SCS ENGINEERS







Run-On and Run-Off Control Plan

Coal Combustion Residue Landfill
Lansing Generating Station
Lansing, Iowa

Prepared for:

Interstate Power and Light Company
Lansing Generating Station
2320 Power Plant Drive
Lansing, Iowa 52151-7539

Prepared by:

SCS ENGINEERS
2830 Dairy Drive
Madison, Wisconsin 53718-6751
(608) 224-2830

September 2016
File No. 25216109.00

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PE CERTIFICATION

LICENSED PROFESSIONAL ENGINEER
ERIC J. NELSON
23136
IOWA
9/21/16

I, Eric J. Nelson, hereby certify that this Run-On and Run-Off Control Plan meets the requirements of 40 CFR 257.81(c), was prepared by me or under my direct supervision, and that I am a duly licensed Professional Engineer under the laws of the State of Iowa.

[signature] 9/21/2016

(signature) (date)

ERIC J. NELSON

(printed or typed name)

License number 23136

My license renewal date is December 31, 2016.

Pages or sheets covered by this seal:

SEPTEMBER 2016 RUN-ON AND RUN-OFF CONTROL PLAN

IPL LANSING GENERATING STATION

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1.0 INTRODUCTION AND PROJECT SUMMARY

On behalf of Interstate Power and Light Company (IPL), SCS Engineers (SCS) has prepared this Run-on and Run-off Control Plan for the Lansing Generating Station (LAN) coal combustion residue (CCR) Landfill in accordance with 40 CFR 257.81(c) as follows.

40 CFR 257.81(c)(1). *"The owner or operator must prepare initial and periodic run-on and run-off control system plans for the CCR unit according to the timeframes specified in paragraphs (c)(3) and (4) of this section. These plans must document how the run-on and run-off control systems have been designed and constructed to meet the applicable requirement of this section. Each plan must be supported by appropriate engineering calculations. The owner or operator has completed the initial run-on and run-off control system plan when the plan has been placed in the facility's operating record as required by Section 257.105(g)(3)."*

The LAN Landfill includes an active CCR landfill, which currently consists of a single existing CCR landfill unit. The LAN Landfill has received CCR both before and after the effective date of the CCR Rule. The existing CCR Landfill is the subject of this Run-on and Run-off Control Plan.

Refer to **Figure 1** for site location. **Figure 2** shows the run-on and run-off drainage areas.

2.0 RUN-ON AND RUN-OFF CONTROL

40 CFR 257.81(a). *"The owner or operator of an existing or new CCR landfill or any lateral expansion of a CCR landfill must design, construct, operate, and maintain:*

(1) A run-on control system to prevent flow onto the active portion of the CCR unit during the peak discharge from a 24-hour, 25-year storm."

The entire site has run-on and run-off control in place, as approved by the Iowa Department of Natural Resources (IDNR). Run-on is controlled by berms and swales around the perimeter of the landfill that divert storm water away from the landfill to the Upper Ash Pond and the swale along the county highway.

(2) "A run-off control system from the active portion of the CCR unit to collect and control at least the water volume resulting from a 24-hour, 25-year storm."

Run-off from the active portions of the CCR unit is handled as contact water and flows to the Upper Ash Pond. Discharge from the Upper Ash Pond is regulated by a National Pollutant Discharge Elimination System (NPDES) permit. Per 257.81(b), this is consistent with the surface water requirements under 40 CFR 257.3-3.

Run-off from areas of the existing CCR unit where final cover is in place (which prevents contact with CCR) is diverted into the perimeter drainage swales, which drain to the Upper Ash Pond. Intermediate swales/berms and rock chutes on the final cover help minimize erosion of the final cover. These features divert water to the perimeter drainage system, and ultimately to the Upper Ash Pond. Per 257.81(b), this is consistent with the surface water requirements under 40 CFR 257.3-3.

2.1 DESIGN CRITERIA

The storm water features described above are designed to handle run-on and run-off from a 25-year, 24-hour storm event, as required by 40 CFR 257.81(a)(1) and (2). The run-on and run-off design calculations for the facility, except for the northern perimeter swale, were updated in 2015. The calculations were performed assuming a 25-year, 24-hour precipitation depth of 5.46 inches, based on NOAA Atlas 14 precipitation data published in April 2013. Design calculations for the northern perimeter swale were performed in 2001, and assumed a 25-year, 24-hour precipitation depth of 4.95 inches, based on Technical Paper-40 (TP-40) precipitation data published in May 1961.

The on-site Upper Ash Pond provides adequate sediment removal to meet the NPDES permit.

2.2 DESIGN WITH CALCULATIONS

Storm water management design calculations (as described above) from the IDNR approved 2001 Permit Application and the 2015 Phase 2 Final Cover Construction Documentation Report are contained in **Appendix A**. As described in Section 2.1, the calculations from the 2001 Permit Application describe the storm water management design and provide calculations showing that the run-on control system will prevent flow onto the active portion of the CCR unit during the peak discharge from a 25-year, 24-hour storm. The calculations from the 2015 Final Cover Construction Documentation Report describe the storm water management design and provide calculations showing that the run-off control system for the active portions of the CCR unit will collect and control the water volume resulting from a 25-year, 24-hour storm. The calculations were performed or overseen by professional engineers licensed in the State of Iowa.

2.3 CONSTRUCTION

Existing perimeter swales were constructed to site specifications with construction oversight directed by a professional engineer licensed in the State of Iowa. Construction documentation reports for the storm water management features were prepared, submitted to the IDNR, and approved by the IDNR.

3.0 CERTIFICATIONS

40 CFR 257.81(c)(5). *"The owner or operator must obtain a certification from a qualified professional engineer stating that the initial and periodic run-on and run-off control system plans meet the requirements of this section."*

Eric Nelson, PE, a licensed professional engineer in the State of Iowa, has overseen the preparation of this Run-on and Run-off Control Plan. A certification statement is provided on **page iii** of this plan.

4.0 RECORDKEEPING AND PERIODIC UPDATES

40 CFR 257.81(d). *"The owner or operator of the CCR unit must comply with the recordkeeping requirements specified in Section 257.105(g), the notification requirements specified in Section 257.106(g), and the internet requirements specified in Section 257.107(g)."*

This Run-On and Run-Off Control Plan, and all periodic plans, will be placed in facility's operating record and on Alliant Energy's CCR Rule Compliance Data and Information website, as will all amendments. Periodic plans will be completed every 5 years per 40 CFR 257.81(c)(4).

Notification will be provided when this Run-On and Run-Off Control Plan, and all periodic plans, are available in the facility's operating record and on the facility's website per 40 CFR 257.105(g), 257.106(g), and 2571.7(g).

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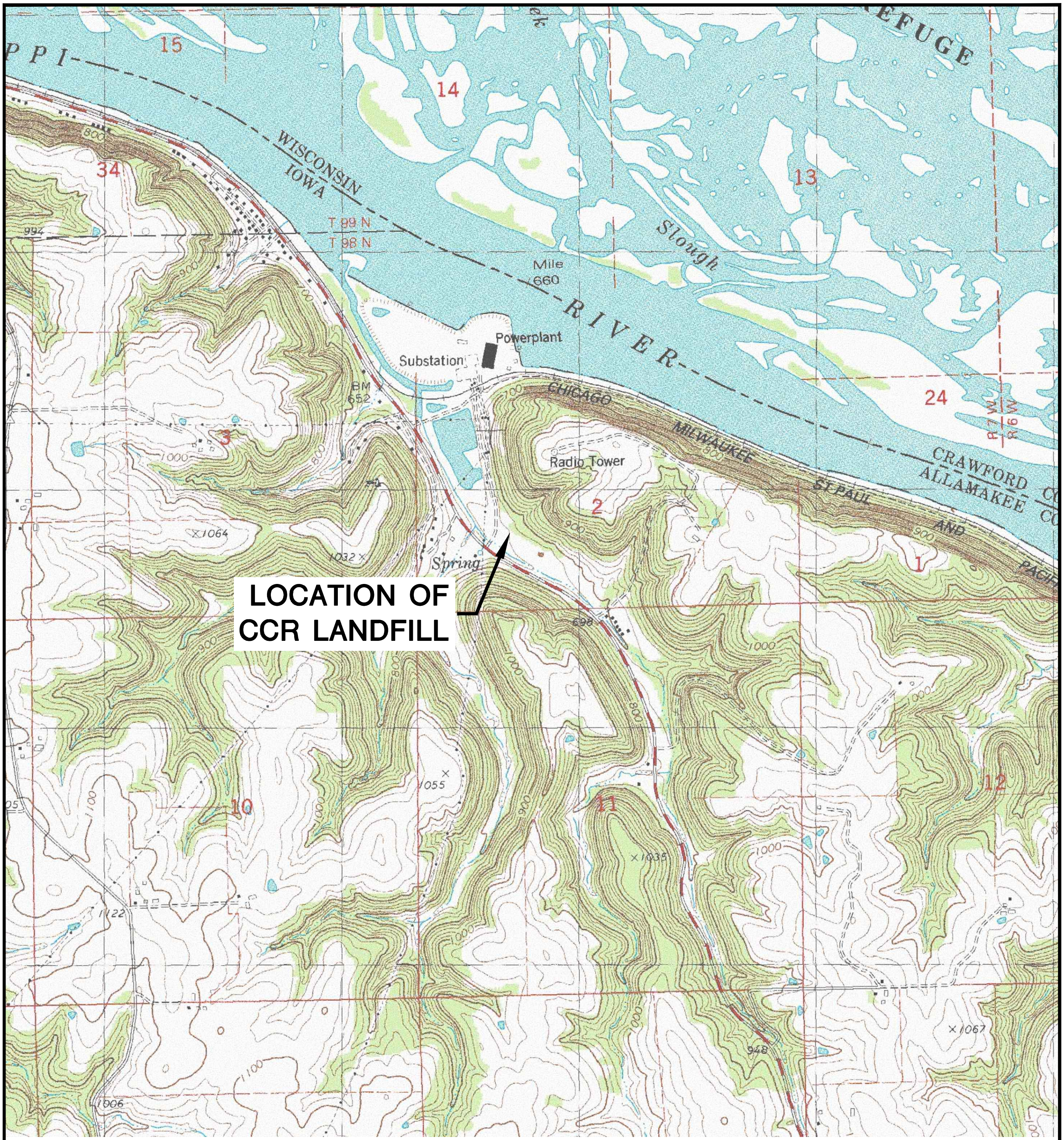
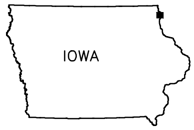
FIGURES

1 Site Location Map
2 Run-On/Run-Off Control Plan



N

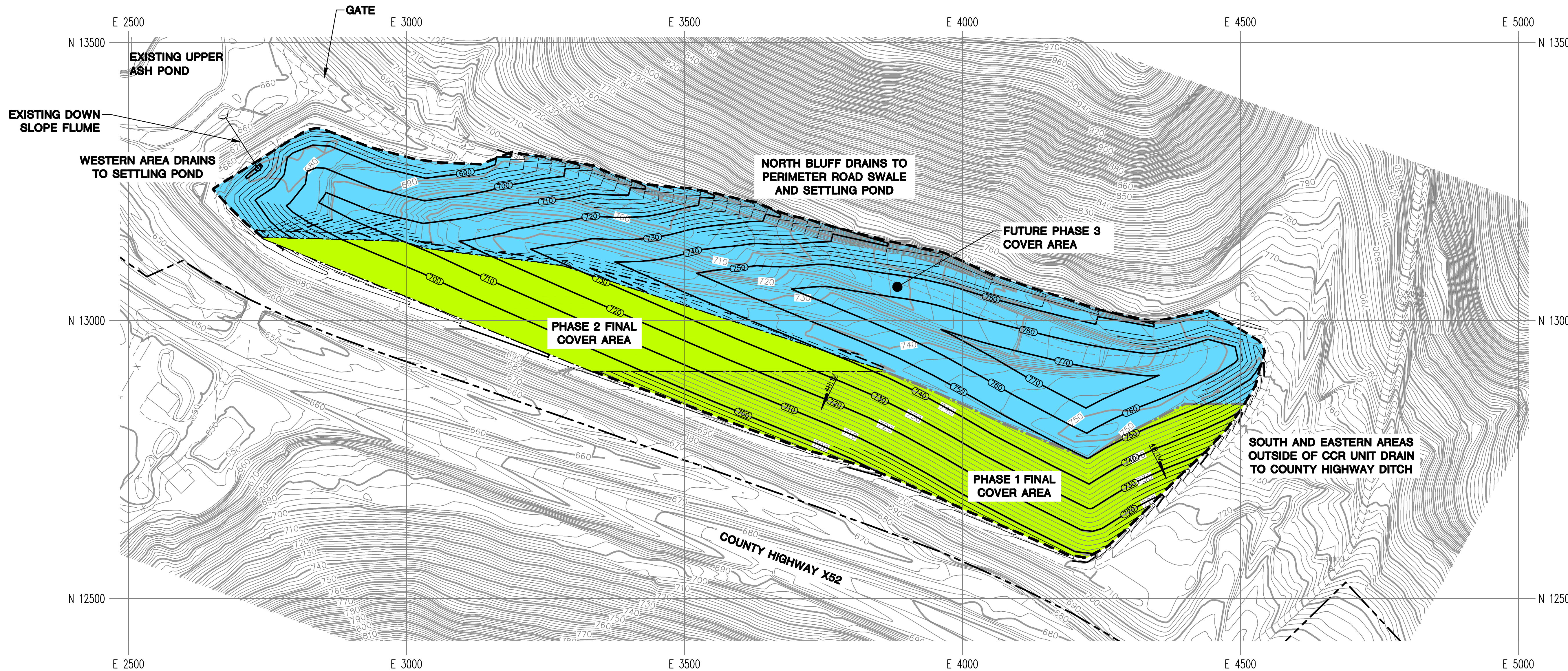
LANSING QUADRANGLE
IOWA–ALLAMAKEE CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
SW/4 FERRYVILLE 15' QUADRANGLE
1983
SCALE: 1" = 2,000'



CLIENT	SITE	
INTERSTATE POWER AND LIGHT CO. 2320 POWER PLANT DRIVE LANSING, IA 52151–9733	RUN–ON AND RUN–OFF CONTROL PLAN COAL COMBUSTION RESIDUE LANDFILL LANSING, IOWA	SITE LOCATION MAP

				ENGINEER	
PROJECT NO.	25216109.00	DRAWN BY:	AHB	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718–6751 PHONE: (608) 224–2830	FIGURE
DRAWN:	05/01/13	CHECKED BY:	LB		1
REVISED:	09/08/16	APPROVED BY:	EN 09/21/16		

I:\25216109.00\Drawings\Runon-Runoff\Figure1.dwg, 9/21/2016 10:28:11 AM



LEGEND

- APPROXIMATE PROPERTY LINE
- APPROVED LIMITS OF WASTE
- PROPOSED PHASE LIMIT
- LIMITS OF PHASE 1 FINAL COVER
- LIMITS OF PHASE 2 FINAL COVER
- 760 — EXISTING 10' CONTOUR
- EXISTING 2' CONTOUR
- EXISTING PERIMETER/UNPAVED ROAD
- EXISTING RIPRAP
- 700 — PERMITTED FINAL GRADE (10' CONTOUR)
- PERMITTED FINAL GRADE (2' CONTOUR)
- 4H:1V SLOPE AND DIRECTION
- EXISTING COVER AREA
- PROPOSED FUTURE COVER AREA

NOTES:

1. TOPOGRAPHIC SURVEY OF EXISTING LANDFILL GRADES AREA FOR THE PHASE 2 FINAL COVER WAS COMPLETED BY MOHN SURVEYING ON MARCH 12, 2015.
2. TOPOGRAPHIC SURVEY OF EXISTING LANDFILL GRADES WITHIN THE EXISTING FINAL COVER WAS COMPLETED BY MOHN SURVEYING IN APRIL 2015.
3. THE REMAINING TOPOGRAPHIC SURVEY OF EXISTING LANDFILL GRADES WITHIN LIMITS OF WASTE WAS COMPLETED BY SCS ENGINEERS ON JUNE 2–3, 2014.
4. EXISTING GRADES OUTSIDE THE 2014–2015 TOPOGRAPHIC SURVEY LIMITS ARE BASED ON KBM, INC.'S AERIAL SURVEY COMPLETED APRIL 18. 2001.
5. PERIMETER ROAD LOCATION BASED ON 2002 SURVEY AND UPDATED WITH AS–BUILT LOCATION AROUND LIMITS OF PHASE 1 FINAL COVER AREA.

GRID NORTH

N

200 0 200

SCALE: 1" = 200'

PROJECT NO.	25216109.00	DRAWN BY:	AHB
DRAWN:	08/22/16	CHECKED BY:	DN
REVISED:	08/22/16	APPROVED BY:	EN 09/21/16

ENGINEER: SCS ENGINEERS
2830 DAIRY DRIVE MADISON, WI 53718–6751
PHONE: (608) 224–2830

CLIENT: INTERSTATE POWER AND LIGHT CO.
2320 POWER PLANT DRIVE
LANSING, IA 52151–9733

SITE: RUN–ON AND RUN–OFF CONTROL PLAN
COAL COMBUSTION RESIDUE LANDFILL
LANSING POWER STATION
LANSING, IOWA

RUN–ON AND RUN–OFF CONTROL PLAN

FIGURE 2

I:\25216109.00\Drawings\Runon-Runoff\Phase 2 Waste Grades.dwg, 9/21/2016 10:36:38 AM

APPENDIX A

Drainage Design Calculations

A1 2001 Design
A2 Phase 1 Final Cover
A3 Phase 2 Final Cover

A1 2001 Design

BT² inc.

		Sheet No. 1 of 37	
		Calc. No. 1	
		Rev. No.	
Job No. 1792	Job ALLIANT - LANSING ASH FILL	By TR	Date 7/11/01
Client ALLIANT ENERGY	Subject SURFACE WATER DRAINAGE	Chk'd. MRH	Date 7-19-01

PURPOSE: TO DETERMINE THE SIZE OF ALL PERIMETER DITCHES, DIVERSION BERMS AND CULVERTS USED TO MANAGE STORM WATER AT THE PROPOSED SITE.

APPROACH: DETERMINE WATERSHED AREAS CONTRIBUTING TO EACH DITCH, DIVERSION BERM, OR CULVERT USING AUTOCAD AND PLANIMETER

USE PONDPACK SOFTWARE TO DETERMINE THE TIME OF CONCENTRATION FOR EACH WATERSHED AREA USING THE TR-55 METHOD.

USE PONDPACK SOFTWARE TO COMPUTE HYDROGRAPHS FOR EACH DITCH USING THE TR-55 TABULAR METHOD. OBTAIN MAXIMUM FLOWS FOR EACH DITCH, DIVERSION BERM, AND CULVERT USING THE COMPUTED HYDROGRAPHS.

USE FLOWMASTER VERSION 6.0 TO CALCULATE THE MAXIMUM DEPTH AND VELOCITY FOR MAXIMUM FLOWS FOR ALL DITCHES, DIVERSION BERMS AND CULVERTS

REFERENCES:

URBAN HYDROLOGY FOR SMALL WATERSHEDS, SOIL CONSERVATION SERVICES, WASHINGTON DC JUNE 1986

INTERSTATE POWER COMPANY COAL COMBUSTION RESIDUE FILL SITE - LANSING IOWA 1997 SHEET NO. 2 PREPARED BY HOWARD R GREEN COMPANY

ALLIANT ENERGY - LANSING COAL COMBUSTION RESIDUE FILL SITE FINAL GRADES DRAWING PREPARED BY BT², INC.

Calc. No. 1
Rev. No.
By TR Date 7/11/01
Chk'd. MRH Date 7-19-01

Job No. 1792 Job ALLIANT LANSING ASH FILL
Client ALLIANT ENERGY Subject SURFACE WATER DRAINAGE

ASSUMPTIONS: MANNINGS NO. FOR SHEET FLOW IS EQUAL TO 0.19 WHICH IS THE AVERAGE OF 0.15 FOR SHORT GRASS PRAIRIE AND 0.24 FOR DENSE GRASSES LISTED IN TABLE 3.1 OF URBAN HYDROLOGY FOR SMALL WATERSHEDS.

MANNINGS NO. FOR CHANNEL FLOW IS EQUAL TO 0.30 FOR ROUGH CHANNEL WITH GRASS AS LISTED AS AN OPTION IN FLOWMASTER VERSION 6.0

THE 2 YR 24 HR PRECIPITATION IS 2.95 inches AS SHOWN IN ATTACHED FIGURE 1

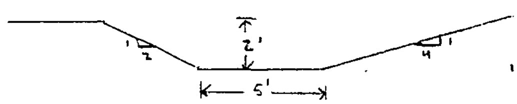
THE 25 YR 24 HR RAINFALL DEPTH IS 4.95 INCHES AS SHOWN ON FIGURE 2.

A CN NUMBER EQUAL TO 74 IS USED IN THE HYDROGRAPH COMPUTATION FOR LANDFILL AREAS AS AN AVERAGE BETWEEN C AND D SOIL GROUPS AND CONTINUOUS GRASS COVER.

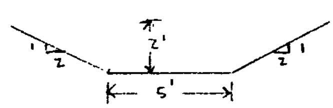
A CN NUMBER EQUAL TO 74 IS USED FOR THE NORTH WOODED AREA AS AN AVERAGE BETWEEN C AND D SOIL GROUPS FOR WOODS IN GOOD CONDITION

CROSS SECTIONS OF DIVERSION BERMS AND DITCHES ARE AS FOLLOWS

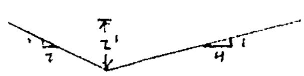
SOUTH PERIMETER DITCH:



NORTH PERIMETER DITCH:



DIVERSION BERM:



BT² inc.		Sheet No. 3 of 37
		Calc. No. 1
		Rev. No.
Job No. 1792	Job ALLIANT - LANSING ASH FILL	By TR Date 7/11/01
Client ALLIANT ENERGY	Subject SURFACE WATER	Chk'd. MRH Date 7-19-01

ASSUMPTIONS: SLOPE OF CULVERT UNDER ROAD = 2.5%

SLOPE OF CULVERTS TO DRAIN DIVERSION BERM + SOUTH PERIMETER DITCH = 25%

CALCULATIONS: SOUTH PERIMETER DITCH AREA = $\frac{1}{2}(17+5)\times 2 = 22$ FT²

SOUTH PERIMETER DITCH WETTED PERIMETER = $\sqrt{4^2+2^2} + \sqrt{8^2+2^2} + 5 = 17.71$ FT

NORTH PERIMETER DITCH AREA = $\frac{1}{2}(13+5)\times 2 = 18$ FT²

NORTH PERIMETER DITCH WETTED PERIMETER = $\sqrt{4^2+2^2} \times 2 + 5 = 13.94$ FT

DIVERSION BERM AREA = $\frac{1}{2} \times 12 \times 2 = 12$ FT²

DIVERSION BERM WETTED PERIMETER = $\sqrt{4^2+2^2} + \sqrt{8^2+2^2} = 12.71$ FT

OUTPUT SHEETS ARE ATTACHED

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	North Slope
Flow Element	Trapezoidal Channe
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.030	
Slope	0.080000	ft/ft
Left Side Slope	0.50	V : H
Right Side Slope	0.50	V : H
Bottom Width	5.00	ft
Discharge	95.00	cfs

Results		
Depth	1.10	ft
Flow Area	7.9	ft²
Wetted Perimeter	9.91	ft
Top Width	9.39	ft
Critical Depth	1.76	ft
Critical Slope	0.013322	ft/ft
Velocity	12.04	ft/s
Velocity Head	2.25	ft
Specific Energy	3.35	ft
Froude Number	2.31	
Flow Type	Supercritical	

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	North Slope
Flow Element	Trapezoidal Channe
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.030	
Slope	0.020000	ft/ft
Left Side Slope	0.50	V : H
Right Side Slope	0.50	V : H
Bottom Width	5.00	ft
Discharge	95.00	cfs

Results		
Depth	1.59	ft
Flow Area	13.0	ft^2
Wetted Perimeter	12.09	ft
Top Width	11.34	ft
Critical Depth	1.76	ft
Critical Slope	0.013322	ft/ft
Velocity	7.33	ft/s
Velocity Head	0.84	ft
Specific Energy	2.42	ft
Froude Number	1.21	
Flow Type	Supercritical	

Type.... TR-55 Tabular Hyd.Peaks
Name.... NORTH SLOPE Tag: 25

File.... I:\1792\CALCS\PONDPACK\N_SLOPE.PPK
HYG Dir = I:\1792\CALCS\PONDPACK\
HYG file = NONE STORED NORTH SLOPE 25

TR-55 TABULAR HYDROGRAPH METHOD
TYPE II Distribution
25yr, 24hr Rainfall Depth = 4.95 in

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
North Woods	36	12.3
Ravine	59	12.2
Composite Watershed	95	12.3

S/N: H0M0L0139361 BT 2, Inc
Pond Pack Ver: 5-05-97 :050 Compute Time: 16:04:58 Date: 07-19-2001

Type.... TR-55 Tabular Hyd.Input Data
Name.... NORTH SLOPE Tag: 25

File.... I:\1792\CALCS\PONDPACK\N_SLOPE.PPK
HYG Dir = I:\1792\CALCS\PONDPACK\
HYG file = NONE STORED NORTH SLOPE 25

TR-55 TABULAR HYDROGRAPH METHOD
TYPE II Distribution
25yr, 24hr Rainfall Depth = 4.95 in

Total Area = 40.000 acres or .062500 sq.mi.
Peak Discharge = 95 cfs

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input	Ia/p used
North Woods	15.000	74.0	.3000	.0000	4.95	2.32	I.14	.14
Ravine	25.000	74.0	.3000	.0000	4.95	2.32	I.14	.14

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hrs)	Input Values * Tt (hrs)	Rounded Values Tc (hrs)	Rounded Values * Tt (hrs)	Ia/p Interpolated (Yes/No)	Ia/p Messages
North Woods	.3294	.0000	.30	.00	Yes	--
Ravine	.2647	.0000	.30	.00	Yes	--

* Travel time from subarea outfall to composite watershed outfall point.

