	16690	18060	**19000**			9'- 4"
31	10230	11550	12890	14250	15630	17020	18430	**19670**			9'- 5"
32	10380	11730	13100	14500	15910	17350	18790	**20280**			9'- 6"
33	10530	11910	13310	14740	16190	17660	19140	20640	**20920**		9'- 7"
34	10670	12080	13520	14980	16460	17970	19490	21020	**21540**		9'- 8"
35	10810	12240	13710	15200	16720	18260	19820	21390	**22190**		9'- 9"
36	10940	12400	13900	15420	16980	18550	20140	21750	**22830**		9'-10"
37	11060	12550	14080	15640	17220	18830	20460	22100	**23500**		9'-11"
38	11180	12700	14250	15840	17460	19100	20760	22440	**24110**		10'- 0"
39	11290	12840	14420	16040	17680	19360	21060	22770	24510	**24760**	10'- 1"
40	11400	12970	14580	16230	17910	19610	21340	23100	24870	**25400**	10'- 2"

D — SATURATED CLAY Kμ'—0.110

TRENCH WIDTH AT TOP OF PIPE 6'-0"	6'-6"	7'-0"	7'-6"	8'-0"	8'-6"	9'-0"	9'-6"	10'-0"	11'-0"	▲TRANSITION WIDTH	HEIGHT OF BACKFILL H ABOVE TOP OF PIPE, FEET
2671										5'-10"	5
3231	**3361**									6'- 3"	6
3704	4051	**4114**								6'- 7"	7
4160	4555	**4932**								7'- 0"	8
4599	5042	5467	**5582**							7'- 1"	9
5022	5514	6006	**6227**							7'- 3"	10
5431	5969	6509	**6869**							7'- 4"	11
5824	6410	6997	**7510**							7'- 5"	12
6204	6836	7470	**8150**							7'- 6"	13
6570	7247	7928	8611	**8789**						7'- 7"	14
6922	7645	8372	9101	**9434**						7'- 9"	15
7262	8030	8802	9577	**10070**						7'-10"	16
7590	8402	9218	10040	**10710**						7'-11"	17
7906	8761	9622	10490	**11350**						8'- 0"	18
8210	9109	10010	10920	11840	**11980**					8'- 1"	19
8504	9445	10390	11350	12310	**12630**					8'- 2"	20
8787	9770	10760	11760	12760	**13270**					8'- 3"	21
9059	10080	11120	12160	13200	**13900**					8'- 4"	22
9322	10390	11460	12540	13640	**14550**					8'- 5"	23
9576	10680	11800	12920	14060	**15190**					8'- 6"	24
9820	10960	12120	13290	14460	15640	**15830**				8'- 7"	25
10060	11240	12440	13640	14860	16080	**16470**				8'- 8"	26
10280	11500	12740	13990	15240	16510	**17090**				8'- 9"	27
10500	11760	13030	14320	15620	16930	**17740**				8'-10"	28
10710	12010	13320	14650	15990	17340	**18380**				8'-10"	29
10920	12250	13600	14960	16340	17730	**19000**				9'- 0"	30
11110	12480	13860	15270	16690	18120	**19670**				9'- 0"	31
11300	12700	14120	15570	17020	18500	19980	**20280**			9'- 1"	32
11480	12920	14380	15860	17350	18860	20380	**20920**			9'- 2"	33
11660	13130	14620	16140	17670	19220	20780	**21540**			9'- 3"	34
11830	13330	14860	16410	17980	19570	21170	**22190**			9'- 4"	35
11990	13530	15090	16670	18280	19910	21550	**22830**			9'- 5"	36
12150	13720	15310	16930	18570	20240	21920	**23500**			9'- 6"	37
12300	13900	15520	17180	18860	20560	22280	**24110**			9'- 6"	38
12450	14070	15730	17420	19140	20870	22630	24400	**24760**		9'- 7"	39
12590	14240	15940	17660	19410	21180	22970	24780	**25400**		9'- 8"	40

* *For backfill weighing 110 pounds per cubic foot, increase loads 10%; for 120 pounds per cubic foot, increase 20%; etc.*

▲ *Transition loads (bold type) and widths based on Kμ—0.19, $r_{sd}p$—0.5 in the embankment equation.*

000365

TABLE 42

DESIGN VALUES OF SETTLEMENT RATIO

Installation and Foundation Condition	Settlement Ratio r_{sd} Usual Range	Settlement Ratio r_{sd} Design Value
Positive Projecting	0.0 to +1.0	
Rock or Unyielding Soil	+1.0	+1.0
*Ordinary Soil	+0.5 to +0.8	+0.7
Yielding Soil	0.0 to +0.5	+0.3
Zero Projecting		0.0
Negative Projecting	−1.0 to 0.0	
p′ = 0.5		−0.1
p′ = 1.0		−0.3
p′ = 1.5		−0.5
p′ = 2.0		−1.0
Induced Trench	−2.0 to 0.0	
p′ = 0.5		−0.5
p′ = 1.0		−0.7
p′ = 1.5		−1.0
p′ = 2.0		−2.0

The value of the settlement ratio depends on the degree of compaction of the fill material adjacent to the sides of the pipe. With good construction methods resulting in proper compaction of bedding and sidefill materials, a settlement ratio design value of +0.5 is recommended.

TABLE 43

DESIGN VALUES OF COEFFICIENT OF COHESION

Type of Soil	Values of c
Clay	
Soft	40
Medium	250
Hard	1000
Sand	
Loose Dry	0
Silty	100
Dense	300
Top Soil	
Saturated	100

TABLE 8

HIGHWAY LOADS

POUNDS PER LINEAR FOOT

CIRCULAR PIPE

PIPE SIZE D IN INCHES	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	PIPE SIZE D IN INCHES
12	4849	2730	1524	954	574	361	316	237	168	46	12
15	5915	3322	1872	1163	700	441	358	289	205	56	15
18		3926	2196	1369	825	520	454	341	242	66	18
21		4498	2525	1580	950	599	522	392	279	77	21
24			2856	1788	1077	679	592	444	316	87	24
27			3096	1998	1201	757	660	496	353	97	27
30				2204	1328	837	731	548	390	107	30
33				2370	1452	915	798	599	426	117	33
36					1580	996	869	652	463	127	36
42					1679	1154	1007	755	537	147	42
48						1221	1146	859	611	168	48
54							1185	962	684	188	54
60								998	758	208	60
66									832	228	66
72									857	249	72
78										269	78
84										275	84

HORIZONTAL ELLIPTICAL PIPE

PIPE SIZE R × S IN INCHES	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	PIPE SIZE R × S IN INCHES
14×23	5915	4498	2716	1699	1022	644	561	422	300	82	14×23
19×30			3096	2177	1309	825	719	451	384	105	19×30
22×34				2370	1471	927	808	607	432	118	22×34
24×38					1631	1028	896	674	479	131	24×38
27×42					1679	1119	975	733	521	143	27×42
29×45						1221	1064	800	569	156	29×45
32×49							1152	866	616	169	32×49
34×53							1185	933	663	182	34×53
38×60								998	748	205	38×60
43×68									842	231	43×68
48×76									857	257	48×76
53×83										275	53×83

ARCH PIPE

PIPE SIZE R × S IN INCHES	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	PIPE SIZE R × S IN INCHES
11×18	5915	3840	2144	1342	807	509	443	333	237	65	11×18
13½×22		4498	2573	1610	968	520	532	400	284	78	13½×22
15½×26			3000	1879	1130	712	621	467	332	91	15½×26
18×28½			3096	2058	1238	780	680	511	363	100	18×28½
22½×36¼				2370	1533	966	842	633	450	124	22½×36¼
26¾×43¾					1679	1170	1019	766	545	150	26¾×43¾
31⅝×51⅛						1221	1185	981	633	174	31⅝×51⅛
36×58½								998	721	198	36×58½
40×65									800	220	40×65
45×73									857	246	45×73
54×88										275	54×88

Unsurfaced Roadway; 16,000-Pound Wheel Load; Dual Tires; 80 p.s.i. Tire Pressure; Impact Included. Last number in each column **(bold type)** *indicates maximum load for any given fill height. Interpolate for intermediate fill heights.*

366

239

43/44

FIGURE 142

TRENCH BEDDINGS
CIRCULAR PIPE

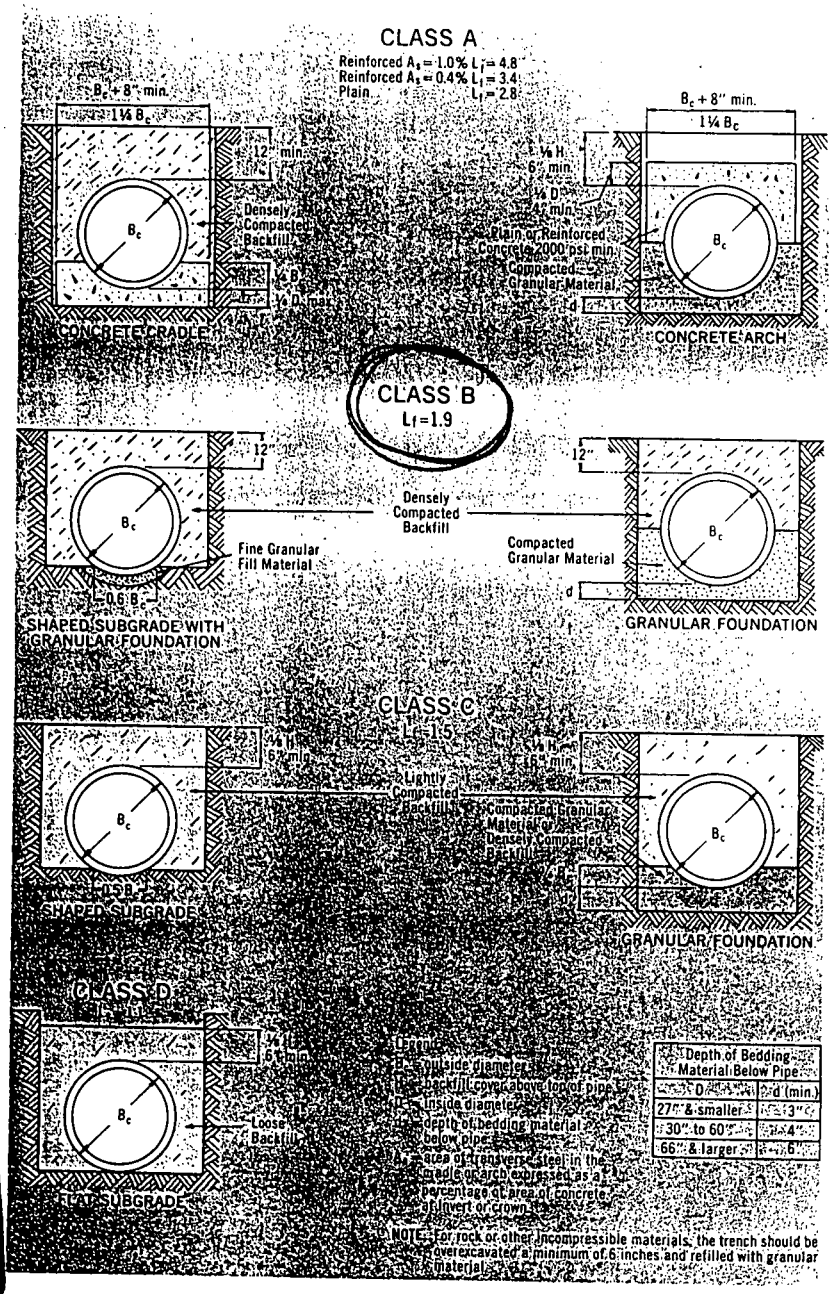
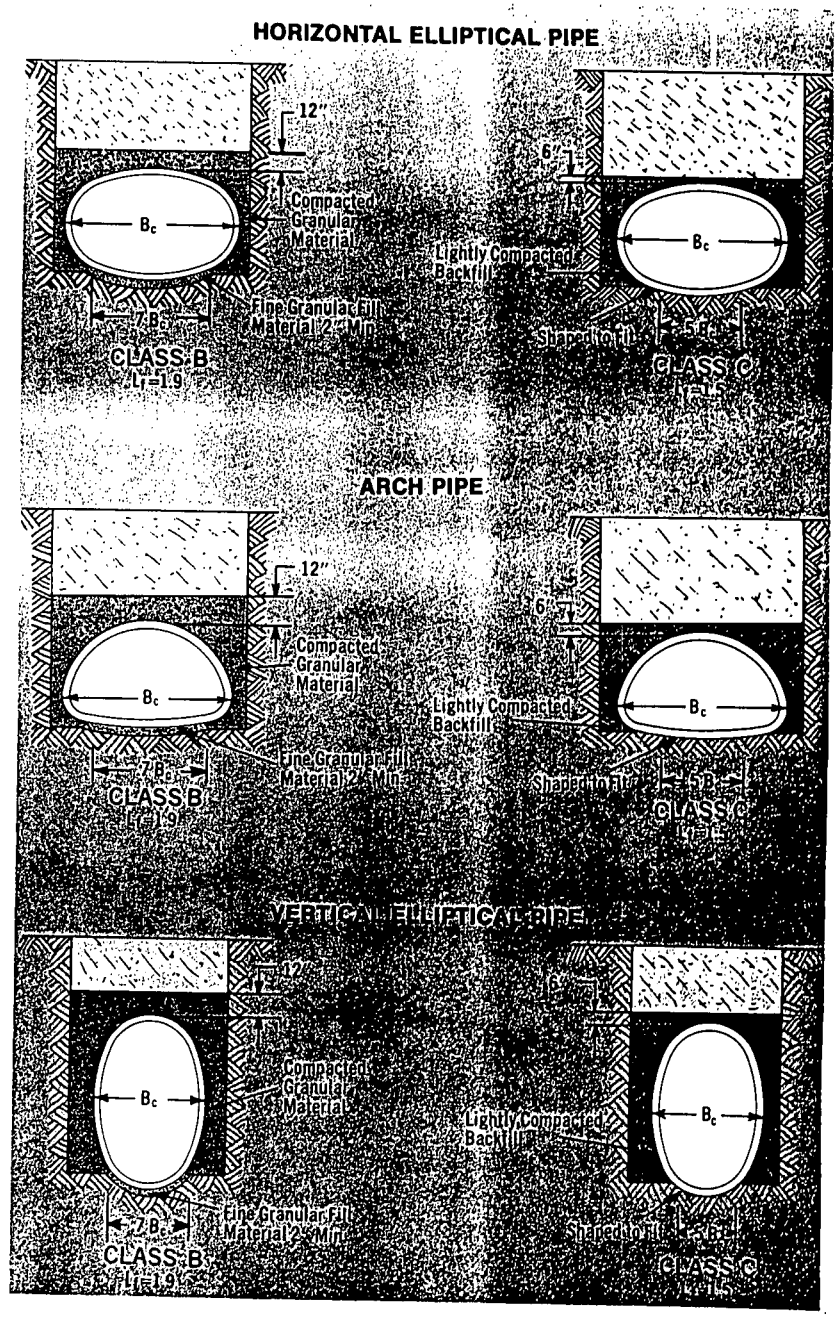


FIGURE 143

TRENCH BEDDINGS



44/44

APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATION PACKAGE HydroCAD™ STORMWATER MODELING SYSTEM

Applied Microcomputer Systems, *"HydroCAD™ Stormwater Modeling System"*, version 3.10, Chocorva, NH, 1993.

For documentation of computer programs see

1.2 Computer Program Validation

12.2 OSDF Sediment Basins

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: SURFACE-WATER MANAGEMENT DURING OSDF CONSTRUCTION/ FILLING/CLOSURE - OSDF SEDIMENT BASIN

Computations By: (Cognizant Engineer)
Signature [signature] Date 19 Feb 96
Printed Name and Title Robert S Cobb II, Senior Staff Engineer

Assumptions and Procedures Checked by: (Checker)
Signature [signature] Date 20 Feb 96
Printed Name and Title Eric S. Steinhauser, Senior Project Engineer

Computations Checked by:
Signature [signature] Date 21 Feb 96
Printed Name and Title Eric S. Steinhauser, Senior Project Engineer

Computations Backchecked by: (Cognizant Engineer)
Signature [signature] Date 21 Feb 96
Printed Name and Title Robert S Cobb II, Senior Staff Engineer

Approved by: (PDP)
Signature [signature] Date 22 Feb 96
Printed Name and Title Eric S. Steinhauser, Senior Project Engineer

Approved by: (DTL and TETL)
Signature [signature] Date 23 Feb 96
Printed Name and Title Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

Rev. No.	Reason	Date	By	Checked	Approval
C	Intermediate Design	—			—
D	Intermediate Design - EPA Submittal	4 Apr 96	[initials]	—	—
G	Final Design Package	4 Oct 96	—	—	[initials]
O	Response to Final Design Cmts	9 May 97	—	—	[initials]

GE3900-08.1/F9530049

Written by: Ganesh Gopalakrishnan GG 5 May 97 Date: 5/5/97 Reviewed by: Ken W. Cargill Date:

Client: FDF Project: OSDF Project/Proposal No.: GQ 0131 Task No.: 12.1

ADDENDUM

(Added to the Revision 0 Package)

Calculations performed in this package for minimum sediment storage volume of the sediment basin are based on assumed drainage areas during the construction/filling/closure of the OSDF. These calculations will be treated as an example for future calculations that will be performed to evaluate the required sediment storage volume of the OSDF sediment basin based on clearly defined drainage areas and other site conditions.

[redacted]

GEOSYNTEC CONSULTANTS

Written by: Asc Date: 21/Feb/96 Reviewed by: GSS Date: 22/Feb/96

lient: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

SURFACE-WATER MANAGEMENT DURING OSDF CONSTRUCTION/FILLING/CLOSURE

OSDF SEDIMENT BASIN

EXECUTIVE SUMMARY

Purpose of Analysis

The purpose of this analysis is to present a summary of the OSDF sediment basin design features.

Method of Analysis

Stormwater Runoff: The amount of stormwater runoff was calculated using the computer program "HydroCAD™ Stormwater Modeling System" (HydroCAD™). This program uses the hydraulic modeling methods presented in USDA-SCS Technical Releases 20 and 55.

Sediment Basin: Due to the need for additional details and phasing requirements, the sediment basin cannot be designed at this time. A initial estimate of the sediment storage volume that the basin will need can be provided. The Ohio Administrative Code, Chapter 3745-27 requires that the "minimum storage volume shall be provided on either the calculated runoff volume from a ten-year/twenty-four-hour storm event, or 0.125 acre-feet per year (for each acre of disturbed area within the upstream drainage area) multiplied by the frequency of pond clean-out (in years), whichever is greater..."

Conclusions

The minimum sediment storage volume required for the sediment basin during OSDF construction/filling/closure is 421,000 cubic-feet.

TABLE OF CONTENTS

SURFACE-WATER MANAGEMENT DURING OSDF CONSTRUCTION/FILLING/CLOSURE
OSDF Sediment Basins

Calculation Procedures

Purpose	1 of 5
Scope	1 of 5
Calculation Procedures	1 of 5
General	1 of 5
Storm Runon and Runoff Quantities	2 of 5
References	5 of 5

Data Verification

Purpose	1 of 4
Scope	1 of 4
Parameters for Design	1 of 4
Rainfall Information	2 of 4
References	4 of 4

Tables

1 Rainfall Depth for a given duration	3 of 4

Calculations

Purpose	1 of 20
Scope	1 of 20
Initial Stripping Summary of Input Data	1 of 20
Early Construction Summary of Input Data	1 of 20
Summary of Calculation Results	3 of 20
Drainage Area Map	5 of 20
Worksheets for weighted runoff curve numbers	8 of 20
HydroCad Runs Runoff	12 of 20

Tables

1 Initial stripping drainage areas	2 of 20
2 Early construction drainage areas	3 of 20
3 Sediment volume results	4 of 20

Appendix A HydroCAD Stormwater modeling System (Manual)	1 of 26

Written by: ASC Date: 19 / Feb / 96 Reviewed by: [illegible] Date: 20 / Feb / 96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

25 Feb 96

SURFACE-WATER MANAGEMENT DURING OSDF CONSTRUCTION/FILLING/CLOSURE

OSDF SEDIMENT BASIN

CALCULATION PROCEDURES

Purpose

The purpose of this document is to present the calculation procedures used to design the sediment basin that will collect the OSDF stormwater runoff during the early construction stages.

The calculations are performed in accordance with, and to verify compliance with, the DCP and Ohio-EPA regulations. The DCP and Ohio-EPA requirements relevant to these calculations are:

- the sediment storage volume shall be the greater of 0.125 acre-feet per disturbed acre or the runoff volume from a ten-year/twenty-four-hour storm event.

Scope

The procedures presented in this document will be used to perform the following calculations for each drainage area and for the design storm event:

- runoff quantities; and
- required storage volumes.

Calculation Procedures

General

The computer program "HydroCAD™ Stormwater Modeling System" [Applied Microcomputer Systems, 1993] (HydroCAD™), will be used to calculate runoff quantities.

Written by: RSC Date: 19 / Feb / 96 Reviewed by: DSS Date: 20 / Feb / 96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

23Feb96

HydroCAD™ uses the hydrologic modeling methods presented in Technical Release 20 (TR20) [USDA-SCS, 1975] and TR55 [USDA-SCS, 1986a]. (See Appendix A for information related to HydroCAD™.)

Stormwater Runon and Runoff Quantities

The procedure for calculating stormwater runoff quantities consists of the following steps.

1. Define the drainage area to be analyzed. These data are presented in the design verification document.

2. Calculate the weighted CN using the runoff curve number worksheet [USDA-SCS, 1986a], except for the OSDF cover slopes. A weighted CN of 98 is assigned for the OSDF final cover slopes.

3. Define the parameters associated with the surface-water flow segments for each drainage area. The flow segments consist of sheet flow, shallow concentrated flow, and open channel flow. The engineering parameters needed to define these flow segments are listed below:

   - for sheet flow:

     - surface type which yields a Manning's coefficient for sheet flow;
     - the flow length (ft);
     - slope of land (ft/ft);

   - for shallow concentrated flow:

     - flow length (ft);
     - surface type (paved or unpaved); and
     - average slope of land (ft/ft); are

   - for open channel flow:

     - Manning's coefficient for open channel flow;
     - channel length (ft);
     - channel slope (ft/ft); and

23 Feb 96

- pertinent channel geometry (e.g., side slopes (H:V) and depth (ft) or cross-sectional area (ft^2), and wetted perimeter (ft)).

These data are also presented in the data verification document.

4. Calculate the amount of runoff for a drainage area, a design storm event, and a vegetative cover type. The data defined in Steps 1 through 3 are used as input to HydroCAD™. HydroCAD™ uses the data to develop a "runoff hydrograph" as described below.

   a. Calculate the Time of Concentration (T_c) for a drainage area. The Tc represents the time required for stormwater to travel from the most hydrologically distance point of a drainage area to the point of interest. Tc is calculated by summing the individual travel times (T_t) for each flow segment define in a drainage area.

   Travel time for each flow segment is calculated as follows:

   for sheet flow:

$$T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5} S^{0.4}}$$

where: T_t = Travel time for sleet flow (hours);
n = Manning's coefficient for sheet flow, based on surface types;
L = flow length (ft);
P_2 = amount of rainfall from a 2-year, 24-hour design storm event (in.); and
S = slope of land (ft/ft).

   for shallow concentrated flow:

$$T_t = \frac{L}{3600V}$$

where: T_t = Travel time for shallow concentrated flow (hours);
L = Flow length (ft);
V = average flow velocity (ft/s).

for open channel flow:

$$T_t = \frac{nL}{(3600)(1.486)r^{0.67}S^{0.5}}$$

where: T_t = Travel time for open channel flow (hours);
n = Manning's coefficient for open channel flow;
L = channel length (ft)
r = hydraulic radius (ft) = a/Pw;
a = cross-sectional area of flow (ft^2);
P_w = wetted perimeter (ft);
S = channel slope (ft).

b. Develop a unit hydrograph for the project site. The unit hydrograph is a dimensionless curve that represent the runoff distribution resulting from 1 in. of rainfall excess over the drainage area. To develop a unit hydrograph, HydroCAD™ uses the CN value and the anticipated rainfall distribution. HydroCAD™ then develops a runoff hydrograph for the design storm event. HydroCAD™ develops the runoff hydrograph by summing the amount of runoff calculated over a series of discrete time intervals during the storm event. The amount of runoff is calculated as follows:

$$Q = \frac{(P-0.2S)^2}{P+0.8S} \quad (Q = \text{zero if } P < 0.2S)$$

where: Q = amount of runoff (in.);
P = cumulative rainfall (in.);
S = potential maximum retention after runoff begins (in.);
S = 1000/CN - 10
CN = runoff curve number.

The discrete time interval or rainfall burst duration for which runoff calculations are performed is calculated as follows:

$$D = \frac{2}{15}Tc$$

where: D = duration (hours); and
T_c = time of concentration (hours).

23 Feb 96

5. The resulting runoff hydrograph provides the runoff quantities for the storm event as well as the peak runon/runoff quantity.

6. Multiply the drainage area to be analyzed by 0.125 acre-feet per acre for alternate sediment storage volume.

References

Applied Microcomputer Systems, "HydroCAD™ Stormwater Modeling System," version 3.10, Chocorna, NH, 1993.

Chow, "Open Channel Hydraulics," 1959

USDA-SCS, "Computer Program for Project Formulation, Hydrology", Technical Release 10 (TR20), U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., 1975.

USDA - SCS "National Engineering Handbook, Section 4 - Hydrology," Washington, DC, Mar 1985.

USDA-SCS, *"Urban Hydrology for Small Watersheds"*, Technical Release 55 (TR55), U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., 2nd Edition, 1986a.

USDA-SCS, *"Engineering Field Manual for Conservation Practices"*, U.S. Department of Agriculture, Soil conservation Service, Washington, D.C., 1986b.

USDA-SCS, *"Water Management and Sediment Control for Urbanizing Areas"*, U.S. Department of Agriculture, Soil Conservation Services, Washington, D.C., 1987.

GEOSYNTEC CONSULTANTS

Written by: Rsc Date: 19/Feb/96 Reviewed by: JSS Date: 20/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

23Feb96

SURFACE-WATER MANAGEMENT DURING CONSTRUCTION/FILLING/CLOSURE

OSDF SEDIMENT BASIN

DATA VERIFICATION

PURPOSE

The purpose of this document is to present the engineering data used to design the sediment basin that will collect the stormwater runoff during the early construction stage of the On-Site Disposal Facility (OSDF).

The data presented in this document are used to satisfy the requirements presented in the DCP and Ohio-EPA Administrative Code. The Ohio-EPA requirements relevant to the data verification are:

- the sediment basin shall be designed to retain the runoff from the 10-year, 24-hour design storm event; or
- 0.125 acre-feet of sediment per disturbed acre.

SCOPE

The data presented in this document will be used to perform the following calculations:

- runoff quantities; and
- sediment storage volumes.

PARAMETERS FOR DESIGN

General

Data required to perform the calculations include: (i) rainfall information (i.e., quantities, durations, distribution); (ii) drainage area information (i.e., drainage channel dimensions and geometries, Manning's coefficients for sheet flow and open channel flow, soil and vegetative cover types); and (iii) culvert information (i.e., size, type, cover,

RC 23 Feb 96

loadings). All data are provided in Section 12.1, Surface-Water Management During Construction/Filling/Closure, with the exception of the 10-year, 24-hour rainfall quantity.

Rainfall Information

Rainfall Quantities and Durations

Rainfall quantities for specific design storm events were summarized by Parsons [1995] and are presented in Table 1. Rainfall for the design storm required by the DCP or by the Ohio-EPA include:

Storm Event	Rainfall (in.)
2-Year, 24-Hour	2.55
10-Year, 24-Hour	4.1
25-Year, 24-Hour	4.7

Asc 2/19/96 3/4

RSS 20feb96 23Feb96

TABLE 1 - RAINFALL DEPTH FOR A GIVEN DURATION (INCHES)

DURATION (YEARS)	TIME							
	HYDRO-35			TP-40				
	5 MIN	15 MIN	60 MIN	2 HOURS	3 HOURS	6 HOURS	12 HOURS	24 HOURS
2	0.387	0.739	1.223	1.408	1.54	1.848	2.2	2.552
5	0.49	0.979	1.69	2.016	2.112	2.496	2.88	3.072
10	0.564	1.139	1.99	2.277	2.475	3.069	3.465	4.059
25	0.65	1.34	2.38	2.6	3.0	3.4	4.0	4.7
50	0.72	1.49	2.67	3.0	3.25	3.9	4.2	5.2
* 100	0.78	1.64	2.95	3.3	3.6	4.1	5.0	5.6
* 500	0.93	2.1	4.3	5.2	5.9	7.3	8.5	9.4
2000	1.2	2.6	5.8	7.2	8.2	10.2	12.0	13.0
10,000	1.4	3.4	8.2	10.5	12.0	15.5	18.0	19.2
100,000	1.9	5.0	13.3	17.7	20.8	27.4	31.8	33.4
	DESIGN OF SMALL DAMS					HMR-51		

NOTE: Rainfall Points For 2, 5, and 10 year rainfall events were adjusted per TP-40. Values for the 500, 2000, and 10,000 Year Events were interpolated from Figure 3 (Appendix E)

* These values are used on PH Records for HEC-1.

REF: PARSONS, "2,000-YEAR FLOOD AND PROBABLE MAXIMUM FLOOD, SITEWIDE FLOOD PLAIN DETERMINATION", AUG 1995.

Written by: Asc Date: 19 /Feb/ 96 Reviewed by: SSS Date: 20 /Feb/ 96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

23 Feb 96

REFERENCES

Chow, *"Open Channel Hydraulics"*, 1959.

Earth Systems Associates, *"Vegetation Cover Recommendations for the On-Site Disposal Facility at the Fernald Environmental Management Project Site"*, February 1996.

GeoSyntec Consultants, *"Design Criteria Package"*, document in preparation.

Parsons Engineering, *"2000-Year Flood and Probable Maximum Flood, Sitewide Flood Plain Determination"*, Revision A, Aug 1995.

USDA-SCS, *"National Engineering Handbook, Section 4 - Hydrology"*, U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., Mar 1985.

USDA-SCS, *"Urban Hydrology for Small Watersheds"*, Technical Release 55 (TR-55), U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., Jun 1986a.

USDA-SCS, *"Engineering Field manual for Conservation Practices"*, U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., Nov 1986b.

USDA-SCS, *"Water Management and Sediment Control for Urbanizing Areas'*, U.S. Department of Agriculture, Soil Conservation Services, Washington, D.C., 1987.

Written by: RJC Date: 21/Feb/96 Reviewed by: [illegible] Date: 28/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

SURFACE-WATER MANAGEMENT DURING OSDF CONSTRUCTION/FILLING/CLOSURE

OSDF SEDIMENT BASIN

CALCULATIONS

Purpose

The purpose of this document is to provide the engineering calculations used in the design of the sediment basin system during the early construction stages.

Scope

The calculation procedures used in this document are presented in the calculations procedures document. The data used in the calculations is presented in the data verification document.

For clarity, these calculations are divided into 3 sections: (i) runoff after initial stripping; (ii) runoff during early construction; and (iii) total disturbed area sediment volume. In general, each set of calculations consists of: (i) a summary of the input data; (ii) a summary of the calculation results; and (iii) the calculations (i.e., worksheets, computer runs).

Initial Stripping Summary of Input Data

A summary of the HydroCAD™ input data is presented in Table 1.

Early Construction Summary of Input Data

A summary of the HydroCAD™ input data is presented in Table 2.

Disturbed Area Sediment Volume

The alternate sediment storage volume is:

$$43.5 \text{ acres} \times 0.125 \text{ AF/acre} = 5.4 \text{ acre-feet}$$
$$= 237{,}000 \text{ cubic feet}$$

Table 1. Initial Stripping Drainage Areas

			Sheet Flow			Shallow Concentrated Flow			Open Channel Flow					
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	Total Length (ft)	Manning's n	Depth (ft)	Channel Slope (%)	Right Slope	Left Slope
E	29.0	90	100	0.02	fallow	240	0.02	unpaved	2,570	0.05	4.5	0.5	3:1	3:1
W	14.5	90	100	0.02	fallow	340	0.010	unpaved	2,120	0.05	4.5	0.5	3:1	3:1

Acc 21 Feb 96
2/16/96

739
2/20

Early Construction

Table 2. ~~Initial Stripping~~ Drainage Areas

			Sheet Flow			Shallow Concentrated Flow			Open Channel Flow					
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	Total Length (ft)	Manning's n	Depth (ft)	Channel Slope (%)	Right Slope	Left Slope
E	15.6	94	147	0.07	fallow	325	0.167	unpaved	2,150	0.05	4.5	0.5	3:1	3:1
W	20.6	97	147	0.07	fallow	325	0.167	unpaved	2,630	0.05	4.5	0.5	3:1	3:1

Asc 21 Feb 96
RSS
21 Feb 96

Written by: RSC Date: 21/Feb/96 Reviewed by: [illegible] Date: 21 Feb 1996

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

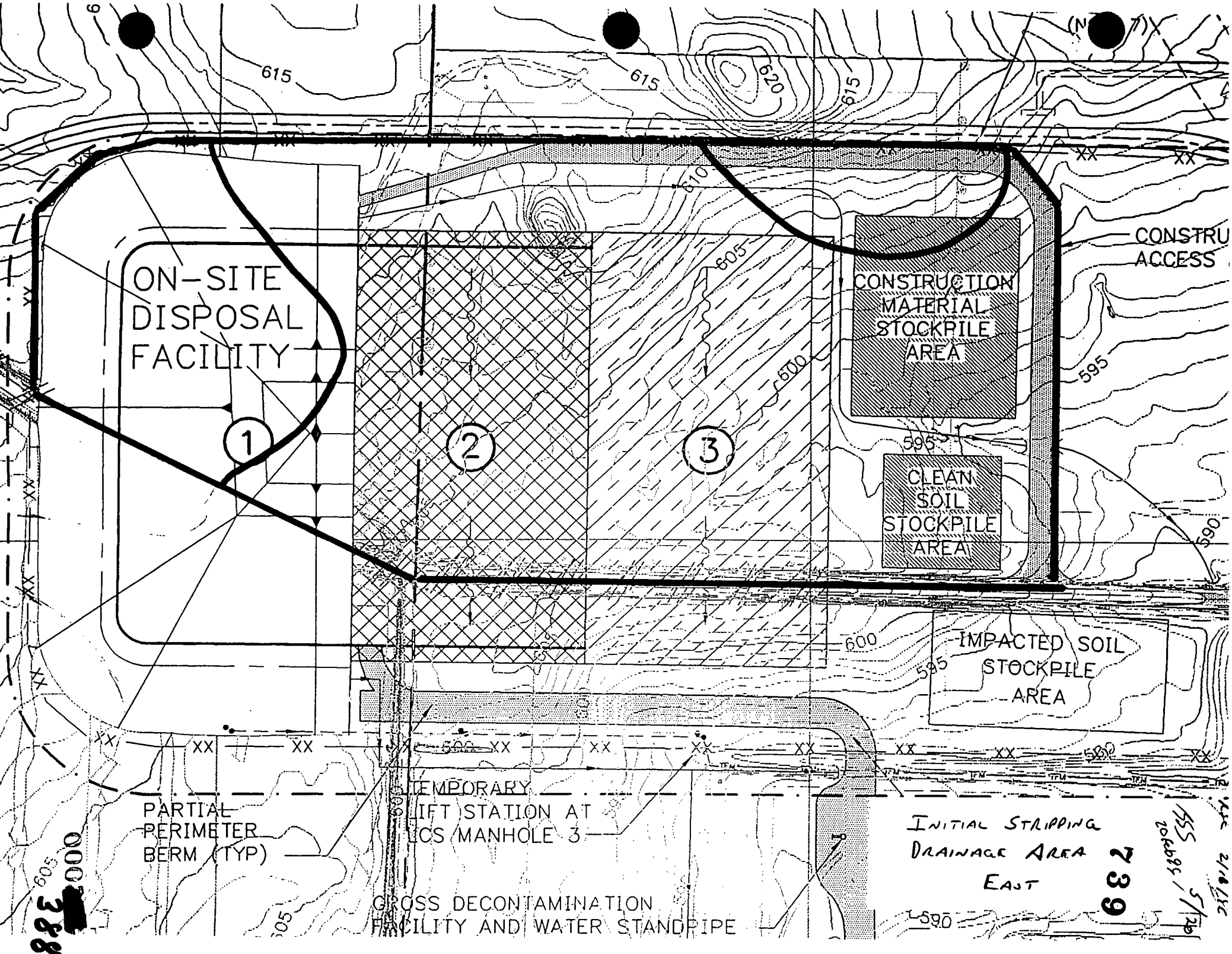
Summary of Calculation Results

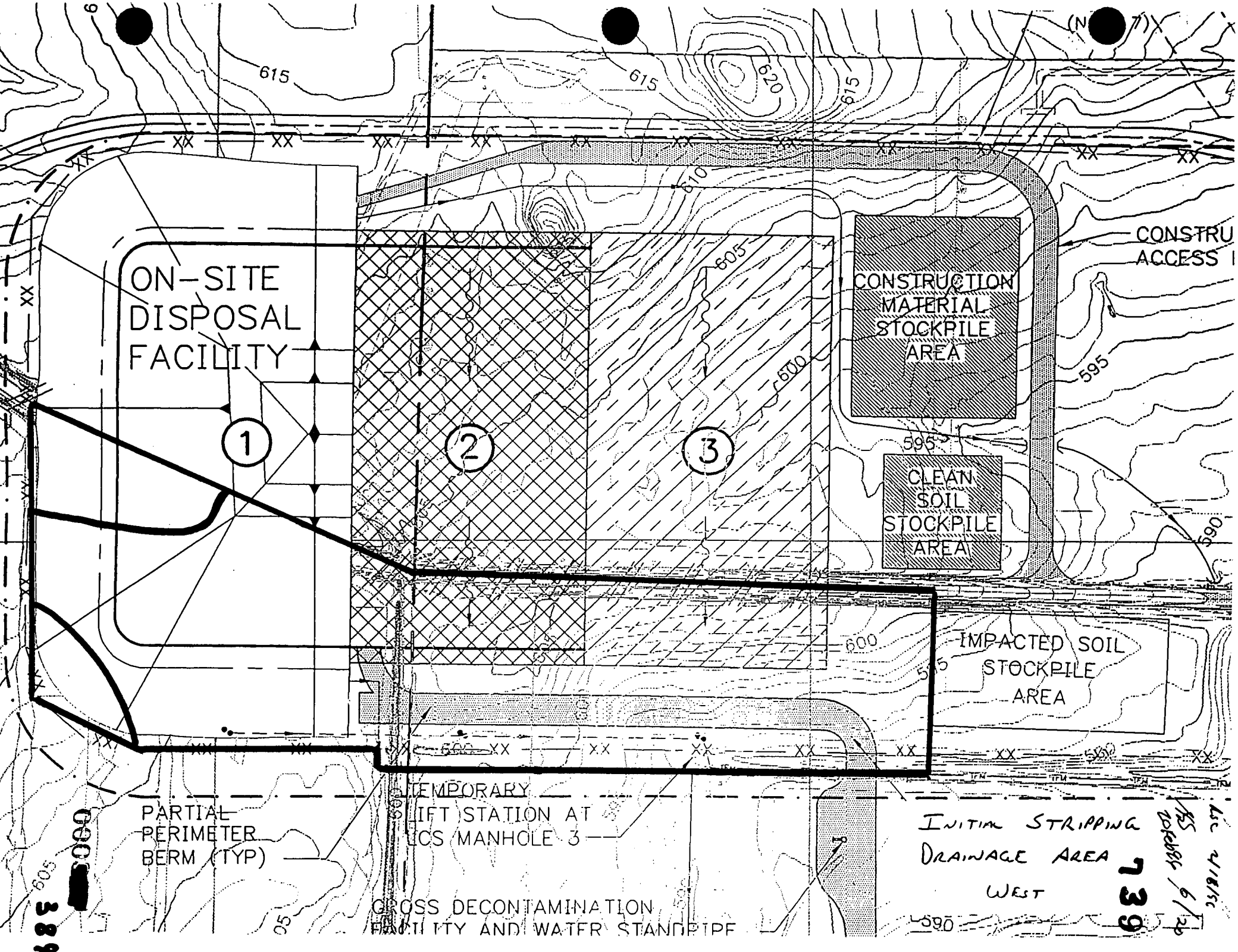
A summary of the calculation results is presented in Table 3.

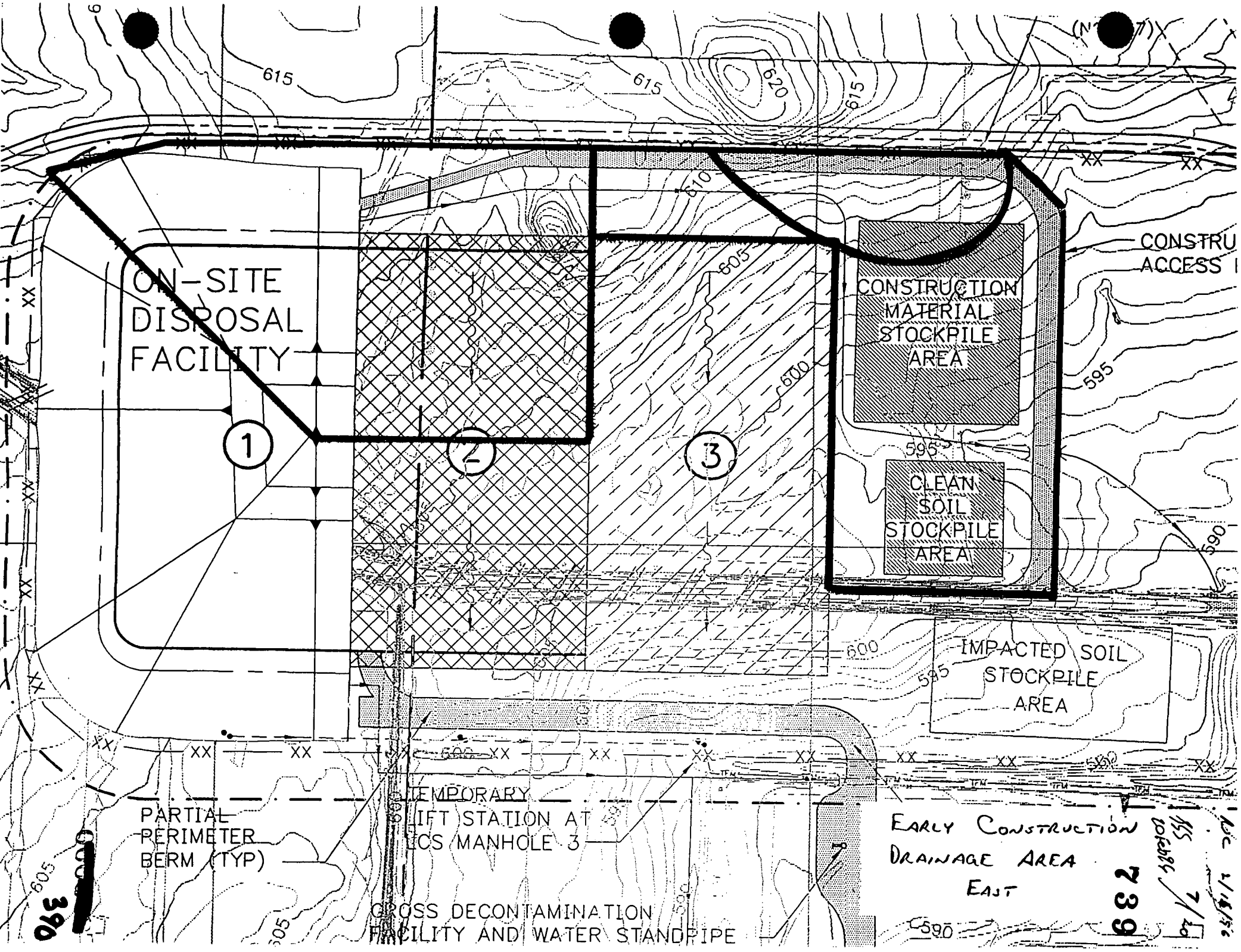
Table 3. Sediment Volume Results

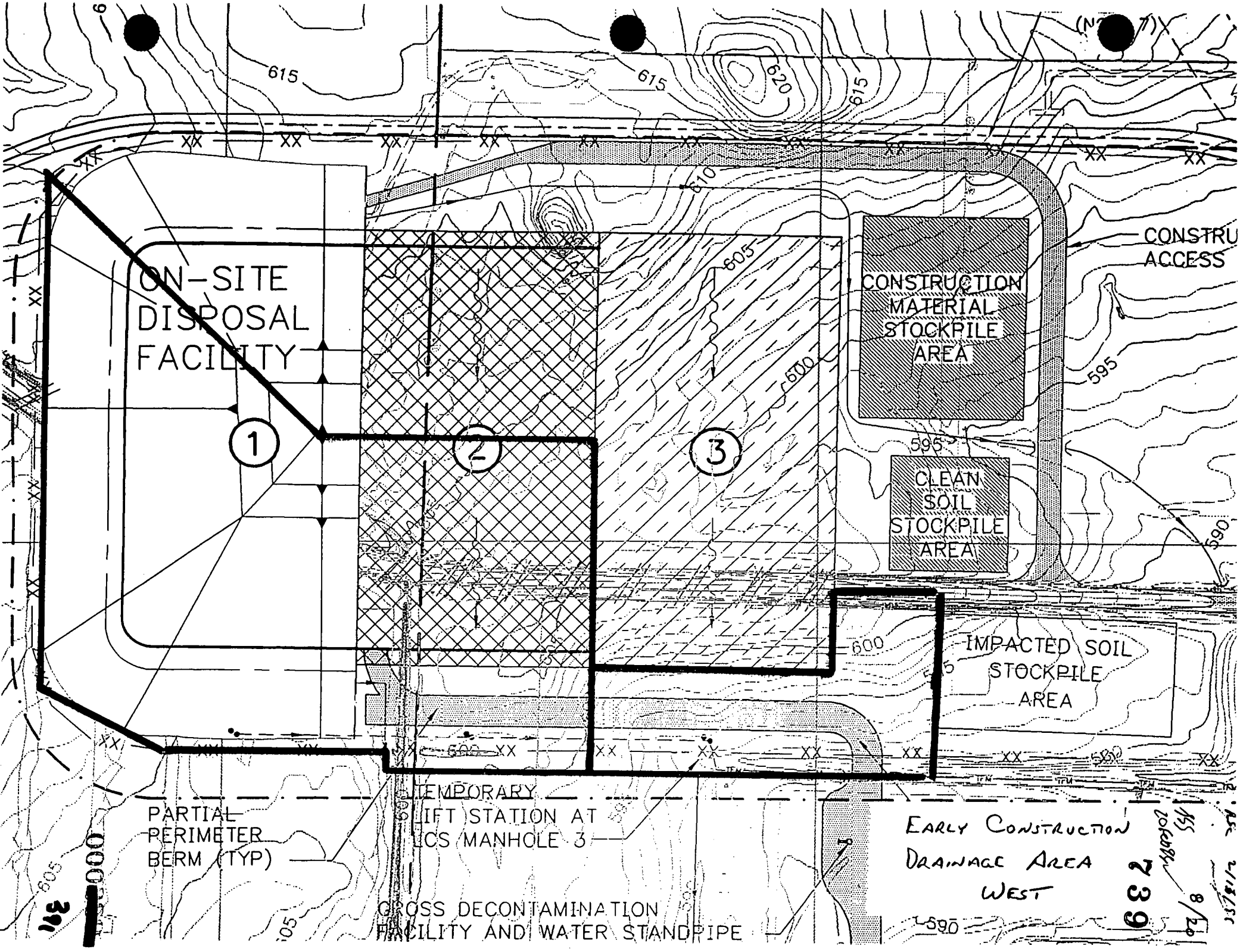
Case	Required Sediment Storage Volume (CF)
Initial Stripping, 10-Year Storm	421,000
Early Construction, 10-Year Storm	399,000
Disturbed Area Method	237,000

DRAINAGE AREA MAPS


ON-SITE DISPOSAL FACILITY
1
2
3
CONSTRUCTION MATERIAL STOCKPILE AREA
CLEAN SOIL STOCKPILE AREA
IMPACTED SOIL STOCKPILE AREA
CONSTRU
ACCESS
PARTIAL PERIMETER BERM (TYP)
TEMPORARY LIFT STATION AT LCS MANHOLE 3
GROSS DECONTAMINATION FACILITY AND WATER STANDPIPE
INITIAL STRIPPING DRAINAGE AREA EAST
615
620
610
605
600
595
590


ON-SITE DISPOSAL FACILITY
1
2
3
CONSTRUCTION MATERIAL STOCKPILE AREA
CLEAN SOIL STOCKPILE AREA
IMPACTED SOIL STOCKPILE AREA
CONSTRU
ACCESS
PARTIAL PERIMETER BERM (TYP)
TEMPORARY LIFT STATION AT LCS MANHOLE 3
GROSS DECONTAMINATION FACILITY AND WATER STANDPIPE
INITIAL STRIPPING DRAINAGE AREA WEST
615
620
610
605
600
595
590


ON-SITE DISPOSAL FACILITY
1
2
3
CONSTRUCTION MATERIAL STOCKPILE AREA
CLEAN SOIL STOCKPILE AREA
IMPACTED SOIL STOCKPILE AREA
CONSTRU
ACCESS
PARTIAL PERIMETER BERM (TYP)
TEMPORARY LIFT STATION AT ICS MANHOLE 3
GROSS DECONTAMINATION FACILITY AND WATER STANDPIPE
EARLY CONSTRUCTION DRAINAGE AREA EAST
615
620
610
605
600
595
590


ON-SITE DISPOSAL FACILITY
1
2
3
CONSTRUCTION MATERIAL STOCKPILE AREA
CLEAN SOIL STOCKPILE AREA
IMPACTED SOIL STOCKPILE AREA
CONSTRU ACCESS
PARTIAL PERIMETER BERM (TYP)
TEMPORARY LIFT STATION AT LCS MANHOLE 3
GROSS DECONTAMINATION FACILITY AND WATER STANDPIPE
EARLY CONSTRUCTION DRAINAGE AREA WEST
615
620
610
605
600
595
590

WORKSHEETS FOR

WEIGHTED RUNOFF CURVE NUMBERS

Worksheet 2: Runoff curve number and runoff

Project FERMCO - OSDF By RSC Date 16 FEB 96

Location INITIAL STRIPPING (E) Checked BS Date 20 Feb 96

Circle one: Present Developed

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
RUSSELL - MIAMIAN B	BARE GROUND	86			1.8	154.8
FINCASTLE C	" "	91			21.6	1965.6
XENIA B	" "	86			5.6	481.6
					Totals = 29.0	2602.0

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{2602.0}{29.0} = 89.7$; Use CN = 90

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

Worksheet 2: Runoff curve number and runoff

Project FERMCO - OSDF By ASC Date 16 FEB 96

Location INITIAL STRIPPING (W) Checked KS Date 20Feb96

Circle one: Present Developed

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
FINCASTLE C	BARE GROUND	91			13.0	1183.0
XENIA B	" "	86			1.5	129.0
					Totals =	14.5 / 1312.0

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{1312.0}{14.5} = 90.5$; Use CN = 90

~~2. Runoff~~

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in			

(Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)

Worksheet 2: Runoff curve number and runoff

Project FERMCO - OSDF By RSC Date 16 FEB 96

Location EARLY CONSTRUCTION (E) Checked RS Date 20 Feb 96

Circle one: Present (Developed)

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
COVER	BARE GROUND	98			8.2	803.6
RUSSELL-MIAMIAN B	" "	86			1.8	154.8
FINCASTLE C	" "	91			5.6	509.6
					Totals = 15.6	1468.0

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{1468.0}{15.6} = 94.1$; Use CN = 94

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr			
Rainfall, P (24-hour)	in			
Runoff, Q (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)	in			

Worksheet 2: Runoff curve number and runoff

Project FERMCO OSDF By RSC Date 16 FEB 96

Location EARLY CONSTRUCTION (W) Checked HSS Date 20Feb96

Circle one: Present. Developed

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒acres ☐mi² ☐%	Product of CN x area
COVER	BARE GROUND	98			16.3	1597.4
FINCASTLE C	" "	91			4.3	391.3
					Totals = 20.6	1988.7

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{1988.7}{20.6} = 96.5$; Use CN = 97

~~2. Runoff~~

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

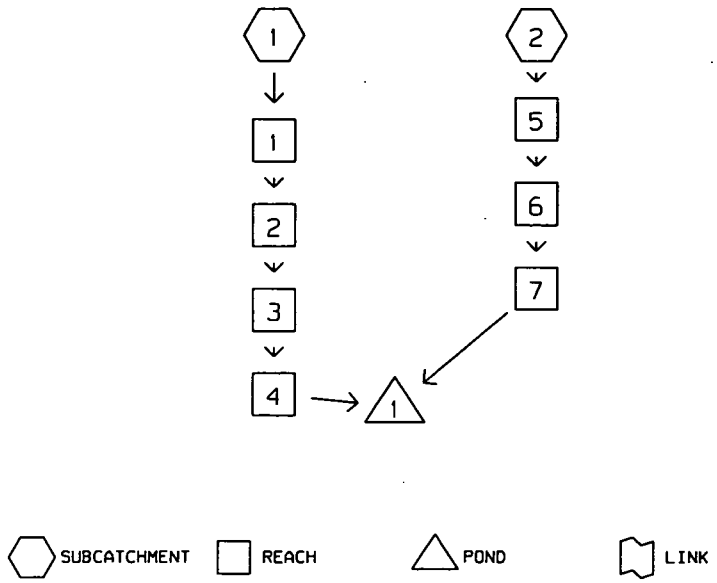
HYDROCAD™ RUNS

RUNOFF

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 21 Feb 96

WATERSHED ROUTING ==========



739 13/20

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

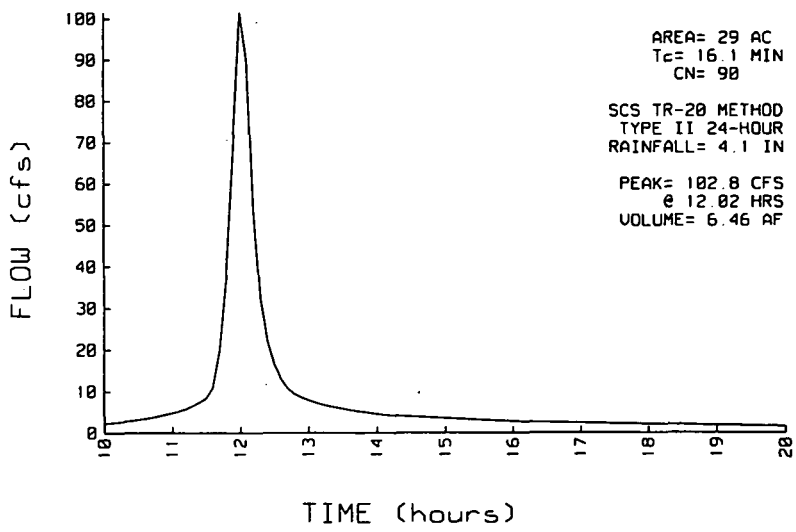
SUBCATCHMENT 1 **INITIAL STRIPPING - EAST**

ACRES	CN
29.00	90

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.1 IN
PEAK= 102.8 CFS @ 12.02 HRS
VOLUME= 6.46 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	4.5
Fallow n=.05 L=100' P2=2.6 in s=.02 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	1.8
Unpaved Kv=16.1345 L=240' s=.02 '/' V=2.28 fps		
CHANNEL FLOW	**Segment ID:**	9.8
a=60.8 sq-ft Pw=28.5' r=2.133'		
s=.005 '/' n=.05 V=3.48 fps L=2050' Capacity=211.7 cfs		
	Total Length= 2390 ft Total Tc=	16.1

SUBCATCHMENT 1 RUNOFF
INITIAL STRIPPING - EAST



[redacted]

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

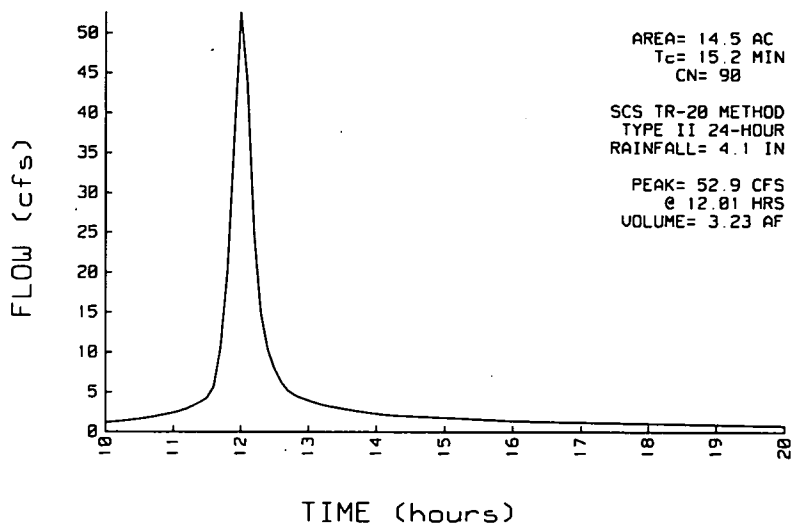
SUBCATCHMENT 2 **INITIAL STRIPPING AREA - WEST**

ACRES	CN
14.50	90

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.1 IN
PEAK= 52.9 CFS @ 12.01 HRS
VOLUME= 3.23 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	4.5
Fallow n=.05 L=100' P2=2.6 in s=.02 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	3.5
Unpaved Kv=16.1345 L=340' s=.01 '/' V=1.61 fps		
CHANNEL FLOW	**Segment ID:**	7.2
a=60.8 sq-ft Pw=28.5' r=2.133'		
s=.005 '/' n=.05 V=3.48 fps L=1500' Capacity=211.7 cfs		
	Total Length= 1940 ft Total Tc=	15.2

SUBCATCHMENT 2 RUNOFF
INITIAL STRIPPING AREA - WEST



[redacted]

739 14' 20

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

POND 1 **SEDIMENT POND STORAGE VOLUME**

STARTING ELEV= 0.0 FT
FLOOD ELEV= 6.0 FT

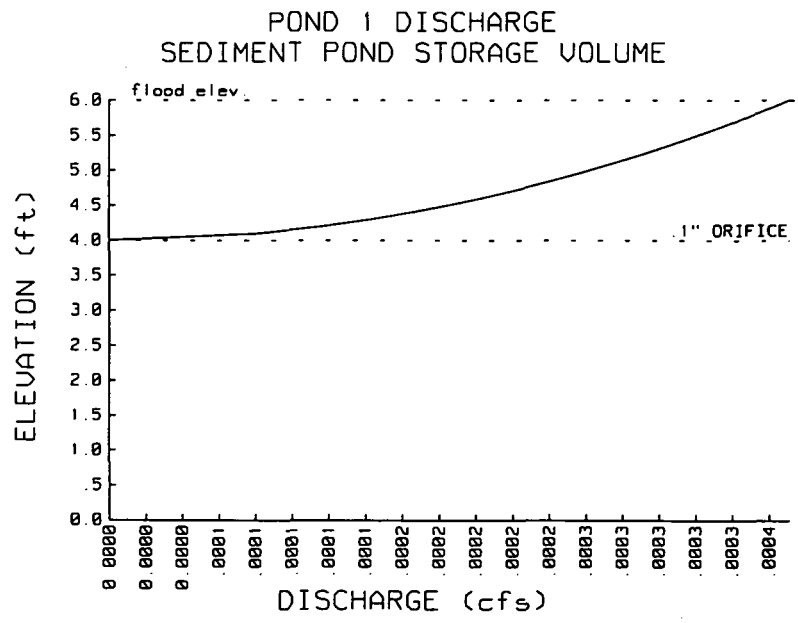
ELEVATION (FT)	INC.STOR (CF)	CUM.STOR (CF)
0.0	0	0
1.0	10000	10000
2.0	20000	30000
3.0	40000	70000
4.0	80000	150000
5.0	100000	250000
6.0	200000	450000

STOR-IND METHOD
PEAK ELEVATION= 5.9 FT
PEAK STORAGE = 420692 CF
Qin = 148.4 CFS @ 12.07 HRS
Qout= 0.0 CFS @ 20.00 HRS
ATTEN=100 % LAG= 475.8 MIN
IN/OUT= 9.67 / 0.00 AF

INVERT (FT)	OUTLET DEVICES
4.0	**.1" ORIFICE**
	Q=.6 PI r^2 SQR(2g) SQR(H-r)

TOTAL DISCHARGE vs ELEVATION

FEET	0.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.0	0.0									



[redacted]

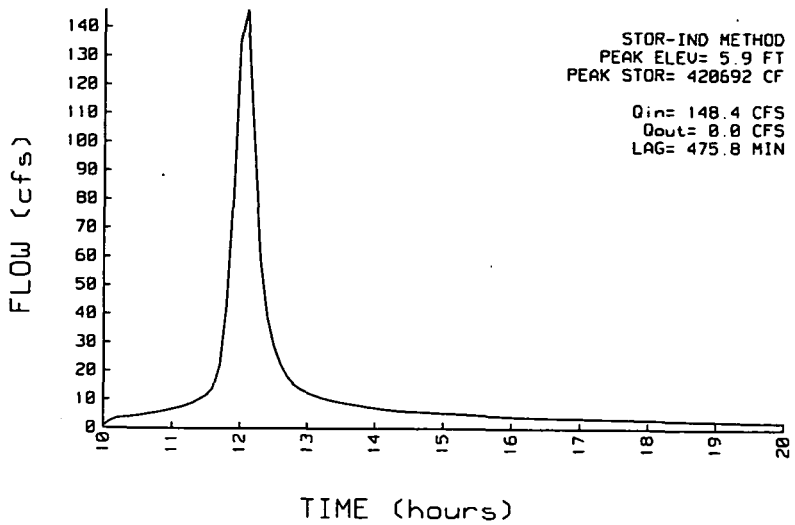
401

Data for **FERMCO, INITIAL STRIPPING DRAINAGE AREAS**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

21 Feb 96

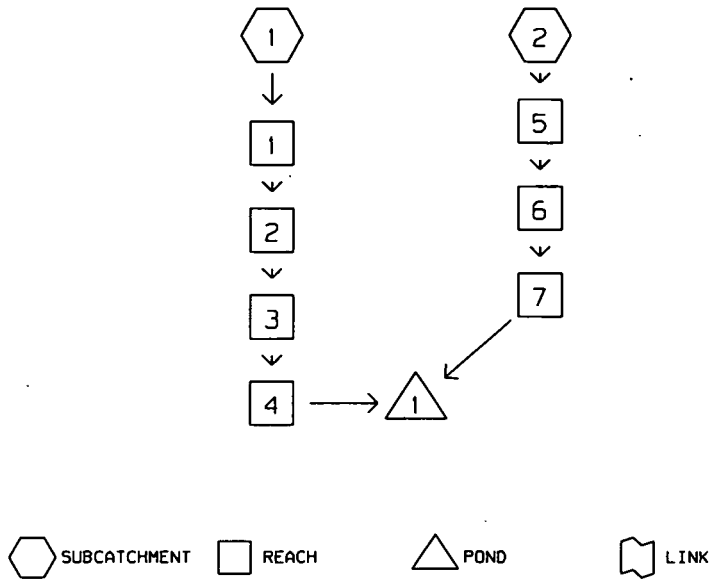
PSC

POND 1 INFLOW & OUTFLOW
SEDIMENT POND STORAGE VOLUME



[redacted]

WATERSHED ROUTING ==========



739 17/20

Data for **FERMCO, EARLY CONSTRUCTION DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

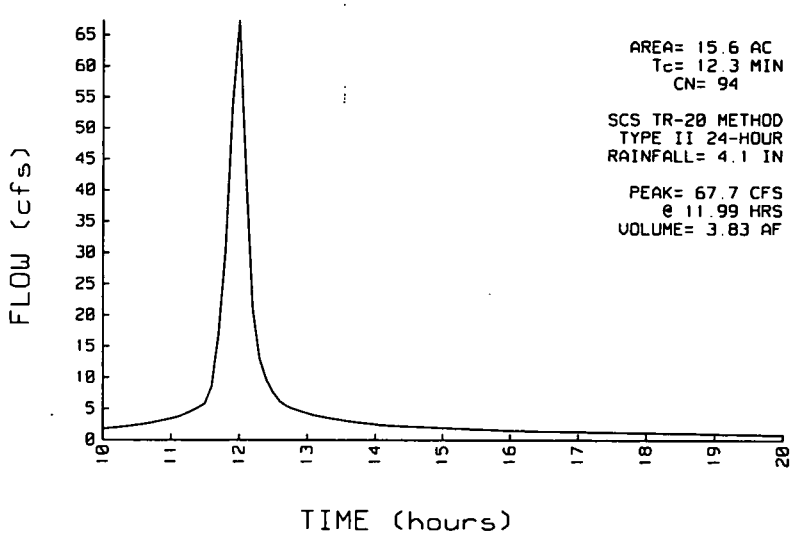
SUBCATCHMENT 1 **EARLY CONSTRUCTION - EAST**

ACRES	CN
15.60	94

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.1 IN
PEAK= 67.7 CFS @ 11.99 HRS
VOLUME= 3.83 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	3.7
Fallow n=.05 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=325' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	7.8
a=60.8 sq-ft Pw=28.5' r=2.133'		
s=.005 '/' n=.05 V=3.48 fps L=1630' Capacity=211.7 cfs		
	Total Length= 2102 ft Total Tc=	12.3

SUBCATCHMENT 1 RUNOFF
EARLY CONSTRUCTION - EAST



[redacted]

404

Data for **FERMCO, EARLY CONSTRUCTION DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

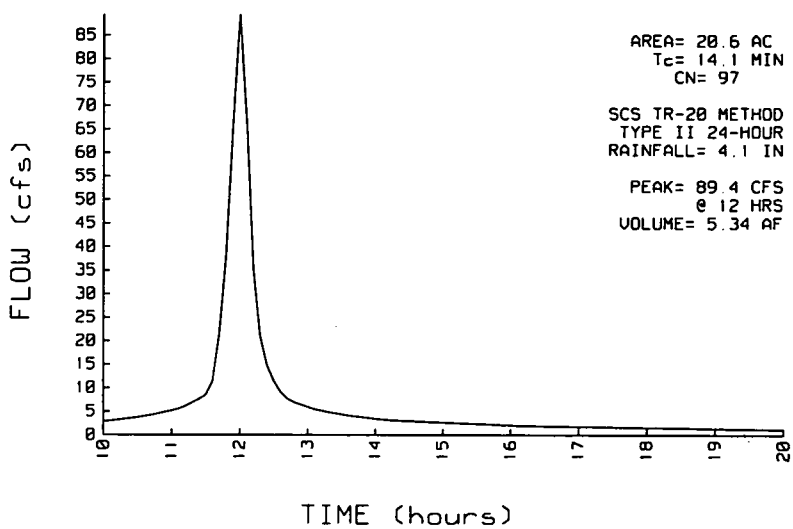
SUBCATCHMENT 2 **EARLY CONSTRUCTION AREA - WEST**

ACRES	CN
20.60	97

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.1 IN
PEAK= 89.4 CFS @ 12.00 HRS
VOLUME= 5.34 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	3.7
Fallow n=.05 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=325' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	9.6
a=60.8 sq-ft Pw=28.5' r=2.133'		
s=.005 '/' n=.05 V=3.48 fps L=2010' Capacity=211.7 cfs		
	Total Length= 2482 ft Total Tc=	14.1

SUBCATCHMENT 2 RUNOFF
EARLY CONSTRUCTION AREA - WEST



[redacted]

Data for **FERMCO, EARLY CONSTRUCTION DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

POND 1 **SEDIMENT STORAGE QUANTITIY**

STARTING ELEV= 0.0 FT
FLOOD ELEV= 6.0 FT

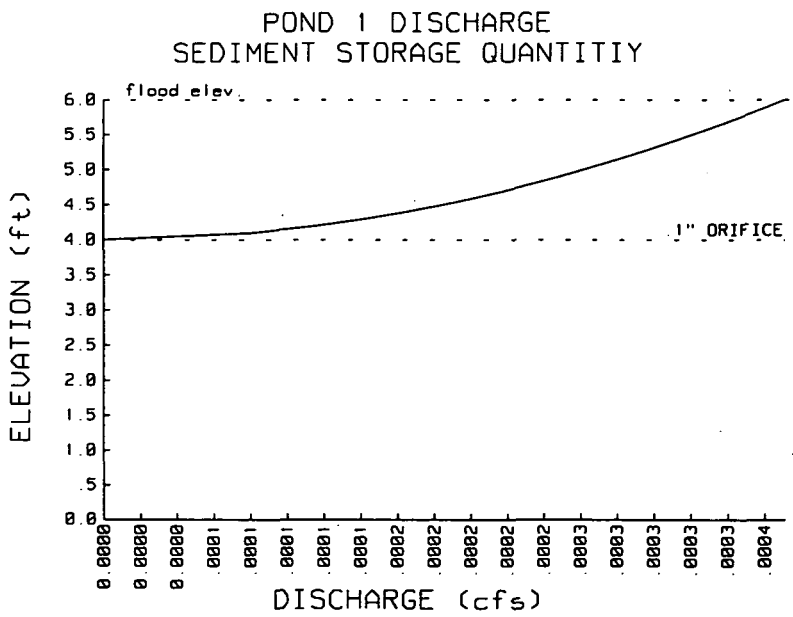
ELEVATION (FT)	INC.STOR (CF)	CUM.STOR (CF)
0.0	0	0
1.0	10000	10000
2.0	20000	30000
3.0	40000	70000
4.0	80000	150000
5.0	100000	250000
6.0	200000	450000

STOR-IND METHOD
PEAK ELEVATION= 5.7 FT
PEAK STORAGE = 398025 CF
Qin = 145.9 CFS @ 12.03 HRS
Qout= 0.0 CFS @ 20.00 HRS
ATTEN=100 % LAG= 478.1 MIN
IN/OUT= 9.15 / 0.00 AF

INVERT (FT)	OUTLET DEVICES
4.0	**.1" ORIFICE**
	Q=.6 PI r^2 SQR(2g) SQR(H-r)

TOTAL DISCHARGE vs ELEVATION

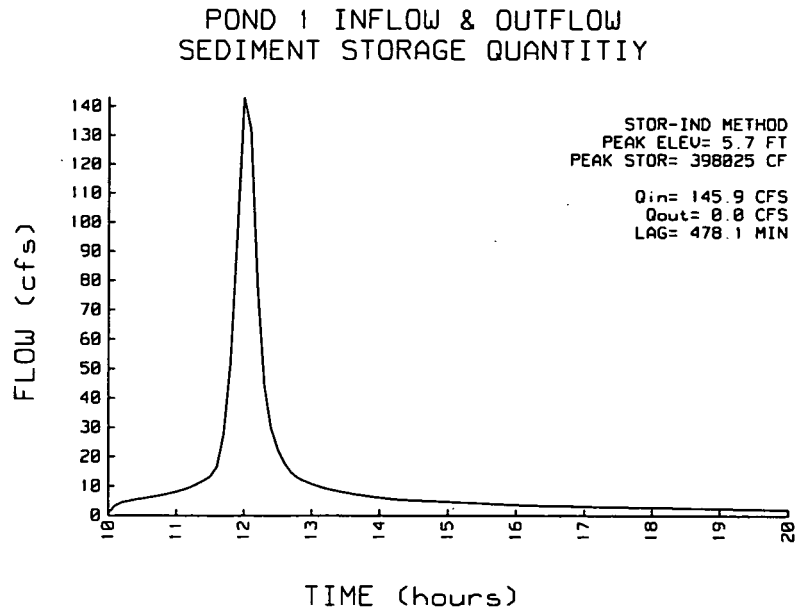
FEET	0.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6.0	0.0									



[redacted]

Data for **FERMCO, EARLY CONSTRUCTION DRAINAGE AREAS**
Prepared by GeoSyntec Consultants 21 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

TSS 226089



[redacted]

APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATION PACKAGE HydroCAD™ STORMWATER MODELING SYSTEM

Applied Microcomputer Systems, *"HydroCAD™ Stormwater Modeling System"*, version 3.10, Chocorva, NH, 1993.

For documentation of computer programs see

1.2 Computer Program Validation

SECTION 13

13. SURFACE-WATER MANAGEMENT AFTER OSDF CLOSURE

13.1 Stormwater Runon/Runoff and Drainage Control Structures
13.2 Drainage Control Structure Erosion Resistance

13.1 Stormwater Runon/Runoff and Drainage Control Structures

- Northern Area Calculations
- Eastern Area Calculations
- Southern Area Calculations
- Western Area Calculations
- Addendum to Southern Area Calculations of 13.1

COMPUTATION COVER SHEET

SUBJECT OF CALCULATION: SURFACE-WATER MANAGEMENT AFTER OSDF CLOSURE - STORMWATER RUNON/RUNOFF AND DRAINAGE CONTROL STRUCTURES

Computations By: (Cognizant Engineer)
Signature: [signature] 2 Feb 96
Date 2/16/96
Printed Name and Title: ROBERT S COBLE II, SENIOR STAFF ENGINEER; R. DAVID ESPINOZA, ASSISTANT PROJECT ENG.

Assumptions and Procedures Checked by: (Checker)
Signature: [signature] 9 Feb 96 // 16 Feb 96
Date
Printed Name and Title: ERIC S. STEINHAUSER, SENIOR PROJECT ENGINEER

Computations Checked by:
Signature: [signature] 12 Feb 96 // 16 Feb 96
Date
Printed Name and Title: ERIC S. STEINHAUSER, SENIOR PROJECT ENGINEER

Computations Backchecked by: (Cognizant Engineer)
Signature: [signature] 14 Feb 96
Date 02/16/96
Printed Name and Title: ROBERT S COBLE II, SENIOR STAFF ENGINEER; R. David Espinoza, Assistant project Eng.

Approved by: (PDP)
Signature: [signature] 16 Feb 96
Date
Printed Name and Title: ERIC S. STEINHAUSER, SENIOR PROJECT ENGINEER

Approved by: (DTL and TETL)
Signature: [signature] 21 Feb 96
Date
Printed Name and Title: Kenneth W Cargill, Associate

Record of Revision (Number and initial all revisions)

NO.	REASON	DATE	BY	CHECKED	APPROVAL	
C	Intermediate Design	21 Feb 96			21 Feb 96	
F	Pre Final Design	25 Jun 96			25 Jun 96	Changes to Southern Area Calc.
G	Final Design Package	4 Oct 96				
O	Response to Final Design Cmts	9 May 97				

Signature: _____
Number: _____
Registration Stamp (if applicable)

GE3900-08.1/~~E953002T~~.CAL
F96 30074 MB

Written by: RSC Date: 1/Feb/96 Reviewed by: SSS Date: 15/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

21 Feb 96

SURFACE-WATER MANAGEMENT AFTER CLOSURE

STORMWATER RUNON/RUNOFF AND DRAINAGE CONTROL STRUCTURES

EXECUTIVE SUMMARY

Purpose of Analysis

The purpose of this analysis is to evaluate the surface-water management system after the On-Site Disposal Facility (OSDF) is closed. This system is designed to protect the OSDF from damage caused by stormwater runon and runoff by diverting stormwater around the OSDF to existing watercourse. This system consists of drainage channels constructed around the perimeter of the OSDF.

Method of Analysis

Stormwater Runon and Runoff: The amount of stormwater runon and runoff was calculated using the computer program "HydroCAD™ Stormwater Modeling System" (HydroCAD™). This program uses the hydraulic modeling methods presented in USDA-SCS Technical Releases 20 and 55.

Drainage Control Structures: The performance of the drainage channels to be constructed around the OSDF was evaluated using HydroCAD™. The performance of culverts was evaluated using methods presented in USDOT FHWA technical report entitled "Hydraulic Design of Highway Culverts" and the "Concrete Pipe" Design Manual", by the American Concrete Pipe Association.

Conclusions

Runon/runoff from the 2,000-year, 24-hour design storm event can be controlled without damaging the OSDF. The drainage channels constructed around the OSDF will not scour or accumulate excessive sediment.

TABLE OF CONTENTS

SURFACE WATER MANAGEMENT AFTER OSDF CLOSURE
Stormwater Runon/Runoff and Drainage Control structures

Calculation Procedures

Purpose	1 of 10
Scope	2 of 10
Calculation Procedures	2 of 10
General	2 of 10
Storm Runon and Runoff Quantities	3 of 10
Peak flow Velocities and Maximum Depth of Flow in Drainage Channels	6 of 10
Culvert Outlet Protection	8 of 10
References	10 of 10

Data Verification

Purpose	1 of 45
Scope	2 of 45
Parameters for Design	2 of 45
General	2 of 45
Rainfall Information	2 of 45
Rainfall Quantities and Durations	2 of 45
Rainfall Distribution	2 of 45
2,000-Year Flood elevation	3 of 45
Drainage Area Data	3 of 45
Drainage Areas	3 of 45
Drainage Flow Types	3 of 45
Hydrology Soil Group (HSG)	4 of 45
Vegetative Cover Type	4 of 45
Hydrologic Condition	4 of 45
Runoff Curve Numbers	5 of 45
Antecedent Runoff Conditions	5 of 45
Vegetation	5 of 45
Summary	6 of 45
Culverts	6 of 45
References	6 of 45

Tables

1	Rainfall depth for a given duration	8 of 45
2	Roughness coefficients (Manning's n) for sheet flow	9 of 45

3	Classification of vegetation cover as to degree of retardance	10 of 45
4	Manning's roughness coefficients	11 of 45
5	Hydrologic soil group for United States soils	12 of 45
6a	Runoff curve numbers for cultivated agricultural lands	19 of 45
6b	Runoff curve numbers for other cultivated agricultural lands	20 of 45
6c	Runoff curve numbers for arid and semiarid range lands	21 of 45
6d	Runoff curve numbers for urban areas	22 of 45
7	Curve numbers (CN) and constants for the case Ia = 0.2 S	23 of 45
8	Northern area input parameters 25-year and 2000-year storm event	24 of 45
9	Eastern area input parameters 25-year and 2000-year storm event	25 of 45
10	Southern area input parameters 25-year and 2000-year storm event	27 of 45
11	Western area input parameters 25-year storm event	28 of 45
12	Highways loads	29 of 45
13	Backfill loads on circular pipe in trench installation	30 of 45

Figures

1	Approximate geographic boundaries for SCS rainfall distributions	31 of 45
2	SCS 24-hour rainfall distributions	32 of 45
3	2000-year flood limits	33 of 45
4	Northern drainage areas	34 of 45
5	Western drainage areas	35 of 45
6	Southern drainage areas	36 of 45
7	Eastern drainage areas	37 of 45
8	Manning's n related to velocity, hydraulic radius and vegetable retardance	38 of 45
9	Channel geometries	39 of 45
10	OSDF runon water shed soil types	40 of 45
11	Culvert and drop inlet cross section	41 of 45
12	Headwater depth for concrete pipe culverts with inlet control	42 of 45
13	Head for concrete pipe culverts flowing full (n=0.012)	43 of 45
14	Trench bedding circular pipe	44 of 45
15	Water management and sediment control for urbanizing areas	45 of 45

Calculations

Purpose	1 of 1
Scope	1 of 1

Northern Area Calculations

Summary of Input Data	1 of 46
Summary of Calculation Results	1 of 46
Drainage Area Maps	4 of 46
Worksheets for weighted runoff curve numbers	8 of 46
HydroCad Runs Runon/Runoff	13 of 46

GeoSyntec Consultants

Written by: _____ Date: ___/___/___ Reviewed by: _____ Date: ___/___/___

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.2

Eastern Area Calculations

Summary of Input Data	1 of 148
Summary of Calculation Results	1 of 148
Drainage Area Maps	6 of 148
Worksheets for weighted runoff curve numbers	22 of 148
HydroCad Runs Runon/Runoff	36 of 148

Southern Area Calculations

Summary of Input Data	1 of 7
Drainage Area Maps	3 of 7
HydroCad Runs Runon/Runoff	5 of 7
Culvert Calculations (Addendum)	1 of 14

Western Area Calculations

Summary of Input Data	1 of 74
Summary of Calculation Results	1 of 74
Drainage Area Maps	5 of 74
Worksheets for weighted runoff curve numbers	8 of 74
HydroCad Runs Runon/Runoff	10 of 74
Culvert Calculations	67 of 74
Culvert Calculations (Addendum)	1 of ~~14~~ 15

Appendix AHydroCAD Stormwater modeling System (Manual)	1 of 1

Written by: Asc Date: 1/Feb/96 Reviewed by: [illegible] Date: 9/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

21 Feb 96

SURFACE-WATER MANAGEMENT AFTER OSDF CLOSURE

STORMWATER RUNON/RUNOFF AND DRAINAGE CONTROL STRUCTURES

CALCULATION PROCEDURES

Purpose

The purpose of this document is to present the calculation procedures used to analyze the drainage control features that will protect the OSDF from stormwater runon and runoff throughout the closure period. Stormwater runon is defined as stormwater that flows from toward the OSDF from outside the battery limit. Likewise, stormwater runoff is the stormwater that flows off of the OSDF final cover slopes. In its final configuration (i.e., after closure), stormwater runon will flow towards the OSDF from the north and east. Stormwater runoff; however, will flow to the north, east, south, and west. Therefore, the calculations are subdivided into: (i) northern area; (ii) eastern area; (iii) southern area; and (iv) western area. The drainage control features include:

- drainage channels constructed around the perimeter of the OSDF that will divert stormwater runon and/or runoff away from the OSDF; and
- culverts constructed in conjunction with the drainage channels to divert stormwater runoff away from the OSDF.

The calculations are performed in accordance with, and to verify compliance with, the DCP. The DCP requirements relevant to these calculations are:

- the drainage channels must accommodate both normal low flows and peak precipitation runon/runoff flows;
- the peak flow velocity in the drainage channels should not initiate scour in the channel; and

SSS 21Feb96

- the freeboard in the drainage channel should be at least 6 in. during the design storm event.

Scope

The procedures presented in this document will be used to perform the following calculations for each drainage area and for each design storm event:

- runon/runoff quantities;
- peak flow velocities and maximum depth of flow in drainage channels; and
- flow capacity of the culverts.

In addition, the structural capacity of the culverts will be analyzed.

Calculation Procedures

General

The computer program "HydroCAD™ Stormwater Modeling System" [Applied Microcomputer Systems, 1993] (HydroCAD™), will be used to calculate runon and runoff quantities, and the peak flow velocities and maximum depth of flow in the drainage channels. HydroCAD™ uses the hydrologic modeling methods presented in Technical Release 20 (TR20) [USDA-SCS, 1975] and TR55 [USDA-SCS, 1986a]. (See Appendix A for information related to HydroCAD™.) The flow capacity of the culverts will be analyzed using the methods presented in the document entitled *"Hydraulic Design of Highway Culverts"* [USDOT-FHWA, 1985]. The structural capacity of the culverts will be analyzed using the "Concrete Design Manual [American Concrete Pipe Association, 1970].

Written by: RSC Date: 1/Feb/96 Reviewed by: SSS Date: 9/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

21Feb96

Stormwater Runon and Runoff Quantities

The procedure for calculating stormwater runon and runoff quantities consists of the following steps.

1. Define the drainage area to be analyzed. These data are presented in the design verification document.

2. Calculate the weighted CN using the runoff curve number worksheet [USDA-SCS, 1986a], except for the OSDF cover slopes. A weighted CN of 98 is assigned for the OSDF final cover slopes.

3. Define the parameters associated with the surface-water flow segments for each drainage area. The flow segments consist of sheet flow, shallow concentrated flow, and open channel flow. The engineering parameters needed to define these flow segments are listed below:

   - for sheet flow:

     - surface type which yields a Manning's coefficient for sheet flow;
     - the flow length (ft);
     - slope of land (ft/ft);

   - for shallow concentrated flow:

     - flow length (ft);
     - surface type (paved or unpaved); and
     - average slope of land (ft/ft); are

   - for open channel flow:

     - Manning's coefficient for open channel flow;
     - channel length (ft);
     - channel slope (ft/ft); and

KAC 21 Feb 96

- pertinent channel geometry (e.g., side slopes (H:V) and depth (ft) or cross-sectional area (ft^2), and wetted perimeter (ft)).

These data are also presented in the data verification document.

4. Calculate the amount of runon/runoff for a drainage area and a design storm event and vegetative cover type. The data defined in Steps 1 through 3 are used as input to HydroCAD™. HydroCAD™ uses the data to develop a "runoff hydrograph" as described below.

   a. Calculate the Time of Concentration (T_c) for a drainage area. The Tc represents the time required for stormwater to travel from the most hydrologically distance point of a drainage area to the point of interest. Tc is calculated by summing the individual travel time (T_t) for each flow segment define in a drainage area.

   Travel time for each flow segment is calculated as follows:

   for sheet flow:

$$T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5}\, S^{0.4}}$$

KC 30 Jan 96

where: T_c = Travel time for sleet flow (hours);
n = Manning's coefficient for sheet flow, based on surface types;
L = flow length (ft);
P_2 = amount of rainfall from a 2-year, 24-hour design storm event (in.); and
s = slope of land (ft/ft).

21 Feb 96

for shallow concentrated flow:

$$T_t = \frac{L}{3600V}$$

where: T_t = Travel time for shallow concentrated flow (hours);
L = Flow length (ft);
V = average flow velocity (ft/s). ~~obtained from Figure 1~~ [USDA-SCS, 1986a].

for open channel flow:

$$T_t = \frac{nL}{(3600)(1,486)r^{0.67}S^{0.5}}$$

30 Jan 96

where: T_t = Travel time for open channel flow (hours);
n = Manning's coefficient for open channel flow;
L = channel length (ft)
r = hydraulic radius (ft) = a/Pw;
a = cross-sectional area of flow (ft^2);
P_w = wetted perimeter (ft);
s = channel slope (ft).

b. Develop a unit hydrograph for the project site. The unit hydrograph is a dimensionless curve that represent the runoff distribution resulting from 1 in. of rainfall over the drainage area. To develop a unit hydrograph, HydroCAD™ uses the CN value and the anticipated rainfall distribution. Develop a runoff hydrograph for the design storm event. HydroCAD™ develops the runoff hydrograph by summing the amount of runoff calculated over a series of discrete time intervals during the storm event. The amount of runoff is calculated as follows:

21 Feb 96

30 Apr 96

$$Q = \frac{(P-0.2S)^2}{P+0.8s} \quad (Q = O \text{ if } P<0.2S)$$

where: Q = amount of runoff (in.);
P = cumulative rainfall (in.);
S = potential maximum retention after run off begins (in.);
S = 1000/CN - 10
CN = runoff curve number.

The discrete time interval or duration during which runoff calculations are performed is calculated as follows:

$$D = \frac{2}{15} Tc$$

where: D = duration (hours); and
T_c = time of concentration (hours).

5. The resulting runoff hydrograph provides the runon/runoff quantities for the storm event as well as the peak runon/runoff quantity.

Peak Flow Velocities and Maximum Depth of Flow in Drainage Channels

The procedures for calculating the peak flow velocity and the maximum depth of flow in a drainage channel consists of the following steps.

1. Define points of interest along the drainage channel. These points include the locations of culverts or where multiple drainage areas converge. These locations are presented in the data verification document.

2. Define the dimensions and geometry of the drainage channel at each point of interest. This information is also presented in the data verification document.

21 Feb 96

3. Develop a discharge versus depth curve for the drainage channel by calculating the flow rate for various flow depths in the drainage channel based on the channel geometry. Flow rate is calculated as follows:

$$Q = \frac{1{,}486 a r^{0.67} s^{0.5}}{n}$$

30 Oct 96

where: Q = flow rate (cfs);
a = cross-section area of flow (ft^2);
r = hydraulic radius (ft) = a/P_w;
P_w = wetted perimeter (ft);
s = channel slope (ft/ft); and
n = Manning's coefficient for open channel flow.

4. Calculate the peak flow velocity and the maximum depth of flow in a drainage channel at the point of interest. The runoff hydrograph previously calculated, the data defined in Steps 1 and 2, and the data calculated in Step 3 are used as input to HydroCAD™ to route a design storm through the drainage channel. The routing calculation uses the runoff hydrograph as an inflow hydrograph to the point of interest. The result of this routing is an outflow hydrograph from which the peak flow is obtained. HydroCAD™ simultaneously solves for the peak flow velocity and the maximum depth of flow by comparing the discharge versus depth curve and the following equation:

$$V_p = \frac{Q_p}{A_p}$$

where: V_p = peak flow velocity (ft/s);
Q_p = peak flow (cfs);
A_p = cross-sectional area of flow a peak flow (ft^2)

5. Verify that the drainage channel satisfies the design criteria.

21 Feb 90

4. Calculate pipe strength (D-load) using the following equation:

$$\text{D-load} = \left[\left(\frac{W_L}{L_f}\right) + \left(\frac{W_E}{L_f}\right)\right]\frac{F_s}{D} \text{ for } L_f \leq 1.5$$

or

$$\text{D-load} = \left[\left(\frac{W_L}{1.5}\right) + \left(\frac{W_L}{L_f}\right)\right]\frac{F_s}{D} \text{ for } L_f > 1.5$$

where:

D-load	=	pipe strength
D	=	inside diameter (ft);
F_s	=	factor of safety;
W_L	=	live load (kips);
W_E	=	earth load (kips); and
L_f	=	loading factor.

Culvert Outlet Protection

The procedure for calculating the riprap culvert outlet consists of the following steps.

1. Define culvert discharge. These data were previously calculated.

2. Use the USDA-SCS [1987] design chart to select a D_{50} for the riprap and the length of the outlet apron.

3. Calculate the apron size using the relationships shown on the design chart [USDA-SCS, 1987].

21Feb96

4. Calculate the D_{max} and D_{15} of the riprap as follows:

$$D_{max} = 1.5 \times D_{50}$$
$$D_{15} = 0.5 \text{ to } 0.75 \times D_{50}$$

where: D_{50} = theoretical spherical diameter of average stone size;
D_{max} = theoretical spherical diameter of largest stone size; and
D_{15} = theoretical spherical diameter of the stone size for which 15 percent of the material is smaller.

5. Calculate the minimum thickness of the riprap, which should be two times the D_{50}, but not less than 6 in.

6. Calculate granular filter blanket using the following relationships:

$$\frac{D_{15}^{filter}}{D_{85}^{base}} < 5 < \frac{D_{15}^{filter}}{D_{15}^{base}} < 40$$

and,

$$\frac{D_{50}^{filter}}{D_{50}^{base}} < 40$$

The granular filter layer of filter should be approximately 6 in. thick.

21 Feb 96

References

American Concrete Pipe Association, "*Concrete Pipe Design Manual*", Arlington, VA, 1970.

Applied Microcomputer Systems, "HydroCAD™ Stormwater Modeling System," version 3.10, Chocorna, NH, 1993.

Chow, "Open Channel Hydraulics," 1959

USDA-SCS, "Computer Program for Project Formulation, Hydrology", Technical Release 10 (TR20), U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., 1975.

USDA - SCS "National Engineering Handbook, Section 4 - Hydrology," Washington, DC, Mar 1985.

USDA-SCS, *"Urban Hydrology for Small Watersheds"*, Technical Release 55 (TR55), U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., 2nd Edition, 1986a.

USDA-SCS, *"Engineering Field Manual for Conservation Practices"*, U.S. Department of Agriculture, Soil conservation Service, Washington, D.C., 1986b.

USDA-SCS, *"Water Management and Sediment Control for Urbanizing Areas"*, U.S. Department of Agriculture, Soil Conservation Services, Washington, D.C., 1987.

USDOT-FHWA, *"Hydraulic Design of Highway Culverts"*, Hydraulic Design Series No.5, Report No. FHWA-1P-85-15, U.S. Department of Transportation, Federal Highway Administration, McLean, VA, 1985.

Written by: Asc Date: 7/Feb/96 Reviewed by: SSS Date: 9/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

21 Feb 96

SURFACE-WATER MANAGEMENT AFTER OSDF CLOSURE

STORMWATER RUNON/RUNOFF AND DRAINAGE CONTROL STRUCTURES

DATA VERIFICATION

PURPOSE

The purpose of this document is to present the engineering data used to design drainage control features that will protect the OSDF from stormwater runon and runoff throughout the post-closure period. Stormwater runon is defined as stormwater that flows toward the OSDF from outside the battery limit. Likewise, stormwater runoff is the stormwater that flows off of the OSDF final cover slopes. In its final configuration (i.e., after closure), stormwater runon will flow towards the OSDF from the north and east. Stormwater runoff; however, will flow to the north, east, south, and west. Therefore, the calculations are subdivided into: (i) northern area; (ii) eastern area; (iii) southern area; and (iv) western area. The drainage control features include:

- drainage channels constructed around the perimeter of the OSDF that will divert stormwater runon and/or runoff away from the OSDF; and
- culverts constructed in conjunction with the drainage channels to divert stormwater runoff away from the OSDF.

The data presented in this document are used to satisfy the requirements presented in the DCP. The DCP requirements relevant to the data verification are:

- the drainage control structures designed to control runon shall be designed to limit interruption and damage (i.e., washout) of the OSDF from the 2,000-year, 24-hour design storm event;
- the drainage control structures designed to control runoff shall be designed to limit interruption and damage of the OSDF from the 2,000-year, 24-hour design storm event; and
- the slope of the drainage channels shall be no less than 0.5 percent.

Written by: RSC Date: 7 / Feb / 96 Reviewed by: JSS Date: 9 / Feb / 96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

21 Feb 96

SCOPE

The data presented in this document will be used to perform the following calculations:

- runon/runoff quantities;
- peak flow velocities and maximum depth of flow in the drainage channels;
- flow capacity of culverts; and
- structural capacity of culverts.

PARAMETERS FOR DESIGN

General

Data required to perform the calculations include: (i) rainfall information (i.e., quantities, durations, distribution); (ii) flood elevation resulting from a 2,000-year, 24-hour storm event; (iii) drainage area information (i.e., drainage channel dimensions and geometries, Manning's coefficients for sheet flow and open channel flow, soil and vegetative cover types); and (iv) culvert information (i.e., size, type, cover, loadings). Engineering data will be obtained from site-specific studies and published engineering texts.

Rainfall Information

Rainfall Quantities and Durations

Rainfall quantities for specific design storm events were summarized by Parsons [1995] and are presented in Table 1. Rainfall for the design storm required by the DCP or by the calculation method include:

Storm Event	Rainfall (in.)
2-Year, 24-Hour	2.55
25-Year, 24-Hour	4.7
2000-Year, 24-Hour	13.0

Rainfall Distribution

According to USDA-SCS [1986a], storm events that occur in the area of the OSDF site will have a Type II storm distribution, see Figure 1. Rainfall intensities for a Type II, 24-hour storm are shown on Figure 2.

21Feb96

2,000-Year Flood Elevation

The maximum expected flood elevation resulting from a 2,000-year, 24-hour design storm event must be considered for the OSDF flood protection system. As shown on Figure 3 [Parsons, 1995], the flood water footprint for the 2,000-year storm does not impact the OSDF.

Drainage Area Data

Drainage Areas

The watershed containing the OSDF is divided into drainage areas (e.g., northern (N), eastern (E), southern (S), and western (W)). Each drainage area is further subdivided into drainage subareas (e.g., E-1, E-2, W-1, W-2, etc.) to accurately model the hydrologic and soil conditions of the drainage area. The drainage areas and their subareas are shown on Figures 4, 5, 6, and 7.

Drainage Flow Types

Surface water flow within a drainage area is characterized as a series of flow segments. The flow segments will consist of sheet flow, shallow concentrated flow, and open channel flow. The engineering parameters needed to define these flow segments, along with the reference source for the data, is listed below:

- for sheet flow:
  - surface type which yields a Manning's coefficient for sheet flow, Table 2 [USDA-SCS, 1986a];
  - flow length (ft), Figures 4, 5, 6, and 7;
  - slope of land (ft/ft), Figures 4, 5, 6, and 7;
- for shallow concentrated flow:
  - flow length (ft), Figures 4, 5, 6, and 7;
  - surface type (paved or unpaved);
  - average slope of land (ft/ft), Figures 4, 5, 6, and 7; and
- for open channel flow:
  - Manning's coefficient for open channel flow, Figure 8 and Tables 3 and 4 [USDA-SCS, 1986b and Chow, 1959];
  - channel length (ft), Figures 4, 5, 6, and 7;

SC 21 Feb 96

- channel slope (ft/ft), Figures 4, 5, 6, and 7;
- pertinent channel geometry (e.g., side slopes (H:V) and depth (ft) or cross-sectional area (ft^2), and wetted perimeter (ft)), Figure 9.

Cross sections of the various drainage channels are shown in Figure 9.

Hydrologic Soil Group (HSG)

The soil types found within the OSDF watershed are illustrated in Figure 10 [USDA-SCS, 1992]. The HSG classification for each soil type identified were obtained from Table 5 [USDA-SCS, 1986a]. Soils found within the OSDF watershed and their associated HSG are:

SCS Map Designator	Soil Name	HSG Group
DaB	Dana	B
EcE2	Eden	C
EcF2	Eden	C
FcA	Fincastle	C
FdA	Fincastle	C
MsC2	Miamian-Russell	C
MsD2	Miamian-Russell	C
Ra	Ragsdale	B
RvB2	Russell-Miamian	B
RwB2	Russell-Miamian	B
XeB	Xenia	B
XeB2	Xenia	B
XfA	Xenia	B
XfB2	Xenia	B

Vegetative Cover Type

The HSGs identified within the drainage are subdivided by vegetative cover type. The vegetative cover types were selected based on a 1993 aerial photograph of the OSDF site. Vegetative cover types recognized by Technical Release 55 [USDA-SCS, 1986a] (i.e., the hydrology model used in these calculations) are presented in Table 6 [USDA-SCS, 1986a].

Hydrologic Condition

Hydrologic condition and treatment are cover type modifiers used to describe: (i) the density of plant and crop residue in the drainage area; and (ii) the management of cultivated agricultural lands (i.e., contour farming). The hydrologic condition is assumed to be fair to

FC 21 Feb 96

good because the majority of the land is not used for grazing. These modifiers are also included in Table 6.

Runoff Curve Numbers

Runoff Curve Numbers (CN) are factors used to account for the influence that each of the HSG, vegetative cover type, and hydrologic condition and treatment have on the amount of runoff. CN values may be obtained from Table 6 [USDA-SCS, 1986a].

Antecedent Runoff Conditions

The antecedent runoff condition (ARC) is the runoff potential of a drainage area before a storm event occurs. ARC accounts for variations in the CN due to soil saturation from previous storms. The CN values given in Table 6 [USDA-SCS, 1985] represent average ARC conditions which are normally used in design.

For calculating the quantity of runoff from a 2,000-year, 24-hour storm event, it reasonable to assume that there will be some smaller storms preceding the storm of interest. These smaller storms are referred to as antecedent storms. The water from a series of antecedent storms will saturate the soil which, in turn, will reduce the amount of soil infiltration that can occur.

A correlation between the standard CN values (i.e., Condition II) and the saturated CN values (i.e., Condition III) is provided on Table 7 [USDA-SCS, 1985].

Vegetation

The vegetative cover of the OSDF is expected to change throughout the OSDF post-closure period. To account for this expected variation in vegetation, the following three scenarios were developed.

Light Cover. This scenario represents the early, vegetative growth at the OSDF. The vegetation on the OSDF slopes is anticipated to consist of short grasses. The drainage channels are anticipated to consist of riprap and short grasses.

Moderate Cover. This case represents dense grasses on the OSDF slopes and riprap and short grasses in the drainage channel.

Heavy Cover. This scenario represents dense grass on the OSDF slopes and riprap and dense grass in the drainage channel.

RC 21 Feb 96

The Manning's coefficient (n) for grass-lined open channels is dependent on the three factors: (i) vegetation type; (ii) flow velocity; and (iii) hydraulic radius. Therefore, it is unreasonable to assume that a single n value will satisfy each possible condition in the channel throughout the OSDF post-closure period. According to Earth Systems Associates, Ltd. [1996], the vegetative cover types may be categorized into reference groups "A" or "B" [USDA-SCS, 1986b]. Manning's n for various vegetative retardance groups may be obtained from Figure 8 [USDA-1986b]. Because the vegetation in the drainage channel will vary over time, a minimum and maximum Manning's n was selected, 0.030 and 0.10, respectively. These Manning's n values fall within the range presented in Chow [1959], see Table 4.

Summary

A summary of the drainage area data is presented in Tables 8, 9, 10, and 11.

Culverts

Culverts will be used to carry the stormwater runoff from a 25-year, 24-hour design storm event away from the OSDF under the perimeter access road on the west side of the OSDF. A drop inlet structure will be used to pool the water to be carried by the culvert. The culverts will be 18-in. diameter concrete pipes placed in a Class B type trench with a granular foundation. A cross-section of the road and culvert is provided in Figure 11. Culvert design charts [USDOT-FHWA, 1985] are presented as Figures 12 and 13. These culverts must function with a factor of safety between 1.25 and 1.5 under an AASHTO H-20 live load (i.e., maximum axle load of 32 kips) and applicable dead loads, see Tables 12 and 13 [American Concrete Pipe Association, 1970]. For cover thickness less than 3 ft, increase the live load by an impact factor I_F as follows:

- 0 - 1 ft, I_F = 1.3;
- 1 - 2 ft, I_F = 1.2; and
- 2 - 3 ft, I_F = 1.1.

Pipe bedding and loading factors are presented in Figure 14. Riprap for the culvert outlet will be size using the USDa-SCS [1982] design chart presented in Figure 15.

REFERENCES

American Concrete Pipe Association, *"Concrete Pipe Design Manual"*, Arlington, VA, 1970.

Chow, *"Open Channel Hydraulics"*, 1959.

Earth Systems Associates, *"Vegetation Cover Recommendations for the On-Site Disposal Facility at the Fernald Environmental Management Project Site"*, February 1996. 21 Feb 96

GeoSyntec Consultants, *"Design Criteria Package"*, document in preparation.

Parsons Engineering, *"2000-Year Flood and Probable Maximum Flood, Sitewide Flood Plain Determination"*, Revision A, Aug 1995.

USDA-SCS, *"National Engineering Handbook, Section 4 - Hydrology"*, U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., Mar 1985.

USDA-SCS, *"Urban Hydrology for Small Watersheds"*, Technical Release 55 (TR-55), U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., Jun 1986a.

USDA-SCS, *"Engineering Field manual for Conservation Practices"*, U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C., Nov 1986b.

USDA-SCS, *"Water Management and Sediment Control for Urbanizing Areas'*, U.S. Department of Agriculture, Soil Conservation Services, Washington, D.C., 1987.

USDOT-FHWA, *"Hydraulic Design of Highway Culverts"*, Hydraulic Design Series No. 5, Report No. FHWA-IP-85-15, U.S. Department of Transportation, Federal Highway Administration, McLean, Virginia, 1985.

739 ASC 16 Dec 95

SSS 9 Feb 96
8/45

Lee 21 Feb 96

TABLE 1 - RAINFALL DEPTH FOR A GIVEN DURATION (INCHES)

DURATION (YEARS)	TIME							
	HYDRO-35			TP-40				
	5 MIN	15 MIN	60 MIN	2 HOURS	3 HOURS	6 HOURS	12 HOURS	24 HOURS
2	0.387	0.739	1.223	1.408	1.54	1.848	2.2	2.552
5	0.49	0.979	1.69	2.016	2.112	2.496	2.88	3.072
10	0.564	1.139	1.99	2.277	2.475	3.069	3.465	4.059
25	0.65	1.34	2.38	2.6	3.0	3.4	4.0	4.7
50	0.72	1.49	2.67	3.0	3.25	3.9	4.2	5.2
* 100	0.78	1.64	2.95	3.3	3.6	4.1	5.0	5.6
* 500	0.93	2.1	4.3	5.2	5.9	7.3	8.5	9.4
2000	1.2	2.6	5.8	7.2	8.2	10.2	12.0	13.0
10,000	1.4	3.4	8.2	10.5	12.0	15.5	18.0	19.2
100,000	1.9	5.0	13.3	17.7	20.8	27.4	31.8	33.4
	DESIGN OF SMALL DAMS					HMR-51		

NOTE: Rainfall Points For 2, 5, and 10 year rainfall events were adjusted per TP-40. Values for the 500, 2000, and 10,000 Year Events were interpolated from Figure 3 (Appendix E)

* These values are used on PH Records for HEC-1.

REF: PARSONS, "2,000-YEAR FLOOD AND PROBABLE MAXIMUM FLOOD, SITEWIDE FLOOD PLAN DETERMINATION", AUG 1995.

[redacted]

739 LSC 16 Dec 95
SSS 9Feb96
9145
KC 21Feb96

Table 2.—Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1]The n values are a composite of information compiled by Engman (1986).
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3]When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

USDA-SCS

(210-VI-TR-55, Second Ed., June 1986)

[redacted]

Retar-dance	Cover	Condition
A	Reed canarygrass	Excellent stand, tall (average 36 inches)
	Yellow bluestem Ischaemum	Excellent stand, tall (average 36 inches)
B	Smooth bromegrass	Good stand, mowed (average 12 to 15 inches)
	Bermudagrass	Good stand, tall (average 12 inches)
	Native grass mixture (little bluestem, blue grama, and other long and short midwest grasses)	Good stand, unmowed
	Tall fescue	Good stand, unmowed (average 18 inches)
	Lespedeza sericea	Good stand, not woody, tall (average 19 inches)
	Grass-legume mixture--Timothy, smooth bromegrass, or orchard grass	Good stand, uncut (average 20 inches)
	Reed canarygrass	Good stand, mowed (average 12 to 15 inches)
	Tall fescue, with bird's foot trefoil or lodino ..	Good stand, uncut (average 18 inches)
	Blue grama	Good stand, uncut (average 13 inches)
C	Bahia	Good stand, uncut (6 to 8 inches)
	Bermudagrass	Good stand, mowed (average 6 inches)
	Redtop	Good stand, headed (15 to 20 inches)
	Grass-legume mixture--summer (Orchard grass, redtop, Italian ryegrass, and common lespedeza) ...	Good stand, uncut (6 to 8 inches)
	Centipedegrass	Very dense cover (average 6 inches)
	Kentucky bluegrass	Good stand, headed (6 to 12 inches)
D	Bermudagrass	Good stand, cut to 2.5-inch height
	Red fescue	Good stand, headed (12 to 18 inches)
	Buffalograss	Good stand, uncut (3 to 6 inches)
	Grass-legume mixture--fall, spring (Orchard grass, redtop, Italian ryegrass, and common lespedeza).	Good stand, uncut (4 to 5 inches)
	Lespedeza sericea	After cutting to 2-inch height. Very good stand before cutting
E	Bermudagrass	Good stand, cut to 1.5-inch height.
	Bermudagrass	Burned stubble.

TABLE 3. Classification of vegetation cover as to degree of retardance.

USDA-SCS, 19866

435

VALUES OF THE ROUGHNESS COEFFICIENT n
(Boldface figures are values generally recommended in design)

Type of channel and description	Minimum	Normal	Maximum
A. CLOSED CONDUITS FLOWING PARTLY FULL			
A-1. Metal			
a. Brass, smooth	0.009	0.010	0.013
b. Steel			
1. Lockbar and welded	0.010	0.012	0.014
2. Riveted and spiral	0.013	0.016	0.017
c. Cast iron			
1. Coated	0.010	0.013	0.014
2. Uncoated	0.011	0.014	0.016
d. Wrought iron			
1. Black	0.012	0.014	0.015
2. Galvanized	0.013	0.016	0.017
e. Corrugated metal			
1. Subdrain	0.017	0.019	0.021
2. Storm drain	0.021	0.024	0.030
A-2. Nonmetal			
a. Lucite	0.008	0.009	0.010
b. Glass	0.009	0.010	0.013
c. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
d. Concrete			
1. Culvert, straight and free of debris	0.010	0.011	0.013
2. Culvert with bends, connections, and some debris	0.011	0.013	0.014
3. Finished	0.011	0.012	0.014
4. Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
5. Unfinished, steel form	0.012	0.013	0.014
6. Unfinished, smooth wood form	0.012	0.014	0.016
7. Unfinished, rough wood form	0.015	0.017	0.020
e. Wood			
1. Stave	0.010	0.012	0.014
2. Laminated, treated	0.015	0.017	0.020
f. Clay			
1. Common drainage tile	0.011	0.013	0.017
2. Vitrified sewer	0.011	0.014	0.017
3. Vitrified sewer with manholes, inlet, etc.	0.013	0.015	0.017
4. Vitrified subdrain with open joint	0.014	0.016	0.018
g. Brickwork			
1. Glazed	0.011	0.013	0.015
2. Lined with cement mortar	0.012	0.015	0.017
h. Sanitary sewers coated with sewage slimes, with bends and connections	0.012	0.013	0.016
i. Paved invert, sewer, smooth bottom	0.016	0.019	0.020
j. Rubble masonry, cemented	0.018	0.025	0.030

VALUES OF THE ROUGHNESS COEFFICIENT n (*continued*)

Type of channel and description	Minimum	Normal	Maximum
B. LINED OR BUILT-UP CHANNELS			
B-1. Metal			
a. Smooth steel surface			
1. Unpainted	0.011	0.012	0.014
2. Painted	0.012	0.013	0.017
b. Corrugated	0.021	0.025	0.030
B-2. Nonmetal			
a. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
b. Wood			
1. Planed, untreated	0.010	0.012	0.014
2. Planed, creosoted	0.011	0.012	0.015
3. Unplaned	0.011	0.013	0.015
4. Plank with battens	0.012	0.015	0.018
5. Lined with roofing paper	0.010	0.014	0.017
c. Concrete			
1. Trowel finish	0.011	0.013	0.015
2. Float finish	0.013	0.015	0.016
3. Finished, with gravel on bottom	0.015	0.017	0.020
4. Unfinished	0.014	0.017	0.020
5. Gunite, good section	0.016	0.019	0.023
6. Gunite, wavy section	0.018	0.022	0.025
7. On good excavated rock	0.017	0.020	
8. On irregular excavated rock	0.022	0.027	
d. Concrete bottom float finished with sides of			
1. Dressed stone in mortar	0.015	0.017	0.020
2. Random stone in mortar	0.017	0.020	0.024
3. Cement rubble masonry, plastered	0.016	0.020	0.024
4. Cement rubble masonry	0.020	0.025	0.030
5. Dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0.023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. Glazed	0.011	0.013	0.015
2. In cement mortar	0.012	0.015	0.018
g. Masonry			
1. Cemented rubble	0.017	0.025	0.030
2. Dry rubble	0.023	0.032	0.035
h. Dressed ashlar	0.013	0.015	0.017
i. Asphalt			
1. Smooth	0.013	0.013	
2. Rough	0.016	0.016	
j. Vegetal lining	0.030	.....	0.500

USE 0.030 to account for siltation.

TABLE 4. MANNING'S ROUGHNESS COEFFICIENTS

This table reprinted from OPEN CHANNEL HYDRAULICS by Ven Te Chow, Copyright 1959 by McGraw-Hill.