S/N: H0M0L0139361 BT 2, Inc
Pond Pack Ver: 5-05-97 :050 Compute Time: 16:04:58 Date: 07-19-2001

```
Type.... TcCalcs                                        Page 1.01
Name.... NORTH WOODS

File.... I:\1792\CALCS\PONDPACK\N_SLOPE.PPK

    :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
    TIME OF CONCENTRATION CALCULATOR
    :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::


    -----------------------------------------------------------------------


    Segment #1:  Tc: TR-55 Sheet
    Description: North Woods Sheet Flow

    Mannings n              .1900
    Hydraulic Length      300.00 ft
    2yr, 24hr P           2.9500 in
    Slope                .100000 ft/ft

    Avg.Velocity             .32 ft/sec

                                         Segment #1 Time:      .2599 hrs
    -----------------------------------------------------------------------

    Segment #2:  Tc: TR-55 Shallow
    Description: North Woods Shallow Conc. 1

    Hydraulic Length      100.00 ft
    Slope                .100000 ft/ft
    Unpaved

    Avg.Velocity            5.10 ft/sec

                                         Segment #2 Time:      .0054 hrs
    -----------------------------------------------------------------------

    Segment #3:  Tc: TR-55 Shallow
    Description: North Woods Shallow Conc. 2

    Hydraulic Length      700.00 ft
    Slope                .370000 ft/ft
    Unpaved

    Avg.Velocity            9.81 ft/sec

                                         Segment #3 Time:      .0198 hrs
    -----------------------------------------------------------------------
```

File.... I:\1792\CALCS\PONDPACK\N_SLOPE.PPK

Segment #4: Tc: TR-55 Channel
Description: North Woods Channel 1

Flow Area	18.0000	sq.ft
Wetted Perimeter	13.94	ft
Hydraulic Radius	1.29	ft
Slope	.020000	ft/ft
Mannings n	.0300	
Hydraulic Length	700.00	ft
Avg.Velocity	8.33	ft/sec

Segment #4 Time: .0233 hrs

Segment #5: Tc: TR-55 Channel
Description: North Woods Channel 2

Flow Area	18.0000	sq.ft
Wetted Perimeter	13.94	ft
Hydraulic Radius	1.29	ft
Slope	.080000	ft/ft
Mannings n	.0300	
Hydraulic Length	1250.00	ft
Avg.Velocity	16.66	ft/sec

Segment #5 Time: .0208 hrs

Total Tc: .3294 hrs

File.... I:\1792\CALCS\PONDPACK\N_SLOPE.PPK

```
----------------------------------------------------------------------
Tc Equations used...
----------------------------------------------------------------------


==== SCS TR-55 Sheet Flow ============================================

     Tc = (.007 * ((n * Lf)**0.8)) / ((P**.5) * (Sf**.4))

     Where:  Tc = Time of concentration, hrs
             n  = Mannings n
             Lf = Flow length, ft
             P  = 2yr, 24hr Rain depth, inches
             Sf = Slope, ft/ft


==== SCS TR-55 Shallow Concentrated Flow =============================

     Unpaved surface:
     V  = 16.1345 * (Sf**0.5)

     Paved surface:
     V  = 20.3282 * (Sf**0.5)

     Tc = (Lf / V) / (3600sec/hr)

     Where:  V  = Velocity, ft/sec
             Sf = Slope, ft/ft
             Tc = Time of concentration, hrs
             Lf = Flow length, ft
```

File.... I:\1792\CALCS\PONDPACK\N_SLOPE.PPK

==== SCS Channel Flow ==

```
R  = Aq / Wp
V  = (1.49 * (R**(2/3)) * (Sf**-0.5)) / n

Tc = (Lf / V) / (3600sec/hr)

Where:  R  = Hydraulic radius
        Aq = Flow area, sq.ft.
        Wp = Wetted perimeter, ft
        V  = Velocity, ft/sec
        Sf = Slope, ft/ft
        n  = Mannings n
        Tc = Time of concentration, hrs
        Lf = Flow length, ft
```

Type.... TcCalcs
Name.... RAVINE

File.... I:\1792\CALCS\PONDPACK\N_SLOPE.PPK
Title... Ravine

::
TIME OF CONCENTRATION CALCULATOR
::

Ravine

Segment #1: Tc: TR-55 Sheet
Description: Ravine Sheet Flow

Mannings n	.1900
Hydraulic Length	300.00 ft
2yr, 24hr P	2.9500 in
Slope	.180000 ft/ft

Avg.Velocity .41 ft/sec

Segment #1 Time: .2055 hrs

Segment #2: Tc: TR-55 Shallow
Description: Ravine Shallow Conc. 1

Hydraulic Length	200.00 ft
Slope	.180000 ft/ft
Unpaved	

Avg.Velocity 6.85 ft/sec

Segment #2 Time: .0081 hrs

Segment #3: Tc: TR-55 Shallow
Description: Ravine Shallow Conc. 2

Hydraulic Length	400.00 ft
Slope	.150000 ft/ft
Unpaved	

Avg.Velocity 6.25 ft/sec

Segment #3 Time: .0178 hrs

File.... I:\1792\CALCS\PONDPACK\N_SLOPE.PPK
Title... Ravine

Segment #4: Tc: TR-55 Shallow
Description: Ravine Shallow Conc. 3

Hydraulic Length	900.00	ft
Slope	.280000	ft/ft
Unpaved		
Avg.Velocity	8.54	ft/sec

Segment #4 Time: .0293 hrs

Segment #5: Tc: TR-55 Channel
Description: Ravine Channel 1

Flow Area	18.0000	sq.ft
Wetted Perimeter	13.94	ft
Hydraulic Radius	1.29	ft
Slope	.280000	ft/ft
Mannings n	.0300	
Hydraulic Length	450.00	ft
Avg.Velocity	31.16	ft/sec

Segment #5 Time: .0040 hrs

========================
Total Tc: .2647 hrs
========================

```
-----------------------------------------------------------------------
Tc Equations used...
-----------------------------------------------------------------------


==== SCS TR-55 Sheet Flow =============================================

     Tc = (.007 * ((n * Lf)**0.8)) / ((P**.5) * (Sf**.4))

     Where:  Tc = Time of concentration, hrs
             n  = Mannings n
             Lf = Flow length, ft
             P  = 2yr, 24hr Rain depth, inches
             Sf = Slope, ft/ft


==== SCS TR-55 Shallow Concentrated Flow ==============================

     Unpaved surface:
     V  = 16.1345 * (Sf**0.5)

     Paved surface:
     V  = 20.3282 * (Sf**0.5)

     Tc = (Lf / V) / (3600sec/hr)

     Where:  V  = Velocity, ft/sec
             Sf = Slope, ft/ft
             Tc = Time of concentration, hrs
             Lf = Flow length, ft
```

```
==== SCS Channel Flow =============================================

        R  = Aq / Wp
        V  = (1.49 * (R**(2/3)) * (Sf**-0.5)) / n

        Tc = (Lf / V) / (3600sec/hr)

        Where:  R  = Hydraulic radius
                Aq = Flow area, sq.ft.
                Wp = Wetted perimeter, ft
                V  = Velocity, ft/sec
                Sf = Slope, ft/ft
                n  = Mannings n
                Tc = Time of concentration, hrs
                Lf = Flow length, ft
```

Worksheet
Worksheet for Triangular Channel

Project Description	
Worksheet	North Landfill Slope
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.030	
Slope	0.014000	ft/ft
Left Side Slope	0.25	V : H
Right Side Slope	0.50	V : H
Discharge	16.00	cfs

Results			
Depth	1.16	ft	< 2ft ok
Flow Area	4.1	ft²	
Wetted Perimeter	7.41	ft	
Top Width	6.99	ft	
Critical Depth	1.12	ft	
Critical Slope	0.017190	ft/ft	
Velocity	3.93	ft/s	ok
Velocity Head	0.24	ft	
Specific Energy	1.40	ft	
Froude Number	0.91		
Flow Type	Subcritical		

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Worksheet
Worksheet for Triangular Channel

Project Description	
Worksheet	North Landfill Slope
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.030	
Slope	0.080000	ft/ft
Left Side Slope	0.25	V : H
Right Side Slope	0.50	V : H
Discharge	16.00	cfs

Results		
Depth	0.84	ft < 2' ok
Flow Area	2.1	ft²
Wetted Perimeter	5.34	ft
Top Width	5.04	ft
Critical Depth	1.12	ft
Critical Slope	0.017190	ft/ft
Velocity	7.56	ft/s —
Velocity Head	0.89	ft
Specific Energy	1.73	ft
Froude Number	2.06	
Flow Type	Supercritical	

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Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	South Ditch
Flow Element	Trapezoidal Channe
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.030	
Slope	0.078000	ft/ft
Left Side Slope	0.50	V : H
Right Side Slope	0.25	V : H
Bottom Width	5.00	ft
Discharge	17.00	cfs

Results		
Depth	0.41	ft <2ft ok
Flow Area	2.5	ft²
Wetted Perimeter	7.60	ft
Top Width	7.45	ft
Critical Depth	0.62	ft
Critical Slope	0.017206	ft/ft
Velocity	6.67	ft/s
Velocity Head	0.69	ft
Specific Energy	1.10	ft
Froude Number	2.01	
Flow Type	Supercritical	

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Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	South Ditch
Flow Element	Trapezoidal Channe
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.030	
Slope	0.012000	ft/ft
Left Side Slope	0.50	V : H
Right Side Slope	0.25	V : H
Bottom Width	5.00	ft
Discharge	17.00	cfs

Results		
Depth	0.69	ft < 2' ok
Flow Area	4.9	ft²
Wetted Perimeter	9.37	ft
Top Width	9.13	ft
Critical Depth	0.62	ft
Critical Slope	0.017206	ft/ft
Velocity	3.50	ft/s
Velocity Head	0.19	ft
Specific Energy	0.88	ft
Froude Number	0.85	
Flow Type	Subcritical	

Worksheet
Worksheet for Triangular Channel

Project Description	
Worksheet	South Berm
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.030	
Slope	0.020000	ft/ft
Left Side Slope	0.50	V : H
Right Side Slope	0.25	V : H
Discharge	9.00	cfs

Results		
Depth	0.88	ft < 2' ok
Flow Area	2.3	ft²
Wetted Perimeter	5.58	ft
Top Width	5.27	ft
Critical Depth	0.89	ft
Critical Slope	0.018560	ft/ft
Velocity	3.89	ft/s
Velocity Head	0.24	ft
Specific Energy	1.11	ft
Froude Number	1.04	
Flow Type	Supercritical	

Type.... TR-55 Tabular Hyd.Input Data
Name.... LANDFILL Tag: 25

File.... I:\1792\CALCS\PONDPACK\Final_LF.ppk
HYG Dir = I:\1792\CALCS\PONDPACK\
HYG file = NONE STORED LANDFILL 25

TR-55 TABULAR HYDROGRAPH METHOD
TYPE II Distribution
25yr, 24hr Rainfall Depth = 4.95 in

Total Area = 13.500 acres or .021094 sq.mi.
Peak Discharge = 39 cfs

>>>> Input Parameters Used to Compute Hydrograph <<<<

Subarea Description	AREA (acres)	CN	Tc (hrs)	* Tt (hrs)	Precip. (in)	Runoff (in)	Ia/p input	Ia/p used
North Landfill	4.300	74.0	.1000	.0000	4.95	2.32	I.14	.14
South Berm	3.300	74.0	.2000	.0000	4.95	2.32	I.14	.14
South Ditch	5.900	74.0	.2000	.0000	4.95	2.32	I.14	.14

* Travel time from subarea outfall to composite watershed outfall point.
I -- Subarea where user specified interpolation between Ia/p tables.

>>>> Computer Modifications of Input Parameters <<<<<

Subarea Description	Input Values Tc (hrs)	Input Values * Tt (hrs)	Rounded Values Tc (hrs)	Rounded Values * Tt (hrs)	Ia/p Interpolated (Yes/No)	Ia/p Messages
North Landfill	.1338	.0000	.10	.00	Yes	--
South Berm	.1612	.0000	.20	.00	Yes	--
South Ditch	.1797	.0000	.20	.00	Yes	--

* Travel time from subarea outfall to composite watershed outfall point.

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Type.... TR-55 Tabular Hyd.Peaks
Name.... LANDFILL Tag: 25

File.... I:\1792\CALCS\PONDPACK\Final_LF.ppk
HYG Dir = I:\1792\CALCS\PONDPACK\
HYG file = NONE STORED LANDFILL 25

TR-55 TABULAR HYDROGRAPH METHOD
TYPE II Distribution
25yr, 24hr Rainfall Depth = 4.95 in

>>>> Summary of Subarea Times to Peak <<<<

Subarea	Peak Discharge at Composite Outfall (cfs)	Time to Peak at Composite Outfall (hrs)
North Landfill	16	12.1
South Berm	9	12.2
South Ditch	17	12.2
Composite Watershed	39	12.1

File.... I:\1792\CALCS\PONDPACK\Final_LF.ppk
Title... North Landfill

::
TIME OF CONCENTRATION CALCULATOR
::

North Landfill

Segment #1: Tc: TR-55 Sheet
Description: North Slope Sheet Flow

Mannings n	.1900	
Hydraulic Length	107.00	ft
2yr, 24hr P	2.9500	in
Slope	.250000	ft/ft
Avg.Velocity	.38	ft/sec

Segment #1 Time: .0790 hrs

Segment #2: Tc: TR-55 Channel
Description: North Side Channel 1

Flow Area	12.0000	sq.ft
Wetted Perimeter	12.70	ft
Hydraulic Radius	.94	ft
Slope	.020000	ft/ft
Mannings n	.0300	
Hydraulic Length	498.00	ft
Avg.Velocity	6.76	ft/sec

Segment #2 Time: .0205 hrs

Segment #3: Tc: TR-55 Channel
Description: North Side Channel 2

Flow Area	12.0000	sq.ft
Wetted Perimeter	12.70	ft
Hydraulic Radius	.94	ft
Slope	.080000	ft/ft
Mannings n	.0300	
Hydraulic Length	622.00	ft
Avg.Velocity	13.53	ft/sec

Segment #3 Time: .0128 hrs

Segment #4: Tc: TR-55 Channel
Description: North Side Channel 3

Flow Area	12.0000	sq.ft
Wetted Perimeter	12.70	ft
Hydraulic Radius	.94	ft
Slope	.014000	ft/ft
Mannings n	.0300	
Hydraulic Length	439.00	ft

Avg.Velocity 5.66 ft/sec

Segment #4 Time: .0216 hrs

Total Tc: .1338 hrs

Tc Equations used...

==== SCS TR-55 Sheet Flow ====

```
Tc = (.007 * ((n * Lf)**0.8)) / ((P**.5) * (Sf**.4))

Where:  Tc = Time of concentration, hrs
        n  = Mannings n
        Lf = Flow length, ft
        P  = 2yr, 24hr Rain depth, inches
        Sf = Slope, ft/ft
```

==== SCS Channel Flow ====

```
R  = Aq / Wp
V  = (1.49 * (R**(2/3)) * (Sf**-0.5)) / n

Tc = (Lf / V) / (3600sec/hr)

Where:  R  = Hydraulic radius
        Aq = Flow area, sq.ft.
        Wp = Wetted perimeter, ft
        V  = Velocity, ft/sec
        Sf = Slope, ft/ft
        n  = Mannings n
        Tc = Time of concentration, hrs
        Lf = Flow length, ft
```

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Type.... Tc Calcs
Name.... SOUTH BERM

File.... I:\1792\CALCS\PONDPACK\Final_LF.ppk
Title... South Berm

:::

TIME OF CONCENTRATION CALCULATOR

:::

South Berm

Segment #1: Tc: TR-55 Sheet
Description: South Berm Sheet

Mannings n	.1900	
Hydraulic Length	140.00	ft
2yr, 24hr P	2.9500	in
Slope	.250000	ft/ft
Avg.Velocity	.40	ft/sec

Segment #1 Time: .0979 hrs

Segment #2: Tc: TR-55 Channel
Description: South Berm Channel 1

Flow Area	12.0000	sq.ft
Wetted Perimeter	12.70	ft
Hydraulic Radius	.94	ft
Slope	.020000	ft/ft
Mannings n	.0300	
Hydraulic Length	1540.00	ft
Avg.Velocity	6.76	ft/sec

Segment #2 Time: .0632 hrs

=========================
Total Tc: .1612 hrs
=========================

File.... I:\1792\CALCS\PONDPACK\Final_LF.ppk
Title... South Berm

Tc Equations used...

==== SCS TR-55 Sheet Flow ====

```
Tc = (.007 * ((n * Lf)**0.8)) / ((P**.5) * (Sf**.4))

Where:  Tc = Time of concentration, hrs
        n  = Mannings n
        Lf = Flow length, ft
        P  = 2yr, 24hr Rain depth, inches
        Sf = Slope, ft/ft
```

==== SCS Channel Flow ====

```
R  = Aq / Wp
V  = (1.49 * (R**(2/3)) * (Sf**-0.5)) / n

Tc = (Lf / V) / (3600sec/hr)

Where:  R  = Hydraulic radius
        Aq = Flow area, sq.ft.
        Wp = Wetted perimeter, ft
        V  = Velocity, ft/sec
        Sf = Slope, ft/ft
        n  = Mannings n
        Tc = Time of concentration, hrs
        Lf = Flow length, ft
```

:::

TIME OF CONCENTRATION CALCULATOR

:::

South Landfill

Segment #1: Tc: TR-55 Sheet
Description: South Ditch Sheet

Mannings n	.1900	
Hydraulic Length	148.00	ft
2yr, 24hr P	2.9500	in
Slope	.250000	ft/ft
Avg.Velocity	.40	ft/sec

Segment #1 Time: .1024 hrs

Segment #2: Tc: TR-55 Channel
Description: South Ditch Channel 1

Flow Area	22.0000	sq.ft
Wetted Perimeter	17.71	ft
Hydraulic Radius	1.24	ft
Slope	.078000	ft/ft
Mannings n	.0300	
Hydraulic Length	332.00	ft
Avg.Velocity	16.03	ft/sec

Segment #2 Time: .0058 hrs

Segment #3: Tc: TR-55 Channel
Description: South Ditch Channel 2

Flow Area	22.0000	sq.ft
Wetted Perimeter	17.71	ft
Hydraulic Radius	1.24	ft
Slope	.030000	ft/ft
Mannings n	.0300	
Hydraulic Length	464.00	ft
Avg.Velocity	9.94	ft/sec

Segment #3 Time: .0130 hrs

File.... I:\1792\CALCS\PONDPACK\Final_LF.ppk
Title... South Landfill

Segment #4: Tc: TR-55 Channel
Description: South Ditch Channel 3

Flow Area	22.0000	sq.ft
Wetted Perimeter	17.71	ft
Hydraulic Radius	1.24	ft
Slope	.012000	ft/ft
Mannings n	.0300	
Hydraulic Length	1326.00	ft
Avg.Velocity	6.29	ft/sec

Segment #4 Time: .0586 hrs

Total Tc: .1797 hrs

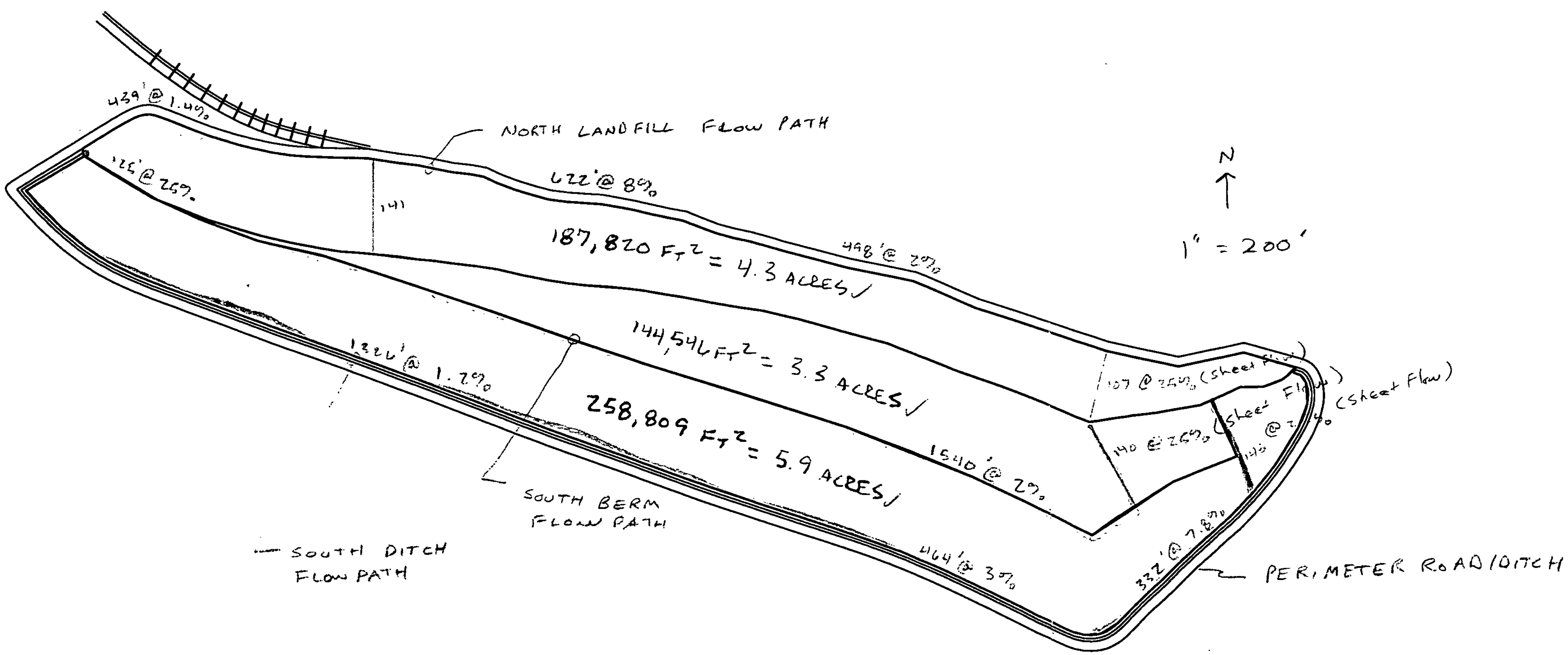
Tc Equations used...

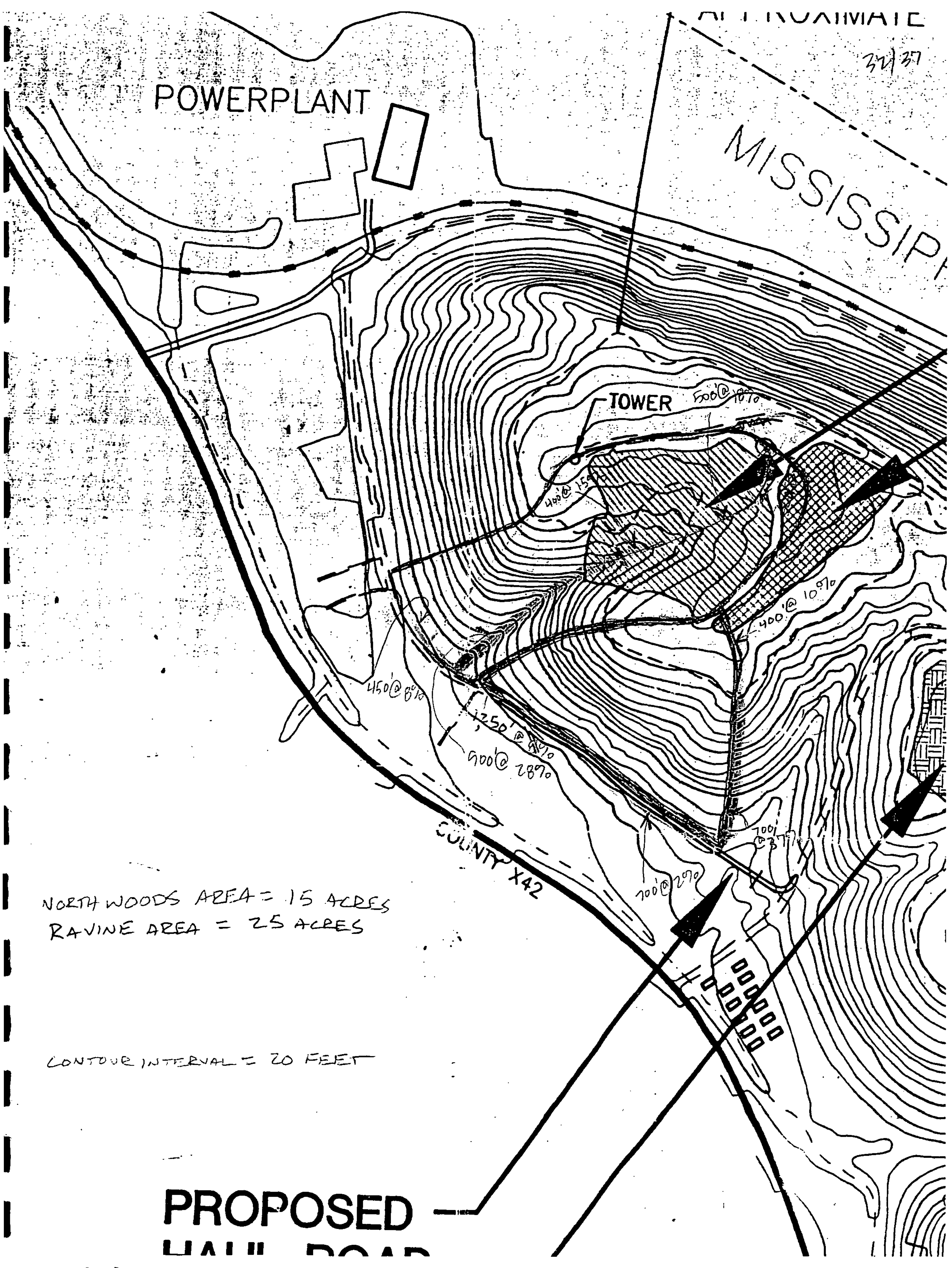
==== SCS TR-55 Sheet Flow ====

```
Tc = (.007 * ((n * Lf)**0.8)) / ((P**.5) * (Sf**.4))

Where:  Tc = Time of concentration, hrs
        n  = Mannings n
        Lf = Flow length, ft
        P  = 2yr, 24hr Rain depth, inches
        Sf = Slope, ft/ft
```

==== SCS Channel Flow ====

```
R  = Aq / Wp
V  = (1.49 * (R**(2/3)) * (Sf**-0.5)) / n

Tc = (Lf / V) / (3600sec/hr)

Where:  R  = Hydraulic radius
        Aq = Flow area, sq.ft.
        Wp = Wetted perimeter, ft
        V  = Velocity, ft/sec
        Sf = Slope, ft/ft
        n  = Mannings n
        Tc = Time of concentration, hrs
        Lf = Flow length, ft
```


NORTH LANDFILL FLOW PATH
439' @ 1.4%
125' @ 25%
141
622' @ 8%
187,820 FT² = 4.3 ACRES
498' @ 2%
144,546 FT² = 3.3 ACRES
1326' @ 1.7%
258,809 FT² = 5.9 ACRES
1540' @ 2%
107 @ 25% (Sheet Flow)
140 @ 26% (Sheet Flow)
(Sheet Flow)
464' @ 3%
332' @ 7.8%
N
1" = 200'
SOUTH BERM FLOW PATH
SOUTH DITCH FLOW PATH
PERIMETER ROAD/DITCH


POWERPLANT
TOWER
500'@10%
400'@15%
400'@10%
450'@8%
900'@28%
700'@37%
700'@27%
COUNTY X42
NORTH WOODS AREA = 15 ACRES
RAVINE AREA = 25 ACRES
CONTOUR INTERVAL = 20 FEET
PROPOSED

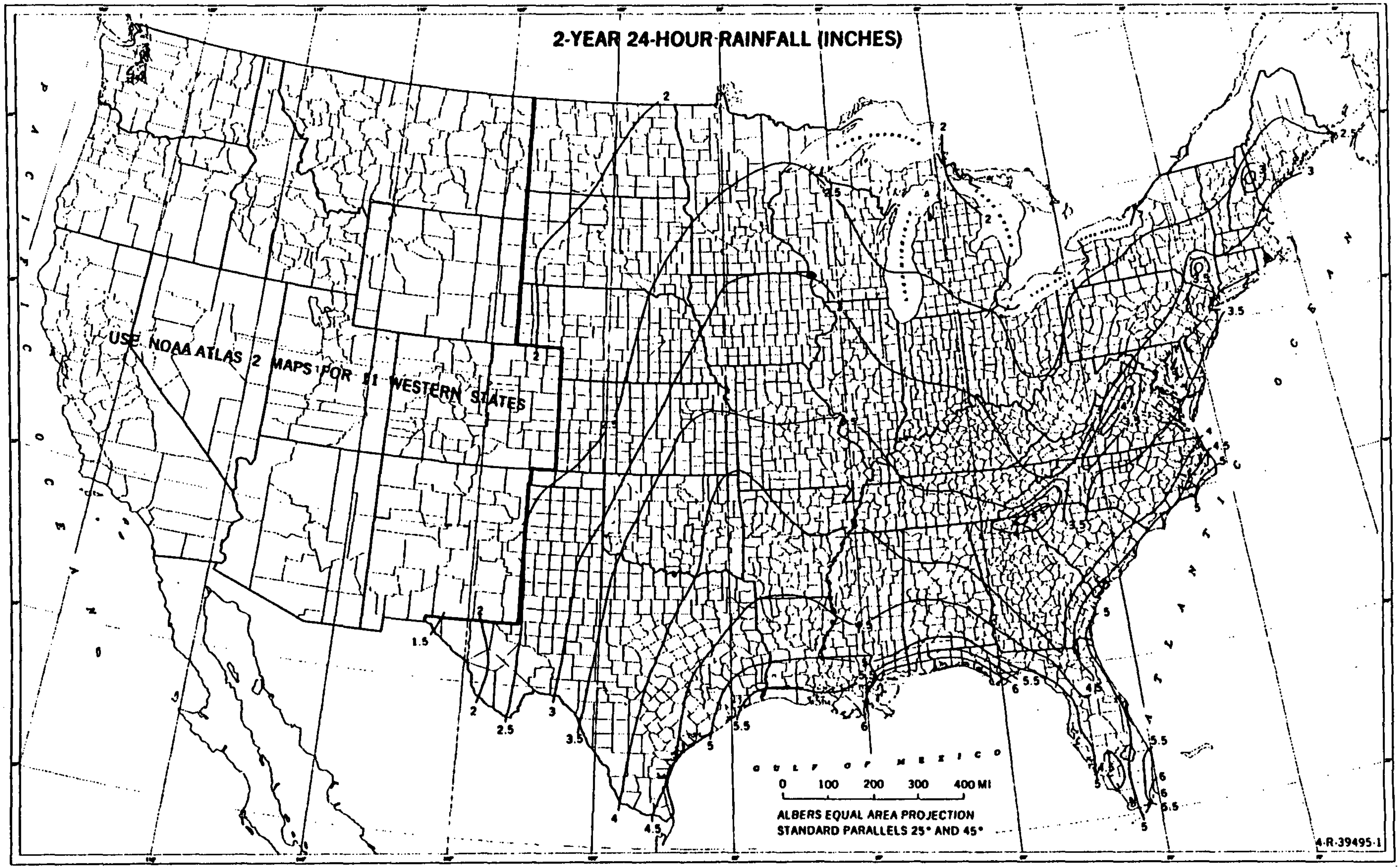


Figure B-3.--Two-year, 24-hour rainfall.

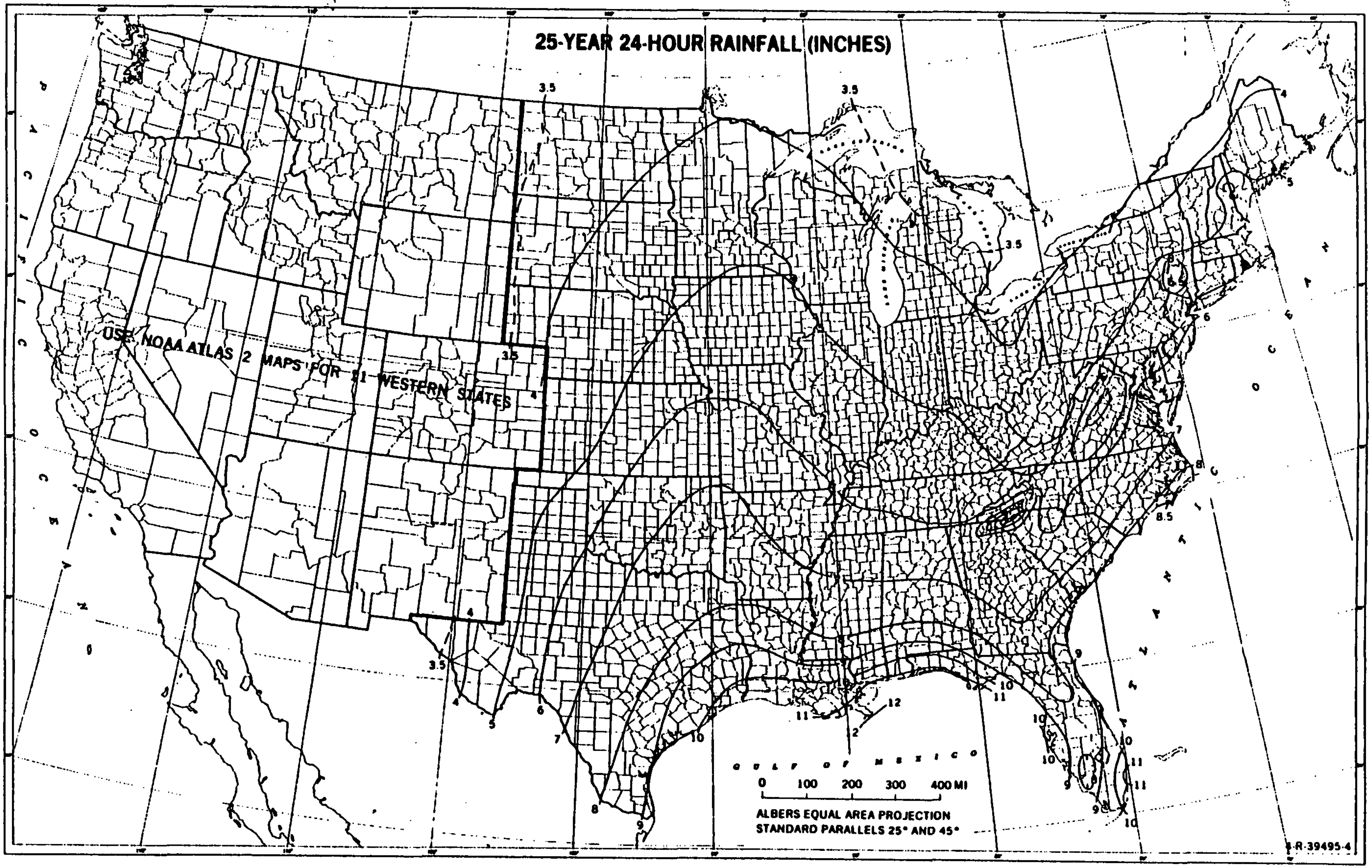


Figure B-6.—Twenty-five-year, 24-hour rainfall.

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Worksheet
Worksheet for Circular Channel

Project Description	
Worksheet	Circular Channel - 1
Flow Element	Circular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.024	
Slope	0.025000	ft/ft
Diameter	48	in
Discharge	90.00	cfs

Results		
Depth	2.54	ft
Flow Area	8.4	ft^2
Wetted Perimeter	7.38	ft
Top Width	3.85	ft
Critical Depth	2.88	ft
Percent Full	63.5	%
Critical Slope	0.017817	ft/ft
Velocity	10.69	ft/s
Velocity Head	1.78	ft
Specific Energy	4.32	ft
Froude Number	1.27	
Maximum Dischar(	132.33	cfs
Discharge Full	123.02	cfs
Slope Full	0.013381	ft/ft
Flow Type	Supercritical	

BT Squared, Inc.
37 Brookside Road Waterbury, CT 06708 USA (203) 755-1666
Project Engineer: Mark Huber

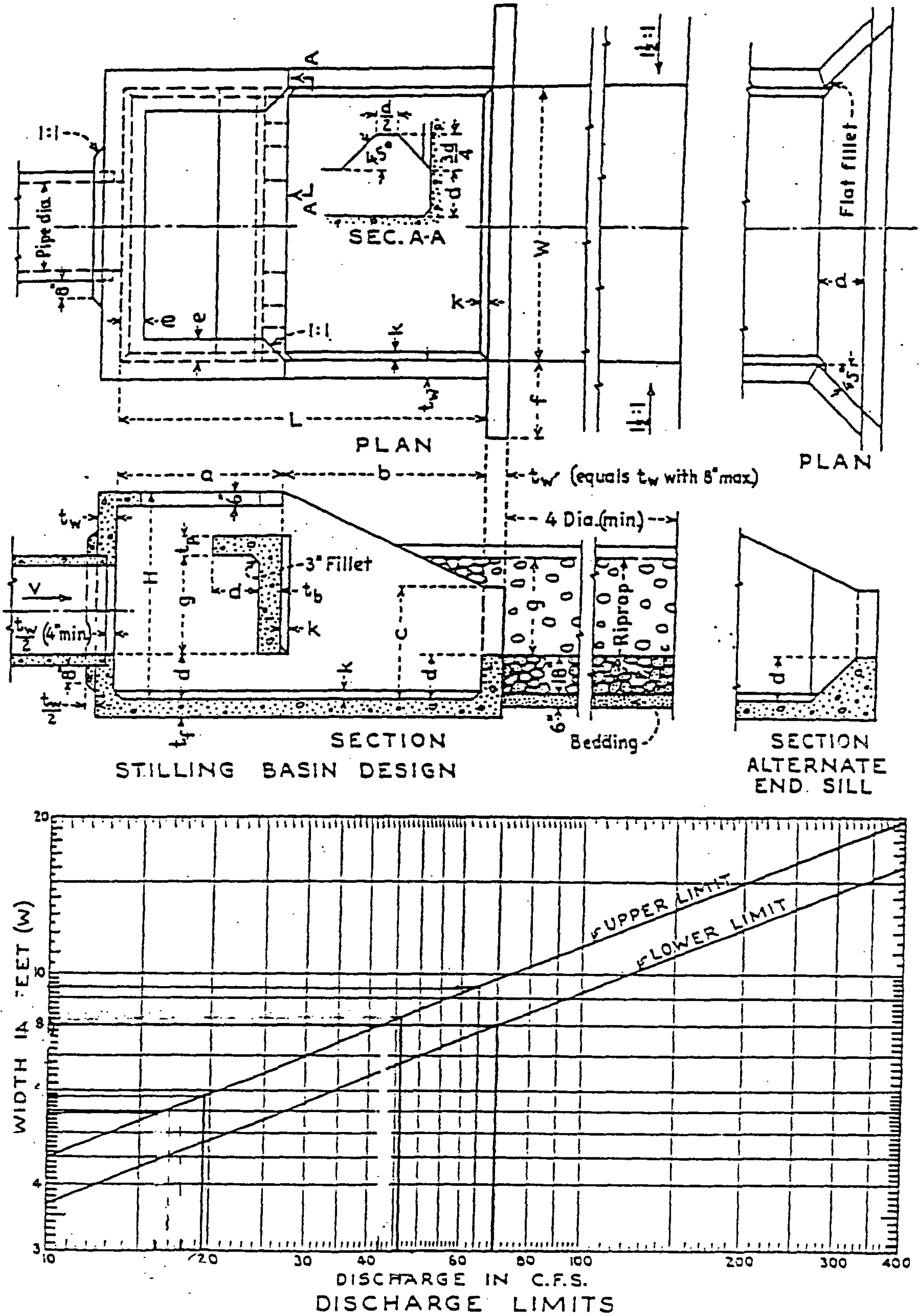


FIGURE 42.—*Impact-type energy dissipator (Basin VI).*

TABLE 11.—*Stilling basin dimensions (Basin VI). Impact-type energy dissipator.*

Suggested pipe size[1]		Max discharge Q	Feet and inches										Inches					
Dia in.	Area (sq ft)		W	H	L	a	b	c	d	e	f	g	t_w	t_f	t_b	t_p	K	Suggested riprap size
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)[3]
18	1.77	[2] 21	5-6	4-3	7-4	3-3	4-1	2-4	0-11	0-6	1-6	2-1	6	6½	6	6	3	4.0
24	3.14	38	6-9	5-3	9-0	3-11	5-1	2-10	1-2	0-6	2-0	2-6	6	6½	6	6	3	7.0
30	4.91	59	8-0	6-3	10-8	4-7	6-1	3-4	1-4	0-8	2-6	3-0	6	6½	7	7	3	8.5
36	7.07	85	9-3	7-3	12-4	5-3	7-1	3-10	1-7	0-8	3-0	3-6	7	7½	8	8	3	9.0
42	9.62	115	10-6	8-0	14-0	6-0	8-0	4-5	1-9	0-10	3-0	3-11	8	8½	9	8	4	9.5
48	12.57	151	11-9	9-0	15-8	6-9	8-11	4-11	2-0	0-10	3-0	4-5	9	9½	10	8	4	10.5
54	15.90	191	13-0	9-9	17-4	7-4	10-0	5-5	2-2	1-0	3-0	4-11	10	10½	10	8	4	12.0
60	19.63	236	14-3	10-9	19-0	8-0	11-0	5-11	2-5	1-0	3-0	5-4	11	11½	11	8	6	13.0
72	28.27	339	16-6	12-3	22-0	9-3	12-9	6-11	2-9	1-3	3-0	6-2	12	12½	12	8	6	14.0

USE SMALLEST POSSIBLE FOR Q, CFS

[1] Suggested pipe will run full when velocity is 12 feet per second or half full when velocity is 24 feet per second. Size may be modified for other velocities by Q=AV, but relation between Q and basin dimensions shown must be maintained.

[2] For discharges less than 21 second-feet, obtain basin width from curve of Fig. 42. Other dimensions proportional to W; $H=\frac{3W}{4}$, $L=\frac{4W}{3}$, $d=\frac{W}{6}$, etc.

[3] Determination of riprap size explained in Sec. 10.

Worksheet
Worksheet for Circular Channel

Project Description	
Worksheet	Road Culvert
Flow Element	Circular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.024	
Slope	0.025000	ft/ft
Diameter	48	in
Discharge	95.00	cfs

Results		
Depth	2.64	ft
Flow Area	8.8	ft²
Wetted Perimeter	7.58	ft
Top Width	3.79	ft
Critical Depth	2.95	ft
Percent Full	66.0	%
Critical Slope	0.018582	ft/ft
Velocity	10.80	ft/s
Velocity Head	1.81	ft
Specific Energy	4.45	ft
Froude Number	1.25	
Maximum Dischar(	132.33	cfs
Discharge Full	123.02	cfs
Slope Full	0.014909	ft/ft
Flow Type	Supercritical	

BT² inc.		Sheet No. 1 OF 9	
		Calc. No. 2	
		Rev. No.	
Job No. 1792	Job ALLIANT - LANSING ASH FILL	By TR	Date 7/19/01
Client ALLIANT	Subject EROSION CONTROL	Chk'd. MRH	Date 7-20-01

PURPOSE: TO DETERMINE WHAT KIND OF EROSION CONTROL PRODUCTS WILL BE REQUIRED IN THE PERIMETER DITCHES AND DIVERSION BERMS.

APPROACH: USE FLOW MASTER TO DETERMINE VELOCITIES FOR VARIOUS SCENARIOS USING MANNINGS NUMBERS FOR DIFFERENT EROSION CONTROL PRODUCTS.

REFERENCES: CALCULATION NO. 1

BON TERRA PRODUCT GUIDE.

PYRAMAT PRODUCT LITERATURE

PERMIT APPLICATION DRAWINGS

CALCULATIONS: REFER TO THE ATTACHED FLOWMASTER OUTPUT SHEETS

CONCLUSIONS:

NORTH PERIMETER DITCH 2% SLOPE - BON TERRA S2

NORTH PERIMETER DITCH 8% SLOPE - BON TERRA CP2 OVER PYRAMAT

NORTH BERM - BON TERRA S2

SOUTH PERIMETER DITCH - BON TERRA S2

SOUTH BERM - BON TERRA S2

Worksheet
Worksheet for Triangular Channel

Project Description	
Worksheet	North Berm
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.021	
Slope	0.020000	ft/ft
Left Side Slope	0.25	V : H
Right Side Slope	0.50	V : H
Discharge	16.00	cfs

Results			
Depth	0.96	ft	
Flow Area	2.8	ft²	
Wetted Perimeter	6.09	ft	
Top Width	5.75	ft	
Critical Depth	1.12	ft	
Critical Slope	0.008665	ft/ft	
Velocity	5.81	ft/s	< 10 fps OK WITH BON TERRA S2
Velocity Head	0.52	ft	
Specific Energy	1.48	ft	
Froude Number	1.48		
Flow Type	Supercritical		

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	North Ditch
Flow Element	Trapezoidal Channe
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.021	
Slope	0.020000	ft/ft
Left Side Slope	0.50	V : H
Right Side Slope	0.50	V : H
Bottom Width	5.00	ft
Discharge	36.00	cfs

Results		
Depth	0.78	ft
Flow Area	5.1	ft²
Wetted Perimeter	8.49	ft
Top Width	8.12	ft
Critical Depth	1.02	ft
Critical Slope	0.007666	ft/ft
Velocity	7.04	ft/s
Velocity Head	0.77	ft
Specific Energy	1.55	ft
Froude Number	1.56	
Flow Type	Supercritical	

< 10 fps OK WITH BON TERRA SZ

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	North Ditch
Flow Element	Trapezoidal Channe
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.020	
Slope	0.080000	ft/ft
Left Side Slope	0.50	V : H
Right Side Slope	0.50	V : H
Bottom Width	5.00	ft
Discharge	95.00	cfs

Results		
Depth	0.88	ft
Flow Area	5.9	ft²
Wetted Perimeter	8.93	ft
Top Width	8.51	ft
Critical Depth	1.76	ft
Critical Slope	0.005921	ft/ft
Velocity	16.01	ft/s < 18 fps O.K WITH BON TERRA CP2 + PYRAMAT
Velocity Head	3.98	ft
Specific Energy	4.86	ft
Froude Number	3.38	
Flow Type	Supercritical	

Worksheet
Worksheet for Triangular Channel

Project Description	
Worksheet	south berm
Flow Element	Triangular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.021	
Slope	0.020000	ft/ft
Left Side Slope	0.50	V : H
Right Side Slope	0.25	V : H
Discharge	9.00	cfs

Results		
Depth	0.77	ft
Flow Area	1.8	ft²
Wetted Perimeter	4.91	ft
Top Width	4.63	ft
Critical Depth	0.89	ft
Critical Slope	0.009356	ft/ft
Velocity	5.03	ft/s < 10 fps O.K. WITH BON TERRA SZ
Velocity Head	0.39	ft
Specific Energy	1.17	ft
Froude Number	1.43	
Flow Type	Supercritical	

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	South Ditch
Flow Element	Trapezoidal Channe
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.021	
Slope	0.075000	ft/ft
Left Side Slope	0.50	V : H
Right Side Slope	0.25	V : H
Bottom Width	5.00	ft
Discharge	17.00	cfs

Results		
Depth	0.34	ft
Flow Area	2.0	ft²
Wetted Perimeter	7.16	ft
Top Width	7.04	ft
Critical Depth	0.62	ft
Critical Slope	0.008674	ft/ft
Velocity	8.29	ft/s < 10 fps OK. WITH BON TERRA SC
Velocity Head	1.07	ft
Specific Energy	1.41	ft
Froude Number	2.71	
Flow Type	Supercritical	

S2

Use on slopes with medium run off conditions. Made from 100% straw with lightweight photodegradable netting on both sides.

Mass/Unit Area: 8 oz./SY min
Thickness: .25 in.
Tensile Strength: 112x64 lb. ft.
Elongation: 42%x28%
Flexibility: 4780 x 7730 (mg-cm)
Flow Velocity: 10 fps
Permissible Shear Stress: 2.2 lbs/sq.ft.
Manning's N-Value: 0.0213
Size: 7.5 ft x 90 ft = 75 SY
"C" Factor: 0.002

S1

Use on slopes with moderate run off conditions. Made from 100% straw with lightweight photodegradable netting on top side.

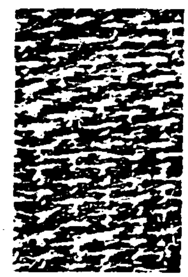
Mass/Unit Area: 8 oz./SY min
Thickness: .25 in.
Tensile Strength: 90x60 lb.ft.
Elongation: 30%x30%
Flexibility: 3450 (mg-cm)
Flow Velocity: 6 fps
Permissible Shear Stress: 2 lbs/sq.ft.
Manning's N-Value: 0.0246
Size: 7.5 ft x 90 ft = 75 SY
"C" Factor: 0.002

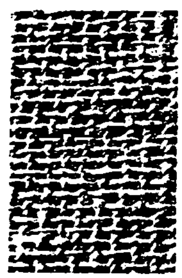
HP90

Made from 100% natural coir (coconut) fiber, needlepunched with latex into a high tensile three dimensional matrix. HP90 serves as bioengineering media for live stake layering, controls erosion in high velocity intermittent flow channels or sediment trapping.

Mass/Unit Area: 18.84 oz./SY min
Thickness: .25 in.
Absorptive Capacity: 2.29
Resiliency: 33%
Tensile Strength: 13x8 lb.ft.
Elongation: 18%x16%
Flexibility: 4.67
Permeability: 5.02 cm/s
Tear Resistance: 19x16 lb.
Permittivity: 8.00
Flow Velocity: 598.80 gal/min/ft.^{2}
Size: 36"/48"x60'
"C" Factor: 0.003

CFMats





Made from 100% coir fiber twine woven into high strength mats for extreme slope stabilization, protection of high velocity streambanks and high velocity intermittent flow channels; used for frost shear protection.

	CF4	CF7	CF9
Thickness:	.30 in	.30 in.	.30 in
Tensile Strength:	432x138 lb/ft.	1348x626 lb/ft.	1648x670 lb/ft
Elongation:	26%x32	34%x38%	42%x32%
Flexibility (mg-cm):	19920x16790	65030x29590	89270x39360
Flow Velocity:	Observed 9 ft./sec.	Observed 11ft./sec.	Observed 16 ft./sec.
Weight:	11.8 oz/SY	20 oz/SY	26 oz/SY
Size:	6.6x164 ft (120 sy) or (100 sm)		
"C" Factor:	0.002	0.002	0.003
Open Area (measured):	65%	50%	39%

Distributed By:

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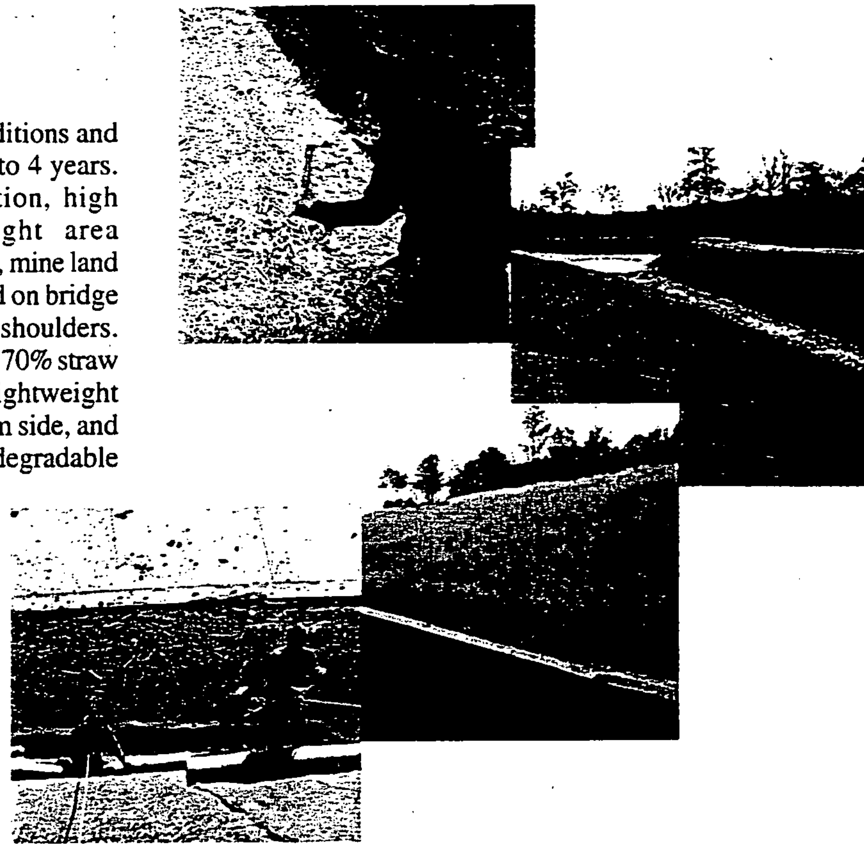
e-mail: bonterra@moscow.com

CS2

For slopes with heavy runoff conditions and where protection is needed for 2 to 4 years. Handles steep slide rehabilitation, high elevation reclamation, drought area revegetation, long slope cut and fill, mine land and landfill reclamation; also used on bridge abutments, ski runs, and channel shoulders. Made from a homogenous blend of 70% straw and 30% coir fiber. CS2 has a lightweight photodegradable netting on bottom side, and long lasting UV stabilized, photodegradable netting on the top side.



Mass/Unit Area: 8 oz./SYmin
Thickness: .25 in.
Tensile Strength: 126x94 lb. ft.
Elongation: 38%x30%
Flexibility: 810 (mg-cm)
Flow Velocity: 12 fps
Permissible Shear Stress: 2.5 lbs/sq.ft.
Manning's N-Value: 0.0213
Size: 7.5 ft x 90 ft = 75 SY
"C" Factor: 0.002

SFB12

Use in applications where flow exceeds 20 fps and where shear stress or tensile strength requirements exceed standard SFB. Made from 100% synthetic fibers with long lasting UV stabilized netting on bottom, heavy duty UV stabilized netting on top.