239
Rsc 16 Dec 95

RSS 9Feb99 12/45

Ke 21Feb98

TABLE 5: Hydrologic soil groups for United States soils

DACONO	B	DARLAND	B	DECKERVILLE,	C	DELLO, CLAY	B	DESCHUTE	B
DACONO, CORBLY	C	DARLEY	C	DRAINED		SUBSTRATUM		DESCHUTES	C
SUBSTRATUM		DARLING	B	DECLO	B	DELLROSE	B	DESCUT	B
DACORE	B	DARNSTADT	D	DECOLNEY	B	DELLS	C	DESERD	C
DACOSTA	D	DARNELL	C	DECORDOVA	B	DELLWOOD	A	DESERET	C
DADE	A	DARNEN	B	DECRAM	C	DELMA	C	DESHA	D
DADINA	D	DAROW	C	DECROSS	B	DELMITA	C	DESHLER	C
DAGAN	B	DARR	B	DECY	C	DELMONT	B	DESKAMP	C
DAGFLAT	C	DARRET	C	DEDAS	C	DELNORTE	C	DESMET	B
DAGLUM	D	DARROCH	B	DEDMOUNT	C	DELORO	C	DESOLATION	B
DAGOR	B	DARROCH, BEDROCK	C	DEDRICK	C	DELUSS	B/D	DESPAIN	B
DAGUAO	C	SUBSTRATUM		DEE	C	DELP	A	DESTAZO	B
DAGUEY	C	DARROUZETT	C	DEECREE	B	DELPHI	B	DESTER	C
DAHAR	C	DARSIL	C	DEEFAR	C	DELPHILL	C	DETER	C
DAHLQUIST	B	DARST	C	DEEMER	B	DELPIEDRA	D	DETOUR	B
DAICK	D	DART	A	DEEPCUT	C	DELPLAIN	D	DETRA	B
DAIGLE	C	DARTMOUTH	B	DEEPER	D	DELPOINT	C	DETROIT	C
DAILEY	A	DARVEY	B	DEEPWATER	C	DELRAY	B/D	DEUNAN	D
DAILEY, LOAMY	B	DARWIN	C	DEER CREEK	C	DELRAY,	D	DEV	A
SUBSTRATUM		DASHER	D	DEER PARK	A	DEPRESSIONAL		DEVADA	D
DAINT	B	DASSEL	B/D	DEERFIELD	B	DELRIDGE	B	DEVEN	D
DAKENT	B	DAST	B	DEERFORD	D	DELSON	C	DEVILS	D
DAKOTA	B	DATELAND	B	DEERHORN	C	DELTAJO	C	DEVILSCREEK	C
DALBO	B	DATEMAN	C	DEERLODGE	C	DELTON	B	DEVILSGATE	D
DALBY	D	DATIL	C	DEERTON	A	DELWIN	A	DEVILSGATE,	B
DALCAN	C	DATINO	C	DEERTRAIL	C	DELYNDIA	A	DRAINED,	
DALCO	D	DATINO, STONY	B	DEERWOOD	B/D	DEMAR	D	OCCASIONALLY	
DALE	B	DATWYLER	C	DEETZ	A	DEMAST	C	DEVILSGATE,	B
DALECREEK	C	DAULTON	C	DEFENBAUGH	B	DEMENT	B	DRAINED	
DALEVILLE	D	DAVEY	B	DEFIANCE	D	DEMING	B	DEVINE	C
DALHART	B	DAVEY, WARM	A	DEFLER	B	DEMKY	D	DEVISADERO	C
DALIAN	B	DAVIDELL	B	DEFORD	A/D	DEMNER	B	DEVOE	D
DALIG	C	DAVIDSON	B	DEGARMO	D	DEMOGUL	C	DEVOIGNES	D
DALKENA	C	DAVIS	B	DEGNER	B	DEMONA	C	DEVOIGNES, DRAINED	C
DALLAM	B	DAVISON	B	DEGOLA	B	DEMONTREVILLE	B	DEVOIGNES,	C
DALLARDSVILLE	C	DAYTONE	B	DEGRAND	B	DEMOPOLIS	C	PROTECTED	
DALLESPORT	B	DAWES	C	DEGREY	D	DEMOPOLIS, COBBLY	D	DEVOL	B
ALTON	C	DAWMOO	B/D	DEHAKA	C	DEMOSS	D	DEVONE	B
ALUPE	B	DAWSON	A/D	DEHART	B	DEMOX	B	DEVOY	C
DALZELL	C	DAXTONIA	C	DEHAVEN	B	DEMPSEY	B	DEVRIES	C
DAMASCUS	B/D	DAXTY	C	DEHILL	B	DEMPSTER	B	DEWAR	D
DAMERON	B	DAY	D	DEHLINGER	B	DENAUD	B/D	DEWEY	C
DAMEWOOD	C	DAYBELL	A	DEJARNET	B	DENAY	B	DEWEYVILLE	D
DAMLUIS	C	DAYSCHOOL	B	DEKALB	C	DENBAR	C	DEWMINE	D
DAMON	D	DAYTON	D	DEKOOM	B	DENBY	C	DEWVILLE	B
DANA	B	DAYTONA	B	DEKOVEN	D	DENCO	D	DEXTER	D
DANAHER	C	DAYVILLE	C	DEL REY	C	DENHAWKEN	D	DIA	C
DANAVORE	B	DAZE	C	DELA	C	DENISON	C	DIA, WET, SALINE	D
DANCY	B/D	DE MASTERS	C	DELAMETER	A	DENMAN	C	DIA, WET	D
DANDAN	C	DEACON	D	DELANCO	C	DENMARK	D	DIABLO	D
DANDREA	C	DEADFALL	C	DELAND	A	DENNIS	C	DIAGULCH	B
DANDRIDGE	D	DEADHORSE	C	DELANEY	A	DENNIT	B	DIAMANTE	B
DANFORTH	B	DEADMAN	B	DELANO	B	DENNY	D	DIAMOND	D
DANGBERG	D	DEADWOOD	D	DELASSUS	C	DENROCK	D	DIAMOND SPRINGS	C
DANIA	B/D	DEADYON	B	DELCOMB	D	DENTON	D	DIAMONDVILLE	C
DANJER	D	DEAMA	D	DELDLTA	C	DENURE	B	DIANEY	C
DANKO	D	DEAN	B	DELECO	D	DENVER	C	DIANOLA	D
DANLEY	C	DEANDALE	D	DELENA	D	DEPALT	D	DIASPAR	B
DANN	C	DEARBORN	B	DELEON	C	DEPCOR	B	DIATIE	B
DANNEMORA	D	DEARYTON	C	DELEPLAIN	D	DEPOE	D	DIAZ	C
DANSKIN	B	DEATMAN	C	DELFITE	C	DEPORT	D	DIBBLE	C
DANT	D	DEAVER	C	DELFINA	B	DEPPY	D	DIBULL	D
DANVERS	C	DEBAR	C	DELFT	B/C	DEPUTY	C	DICK	A
DANVILLE	C	DEBENGER	C	DELGADO	D	DERA	B	DICKERSON	D
DAPHNEDALE	C	DEBEQUE	B	DELHI	A	DERALLO	B	DICKEY	B
DAPOIN	C	DEBONE	D	DELICIAS	B	DERB	C	DICKINSON, MAP<25	B
DARBONNE	B	DEBORAH	D	DELKS	C/D	DERBY	A	DICKINSON, TILL	A
DARBY	C	DEBUS	D	DELL	C	DERECHO	B	SUBSTRATUM	
DARCO	A	DEBUTE	C	DELLEKER	D	DERINDA	C	DICKINSON, MAAT>50	B
DARDANELLE	B	DECAN	C	DELLO, OVERWASH	A	DERLY	D	DICKINSON, MAAT<50	B
DARDEN	A	DECANTEL	D	DELLO, SALINE	C	DEROUX	C	DICKMAN	A
DARDOON	B	DECATHON	C	DELLO, GRAVELLY	D	DERR	C	DICKSON	C
DARE	D	DECATUR	B	SUBSTRATUM, WET		DERRICK	B	DIDDY	D
DARFUR	B/D	DECCA	B	DELLO,	A	DES MOINES, DRY	B	DIEHLSTADT	C
DARGOL	D	DECCA, NONGRAVELLY	C	SALINE-ALKALI		DES MOINES, COBBLY	C	DIERSSEN	D
DARIEN	C	DECHEL	D	DELLO, MODERATELY	C	DESAN	A	DIETRICH	C
DARKBULL	B	DECKER	C	WET		DESART	C	DIGBY	B
DARKCANYON	C	DECKERVILLE	B	DELLO, DRAINED	A	DESAICYA	C	DIGGER	C
DARL	C					DESCALABRADO	D	DIGHTON	B

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

[redacted]
437

739 Rec 16 Dec 85

SSS 9Feb96
13/45

Fee 21Feb96

TABLE 5, continued: Hydrologic soil groups for United States soils

ECONFINA	A	ELBOWLAKE	B	ELRICK	B	ENOCHVILLE,	C	ESTER	D
ECTOR	D	ELBURN	B	ELRIN	F	DRAINED		ESTER, THAWED	C
EDALGO	C	ELBUTTE	C	ELROSE	H	ENOLA	B	ESTERO	D
EDDINGS	B	ELCO	F	ELS	A	ENON	C	ESTES	D
EDDS	B	ELD	D	ELSAM	P	ENOREE	D	ESTESLAKE	C
EDDY	C	ELDEAN	F	ELSIE	E	ENOS	C	ESTHERVILLE	B
EDEN	C	ELDER	B	ELSINBORO	B	ENOSBURG	C	ESTO	B
EDENBOWER	D	ELDER HOLLOW	D	ELSMERE	A	ENSENADA	B	ESTRELLA	B
EDENTON	C	ELDERON	B	ELSION	B	ENSIGN	D	ETACH	C
EDFRO	D	ELDERON, STONY	A	ELTREE	H	ENSLEY	B/D	ETCHEN	C
EDGAR	B	ELDGIN	B	ELTSAC	D	ENSTROM	B	ETELKA	C
EDGE	D	ELDON	B	ELVE	P	ENTENTE	B	ETHAN	B
EDGEHILL	C	ELDORADO	P	ELVEDERE	C	ENTERO	D	ETHANIA	B
EDGELEY	C	ELDRIDGE	C	ELVERS	B/D	ENTERPRISE	B	ETHELMAN	B
EDGEMONT	B	ELECTRA	C	ELVIRA	B/D	ENTIAT	D	ETHETE	B
EDGEWATER	C	ELEROY	B	ELWELL	C	ENTIMOCI	C	ETHETE, SALINE	C
EDGEWICK	C	ELEVA	F	ELWHA	C	ENVILLE	C	ETHRIDGE	C
EDGINGTON	C/D	ELFCREEK	C	ELWOOD	C	ENVOL	D	ETIL	A
EDINA	D	ELFRIDA	B	ELY	P	ENZIAN	D	ETOE	B
EDINBURG	C	ELGEE	A	ELYSIAN	B	EOJ	C	ETOILE	D
EDISTO	C	ELMINA	C	ELZINGA	P	EOLA	D	ETOWAH	B
EDLIN	B	ELIJAH	C	EMPAL	B	EPHRATA	C	ETOWN	B
EDLOE	B	ELINDIO	C	EMBARGO	C	EPHRATA	B	ETSEL	D
EDMINSTER	D	ELIOAK	C	EMBDEN	B	EPIKON	D	ETTA	B
EDMONDS	D	ELIZA	D	EMBERTON	C	EPLEY	C	ETTER	B
EDMORE	D	ELK	B	EMBLEM	B	EPOKE	B	ETTERSBURG	B
EDMUND	D	ELK HOLLOW	B	EMBRY	C	EPOT	F	ETTRICK	B/D
EDMUNDSTON	H	ELK MOUNTAIN	B	EMBUDO	F	EPOUFETTE	B/D	EUBANKS	B
EDNA	D	ELKA	C	EMDENT	D	EPPING	D	EUCLID	C
EDNEYTOWN	B	ELKADER	D	EMDENT, BEDROCK	C	EPSIE	D	EUDORA	B
EDNEYVILLE	B	ELKCREEK	C	SUBSTRATUM,		EPVIR	D	EUER	B
EDOM	C	ELKHART	B	DRAINED		EQUIS	D	EUFAULA	A
EDROY	D	ELKHILLS	B	EMDENT, DRAINED	C	ERA	B	EUHARLEE	C
EDSON	C	ELKHORN	C	EMERALD	P	ERAKATAK	C	EULONIA	C
EDWARDS	B/D	ELKINS	D	EMERALDA	D	ERAM	C	EUNOLA	C
EEL	B	ELKINSVILLE	P	EMERSON	P	ERAMOSH	D	EUREKA	D
EELCOVE	D	ELKMOUND	D	EMIGRANT	C	ERBER	C	EUSETIS	C
EELPOINT	D	ELKNER	D	EMIGRATION	E	ERCAN	F	EUSTIS	A
EEP	C	ELKOL	D	EMILY	E	ERD	D	EUTAW	D
EFFIE	C	ELKRIDGE	B	EMLIN	C	ERICSON	B	EVADALE	D
EFFINGTON	D	ELKSEL	C	EMMA	C	ERIE	C	EVANGELINE	C
EGAN	C	ELKTON	C/D	EMMERT	A	ERIN	B	EVANS	B
EGAN	B	ELLABELLE	D	EMMET	B	ERNEM	D	EVANSHAM	D
EGAS	D	ELLEDGE	C	EMMONS	E	ERNEST	C	EVANSTON	B
EGBERT	D	ELLEN	E	EMORY	B	ERNO	B	EVANSVILLE	B/D
EGBERT, STRATIFIED	C	ELLETT	D	EMOT	B	ERAMGUSPE	C	EVANT	C
SUBSTRATUM		ELLIHER	A	EMPEDRADO	B	EPVIDE	C	EVARD	D
EGBERT, MODERATELY	C	ELLICOTT	A	EMPEYVILLE	C	ESCAPOSA	C	EVARD	D
WET		ELLINGTON	B	EMPIRE	B	ESCALANTE	B	EVART	D
EGBERT, DRAINED	C	ELLINOR	C	EMPORIA	C	ESCAMPIA	C	EVENDALE	C
EGBERT, SANDY	C	ELLIOTT	C	EMRICK	B	ESCANABA	A	EVERETT	A
SUBSTRATUM		ELLIOTTSVILLE	B	EMRO	C	ESCANO	C	EVERETT, HARD	B
EGBERT, SLOPING	C	ELLIS	D	EMRAY	B	ESCARLO	F	SUBSTRATUM	
EGELAND	D	ELLISFORDE	B	ENBAR, WET	D	ESCONDIDO	C	EVERGLADES	B/D
EGINBENCH	C	ELLISVILLE	B	ENCAMPMENT	F	ESMANY	B	EVERLY	B
EGLIN	A	ELLOAM	C	ENCHANTED	F	ESLENDO	D	EVERMAN	C
EGYPT	D	ELLOREE	D	ENCIERRO	D	ESMERALDA	B	EVERSON	D
EICKS	C	ELLSWORTH	C	ENCINA	B	ESMOND	B	EVERWHITE	C
EIGHTLAR	D	ELLUM	C	ENCLAY	C	ESPARTO	P	EVESBORO	A
EIGHTMILE	D	ELLZEY	B/D	ENDERS	C	ESPELIE	B/D	EVRIDGE	B
EILERTSEN	B	ELM LAKE	A/D	ENDERSBY	F	ESPIL	D	EWA	B
EITZEN	B	ELMDALE	B	ENDICOTT	C	ESPINAL	A	EWA, BEDROCK	C
EKAM	C	ELMENDORF	D	ENDLICH	D	ESPINOSA	B	SUBSTRATUM	
EKALAKA	D	ELMINA	C	ENDSAW	C	ESPINT	D	EWALL	A
EKIM	C	ELMIRA	A	ENERGY	B	ESPLIN	D	EXCELSIOR	B
EKRUD	D	ELMONT	P	ENET	B	ESPY	C	EXCHEQUER	D
EL DARA	B	ELMORE	B	ENFIELD	B	ESQUATZEL	B	EXCLOSE	B
EL PECO	C	ELMRIDGE	C	ENGELHARD	B/D	ESRO	D	EXEL	C
EL RANCHO	B	ELMVILLE	B	ENGETT	A	ESRO, MODERATELY	C	EXETER	C
EL SOLYO	C	ELMWOOD	C	ENGLE	B	WET		EXETER, THICK	B
ELAM	A	ELNIDO	C	ENGLEWOOD	C	ESS	B	SOLUM	
ELAM, HARDPAN	B	ELNORA	B	ENKO	C	ESSAL	B	EXETTE	B
SUBSTRATUM		ELOCHOMAN	B	ENKO, OVERBLOWN	B	ESSEN	C	EXIRA	B
ELANDCO	B	ELOCIN	D	ENLOE	D	ESSEX	C	EXLINE	D
ELBA	C	ELOIKA	B	ENNING	C	ESSEXVILLE	A/D	EXRAY	D
ELBAVILLE	B	ELOMA	C	ENNIS	B	ESTACADO	B	EXUM	C
ELBERT	D	ELPAM	D	ENOCH	C	ESTACION	B	EYAK	C
ELBETH	B	ELPEDRO	B	ENOCHVILLE	D	ESTATE	C	EYEBROW	C
ELBON	B	ELRED	B/D			ESTELLINE	B	EYLAU	C

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

[redacted]

438

739 Rec 16 Dec 96
SSS 9Feb96
141/45
21Feb96

TABLE 5, continued: Hydrologic soil groups for United States soils

EYOTA	A	FARRAGUT	C	FETTIC	D	FLATRON	D	FORKWOOD	B
EYRE	D	FARRAR	B	FETZER	C	FLATTOP	D	FORMADER	C
EZBIN	B	FARRELL	B	FEZ	C	FLAXTON	B	FORMAN	B
FABIUS	B	FARRENBURG	B	FIANDER	D	FLEAK	D	FORMDALE	B
FACEVILLE	B	FARROT	C	FIANDER, DRAINED	C	FLEER	A/D	FORNEY	D
FACEY	B	FARSON	B	FIAT	C	FLEISCHMANN	D	FORNOR	B
FACTORY	C	FARSON, WET	C	FIDALGO	C	FLEMING	C	FORREST	C
FACTORY, MOIST	B	FARVA	C	FIDDLER	C	FLEMINGTON	D	FORSEER	C
FADDIN	D	FARVANT	D	FIDDLETOWN	B	FLETCHER	B	FORSEY	B
FADOLL	B	FASHING	D	FIDDYMENT	D	FLEWSIE	B	FORSGREN	C
FAGAN	C	FASKIN	B	FIELD	C	FLEX	D	FORSYTH	A
FAGASA	C	FATHOM	A	FIELDCREEK	B	FLO	A	FORT COLLINS	B
FAHEY	B	FATINA	B	FIELDING	B	FLOER	D	FORT MEADE	A
FAIR	C	FATTIG	C	FIELDON	B/D	FLOKE	D	FORT MOTT	A
FAIR, MOIST	B	FAUNCE	A	FIFER	D	FLOM	B/D	FORT ROCK	C
FAIRBANKS	B	FAUNSDALE	D	FIFIELD	C	FLOMATON	A	FORTANK	C
FAIRBURN	D	FAUQUIER	C	FILION	D	FLOMOT	B	FORTESCUE	C/D
FAIRCHILD	C	FAUSSE	D	FILIRAN	D	FLOODWOOD	B	FORTUNA	D
FAIRDALE	B	FAVRET	C	FILLMORE	D	FLORAHOME	A	FORTWINGATE	C
FAIRFAX	B	FAWIN	B	FINCASTLE	C	FLORALA	C	FORTYFOUR	C
FAIRFIELD	B	FAX	C	FINCH	C	FLORENCE	C	FORVIC	C
FAIRHAVEN	B	FAXON	B/D	FINCHFORD	A	FLORESVILLE	C	FORWARD	B
FAIRLIE	D	FAYETTE	B	FINDOUT	D	FLORIDANA	B/D	FOSS	B
FAIRLO	B	FAYETTEVILLE	B	FINGAL	C	FLORIDANA, DEPRESSIONAL	D	FOSSILON	D
FAIRMOUNT	D	FAYWOOD	C	FINGEROCK	D			FOSSUM	A/D
FAIRPLAY	B	FE	D	FINLAND	C	FLORIDANA, FLOODED	D	FOSIER	C
FAIRPOINT	C	FEARS	B	FINLEY	B	FLORIN	C	FOSTORIA	B
FAIRPORT	C	FEATHERLEGS	B	FINLEYPOINT	B	FLORISSANT	C	FOUNTAIN	D
FAIRWAY	C	FEATHERSTONE	D	FINNERTY	D	FLORITA	B	FOUR STAR	C
FAIRYDELL	C	FEDJI	A	FINO	B	FLOTAG	B	FOUR STAR, DRAINED	B
FAIRYLAWN	D	FEDORA	B/D	FINOL	C	FLOWELL	C	FOURCHE	B
FAJARDO	C	FEDSCREEK	B	FIONE	B	FLOWEREE	B	FOURLOG	D
FALAYA	D	FELAN	B	FIFADA	C	FLOYD	B	FOURME	B
FALBA	D	FELCHER	B	FIREBALL	B	FLUETSCH	B	FOURMILE	B
FALCON	D	FELDA	B/D	FIREBOX	B	FLUGLE	B	FOX	B
FALFA	C	FELDA, DEPRESSIONAL	D	FIRESTEEL	B	FLUKER	C	FOXCREEK	D
FALFURRIAS	A			FIRESTONE	C	FLUVANNA	C	FOXCREEK, DRAINED	C
FALK	C	FELICITY	A	FIRMAGE	B	FLYBOW	D	FOXHOME	B
FALKIRK	B	FELIPE	D	FIRO	D	FLYGARE	B	FOXMOUNT	C
FALKNER	C	FELIZ	B	FIROKE	B	FLYNN	B	FOXOL	D
FALLBROOK	B	FELKER	B	FIRSTVIEW	C	FLYNNCOVE	B	FOXTON	C
FALLCREEK	C	FELLOWSHIP	D	FIRTH	C	FOAD	C	FOXWORTH	A
FALLERT	B	FELOR	B	FIRTH, DRAINED	B	FOARD	D	FRADDLE	B
FALLON	C	FELT	B	FISHERMAN	D	FOEHLIN	B	FRAILEY	B
FALLON, NONFLOODED	B	FELTA	C	FISHERS	B	FOIDEL	B	FRAILTON	D
FALLSAM	D	FELTHAM	B	FISHFIN	D	FOLA	B	FRAM	B
FALLSINGTON	B/D	FELTNER	D	FISHHOOK	D	FOLDAHL	B	FRANCIS	A
FALOMA	D	FELTON	B	FISHLAKE	D	FOLEY	D	FRANCISCAN	C
FALSEN	A	FELTONIA	B	FISHPOT	C	FOLLET	D	FRANCISQUITO	C
FALULA	D	FENCE	B	FISHRUCK	D	FOMSENG	C	FRANCITAS	D
FAMAL	C	FENDALL	C	FISHTRAP	D	FONDA	D	FRANDSEN	B
FANCHER	C	FENELON	C	FISK	B	FONDIS	C	FRANKFORT	C
FANDANGLE	C	FENN	D	FITCHVILLE	C	FONNER	B	FRANKIRK	C
FANDOW	D	FENSTER	B	FITZGERALD	B	FONS	B	FRANKLIN	B
FANG	B	FENWICK	C	FITZHUGH	B	FONTANA	B	FRANKSTOWN	B
FANNIN	B	FENWOOD	B	FIVEBLOCK	C	FONTREEN	B	FRANKTOWN	D
FANNO	C	FERA	C	FIVEMILE	B	FOPIANO	D	FRANKVILLE	B
FANSHAW	B	FERDELFORD	C	FIVEMILE, SALINE	C	FORADA	B/D	FRATERNIDAD	D
FANTZ	C	FERDINAND	C	FIVEOH	B	FORAKER	D	FRAVAL	C
FANU	B	FEREBEE	D	FIVEPINE	D	FORBAR	D	FRAVAL, GRAVELLY	B
FAPS	C	FERGUS	B	FIVES	B	FORBES	C	FRAZER	C
FARAWAY	D	FERN CLIFF	B	FIVESPRINGS	C	FORBESVILLE	C	FRAZERTON	B
FARB	D	FERNANDO	B	FLACO	C	FORBING	D	FRED	C
FARBER	B	FERNCREEK	D	FLAGG	B	FORD	D	FREDENSBORG	C
FARGO	D	FERNDALE	B	FLAGLER	B	FORDICE	B	FREDERICK	B
FARISITA	D	FERNEY	D	FLAGSTAFF	D	FORDNEY	A	FREDON	C
FARLAND	B	FERNHAVEN	B	FLAK	C	FORDNEY, WET	C	FREDONIA	C
FARLOW	B	FERNLEY	C	FLAMBEAU	B	FORDTRAN	C	FREDONYER	C
FARLOW, HIGH RAINFALL	C	FERNOW	B	FLAMING	A	FORDUM	D	FREE	B/D
		FERNPOINT	B	FLANAGAN	B	FORDVILLE	B	FREEBURG	C
FARNELL	B	FERNWOOD	B	FLANDREAU	B	FORELAND	D	FREECE	D
FARMINGTON	C	FERRELO	B	FLANE	C	FORELLE	B	FREEDOM	C
FARNSWORTH	D	FERRIS	D	FLANLY	B	FORESMAN	B	FREEDOM, SALINE	B
FARNTON	D	FERROBURRO	D	FLASHER	D	FORESTBURG	A	FREEHOLD	B
FARNHAM	B	FERRON	D	FLAT HORN	B	FORESTDALE	D	FREELAND	C
FARNHAMTON	C	FERTALINE	D	FLATHEAD	B	FORESTER	C	FREEMAN	C
FARNUF	B	FERTEG	C	FLATIRONS	C	FORESTON	C	FREEMANVILLE	B
FARNUF, WET	C	FESTINA	B	FLATNOSE	B	FORGAY	B	FREEON	B
FARNUM	B	FETT	D	FLATONIA	D	FORK	C	FREER	C

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

[redacted]
439

739 Asc 16 Dec 95

ASS 9Feb96 V5/45

Fin 21Feb96

TABLE 5., continued: Hydrologic soil groups for United States soils

MCDERMOTT	B	MECKLENBURG	C	MERDEN	D	MIKIM, WET	C	MINNEOSA	B
MCDOLE	B	MECOSTA	A	MERECITH	B	SUBSTRATUM		MINNEQUA	C
MCDONALD	C	MEDA	B	MERETA	C	MIKKALO	C	MINNETONKA	D
MCDONALDSVILLE	C/D	MEDAND	D	MERGEL	B	MILACA	C	MINNETONKA, SILTY	C/D
MCDUFF	C	MEDARY	C	MERIDIAN	B	MILAN	B	SUBSTRATUM	
MCELMO	C	MEDBURN	B	MERINO	D	MILBURY	C	MINNEWAUKAN	A/D
MCELROY	B	MEDCO	D	MERKEL	B	MILBY	B	MINNIECE	D
MCEWEN	B	MEDFORD	B	MERLIN	D	MILCAN	C	MINNIEPEAK	A
MCFADDEN	D	MEDFRA	D	MERMENTAU	D	MILDRED	C	MINNIEPEAK,	B
MCFAIN	C	MEDICINE	B	MERMILL	B/D	MILES	B	OVERBLOWN,	
MCFARLAND	B	MEDLEY	B	MERNA	B	MILFORD	B/D	GRAVELLY	
MCFAUL	C	MEDLIN	D	MEROS	A	MILHAM	B	MINNIEPEAK,	B
MCGAFFEY	B	MEDOMAK	D	MERRICK	B	MILITARY	B	OVERBLOWN	
MCGARR	C	MEDORA	B	MERRILL	C	MILL HOLLOW	B	MINNIEVILLE	C
MCGARVEY	C	MEDWAY	B	MERRILLAN	C	MILLADORE	C	MINNIMAUD	C
MCGARY	C	MEEGERNOT	B	MERRIMAC	A	MILLARD	B	MINNITH	C
MCGEHEE	C	MEEGERO	B	MERRITT	C	MILLBORO	D	MINNYE	B
MCGILVERY	D	MEEHAN	B	MERRITT, CLAYEY	B	MILLBROOK	B	MINOA	C
MCGINNIS	C	MEEAS	B	SUBSTRATUM,		MILLBURNE	B	MINOCQUA	B/D
MCGINTY	B	MEETEETSE	D	DRAINED		MILLER	D	MINTER	D
MCGIRK	C	MEGALOS	D	MERRITT, DRAINED	B	MILLERLAKE	B	MINTO	C
MCGIRK, LOW	D	MEGGETT	D	MERSHON	C	MILLERLUX	D	MINU	D
PRECIPITATION		MEGONOT	C	MERTON	D	MILLERTON	D	MINVALE	B
MCGOWAN	B	MEGUIN	B	MERTZ	C	MILLERVILLE	A/D	MINVENO	D
MCGRATH	B	MEHLHORN	C	MERWIN	A/D	MILLETT	B	MINWELLS	C
MCGREW	B	MEIKLE	D	MESA	B	MILLGROVE	B/D	MION	D
MCGUFFEY	D	MEISS	D	MESABA	C	MILLHEIM	C	MIPEON	C
MCGUIRE	B	MEKINOCK	D	MESCAL	C	MILLHI	D	MIRAMAL	C
MCHENRY	D	MELAKWA	C	MESCALERO	C	MILLHOPPER	A	MIRACH	C
MCILWAINE	B	MELAND	C	MESEI	D	MILLICH	D	MIRAGE	C
MCINTOSH	D	MELBOURNE	B	MESPUN	A	MILLICOMA	C	MIRAMAR	B
MCINTYRE	B	MELBY	B	MESSER	C	MILLIGAN	C	MIRAND	D
MCISEY	C	MELD	C	MET	B	MILLING	D	MIRANDA	D
MCKENZIE	D	MELDER	B	METAMORA	B	MILLINGTON	B/D	MIRES	A
MCKAY	C	MELGA	D	METCALF	D	MILLIS	C	MIRES, STONY	B
MCKEE	D	MELHOMES	D	METEA	B	MILLPAW	C	MIRKWOOD	D
KEETH	B	MELITA	A	METH	C	MILLPOI	B	MIRROR	C
KELVIE	A	MELLENTHIN	D	METIGOSHE	B	MILLRACE	B	MIRROR LAKE	A
MCKENNA	D	MELLOR	D	METOLIUS	B	MILLROCK	A	MISAD	B
MCKENNA, DRAINED	C	MELLOR, STRATIFIED	C	METRE	D	MILLSAP	D	MISENHEIMER	C
MCKENZIE	D	SUBSTRATUM		METZ	B	MILLSDALE	B/D	MISHAK	D
MCKINLEY	B	MELLOTT	B	MEXICO	D	MILLSHOLM	D	MISHAK, DRAINED	C
MCKINNEY	C	MELOCHE	D	MEXISPRING	D	MILLSITE	B	MISSION	D
MCKNIGHT	B	MELOLAND	C	MEYSIRE	B	MILLVILLE	B	MISSISQUOI	A
MCLAIN	C	MELROSE	C	MICON	D	MILLWOOD	D	MISSLER	B
MCLAURIN	B	MELTON	D	MIAMI	B	MILNER	B	MISSOULA	D
MCLEOD	B	MELVILLE	B	MIAMIAN	C	MILOK	D	MITCH	B
MCLOUGHLIN	D	MELVIN	D	MICANOPY	C	MILPITAS	C	MITCH, RARELY	C
MCMEEN	C	MEMALOOSE	C	MICCO	B/D	MILREN	C	FLOODED	
MCMILLE	B	MEMPHIS	B	MICHELSON	B	MILTON	C	MITCHELL	B
MCMULLIN	D	MENANGA	B	MICHIGAMME	C	MILVAR	C	MITIWANGA	C
MCMURDIE	C	MENARD	B	MICKEY	D	MIMBRES	B	MITKOF	D
MCMURRAY	D	MENASHA	D	MICROY	C	MIMOSA	C	MITKOF, MODERATELY	C
MCMURRAY, DRAINED	C	MENBO	C	MIDAS	C	MINA	B	WET	
MCNARY	D	MENDEBURE	C	MIDCO	A	MINALINGA	B	MITRI	C
MCNEAL	B	MENDELINA	D	MIDDLE	C	MINAR	B	MITRING	C
MCNULL	C	MENDELINA,	B	MIDDLEBURY	B	MINES	B	MITTEN	B
MCNULTY	B	LACUSTRINE		MIDDLEMARCH	B	MINATARE	D	MIVIDA	B
MCPAUL	B	SUBSTRATUM		MIDDLETOWN	B	MINCHEY	B	MIZEL	D
MCPHIE	B	MENDENHALL	D	MIDDLEWOOD	D	MINCHUMINA	D	MOAB	B
MCQUARRIE	D	MENDI	B	MIDELIGHT	B	MINCO	B	MOAG	D
MCQUEEN	C	MENDOCINO	B	MIDESSA	B	MINDEGO	C	MOAND	D
MCRAE	B	MENDON	B	MIDFORK	B	MINDEN	D	MOAPA	C
MCRAVEN	C	MENDUTA	B	MIDLAND	D	MINE	B	MOAULA	A
MCTAGGART	B	MENEFEE	D	MIDMONT	C	MINEOLA	A	MOBATE	D
MCVEGAS	D	MENFRO	B	MIDNIGHT	D	MINER	D	MOBEETIE	B
MCVICKERS	C	MENLO	D	MIDO	A	MINERAL	C	MOBERG	B
MEAD	D	MENO	C	MIDRAW	D	MINERAL MOUNTAIN	C	MOBL	B
MEADIN	A	MENOKEN	C	MIDVALE	C	MINERSVILLE	B	MOBRIDGE	B
MEADLAND	C	MENOMINEE	A	MIDWAY	D	MINESINGER	C	MOCA	D
MEADOWBROOK	B/D	MENTO	C	MIERMILL	C	MINETA	C	MOCAREY	D
MEADOWCREEK	C	MENTOR	B	MIERUF	B	MINGO	C	MOCHO	B
MEADOWLAKE	C	MENZEL	B	MIESEN	C	MINGUS	D	MOCKLEP	B
MEADOWVILLE	B	MEQUON	C	MIFFLIN	B	MINIDOKA	C	MOCMONT	B
MEANS	C	MER ROUGE	B	MIGEIN	B	MINKLER	D	MOCTILEME	C
MEARES	D	MERCED	D	MIGUEL	D	MINLITH	D	MODA	D
MECAN	B	MERCEDES	D	MIKE	D	MINNEHA	C	MODALE	C
MECHANICSBURG	C	MERCER	C	MIKESELL	C	MINNELISKA	B	MODENA	B
MECKESVILLE	C	MERCEY	C	MIKIM	B	MINNEOPA	B	MODESTO	C

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

[redacted]

440

739

Rec 16 Dec 95
NSS 96696
16/45
21 Feb 96

TABLE 5, continued: Hydrologic soil groups for United States soils

POQUONOCK	C	PREMIER	B	PUNCHBOWL	D	QUINLIVEN	C	RAMROD	C
PORFIRIO	C	PRENTISS	C	PUNG	C	QUINN	B/D	RAMSDELL	D
PORRETT	D	PRESA	B	PUNGO	D	QUINNEY	C	RAMSDELL, DRAINED	C
PORRONE	B	PRESHER	B	PUNOHU	A	QUINTANA	B	RAMSEY	D
PORT	B	PRESTO	B	PUNSIT	C	QUINTO	D	RAMSHORN	B
PORT BYRON	B	PRESTON	A	PUNTA	B/D	QUINTON	C	RANA	D
PORTAGE	D	PREVITT	B	PUNTILLA	B	QUITERIA	B	RANCE	C
PORTAGEVILLE	D	PREY	C	PURCELLA	B	QUITMAN	C	RANCHOSECO	D
PORTALES	B	PRICE	B	PURCHES	C	QUIVERA	C	RANDADO	C
PORTALTO	B	PRIDA	C	PURDAM	C	QUONSET	A	RANDALL	D
PORTERFIELD	C	PRIDHAM	D	PURDY	D	QUOPANT	D	RANDCORE	D
PORTERS	B	PRIESTLAKE	B	PURETT	B	QUOSATANA	D	RANDMAN	D
PORTERVILLE	D	PRIETA	D	PURGATORY	C	RABBITEX	B	RANDOLPH	C
PORTHILL	D	PRIM	D	PURNER	D	RABER	C	RANDS	C
PORTIA	C	PRIMEAUX	C	PUROB	D	RABIDEUX	B	RANDSBURG	D
PORTINO	C	PRIMEN	D	PURSLEY	B	RABUN	B	RANGEE	D
PORTLAND	D	PRINGHAR	B	PURVES	D	RACE	B	RANGER	C
PORTMOUNT	B	PRINCETON	B	PUSHMATAHA	C	RACINE	B	RANPUFF	D
PORTNEUF	B	PRINEVILLE	C	PUSTOI	B	RACKER	A	RANSLO	D
PORTOLA	B	PRING	B	PUTNAM	D	RACOMBES	B	RANSOM	B
PORTSMOUTH	B/D	PRINGLE	D	PUTNEY	B	RACOON	C/D	RANSTEIN	B
PORUM	D	PRITCHARD	C	PUTT	C	RAD	B	RANTOUL	D
POSANT	D	PRITCHETT	C	PUTTSTER	C	RAD, LACUSTRINE	C	RAPATEE	D
POSEN	B	PROCHASKA	A/D	PUU OO	A	SUBSTRATUM		RAPELJE	B
POSEY	B	PROCTOR	B	PUU OPAE	B	RAD, FLOODED	C	RAPH	B
POSEYVILLE	C	PROGRESSO	C	PUU PA	A	RADDLE	B	RAPHO	B
POSITAS	D	PROMISE	D	PUU PA, NONSTONY	B	RADER	D	RAPIDAN	B
POSKIN	C	PROMO	D	PUUKALA	C	RADERSBURG	B	RAPLEE	C
POSO	B	PRONG	C	PUUONE	C	RADFORD	B	RAPPAHANNOCK	D
POSOS	C	PROPHETSTOWN	B/D	PUYALLUP	B	RADLEY	B	RAPSON	B
POST	D	PROSPECT	B	PYBURN	D	RADNOR	C	RARDEN	C
POTAMUS	B	PROSPER	B	PYLE	B	RAFAEL	D	RARICK	C
POTCHUB	C	PROSSER	C	PYLON	D	RAFTON	D	RARITAN	C
POTEET	C	PROTIVIN	C	PYOTE	A	RAFTRIVER	C	RASBAND	B
POTELL	B	PROUT	C	PYRAMID	D	RAGLAN	B	RASILLE	B
POTH	C	PROUTY	C	PYRMONT	D	RAGNAR	B	RASSER	B
POTLATCH	C	PROVIDENCE	C	PYRMONT, BEDROCK	C	RAGNEL	B	RASSET	B
POTOMAC	A	PROVIG	C	SUBSTRATUM		RAGO	C	RASTUS	C
POTOSI	A	PROVO	D	PYWELL	D	RAGPIE	D	RATAKE	D
POTRATZ	C	PROVO BAY	D	QUAFEND	C	RAGSDALE	B/D	RATHBUN	C
POTSDAM	C	PROW	D	QUAKER	C	RAGSDALE, OVERWASH	B	RATHDRUM	B
POTTER	C	PRUDY	B	QUAKERTOWN	C	RAGTOWN	C	RATLAKE	D
POTTINGER	B	PRUE	B	QUAM	B/D	RAHAL	C	RATLEFLAT	B
POTTS	B	PRUITTON	B	QUAMON	A	RAHM	C	RATLIFF	B
POTTSBURG	B/D	PRUNIE	D	QUANAH	B	RAHWORTH	B	RATON	D
POUDRE	D	PRYOR	C	QUANDER	B	RAIL	D	RATSOW	C
POUJADE	D	PSUGA	B	QUANTICO	B	RAILCITY	A	RATTLER	D
POULSBO	D	PTARMIGAN	C	QUARLES	D	RAINBOW	C	RATTO	C
POUNCEY	D	PUAPUA	D	QUARTZBURG	C	RAINEY	C	RATTO, STONY	D
POVERTY	D	PUAULU	A	QUARTZVILLE	B	RAINIER	C	RAUB	C
POVEY	B	PUCHYAN	B	QUARZ	C	RAINO	D	RAUGHT	B
POWDER	B	PUDDLE	B	QUATAMA	C	RAINS	B/D	RAUVILLE	D
POWDERHORN	C	PUERCO	D	QUAY	B	RAINS, FLOODED	D	RAUZI	B
POWDERWASH	C	PUERTA	D	QUAZO	D	RAINSBORO	C	RAVALLI	D
POWEEN	C	PUERTECITO	D	QUEALMAN	C	RAINSVILLE	B	RAVALLI, BEDROCK	B
POWELL	C	PUETT	D	QUEALY	D	RAIRDENT	B	SUBSTRATUM	
POWER	B	PUFFER	D	QUEBRADA	C	RAISIO	C	RAVEN	A
POWERLINE	C	PUGET	D	QUEENY	D	RAKANE	C	RAVENDALE	D
POWLEY	D	PUGET, PROTECTED	C	QUEETS	B	RAKE	D	RAVENELL	D
POWMENT	C	PUGSLEY	C	QUEMADO	C	RAKIED	C	RAVENNA	C
POWWAHKEE	B	PUHI	B	QUENZER	D	RALEIGH	D	RAVENSWOOD	C
POWWATKA	C	PUHINAU	D	QUERC	C	RALLOD	D	RAVIA	C
POY	D	PUICE	C	QUERENCIA	B	RALLS	B	RAVOLA	B
POYGAN	D	PULA	C	QUETICO	D	RALPH	B	RAWAH	C
POYNOR	B	PULANTAT	C	QUICKSELL	C	RALPHSTON	B	RAWE	C
POZO	C	PULASKI	B	QUICKSILVER	D	RALSEN	D	RAWLES	B
POZO BLANCO	B	PULCAN	C	QUICKVERT	C	RAMADERO	B	RAWLINS	B
PRAG	C	PULEHU	B	QUIDEN	B	RAMBLA	C	RAWSON	B
PRAIRIEVILLE	B	PULEXAS	B	QUIENSABE	C	RAMBOUILLET	B	RAWSONVILLE	C
PRAMISS	C	PULLMAN	D	QUIETUS	C	RAMELLI	D	RAYBURN	D
PRATHER	C	PULPIT	C	QUIGLEY	B	RAMIRES	C	RAYEX	D
PRATLEY	C	PULS	D	QUIHI	C	RAMMEL	C	RAYFORD	C
PRATT	A	PULSIPHER	D	QUILCENE	C	RAMO	C	RAYLAKE	D
PREACHER	B	PULTNEY	C	QUILLAYUTE	B	RAMONA	B	RAYMONDVILLE	D
PREAKNESS	B/D	PUMEL	D	QUILOTOSA	D	RAMONA, HARD	C	RAYNE	B
PREATORSON	B	PUMEL, NONGRAVELLY	C	QUILT	D	SUBSTRATUM		RAYNESFORD	B
PREBISH	C/D	PUMPER	B	QUINA	B	RAMPART	B	RAYNHAM	C
PREBLE	D	PUNA	A	QUINCY	A	RAMPARTER	B	RAYNOLDSON	B
PRELO	B	PUNALUU	D	QUINLAN	C	RAMPS	B	RAYOHILL	C

OTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

[redacted]

441

739 Asc 16 Dec 95
ISS 9 Feb 96
17/45
Acc 21 Feb 96

TABLE 5, continued: Hydrologic soil groups for United States soils

RODIE	A	ROSENDALE	C	RUBY	B	SABENYO	B	SAMINIEGO	C
RODMAN	A	ROSENWALL	D	RUBYHILL	C	SABINA	C	SAMISH	D
RODROF	D	ROSEVILLE	B	RUCH	B	SABINE	A	SAMMAMISH	D
ROEBUCK	D	ROSEWOOD	A/D	RUCKER	B	SABLE	B/D	SAMOIST	D
ROELLEN	D	ROSEWOOD, WET	D	RUCKLES	D	SAC	B	SAMOR	D
ROEMER	C	ROSEWORTH	D	RUCLICK	C	SACHEEN	A	SAMPSEL	D
ROETEX	D	ROSHE SPRINGS	D	RUDD	D	SACHETT	C	SAMPSON	B
ROFISS	B	ROSHE SPRINGS,	C	RUDDLEY	D	SACO	D	SAMSIL	D
ROGAN	B	DRAINED		RUDEEN	C	SACRAMENTO	D	SAMSULA	B/D
ROGERSON	D	ROSHOLT	B	RUDYARD	C	SACTUS	D	SAN ANDREAS	B
ROGERT	D	ROSINE	B	RUEDLOFF	B	SACUL	C	SAN ANTON	B
ROGRUBE	B	ROSITAS	A	RUELLA	B	SADDLE	C	SAN ANTONIO	C
ROGUE	B	ROSITAS, CLAYEY	C	RUFUS	D	SADDLEBACK	C/D	SAN ARCACIO	C
ROHAN	D	SUBSTRATUM		RUGAR	C	SADDLEGAP	B	SAN BENITO	B
ROHNERVILLE	B	ROSITAS, LOAMY,	C	RUGG	B	SADDLEROCK	D	SAN EMIGDIO	B
ROHONDA	C	WET		RUGLES	F	SADER	D	SAN GERMAN	D
ROHRERSVILLE	D	ROSITAS, WET	C	RUHE	D	SADIE	C	SAN ISABEL	A
ROIC	D	ROSLYN	B	RUIDOSO	C	SADLER	C	SAN JOAQUIN	D
ROJO	C	ROSMAN	B	RUINPOINT	B	SAFFELL	B	SAN JON	C
ROLETTE	C	ROSNEY	B	RUIZ	A	SAG	B	SAN JOSE	B
ROLFE	C	ROSS	B	RUKO	D	SAGANING	A/D	SAN JUAN	A
ROLIE	D	ROSSBURG	B	RULE	B	SAGASER	B	SAN LUIS	C
ROLISS	B/D	ROSSFIELD	B	RUMBLECREEK	B	SAGE	D	SAN MATEO	B
ROLLA	C	ROSSMOOR	B	RUMBO	C	SAGECREEK	B	SAN MIGUEL	D
ROLLINGSTONE	C	ROSSMOYNE	C	RUMFORD	B	SAGEDALE	C	SAN SABA	D
ROLOC	D	ROSWELL	A	RUMLEY	B	SAGEHILL	B	SAN SEBASTIAN	B
ROLOFF	C	ROSY	B	RUMNEY	C	SAGEMOOR	B	SAN SIMEON	D
ROMBERG	B	ROTAMER	B	RUMPAH	D	SAGERS	B	SAN TIMOTEO	C
ROMBO	C	ROTAN	C	RUMPLE	C	SAGERTON	C	SAN YSIDRO	D
ROME	B	ROTHICAN	B	RUMUNG	C	SAGLE	C	SANCHEZ	D
ROMEO	D	ROTHIEMAY	C	RUNE	C	SAGO	D	SANCLEMENTE	D
ROMERO	D	ROTHSAY	B	RUNEBERG	C/D	SAGOUSPE	C	SANDALL	C
ROMGAN	C	ROTINOM	B	RUNGE	B	SAGOUSPE, DRAINED	B	SANDBRANCH	B
ROMIA	B	ROTO	C	RUNN	D	SAGUACHE	B	SANDCREEK	D
ROMINE	B	ROTTULSE	C	RUPLE	C	SAHALIE	B	SANDERSON	B
ROMINELL	C	ROUBIDEAU	C	RUPLEY	A	SAHUARITA	B	SANDHILL	B
ROMNELL	B/D	ROUEN	C	RUSCO	C	SAID	B	SANDIA	B
RONSTOCK	B	ROUGHCREEK	D	RUSCO, PONDED	D	SAIDO	B	SANDOSE	A
ROMULUS	D	ROUGHLOCK	B	RUSE	D	SAILBOAT	C	SANDOVAL	D
RONAN	D	ROUGHMOUNT	C	RUSH	D	SAILBOAT, DRAINED	B	SANDRIDGE	A
RONO	C	ROUND BUTTE	D	RUSHMORE	B/D	SAIPAN	B	SANDSPRING	B
RONDEAU	A/D	ROUNDABOUT	C	RUSHTOWN	A	SAL	D	SANDUN	B
RONDELL	B	ROUNDBARN	E	RUSHVILLE	D	SALADAR	D	SANDUSKY	D
RONDOWA	B	ROUNDHEAD	B/D	RUSG	B	SALADON	D	SANDVIEW	B
RONNEBY	C	ROUNDOR	C	RUSDN	C	SALAL	C	SANDWASH	C
RONSEL	B	ROUNDTOP	C	RUSS	B	SALAMATOF	D	SANDWICK	B
RONSON	B	ROUNDUP	C	RUSSELL	B	SALANDER	B	SANELI	D
ROONEY	D	ROUNDY	C	RUSSIAN	B	SALAS	C	SANFORD	B
ROOSET	C	ROUSSEAU	A	RUSSLER	C	SALCHAKET	B	SANGER	D
ROOSEVELT	C	ROUTON	D	RUSTICO	B	SALCO	B	SANGO	C
ROOT	B/D	ROUTT	C	RUSTIGATE	C	SALEM	B	SANHEDRIN	B
ROOTEL	C	ROYAL	D	RUSTON	B	SALERATUS	C	SANIDEL	B/D
ROPER	B/D	ROYDEN	C	RUSTY	B	SALERNO	B/D	SANILAC	B
ROSALIE	B	ROYDY	B	RUTAB	B	SALGA	C	SANJE	D
ROSAMOND	B	ROYE	D	RUTERSVILLE	C	SALIDA	A	SANLOREN	B
ROSAMOND,	C	ROYEL	D	RUTHERFORD	C	SALINAS	B	SANPETE	B
SALINE-ALKALI,		ROYENA	C	RUTLAND	C	SALISBURY	C	SANPITCH	C
FLOODED		ROYLAND	C	RUTLEGE	B/D	SALIX	B	SANPOIL	D
ROSANE	D	ROYLEY	C	RYAN	D	SALKUM	B	SANSARC	D
ROSANKY	C	ROYAL	D	RYAN PARK	B	SALLISAW	B	SANTA	D
ROSARIO	C	ROYANA	B	RYARK	A	SALLYANN	C	SANTA CLARA	C
ROSCOE	D	ROYBURY	B	RYCO	D	SALMO	C/D	SANTA FE	D
ROSCOMMON	A/D	ROYER	B	RYDE	C	SALMON	B	SANTA ISABEL	D
ROSE CREEK	C	ROYTON	D	RYDER	C	SALONIE	D	SANTA LUCIA	C
ROSE CREEK,	B	ROY	B	RYDOLPH	C	SALT CHUCK	A	SANTA MARTA	C
DRAINED		ROYAL	B	RYEGATE	C	SALT LAKE	D	SANTA YNEZ	D
ROSE VALLEY	D	ROYCE	C	RYELL	B	SALTAIR	D	SANTANA	D
ROSEBERRY	D	ROYGORGE	D	RYELL, SALINE	D	SALTER	B	SANTANELA	D
ROSEBLOOM	D	ROYOSA	A	RYEPATCH	C	SALTERY	D	SANTAQUIN	A
ROSEBOROUGH	B	ROYST	C	RYER	C	SALTESE	D	SANTAROSA	B
ROSEBUD	B	ROYSTONE	B	RYKER	B	SALTINE	C	SANTEE	D
ROSEBURG	B	ROZA	C	RYMAN	C	SALTON	D	SANTIAGO	B
ROSEDHU	B/D	ROZELLVILLE	B	RYORP	C	SALUDA	C	SANTIAM	C
ROSEGLEN	B	ROZETTA	B	RYPOC	B	SALVISA	C	SANTO	B
ROSEHAVEN	B	ROZLEE	C	RYUS	B	SALZER	D	SANTO TOMAS	B
ROSEHILL	D	RUARK	B/D	SAAR	C	SALZER, PROTECTED	C	SANTONI	D
ROSELAND	B	RUBICON	A	SABANA	D	SAMBA	D	SANWELL	B
ROSELLA	D	RUBIO	C/D	SABANA SECA	C	SAMBRITO	B	SAPEHA	B
ROSELMS	D	RUBSON	B	SABE	B	SAMDAY	D	SAPELO	D

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

[redacted]
442

739 Asc 16 Dec 85

SSS 960896 18/45 Ltr 21Feb86

TABLE 5 , continued: Hydrologic soil groups for United States soils

WILSON	D	WISHARD	C	WOODS CROSS	D	WYNOOSE	D	YEGEN	B
WILSONGULCH	B	WISHBONE	B	WOODSEYE	D	WYOCENA	B	YEGUAS	C
WILSONVILLE	D	WISHEYLU	C	WOODSFIELD	C	WYOMING	A	YELJACK	B
WILSOR	B	WISHKAH	D	WOODSIDE	B	WYRENE	B	YELLOWDAY	B
WILST	C	WISHKAH, DRAINED	C	WOODSLAKE	D	WYSOCKING	C/D	YELLOWHOUND	B
WILTON	B	WISKAN	C	WOODSON	D	XANA	B	YELLOWROCK	A
WINADA	C	WISKIFLAT	B	WOODSTOCK	C/D	XAMADU	B	YELLOWSTONE	D
WINDERRY	C	WISNER	B/D	WOODSTOWN	C	XAVIER	B	YELM	C
WINCHESTER	A	WISTER	C	WOODTELL	D	XENIA	B	YEMASSEE	C
WINCHUCK	C	WITBECK	B/D	WOODVILLE	D	XENO	B	YENCE	C
WIND RIVER	B	WITEFELS	B	WOODWARD	B	XERTA	C	YENLO	B
WINDCOAT	D	WITHAM	D	WOODWEST	D	XERXES	D	YENRAB	A
WINDER	B/D	WITHEE	C	WOOFUS	D	XICA	C	YEOMAN	B
WINDER,	D	WITHERBEE	A/D	WOOLPER	C	XINE	C	YEOPIM	B
DEPRESSIONAL		WITHERELL	D	WOOLSEY	B	XIPE	D	YERINGTON	A
WINDHAM	B	WITHERS	C	WOOLSTALF	B	XIPE, MODERATELY	C	YERMO	B
WINDICREEK	A	WITT	B	WOOLSTED	B	WET		YESUM	B
WINDHILL	B	WITTEN	D	WOONSOCKET	B	XMAN	D	YETTEM	B
WINDSOR	A	WITTENBERG	B	WOOSLEY	C	YACOLT	B	YETULL	A
WINDTHORST	C	WITZEL	D	WOOSTER	C	YAGO	C	YIGO	B
WINDWHISTLE	C	WIX	C	WORCESTER	C	YAHANA	C	YIPOR	B
WINDWHISTLE, WARM	B	WIXOM	B	WORDEN	C	YAHARA	C	YLIG	C
WINDY	B	WOCKLEY	C	WORF	D	YAHNE	C	YOBE	C
WINDYPOINT	B	WODA	D	WORFKA	D	YAHOLA	B	YOCHUM	C
WINEG	B	WODEN	B	WORFMAN	D	YAHOO	D	YOCKEY	C
WINEMA	C	WOOSKOW	C	WORFSTONE	C	YAINAX	B	YODER	B
WINETTI	B	WOOSKOW, DRAINED	B	WORK	C	YAKI	D	YODY	C
WINEVADA	C	WOHLY	B	WORK, GRAVELLY	B	YAKIMA	B	YOHURT	D
WINFALL	B	WOLCO	C	WORLAND	C	YAKUS	D	YOKAYO	D
WINFIELD	B	WOLCOTT	B/D	WORLEY	D	YAKUTAT	A	YOKOHL	D
WING	D	WOLDALE	D	WORMSER	C	YALELAKE	B	YOKUT	B
WINGATE	B	WOLDALE, DRAINED	C	WOROCK	B	YALESVILLE	C	YOLLABOLLY	D
WINGER	B/D	WOLF	B	WORSHAM	D	YALLANI	B	YOLO	B
WINGINAW	D	WOLF POINT	C	WORTH	C	YALMER	B	YOLOGO	D
WINGVILLE	D	WOLFCREEK	B	WORTHEN	B	YAMAC	B	YOMBA	B
WINIFRED	C	WOLFESON	C	WORTHING	D	YAMHILL	C	YOMONT	B
WINK	B	WOLFESON, WET	D	WORTMAN	D	YAMO	B	YONGES	D
WINKEL	D	WOLFEY	C	WORTMAN, SANDY	A	YAMSAY	D	YONNA	D
WINKLEMAN	C	WOLFPEN	A	WOVOKA	C	YANA	B	YORBA	D
WINKLEMAN, WET	D	WOLFTEVER	C	WRANGELL	D	YANCY	D	YORK	C
WINKLER	B	WOLLARD	C	WRANGO	A	YANKEE	D	YORKTOWN	D
WINLER	D	WOLLENT	D	WRAYHA	D	YANKTON	B	YORKTREE	C
WINLO	D	WOLOT	B	WREDAH	B	YANUSH	B	YORKVILLE	D
WINN	C	WOLVERINE	A	WRENCOE	D	YAP	B	YOSI	D
WINNEBAGO	B	WOMACK	C	WRENMAN	C	YAPOAH	B	YOST, DRAINED	C
WINNECONNE	C	WOO	B	WRENTHAM	C	YAQUI	B	YOUD	D
WINNECOOK	C	WOO, OVERWASH	C	WRIGHT	C	YAQUINA	D	YOUGA	B
WINNEMUCCA	B	WOO, WET	C	WRIGHTMAN	C	YAQUINA, DRAINED	C	YOUGA, SANDY	D
WINNESHIEK	B	WOOD RIVER	D	WRIGHTSBORO	C	YARCO	D	SUBSTRATUM	
WINNETT	D	WOODBECK	B	WRIGHTSVILLE	D	YARDLEY	C	YOUJAY	D
WINNSBORO	D	WOODBINE	B	WRIGHTWOOD	B	YARTS	B	YOUMAN	C
WINOM	D	WOODBRIDGE	C	WUKOKI	B	YATAHONEY	C	YOUNGSTON	B
WINONA	D	WOODBURN	C	WUKSI	A	YATAHONEY, STONY	D	YOUNGSTON, WET	C
WINOOSKI	B	WOODBURY	D	WULFERT	D	YATES	D	YOURANE	B
WINOPEE	B	WOODCOCK	B	WUNJEY	B	YAUCO	C	YOUTLKUE	D
WINRIDGE	D	WOODFORD	D	WUPATKI	D	YAUHANNAH	B	YOVIMPA	D
WINSHIP	C	WOODGULCH	A	WURNO	C	YAUPON	D	YPSI	C
WINSPECT	B	WOODHALL	C	WURSTEN	B	YAWDIM	D	YRIBARREN	D
WINSTON	B	WOODHURST	C	WURTSBORO	C	YAWHEE	B	YSIDORA	C
WINT	D	WOODIN	C	WYALUSING	D	YAWKEY	B	YTURBIDE	A
WINTERFIELD	A/D	WOODINGTON	B/D	WYANDOTTE	D	YAXON	B	YTURRIA	A
WINTERHAVEN	B	WOODINVILLE	D	WYANT	C	YEAGER	A	YUBA	D
WINTERIDGE	B	WOODINVILLE,	C	WYARD	B	YFARY	C	YUKO	D
WINTERS	C	DRAINED		WYARNO	B	YEATES HOLLOW	B	YUKON	D
WINTERSBURG	C	WOODLAWN	B	WYATT	C	YEATES HOLLOW,	C	YULEE	D
WINTERSET	C	WOODLEAF	C	WYCOLO	C	LOAMY SUBSTRATUM,		YUNES	D
WINTHROP	A	WOODLY	B	WYE	B	STONY		YUNQUE	C
WINTLEY	B	WOODLYN	D	WYEAST	D	YEATES HOLLOW,	C	YURM	D
WINTON	C	WOODMANSIE	B	WYETH	B	LOAMY SUBSTRATUM		YUTRUE	D
WINTONER	B	WOODMERE	B	WYEVILLE	C	YEATES HOLLOW,	C	YUVAS	D
WINU	C	WOODMONT	C	WYICK	D	STONY		ZAAR	D
WINZ	D	WOODPASS	B	WYKEHAM	B	YEATES HOLLOW,	C	ZABA	B
WIOTA	B	WOODROCK	C	WYKOFF	B	NONSTONY		ZACA	D
WIPPLE	C	WOODROW	B	WYMAN	B	YEATES HOLLOW, DRY	C	ZACHARIAS	B
WIRT	B	WOODROW,	C	WYMORE	D	YEATES HOLLOW,	C	ZACHARY	C
WISCON	D	SALINE-ALKALI		WYNDMERE	B	COBBLY		ZACK	D
WISE	C	WOODROW,	C	WYNN	B	YEATON	C	ZADOG	A/D
WISEMAN	A	OCCASIONALLY		WYNNVILLE	C	YECROSS	A	ZADVAR	D
WISFLAT	D	FLOODED		WYNONA	C	YEDLICK	B	ZAFRA	B

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

[redacted]

443

739 Asc 16 Dec 98 SSS 9 Feb 96 LEWS Ke 21 Feb 89.

Table 6a.—Runoff curve numbers for cultivated agricultural lands[1]

Cover description			Curve numbers for hydrologic soil group—			
Cover type	Treatment[2]	Hydrologic condition[3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Straight row + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	Contoured & terraced + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Straight row + CR	Poor	64	75	83	86
		Good	60	72	80	84
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured + CR	Poor	62	73	81	84
		Good	60	72	80	83
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
	Contoured & terraced + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured & terraced	Poor	63	73	80	83
		Good	51	67	76	80

[1] Average runoff condition.
[2] *Crop residue cover (CR)* applies only if residue is on at least 5% of the surface throughout the year.
[3] Hydrologic condition is based on combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes in rotations, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.
Poor: Factors impair infiltration and tend to increase runoff.
Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

USDA - SCS, 1986a

739 Lsc 16 Dec 85
SS 9/6/96 20/4
Fc 21Feb96

Table 6b.—Runoff curve numbers for other agricultural lands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[4]	48	65	73
Woods-grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30[4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

[1] Average runoff condition.
[2] *Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50% to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.
[3] *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
[4] Actual curve number is less than 30; use CN = 30 for runoff computations.
[5] CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
[6] *Poor:* Forest, litter, small trees, and brush have been destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

USDA-SCS, 1986a

[redacted] 445

739 Asc 16 Dec 95 21/45 SSS 96696 21Feb98

Table 6 c.—Runoff curve numbers for arid and semiarid rangelands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition[2]	A[3]	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

[1] Average runoff condition. For rangelands in humid regions, use table 2-3b.
[2] *Poor:* <30% ground cover (litter, grass, and brush overstory).
Fair: 30% to 70% ground cover.
Good: >70% ground cover.
[3] Curve numbers for group A have been developed only for desert shrub.

USDA-SCS, 1986a

[redacted]

739 Asc 16 Dec 85 SSS 9 Feb 86 224 21 Feb 86

Table 6.d.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2a).					

[1] Average runoff condition.
[2] The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition.
[3] CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4] Composite CN's for natural desert landscaping should be computed based on the impervious area (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

USDA-SCS, 1986a

[redacted]

447

Asc 16 Dec 55

23/45

855 96 696

21 Feb 96

Table 7 . Curve numbers (CN) and constants for the case $I_a = 0.2\ S$

1	2	3	4	5	1	2	3	4	5
CN for condition II	CN for conditions I	CN for conditions III	S values* (inches)	Curve* starts where P = (inches)	CN for condition II	CN for conditions I	CN for conditions III	S values* (inches)	Curve* starts where P = (inches)
100	100	100	0	0	60	40	78	6.67	1.33
99	97	100	.101	.02	59	39	77	6.95	1.39
98	94	99	.204	.04	58	38	76	7.24	1.45
97	91	99	.309	.06	57	37	75	7.54	1.51
96	89	99	.417	.08	56	36	75	7.86	1.57
95	87	98	.526	.11	55	35	74	8.18	1.64
94	85	98	.638	.13	54	34	73	8.52	1.70
93	83	98	.753	.15	53	33	72	8.87	1.77
92	81	97	.870	.17	52	32	71	9.23	1.85
91	80	97	.989	.20	51	31	70	9.61	1.92
90	78	96	1.11	.22	50	31	70	10.0	2.00
89	76	96	1.24	.25	49	30	69	10.4	2.08
88	75	95	1.36	.27	48	29	68	10.8	2.16
87	73	95	1.49	.30	47	28	67	11.3	2.26
86	72	94	1.63	.33	46	27	66	11.7	2.34
85	70	94	1.76	.35	45	26	65	12.2	2.44
84	68	93	1.90	.38	44	25	64	12.7	2.54
83	67	93	2.05	.41	43	25	63	13.2	2.64
82	66	92	2.20	.44	42	24	62	13.8	2.76
81	64	92	2.34	.47	41	23	61	14.4	2.88
80	63	91	2.50	.50	40	22	60	15.0	3.00
79	62	91	2.66	.53	39	21	59	15.6	3.12
78	60	90	2.82	.56	38	21	58	16.3	3.26
77	59	89	2.99	.60	37	20	57	17.0	3.40
76	58	89	3.16	.63	36	19	56	17.8	3.56
75	57	88	3.33	.67	35	18	55	18.6	3.72
74	55	88	3.51	.70	34	18	54	19.4	3.88
73	54	87	3.70	.74	33	17	53	20.3	4.06
72	53	86	3.89	.78	32	16	52	21.2	4.24
71	52	86	4.08	.82	31	16	51	22.2	4.44
70	51	85	4.28	.86	30	15	50	23.3	4.66
69	50	84	4.49	.90					
68	49	84	4.70	.94	25	12	43	30.0	6.00
67	47	83	4.92	.98	20	9	37	40.0	8.00
66	46	82	5.15	1.03	15	6	30	56.7	11.34
65	45	80	5.38	1.08	10	4	22	90.0	18.00
64	44	81	5.62	1.12	5	2	13	190.0	38.00
63	43	80	5.87	1.17	0	0	0	infinity	infinity
62	42	79	6.13	1.23					
61	41	78	6.39	1.28					

*For CN in [illegible]

USDA - SCS, 1985

[redacted]

TABLE 8

NORTHERN AREA INPUT PARAMETERS
25-YEAR STORM EVENT

			Sheet Flow			Shallow Concetrated Flow			Open Channel Flow					
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Manning's n	Depth (ft)	Channel Slope (%)	Right Slope	Left Slope
N-A	22.7	64	200	0.18	SEE	1100	0.1	SEE	420	SEE	4	0.5	6:1	6:1
N-B	2.6	58	180	0.01	NOTE	-	-	NOTE	250	NOTE	4	0.5	6:1	6:1
N-1	4.5	98	147	0.07	A	325	0.167	B	400	C	5	0.5	6:1	6:1

2,000-YEAR STORM EVENT

			Sheet Flow			Shallow Concetrated Flow			Open Channel Flow					
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Manning's n	Depth (ft)	Channel Slope (%)	Right Slope	Left Slope
N-A	22.7	81	200	0.18	SEE	1100	0.1	SEE	420	SEE	4	0.5	6:1	6:1
N-B	2.6	76	180	0.01	NOTE	-	-	NOTE	250	NOTE	4	0.5	6:1	6:1
N-1	4.5	99	147	0.07	A	325	0.167	B	400	C	5	0.5	6:1	6:1

Note A: Light Cover = Short Grass; Moderate & Heavy Cover = Dense Grass

Note B: Unpaved

Note C: Light & Moderate Cover: n = 0.030; Heavy Cover: n = 0.10

739

Asc 5 Feb 96
24/45
SSS 9 Feb 96
21 Feb 96

Table 9

EASTERN AREA INPUT PARAMETERS
25-YEAR STORM EVENT

			Sheet Flow			Shallow Concetrated Flow			Open Channel Flow							
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	X-C Area (sf)	Wetted Perimeter (ft)	Length (ft)	Manning's n	Bottom Width (ft)	Channel Slope (%)	Left Slope	Right Slope
E-A	0.55	73	30	0.3333	SEE NOTE A	-	-	<	272	87	800	SEE NOTE B	0	0.5	6:1	3:1
E-B	0.37	64	30	0.3333		-	-	=	312	97	540		0	0.5	6:1	3:1
E-C	0.33	74	30	0.3333		-	-	UNPAVED	332	102	405		0	0.5	6:1	3:1
E-D	0.23	74	20	0.3333		-	-		348	106	290		0	0.5	6:1	3:1
E-E	0.44	74	20	0.3333		-	-		348	106	550		0	0.5	6:1	3:1
E-F	1.11	72	20	0.3333		-	-		348	106	820		0	0.5	6:1	3:1
E-1	10.5	98	147	0.070		300	0.167		272	87	705		0	0.5	6:1	3:1
E-2	5.3	98	147	0.070		305	0.167		312	97	540		0	0.5	6:1	3:1
E-3	4.2	98	147	0.070		310	0.167		332	102	405		0	0.5	6:1	3:1
E-4	3.0	98	147	0.070		310	0.167		348	106	290		0	0.5	6:1	3:1
E-5	5.8	98	147	0.070		305	0.167		348	106	550		0	0.5	6:1	3:1
E-6	6.3	98	147	0.070		300	0.167	v	348	106	820		0	0.5	6:1	3:1

Note A: Light Cover = Short Grass; Moderate & Heavy Cover = Dense Grass

Note B: Light & Moderate Cover: n = 0.030; Heavy Cover: n = 0.10

ASS 96096
21 Feb 96

ASC 5 Feb 96
25/45

450

TABLE 9
(CONTINUED)

EASTERN AREA INPUT PARAMETERS
2,000-YEAR STORM EVENT

			Sheet Flow			Shallow Concetrated Flow			Open Channel Flow							
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	X-C Area (sf)	Wetted Perimeter (ft)	Length (ft)	Manning's n	Bottom Width (ft)	Channel Slope (%)	Left Slope	Right Slope
E-A	7.6	89	300	0.007	S	320	0.013	^	272	87	465	S	50	0.5	6:1	3:1
E-B	7.4	88	300	0.010	E	615	0.020	=	312	97	30	E	60	0.5	6:1	3:1
E-C	7.1	90	300	0.010	E	655	0.020	U	332	102	0	E	65	0.5	6:1	3:1
E-D	8.7	89	200	0.013		735	0.020	N	348	106	30		69	0.5	6:1	3:1
E-E	7.9	86	200	0.025	N	735	0.020	P	348	106	125	N	69	0.5	6:1	3:1
E-F	11.9	88	200	0.013	O	475	0.017	A	348	106	785	O	69	0.5	6:1	3:1
E-1	10.5	99	147	0.070	T	300	0.167	V	272	87	705	T	50	0.5	6:1	3:1
E-2	5.3	99	147	0.070	E	305	0.167	E	312	97	540	E	60	0.5	6:1	3:1
E-3	4.2	99	147	0.070		310	0.167	D	332	102	405		65	0.5	6:1	3:1
E-4	3.0	99	147	0.070	A	310	0.167	=	348	106	290	B	69	0.5	6:1	3:1
E-5	5.8	99	147	0.070		305	0.167	=	348	106	550		69	0.5	6:1	3:1
E-6	6.3	99	147	0.070		300	0.167	v	348	106	820		69	0.5	6:1	3:1

Note A: Light Cover = Short Grass; Moderate & Heavy Cover = Dense Grass

Note B: Light & Moderate Cover: n = 0.030; Heavy Cover: n = 0.10

Asc 5 Feb 96
26/45
JSS 9 Feb 96
21 Feb 96

239

151

TABLE 10

SOUTHERN AREA INPUT PARAMETERS
25- & 2,000-YEAR STORM EVENTS

			Sheet Flow			Shallow Concetrated Flow		
Subarea Name	Area (Acres)	CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type
S-1	5.6	98/99	147	0.07	Short Grass	330	0.167	Unpaved

ASC 9 Feb 96 739
27743
21 Feb 96

TABLE 11

WESTERN AREA INPUT PARAMETERS
25-YEAR STORM EVENT

			Sheet Flow			Shallow Concetrated Flow			OpenChannel Flow								
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	X-C Area (sf)	Wetted Perimeter (ft)	Length (ft)	Manning's n	Bottom Width (ft)	Channel Slope (%)	Right Slope	Left Slope	Depth (ft)
W-A	2.1	71	300	0.010		100	0.010	^	-	-	-		-	-	-	-	-
W-1	1.6	98	100	0.167		270	0.167	=	10.1	13.87	225		0	0.75	3:1	6:1	1.5
W-2	2.2	98	147	0.070		360	0.167	=	10.1	13.87	200		0	0.75	3:1	6:1	1.5
W-3	2.4	98	147	0.070		360	0.167	=	10.1	13.87	200		0	0.75	3:1	6:1	1.5
W-4	2.4	98	147	0.070	S	360	0.167	=	10.1	13.87	200	S	0	0.75	3:1	6:1	1.5
W-5	2.4	98	147	0.070	E	360	0.167	=	10.1	13.87	200	E	0	0.75	3:1	6:1	1.5
W-6	2.4	98	147	0.070	E	360	0.167	U	10.1	13.87	200	E	0	0.75	3:1	6:1	1.5
W-7	2.4	98	147	0.070		360	0.167	N	10.1	13.87	200		0	0.75	3:1	6:1	1.5
W-8	2.4	98	147	0.070	N	360	0.167	P	10.1	13.87	200	N	0	0.75	3:1	6:1	1.5
W-9	2.4	98	147	0.070	O	360	0.167	A	10.1	13.87	200	O	0	0.75	3:1	6:1	1.5
W-10	2.4	98	147	0.070	T	360	0.167	V	10.1	13.87	200	T	0	0.75	3:1	6:1	1.5
W-11	2.4	98	147	0.070	E	360	0.167	E	10.1	13.87	200	E	0	0.75	3:1	6:1	1.5
W-12	2.4	98	147	0.070		360	0.167	D	10.1	13.87	200		0	0.75	3:1	6:1	1.5
W-13	2.4	98	147	0.070	A	360	0.167	=	10.1	13.87	200	B	0	0.50	3:1	6:1	1.5
W-14	2.4	98	147	0.070		360	0.167	=	10.1	13.87	200		0	0.50	3:1	6:1	1.5
W-15	2.4	98	147	0.070		360	0.167	=	10.1	13.87	200		0	0.50	3:1	6:1	1.5
W-16	2.4	98	147	0.070		360	0.167	=	10.1	13.87	200		0	0.50	3:1	6:1	1.5
W-17	2.4	98	147	0.070		360	0.167	=	10.1	13.87	200		0	0.50	3:1	6:1	1.5
W-18	1.4	98	100	0.167		250	0.167	v	10.1	13.87	350		0	0.50	3:1	6:1	1.5

Note A: Light Cover = Short Grass; Moderate & Heavy Cover = Dense Grass

Note B: Light & Moderate Cover: n = 0.030; Heavy Cover: n = 0.10

239 Asc 5 Feb 96
TSS 28/46
21 Feb 96

453

739 29/45

TABLE 12

HIGHWAY LOADS

POUNDS PER LINEAR FOOT

CIRCULAR PIPE

PIPE SIZE D IN INCHES	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	PIPE SIZE D IN INCHES
12	4849	2730	1524	954	574	361	316	237	168	46	12
15	**5915**	3322	1872	1163	700	441	358	289	205	56	15
18		3926	2196	1369	825	520	454	341	242	66	18
21		**4498**	2525	1580	950	599	522	392	279	77	21
24			2856	1788	1077	679	592	444	316	87	24
27			**3096**	1998	1201	757	660	496	353	97	27
30				2204	1328	837	731	548	390	107	30
33				**2370**	1452	915	798	599	426	117	33
36					1580	996	869	652	463	127	36
42					**1679**	1154	1007	755	537	147	42
48						**1221**	1146	859	611	168	48
54							**1185**	962	684	188	54
60								**998**	758	208	60
66									832	228	66
72									**857**	249	72
78										269	78
84										**275**	84

HORIZONTAL ELLIPTICAL PIPE

PIPE SIZE R × S IN INCHES	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	PIPE SIZE R × S IN INCHES
14×23	**5915**	**4498**	2716	1699	1022	644	561	422	300	82	14×23
19×30			**3096**	2177	1309	825	719	451	384	105	19×30
22×34				**2370**	1471	927	808	607	432	118	22×34
24×38					1631	1028	896	674	479	131	24×38
27×42					**1679**	1119	975	733	521	143	27×42
29×45						**1221**	1064	800	569	156	29×45
32×49							1152	866	616	169	32×49
34×53							**1185**	933	663	182	34×53
38×60								**998**	748	205	38×60
43×68									842	231	43×68
48×76									**857**	257	48×76
53×83										**275**	53×83

ARCH PIPE

PIPE SIZE R × S IN INCHES	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	PIPE SIZE R × S IN INCHES
11×18	**5915**	3840	2144	1342	807	509	443	333	237	65	11×18
13½×22		**4498**	2573	1610	968	520	532	400	284	78	13½×22
15½×26			3000	1879	1130	712	621	467	332	91	15½×26
18×28½			**3096**	2058	1238	780	680	511	363	100	18×28½
22½×36¼				**2370**	1533	966	842	633	450	124	22½×36¼
26⅝×43¾					**1679**	1170	1019	766	545	150	26⅝×43¾
31⅝×51⅛						**1221**	**1185**	981	633	174	31⅝×51⅛
36×58½								**998**	721	198	36×58½
40×65									800	220	40×65
45×73									**857**	246	45×73
54×88										**275**	54×88

Unsurfaced Roadway; 16,000-Pound Wheel Load; Dual Tires; 80 p.s.i. Tire Pressure; Impact Included. Last number in each column **(bold type)** *indicates maximum load for any given fill height. Interpolate for intermediate fill heights.*

[redacted]

[redacted] 454

TABLE 13

18"

BACKFILL LOADS ON CIRCULAR PIPE IN TRENCH INSTALLATION

*100 POUNDS PER CUBIC FOOT BACKFILL MATERIAL — LOADS IN POUNDS PER LINEAR FOOT

18"

A SAND AND GRAVEL Kμ'—0.165

HEIGHT OF BACKFILL H ABOVE TOP OF PIPE, FEET	TRENCH WIDTH AT TOP OF PIPE 2'-6"	2'-9"	3'-0"	3'-3"	3'-6"	4'-0"	4'-6"	5'-0"	6'-0"	7'-0"	▲TRANSITION WIDTH
5	915	1033	1153	1274	**1411**						3'- 6"
6	1036	1176	1317	1460	1603	**1700**					3'- 8"
7	1142	1302	1464	1628	1793	**1989**					3'-10"
8	1235	1414	1596	1780	1966	**2277**					3'-11"
9	1316	1513	1713	1917	2123	**2566**					4'- 0"
10	1388	1601	1819	2041	2266	2723	**2855**				4'- 2"
11	1450	1679	1914	2153	2396	2891	**3145**				4'- 3"
12	1505	1748	1998	2254	2514	3046	**3431**				4'- 4"
13	1553	1810	2074	2345	2622	3189	**3718**				4'- 5"
14	1595	1864	2142	2428	2720	3320	3938	**4012**			4'- 7"
15	1632	1912	2203	2502	2809	3441	4093	**4298**			4'- 8"
16	1664	1955	2258	2570	2890	3553	4238	**4584**			4'- 9"
17	1693	1993	2306	2631	2964	3655	4372	**4877**			4'-10"
18	1717	2027	2350	2686	3032	3750	4497	**5168**			4'-11"
19	1739	2057	2389	2735	3093	3837	4613	**5444**			5'- 0"
20	1758	2083	2425	2780	3148	3917	4720	5552	**5737**		5'- 1"
21	1775	2107	2456	2821	3199	3991	4820	5681	**6035**		5'- 2"
22	1790	2128	2484	2857	3245	4058	4913	5802	**6324**		5'- 3"
23	1802	2146	2510	2891	3287	4121	5000	5915	**6600**		5'- 4"
24	1814	2163	2532	2920	3325	4179	5080	6021	**6887**		5'- 5"
25	1824	2177	2552	2947	3360	4232	5155	6120	**7189**		5'- 6"
26	1832	2190	2571	2972	3392	4280	5224	6213	**7455**		5'- 7"
27	1840	2201	2587	2994	3421	4325	5289	6300	**7768**		5'- 8"
28	1846	2212	2601	3014	3447	4367	5349	6382	**8044**		5'- 9"
29	1852	2221	2614	3032	3471	4405	5404	6458	**8344**		5'-10"
30	1857	2229	2626	3048	3492	4440	5456	6529	**8636**		5'-11"
31	1862	2236	2637	3063	3512	4472	5504	6596	**8901**		6'- 0"
32	1866	2242	2646	3076	3530	4502	5549	6659	9032	**9198**	6'- 1"
33	1869	2247	2654	3088	3546	4529	5590	6717	9132	**9488**	6'- 2"
34	1872	2252	2662	3099	3561	4555	5629	6772	9227	**9771**	6'- 2"
35	1875	2257	2669	3109	3575	4578	5665	6823	9317	**10070**	6'- 3"
36	1877	2261	2675	3118	3587	4599	5698	6871	9402	**10340**	6'- 4"
37	1879	2264	2680	3126	3598	4619	5729	6916	9483	**10630**	6'- 5"
38	1881	2267	2685	3133	3608	4637	5758	6958	9559	**10940**	6'- 6"
39	1882	2270	2689	3139	3618	4654	5784	6998	9631	**11220**	6'- 7"
40	1884	2272	2693	3145	3626	4669	5809	7035	9700	**11520**	6'- 8"

B SATURATED TOP SOIL Kμ'—0.150

HEIGHT OF BACKFILL H ABOVE TOP OF PIPE, FEET	TRENCH WIDTH AT TOP OF PIPE 2'-6"	2'-9"	3'-0"	3'-3"	3'-6"	4'-0"	4'-6"	5'-0"	6'-0"	7'-0"	▲TRANSITION WIDTH
5	939	1059	1180	1301	**1411**						3'- 6"
6	1069	1210	1353	1497	1641	**1700**					3'- 7"
7	1183	1346	1510	1675	1842	**1989**					3'- 9"
8	1285	1467	1652	1838	2026	**2277**					3'-10"
9	1375	1576	1780	1986	2195	**2566**					3'-11"
10	1455	1674	1896	2122	2350	2814	**2855**				4'- 1"
11	1526	1761	2001	2245	2492	2996	**3145**				4'- 2"
12	1589	1840	2096	2357	2623	3164	**3431**				4'- 3"
13	1645	1910	2182	2460	2743	3321	**3718**				4'- 4"
14	1695	1973	2260	2553	2853	3466	**4012**				4'- 5"
15	1738	2030	2330	2639	2954	3601	**4298**				4'- 6"
16	1777	2080	2394	2716	3047	3726	4426	**4584**			4'- 7"
17	1812	2126	2451	2787	3132	3843	4576	**4877**			4'- 8"
18	1843	2167	2504	2852	3210	3950	4716	**5168**			4'- 9"
19	1870	2203	2551	2911	3282	4050	4848	**5444**			4'-10"
20	1894	2236	2593	2965	3347	4143	4970	**5737**			4'-11"
21	1915	2265	2632	3014	3408	4229	5085	**6035**			5'- 0"
22	1934	2292	2667	3058	3463	4309	5192	6107	**6324**		5'- 1"
23	1951	2315	2699	3099	3514	4383	5293	6236	**6600**		5'- 2"
24	1966	2336	2727	3136	3561	4451	5387	6358	**6887**		5'- 3"
25	1979	2355	2753	3170	3604	4515	5475	6473	**7189**		5'- 4"
26	1991	2373	2777	3201	3643	4574	5557	6582	**7455**		5'- 5"
27	2001	2388	2798	3229	3679	4629	5634	6684	**7768**		5'- 6"
28	2010	2401	2817	3255	3712	4680	5706	6780	**8044**		5'- 7"
29	2019	2414	2834	3278	3743	4727	5773	6870	**8344**		5'- 8"
30	2026	2425	2850	3300	3771	4771	5836	6955	**8636**		5'- 9"
31	2032	2435	2864	3319	3796	4811	5895	7036	**8901**		5'- 9"
32	2038	2444	2877	3337	3820	4849	5950	7111	**9198**		5'-10"
33	2043	2451	2889	3353	3842	4884	6002	7182	**9488**		5'-11"
34	2048	2459	2899	3368	3861	4916	6050	7249	**9771**		6'- 0"
35	2052	2465	2909	3381	3880	4946	6095	7312	9914	**10070**	6'- 1"
36	2055	2471	2918	3393	3896	4974	6137	7372	10020	**10340**	6'- 1"
37	2058	2476	2925	3405	3912	5000	6177	7428	10110	**10630**	6'- 2"
38	2061	2480	2932	3415	3926	5024	6214	7480	10200	**10940**	6'- 3"
39	2064	2485	2939	3424	3939	5047	6248	7530	10290	**11220**	6'- 4"
40	2066	2488	2945	3433	3950	5067	6280	7577	10380	**11520**	6'- 5"

C ORDINARY CLAY Kμ'—0.130

HEIGHT OF BACKFILL H ABOVE TOP OF PIPE, FEET	TRENCH WIDTH AT TOP OF PIPE 2'-6"	2'-9"	3'-0"	3'-3"	3'-6"	4'-0"	4'-6"	5'-0"	6'-0"	7'-0"	▲TRANSITION WIDTH
5	974	1095	1217	1339	**1411**						3'- 5"
6	1115	1259	1403	1548	**1700**						3'- 6"
7	1243	1408	1574	1741	1910	**1989**					3'- 7"
8	1357	1543	1731	1920	2110	**2277**					3'- 9"
9	1461	1666	1874	2085	2297	**2566**					3'-10"
10	1554	1778	2006	2237	2470	**2855**					3'-11"
11	1638	1880	2127	2377	2630	**3145**					4'- 0"
12	1713	1973	2238	2506	2779	3332	**3431**				4'- 1"
13	1781	2057	2339	2626	2917	3510	**3718**				4'- 2"
14	1843	2134	2432	2736	3046	3676	**4012**				4'- 3"
15	1898	2204	2518	2838	3165	3832	**4298**				4'- 4"
16	1948	2267	2596	2932	3276	3978	**4584**				4'- 5"
17	1993	2325	2668	3019	3378	4115	**4877**				4'- 6"
18	2034	2378	2734	3099	3474	4243	5035	**5168**			4'- 7"
19	2070	2426	2794	3173	3562	4364	5190	**5444**			4'- 8"
20	2103	2469	2849	3242	3645	4476	5336	**5737**			4'- 9"
21	2133	2509	2900	3305	3721	4582	5473	6035			4'-10"
22	2159	2545	2947	3363	3792	4681	5603	**6324**			4'-11"
23	2184	2578	2989	3417	3858	4773	5726	**6600**			4'-11"
24	2205	2607	3029	3466	3919	4860	5842	**6887**			5'- 0"
25	2225	2635	3064	3512	3975	4942	5951	6994	**7189**		5'- 1"
26	2242	2659	3097	3554	4028	5018	6054	7127	**7455**		5'- 2"
27	2258	2682	3128	3593	4077	5089	6151	7253	**7768**		5'- 3"
28	2273	2702	3155	3630	4122	5156	6243	7373	**8044**		5'- 3"
29	2286	2721	3181	3663	4165	5219	6330	7486	**8344**		5'- 4"
30	2297	2738	3204	3693	4204	5278	6412	7594	**8636**		5'- 5"
31	2308	2753	3225	3722	4240	5333	6489	7697	**8901**		5'- 6"
32	2317	2767	3245	3748	4274	5385	6562	7794	**9198**		5'- 7"
33	2326	2780	3263	3772	4305	5433	6631	7886	**9488**		5'- 7"
34	2333	2791	3279	3794	4334	5478	6696	7974	**9771**		5'- 8"
35	2340	2802	3294	3815	4361	5521	6757	8057	**10070**		5'- 9"
36	2346	2811	3308	3834	4386	5561	6815	8136	**10340**		5'-10"
37	2352	2820	3321	3851	4409	5598	6870	8211	**10630**		5'-10"
38	2357	2828	3333	3868	4431	5633	6921	8282	**10940**		5'-11"
39	2362	2835	3343	3883	4451	5666	6970	8350	**11220**		6'- 0"
40	2366	2842	3353	3896	4470	5696	7016	8414	**11520**		6'- 0"

D SATURATED CLAY Kμ'—0.110

HEIGHT OF BACKFILL H ABOVE TOP OF PIPE, FEET	TRENCH WIDTH AT TOP OF PIPE 2'-6"	2'-9"	3'-0"	3'-3"	3'-6"	4'-0"	4'-6"	5'-0"	6'-0"	7'-0"	▲TRANSITION WIDTH
5	1011	1133	1255	1378	**1411**						3'- 4"
6	1165	1310	1456	1602	**1700**						3'- 5"
7	1306	1473	1642	1811	**1989**						3'- 6"
8	1435	1624	1815	2007	2200	**2277**					3'- 7"
9	1554	1764	1976	2190	2405	**2566**					3'- 8"
10	1662	1892	2126	2361	2598	**2855**					3'- 9"
11	1761	2011	2264	2520	2779	**3145**					3'-10"
12	1852	2121	2394	2670	2949	**3431**					3'-11"
13	1935	2222	2514	2809	3108	**3718**					4'- 0"
14	2012	2315	2625	2940	3258	3905	**4012**				4'- 1"
15	2082	2402	2729	3061	3399	4085	**4298**				4'- 2"
16	2145	2481	2825	3175	3531	4256	**4584**				4'- 3"
17	2204	2555	2914	3282	3655	4417	**4877**				4'- 4"
18	2258	2623	2998	3381	3772	4570	**5168**				4'- 4"
19	2307	2685	3075	3474	3881	4714	**5444**				4'- 5"
20	2352	2743	3147	3561	3984	4851	**5737**				4'- 6"
21	2393	2796	3213	3642	4080	4981	5907	6035			4'- 7"
22	2431	2846	3275	3718	4171	5104	6064	**6324**			4'- 8"
23	2465	2891	3333	3789	4256	5220	6214	**6600**			4'- 8"
24	2497	2933	3387	3855	4336	5329	6357	**6887**			4'- 9"
25	2526	2972	3436	3917	4411	5433	6493	**7189**			4'-10"
26	2552	3008	3483	3975	4481	5532	6622	**7455**			4'-11"
27	2576	3041	3526	4029	4548	5625	6745	**7768**			4'-11"
28	2599	3071	3566	4079	4610	5713	6863	**8044**			5'- 0"
29	2619	3099	3603	4126	4668	5797	6974	8191	**8344**		5'- 1"
30	2638	3125	3637	4171	4723	5876	7081	8328	**8636**		5'- 2"
31	2655	3149	3669	4212	4774	5950	7182	8458	**8901**		5'- 2"
32	2670	3171	3699	4250	4823	6021	7278	8583	**9198**		5'- 3"
33	2685	3192	3727	4286	4868	6088	7370	8703	**9488**		5'- 3"
34	2698	3211	3752	4320	4911	6151	7458	8817	**9771**		5'- 4"
35	2710	3228	3776	4351	4951	6211	7541	8927	**10070**		5'- 5"
36	2721	3244	3798	4381	4988	6268	7620	9032	**10340**		5'- 5"
37	2731	3259	3819	4408	5024	6322	7696	9132	**10630**		5'- 6"
38	2740	3273	3838	4434	5057	6373	7768	9228	**10940**		5'- 7"
39	2749	3285	3856	4458	5088	6421	7836	9320	**11220**		5'- 7"
40	2756	3297	3873	4480	5117	6466	7902	9408	**11520**		5'- 8"

* *For backfill weighing 110 pounds per cubic foot, increase loads 10%; for 120 pounds per cubic foot, increase 20%; etc.*

▲*Transition loads* **(bold type)** *and widths based on Kμ—0.19, $r_{sd}p$—0.5 in the embankment equation*

Interpolate for intermediate heights of backfill and/or trench widths

739 Rec 16 Dec 86
31/45
21 Feb 96

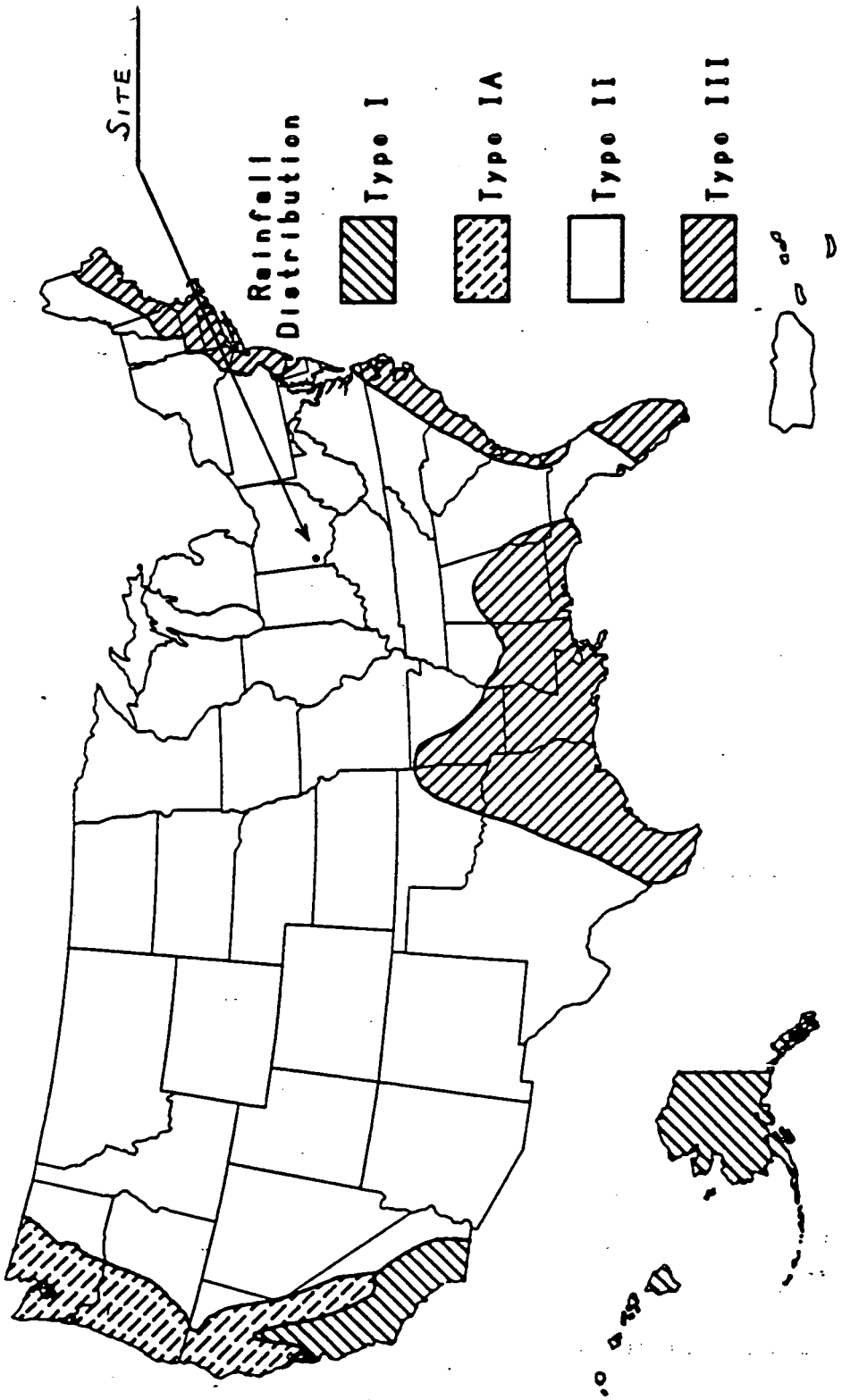


FIGURE 1 —Approximate geographic boundaries for SCS rainfall distributions.

[redacted]
456

739 32/45
Asc 16 Dec 95
SSS 9 Feb 96
Fee 21 Feb 96

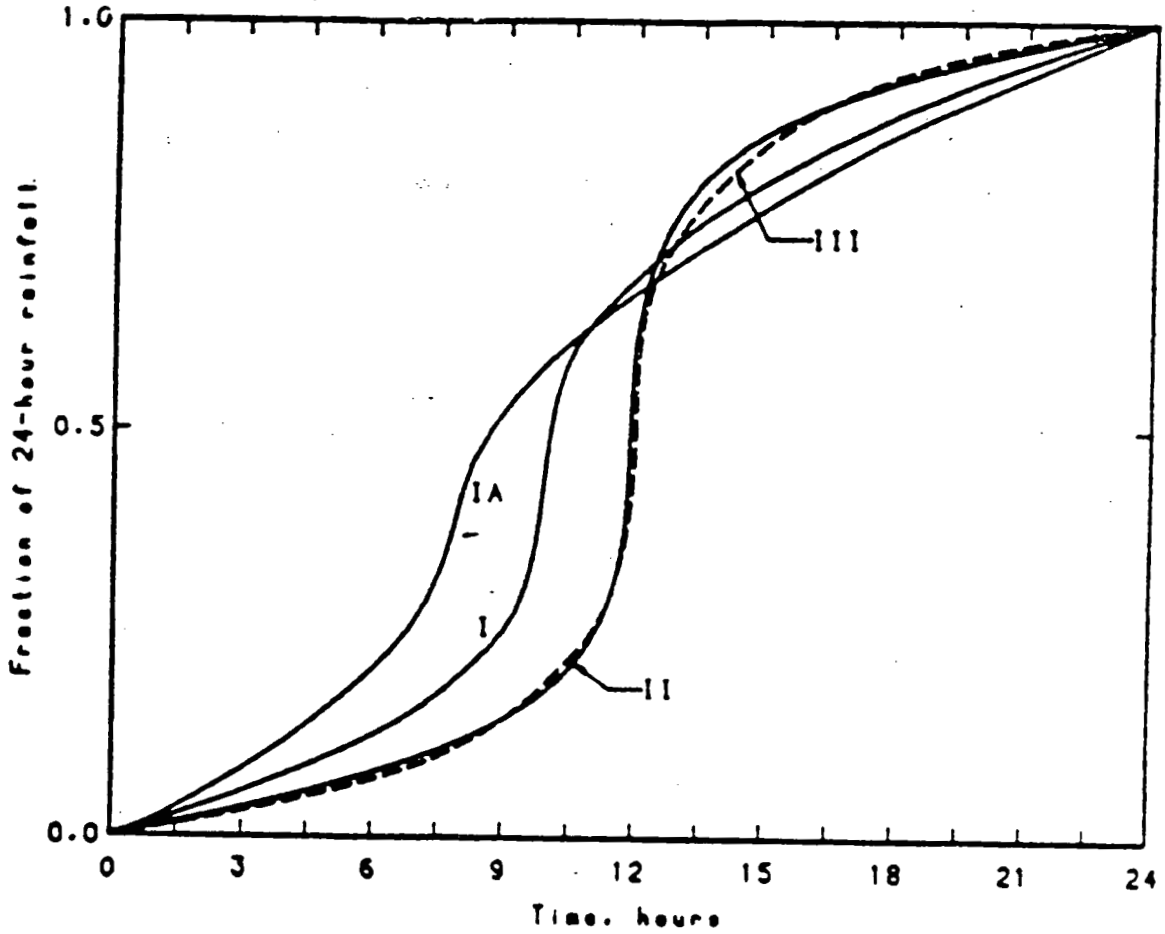


Figure 2 .—SCS 24-hour rainfall distributions.

(210-VI-TR-55, Second Ed., June 1986)

[redacted]

skg03745.m(872.ws322) po148@ws322. Wed Nov 15 14:37:32 CST 1995

RSC 16 FEB 1996
ESS 9 FEB 1996

FIGURE REPLACED W/ BETTER COPY
25 JUNE 1996 PBR

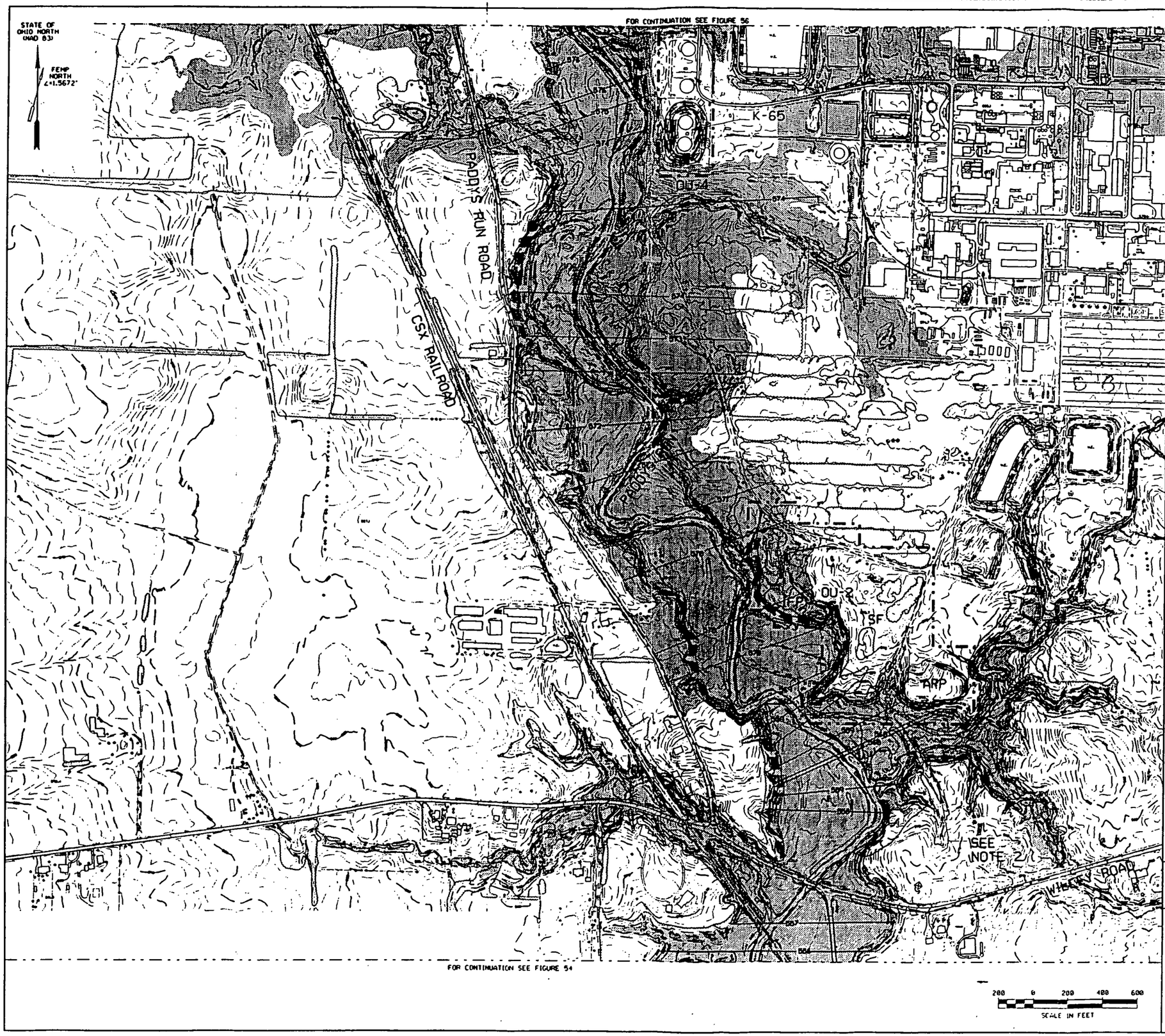


FIGURE 3
2000-YEAR FLOOD LIMITS
PARSONS, 1995

NOTES

1. EXISTING CONDITIONS SHOWN ON THIS DRAWING WERE PREPARED FROM FEMP SITE PROVIDED DATA FROM THE DOCUMENTS LISTED BELOW.

   EXISTING SITE DATA SOURCE (IN PLANT FILES)
   PARSONS TOPOGRAPHY, 1992

2. AREA EAST OF UNIMPROVED ROAD NOT STUDIED.

LEGEND

	FLOOD LIMIT
—559—	APPROXIMATE FLOOD ELEVATION (CONTOUR) LOCATION
	TREE LINE
	PADDYS RUN
	FEMP BOUNDARY
	OU BOUNDARY
AFP	ACTIVE FLY ASH PILE
IFP	INACTIVE FLY ASH PILE
SF	SOUTH FIELD

THIS DRAWING PREPARED BY
PARSONS
THE RALPH M. PARSONS CO. · CHAS. T. MAIN, INC. · ENGINEERING-SCIENCE, INC.
CINCINNATI, OHIO

PADDYS RUN
PMP
FLOOD PLAIN BOUNDARY
(WILLEY ROAD AREA)

FIGURE 55
SCALE: AS SHOWN
CRU2/P0148

000468

F 55

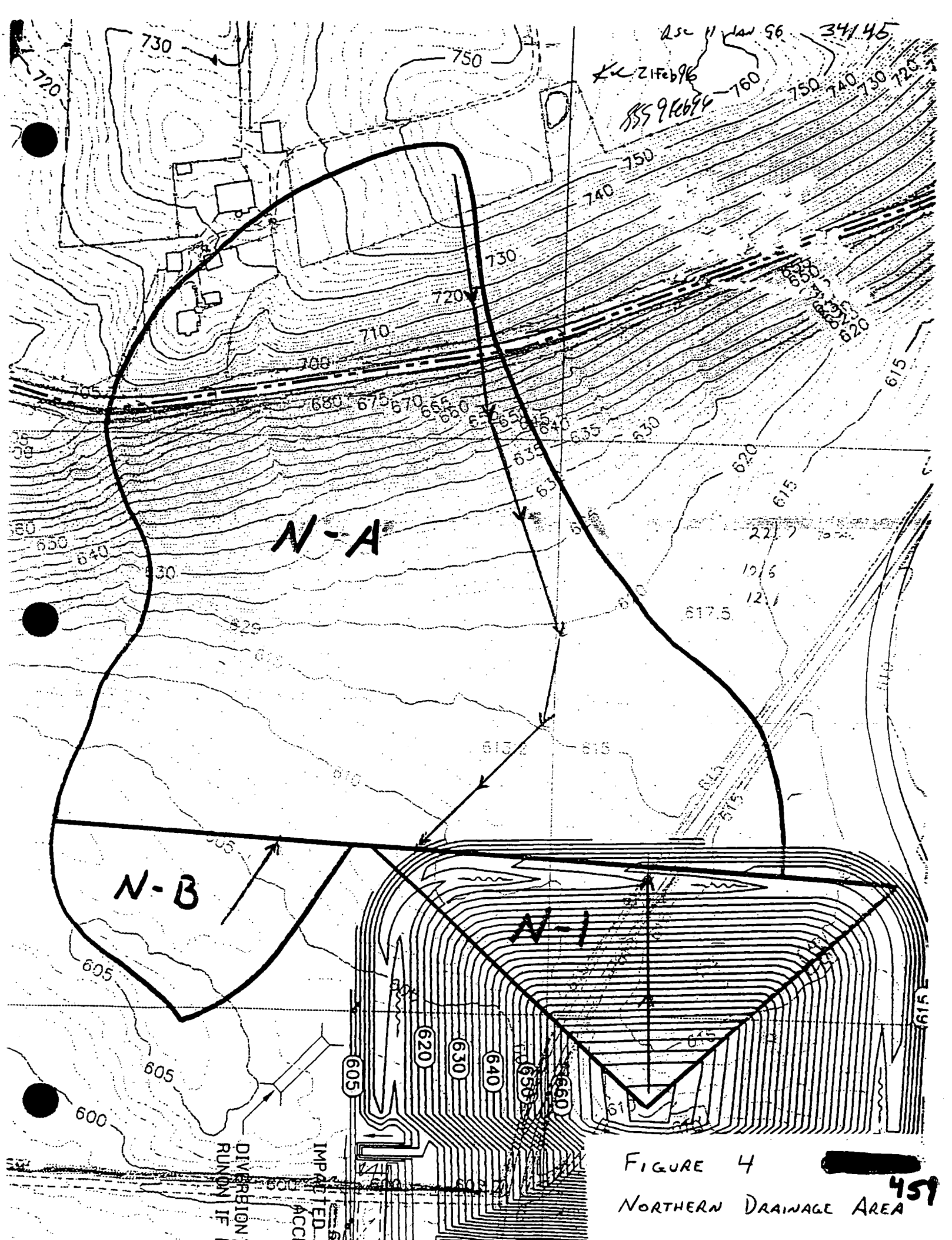


FIGURE 4

NORTHERN DRAINAGE AREA

[redacted]

Rec 11 Jan 96
35145 739
SSS 9 Feb 96 Gen 21 Feb 96

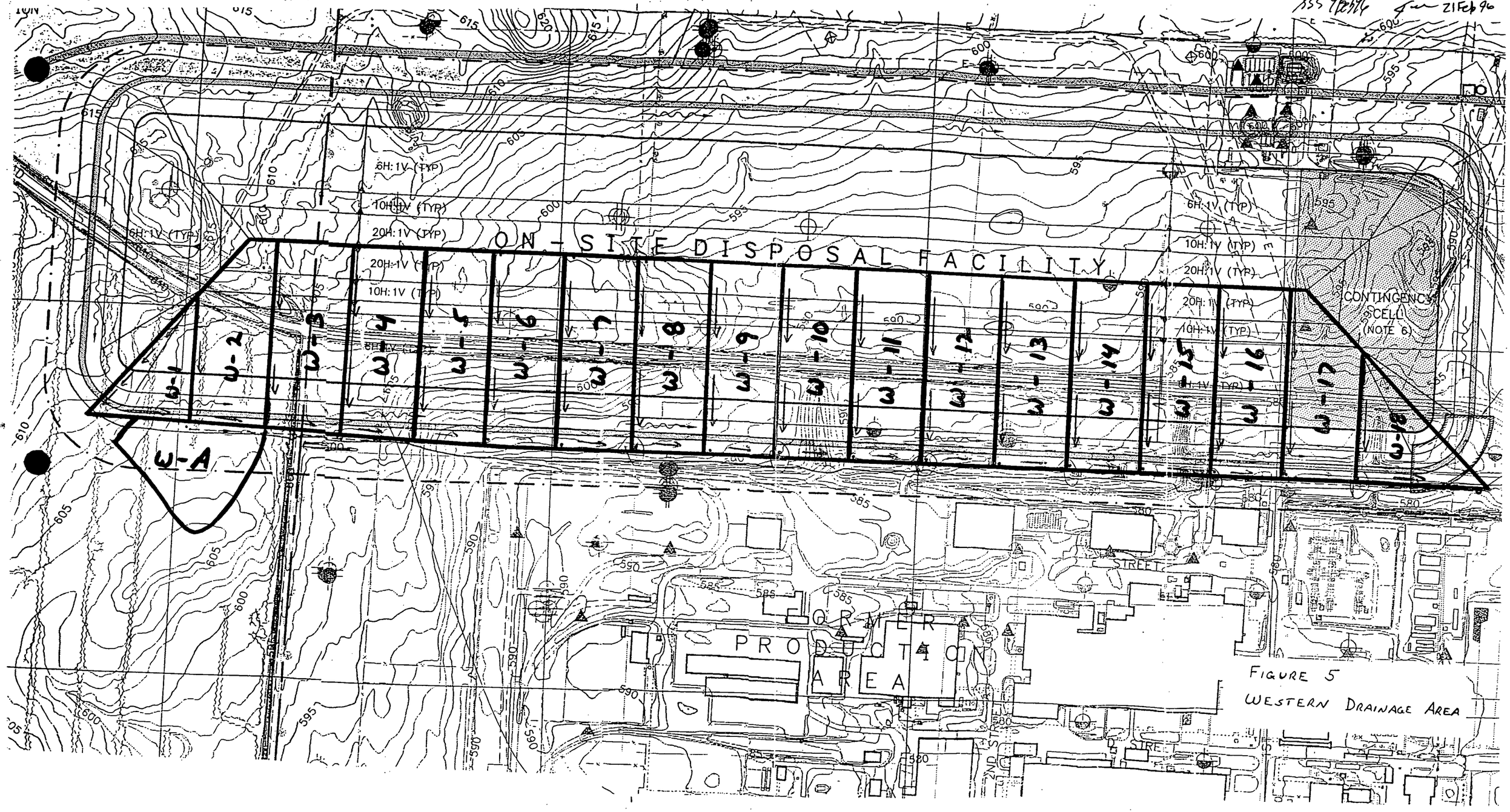


FIGURE 5
WESTERN DRAINAGE AREA

[redacted]

460

FIGURE 6
SOUTHERN DRAINAGE AREA

000[redacted]

461

Asc II dan 9c 37145
SSS 96696 739
Ke 21Feb96

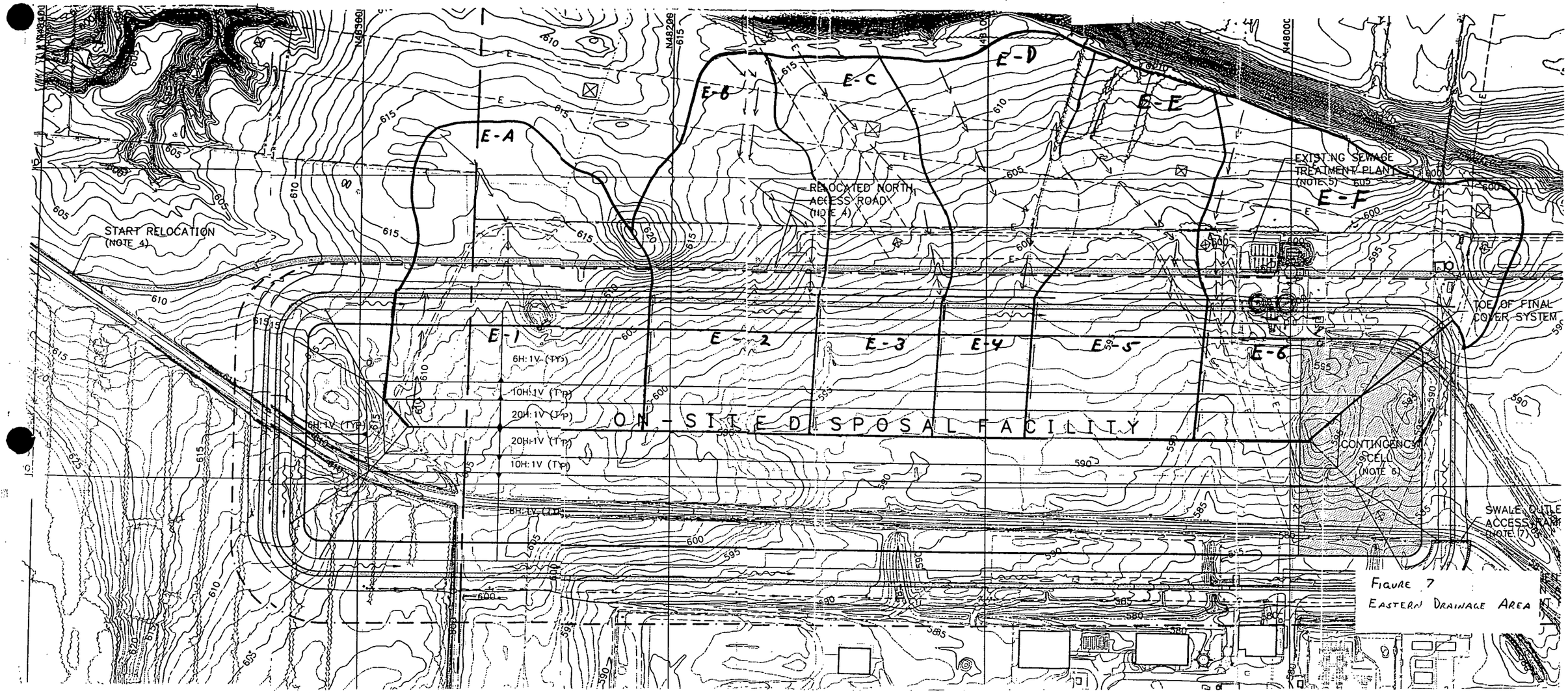
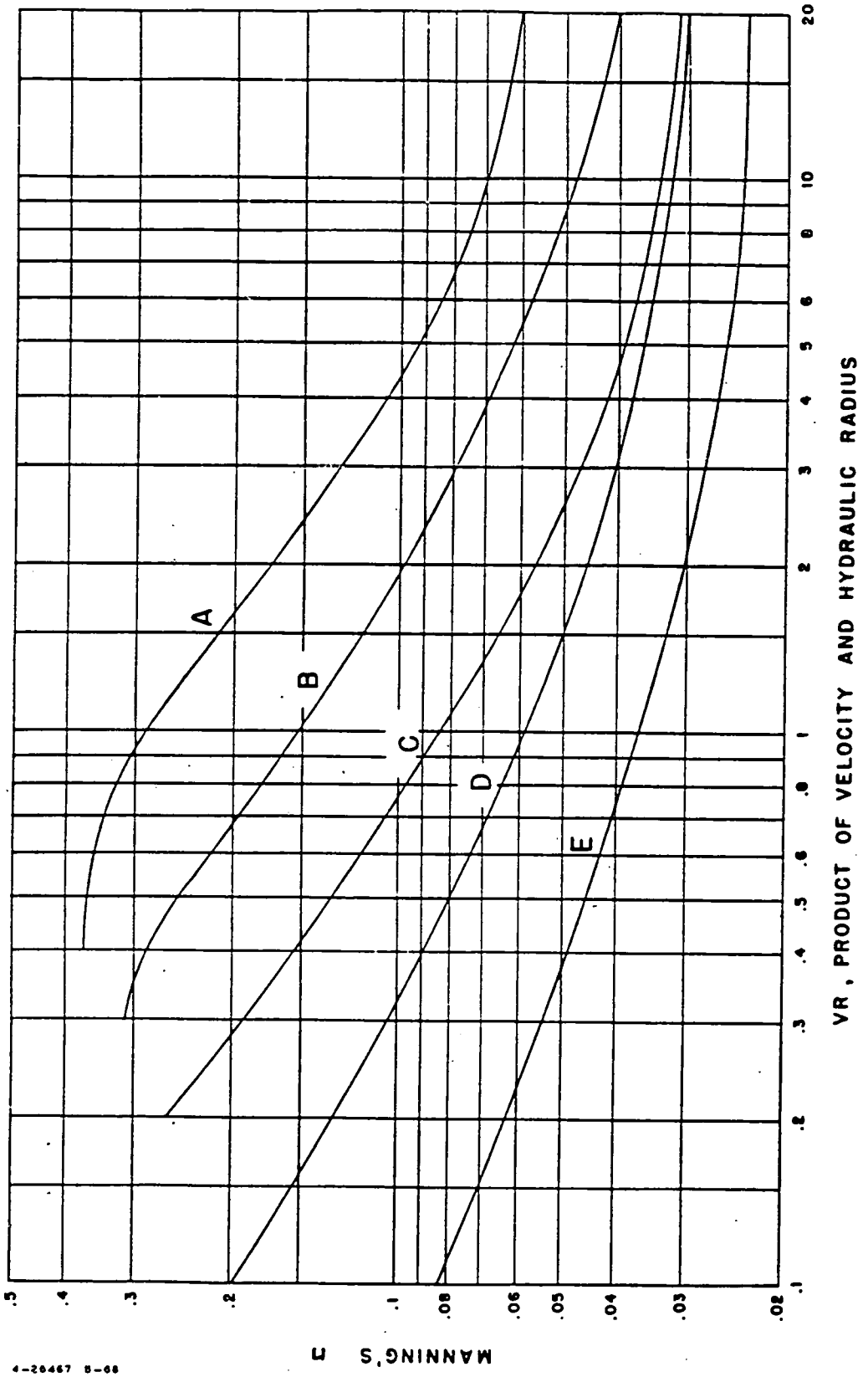


Figure 7
Eastern Drainage Area

[redacted]

462



4-26467 5-66

FIGURE 8. Manning's "n" related to velocity, hydraulic radius, and vegetal retardance.

USDA-SCS, 1986b

739
Asc 16 Dec 95
38/45
SSS 9Feb96
21Feb96
[redacted]
463

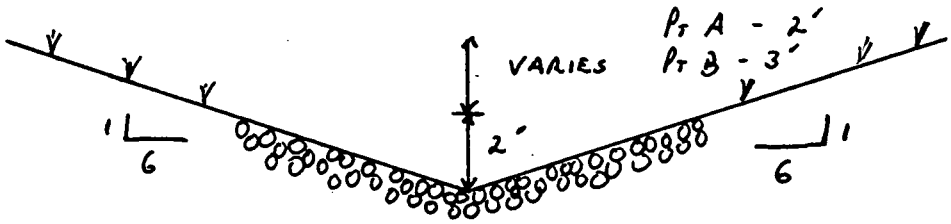
Written by: RSC Date: 96/JAN/11 (YY/MM/DD) Reviewed by: BSS Date: 96/02/09 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GR 3500 Task No.: 08.1

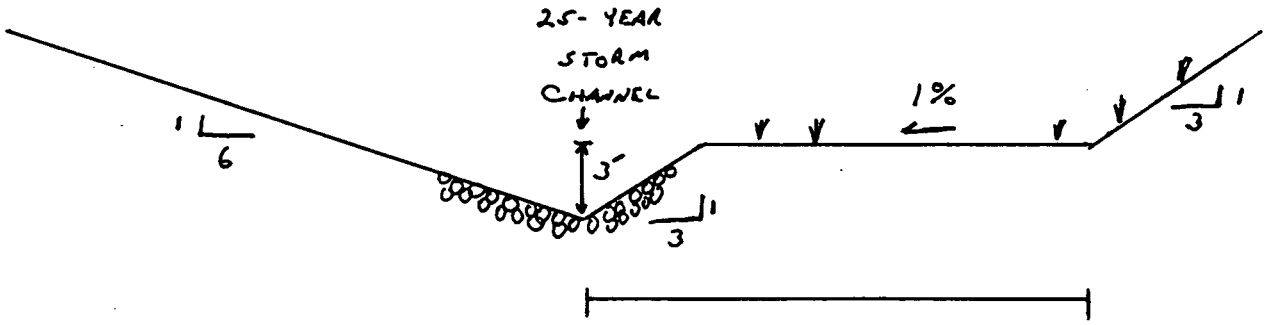
FL 21Feb96

CHANNEL GEOMETRY

NORTH CHANNEL



EAST CHANNEL



PT A - 60'
PT B - 65'
PT C THROUGH PT E - 69'

WEST CHANNEL

FIGURE 9. CHANNEL GEOMETRIES

[redacted]

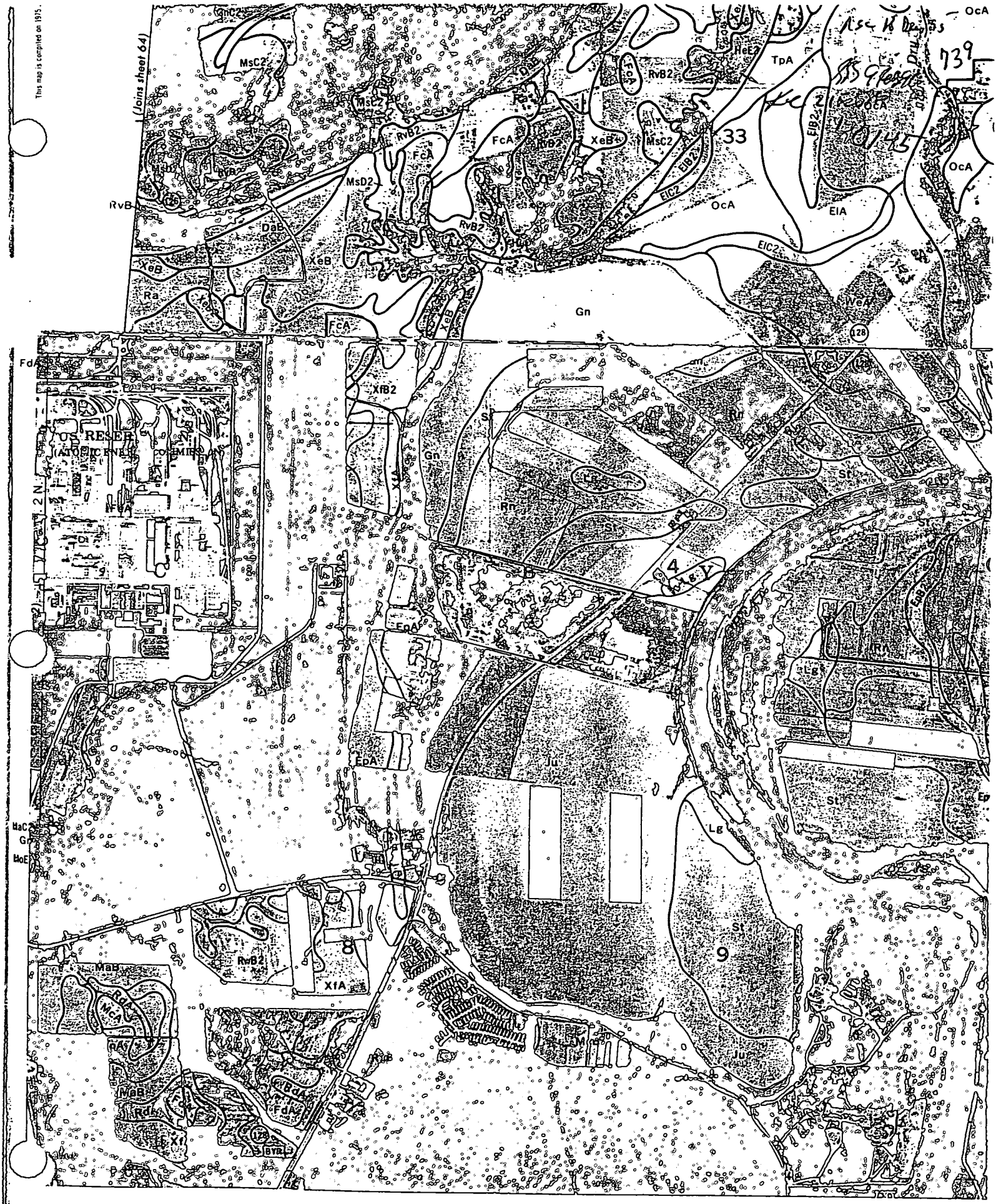
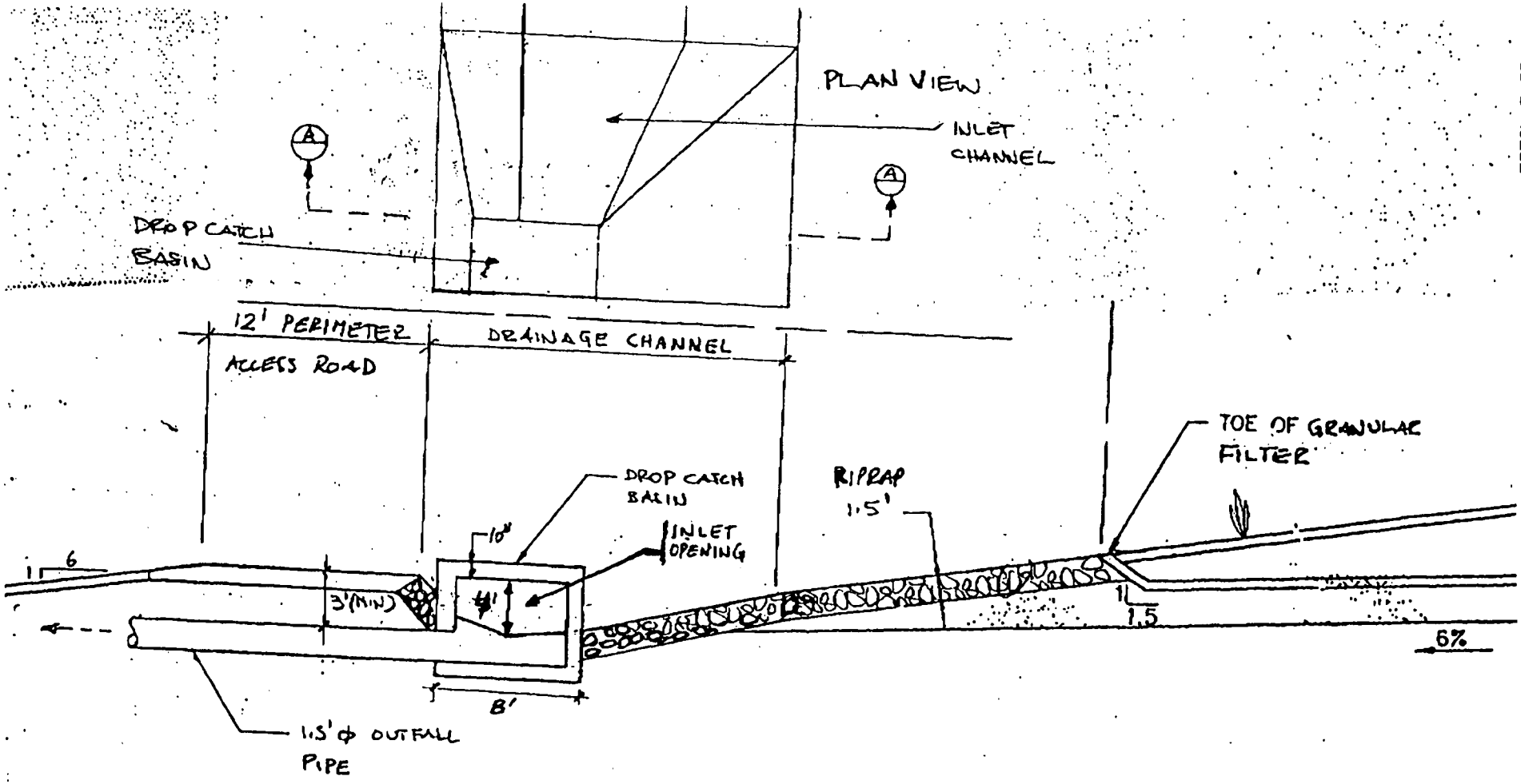


FIGURE 10
OSDF RUNON WATERSHED SOIL TYPES
REF: USDA-SCS 1992, SHEET 3



A SECTION (TYPICAL)

WEST PERIMETER DRAINAGE CHANNEL

FIGURE 11. CULVERT AND DROP INLET CROSS-SECTION

SCALE 1" = 8'

1 of 5 pgs
14
SSS 15 Feb 96
21 Feb 96
239

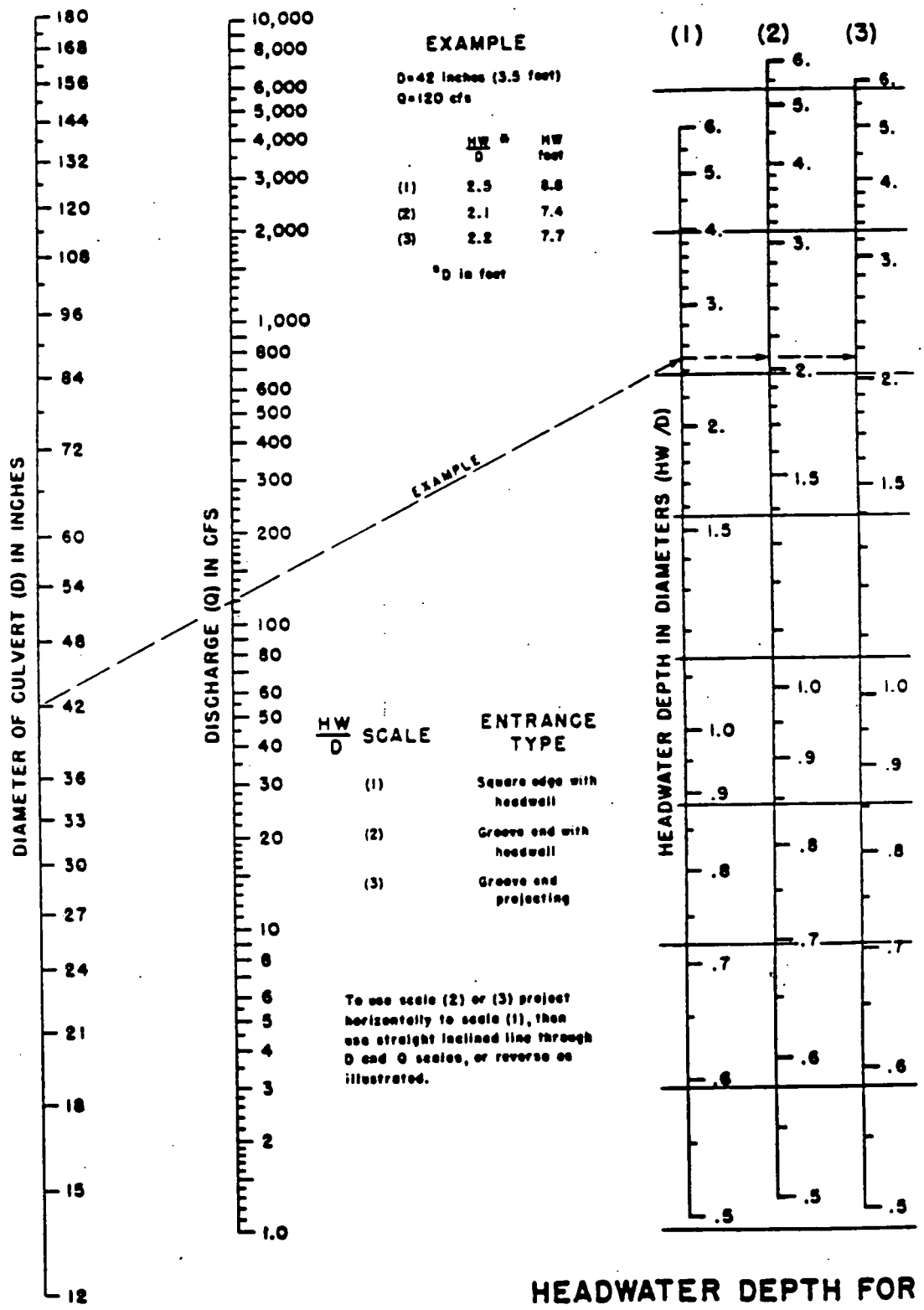
739

Rec 5 Feb 96 Yz 44/45

SSS 96694

Rec 21 Feb 96

CHART 1



HEADWATER SCALES 2&3
REVISED MAY 1964

BUREAU OF PUBLIC ROADS JAN. 1963

HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

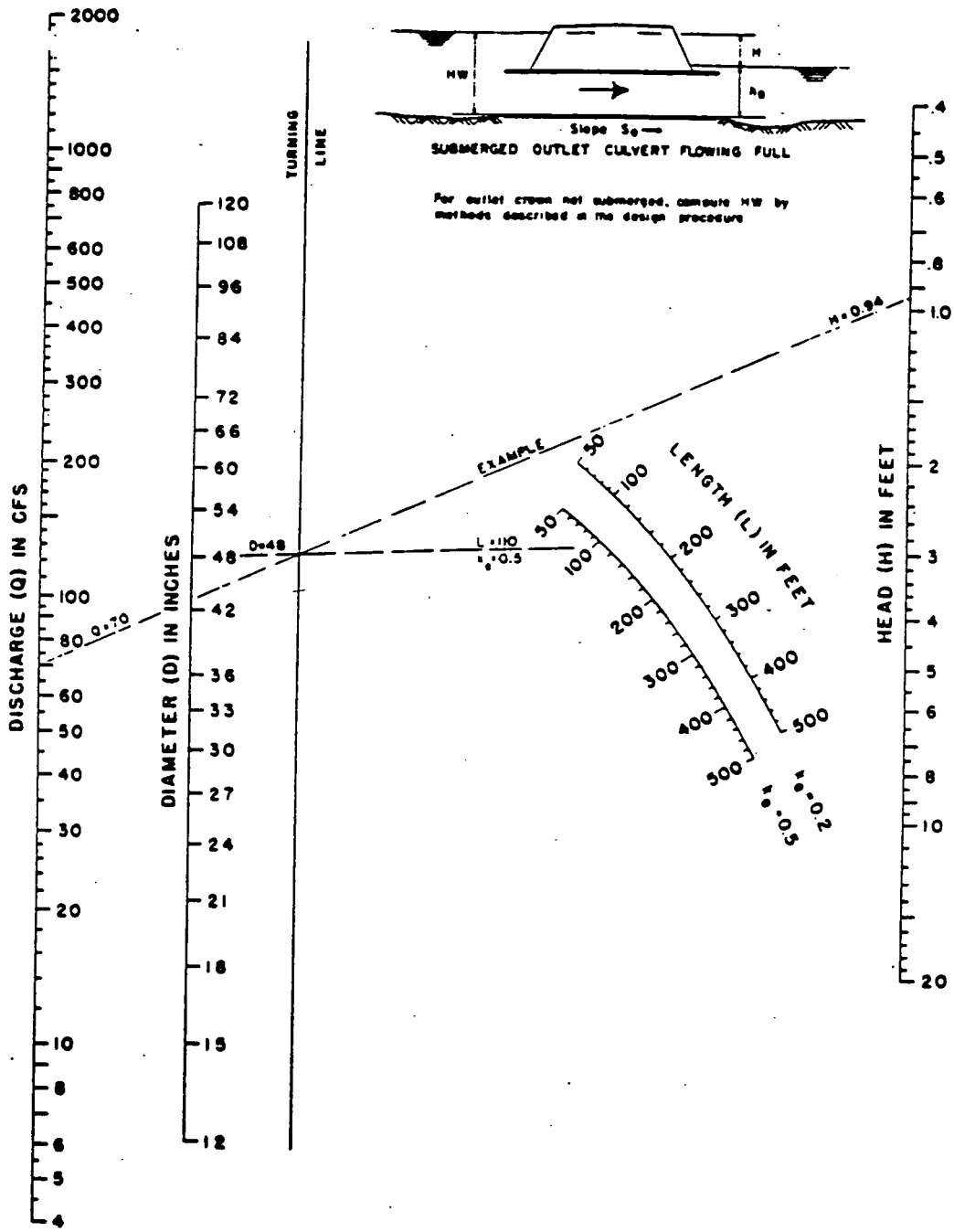
FIGURE 12

[redacted]

467

739 Ase 9 Feb 96 /
LSS 9Feb96 ~~42~~ 45 43
Ase 21Feb96

CHART 5



HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

FIGURE 13

[redacted]

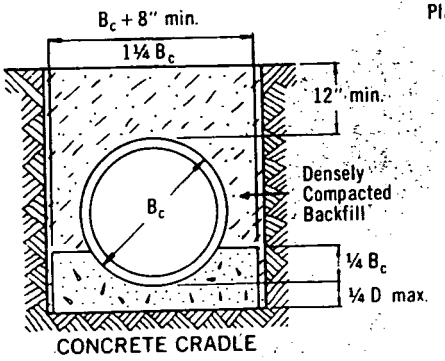
468

FIGURE 14

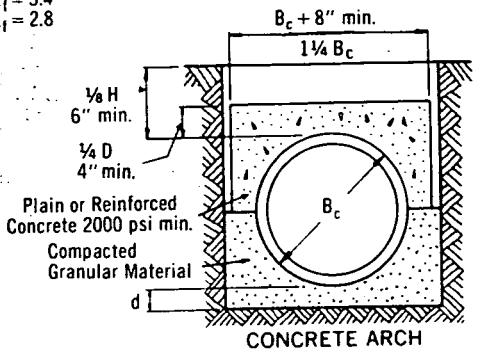
TRENCH BEDDINGS
CIRCULAR PIPE

CLASS A

Reinforced $A_s = 1.0\%$ $L_f = 4.8$
Reinforced $A_s = 0.4\%$ $L_f = 3.4$
Plain $L_f = 2.8$



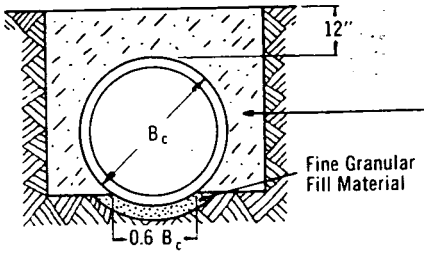
CONCRETE CRADLE



CONCRETE ARCH

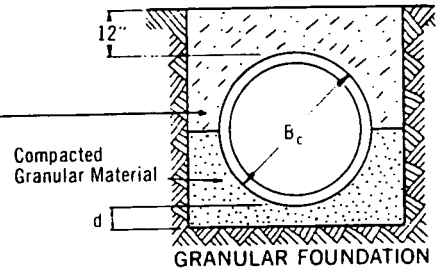
CLASS B

$L_f = 1.9$



SHAPED SUBGRADE WITH GRANULAR FOUNDATION

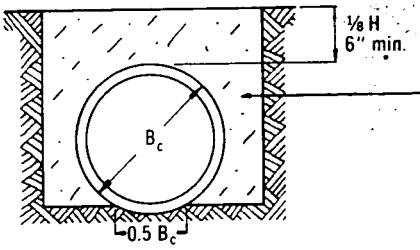
Densely Compacted Backfill



GRANULAR FOUNDATION

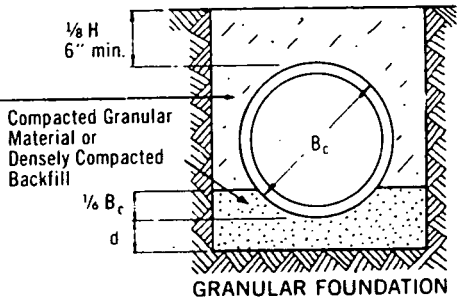
CLASS C

$L_f = 1.5$



SHAPED SUBGRADE

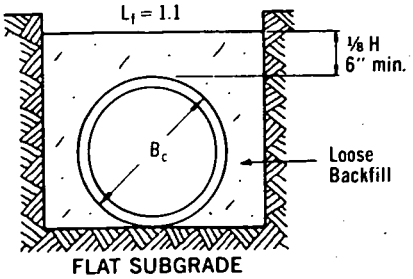
Lightly Compacted Backfill



GRANULAR FOUNDATION

CLASS D

$L_f = 1.1$



FLAT SUBGRADE

Legend
B_c = outside diameter
H = backfill cover above top of pipe
D = inside diameter
d = depth of bedding material below pipe
A_s = area of transverse steel in the cradle or arch expressed as a percentage of area of concrete at invert or crown.