Mass/Unit Area: 12 oz./SYmin
Thickness: .50 in.
Tensile Strength: 280x200 lb.ft.
Elongation: 20%x20%
Flexibility: 12810-6070 (mg-cm)
Flow Velocity: 27fps
Permissible Shear Stress: 6 lbs/sq.ft.
Porosity: 95% (calculated)
Manning's N-Value: 0.0283
UVI Stability: 90%
Size: 7.5 ft x 90 ft = 75 SY
"C" Factor: 0.003

CP2

Made from a 50/50 homogeneous blend of natural coir (coconut) fiber and UV treated polypropylene fibers with photodegradable netting on both sides. For use as slope protection, channel liner, drainage ditch lining and bank stabilization. Developed for areas where long-term erosion control blankets are needed and where humus needs to be increased in the soil. Often used in arid areas to provide long-term soil protection during the 3-5 year revegetation process; also provides permanent support throughout the project's life.

Mass/Unit Area: 8 oz/SY min
Thickness: .25 in.
Tensile Strength: 250x150 lb. ft.
Elongation: 20%x20%
Flexibility: 700x1600 (mg-cm)
Flow Velocity: 18 fps
Permissible Shear Stress: 4 lbs/sq.ft.
Manning's N-Value: 0.02
Size: 7.5 ft x 90 ft = 75 SY
"C" Factor: 0.003

It's Performance That Counts!

BonTerra products are tested by laboratories such as the UWRL (Utah Water Research Laboratories) and other respected laboratories in the U.S. Extensive research is conducted to determine each product's effectivness at reducing soil loss under various site conditions. The tests are conducted using flumes, soil-filled test beds, variable slopes, and rainfall simulation. Test results (shown as ASTM test measurements) are listed in our literature and on our sample labels, making product selection simple when designing to performance parameters.

If the jobsite is environmentally sensitive, EcoNet™ meets the specifications. Call 800-882-9489 for details.

PYRAMAT - HIGH PERFORMANCE TURF REINFORCEMENT MAT PRODUCT LITERATURE PROVIDED BY SYNTHETIC INDUSTRIES

Engineering Specifications

The HIGH PERFORMANCE TURF REINFORCEMENT MAT shall be a three-dimensional, lofty, woven polypropylene geotextile specially designed for erosion control applications on steep slopes, water containment structures and vegetated waterways. The matrix shall be composed of polypropylene monofilament yarns woven into a uniform, dimensionally stable configuration of resilient pyramid-like projections. The material shall exhibit very high interlock and reinforcement capacity with both soil and root systems and demonstrate high tensile modulus. The high performance TRM shall conform to the property values listed below under dry or saturated conditions.

PROPERTY	TEST METHOD	MINIMUM AVERAGE ROLL VALUES (MARV) ENGLISH	MINIMUM AVERAGE ROLL VALUES (MARV) METRIC
MECHANICAL			
Tensile Strength[2]	ASTM D-4595	3,200 X 2,200 lb/ft	46.7 X 32.1 kN/m
	ASTM D-5035	3,100 X 2,000 lb/ft	45.2 X 29.2 kN/m
Tensile Elongation[2]	ASTM D-4595	80% (max)	80% (max)
	ASTM D-5035	55% (max)	55% (max)
Tensile Strength[2] @ 10% Elongation	ASTM D-4595	1,850 X 1,600 lb/ft (typ)	27.0 X 23.4 kN/m (typ)
ENDURANCE			
UV Resistance @ 1000 hours	ASTM D-4355	80%	80%
PHYSICAL			
Thickness	ASTM D-1777	0.5 in	12.7 mm
Resiliency[3]	ASTM D-1777	80%	80%
Mass Per Unit Area	ASTM D-5621	14 oz/yd²	475 g/m²
Ground Cover Factor[4]	Light Projection Analysis	75%	75%

PERFORMANCE	MAXIMUM PERMISSIBLE VALUES Short-Term (1/2 hr)		Long-Term (50 hrs)	
Velocity				
Vegetated	25 ft/sec	7.6 m/sec	14 ft/sec	4.3 m/sec
Unvegetated	20 ft/sec	6.1 m/sec	10 ft/sec	3.0 m/sec
Shear Stress				
Vegetated	10 lb/ft²	48.9 kg/m²	6 lb/ft²	29.3 kg/m²
Unvegetated	8 lb/ft²	39.2 kg/m²	3 lb/ft²	14.7 kg/m²

NOTES:

1. *All published values are Minimum Average Roll Values (MARV) unless otherwise indicated, yielding a 95% confidence level. Additional property values available upon request.*
2. *Values for both machine and cross machine directions under dry or saturated conditions.*
3. *Resiliency defined as percent of original thickness retained after 3 cycles of a 100 psi load (690 kPa) for 60 seconds without load... thickness measured 30 minutes after load removed in accordance with ASTM D-1777.*
4. *Ground Cover Factor represents "% shade" from Lumite® Light Projection Test.*
5. *Values obtained at an independent hydraulics testing laboratory.*

STANDARD ROLL SIZE INFORMATION

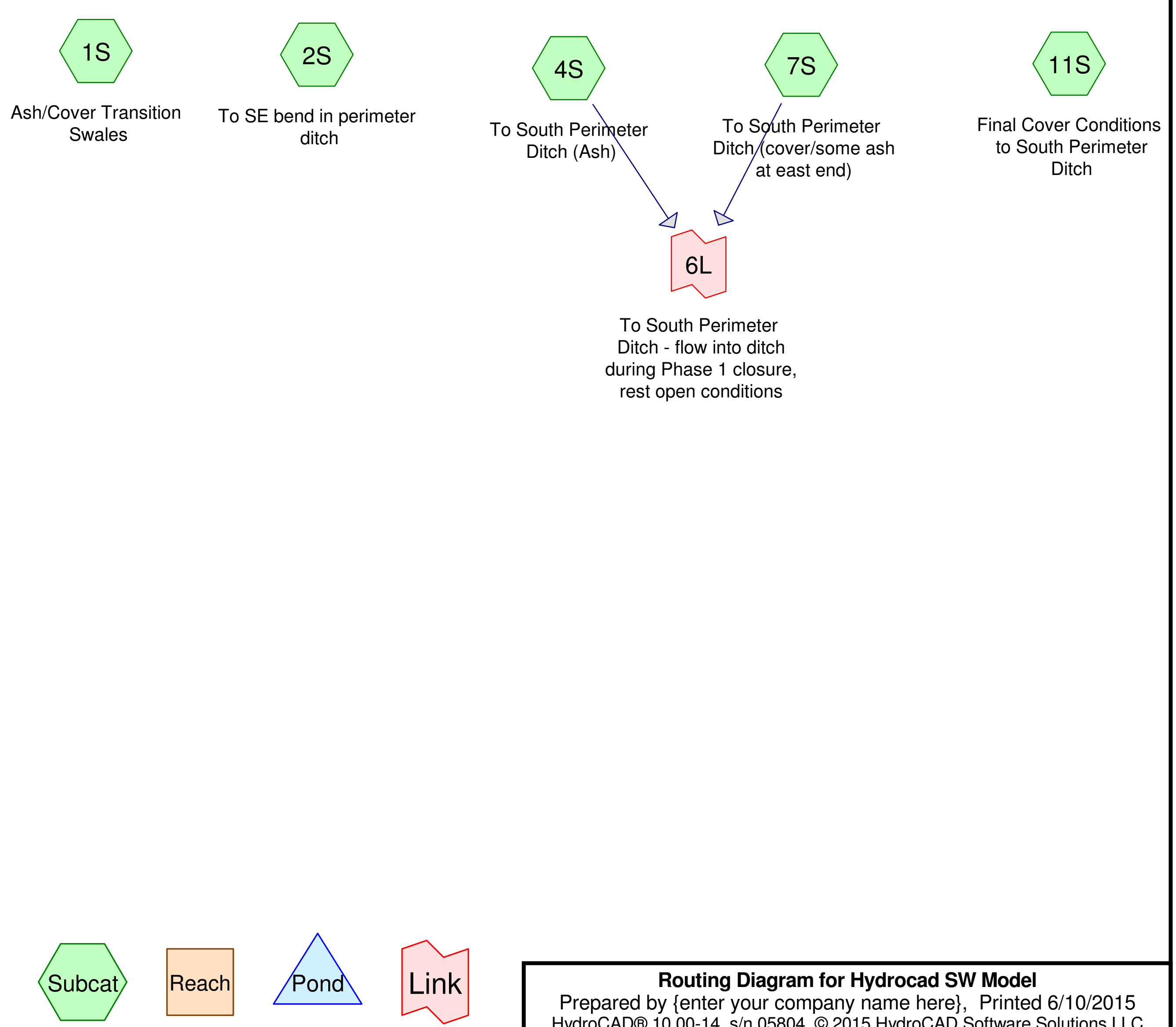
2.59 m x 27.4 m = 71 m²

8.5 ft x 90 ft = 765 ft² = 85 yd²

A2 Phase 1 Final Cover

HydroCAD Output

25-yr, 24-hr Storm Event



Routing Diagram for Hydrocad SW Model
Prepared by {enter your company name here}, Printed 6/10/2015

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
8.988	98	(1S, 4S, 7S)
15.636	74	(2S, 7S, 11S)
24.624	**83**	**TOTAL AREA**

Soil Listing (selected nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
0.000	HSG B	
0.000	HSG C	
0.000	HSG D	
24.624	Other	1S, 2S, 4S, 7S, 11S
24.624		**TOTAL AREA**

Ground Covers (selected nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
0.000	0.000	0.000	0.000	24.624	24.624		1S, 2S, 4S, 7S, 11S
0.000	**0.000**	**0.000**	**0.000**	**24.624**	**24.624**	**TOTAL AREA**	

Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: Ash/Cover Transition Runoff Area=137,773 sf 100.00% Impervious Runoff Depth>4.80"
Flow Length=1,215' Tc=3.6 min CN=98 Runoff=26.05 cfs 1.265 af

Subcatchment 2S: To SE bend in perimeter Runoff Area=55,425 sf 0.00% Impervious Runoff Depth>2.53"
Flow Length=540' Tc=6.0 min CN=74 Runoff=6.03 cfs 0.269 af

Subcatchment 4S: To South Perimeter Runoff Area=5.550 ac 100.00% Impervious Runoff Depth>4.80"
Flow Length=1,215' Tc=3.6 min CN=98 Runoff=45.72 cfs 2.221 af

Subcatchment 7S: To South Perimeter Runoff Area=197,719 sf 6.06% Impervious Runoff Depth>2.62"
Flow Length=1,460' Tc=3.9 min CN=75 Runoff=24.26 cfs 0.993 af

Subcatchment 11S: Final Cover Conditions Runoff Area=10.100 ac 0.00% Impervious Runoff Depth>2.53"
Flow Length=1,460' Tc=8.8 min CN=74 Runoff=44.16 cfs 2.131 af

Link 6L: To South Perimeter Ditch - flow into ditch during Phase 1 closure, Inflow=69.86 cfs 3.213 af
Primary=69.86 cfs 3.213 af

Total Runoff Area = 24.624 ac Runoff Volume = 6.879 af Average Runoff Depth = 3.35"
63.50% Pervious = 15.636 ac 36.50% Impervious = 8.988 ac

Summary for Subcatchment 1S: Ash/Cover Transition Swales

[49] Hint: Tc<2dt may require smaller dt

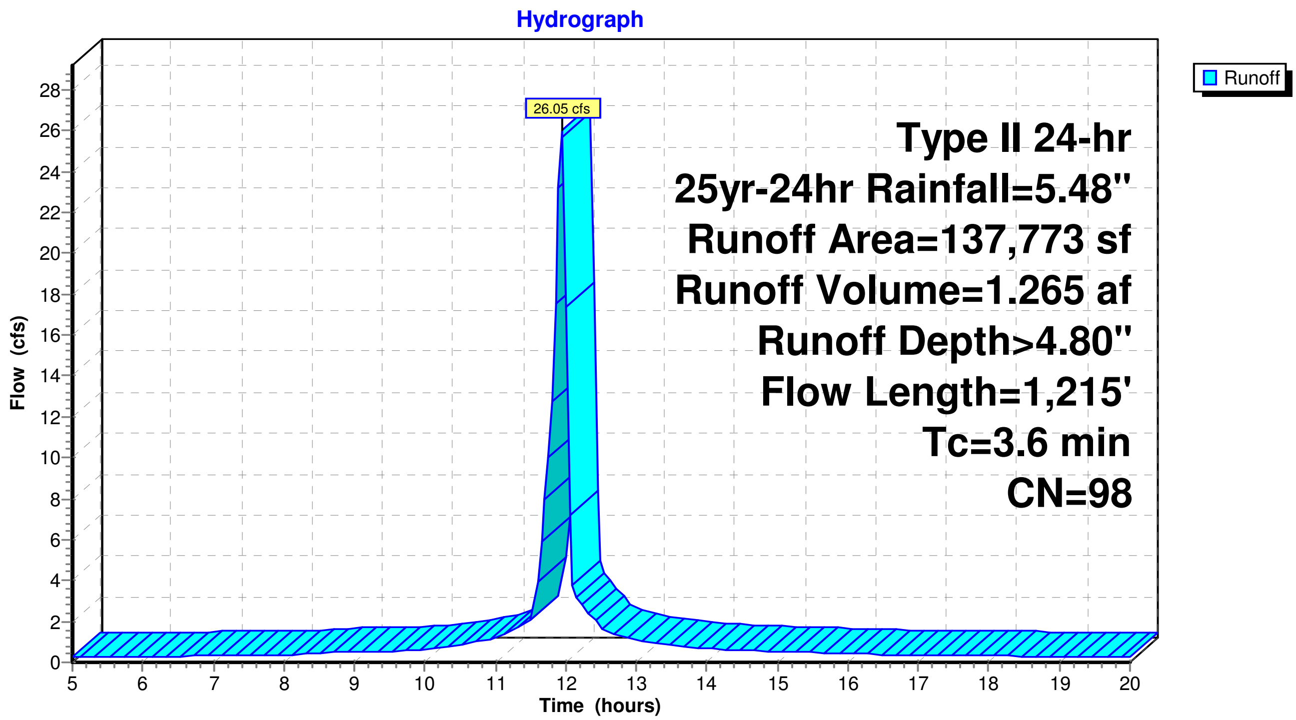
Runoff = 26.05 cfs @ 11.94 hrs, Volume= 1.265 af, Depth> 4.80"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25yr-24hr Rainfall=5.48"

	Area (sf)	CN	Description
*	137,773	98	
	137,773		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	100	0.2500	3.63		**Sheet Flow, First 100 Feet** Smooth surfaces n= 0.011 P2= 2.95"
2.1	580	0.0230	4.51	30.66	**Channel Flow, Channel Flow** Area= 6.8 sf Perim= 9.5' r= 0.72' n= 0.040
1.0	535	0.0970	9.37	80.58	**Channel Flow, Second Channel** Area= 8.6 sf Perim= 11.8' r= 0.73' n= 0.040
3.6	1,215	Total			

Subcatchment 1S: Ash/Cover Transition Swales



Summary for Subcatchment 2S: To SE bend in perimeter ditch

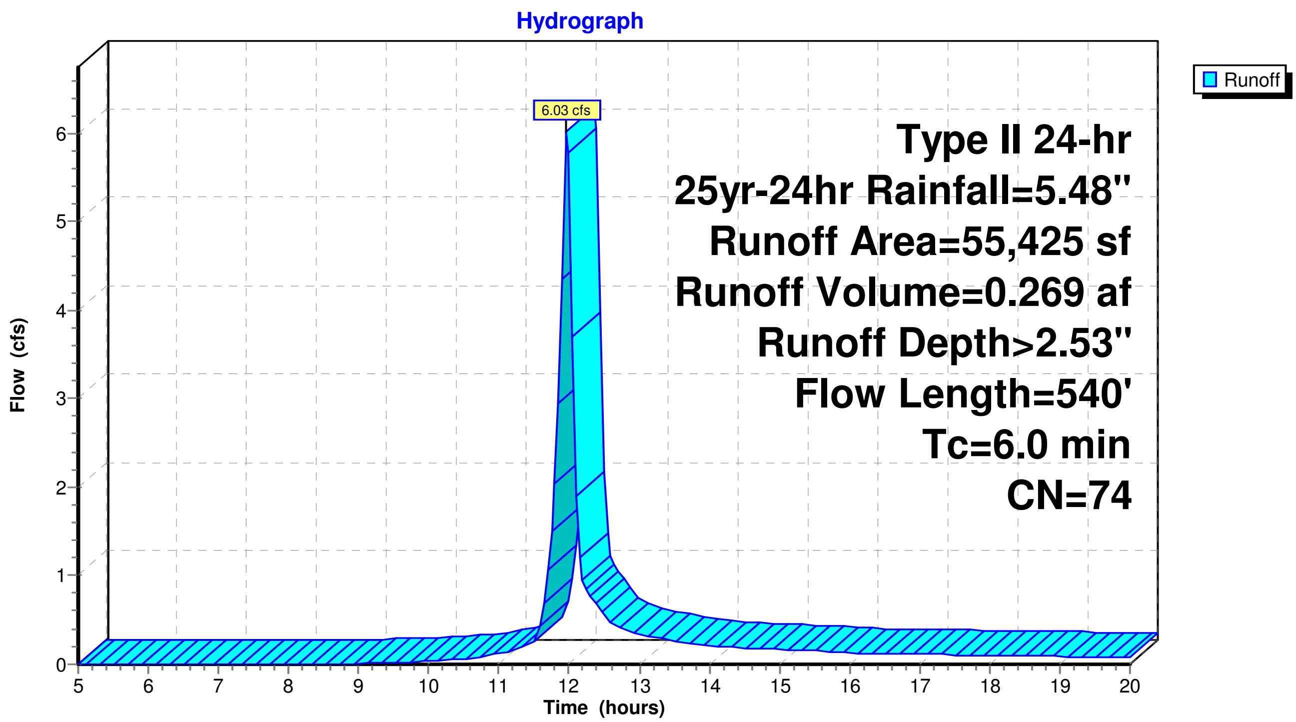
Runoff = 6.03 cfs @ 11.97 hrs, Volume= 0.269 af, Depth> 2.53"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25yr-24hr Rainfall=5.48"

	Area (sf)	CN	Description
*	55,425	74	
	55,425		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.4	100	0.2500	0.31		**Sheet Flow, First 100 Feet** Grass: Dense n= 0.240 P2= 2.95"
0.6	440	0.1000	12.07	265.58	**Channel Flow, Channel Flow** Area= 22.0 sf Perim= 17.7' r= 1.24' n= 0.045
6.0	540	Total			

Subcatchment 2S: To SE bend in perimeter ditch



Summary for Subcatchment 4S: To South Perimeter Ditch (Ash)

[49] Hint: Tc<2dt may require smaller dt

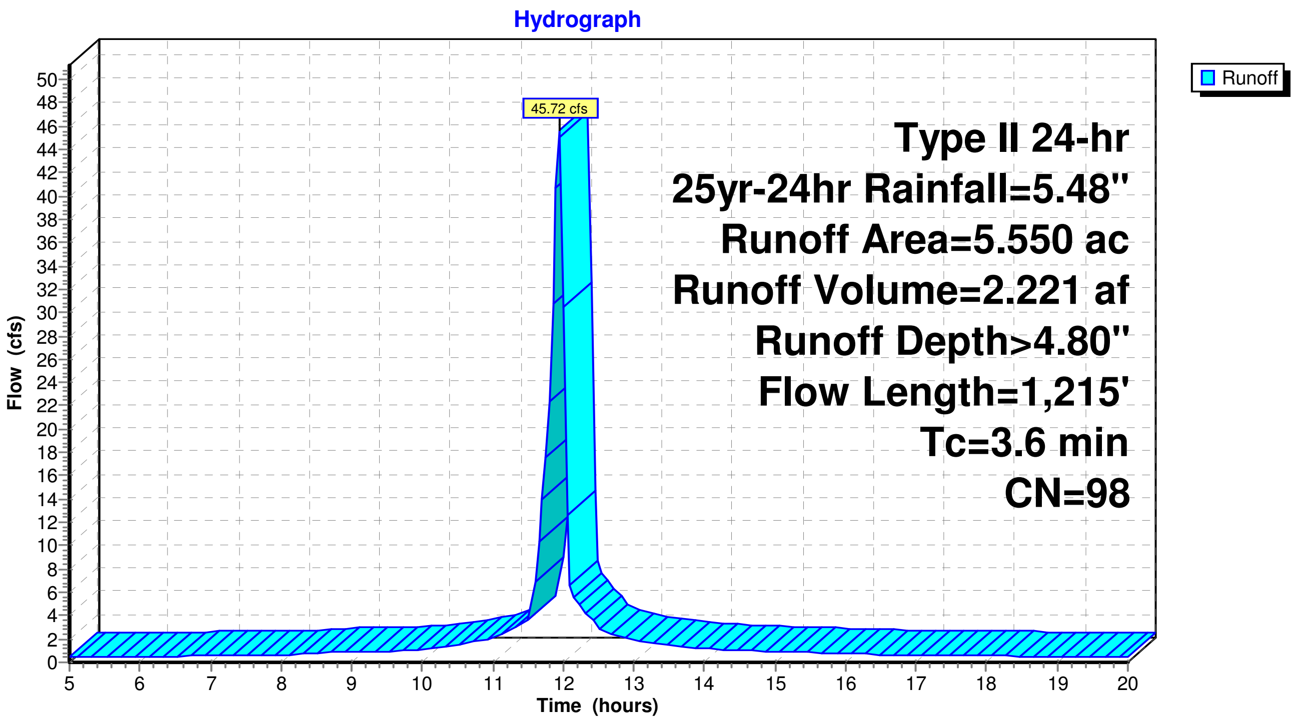
Runoff = 45.72 cfs @ 11.94 hrs, Volume= 2.221 af, Depth> 4.80"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25yr-24hr Rainfall=5.48"

	Area (ac)	CN	Description
*	5.550	98	
	5.550		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	100	0.2500	3.63		**Sheet Flow, First 100 Feet** Smooth surfaces n= 0.011 P2= 2.95"
2.1	580	0.0230	4.51	30.66	**Channel Flow, Channel Flow** Area= 6.8 sf Perim= 9.5' r= 0.72' n= 0.040
1.0	535	0.0970	9.37	80.58	**Channel Flow, Second Channel** Area= 8.6 sf Perim= 11.8' r= 0.73' n= 0.040
3.6	1,215	Total			

Subcatchment 4S: To South Perimeter Ditch (Ash)



Summary for Subcatchment 7S: To South Perimeter Ditch (cover/some ash at east end)

[49] Hint: Tc<2dt may require smaller dt

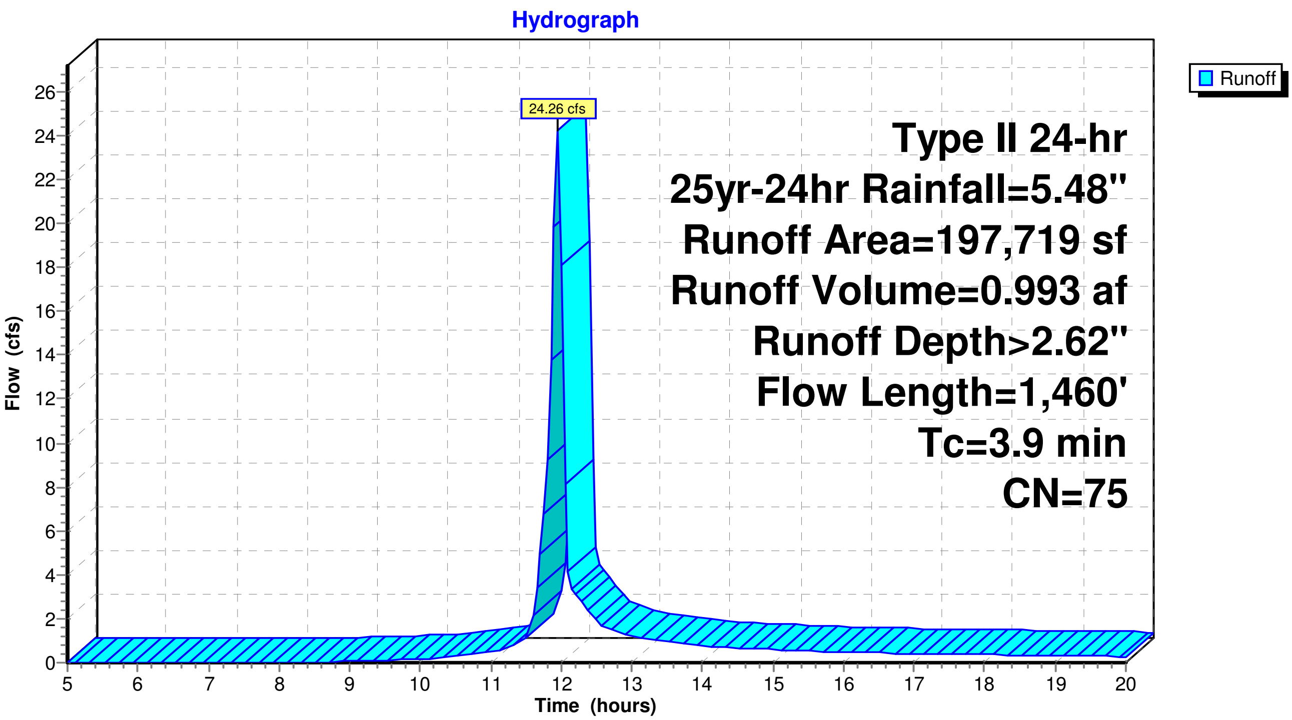
Runoff = 24.26 cfs @ 11.95 hrs, Volume= 0.993 af, Depth> 2.62"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25yr-24hr Rainfall=5.48"

	Area (sf)	CN	Description
*	185,740	74	
*	11,979	98	
	197,719	75	Weighted Average
	185,740		93.94% Pervious Area
	11,979		6.06% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	100	0.2500	3.63		**Sheet Flow, First 100 Feet** Smooth surfaces n= 0.011 P2= 2.95"
0.6	440	0.1000	12.07	265.58	**Channel Flow, Channel Flow** Area= 22.0 sf Perim= 17.7' r= 1.24' n= 0.045
2.8	920	0.0200	5.40	118.77	**Channel Flow, Channel Flow** Area= 22.0 sf Perim= 17.7' r= 1.24' n= 0.045
3.9	1,460	Total			

Subcatchment 7S: To South Perimeter Ditch (cover/some ash at east end)