Depth of Bedding Material Below Pipe	
D	d (min.)
27" & smaller	3"
30" to 60"	4"
66" & larger	6"

NOTE: For rock or other incompressible materials, the trench should be overexcavated a minimum of 6 inches and refilled with granular material.

Outlet Protection (Cont'd)

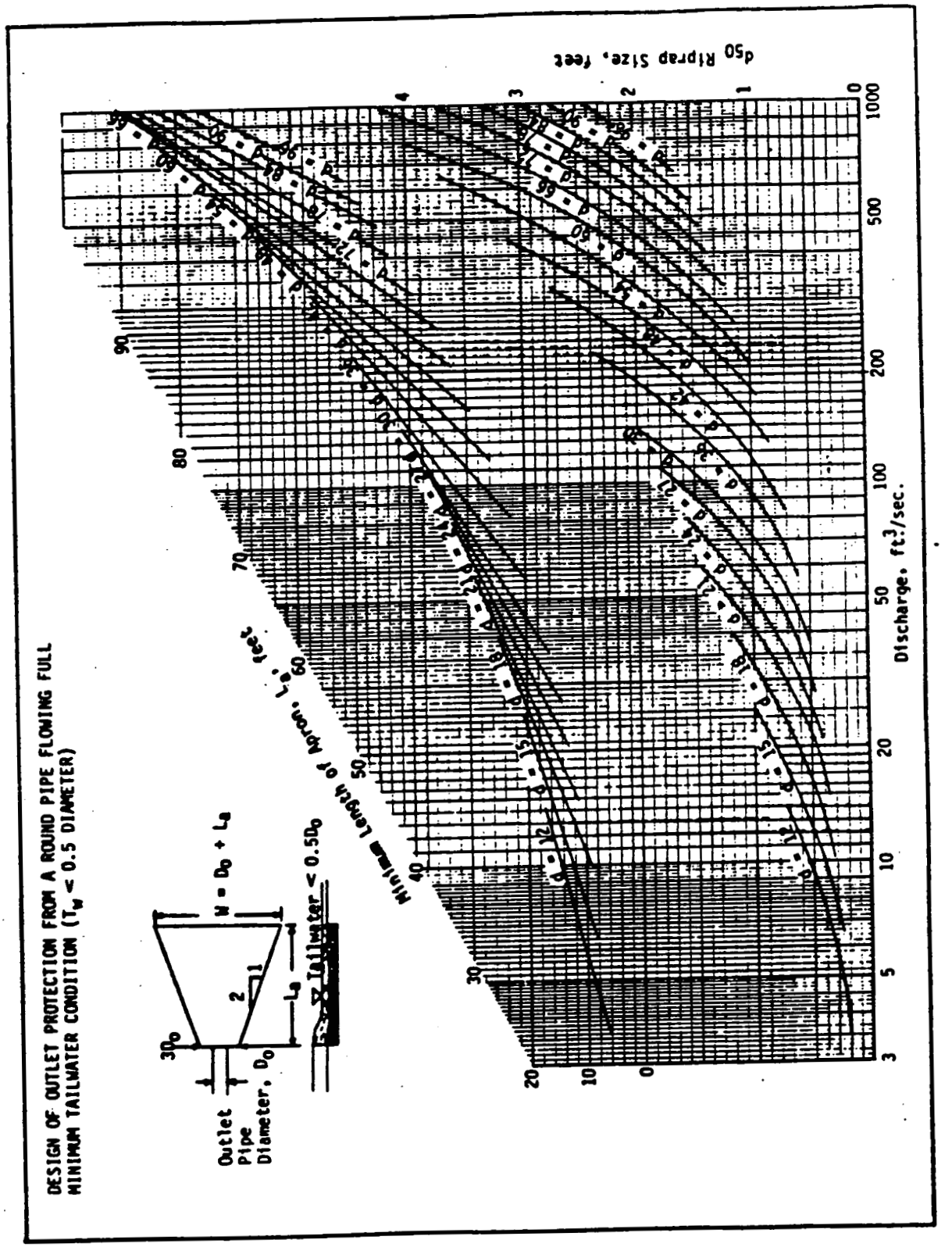


Figure 15

GEOSYNTEC CONSULTANTS

Written by: Rsc Date: 8 / Feb / 96 Reviewed by: [illegible] Date: 12 / Feb / 96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

SURFACE-WATER MANAGEMENT AFTER CLOSURE

STORMWATER RUNON/RUNOFF AND DRAINAGE CONTROL STRUCTURES

CALCULATIONS

Purpose

The purpose of this document is to provide the engineering calculations used in the design of the surface-water management system after the On-Site Disposal Facility (OSDF) is closed.

Scope

The calculation procedures used in this document are presented in the calculations procedures document. The data used in the calculations is presented in the data verification document.

For clarity, these calculations are divided into four sections: (i) northern area; (ii) eastern area; (iii) southern area; and (iv) western area. In general, each set of calculations consists of: (i) a summary of the input data; (ii) a summary of the calculation results; and (iii) the calculations (i.e., worksheets, computer runs).

GeoSyntec Consultants

Written by: Asc Date: 5/Feb/96 Reviewed by: CSS Date: 12/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

Northern Area Calculations

Summary of Input Data

A summary of the HydroCAD™ input data is presented in Table 1.

Summary of Calculation Results

A summary of the calculation results is presented in Tables 2 and 3. Drainage Area maps, worksheets for calculations, weighted runoff curve numbers, and HydroCAD™ runs for runon/runoff and drainage channel routing are attached.

TABLE 1

NORTHERN AREA INPUT PARAMETERS
25-YEAR STORM EVENT

			Sheet Flow			Shallow Concetrated Flow			Open Channel Flow					
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Manning's n	Depth (ft)	Channel Slope (%)	Right Slope	Left Slope
N-A	22.7	64	200	0.18	SEE	1100	0.1	SEE	420	SEE	4	0.5	6:1	6:1
N-B	2.6	58	180	0.01	NOTE	-	-	NOTE	250	NOTE	4	0.5	6:1	6:1
N-1	4.5	98	147	0.07	A	325	0.167	B	400	C	5	0.5	6:1	6:1

2,000-YEAR STORM EVENT

			Sheet Flow			Shallow Concetrated Flow			Open Channel Flow					
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Manning's n	Depth (ft)	Channel Slope (%)	Right Slope	Left Slope
N-A	22.7	81	200	0.18	SEE	1100	0.1	SEE	420	SEE	4	0.5	6:1	6:1
N-B	2.6	76	180	0.01	NOTE	-	-	NOTE	250	NOTE	4	0.5	6:1	6:1
N-1	4.5	99	147	0.07	A	325	0.167	B	400	C	5	0.5	6:1	6:1

Note A: Light Cover = Short Grass; Moderate & Heavy Cover = Dense Grass

Note B: Unpaved

Note C: Light & Moderate Cover: n = 0.030; Heavy Cover: n = 0.10

239

Use 4 Feb 96

SSS 26 Feb 96

24 46

422

Written by: LSC Date: 9 Feb 1996 Reviewed by: SSS Date: 12 Feb 1996

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

Table 2. Summary of HydroCAD™ Results - 25-Year Storm Event

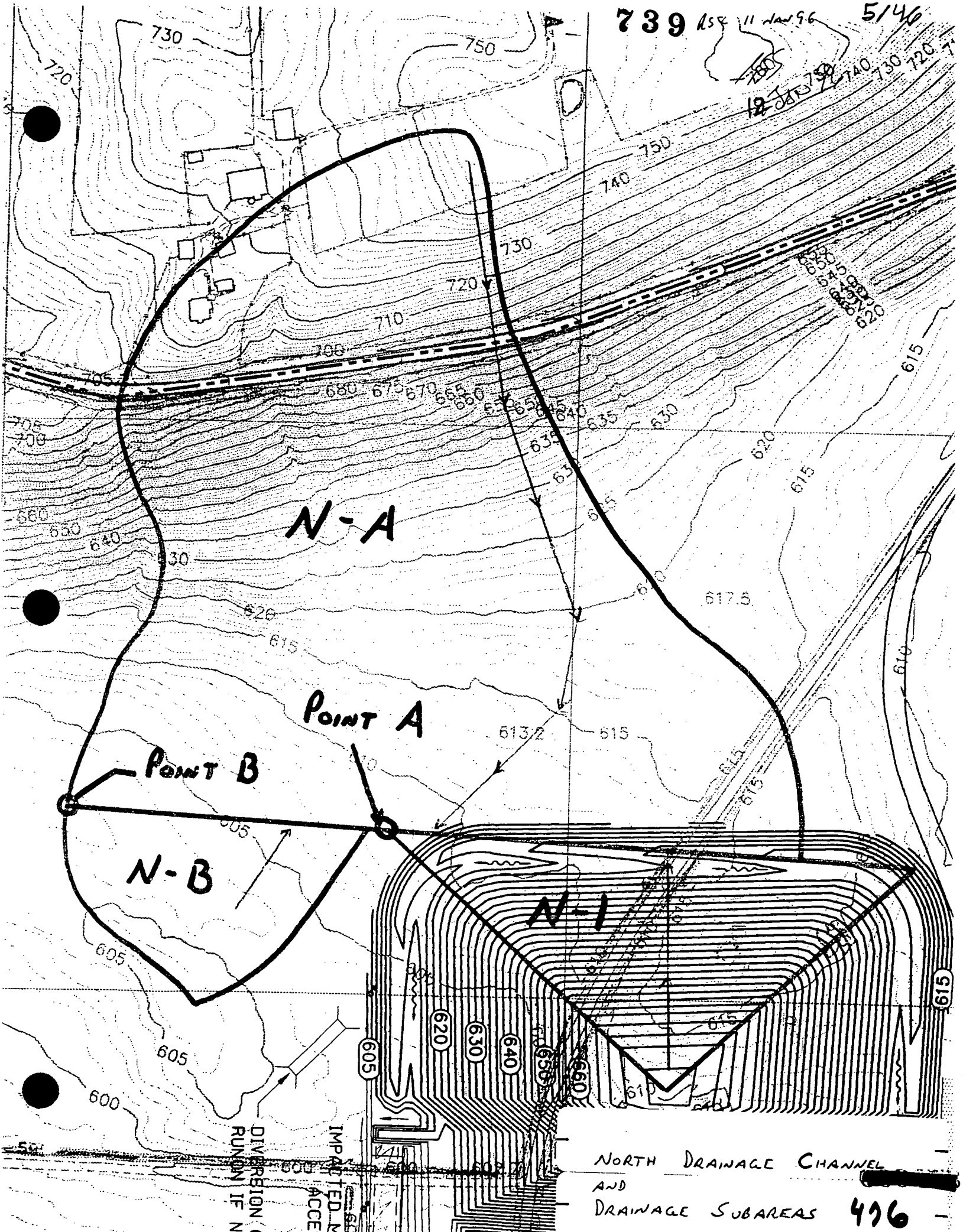
	Point of Interest Along Channel	Peak Flow Quantity (CFS)	Peak Flow Depth (Ft)	Peak Flow Velocity (FPS)
	A			
Light Cover		24.5	1.2	2.6
Moderate Cover		22.8	1.2	2.5
	B			
Light Cover		65.3	1.8	3.2
Moderate Cover		57.7	1.7	3.2

Table 3. Summary of HydroCAD™ Results - 2,000-Year Storm Event

	Point of Interest Along Channel	Peak Flow Quantity (CFS)	Peak Flow Depth (Ft)	Peak Flow Velocity (FPS)
	A			
Light Cover		68.3	1.8	3.3
Moderate Cover		63.5	1.8	3.2
Heavy Cover		63.5	2.7	1.3
	B			
Light Cover		397.8	3.5	5.2
Moderate Cover		351.8	3.3	5.0
Heavy Cover		336.2	5.3	2.0

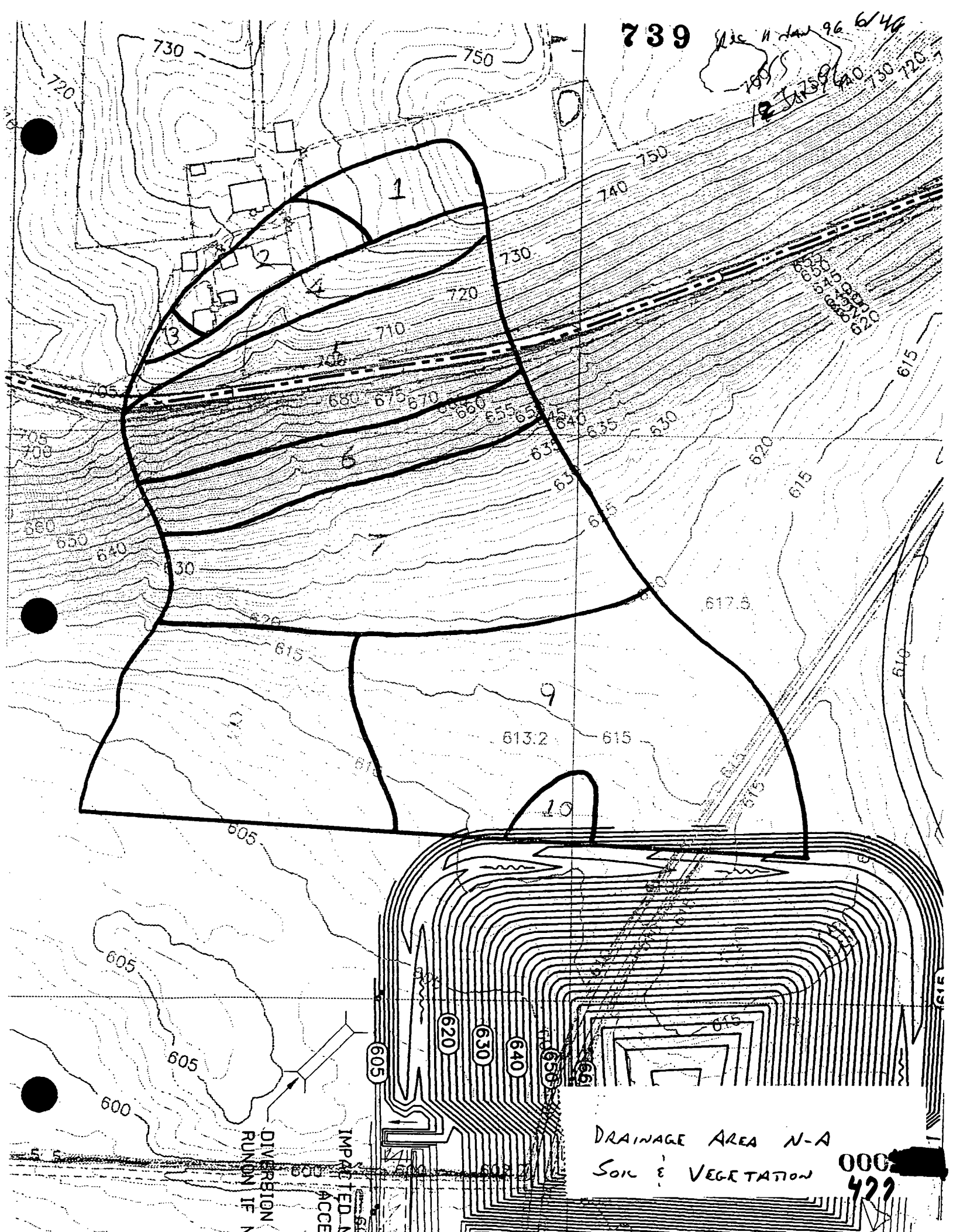
DRAINAGE AREA MAPS

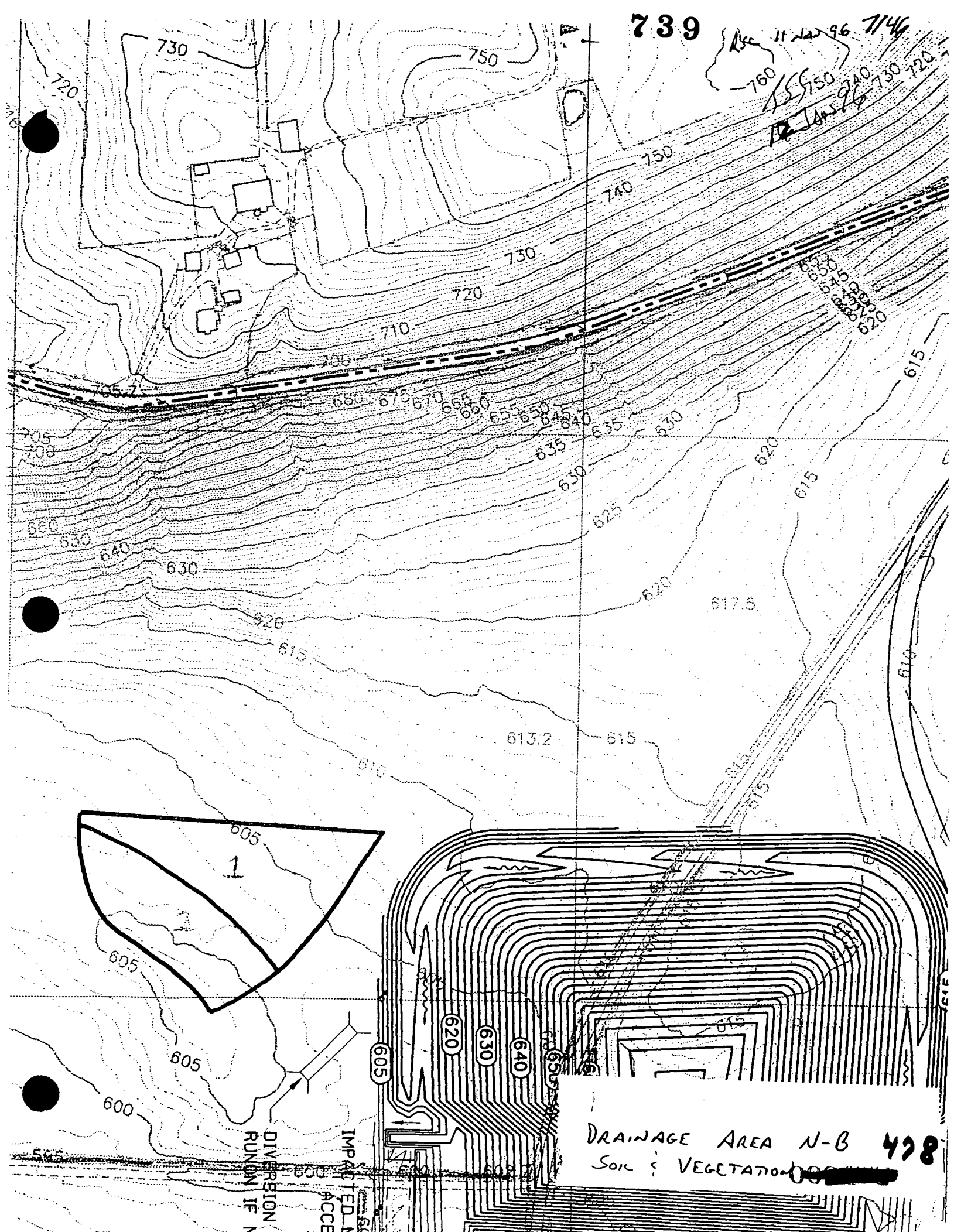
739 RSE 11 Nov 96 5/46



NORTH DRAINAGE CHANNEL [redacted]
AND
DRAINAGE SUBAREAS

739


1
2
3
4
5
6
7
9
10
DIVERSION
RUNON IF
IMPACTED
ACCE
DRAINAGE AREA N-A
SOIL & VEGETATION


DRAINAGE AREA N-B
SOIL & VEGETATION
DIVERSION
RUNOFF IF
IMPACTED
ACCE
1
2
605
600
620
630
640
650
615
610
613.2
617.8
705.7
680
675
670
665
660
655
650
645
640
635
630
625
620
615
610
710
720
730
740
750
760

739 8/40

WORKSHEETS FOR

WEIGHTED RUNOFF CURVE NUMBERS

Worksheet 2: Runoff curve number and runoff

Project FERMCO - OSDF By RSC Date 11 Jan 96

Location DRAINAGE AREA N-A Checked GSS Date 19 JAN 96

Circle one: Present (Developed)

1. Runoff curve number (CN)

SUBAREA	Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒acres ☐mi² ☐%	Product of CN x area
1	RUSSELL - MIAMIAN B	CROP LAND - STRAIGHT ROWS GOOD CONDITION	78			0.8	62.4
2	MIAMIAN - RUSSELL C	FARMSTEAD	82			0.8	65.6
3	MIAMIAN - RUSSELL C	"	82			0.1	8.2
4	EDEN C	"	82			1.1	90.2
	EDEN C	WOODS - GRASS GOOD CONDITION	72			3.3	237.6
6	EDEN C	" "	72			1.6	115.2
7	DANA B	" "	58			4.7	272.6
					Totals =	CONT.	CONT.

1/ Use only one CN source per line.

~~CN (weighted) = total product / total area = ____ = ____; Use CN = ____~~

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

Project FERMCO - OSDF By RSC Date 11 JAN 96

Location DRAINAGE AREA N-A CONT. Checked [illegible] Date 12 JAN 96

Circle one: Present (Developed)

1. Runoff curve number (CN)

SUBAREA	Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
8	RAGSDALE B	WOODS - GRASS GOOD CONDITION	58			3.7	214.6
9	XENIA B	" "	58			6.2	359.6
10	FINCASTLE C	" "	72			0.4	28.8
					Totals =	22.7	1454.8

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{1454.8}{22.7} = 64.1$; Use CN = 64

~~2. Runoff~~

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

[redacted]

Worksheet 2: Runoff curve number and runoff

739 W 46

Project FERMCO - OSDF By RSC Date 11 JAN 96

Location DRAINAGE AREA N-B Checked GSS Date 19 JAN 96

Circle one: Present Developed

1. Runoff curve number (CN)

Subarea	Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
2	RAGSDALE B	WOODS - GRASS GOOD CONDITION	58			1.1	63.8
1	XENIA B	WOOD - GRASS GOOD CONDITION	58			1.5	87.0
					Totals =	2.6	150.8

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{150.8}{2.6} = 58$; Use CN = 58

~~2. Runoff~~

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in			

(Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)

12.46

Asc 9 Fin 86

SS 12 JAN 94

Table 1 Curve numbers (CN) and constants for the case $I_a = 0.2\ S$

1	2	3	4	5	1	2	3	4	5
CN for condition II	CN for conditions I	CN for conditions III	S values*	Curve* starts where P =	CN for condition II	CN for conditions I	CN for conditions III	S values*	Curve* starts where P =
			(inches)	(inches)				(inches)	(inches)
100	100	100	0	0	60	40	78	6.67	1.33
99	97	100	.101	.02	59	39	77	6.95	1.39
98	94	99	.204	.04	58	38	76	7.24	1.45
97	91	99	.309	.06	57	37	75	7.54	1.51
96	89	99	.417	.08	56	36	75	7.86	1.57
95	87	98	.526	.11	55	35	74	8.18	1.64
94	85	98	.638	.13	54	34	73	8.52	1.70
93	83	98	.753	.15	53	33	72	8.87	1.77
92	81	97	.870	.17	52	32	71	9.23	1.85
91	80	97	.989	.20	51	31	70	9.61	1.92
90	78	96	1.11	.22	50	31	70	10.0	2.00
89	76	96	1.24	.25	49	30	69	10.4	2.08
88	75	95	1.36	.27	48	29	68	10.8	2.16
87	73	95	1.49	.30	47	28	67	11.3	2.26
86	72	94	1.63	.33	46	27	66	11.7	2.34
85	70	94	1.76	.35	45	26	65	12.2	2.44
84	68	93	1.90	.38	44	25	64	12.7	2.54
83	67	93	2.05	.41	43	25	63	13.2	2.64
82	66	92	2.20	.44	42	24	62	13.8	2.76
81	64	92	2.34	.47	41	23	61	14.4	2.88
80	63	91	2.50	.50	40	22	60	15.0	3.00
79	62	91	2.66	.53	39	21	59	15.6	3.12
78	60	90	2.82	.56	38	21	58	16.3	3.26
77	59	89	2.99	.60	37	20	57	17.0	3.40
76	58	89	3.16	.63	36	19	56	17.8	3.56
75	57	88	3.33	.67	35	18	55	18.6	3.72
74	55	88	3.51	.70	34	18	54	19.4	3.88
73	54	87	3.70	.74	33	17	53	20.3	4.06
72	53	86	3.89	.78	32	16	52	21.2	4.24
71	52	86	4.08	.82	31	16	51	22.2	4.44
70	51	85	4.28	.86	30	15	50	23.3	4.66
69	50	84	4.49	.90					
68	49	84	4.70	.94	25	12	45	30.0	6.00
67	47	83	4.92	[illegible]	20	9	37	40.0	8.00
66	46	82	5.15	1.03	15	6	30	56.7	11.34
65	45	82	5.38	1.08	10	4	22	90.0	18.00
64	44	81	5.62	1.12	5	2	13	190.0	38.00
63	43	80	[illegible]	1.17	0	0	0	infinity	infinity
62	42	[illegible]	[illegible]	1.22					
61	41	[illegible]	[illegible]	[illegible]					

*For CN in [illegible]

From: USDA-SCS, 1985

739 13/46

HYDROCAD™ RUNS

RUNON/RUNOFF

[redacted]

484

P 739 RSC 14/46

Data for **FERMCO, NORTH CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12 Feb 96

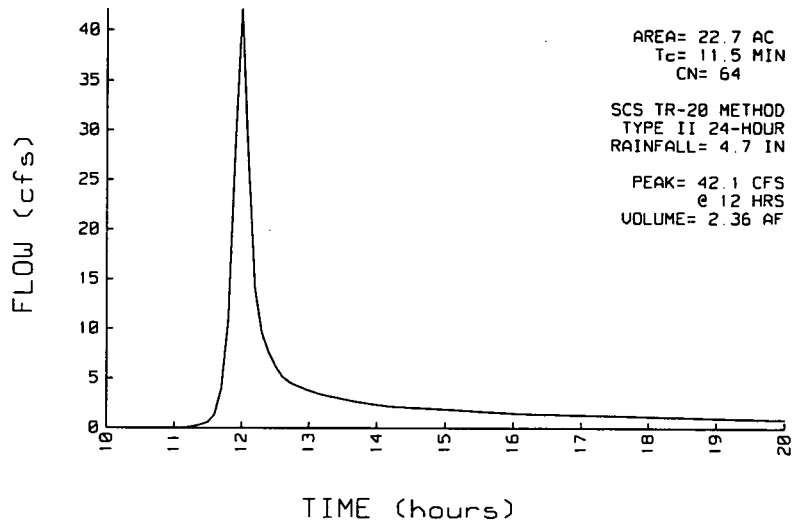
SUBCATCHMENT 2 **N-A**

ACRES	CN
22.70	64

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 42.1 CFS @ 12.00 HRS
VOLUME= 2.36 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	7.9
Grass: Short n=.15 L=200' P2=2.6 in s=.18 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	3.6
Unpaved Kv=16.1345 L=1100' s=.1 '/' V=5.1 fps		
	Total Length= 1300 ft Total Tc=	11.5

SUBCATCHMENT 2 RUNOFF
N-A



[redacted]

485

P- 739 ASC 15/46

Data for **FERMCO, NORTH CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

JSS 12 Feb 96

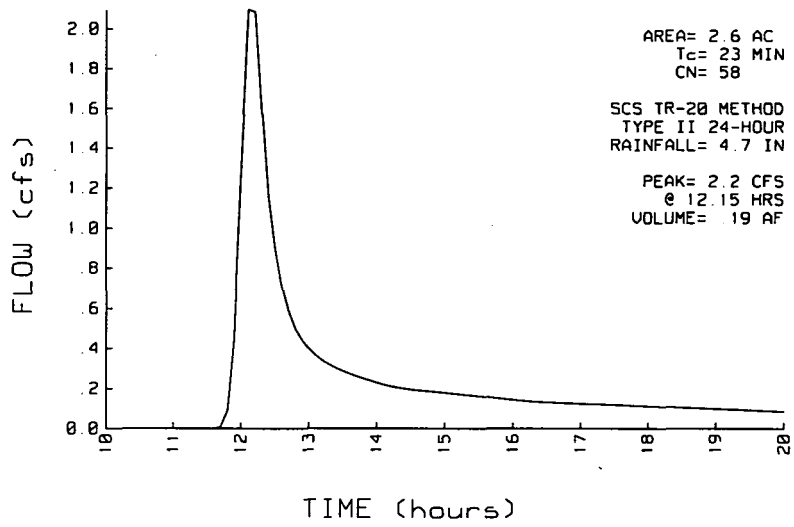
SUBCATCHMENT 3 **N-B**

ACRES	CN
2.60	58

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 2.2 CFS @ 12.15 HRS
VOLUME= .19 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	23.0
Grass: Short n=.15 L=180' P2=2.6 in s=.01 '/'		

SUBCATCHMENT 3 RUNOFF
N-B



[redacted]
486

739 Asc 16/46

Data for **FERMCO, NORTH CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SS 12 Feb 96

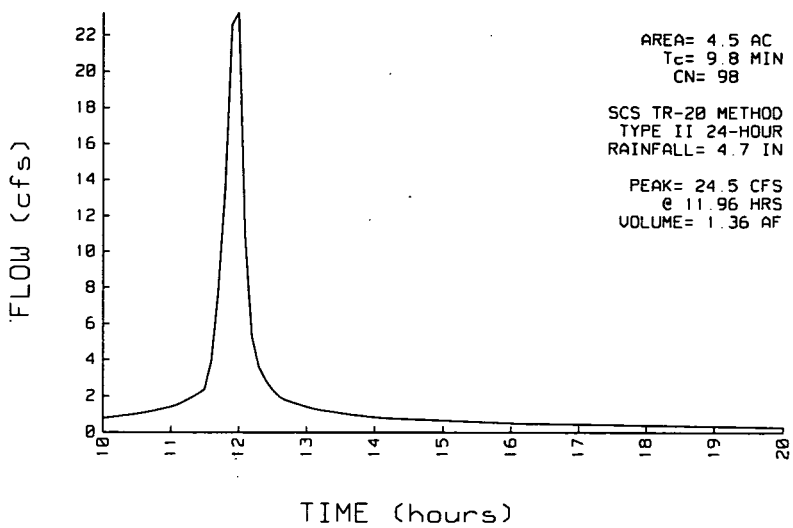
SUBCATCHMENT 1 **N-1**

ACRES	CN
4.50	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 24.5 CFS @ 11.96 HRS
VOLUME= 1.36 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=325' s=.167 '/' V=6.59 fps		
	Total Length= 472 ft Total Tc=	9.8

SUBCATCHMENT 1 RUNOFF
N-1



[redacted]
483

739 17N46

Data for **FERMCO, NORTH CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSFeb94

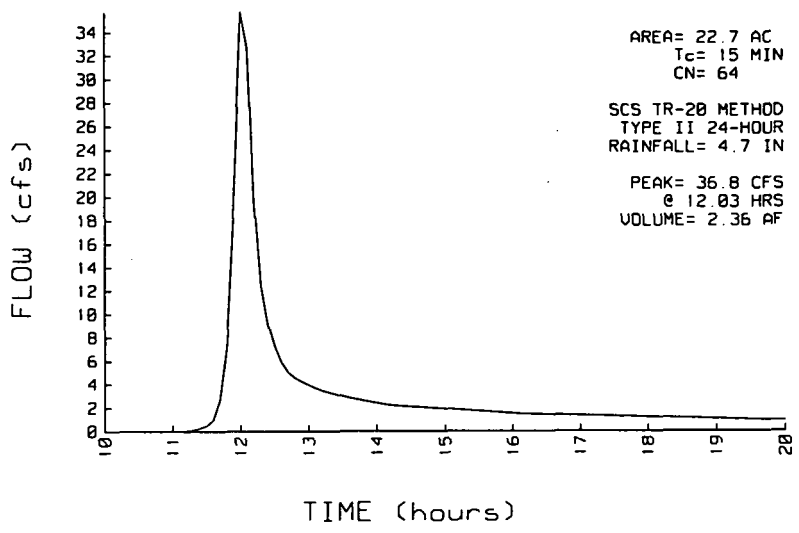
SUBCATCHMENT 2 **N-A**

ACRES	CN
22.70	64

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 36.8 CFS @ 12.03 HRS
VOLUME= 2.36 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	11.4
Grass: Dense n=.24 L=200' P2=2.6 in s=.18 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	3.6
Unpaved Kv=16.1345 L=1100' s=.1 '/' V=5.1 fps		
	Total Length= 1300 ft Total Tc=	15.0

SUBCATCHMENT 2 RUNOFF
N-A



[redacted]
488

739 Rsc 18/46

Data for **FERMCO, NORTH CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

MSS Feb94

SUBCATCHMENT 3 **N-B**

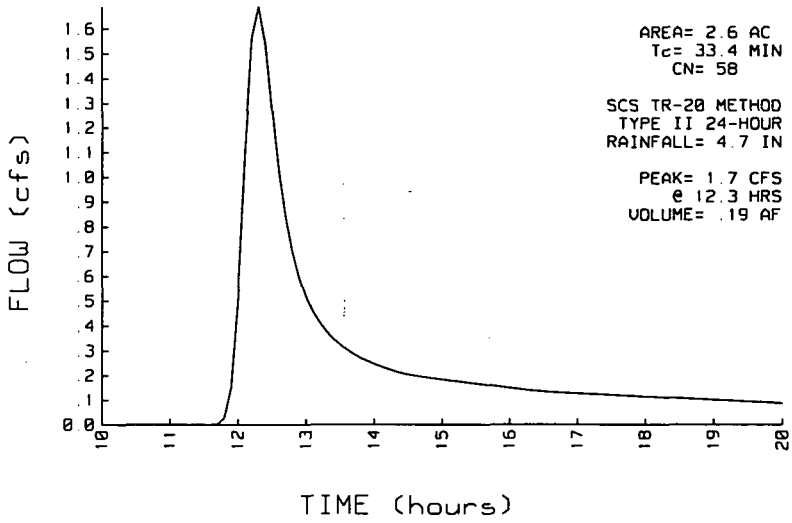
ACRES	CN
2.60	58

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 1.7 CFS @ 12.30 HRS
VOLUME= .19 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	33.4

Grass: Dense n=.24 L=180' P2=2.6 in s=.01 '/'

SUBCATCHMENT 3 RUNOFF
N-B



[redacted]

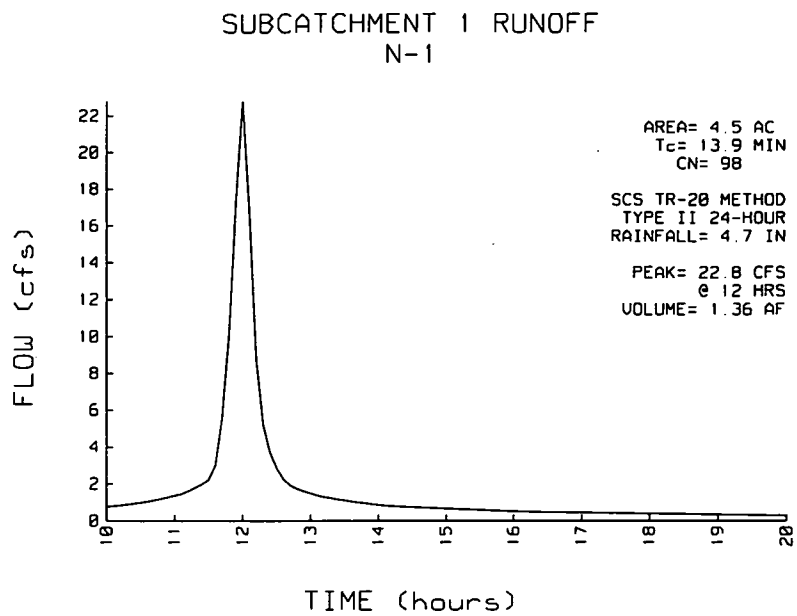
Data for **FERMCO, NORTH CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SUBCATCHMENT 1 **N-1**

ACRES	CN
4.50	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 22.8 CFS @ 12.00 HRS
VOLUME= 1.36 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=325' s=.167 '/' V=6.59 fps		
	Total Length= 472 ft Total Tc=	13.9



[redacted]

739 20/46

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, LIGHT COVE**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

ASS 12 Feb 94

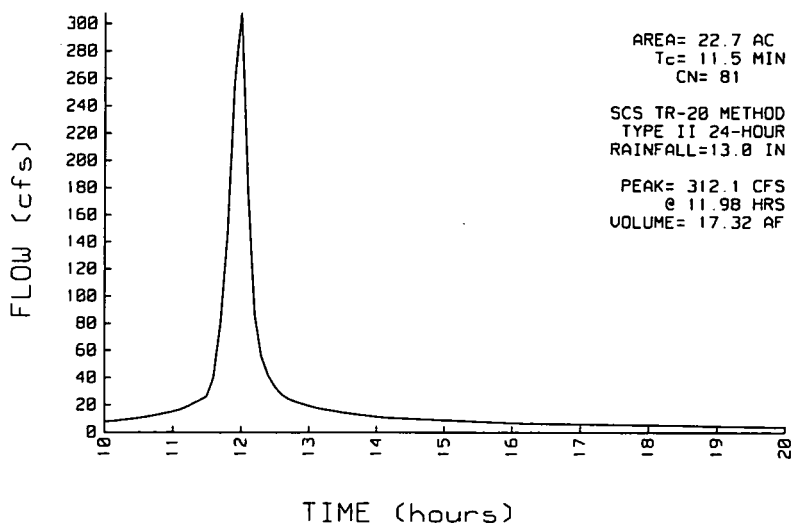
SUBCATCHMENT 2 **N-A**

ACRES	CN
22.70	81

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 312.1 CFS @ 11.98 HRS
VOLUME= 17.32 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	7.9
Grass: Short n=.15 L=200' P2=2.6 in s=.18 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	3.6
Unpaved Kv=16.1345 L=1100' s=.1 '/' V=5.1 fps		
	Total Length= 1300 ft Total Tc=	11.5

SUBCATCHMENT 2 RUNOFF
N-A



[redacted]

P- 739 Asc 21/46

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, LIGHT COVE**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SS 12Feb94

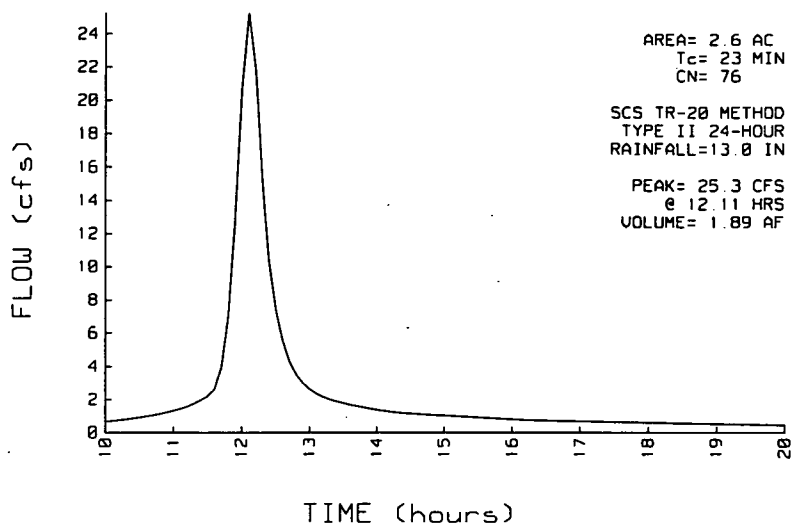
SUBCATCHMENT 3 **N-B**

ACRES	CN
2.60	76

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 25.3 CFS @ 12.11 HRS
VOLUME= 1.89 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	23.0
Grass: Short n=.15 L=180' P2=2.6 in s=.01 '/'		

SUBCATCHMENT 3 RUNOFF
N-B



[redacted]

739 22/46
ASC

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, LIGHT COVE**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12 Feb 96

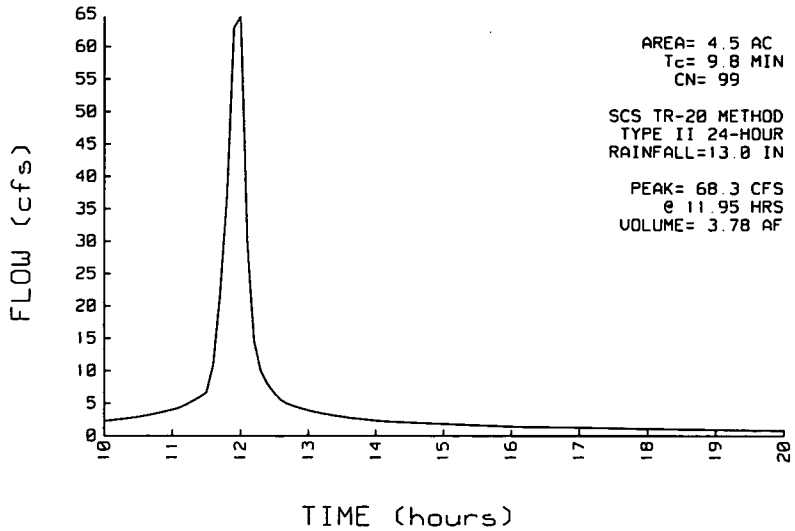
SUBCATCHMENT 1 **N-1**

ACRES	CN
4.50	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 68.3 CFS @ 11.95 HRS
VOLUME= 3.78 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=325' s=.167 '/' V=6.59 fps		
	Total Length= 472 ft Total Tc=	9.8

SUBCATCHMENT 1 RUNOFF
N-1



[redacted]

739 Asc 23/46

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

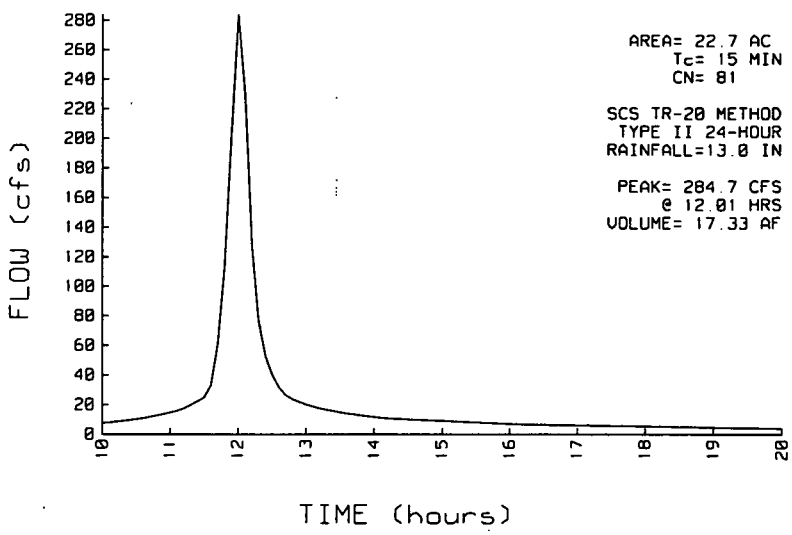
SUBCATCHMENT 2 **N-A**

ACRES	CN
22.70	81

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 284.7 CFS @ 12.01 HRS
VOLUME= 17.33 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	11.4
Grass: Dense n=.24 L=200' P2=2.6 in s=.18 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	3.6
Unpaved Kv=16.1345 L=1100' s=.1 '/' V=5.1 fps		
	Total Length= 1300 ft Total Tc=	15.0

SUBCATCHMENT 2 RUNOFF
N-A



[redacted]

739 24/4E
RSC

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

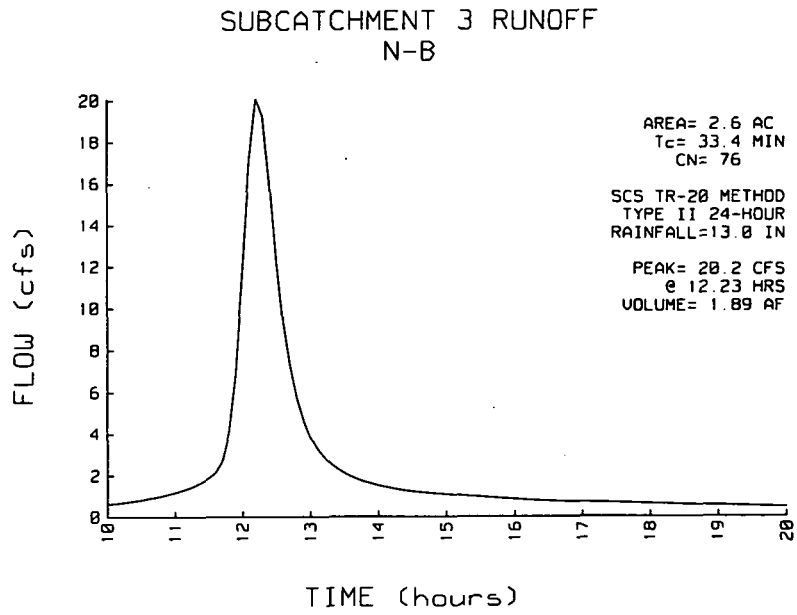
SSS 12Feb96

SUBCATCHMENT 3 **N-B**

ACRES	CN
2.60	76

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 20.2 CFS @ 12.23 HRS
VOLUME= 1.89 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	33.4
Grass: Dense n=.24 L=180' P2=2.6 in s=.01 '/'		



[redacted]

739 25/46
LSC

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

AS 12Feb96

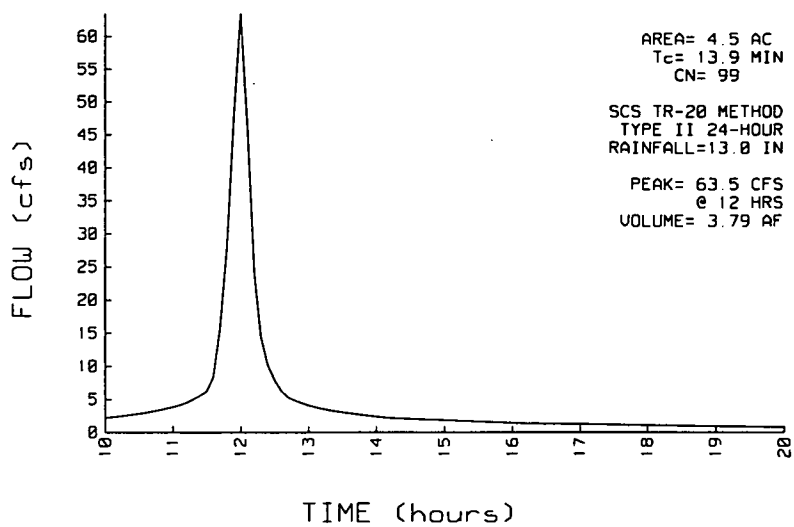
SUBCATCHMENT 1 **N-1**

ACRES	CN
4.50	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 63.5 CFS @ 12.00 HRS
VOLUME= 3.79 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=325' s=.167 '/' V=6.59 fps		
	Total Length= 472 ft Total Tc=	13.9

SUBCATCHMENT 1 RUNOFF
N-1



[redacted]

496

739 261/46
ASC

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, HEAVY COVE**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

AGS 12Feb96

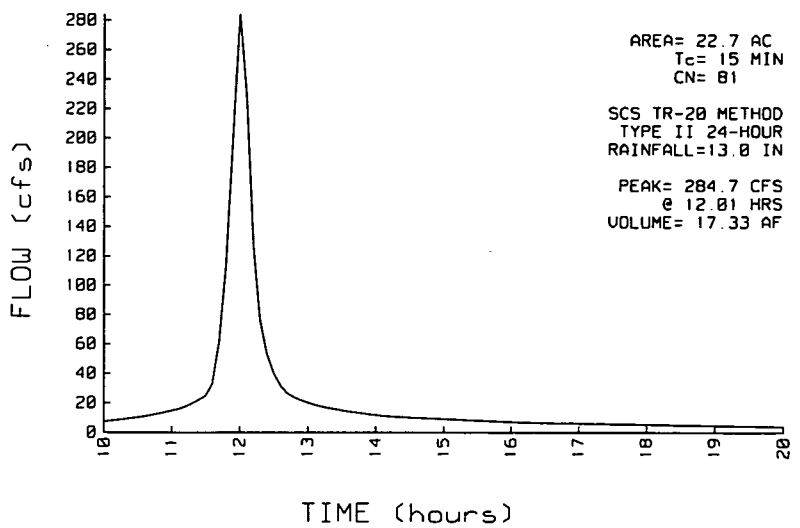
SUBCATCHMENT 2 **N-A**

ACRES	CN
22.70	81

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 284.7 CFS @ 12.01 HRS
VOLUME= 17.33 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	11.4
Grass: Dense n=.24 L=200' P2=2.6 in s=.18 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	3.6
Unpaved Kv=16.1345 L=1100' s=.1 '/' V=5.1 fps		
	Total Length= 1300 ft Total Tc=	15.0

SUBCATCHMENT 2 RUNOFF
N-A



[redacted]
497

P- 759
RSC 27V 46

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, HEAVY COVE**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

ISS 12Feb94

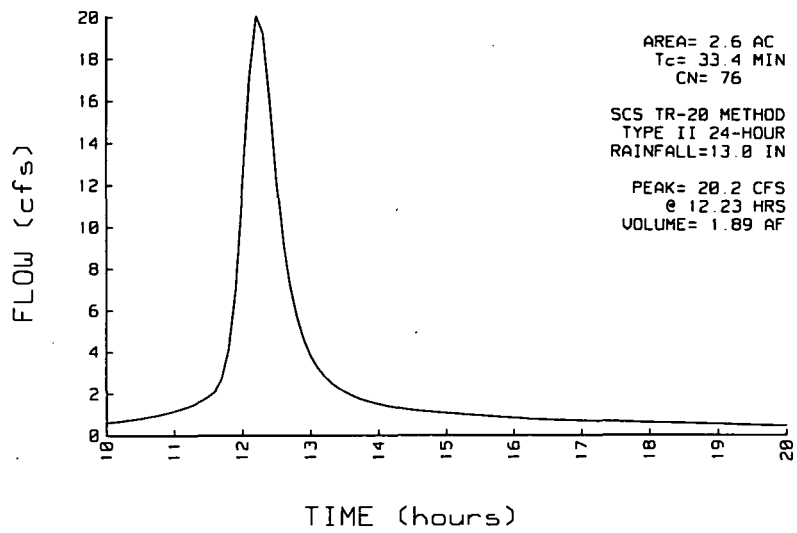
SUBCATCHMENT 3 **N-B**

ACRES	CN
2.60	76

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 20.2 CFS @ 12.23 HRS
VOLUME= 1.89 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	33.4
Grass: Dense n=.24 L=180' P2=2.6 in s=.01 '/'		

SUBCATCHMENT 3 RUNOFF
N-B



[redacted]

739 RSC 28/96

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, HEAVY COVE**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

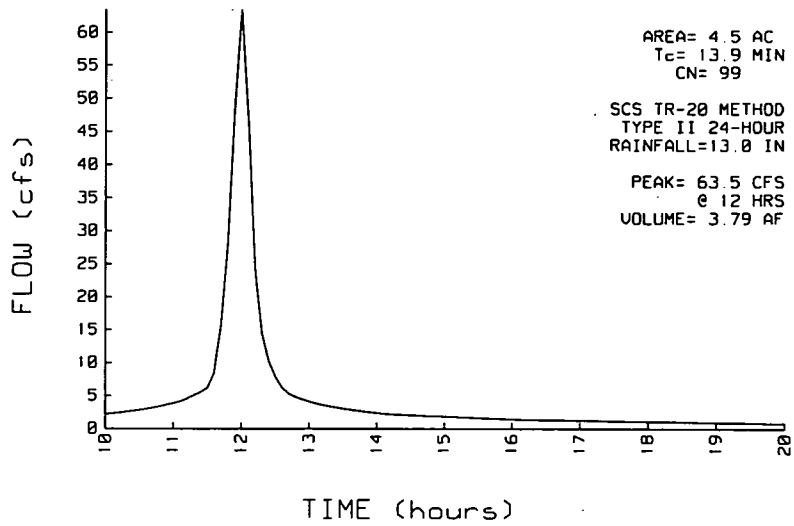
SUBCATCHMENT 1 **N-1**

ACRES	CN
4.50	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 63.5 CFS @ 12.00 HRS
VOLUME= 3.79 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=325' s=.167 '/' V=6.59 fps		
	Total Length= 472 ft Total Tc=	13.9

SUBCATCHMENT 1 RUNOFF
N-1



[redacted]

P- 739 29/4

HYDROCAD™ RUNS

DRAINAGE CHANNEL ROUTING

[redacted]

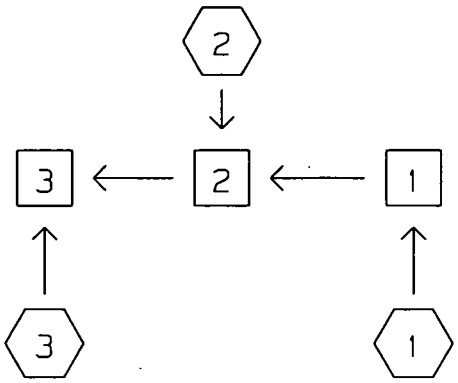
500

739 30146

Data for **FERMCO, NORTH CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12 Feb 96

WATERSHED ROUTING ==========



SUBCATCHMENT REACH POND LINK

[redacted]

501

P- 739 Rsc 3/1/46

Data for **FERMCO, NORTH CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12 Feb 96

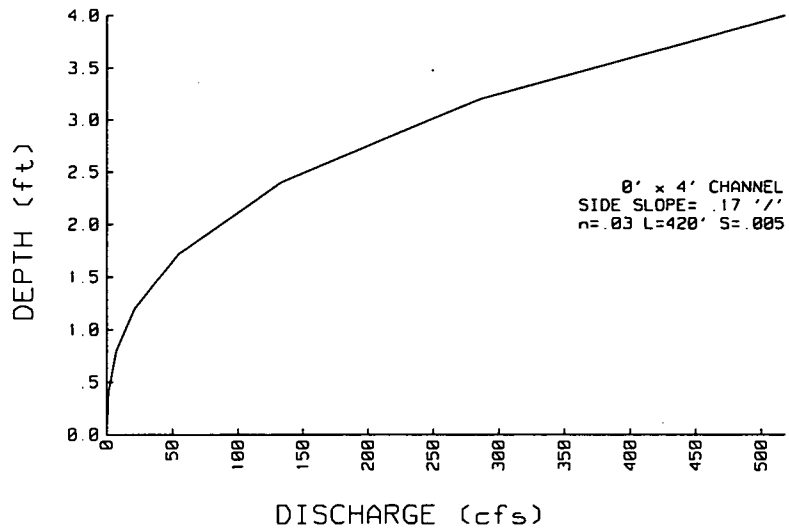
REACH 1 **POINT A**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	.9	1.1
.8	3.8	7.1
1.2	8.5	20.9
1.7	17.4	54.6
2.4	33.9	132.7
3.2	60.2	285.9
4.0	94.1	518.3

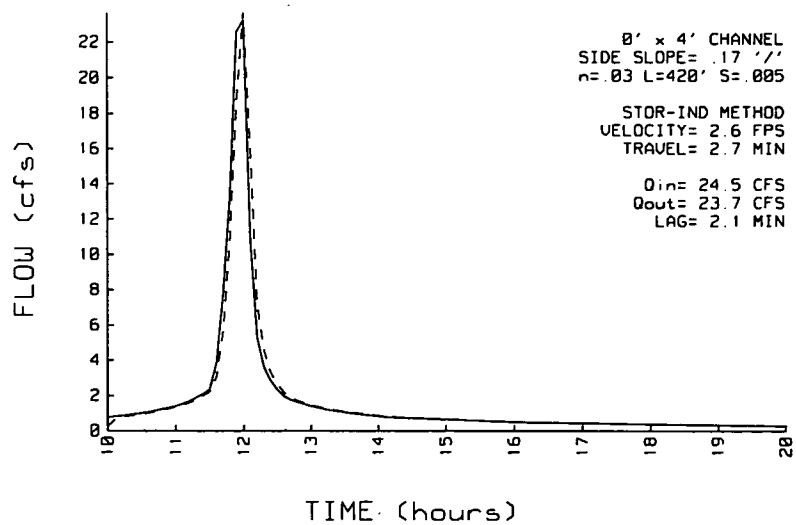
0' x 4' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 420 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.24 FT
PEAK VELOCITY= 2.6 FPS
TRAVEL TIME = 2.7 MIN
Qin = 24.5 CFS @ 11.96 HRS
Qout= 23.7 CFS @ 11.99 HRS
ATTEN= 3 % LAG= 2.1 MIN
IN/OUT= 1.36 / 1.35 AF

REACH 1 DISCHARGE
POINT A



REACH 1 INFLOW & OUTFLOW
POINT A



[redacted]

502

739 RSC 32/46

Data for **FERMCO, NORTH CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

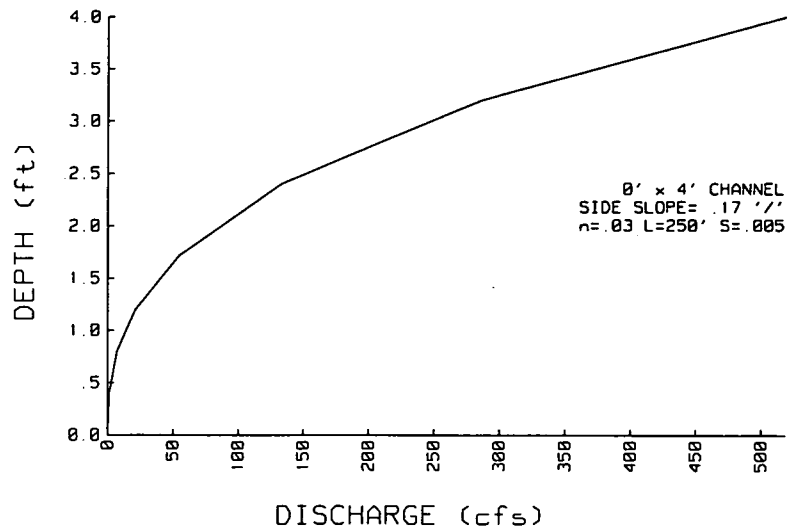
REACH 2

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	.9	1.1
.8	3.8	7.1
1.2	8.5	20.9
1.7	17.4	54.6
2.4	33.9	132.7
3.2	60.2	285.9
4.0	94.1	518.3

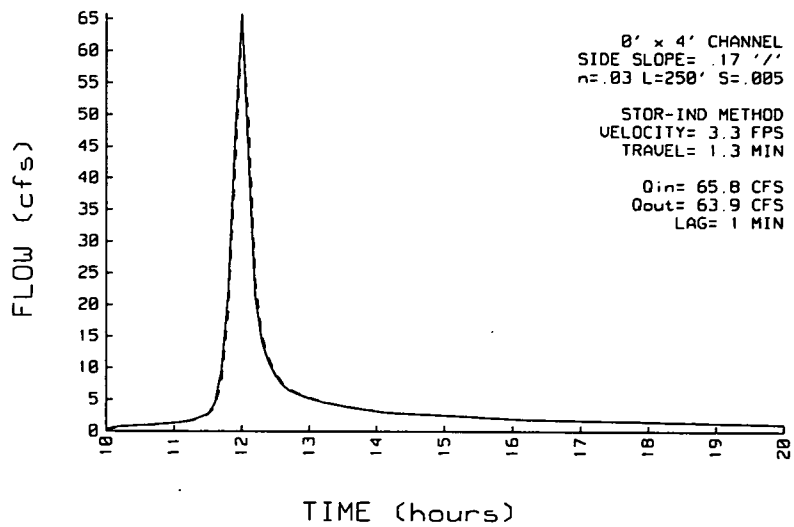
0' x 4' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 250 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.80 FT
PEAK VELOCITY= 3.3 FPS
TRAVEL TIME = 1.3 MIN
Qin = 65.8 CFS @ 12.00 HRS
Qout= 63.9 CFS @ 12.01 HRS
ATTEN= 3 % LAG= 1.0 MIN
IN/OUT= 3.71 / 3.71 AF

REACH 2 DISCHARGE



REACH 2 INFLOW & OUTFLOW



[redacted]

503

Data for **FERMCO, NORTH CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

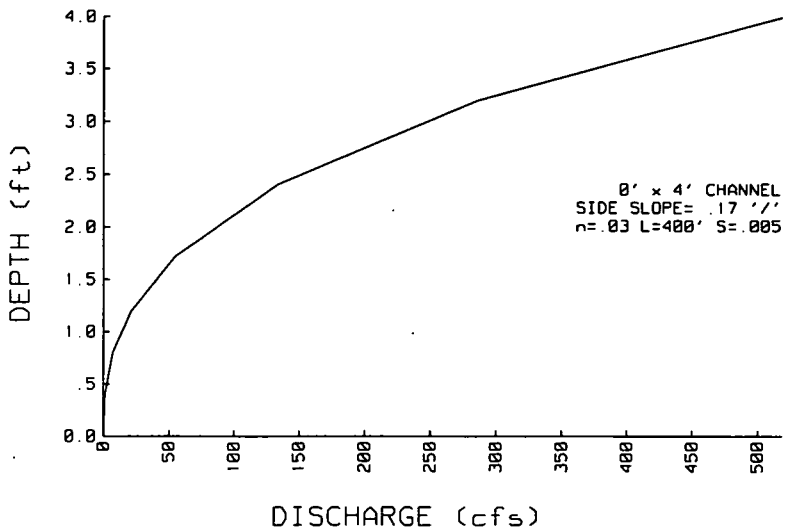
REACH 3 **POINT B**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	.9	1.1
.8	3.8	7.1
1.2	8.5	20.9
1.7	17.4	54.6
2.4	33.9	132.7
3.2	60.2	285.9
4.0	94.1	518.3

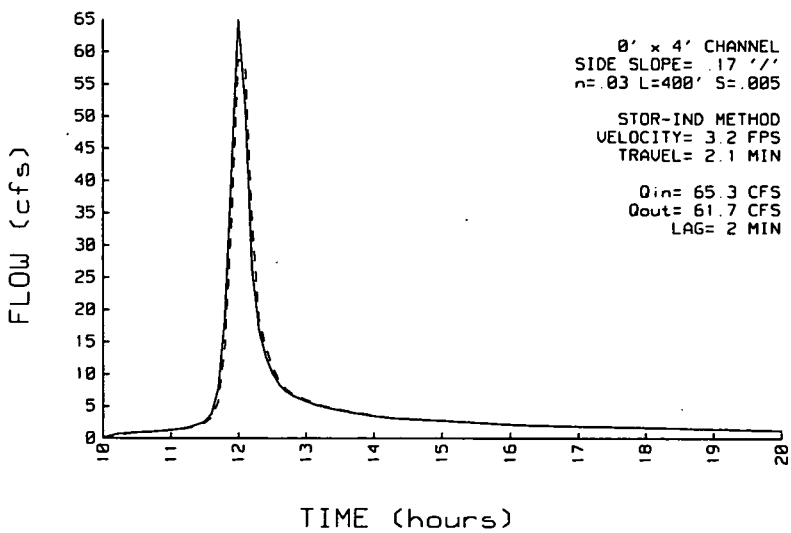
0' x 4' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 400 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.76 FT
PEAK VELOCITY= 3.2 FPS
TRAVEL TIME = 2.1 MIN
Qin = 65.3 CFS @ 12.01 HRS
Qout= 61.7 CFS @ 12.05 HRS
ATTEN= 6 % LAG= 2.0 MIN
IN/OUT= 3.90 / 3.89 AF

REACH 3 DISCHARGE
POINT B



REACH 3 INFLOW & OUTFLOW
POINT B



[redacted]

639
Rsc 34/4

Data for **FERMCO, NORTH CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12 Feb 96

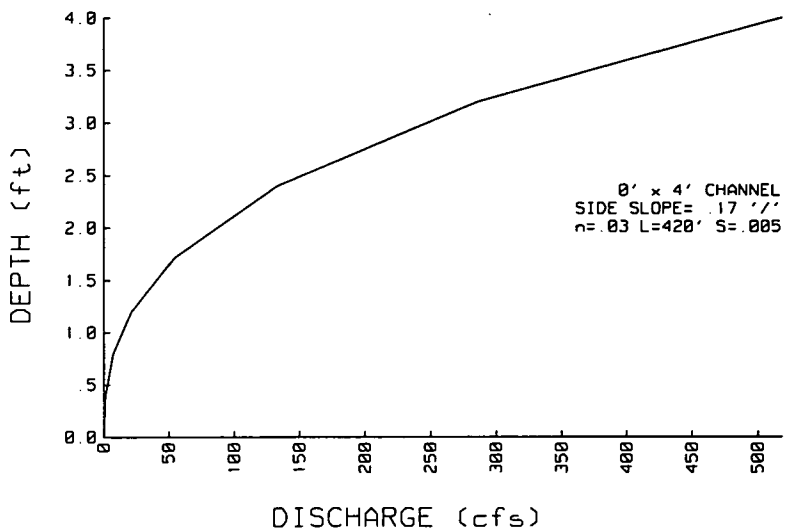
REACH 1 **POINT A**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	.9	1.1
.8	3.8	7.1
1.2	8.5	20.9
1.7	17.4	54.6
2.4	33.9	132.7
3.2	60.2	285.9
4.0	94.1	518.3

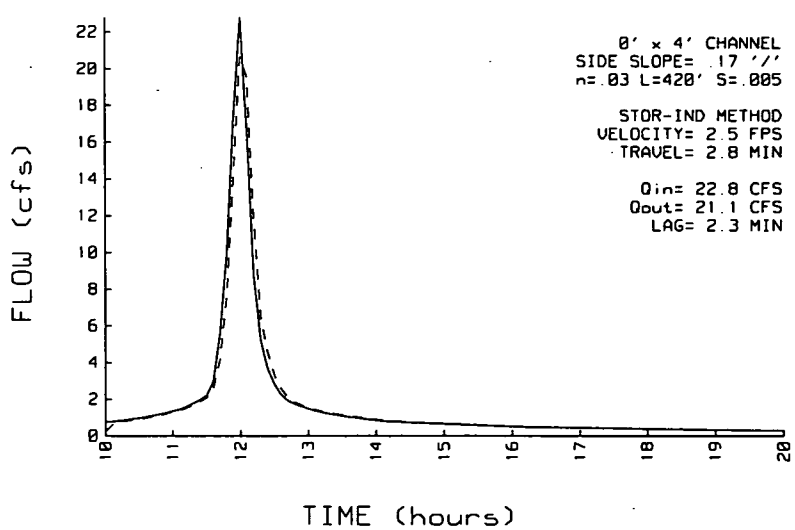
0' x 4' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 420 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.19 FT
PEAK VELOCITY= 2.5 FPS
TRAVEL TIME = 2.8 MIN
Qin = 22.8 CFS @ 12.00 HRS
Qout= 21.1 CFS @ 12.04 HRS
ATTEN= 7 % LAG= 2.3 MIN
IN/OUT= 1.36 / 1.36 AF

REACH 1 DISCHARGE
POINT A



REACH 1 INFLOW & OUTFLOW
POINT A



[redacted]

505

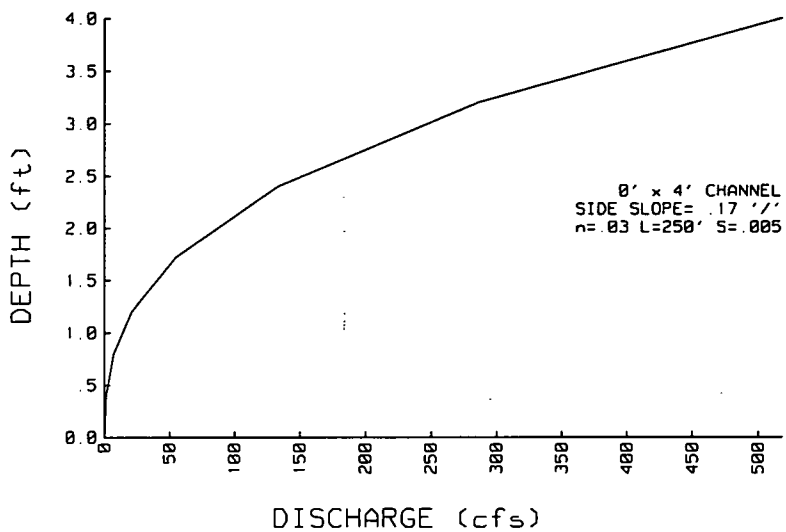
REACH 2

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	.9	1.1
.8	3.8	7.1
1.2	8.5	20.9
1.7	17.4	54.6
2.4	33.9	132.7
3.2	60.2	285.9
4.0	94.1	518.3

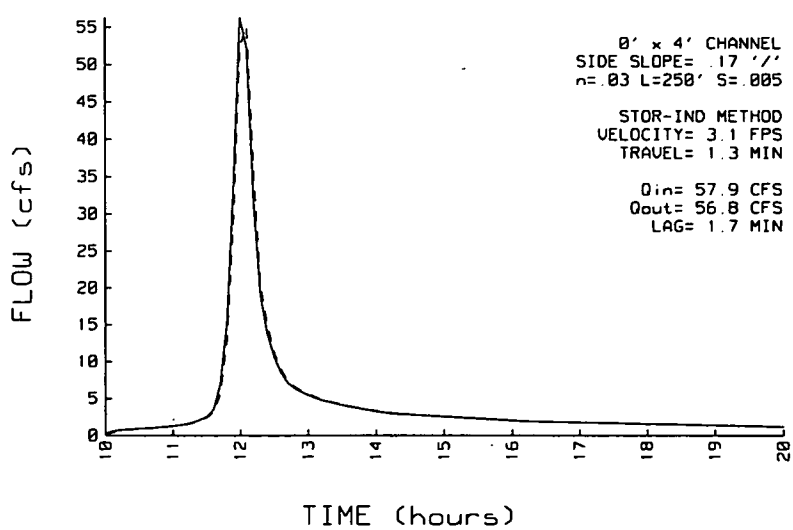
0' x 4' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 250 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.73 FT
PEAK VELOCITY= 3.1 FPS
TRAVEL TIME = 1.3 MIN
Qin = 57.9 CFS @ 12.03 HRS
Qout= 56.8 CFS @ 12.06 HRS
ATTEN= 2 % LAG= 1.7 MIN
IN/OUT= 3.71 / 3.71 AF

REACH 2 DISCHARGE



REACH 2 INFLOW & OUTFLOW



[redacted]

P- 739 36/44
RSC

Data for **FERMCO, NORTH CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

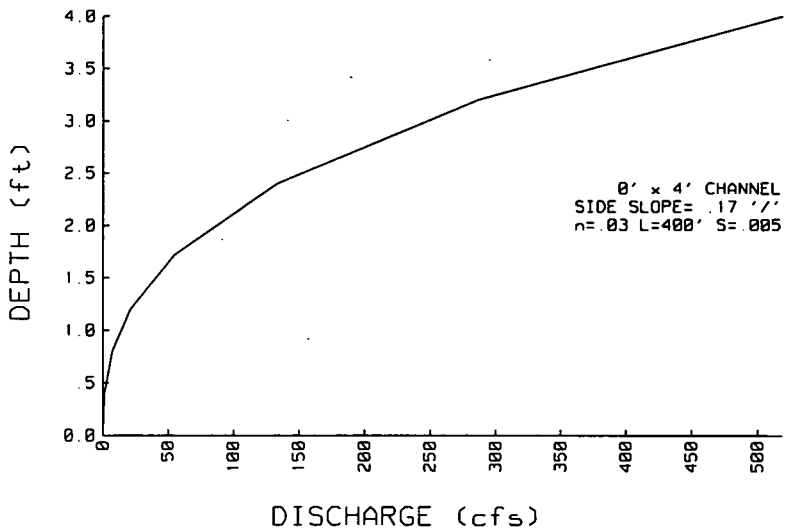
REACH 3 **POINT B**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	.9	1.1
.8	3.8	7.1
1.2	8.5	20.9
1.7	17.4	54.6
2.4	33.9	132.7
3.2	60.2	285.9
4.0	94.1	518.3

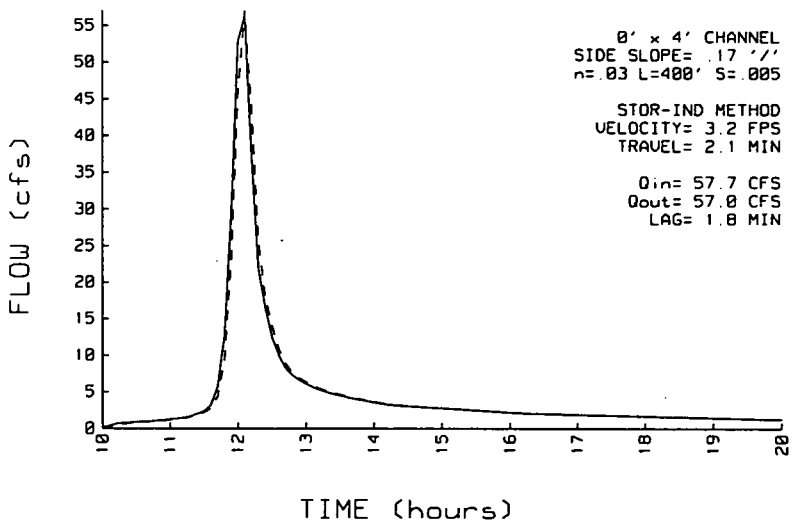
0' x 4' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 400 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.74 FT
PEAK VELOCITY= 3.2 FPS
TRAVEL TIME = 2.1 MIN
Qin = 57.7 CFS @ 12.07 HRS
Qout= 57.0 CFS @ 12.10 HRS
ATTEN= 1 % LAG= 1.8 MIN
IN/OUT= 3.90 / 3.89 AF

REACH 3 DISCHARGE
POINT B



REACH 3 INFLOW & OUTFLOW
POINT B



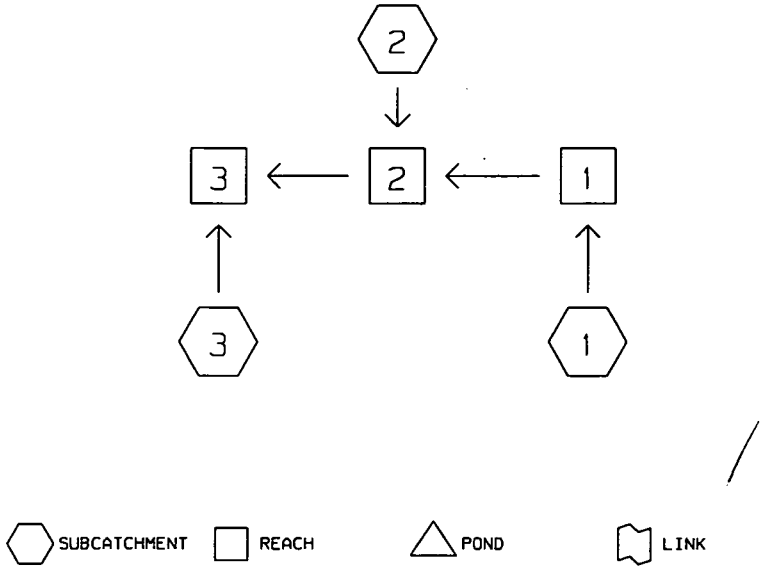
[redacted]

P-LSC 739 3714

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, LIGHT COVE**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12 Feb 96

WATERSHED ROUTING ==========



[redacted]

508

739 3874

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, LIGHT COVE**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

RSC

SSS 12 Feb 96

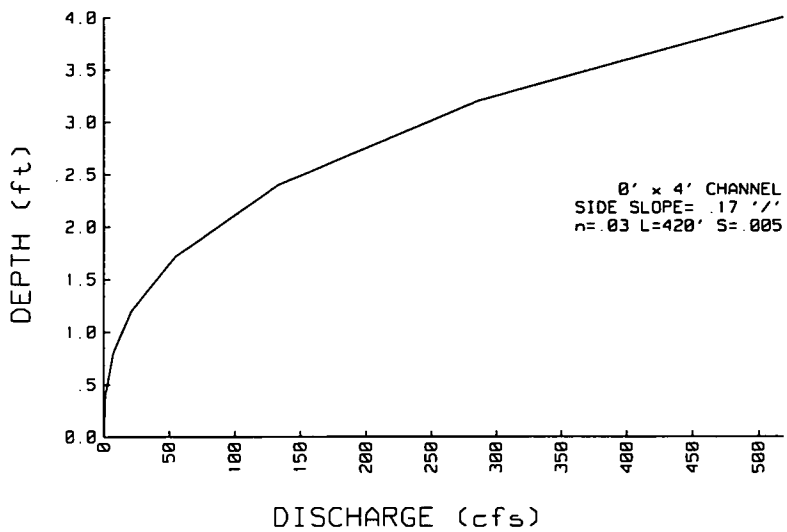
REACH 1 **POINT A**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	.9	1.1
.8	3.8	7.1
1.2	8.5	20.9
1.7	17.4	54.6
2.4	33.9	132.7
3.2	60.2	285.9
4.0	94.1	518.3

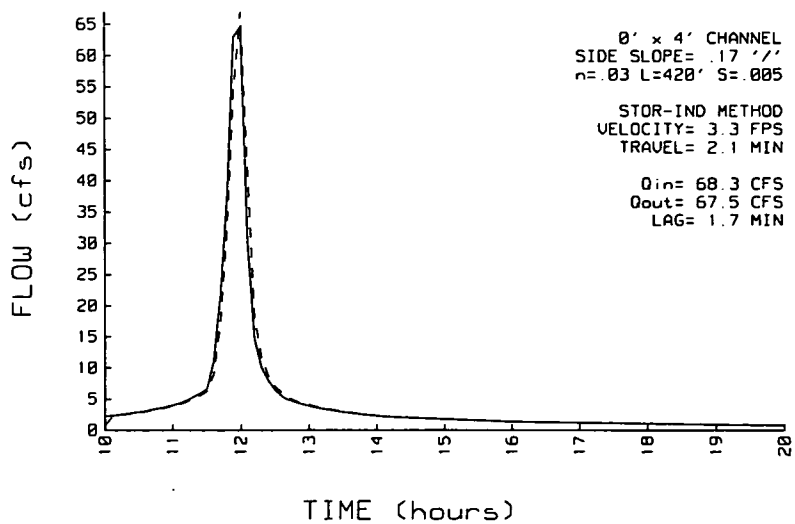
0' x 4' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 420 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.83 FT
PEAK VELOCITY= 3.3 FPS
TRAVEL TIME = 2.1 MIN
Qin = 68.3 CFS @ 11.95 HRS
Qout= 67.5 CFS @ 11.98 HRS
ATTEN= 1 % LAG= 1.7 MIN
IN/OUT= 3.78 / 3.78 AF

REACH 1 DISCHARGE
POINT A



REACH 1 INFLOW & OUTFLOW
POINT A



[redacted]

509

RSC 73939/4

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, LIGHT COVE**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

AGS 12Feb96

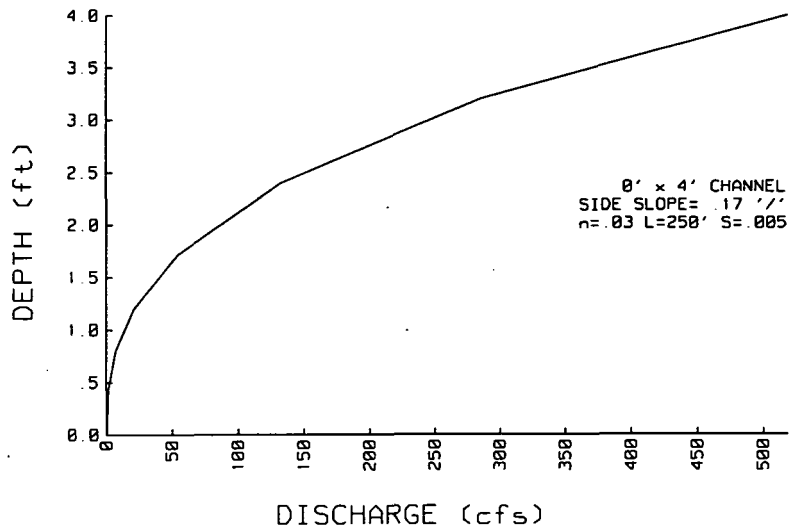
REACH 2

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	.9	1.1
.8	3.8	7.1
1.2	8.5	20.9
1.7	17.4	54.6
2.4	33.9	132.7
3.2	60.2	285.9
4.0	94.1	518.3

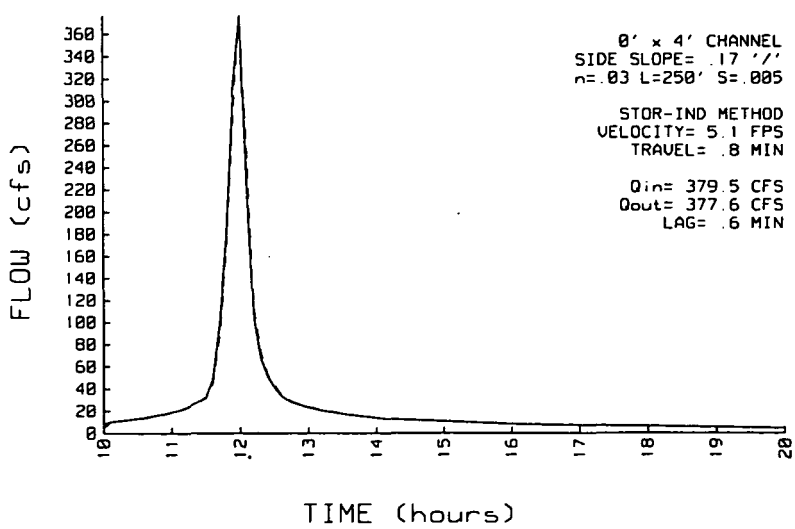
0' x 4' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 250 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 3.51 FT
PEAK VELOCITY= 5.1 FPS
TRAVEL TIME = .8 MIN
Qin = 379.5 CFS @ 11.98 HRS
Qout= 377.6 CFS @ 11.99 HRS
ATTEN= 1 % LAG= .6 MIN
IN/OUT= 21.09 / 21.08 AF

REACH 2 DISCHARGE



REACH 2 INFLOW & OUTFLOW



[redacted]

510

F- 739 40
Asc

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, LIGHT COVE**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb94

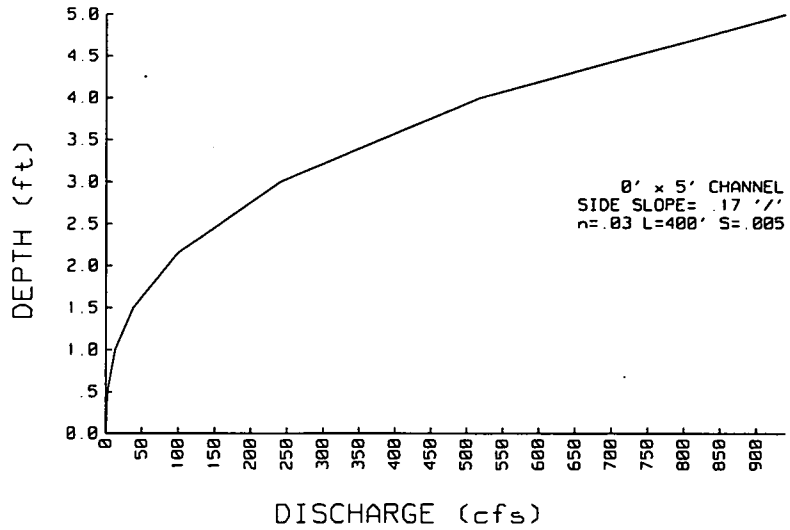
REACH 3 **POINT B**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	1.5	2.0
1.0	5.9	12.9
1.5	13.2	37.9
2.2	27.2	99.0
3.0	52.9	240.7
4.0	94.1	518.3
5.0	147.1	939.8

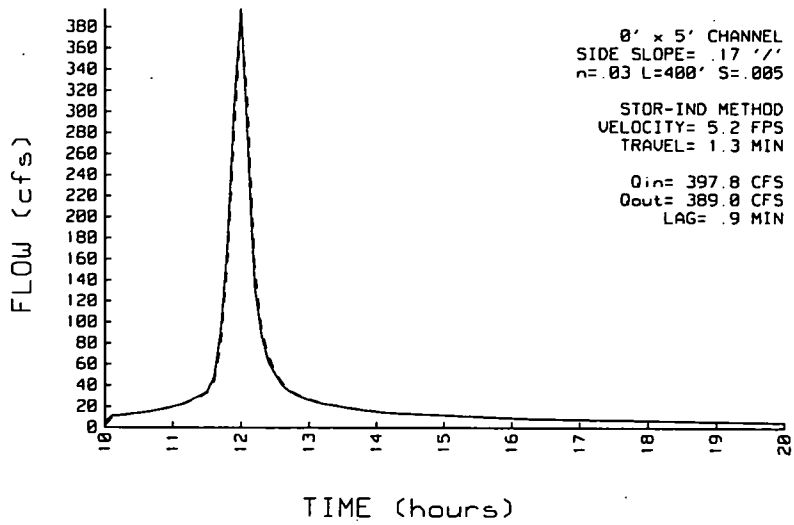
0' x 5' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 400 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 3.53 FT
PEAK VELOCITY= 5.2 FPS
TRAVEL TIME = 1.3 MIN
Qin = 397.8 CFS @ 11.99 HRS
Qout= 389.0 CFS @ 12.01 HRS
ATTEN= 2 % LAG= .9 MIN
IN/OUT= 22.96 / 22.94 AF

REACH 3 DISCHARGE
POINT B



REACH 3 INFLOW & OUTFLOW
POINT B



[redacted]

P- 739 LSC 4/1/96

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

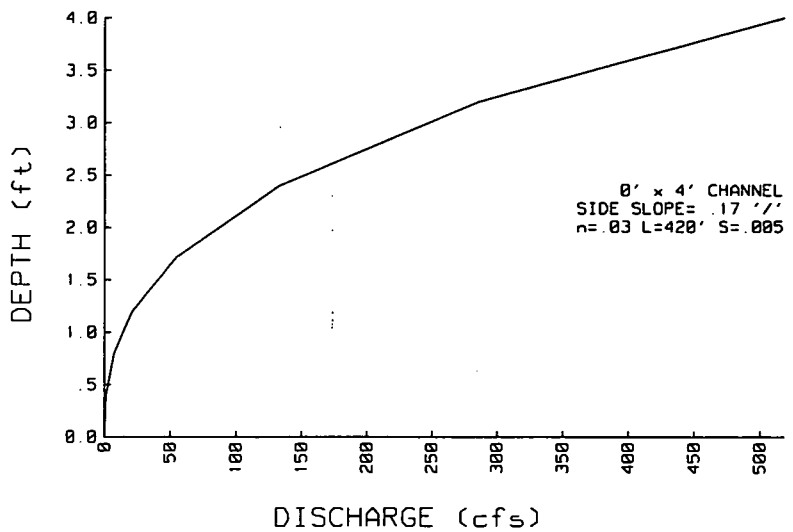
REACH 1 **POINT A**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	.9	1.1
.8	3.8	7.1
1.2	8.5	20.9
1.7	17.4	54.6
2.4	33.9	132.7
3.2	60.2	285.9
4.0	94.1	518.3

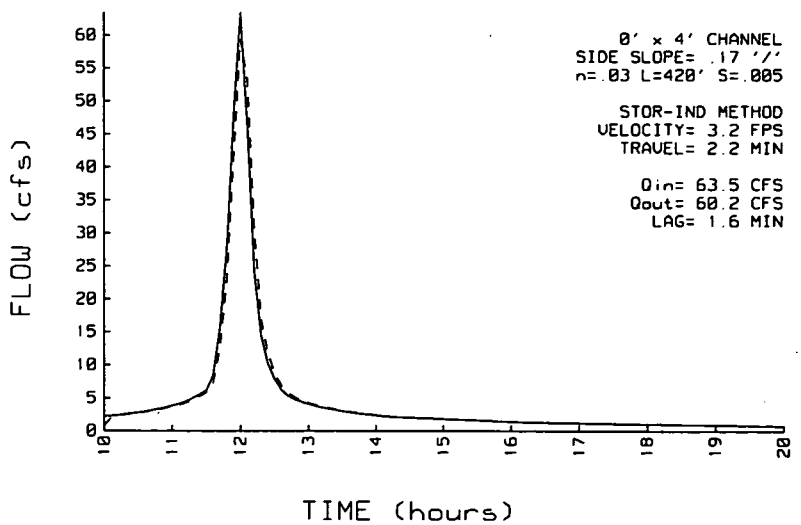
0' x 4' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 420 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.76 FT
PEAK VELOCITY= 3.2 FPS
TRAVEL TIME = 2.2 MIN
Qin = 63.5 CFS @ 12.00 HRS
Qout= 60.2 CFS @ 12.02 HRS
ATTEN= 5 % LAG= 1.6 MIN
IN/OUT= 3.79 / 3.78 AF

REACH 1 DISCHARGE
POINT A



REACH 1 INFLOW & OUTFLOW
POINT A



[redacted]

512

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

ASC 3942\46

SSS 12Feb96

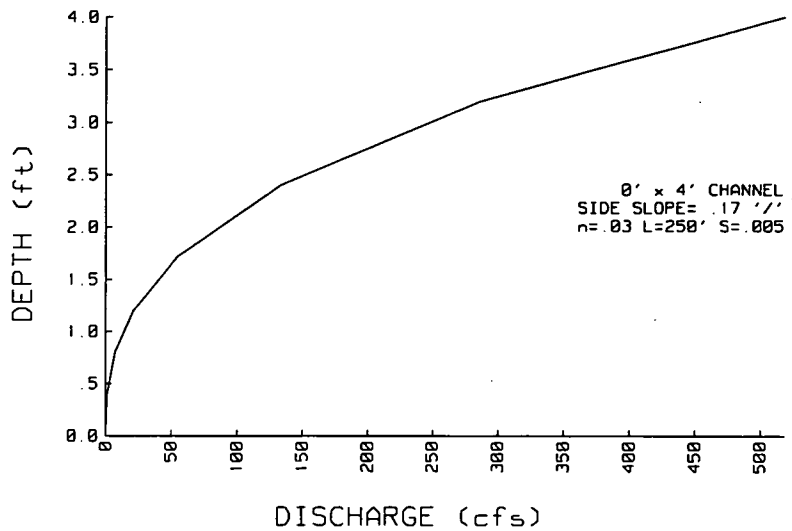
REACH 2

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	.9	1.1
.8	3.8	7.1
1.2	8.5	20.9
1.7	17.4	54.6
2.4	33.9	132.7
3.2	60.2	285.9
4.0	94.1	518.3

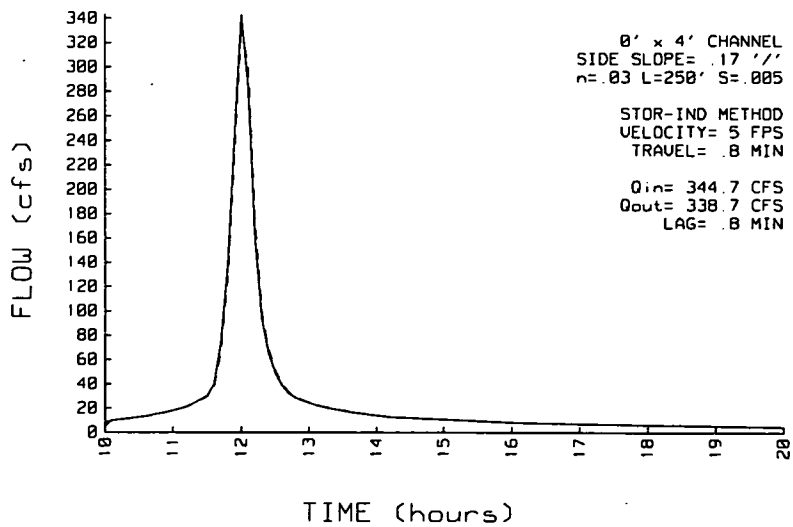
0' x 4' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 250 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 3.37 FT
PEAK VELOCITY= 5.0 FPS
TRAVEL TIME = .8 MIN
Qin = 344.7 CFS @ 12.01 HRS
Qout= 338.7 CFS @ 12.03 HRS
ATTEN= 2 % LAG= .8 MIN
IN/OUT= 21.12 / 21.10 AF

REACH 2 DISCHARGE



REACH 2 INFLOW & OUTFLOW



[redacted]

739 43 14
RSC

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

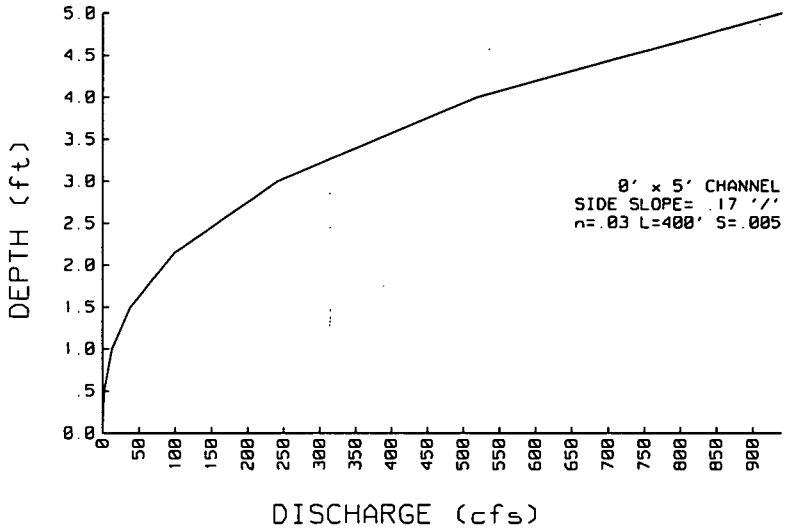
REACH 3 **POINT B**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	1.5	2.0
1.0	5.9	12.9
1.5	13.2	37.9
2.2	27.2	99.0
3.0	52.9	240.7
4.0	94.1	518.3
5.0	147.1	939.8

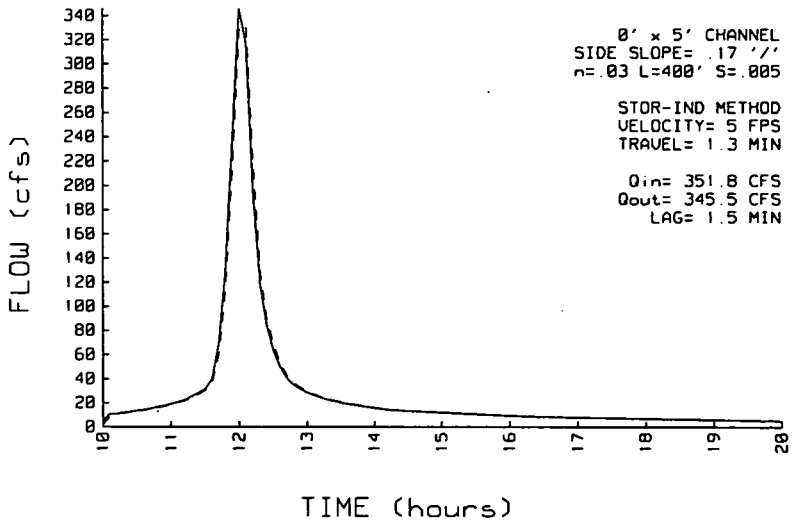
0' x 5' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 400 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 3.33 FT
PEAK VELOCITY= 5.0 FPS
TRAVEL TIME = 1.3 MIN
Qin = 351.8 CFS @ 12.03 HRS
Qout= 345.5 CFS @ 12.05 HRS
ATTEN= 2 % LAG= 1.5 MIN
IN/OUT= 22.99 / 22.96 AF

REACH 3 DISCHARGE
POINT B



REACH 3 INFLOW & OUTFLOW
POINT B



[redacted]

514

739 44146
RSC

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, HEAVY COVE**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SS 12Feb96

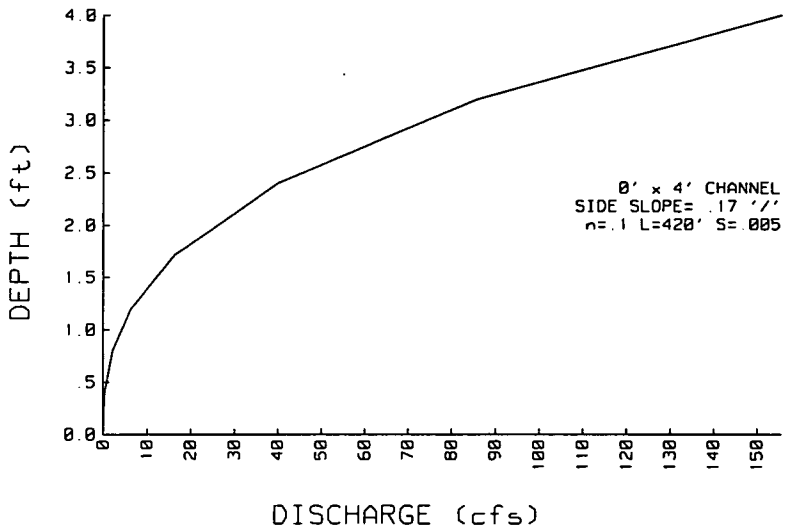
REACH 1 **POINT A**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	.9	.3
.8	3.8	2.1
1.2	8.5	6.3
1.7	17.4	16.4
2.4	33.9	39.8
3.2	60.2	85.8
4.0	94.1	155.5

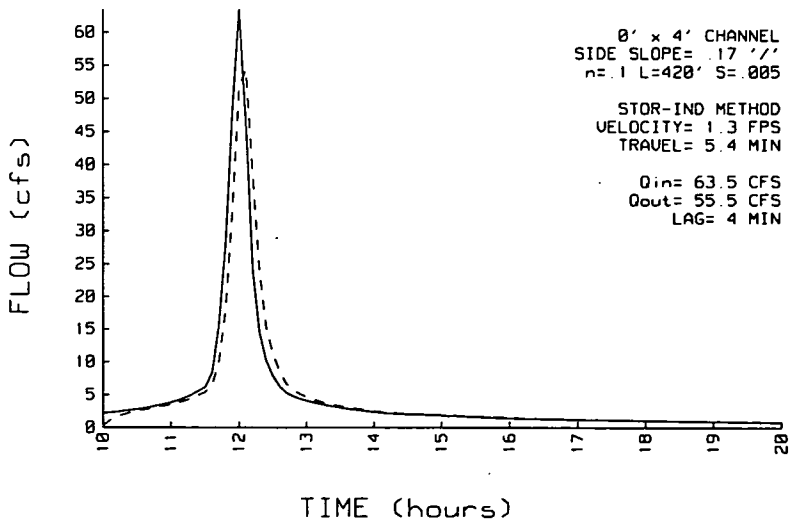
0' x 4' CHANNEL
SIDE SLOPE= .17 '/'
n= .1
LENGTH= 420 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.65 FT
PEAK VELOCITY= 1.3 FPS
TRAVEL TIME = 5.4 MIN
Qin = 63.5 CFS @ 12.00 HRS
Qout= 55.5 CFS @ 12.06 HRS
ATTEN= 13 % LAG= 4.0 MIN
IN/OUT= 3.79 / 3.77 AF

REACH 1 DISCHARGE
POINT A



REACH 1 INFLOW & OUTFLOW
POINT A



[redacted]

RSC 73945/46

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, HEAVY COVE**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

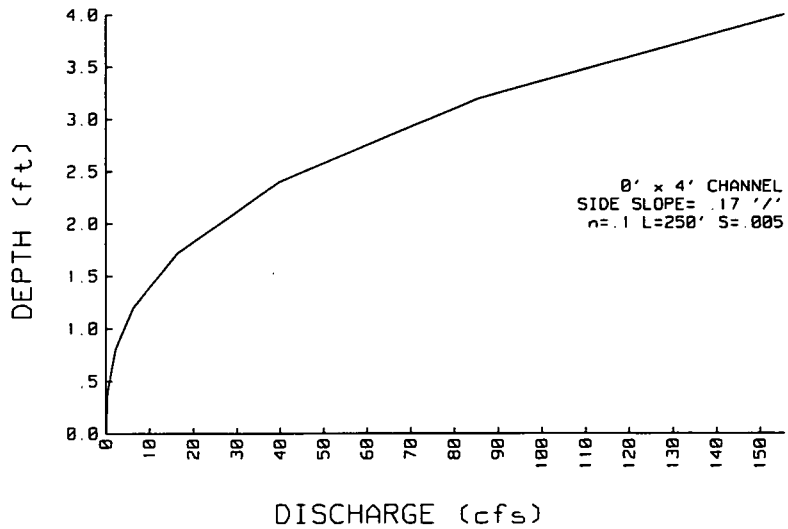
REACH 2

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	.9	.3
.8	3.8	2.1
1.2	8.5	6.3
1.7	17.4	16.4
2.4	33.9	39.8
3.2	60.2	85.8
4.0	94.1	155.5

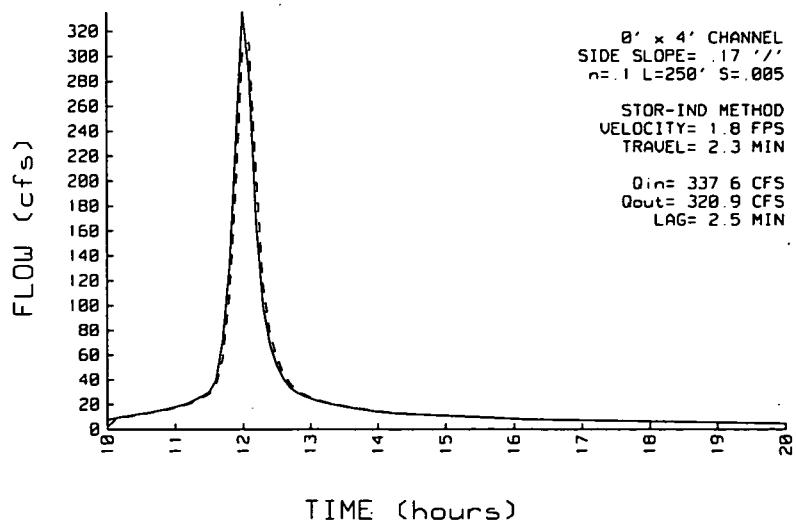
0' x 4' CHANNEL
SIDE SLOPE= .17 '/'
n= .1
LENGTH= 250 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 5.79 FT OK, WITH BOUND OSDV
PEAK VELOCITY= 1.8 FPS
TRAVEL TIME = 2.3 MIN
Qin = 337.6 CFS @ 12.02 HRS
Qout= 320.9 CFS @ 12.06 HRS
ATTEN= 5 % LAG= 2.5 MIN
IN/OUT= 21.11 / 21.07 AF

REACH 2 DISCHARGE



REACH 2 INFLOW & OUTFLOW



[redacted]

P- 739 RSC 46\46

Data for **FERMCO, NORTH CHANNEL, 2000-YR STORM, HEAVY COVE**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

HSS 12Feb96

REACH 3 **POINT B**

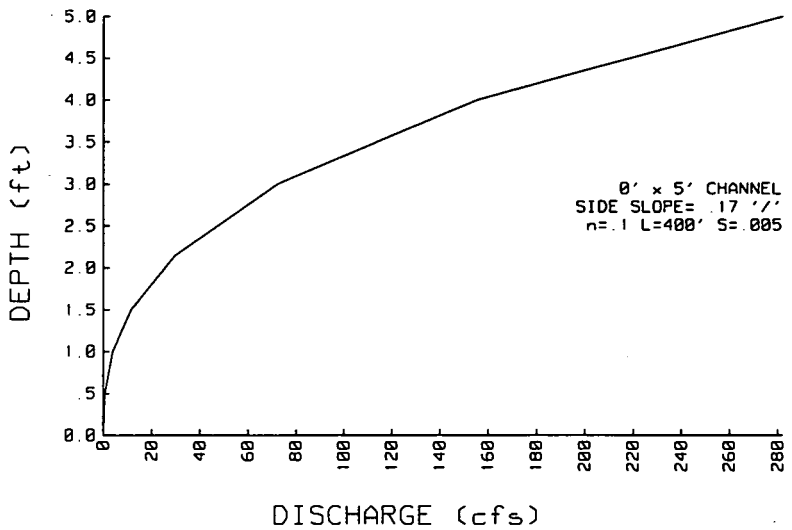
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	1.5	.6
1.0	5.9	3.9
1.5	13.2	11.4
2.2	27.2	29.7
3.0	52.9	72.2
4.0	94.1	155.5
5.0	147.1	281.9

0' x 5' CHANNEL
SIDE SLOPE= .17 '/'
n= .1
LENGTH= 400 FT
SLOPE= .005 FT/FT

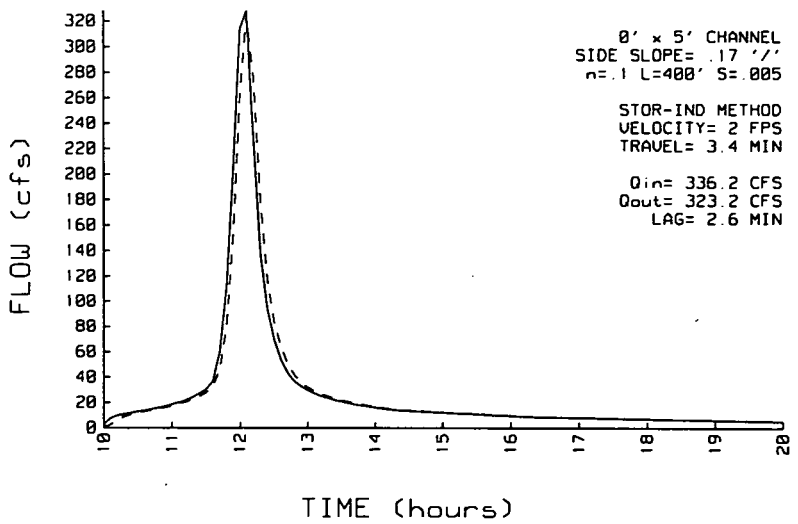
STOR-IND METHOD
MAX. DEPTH= 5.32 FT
PEAK VELOCITY= 2.0 FPS
TRAVEL TIME = 3.4 MIN
Qin = 336.2 CFS @ 12.06 HRS
Qout= 323.2 CFS @ 12.11 HRS
ATTEN= 4 % LAG= 2.6 MIN
IN/OUT= 22.96 / 22.89 AF

OK, WELL BEYOND OSDF

REACH 3 DISCHARGE
POINT B



REACH 3 INFLOW & OUTFLOW
POINT B



[redacted]

517

Written by: RSC Date: 2/Feb/96 Reviewed by: [illegible] Date: 12/Feb/96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

Eastern Area Calculations

Summary of Input Data

A summary of the HydroCAD™ input data is presented in Table 1.

Summary of Calculation Results

A summary of the calculation results is presented in Tables 2 and 3. Drainage area maps, worksheets for calculation weighted runoff curve members, and HydroCAD™ runs for runon/runoff and drainage channel routing are attached.

TABLE 1

EASTERN AREA INPUT PARAMETERS
25-YEAR STORM EVENT

			Sheet Flow			Shallow Concetrated Flow			Open Channel Flow							
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	X-C Area (sf)	Wetted Perimeter (ft)	Length (ft)	Manning's n	Bottom Width (ft)	Channel Slope (%)	Left Slope	Right Slope
E-A	0.55	73	30	0.3333	SEE	-	-	^	272	87	800	SEE	0	0.5	6:1	3:1
E-B	0.37	64	30	0.3333		-	-	=	312	97	540		0	0.5	6:1	3:1
E-C	0.33	74	30	0.3333		-	-	UNPAVED	332	102	405		0	0.5	6:1	3:1
E-D	0.23	74	20	0.3333		-	-		348	106	290		0	0.5	6:1	3:1
E-E	0.44	74	20	0.3333	NOTE A	-	-		348	106	550	NOTE B	0	0.5	6:1	3:1
E-F	1.11	72	20	0.3333		-	-		348	106	820		0	0.5	6:1	3:1
E-1	10.5	98	147	0.070		300	0.167		272	87	705		0	0.5	6:1	3:1
E-2	5.3	98	147	0.070		305	0.167		312	97	540		0	0.5	6:1	3:1
E-3	4.2	98	147	0.070		310	0.167		332	102	405		0	0.5	6:1	3:1
E-4	3.0	98	147	0.070		310	0.167		348	106	290		0	0.5	6:1	3:1
E-5	5.8	98	147	0.070		305	0.167		348	106	550		0	0.5	6:1	3:1
E-6	6.3	98	147	0.070		300	0.167		348	106	820		0	0.5	6:1	3:1

Note A: Light Cover = Short Grass; Moderate & Heavy Cover = Dense Grass

Note B: Light & Moderate Cover: n = 0.030; Heavy Cover: n = 0.10

519

Asc 5 Feb 96
JSS
2/148
239

TABLE 1
(CONTINUED)

EASTERN AREA INPUT PARAMETERS
2,000-YEAR STORM EVENT

			Sheet Flow			Shallow Concetrated Flow			Open Channel Flow							
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	X-C Area (sf)	Wetted Perimeter (ft)	Length (ft)	Manning's n	Bottom Width (ft)	Channel Slope (%)	Left Slope	Right Slope
E-A	7.6	89	300	0.007	SEE	320	0.013	"	272	87	465	SEE	50	0.5	6:1	3:1
E-B	7.4	88	300	0.010		615	0.020	"	312	97	30		60	0.5	6:1	3:1
E-C	7.1	90	300	0.010		655	0.020	UNPAVED	332	102	0		65	0.5	6:1	3:1
E-D	8.7	89	200	0.013		735	0.020		348	106	30		69	0.5	6:1	3:1
E-E	7.9	86	200	0.025	NOTE A	735	0.020		348	106	125	NOTE B	69	0.5	6:1	3:1
E-F	11.9	88	200	0.013		475	0.017		348	106	785		69	0.5	6:1	3:1
E-1	10.5	99	147	0.070		300	0.167		272	87	705		50	0.5	6:1	3:1
E-2	5.3	99	147	0.070		305	0.167		312	97	540		60	0.5	6:1	3:1
E-3	4.2	99	147	0.070		310	0.167		332	102	405		65	0.5	6:1	3:1
E-4	3.0	99	147	0.070		310	0.167		348	106	290		69	0.5	6:1	3:1
E-5	5.8	99	147	0.070		305	0.167		348	106	550		69	0.5	6:1	3:1
E-6	6.3	99	147	0.070		300	0.167		348	106	820		69	0.5	6:1	3:1

Note A: Light Cover = Short Grass; Moderate & Heavy Cover = Dense Grass

Note B: Light & Moderate Cover: n = 0.030; Heavy Cover: n = 0.10

ASC 5 Fm 5C 2 3 9
SSS 12/88
3/148

Table 2. Summary of HydroCAD™ Results - 25-Year Storm Event

	Point of Interest Along Channel	Peak Flow Quantity (CFS)	Peak Flow Depth (Ft)	Peak Flow Velocity (FPS)
	A			
Light Cover		57.5	2.0	3.0
Moderate Cover		51.7	1.5	4.5
Heavy Cover		46.8	1.7	1.0
	B			
Light Cover		83.3	2.3	3.3
Moderate Cover		75.9	1.8	4.9
Heavy Cover		60.8	2.0	1.1
	C			
Light Cover		102.0	2.5	3.5
Moderate Cover		94.4	2.0	5.2
Heavy Cover		69.3	2.2	1.1
	D			
Light Cover		115.1	2.6	3.5
Moderate Cover		107.9	2.1	5.4
Heavy Cover		75.0	2.2	1.1
	E			
Light Cover		158.2	3.0	3.9
Moderate Cover		159.0	2.5	5.9
Heavy Cover		85.6	2.4	1.2

Written by: RSC Date: 9/Feb/96 Reviewed by: [illegible] Date: 12/Feb/96

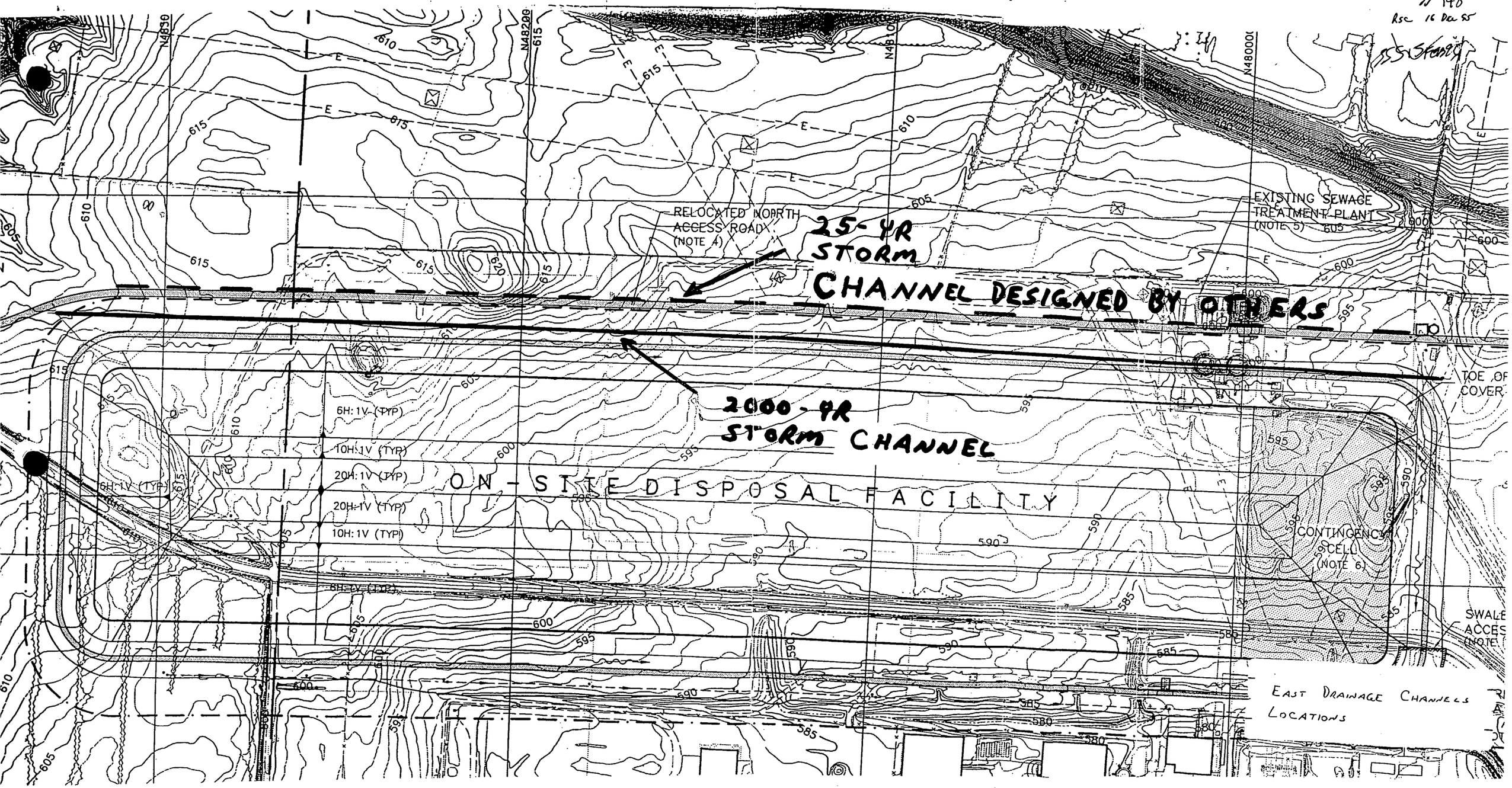
Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

Table 3. Summary of HydroCAD™ Results - 2,000-Year Storm Event

	Point of Interest Along Channel	Peak Flow Quantity (CFS)	Peak Flow Depth (Ft)	Peak Flow Velocity (FPS)
	A			
Light Cover		179.5	0.9	3.1
Moderate Cover		155.5	0.8	2.9
Heavy Cover		142.9	1.5	1.3
	B			
Light Cover		278.5	1.1	3.6
Moderate Cover		233.3	1.0	3.4
Heavy Cover		215.0	1.9	1.5
	C			
Light Cover		361.9	1.2	3.8
Moderate Cover		303.4	1.1	3.6
Heavy Cover		269.7	2.1	1.6
	D			
Light Cover		463.3	1.4	4.2
Moderate Cover		390.1	1.3	4.0
Heavy Cover		355.4	2.5	1.8
	E			
Light Cover		756.3	1.9	5.1
Moderate Cover		650.4	1.8	4.8
Heavy Cover		555.4	3.2	2.1

DRAINAGE AREA MAPS

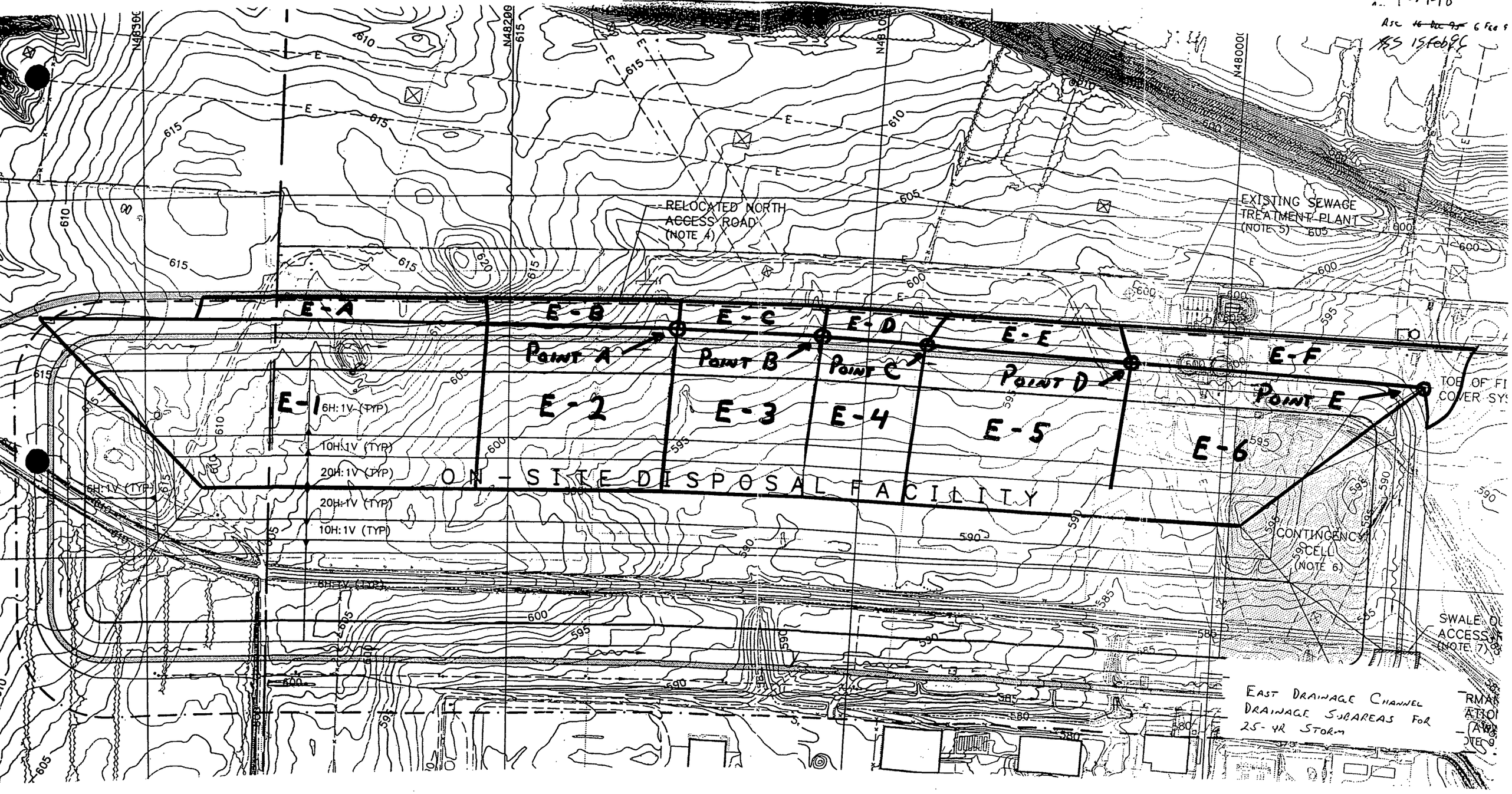
739
7/148
Rec 16 Dec 85



[redacted]
524

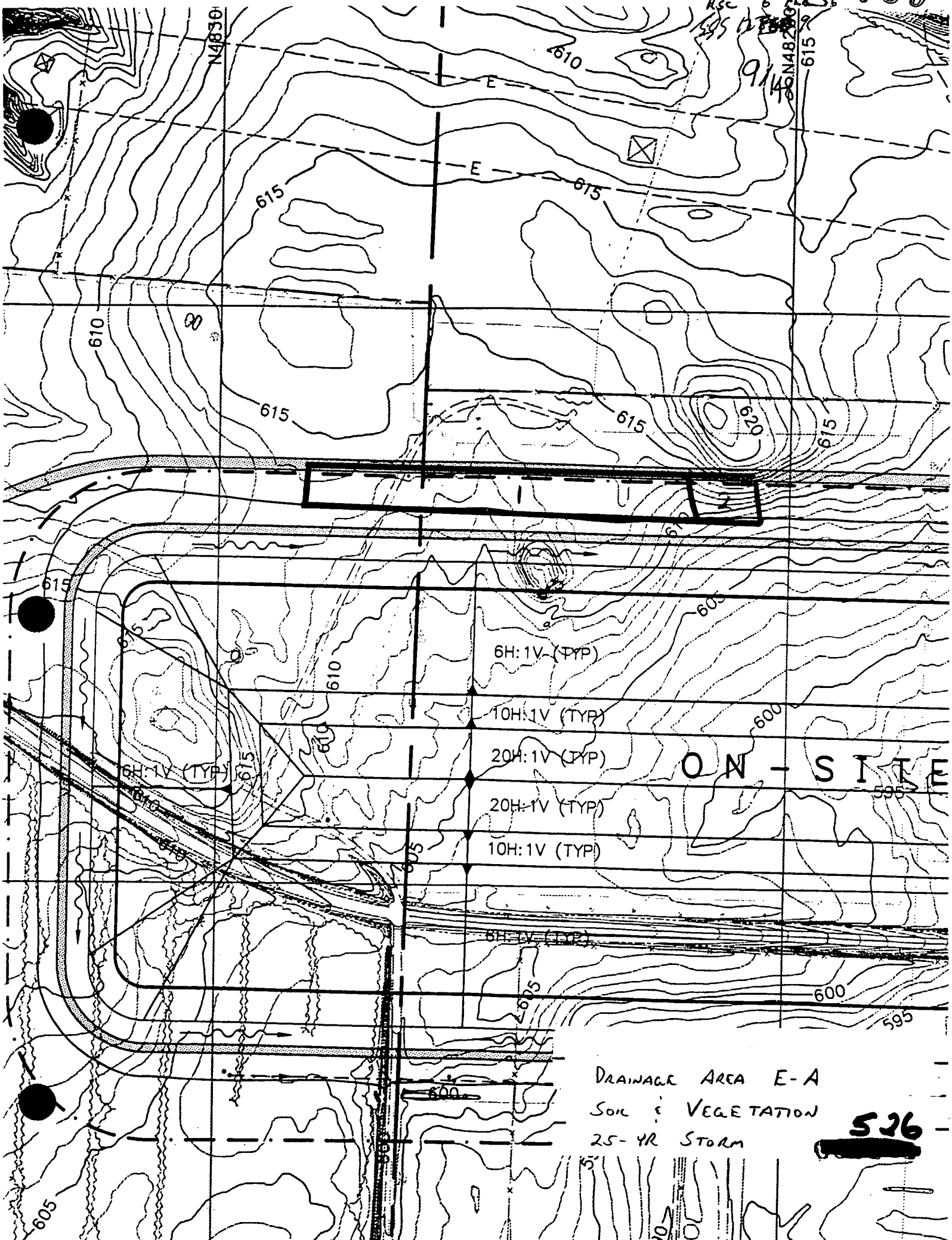
739 | 8/148

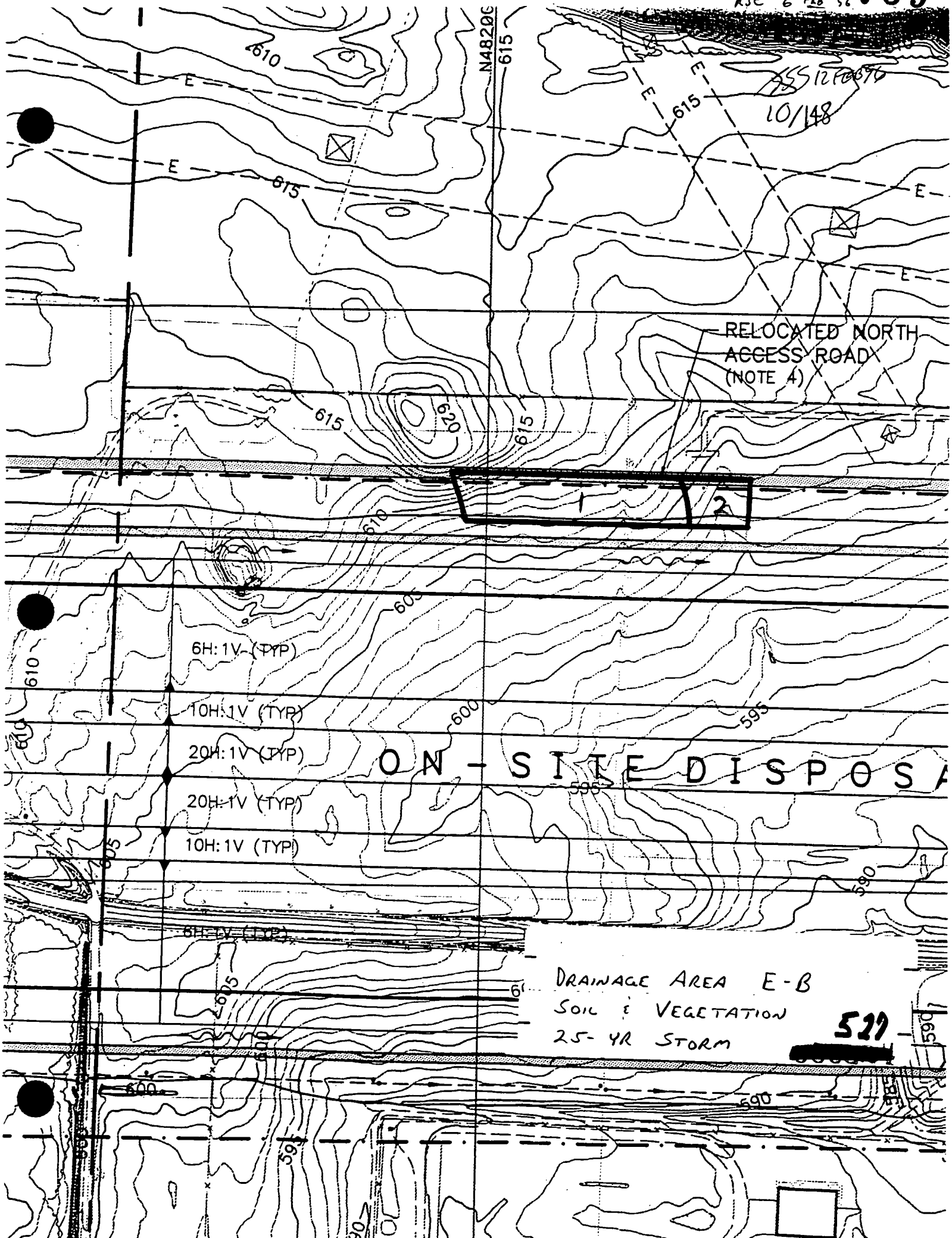
ASC ~~16 Dec 95~~ 6 Feb 9
RSS 15 Feb 96

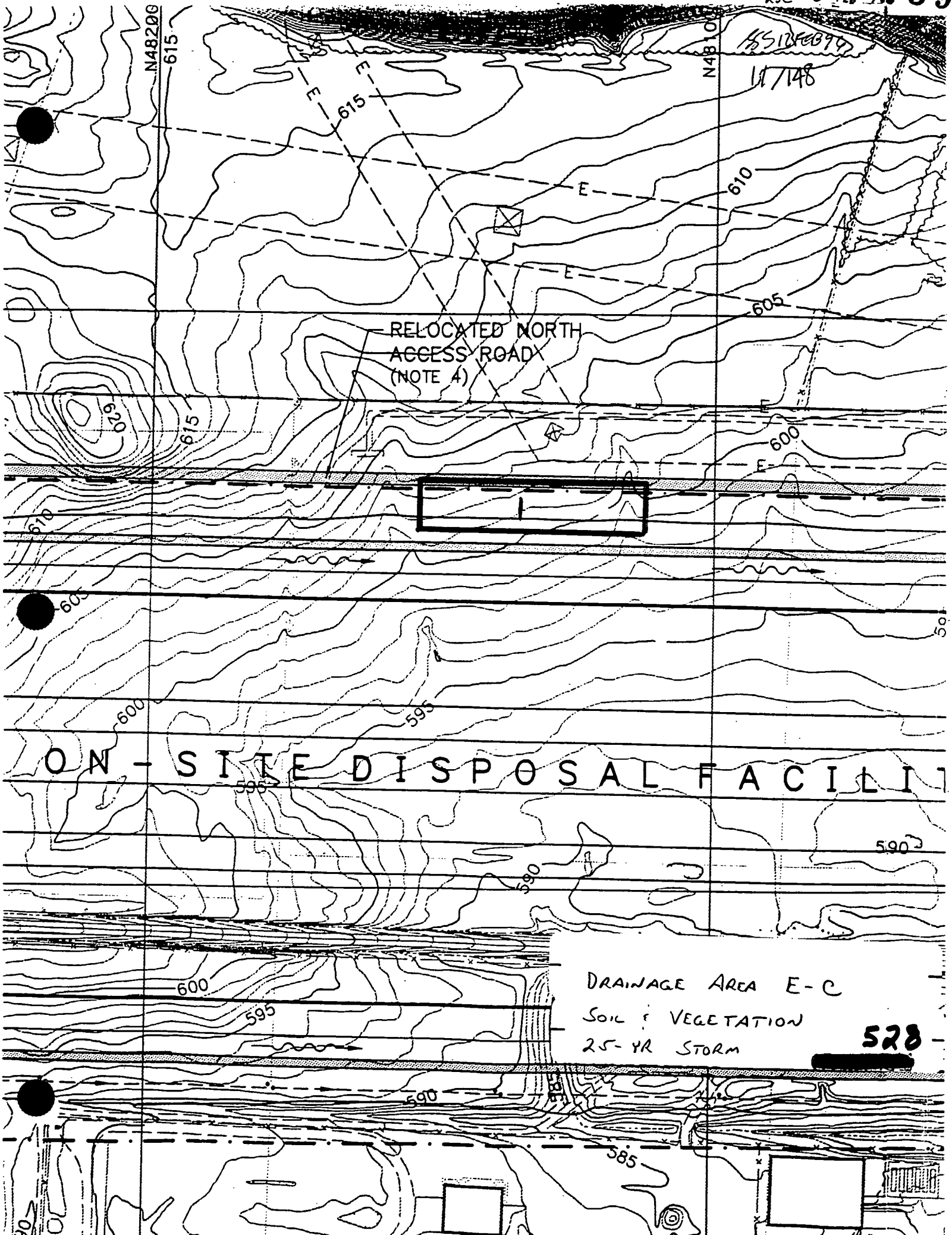


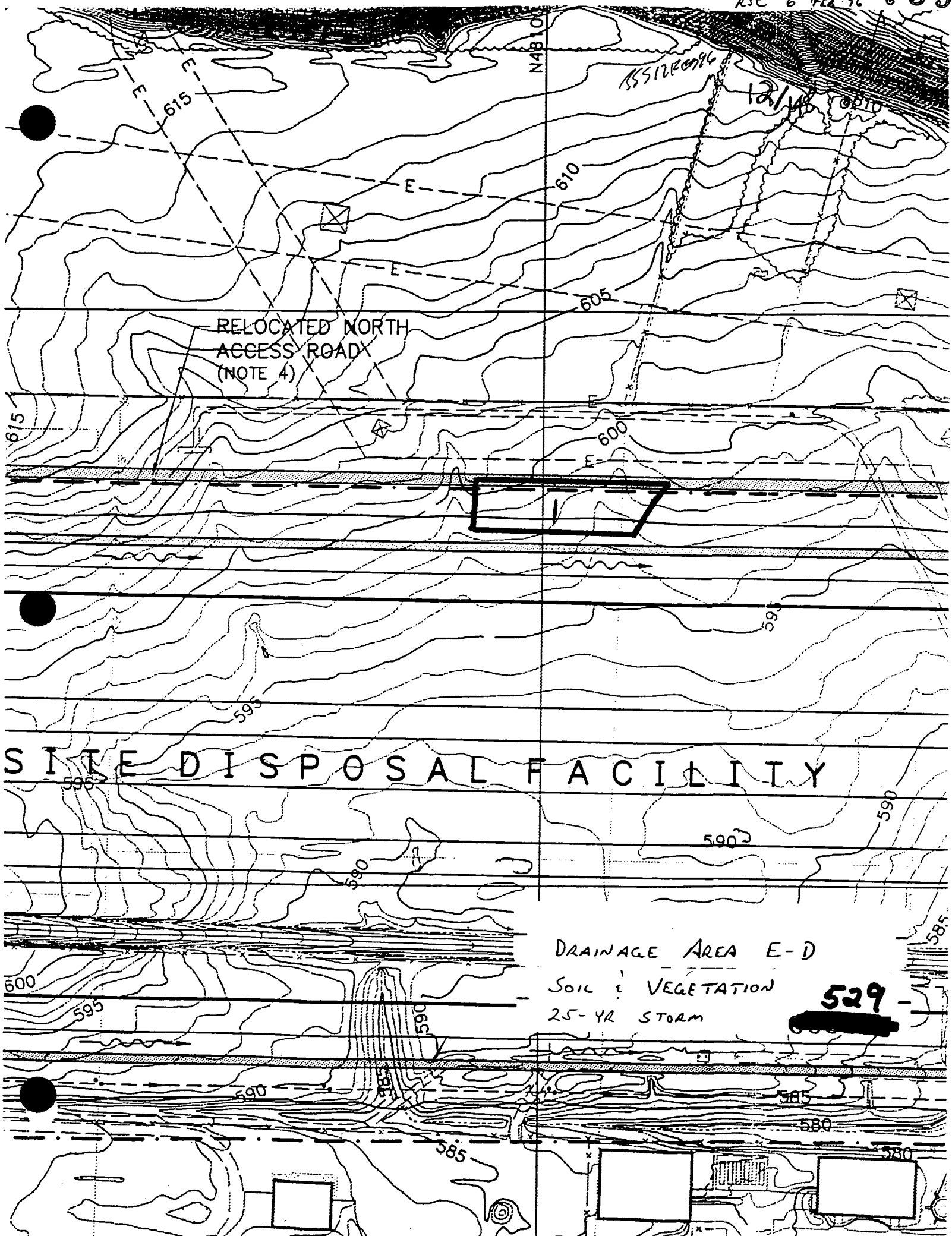
[redacted]

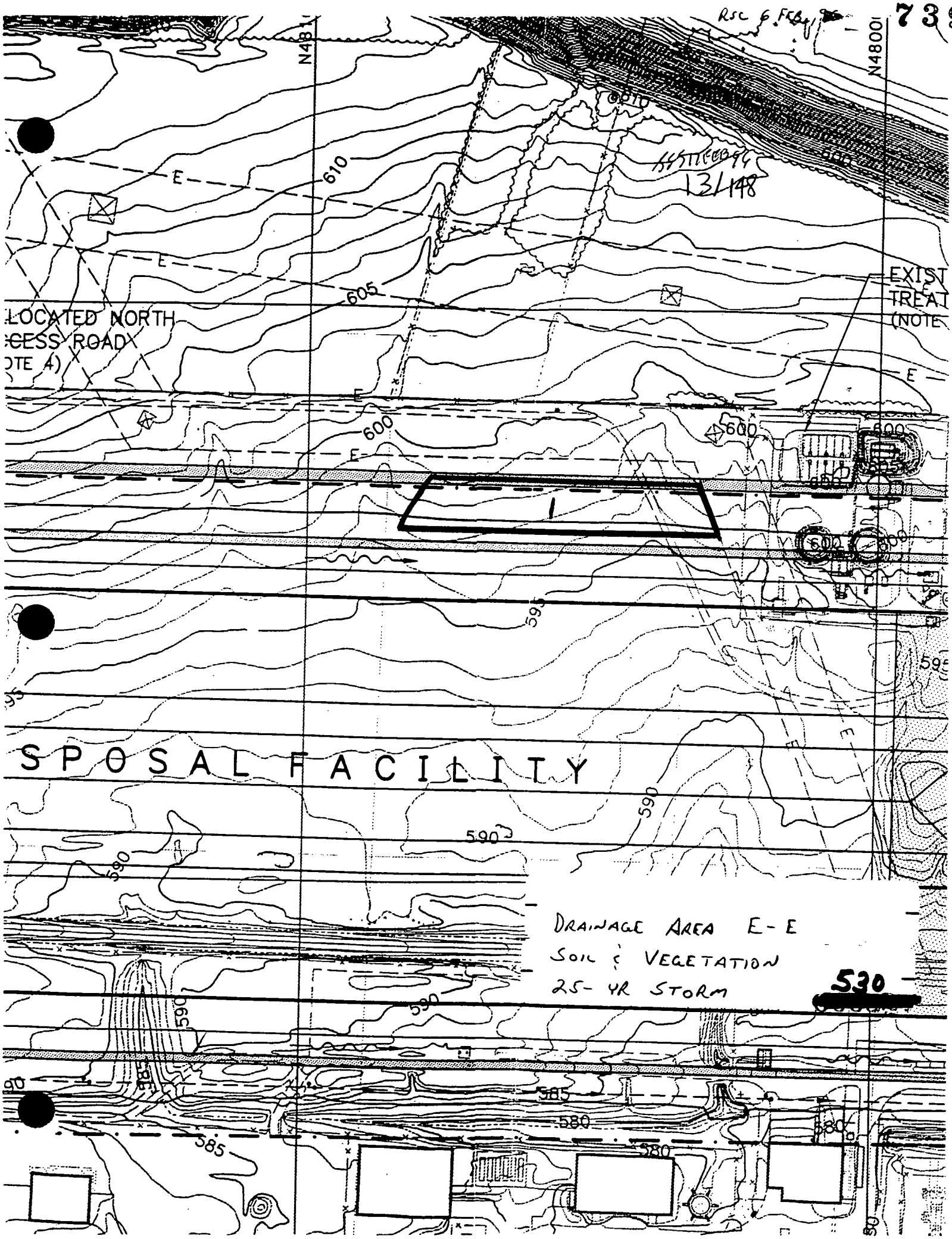
525

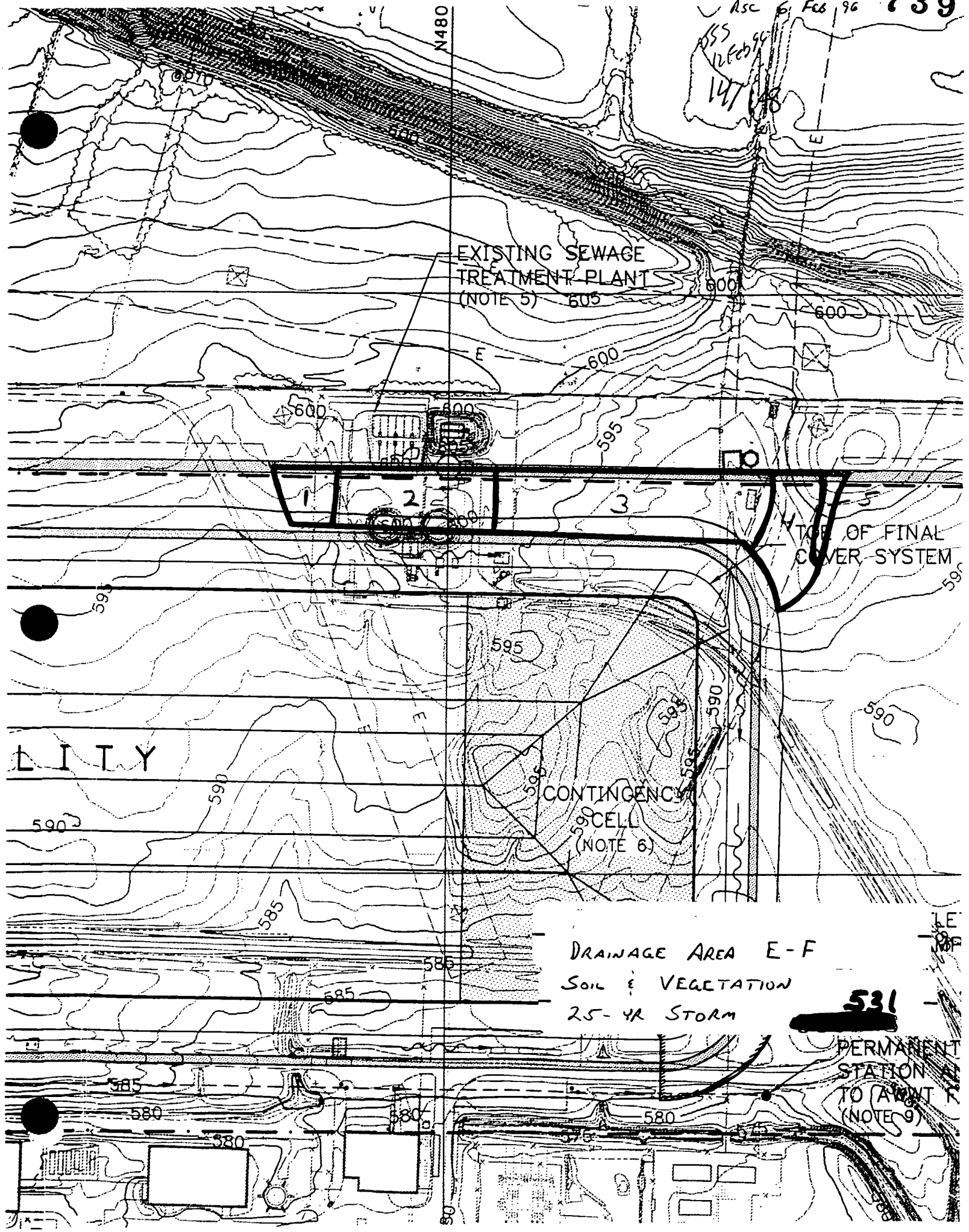

N4830
N4820
610
615
620
605
600
595
E
6H:1V (TYP)
10H:1V (TYP)
20H:1V (TYP)
ON-SITE
DRAINAGE AREA E-A
SOIL & VEGETATION
25-YR STORM
526

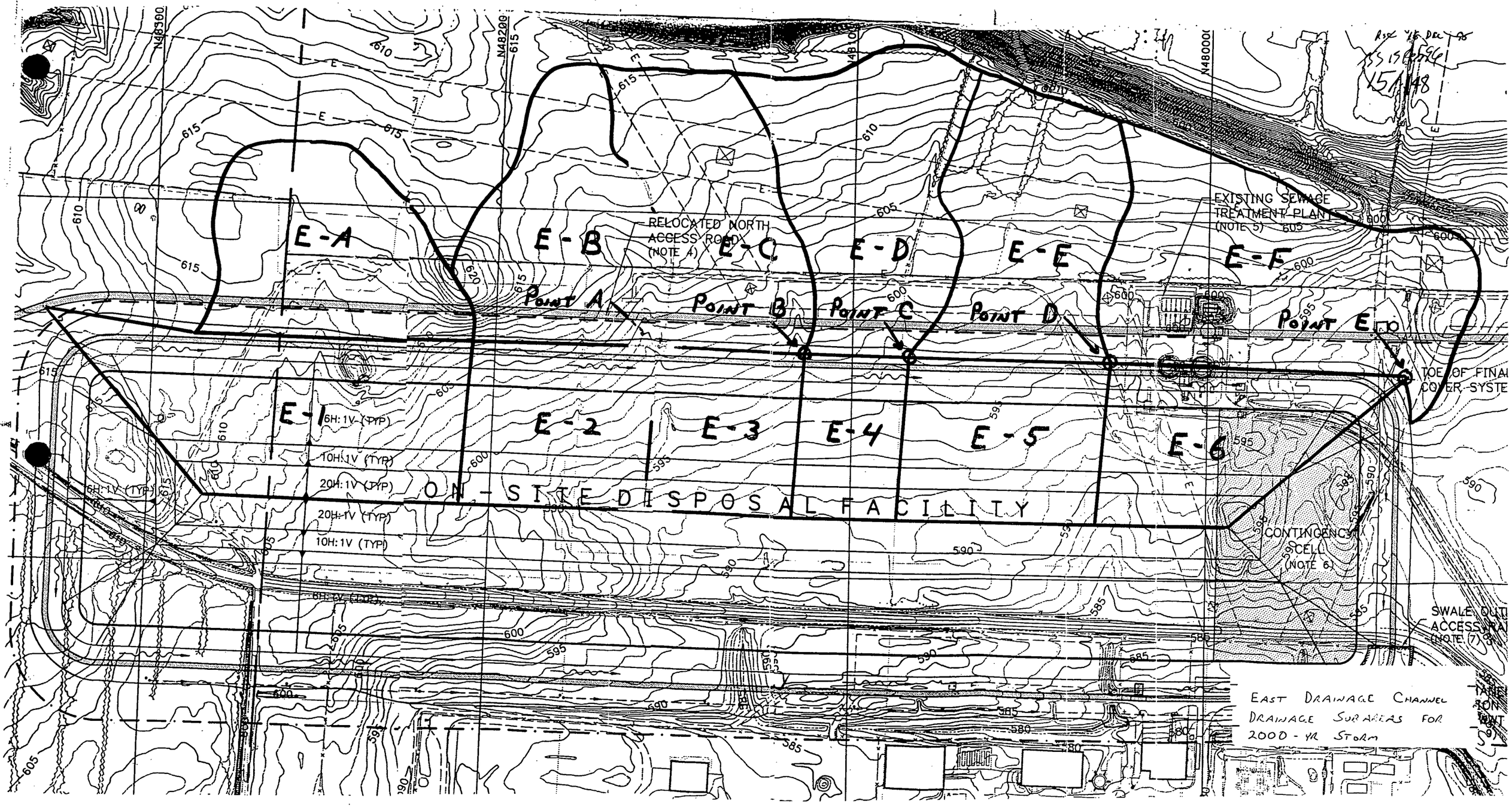

610
615
N4820
E
620
RELOCATED NORTH
ACCESS ROAD
(NOTE 4)
1
2
605
600
595
590
6H:1V (TYP)
10H:1V (TYP)
20H:1V (TYP)
20H:1V (TYP)
10H:1V (TYP)
6H:1V (TYP)
ON-SITE DISPOSA
DRAINAGE AREA E-B
SOIL & VEGETATION
25-YR STORM
527

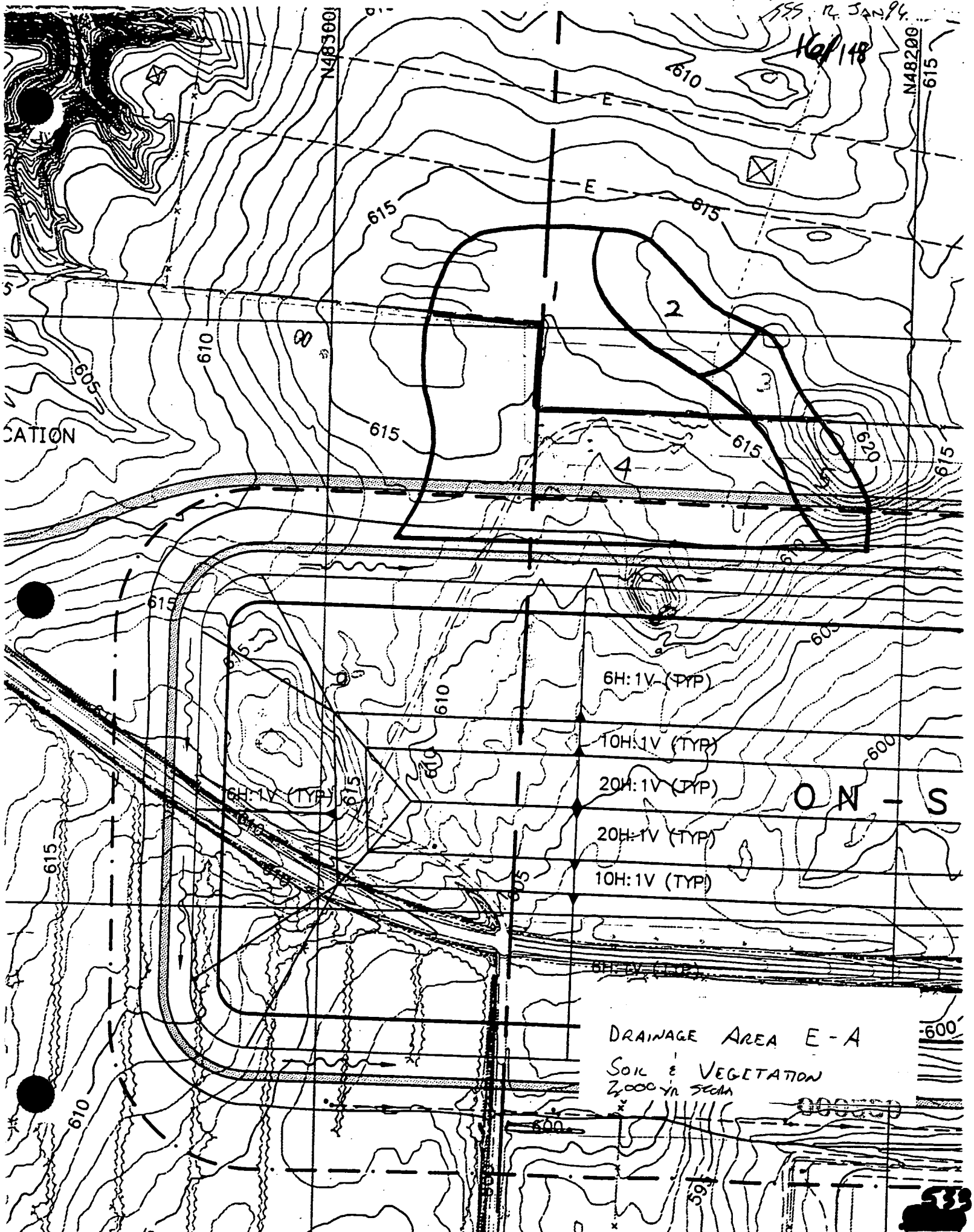

N48200
615
N48100
615
610
605
600
620
615
610
605
600
595
595
590
590
600
595
590
585
RELOCATED NORTH
ACCESS ROAD
(NOTE 4)
ON-SITE DISPOSAL FACILI
DRAINAGE AREA E-C
SOIL & VEGETATION
25-YR STORM
528


RELOCATED NORTH
ACCESS ROAD
(NOTE 4)
N4810
615
610
605
600
595
590
585
580
SITE DISPOSAL FACILITY
DRAINAGE AREA E-D
SOIL & VEGETATION
25-YR STORM
529


739
N48
N48001
610
605
600
595
590
585
580
E
LOCATED NORTH
CESS ROAD
OTE 4)
EXIST
TREAT
(NOTE
SPOSAL FACILITY
DRAINAGE AREA E-E
SOIL & VEGETATION
25-YR STORM
530

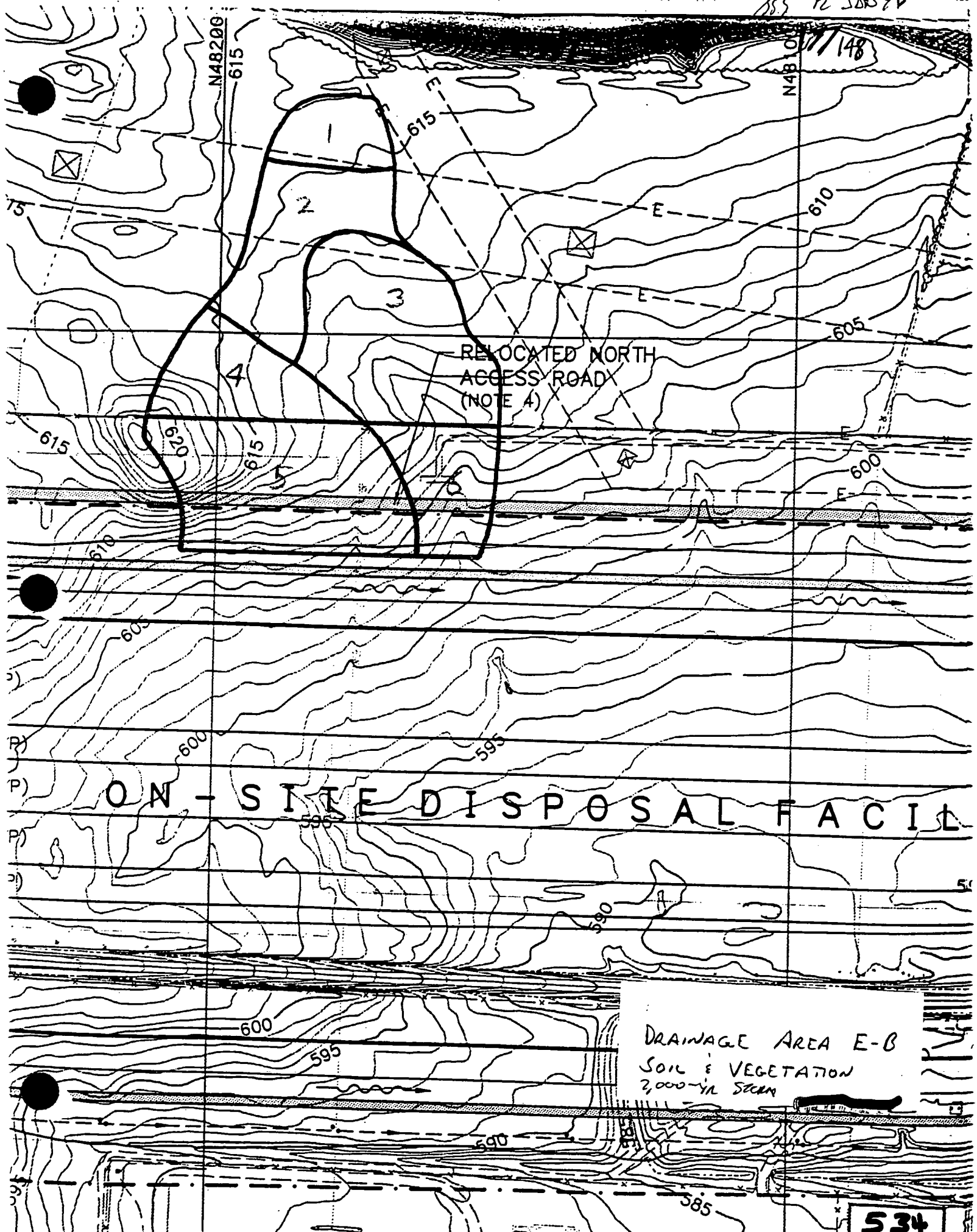

N480
EXISTING SEWAGE TREATMENT PLANT (NOTE 5)
605
600
595
590
585
580
575
1
2
3
TOP OF FINAL COVER SYSTEM
CONTINGENCY CELL (NOTE 6)
DRAINAGE AREA E-F
SOIL & VEGETATION
25-YR STORM
531
PERMANENT
STATION
TO
(NOTE 9)


E-A
E-B
E-C
E-D
E-E
E-F
E-1
E-2
E-3
E-4
E-5
E-6
RELOCATED NORTH ACCESS ROAD (NOTE 4)
EXISTING SEWAGE TREATMENT PLANT (NOTE 5)
POINT A
POINT B
POINT C
POINT D
POINT E
TOE OF FINAL COVER SYSTEM
6H:1V (TYP)
10H:1V (TYP)
20H:1V (TYP)
ON-SITE DISPOSAL FACILITY
CONTINGENCY CELL (NOTE 6)
SWALE OUTLET ACCESS RAMP (NOTE 7)
N48300
N48200
N48000
EAST DRAINAGE CHANNEL
DRAINAGE SUBAREAS FOR
2000-YR STORM

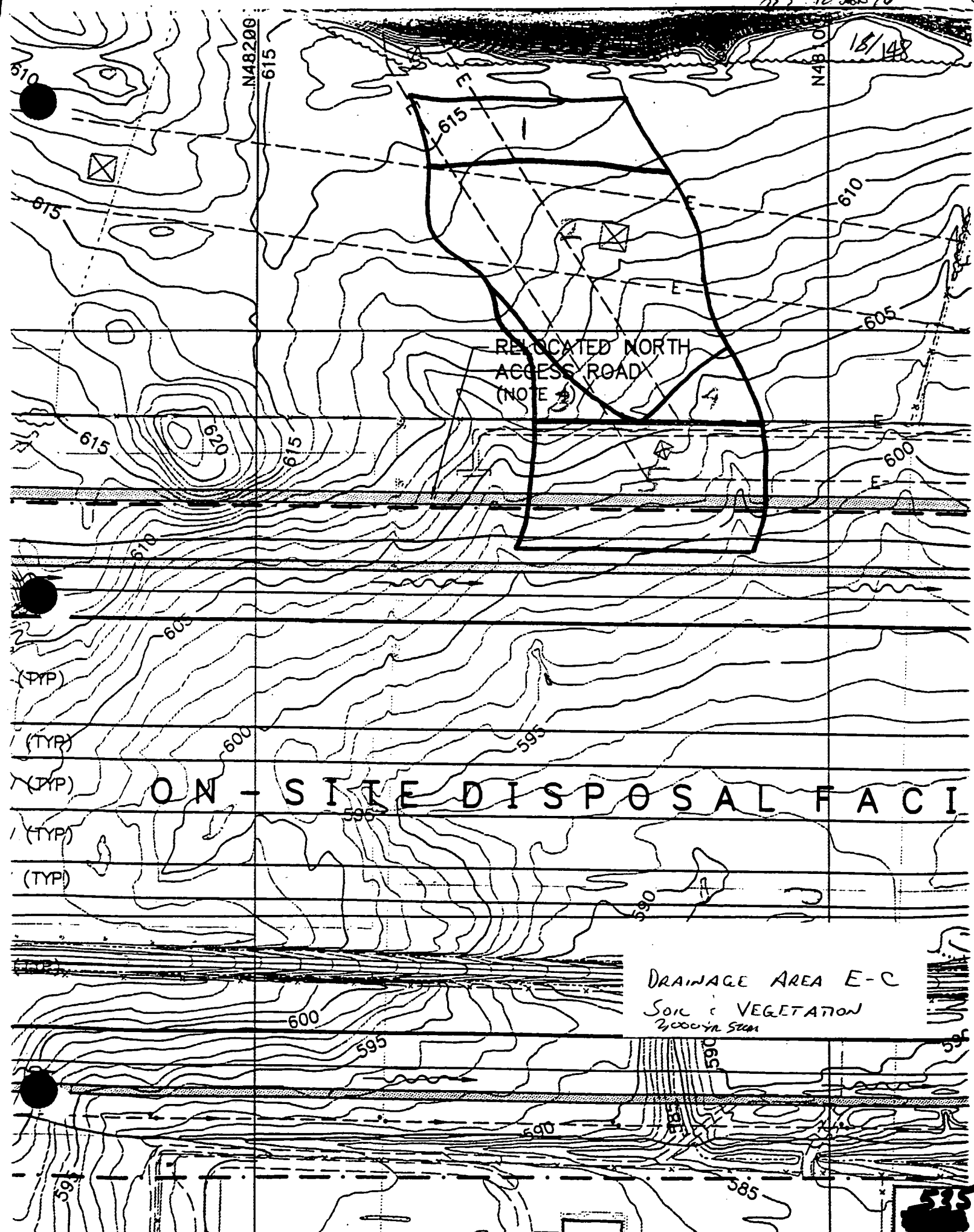

N48300
N48200
610
615
605
620
600
E
CATION
1
2
3
4
6H:1V (TYP)
10H:1V (TYP)
20H:1V (TYP)
20H:1V (TYP)
10H:1V (TYP)
6H:1V (TYP)
6H:1V (TYP)
ON - S
DRAINAGE AREA E-A
SOIL & VEGETATION
2,000 yr SCALE

Rec 16 Dec 90
SSS 12 Jan 94

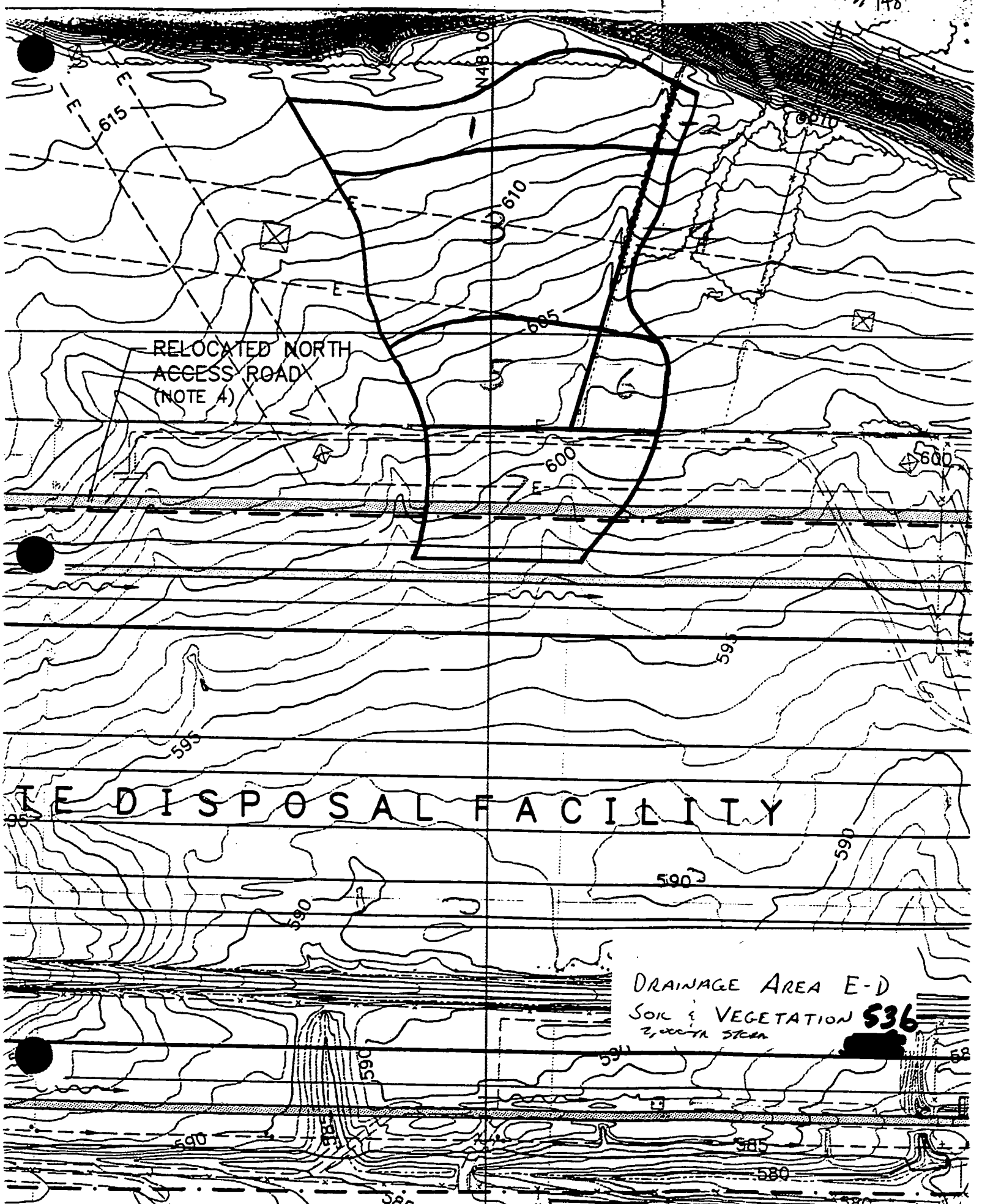
739



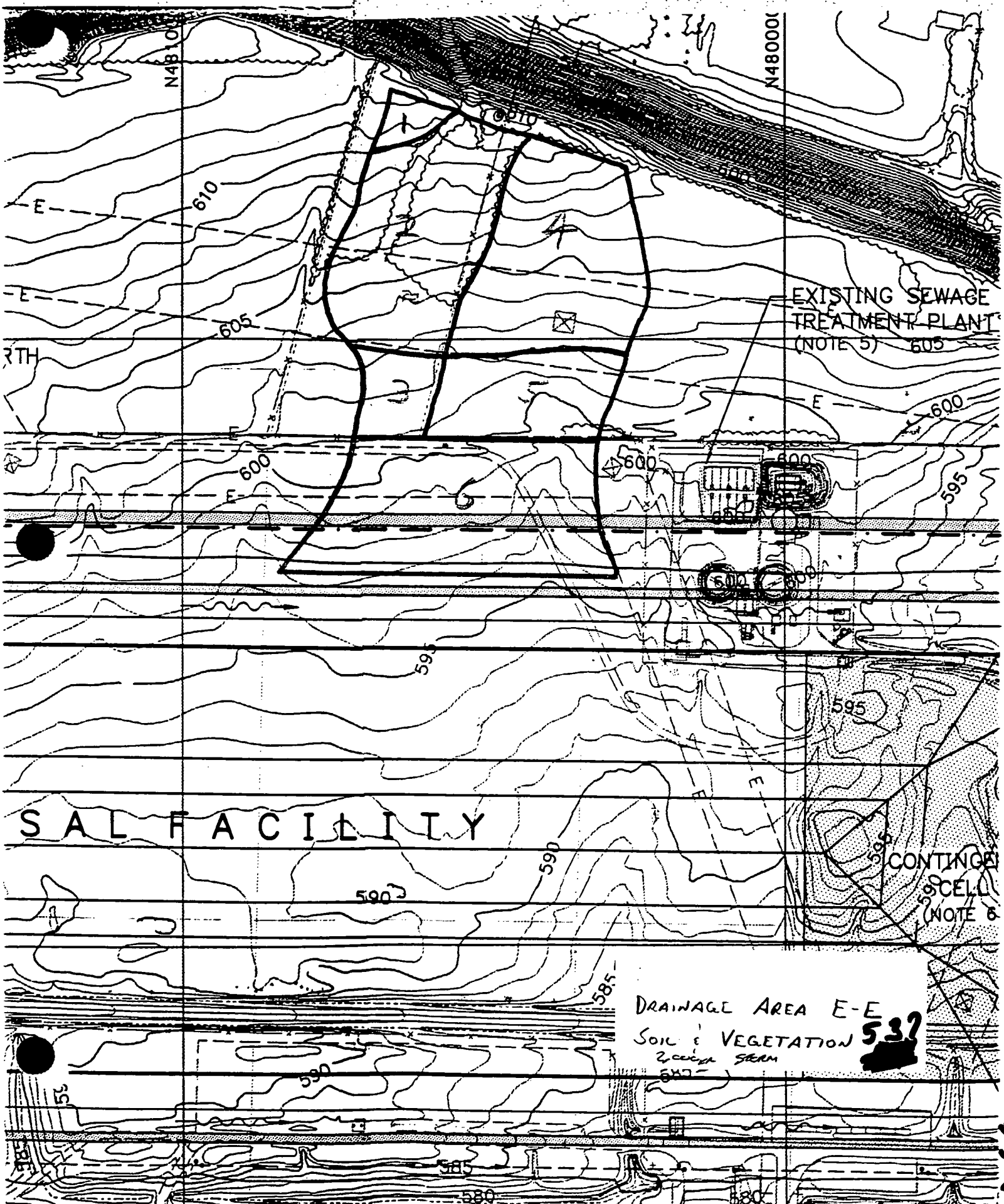
Asc 16 Dec 95 739
ASS 12 Jan 96



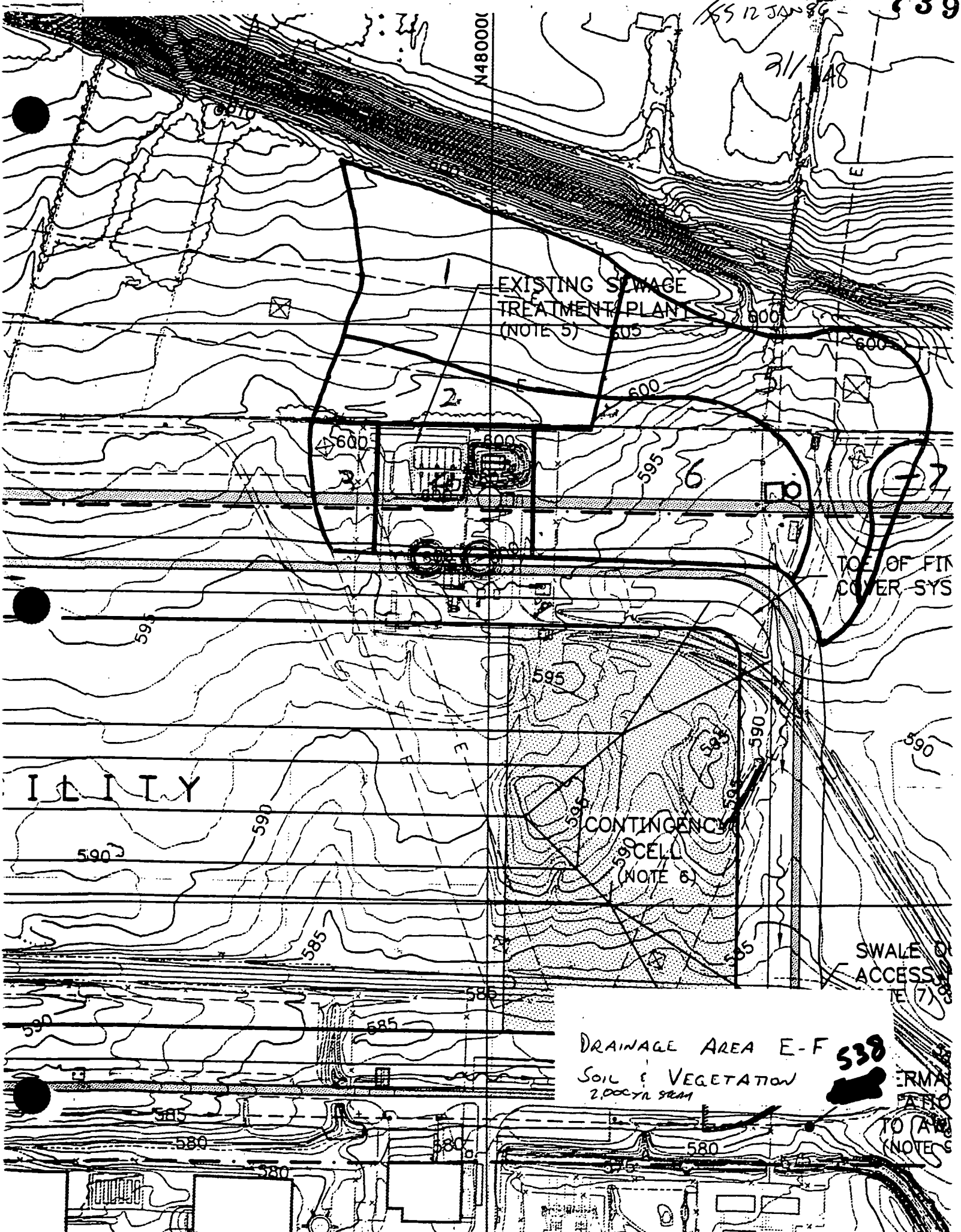
RSC 16 Dec 95 739
155 12 Jan 96
19/148



Rsc 16 Dec 95
155 12 Jan 96
739
20/148



Rsc 16 Dec 85
KS 12 JAN 86



WORKSHEETS FOR

WEIGHTED RUNOFF CURVE NUMBERS

Worksheet ~~7~~ 1: Runoff curve number and runoff

Project FERMCO - OSDF By RSC Date 2/6/96

Location DRAINAGE AREA E-A (25-YR) Checked RSS Date 12 Feb 96

Circle one: Present Developed

1. Runoff curve number (CN)

SUBAREA	Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
1	FINCASTLE C	OPEN SPACE - GOOD COVER	74			0.49	36.~~26~~ 3 RSS
2	RUSSELL B	" "	61			0.06	3.~~66~~ 7 RSS
		Totals =				0.~~55~~ 55	~~39.92~~ 40 RSS

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{\cancel{39.92}\ 40.64}{0.55} = \cancel{72.58}\ 72.7$; Use CN = 73 ✓

2. Runoff

		Storm #1	Storm #2	~~Storm #3~~
Frequency	yr			
Rainfall, P (24-hour)	in			
Runoff, Q (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)	in			

Worksheet ~~8~~ 2: Runoff curve number and runoff

Project FERMCO - OSDF By RJC Date 2/6/96

Location DRAINAGE AREA E-B (25-1A) Checked SSS Date 12 Feb 96

Circle one: Present Developed

1. Runoff curve number (CN)

SUBAREA	Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
1	RUSSELL B	OPEN SPACE - GOOD COVER	61			.30	18.3
2	FINCASTLE C	" "	74			.07	5.~~18~~ 2 SSS
					Totals =	0.37	23.~~48~~ 5 SSS

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{23.\cancel{48}\ 5}{.37} = 63.5$ SSS; Use CN = 64

~~2. Runoff~~

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

Worksheet 3: Runoff curve number and runoff

Project FERMCO - OSDF By RSC Date 2/6/96

Location DRAINAGE AREA E-C (25-yr) Checked RSS Date 12Feb96

Circle one: Present Developed

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
FINCASTLE C	OPEN SPACE - GOOD COVER	74			.33	24.4 ~~22.2~~ RSS
					Totals =	.33 ~~22.2~~ 24.4 RSS

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{\cancel{22.2}\ 24.4\ RSS}{.33} = 74$; Use CN = 74

~~2. Runoff~~

		Storm #1	Storm #2	Storm #3
Frequency	yr			
Rainfall, P (24-hour)	in			
Runoff, Q (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)	in			

Worksheet ~~1~~ 4: Runoff curve number and runoff

Project FERMCO - OSDF By RSC Date 2/6/96

Location DRAINAGE AREA E-D (25-YR) Checked SSS Date 12Feb96

Circle one: Present Developed

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
FINCASTLE C	OPEN SPACE - GOOD COVER	74			.23	17.02 SSS
	Totals =				.23	17.02 SSS

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{17.02}{.23}$ SSS = 74; Use CN = 74

~~2. Runoff~~

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

[redacted]
543

Worksheet 4: Runoff curve number and runoff

Project FERMCO - OSDF By RSC Date 2/6/96

Location DRAINAGE AREA E-E (25-YR) Checked BSS Date 12 Feb 96

Circle one: Present (Developed)

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
FINCASTLE C	OPEN SPACE - GOOD COVER	74			.44	32.56
	Totals =				.44	32.56

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{32.56}{.44} = 74$; Use CN = 74

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

Worksheet ~~12~~ 6 Runoff curve number and runoff

Project FERMCO - OSDF By RSC Date 2/6/96

Location DRAINAGE AREA E-F (25-YR) Checked SSS Date 12Feb96

Circle one: Present Developed

1. Runoff curve number (CN)

SUBAREA	Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area	
1	FINCASTLE C	OPEN SPACE - GOOD COVER	74			0.11	8.14	SSS
2	FINCASTLE C	" "	74			0.32	23.68	SSS
3	FINCASTLE C	" "	74			0.48	35.52	SSS
4	XENIA B	" "	61			0.15	9.15	SSS
5	FINCASTLE C	" "	74			0.05	3.7	
						Totals = 1.11 SSS	80.19 SSS	

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{80.19}{1.11} = 72.2$ SSS; Use CN = 72

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

Worksheet 7: Runoff curve number and runoff

Project FERMCO - OSDF ___ By RSC Date 16 DEC 95

Location DRAINAGE AREA E-A (2000-YR) ___ Checked SS Date 12 JAN 96

Circle one: Present (Developed)

1. Runoff curve number (CN)

SUBAREA	Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
1	FINCASTLE C	CROP LANDS - STRAIGHT ROWS GOOD CONDITION	85			1.8	153.0
2	XENIA B	" " "	78			0.8	62.4
3	RUSSELL B	" " "	78			0.5	39.0
4	FINCASTLE C	OPEN SPACE - GOOD COVER	74			3.9	288.6
	RUSSELL B	" "	61			0.6	36.6
					Totals =	7.6	579.6

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{579.6}{7.6} = 76.3$; Use CN = 76

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

Worksheet 2: Runoff curve number and runoff

301/148

Project FERMCO - OSDF By RSC Date 16 DEC 95

Location DRAINAGE AREA E-B (2000-YR) Checked RSS Date 12 JAN 96

Circle one: Present (Developed)

1. Runoff curve number (CN)

SUBAREA	Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
1	XENIA B	CROP LAND - STRAIGHT ROWS GOOD CONDITION	78			0.6	46.8
2	XENIA B	" " "	78			1.3	101.4
3	FINCASTLE C	" " "	85			1.8	153.0
4	RUSSELL B	" " "	78			0.9	70.2
5	RUSSELL B	OPEN SPACE - GOOD COVER	61			2.0	122.0
6	FINCASTLE C	" "	74			0.8	59.2
					Totals =	7.4	552.6

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{552.6}{7.4} = 74.7$; Use CN = 75

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

[redacted]

Worksheet 3: Runoff curve number and runoff

31/148

Project FERMCO - OSDF By RSC Date 16 DEC 95

Location DRAINAGE AREA E-C (2000-R) Checked SS Date 12 JAN 96

Circle one: Present Developed

1. Runoff curve number (CN)

SUBAREA	Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
1	XENIA B	CROP LAND - STRAIGHT ROWS GOOD CONDITION	78			1.0	78.0
2	XENIA B	" " "	78			3.3	257.4
3	FINCASTLE C	" " "	85			0.4	34.0
4	FINCASTLE C	" " "	85			0.4	34.0
	FINCASTLE C	OPEN SPACE - GOOD COVER	74			2.0	148.0
						Totals = 7.1	551.4

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{551.4}{7.1} = 77.7$; Use CN = 78

~~2. Runoff~~

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

Worksheet 4: Runoff curve number and runoff

32/148

Project FERMCO - OSDF By RSC Date 16 DEC 95

Location DRAINAGE AREA E-D (2000-YR) Checked RSS Date 12 JAN 96

Circle one: Present Developed

1. Runoff curve number (CN)

Subarea	Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
1	XENIA B	CROP LAND - STRAIGHT ROWS GOOD CONDITION	78			1.7	132.6
2	XENIA B	WOODED - FAIR CONDITION	55			0.2	11.0
3	XENIA B	CROP LAND - STRAIGHT ROWS GOOD CONDITION	78			3.0	234.0
4	XENIA B	WOODED - FAIR CONDITION	55			0.2	11.0
	FINCASTLE C	CROP LAND - STRAIGHT ROWS GOOD CONDITION	85			1.2	102.0
6	FINCASTLE C	WOODED - FAIR CONDITION	70			0.5	35.0
7	FINCASTLE C	OPEN SPACE - GOOD COVER	74			1.9	140.6
					Totals =	8.7	666.2

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{666.2}{8.7} = 76.6$; Use CN = 77

~~2. Runoff~~

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

Worksheet 5: Runoff curve number and runoff

Project FERMCO - OSDF By RSC Date 16 DEC 95

Location DRAINAGE AREA E-E (2000-AR) Checked [illegible] Date 12 JAN 94

Circle one: Present Developed

1. Runoff curve number (CN)

SUBAREA	Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
1	XENIA B	WOODED - FAIR CONDITION	55			0.2	11.0
2	XENIA B	" "	55			2.0	110.0
3	FINCASTLE C	" "	70			0.4	28.0
4	XENIA B	CROP LAND - STRAIGHT ROWS GOOD CONDITION	78			2.0	156.0
5	FINCASTLE C	" " "	85			1.0	85.0
6	FINCASTLE C	OPEN SPACE - GOOD COVER	74			2.3	170.2
					Totals =	7.9	560.2

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{560.2}{7.9} = 70.9$; Use CN = 71

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

Worksheet ~~6~~ 4: Runoff curve number and runoff

Project FERMCO - OSDF By RSC Date 16 DEC 95

Location DRAINAGE AREA E-F (2000-YR) Checked [illegible] Date 12JAN96

Circle one: Present (Developed)

1. Runoff curve number (CN)

SUBAREA	Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
1	XENIA B	CROP LAND - STRAIGHT ROWS GOOD CONDITION	78			2.9	226.2
2	FINCASTLE C	" " "	85			1.0	85.0
3	FINCASTLE C	OPEN SPACE - GOOD COVER	74			0.5	37.0
4	FINCASTLE C	INDUSTRIAL	91			1.3	118.3
5	XENIA B	OPEN SPACE - GOOD COVER	61			3.1	189.1
6	FINCASTLE C	" "	74			2.8	207.2
7	FINCASTLE C	" "	74			0.3	22.2
					Totals =	11.9	885.0

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{885.0}{11.9} = 74.4$; Use CN = 74

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)			

Table 1 Curve numbers (CN) and constants for the case $I_a = 0.2\ S$

1	2	3	4	5	1	2	3	4	5
CN for condition II	CN for conditions I	CN for conditions III	S values*	Curve* starts where P =	CN for condition II	CN for conditions I	CN for conditions III	S values*	Curve* starts where P =
			(inches)	(inches)				(inches)	(inches)
100	100	100	0	0	60	40	78	6.67	1.33
99	97	100	.101	.02	59	39	77	6.95	1.39
98	94	99	.204	.04	58	38	76	7.24	1.45
97	91	99	.309	.06	57	37	75	7.54	1.51
96	89	99	.417	.08	56	36	75	7.86	1.57
95	87	98	.526	.11	55	35	74	8.18	1.64
94	85	98	.638	.13	54	34	73	8.52	1.70
93	83	98	.753	.15	53	33	72	8.87	1.77
92	81	97	.870	.17	52	32	71	9.23	1.85
91	80	97	.989	.20	51	31	70	9.61	1.92
90	78	96	1.11	.22	50	31	70	10.0	2.00
89	76	96	1.24	.25	49	30	69	10.4	2.08
88	75	95	1.36	.27	48	29	68	10.8	2.16
87	73	95	1.49	.30	47	28	67	11.3	2.26
86	72	94	1.63	.33	46	27	66	11.7	2.34
85	70	94	1.76	.35	45	26	65	12.2	2.44
84	68	93	1.90	.38	44	25	64	12.7	2.54
83	67	93	2.05	.41	43	25	63	13.2	2.64
82	66	92	2.20	.44	42	24	62	13.8	2.76
81	64	92	2.34	.47	41	23	61	14.4	2.88
80	63	91	2.50	.50	40	22	60	15.0	3.00
79	62	91	2.66	.53	39	21	59	15.6	3.12
* 78	60	90	2.82	.56	38	21	58	16.3	3.26
* 77	59	89	2.99	.60	37	20	57	17.0	3.40
* 76	58	89	3.16	.63	36	19	56	17.8	3.56
* 75	57	89	3.33	.67	35	18	55	18.6	3.72
* 74	55	89	3.51	.70	34	18	54	19.4	3.88
73	54	87	3.70	.74	33	17	53	20.3	4.06
72	53	86	3.89	.78	32	16	52	21.2	4.24
* 71	52	86	4.08	.82	31	16	51	22.2	4.44
70	51	85	4.28	.86	30	15	50	23.3	4.66
69	50	84	4.49	.90					
68	48	84	4.70	.94	25	12	43	30.0	6.00
67	47	83	4.92	.98	20	9	37	40.0	8.00
66	46	82	5.15	1.03	15	6	30	56.7	11.34
65	45	82	5.38	1.08	10	4	22	90.0	18.00
64	44	81	5.62	1.12	5	2	13	190.0	38.00
63	43	80	5.87	1.17	0	0	0	infinity	infinity
62	42	[illegible]	6.12	1.22					
61	41	[illegible]	6.39	1.28					

*For CN in [illegible]

From: USDA-SCS, 1985

HYDROCAD™ RUNS

RUNON/RUNOFF

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 37/148

12 Feb 96

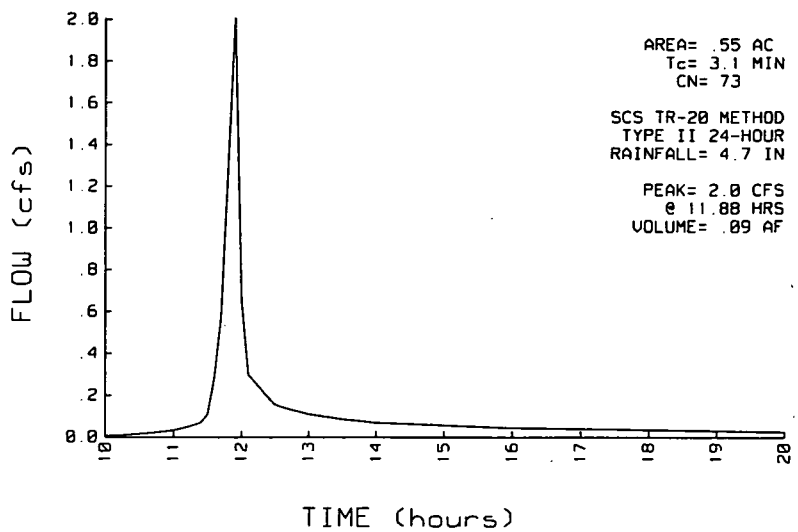
SUBCATCHMENT 1 **E-A**

ACRES	CN
.55	73

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 2.0 CFS @ 11.88 HRS
VOLUME= .09 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	1.3
Grass: Short n=.15 L=30' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	1.8
a=272 sq-ft Pw=87' r=3.126'		
s=.005 '/' n=.03 V=7.49 fps L=800' Capacity=2037 cfs		
	Total Length= 830 ft Total Tc=	3.1

SUBCATCHMENT 1 RUNOFF
E-A



Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 38/148

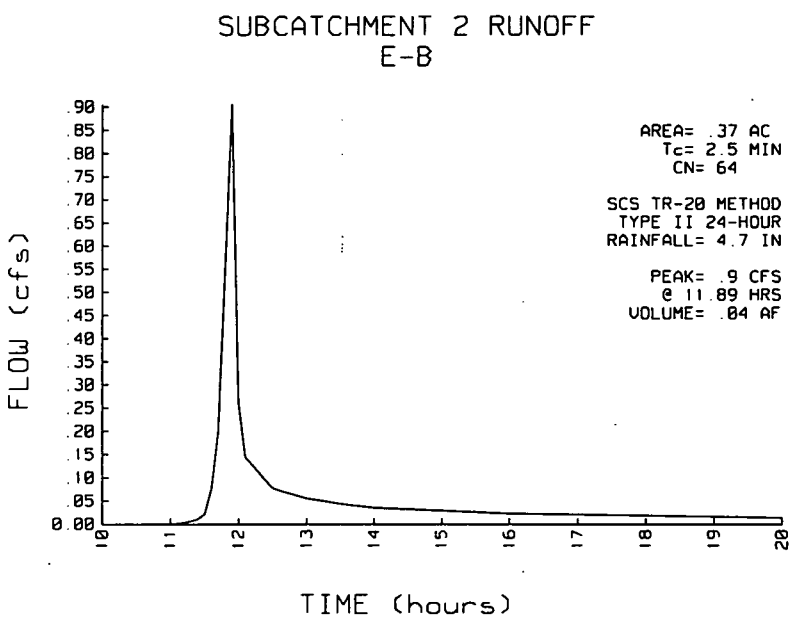
SSS 12 Feb 96

SUBCATCHMENT 2 **E-B**

ACRES	CN
.37	64

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= .9 CFS @ 11.89 HRS
VOLUME= .04 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	1.3
Grass: Short n=.15 L=30' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	1.2
a=312 sq-ft Pw=97' r=3.216'		
s=.005 '/' n=.03 V=7.63 fps L=540' Capacity=2381.2 cfs		
	Total Length= 570 ft Total Tc=	2.5



[redacted]
555

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

739

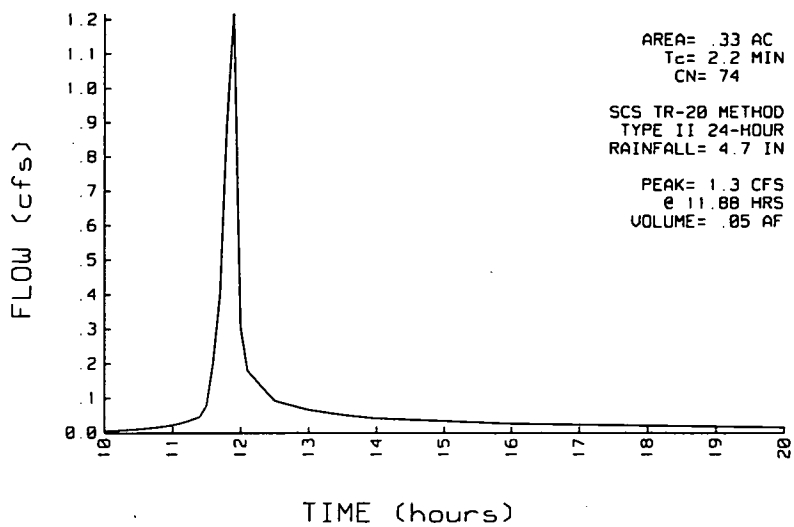
SUBCATCHMENT 3 **E-C**

ACRES	CN
.33	74

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 1.3 CFS @ 11.88 HRS
VOLUME= .05 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW		1.3
Grass: Short n=.15 L=30' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	.9
a=332 sq-ft Pw=102' r=3.255'		
s=.005 '/' n=.03 V=7.69 fps L=405' Capacity=2554 cfs		
	Total Length= 435 ft Total Tc=	2.2

SUBCATCHMENT 3 RUNOFF
E-C



[redacted]
556

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

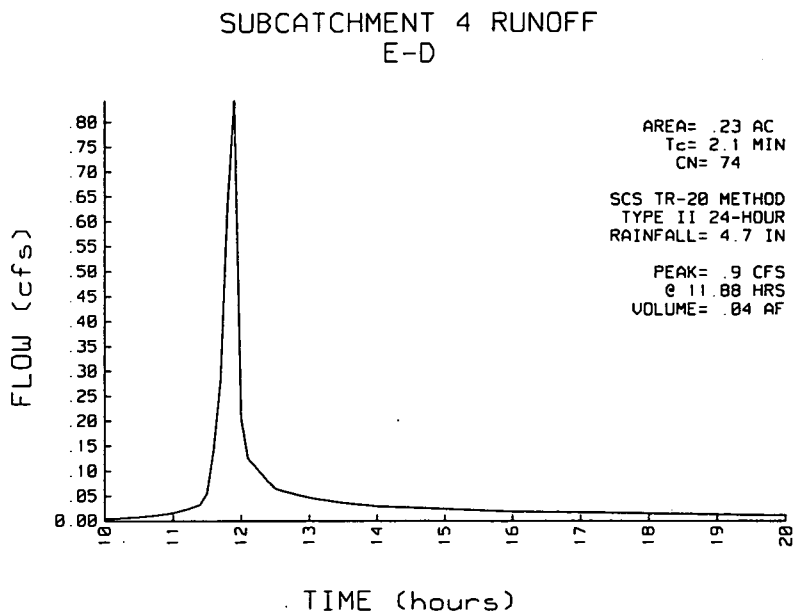
9 Feb 96

SUBCATCHMENT 4 **E-D**

ACRES	CN
.23	74

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= .9 CFS @ 11.88 HRS
VOLUME= .04 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	1.5
Grass: Short n=.15 L=35' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	.6
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=290' Capacity=2692.4 cfs		
	Total Length= 325 ft Total Tc=	2.1



[redacted]

557

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

ASC 739

41/148

ASS 12 Feb 96

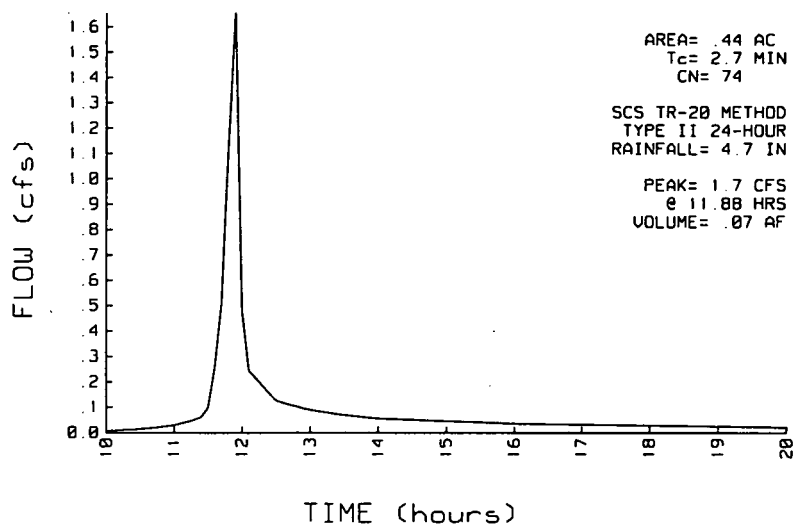
SUBCATCHMENT 5 **E-E**

ACRES	CN
.44	74

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 1.7 CFS @ 11.88 HRS
VOLUME= .07 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	1.5
Grass: Short n=.15 L=35' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	1.2
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=550' Capacity=2692.4 cfs		
	Total Length= 585 ft Total Tc=	2.7

SUBCATCHMENT 5 RUNOFF
E-E



[redacted]
558

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

739

9 Feb 96

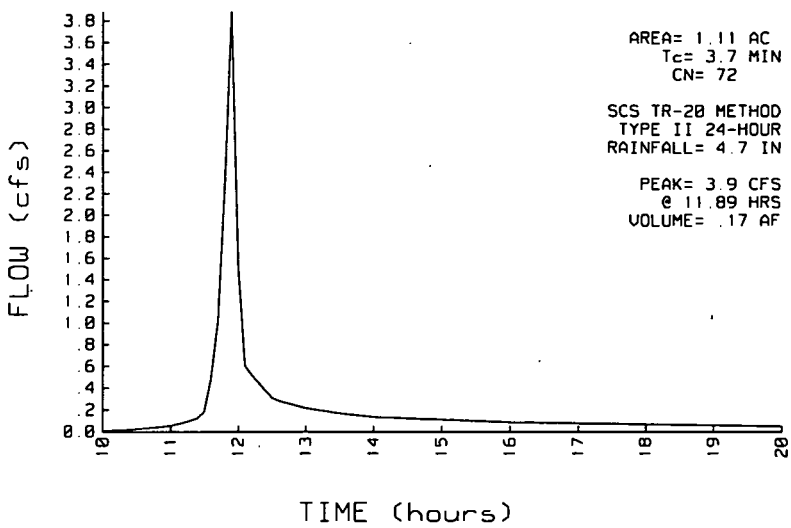
SUBCATCHMENT 6 **E-F**

ACRES	CN
1.11	72

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 3.9 CFS @ 11.89 HRS
VOLUME= .17 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	1.9
Grass: Short n=.15 L=45' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	1.8
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=820' Capacity=2692.4 cfs		
	Total Length= 865 ft Total Tc=	3.7

SUBCATCHMENT 6 RUNOFF
E-F



[redacted]
559

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 43/148

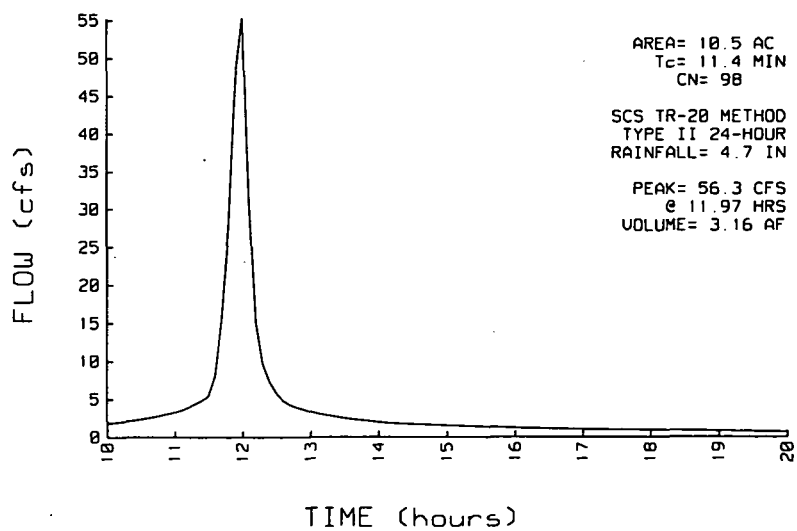
SUBCATCHMENT 7 **E-1**

ACRES	CN
10.50	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 56.3 CFS @ 11.97 HRS
VOLUME= 3.16 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=300' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.6
a=272 sq-ft Pw=87' r=3.126'		
s=.005 '/' n=.03 V=7.49 fps L=705' Capacity=2037 cfs		
	Total Length= 1152 ft Total Tc=	11.4

SUBCATCHMENT 7 RUNOFF
E-1



Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 44/148

SSS 12Feb96

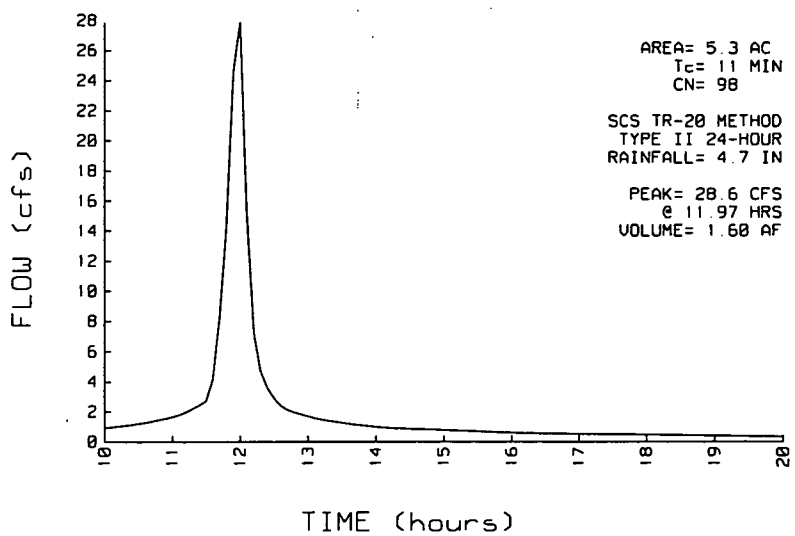
SUBCATCHMENT 8 **E-2**

ACRES	CN
5.30	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 28.6 CFS @ 11.97 HRS
VOLUME= 1.60 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=305' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.2
a=312 sq-ft Pw=97' r=3.216'		
s=.005 '/' n=.03 V=7.63 fps L=540' Capacity=2381.2 cfs		
	Total Length= 992 ft Total Tc=	11.0

SUBCATCHMENT 8 RUNOFF
E-2



[redacted]

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

Asc. 9 Feb 96 45/148

SSS 12 Feb 96

SUBCATCHMENT 9 **E-3**

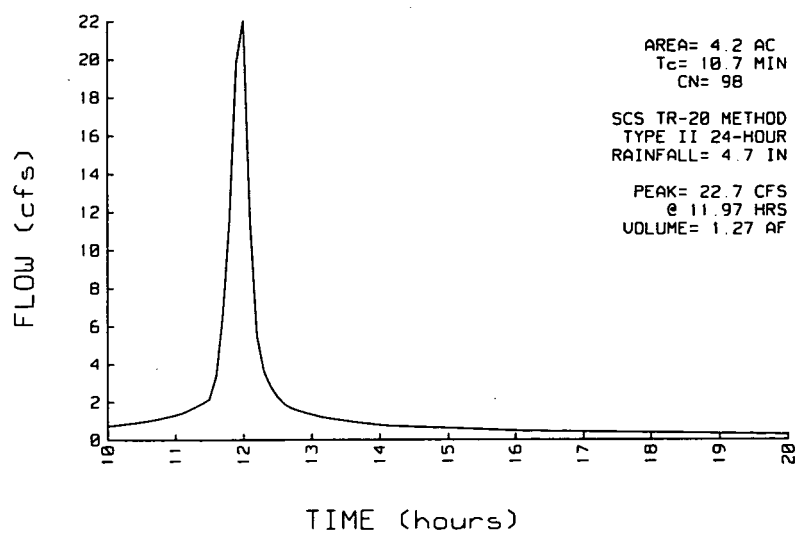
ACRES	CN
4.20	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 22.7 CFS @ 11.97 HRS
VOLUME= 1.27 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=310' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	.9
a=332 sq-ft Pw=102' r=3.255'		
s=.005 '/'/ n=.03 V=7.69 fps L=405' Capacity=2554 cfs		

Total Length= 862 ft Total Tc= 10.7

SUBCATCHMENT 9 RUNOFF
E-3



[redacted]
562

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

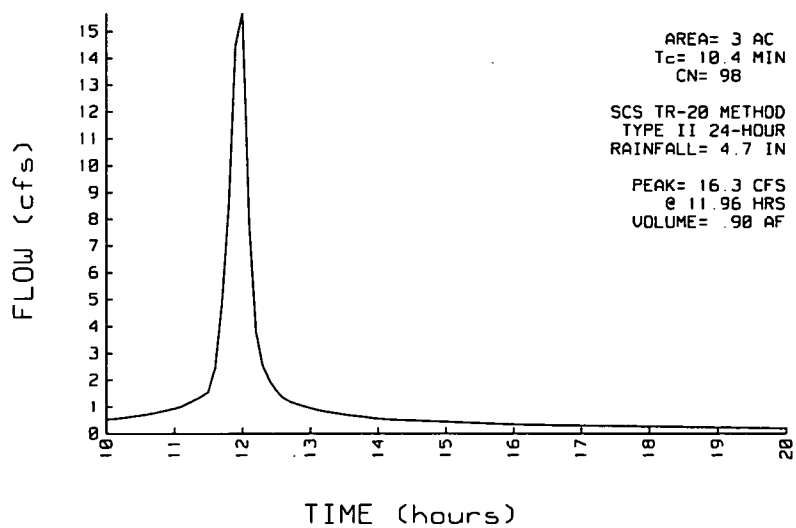
SUBCATCHMENT 10 **E-4**

ACRES	CN
3.00	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 16.3 CFS @ 11.96 HRS
VOLUME= .90 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=310' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	.6
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=290' Capacity=2692.4 cfs		
	Total Length= 747 ft Total Tc=	10.4

SUBCATCHMENT 10 RUNOFF
E-4



Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

47/148

12 Feb 96

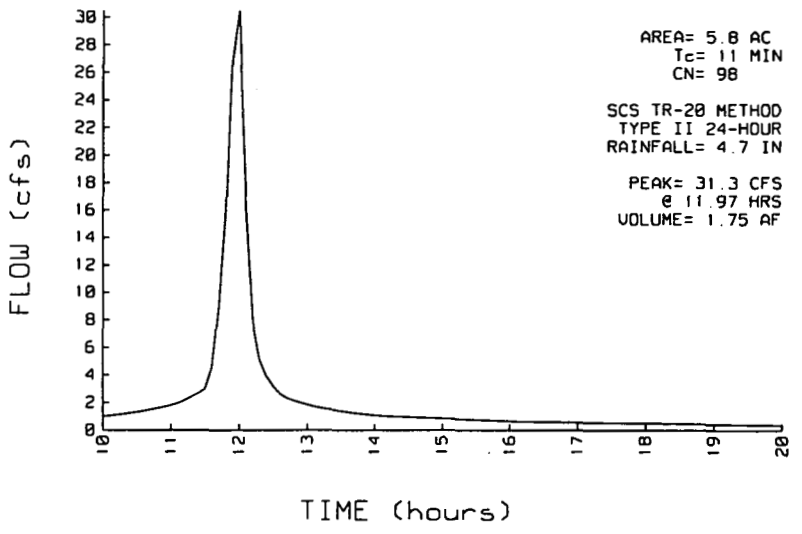
SUBCATCHMENT 11 **E-5**

ACRES	CN
5.80	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 31.3 CFS @ 11.97 HRS
VOLUME= 1.75 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=305' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.2
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=550' Capacity=2692.4 cfs		
	Total Length= 1002 ft Total Tc=	11.0

SUBCATCHMENT 11 RUNOFF
E-5



Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 48/148

ASS 12 Feb 96

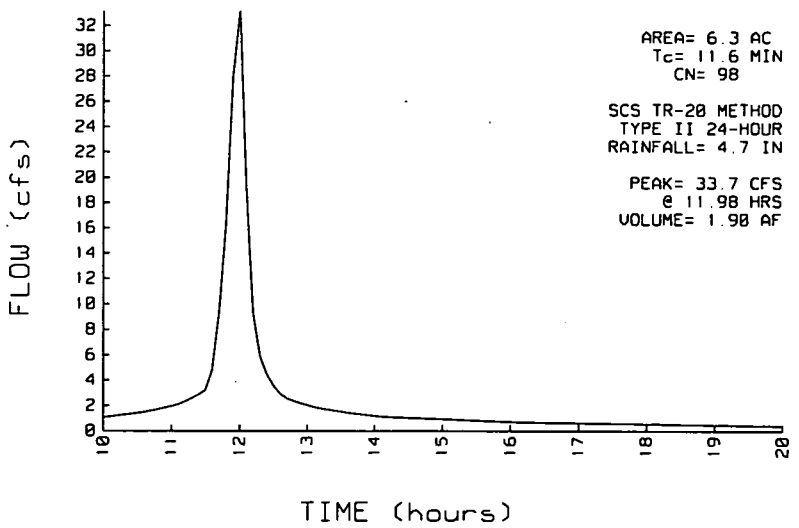
SUBCATCHMENT 12 **E-6**

ACRES	CN
6.30	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 33.7 CFS @ 11.98 HRS
VOLUME= 1.90 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=300' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.8
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=820' Capacity=2692.4 cfs		
	Total Length= 1267 ft Total Tc=	11.6

SUBCATCHMENT 12 RUNOFF
E-6



Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

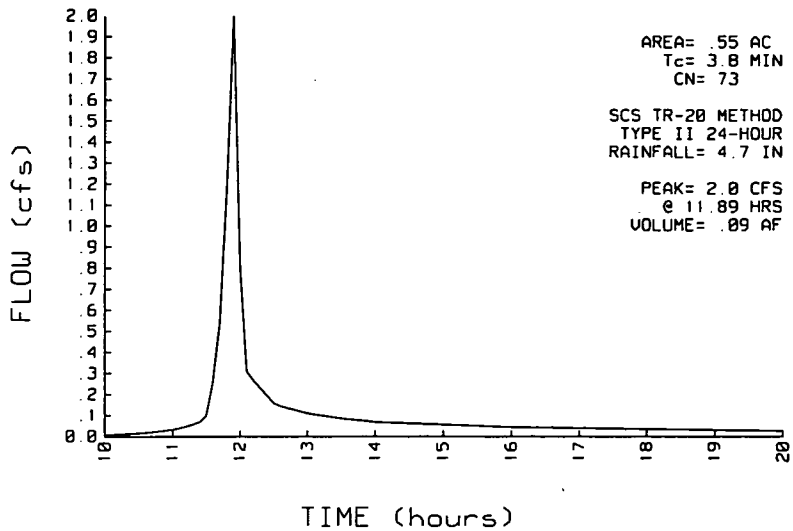
SUBCATCHMENT 1 **E-A**

ACRES	CN
.55	73

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 2.0 CFS @ 11.89 HRS
VOLUME= .09 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	2.0
Grass: Dense n=.24 L=30' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	1.8
a=272 sq-ft Pw=87' r=3.126'		
s=.005 '/' n=.03 V=7.49 fps L=800' Capacity=2037 cfs		
	Total Length= 830 ft Total Tc=	3.8

SUBCATCHMENT 1 RUNOFF
E-A



asc

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 50/148

TSS 12 Feb 96

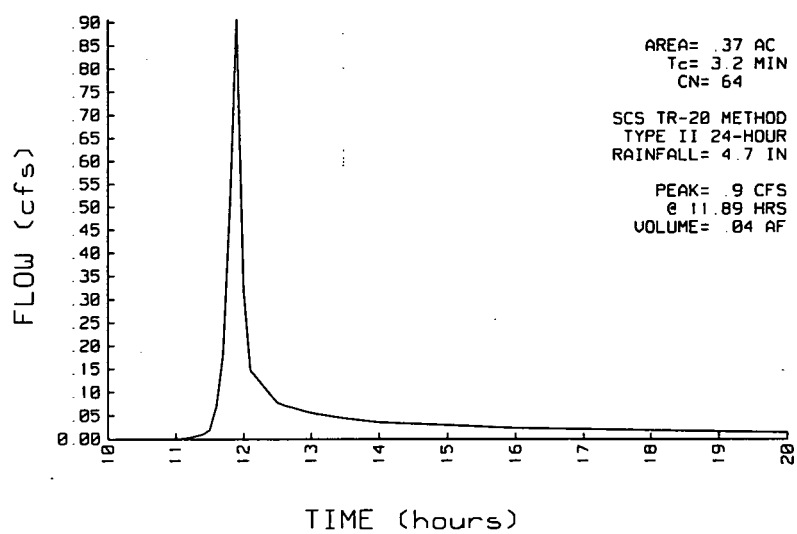
SUBCATCHMENT 2 **E-B**

ACRES	CN
.37	64

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= .9 CFS @ 11.89 HRS
VOLUME= .04 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	2.0
Grass: Dense n=.24 L=30' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	1.2
a=312 sq-ft Pw=97' r=3.216'		
s=.005 '/' n=.03 V=7.63 fps L=540' Capacity=2381.2 cfs		
	Total Length= 570 ft Total Tc=	3.2

SUBCATCHMENT 2 RUNOFF
E-B



[redacted]
567

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 57/148

SSS 12Feb96

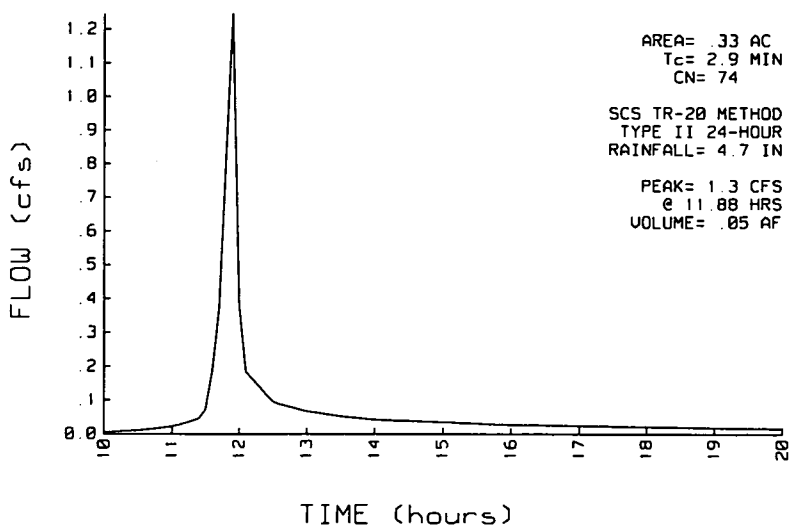
SUBCATCHMENT 3 **E-C**

ACRES	CN
.33	74

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 1.3 CFS @ 11.88 HRS
VOLUME= .05 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW		2.0
Grass: Dense n=.24 L=30' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	.9
a=332 sq-ft Pw=102' r=3.255'		
s=.005 '/' n=.03 V=7.69 fps L=405' Capacity=2554 cfs		
	Total Length= 435 ft Total Tc=	2.9

SUBCATCHMENT 3 RUNOFF
E-C



[redacted]
568

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

ASC 739
9 Feb 96
52/148
KSS 12 Feb 96

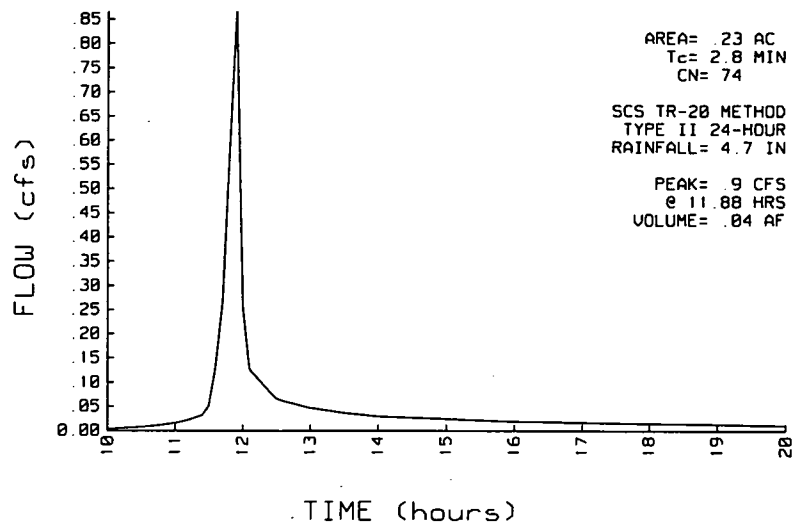
SUBCATCHMENT 4 **E-D**

ACRES	CN
.23	74

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= .9 CFS @ 11.88 HRS
VOLUME= .04 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	2.2
Grass: Dense n=.24 L=35' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	.6
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=290' Capacity=2692.4 cfs		
	Total Length= 325 ft Total Tc=	2.8

SUBCATCHMENT 4 RUNOFF
E-D



[redacted]
569

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

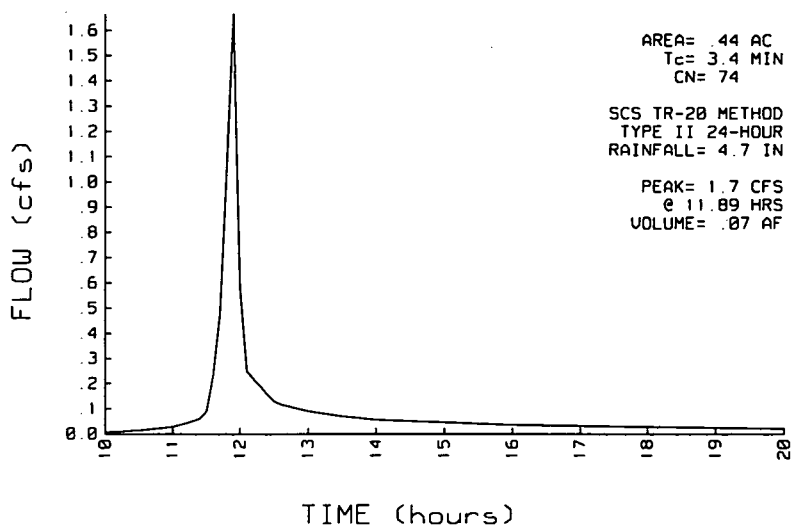
SUBCATCHMENT 5 **E-E**

ACRES	CN
.44	74

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 1.7 CFS @ 11.89 HRS
VOLUME= .07 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	2.2
Grass: Dense n=.24 L=35' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	1.2
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=550' Capacity=2692.4 cfs		
	Total Length= 585 ft Total Tc=	3.4

SUBCATCHMENT 5 RUNOFF
E-E



Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 541/148

SSS 12 Feb 96

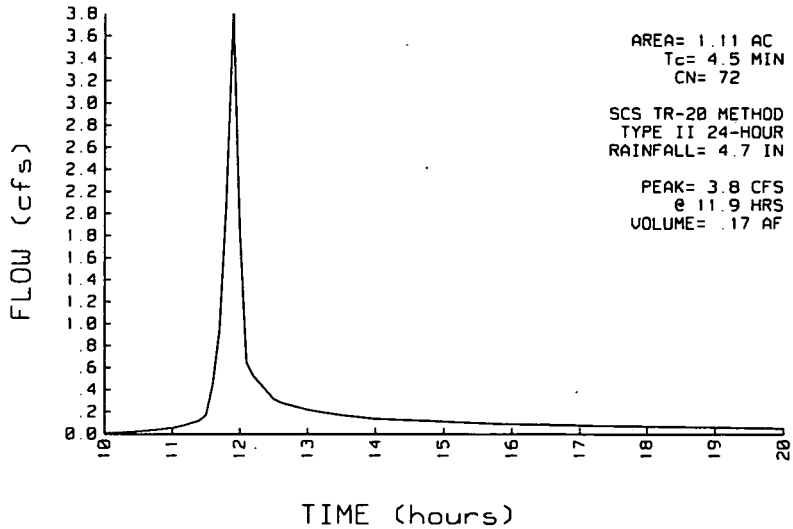
SUBCATCHMENT 6 **E-F**

ACRES	CN
1.11	72

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 3.8 CFS @ 11.90 HRS
VOLUME= .17 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	2.7
Grass: Dense n=.24 L=45' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	1.8
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=820' Capacity=2692.4 cfs		
	Total Length= 865 ft Total Tc=	4.5

SUBCATCHMENT 6 RUNOFF
E-F



[redacted]
571

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

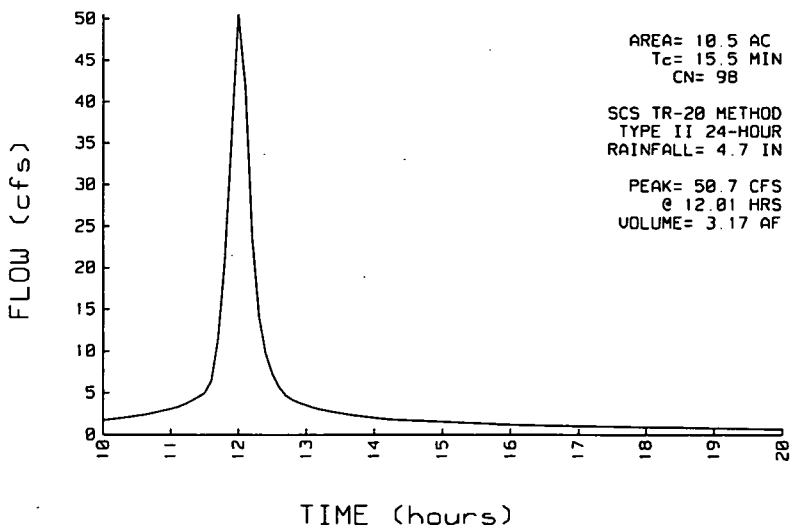
SUBCATCHMENT 7 **E-1**

ACRES	CN
10.50	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 50.7 CFS @ 12.01 HRS
VOLUME= 3.17 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=300' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.6
a=272 sq-ft Pw=87' r=3.126'		
s=.005 '/' n=.03 V=7.49 fps L=705' Capacity=2037 cfs		
	Total Length= 1152 ft Total Tc=	15.5

SUBCATCHMENT 7 RUNOFF
E-1



Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

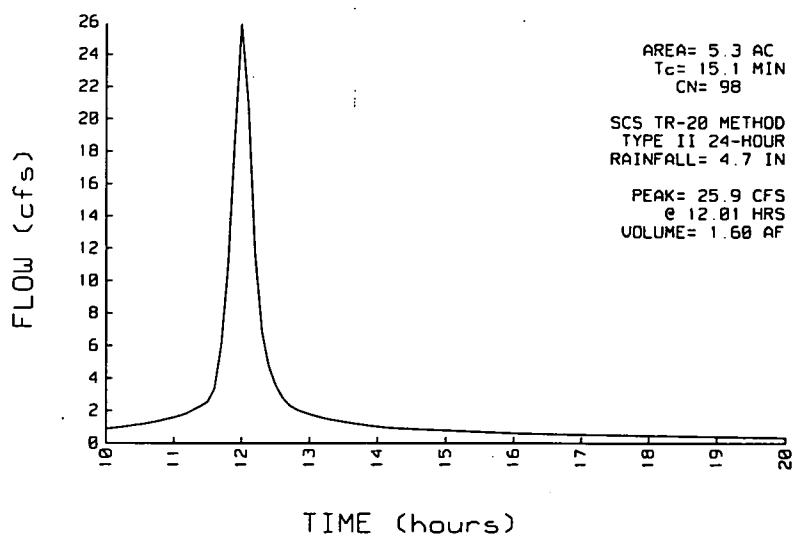
SUBCATCHMENT 8 **E-2**

ACRES	CN
5.30	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 25.9 CFS @ 12.01 HRS
VOLUME= 1.60 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=305' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.2
a=312 sq-ft Pw=97' r=3.216'		
s=.005 '/' n=.03 V=7.63 fps L=540' Capacity=2381.2 cfs		
	Total Length= 992 ft Total Tc=	15.1

SUBCATCHMENT 8 RUNOFF
E-2



[redacted]
573

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

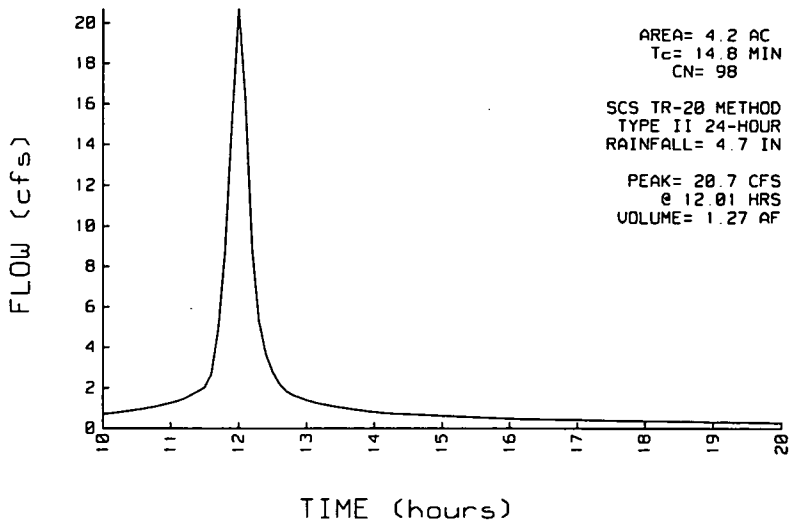
SUBCATCHMENT 9 **E-3**

ACRES	CN
4.20	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 20.7 CFS @ 12.01 HRS
VOLUME= 1.27 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=310' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	.9
a=332 sq-ft Pw=102' r=3.255'		
s=.005 '/' n=.03 V=7.69 fps L=405' Capacity=2554 cfs		
	Total Length= 862 ft Total Tc=	14.8

SUBCATCHMENT 9 RUNOFF
E-3



[redacted]

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER** 739
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 581/148

SSS 12 Feb 96

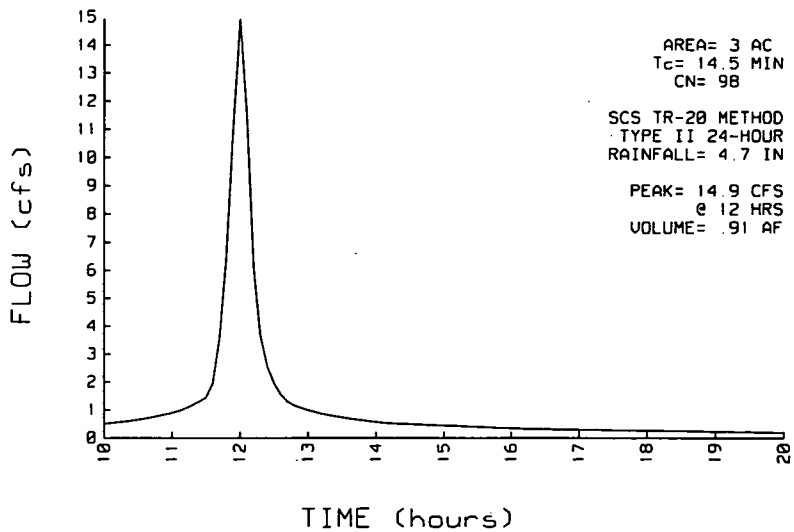
SUBCATCHMENT 10 **E-4**

ACRES	CN
3.00	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 14.9 CFS @ 12.00 HRS
VOLUME= .91 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=310' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	.6
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=290' Capacity=2692.4 cfs		
	Total Length= 747 ft Total Tc=	14.5

SUBCATCHMENT 10 RUNOFF
E-4



[redacted]
525

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

SSS 12 Feb 96

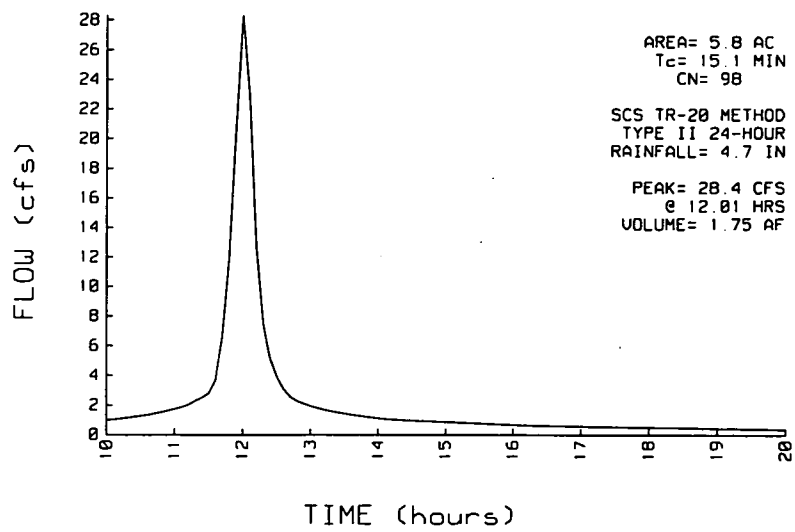
SUBCATCHMENT 11 **E-5**

ACRES	CN
5.80	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 28.4 CFS @ 12.01 HRS
VOLUME= 1.75 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=305' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.2
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=550' Capacity=2692.4 cfs		
	Total Length= 1002 ft Total Tc=	15.1

SUBCATCHMENT 11 RUNOFF
E-5



[redacted]

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

739
9 Feb 96
60/148
SS 12 Feb 96

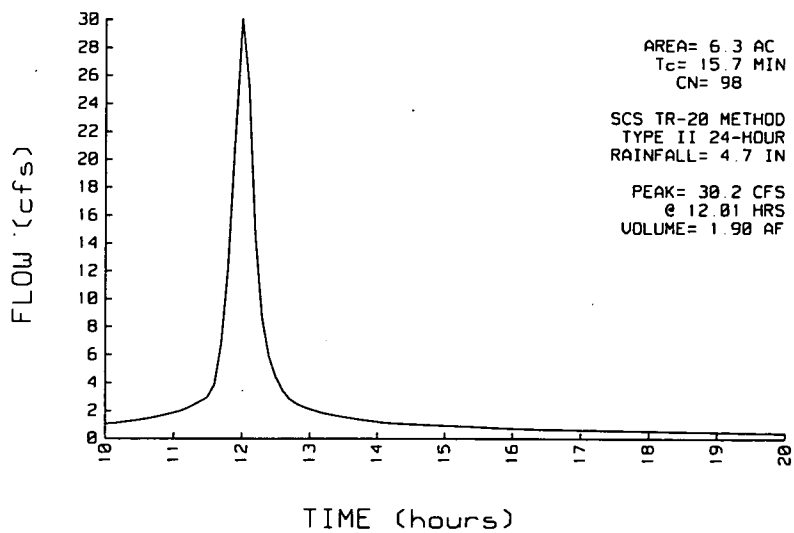
SUBCATCHMENT 12 **E-6**

ACRES	CN
6.30	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 30.2 CFS @ 12.01 HRS
VOLUME= 1.90 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=300' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.8
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=820' Capacity=2692.4 cfs		
	Total Length= 1267 ft Total Tc=	15.7

SUBCATCHMENT 12 RUNOFF
E-6



[redacted]
577

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

739

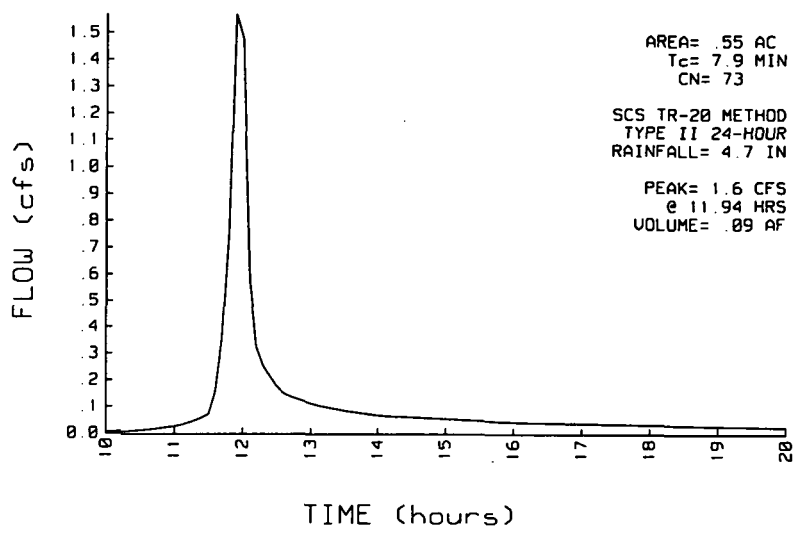
SUBCATCHMENT 1 **E-A**

ACRES	CN
.55	73

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 1.6 CFS @ 11.94 HRS
VOLUME= .09 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	2.0
Grass: Dense n=.24 L=30' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	5.9
a=272 sq-ft Pw=87' r=3.126'		
s=.005 '/' n=.1 V=2.25 fps L=800' Capacity=611.1 cfs		
	Total Length= 830 ft Total Tc=	7.9

SUBCATCHMENT 1 RUNOFF
E-A



[redacted]

578

739

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

G3/148
15512 Feb 96
NO RAGGS 62

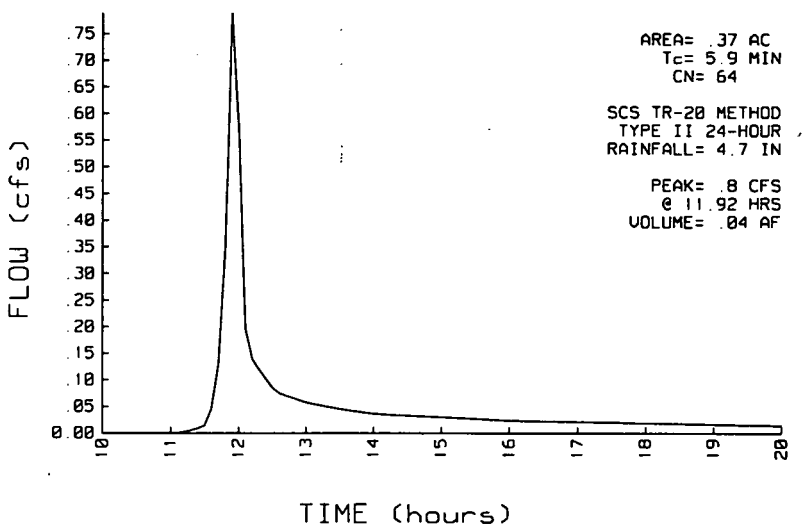
SUBCATCHMENT 2 **E-B**

ACRES	CN
.37	64

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= .8 CFS @ 11.92 HRS
VOLUME= .04 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	2.0
Grass: Dense n=.24 L=30' P2=2.6 in s=.333 '/'		
CHANNEL FLOW	**Segment ID:**	3.9
a=312 sq-ft Pw=97' r=3.216'		
s=.005 '/' n=.1 V=2.29 fps L=540' Capacity=714.4 cfs		
	Total Length= 570 ft Total Tc=	5.9

SUBCATCHMENT 2 RUNOFF
E-B



[redacted]

579

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 64/148

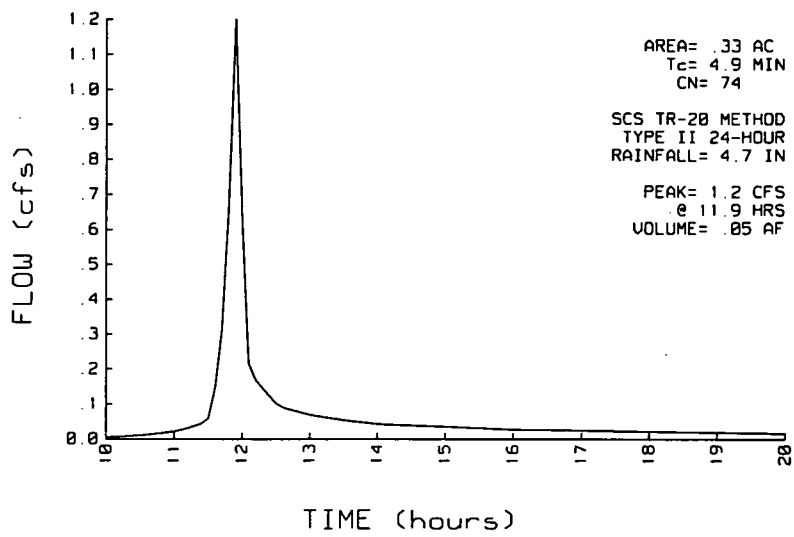
SUBCATCHMENT 3 **E-C**

ACRES	CN
.33	74

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 1.2 CFS @ 11.90 HRS
VOLUME= .05 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW		2.0
Grass: Dense n=.24 L=30' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	2.9
a=332 sq-ft Pw=102' r=3.255'		
s=.005 '/' n=.1 V=2.31 fps L=405' Capacity=766.2 cfs		
	Total Length= 435 ft Total Tc=	4.9

SUBCATCHMENT 3 RUNOFF
E-C



[redacted]

580

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

739

9 Feb 96

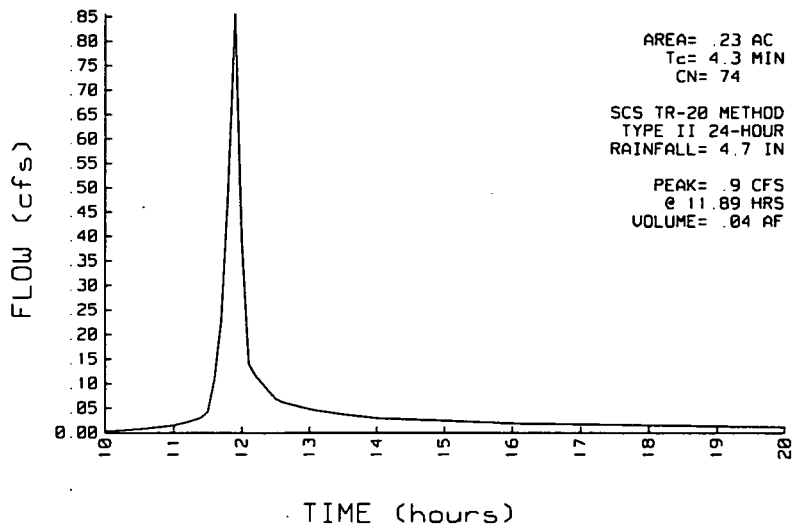
SUBCATCHMENT 4 **E-D**

ACRES	CN
.23	74

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= .9 CFS @ 11.89 HRS
VOLUME= .04 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	2.2
Grass: Dense n=.24 L=35' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	2.1
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.1 V=2.32 fps L=290' Capacity=807.7 cfs		
	Total Length= 325 ft Total Tc=	4.3

SUBCATCHMENT 4 RUNOFF
E-D



[redacted]

581

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

66/148
SSS 12/06/94

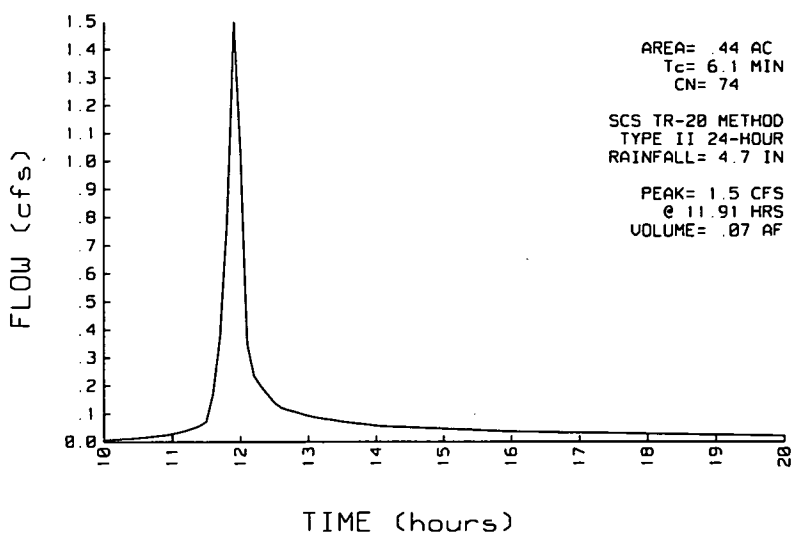
SUBCATCHMENT 5 **E-E**

ACRES	CN
.44	74

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 1.5 CFS @ 11.91 HRS
VOLUME= .07 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	2.2
Grass: Dense n=.24 L=35' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	3.9
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.1 V=2.32 fps L=550' Capacity=807.7 cfs		
	Total Length= 585 ft Total Tc=	6.1

SUBCATCHMENT 5 RUNOFF
E-E



[redacted]
582

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

671 148
SS 12Feb96

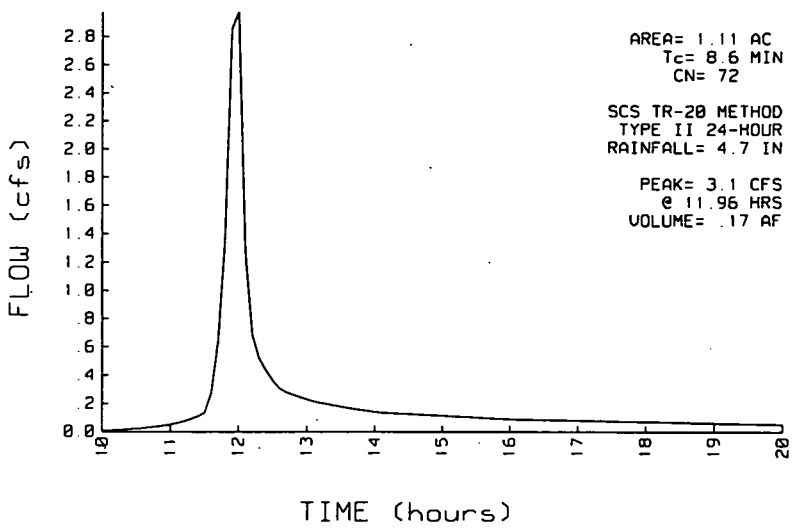
SUBCATCHMENT 6 **E-F**

ACRES	CN
1.11	72

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 3.1 CFS @ 11.96 HRS
VOLUME= .17 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	2.7
Grass: Dense n=.24 L=45' P2=2.6 in s=.3333 '/'		
CHANNEL FLOW	**Segment ID:**	5.9
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.1 V=2.32 fps L=820' Capacity=807.7 cfs		
	Total Length= 865 ft Total Tc=	8.6

SUBCATCHMENT 6 RUNOFF
E-F



[redacted]
583

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

739
9 Feb 96
681 148
SS 12Feb96

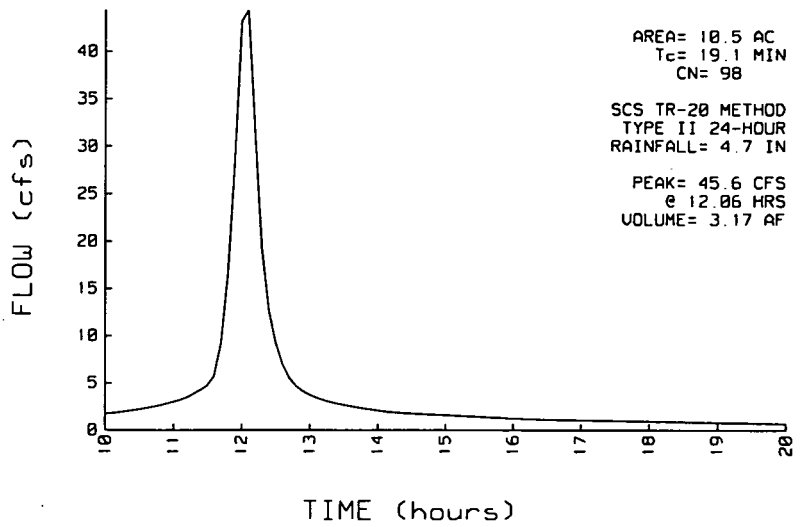
SUBCATCHMENT 7 **E-1**

ACRES	CN
10.50	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 45.6 CFS @ 12.06 HRS
VOLUME= 3.17 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=300' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	5.2
a=272 sq-ft Pw=87' r=3.126'		
s=.005 '/' n=.1 V=2.25 fps L=705' Capacity=611.1 cfs		
	Total Length= 1152 ft Total Tc=	19.1

SUBCATCHMENT 7 RUNOFF
E-1



[redacted]
584

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

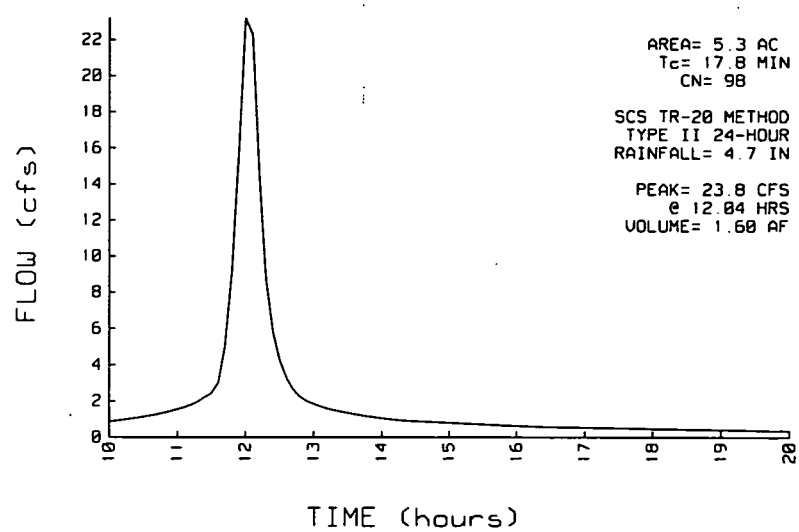
SUBCATCHMENT 8 **E-2**

ACRES	CN
5.30	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 23.8 CFS @ 12.04 HRS
VOLUME= 1.60 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=305' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	3.9
a=312 sq-ft Pw=97' r=3.216'		
s=.005 '/' n=.1 V=2.29 fps L=540' Capacity=714.4 cfs		
	Total Length= 992 ft Total Tc=	17.8

SUBCATCHMENT 8 RUNOFF
E-2



[redacted]

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

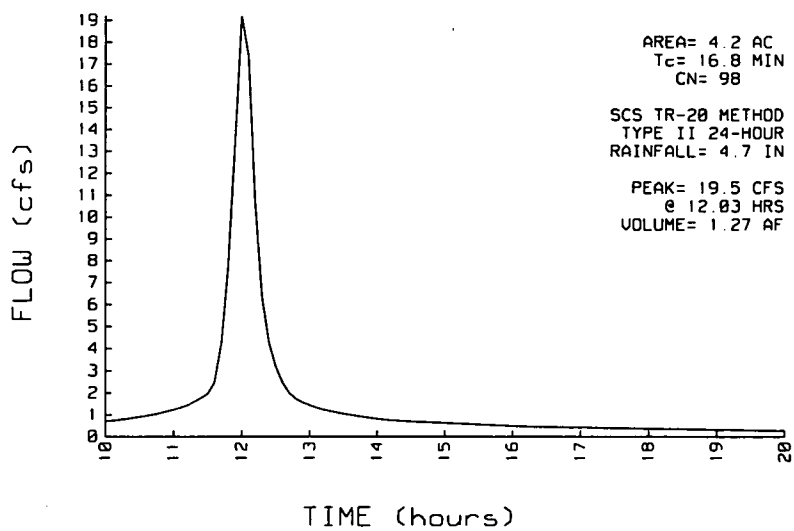
SUBCATCHMENT 9 **E-3**

ACRES	CN
4.20	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 19.5 CFS @ 12.03 HRS
VOLUME= 1.27 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=310' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	2.9
a=332 sq-ft Pw=102' r=3.255'		
s=.005 '/' n=.1 V=2.31 fps L=405' Capacity=766.2 cfs		
	Total Length= 862 ft Total Tc=	16.8

SUBCATCHMENT 9 RUNOFF
E-3



[redacted]

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

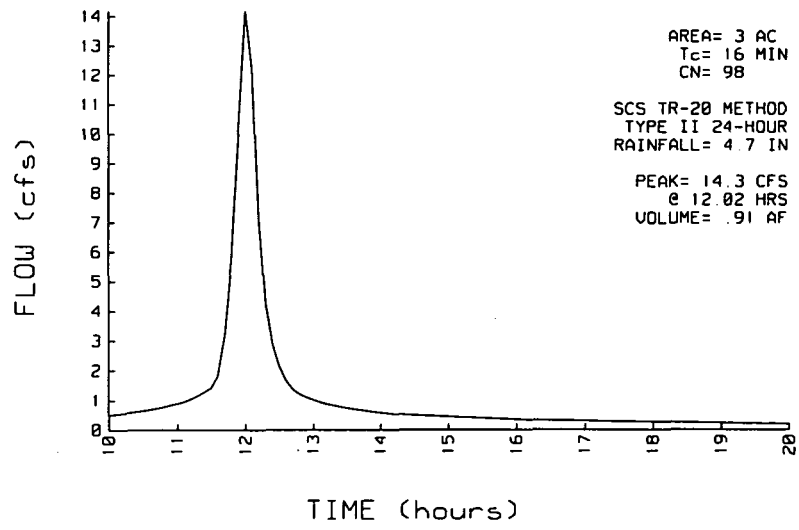
SUBCATCHMENT 10 **E-4**

ACRES	CN
3.00	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 14.3 CFS @ 12.02 HRS
VOLUME= .91 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=310' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	2.1
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.1 V=2.32 fps L=290' Capacity=807.7 cfs		
	Total Length= 747 ft Total Tc=	16.0