Summary for Subcatchment 11S: Final Cover Conditions to South Perimeter Ditch

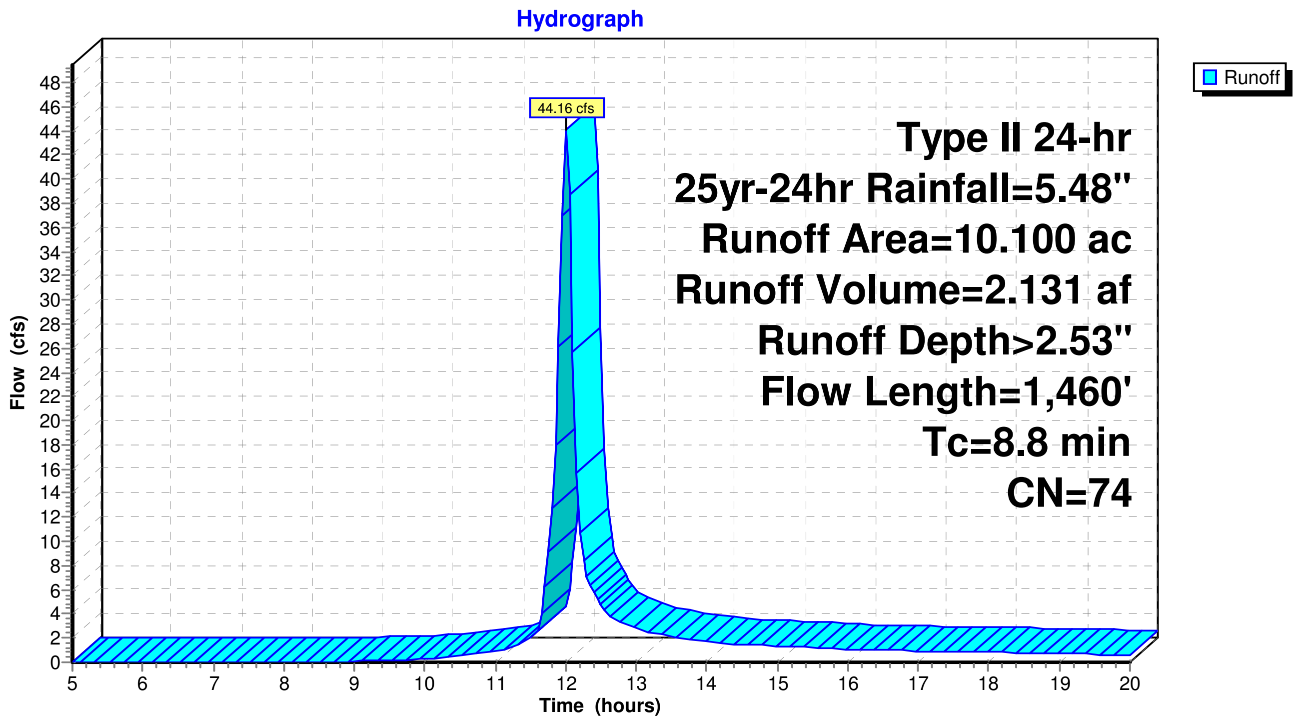
Runoff = 44.16 cfs @ 12.00 hrs, Volume= 2.131 af, Depth> 2.53"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25yr-24hr Rainfall=5.48"

	Area (ac)	CN	Description
*	10.100	74	
	10.100		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.4	100	0.2500	0.31		**Sheet Flow, First 100 Feet** Grass: Dense n= 0.240 P2= 2.95"
0.6	440	0.1000	12.07	265.58	**Channel Flow, Channel Flow** Area= 22.0 sf Perim= 17.7' r= 1.24' n= 0.045
2.8	920	0.0200	5.40	118.77	**Channel Flow, Channel Flow** Area= 22.0 sf Perim= 17.7' r= 1.24' n= 0.045
8.8	1,460	Total			

Subcatchment 11S: Final Cover Conditions to South Perimeter Ditch

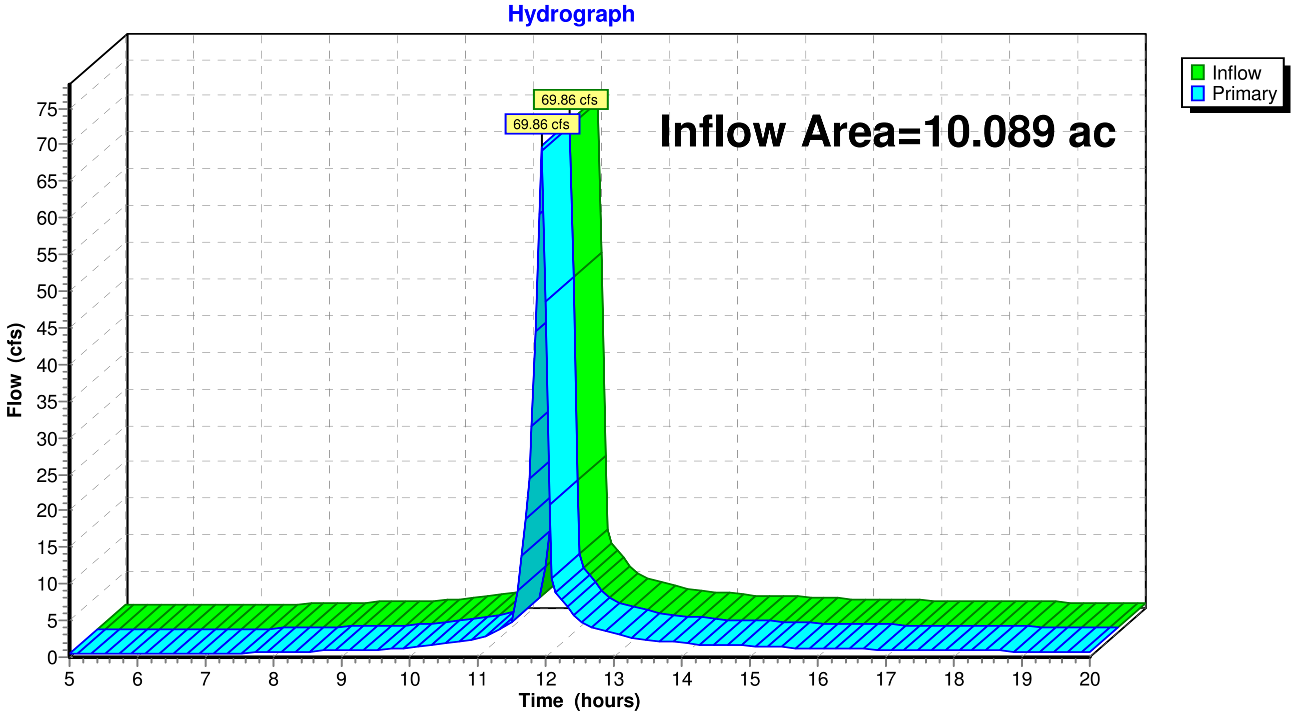


ummary for Link 6L: To South Perimeter Ditch - flow into ditch during Phase 1 closure, rest open condition

Inflow Area = 10.089 ac, 57.74% Impervious, Inflow Depth > 3.82" for 25yr-24hr event
Inflow = 69.86 cfs @ 11.94 hrs, Volume= 3.213 af
Primary = 69.86 cfs @ 11.94 hrs, Volume= 3.213 af, Atten= 0%, Lag= 0.0 min

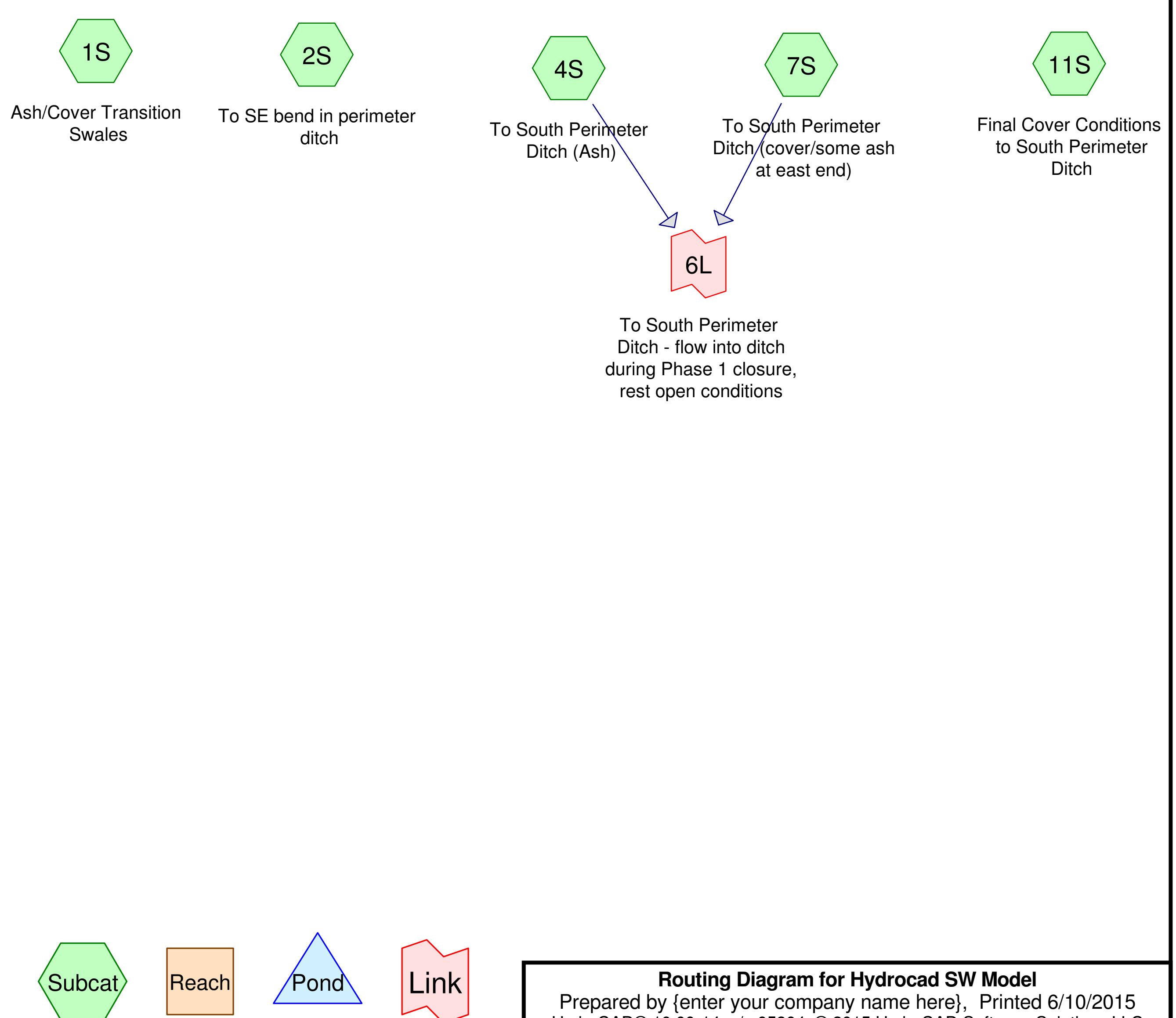
Primary outflow = Inflow, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Link 6L: To South Perimeter Ditch - flow into ditch during Phase 1 closure, rest open conditions



HydroCAD Output

100-yr, 24-hr Storm Event



Routing Diagram for Hydrocad SW Model
Prepared by {enter your company name here}, Printed 6/10/2015
HydroCAD® 10.00-14 s/n 05804 © 2015 HydroCAD Software Solutions LLC

Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: Ash/Cover Transition Runoff Area=137,773 sf 100.00% Impervious Runoff Depth>6.68"
Flow Length=1,215' Tc=3.6 min CN=98 Runoff=36.11 cfs 1.762 af

Subcatchment 2S: To SE bend in perimeter Runoff Area=55,425 sf 0.00% Impervious Runoff Depth>4.23"
Flow Length=540' Tc=6.0 min CN=74 Runoff=9.84 cfs 0.448 af

Subcatchment 4S: To South Perimeter Runoff Area=5.550 ac 100.00% Impervious Runoff Depth>6.68"
Flow Length=1,215' Tc=3.6 min CN=98 Runoff=63.36 cfs 3.092 af

Subcatchment 7S: To South Perimeter Runoff Area=197,719 sf 6.06% Impervious Runoff Depth>4.34"
Flow Length=1,460' Tc=3.9 min CN=75 Runoff=39.07 cfs 1.641 af

Subcatchment 11S: Final Cover Conditions Runoff Area=10.100 ac 0.00% Impervious Runoff Depth>4.22"
Flow Length=1,460' Tc=8.8 min CN=74 Runoff=72.28 cfs 3.553 af

Link 6L: To South Perimeter Ditch - flow into ditch during Phase 1 closure, Inflow=102.32 cfs 4.732 af
Primary=102.32 cfs 4.732 af

Total Runoff Area = 24.624 ac Runoff Volume = 10.495 af Average Runoff Depth = 5.11"
63.50% Pervious = 15.636 ac 36.50% Impervious = 8.988 ac

Summary for Subcatchment 1S: Ash/Cover Transition Swales

[49] Hint: Tc<2dt may require smaller dt

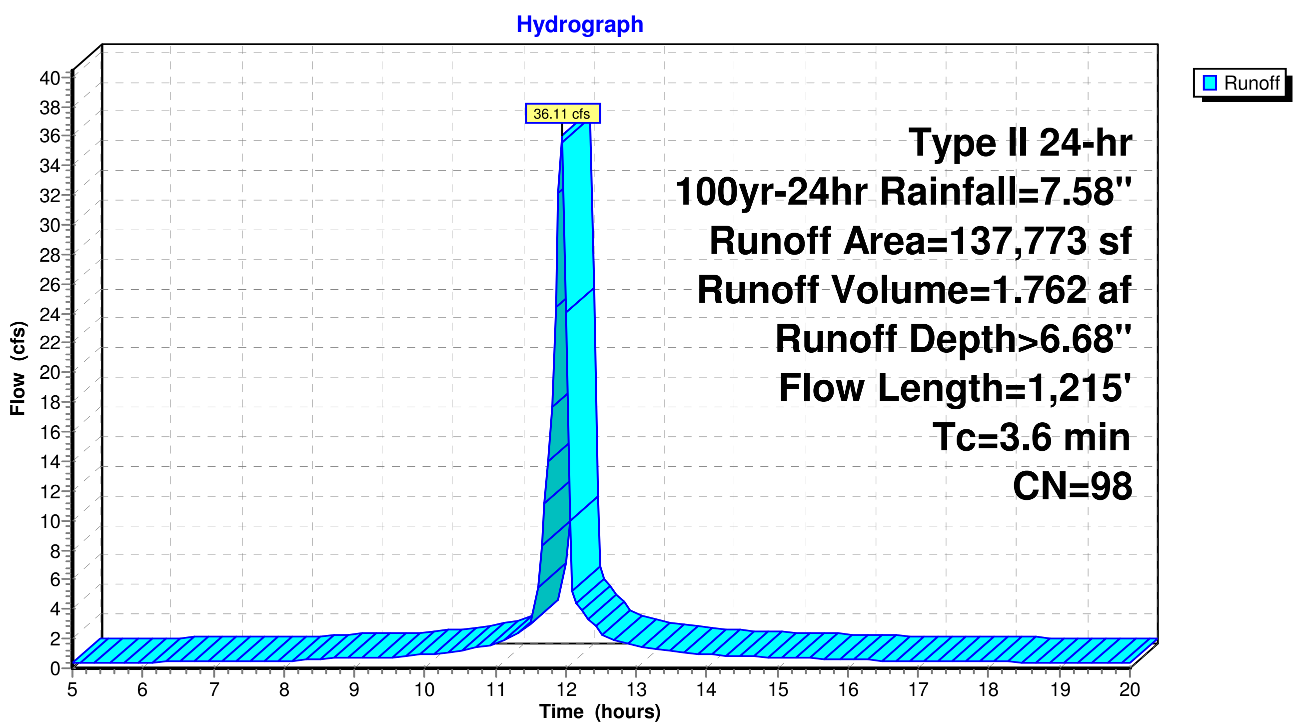
Runoff = 36.11 cfs @ 11.94 hrs, Volume= 1.762 af, Depth> 6.68"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100yr-24hr Rainfall=7.58"

	Area (sf)	CN	Description
*	137,773	98	
	137,773		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	100	0.2500	3.63		**Sheet Flow, First 100 Feet** Smooth surfaces n= 0.011 P2= 2.95"
2.1	580	0.0230	4.51	30.66	**Channel Flow, Channel Flow** Area= 6.8 sf Perim= 9.5' r= 0.72' n= 0.040
1.0	535	0.0970	9.37	80.58	**Channel Flow, Second Channel** Area= 8.6 sf Perim= 11.8' r= 0.73' n= 0.040
3.6	1,215	Total			

Subcatchment 1S: Ash/Cover Transition Swales



Summary for Subcatchment 2S: To SE bend in perimeter ditch

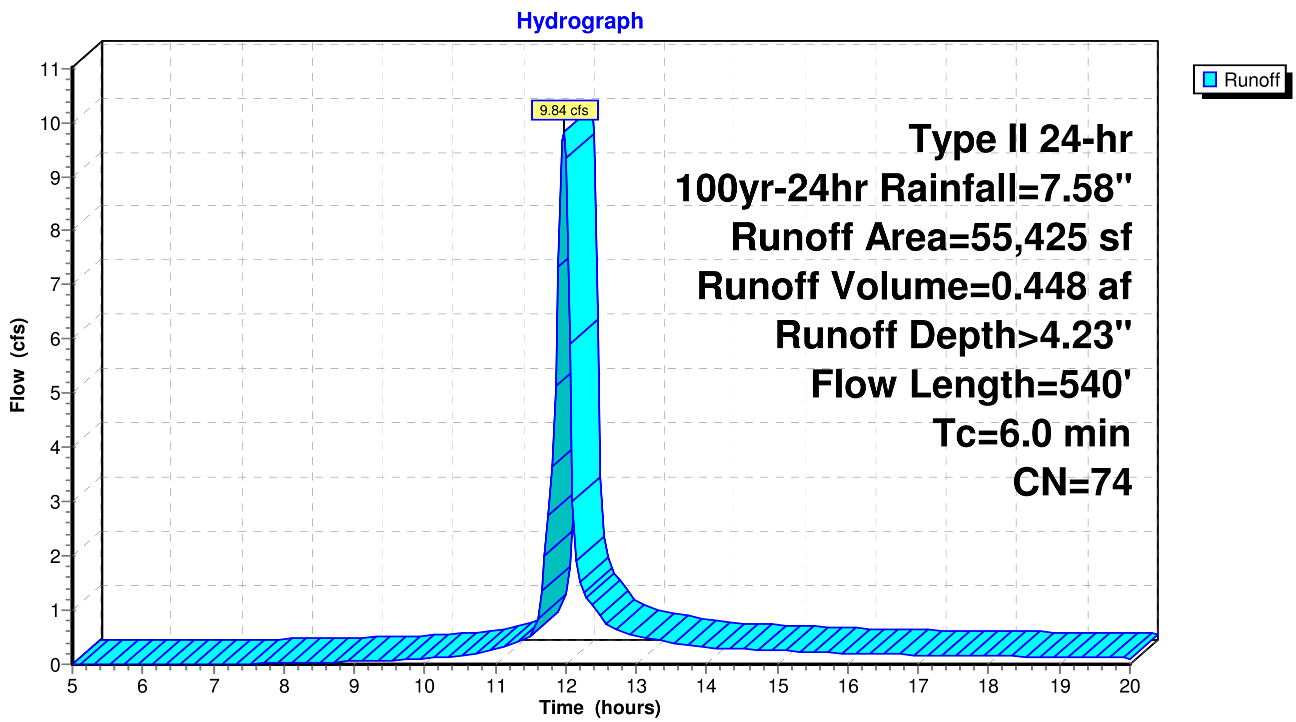
Runoff = 9.84 cfs @ 11.97 hrs, Volume= 0.448 af, Depth> 4.23"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100yr-24hr Rainfall=7.58"

	Area (sf)	CN	Description
*	55,425	74	
	55,425		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.4	100	0.2500	0.31		**Sheet Flow, First 100 Feet** Grass: Dense n= 0.240 P2= 2.95"
0.6	440	0.1000	12.07	265.58	**Channel Flow, Channel Flow** Area= 22.0 sf Perim= 17.7' r= 1.24' n= 0.045
6.0	540	Total			

Subcatchment 2S: To SE bend in perimeter ditch



Summary for Subcatchment 4S: To South Perimeter Ditch (Ash)

[49] Hint: Tc<2dt may require smaller dt

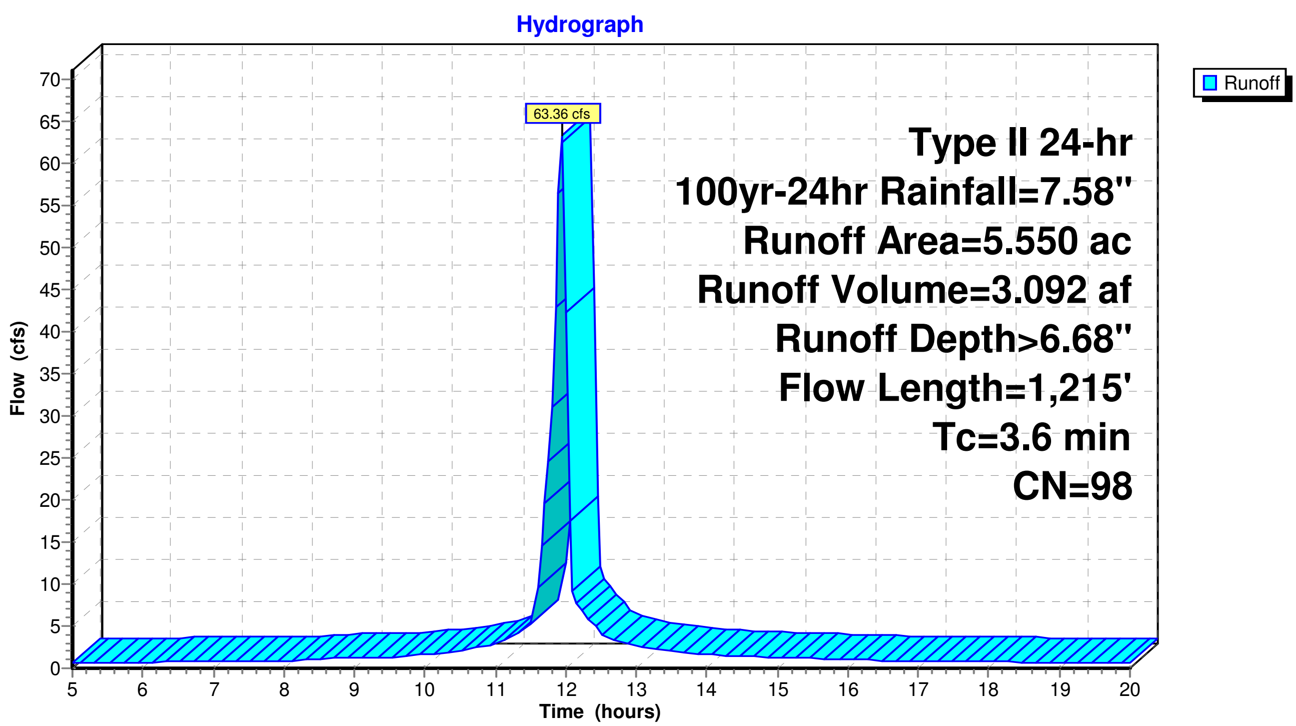
Runoff = 63.36 cfs @ 11.94 hrs, Volume= 3.092 af, Depth> 6.68"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100yr-24hr Rainfall=7.58"

	Area (ac)	CN	Description
*	5.550	98	
	5.550		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	100	0.2500	3.63		**Sheet Flow, First 100 Feet** Smooth surfaces n= 0.011 P2= 2.95"
2.1	580	0.0230	4.51	30.66	**Channel Flow, Channel Flow** Area= 6.8 sf Perim= 9.5' r= 0.72' n= 0.040
1.0	535	0.0970	9.37	80.58	**Channel Flow, Second Channel** Area= 8.6 sf Perim= 11.8' r= 0.73' n= 0.040
3.6	1,215	Total			

Subcatchment 4S: To South Perimeter Ditch (Ash)



Summary for Subcatchment 7S: To South Perimeter Ditch (cover/some ash at east end)

[49] Hint: Tc<2dt may require smaller dt

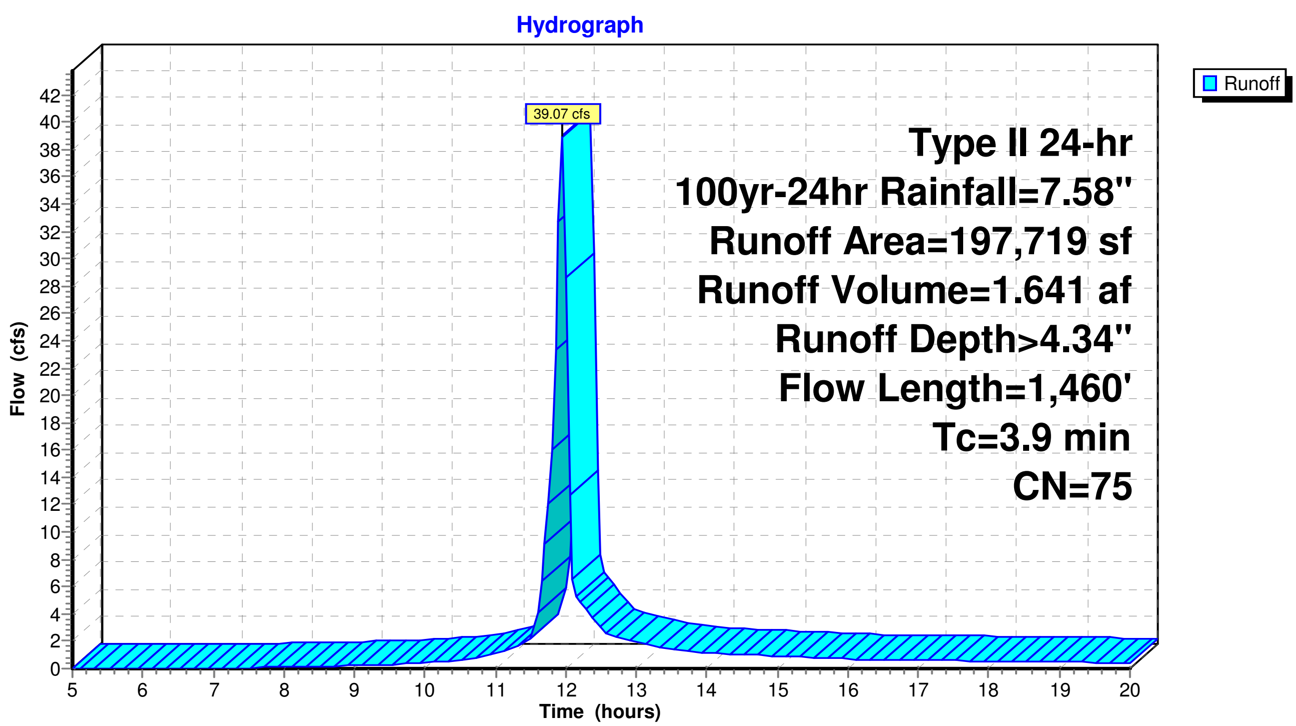
Runoff = 39.07 cfs @ 11.94 hrs, Volume= 1.641 af, Depth> 4.34"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100yr-24hr Rainfall=7.58"

	Area (sf)	CN	Description
*	185,740	74	
*	11,979	98	
	197,719	75	Weighted Average
	185,740		93.94% Pervious Area
	11,979		6.06% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	100	0.2500	3.63		**Sheet Flow, First 100 Feet** Smooth surfaces n= 0.011 P2= 2.95"
0.6	440	0.1000	12.07	265.58	**Channel Flow, Channel Flow** Area= 22.0 sf Perim= 17.7' r= 1.24' n= 0.045
2.8	920	0.0200	5.40	118.77	**Channel Flow, Channel Flow** Area= 22.0 sf Perim= 17.7' r= 1.24' n= 0.045
3.9	1,460	Total			

Subcatchment 7S: To South Perimeter Ditch (cover/some ash at east end)



Summary for Subcatchment 11S: Final Cover Conditions to South Perimeter Ditch

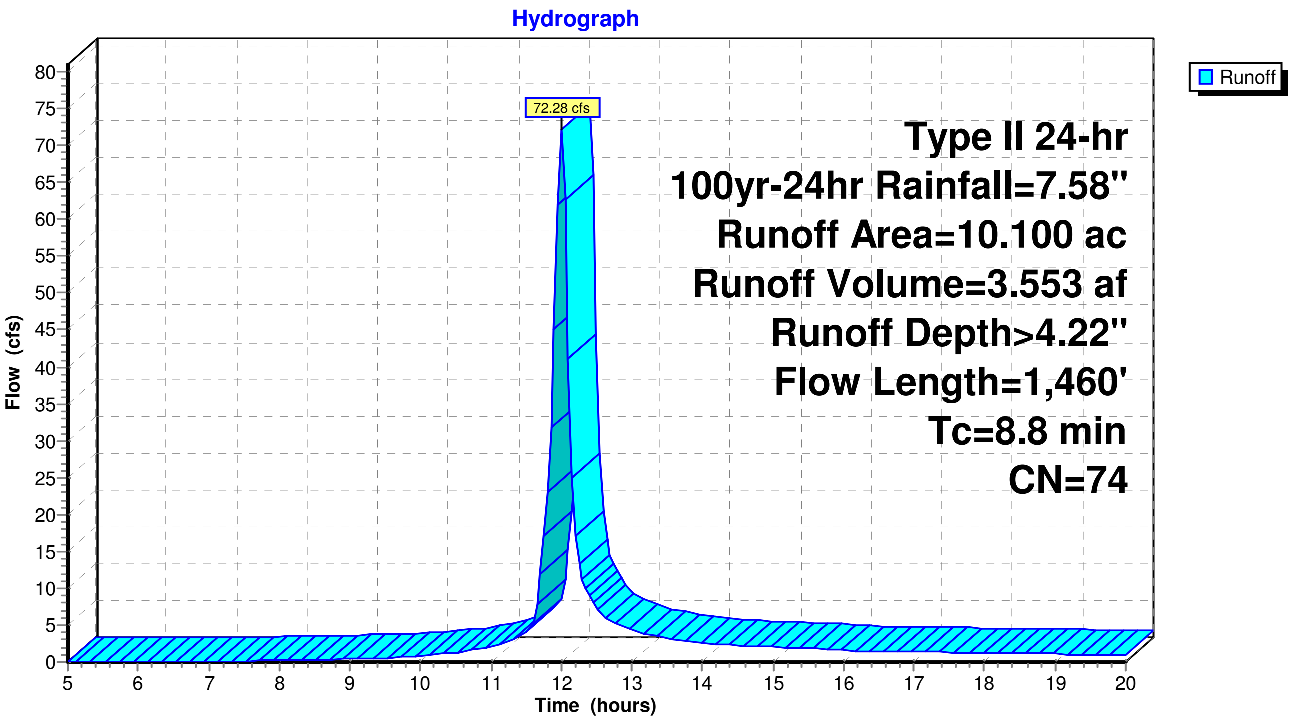
Runoff = 72.28 cfs @ 12.00 hrs, Volume= 3.553 af, Depth> 4.22"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100yr-24hr Rainfall=7.58"

	Area (ac)	CN	Description
*	10.100	74	
	10.100		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.4	100	0.2500	0.31		**Sheet Flow, First 100 Feet** Grass: Dense n= 0.240 P2= 2.95"
0.6	440	0.1000	12.07	265.58	**Channel Flow, Channel Flow** Area= 22.0 sf Perim= 17.7' r= 1.24' n= 0.045
2.8	920	0.0200	5.40	118.77	**Channel Flow, Channel Flow** Area= 22.0 sf Perim= 17.7' r= 1.24' n= 0.045
8.8	1,460	Total			

Subcatchment 11S: Final Cover Conditions to South Perimeter Ditch

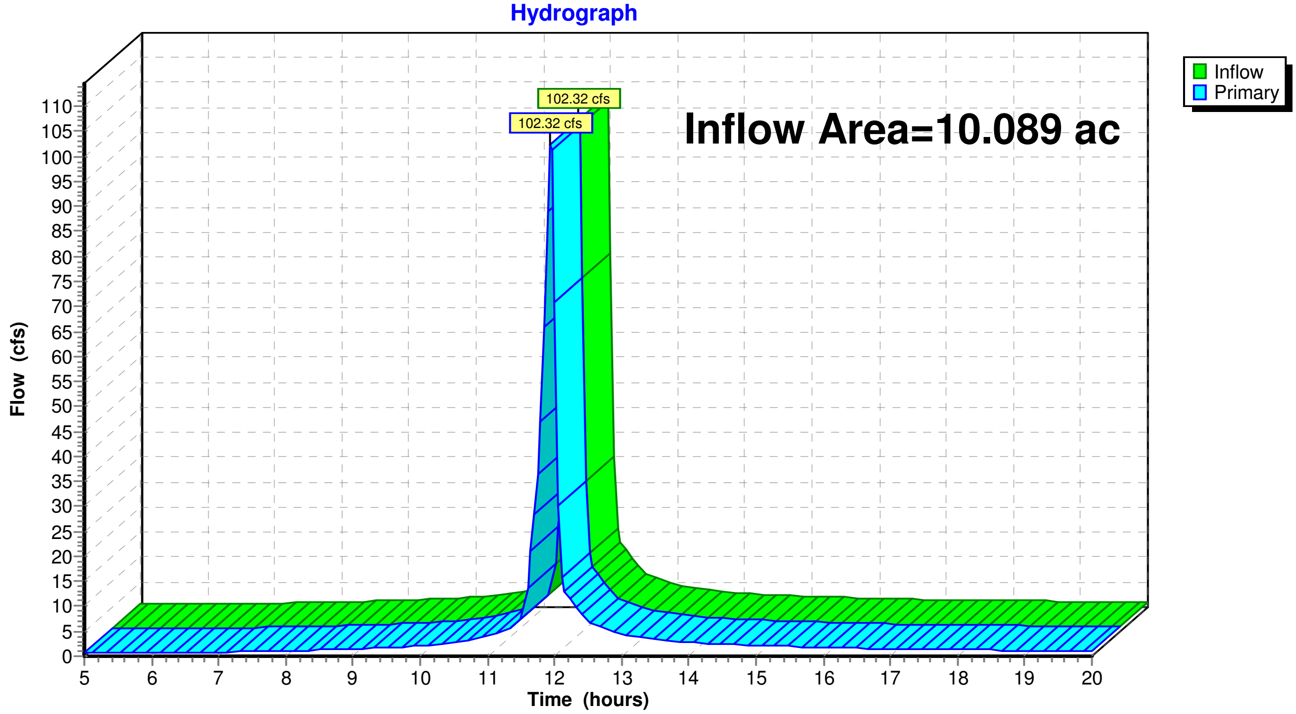


ummary for Link 6L: To South Perimeter Ditch - flow into ditch during Phase 1 closure, rest open condition

Inflow Area = 10.089 ac, 57.74% Impervious, Inflow Depth > 5.63" for 100yr-24hr event
Inflow = 102.32 cfs @ 11.94 hrs, Volume= 4.732 af
Primary = 102.32 cfs @ 11.94 hrs, Volume= 4.732 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Link 6L: To South Perimeter Ditch - flow into ditch during Phase 1 closure, rest open conditions



Grass-Lined Channel Sizing

Lining Type: Vegetation

Project ID: Alliant Lansing	
Location:	
Designer/Checker: BLP/JMO	
Date: 9/4/14 / 6/10/15	

	Ash/Cover Transition Swales		To SE bend in Perimeter ditch.		Ash and Ph 1 cover conditions To south perimeter ditch		Final cover conditions To south perimeter ditch	
	2% slope	**2% slope**	**10% slope**	**10% slope**	**2.0% slope**	**2.0% slope**	**1.2% slope**	**1.2% slope**
	ok	**ok**	**ok**	**ok**	**ok**	**ok**	**ok**	**ok**
Channel/Ditch Geometry	25 yr	100 yr	25 yr	100 yr	25 yr	100 yr	25 yr	100 yr
Channel Slope, S_o (ft/ft)	**0.02**	**0.02**	**0.10**	**0.10**	**0.02**	**0.02**	**0.012**	**0.012**
Channel Bottom Width, B (ft)	**0**	**0**	**5**	**5**	**5**	**5**	**5**	**5**
Channel Side Slope, z_1	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Channel Side Slope, z_2	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Flow Depth, d (ft) Solve iteratively	**1.61**	**1.79**	**0.26**	**0.33**	**1.55**	**1.85**	**1.56**	**1.92**
Safety Factor, SF	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
Vegetation/Soil Parameters								
Vegetation Retardance Class	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**
Vegetation Condition	**good**	**good**	**good**	**good**	**good**	**good**	**good**	**good**
Vegetation Growth Form	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**
Soil Type	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**
D_{75} (in) (Set at 0.00 for cohesive soils)								
ASTM Soil Class	**SC**	**SC**	**SC**	**SC**	**SC**	**SC**	**SC**	**SC**
Plasticity Index, PI	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**
Results Summary								
Design Q (ft^3/s)	**26.0**	**36.0**	**6.0**	**10.0**	**69.0**	**102.0**	**44.0**	**72.0**
Calculated Q (ft^3/s)	26.2	36.2	6.0	10.2	68.8	103.4	43.6	71.9
Difference Between Design & Calc. Flow (%)	0.9%	0.5%	0.8%	1.8%	-0.3%	1.4%	-0.9%	-0.2%
Stable (Yes or No)	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Channel Parameters								
Vegetation Height, h (ft)	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Grass Roughness Coefficient, C_n	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238
Cover Factor, C_f	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Noncohesive Soil								
Soil Grain Roughness, n_s	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Permissible Soil Shear Stress, τ_p (lb/ft^2)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cohesive Soil								
Porosity, e	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Soil Coefficient 1, c_1	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700
Soil Coefficient 2, c_2	14.30	14.30	14.30	14.30	14.30	14.30	14.30	14.30
Soil Coefficient 3, c_3	47.700	47.700	47.700	47.700	47.700	47.700	47.700	47.700
Soil Coefficient 4, c_4	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42
Soil Coefficient 5, c_5	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61
Soil Coefficient 6, c_6	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010
Permissible Soil Shear Stress, τ_p (lb/ft^2)	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Total Permissible Shear Stress, τ_p (lb/ft^2)	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Cross Sectional Area, A (ft^2)	7.776	9.612	1.516	2.010	14.958	19.518	15.101	20.659
Wetted Perimeter, P (ft)	10.24	11.38	6.67	7.13	14.86	16.76	14.92	17.21
Hydraulic Radius, R (ft)	0.760	0.844	0.227	0.282	1.007	1.164	1.012	1.200
Top Width, T (ft)	9.66	10.74	6.57	7.01	14.30	16.10	14.36	16.52
Hydraulic Depth, D (ft)	0.805	0.895	0.231	0.287	1.046	1.212	1.052	1.251
Froude Number (Q design)	0.663	0.701	1.464	1.667	0.793	0.848	0.496	0.548
Channel Shear Stress, τ_o (lb/ft^2)	0.95	1.05	1.42	1.76	1.26	1.45	0.76	0.90
Actual Sheer Stress, τ_d (lb/ft^2)	2.01	2.23	1.63	2.09	1.93	2.31	1.17	1.44
Mannings n	0.052	0.050	0.044	0.040	0.046	0.044	0.057	0.053
Average Velocity, V (ft/s)	3.34	3.75	3.96	4.97	4.61	5.23	2.91	3.49
Calculated Flow, Q (ft^3/s)	26.2	36.2	6.0	10.2	68.8	103.4	43.6	71.9
Difference Between Design & Calc. Flow (%)	0.9%	0.5%	0.8%	1.8%	-0.3%	1.4%	-0.9%	-0.2%
Effective Shear on Soil Surface, τ_e (lb/ft^2)	0.019	0.023	0.022	0.033	0.023	0.031	0.009	0.013
Total Permissible Shear on Veg., $\tau_{p,veg}$ (lb/ft^2)	8.46	7.82	6.06	5.01	6.62	6.06	10.17	8.79
Stable (Y or N)	YES	YES	YES	YES	YES	YES	YES	YES

Rock-Lined Channel Sizing

1	**Lining Type: Riprap**		
2	**Project ID: Alliant Lansing**		
3	**Location:**		
4	**Designer/Checker: BLP/JMO**		
5	**Date: 9/4/14 / 6/10/15**		
6			
7			
8		**9.7% swale**	**9.7% swale**
9	***Channel Geometry***	25 yr	100 yr
10	Channel Slope, S_o (ft/ft)	0.097	0.097
11	Channel Bottom Width, B (ft)	0	0
12	Channel Side Slope, z_1	4.3	4.3
13	Channel Side Slope, z_2	3.3	3.3
14	Curvature Radius, R_c (ft)	0	0
15	Depth of Flow, d (ft) Solve iteratively	1.28	1.41
16	***Riprap Parameters***		
17	Median Riprap Size, D_{50} (ft)	1.33	1.33
18	Riprap Specific Weight, γ_s (lb/ft^3)	165	165
19	Riprap Angle of Repose, ϕ , (degrees)	41.8	41.8
20	Safety Factor, SF	1.20	1.20
21	Safety Factor, SF (used in calculation)	1.50	1.50
22	***Results Summary***		
23	Design Flow, Q (ft^3/s)	26	36
24	Calculated Flow, Q (cfs)	26.00	36.0
25	Difference Between Design & Calc. Flow (%)	0.0%	0.0%
26	**Bottom Lining Stable (Yes or No)**	Yes	Yes
27	**Side Lining Stable (Yes or No)**		
28	**Bottom in Bend Stable (Yes or No)**	N/A	N/A
29	**Side in Bend Stable (Yes or No)**	N/A	N/A
30	**Downstream Length of Protection (ft)**	N/A	N/A
31	**Additional Freeboard Required, (ft)**	N/A	N/A
32	***Channel Parameters***		
33	Cross Sectional Area, A (ft^2)	6.19	7.60
34	Top Width, T (ft)	9.7	10.7
35	Average Depth, d_a (ft)	0.638	0.707
36	Wetted Perimeter, P (ft)	10.03	11.12
37	Hydraulic Radius, R (ft)	0.617	0.683
38	Depth to D_{50} Ratio, d_a/D_{50}	0.5	0.5
39	Mannings n	0.080	0.076
40	Average Velocity, V (ft/s)	4.20	4.74
41	Calculated Flow, Q (ft^3/s)	26.0	36.0
42	Difference Between Design & Calc. Flow (%)	0%	0%
43	Suggested Trial Depth, d_{i+1} (ft)	1.276	1.414
44	***Manning's n***		
45	Manning's n (Blodgett)	0.000	0.000
46	Manning's n (Bathurst)	0.080	0.076
47	Effective Roughness Concentration, b	0.255	0.265
48	Froude Number, Fr (design Q)	0.927	0.993
49	Froude Number function, f(Fr)	1.009	1.023
50	Roughness Element Geometry, f(REG)	6.1	6.6
51	Channel Geometry Function, f(CG)	0.500	0.487

52	***Bottom Shear***		
53	Shear Velocity, V_* (ft/s)	2.00	2.10
54	Reynolds Number, R_e	2.2E+05	2.3E+05
55	Shield's Parameter, F*	0.150	0.150
56	Safety Factor, SF	1.50	1.50
57	Maximum Shear Stress, τ_d (lb/ft^2)	7.72	8.56
58	Permissible Shear Stress, S_o<=10%, τ_p (lb/ft^2)	20.5	20.47
59	Stability Number, η	0.36	0.40
60	Steepest Channel Side Slope, z	3	3
61	Channel Side Slope Angle, θ (radians)	0.29	0.29
62	Channel Bottom Slope Angle, α (radians)	0.10	0.10
63	Riprap Angle of Repose, ϕ , (radians)	0.730	0.730
64	Weight Vector Angle, B (radians)	0.48	0.52
65	Channel Geometry and Riprap Size Func, Δ	1.40	1.40
66	Permissible Shear Stress, S_o>=5%, τ_p (lb/ft^2)	14.7	14.60
67	Permissible Shear based on Slope, τ_p (lb/ft^2)	14.7	14.6
68	Adjusted Permissible Shear, τ_p/SF (lb/ft^2)	9.8	9.7
69	Bottom Lining Stable (Yes or No)	Yes	Yes
70	Stable D_{50} (ft)	1.05	1.17
71	***Side Shear***		
72	Channel Side to Bottom Shear Stress Ratio, K_1	0.95	0.95
73	Channel Side Shear Stress, τ_s (lb/ft^2)	7.34	8.13
74	Side Slope Angle, θ (radians)	0.228	0.228
75	Side Slope Angle, θ (degrees)	13.1	13.1
76	Tractive Force Ratio, K_2	0.94	0.94
77	Permissible Side Tractive Force, τ_{ps} (lb/ft^2)		
78	Side Lining Stable (Yes or No)		
79	Stable D_{50} (ft)		
80	***Bend Shear***		
81	Curvature Radius, R_c (ft)	0	0
82	Ratio of Radius of Curvature to Top Width, R_c/T	N/A	N/A
83	f(Channel Bend and Bottom Shear Stress), K_b	N/A	N/A
84	Shear Stress on the Channel Bottom, τ_b (lb/ft^2)	N/A	N/A
85	Bottom in Bend Stable (Yes or No)	N/A	N/A
86	Shear Stress on the Channel Side, τ_{bs} (lb/ft^2)	N/A	N/A
87	Side in Bend Stable (Yes or No)	N/A	N/A
88	Downstream Length of Protection, L_p (ft)	N/A	N/A
89	Addition Freeboard Required, Δd (ft)	N/A	N/A

Ditch Transition Sizing

Rock Chute Design Data

(Version 4.03 - 11/29/11, Based on Design of Rock Chutes by Robinson, Rice, Kadavy, ASAE, 1998)

Project: WPL Lansing
County:
Designer: BLP
Checked by: JMO
Date: 09/08/14
Date: 06/10/15

Input Channel Geometry

Inlet Channel	Chute	Outlet Channel
Bw = 0.0 ft.	Bw = 5.0 ft.	Bw = 5.0 ft.
Side slopes = 4.3 (m:1)	Factor of safety = 1.20 (F_s)	Side slopes = 3.0 (m:1)
n-value = 0.040	Side slopes = 3.0 (m:1) → 2.0:1 max.	n-value = 0.030
Bed slope = 0.0200 ft./ft.	Bed slope (2.5:1) = 0.400 ft./ft. → 2.5:1 max.	Bed slope = 0.0150 ft./ft.
Minimum Fill = 0.0 ft.	Outlet apron depth, d = 1.0 ft.	Base flow = 0.0 cfs
Freeboard = 0.5 ft.		

Design Storm Data (Table 2, NHCP, NRCS Grade Stabilization Structure No. 410)

Drainage area = acres   Rainfall = ○ 0 - 3 in. ◉ 3 - 5 in. ○ 5+ in.

Apron elev. --- Inlet = 690.0 ft. --- Outlet = 686.0 ft. --- (H_{drop} = 3 ft.)

Chute capacity = Q5-year
Total capacity = Q10-year

Minimum capacity (based on a 5-year, 24-hour storm with a 3 - 5 inch rainfall)

Q_{high} = 75.0 cfs   High flow storm through chute → Tw (ft.) = Program   0.40

Q_{low} = 50.0 cfs   Low flow storm through chute → Tw (ft.) = Program

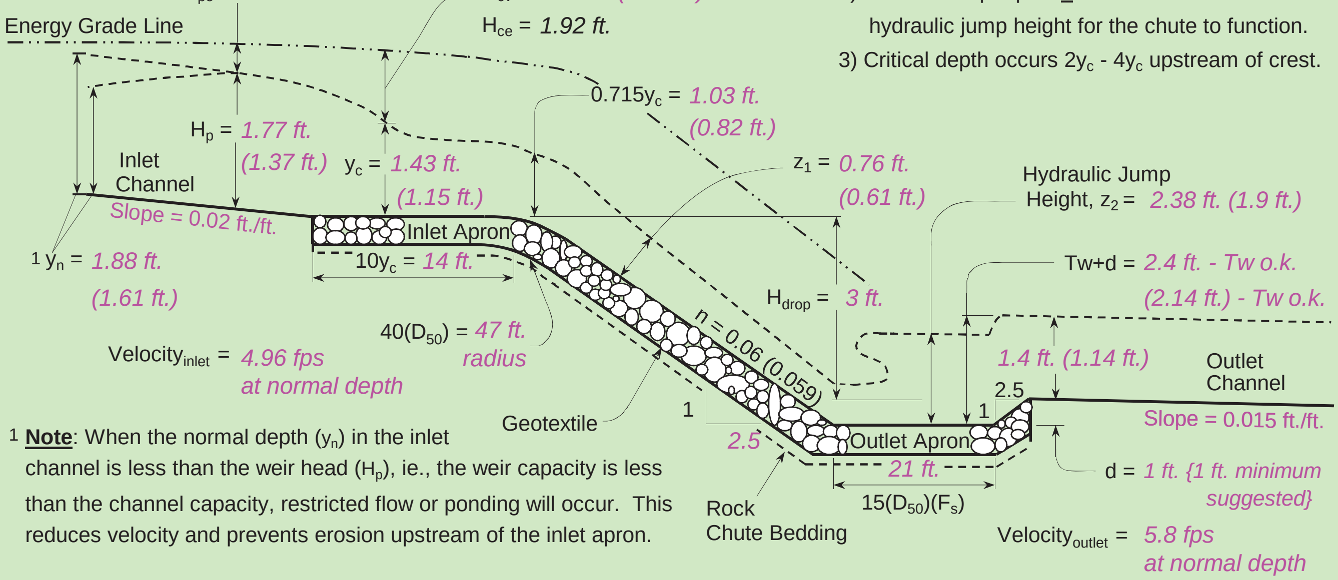
***Note**: The total required capacity is routed through the chute (principal spillway) or in combination with an auxiliary spillway.*

***Input tailwater (Tw)**:*

Profile and Cross Section (Output)

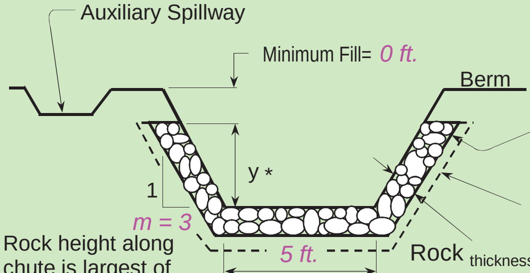
Notes:

1) Output given as ***High Flow (Low Flow)*** values.
2) Tailwater depth plus d must be at or above the hydraulic jump height for the chute to function.
3) Critical depth occurs $2y_c$ - $4y_c$ upstream of crest.



[1] **Note**: When the normal depth (y_n) in the inlet channel is less than the weir head (H_p), ie., the weir capacity is less than the channel capacity, restricted flow or ponding will occur. This reduces velocity and prevents erosion upstream of the inlet apron.

Profile Along Centerline of Chute



*Rock height along chute is largest of H_p(Qhigh), H_p(Qlow) + FB, and z_2.