SUBCATCHMENT 10 RUNOFF
E-4



[redacted]

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

739

9 Feb 96

721 148

SSS 12Feb96

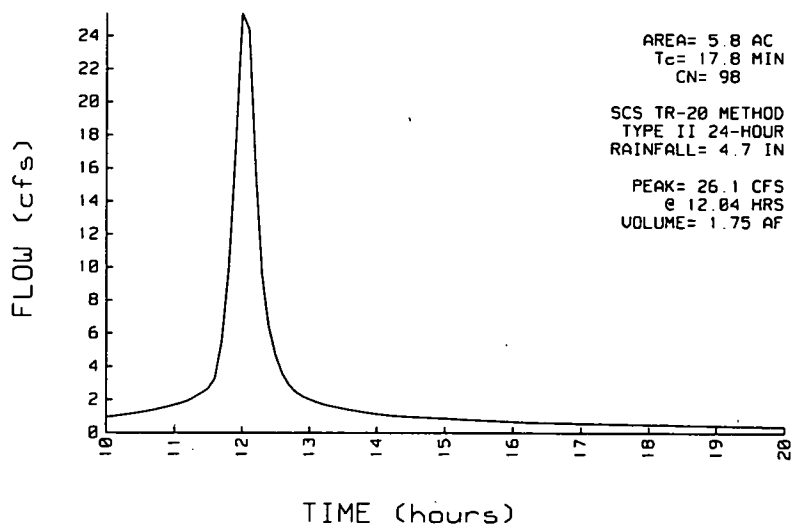
SUBCATCHMENT 11 **E-5**

ACRES	CN
5.80	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 26.1 CFS @ 12.04 HRS
VOLUME= 1.75 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=305' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	3.9
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.1 V=2.32 fps L=550' Capacity=807.7 cfs		
	Total Length= 1002 ft Total Tc=	17.8

SUBCATCHMENT 11 RUNOFF
E-5



[redacted]

588

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96
73/148
SSS 12Feb96

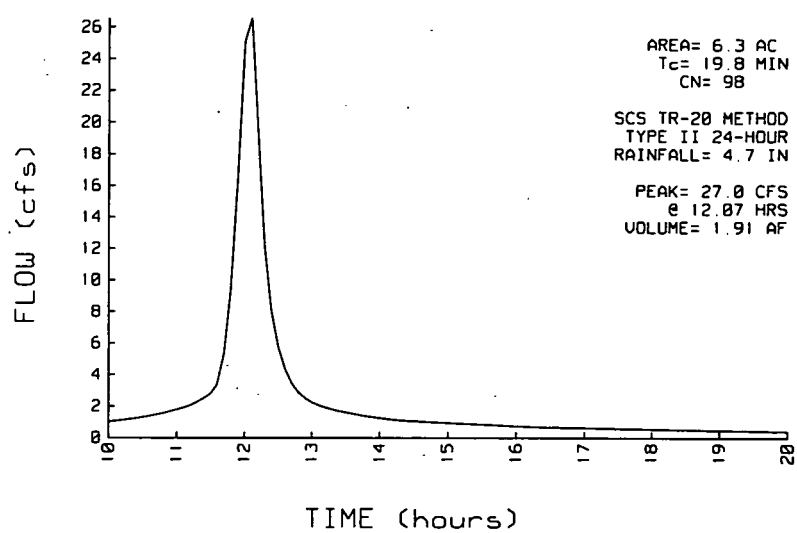
SUBCATCHMENT 12 **E-6**

ACRES	CN
6.30	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 27.0 CFS @ 12.07 HRS
VOLUME= 1.91 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=300' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	5.9
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.1 V=2.32 fps L=820' Capacity=807.7 cfs		
	Total Length= 1267 ft Total Tc=	19.8

SUBCATCHMENT 12 RUNOFF
E-6



[redacted]

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

74/148
SS 12 Feb 96

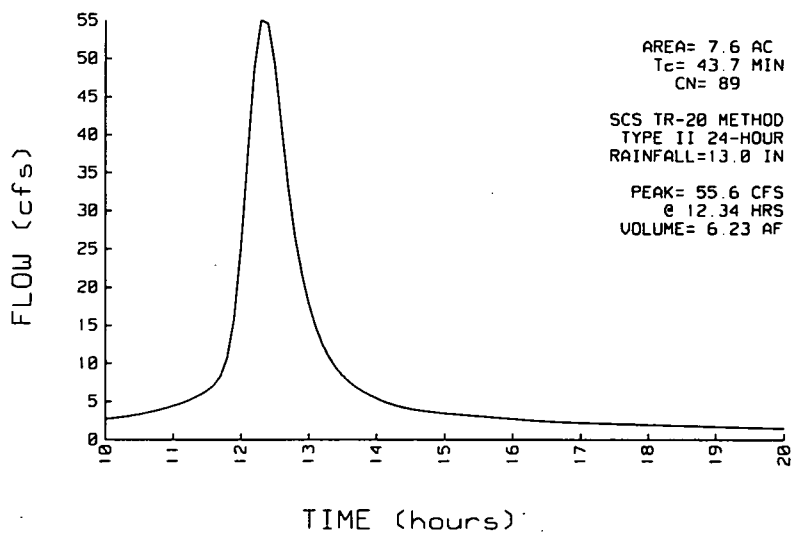
SUBCATCHMENT 1 **E-A**

ACRES	CN
7.60	89

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 55.6 CFS @ 12.34 HRS
VOLUME= 6.23 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	39.8
Grass: Short n=.15 L=300' P2=2.6 in s=.007 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	2.9
Unpaved Kv=16.1345 L=320' s=.013 '/' V=1.84 fps		
CHANNEL FLOW	**Segment ID:**	1.0
a=272 sq-ft Pw=87' r=3.126'		
s=.005 '/' n=.03 V=7.49 fps L=465' Capacity=2037 cfs		
	Total Length= 1085 ft Total Tc=	43.7

SUBCATCHMENT 1 RUNOFF
E-A



[redacted]

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

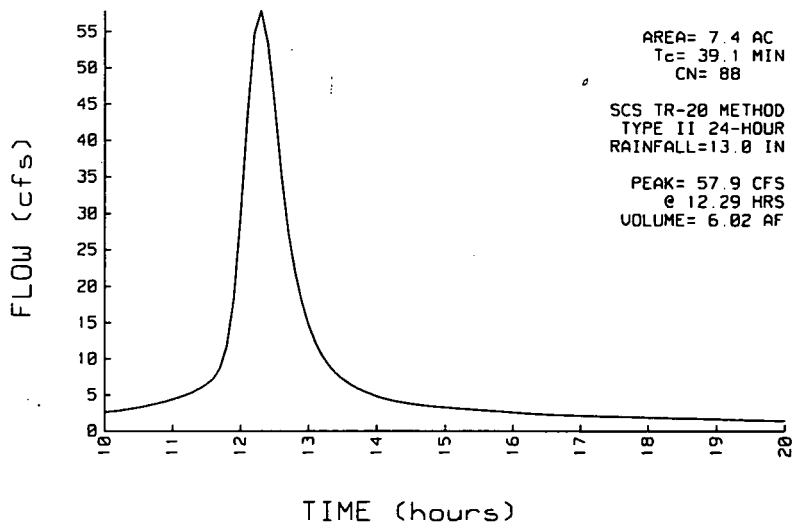
SUBCATCHMENT 2 **E-B**

ACRES	CN
7.40	88

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 57.9 CFS @ 12.29 HRS
VOLUME= 6.02 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	34.5
Grass: Short n=.15 L=300' P2=2.6 in s=.01 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	4.5
Unpaved Kv=16.1345 L=615' s=.02 '/' V=2.28 fps		
CHANNEL FLOW	**Segment ID:**	.1
a=312 sq-ft Pw=97' r=3.216'		
s=.005 '/' n=.03 V=7.63 fps L=30' Capacity=2381.2 cfs		
	Total Length= 945 ft Total Tc=	39.1

SUBCATCHMENT 2 RUNOFF
E-B



Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

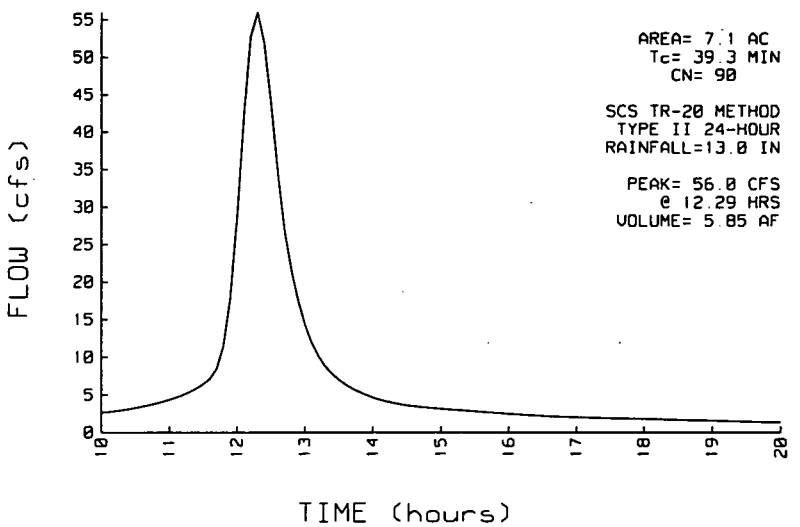
SUBCATCHMENT 3 **E-C**

ACRES	CN
7.10	90

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 56.0 CFS @ 12.29 HRS
VOLUME= 5.85 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW		34.5
Grass: Short n=.15	L=300' P2=2.6 in s=.01 '/'	
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	4.8
Unpaved Kv=16.1345	L=655' s=.02 '/' V=2.28 fps	
	Total Length= 955 ft Total Tc=	39.3

SUBCATCHMENT 3 RUNOFF
E-C



[redacted]

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

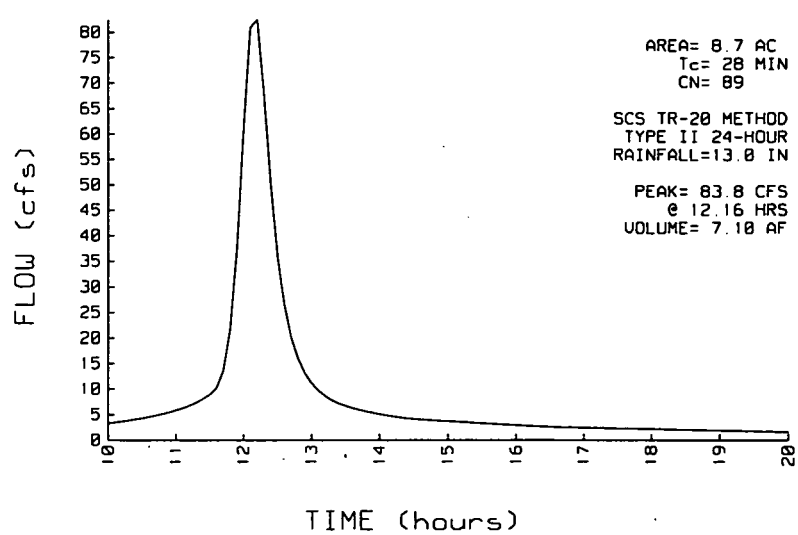
SUBCATCHMENT 4 **E-D**

ACRES	CN
8.70	89

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 83.8 CFS @ 12.16 HRS
VOLUME= 7.10 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	22.5
Grass: Short n=.15 L=200' P2=2.6 in s=.013 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	5.4
Unpaved Kv=16.1345 L=735' s=.02 '/' V=2.28 fps		
CHANNEL FLOW	**Segment ID:**	.1
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=30' Capacity=2692.4 cfs		
	Total Length= 965 ft Total Tc=	28.0

SUBCATCHMENT 4 RUNOFF
E-D



[redacted]
593

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

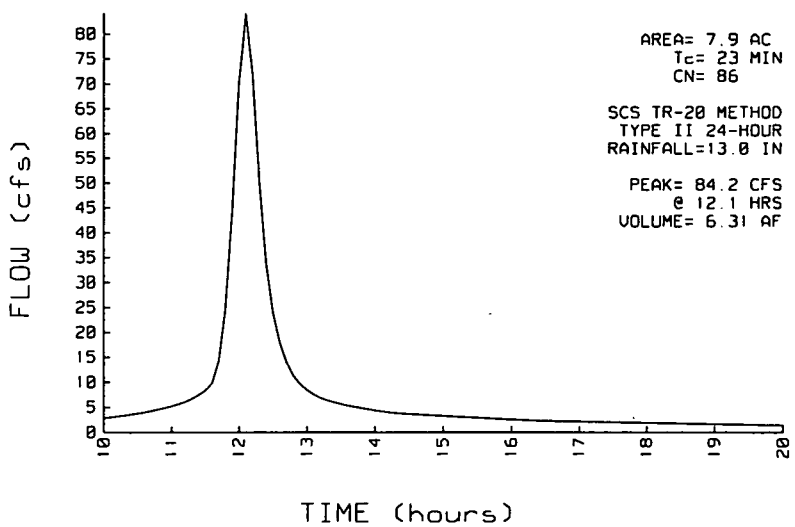
SUBCATCHMENT 5 **E-E**

ACRES	CN
7.90	86

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 84.2 CFS @ 12.10 HRS
VOLUME= 6.31 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	17.3
Grass: Short n=.15 L=200' P2=2.6 in s=.025 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	5.4
Unpaved Kv=16.1345 L=735' s=.02 '/' V=2.28 fps		
CHANNEL FLOW	**Segment ID:**	.3
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=125' Capacity=2692.4 cfs		
	Total Length= 1060 ft Total Tc=	23.0

SUBCATCHMENT 5 RUNOFF
E-E



Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

Lsc 739
9 Feb 96
79/148
SSS 12 Feb 96

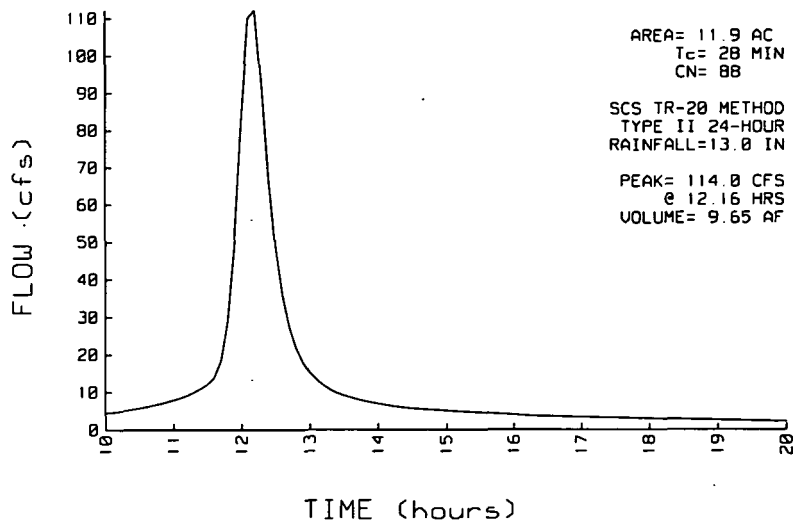
SUBCATCHMENT 6 **E-F**

ACRES	CN
11.90	88

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 114.0 CFS @ 12.16 HRS
VOLUME= 9.65 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	22.5
Grass: Short n=.15 L=200' P2=2.6 in s=.013 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	3.8
Unpaved Kv=16.1345 L=475' s=.017 '/' V=2.1 fps		
CHANNEL FLOW	**Segment ID:**	1.7
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=785' Capacity=2692.4 cfs		
	Total Length= 1460 ft Total Tc=	28.0

SUBCATCHMENT 6 RUNOFF
E-F



595

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

801 148
SSS 12 Feb 96

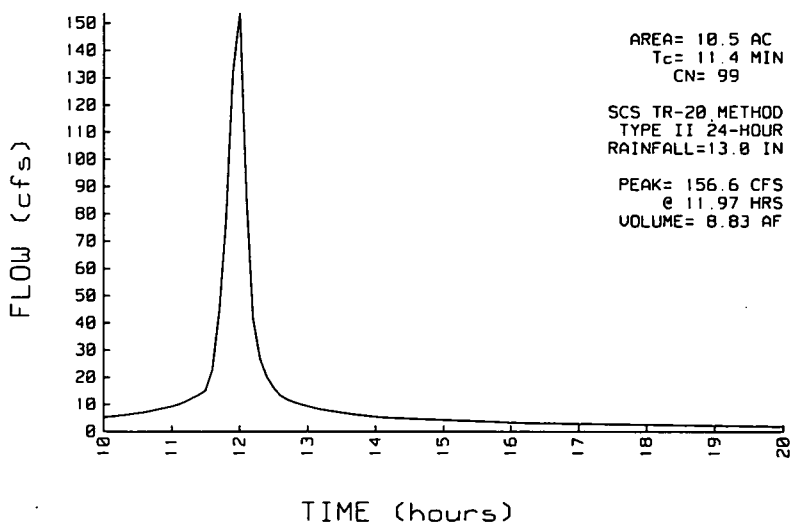
SUBCATCHMENT 7 **E-1**

ACRES	CN
10.50	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 156.6 CFS @ 11.97 HRS
VOLUME= 8.83 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=300' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.6
a=272 sq-ft Pw=87' r=3.126'		
s=.005 '/' n=.03 V=7.49 fps	L=705' Capacity=2037 cfs	
	Total Length= 1152 ft Total Tc=	11.4

SUBCATCHMENT 7 RUNOFF
E-1



[redacted]
596

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

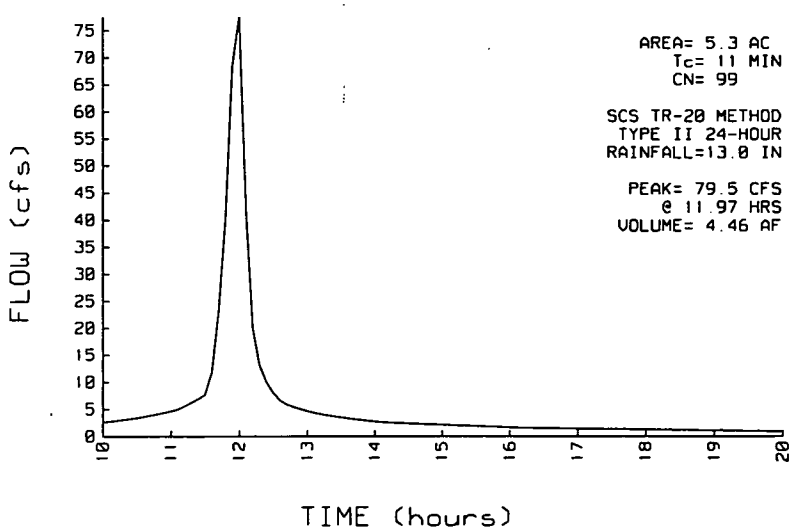
SUBCATCHMENT 8 **E-2**

ACRES	CN
5.30	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 79.5 CFS @ 11.97 HRS
VOLUME= 4.46 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=305' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.2
a=312 sq-ft Pw=97' r=3.216'		
s=.005 '/' n=.03 V=7.63 fps L=540' Capacity=2381.2 cfs		
	Total Length= 992 ft Total Tc=	11.0

SUBCATCHMENT 8 RUNOFF
E-2



Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER** 739
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 821/148
SSS 12 Feb 96

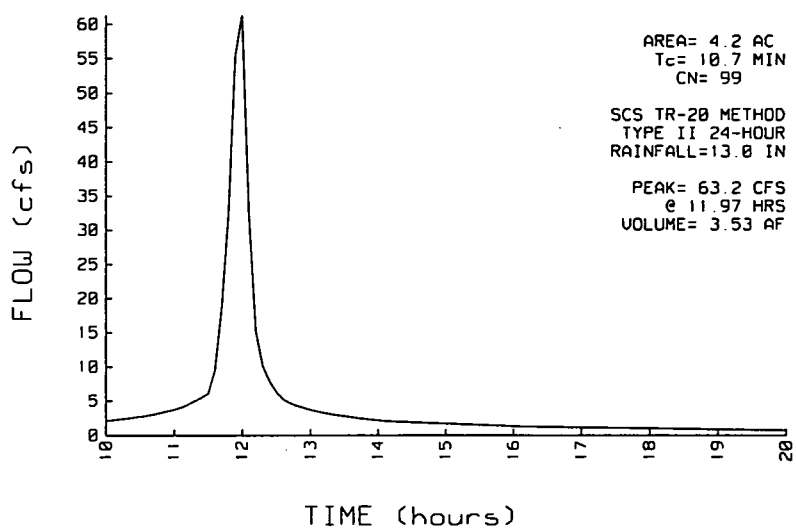
SUBCATCHMENT 9 **E-3**

ACRES	CN
4.20	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 63.2 CFS @ 11.97 HRS
VOLUME= 3.53 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=310' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	.9
a=332 sq-ft Pw=102' r=3.255'		
s=.005 '/' n=.03 V=7.69 fps L=405' Capacity=2554 cfs		
	Total Length= 862 ft Total Tc=	10.7

SUBCATCHMENT 9 RUNOFF
E-3



[redacted]
598

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

Loc 739
9 Feb 96
B3/148
SS 12 Feb 96

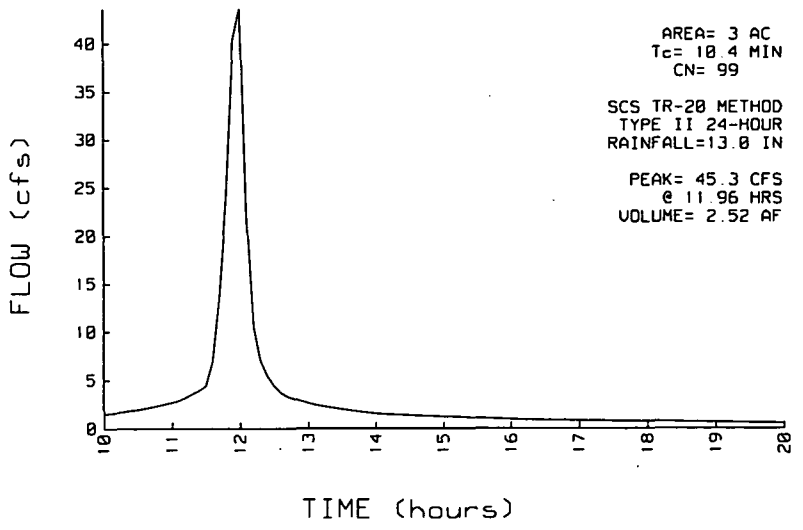
SUBCATCHMENT 10 **E-4**

ACRES	CN
3.00	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 45.3 CFS @ 11.96 HRS
VOLUME= 2.52 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=310' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	.6
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=290' Capacity=2692.4 cfs		
	Total Length= 747 ft Total Tc=	10.4

SUBCATCHMENT 10 RUNOFF
E-4



[redacted]
599

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

ISU 64/148
ISS 12 Feb 96

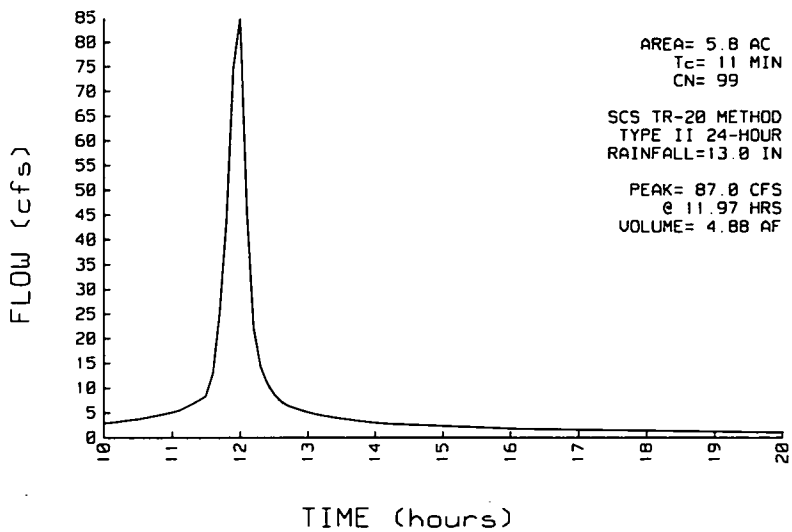
SUBCATCHMENT 11 **E-5**

ACRES	CN
5.80	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 87.0 CFS @ 11.97 HRS
VOLUME= 4.88 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=305' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.2
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=550' Capacity=2692.4 cfs		
	Total Length= 1002 ft Total Tc=	11.0

SUBCATCHMENT 11 RUNOFF
E-5



[redacted]
600

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER** 739
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 85/148
BSS 12 Feb 96

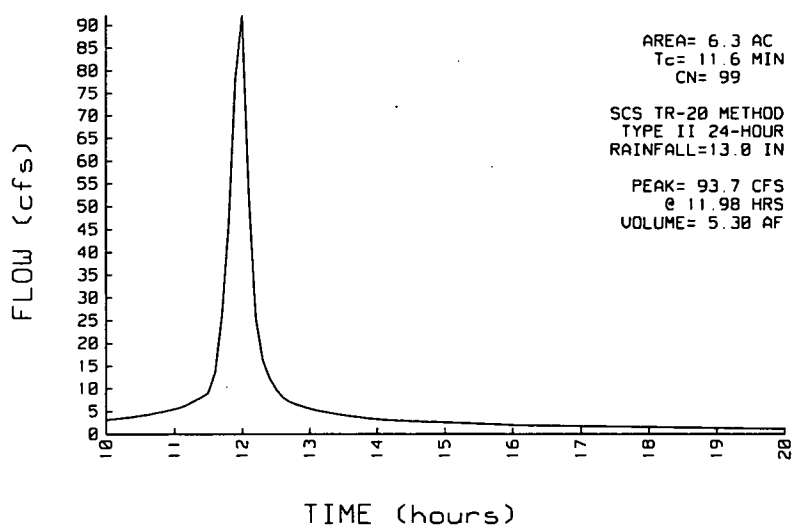
SUBCATCHMENT 12 **E-6**

ACRES	CN
6.30	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 93.7 CFS @ 11.98 HRS
VOLUME= 5.30 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=300' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.8
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=820' Capacity=2692.4 cfs		
	Total Length= 1267 ft Total Tc=	11.6

SUBCATCHMENT 12 RUNOFF
E-6



[redacted]
601

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

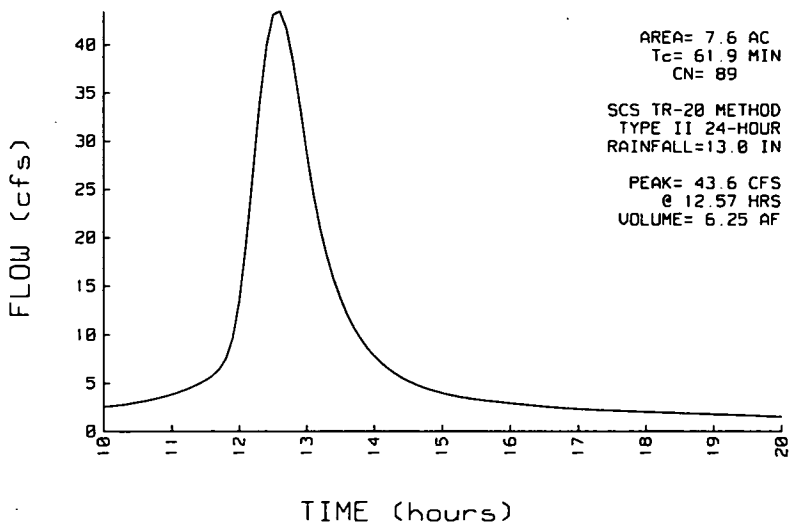
SUBCATCHMENT 1 **E-A**

ACRES	CN
7.60	89

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 43.6 CFS @ 12.57 HRS
VOLUME= 6.25 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	58.0
Grass: Dense n=.24 L=300' P2=2.6 in s=.007 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	2.9
Unpaved Kv=16.1345 L=320' s=.013 '/' V=1.84 fps		
CHANNEL FLOW	**Segment ID:**	1.0
a=272 sq-ft Pw=87' r=3.126'		
s=.005 '/' n=.03 V=7.49 fps L=465' Capacity=2037 cfs		
	Total Length= 1085 ft Total Tc=	61.9

SUBCATCHMENT 1 RUNOFF
E-A



[redacted]
602

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

Exc 739
87/148
SSS 12 Feb 96

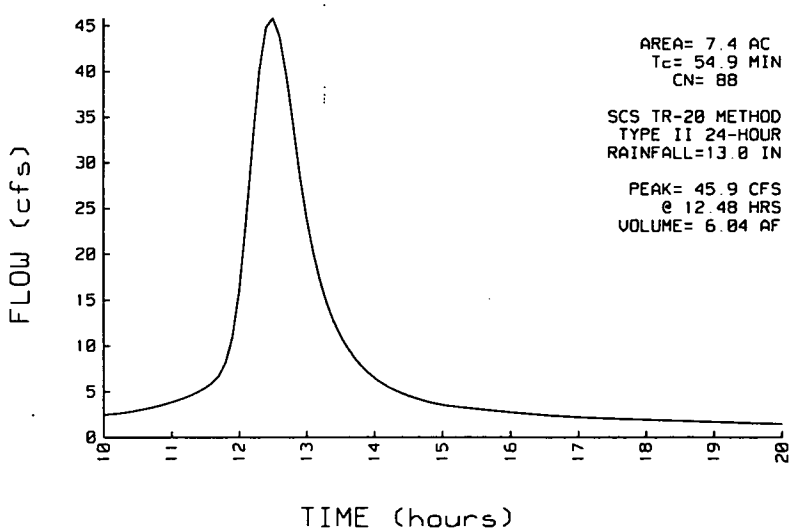
SUBCATCHMENT 2 **E-B**

ACRES	CN
7.40	88

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 45.9 CFS @ 12.48 HRS
VOLUME= 6.04 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	50.3
Grass: Dense n=.24 L=300' P2=2.6 in s=.01 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	4.5
Unpaved Kv=16.1345 L=615' s=.02 '/' V=2.28 fps		
CHANNEL FLOW	**Segment ID:**	.1
a=312 sq-ft Pw=97' r=3.216'		
s=.005 '/' n=.03 V=7.63 fps L=30' Capacity=2381.2 cfs		
	Total Length= 945 ft Total Tc=	54.9

SUBCATCHMENT 2 RUNOFF
E-B



[redacted]
603

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SS/148
SS 12 Feb96

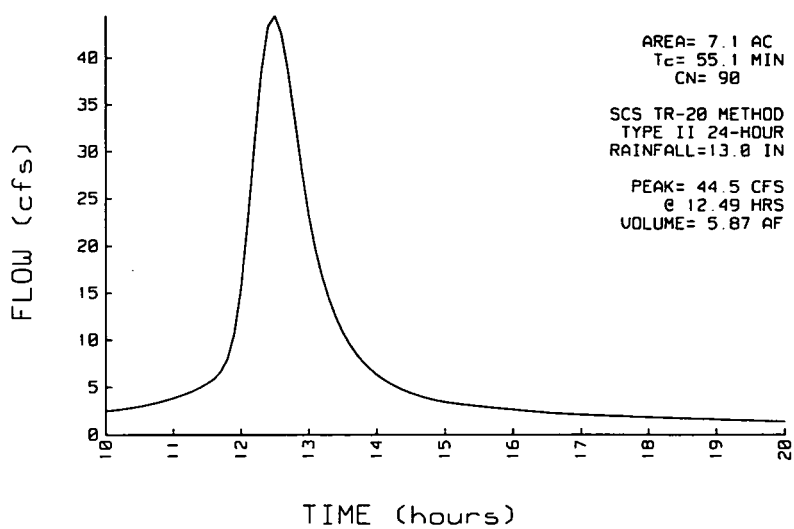
SUBCATCHMENT 3 **E-C**

ACRES	CN
7.10	90

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 44.5 CFS @ 12.49 HRS
VOLUME= 5.87 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW		50.3
Grass: Dense n=.24 L=300' P2=2.6 in s=.01 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	4.8
Unpaved Kv=16.1345 L=655' s=.02 '/' V=2.28 fps		
	Total Length= 955 ft Total Tc=	55.1

SUBCATCHMENT 3 RUNOFF
E-C



[redacted]

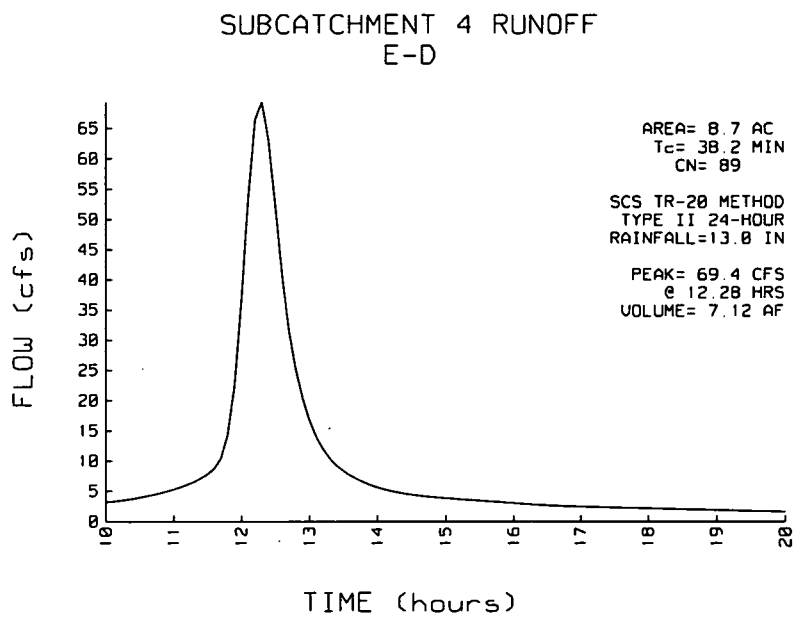
Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SUBCATCHMENT 4 **E-D**

ACRES	CN
8.70	89

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 69.4 CFS @ 12.28 HRS
VOLUME= 7.12 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	32.7
Grass: Dense n=.24 L=200' P2=2.6 in s=.013 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	5.4
Unpaved Kv=16.1345 L=735' s=.02 '/' V=2.28 fps		
CHANNEL FLOW	**Segment ID:**	.1
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=30' Capacity=2692.4 cfs		
	Total Length= 965 ft Total Tc=	38.2



[redacted]

605

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

739
9 Feb 96
901 148
BS 12Feb96

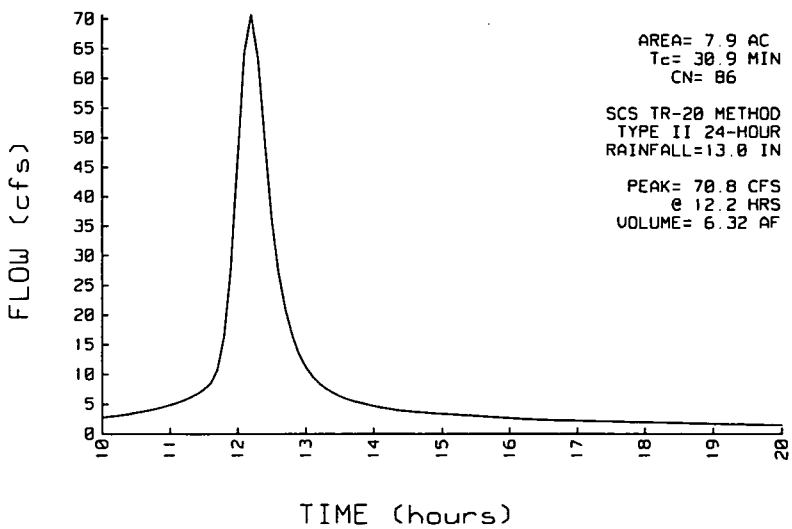
SUBCATCHMENT 5 **E-E**

ACRES	CN
7.90	86

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 70.8 CFS @ 12.20 HRS
VOLUME= 6.32 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	25.2
Grass: Dense n=.24 L=200' P2=2.6 in s=.025 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	5.4
Unpaved Kv=16.1345 L=735' s=.02 '/' V=2.28 fps		
CHANNEL FLOW	**Segment ID:**	.3
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=125' Capacity=2692.4 cfs		
	Total Length= 1060 ft Total Tc=	30.9

SUBCATCHMENT 5 RUNOFF
E-E



[redacted]

606

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

739

9 Feb 96
91/148
BSS 12Feb96

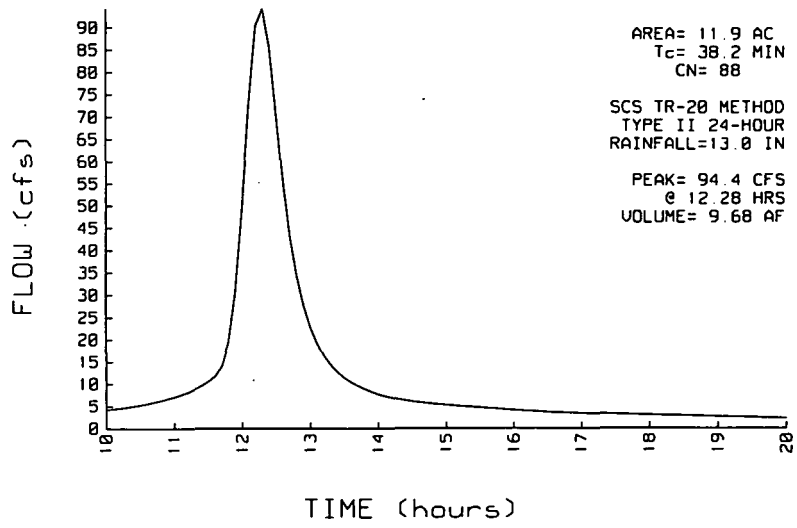
SUBCATCHMENT 6 **E-F**

ACRES	CN
11.90	88

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 94.4 CFS @ 12.28 HRS
VOLUME= 9.68 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	32.7
Grass: Dense n=.24 L=200' P2=2.6 in s=.013 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	3.8
Unpaved Kv=16.1345 L=475' s=.017 '/' V=2.1 fps		
CHANNEL FLOW	**Segment ID:**	1.7
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=785' Capacity=2692.4 cfs		
	Total Length= 1460 ft Total Tc=	38.2

SUBCATCHMENT 6 RUNOFF
E-F



[redacted]

607

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

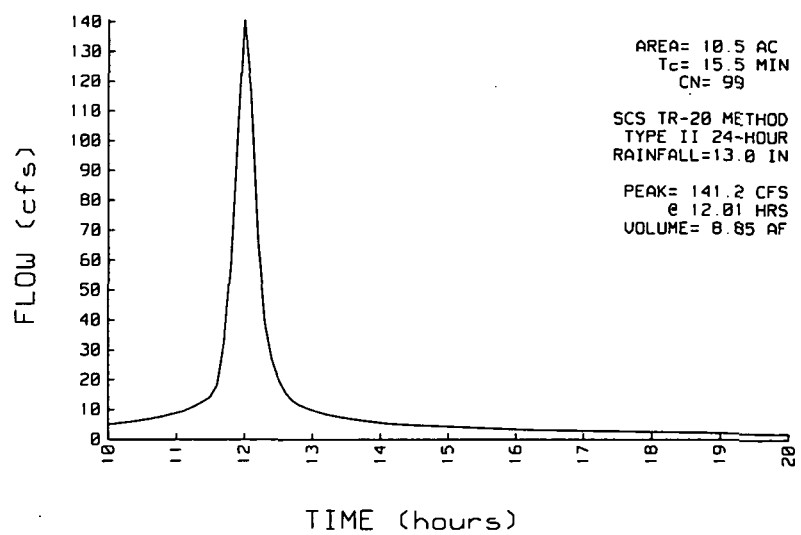
SUBCATCHMENT 7 **E-1**

ACRES	CN
10.50	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 141.2 CFS @ 12.01 HRS
VOLUME= 8.85 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=300' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.6
a=272 sq-ft Pw=87' r=3.126'		
s=.005 '/' n=.03 V=7.49 fps L=705' Capacity=2037 cfs		
	Total Length= 1152 ft Total Tc=	15.5

SUBCATCHMENT 7 RUNOFF
E-1



[redacted]

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96
93/148
SSS 12 Feb 96

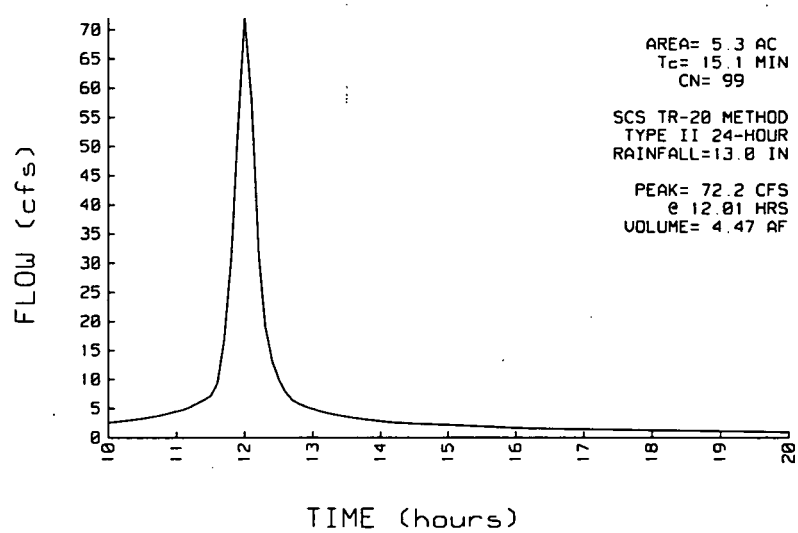
SUBCATCHMENT 8 **E-2**

ACRES	CN
5.30	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 72.2 CFS @ 12.01 HRS
VOLUME= 4.47 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=305' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.2
a=312 sq-ft Pw=97' r=3.216'		
s=.005 '/' n=.03 V=7.63 fps L=540' Capacity=2381.2 cfs		
	Total Length= 992 ft Total Tc=	15.1

SUBCATCHMENT 8 RUNOFF
E-2



[redacted]

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

A/C 739
9 Feb 96
941 KB
SSS 12 Feb 96

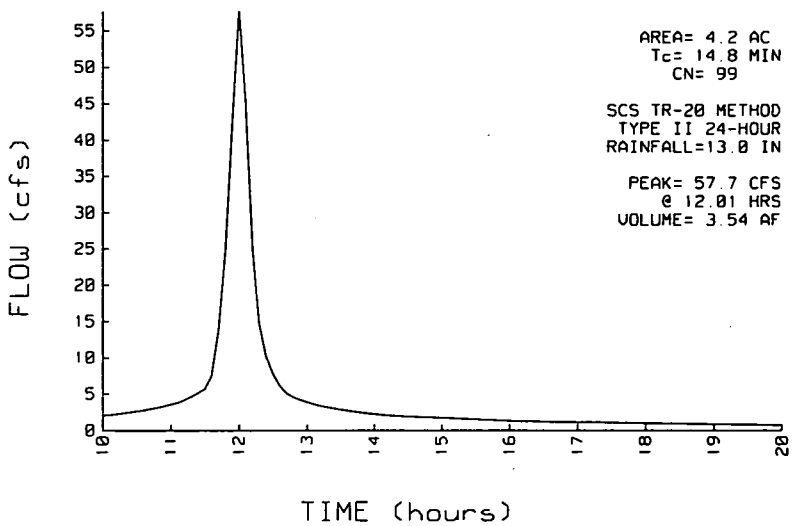
SUBCATCHMENT 9 **E-3**

ACRES	CN
4.20	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 57.7 CFS @ 12.01 HRS
VOLUME= 3.54 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=310' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	.9
a=332 sq-ft Pw=102' r=3.255'		
s=.005 '/' n=.03 V=7.69 fps L=405' Capacity=2554 cfs		
	Total Length= 862 ft Total Tc=	14.8

SUBCATCHMENT 9 RUNOFF
E-3



[redacted]

610

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 95
95/148
SSS 12 Feb94

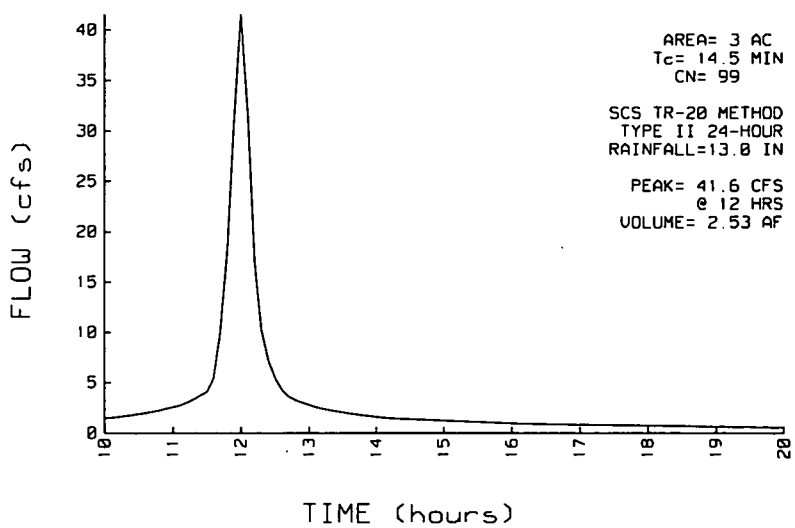
SUBCATCHMENT 10 **E-4**

ACRES	CN
3.00	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 41.6 CFS @ 12.00 HRS
VOLUME= 2.53 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=310' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	.6
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=290' Capacity=2692.4 cfs		
	Total Length= 747 ft Total Tc=	14.5

SUBCATCHMENT 10 RUNOFF
E-4



[redacted]

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

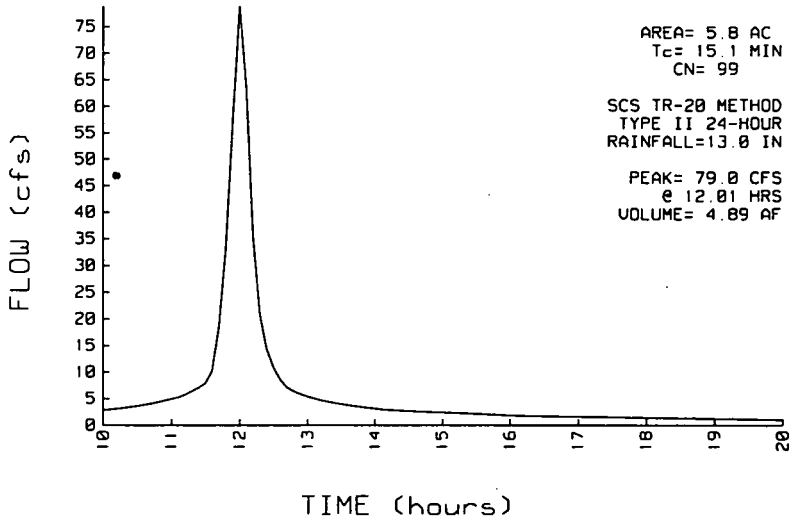
SUBCATCHMENT 11 **E-5**

ACRES	CN
5.80	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 79.0 CFS @ 12.01 HRS
VOLUME= 4.89 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=305' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.2
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=550' Capacity=2692.4 cfs		
	Total Length= 1002 ft Total Tc=	15.1

SUBCATCHMENT 11 RUNOFF
E-5



Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

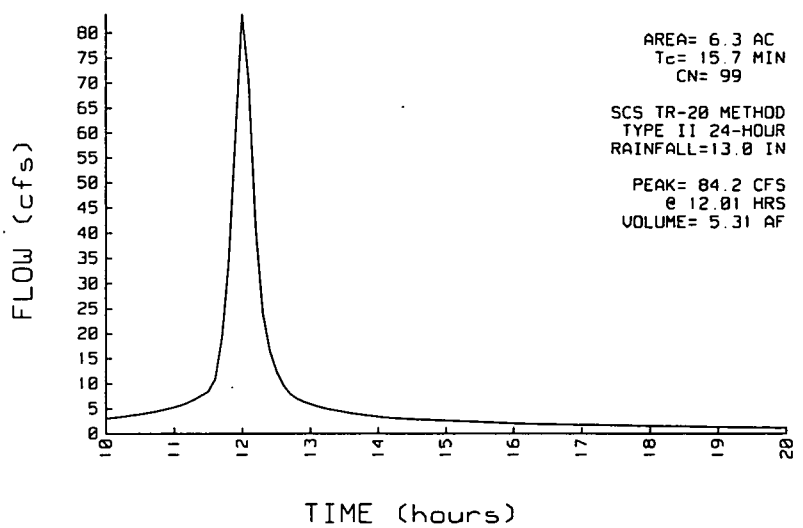
SUBCATCHMENT 12 **E-6**

ACRES	CN
6.30	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 84.2 CFS @ 12.01 HRS
VOLUME= 5.31 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=300' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.8
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.03 V=7.74 fps L=820' Capacity=2692.4 cfs		
	Total Length= 1267 ft Total Tc=	15.7

SUBCATCHMENT 12 RUNOFF
E-6



Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

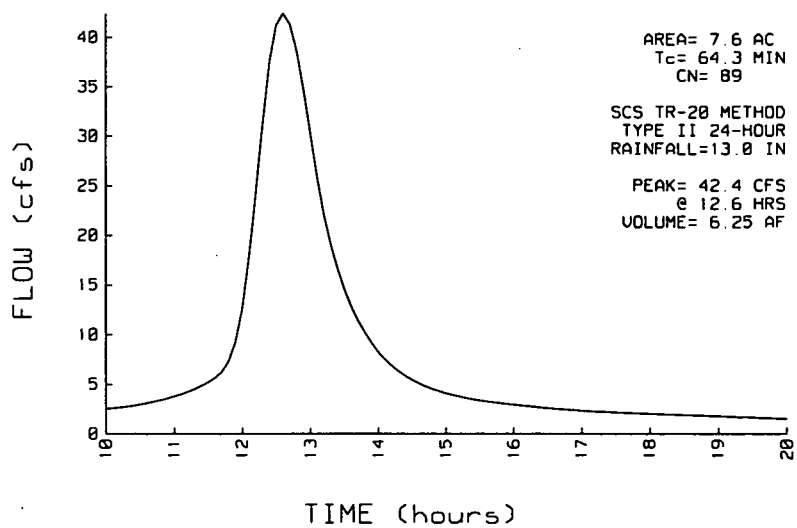
SUBCATCHMENT 1 **E-A**

ACRES	CN
7.60	89

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 42.4 CFS @ 12.60 HRS
VOLUME= 6.25 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	58.0
Grass: Dense n=.24 L=300' P2=2.6 in s=.007 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	2.9
Unpaved Kv=16.1345 L=320' s=.013 '/' V=1.84 fps		
CHANNEL FLOW	**Segment ID:**	3.4
a=272 sq-ft Pw=87' r=3.126'		
s=.005 '/' n=.1 V=2.25 fps L=465' Capacity=611.1 cfs		
	Total Length= 1085 ft Total Tc=	64.3

SUBCATCHMENT 1 RUNOFF
E-A



[redacted]

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

ASC 9 Feb 96 991148 SSS 12/6/99

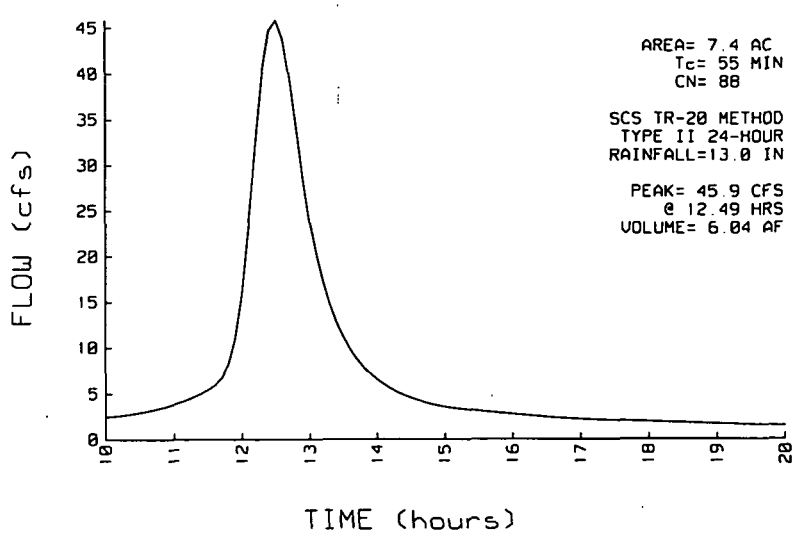
SUBCATCHMENT 2 **E-B**

ACRES	CN
7.40	88

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 45.9 CFS @ 12.49 HRS
VOLUME= 6.04 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	50.3
Grass: Dense n=.24 L=300' P2=2.6 in s=.01 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	4.5
Unpaved Kv=16.1345 L=615' s=.02 '/' V=2.28 fps		
CHANNEL FLOW	**Segment ID:**	.2
a=312 sq-ft Pw=97' r=3.216'		
s=.005 '/' n=.1 V=2.29 fps L=30' Capacity=714.4 cfs		
	Total Length= 945 ft Total Tc=	55.0

SUBCATCHMENT 2 RUNOFF
E-B



[redacted]

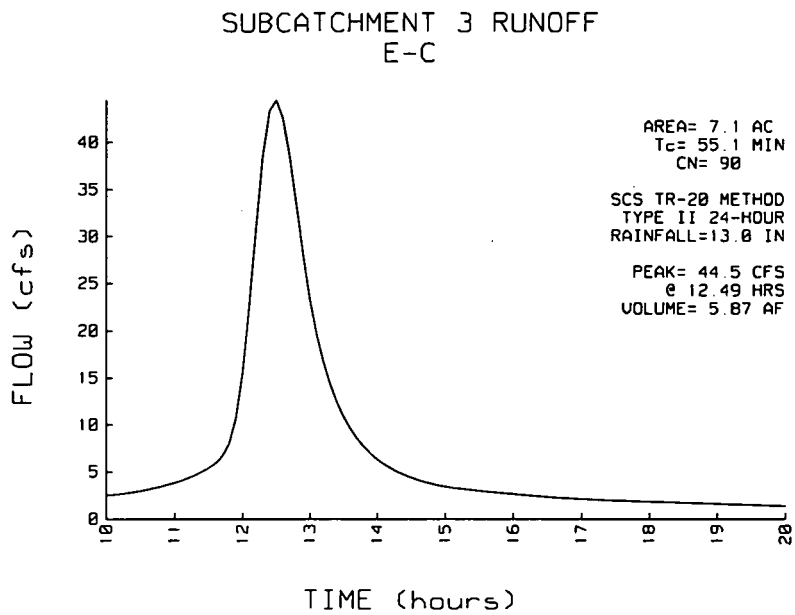
Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SUBCATCHMENT 3 **E-C**

ACRES	CN
7.10	90

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 44.5 CFS @ 12.49 HRS
VOLUME= 5.87 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW		50.3
Grass: Dense n=.24 L=300' P2=2.6 in s=.01 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	4.8
Unpaved Kv=16.1345 L=655' s=.02 '/' V=2.28 fps		
	Total Length= 955 ft Total Tc=	55.1



[redacted]

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

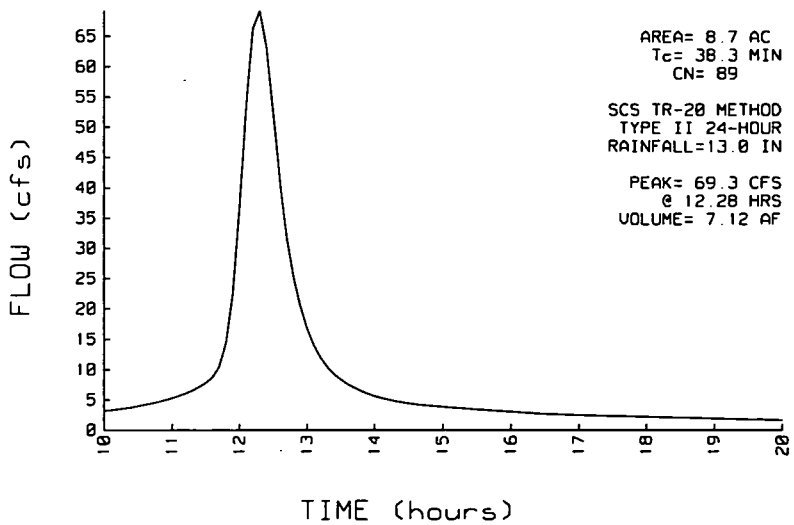
SUBCATCHMENT 4 **E-D**

ACRES	CN
8.70	89

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 69.3 CFS @ 12.28 HRS
VOLUME= 7.12 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	32.7
Grass: Dense n=.24 L=200' P2=2.6 in s=.013 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	5.4
Unpaved Kv=16.1345 L=735' s=.02 '/' V=2.28 fps		
CHANNEL FLOW	**Segment ID:**	.2
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.1 V=2.32 fps L=30' Capacity=807.7 cfs		
	Total Length= 965 ft Total Tc=	38.3

SUBCATCHMENT 4 RUNOFF
E-D



[redacted]
617

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

RSC - 9 Feb 96
1021/148
SSS 12 Feb 96

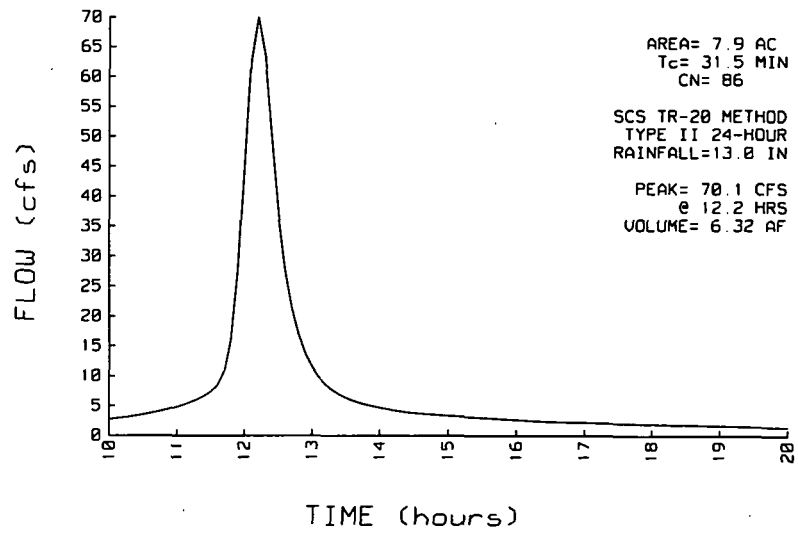
SUBCATCHMENT 5 **E-E**

ACRES	CN
7.90	86

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 70.1 CFS @ 12.20 HRS
VOLUME= 6.32 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	25.2
Grass: Dense n=.24 L=200' P2=2.6 in s=.025 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	5.4
Unpaved Kv=16.1345 L=735' s=.02 '/' V=2.28 fps		
CHANNEL FLOW	**Segment ID:**	.9
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.1 V=2.32 fps L=125' Capacity=807.7 cfs		
	Total Length= 1060 ft Total Tc=	31.5

SUBCATCHMENT 5 RUNOFF
E-E



[redacted]

618

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

ASC 739
9 Feb 96
103/148
SSS March 96

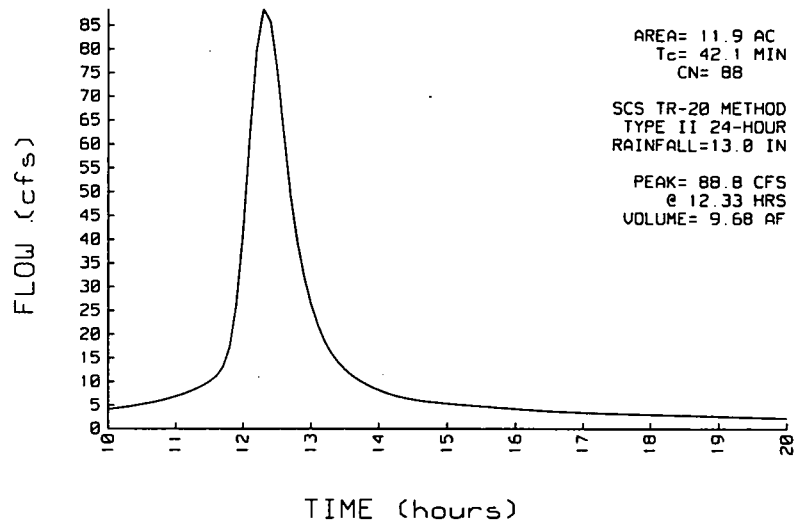
SUBCATCHMENT 6 **E-F**

ACRES	CN
11.90	88

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 88.8 CFS @ 12.33 HRS
VOLUME= 9.68 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	32.7
Grass: Dense n=.24 L=200' P2=2.6 in s=.013 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	3.8
Unpaved Kv=16.1345 L=475' s=.017 '/' V=2.1 fps		
CHANNEL FLOW	**Segment ID:**	5.6
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.1 V=2.32 fps L=785' Capacity=807.7 cfs		
	Total Length= 1460 ft Total Tc=	42.1

SUBCATCHMENT 6 RUNOFF
E-F



[redacted]
619

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

1041/148
SSS 12Feb96

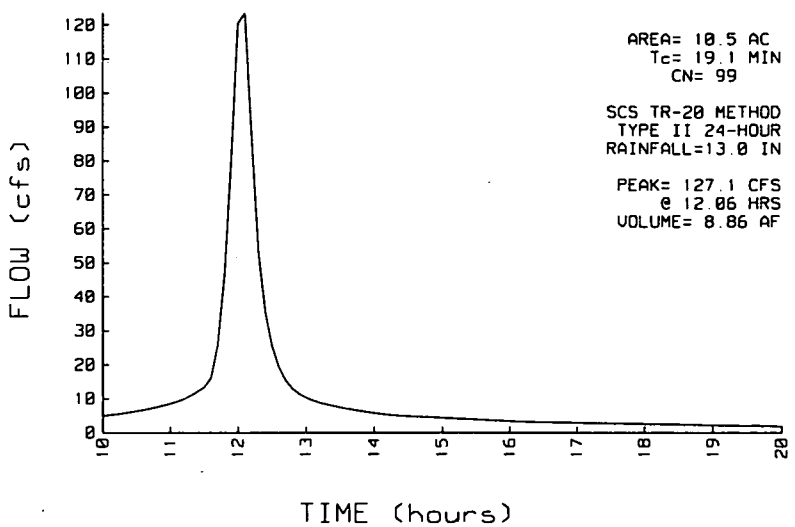
SUBCATCHMENT 7 **E-1**

ACRES	CN
10.50	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 127.1 CFS @ 12.06 HRS
VOLUME= 8.86 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=300' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	5.2
a=272 sq-ft Pw=87' r=3.126'		
s=.005 '/' n=.1 V=2.25 fps L=705' Capacity=611.1 cfs		
	Total Length= 1152 ft Total Tc=	19.1

SUBCATCHMENT 7 RUNOFF
E-1



[redacted]

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

105/148
RSS 12Feb96

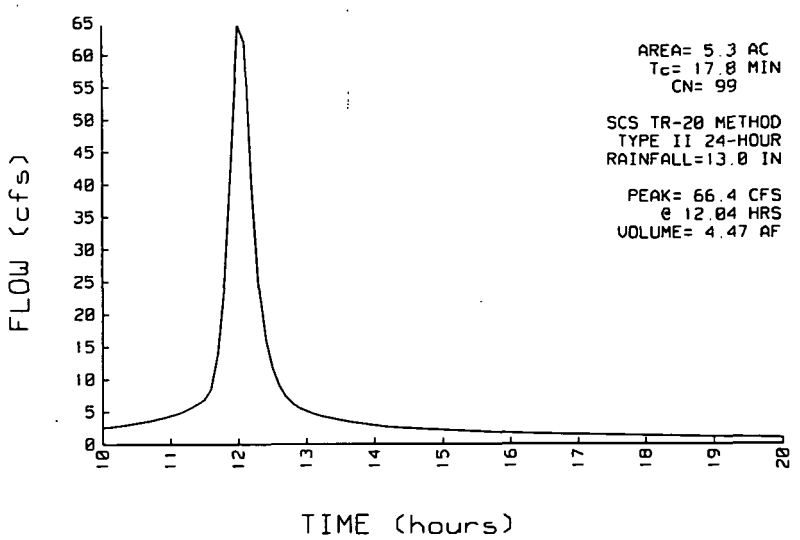
SUBCATCHMENT 8 **E-2**

ACRES	CN
5.30	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 66.4 CFS @ 12.04 HRS
VOLUME= 4.47 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=305' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	3.9
a=312 sq-ft Pw=97' r=3.216'		
s=.005 '/' n=.1 ~~V=2.~~29 fps L=540' Capacity=714.4 cfs		
	Total Length= 992 ft Total Tc=	17.8

SUBCATCHMENT 8 RUNOFF
E-2



[redacted]
621

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

Rsc. 106/148
SSS 12Feb96

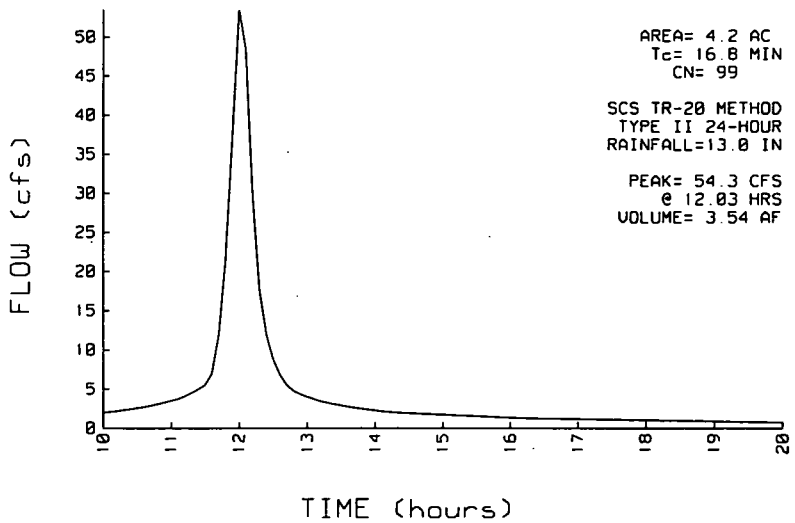
SUBCATCHMENT 9 **E-3**

ACRES	CN
4.20	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 54.3 CFS @ 12.03 HRS
VOLUME= 3.54 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=310' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	2.9
a=332 sq-ft Pw=102' r=3.255'		
s=.005 '/' n=.1 V=2.31 fps L=405' Capacity=766.2 cfs		
	Total Length= 862 ft Total Tc=	16.8

SUBCATCHMENT 9 RUNOFF
E-3



[redacted]

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

1071148
BSS 12Feb96

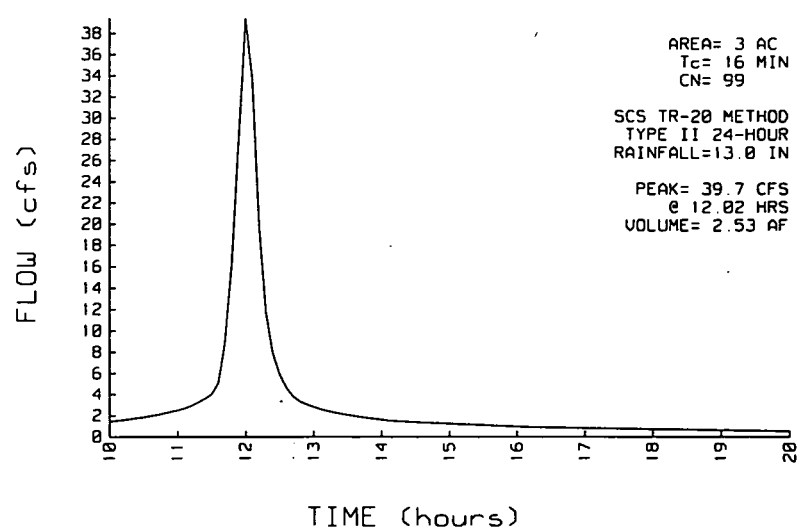
SUBCATCHMENT 10 **E-4**

ACRES	CN
3.00	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 39.7 CFS @ 12.02 HRS
VOLUME= 2.53 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=310' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	2.1
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.1 V=2.32 fps L=290' Capacity=807.7 cfs		
	Total Length= 747 ft Total Tc=	16.0

SUBCATCHMENT 10 RUNOFF
E-4



Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96
108/148
ASS 12Feb96

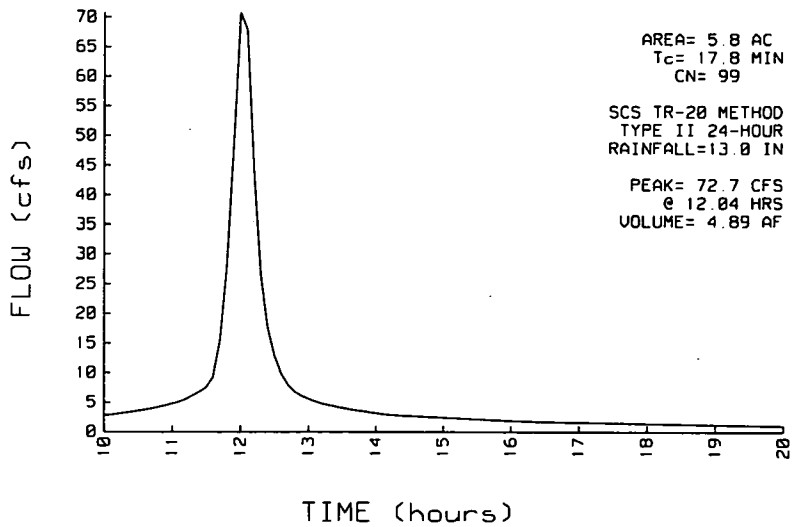
SUBCATCHMENT 11 **E-5**

ACRES	CN
5.80	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 72.7 CFS @ 12.04 HRS
VOLUME= 4.89 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=305' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	3.9
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.1 V=2.32 fps L=550' Capacity=807.7 cfs		
	Total Length= 1002 ft Total Tc=	17.8

SUBCATCHMENT 11 RUNOFF
E-5



[redacted]
624

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

109/148
SSS 12 Feb 96

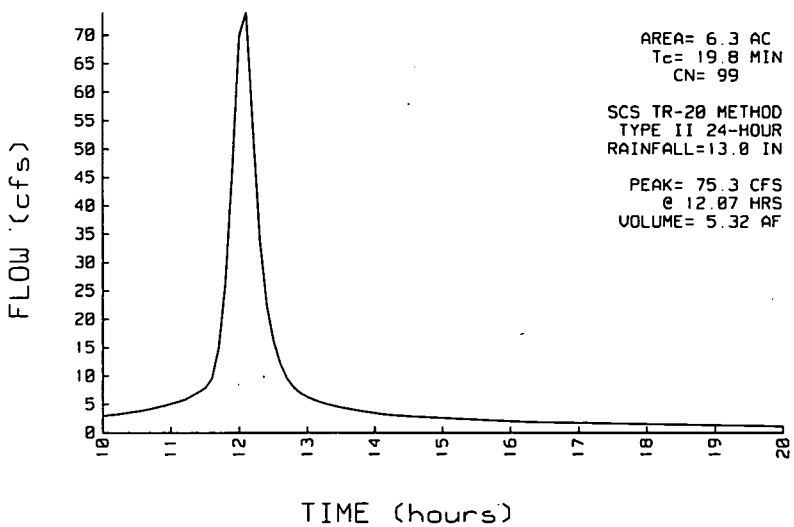
SUBCATCHMENT 12 **E-6**

ACRES	CN
6.30	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 75.3 CFS @ 12.07 HRS
VOLUME= 5.32 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=300' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	5.9
a=348 sq-ft Pw=106' r=3.283'		
s=.005 '/' n=.1 V=2.32 fps L=820' Capacity=807.7 cfs		
	Total Length= 1267 ft Total Tc=	19.8

SUBCATCHMENT 12 RUNOFF
E-6



[redacted]
625

739
100/148

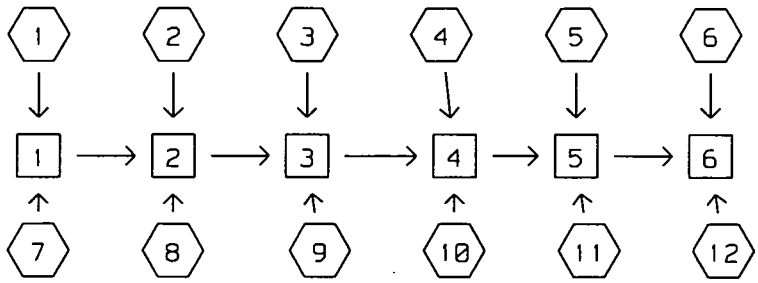
HYDROCAD™ RUNS

DRAINAGE CHANNEL ROUTING

[redacted]
626

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

WATERSHED ROUTING ==========



SUBCATCHMENT REACH POND LINK

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

LSC 9 Feb 96 112/148
SSS 12Feb96

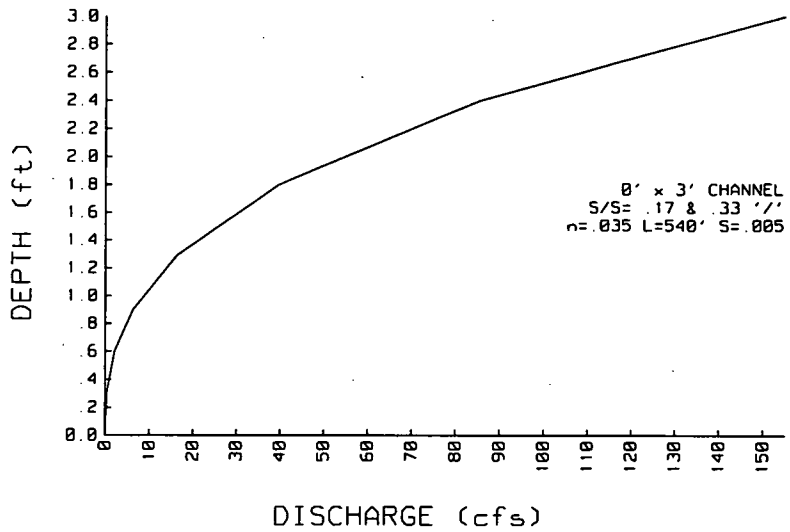
REACH 1 **POINT A**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.4	.3
.6	1.6	2.1
.9	3.6	6.2
1.3	7.4	16.3
1.8	14.4	39.7
2.4	25.7	85.5
3.0	40.1	155.0

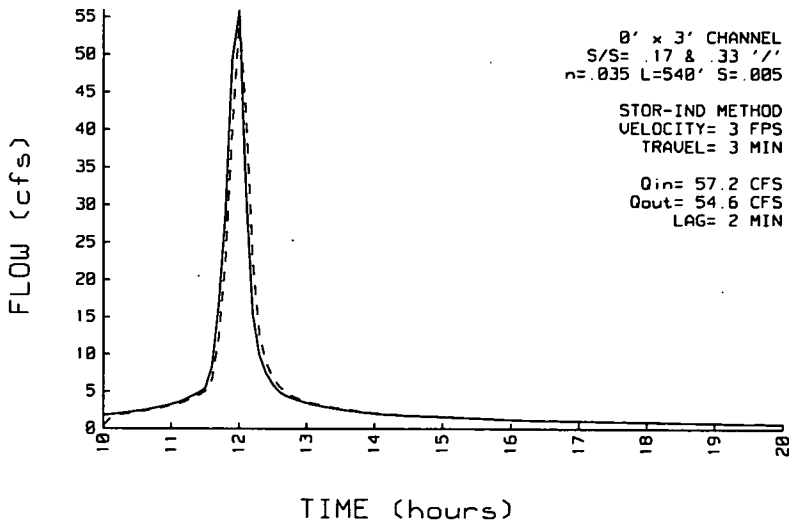
0' x 3' CHANNEL
S/S= .17 & .33 '/'
n= .035
LENGTH= 540 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.99 FT
PEAK VELOCITY= 3.0 FPS
TRAVEL TIME = 3.0 MIN
Qin = 57.2 CFS @ 11.97 HRS
Qout= 54.6 CFS @ 12.00 HRS
ATTEN= 5 % LAG= 2.0 MIN
IN/OUT= 3.25 / 3.24 AF

REACH 1 DISCHARGE
POINT A



REACH 1 INFLOW & OUTFLOW
POINT A



[redacted]

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

739
9 Feb 96
1131 148
SS 12Feb94

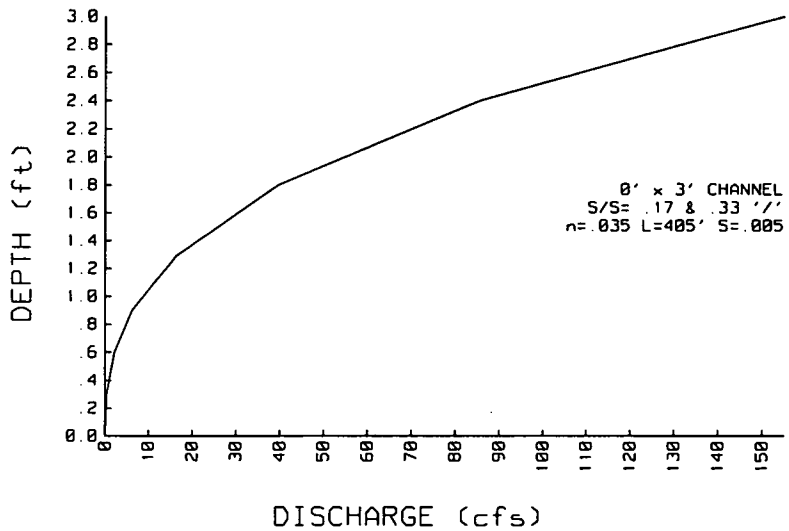
REACH 2 **POINT B**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.4	.3
.6	1.6	2.1
.9	3.6	6.2
1.3	7.4	16.3
1.8	14.4	39.7
2.4	25.7	85.5
3.0	40.1	155.0

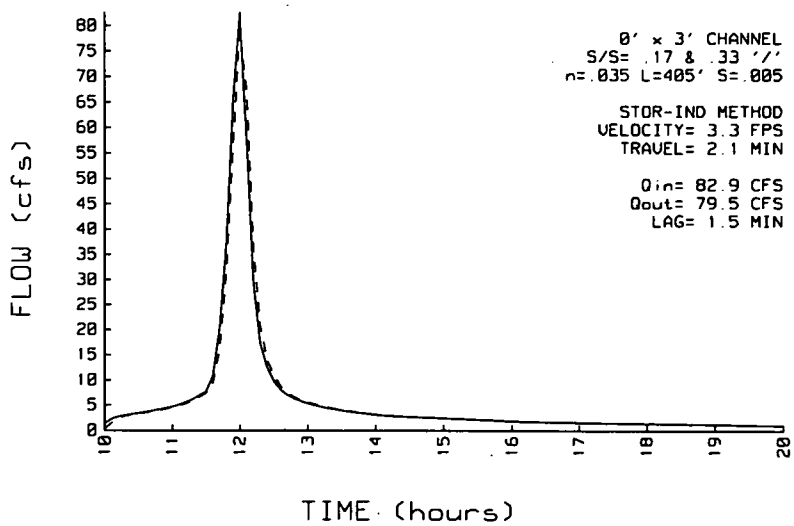
0' x 3' CHANNEL
S/S= .17 & .33 '/'
n= .035
LENGTH= 405 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.32 FT
PEAK VELOCITY= 3.3 FPS
TRAVEL TIME = 2.1 MIN
Qin = 82.9 CFS @ 11.99 HRS
Qout= 79.5 CFS @ 12.02 HRS
ATTEN= 4 % LAG= 1.5 MIN
IN/OUT= 4.88 / 4.87 AF

REACH 2 DISCHARGE
POINT B



REACH 2 INFLOW & OUTFLOW
POINT B



[redacted]
629

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 141/148

SS 12 Feb 96

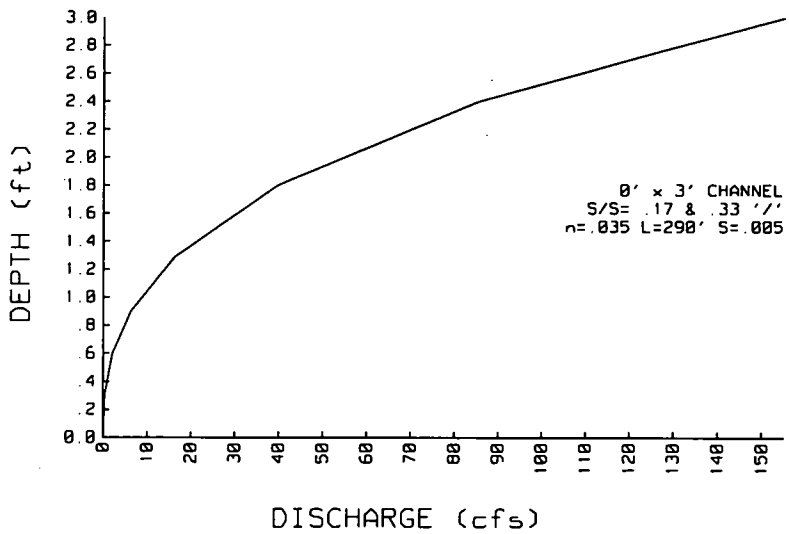
REACH 3 **POINT C**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.4	.3
.6	1.6	2.1
.9	3.6	6.2
1.3	7.4	16.3
1.8	14.4	39.7
2.4	25.7	85.5
3.0	40.1	155.0

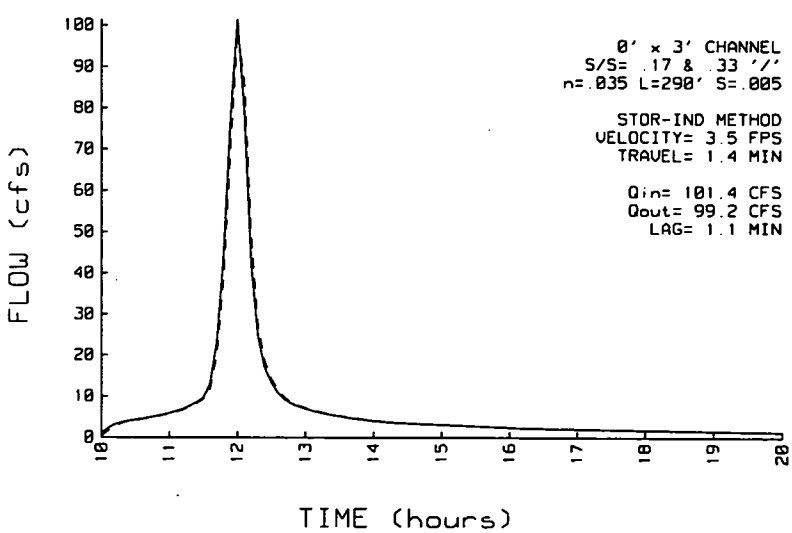
0' x 3' CHANNEL
S/S= .17 & .33 '/'
n= .035
LENGTH= 290 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.51 FT
PEAK VELOCITY= 3.5 FPS
TRAVEL TIME = 1.4 MIN
Qin = 101.4 CFS @ 12.00 HRS
Qout= 99.2 CFS @ 12.02 HRS
ATTEN= 2 % LAG= 1.1 MIN
IN/OUT= 6.19 / 6.18 AF

REACH 3 DISCHARGE
POINT C



REACH 3 INFLOW & OUTFLOW
POINT C



[redacted]
630

RSC 9 Feb 96

739

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 115/148

BSS 12 Feb 96

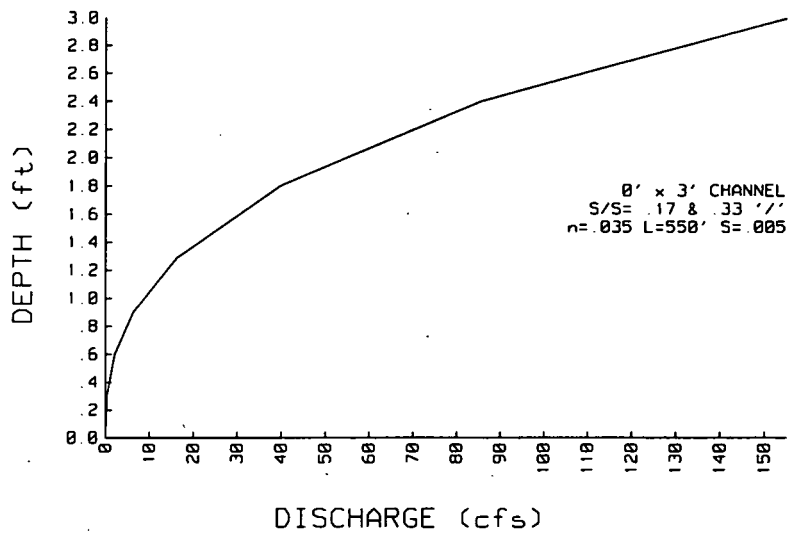
REACH 4 **POINT D**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.4	.3
.6	1.6	2.1
.9	3.6	6.2
1.3	7.4	16.3
1.8	14.4	39.7
2.4	25.7	85.5
3.0	40.1	155.0

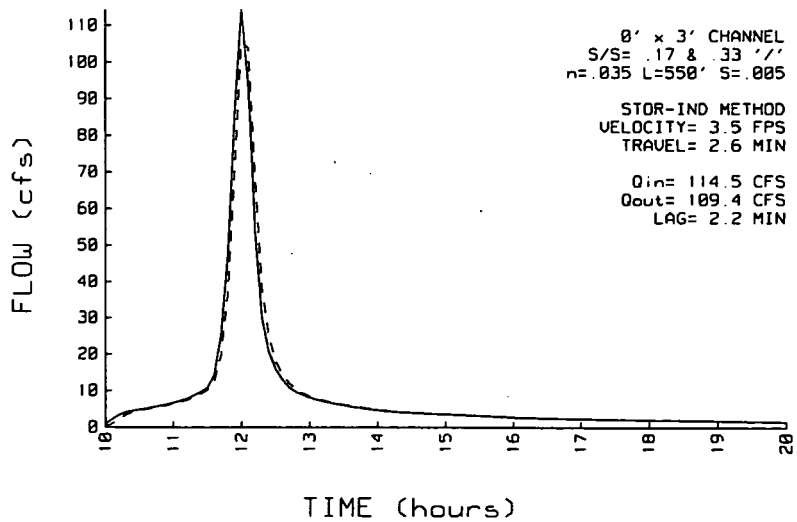
0' x 3' CHANNEL
S/S= .17 & .33 '/'
n= .035
LENGTH= 550 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.57 FT
PEAK VELOCITY= 3.5 FPS
TRAVEL TIME = 2.6 MIN
Qin = 114.5 CFS @ 12.01 HRS
Qout= 109.4 CFS @ 12.05 HRS
ATTEN= 4 % LAG= 2.2 MIN
IN/OUT= 7.12 / 7.11 AF

REACH 4 DISCHARGE
POINT D



REACH 4 INFLOW & OUTFLOW
POINT D



[redacted]

631

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

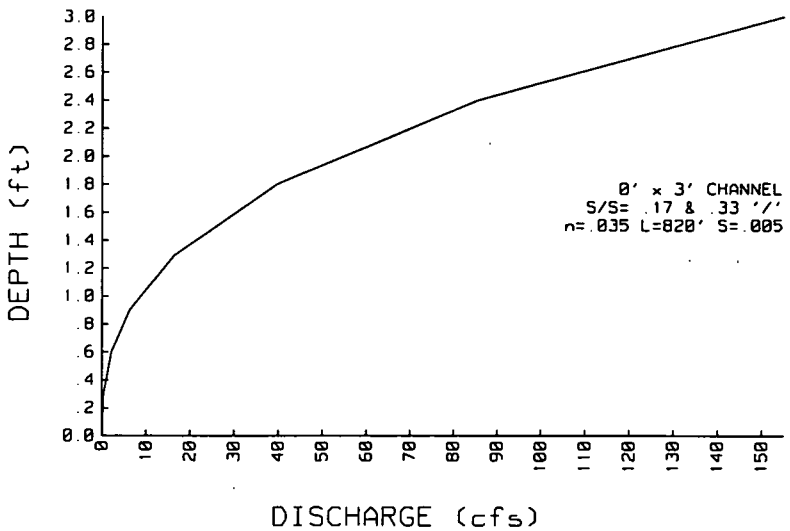
REACH 5

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.4	.3
.6	1.6	2.1
.9	3.6	6.2
1.3	7.4	16.3
1.8	14.4	39.7
2.4	25.7	85.5
3.0	40.1	155.0

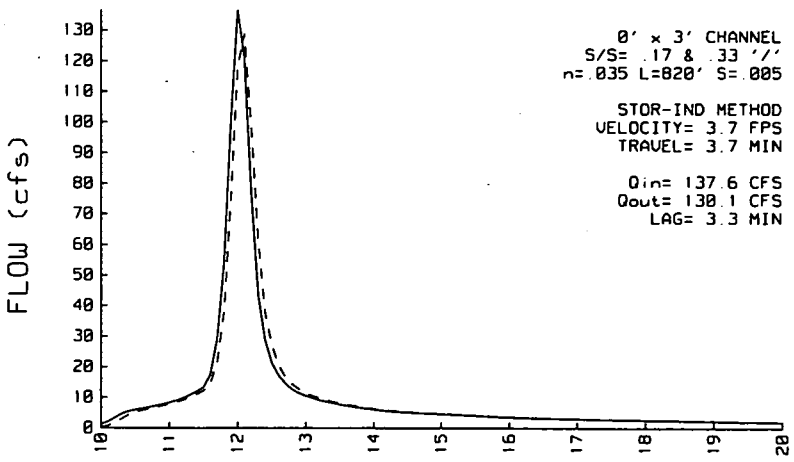
0' x 3' CHANNEL
S/S= .17 & .33 '/'
n= .035
LENGTH= 820 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.77 FT
PEAK VELOCITY= 3.7 FPS
TRAVEL TIME = 3.7 MIN
Qin = 137.6 CFS @ 12.02 HRS
Qout= 130.1 CFS @ 12.08 HRS
ATTEN= 5 % LAG= 3.3 MIN
IN/OUT= 8.93 / 8.90 AF

REACH 5 DISCHARGE



REACH 5 INFLOW & OUTFLOW



[redacted]

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

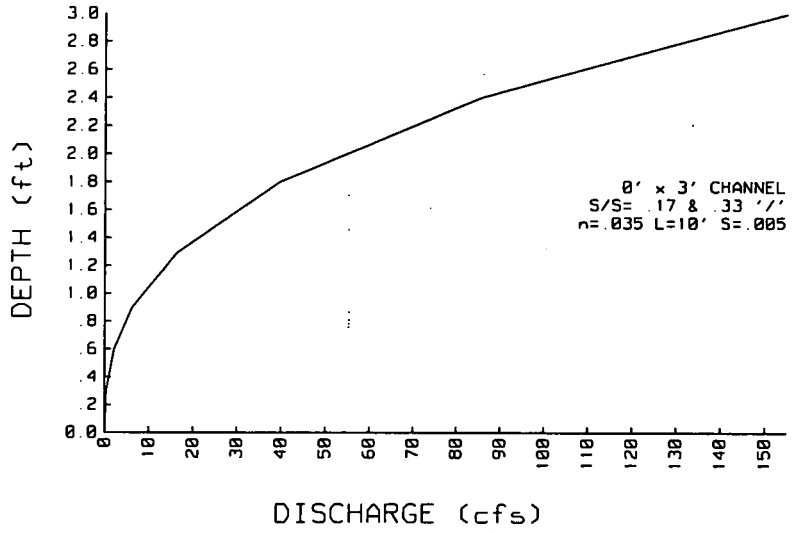
REACH 6 **POINT E**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.4	.3
.6	1.6	2.1
.9	3.6	6.2
1.3	7.4	16.3
1.8	14.4	39.7
2.4	25.7	85.5
3.0	40.1	155.0

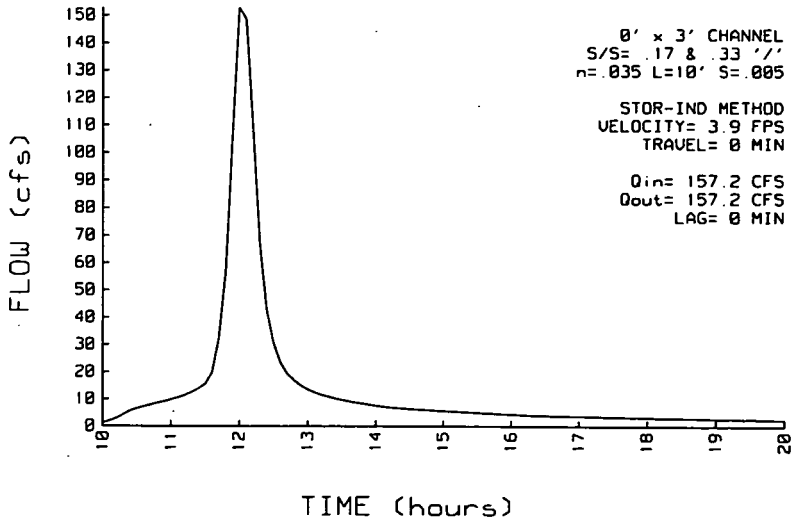
0' x 3' CHANNEL
S/S= .17 & .33 '/'
n= .035
LENGTH= 10 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.98 FT
PEAK VELOCITY= 3.9 FPS
TRAVEL TIME = 0.0 MIN
Qin = 157.2 CFS @ 12.04 HRS
Qout= 157.2 CFS @ 12.04 HRS
ATTEN= 0 % LAG= 0.0 MIN
IN/OUT= 10.96 / 10.96 AF

REACH 6 DISCHARGE
POINT E



REACH 6 INFLOW & OUTFLOW
POINT E



[redacted]

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER** 739
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 118/148
SSS 12 Feb 96

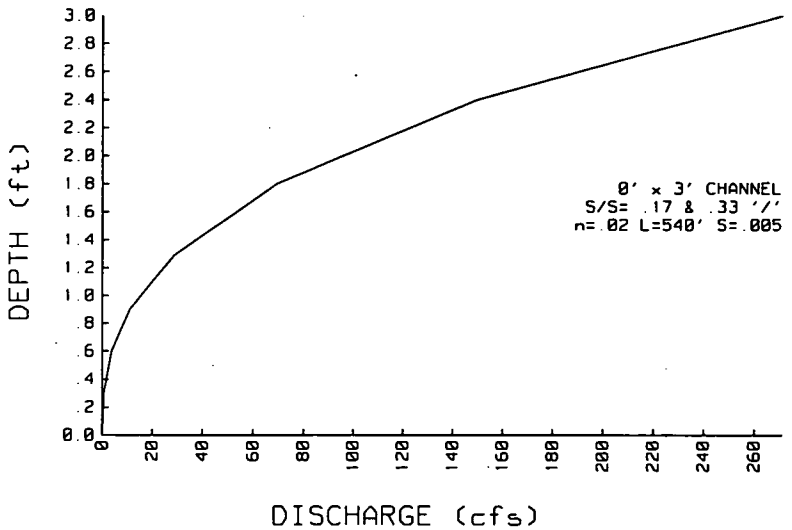
REACH 1 **POINT A**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.4	.6
.6	1.6	3.7
.9	3.6	10.9
1.3	7.4	28.6
1.8	14.4	69.4
2.4	25.7	149.6
3.0	40.1	271.2

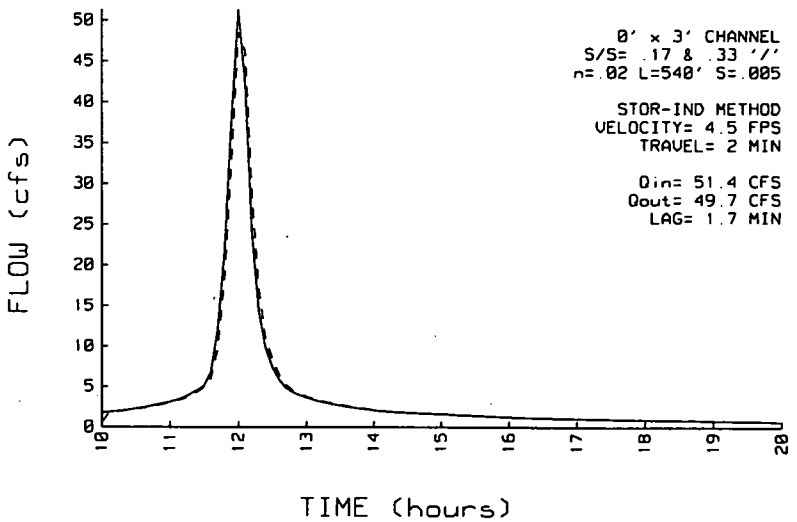
0' x 3' CHANNEL
S/S= .17 & .33 '/'
n= .02
LENGTH= 540 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.54 FT
PEAK VELOCITY= 4.5 FPS
TRAVEL TIME = 2.0 MIN
Qin = 51.4 CFS @ 12.01 HRS
Qout= 49.7 CFS @ 12.04 HRS
ATTEN= 3 % LAG= 1.7 MIN
IN/OUT= 3.26 / 3.25 AF

REACH 1 DISCHARGE
POINT A



REACH 1 INFLOW & OUTFLOW
POINT A



[redacted]
634

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 119/148

SSS 12 Feb 96

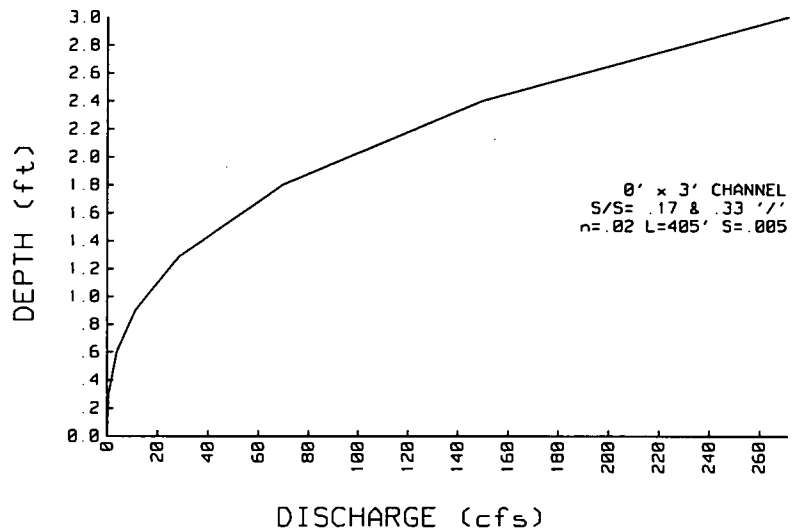
REACH 2 **POINT B**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.4	.6
.6	1.6	3.7
.9	3.6	10.9
1.3	7.4	28.6
1.8	14.4	69.4
2.4	25.7	149.6
3.0	40.1	271.2

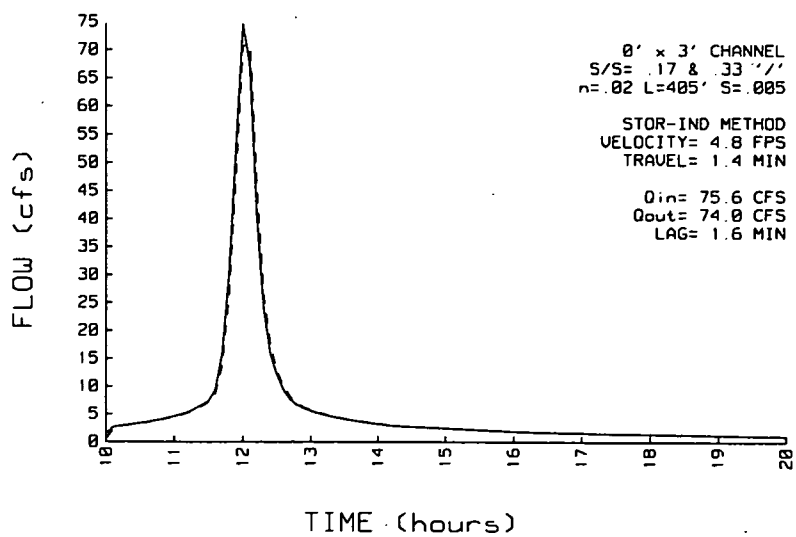
0' x 3' CHANNEL
S/S= .17 & .33 '/'
n= .02
LENGTH= 405 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.81 FT
PEAK VELOCITY= 4.8 FPS
TRAVEL TIME = 1.4 MIN
Qin = 75.6 CFS @ 12.02 HRS
Qout= 74.0 CFS @ 12.05 HRS
ATTEN= 2 % LAG= 1.6 MIN
IN/OUT= 4.89 / 4.88 AF

REACH 2 DISCHARGE
POINT B



REACH 2 INFLOW & OUTFLOW
POINT B



[redacted]

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 120/148
SSS 12 Feb 96

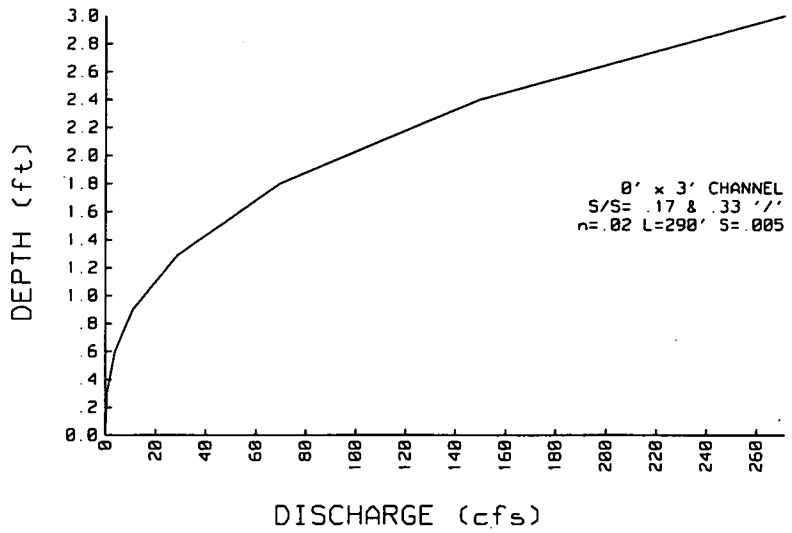
REACH 3 **POINT C**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.4	.6
.6	1.6	3.7
.9	3.6	10.9
1.3	7.4	28.6
1.8	14.4	69.4
2.4	25.7	149.6
3.0	40.1	271.2

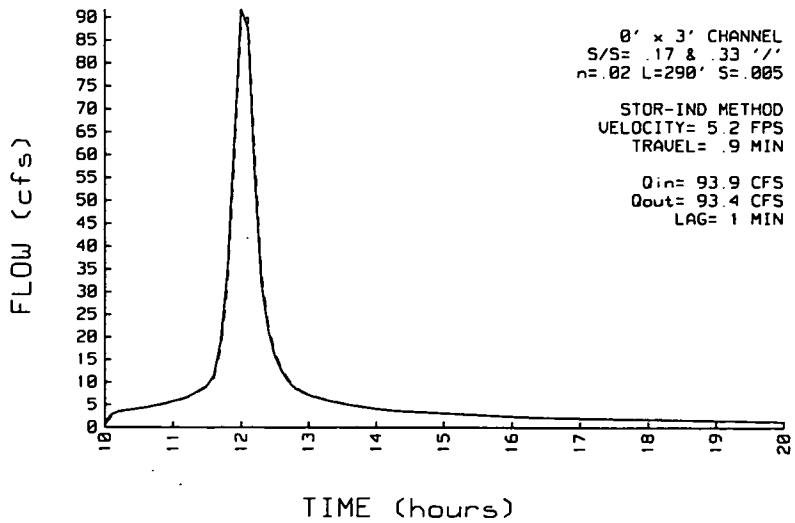
0' x 3' CHANNEL
S/S= .17 & .33 '/'
n= .02
LENGTH= 290 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.95 FT
PEAK VELOCITY= 5.2 FPS
TRAVEL TIME = .9 MIN
Qin = 93.9 CFS @ 12.04 HRS
Qout= 93.4 CFS @ 12.05 HRS
ATTEN= 1 % LAG= 1.0 MIN
IN/OUT= 6.21 / 6.20 AF

REACH 3 DISCHARGE
POINT C



REACH 3 INFLOW & OUTFLOW
POINT C



[redacted]

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

739

9 Feb 96

121/148

SSS 12 Feb 96

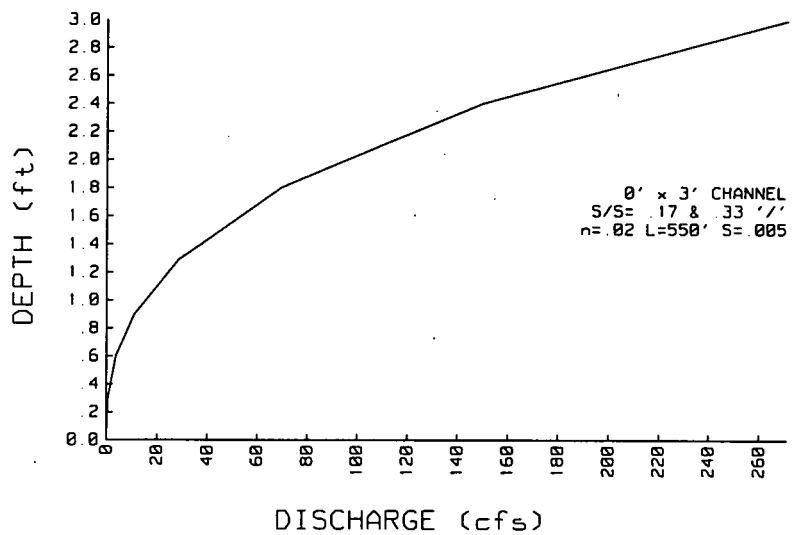
REACH 4 **POINT D**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.4	.6
.6	1.6	3.7
.9	3.6	10.9
1.3	7.4	28.6
1.8	14.4	69.4
2.4	25.7	149.6
3.0	40.1	271.2

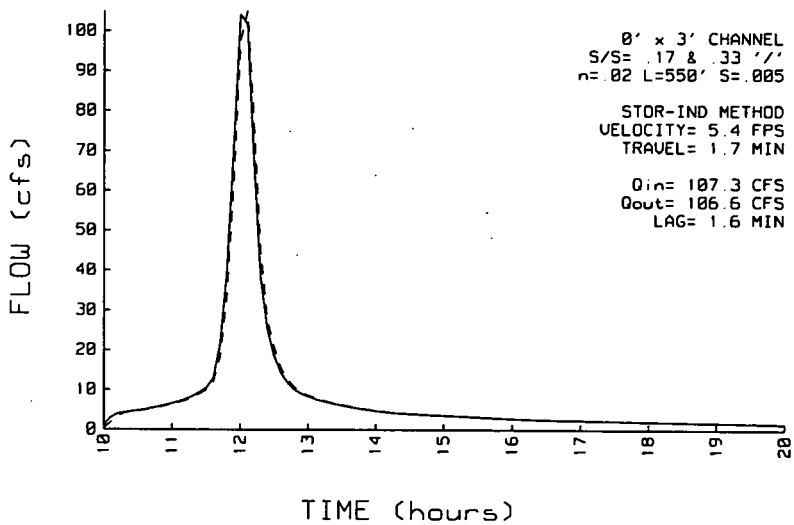
0' x 3' CHANNEL
S/S= .17 & .33 '/'
n= .02
LENGTH= 550 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.07 FT
PEAK VELOCITY= 5.4 FPS
TRAVEL TIME = 1.7 MIN
Qin = 107.3 CFS @ 12.04 HRS
Qout= 106.6 CFS @ 12.07 HRS
ATTEN= 1 % LAG= 1.6 MIN
IN/OUT= 7.14 / 7.13 AF

REACH 4 DISCHARGE
POINT D



REACH 4 INFLOW & OUTFLOW
POINT D



[redacted]

637

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

ASC: 122/148
SSS 12Feb96

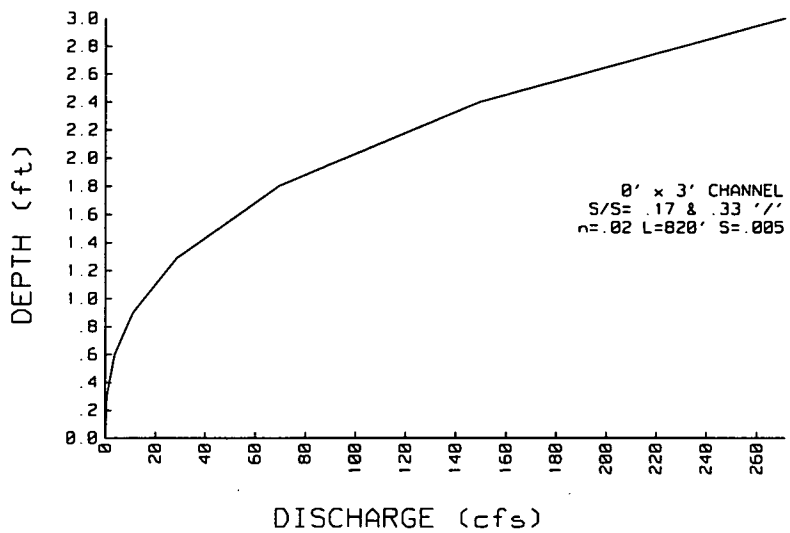
REACH 5

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.4	.6
.6	1.6	3.7
.9	3.6	10.9
1.3	7.4	28.6
1.8	14.4	69.4
2.4	25.7	149.6
3.0	40.1	271.2

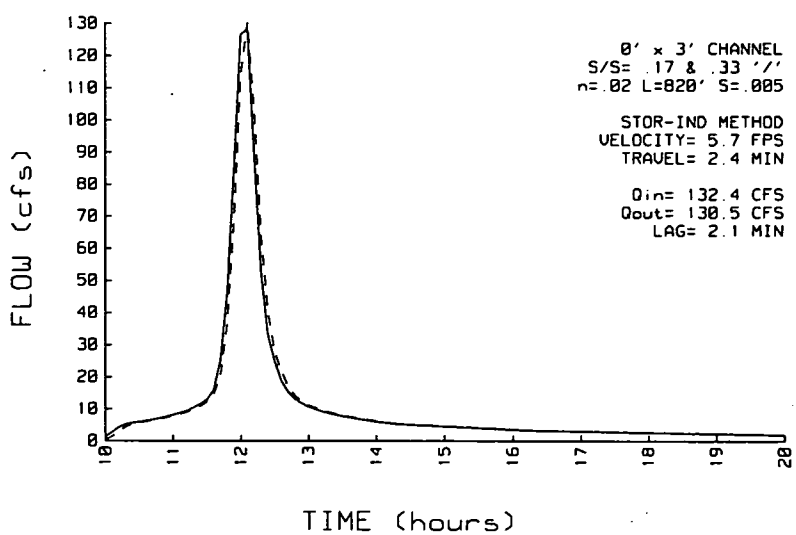
0' x 3' CHANNEL
S/S= .17 & .33 '/'
n= .02
LENGTH= 820 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.26 FT
PEAK VELOCITY= 5.7 FPS
TRAVEL TIME = 2.4 MIN
Qin = 132.4 CFS @ 12.05 HRS
Qout= 130.5 CFS @ 12.09 HRS
ATTEN= 1 % LAG= 2.1 MIN
IN/OUT= 8.96 / 8.94 AF

REACH 5 DISCHARGE



REACH 5 INFLOW & OUTFLOW



[redacted]
638

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 123/148

SSS 12/26/96

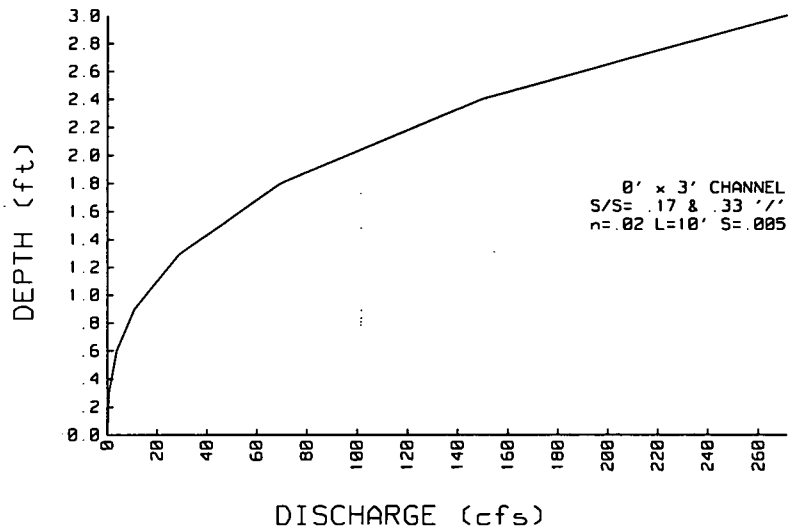
REACH 6 **POINT E**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.4	.6
.6	1.6	3.7
.9	3.6	10.9
1.3	7.4	28.6
1.8	14.4	69.4
2.4	25.7	149.6
3.0	40.1	271.2

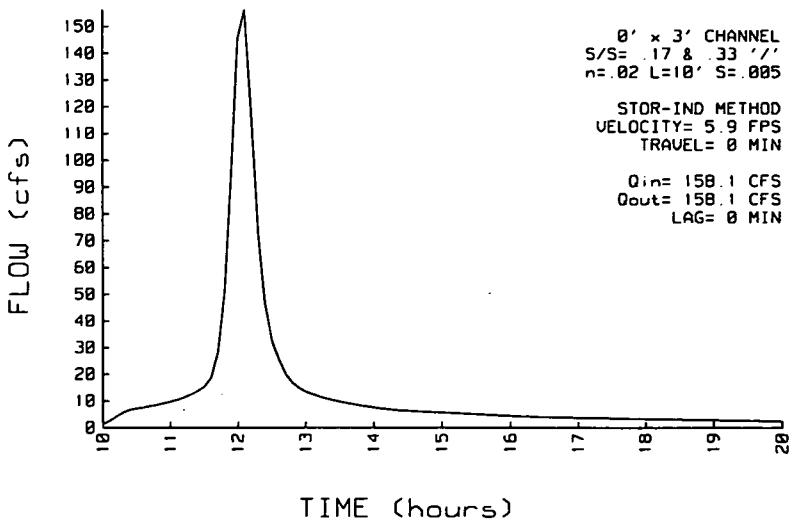
0' x 3' CHANNEL
S/S= .17 & .33 '/'
n= .02
LENGTH= 10 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.43 FT
PEAK VELOCITY= 5.9 FPS
TRAVEL TIME = 0.0 MIN
Qin = 158.1 CFS @ 12.07 HRS
Qout= 158.1 CFS @ 12.07 HRS
ATTEN= 0 % LAG= 0.0 MIN
IN/OUT= 11.01 / 11.01 AF

REACH 6 DISCHARGE
POINT E



REACH 6 INFLOW & OUTFLOW
POINT E



[redacted]

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 124/148

SSS 12Feb96

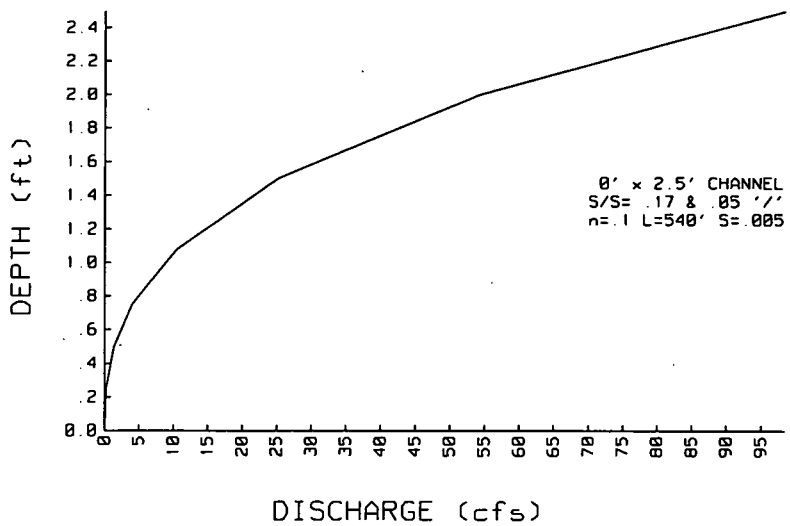
REACH 1 **POINT A**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.8	.2
.5	3.2	1.3
.8	7.3	4.0
1.1	15.0	10.4
1.5	29.1	25.2
2.0	51.8	54.2
2.5	80.9	98.3

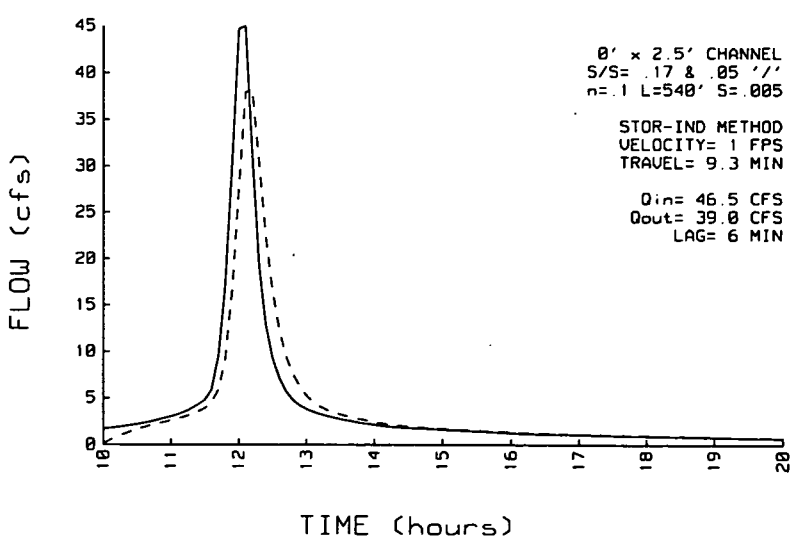
0' x 2.5' CHANNEL
S/S= .17 & .05 '/'
n= .1
LENGTH= 540 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.72 FT
PEAK VELOCITY= 1.0 FPS
TRAVEL TIME = 9.3 MIN
Qin = 46.5 CFS @ 12.05 HRS
Qout= 39.0 CFS @ 12.15 HRS
ATTEN= 16 % LAG= 6.0 MIN
IN/OUT= 3.26 / 3.24 AF

REACH 1 DISCHARGE
POINT A



REACH 1 INFLOW & OUTFLOW
POINT A



[redacted]

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 125/148

SSS 12Feb96

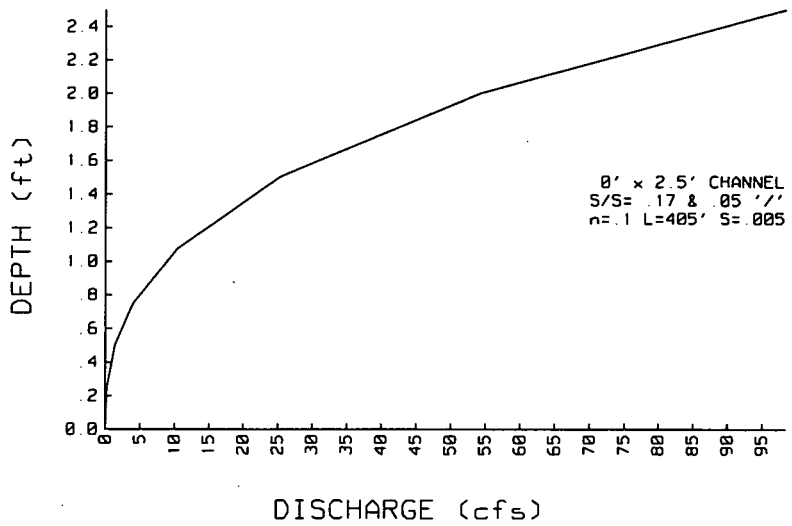
REACH 2 **POINT B**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.8	.2
.5	3.2	1.3
.8	7.3	4.0
1.1	15.0	10.4
1.5	29.1	25.2
2.0	51.8	54.2
2.5	80.9	98.3

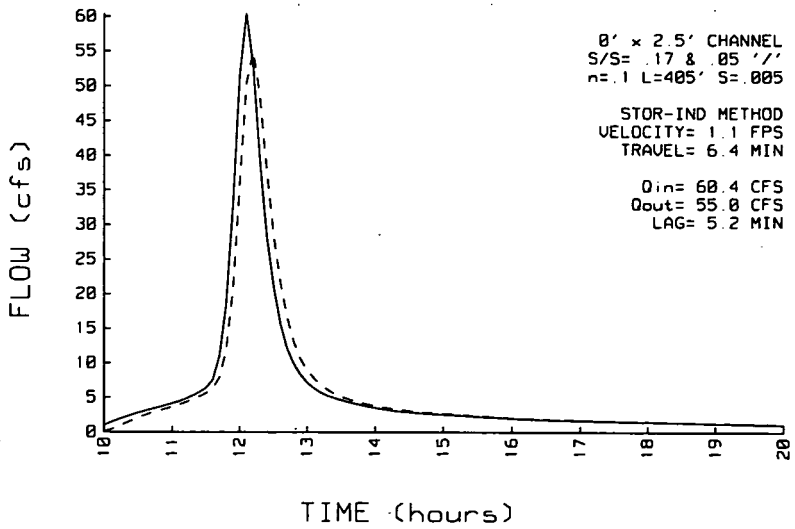
0' x 2.5' CHANNEL
S/S= .17 & .05 '/'
n= .1
LENGTH= 405 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.01 FT
PEAK VELOCITY= 1.1 FPS
TRAVEL TIME = 6.4 MIN
Qin = 60.4 CFS @ 12.10 HRS
Qout= 55.0 CFS @ 12.19 HRS
ATTEN= 9 % LAG= 5.2 MIN
IN/OUT= 4.88 / 4.85 AF

REACH 2 DISCHARGE
POINT B



REACH 2 INFLOW & OUTFLOW
POINT B



[redacted]
641

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

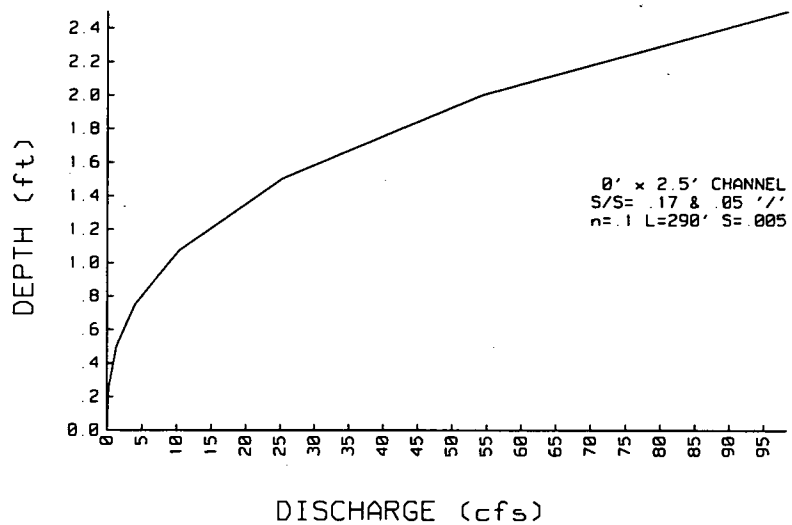
REACH 3 **POINT C**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.8	.2
.5	3.2	1.3
.8	7.3	4.0
1.1	15.0	10.4
1.5	29.1	25.2
2.0	51.8	54.2
2.5	80.9	98.3

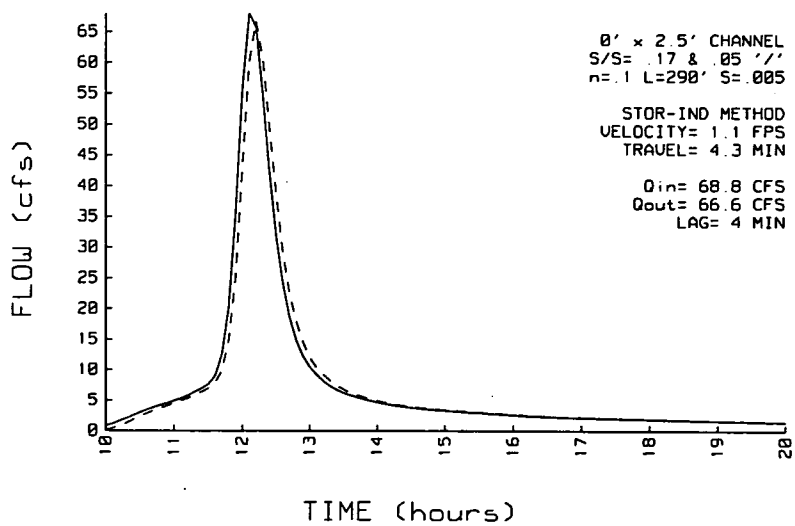
0' x 2.5' CHANNEL
S/S= .17 & .05 '/'
n= .1
LENGTH= 290 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.14 FT
PEAK VELOCITY= 1.1 FPS
TRAVEL TIME = 4.3 MIN
Qin = 68.8 CFS @ 12.14 HRS
Qout= 66.6 CFS @ 12.20 HRS
ATTEN= 3 % LAG= 4.0 MIN
IN/OUT= 6.17 / 6.15 AF