Typical Cross Section

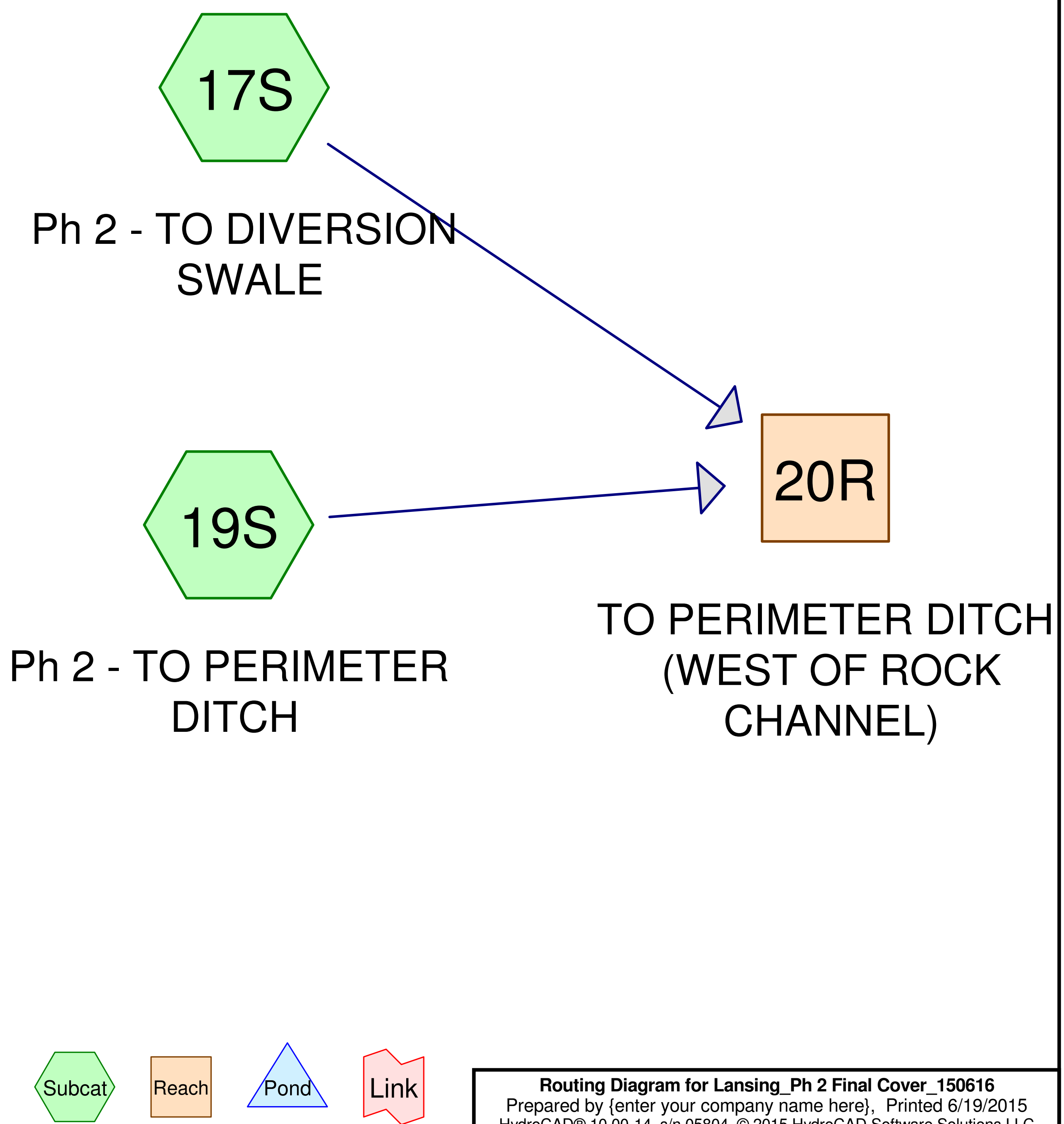
q_t =	9.75 cfs/ft.	Equivalent unit discharge
F_S =	1.20	Factor of safety (multiplier)
z_1 =	0.76 ft.	Normal depth in chute
n-value =	0.06	Manning's roughness coefficient
$D_{50}(F_s)$ =	16.8 in. (343 lbs.) - angular riprap	
$2(D_{50})(F_s)$ =	33.5 in.	Rock chute thickness
Tw + d =	2.4 ft.	Tailwater above outlet apron
z_2 =	2.38 ft.	Hydraulic jump height
****** The outlet***	***will***	***function adequately***

High Flow Storm Information

A3 Phase 2 Final Cover

HydroCAD Output

25-yr, 24-hr Storm Event



Routing Diagram for Lansing_Ph 2 Final Cover_150616
Prepared by {enter your company name here}, Printed 6/19/2015

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
2.390	98	Ash surface (17S)
7.070	74	Final Cover (19S)
9.460	**80**	**TOTAL AREA**

Soil Listing (selected nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
0.000	HSG B	
0.000	HSG C	
0.000	HSG D	
9.460	Other	17S, 19S
9.460		**TOTAL AREA**

Ground Covers (selected nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
0.000	0.000	0.000	0.000	2.390	2.390	Ash surface	17S
0.000	0.000	0.000	0.000	7.070	7.070	Final Cover	19S
0.000	**0.000**	**0.000**	**0.000**	**9.460**	**9.460**	**TOTAL AREA**	

Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 17S: Ph 2 - TO DIVERSION Runoff Area=2.390 ac 100.00% Impervious Runoff Depth>4.80"
Flow Length=1,766' Tc=5.0 min CN=98 Runoff=18.86 cfs 0.956 af

Subcatchment 19S: Ph 2 - TO PERIMETER Runoff Area=7.070 ac 0.00% Impervious Runoff Depth>2.53"
Flow Length=1,985' Tc=14.0 min CN=74 Runoff=25.85 cfs 1.489 af

Reach 20R: TO PERIMETER DITCH (WEST OF ROCK CHANNEL) Inflow=37.99 cfs 2.445 af
Outflow=37.99 cfs 2.445 af

Total Runoff Area = 9.460 ac Runoff Volume = 2.445 af Average Runoff Depth = 3.10"
74.74% Pervious = 7.070 ac 25.26% Impervious = 2.390 ac

Summary for Subcatchment 17S: Ph 2 - TO DIVERSION SWALE

[49] Hint: Tc<2dt may require smaller dt

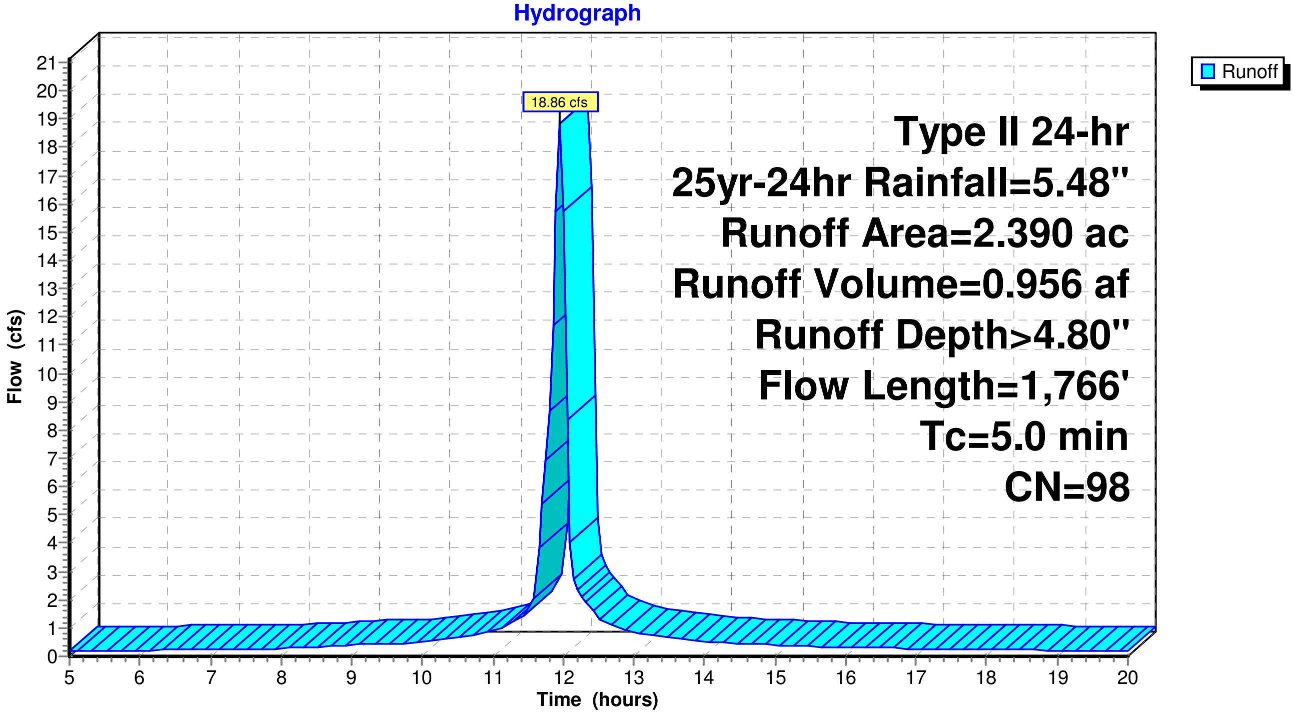
Runoff = 18.86 cfs @ 11.95 hrs, Volume= 0.956 af, Depth> 4.80"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25yr-24hr Rainfall=5.48"

	Area (ac)	CN	Description
*	2.390	98	Ash surface
	2.390		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	100	0.2500	3.63		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.95"
1.3	508	0.0200	6.68	45.06	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.50' Z= 4.0 & 2.0 '/' Top.W=9.00' n= 0.025
1.6	626	0.0180	6.33	42.75	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.50' Z= 4.0 & 2.0 '/' Top.W=9.00' n= 0.025
0.8	215	0.0760	4.65	31.37	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.50' Z= 4.0 & 2.0 '/' Top.W=9.00' n= 0.070
0.3	121	0.0170	6.15	41.54	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.50' Z= 4.0 & 2.0 '/' Top.W=9.00' n= 0.025
0.5	196	0.1500	6.53	44.07	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.50' Z= 4.0 & 2.0 '/' Top.W=9.00' n= 0.070
5.0	1,766	Total			

Subcatchment 17S: Ph 2 - TO DIVERSION SWALE



Summary for Subcatchment 19S: Ph 2 - TO PERIMETER DITCH

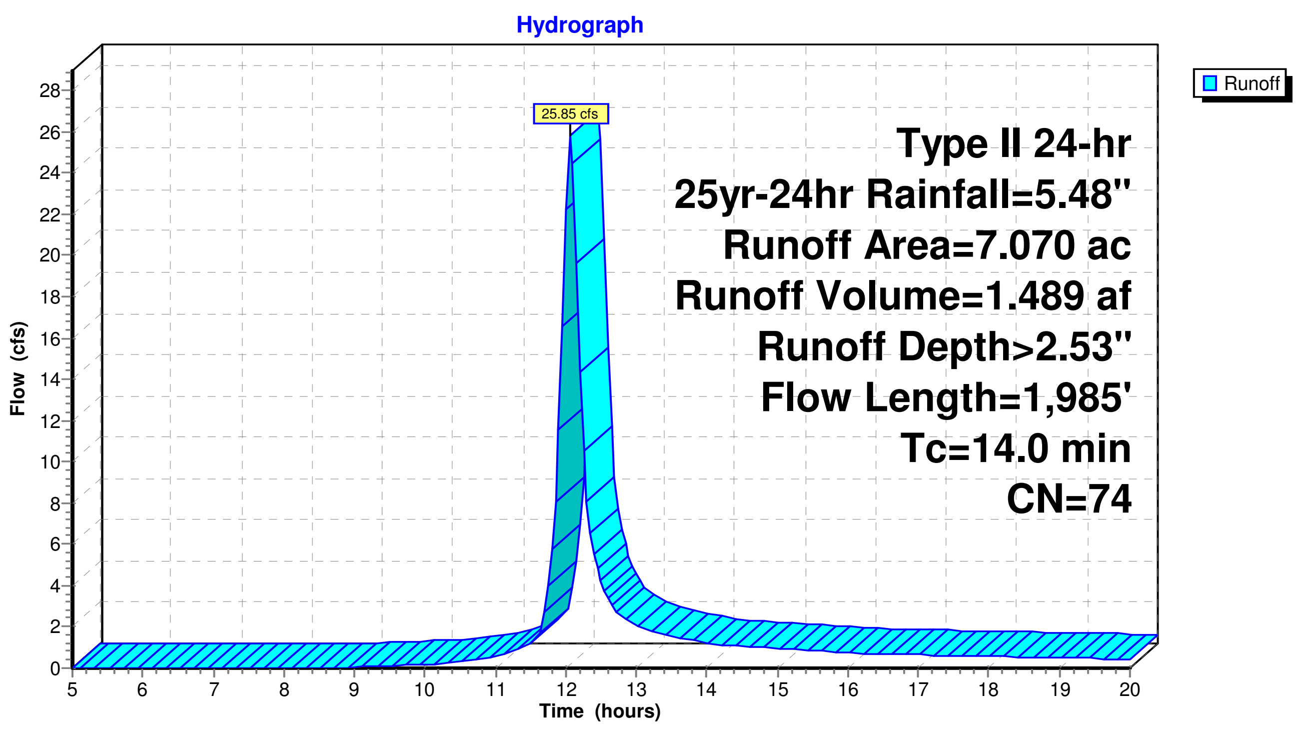
Runoff = 25.85 cfs @ 12.06 hrs, Volume= 1.489 af, Depth> 2.53"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25yr-24hr Rainfall=5.48"

	Area (ac)	CN	Description
*	7.070	74	Final Cover
	7.070		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.4	100	0.2500	0.31		**Sheet Flow, First 100 Feet** Grass: Dense n= 0.240 P2= 2.95"
0.6	270	0.0722	7.02	56.19	**Trap/Vee/Rect Channel Flow,** Bot.W=5.00' D=1.00' Z= 2.0 & 4.0 '/' Top.W=11.00' n= 0.045
4.8	1,030	0.0185	3.56	28.44	**Trap/Vee/Rect Channel Flow,** Bot.W=5.00' D=1.00' Z= 2.0 & 4.0 '/' Top.W=11.00' n= 0.045
3.2	585	0.0137	3.06	24.48	**Trap/Vee/Rect Channel Flow,** Bot.W=5.00' D=1.00' Z= 4.0 & 2.0 '/' Top.W=11.00' n= 0.045
14.0	1,985	Total			

Subcatchment 19S: Ph 2 - TO PERIMETER DITCH



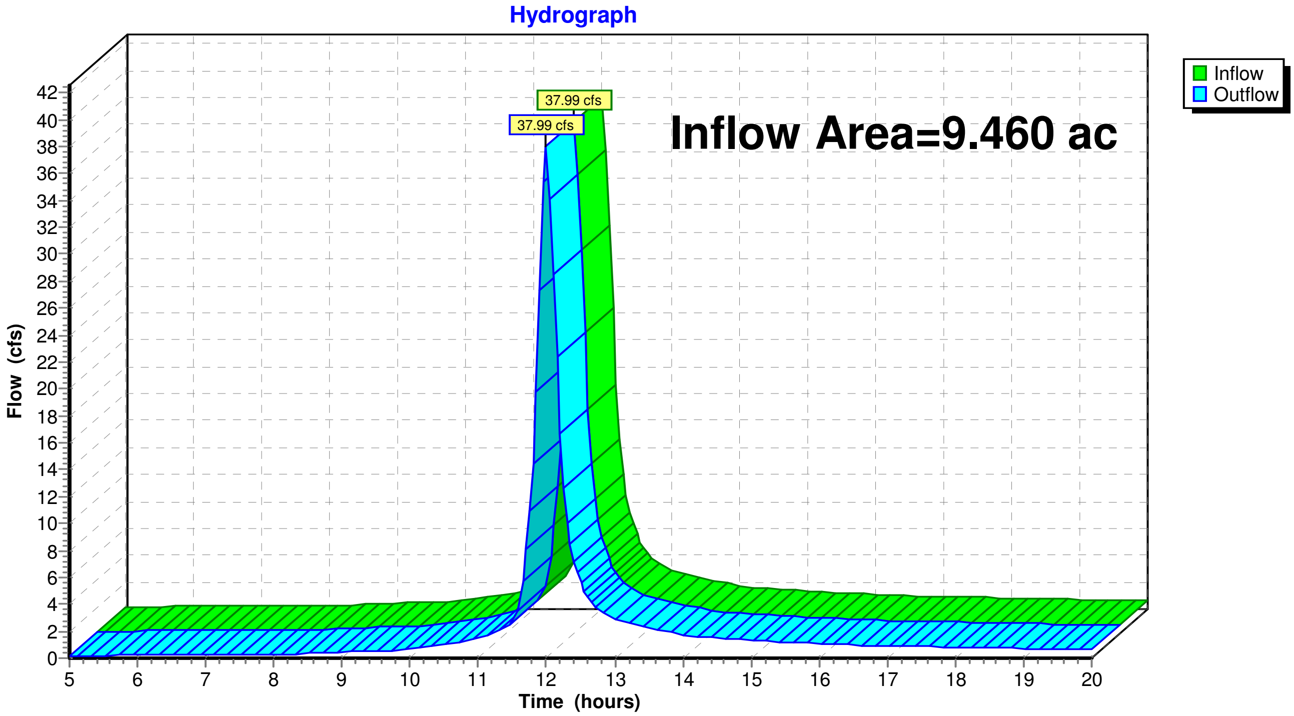
Summary for Reach 20R: TO PERIMETER DITCH (WEST OF ROCK CHANNEL)

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 9.460 ac, 25.26% Impervious, Inflow Depth > 3.10" for 25yr-24hr event
Inflow = 37.99 cfs @ 11.99 hrs, Volume= 2.445 af
Outflow = 37.99 cfs @ 11.99 hrs, Volume= 2.445 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Reach 20R: TO PERIMETER DITCH (WEST OF ROCK CHANNEL)



Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 17S: Ph 2 - TO DIVERSION Runoff Area=2.390 ac 100.00% Impervious Runoff Depth>6.69"
Flow Length=1,766' Tc=5.0 min CN=98 Runoff=26.14 cfs 1.331 af

Subcatchment 19S: Ph 2 - TO PERIMETER Runoff Area=7.070 ac 0.00% Impervious Runoff Depth>4.21"
Flow Length=1,985' Tc=14.0 min CN=74 Runoff=42.57 cfs 2.483 af

Reach 20R: TO PERIMETER DITCH (WEST OF ROCK CHANNEL) Inflow=59.15 cfs 3.814 af
Outflow=59.15 cfs 3.814 af

Total Runoff Area = 9.460 ac Runoff Volume = 3.814 af Average Runoff Depth = 4.84"
74.74% Pervious = 7.070 ac 25.26% Impervious = 2.390 ac

Summary for Subcatchment 17S: Ph 2 - TO DIVERSION SWALE

[49] Hint: Tc<2dt may require smaller dt

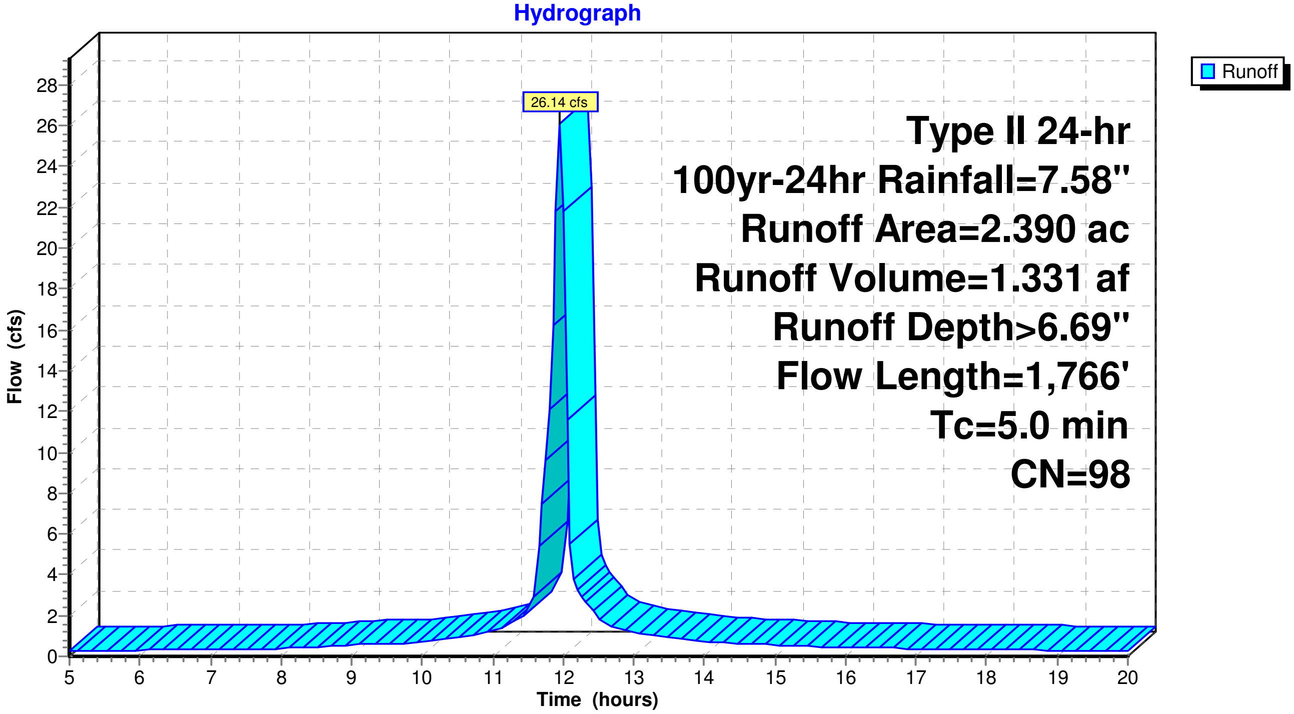
Runoff = 26.14 cfs @ 11.95 hrs, Volume= 1.331 af, Depth> 6.69"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100yr-24hr Rainfall=7.58"

	Area (ac)	CN	Description
*	2.390	98	Ash surface
	2.390		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.5	100	0.2500	3.63		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 2.95"
1.3	508	0.0200	6.68	45.06	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.50' Z= 4.0 & 2.0 '/' Top.W=9.00' n= 0.025
1.6	626	0.0180	6.33	42.75	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.50' Z= 4.0 & 2.0 '/' Top.W=9.00' n= 0.025
0.8	215	0.0760	4.65	31.37	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.50' Z= 4.0 & 2.0 '/' Top.W=9.00' n= 0.070
0.3	121	0.0170	6.15	41.54	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.50' Z= 4.0 & 2.0 '/' Top.W=9.00' n= 0.025
0.5	196	0.1500	6.53	44.07	**Trap/Vee/Rect Channel Flow,** Bot.W=0.00' D=1.50' Z= 4.0 & 2.0 '/' Top.W=9.00' n= 0.070
5.0	1,766	Total			

Subcatchment 17S: Ph 2 - TO DIVERSION SWALE



Summary for Subcatchment 19S: Ph 2 - TO PERIMETER DITCH

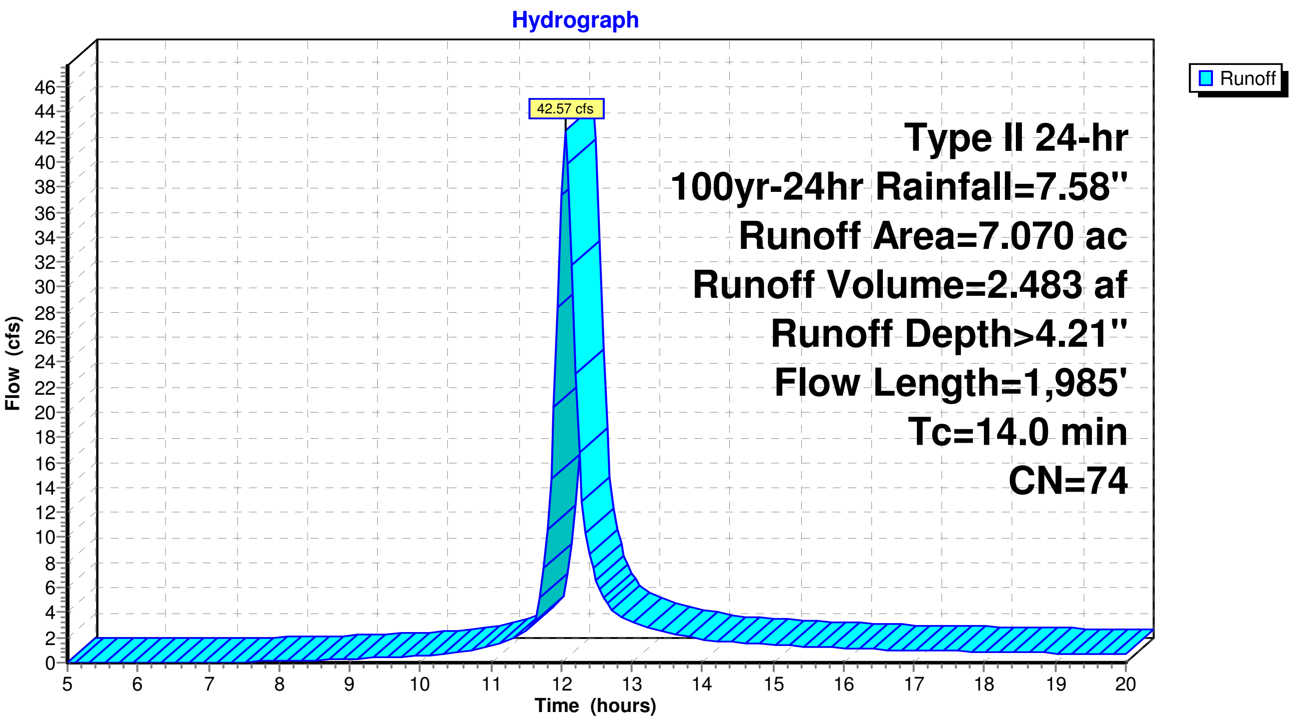
Runoff = 42.57 cfs @ 12.06 hrs, Volume= 2.483 af, Depth> 4.21"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100yr-24hr Rainfall=7.58"

	Area (ac)	CN	Description
*	7.070	74	Final Cover
	7.070		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.4	100	0.2500	0.31		**Sheet Flow, First 100 Feet** Grass: Dense n= 0.240 P2= 2.95"
0.6	270	0.0722	7.02	56.19	**Trap/Vee/Rect Channel Flow,** Bot.W=5.00' D=1.00' Z= 2.0 & 4.0 '/' Top.W=11.00' n= 0.045
4.8	1,030	0.0185	3.56	28.44	**Trap/Vee/Rect Channel Flow,** Bot.W=5.00' D=1.00' Z= 2.0 & 4.0 '/' Top.W=11.00' n= 0.045
3.2	585	0.0137	3.06	24.48	**Trap/Vee/Rect Channel Flow,** Bot.W=5.00' D=1.00' Z= 4.0 & 2.0 '/' Top.W=11.00' n= 0.045
14.0	1,985	Total			

Subcatchment 19S: Ph 2 - TO PERIMETER DITCH



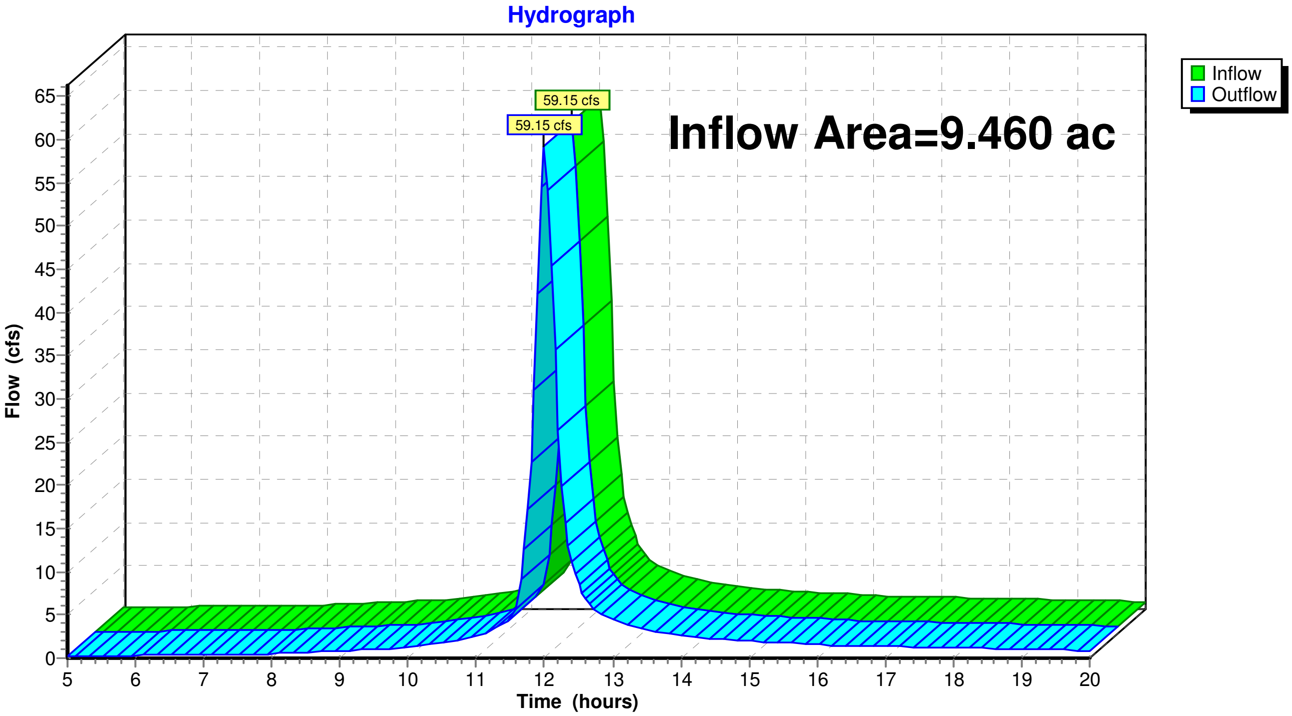
Summary for Reach 20R: TO PERIMETER DITCH (WEST OF ROCK CHANNEL)

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 9.460 ac, 25.26% Impervious, Inflow Depth > 4.84" for 100yr-24hr event
Inflow = 59.15 cfs @ 12.00 hrs, Volume= 3.814 af
Outflow = 59.15 cfs @ 12.00 hrs, Volume= 3.814 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Reach 20R: TO PERIMETER DITCH (WEST OF ROCK CHANNEL)



Grass-Lined Channel Sizing

Lining Type: Vegetation

Project ID: Alliant Lansing Ph 2 Final Cover	
Location:	
Designer/Checker: JMO/BJM	
Date: 6/17/15, Revised: 7/7/15	

	Ash/Cover Transition Swales						Ash, Ph 1 & Ph 2 cover conditions To south perimeter ditch	
	2.0% slope	**2.0% slope**	**7.6% slope**	**7.6% slope**	**1.7% slope**	**1.7% slope**	**1.37% slope**	**1.37% slope**
	Check Stability - OK		**Check Stability - Not OK, Use Rock Lining**		**Check Capacity - OK**		**Check Capacity - OK**	
Channel/Ditch Geometry	25 yr	100 yr	25 yr	100 yr	25 yr	100 yr	25 yr	100 yr
Channel Slope, S_o (ft/ft)	**0.02**	**0.02**	**0.076**	**0.076**	**0.017**	**0.017**	**0.0137**	**0.0137**
Channel Bottom Width, B (ft)	**0**	**0**	**0**	**0**	**0**	**0**	**5**	**5**
Channel Side Slope, z_1	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Channel Side Slope, z_2	**4**	**4**	**3**	**2**	**4**	**4**	**2**	**2**
Flow Depth, d (ft) Solve iteratively	**1.30**	**1.45**	**0.92**	**1.09**	**1.36**	**1.52**	**1.42**	**1.72**
Safety Factor, SF	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	
Vegetation/Soil Parameters								
Vegetation Retardance Class	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**
Vegetation Condition	**good**	**good**	**good**	**good**	**good**	**good**	**good**	**good**
Vegetation Growth Form	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**	**turf**
Soil Type	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**	**cohesive**
D_{75} (in) (Set at 0.00 for cohesive soils)								
ASTM Soil Class	**SM**	**SM**	**SM**	**SM**	**SM**	**SM**	**SM**	**SM**
Plasticity Index, PI	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**
Results Summary								
Design Q (ft^3/s)	**18.86**	**26.14**	**18.33**	**26.14**	**18.33**	**26.14**	**39.87**	**61.98**
Calculated Q (ft^3/s)	18.7	26.4	18.6	26.2	18.5	26.2	39.9	62.3
Difference Between Design & Calc. Flow (%)	-0.8%	1.2%	1.363%	0.1%	0.7%	0.1%	0.2%	0.5%
Stable (Yes or No)	**YES**	**YES**	**NO**	**NO**	**YES**	**YES**	**YES**	**YES**
Channel Parameters								
Vegetation Height, h (ft)	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Grass Roughness Coefficient, C_n	0.238	0.238	0.238	0.238	0.238	0.238	0.238	0.238
Cover Factor, C_f	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Noncohesive Soil								
Soil Grain Roughness, n_s	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Permissible Soil Shear Stress, τ_p (lb/ft^2)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cohesive Soil								
Porosity, e	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Soil Coefficient 1, c_1	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700	1.0700
Soil Coefficient 2, c_2	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15
Soil Coefficient 3, c_3	11.900	11.900	11.900	11.900	11.900	11.900	11.900	11.900
Soil Coefficient 4, c_4	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42
Soil Coefficient 5, c_5	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61	-0.61
Soil Coefficient 6, c_6	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010	0.00010
Permissible Soil Shear Stress, τ_p (lb/ft^2)	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
Total Permissible Shear Stress, τ_p (lb/ft^2)	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
Cross Sectional Area, A (ft^2)	6.760	8.410	2.962	3.571	7.398	9.242	13.149	17.475
Wetted Perimeter, P (ft)	10.72	11.96	6.70	6.94	11.21	12.53	14.03	15.94
Hydraulic Radius, R (ft)	0.631	0.703	0.442	0.515	0.660	0.737	0.937	1.096
Top Width, T (ft)	10.40	11.60	6.44	6.55	10.88	12.16	13.52	15.32
Hydraulic Depth, D (ft)	0.650	0.725	0.460	0.546	0.680	0.760	0.973	1.141
Froude Number (Q design)	0.605	0.651	1.630	1.748	0.533	0.572	0.543	0.588
Channel Shear Stress, τ_o (lb/ft^2)	0.79	0.88	2.10	2.44	0.70	0.78	0.80	0.94
Actual Sheer Stress, τ_d (lb/ft^2)	1.62	1.81	4.36	5.17	1.44	1.61	1.21	1.47
Mannings n	0.056	0.053	0.038	0.036	0.059	0.056	0.055	0.052
Average Velocity, V (ft/s)	2.79	3.11	6.19	7.32	2.48	2.83	3.03	3.55
Calculated Flow, Q (ft^3/s)	18.7	26.4	18.6	26.2	18.5	26.2	39.9	62.3
Difference Between Design & Calc. Flow (%)	-0.8%	1.2%	1.4%	0.1%	0.7%	0.1%	0.2%	0.5%
Effective Shear on Soil Surface, τ_e (lb/ft^2)	0.013	0.016	0.077	0.102	0.011	0.013	0.010	0.014
Total Permissible Shear on Veg., $\tau_{p,veg}$ (lb/ft^2)	7.58	6.79	3.49	3.13	8.41	7.58	7.31	6.53
Stable (Y or N)	YES	YES	NO	NO	YES	YES	YES	YES

Rock-Lined Channel Sizing

Lining Type: Riprap

Project ID: Alliant Lansing Ph 2 Final Cover
Location:
Designer/Checker: JMO/BJM
Date: 06/17/2015, Revised: 07/06/15

	7.6% swale	**7.6% swale**	**15% swale**	**15% swale**
Channel Geometry	25 yr	100 yr	25 yr	100 yr
Channel Slope, S_o (ft/ft)	0.076	0.076	0.15	0.15
Channel Bottom Width, B (ft)	0	0	0	0
Channel Side Slope, z_1	4	4	4	4
Channel Side Slope, z_2	4	4	4	4
Curvature Radius, R_c (ft)	0	0	0	0
Depth of Flow, d (ft) Solve iteratively	1.22	1.35	0.98	1.09
Riprap Parameters				
Median Riprap Size, D_{50} (ft)	1.33	1.33	1.33	1.33
Riprap Specific Weight, γ_s (lb/ft^3)	165	165	165	165
Riprap Angle of Repose, ϕ , (degrees)	41.8	41.8	41.8	41.8
Safety Factor, SF	1.20	1.20	1.20	1.20
Safety Factor, SF (used in calculation)	1.47	1.50	1.50	1.50
Results Summary				
Design Flow, Q (ft^3/s)	**18.86**	**26.14**	**18.86**	**26.14**
Calculated Flow, Q (cfs)	18.9	26.3	19.0	26.4
Difference Between Design & Calc. Flow (%)	0.4%	0.4%	0.8%	0.9%
Bottom Lining Stable (Yes or No)	Yes	Yes	Yes	Yes
Side Lining Stable (Yes or No)				
Bottom in Bend Stable (Yes or No)	N/A	N/A	N/A	N/A
Side in Bend Stable (Yes or No)	N/A	N/A	N/A	N/A
Downstream Length of Protection (ft)	N/A	N/A	N/A	N/A
Additional Freeboard Required, (ft)	N/A	N/A	N/A	N/A
Channel Parameters				
Cross Sectional Area, A (ft^2)	5.95	7.29	3.84	4.75
Top Width, T (ft)	9.8	10.8	7.8	8.7
Average Depth, d_a (ft)	0.610	0.675	0.490	0.545
Wetted Perimeter, P (ft)	10.06	11.13	8.08	8.99
Hydraulic Radius, R (ft)	0.592	0.655	0.475	0.529
Depth to D_{50} Ratio, d_a/D_{50}	0.5	0.5	0.4	0.4
Mannings n	0.091	0.086	0.071	0.068
Average Velocity, V (ft/s)	3.18	3.60	4.95	5.55
Calculated Flow, Q (ft^3/s)	18.9	26.3	19.0	26.4
Difference Between Design & Calc. Flow (%)	0%	0%	1%	1%

Suggested Trial Depth, d_{i+1} (ft)	1.218	1.348	0.977	1.086
Manning's n				
Manning's n (Blodgett)	0.000	0.000	0.000	0.000
Manning's n (Bathurst)	0.091	0.086	0.071	0.068
Effective Roughness Concentration, b	0.245	0.254	0.226	0.235
Froude Number, Fr (design Q)	0.715	0.769	1.236	1.313
Froude Number function, f(Fr)	0.906	0.925	1.248	1.254
Roughness Element Geometry, f(REG)	5.8	6.2	4.9	5.3
Channel Geometry Function, f(CG)	0.507	0.494	0.534	0.521
Bottom Shear				
Shear Velocity, V_* (ft/s)	1.73	1.82	2.18	2.29
Reynolds Number, R_e	1.9E+05	2.0E+05	2.4E+05	2.5E+05
Shield's Parameter, F*	0.143	0.149	0.150	0.150
Safety Factor, SF	1.47	1.50	1.50	1.50
Maximum Shear Stress, τ_d (lb/ft^2)	5.79	6.40	9.17	10.20
Permissible Shear Stress, S_o<=10%, τ_p (lb/ft^2)	19.5	20.33	20.5	20.47
Stability Number, η	0.28	0.29	0.42	0.46
Steepest Channel Side Slope, z	4	4	4	4
Channel Side Slope Angle, θ (radians)	0.24	0.24	0.24	0.24
Channel Bottom Slope Angle, α (radians)	0.08	0.08	0.15	0.15
Riprap Angle of Repose, ϕ , (radians)	0.730	0.730	0.730	0.730
Weight Vector Angle, Β (radians)	0.45	0.48	0.60	0.64
Channel Geometry and Riprap Size Func, Δ	1.14	1.16	1.23	1.24
Permissible Shear Stress, S_o>=5%, τ_p (lb/ft^2)	17.1	17.48	16.6	16.57
Permissible Shear based on Slope, τ_p (lb/ft^2)	17.1	17.5	16.6	16.6
Adjusted Permissible Shear, τ_p/SF (lb/ft^2)	11.6	11.7	11.1	11.0
Bottom Lining Stable (Yes or No)	Yes	Yes	Yes	Yes
Stable D_{50} (ft)	0.66	0.73	1.10	1.23
Side Shear				
Channel Side to Bottom Shear Stress Ratio, K_1	0.93	0.93	0.93	0.93

Channel Side Shear Stress, τ_s (lb/ft^2)	5.38	5.95	8.53	9.49
Side Slope Angle, θ (radians)	0.245	0.245	0.245	0.245
Side Slope Angle, θ (degrees)	14.0	14.0	14.0	14.0
Tractive Force Ratio, K_2	0.93	0.93	0.93	0.93
Permissible Side Tractive Force, τ_{ps} (lb/ft^2)				
Side Lining Stable (Yes or No)				
Stable D_{50} (ft)				
Bend Shear				
Curvature Radius, R_c (ft)	0	0	0	0
Ratio of Radius of Curvature to Top Width, R_c/T	N/A	N/A	N/A	N/A
f(Channel Bend and Bottom Shear Stress), K_b	N/A	N/A	N/A	N/A
Shear Stress on the Channel Bottom, τ_b (lb/ft^2)	N/A	N/A	N/A	N/A
Bottom in Bend Stable (Yes or No)	N/A	N/A	N/A	N/A
Shear Stress on the Channel Side, τ_{bs} (lb/ft^2)	N/A	N/A	N/A	N/A
Side in Bend Stable (Yes or No)	N/A	N/A	N/A	N/A
Downstream Length of Protection, L_p (ft)	N/A	N/A	N/A	N/A
Addition Freeboard Required, Δd (ft)	N/A	N/A	N/A	N/A

Ditch Transition Sizing

Rock Chute Design Data

(Version 4.03 - 11/29/11, Based on Design of Rock Chutes by Robinson, Rice, Kadavy, ASAE, 1998)

Project: *WPL Lansing Ph 2 Final Cover* **County:** *Allamakee*
Designer: *JMO* **Checked by:** BJM
Date: 06/17/15 **Date:** 10/14/15

Input Channel Geometry

Inlet Channel	Chute	Outlet Channel
Bw = *0.0* ft.	Bw = *0.0* ft.	Bw = *5.0* ft.
Side slopes = *4.3* (m:1)	Factor of safety = *1.20* (F_s)	Side slopes = *3.0* (m:1)
n-value = *0.070*	Side slopes = *4.0* (m:1) → ***2.0:1 max.***	n-value = *0.045*
Bed slope = *0.0170* ft./ft.	Bed slope (6.7:1) = *0.150* ft./ft. → ***2.5:1 max.***	Bed slope = *0.0150* ft./ft.
Minimum Fill = *0.0* ft.	Outlet apron depth, d = *1.0* ft.	Base flow = *0.0* cfs
Freeboard = *0.5* ft.		

Design Storm Data (Table 2, NHCP, NRCS Grade Stabilization Structure No. 410)

Drainage area = acres Rainfall = ○ 0 - 3 in. ◉ 3 - 5 in. ○ 5+ in.

Apron elev. --- Inlet = *712.0* ft. --- Outlet = *682.0* ft. --- (H_{drop} = 29 ft.)

Chute capacity = Q25-year *Minimum capacity (based on a 5-year,*
Total capacity = Q100-year *24-hour storm with a 3 - 5 inch rainfall)*

Q_{high}= *26.1* cfs High flow storm through chute → Tw (ft.) = *Program*

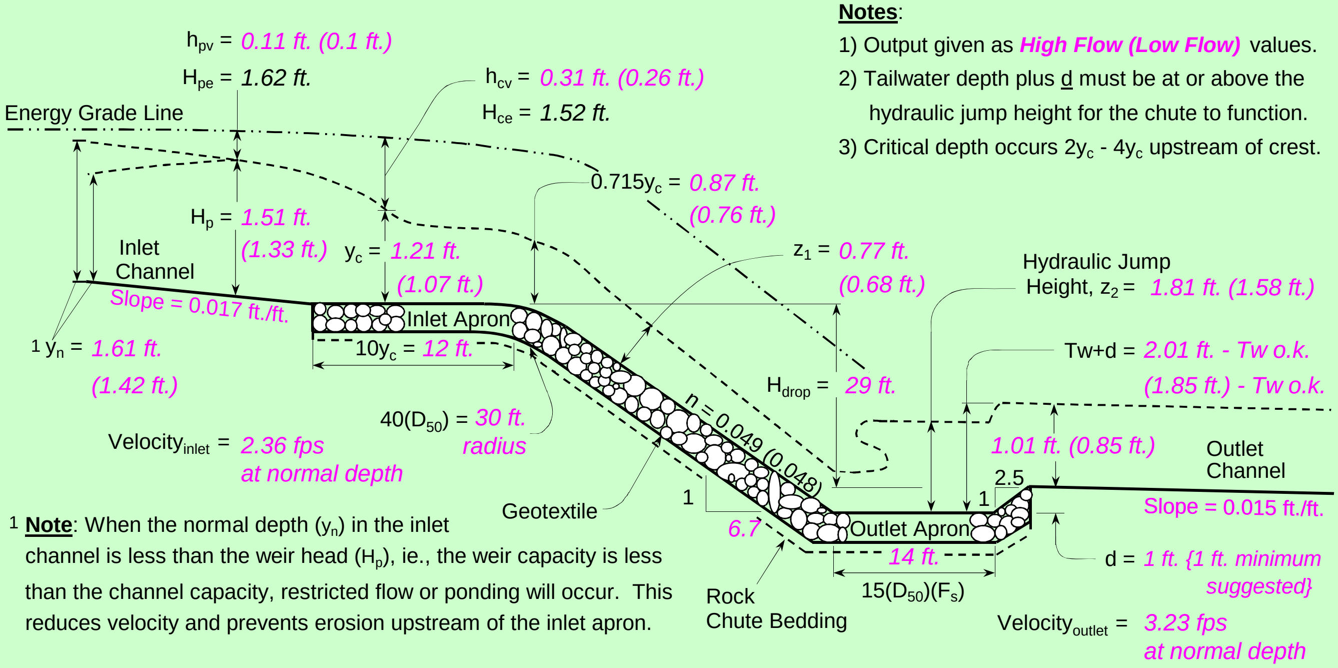
Q_{low} = *18.9* cfs Low flow storm through chute → Tw (ft.) = *Program*

***Note**: The total required capacity is routed through the chute (principal spillway) or in combination with an auxiliary spillway.*

***Input tailwater (Tw)**:*

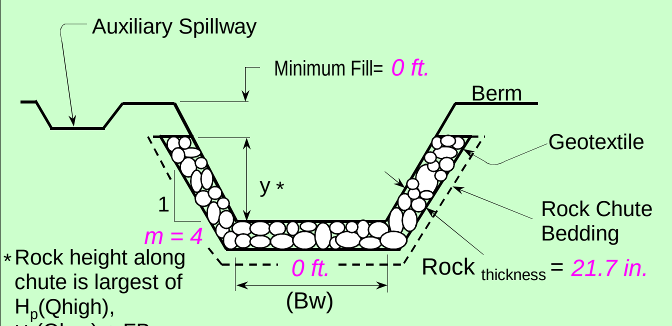
Profile and Cross Section (Output)

Notes:
1) Output given as ***High Flow (Low Flow)*** values.
2) Tailwater depth plus d must be at or above the hydraulic jump height for the chute to function.
3) Critical depth occurs $2y_c$ - $4y_c$ upstream of crest.



[1] **Note**: When the normal depth (y_n) in the inlet channel is less than the weir head (H_p), ie., the weir capacity is less than the channel capacity, restricted flow or ponding will occur. This reduces velocity and prevents erosion upstream of the inlet apron.

Profile Along Centerline of Chute



*Rock height along chute is largest of H_p(Qhigh), H_p(Qlow) + FB, and z_2.

Typical Cross Section

q_t =	*7.6 cfs/ft.*	Equivalent unit discharge
F_S =	*1.20*	Factor of safety (multiplier)
z_1 =	*0.77 ft.*	Normal depth in chute
n-value =	*0.049*	Manning's roughness coefficient
$D_{50}(F_S)$ =	*10.9 in. (94 lbs.) - angular riprap*	
$2(D_{50})(F_S)$ =	*21.7 in.*	Rock chute thickness
Tw + d =	*2.01 ft.*	Tailwater above outlet apron
z_2 =	*1.81 ft.*	Hydraulic jump height
****** The outlet***	***will***	***function adequately***

High Flow Storm Information

Rock_Chute.xls

Perimeter Ditch Transition

Rock Chute Design Data

(Version 4.03 - 11/29/11, Based on Design of Rock Chutes by Robinson, Rice, Kadavy, ASAE, 1998)

Project: *WPL Lansing Ph 2 Final Cover* **County:** *Allamakee*
Designer: *JMO* **Checked by:** BJM
Date: 06/18/15 **Date:** 10/14/15

Input Channel Geometry

Inlet Channel	Chute	Outlet Channel
Bw = *0.0* ft.	Bw = *5.0* ft.	Bw = *5.0* ft.
Side slopes = *4.3* (m:1)	Factor of safety = *1.20* (F_s)	Side slopes = *3.0* (m:1)
n-value = *0.040*	Side slopes = *3.0* (m:1) → ***2.0:1 max.***	n-value = *0.030*
Bed slope = *0.0200* ft./ft.	Bed slope (2.5:1) = *0.400* ft./ft. → ***2.5:1 max.***	Bed slope = *0.0150* ft./ft.
Minimum Fill = *0.0* ft.	Outlet apron depth, d = *1.0* ft.	Base flow = *0.0* cfs
Freeboard = *0.5* ft.		

Design Storm Data (Table 2, NHCP, NRCS Grade Stabilization Structure No. 410)

Drainage area = acres Rainfall = ○ 0 - 3 in. ◉ 3 - 5 in. ○ 5+ in.

Apron elev. --- Inlet = *684.0* ft. --- Outlet = *680.0* ft. --- (H_{drop} = 3 ft.)

Chute capacity = Q5-year | *Minimum capacity (based on a 5-year,*
Total capacity = Q10-year | *24-hour storm with a 3 - 5 inch rainfall)*

Q_{high} = *62.0* cfs High flow storm through chute → Tw (ft.) = *Program*

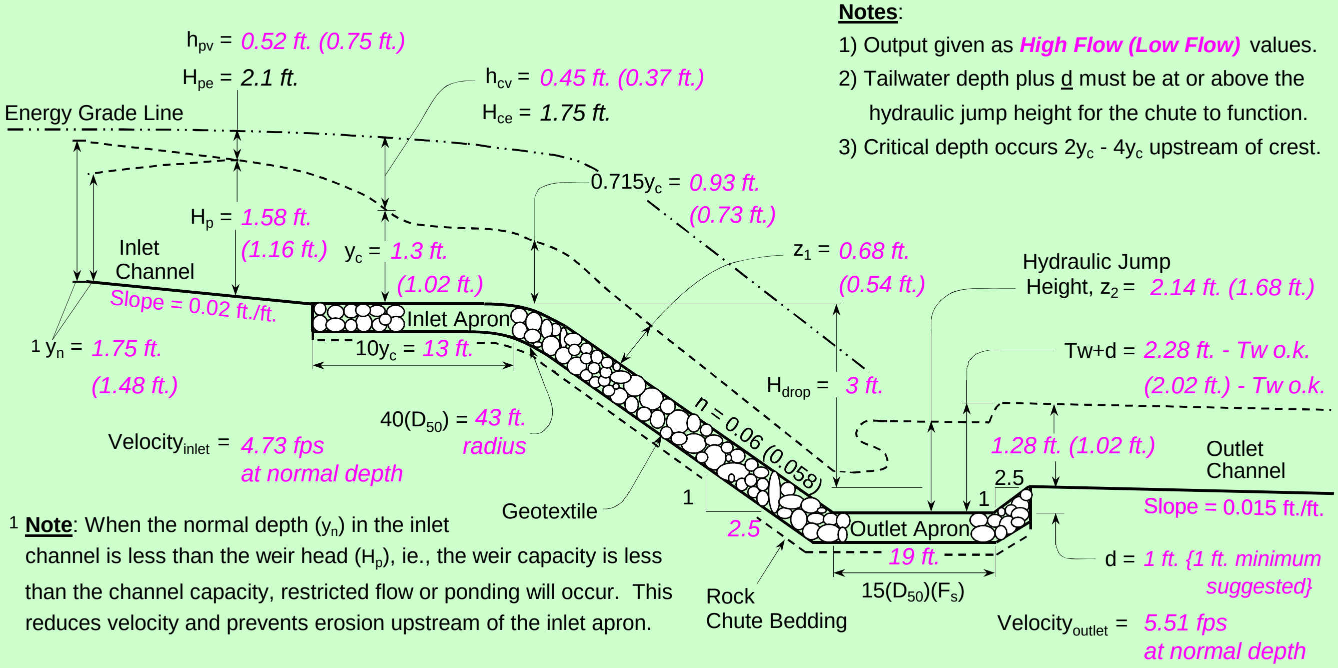
Q_{low} = *39.9* cfs Low flow storm through chute → Tw (ft.) = *Program*

***Note**: The total required capacity is routed through the chute (principal spillway) or in combination with an auxiliary spillway.*

***Input tailwater (Tw)**:*

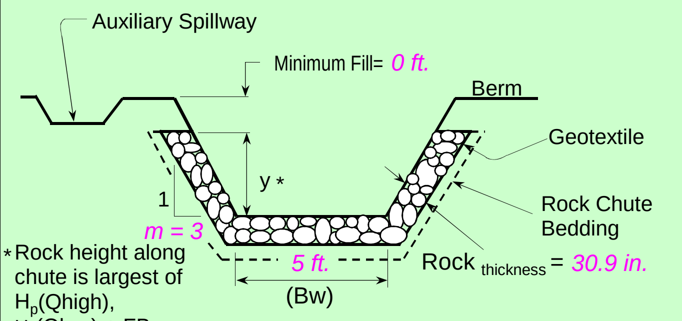
Profile and Cross Section (Output)

Notes:
1) Output given as ***High Flow (Low Flow)*** values.
2) Tailwater depth plus d must be at or above the hydraulic jump height for the chute to function.
3) Critical depth occurs $2y_c$ - $4y_c$ upstream of crest.



[1] **Note**: When the normal depth (y_n) in the inlet channel is less than the weir head (H_p), ie., the weir capacity is less than the channel capacity, restricted flow or ponding will occur. This reduces velocity and prevents erosion upstream of the inlet apron.

Profile Along Centerline of Chute



*Rock height along chute is largest of H_p(Qhigh), H_p(Qlow) + FB, and z_2.

Typical Cross Section

q_t =	*8.36 cfs/ft.*	Equivalent unit discharge
F_S =	*1.20*	Factor of safety (multiplier)
z_1 =	*0.68 ft.*	Normal depth in chute
n-value =	*0.06*	Manning's roughness coefficient
$D_{50}(F_S)$ =	*15.5 in. (269 lbs.) - angular riprap*	
$2(D_{50})(F_S)$ =	*30.9 in.*	Rock chute thickness
Tw + d =	*2.28 ft.*	Tailwater above outlet apron
z_2 =	*2.14 ft.*	Hydraulic jump height
****** The outlet***	***will***	***function adequately***

High Flow Storm Information