REACH 3 DISCHARGE
POINT C



REACH 3 INFLOW & OUTFLOW
POINT C



[redacted]
642

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems 127/148

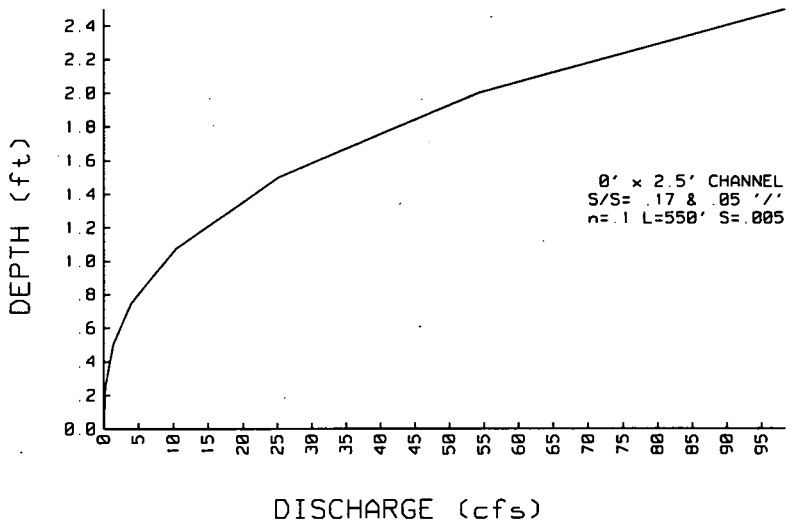
REACH 4 **POINT D**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.8	.2
.5	3.2	1.3
.8	7.3	4.0
1.1	15.0	10.4
1.5	29.1	25.2
2.0	51.8	54.2
2.5	80.9	98.3

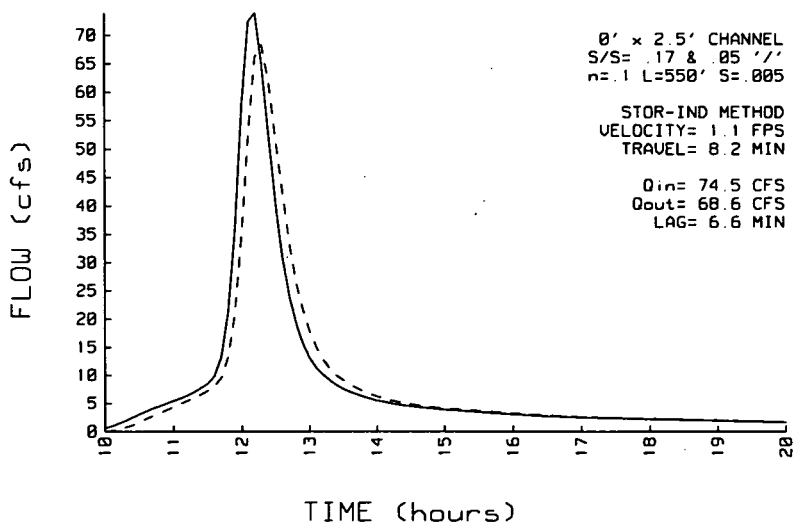
0' x 2.5' CHANNEL
S/S= .17 & .05 '/'
n= .1
LENGTH= 550 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.16 FT
PEAK VELOCITY= 1.1 FPS
TRAVEL TIME = 8.2 MIN
Qin = 74.5 CFS @ 12.16 HRS
Qout= 68.6 CFS @ 12.27 HRS
ATTEN= 8 % LAG= 6.6 MIN
IN/OUT= 7.09 / 7.05 AF

REACH 4 DISCHARGE
POINT D



REACH 4 INFLOW & OUTFLOW
POINT D



[redacted]

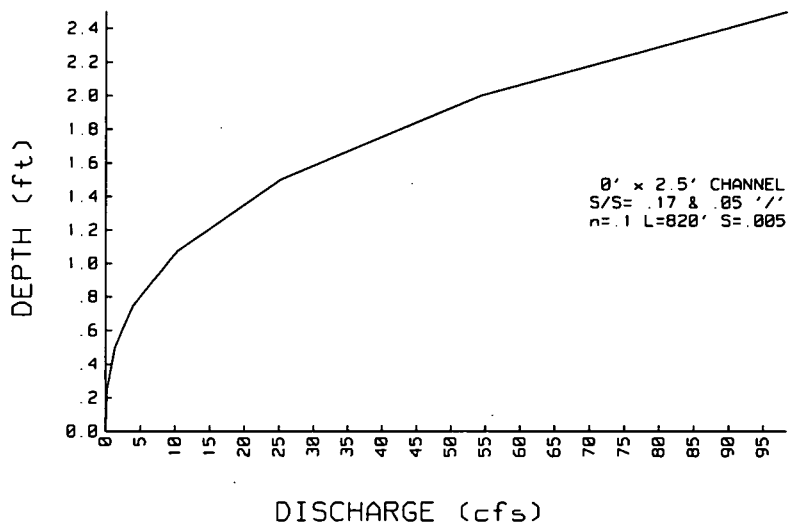
REACH 5

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.8	.2
.5	3.2	1.3
.8	7.3	4.0
1.1	15.0	10.4
1.5	29.1	25.2
2.0	51.8	54.2
2.5	80.9	98.3

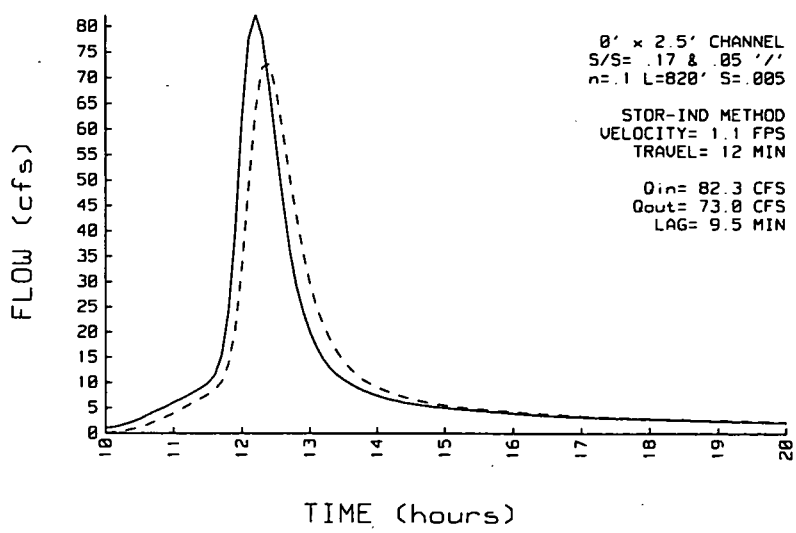
0' x 2.5' CHANNEL
S/S= .17 & .05 '/'
n= .1
LENGTH= 820 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.21 FT
PEAK VELOCITY= 1.1 FPS
TRAVEL TIME = 12.0 MIN
Qin = 82.3 CFS @ 12.20 HRS
Qout= 73.0 CFS @ 12.36 HRS
ATTEN= 11 % LAG= 9.5 MIN
IN/OUT= 8.87 / 8.78 AF

REACH 5 DISCHARGE



REACH 5 INFLOW & OUTFLOW



[redacted]
644

Data for **FERMCO, EAST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

739
9 Feb 96
129/148
RSS 12 Feb 96

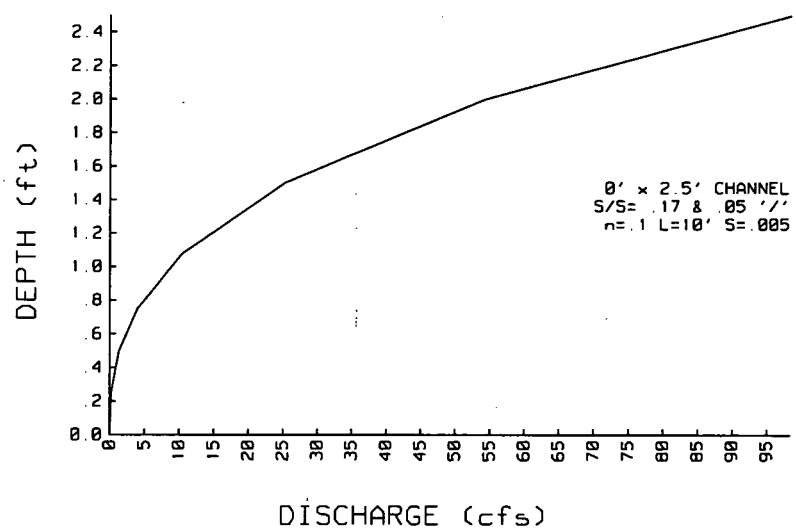
REACH 6 **POINT E**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.3	.8	.2
.5	3.2	1.3
.8	7.3	4.0
1.1	15.0	10.4
1.5	29.1	25.2
2.0	51.8	54.2
2.5	80.9	98.3

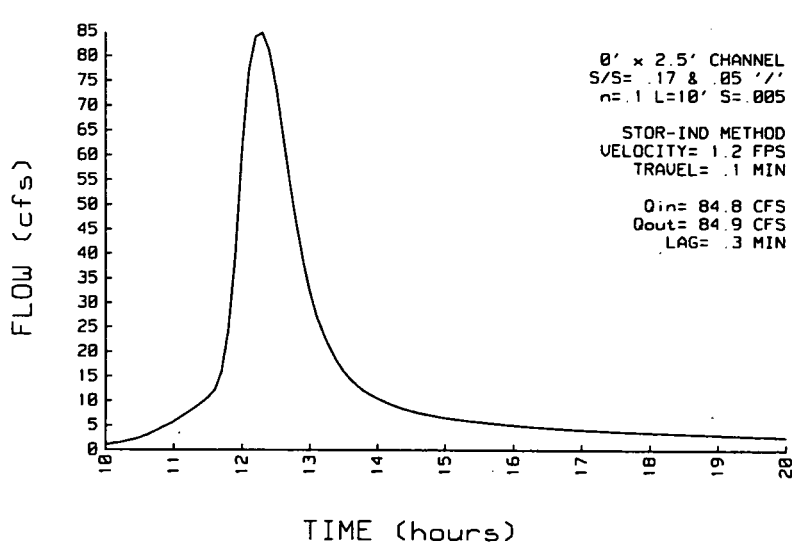
0' x 2.5' CHANNEL
S/S= .17 & .05 '/'
n= .1
LENGTH= 10 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.35 FT
PEAK VELOCITY= 1.2 FPS
TRAVEL TIME = .1 MIN
Qin = 84.8 CFS @ 12.27 HRS
Qout= 84.9 CFS @ 12.27 HRS
ATTEN= 0 % LAG= .3 MIN
IN/OUT= 10.86 / 10.86 AF

REACH 6 DISCHARGE
POINT E

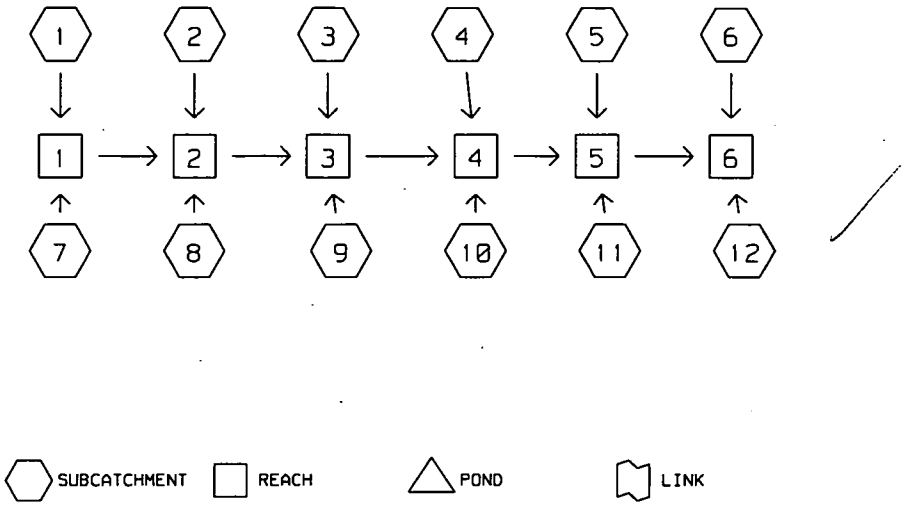


REACH 6 INFLOW & OUTFLOW
POINT E



[redacted]
645

WATERSHED ROUTING ==========



Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

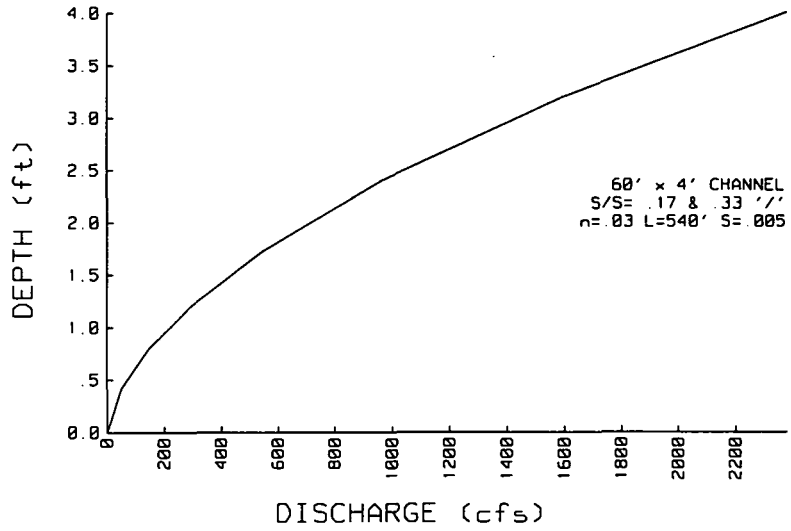
REACH 1 **POINT A**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	24.7	46.1
.8	50.9	147.7
1.2	78.4	293.5
1.7	116.4	542.8
2.4	169.7	965.1
3.2	237.6	1598.2
4.0	311.3	2378.3

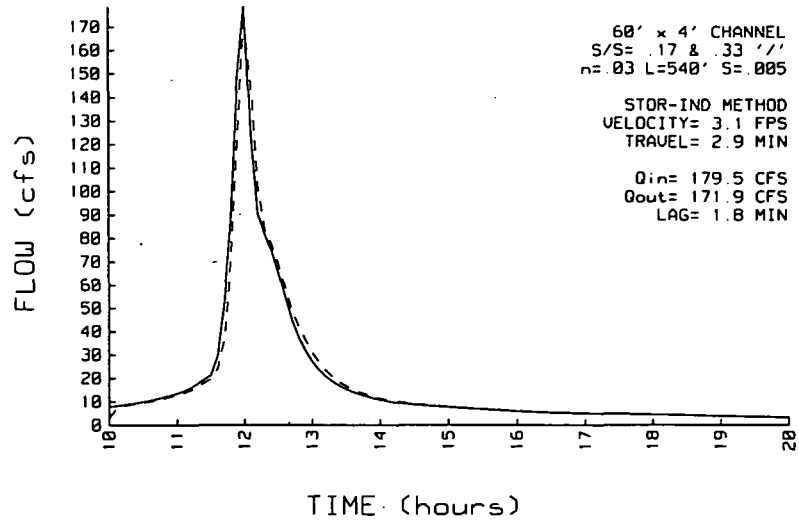
60' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 540 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= .86 FT
PEAK VELOCITY= 3.1 FPS
TRAVEL TIME = 2.9 MIN
Qin = 179.5 CFS @ 11.99 HRS
Qout= 171.9 CFS @ 12.02 HRS
ATTEN= 4 % LAG= 1.8 MIN
IN/OUT= 15.06 / 15.04 AF

REACH 1 DISCHARGE
POINT A



REACH 1 INFLOW & OUTFLOW
POINT A



[redacted]
643

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

LSC
9 Feb 96
132/148
SS 12/6/94

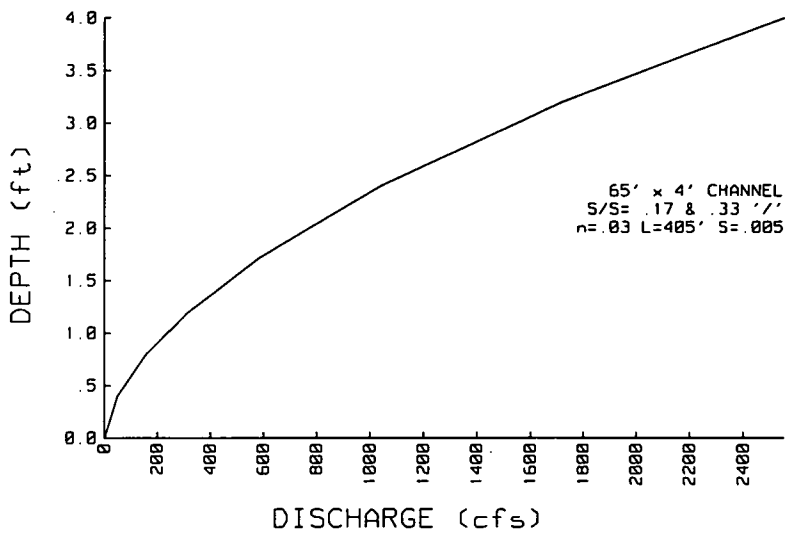
REACH 2 **POINT B**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	26.7	49.9
.8	54.9	159.8
1.2	84.4	317.2
1.7	125.0	585.7
2.4	181.7	1039.7
3.2	253.6	1718.0
4.0	331.3	2551.2

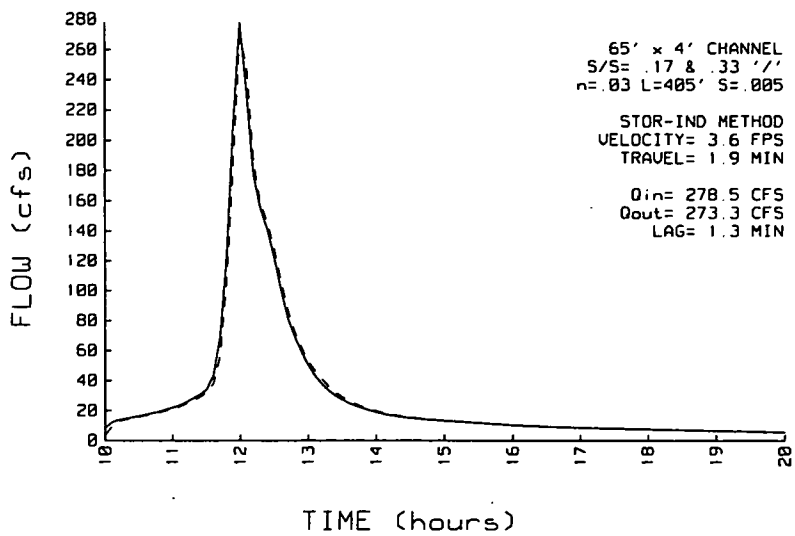
65' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 405 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.08 FT
PEAK VELOCITY= 3.6 FPS
TRAVEL TIME = 1.9 MIN
Qin = 278.5 CFS @ 12.01 HRS
Qout= 273.3 CFS @ 12.03 HRS
ATTEN= 2 % LAG= 1.3 MIN
IN/OUT= 25.51 / 25.49 AF

REACH 2 DISCHARGE
POINT B



REACH 2 INFLOW & OUTFLOW
POINT B



[redacted]
648

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

133/148

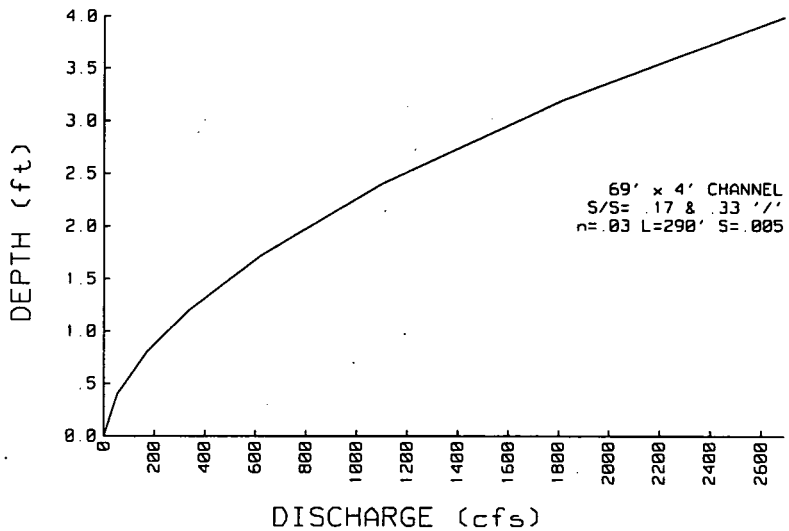
REACH 3 **POINT C**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	28.3	52.9
.8	58.1	169.4
1.2	89.2	336.1
1.7	131.9	620.1
2.4	191.3	1099.4
3.2	266.4	1814.0
4.0	347.3	2689.7

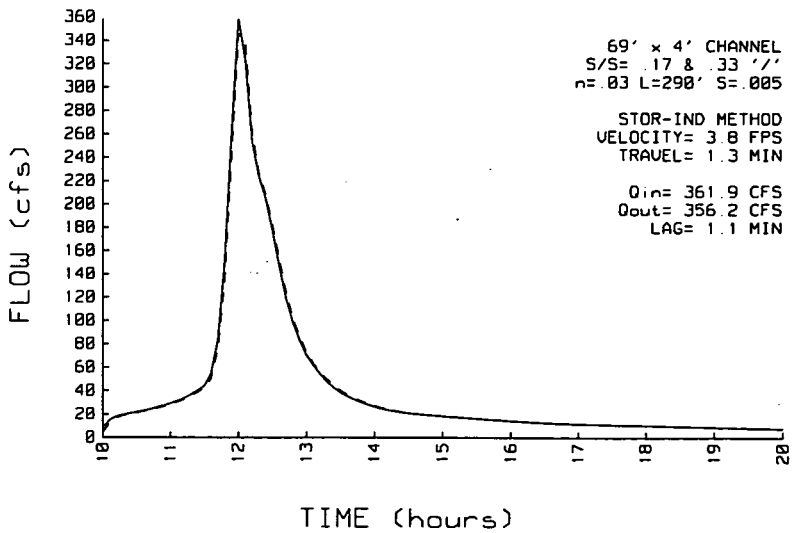
69' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 290 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.22 FT
PEAK VELOCITY= 3.8 FPS
TRAVEL TIME = 1.3 MIN
Qin = 361.9 CFS @ 12.02 HRS
Qout= 356.2 CFS @ 12.04 HRS
ATTEN= 2 % LAG= 1.1 MIN
IN/OUT= 34.87 / 34.84 AF

REACH 3 DISCHARGE
POINT C



REACH 3 INFLOW & OUTFLOW
POINT C



[redacted]
649

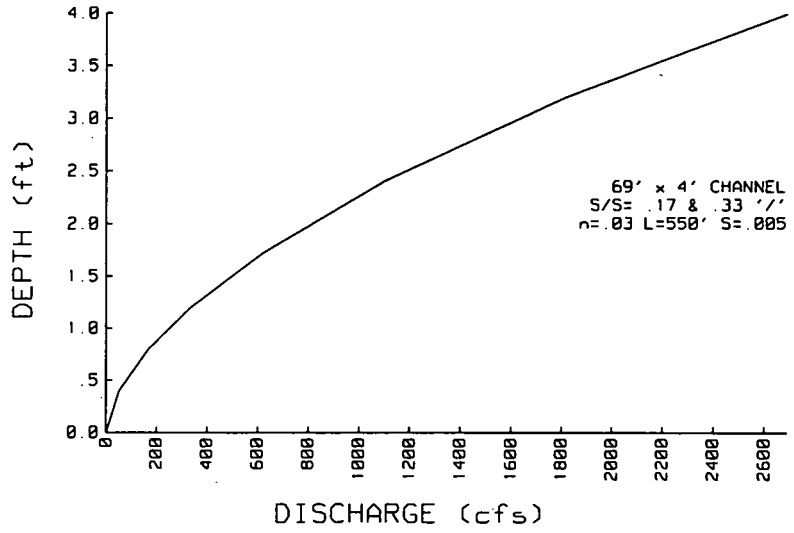
REACH 4 **POINT D**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	28.3	52.9
.8	58.1	169.4
1.2	89.2	336.1
1.7	131.9	620.1
2.4	191.3	1099.4
3.2	266.4	1814.0
4.0	347.3	2689.7

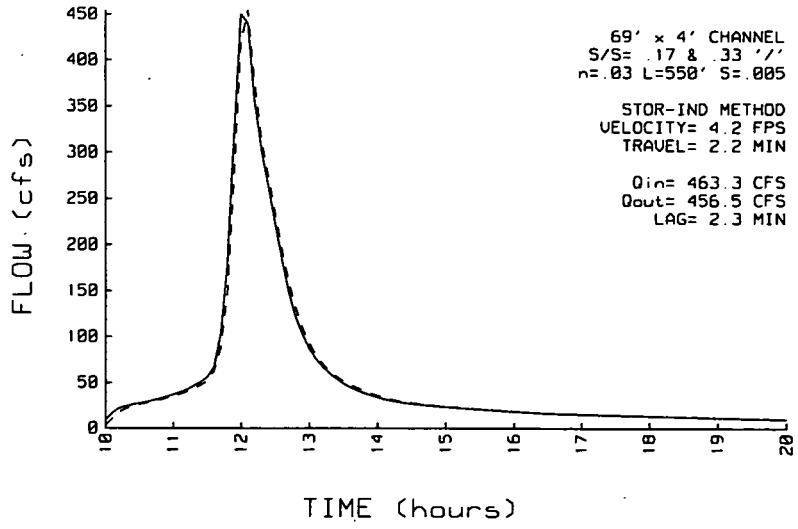
69' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 550 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.42 FT
PEAK VELOCITY= 4.2 FPS
TRAVEL TIME = 2.2 MIN
Qin = 463.3 CFS @ 12.04 HRS
Qout= 456.5 CFS @ 12.08 HRS
ATTEN= 1 % LAG= 2.3 MIN
IN/OUT= 44.46 / 44.39 AF

REACH 4 DISCHARGE
POINT D



REACH 4 INFLOW & OUTFLOW
POINT D



Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

135/148

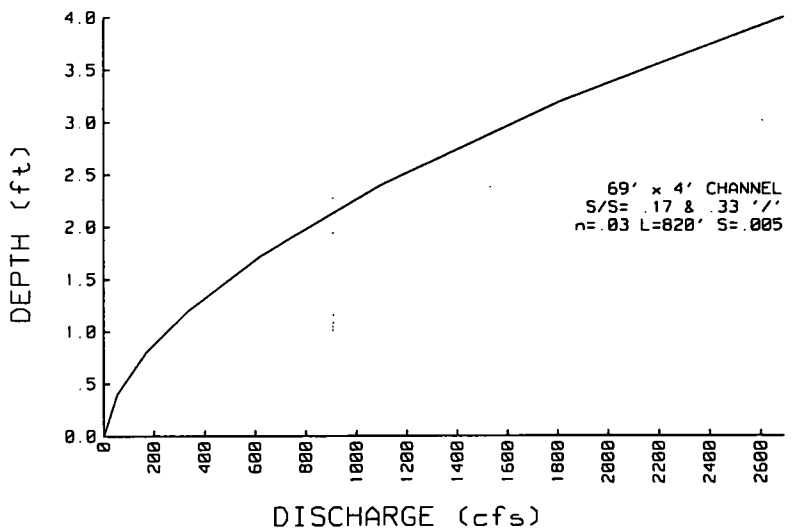
REACH 5

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	28.3	52.9
.8	58.1	169.4
1.2	89.2	336.1
1.7	131.9	620.1
2.4	191.3	1099.4
3.2	266.4	1814.0
4.0	347.3	2689.7

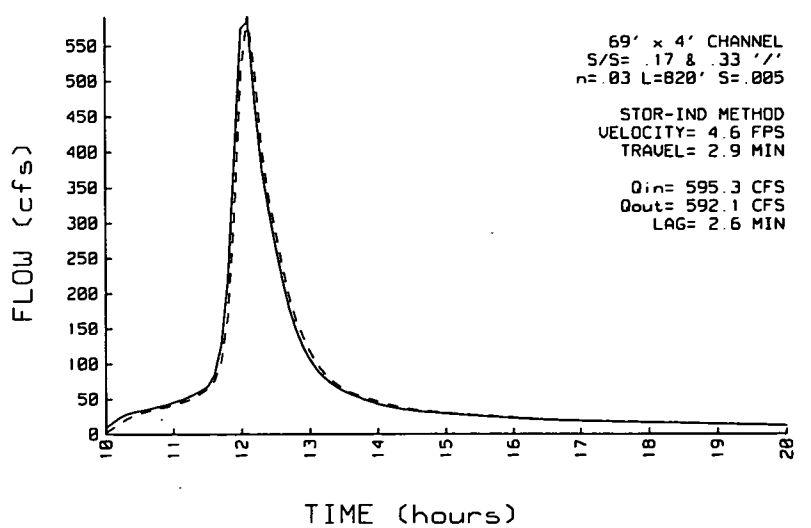
69' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 820 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.67 FT
PEAK VELOCITY= 4.6 FPS
TRAVEL TIME = 2.9 MIN
Qin = 595.3 CFS @ 12.06 HRS
Qout= 592.1 CFS @ 12.10 HRS
ATTEN= 1 % LAG= 2.6 MIN
IN/OUT= 55.58 / 55.45 AF

REACH 5 DISCHARGE



REACH 5 INFLOW & OUTFLOW



[redacted]
651

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

Tsc 739
9 Feb 96
136/148
155 12Feb96

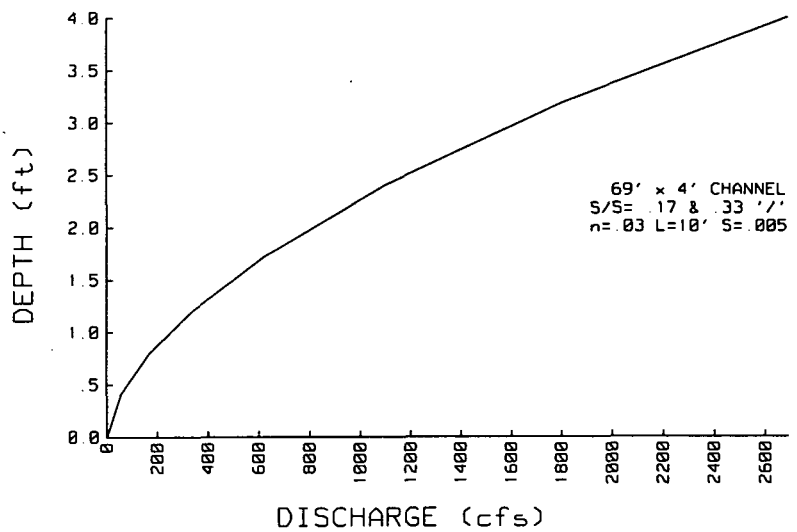
REACH 6 **POINT E**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	28.3	52.9
.8	58.1	169.4
1.2	89.2	336.1
1.7	131.9	620.1
2.4	191.3	1099.4
3.2	266.4	1814.0
4.0	347.3	2689.7

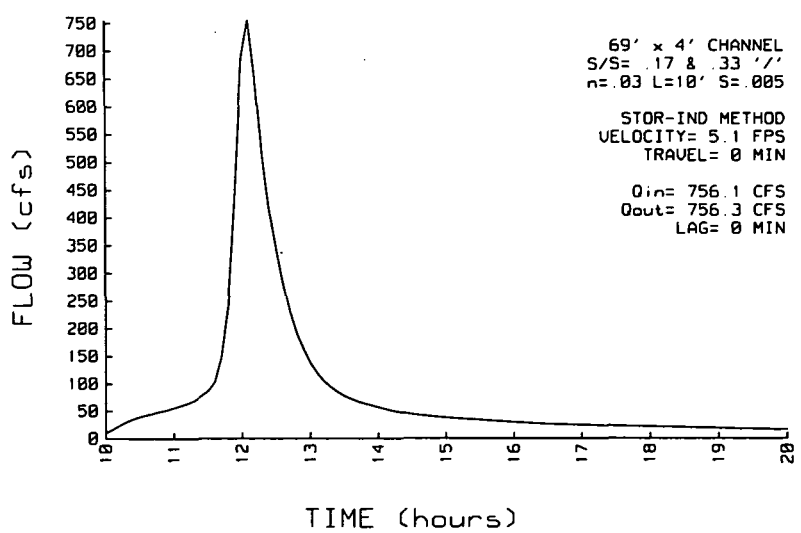
69' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 10 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.91 FT
PEAK VELOCITY= 5.1 FPS
TRAVEL TIME = 0.0 MIN
Qin = 756.1 CFS @ 12.09 HRS
Qout= 756.3 CFS @ 12.09 HRS
ATTEN= 0 % LAG= 0.0 MIN
IN/OUT= 70.40 / 70.40 AF

REACH 6 DISCHARGE
POINT E



REACH 6 INFLOW & OUTFLOW
POINT E



[redacted]
652

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12/06/94

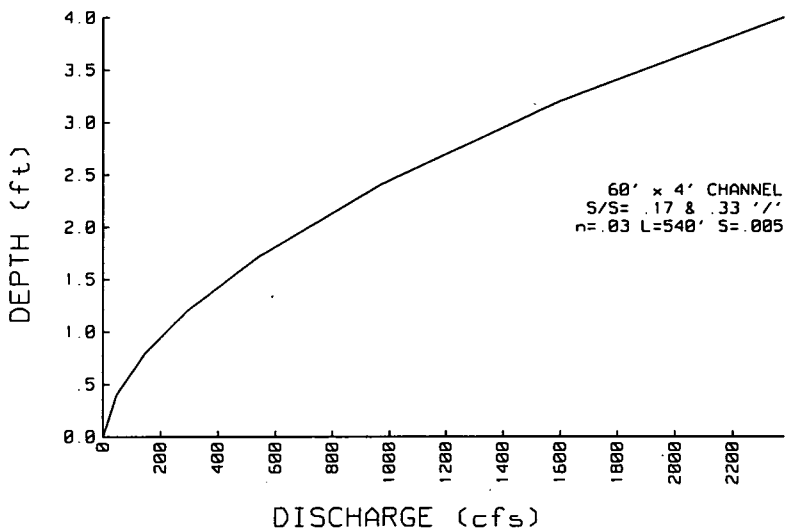
REACH 1 **POINT A**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	24.7	46.1
.8	50.9	147.7
1.2	78.4	293.5
1.7	116.4	542.8
2.4	169.7	965.1
3.2	237.6	1598.2
4.0	311.3	2378.3

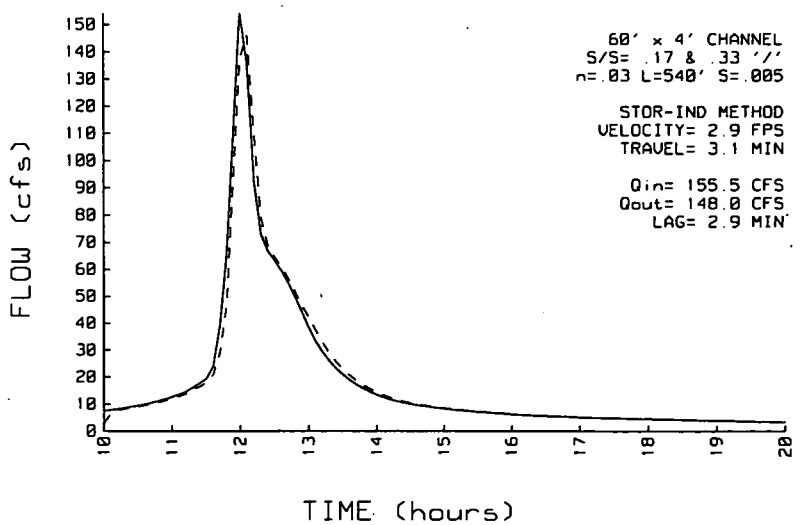
60' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 540 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= .79 FT
PEAK VELOCITY= 2.9 FPS
TRAVEL TIME = 3.1 MIN
Qin = 155.5 CFS @ 12.02 HRS
Qout= 148.0 CFS @ 12.07 HRS
ATTEN= 5 % LAG= 2.9 MIN
IN/OUT= 15.10 / 15.08 AF

REACH 1 DISCHARGE
POINT A



REACH 1 INFLOW & OUTFLOW
POINT A



[redacted]
653

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

Asc 739
138/148
SSS 12Feb96

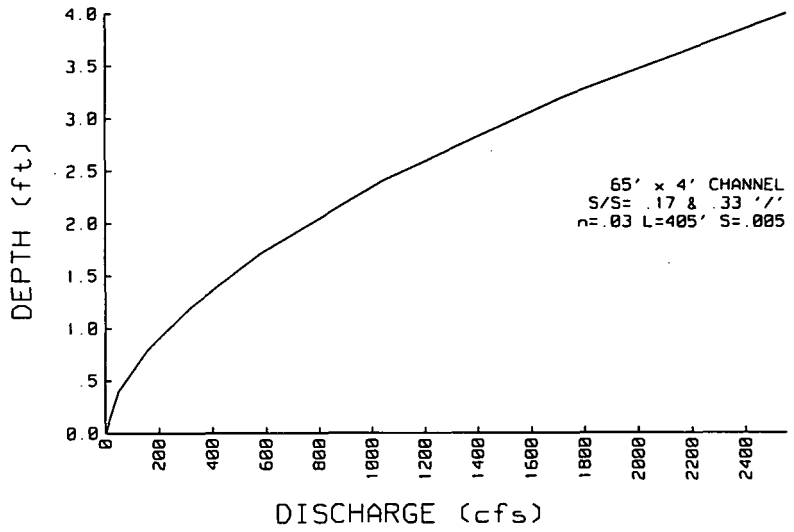
REACH 2 **POINT B**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	26.7	49.9
.8	54.9	159.8
1.2	84.4	317.2
1.7	125.0	585.7
2.4	181.7	1039.7
3.2	253.6	1718.0
4.0	331.3	2551.2

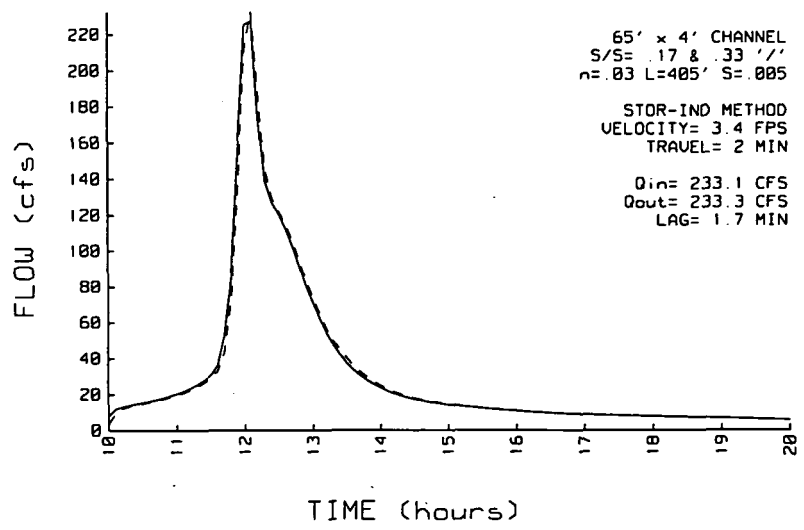
65' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 405 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= .98 FT
PEAK VELOCITY= 3.4 FPS
TRAVEL TIME = 2.0 MIN
Qin = 233.1 CFS @ 12.05 HRS
Qout= 233.3 CFS @ 12.08 HRS
ATTEN= 0 % LAG= 1.7 MIN
IN/OUT= 25.58 / 25.55 AF

REACH 2 DISCHARGE
POINT B



REACH 2 INFLOW & OUTFLOW
POINT B



[redacted]
654

739

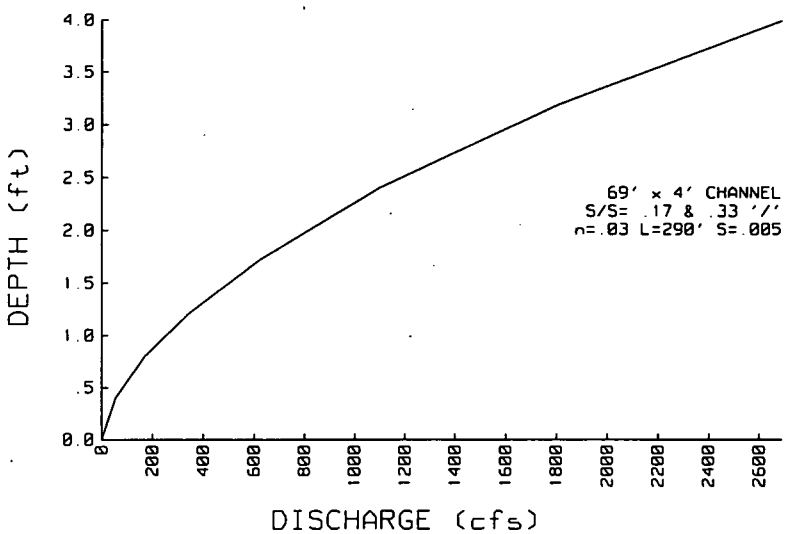
REACH 3 **POINT C**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	28.3	52.9
.8	58.1	169.4
1.2	89.2	336.1
1.7	131.9	620.1
2.4	191.3	1099.4
3.2	266.4	1814.0
4.0	347.3	2689.7

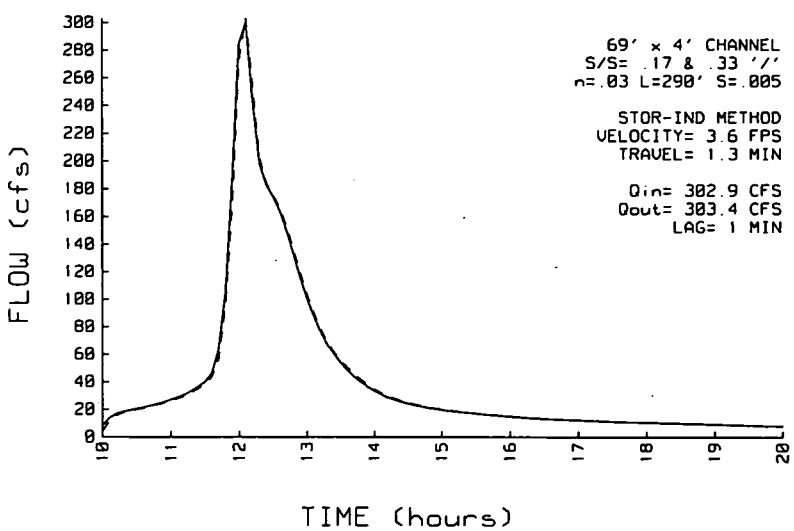
69' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 290 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.12 FT
PEAK VELOCITY= 3.6 FPS
TRAVEL TIME = 1.3 MIN
Qin = 302.9 CFS @ 12.07 HRS
Qout= 303.4 CFS @ 12.09 HRS
ATTEN= 0 % LAG= 1.0 MIN
IN/OUT= 34.96 / 34.93 AF

REACH 3 DISCHARGE
POINT C



REACH 3 INFLOW & OUTFLOW
POINT C



[redacted]
655

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

ASC 140/148
ISS 12Feb96

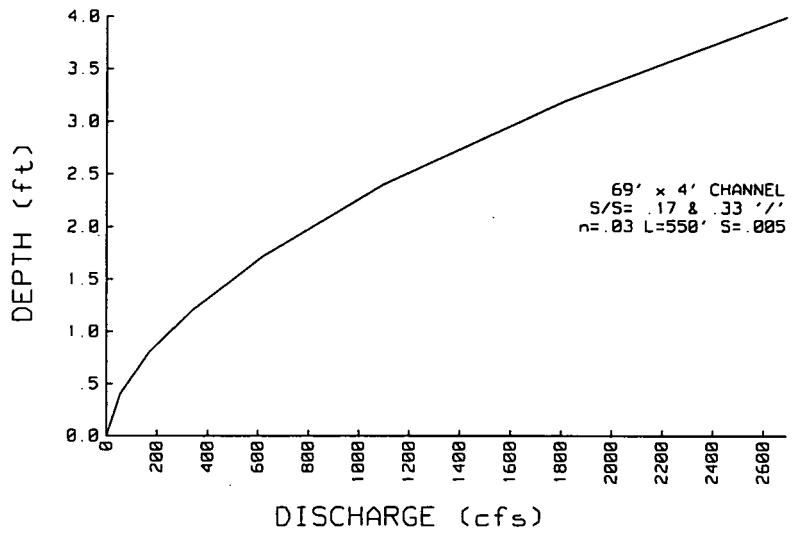
REACH 4 **POINT D**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	28.3	52.9
.8	58.1	169.4
1.2	89.2	336.1
1.7	131.9	620.1
2.4	191.3	1099.4
3.2	266.4	1814.0
4.0	347.3	2689.7

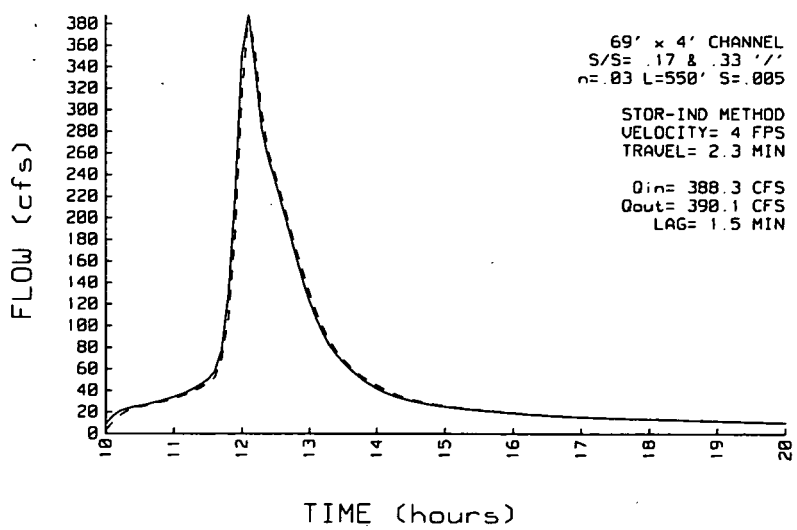
69' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 550 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.30 FT
PEAK VELOCITY= 4.0 FPS
TRAVEL TIME = 2.3 MIN
Qin = 388.3 CFS @ 12.09 HRS
Qout= 390.1 CFS @ 12.12 HRS
ATTEN= 0 % LAG= 1.5 MIN
IN/OUT= 44.58 / 44.51 AF

REACH 4 DISCHARGE
POINT D



REACH 4 INFLOW & OUTFLOW
POINT D



[redacted]

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

RSC 9 Feb 96

141/148

BSS 12Feb96

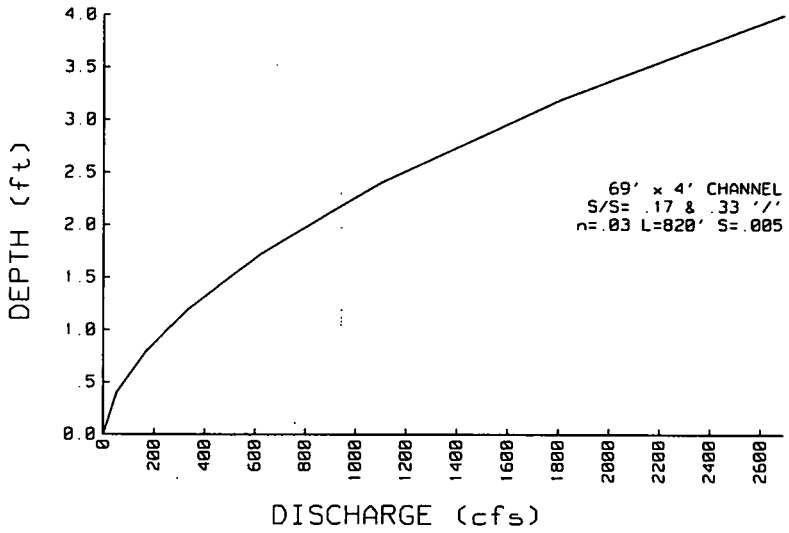
REACH 5

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	28.3	52.9
.8	58.1	169.4
1.2	89.2	336.1
1.7	131.9	620.1
2.4	191.3	1099.4
3.2	266.4	1814.0
4.0	347.3	2689.7

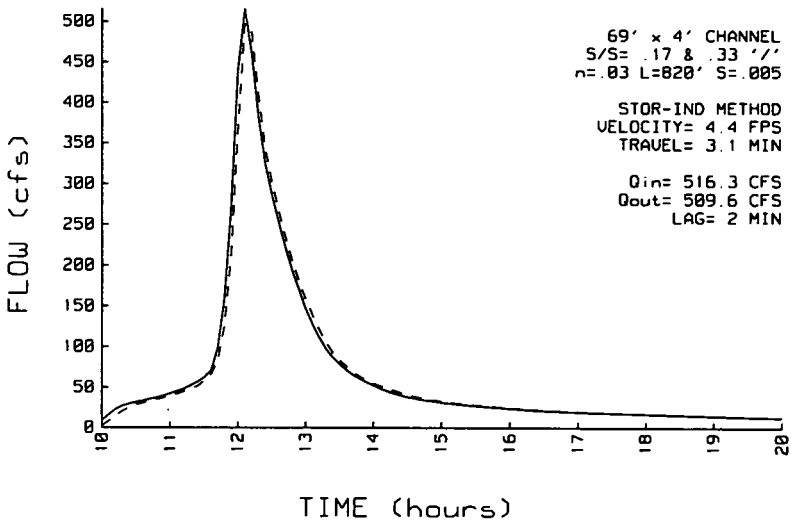
69' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 820 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.49 FT
PEAK VELOCITY= 4.4 FPS
TRAVEL TIME = 3.1 MIN
Qin = 516.3 CFS @ 12.11 HRS
Qout= 509.6 CFS @ 12.14 HRS
ATTEN= 1 % LAG= 2.0 MIN
IN/OUT= 55.71 / 55.58 AF

REACH 5 DISCHARGE



REACH 5 INFLOW & OUTFLOW



[redacted]

739

RSC

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96 142/148
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

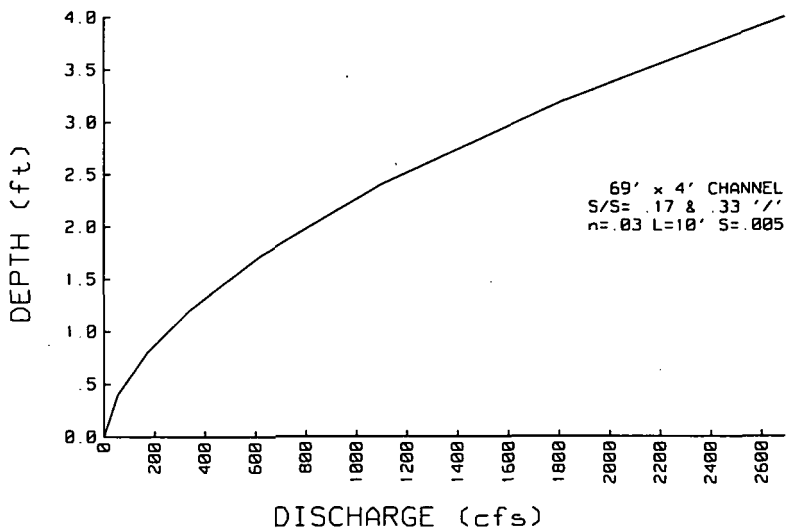
REACH 6 **POINT E**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	28.3	52.9
.8	58.1	169.4
1.2	89.2	336.1
1.7	131.9	620.1
2.4	191.3	1099.4
3.2	266.4	1814.0
4.0	347.3	2689.7

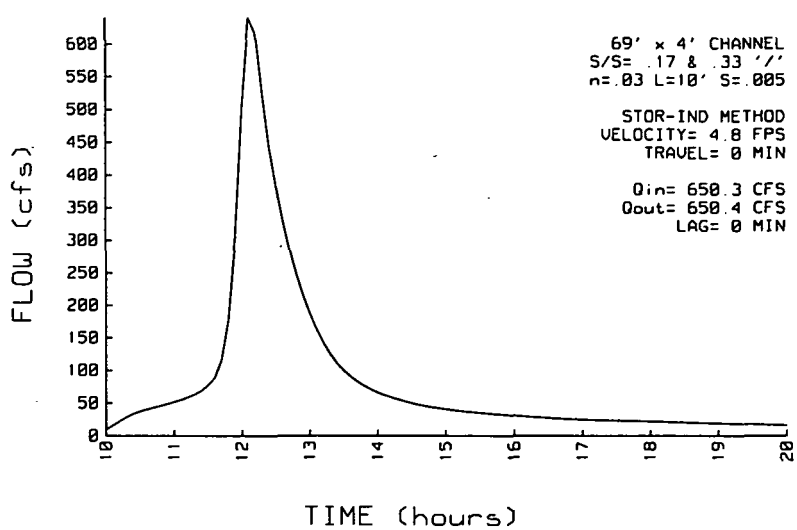
69' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 10 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.75 FT
PEAK VELOCITY= 4.8 FPS
TRAVEL TIME = 0.0 MIN
Qin = 650.3 CFS @ 12.14 HRS
Qout= 650.4 CFS @ 12.14 HRS
ATTEN= 0 % LAG= 0.0 MIN
IN/OUT= 70.57 / 70.57 AF

REACH 6 DISCHARGE
POINT E



REACH 6 INFLOW & OUTFLOW
POINT E



[redacted]

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

143/148

RSS 12Feb96

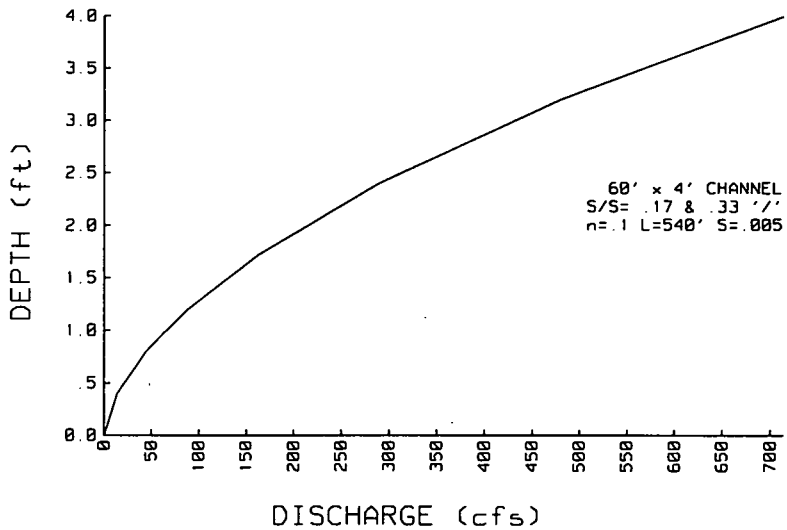
REACH 1 **POINT A**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	24.7	13.8
.8	50.9	44.3
1.2	78.4	88.0
1.7	116.4	162.8
2.4	169.7	289.5
3.2	237.6	479.5
4.0	311.3	713.5

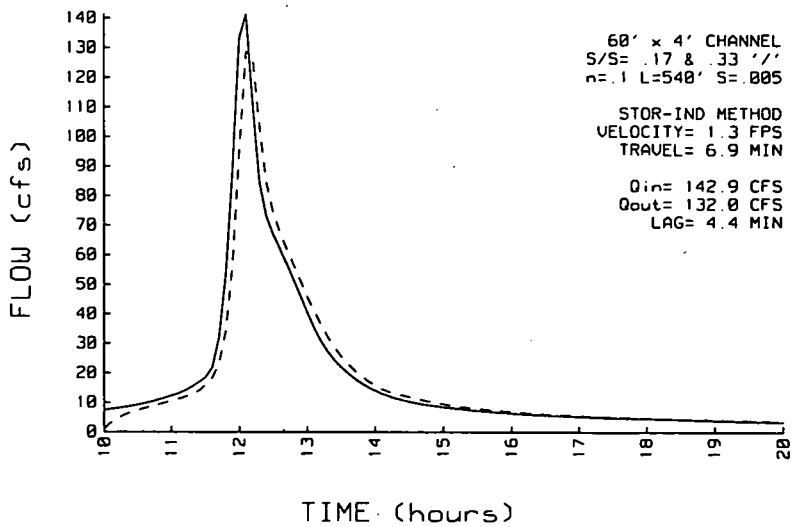
60' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .1
LENGTH= 540 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.48 FT
PEAK VELOCITY= 1.3 FPS
TRAVEL TIME = 6.9 MIN
Qin = 142.9 CFS @ 12.07 HRS
Qout= 132.0 CFS @ 12.14 HRS
ATTEN= 8 % LAG= 4.4 MIN
IN/OUT= 15.12 / 15.04 AF

REACH 1 DISCHARGE
POINT A



REACH 1 INFLOW & OUTFLOW
POINT A



[redacted]
659

ISC 739
144/148
SSS 12Feb96

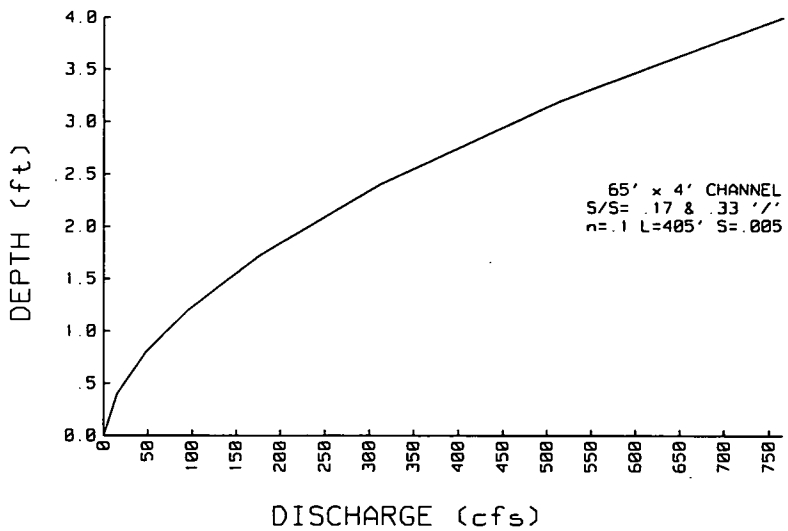
REACH 2 **POINT B**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	26.7	15.0
.8	54.9	47.9
1.2	84.4	95.1
1.7	125.0	175.7
2.4	181.7	311.9
3.2	253.6	515.4
4.0	331.3	765.3

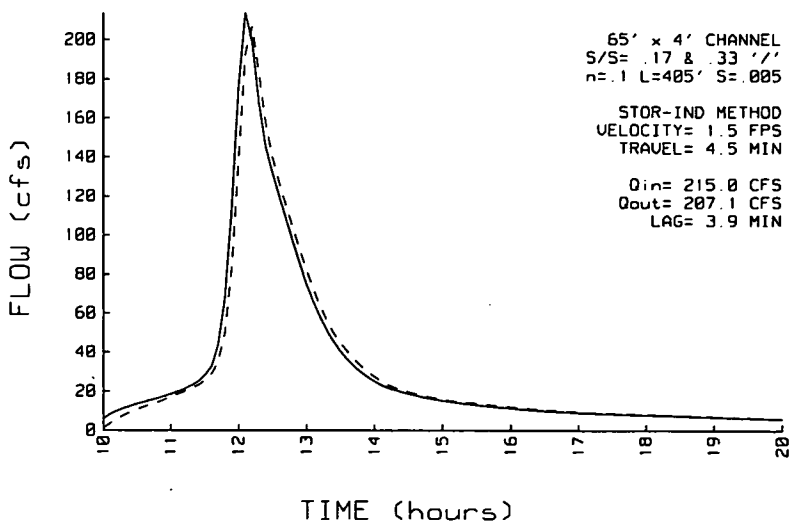
65' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .1
LENGTH= 405 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.87 FT
PEAK VELOCITY= 1.5 FPS
TRAVEL TIME = 4.5 MIN
Qin = 215.0 CFS @ 12.12 HRS
Qout= 207.1 CFS @ 12.19 HRS
ATTEN= 4 % LAG= 3.9 MIN
IN/OUT= 25.55 / 25.44 AF

REACH 2 DISCHARGE
POINT B



REACH 2 INFLOW & OUTFLOW
POINT B



[redacted]
660

739
145/148
SS 12Feb96

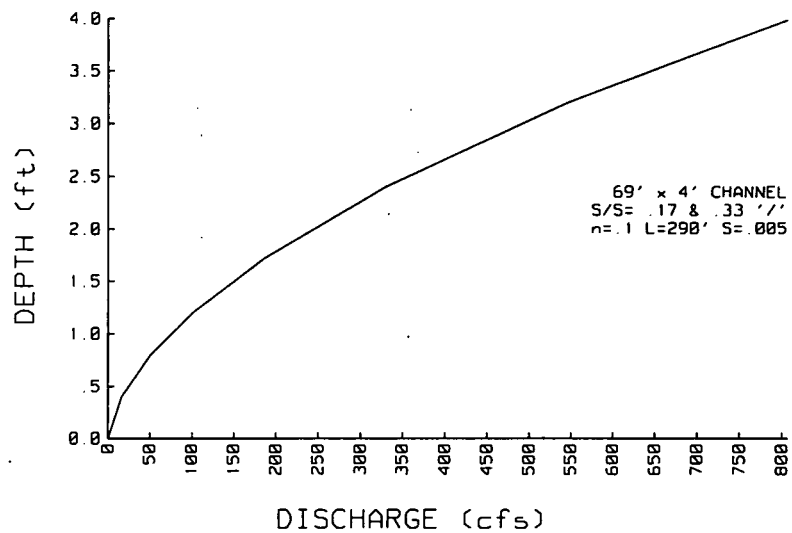
REACH 3 **POINT C**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	28.3	15.9
.8	58.1	50.8
1.2	89.2	100.8
1.7	131.9	186.0
2.4	191.3	329.8
3.2	266.4	544.2
4.0	347.3	806.9

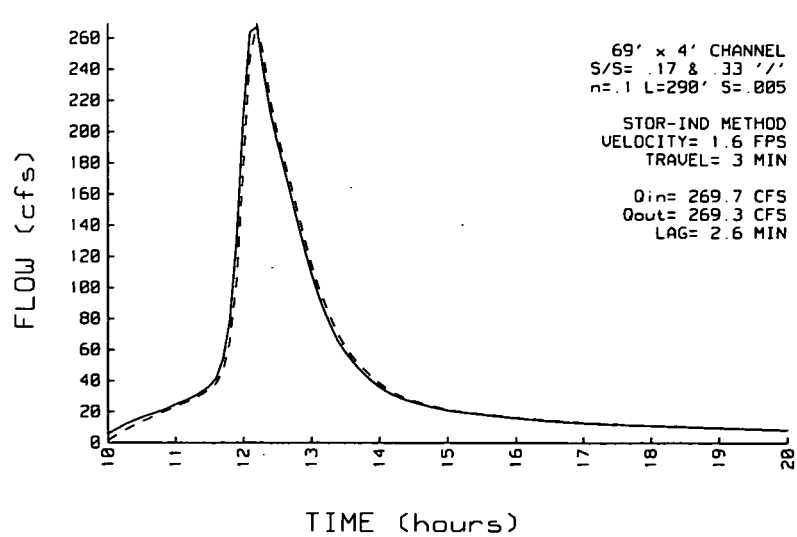
69' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .1
LENGTH= 290 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.11 FT
PEAK VELOCITY= 1.6 FPS
TRAVEL TIME = 3.0 MIN
Qin = 269.7 CFS @ 12.16 HRS
Qout= 269.3 CFS @ 12.20 HRS
ATTEN= 0 % LAG= 2.6 MIN
IN/OUT= 34.86 / 34.76 AF

REACH 3 DISCHARGE
POINT C



REACH 3 INFLOW & OUTFLOW
POINT C



[redacted]
661

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12 Feb 96

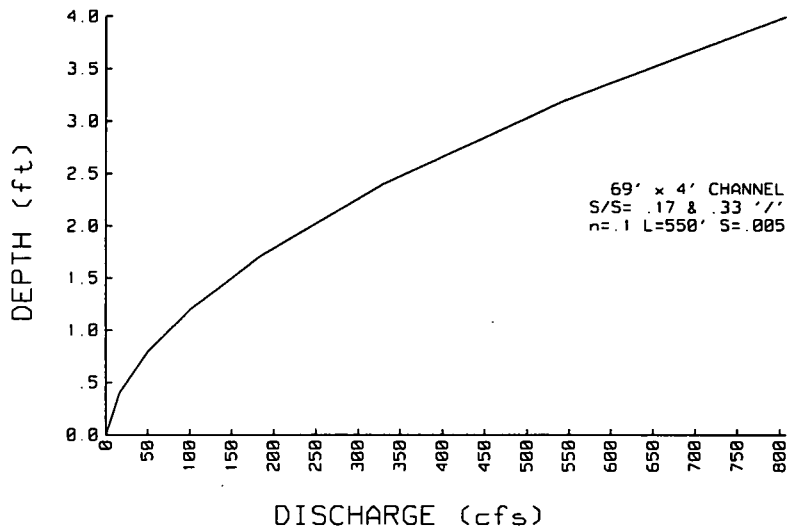
REACH 4 **POINT D**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	28.3	15.9
.8	58.1	50.8
1.2	89.2	100.8
1.7	131.9	186.0
2.4	191.3	329.8
3.2	266.4	544.2
4.0	347.3	806.9

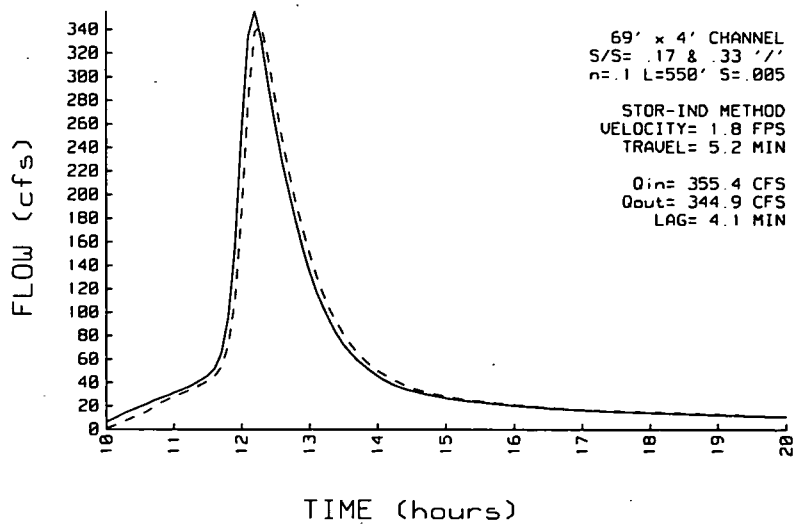
69' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .1
LENGTH= 550 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.45 FT
PEAK VELOCITY= 1.8 FPS
TRAVEL TIME = 5.2 MIN
Qin = 355.4 CFS @ 12.20 HRS
Qout= 344.9 CFS @ 12.26 HRS
ATTEN= 3 % LAG= 4.1 MIN
IN/OUT= 44.40 / 44.16 AF

REACH 4 DISCHARGE
POINT D



REACH 4 INFLOW & OUTFLOW
POINT D



[redacted]
662

739
147/148
SSS 12 Feb 96

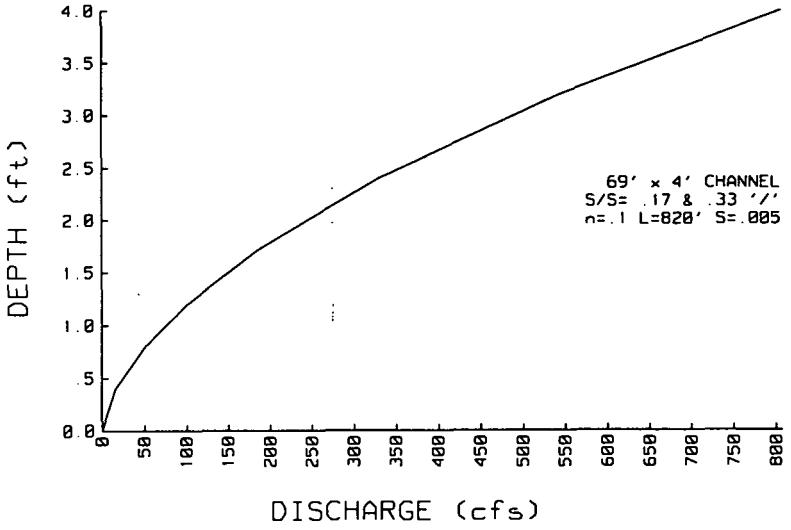
REACH 5

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	28.3	15.9
.8	58.1	50.8
1.2	89.2	100.8
1.7	131.9	186.0
2.4	191.3	329.8
3.2	266.4	544.2
4.0	347.3	806.9

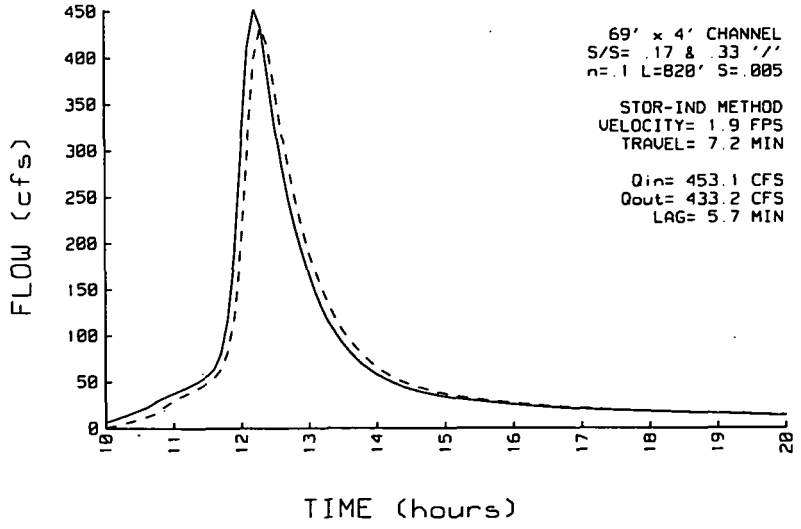
69' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .1
LENGTH= 820 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 2.78 FT
PEAK VELOCITY= 1.9 FPS
TRAVEL TIME = 7.2 MIN
Qin = 453.1 CFS @ 12.22 HRS
Qout= 433.2 CFS @ 12.31 HRS
ATTEN= 4 % LAG= 5.7 MIN
IN/OUT= 55.37 / 54.89 AF

REACH 5 DISCHARGE



REACH 5 INFLOW & OUTFLOW



[redacted]
663

Data for **FERMCO, EAST CHANNEL, 2000-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

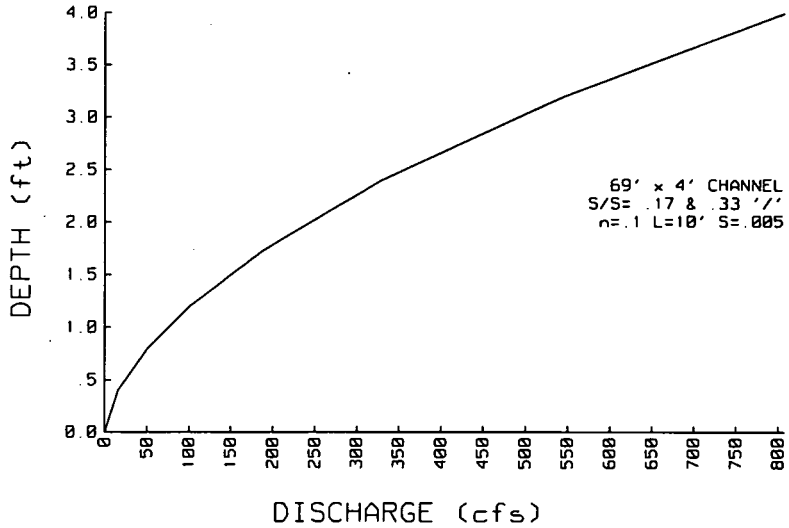
REACH 6 **POINT E**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.4	28.3	15.9
.8	58.1	50.8
1.2	89.2	100.8
1.7	131.9	186.0
2.4	191.3	329.8
3.2	266.4	544.2
4.0	347.3	806.9

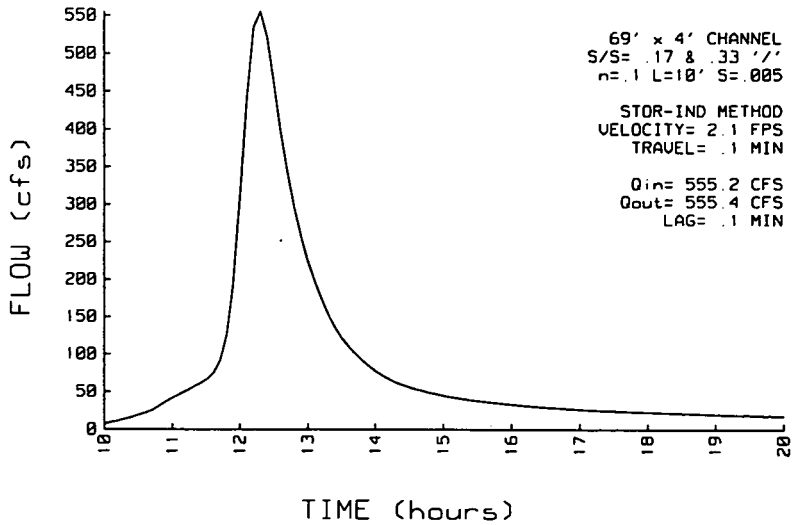
69' x 4' CHANNEL
S/S= .17 & .33 '/'
n= .1
LENGTH= 10 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 3.23 FT
PEAK VELOCITY= 2.1 FPS
TRAVEL TIME = .1 MIN
Qin = 555.2 CFS @ 12.29 HRS
Qout= 555.4 CFS @ 12.29 HRS
ATTEN= 0 % LAG= .1 MIN
IN/OUT= 69.89 / 69.89 AF

REACH 6 DISCHARGE
POINT E



REACH 6 INFLOW & OUTFLOW
POINT E



[redacted]

GeoSyntec Consultants

Written by: RSC Date: 9 / Feb / 96 Reviewed by: GSS Date: 12 / Feb / 96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

Southern Area Calculations

Summary of Input Data

A summary of the calculation results are presented in Table 1. The drainage area map and the HydroCAD™ runs for runon/runoff are attached.

A Summary of HydroCAD™ Results are listed below:

25-Year Storm Peak Runoff:	30.4 cfs
2,000-Year Storm Peak Runoff:	84.6 cfs

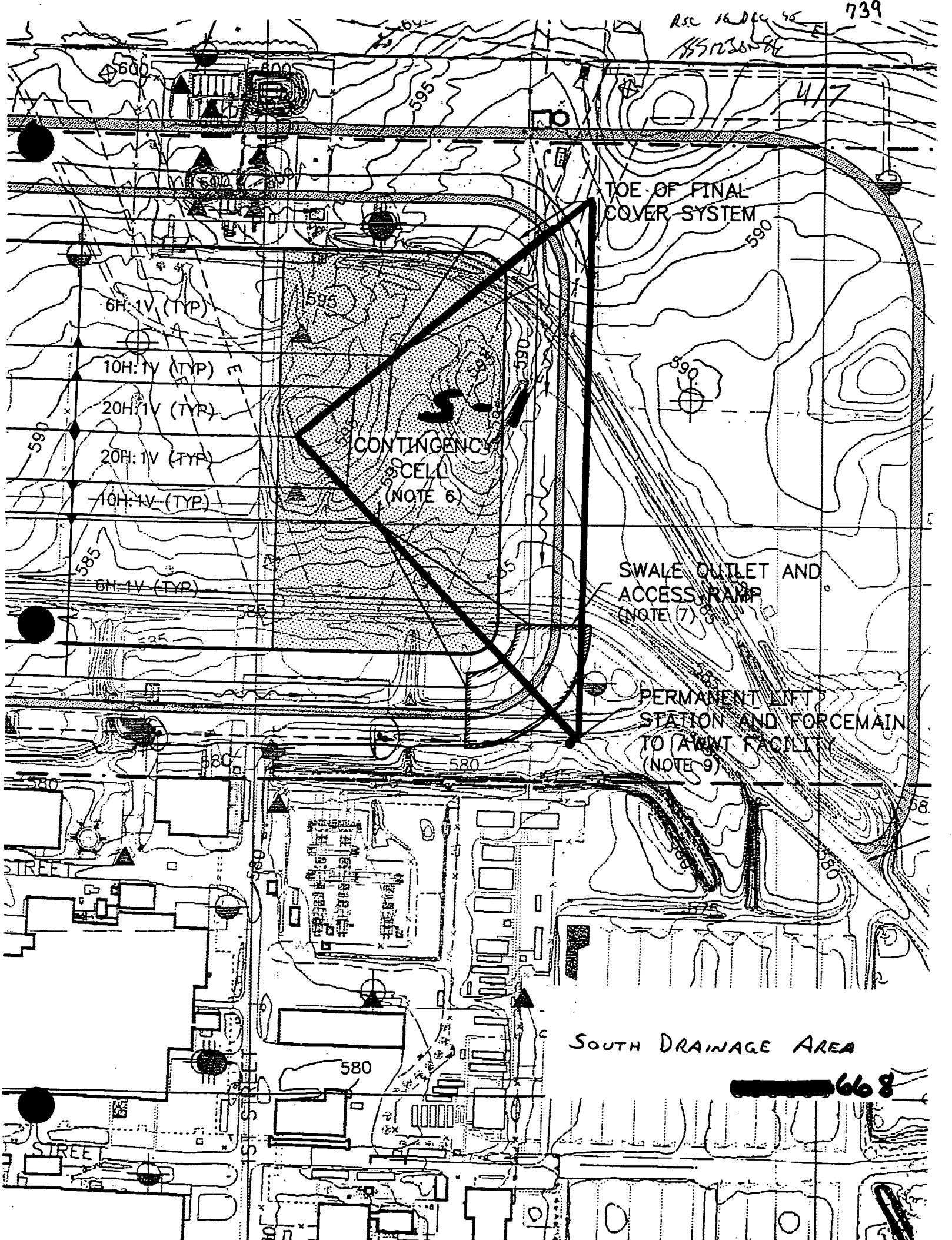
TABLE 1

SOUTHERN DRAINAGE AREA INPUT PARAMETERS
25- & 2,000-YEAR STORM MODELS

			Sheet Flow			Shallow Concetrated Flow		
Subarea Name	Area (Acres)	CN	Length (ft)	Slope	Surface Type	Length (ft)	Slope	Surface Type
S-1	5.6	98/99	147	0.07	Short Grass	330	0.167	Unpaved

739 Aug 4 PM 95
SSS 12Feb96
217
666

DRAINAGE AREA MAPS


TOE OF FINAL COVER SYSTEM
6H:1V (TYP)
10H:1V (TYP)
20H:1V (TYP)
20H:1V (TYP)
10H:1V (TYP)
6H:1V (TYP)
CONTINGENCY CELL (NOTE 6)
SWALE OUTLET AND ACCESS RAMP (NOTE 7)
PERMANENT LIFT STATION AND FORCEMAIN TO AWWT FACILITY (NOTE 9)
SOUTH DRAINAGE AREA
STREET
STREET
600
595
590
585
580
575

HYDROCAD™ RUNS

RUNON/RUNOFF

Data for **FERMCO, SOUTH AREA, 25-YR STORM, ALL COVERS**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

ASC 9 Feb 96
SSS 12Feb94

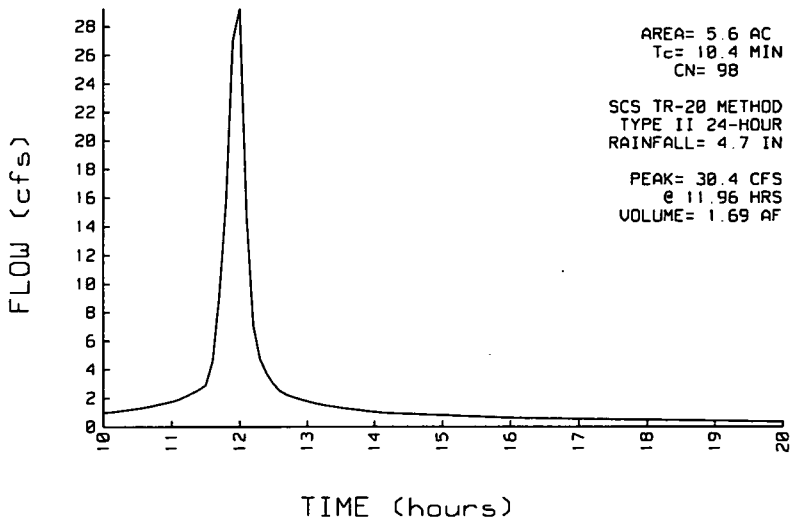
SUBCATCHMENT 1 **S-1**

ACRES	CN
5.60	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 30.4 CFS @ 11.96 HRS
VOLUME= 1.69 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.6
Grass: Short n=.15 L=160' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=330' s=.167 '/' V=6.59 fps		
	Total Length= 490 ft Total Tc=	10.4

SUBCATCHMENT 1 RUNOFF
S-1



[redacted]

Data for **FERMCO, SOUTH AREA, 2000-YR STORM, ALL COVERS**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

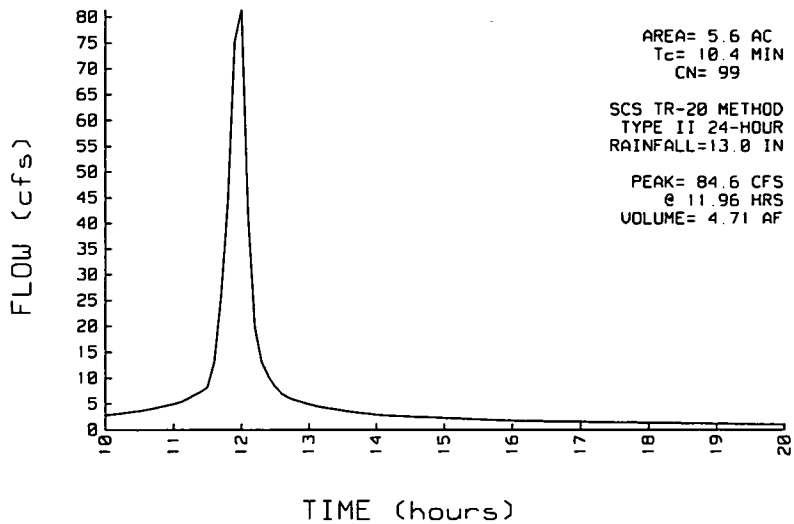
SUBCATCHMENT 1 **S-1**

ACRES	CN
5.60	99

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL=13.0 IN
PEAK= 84.6 CFS @ 11.96 HRS
VOLUME= 4.71 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.6
Grass: Short n=.15 L=160' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.8
Unpaved Kv=16.1345 L=330' s=.167 '/' V=6.59 fps		
	Total Length= 490 ft Total Tc=	10.4

SUBCATCHMENT 1 RUNOFF
S-1



[redacted]

Written by: RSC Date: 9 Feb 96 Reviewed by: SSS Date: 16 Feb 96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

Western Area Calculations

Summary of Input Data

A summary of the HydroCAD™ input data is presented in Table 1.

Summary of Calculation Results

A summary of the calculation results is presented in Tables 2 and 3. Drainage area maps, a worksheet for calculating weighted runoff curve numbers, HydroCAD™ runs for runon/runoff and drainage channel routing, and culvert calculations are attached.

TABLE 1

WESTERN AREA INPUT PARAMETERS
25-YEAR STORM EVENT

			Sheet Flow			Shallow Concetrated Flow			OpenChannel Flow								
Subarea Name	Area (Acres)	Weighted CN	Length (ft)	Slope (ft/ft)	Surface Type	Length (ft)	Slope (ft/ft)	Surface Type	X-C Area (sf)	Wetted Perimeter (ft)	Length (ft)	Manning's n	Bottom Width (ft)	Channel Slope (%)	Right Slope	Left Slope	Depth (ft)
W-A	2.1	71	300	0.010		100	0.010	^	-	-	-		-	-	-	-	-
W-1	1.6	98	100	0.167		270	0.167	=	10.1	13.87	225		0	0.75	3:1	6:1	1.5
W-2	2.2	98	147	0.070		360	0.167	=	10.1	13.87	200		0	0.75	3:1	6:1	1.5
W-3	2.4	98	147	0.070		360	0.167	=	10.1	13.87	200		0	0.75	3:1	6:1	1.5
W-4	2.4	98	147	0.070	S	360	0.167	=	10.1	13.87	200	S	0	0.75	3:1	6:1	1.5
W-5	2.4	98	147	0.070	E	360	0.167	=	10.1	13.87	200	E	0	0.75	3:1	6:1	1.5
W-6	2.4	98	147	0.070	E	360	0.167	U	10.1	13.87	200	E	0	0.75	3:1	6:1	1.5
W-7	2.4	98	147	0.070		360	0.167	N	10.1	13.87	200		0	0.75	3:1	6:1	1.5
W-8	2.4	98	147	0.070	N	360	0.167	P	10.1	13.87	200	N	0	0.75	3:1	6:1	1.5
W-9	2.4	98	147	0.070	O	360	0.167	A	10.1	13.87	200	O	0	0.75	3:1	6:1	1.5
W-10	2.4	98	147	0.070	T	360	0.167	V	10.1	13.87	200	T	0	0.75	3:1	6:1	1.5
W-11	2.4	98	147	0.070	E	360	0.167	E	10.1	13.87	200	E	0	0.75	3:1	6:1	1.5
W-12	2.4	98	147	0.070		360	0.167	D	10.1	13.87	200		0	0.75	3:1	6:1	1.5
W-13	2.4	98	147	0.070	A	360	0.167	=	10.1	13.87	200	B	0	0.50	3:1	6:1	1.5
W-14	2.4	98	147	0.070		360	0.167	=	10.1	13.87	200		0	0.50	3:1	6:1	1.5
W-15	2.4	98	147	0.070		360	0.167	=	10.1	13.87	200		0	0.50	3:1	6:1	1.5
W-16	2.4	98	147	0.070		360	0.167	=	10.1	13.87	200		0	0.50	3:1	6:1	1.5
W-17	2.4	98	147	0.070		360	0.167	=	10.1	13.87	200		0	0.50	3:1	6:1	1.5
W-18	1.4	98	100	0.167		250	0.167	v	10.1	13.87	350		0	0.50	3:1	6:1	1.5

Note A: Light Cover = Short Grass; Moderate & Heavy Cover = Dense Grass

Note B: Light & Moderate Cover: n = 0.030; Heavy Cover: n = 0.10

739 Asc 5 Feb 96
12 Feb 96
2/74

673

Written by: lsc Date: 9 / Feb / 96 Reviewed by: [illegible] Date: 16 Feb 96

Client: FERMCO Project: OSDF Proj./Proposal No.: GE3900 Task No.: 08.1

Table 2. Summary of HydroCAD™ Results - 25-Year Storm

Point of Interest Along Channel	Peak Flow Quantity (CFS)	Peak Flow Depth (Ft)	Peak Flow Velocity (FPS)
MH-1			
Light Cover	9.3	0.9	2.5
Moderate Cover	9.3	0.9	2.1
MH-1.5			
Light Cover	12.0	1.1	2.3
Moderate Cover	12.1	1.1	2.3
MH-2 THROUGH MH-10			
Light Cover	13.1	1.1	2.3
Moderate Cover	11.8	1.0	2.3

Table 3. Summary of Culvert Design Results

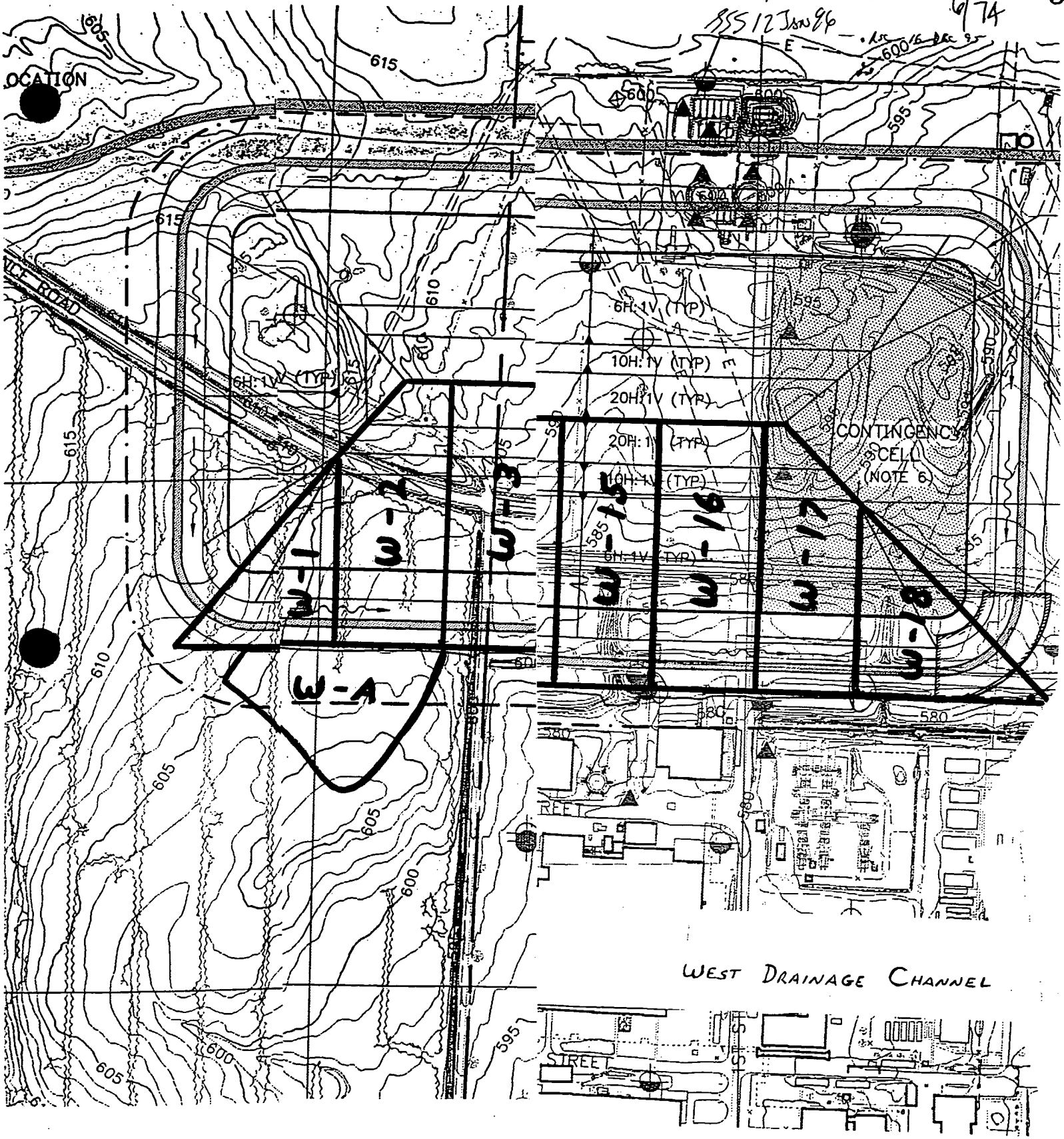
Culvert diameter	= 18 in.
Culvert pipe strength	= 831 lb/ft per foot of inside diameter, with at least 3 ft. of soil cover
Peak flow through culvert	= 13.0 cfs (MH-2 through MH-10, light cover)
Maximum headwater	= 3.5 ft
Riprap Size:	D_{max} = 6 in. D_{50} = 4 in. D_{15} = 2 to 3 in.
Riprap thickness:	8 in. (minimum)
Length of riprap apron:	10 ft. or to top of channel slope
Width of riprap apron:	4.5 ft at culvert, 11.5 at end of apron
Gravel Filter Blanket:	
	D_{85} > 0.4 to 0.6 in. D_{50} > 0.1 in. 0.05 to 0.08 < D_{15} < 0.4 to 0.6 in.

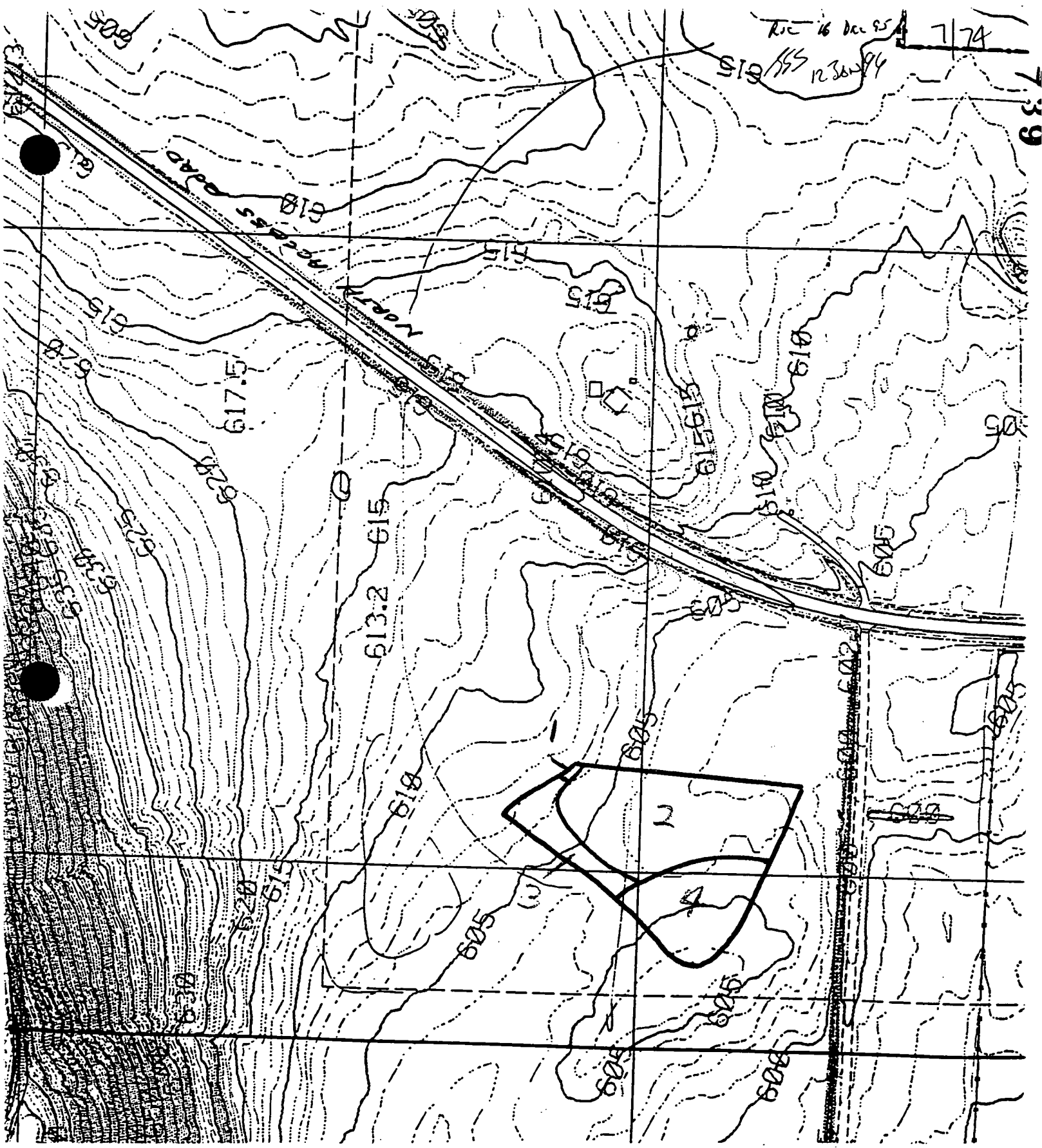
DRAINAGE AREA MAPS

Asc 9 Feb 96

SSS 12 Jan 96

6/74





DRAINAGE AREA W-A
SOIL & VEGETATION

678

739 8/74

WORKSHEETS FOR

WEIGHTED RUNOFF CURVE NUMBERS

629

Worksheet 2: Runoff curve number and runoff

Project FERMCO - OSDF ___ By RSC Date 16 DEC 95

Location DRAINAGE AREA W-3 ___ Checked RSS Date 12 JAN 96

Circle one: Present Developed

1. Runoff curve number (CN)

SUBAREA	Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
1	XENIA B	WOOD, GRASS - FAIR CONDITION	65			0.1	6.5
2	FINCASTLE C	" "	76			1.1	83.6
3	RAGSDALE B	" "	65			0.3	19.5
4	XENIA B	" "	65			0.6	39.0
					Totals =	2.1 ✓	148.6 ✓

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{148.6}{2.1} = 70.8$; Use CN = 71 ✓

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency ..... yr			
Rainfall, P (24-hour) ..... in			
Runoff, Q ..... in			

(Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)

[redacted]

HYDROCAD™ RUNS

RUNON/RUNOFF

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER** 739 Asc 11/74
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

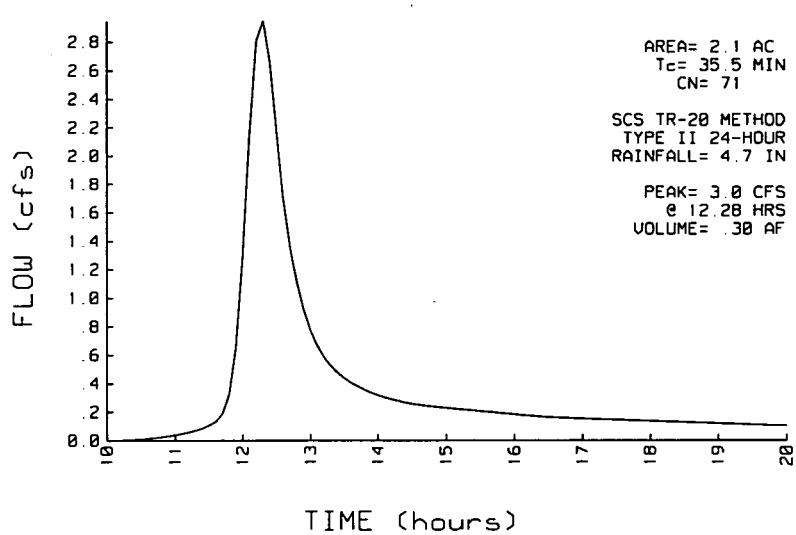
SUBCATCHMENT 20 **W-A**

ACRES	CN
2.10	71

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 3.0 CFS @ 12.28 HRS
VOLUME= .30 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	34.5
Grass: Short n=.15 L=300' P2=2.6 in s=.01 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	1.0
Unpaved Kv=16.1345 L=100' s=.01 '/' V=1.61 fps		
	Total Length= 400 ft Total Tc=	35.5

SUBCATCHMENT 20 RUNOFF
W-A



[redacted]
682

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER** 739 Asc 12/74
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

ESS12Feb96

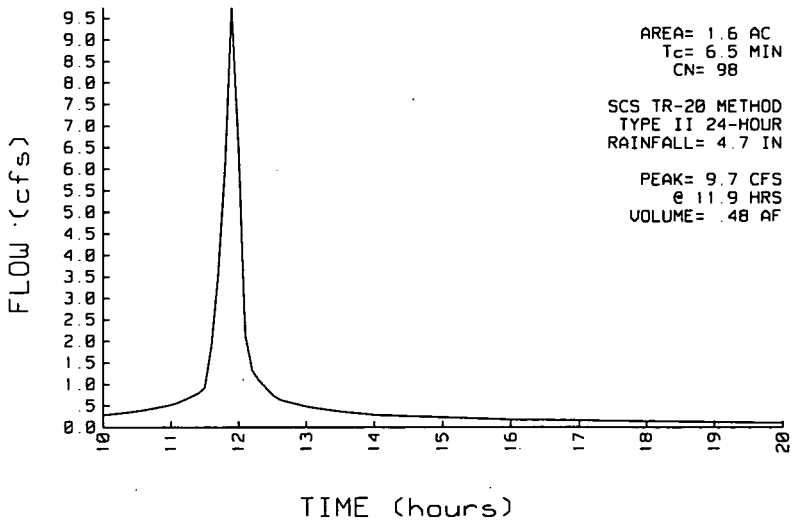
SUBCATCHMENT 1 **W-1** CW-18

ACRES	CN
1.60	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 9.7 CFS @ 11.90 HRS
VOLUME= .48 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	4.7
Grass: Short n=.15 L=100' P2=2.6 in s=.167 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.7
Unpaved Kv=16.1345 L=270' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.1
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.03 V=3.47 fps L=225' Capacity=35 cfs		
	Total Length= 595 ft Total Tc=	6.5

SUBCATCHMENT 1 RUNOFF
W-1



[redacted]
683

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

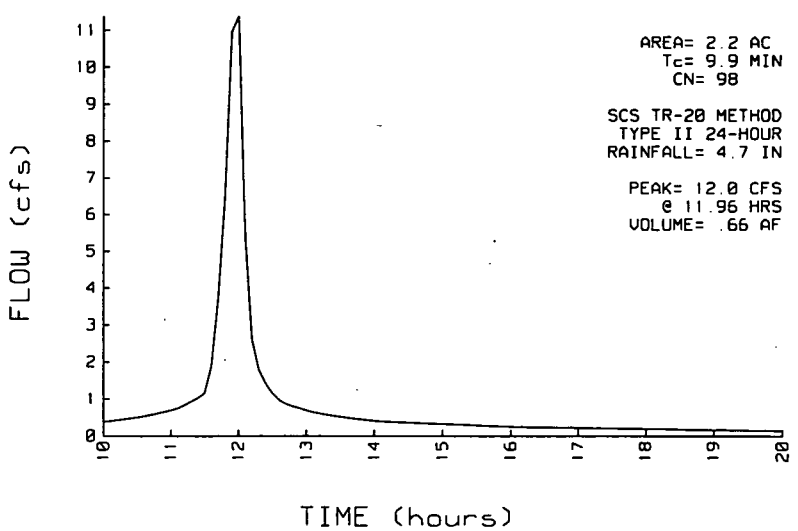
SUBCATCHMENT 2 **W-2**

ACRES	CN
2.20	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 12.0 CFS @ 11.96 HRS
VOLUME= .66 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
	Total Length= 507 ft Total Tc=	9.9

SUBCATCHMENT 2 RUNOFF
W-2



739 Asc 14/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SS 12 Feb 96

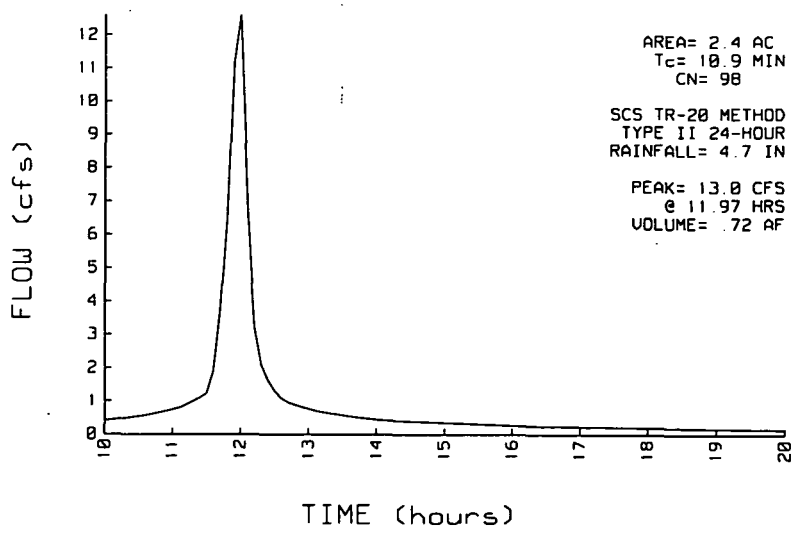
SUBCATCHMENT 3 **W-3**

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 13.0 CFS @ 11.97 HRS
VOLUME= .72 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.0
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.03 V=3.47 fps L=200' Capacity=35 cfs		
	Total Length= 707 ft Total Tc=	10.9

SUBCATCHMENT 3 RUNOFF
W-3



Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

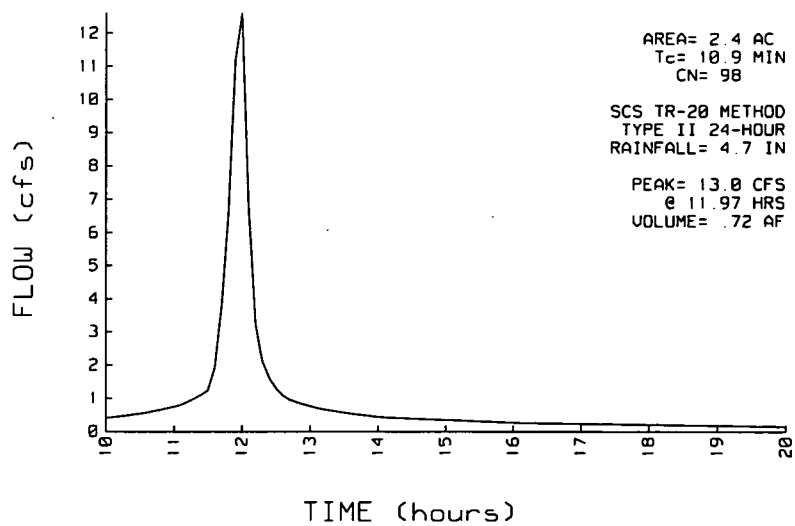
SUBCATCHMENT 4 **W-4**

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 13.0 CFS @ 11.97 HRS
VOLUME= .72 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.0
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.03 V=3.47 fps L=200' Capacity=35 cfs		
	Total Length= 707 ft Total Tc=	10.9

SUBCATCHMENT 4 RUNOFF
W-4



[redacted]
686

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

9 Feb 96

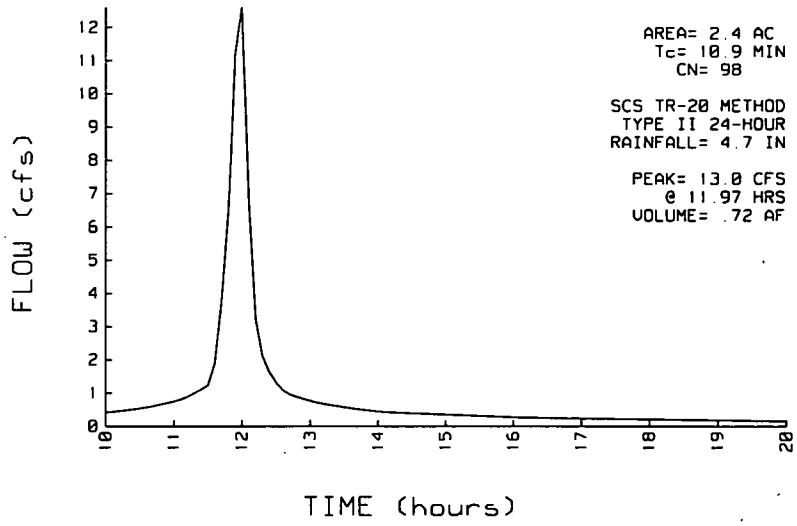
SUBCATCHMENT 5 **W-5**

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 13.0 CFS @ 11.97 HRS
VOLUME= .72 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.0
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.03 V=3.47 fps L=200' Capacity=35 cfs		
	Total Length= 707 ft Total Tc=	10.9

SUBCATCHMENT 5 RUNOFF
W-5



Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

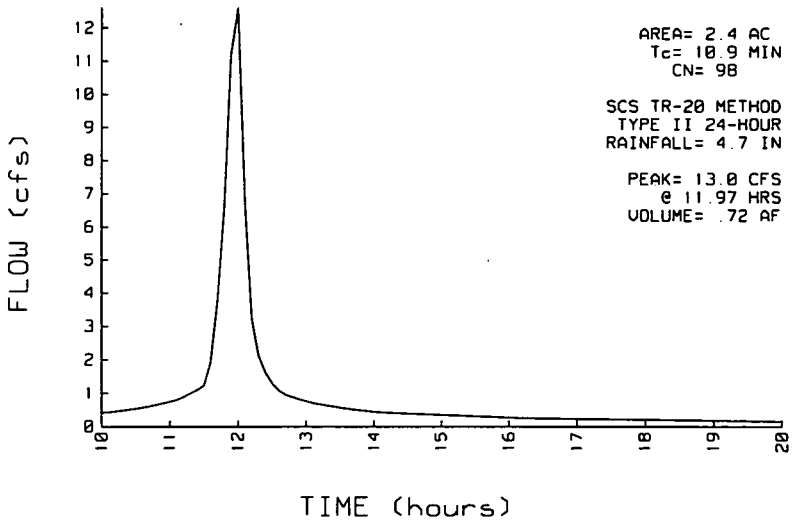
SUBCATCHMENT 6 **W-6 THROUGH W-12**

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 13.0 CFS @ 11.97 HRS
VOLUME= .72 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.0
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.03 V=3.47 fps L=200' Capacity=35 cfs		
	Total Length= 707 ft Total Tc=	10.9

SUBCATCHMENT 6 RUNOFF
W-6 THROUGH W-12



739 18/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

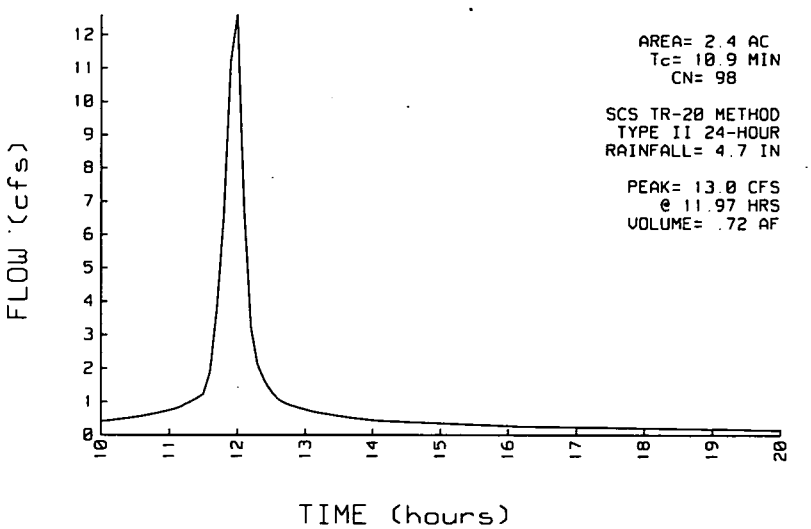
SUBCATCHMENT 7 W-13 THROUGH W-17

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 13.0 CFS @ 11.97 HRS
VOLUME= .72 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	9.0
Grass: Short n=.15 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW		1.0
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.03 V=3.47 fps L=200' Capacity=35 cfs		
	Total Length= 707 ft Total Tc=	10.9

SUBCATCHMENT 7 RUNOFF



[redacted]
689

739 Asc 19/19

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 11Feb96

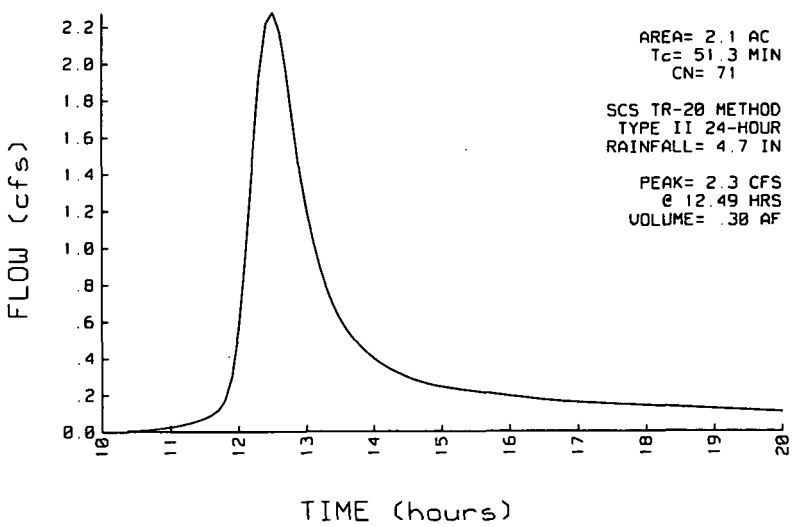
SUBCATCHMENT 20 **W-A**

ACRES	CN
2.10	71

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 2.3 CFS @ 12.49 HRS
VOLUME= .30 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	50.3
Grass: Dense n=.24 L=300' P2=2.6 in s=.01 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	1.0
Unpaved Kv=16.1345 L=100' s=.01 '/' V=1.61 fps		
	Total Length= 400 ft Total Tc=	51.3

SUBCATCHMENT 20 RUNOFF
W-A



[redacted]
690

739 ASC 20/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SS 12 Feb 96

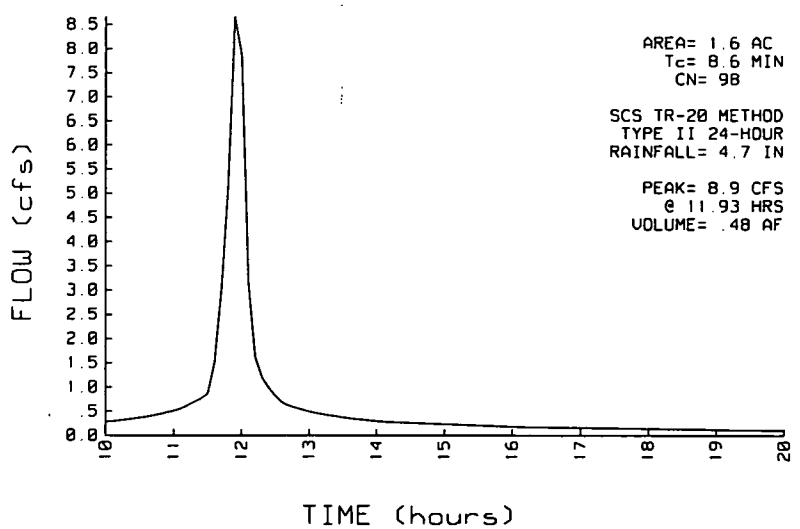
SUBCATCHMENT 1 **W-1** & W-18

ACRES	CN
1.60	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 8.9 CFS @ 11.93 HRS
VOLUME= .48 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	6.8
Grass: Dense n=.24 L=100' P2=2.6 in s=.167 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.7
Unpaved Kv=16.1345 L=270' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.1
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.03 V=3.47 fps L=225' Capacity=35 cfs		
	Total Length= 595 ft Total Tc=	8.6

SUBCATCHMENT 1 RUNOFF
W-1



[redacted]

691

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER** 739 ASC 21/74
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SS 12 Feb 96

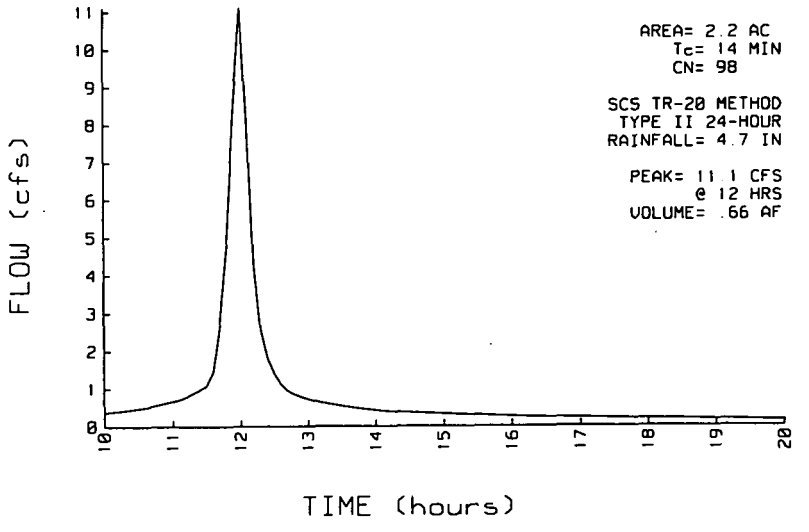
SUBCATCHMENT 2 **W-2**

ACRES	CN
2.20	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 11.1 CFS @ 12.00 HRS
VOLUME= .66 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
	Total Length= 507 ft Total Tc=	14.0

SUBCATCHMENT 2 RUNOFF
W-2



[redacted]
692

739 ASC 22/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12/6/96

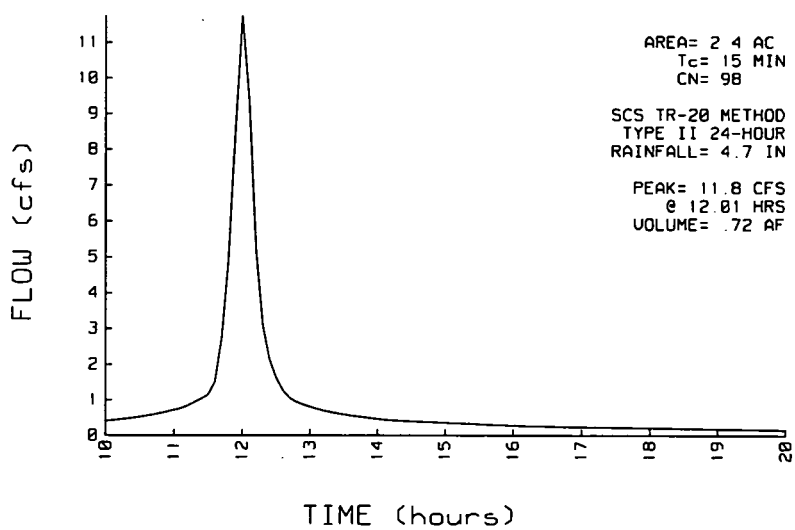
SUBCATCHMENT 3 **W-3**

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 11.8 CFS @ 12.01 HRS
VOLUME= .72 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.0
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.03 V=3.47 fps L=200' Capacity=35 cfs		
	Total Length= 707 ft Total Tc=	15.0

SUBCATCHMENT 3 RUNOFF
W-3



[redacted]
693

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER** 759 LSC 23/74
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

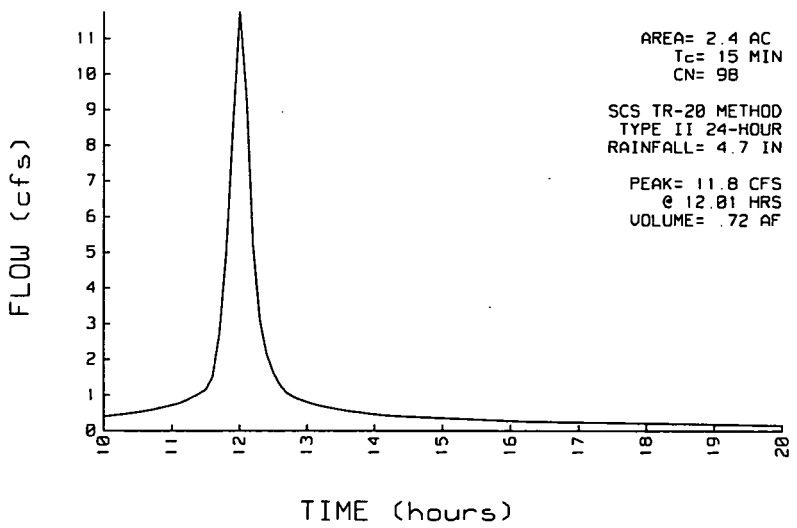
SUBCATCHMENT 4 **W-4**

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 11.8 CFS @ 12.01 HRS
VOLUME= .72 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.0
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.03 V=3.47 fps L=200' Capacity=35 cfs		
	Total Length= 707 ft Total Tc=	15.0

SUBCATCHMENT 4 RUNOFF
W-4



[redacted]
694

739 LSC 24/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SS 12Feb96

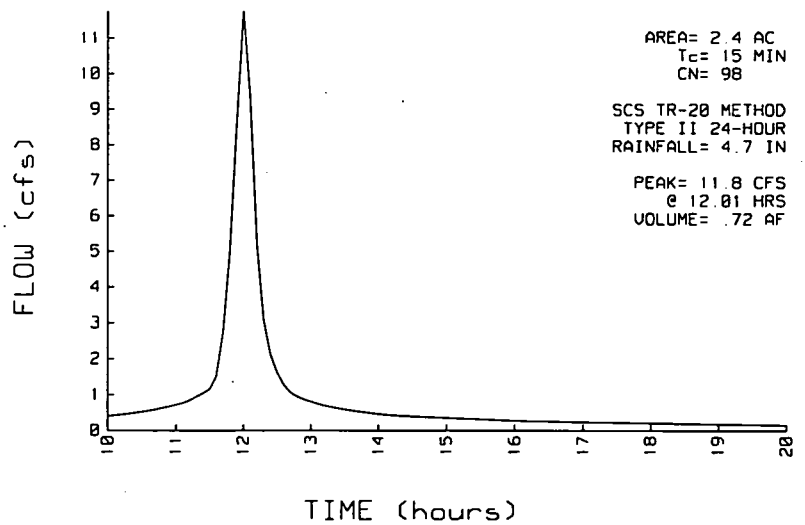
SUBCATCHMENT 5 **W-5**

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 11.8 CFS @ 12.01 HRS
VOLUME= .72 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.0
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.03 V=3.47 fps L=200' Capacity=35 cfs		
	Total Length= 707 ft Total Tc=	15.0

SUBCATCHMENT 5 RUNOFF
W-5



[redacted]
695

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

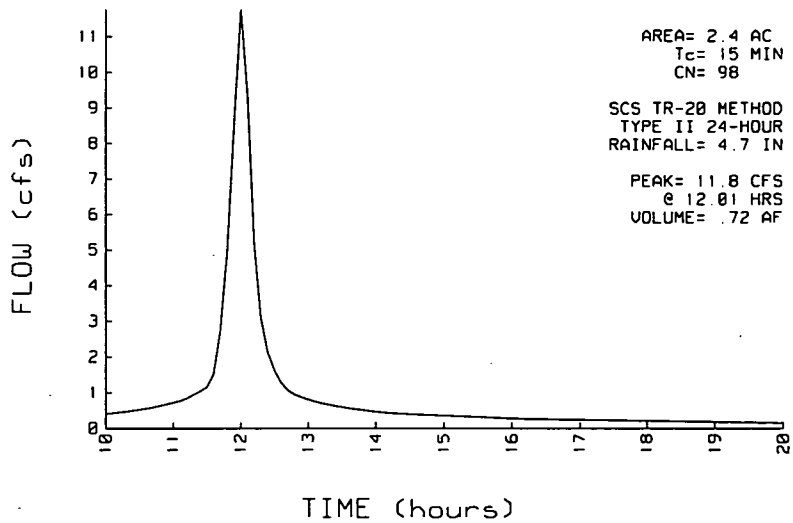
SUBCATCHMENT 6 **W-6 THROUGH W-12**

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 11.8 CFS @ 12.01 HRS
VOLUME= .72 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	1.0
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.03 V=3.47 fps L=200' Capacity=35 cfs		
	Total Length= 707 ft Total Tc=	15.0

SUBCATCHMENT 6 RUNOFF
W-6 THROUGH W-12



[redacted]
696

739 ASC 26/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

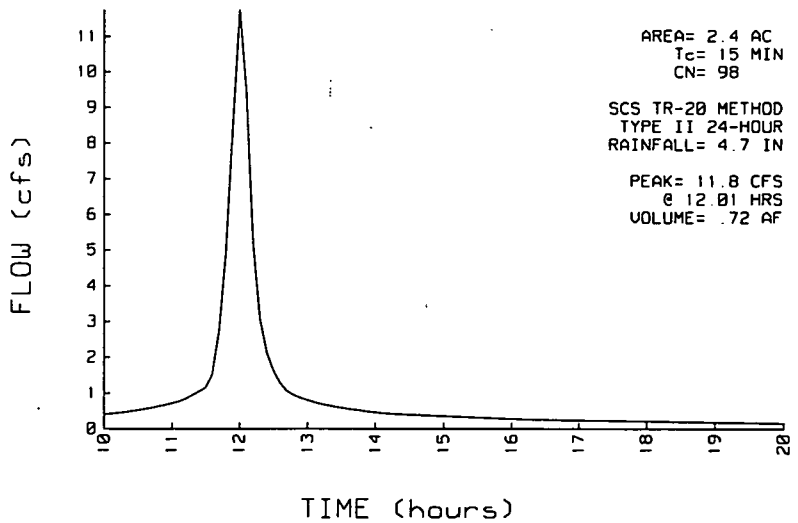
SUBCATCHMENT 7 W-13 THROUGH W-17

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 11.8 CFS @ 12.01 HRS
VOLUME= .72 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW		1.0
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.03 V=3.47 fps L=200' Capacity=35 cfs		
	Total Length= 707 ft Total Tc=	15.0

SUBCATCHMENT 7 RUNOFF



[redacted]
699

739 27/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SS 12Feb96

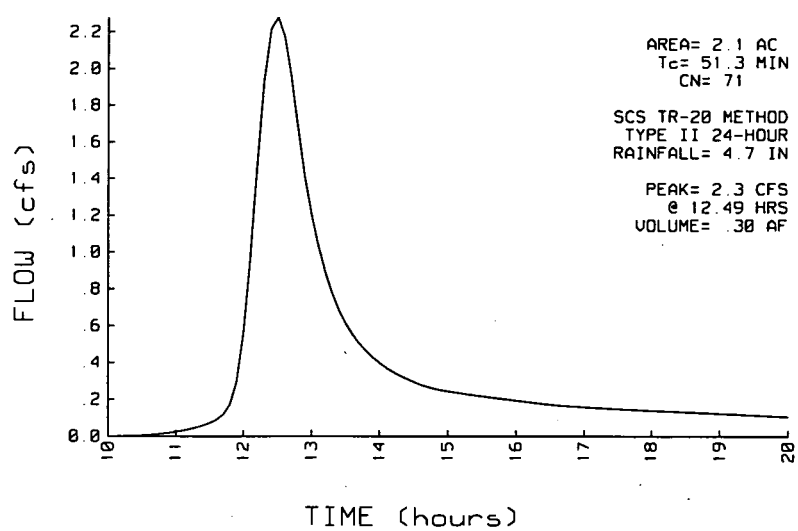
SUBCATCHMENT 20 **W-A**

ACRES	CN
2.10	71

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 2.3 CFS @ 12.49 HRS
VOLUME= .30 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	50.3
Grass: Dense n=.24 L=300' P2=2.6 in s=.01 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	1.0
Unpaved Kv=16.1345 L=100' s=.01 '/' V=1.61 fps		
	Total Length= 400 ft Total Tc=	51.3

SUBCATCHMENT 20 RUNOFF
W-A



[redacted]

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, HEAVY COVER** 739 28/74
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

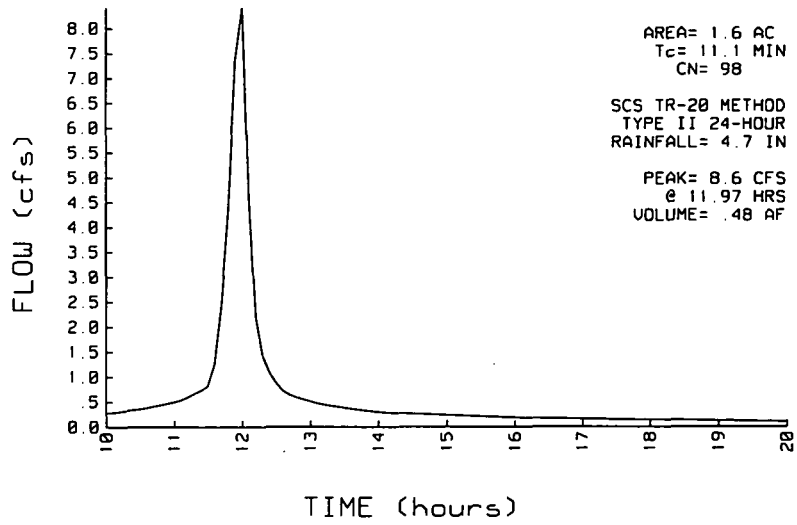
SUBCATCHMENT 1 W-1 EW-18

ACRES	CN
1.60	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 8.6 CFS @ 11.97 HRS
VOLUME= .48 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	6.8
Grass: Dense n=.24 L=100' P2=2.6 in s=.167 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.7
Unpaved Kv=16.1345 L=270' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	3.6
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.1 V=1.04 fps L=225' Capacity=10.5 cfs		
	Total Length= 595 ft Total Tc=	11.1

SUBCATCHMENT 1 RUNOFF
W-1



[redacted] 699

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

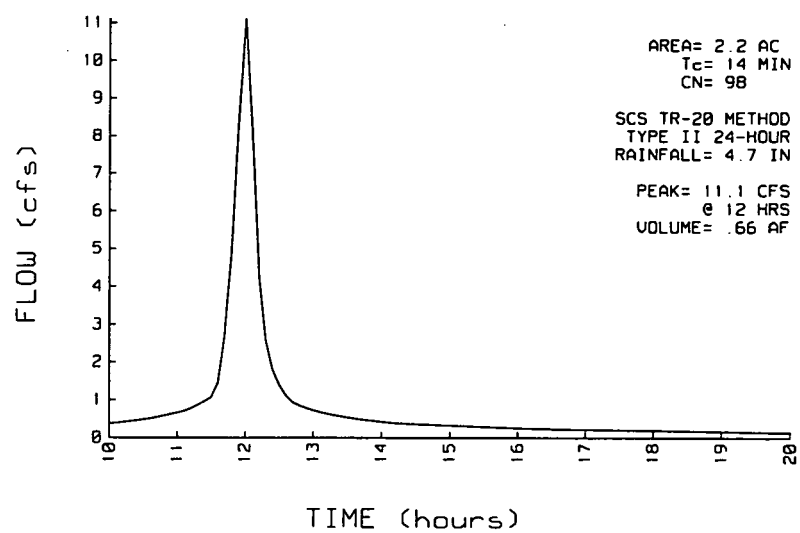
SUBCATCHMENT 2 **W-2**

ACRES	CN
2.20	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 11.1 CFS @ 12.00 HRS
VOLUME= .66 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
	Total Length= 507 ft Total Tc=	14.0

SUBCATCHMENT 2 RUNOFF
W-2



[redacted]

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, HEAVY COVER** 739 30/74
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

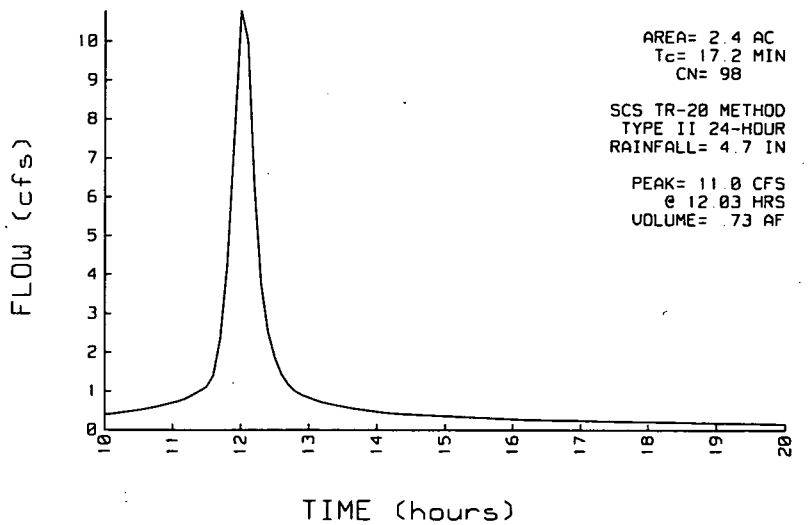
SUBCATCHMENT 3 **W-3**

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 11.0 CFS @ 12.03 HRS
VOLUME= .73 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	3.2
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.1 V=1.04 fps L=200' Capacity=10.5 cfs		
	Total Length= 707 ft Total Tc=	17.2

SUBCATCHMENT 3 RUNOFF
W-3



[redacted]

701

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

JSS 12Feb96

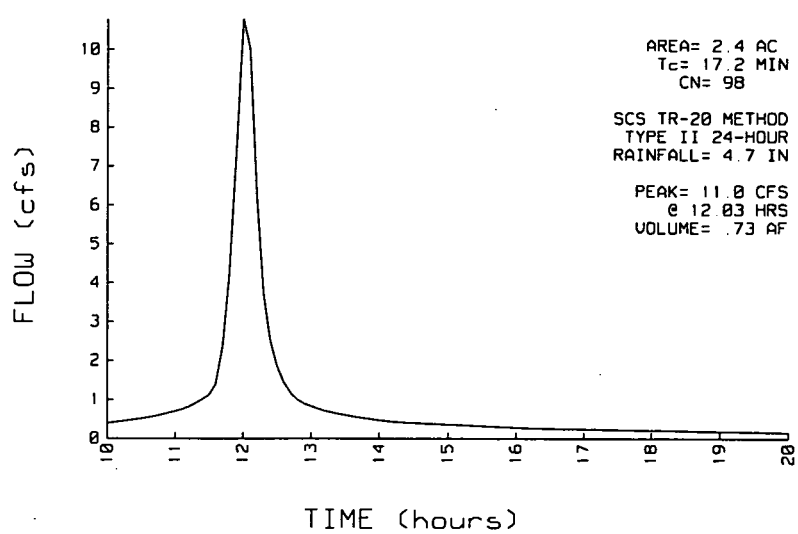
SUBCATCHMENT 4 **W-4**

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 11.0 CFS @ 12.03 HRS
VOLUME= .73 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	3.2
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.1 V=1.04 fps L=200' Capacity=10.5 cfs		
	Total Length= 707 ft Total Tc=	17.2

SUBCATCHMENT 4 RUNOFF
W-4



[redacted]
202

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

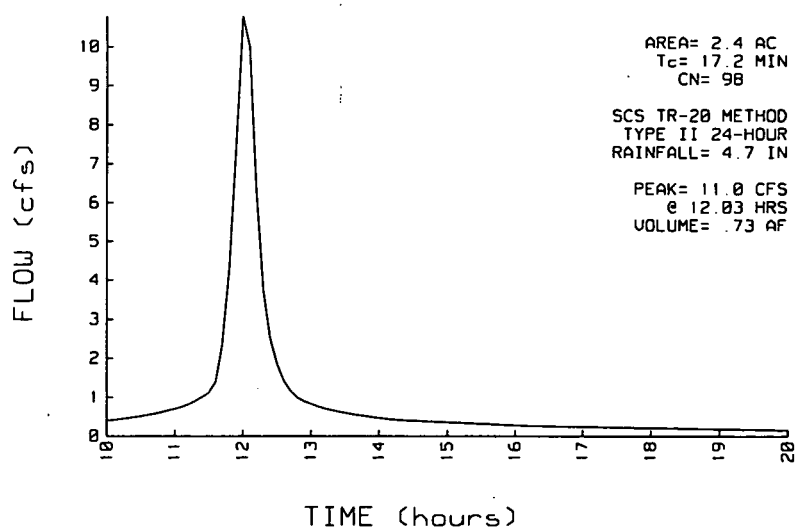
SUBCATCHMENT 5 **W-5**

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 11.0 CFS @ 12.03 HRS
VOLUME= .73 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	3.2
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.1 V=1.04 fps L=200' Capacity=10.5 cfs		
	Total Length= 707 ft Total Tc=	17.2

SUBCATCHMENT 5 RUNOFF
W-5



739 ave 33/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

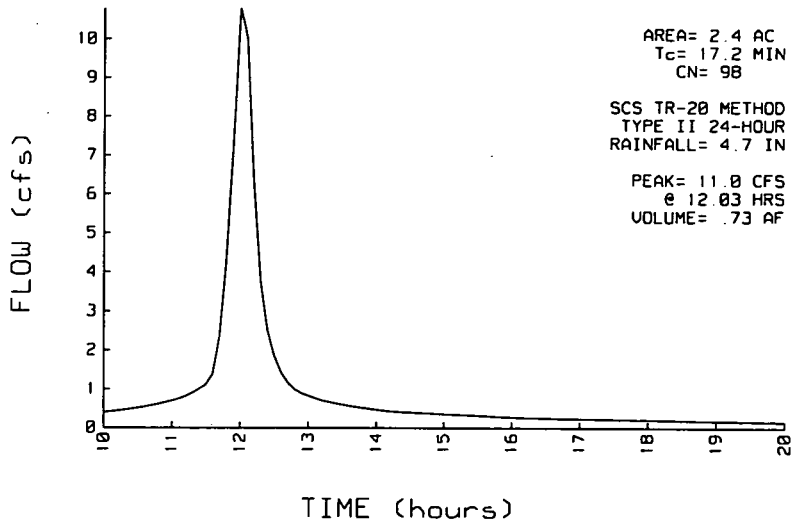
SUBCATCHMENT 6 **W-6 THROUGH W-12**

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 11.0 CFS @ 12.03 HRS
VOLUME= .73 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW	**Segment ID:**	3.2
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.1 V=1.04 fps L=200' Capacity=10.5 cfs		
	Total Length= 707 ft Total Tc=	17.2

SUBCATCHMENT 6 RUNOFF
W-6 THROUGH W-12



[redacted]
204

739 NSC 34/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, HEAVY COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

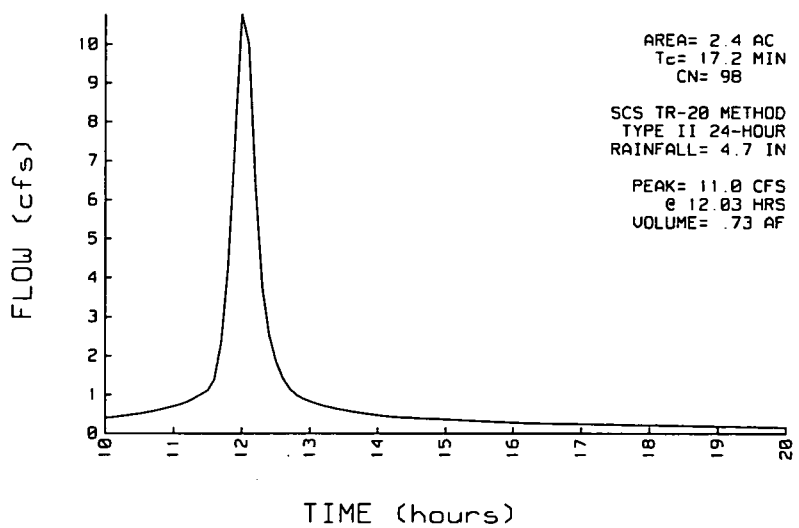
SUBCATCHMENT 7 W-13 THROUGH W-17

ACRES	CN
2.40	98

SCS TR-20 METHOD
TYPE II 24-HOUR
RAINFALL= 4.7 IN
PEAK= 11.0 CFS @ 12.03 HRS
VOLUME= .73 AF

Method	Comment	Tc (min)
TR-55 SHEET FLOW	**Segment ID:**	13.1
Grass: Dense n=.24 L=147' P2=2.6 in s=.07 '/'		
SHALLOW CONCENTRATED/UPLAND FLOW	**Segment ID:**	.9
Unpaved Kv=16.1345 L=360' s=.167 '/' V=6.59 fps		
CHANNEL FLOW		3.2
a=10.1 sq-ft Pw=13.9' r=.727'		
s=.0075 '/' n=.1 V=1.04 fps L=200' Capacity=10.5 cfs		
	Total Length= 707 ft Total Tc=	17.2

SUBCATCHMENT 7 RUNOFF



[redacted]
205

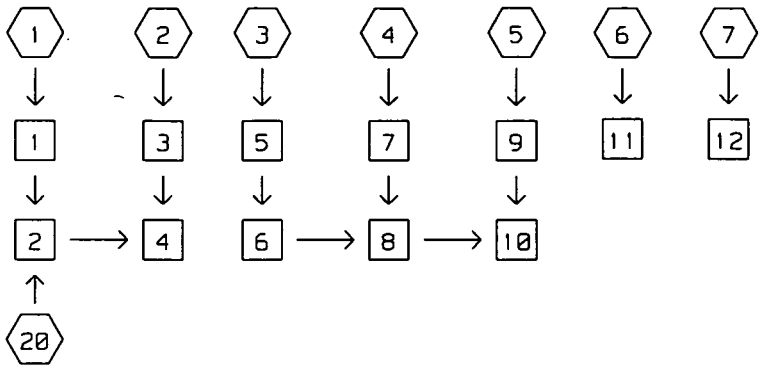
HYDROCAD™ RUNS

DRAINAGE CHANNEL ROUTING

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER** 739 NSC 36/74
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

155 12 Feb 96

WATERSHED ROUTING ==========



[redacted]

207

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER** 739 1/2 37/74
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

JSS 12 Feb 96

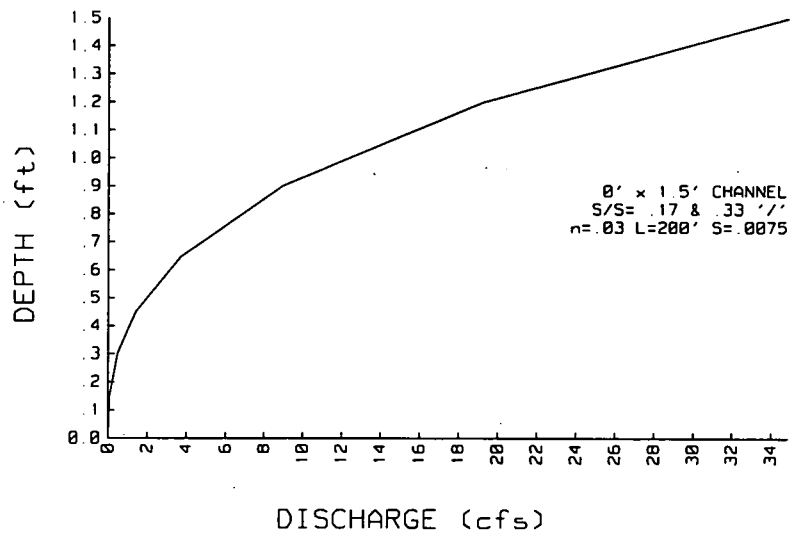
REACH 1 **MH-1**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.1
.3	.4	.5
.5	.9	1.4
.6	1.9	3.7
.9	3.6	8.9
1.2	6.4	19.2
1.5	10.0	34.9

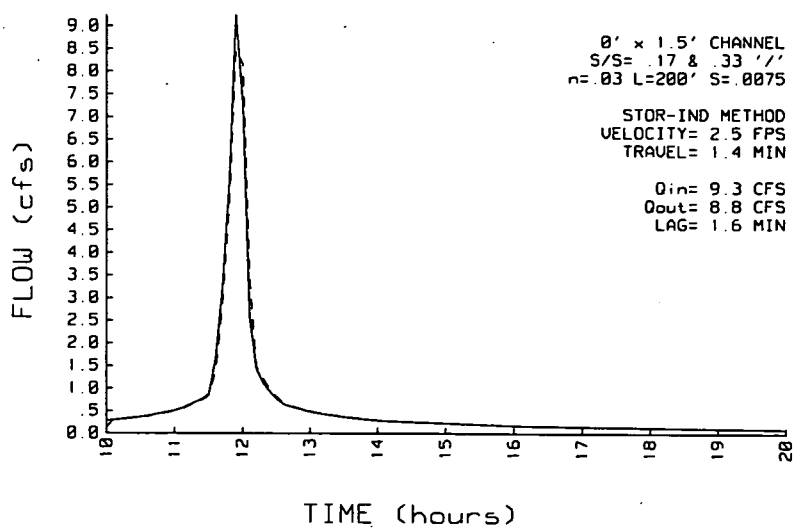
0' x 1.5' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 200 FT
SLOPE= .0075 FT/FT

STOR-IND METHOD
MAX. DEPTH= .88 FT
PEAK VELOCITY= 2.5 FPS
TRAVEL TIME = 1.4 MIN
Qin = 9.3 CFS @ 11.91 HRS
Qout= 8.8 CFS @ 11.94 HRS
ATTEN= 6 % LAG= 1.6 MIN
IN/OUT= .48 / .48 AF

REACH 1 DISCHARGE
MH-1



REACH 1 INFLOW & OUTFLOW
MH-1



[redacted]

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER** 739 ASC 38/74
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

ASS 12 Feb 96

REACH 1 **MH-1**

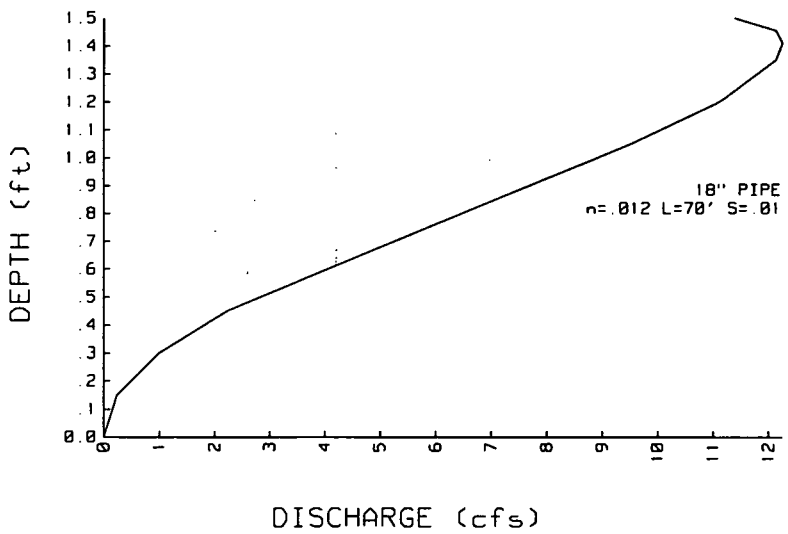
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.2
.3	.3	1.0
.5	.4	2.2
1.1	1.3	9.5
1.2	1.5	11.1
1.4	1.7	12.1
1.4	1.7	12.2
1.5	1.8	12.1
1.5	1.8	11.4

18" PIPE

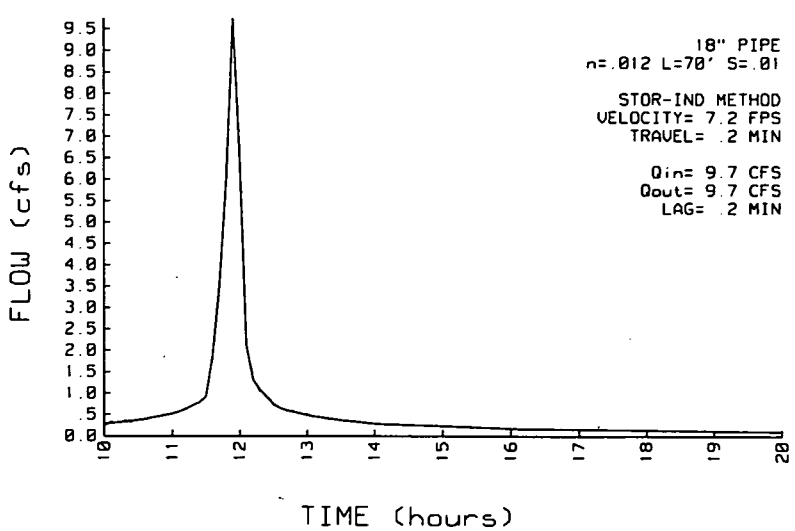
n= .012
LENGTH= 70 FT
SLOPE= .01 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.06 FT
PEAK VELOCITY= 7.2 FPS
TRAVEL TIME = .2 MIN
Qin = 9.7 CFS @ 11.90 HRS
Qout= 9.7 CFS @ 11.91 HRS
ATTEN= 1 % LAG= .2 MIN
IN/OUT= .48 / .48 AF

REACH 1 DISCHARGE
MH-1



REACH 1 INFLOW & OUTFLOW
MH-1



[redacted] 709

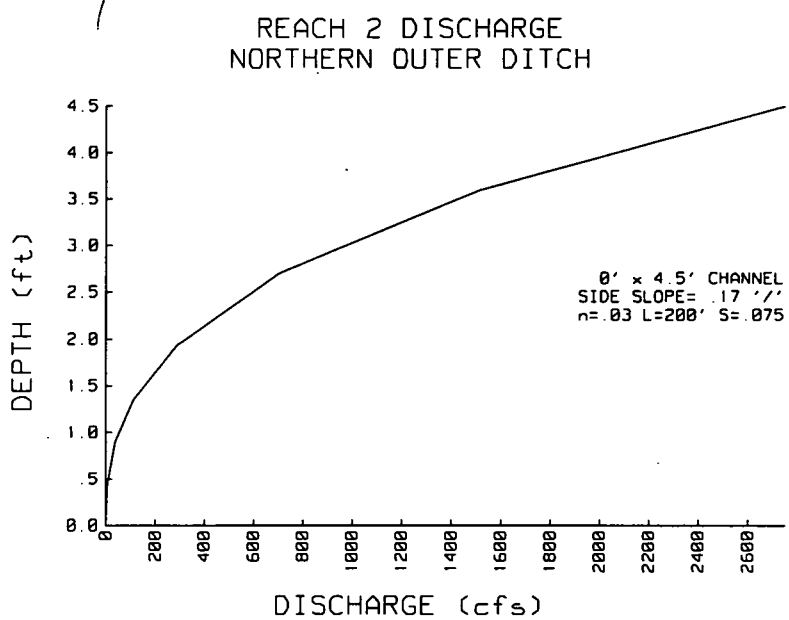
SSS 12 Feb 96

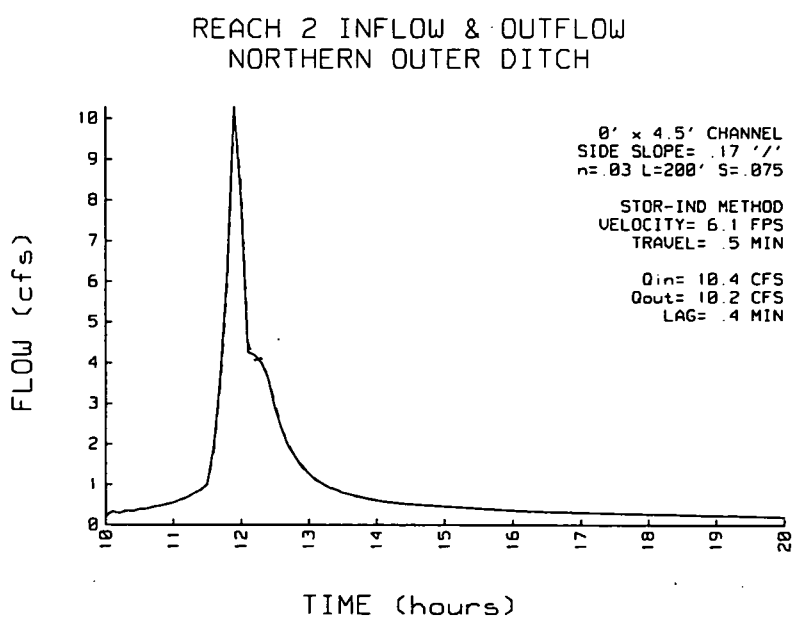
REACH 2 **NORTHERN OUTER DITCH**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	1.2	5.9
.9	4.8	37.6
1.4	10.7	110.8
1.9	22.0	289.5
2.7	42.9	703.8
3.6	76.2	1515.8
4.5	119.1	2748.3

0' x 4.5' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 200 FT
SLOPE= .075 FT/FT

STOR-IND METHOD
MAX. DEPTH= .51 FT
PEAK VELOCITY= 6.1 FPS
TRAVEL TIME = .5 MIN
Qin = 10.4 CFS @ 11.91 HRS
Qout= 10.2 CFS @ 11.92 HRS
ATTEN= 1 % LAG= .4 MIN
IN/OUT= .78 / .78 AF





739 ASC 40/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

JSS 12 Feb 96

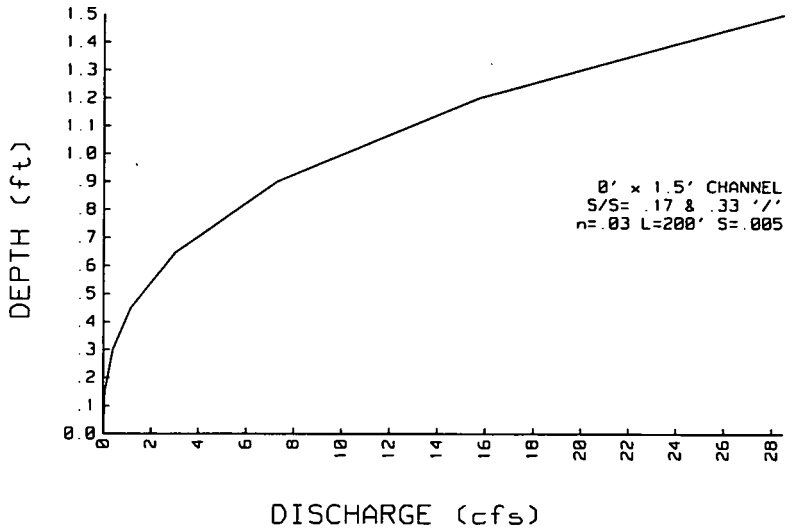
REACH 3 **MH-1.5**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.1
.3	.4	.4
.5	.9	1.1
.6	1.9	3.0
.9	3.6	7.3
1.2	6.4	15.7
1.5	10.0	28.5

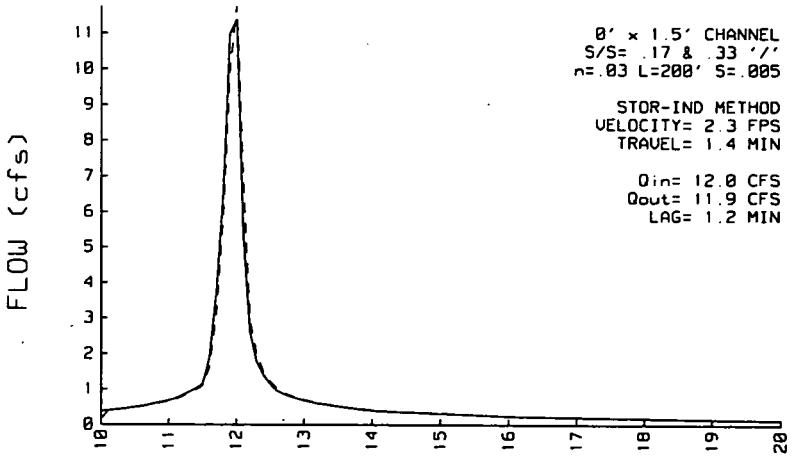
0' x 1.5' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 200 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.06 FT
PEAK VELOCITY= 2.3 FPS
TRAVEL TIME = 1.4 MIN
Qin = 12.0 CFS @ 11.96 HRS
Qout= 11.9 CFS @ 11.98 HRS
ATTEN= 1 % LAG= 1.2 MIN
IN/OUT= .66 / .66 AF

REACH 3 DISCHARGE
MH-1.5



REACH 3 INFLOW & OUTFLOW
MH-1.5



[redacted]

211

739 LJC 41/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

GSS 12Feb96

REACH 3 MH-1.5

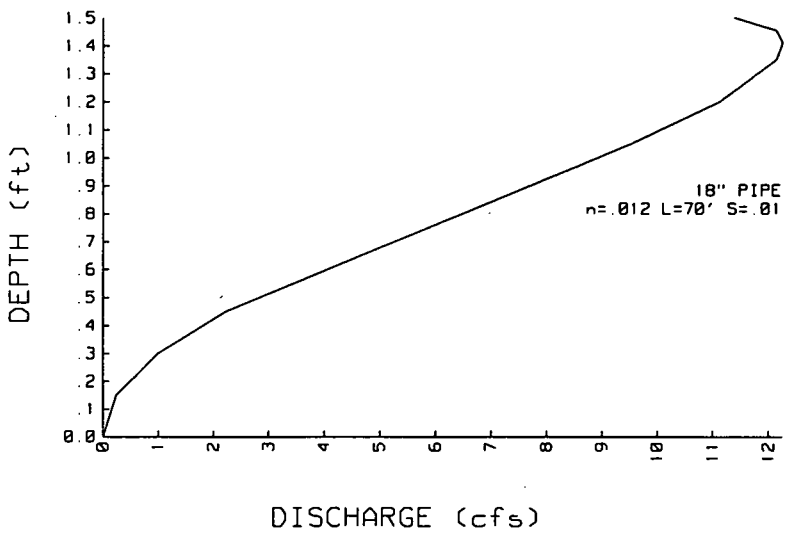
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.2
.3	.3	1.0
.5	.4	2.2
1.1	1.3	9.5
1.2	1.5	11.1
1.4	1.7	12.1
1.4	1.7	12.2
1.5	1.8	12.1
1.5	1.8	11.4

18" PIPE

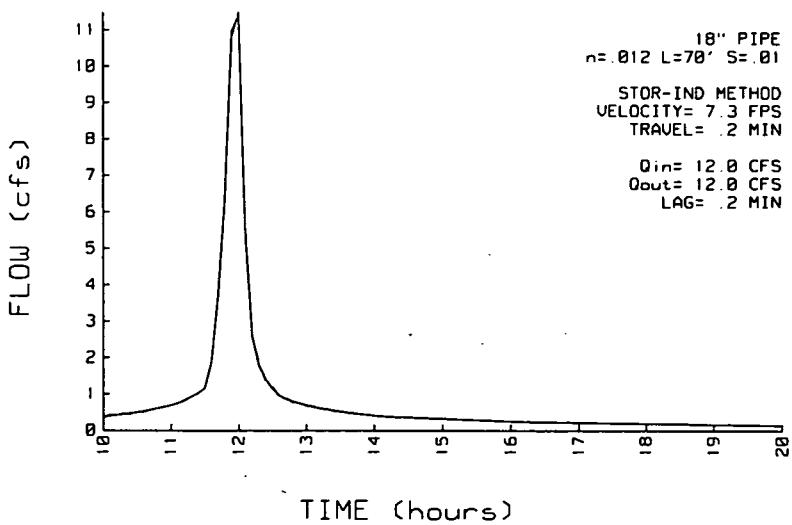
n= .012
LENGTH= 70 FT
SLOPE= .01 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.25 FT
PEAK VELOCITY= 7.3 FPS
TRAVEL TIME = .2 MIN
Qin = 12.0 CFS @ 11.96 HRS
Qout= 12.0 CFS @ 11.96 HRS
ATTEN= 0 % LAG= .2 MIN
IN/OUT= .66 / .66 AF

REACH 3 DISCHARGE



REACH 3 INFLOW & OUTFLOW



[redacted]

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER** 739 Asc 42/74
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12 Feb 96

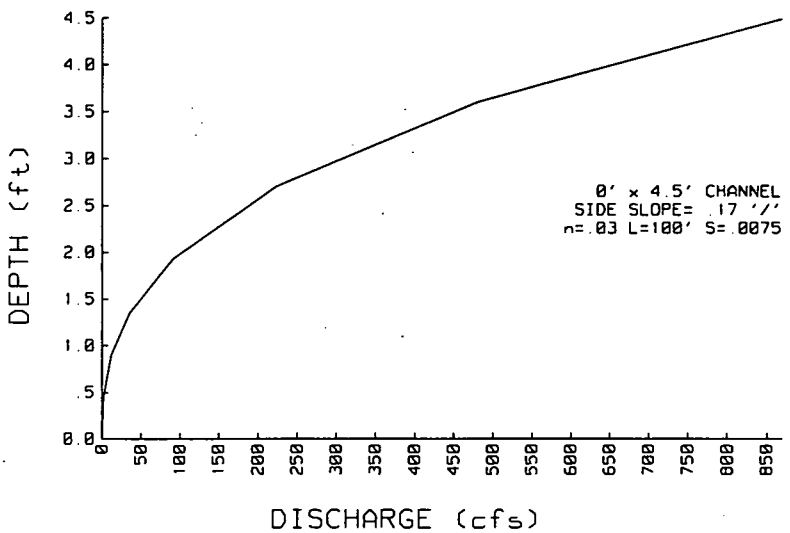
REACH 4

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	1.2	1.9
.9	4.8	11.9
1.4	10.7	35.1
1.9	22.0	91.5
2.7	42.9	222.6
3.6	76.2	479.3
4.5	119.1	869.1

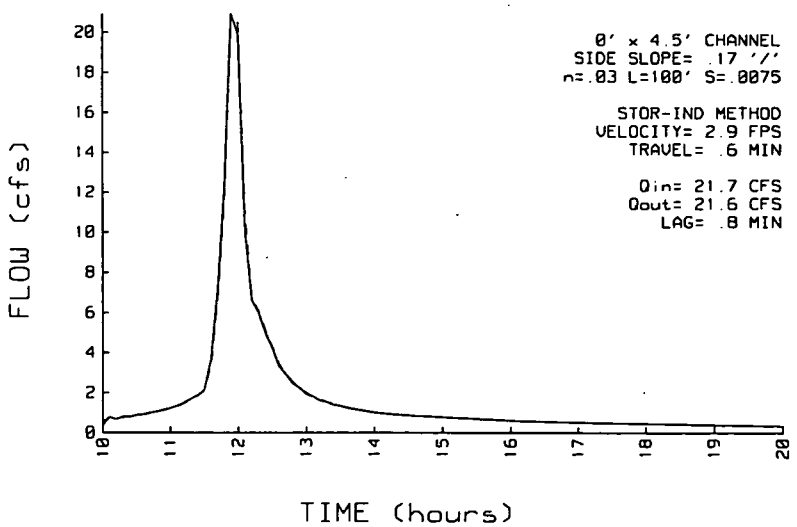
0' x 4.5' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 100 FT
SLOPE= .0075 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.07 FT
PEAK VELOCITY= 2.9 FPS
TRAVEL TIME = .6 MIN
Qin = 21.7 CFS @ 11.94 HRS
Qout= 21.6 CFS @ 11.95 HRS
ATTEN= 0 % LAG= .8 MIN
IN/OUT= 1.44 / 1.44 AF

REACH 4 DISCHARGE



REACH 4 INFLOW & OUTFLOW



[redacted] 713

SSS 12feb96

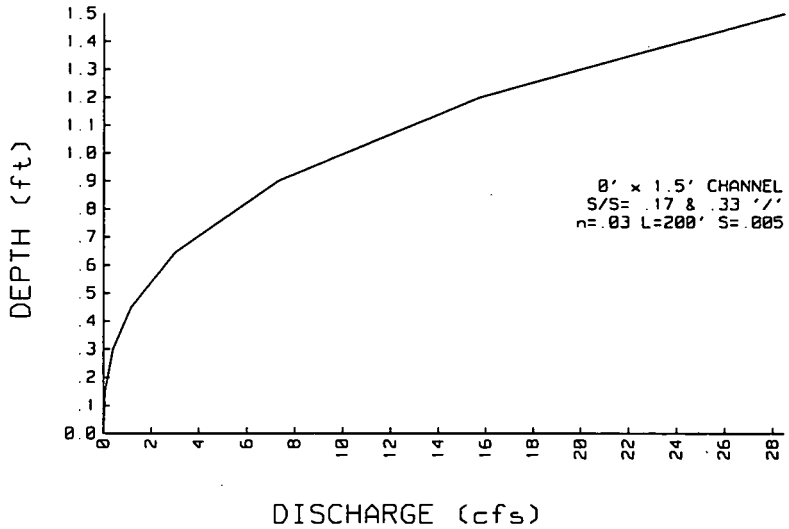
REACH 7 **MH-2 THROUGH MH-10**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.1
.3	.4	.4
.5	.9	1.1
.6	1.9	3.0
.9	3.6	7.3
1.2	6.4	15.7
1.5	10.0	28.5

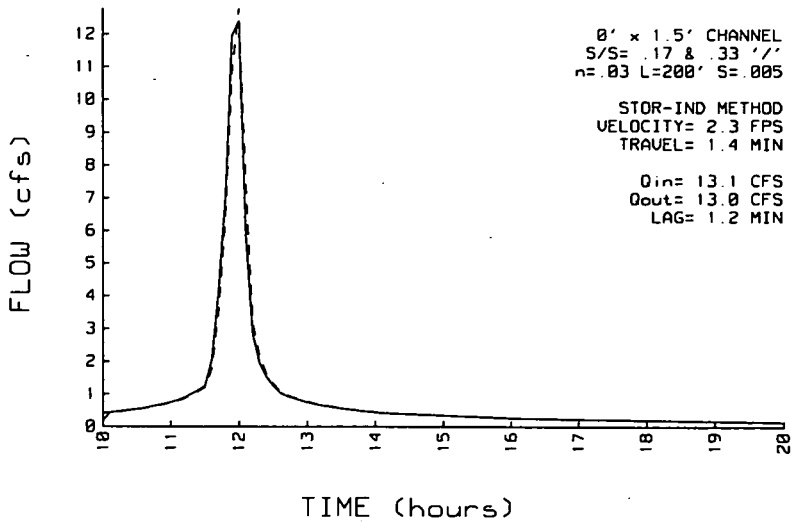
0' x 1.5' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 200 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.10 FT
PEAK VELOCITY= 2.3 FPS
TRAVEL TIME = 1.4 MIN
Qin = 13.1 CFS @ 11.96 HRS
Qout= 13.0 CFS @ 11.98 HRS
ATTEN= 1 % LAG= 1.2 MIN
IN/OUT= .72 / .72 AF

REACH 7 DISCHARGE
MH-2 THROUGH MH-10



REACH 7 INFLOW & OUTFLOW
MH-2 THROUGH MH-10



[redacted]
214

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER** 739 ASC 44/74
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SS 12 Feb 96

REACH 5 **MH-2** THROUGH MH-10

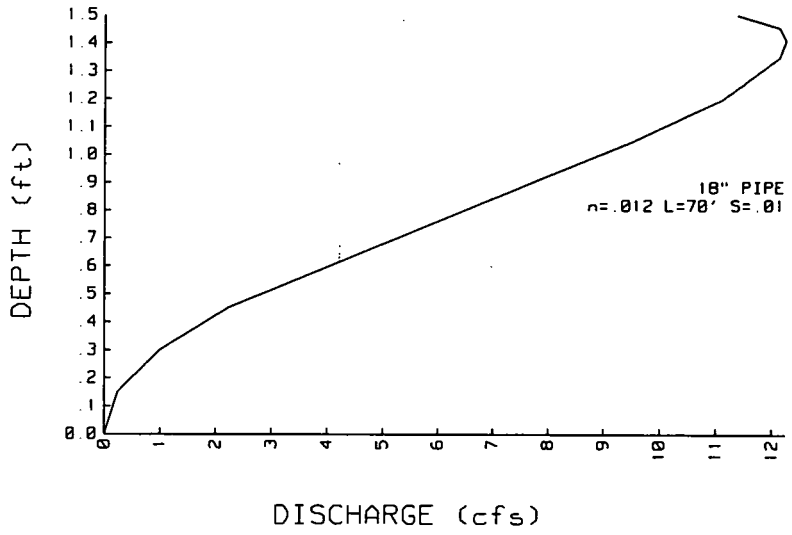
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.2
.3	.3	1.0
.5	.4	2.2
1.1	1.3	9.5
1.2	1.5	11.1
1.4	1.7	12.1
1.4	1.7	12.2
1.5	1.8	12.1
1.5	1.8	11.4

18" PIPE

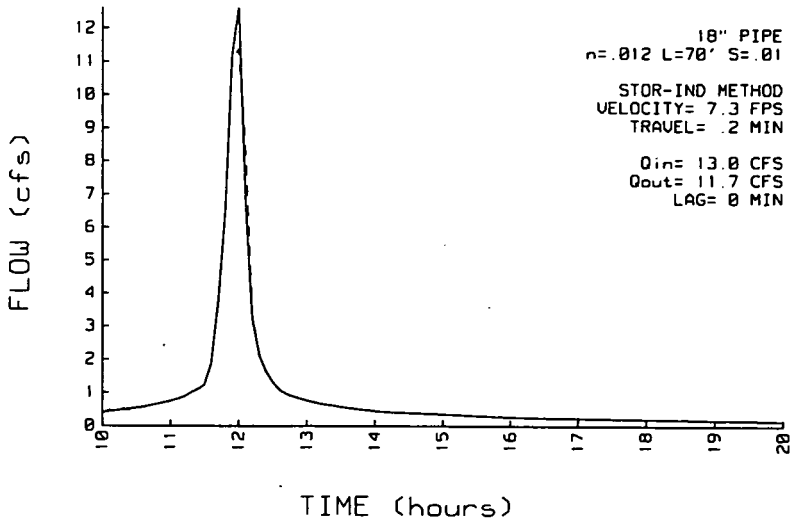
n= .012
LENGTH= 70 FT
SLOPE= .01 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.50 FT
PEAK VELOCITY= 7.3 FPS
TRAVEL TIME = .2 MIN
Qin = 13.0 CFS @ 11.97 HRS
Qout= 11.7 CFS @ 11.96 HRS
ATTEN= 10 % LAG= 0.0 MIN
IN/OUT= .72 / .72 AF

REACH 5 DISCHARGE
MH-2



REACH 5 INFLOW & OUTFLOW
MH-2



[redacted]

215

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

AJS 12 Feb 96

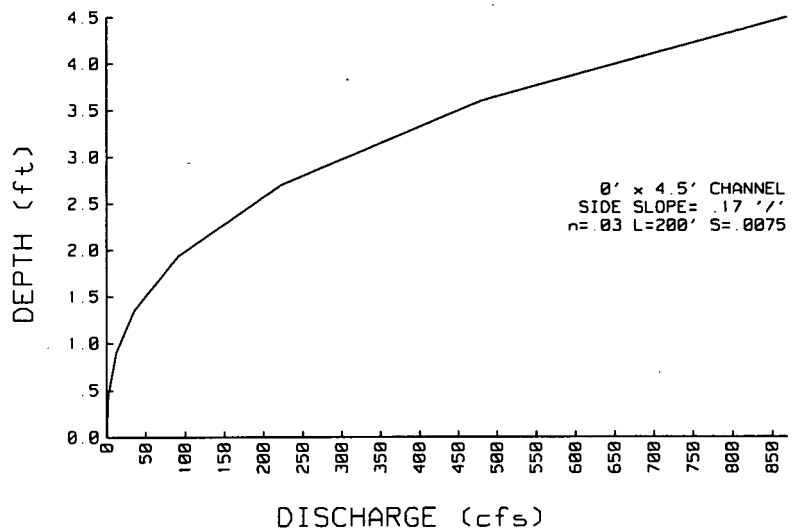
REACH 6 **CENTRAL OUTER DITCH**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	1.2	1.9
.9	4.8	11.9
1.4	10.7	35.1
1.9	22.0	91.5
2.7	42.9	222.6
3.6	76.2	479.3
4.5	119.1	869.1

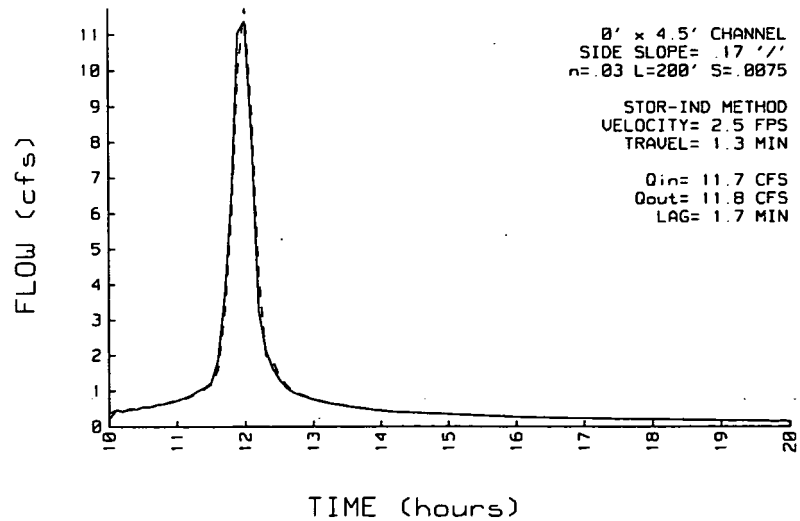
0' x 4.5' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 200 FT
SLOPE= .0075 FT/FT

STOR-IND METHOD
MAX. DEPTH= .89 FT
PEAK VELOCITY= 2.5 FPS
TRAVEL TIME = 1.3 MIN
Qin = 11.7 CFS @ 11.96 HRS
Qout= 11.8 CFS @ 11.99 HRS
ATTEN= 0 % LAG= 1.7 MIN
IN/OUT= .72 / .72 AF

REACH 6 DISCHARGE
CENTRAL OUTER DITCH



REACH 6 INFLOW & OUTFLOW
CENTRAL OUTER DITCH



[redacted]

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12 Feb 96

REACH 7

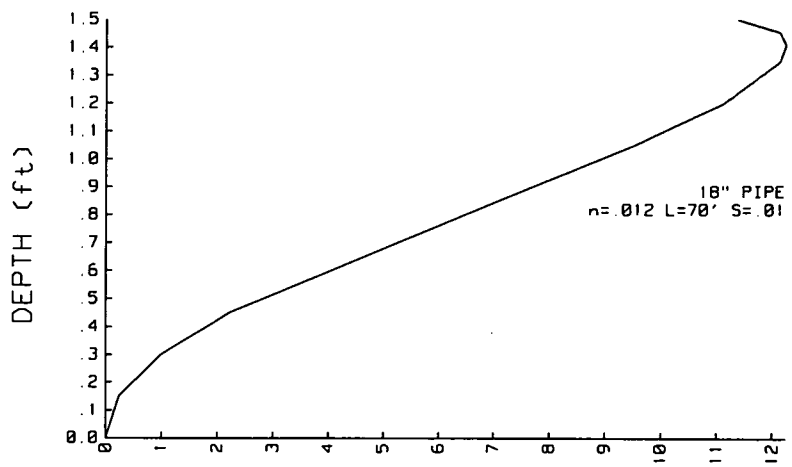
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.2
.3	.3	1.0
.5	.4	2.2
1.1	1.3	9.5
1.2	1.5	11.1
1.4	1.7	12.1
1.4	1.7	12.2
1.5	1.8	12.1
1.5	1.8	11.4

18" PIPE

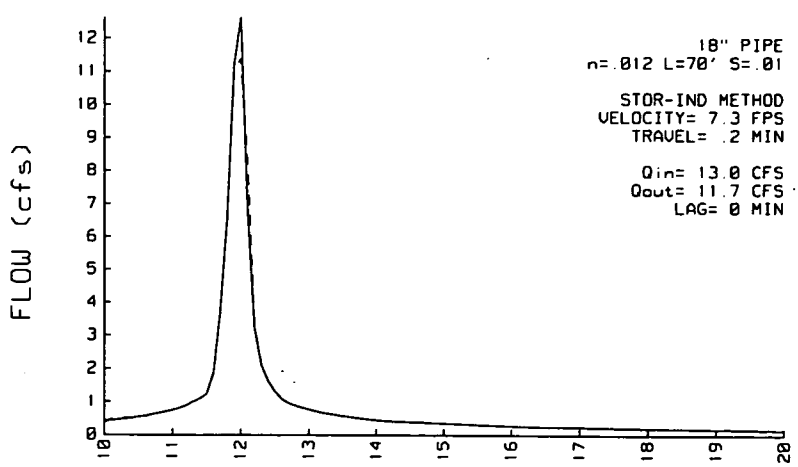
n= .012
LENGTH= 70 FT
SLOPE= .01 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.50 FT
PEAK VELOCITY= 7.3 FPS
TRAVEL TIME = .2 MIN
Qin = 13.0 CFS @ 11.97 HRS
Qout= 11.7 CFS @ 11.96 HRS
ATTEN= 10 % LAG= 0.0 MIN
IN/OUT= .72 / .72 AF

REACH 7 DISCHARGE



REACH 7 INFLOW & OUTFLOW



[redacted]

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER** 739 Asc 47/74
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

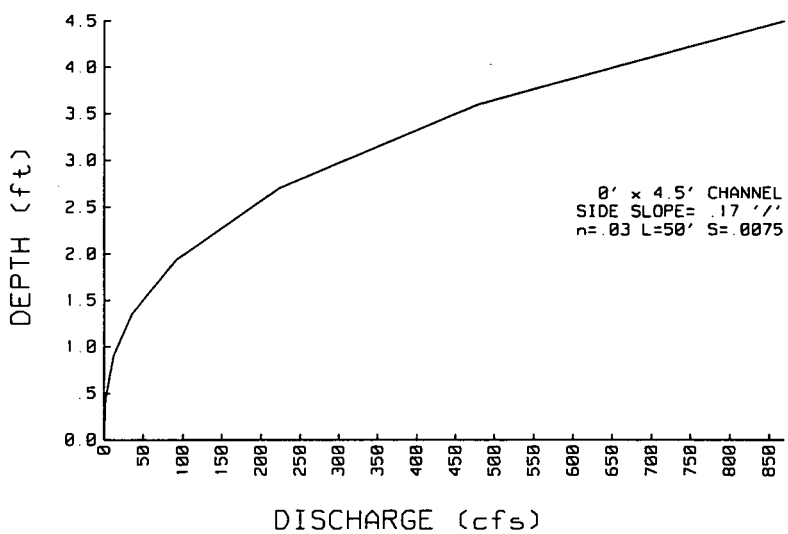
REACH 8 **CENTRAL OUTER DITCH**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	1.2	1.9
.9	4.8	11.9
1.4	10.7	35.1
1.9	22.0	91.5
2.7	42.9	222.6
3.6	76.2	479.3
4.5	119.1	869.1

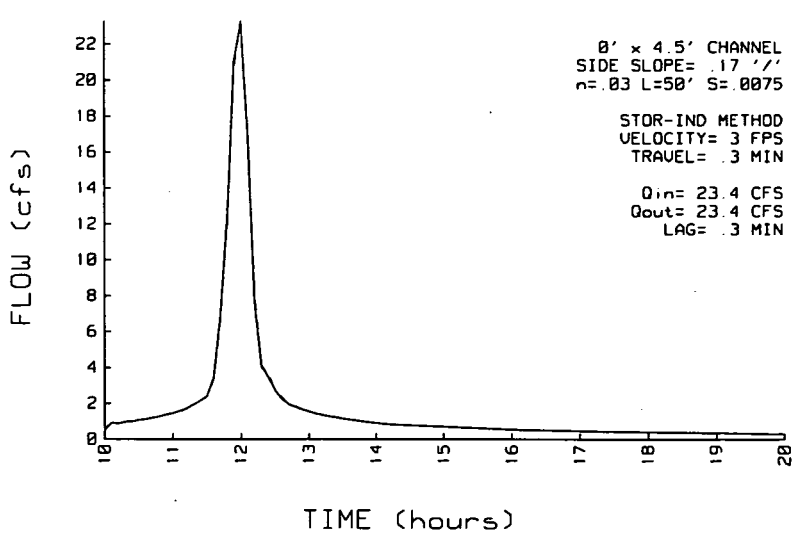
0' x 4.5' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 50 FT
SLOPE= .0075 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.12 FT
PEAK VELOCITY= 3.0 FPS
TRAVEL TIME = .3 MIN
Qin = 23.4 CFS @ 11.98 HRS
Qout= 23.4 CFS @ 11.98 HRS
ATTEN= 0 % LAG= .3 MIN
IN/OUT= 1.45 / 1.45 AF

REACH 8 DISCHARGE
CENTRAL OUTER DITCH



REACH 8 INFLOW & OUTFLOW
CENTRAL OUTER DITCH



[redacted]

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

REACH 9 **MH-3**

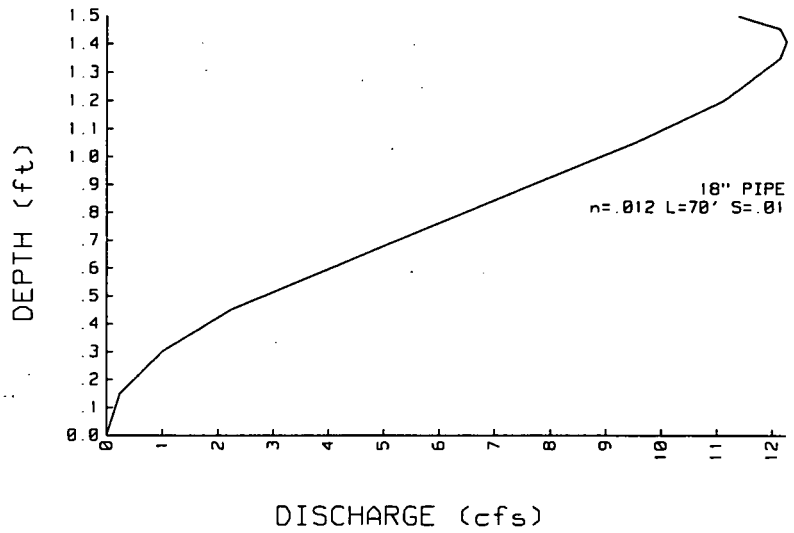
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.2
.3	.3	1.0
.5	.4	2.2
1.1	1.3	9.5
1.2	1.5	11.1
1.4	1.7	12.1
1.4	1.7	12.2
1.5	1.8	12.1
1.5	1.8	11.4

18" PIPE

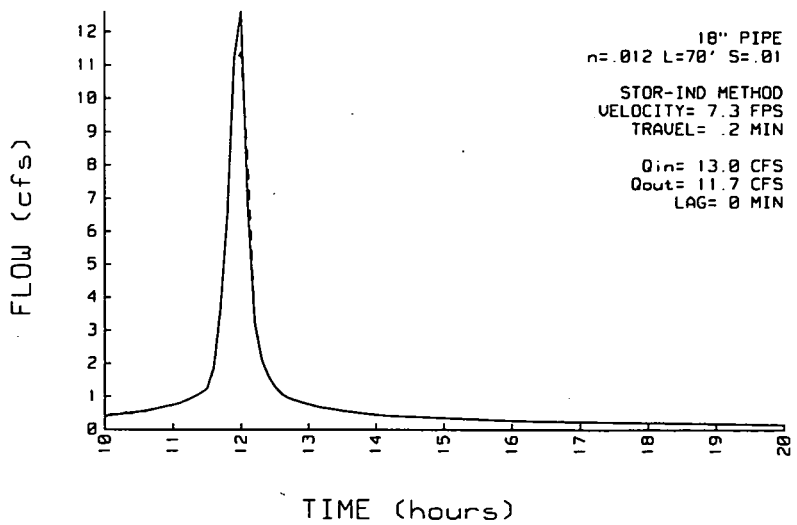
n= .012
LENGTH= 70 FT
SLOPE= .01 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.50 FT
PEAK VELOCITY= 7.3 FPS
TRAVEL TIME = .2 MIN
Qin = 13.0 CFS @ 11.97 HRS
Qout= 11.7 CFS @ 11.96 HRS
ATTEN= 10 % LAG= 0.0 MIN
IN/OUT= .72 / .72 AF

REACH 9 DISCHARGE
MH-3



REACH 9 INFLOW & OUTFLOW
MH-3



739

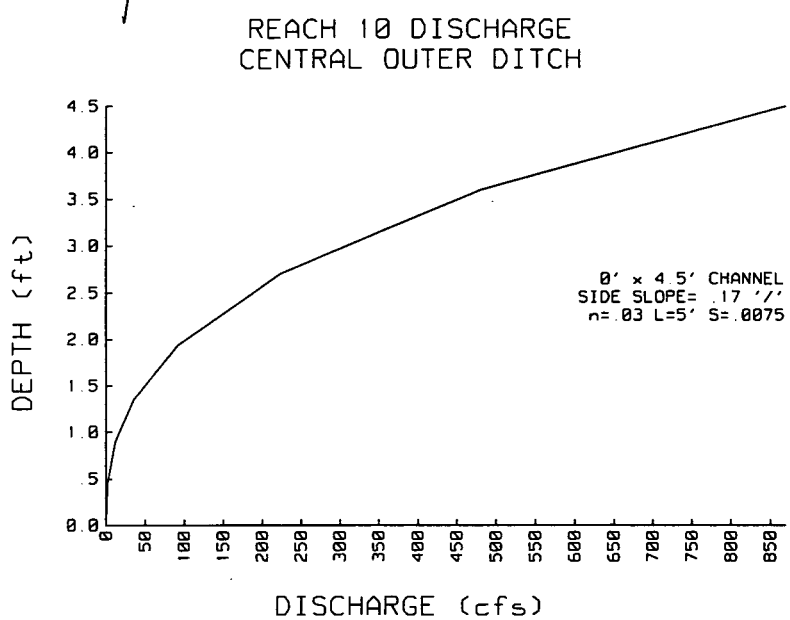
Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

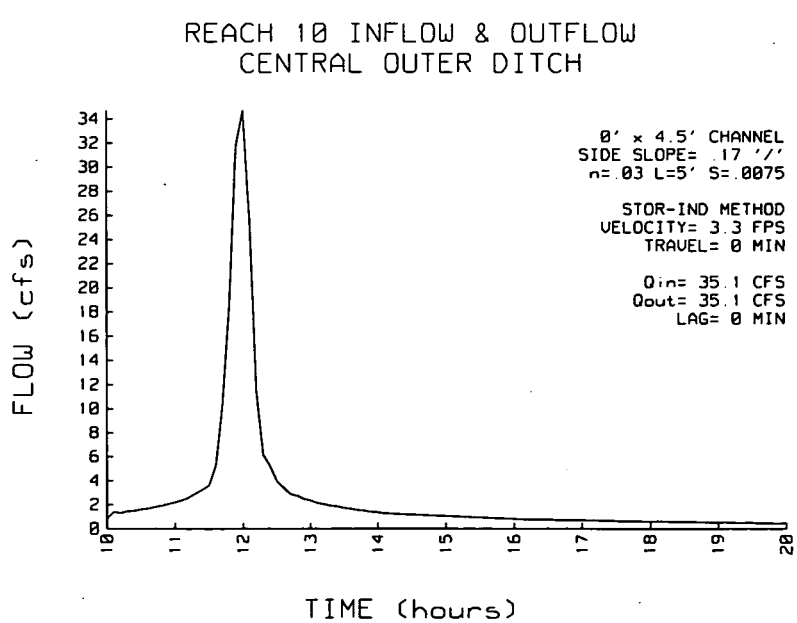
REACH 10 **CENTRAL OUTER DITCH**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	1.2	1.9
.9	4.8	11.9
1.4	10.7	35.1
1.9	22.0	91.5
2.7	42.9	222.6
3.6	76.2	479.3
4.5	119.1	869.1

0' x 4.5' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 5 FT
SLOPE= .0075 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.34 FT
PEAK VELOCITY= 3.3 FPS
TRAVEL TIME = 0.0 MIN
Qin = 35.1 CFS @ 11.97 HRS
Qout= 35.1 CFS @ 11.97 HRS
ATTEN= 0 % LAG= 0.0 MIN
IN/OUT= 2.17 / 2.17 AF





[redacted]

REACH 11 **CULVERTS**

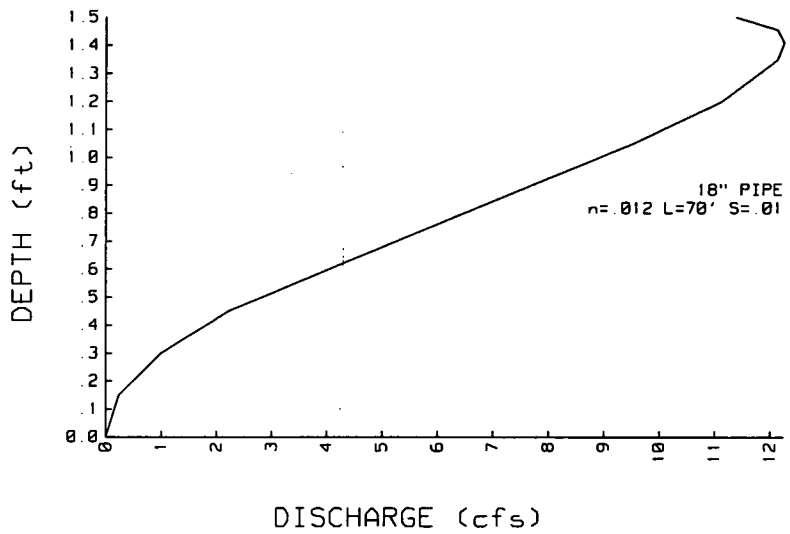
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.2
.3	.3	1.0
.5	.4	2.2
1.1	1.3	9.5
1.2	1.5	11.1
1.4	1.7	12.1
1.4	1.7	12.2
1.5	1.8	12.1
1.5	1.8	11.4

18" PIPE

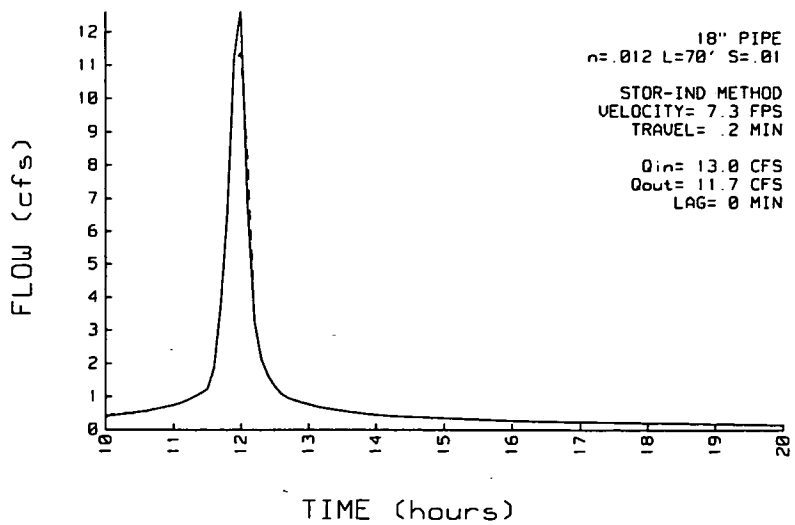
n= .012
LENGTH= 70 FT
SLOPE= .01 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.50 FT
PEAK VELOCITY= 7.3 FPS
TRAVEL TIME = .2 MIN
Qin = 13.0 CFS @ 11.97 HRS
Qout= 11.7 CFS @ 11.96 HRS
ATTEN= 10 % LAG= 0.0 MIN
IN/OUT= .72 / .72 AF

REACH 11 DISCHARGE
CULVERTS



REACH 11 INFLOW & OUTFLOW
CULVERTS



[redacted]

F- 739

RSC 51/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, LIGHT COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

REACH 12 **CULVERTS**

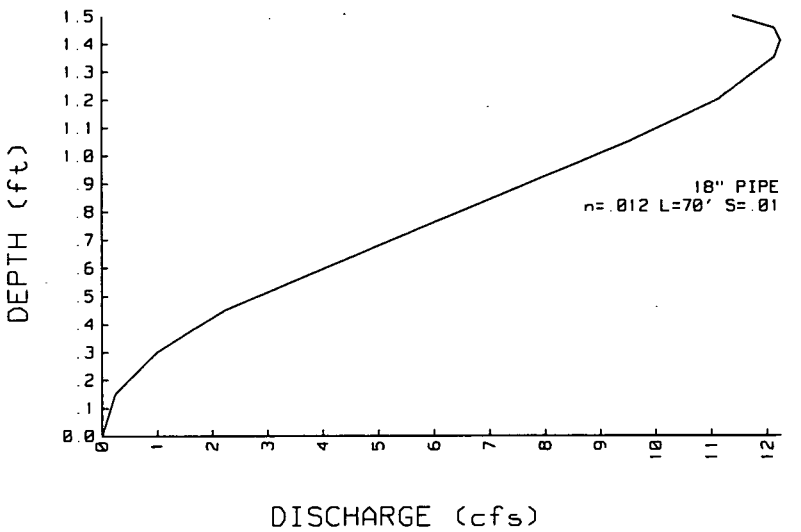
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.2
.3	.3	1.0
.5	.4	2.2
1.1	1.3	9.5
1.2	1.5	11.1
1.4	1.7	12.1
1.4	1.7	12.2
1.5	1.8	12.1
1.5	1.8	11.4

18" PIPE

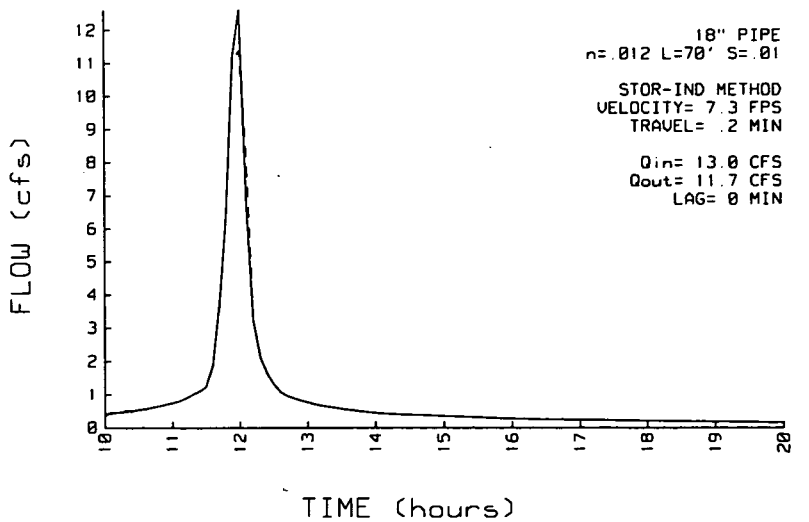
n= .012
LENGTH= 70 FT
SLOPE= .01 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.50 FT
PEAK VELOCITY= 7.3 FPS
TRAVEL TIME = .2 MIN
Qin = 13.0 CFS @ 11.97 HRS
Qout= 11.7 CFS @ 11.96 HRS
ATTEN= 10 % LAG= 0.0 MIN
IN/OUT= .72 / .72 AF

REACH 12 DISCHARGE
CULVERTS



REACH 12 INFLOW & OUTFLOW
CULVERTS



[redacted]
122

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12 Feb 96

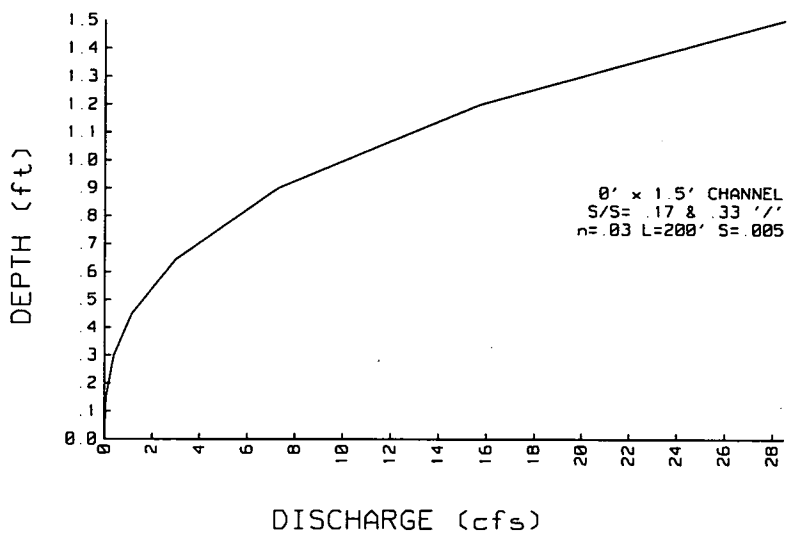
REACH 1 **MH-1**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.1
.3	.4	.4
.5	.9	1.1
.6	1.9	3.0
.9	3.6	7.3
1.2	6.4	15.7
1.5	10.0	28.5

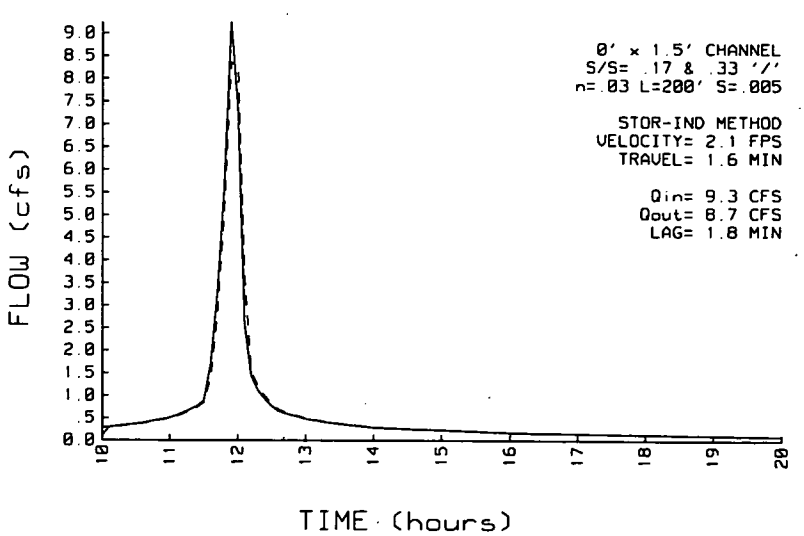
0' x 1.5' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 200 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= .94 FT
PEAK VELOCITY= 2.1 FPS
TRAVEL TIME = 1.6 MIN
Qin = 9.3 CFS @ 11.91 HRS
Qout= 8.7 CFS @ 11.95 HRS
ATTEN= 6 % LAG= 1.8 MIN
IN/OUT= .48 / .48 AF

REACH 1 DISCHARGE
MH-1



REACH 1 INFLOW & OUTFLOW
MH-1



739

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

ASC 53/74

9 Feb 96

SSS 12 Feb 96

REACH 1 **MH-1**

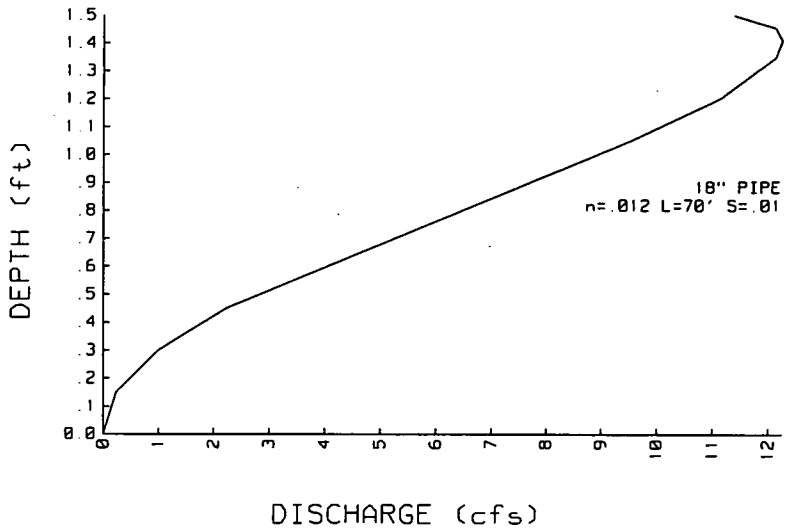
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.2
.3	.3	1.0
.5	.4	2.2
1.1	1.3	9.5
1.2	1.5	11.1
1.4	1.7	12.1
1.4	1.7	12.2
1.5	1.8	12.1
1.5	1.8	11.4

18" PIPE

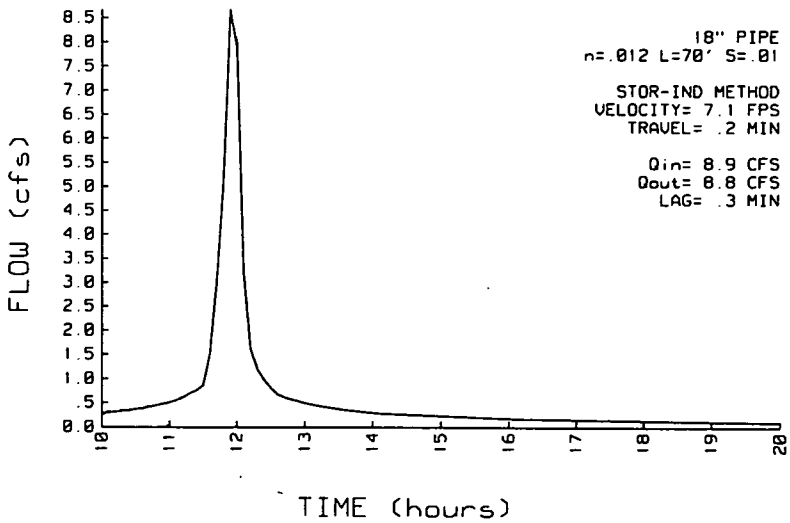
n= .012
LENGTH= 70 FT
SLOPE= .01 FT/FT

STOR-IND METHOD
MAX. DEPTH= .97 FT
PEAK VELOCITY= 7.1 FPS
TRAVEL TIME = .2 MIN
Qin = 8.9 CFS @ 11.93 HRS
Qout= 8.8 CFS @ 11.94 HRS
ATTEN= 1 % LAG= .3 MIN
IN/OUT= .48 / .48 AF

REACH 1 DISCHARGE
MH-1



REACH 1 INFLOW & OUTFLOW
MH-1



[redacted]

724

739 LSC 54/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

KSS 12Feb96

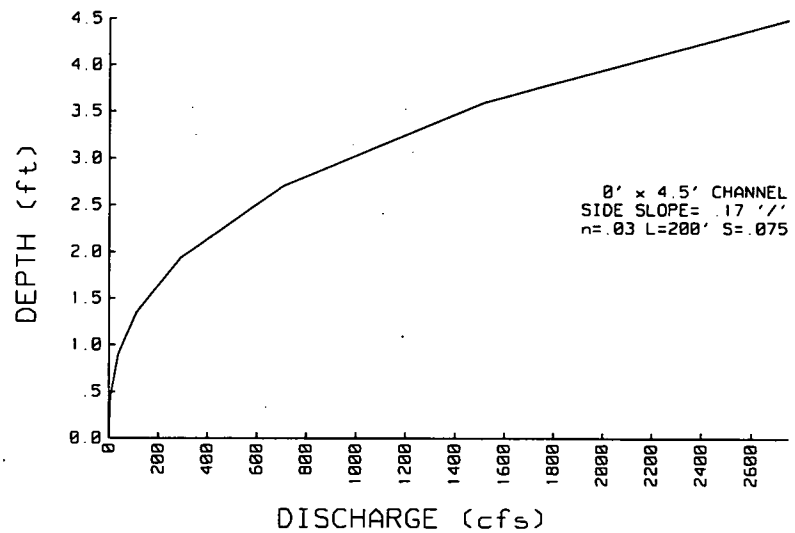
REACH 2 **NORTHERN OUTER DITCH**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	1.2	5.9
.9	4.8	37.6
1.4	10.7	110.8
1.9	22.0	289.5
2.7	42.9	703.8
3.6	76.2	1515.8
4.5	119.1	2748.3

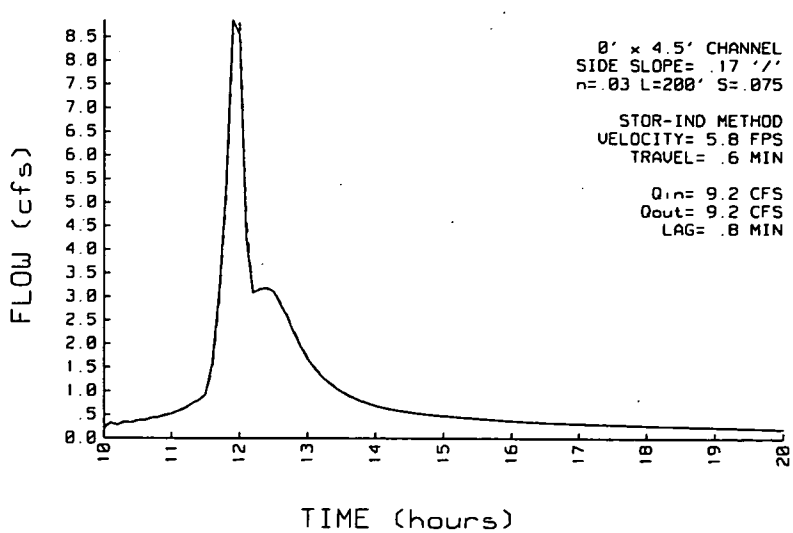
0' x 4.5' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 200 FT
SLOPE= .075 FT/FT

STOR-IND METHOD
MAX. DEPTH= .49 FT
PEAK VELOCITY= 5.8 FPS
TRAVEL TIME = .6 MIN
Qin = 9.2 CFS @ 11.94 HRS
Qout= 9.2 CFS @ 11.96 HRS
ATTEN= 0 % LAG= .8 MIN
IN/OUT= .78 / .78 AF

REACH 2 DISCHARGE
NORTHERN OUTER DITCH



REACH 2 INFLOW & OUTFLOW
NORTHERN OUTER DITCH



[redacted]
725

739 RSC 55/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

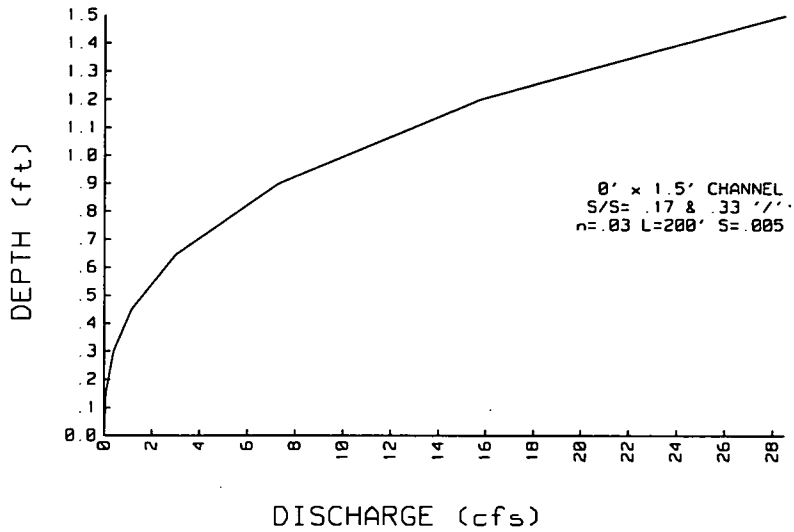
REACH 3 **MH-1.5**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.1
.3	.4	.4
.5	.9	1.1
.6	1.9	3.0
.9	3.6	7.3
1.2	6.4	15.7
1.5	10.0	28.5

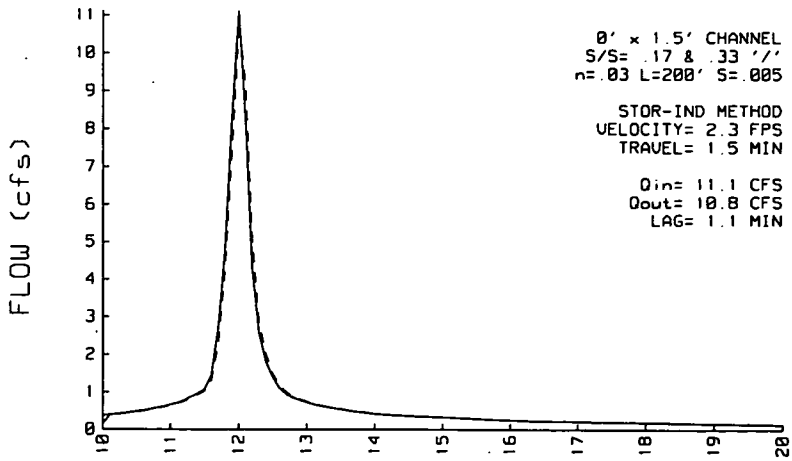
0' x 1.5' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 200 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.02 FT
PEAK VELOCITY= 2.3 FPS
TRAVEL TIME = 1.5 MIN
Qin = 11.1 CFS @ 12.00 HRS
Qout= 10.8 CFS @ 12.02 HRS
ATTEN= 3 % LAG= 1.1 MIN
IN/OUT= .66 / .66 AF

REACH 3 DISCHARGE
MH-1.5



REACH 3 INFLOW & OUTFLOW
MH-1.5



[redacted] 326

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

REACH 3

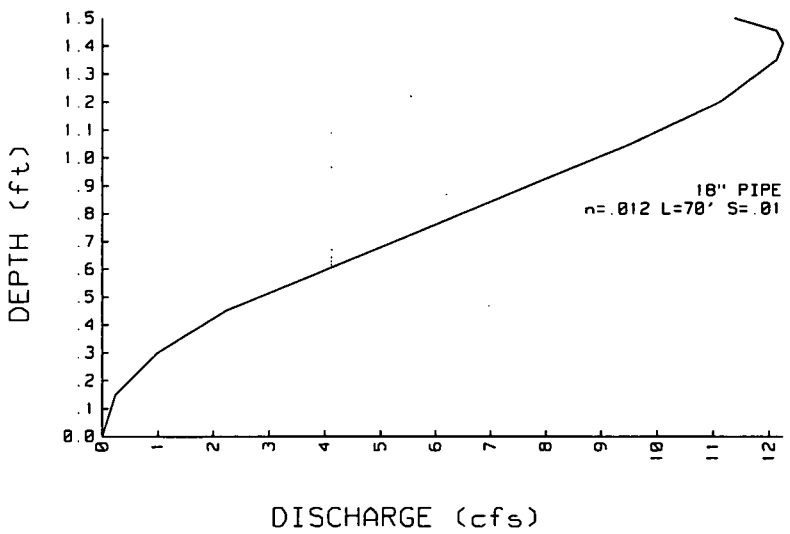
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.2
.3	.3	1.0
.5	.4	2.2
1.1	1.3	9.5
1.2	1.5	11.1
1.4	1.7	12.1
1.4	1.7	12.2
1.5	1.8	12.1
1.5	1.8	11.4

18" PIPE

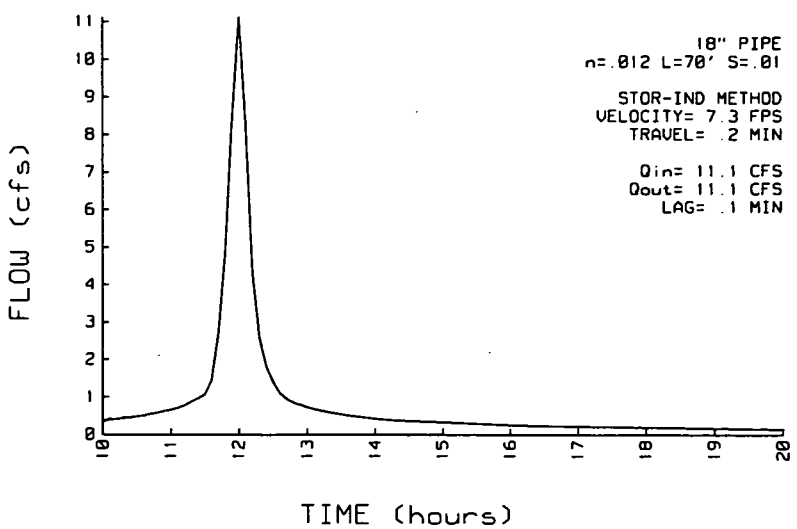
n= .012
LENGTH= 70 FT
SLOPE= .01 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.20 FT
PEAK VELOCITY= 7.3 FPS
TRAVEL TIME = .2 MIN
Qin = 11.1 CFS @ 12.00 HRS
Qout= 11.1 CFS @ 12.00 HRS
ATTEN= 0 % LAG= .1 MIN
IN/OUT= .66 / .66 AF

REACH 3 DISCHARGE



REACH 3 INFLOW & OUTFLOW



[redacted]

739 ASC 57/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

RSS 12 Feb 96

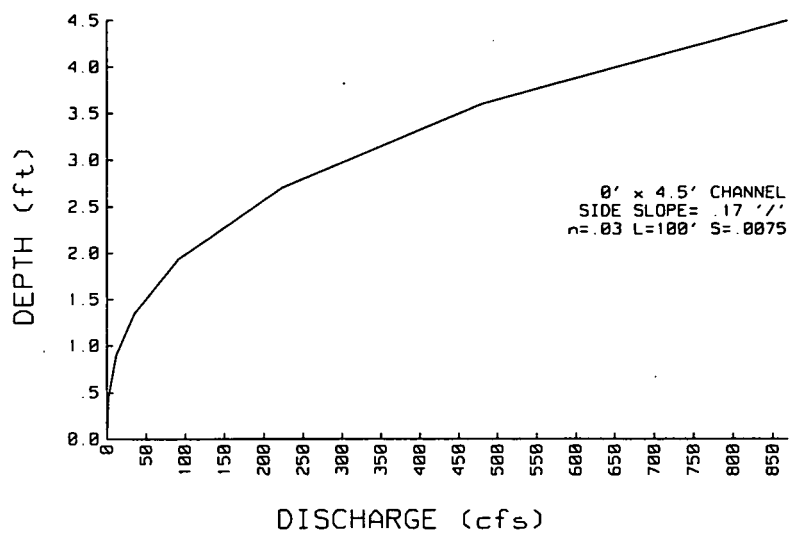
REACH 4

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	1.2	1.9
.9	4.8	11.9
1.4	10.7	35.1
1.9	22.0	91.5
2.7	42.9	222.6
3.6	76.2	479.3
4.5	119.1	869.1

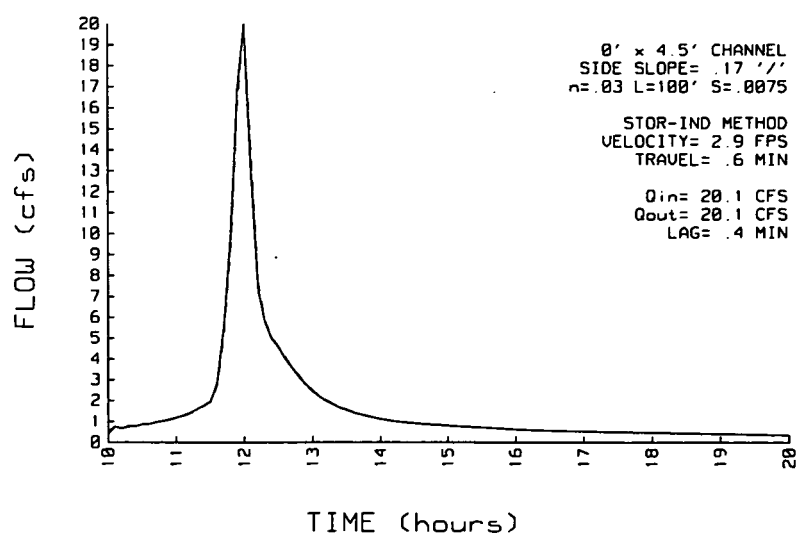
0' x 4.5' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 100 FT
SLOPE= .0075 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.06 FT
PEAK VELOCITY= 2.9 FPS
TRAVEL TIME = .6 MIN
Qin = 20.1 CFS @ 11.98 HRS
Qout= 20.1 CFS @ 11.99 HRS
ATTEN= 0 % LAG= .4 MIN
IN/OUT= 1.44 / 1.44 AF

REACH 4 DISCHARGE



REACH 4 INFLOW & OUTFLOW



739 RSC 58/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

ASS 12 Feb 96

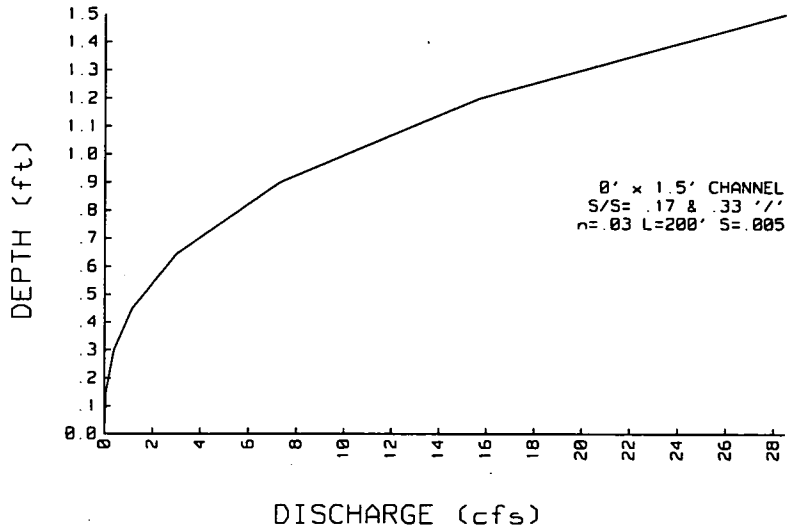
REACH 5 **MH-2 THROUGH MH-10**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.1
.3	.4	.4
.5	.9	1.1
.6	1.9	3.0
.9	3.6	7.3
1.2	6.4	15.7
1.5	10.0	28.5

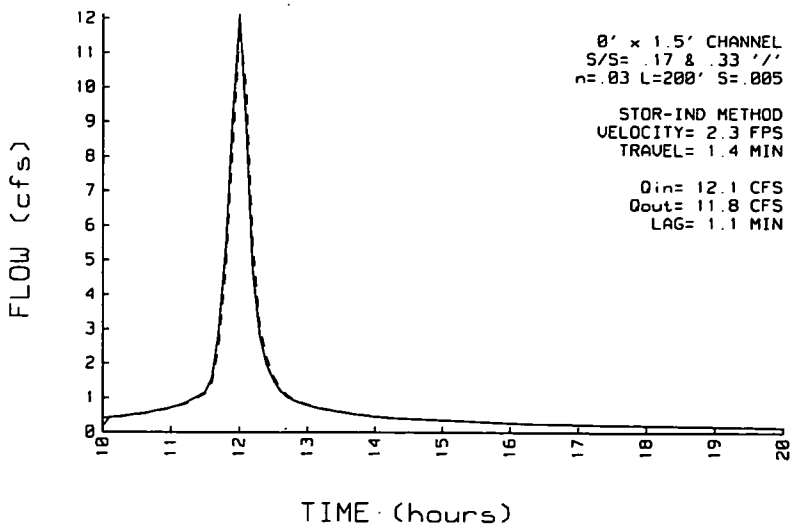
0' x 1.5' CHANNEL
S/S= .17 & .33 '/'
n= .03
LENGTH= 200 FT
SLOPE= .005 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.06 FT
PEAK VELOCITY= 2.3 FPS
TRAVEL TIME = 1.4 MIN
Qin = 12.1 CFS @ 12.00 HRS
Qout= 11.8 CFS @ 12.02 HRS
ATTEN= 3 % LAG= 1.1 MIN
IN/OUT= .72 / .72 AF

REACH 5 DISCHARGE
MH-2 THROUGH MH-10



REACH 5 INFLOW & OUTFLOW
MH-2 THROUGH MH-10



[redacted]

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

REACH 5 **MH-2**

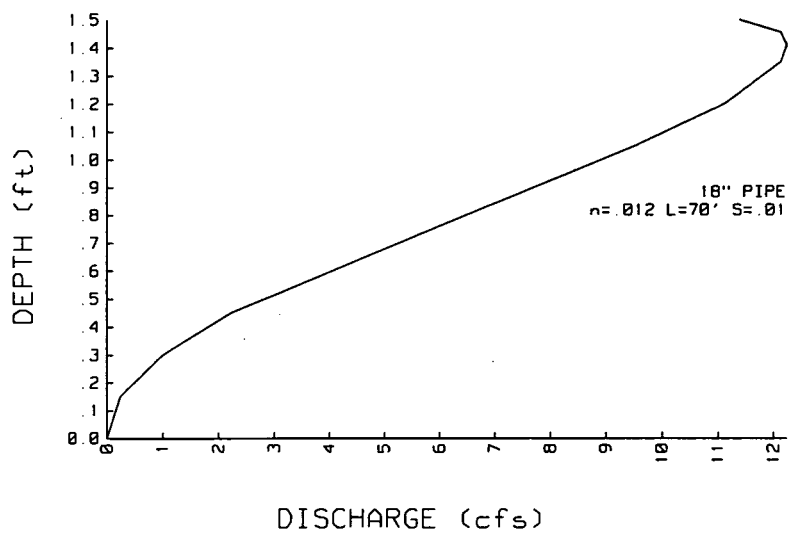
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.2
.3	.3	1.0
.5	.4	2.2
1.1	1.3	9.5
1.2	1.5	11.1
1.4	1.7	12.1
1.4	1.7	12.2
1.5	1.8	12.1
1.5	1.8	11.4

18" PIPE

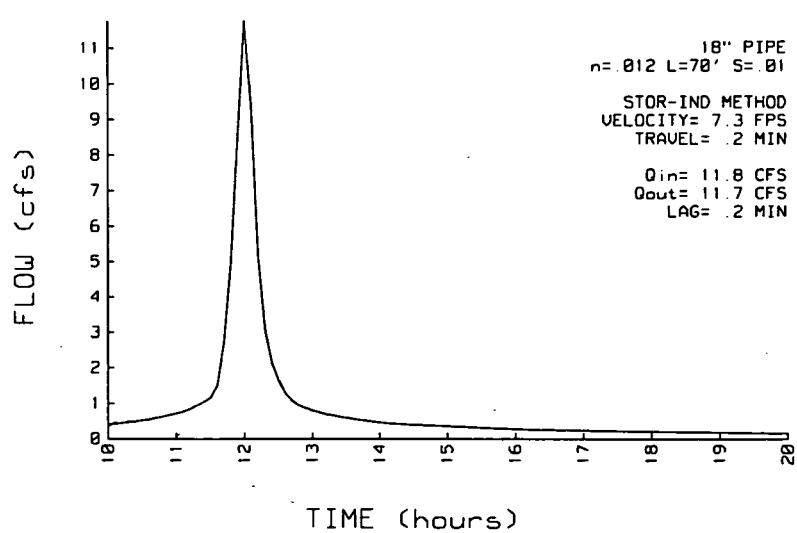
n= .012
LENGTH= 70 FT
SLOPE= .01 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.29 FT
PEAK VELOCITY= 7.3 FPS
TRAVEL TIME = .2 MIN
Qin = 11.8 CFS @ 12.01 HRS
Qout= 11.7 CFS @ 12.01 HRS
ATTEN= 0 % LAG= .2 MIN
IN/OUT= .72 / .72 AF

REACH 5 DISCHARGE
MH-2



REACH 5 INFLOW & OUTFLOW
MH-2



[redacted]

739 Nec 60/74

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

155 12Feb96

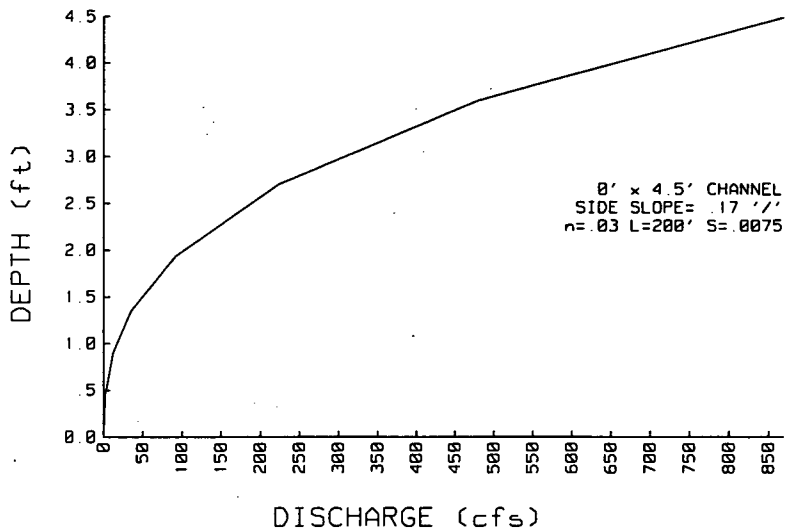
REACH 6 **CENTRAL OUTER DITCH**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	1.2	1.9
.9	4.8	11.9
1.4	10.7	35.1
1.9	22.0	91.5
2.7	42.9	222.6
3.6	76.2	479.3
4.5	119.1	869.1

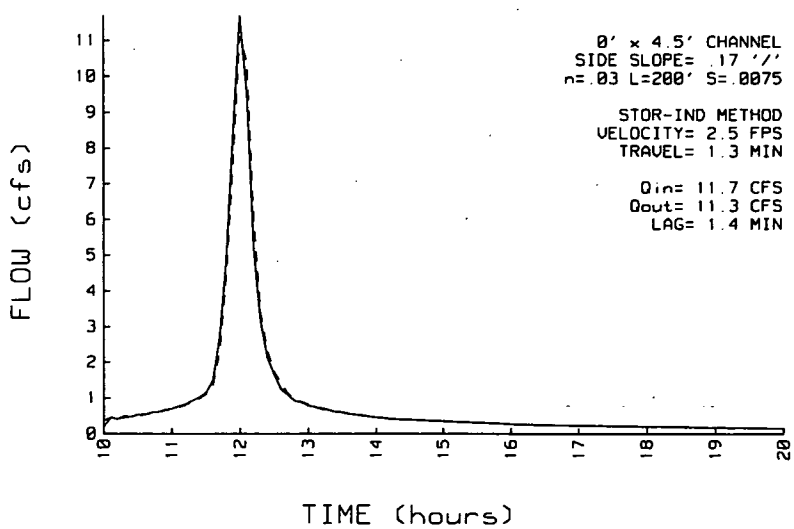
0' x 4.5' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 200 FT
SLOPE= .0075 FT/FT

STOR-IND METHOD
MAX. DEPTH= .86 FT
PEAK VELOCITY= 2.5 FPS
TRAVEL TIME = 1.3 MIN
Qin = 11.7 CFS @ 12.01 HRS
Qout= 11.3 CFS @ 12.03 HRS
ATTEN= 3 % LAG= 1.4 MIN
IN/OUT= .72 / .72 AF

REACH 6 DISCHARGE
CENTRAL OUTER DITCH



REACH 6 INFLOW & OUTFLOW
CENTRAL OUTER DITCH



[redacted]
231

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

LS 739 6/74

LSS 12 Feb 96

REACH 7

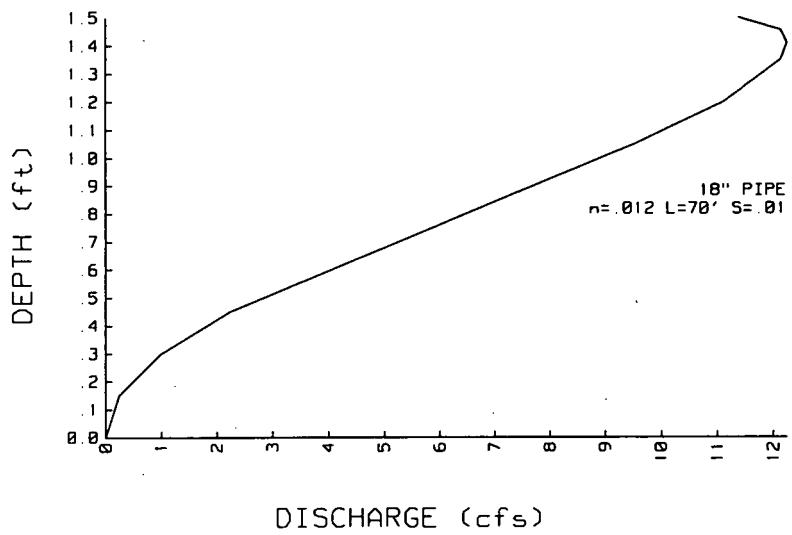
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.2
.3	.3	1.0
.5	.4	2.2
1.1	1.3	9.5
1.2	1.5	11.1
1.4	1.7	12.1
1.4	1.7	12.2
1.5	1.8	12.1
1.5	1.8	11.4

18" PIPE

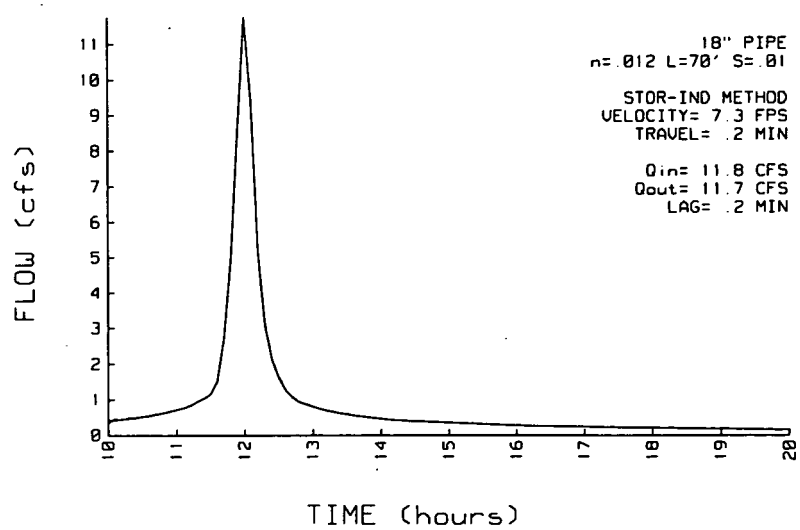
n= .012
LENGTH= 70 FT
SLOPE= .01 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.29 FT
PEAK VELOCITY= 7.3 FPS
TRAVEL TIME = .2 MIN
Qin = 11.8 CFS @ 12.01 HRS
Qout= 11.7 CFS @ 12.01 HRS
ATTEN= 0 % LAG= .2 MIN
IN/OUT= .72 / .72 AF

REACH 7 DISCHARGE



REACH 7 INFLOW & OUTFLOW



[redacted]

232

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

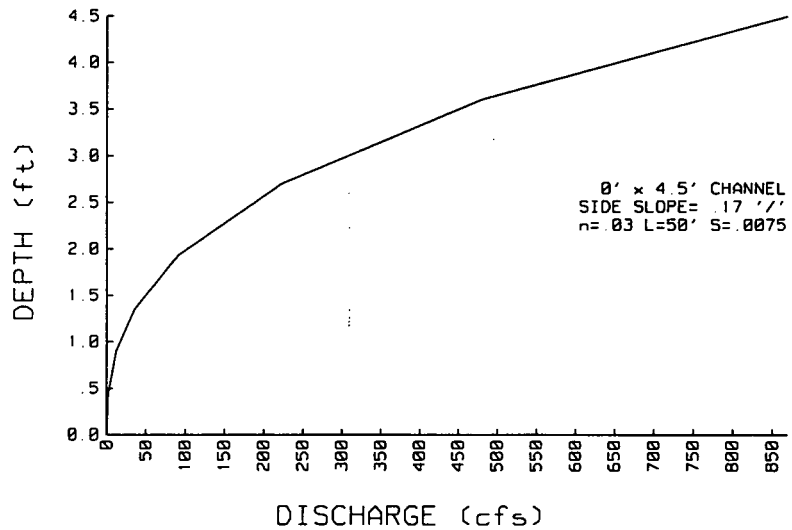
REACH 8 **CENTRAL OUTER DITCH**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	1.2	1.9
.9	4.8	11.9
1.4	10.7	35.1
1.9	22.0	91.5
2.7	42.9	222.6
3.6	76.2	479.3
4.5	119.1	869.1

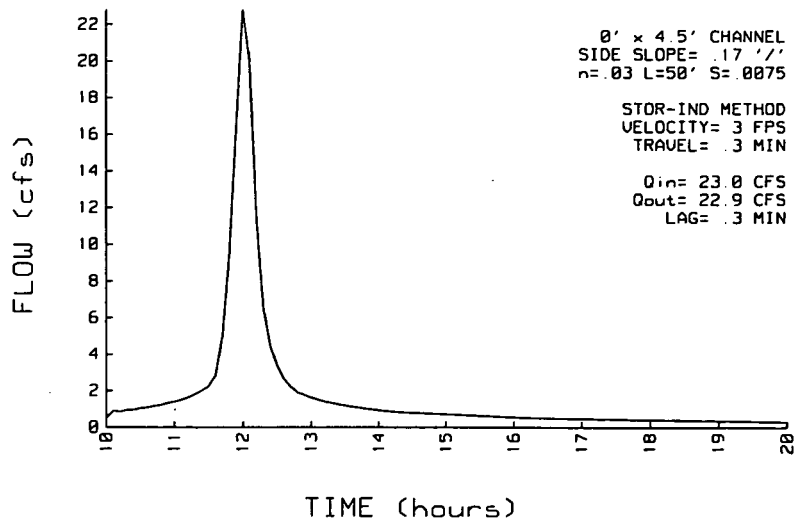
0' x 4.5' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 50 FT
SLOPE= .0075 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.11 FT
PEAK VELOCITY= 3.0 FPS
TRAVEL TIME = .3 MIN
Qin = 23.0 CFS @ 12.02 HRS
Qout= 22.9 CFS @ 12.03 HRS
ATTEN= 0 % LAG= .3 MIN
IN/OUT= 1.45 / 1.45 AF

REACH 8 DISCHARGE
CENTRAL OUTER DITCH



REACH 8 INFLOW & OUTFLOW
CENTRAL OUTER DITCH



[redacted]
233

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12Feb96

REACH 9 **MH-3**

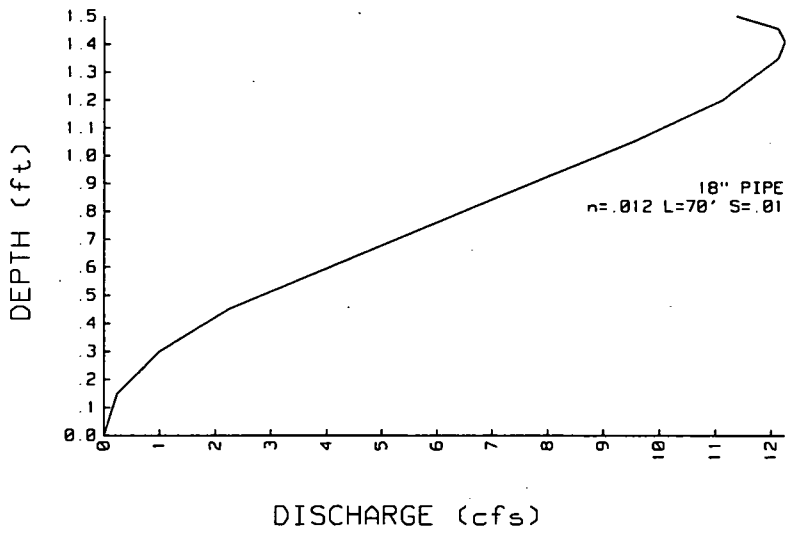
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.2
.3	.3	1.0
.5	.4	2.2
1.1	1.3	9.5
1.2	1.5	11.1
1.4	1.7	12.1
1.4	1.7	12.2
1.5	1.8	12.1
1.5	1.8	11.4

18" PIPE

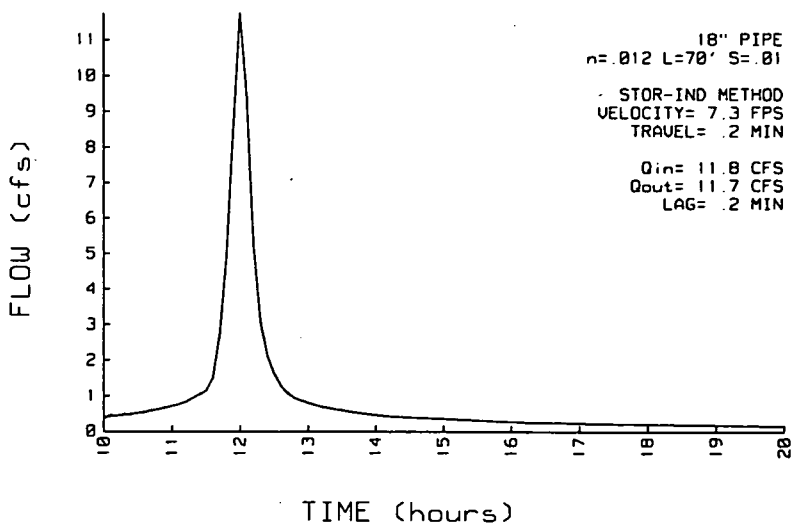
n= .012
LENGTH= 70 FT
SLOPE= .01 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.29 FT
PEAK VELOCITY= 7.3 FPS
TRAVEL TIME = .2 MIN
Qin = 11.8 CFS @ 12.01 HRS
Qout= 11.7 CFS @ 12.01 HRS
ATTEN= 0 % LAG= .2 MIN
IN/OUT= .72 / .72 AF

REACH 9 DISCHARGE
MH-3



REACH 9 INFLOW & OUTFLOW
MH-3



[redacted]

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

ASC 739 4/74

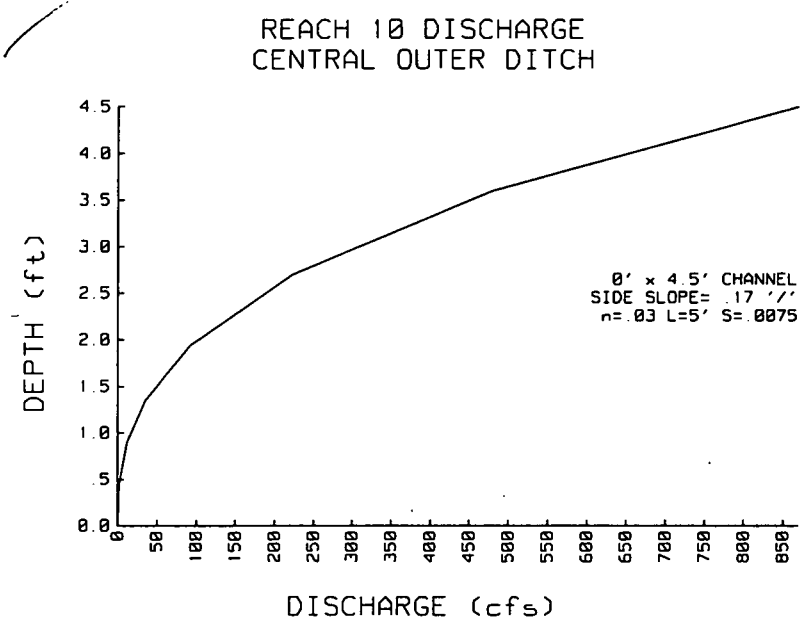
ASS 12 Feb 96

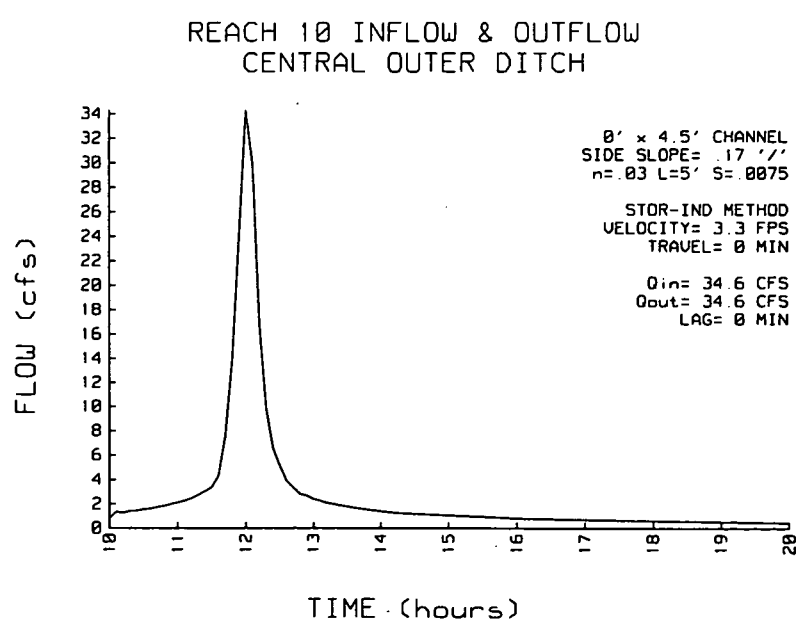
REACH 10 **CENTRAL OUTER DITCH**

DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.5	1.2	1.9
.9	4.8	11.9
1.4	10.7	35.1
1.9	22.0	91.5
2.7	42.9	222.6
3.6	76.2	479.3
4.5	119.1	869.1

0' x 4.5' CHANNEL
SIDE SLOPE= .17 '/'
n= .03
LENGTH= 5 FT
SLOPE= .0075 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.33 FT
PEAK VELOCITY= 3.3 FPS
TRAVEL TIME = 0.0 MIN
Qin = 34.6 CFS @ 12.02 HRS
Qout= 34.6 CFS @ 12.02 HRS
ATTEN= 0 % LAG= 0.0 MIN
IN/OUT= 2.17 / 2.17 AF





[redacted]

Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

SSS 12/6/96

REACH 11 **CULVERTS**

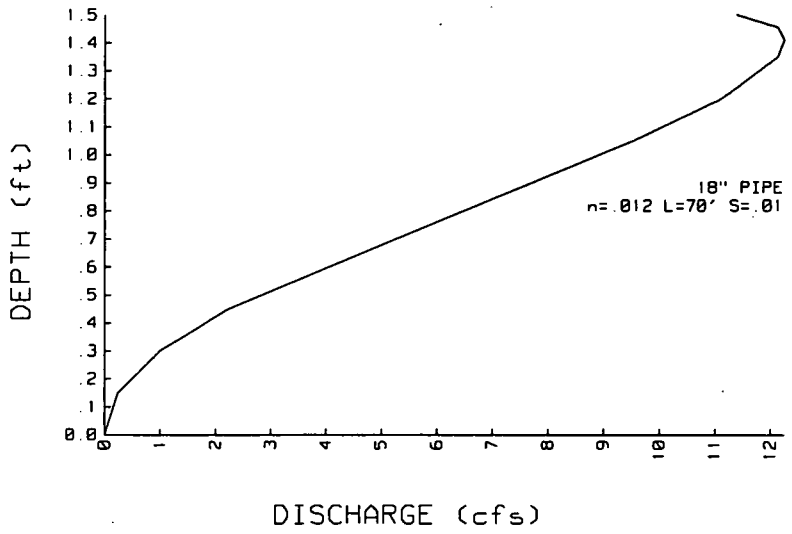
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.2
.3	.3	1.0
.5	.4	2.2
1.1	1.3	9.5
1.2	1.5	11.1
1.4	1.7	12.1
1.4	1.7	12.2
1.5	1.8	12.1
1.5	1.8	11.4

18" PIPE

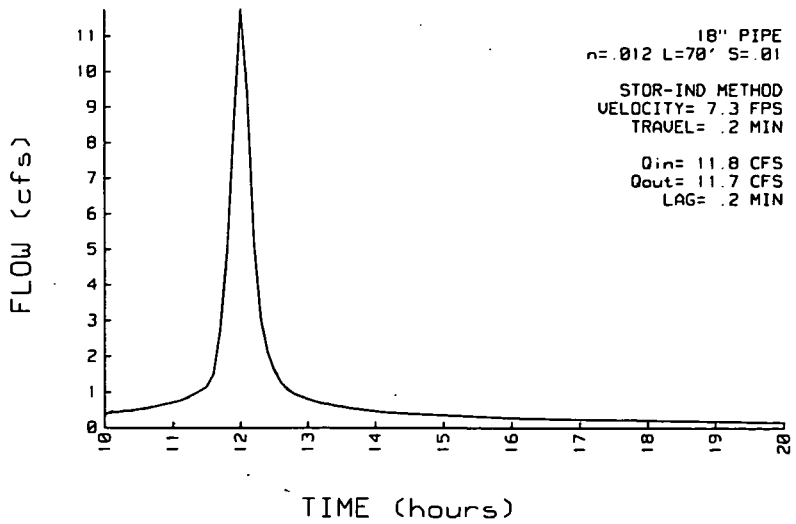
n= .012
LENGTH= 70 FT
SLOPE= .01 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.29 FT
PEAK VELOCITY= 7.3 FPS
TRAVEL TIME = .2 MIN
Qin = 11.8 CFS @ 12.01 HRS
Qout= 11.7 CFS @ 12.01 HRS
ATTEN= 0 % LAG= .2 MIN
IN/OUT= .72 / .72 AF

REACH 11 DISCHARGE
CULVERTS



REACH 11 INFLOW & OUTFLOW
CULVERTS



Data for **FERMCO, WEST CHANNEL, 25-YR STORM, MOD. COVER**
Prepared by GeoSyntec Consultants 9 Feb 96
HydroCAD 3.10 000663 (c) 1986-1993 Applied Microcomputer Systems

LSC 2/66/74 3 9

JSS 12 Feb 96

REACH 12 **CULVERTS**

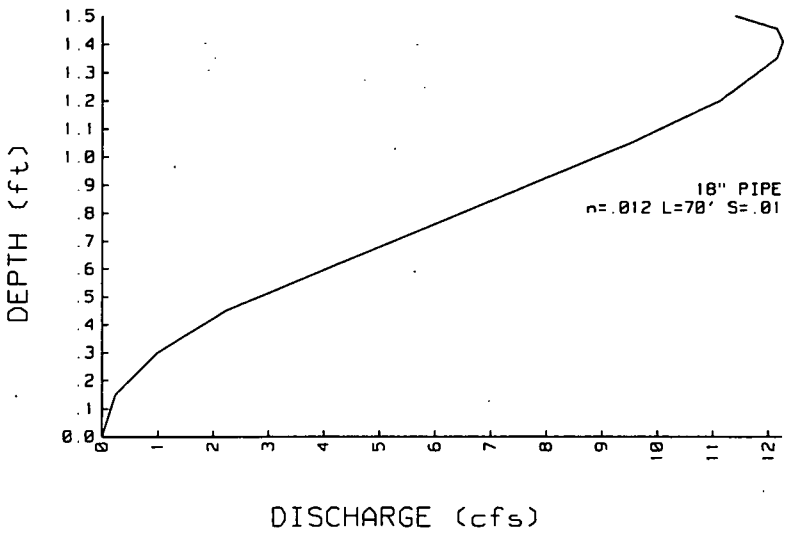
DEPTH (FT)	END AREA (SQ-FT)	DISCH (CFS)
0.0	0.0	0.0
.2	.1	.2
.3	.3	1.0
.5	.4	2.2
1.1	1.3	9.5
1.2	1.5	11.1
1.4	1.7	12.1
1.4	1.7	12.2
1.5	1.8	12.1
1.5	1.8	11.4

18" PIPE

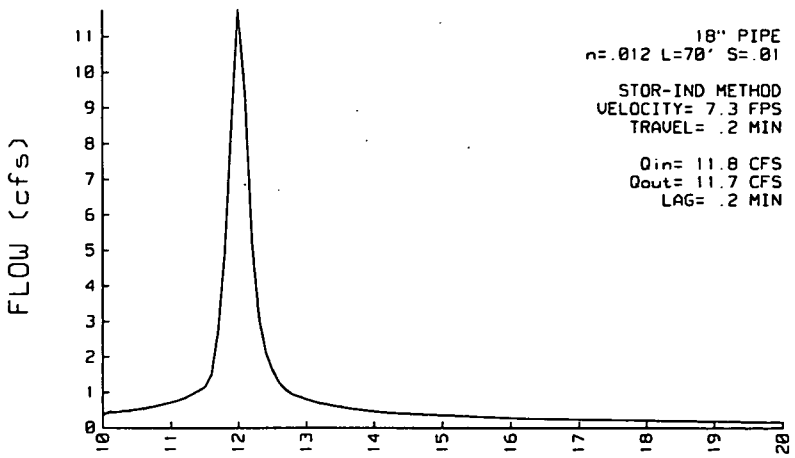
n= .012
LENGTH= 70 FT
SLOPE= .01 FT/FT

STOR-IND METHOD
MAX. DEPTH= 1.29 FT
PEAK VELOCITY= 7.3 FPS
TRAVEL TIME = .2 MIN
Qin = 11.8 CFS @ 12.01 HRS
Qout= 11.7 CFS @ 12.01 HRS
ATTEN= 0 % LAG= .2 MIN
IN/OUT= .72 / .72 AF

REACH 12 DISCHARGE
CULVERTS



REACH 12 INFLOW & OUTFLOW
CULVERTS



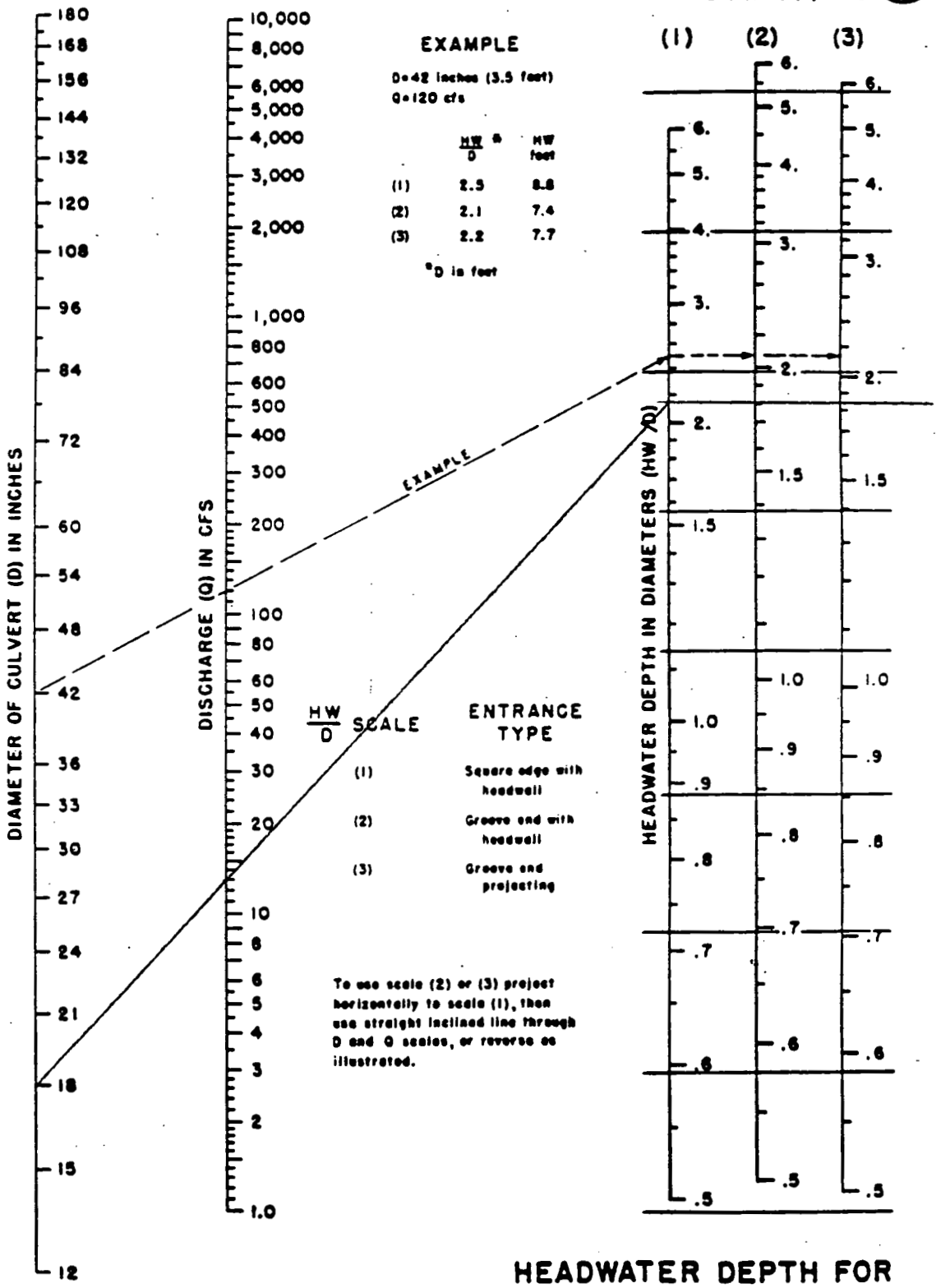
[redacted]

CULVERT CALCULATIONS

Rsc 9 Feb 96
SSS 12 Feb 96 68/74

739

CHART 1



HEADWATER SCALES 2&3
REVISED MAY 1964

BUREAU OF PUBLIC ROADS JAN. 1963

HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

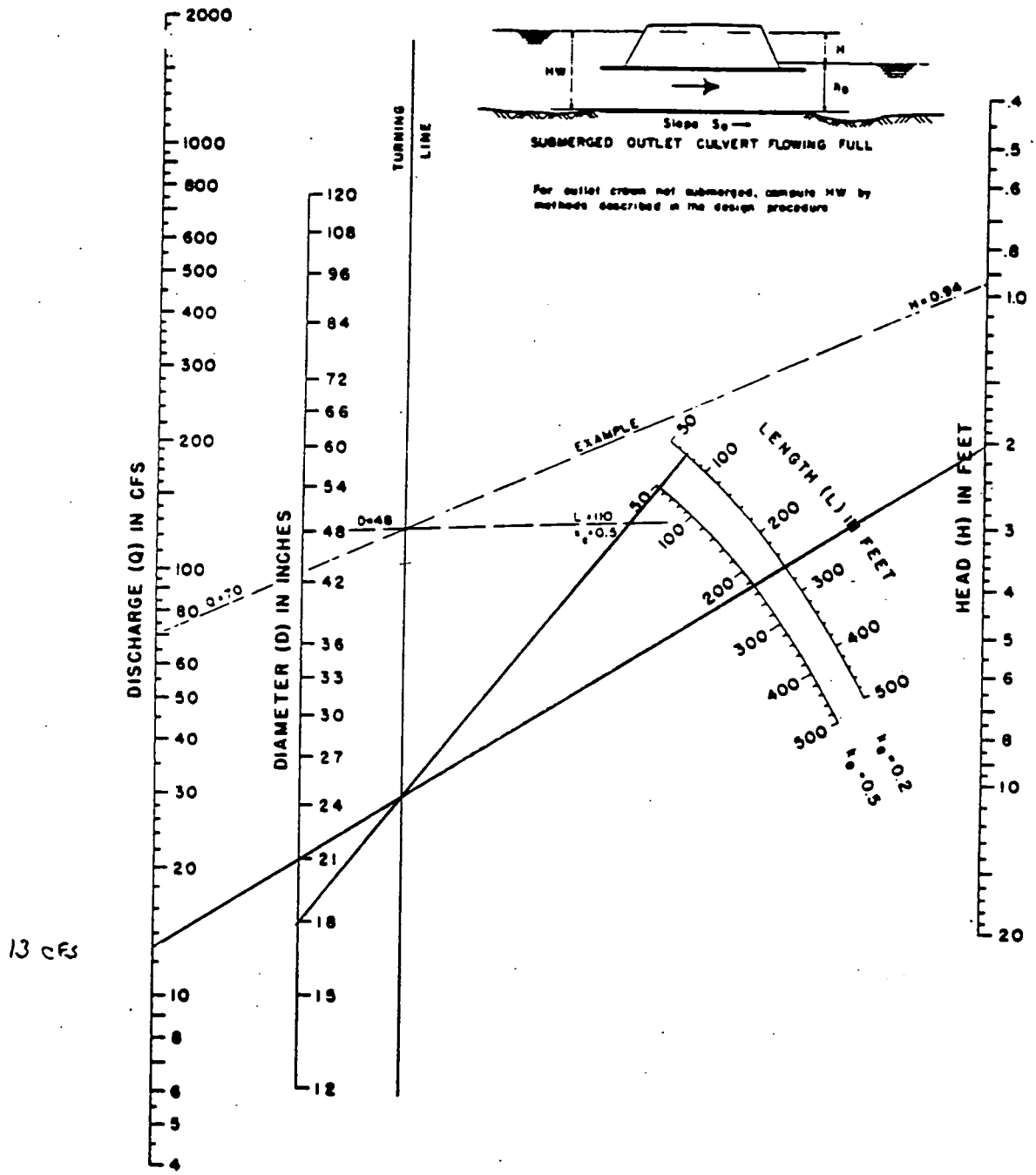
[redacted]

239

RSC 9 Feb 96
LSS 12 Feb 96 VA/TA

739

CHART 5



TOTAL HEAD AT INLET
1.5 Ft + 2.0 F
= 3.5 Ft
OK

HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

[redacted]

740

GEOSYNTEC CONSULTANTS

Written by: RSC Date: 96/02/12 (YY/MM/DD) Reviewed by: JSS Date: 96/02/15 (YY/MM/DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3500 Task No.: 08.1

CULVERT OUTLET PROTECTION CALCULATIONS

1. DEFINE CULVERT DISCHARGE.

   FROM PERIMETER DRAINAGE CHANNEL CALCULATIONS

   Q_{MAX} = 13 CFS (MH-2 THROUGH MH-10, LIGHTCOURT)

2. USE USDA-SCS DESIGN CHART TO SELECT D_{50} FOR RIPRAP AND LENGTH OF OUTLET APRON.

   SEE FIGURE 1 ; D_{50} = 4 in.

3. CALCULATE APRON DIMENSIONS (SEE FIGURE 1)

   MIN. LENGTH = 10 FT

   MAXIMUM WIDTH = 10+1.5 = 11.5 FT (OR TO TOP OF CHANNEL SIDES)
   MIN. WIDTH = 3+1.5 = 4.5 FT

4. CALCULATE D_{MAX} AND D_{15} OF RIPRAP:

   D_{50} = .35 FT ≈ 4 IN

   D_{MAX} = 1.5 x D_{50} = .53 FT ≈ 6 IN

   D_{15} = 0.5 TO 0.75 x D_{50} = .18 FT TO .26 FT
   ≈ 2 IN TO 3 IN

5. CALCULATE RIPRAP THICKNESS

   MIN. THICKNESS = ~~6 IN~~ 2 x D_{50}
   = 2 x 4 IN. = 8 IN.

[redacted]

GEOSYNTEC CONSULTANTS

Written by: RSC Date: 96/02/12 (YY MM DD) Reviewed by: SSS Date: 96/02/15 (YY MM DD)

Client: FEMCO Project: OSDF Project/Proposal No.: GR 3500 Task No.: 08.1

6. CALCULATE FILTER BLANKET GRADATION

$$\frac{D_{15}\ \text{FILTER}}{D_{85}\ \text{BASE}} < 5 < \frac{D_{15}\ \text{FILTER}}{D_{15}\ \text{BASE}} < 40$$

AND $$\frac{D_{50}\ \text{FILTER}}{D_{50}\ \text{BASE}} < 40$$

D_{15} FILTER = 2 - 3 IN
D_{50} FILTER = 4 IN

$$\frac{2\ \text{TO}\ 3\ \text{IN}}{D_{85}\ \text{BASE}} < 5 < \frac{2\ \text{TO}\ 3\ \text{IN}}{D_{15}\ \text{BASE}} < 40$$

AND $$\frac{4\ \text{IN}}{D_{50}\ \text{BASE}} < 40$$

$$D_{50}\ \text{BASE} > \frac{4\ \text{IN}}{40} = 0.1\ \text{IN}$$

$$D_{85}\ \text{BASE} > \frac{2\ \text{TO}\ 3\ \text{IN}}{5} = 0.4\ \text{TO}\ 0.6\ \text{IN}$$

$$D_{15}\ \text{BASE} > \frac{2\ \text{TO}\ 3\ \text{IN}}{40} = 0.05\ \text{TO}\ 0.08\ \text{IN}$$

$$D_{15}\ \text{BASE} < \frac{2\ \text{TO}\ 3\ \text{IN}}{5} = 0.4\ \text{TO}\ 0.6\ \text{IN}$$

[redacted]

Outlet Protection (Cont'd)

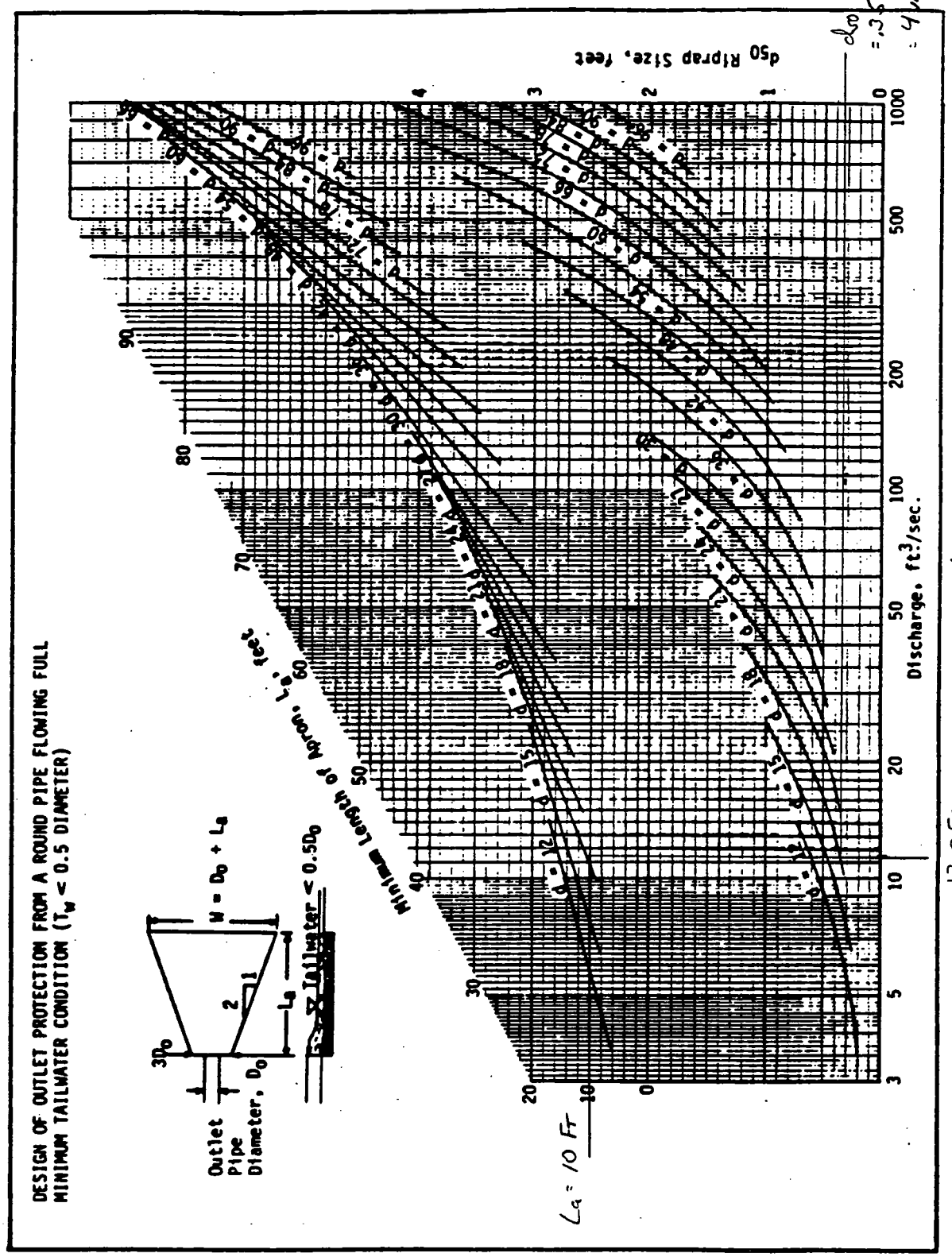


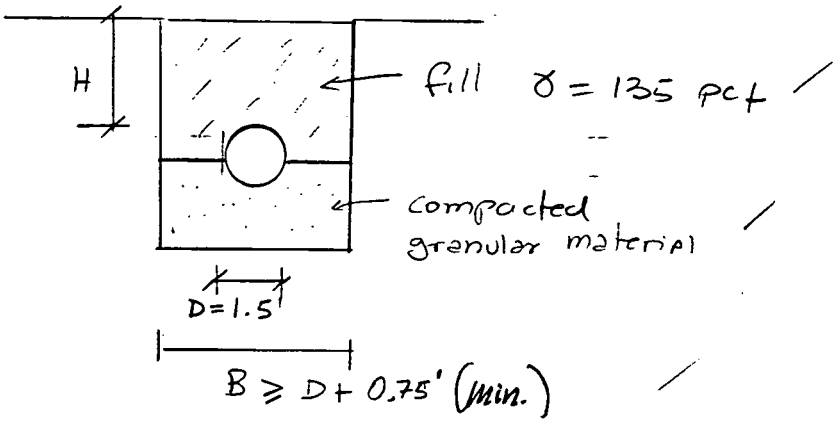
Figure 1

GEOSYNTEC CONSULTANTS

Written by: David Espinoza Date: 96/02/16 (YY MM DD) Reviewed by: SSS Date: 96/02/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE3202 Task No.: 08.1

Culvert Design



1) Assuming that the fill will be sand & Gravel, from table 17A, the earth load e_s (based on $\gamma = 100$ pcf)

$W_E = 915$

correction due to fill unit weight ($\gamma = 135$ pcf)

$$W_E = \frac{135}{100}(915) = 1{,}235 \text{ lb/lf}$$

the live load can be extrated from table 44

$W_L = 520$ lb/lf.

no correction is necessary as the table are constructed for a wheel load of 16,000 pound/wheel (dual tires), i.e. 32,000 pounds.

GEOSYNTEC CONSULTANTS

Written by: David Espinoza Date: 96/02/16 (YY MM DD) Reviewed by: SSS Date: 96/02/16 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GC3900 Task No.: 08 1

2) the Bedding Type is cassified as type B with a loading factor $L_f = 1.9$ (see Figure 12)

3) the pipe will be unreinforced. The factor of safety suggested for unreinforced pipe range from 1.25 to 1.5. A $F_s = 1.5$ is used.

4) The strength required is:

$$D\text{-load} = \left(\frac{W_c}{1.5} + \frac{W_E}{1.9}\right) \times \frac{F_s}{D}$$

$$D\text{-load} = \left(\frac{520}{1.5} + \frac{1,235}{1.9}\right) \times \frac{1.5}{1.8}$$

$$D\text{-load} = 830.6$$

[redacted]

74a/74b 39
DE
2/16/91
1552/16/99

TABLE 44

HIGHWAY LOADS

POUNDS PER LINEAR FOOT

CIRCULAR PIPE

PIPE SIZE D IN INCHES	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	PIPE SIZE D IN INCHES
12	4849	2730	1524	954	574	361	316	237	168	46	12
15	5915	3322	1872	1163	700	441	358	289	205	56	15
18		3926	2196	1369	825	520	454	341	242	66	18
21		4498	2525	1580	950	599	522	392	279	77	21
24			2856	1788	1077	679	592	444	316	87	24
27			3096	1998	1201	757	660	496	353	97	27
30				2204	1328	837	731	548	390	107	30
33				2370	1452	915	798	599	426	117	33
36					1580	996	869	652	463	127	36
42					1679	1154	1007	755	537	147	42
48						1221	1146	859	611	168	48
54							1185	962	684	188	54
60								998	758	208	60
66									832	228	66
72									857	249	72
78										269	78
84										275	84

HORIZONTAL ELLIPTICAL PIPE

PIPE SIZE R × S IN INCHES	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	PIPE SIZE R × S IN INCHES
14×23	5915	4498	2716	1699	1022	644	561	422	300	82	14×23
19×30			3096	2177	1309	825	719	451	384	105	19×30
22×34				2370	1471	927	808	607	432	118	22×34
24×38					1631	1028	896	674	479	131	24×38
27×42					1679	1119	975	733	521	143	27×42
29×45						1221	1064	800	569	156	29×45
32×49							1152	866	616	169	32×49
34×53							1185	933	663	182	34×53
38×60								998	748	205	38×60
43×68									842	231	43×68
48×76									857	257	48×76
53×83										275	53×83

ARCH PIPE

PIPE SIZE R × S IN INCHES	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	PIPE SIZE R × S IN INCHES
11×18	5915	3840	2144	1342	807	509	443	333	237	65	11×18
13½×22		4498	2573	1610	968	520	532	400	284	78	13½×22
15½×26			3000	1879	1130	712	621	467	332	91	15½×26
18×28½			3096	2058	1238	780	680	511	363	100	18×28½
22½×36¼				2370	1533	966	842	633	450	124	22½×36¼
26¾×43¾					1679	1170	1019	766	545	150	26¾×43¾
31⅝×51⅛						1221	1185	981	633	174	31⅝×51⅛
36×58½								998	721	198	36×58½
40×65									800	220	40×65
45×73									857	246	45×73
54×88										275	54×88

Unsurfaced Roadway; 16,000-Pound Wheel Load; Dual Tires; 80 p.s.i. Tire Pressure; Impact Included. Last number in each column **(bold type)** *indicates maximum load for any given fill height. Interpolate for intermediate fill heights.*

H20 LOADING

[redacted]

746

[redacted] 739

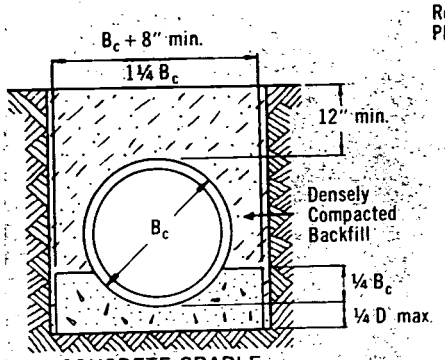
746/74
DE
2/16/96
SSS 2/16/96

~~FIGURE 142~~

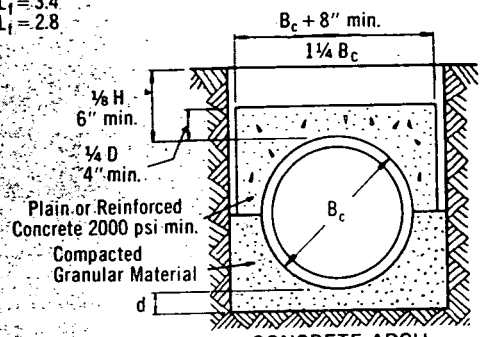
TRENCH BEDDINGS
CIRCULAR PIPE

CLASS A

Reinforced $A_s = 1.0\%$ $L_f = 4.8$
Reinforced $A_s = 0.4\%$ $L_f = 3.4$
Plain $L_f = 2.8$



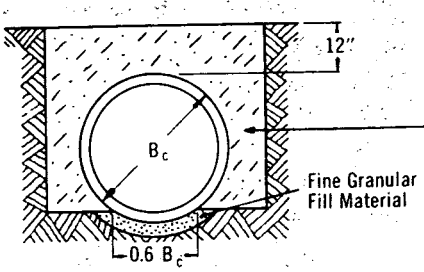
CONCRETE CRADLE



CONCRETE ARCH

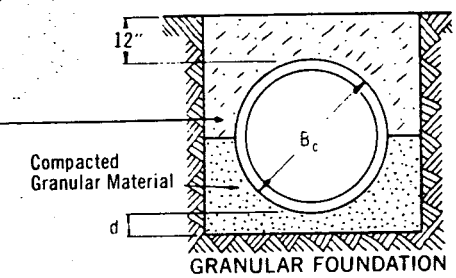
CLASS B

$L_f = 1.9$



SHAPED SUBGRADE WITH GRANULAR FOUNDATION

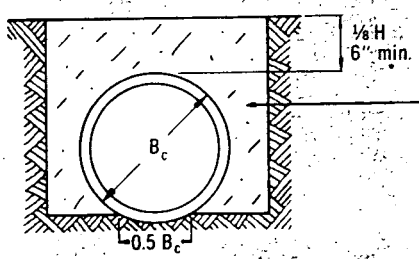
Densely Compacted Backfill



GRANULAR FOUNDATION

CLASS C

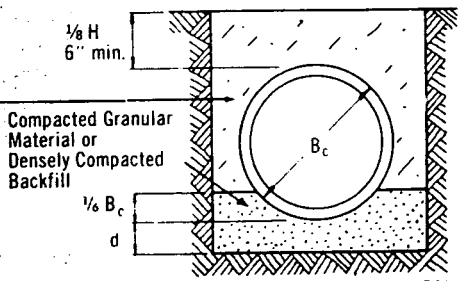
$L_f = 1.5$



SHAPED SUBGRADE

Lightly Compacted Backfill

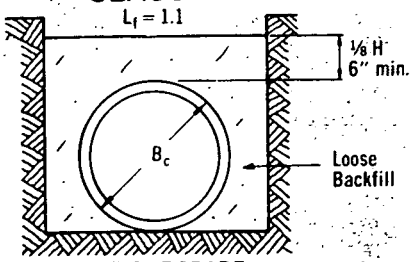
Compacted Granular Material or Densely Compacted Backfill



GRANULAR FOUNDATION

CLASS D

$L_f = 1.1$



FLAT SUBGRADE

Legend
B_c = outside diameter
H = backfill cover above top of pipe
D = inside diameter
d = depth of bedding material below pipe
A_s = area of transverse steel in the cradle or arch expressed as a percentage of area of concrete at invert or crown.

Depth of Bedding Material Below Pipe	
D	d (min.)
27" & smaller	3"
30" to 60"	4"
66" & larger	6"

NOTE: For rock or other incompressible materials, the trench should be overexcavated a minimum of 6 inches and refilled with granular material.

[redacted] 747

DE 739

74c/74 2/16/96

ISS 2/16/95

TABLE 17

18" BACKFILL LOADS ON CIRCULAR PIPE IN TRENCH INSTALLATION 18"

*100 POUNDS PER CUBIC FOOT BACKFILL MATERIAL — LOADS IN POUNDS PER LINEAR FOOT

A — SAND AND GRAVEL Kμ'—0.165

	TRENCH WIDTH AT TOP OF PIPE										▲TRANSITION WIDTH
HEIGHT OF BACKFILL H ABOVE TOP OF PIPE, FEET	2'-6"	2'-9"	3'-0"	3'-3"	3'-6"	4'-0"	4'-6"	5'-0"	6'-0"	7'-0"	
5	915	1033	1153	1274	**1411**						3'-6"
6	1036	1176	1317	1460	1603	**1700**					3'-8"
7	1142	1302	1464	1628	1793	**1989**					3'-10"
8	1235	1414	1596	1780	1966	**2277**					3'-11"
9	1316	1513	1713	1917	2123	**2566**					4'-0"
10	1388	1601	1819	2041	2266	2723	**2855**				4'-2"
11	1450	1679	1914	2153	2396	2891	**3145**				4'-3"
12	1505	1748	1998	2254	2514	3046	**3431**				4'-4"
13	1553	1810	2074	2345	2622	3189	**3718**				4'-5"
14	1595	1864	2142	2428	2720	3320	3938	**4012**			4'-7"
15	1632	1912	2203	2502	2809	3441	4093	**4298**			4'-8"
16	1664	1955	2258	2570	2890	3553	4238	**4584**			4'-9"
17	1693	1993	2306	2631	2964	3655	4372	**4877**			4'-10"
18	1717	2027	2350	2686	3032	3750	4497	**5168**			4'-11"
19	1739	2057	2389	2735	3093	3837	4613	**5444**			5'-0"
20	1758	2083	2425	2780	3148	3917	4720	5552	**5737**		5'-1"
21	1775	2107	2456	2821	3199	3991	4820	5681	**6035**		5'-2"
22	1790	2128	2484	2857	3245	4058	4913	5802	**6324**		5'-3"
23	1802	2146	2510	2891	3287	4121	5000	5915	**6600**		5'-4"
24	1814	2163	2532	2920	3325	4179	5080	6021	**6887**		5'-5"
25	1824	2177	2552	2947	3360	4232	5155	6120	**7189**		5'-6"
26	1832	2190	2571	2972	3392	4280	5224	6213	**7455**		5'-7"
27	1840	2201	2587	2994	3421	4325	5289	6300	**7768**		5'-8"
28	1846	2212	2601	3014	3447	4367	5349	6382	**8044**		5'-9"
29	1852	2221	2614	3032	3471	4405	5404	6458	**8344**		5'-10"
30	1857	2229	2626	3048	3492	4440	5456	6529	**8636**		5'-11"
31	1862	2236	2637	3063	3512	4472	5504	6596	**8901**		6'-0"
32	1866	2242	2646	3076	3530	4502	5549	6659	9032	**9198**	6'-1"
33	1869	2247	2654	3088	3546	4529	5590	6717	9132	**9488**	6'-2"
34	1872	2252	2662	3099	3561	4555	5629	6772	9227	**9771**	6'-2"
35	1875	2257	2669	3109	3575	4578	5665	6823	9317	**10070**	6'-3"
36	1877	2261	2675	3118	3587	4599	5698	6871	9402	**10340**	6'-4"
37	1879	2264	2680	3126	3598	4619	5729	6916	9483	**10630**	6'-5"
38	1881	2267	2685	3133	3608	4637	5758	6958	9559	**10940**	6'-6"
39	1882	2270	2689	3139	3618	4654	5784	6998	9631	**11220**	6'-7"
40	1884	2272	2693	3145	3626	4669	5809	7035	9700	**11520**	6'-8"

B — SATURATED TOP SOIL Kμ'—0.150

TRENCH WIDTH AT TOP OF PIPE										▲TRANSITION WIDTH	
2'-6"	2'-9"	3'-0"	3'-3"	3'-6"	4'-0"	4'-6"	5'-0"	6'-0"	7'-0"		HEIGHT OF BACKFILL H ABOVE TOP OF PIPE, FEET
939	1059	1180	1301	**1411**						3'-6"	5
1069	1210	1353	1497	1641	**1700**					3'-7"	6
1183	1346	1510	1675	1842	**1989**					3'-9"	7
1285	1467	1652	1838	2026	**2277**					3'-10"	8
1375	1576	1780	1986	2195	**2566**					3'-11"	9
1455	1674	1896	2122	2350	2814	**2855**				4'-1"	10
1526	1761	2001	2245	2492	2996	**3145**				4'-2"	11
1589	1840	2096	2357	2623	3164	**3431**				4'-3"	12
1645	1910	2182	2460	2743	3321	**3718**				4'-4"	13
1695	1973	2260	2553	2853	3466	**4012**				4'-5"	14
1738	2030	2330	2639	2954	3601	**4298**				4'-6"	15
1777	2080	2394	2716	3047	3726	4426	**4584**			4'-7"	16
1812	2126	2451	2787	3132	3843	4576	**4877**			4'-8"	17
1843	2167	2504	2852	3210	3950	4716	**5168**			4'-9"	18
1870	2203	2551	2911	3282	4050	4848	**5444**			4'-10"	19
1894	2236	2593	2965	3347	4143	4970	**5737**			4'-11"	20
1915	2265	2632	3014	3408	4229	5085	**6035**			5'-0"	21
1934	2292	2667	3058	3463	4309	5192	6107	**6324**		5'-1"	22
1951	2315	2699	3099	3514	4383	5293	6236	**6600**		5'-2"	23
1966	2336	2727	3136	3561	4451	5387	6338	**6887**		5'-3"	24
1979	2355	2753	3170	3604	4515	5475	6473	**7189**		5'-4"	25
1991	2373	2777	3201	3643	4574	5557	6582	**7455**		5'-5"	26
2001	2388	2798	3229	3679	4629	5634	6684	**7768**		5'-6"	27
2010	2401	2817	3255	3712	4680	5706	6780	**8044**		5'-7"	28
2019	2414	2834	3278	3743	4727	5773	6870	**8344**		5'-8"	29
2026	2425	2850	3300	3771	4771	5836	6955	**8636**		5'-9"	30
2032	2435	2864	3319	3796	4811	5895	7036	**8901**		5'-9"	31
2038	2444	2877	3337	3820	4849	5950	7111	**9198**		5'-10"	32
2043	2451	2889	3353	3842	4884	6002	7182	**9488**		5'-11"	33
2048	2459	2899	3368	3861	4916	6050	7249	**9771**		6'-0"	34
2052	2465	2909	3381	3880	4946	6095	7312	9914	**10070**	6'-1"	35
2055	2471	2918	3393	3896	4974	6137	7372	10020	**10340**	6'-1"	36
2058	2476	2925	3405	3912	5000	6177	7428	10110	**10630**	6'-2"	37
2061	2480	2932	3415	3926	5024	6214	7480	10200	**10940**	6'-3"	38
2064	2485	2939	3424	3939	5047	6248	7530	10290	**11220**	6'-4"	39
2066	[illegible]	2945	3433	3950	5067	6280	7577	10380	**11520**	6'-5"	40

C — ORDINARY CLAY Kμ'—0.130

	TRENCH WIDTH AT TOP OF PIPE										▲TRANSITION WIDTH
HEIGHT OF BACKFILL H ABOVE TOP OF PIPE, FEET	2'-6"	2'-9"	3'-0"	3'-3"	3'-6"	4'-0"	4'-6"	5'-0"	6'-0"	7'-0"	
5	974	1095	1217	1339	**1411**						3'-5"
6	1115	1259	1403	1548	**1700**						3'-6"
7	1243	1408	1574	1741	1910	**1989**					3'-7"
8	1357	1543	1731	1920	2110	**2277**					3'-9"
9	1461	1666	1874	2085	2297	**2566**					3'-10"
10	1554	1778	2006	2237	2470	**2855**					3'-11"
11	1638	1880	2127	2377	2630	**3145**					4'-0"
12	1713	1973	2238	2506	2779	3332	**3431**				4'-1"
13	1781	2057	2339	2626	2917	3510	**3718**				4'-2"
14	1843	2134	2432	2736	3046	3676	**4012**				4'-3"
15	1898	2204	2518	2838	3165	3832	**4298**				4'-4"
16	1948	2267	2596	2932	3276	3978	**4584**				4'-5"
17	1993	2325	2668	3019	3378	4115	**4877**				4'-6"
18	2034	2378	2734	3099	3474	4243	5035	**5168**			4'-7"
19	2070	2426	2794	3173	3562	4364	5190	**5444**			4'-8"
20	2103	2469	2849	3242	3645	4476	5336	**5737**			4'-9"
21	2133	2509	2900	3305	3721	4582	5473	**6035**			4'-10"
22	2159	2545	2947	3363	3792	4681	5603	**6324**			4'-11"
23	2184	2578	2989	3417	3858	4773	5726	**6600**			4'-11"
24	2205	2607	3029	3466	3919	4860	5842	**6887**			5'-0"
25	2225	2635	3064	3512	3975	4942	5951	6994	**7189**		5'-1"
26	2242	2659	3097	3554	4028	5018	6054	7127	**7455**		5'-2"
27	2258	2682	3128	3593	4077	5089	6151	7253	**7768**		5'-3"
28	2273	2702	3155	3630	4122	5156	6243	7373	**8044**		5'-3"
29	2286	2721	3181	3663	4165	5219	6330	7486	**8344**		5'-4"
30	2297	2738	3204	3693	4204	5278	6412	7594	**8636**		5'-5"
31	2308	2753	3225	3722	4240	5333	6489	7697	**8901**		5'-6"
32	2317	2767	3245	3748	4274	5385	6562	7794	**9198**		5'-7"
33	2326	2780	3263	3772	4305	5433	6631	7886	**9488**		5'-7"
34	2333	2791	3279	3794	4334	5478	6696	7974	**9771**		5'-8"
35	2340	2802	3294	3815	4361	5521	6757	8057	**10070**		5'-9"
36	2346	2811	3308	3834	4386	5561	6815	8136	**10340**		5'-10"
37	2352	2820	3321	3851	4409	5598	6870	8211	**10630**		5'-10"
38	2357	2828	3333	3868	4431	5633	6921	8282	**10940**		5'-11"
39	2362	2835	3343	3883	4451	5666	6970	8350	**11220**		6'-0"
40	2366	2842	3353	3896	4470	5696	7016	8414	**11520**		6'-0"

D — SATURATED CLAY Kμ'—0.110

TRENCH WIDTH AT TOP OF PIPE										▲TRANSITION WIDTH	
2'-6"	2'-9"	3'-0"	3'-3"	3'-6"	4'-0"	4'-6"	5'-0"	6'-0"	7'-0"		HEIGHT OF BACKFILL H ABOVE TOP OF PIPE, FEET
1011	1133	1255	1378	**1411**						3'-4"	5
1165	1310	1456	1602	**1700**						3'-5"	6
1306	1473	1642	1811	**1989**						3'-6"	7
1435	1624	1815	2007	2200	**2277**					3'-7"	8
1554	1764	1976	2190	2405	**2566**					3'-8"	9
1662	1892	2126	2361	2598	**2855**					3'-9"	10
1761	2011	2264	2520	2779	**3145**					3'-10"	11
1852	2121	2394	2670	2949	**3431**					3'-11"	12
1935	2222	2514	2809	3108	**3718**					4'-0"	13
2012	2315	2625	2940	3258	3905	**4012**				4'-1"	14
2082	2402	2729	3061	3399	4085	**4298**				4'-2"	15
2145	2481	2825	3175	3531	4256	**4584**				4'-3"	16
2204	2555	2914	3282	3655	4417	**4877**				4'-4"	17
2258	2623	2998	3381	3772	4570	**5168**				4'-4"	18
2307	2685	3075	3474	3881	4714	**5444**				4'-5"	19
2352	2743	3147	3561	3984	4851	**5737**				4'-6"	20
2393	2796	3213	3642	4080	4981	5907	**6035**			4'-7"	21
2431	2846	3275	3718	4171	5104	6064	**6324**			4'-8"	22
2465	2891	3333	3789	4256	5220	6214	**6600**			4'-8"	23
2497	2933	3387	3855	4336	5329	6357	**6887**			4'-9"	24
2526	2972	3436	3917	4411	5433	6493	**7189**			4'-10"	25
2552	3008	3483	3975	4481	5532	6622	**7455**			4'-11"	26
2576	3041	3526	4029	4548	5625	6745	**7768**			4'-11"	27
2599	3071	3566	4079	4610	5713	6863	**8044**			5'-0"	28
2619	3099	3603	4126	4668	5797	6974	8191	**8344**		5'-1"	29
2638	3125	3637	4171	4723	5876	7081	8328	**8636**		5'-2"	30
2655	3149	3669	4212	4774	5950	7182	8458	**8901**		5'-2"	31
2670	3171	3699	4250	4823	6021	7278	8583	**9198**		5'-3"	32
2685	3192	3727	4286	4868	6088	7370	8703	**9488**		5'-3"	33
2698	3211	3752	4320	4911	6151	7458	8817	**9771**		5'-4"	34
2710	3228	3776	4351	4951	6211	7541	8927	**10070**		5'-5"	35
2721	3244	3798	4381	4988	6268	7620	9032	**10340**		5'-5"	36
2731	3259	3819	4408	5024	6322	7696	9132	**10630**		5'-6"	37
2740	3273	3838	4434	5057	6373	7768	9228	**10940**		5'-7"	38
2749	3285	3856	4458	5088	6421	7836	9320	**11220**		5'-7"	39
2756	3297	3873	4480	5117	6466	7902	9408	**11520**		5'-8"	40

** For backfill weighing 110 pounds per cubic foot, increase loads 10%; for 120 pounds per cubic foot, increase 20%; etc.*

*▲Transition loads (**bold type**) and widths based on Kμ—0.19, $r_{sd}p$—0.5 in the embankment equation*

Interpolate for intermediate heights of backfill and/or trench widths

748

[redacted]

GEOSYNTEC CONSULTANTS

Written by: RSC Date: 96 / 03 / 22 (YY MM DD) Reviewed by: GSS Date: 96 / 03 / 27 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 08.1

WEST PERIMETER SWALE DROP INLET CALCULATIONS

PROBLEM: DESIGN A STORMWATER DROP INLET THAT WILL PASS THE FLOW FROM A 25-YEAR, 24-HOUR STORM WITHOUT OVERTOPPING THE THE WESTERN PERIMETER CHANNEL

GIVEN:

1) ESTIMATED PEAK FLOW FROM THE 25-YEAR, 24-HOUR STORM: (FROM HYDROCAD WEST CHANNEL CALCULATIONS)

13.1 CFS ✓

2) CHANNEL GEOMETRY (SEE FIGURE 1) ✓

CALCULATIONS:

SEE SUPPLIER DESIGN CHARTS (FIGURES 2 AND 3)

FOR A 36" I.D RISER AND 9.5 IN. OF HEAD:

Q_{MAX} = 15 CFS ✓ > 13.1 CFS OK

HAND CALCS.

FOR BROADCRESTED WEIR FLOW:

$$Q = B \times (2/3)^{1.5} \times g^{0.5} \times H^{1.5} \quad \text{(FIGURE 3)}$$

$$C_c = .1 \times n \times H$$

B = EFFECTIVE LENGTH OF WEIR $= \pi \times \left(\frac{3 \times 90}{360}\right) \times 3' - C_c$

g = GRAVITY $(Ft/s^2) = 32.2\ ft/s^2$

H = HEAD ABOVE WEIR $(Ft) = 0.8\ ft$

n = NUMBER OF CONTRACTIONS = 6

[redacted]

GEOSYNTEC CONSULTANTS

Written by: RSC Date: 96 / 03 / 22 (YY MM DD) Reviewed by: [illegible] Date: 96 / 03 / 22 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 08.1

$C_c = .1 \times 6 \times .8$

$= .48 \text{ Ft}$

$B = \pi \times \left(\frac{3 \times 90}{360}\right) \times 3 \text{ Ft} - .48$

$= 6.59 \text{ Ft}$

$Q = 6.59 \text{ Ft} \times (2/3)^{1.5} \times (32.2 \text{ Ft/s}^2)^{0.5} \times (0.8 \text{ Ft})^{1.5}$

$= 14.57 \text{ CFS}$ [illegible]

[redacted]

GeoSyntec Consultants

Written by: RSL Date: 96/03/22 (YY MM DD) Reviewed by: [illegible] Date: 96/03/27 (YY MM DD)

Client: Fernco Project: OSDF Project/Proposal No.: GE 3900 Task No.: 08.1

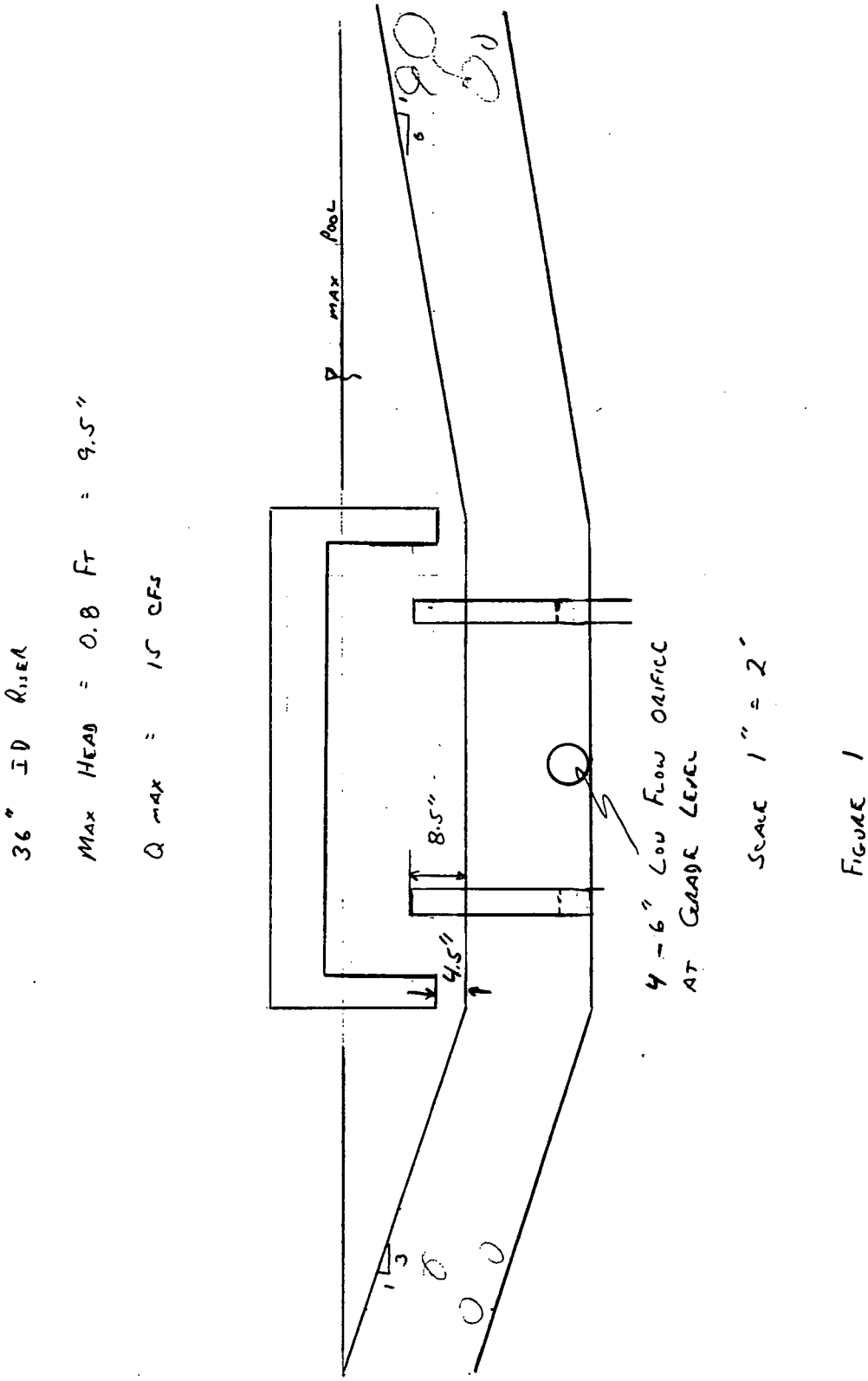
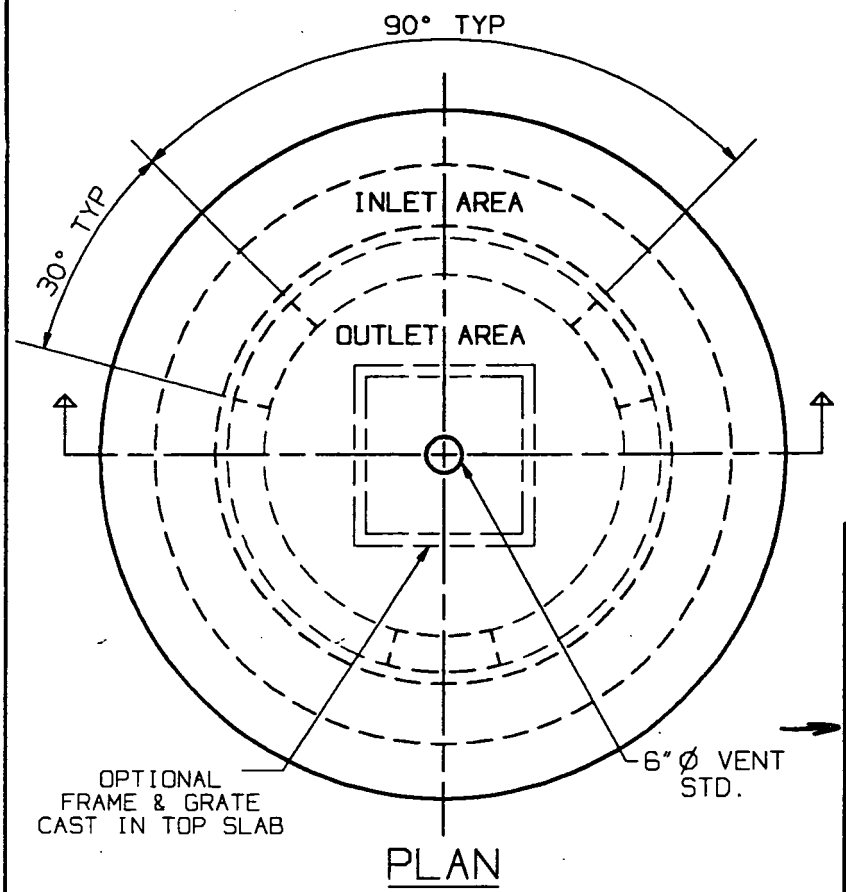


Figure 1



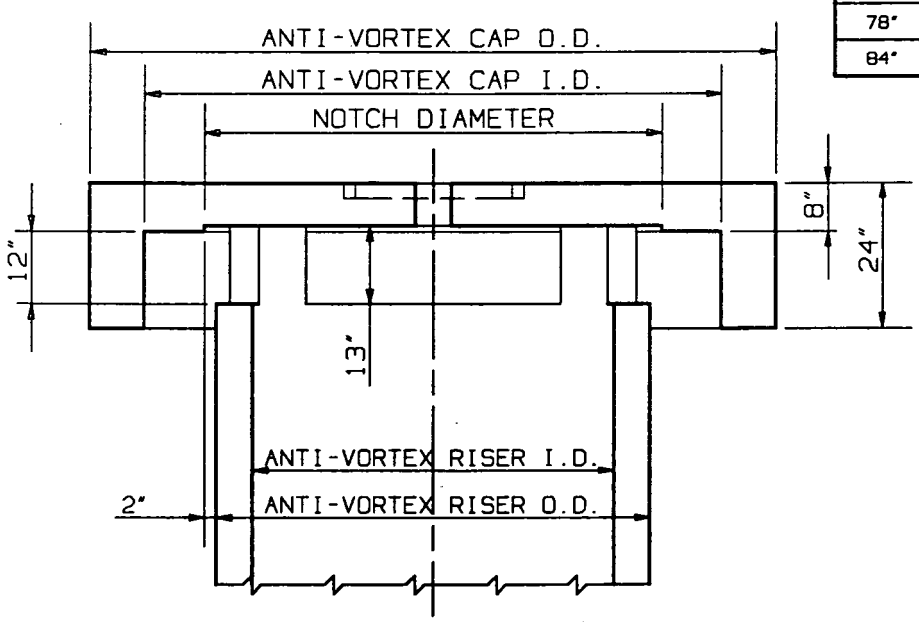
PLAN

NOTE:

RSS 96/03/27

1. ANTI-VORTEX DEVICE (CAP AND RISER) MANUFACTURED IN ACCORDANCE WITH ASTM C478.
2. DIMENSIONS SUBJECT TO PERMISSIBLE VARIATIONS OF ASTM C478.
3. INLET AREA (AREA BETWEEN DEVICE I.D. AND RISER O.D.) IS GREATER THAN OUTLET AREA (AREA OF RISER I.D.)
4. SLAB REINFORCEMENT TO BE ASTM A615 #4 BARS @ 8" E.W. CIRCUMFERENTIAL REINFORCEMENT TO BE Asc = 1 @ 0.150 2x6 W2.5 x w2.5 WWF MINIMUM. MATERIAL PROPERTIES: fy = 60 ksi. fc = 4 ksi. CONCRETE COVER OVER REINFORCEMENT (CCOR) = 1", UNLESS NOTED
5. DI-1 FRAME & GRATE IS AVAILABLE FOR 48" I.D. RISERS AND LARGER.

RISER		ANTI-VORTEX CAP		NOTCH DIAMETER	APPROX. CAP WEIGHT
I.D.	O.D.	I.D.	O.D.		
24"	30"	48"	58"	34"	1.49 T
27"	33½"	60"	70" OR 72"	37½"	2.28 T
30"	37"	60"	70" OR 72"	41"	2.26 T
36"	44"	60"	70" OR 72"	48"	2.22 T
42"	51"	72"	86"	55"	3.16 T
48"	58"	84"	100"	62"	4.27 T
54"	66½"	84"	100"	70½"	4.20 T
60"	72"	96"	114"	76"	5.48 T
66"	80½"	96"	114"	84½"	5.39 T
72"	86"	108"	128"	90"	6.83 T
78"	94½"	126"	147"	98½"	8.97 T
84"	100"	126"	147"	104"	8.90 T

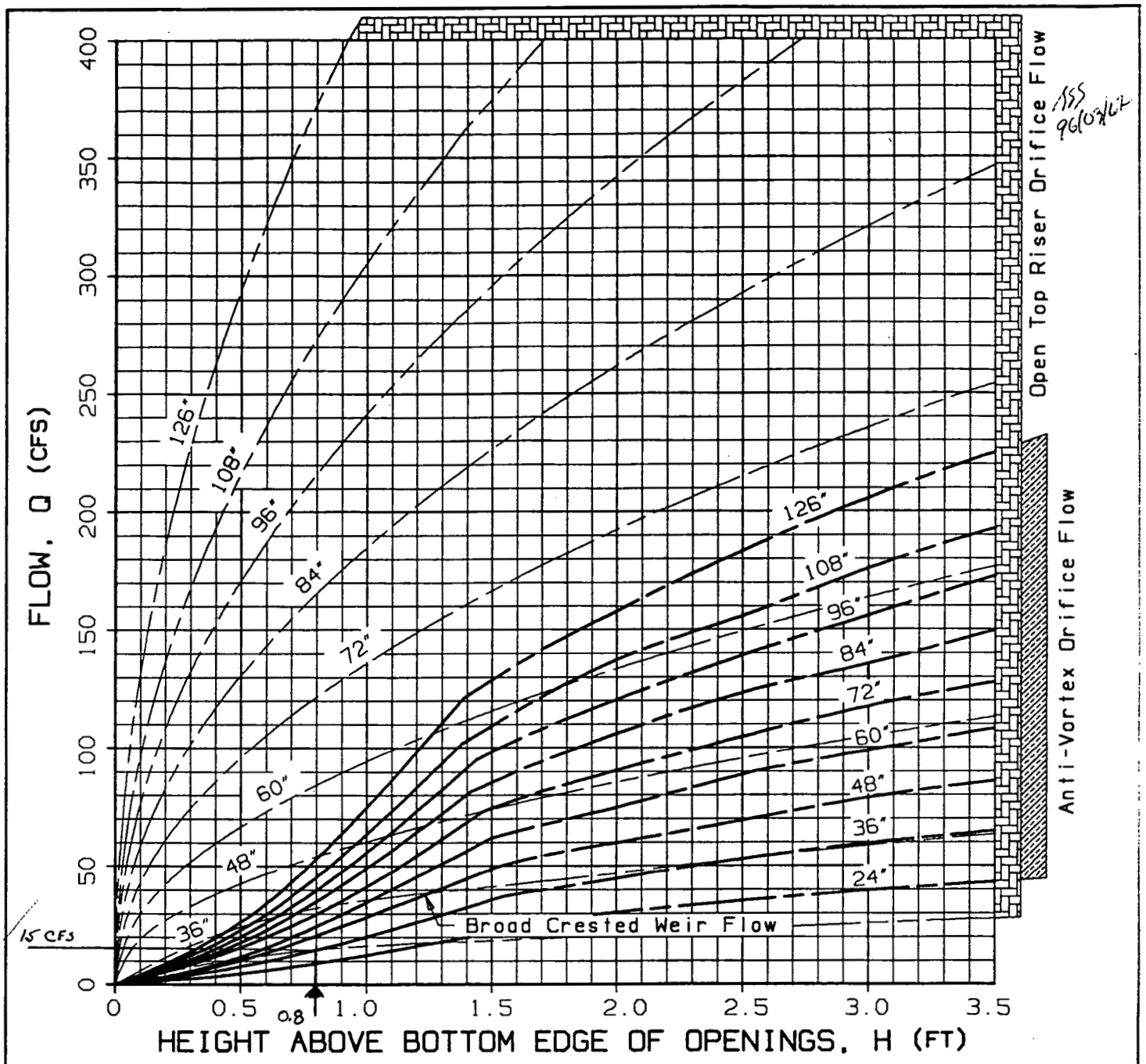


SECTION

Technical Manual page 14.1

PRECAST ANTI-VORTEX DEVICE (CAP AND RISER)	ORIGINAL DATE	02-01-95	RCH
	LAST REVISION		
	SCALE	3/8 = 1'-0"	
CONCRETE PIPE & PRODUCTS CO., INC. P.O. Box 1223 □ Richmond, Virginia 23209 □ 804-233-5471	TOPIC - PROJECT # - DRAWING #		
	ST-0847-63		

FIGURE 2



Flow Type	FLOW, Q (CFS)	Cc	Area, A (SQFT)
Anti-Vortex Orifice	$Cc \times A \times [2 \times g \times (H-hs/2)]^{0.5}$	0.61	PixIDxscxhs
Open Top Riser Orifice	$Cc \times A \times (2 \times g \times H)^{0.5}$	0.60	$PixID^2/4$
Broad Crested Weir	$B_{eff} \times (2/3)^{1.5} \times g^{0.5} \times H^{1.5}$	0.1xNcxH	Width, B_{eff} (FT) PixscxID-Cc

Where: for 3 - 90° x 1.08' A/V openings Pi = 3.1415
Gravitational acceleration, g = 32.2 FT/s²
Height of slot....., hs = 1.08'
Number of contracting sides, Nc = 3x2 = 6
Slot/Circumference ratio, sc = 3x90/360 = 0.75

CP&P

Technical Manual page 14.2

OPEN TOP RISER VS. ANTI-VORTEX FLOW RATE CHART

ORIGINAL DATE	02-01-95	RCH
LAST REVISION		
SCALE	3/8 = 1'-0"	
TOPIC - PROJECT # - DRAWING #		
ST-0846-43		

CONCRETE PIPE & PRODUCTS CO., INC.
P.O. Box 1223 □ Richmond, Virginia 23209 □ 804-233-5471

FIGURE 3

Written by: Ganesh Gopalakrishnan Date: 5/5/97 Reviewed by: Ken W. Cargill Date:

Client: FDF Project: OSDF Project/Proposal No.: GQ 0131 Task No.: 12.1

ADDENDUM
(to Southern Area Calcluations of Section 13.1)

The following section is an Addendum to Section 13.1 of the OSDF Calculation Package entitled "Stormwater Runon/Runoff and Drainage Control Structures". This Addendum is part of the Southern Area Calculations subsection. All relative and pertinent calculations to this Addendum can be found in Section 13.1 of the OSDF Calculation Package.

This Addendum presents calculations for sizing a culvert system to transmit the 25-year, 24-hour storm under the Access corridor. The Addendum is presented in two parts:

Section I: This section presents the calculations for different culvert cross-section scenarios to pass the design storm under the Access Corridor. It is concluded that a system of three 5'x3' box culverts with upstream headwalls would be required to pass the design storm.

Section II: This section presents the calculation to verify that a system of three 6'x3' box culverts without headwalls would pass the design storm under the Access Corridor.

SECTION I

GEOSYNTEC CONSULTANTS

Written by: RSC Date: 96/03/22 (YY MM DD) Reviewed by: [illegible] Date: 96/03/27 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 08.1

SOUTHERN CULVERT CALCULATIONS

PROBLEM: DESIGN A CULVERT THAT WILL PASS THE RUNOFF FROM A 25-YEAR, 24-HOUR STORM UNDER THE WESTERN ACCESS ROAD WITHOUT OVERTOPPING THE ROAD

GIVEN:

1) ESTIMATED PEAK FLOW FROM 25-YEAR, 24-HOUR STORM: (FROM HYDROCAD RESULTS)

EAST CHANNEL	159.0 CFS
SOUTH CHANNEL	30.4 CFS
TOTAL RUNOFF	189.4 CFS

ROUND-OFF TO 190 CFS

2) MAXIMUM ALLOWABLE HEADWATER POOL: (SEE DRAWING G-12)

LOWEST ELEVATION OF ACCESS ROAD: 580.5

CULVERT INLET INVERT ELEVATION: 577.0

MAX. POOL DEPTH 3.5 FT

3) CULVERT LENGTH 40 FT (SEE DRAWING G-12)

CALCULATIONS:

USING THE FHWA WORKSHEETS AND CHARTS FOR THE DESIGN OF CULVERTS, THE CALCULATIONS ARE PERFORMED FOR THE FOLLOWING CULVERT TYPES:

a) ROUND CORRUGATED METAL PIPE (CMP)
b) ROUND REINFORCED CONCRETE PIPE (RCP)
c) REINFORCED CONCRETE BOX

[redacted]

GEOSYNTEC CONSULTANTS

Written by: RSC Date: 96 / 03 / 22 (YY MM DD) Reviewed by: [illegible] Date: 96 / 03 / 27 (YY MM DD)

Client: FERACO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 08.1

STRUCTURAL CAPACITY OF CULVERTS

1) THE PRECAST REINFORCED CONCRETE BOX CULVERT MATERIALS AND DESIGN SHALL MEET ASTM C 850 STANDARDS "PRECAST REINFORCED CONCRETE BOX SECTIONS FOR CULVERTS, STORM DRAINS AND SEWERS WITH LESS THAN 2 FEET OF COVER SUBJECTED TO HIGHWAY LOADINGS."

2) CULVERT INSTALLATION SHALL MEET AASHTO DIVISION II, SECTION 27 STANDARDS AND STATE MODIFICATIONS THERETO

RESULTS

THREE 5 FT SPAN x 3 FT RISE, RCP BOX CULVERTS WITH A SQUARE HEADWALL WILL PASS THE 25-YR, 24-HR STORM RUNOFF WITHOUT OVERTOPPING THE ROAD.

PROJECT: West Access Road Culverts

STATION: _____

SHEET ____ **OF** ____

CULVERT DESIGN FORM

DESIGNER / DATE: RSC / 3/21

REVIEWER / DATE: GSS / 3/27/96

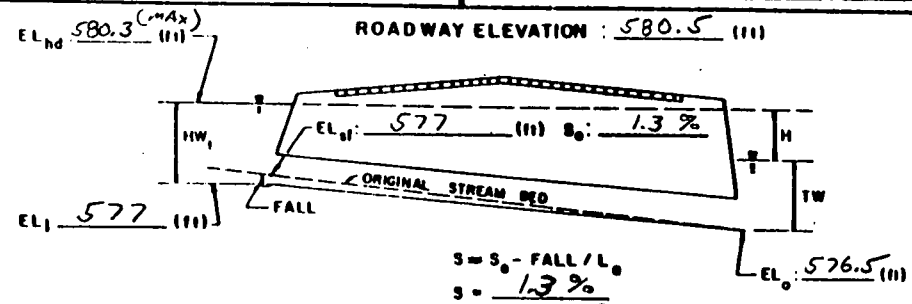
HYDROLOGICAL DATA

SEE ADD'L SHTS.

- ☐ METHOD: _____
- ☐ DRAINAGE AREA: _____ ☐ STREAM SLOPE: _____
- ☐ CHANNEL SHAPE: _____
- ☐ ROUTING: _____ ☐ OTHER: _____

DESIGN FLOWS/TAILWATER

R.I. (YEARS)	FLOW (cfs)	TW (ft)
25 YR	190	0



$S = S_o - FALL / L_a$

$S = 1.3\%$

$L_a = 40$ Ft

CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW Q (cfs)	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS: INLET CONTROL HW_i/D (2)	HW_i	FALL (3)	EL_hi (4)	OUTLET CONTROL TW (5)	d_c	(d_c+D)/2	h_o (6)	h_a	H (7)	EL_ho (8)	CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
CMP - Round - 5-36" - Square	190	38.0	1.1	3.3	Ø	580.3	Ø	2.0	2.5	2.5	0.5	1.3	580.3	580.3	N/A	Acceptable
RCP - Box - 8'x3' - Square	190	23.75	1.65	4.95	Ø	582	Ø								N/A	Unacceptable
RCP - Box - Three, 5'x3' - Square	190	12.7	.975	2.9	Ø	579.9	Ø	1.25	2.4	2.4	0.5	0.5	579.4	579.9	N/A	Acceptable
RCP - Round - 5-36" - Square	190	38.0	1.1	3.3	Ø	580.3	Ø	2.0	2.5	2.5	0.5	0.82	579.8	580.3	N/A	Acceptable

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) $HW_i/D = HW/D$ OR HW_i/D FROM DESIGN CHARTS

(3) $FALL = HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $EL_{hi} = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL.

(6) $h_o = TW$ or $(d_c + D/2)$ (WHICHEVER IS GREATER)

(7) $H = \left[1 + h_o + (29n^2 L)/R^{1.33}\right] V^2/2g$

(8) $EL_{ho} = EL_o + H + h_o$

SUBSCRIPT DEFINITIONS:

a. APPROXIMATE
f CULVERT FACE
hd. DESIGN HEADWATER
hi. HEADWATER IN INLET CONTROL
ho HEADWATER IN OUTLET CONTROL
i. INLET CONTROL SECTION
o. OUTLET
sf STREAMBED AT CULVERT FACE
tw. TAILWATER

COMMENTS / DISCUSSION:

Rough Cost Est:

CMP - $9,000 - 5-36"Ø
RCP Box - $11,700 - 3, 5'x3'
RCP - $13,200 - 5-36"Ø
} without headwalls

CULVERT BARREL SELECTED:

SIZE: 5 Ft x 3 Ft

SHAPE: Box

MATERIAL: RCP n .012

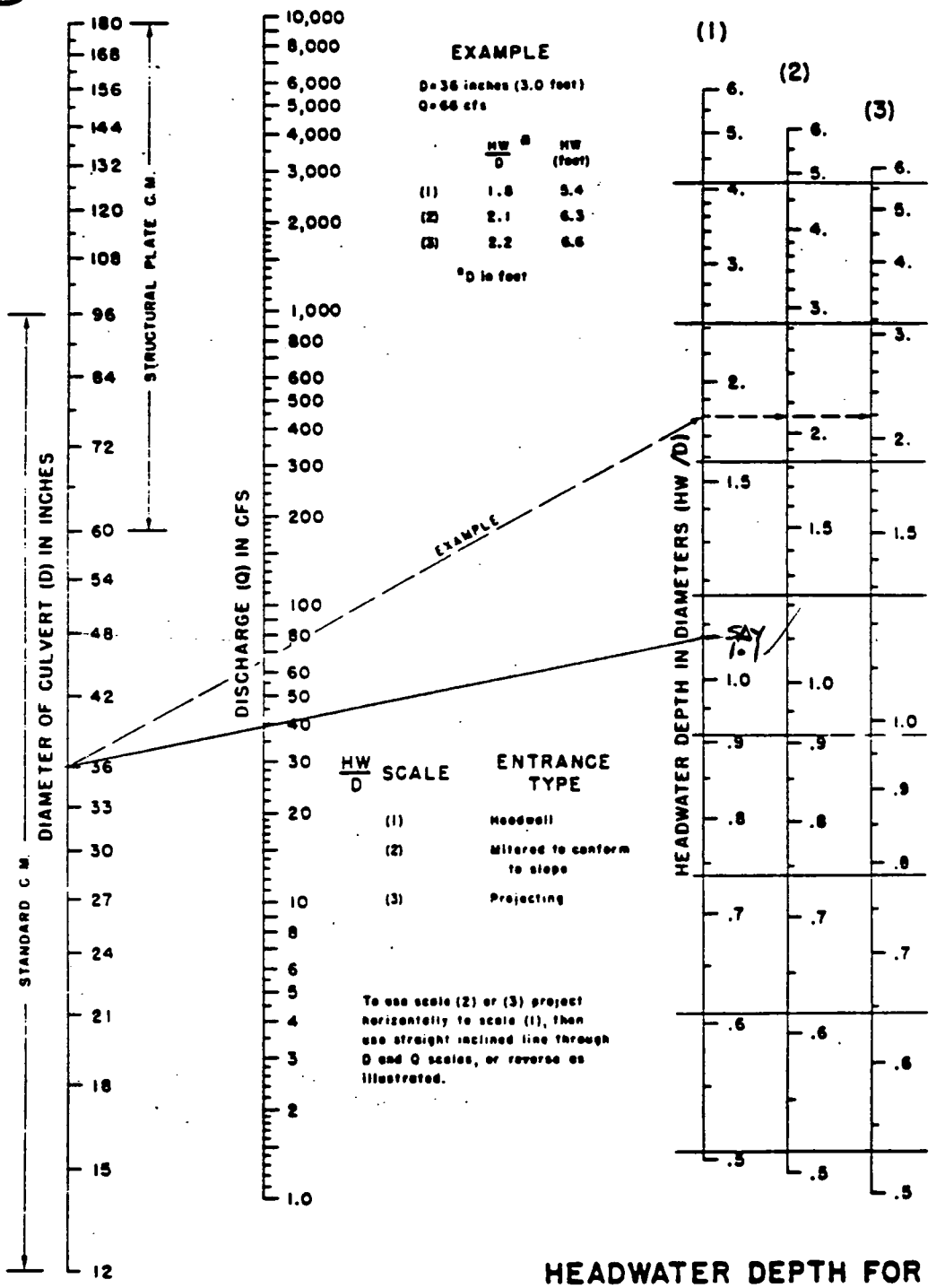
ENTRANCE: Square Headwall

RSC 3/27/96

GSS 3/27/96

ASC
3/22/96
SS
3/27/96

CHART 2

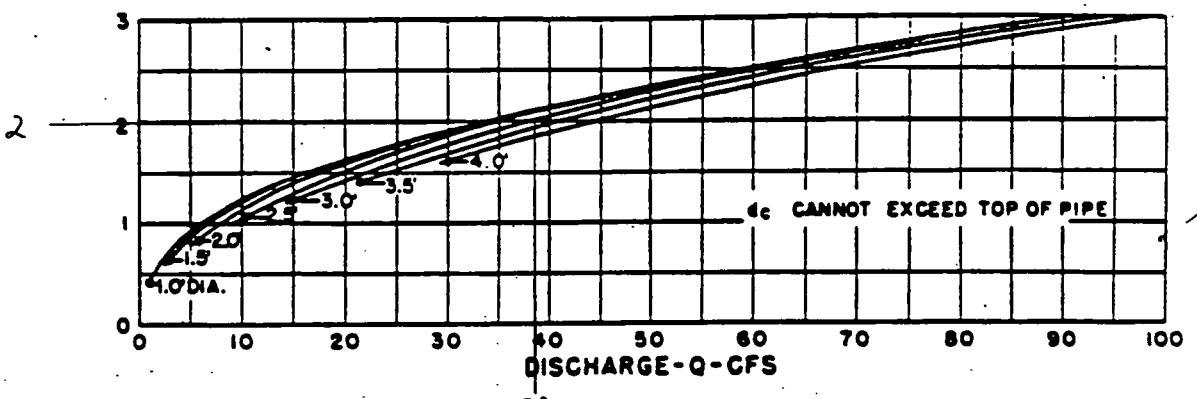


HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

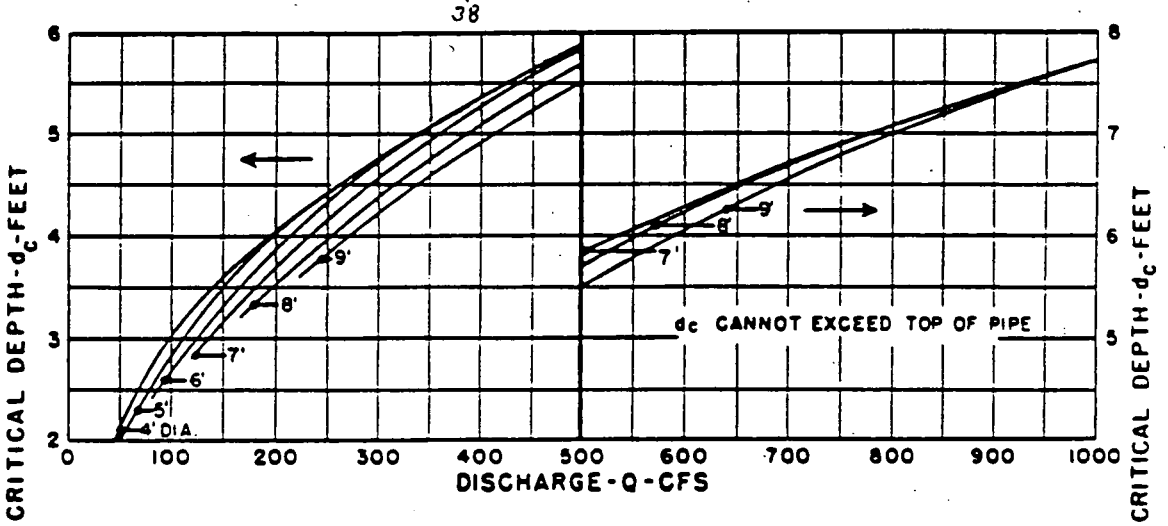
BUREAU OF PUBLIC ROADS JAN. 1963

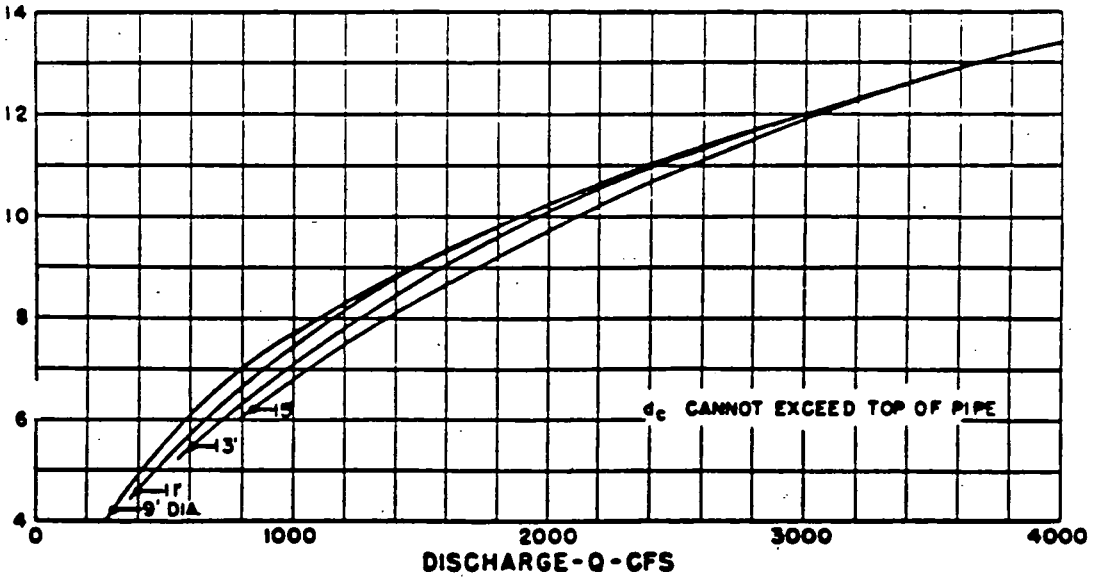
[redacted]
759

CHART 4



38





BUREAU OF PUBLIC ROADS
JAN. 1964

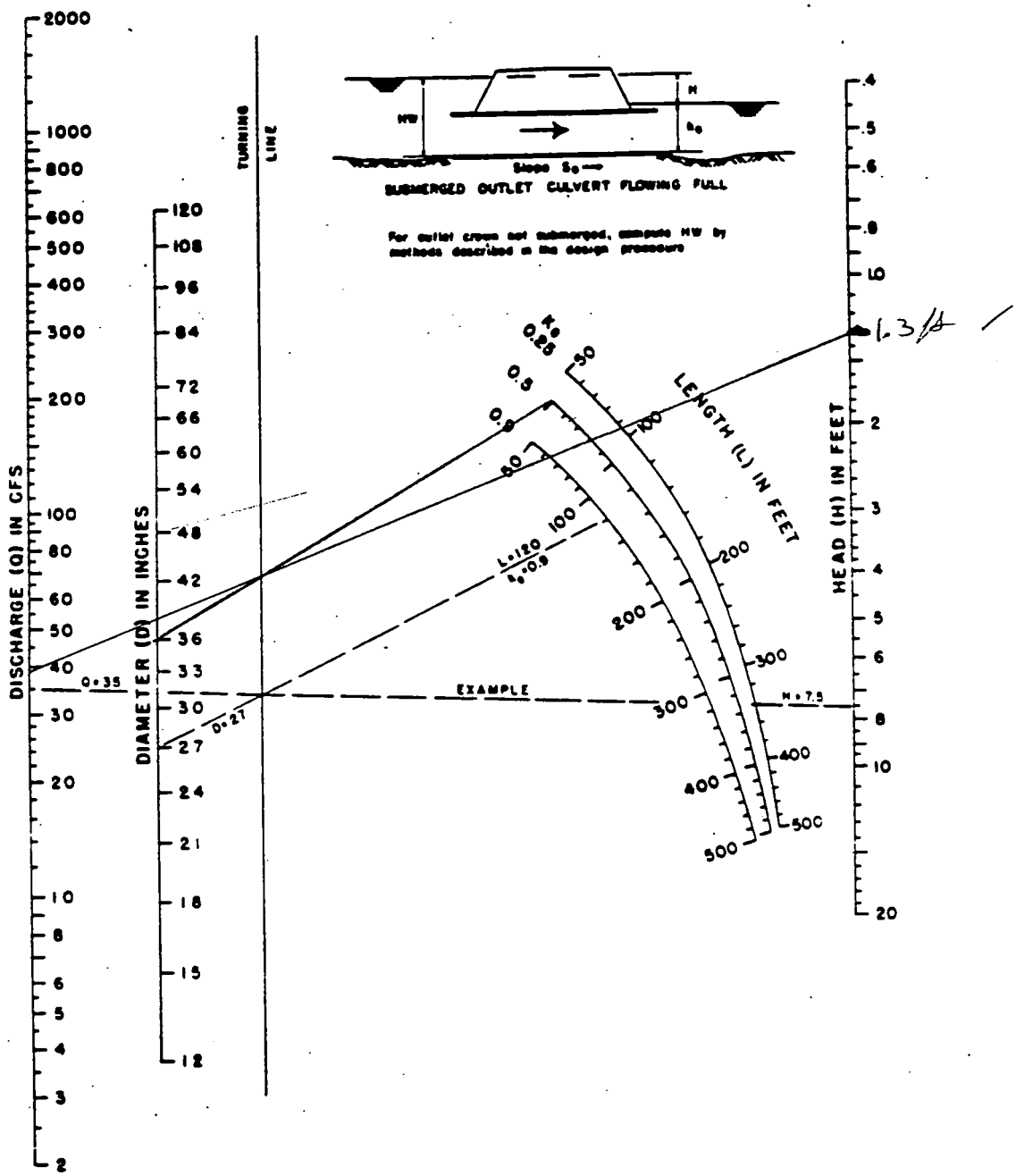
CRITICAL DEPTH
CIRCULAR PIPE

[redacted]
760

QSC
3/22/56

TSS
3/27/96

CHART 6



HEAD FOR
STANDARD
C. M. PIPE CULVERTS
FLOWING FULL
n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

[redacted]
261

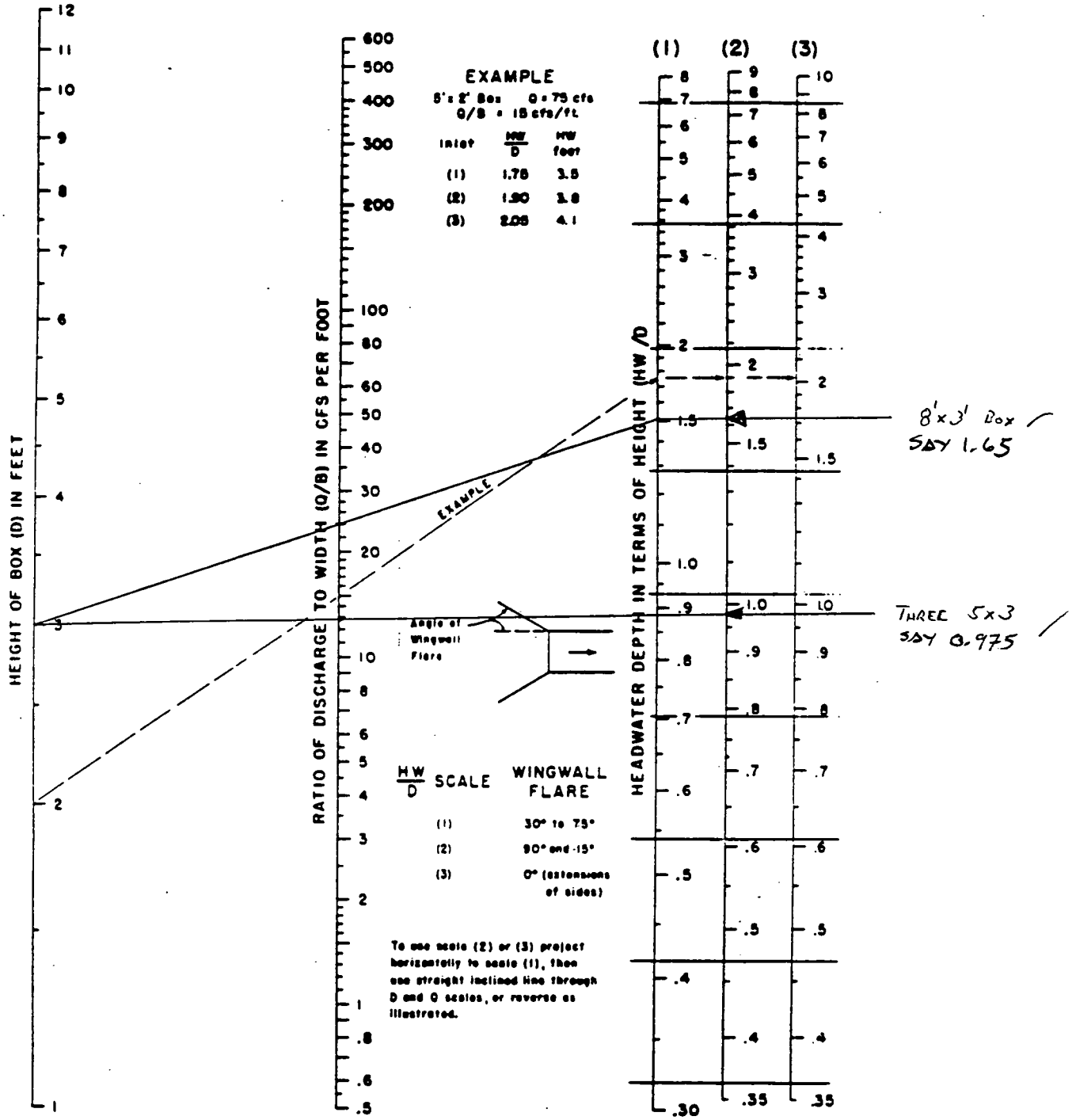
ASC
3/22/96

7 OF 14

739

GSS
3/27/96

CHART 8



HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

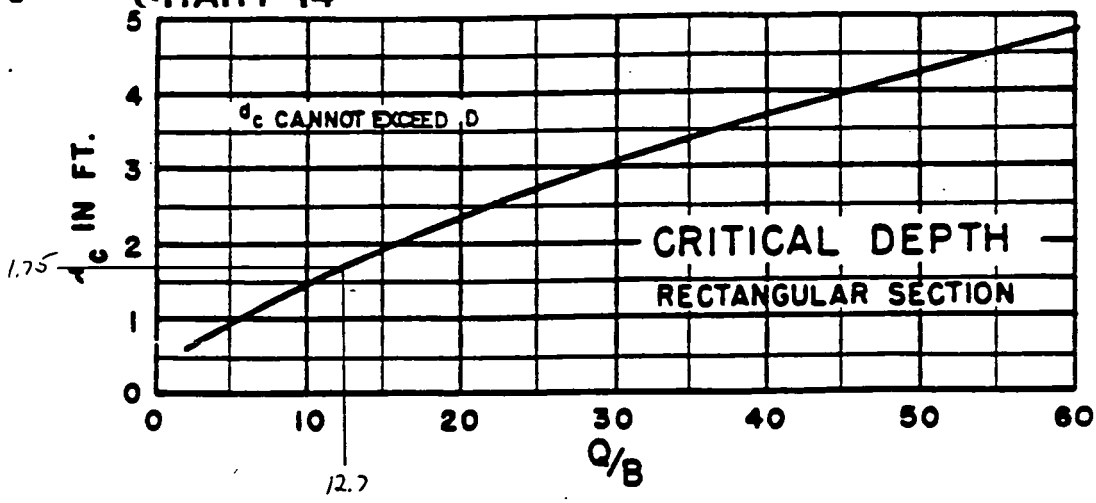
BUREAU OF PUBLIC ROADS JAN. 1963

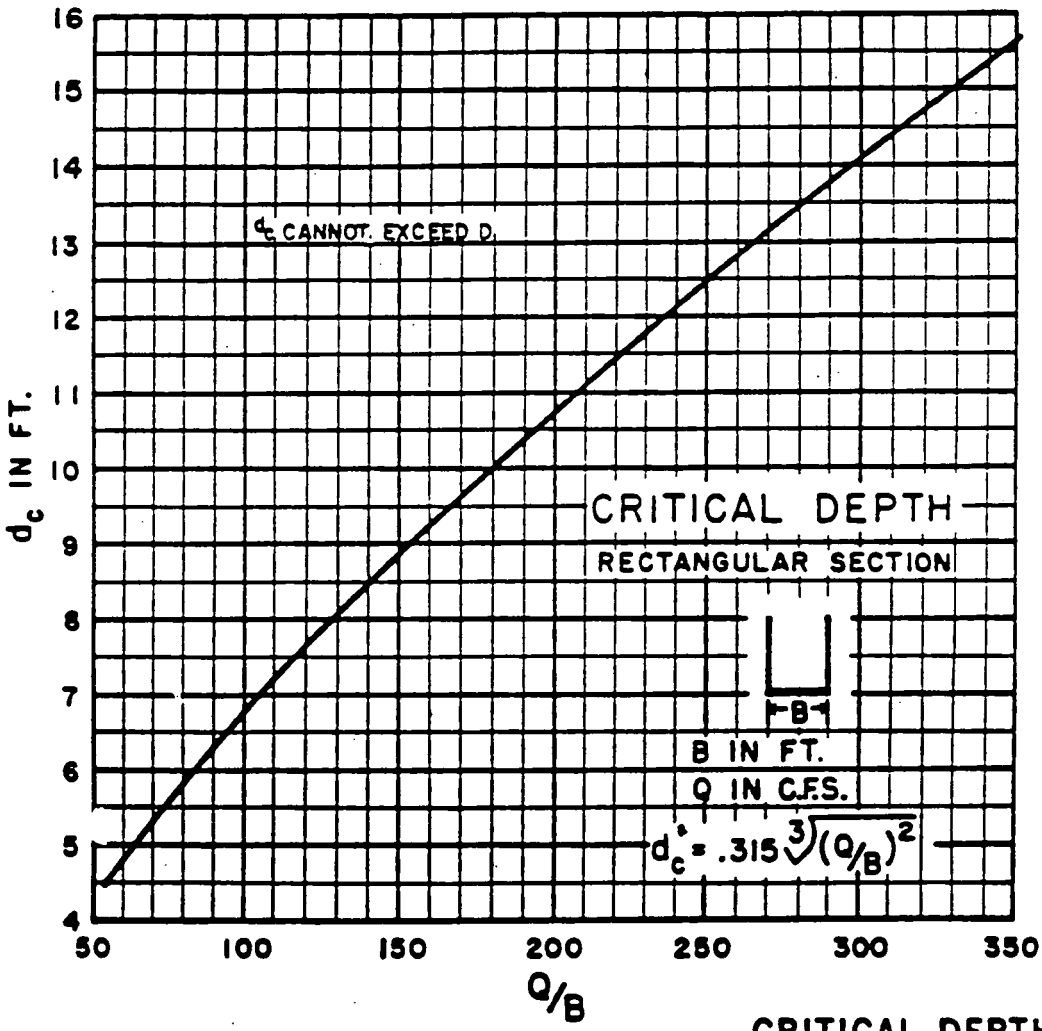
[redacted] 762

ASC
3/22/96

739

CHART 14



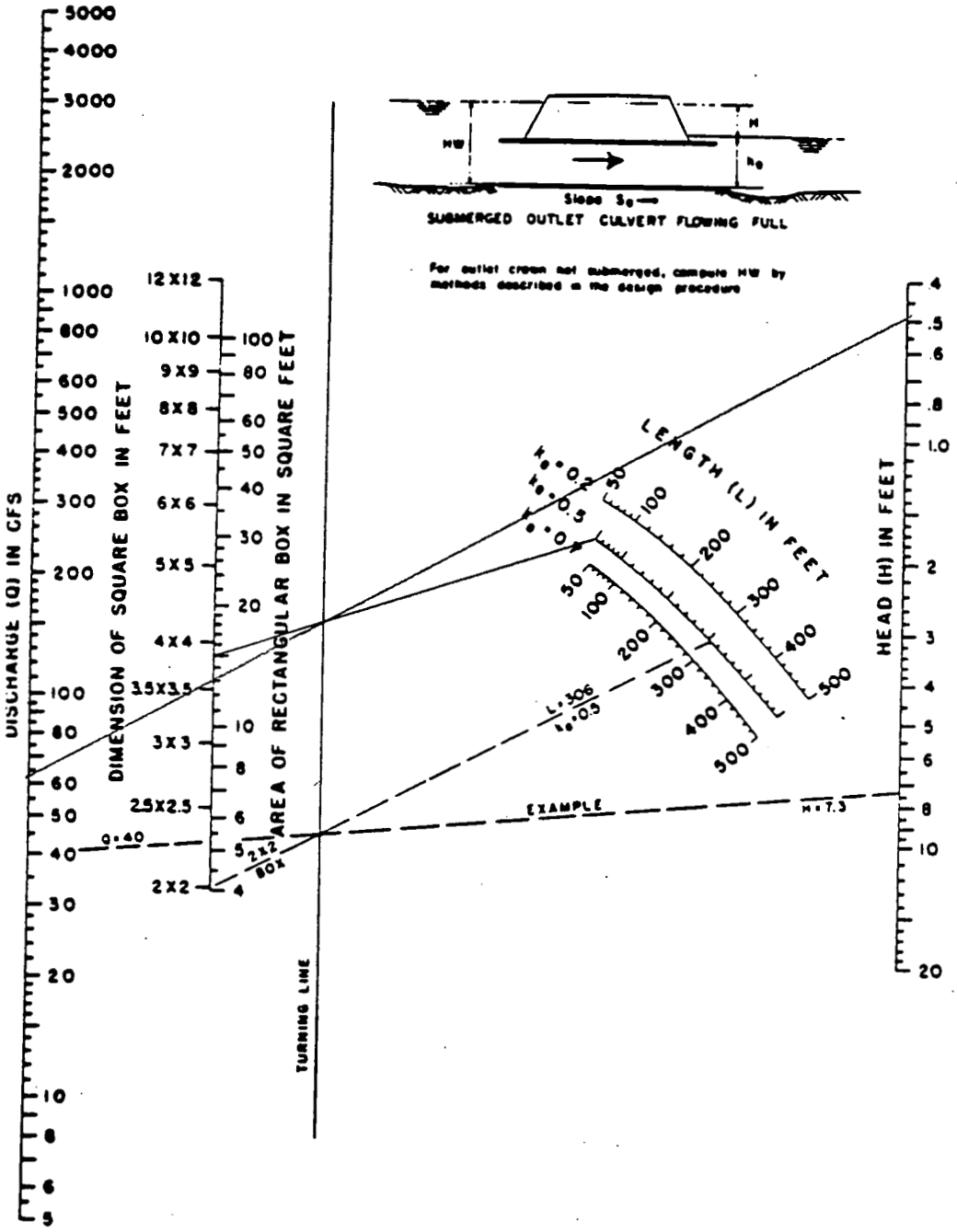


BUREAU OF PUBLIC ROADS JAN. 1963

CRITICAL DEPTH
RECTANGULAR SECTION

[redacted] 263

CHART 15



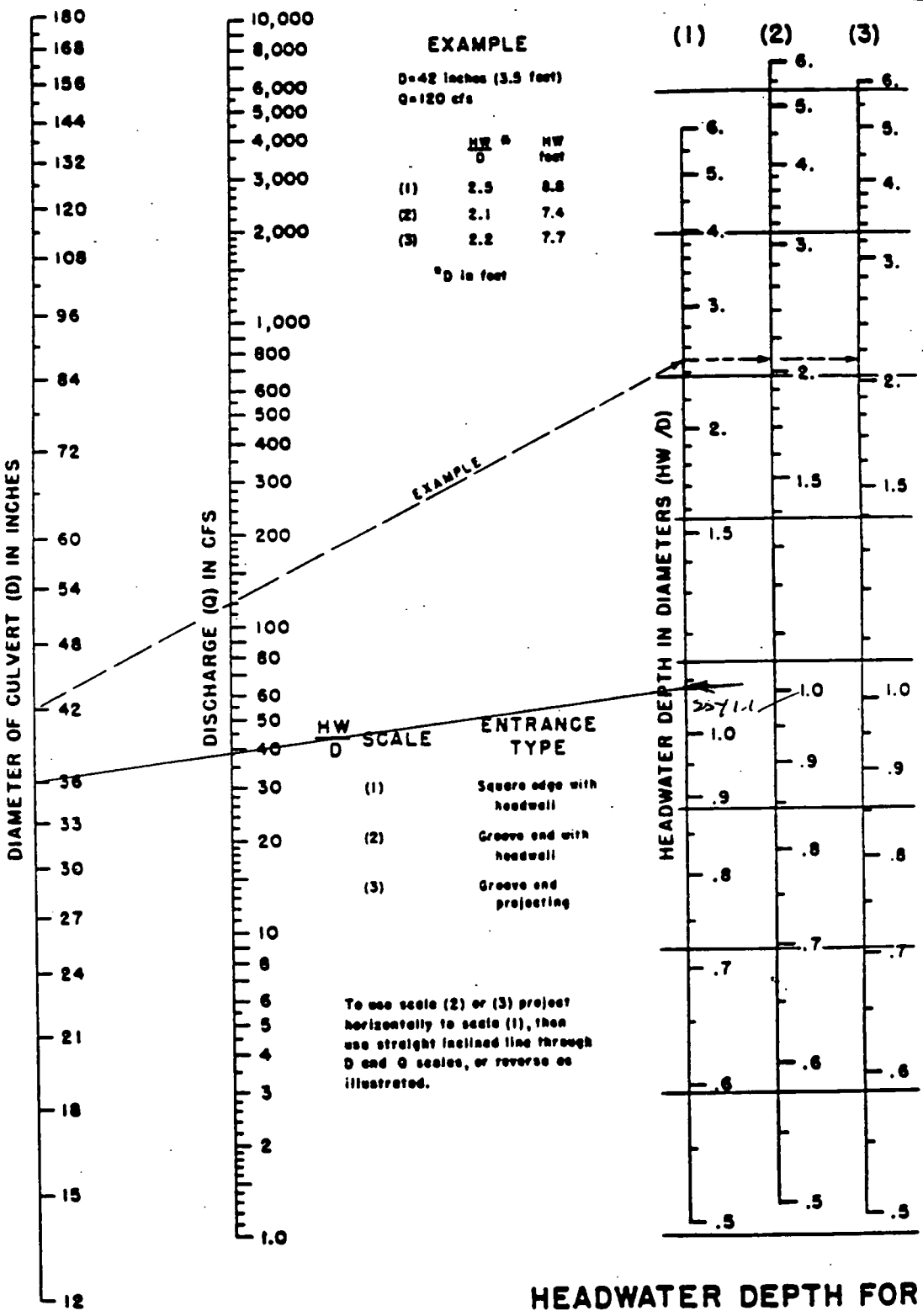
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BU OF PUBLIC ROADS JAN. 1963

RSC
3/22/96

SSS
3/27/94

CHART 1



HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

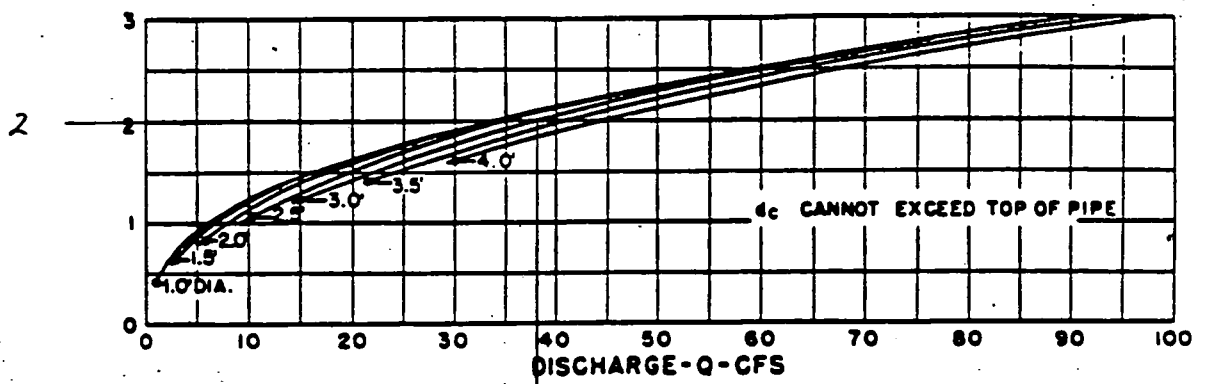
HEADWATER SCALES 2&3
REVISED MAY 1964

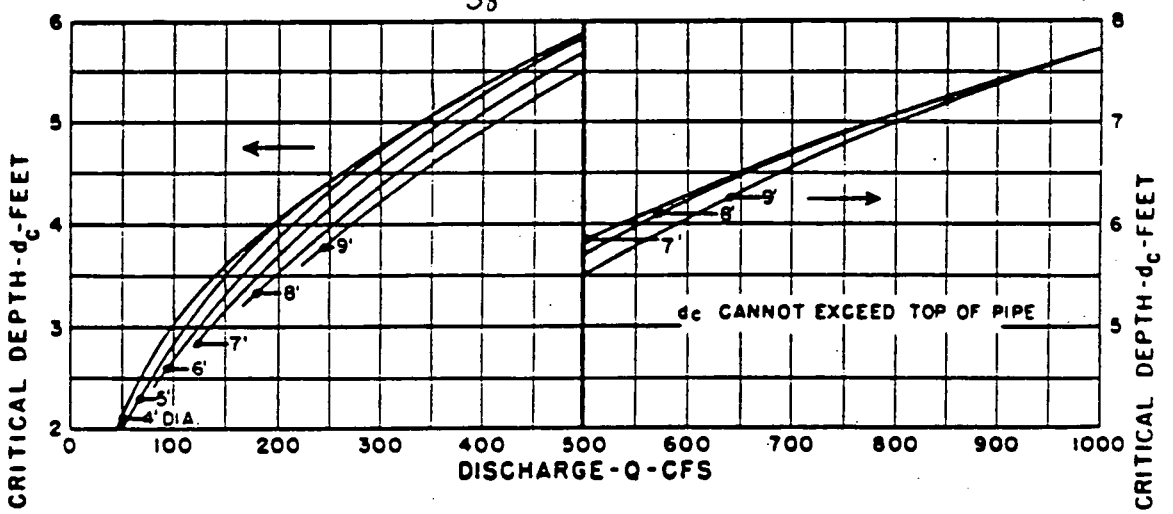
BUREAU OF PUBLIC ROADS JAN. 1963

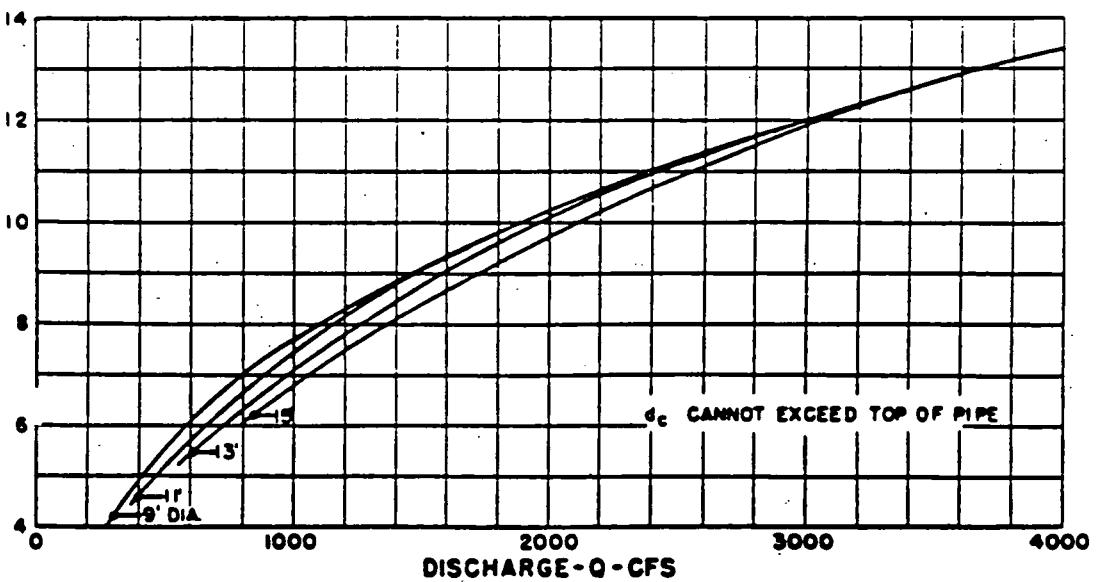
765

155 3/2/94

CHART 4







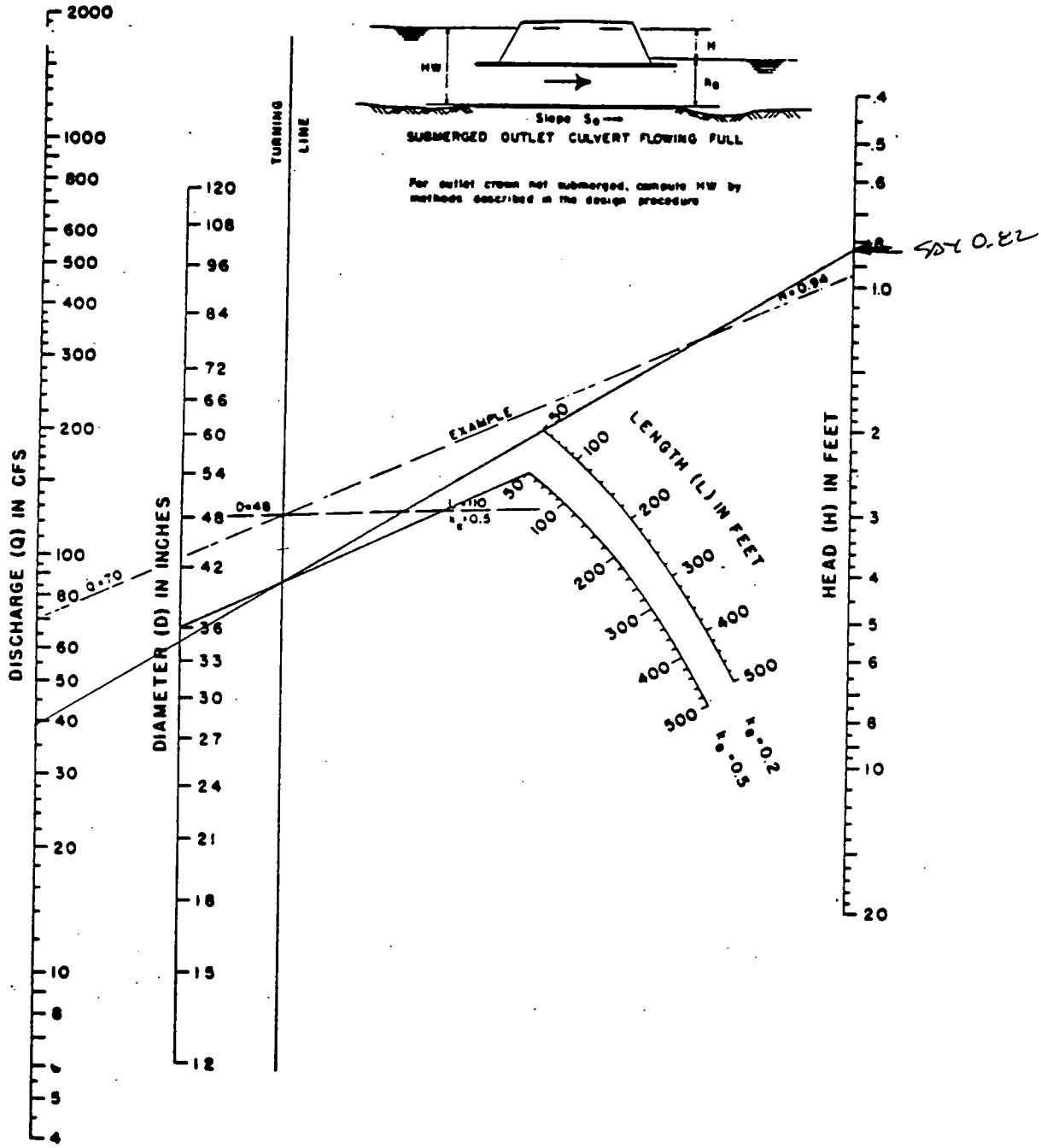
BUREAU OF PUBLIC ROADS
JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

[redacted] 766

RSC
3/22/96
SSS
3/27/96

CHART 5



HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

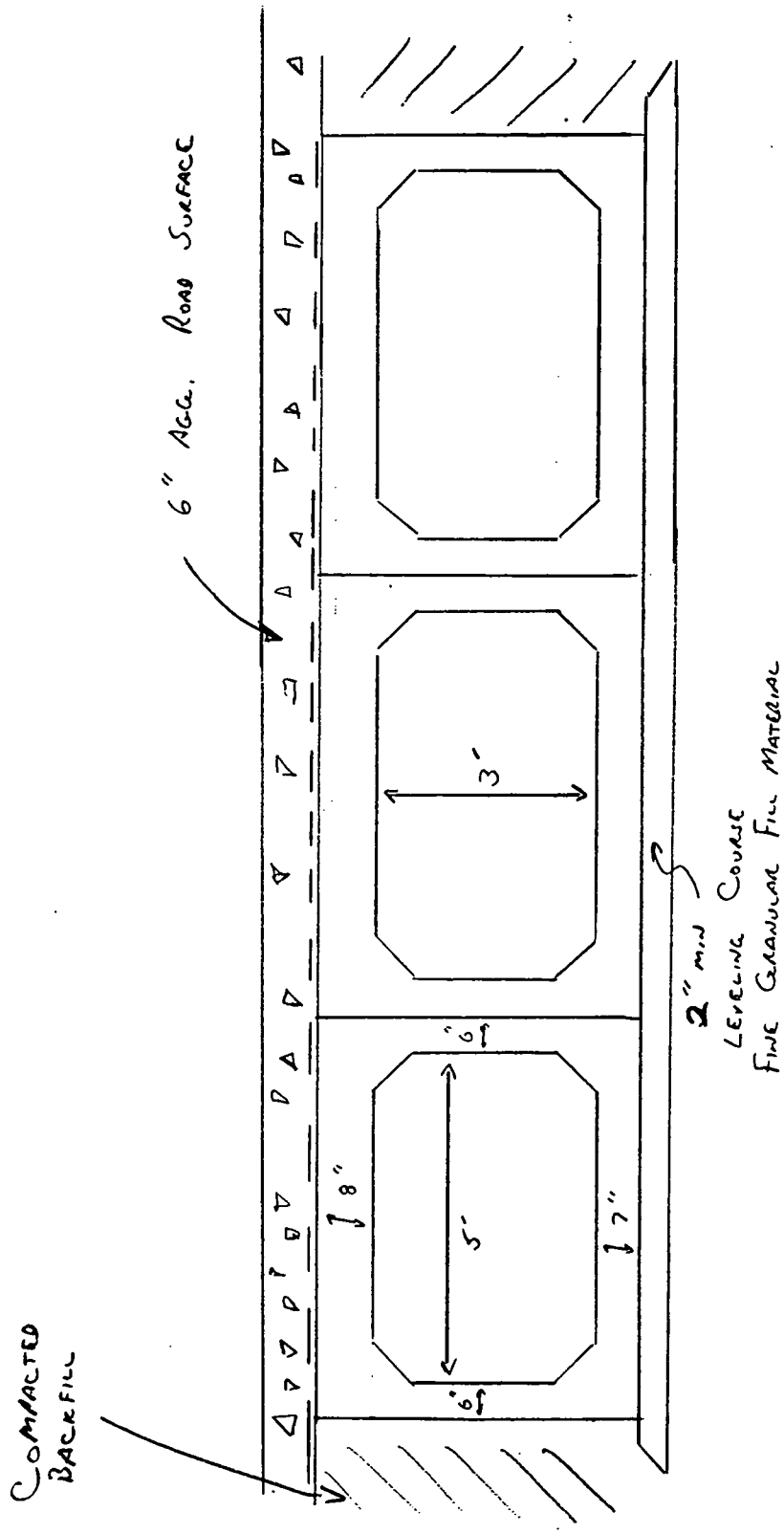
[redacted]

267

GEOSYNTEC CONSULTANTS

Written by: RSC Date: 96/03/22 (YY MM DD) Reviewed by: [illegible] Date: 96/03/27 (YY MM DD)

Client: FERMCO Project: OSDF Project/Proposal No.: GE 3900 Task No.: 08.1



NOTE: ① REINFORCED CONCRETE BOX CULVERT MATERIALS AND DESIGN SHALL MEET ASTM C 850 STANDARDS

② CULVERT INSTALLATION SHALL MEET AASHTO DIVISION II, SECTION 27 STANDARDS AND STATE MODIFICATIONS THERETO.

[redacted]

ASS 3/27/96

TABLE 12 - ENTRANCE LOSS COEFFICIENTS

Outlet Control, Full or Partly Full Entrance head loss

$$H_e = k_e \left(\frac{V^2}{2g} \right)$$

Type of Structure and Design of Entrance	Coefficient k_e
Pipe, Concrete	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end)	0.2
Square-edge	0.5
Rounded (radius = 1/12D)	0.2
Mitered to conform to fill slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side-or slope-tapered inlet	0.2
Pipe, or Pipe-Arch, Corrugated Metal	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls square-edge	0.5
Mitered to conform to fill slope, paved or unpaved slope	0.7
*End-Section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side-or slope-tapered inlet	0.2
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of 1/12 barrel dimension, or beveled edges on 3 sides	0.2
Wingwalls at 30° to 75° to barrel	
Square-edged at crown	0.4
Crown edge rounded to radius of 1/12 barrel dimension, or beveled top edge	0.2
Wingwall at 10° to 25° to barrel	
Square-edged at crown	0.5
Wingwalls parallel (extension of sides)	
Square-edged at crown	0.7
Side-or slope-tapered inlet	0.2

*Note: "End Section conforming to fill slope," made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections, incorporating a closed taper in their design have a superior hydraulic performance. These latter sections can be

[redacted]

SECTION II

PROJECT: West Access Road Culverts
Fernco

STATION: —

SHEET — OF —

CULVERT DESIGN FORM

DESIGNER / DATE: ASC / 5/13/96
REVIEWER / DATE: [illegible] / 13 MAY 96

HYDROLOGICAL DATA

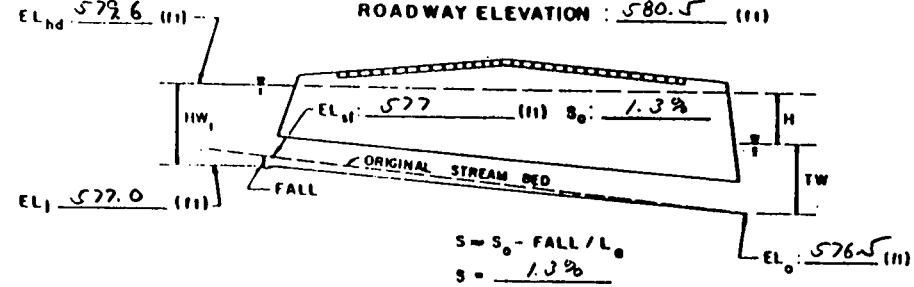
SEE ADD'L SHTS.

- ☐ METHOD: — —
- ☐ DRAINAGE AREA: — ☐ STREAM SLOPE —
- ☐ CHANNEL SHAPE: —
- ☐ ROUTING: — ☐ OTHER

DESIGN FLOWS/TAILWATER

R.I. (YEARS)	FLOW (cfs)	TW (ft)
25	190	Ø

ROADWAY ELEVATION: 580.5 (ft)



$S = S_o - FALL / L_a$
$S = 1.3\%$
$L_a = 40$ Ft

CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW Q (cfs)	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS: INLET CONTROL HW i/D (2)	HW i	FALL (3)	EL hi (4)	OUTLET CONTROL TW (5)	d c	(d c + D)/2	h o (6)	h e	H (7)	EL ho (8)	CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS
RCP - Box - 3 (6'x3') - None	190	10.6	.87	2.6	Ø	579.6	Ø	1.5	2.25	2.25	0.7	0.4	579.2	579.6	N/A	Acceptable
		Chart 8	↑				Chart 14	↑			Chart 15	↑				

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) $HW_i/D = HW/D$ OR HW_i/D FROM DESIGN CHARTS

(3) $FALL = HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $EL_{hi} = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL.

(6) $h_o = TW$ or $(d_c + D/2)$ (WHICHEVER IS GREATER)

(7) $H = \left[1 + h_e + (29n^2 L)/R^{1.33}\right] V^2/2g$

(8) $EL_{ho} = EL_o + H + h_o$

SUBSCRIPT DEFINITIONS:

a. APPROXIMATE
f CULVERT FACE
hd. DESIGN HEADWATER
hi. HEADWATER IN INLET CONTROL
ho HEADWATER IN OUTLET CONTROL
i. INLET CONTROL SECTION
o. OUTLET
sf STREAMBED AT CULVERT FACE
tw. TAILWATER

COMMENTS / DISCUSSION:

CULVERT BARREL SELECTED:

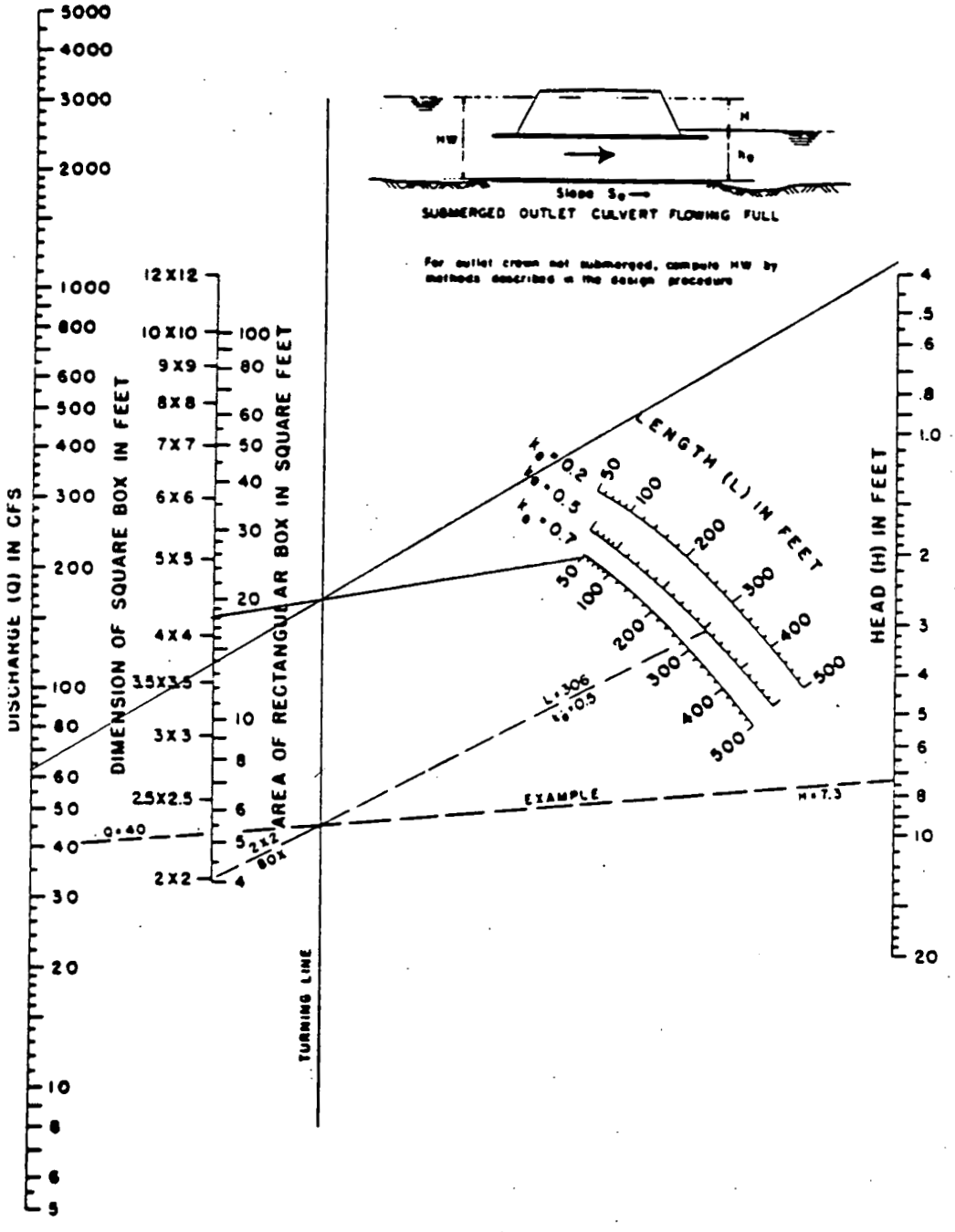
SIZE: Three 6' x 3'
SHAPE: Box
MATERIAL: RCP n .012
ENTRANCE: Square Extension

240

121

239 / 1 of 4

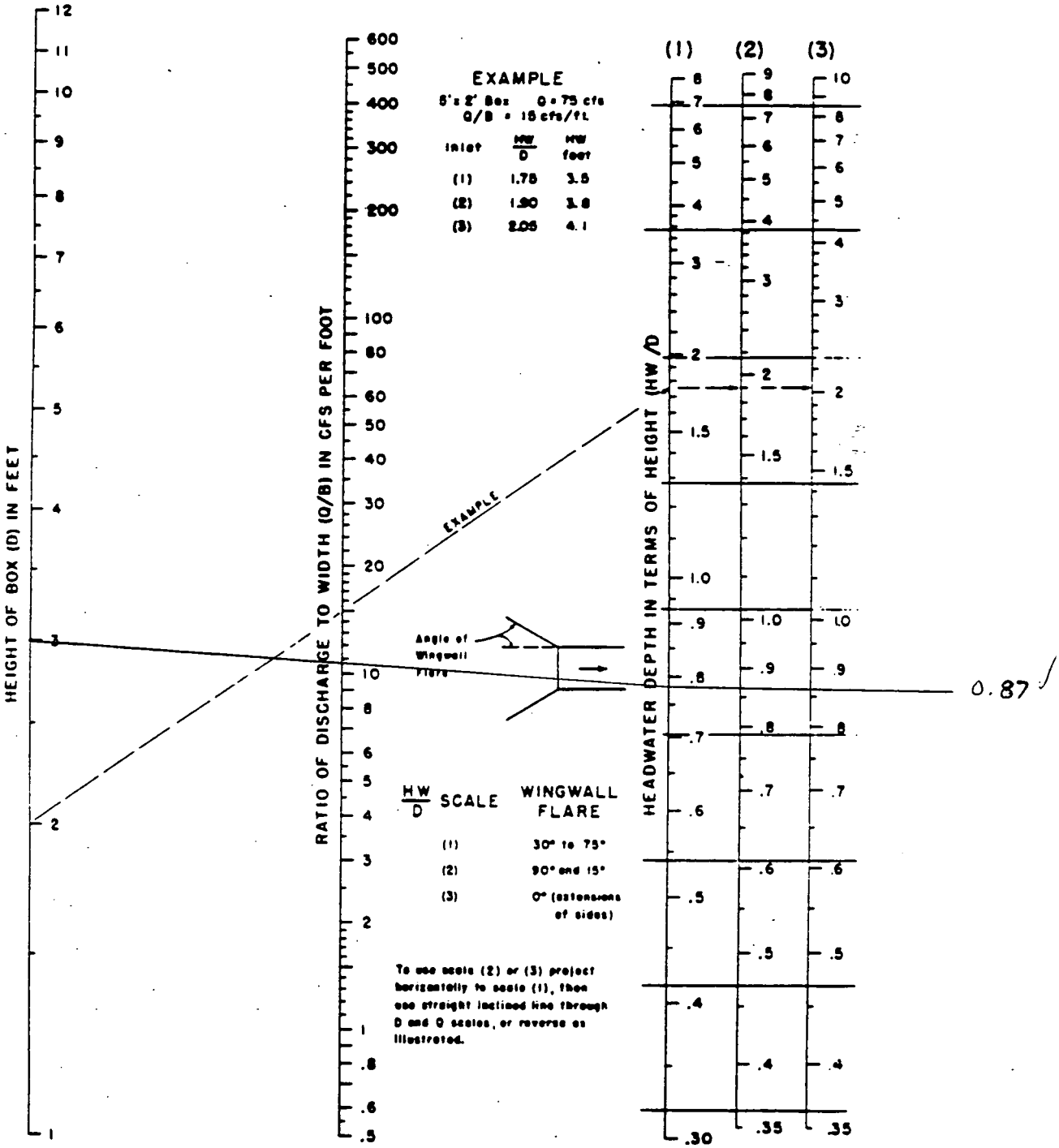
CHART 15



HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

AJ OF PUBLIC ROADS JAN. 1963

CHART 8



HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

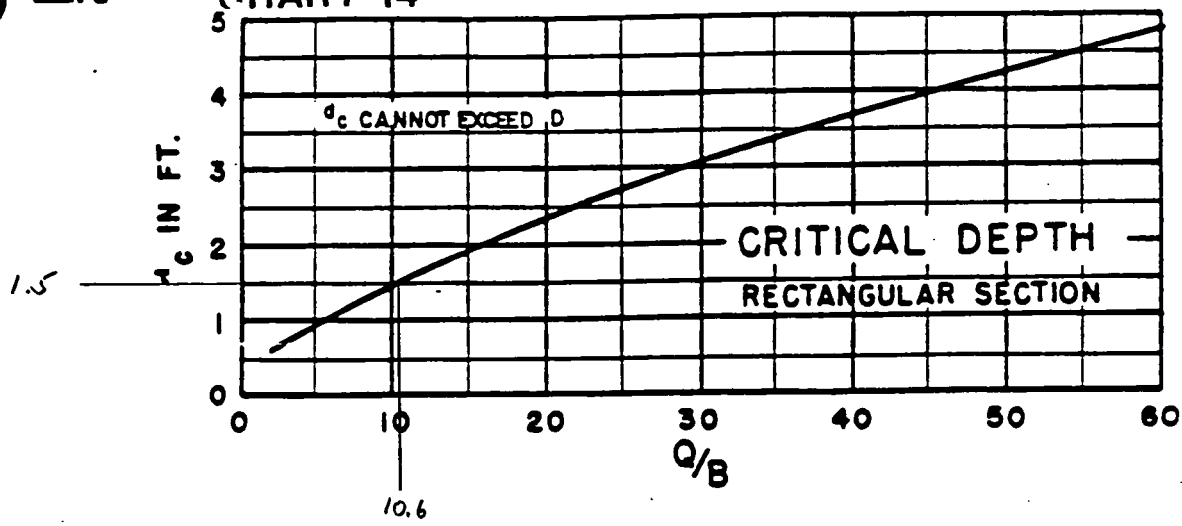
[redacted]
723

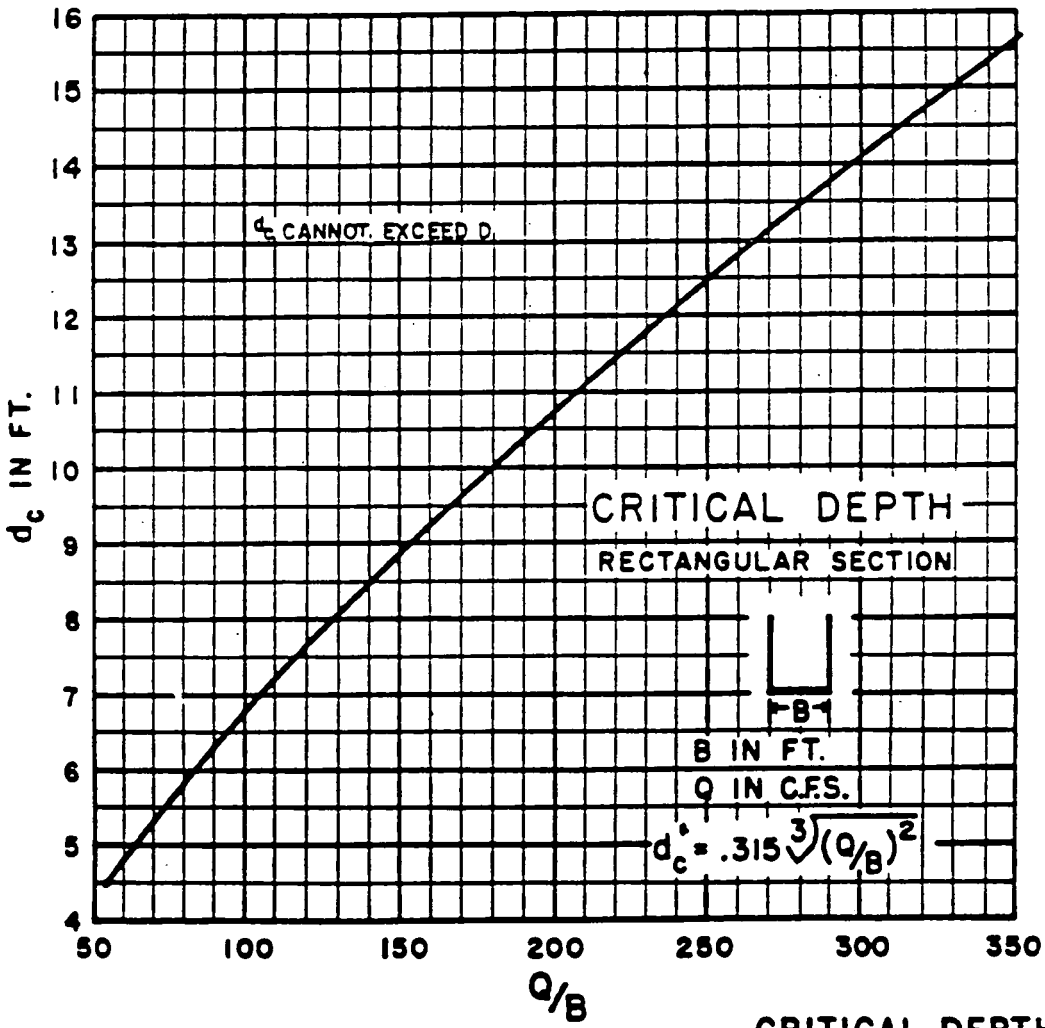
ASC 5/13/96

739

HSS 13 MAY 1996

CHART 14





BUREAU OF PUBLIC ROADS JAN. 1963

CRITICAL DEPTH
RECTANGULAR SECTION

[redacted]

774

APPENDIX A

COMPUTER SOFTWARE USED TO PREPARE CALCULATION PACKAGE HydroCAD™ STORMWATER MODELING SYSTEM

Applied Microcomputer Systems, *"HydroCAD™ Stormwater Modeling System"*, version 3.10, Chocorva, NH, 1993.

For documentation of computer programs see

1.2 Computer Program Validation