ENVIRONMENTAL • GEOTECHNICAL
BUILDING SCIENCES • MATERIALS TESTING

RUN-ON AND RUN-OFF CONTROL SYSTEM PLAN

TYPE III RESTRICTED WASTE LANDFILL
A.B. BROWN GENERATING STATION
8511 WELBORN ROAD
MOUNT VERNON, INDIANA 47620

ATC PROJECT NO. 170LF00271

OCTOBER 12, 2016

PREPARED FOR:

A.B. BROWN GENERATING STATION
8511 WELBORN ROAD
MOUNT VERNON, INDIANA 47620
ATTENTION: MS. LISA MESSINGER

October 12, 2016

Ms. Lisa Messinger
Director of Environmental Affairs
Vectren Corporation
1 Vectren Square
Evansville, IN 47702

ATC Group Services LLC

7988 Centerpoint Dr.
Suite 100
Indianapolis, IN 46256

Phone **+1 317 849 4990**
Fax +1 317 849 4278

www.atcgroupservices.com

Re: **Run-on and Run-off Controls System Plan**
Type III Restricted Waste Landfill
A.B. Brown Generating Station
Mount Vernon, IN 47620
ATC Project No. 170LF00271

Dear Ms. Messinger:

ATC Group Services LLC (ATC) is pleased to present the following Run-On Run-Off Control System (ROROCS) Plan for the A.B. Brown Generating Station Type III Restricted Waste Landfill located at 8511 Welborn Road, Mount Vernon, IN 47620.

As required by 40 CFR 257.81, the owner or operator of a coal combustion residuals (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; and
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.

Contained here within is a summary report which demonstrates that the A.B. Brown Type III Restricted Waste Landfill design measures are compliant with the CCR Rule.

We appreciate the opportunity to assist you with this project. If you have any questions concerning information contained in this letter, please do not hesitate to call either of the undersigned at 317.849.4990.

Sincerely,

ATC Group Services LLC

Charles Dewes

Charles Dewes, E.I., CFM
Project Engineer

Donald L. Bryenton

Donald L. Bryenton, P.E.
Principal Engineer

DONALD LEE BRYENTON
REGISTERED
No. 17817
STATE OF INDIANA
PROFESSIONAL ENGINEER

David L. Stelzer

David L. Stelzer, PhD, P.E.
Senior Project Engineer

Prepared for:

SOUTHERN INDIAN GAS AND ELECTRIC COMPANY
dba VECTREN POWER SUPPLY, INC

A.B. BROWN GENERATING STATION
TYPE III RESTRICTED WASTE LANDFILL

RUN-ON RUN-OFF CONTROL SYSTEMS PLAN

A.B. Brown Generating Station
8511 Welborn Road
Mount Vernon, Indiana 47620

OCTOBER 12, 2016

Prepared by:
ATC
7988 Centerpoint Drive, Suite 100
Indianapolis, Indiana 46256

Executive Summary

The A.B. Brown Generating Station Type III Restricted Waste Landfill located at 8511 Welborn Road in Mount Vernon, IN 47620, received its initial Solid Waste Land Disposal Facility Permit from Indiana Department of Environmental Management (IDEM) in 1979 and an expansion permit in 1992. The IDEM-approved plans for this facility include a number of erosion control and run-off measures designed to contain stormwater flow from both interim and final cover conditions of the landfill. Additional grading measures and perimeter features prevent run-on flow from entering the site.

The CCR Rule requires that all stormwater drainage structures, including channels, culverts, and pipe systems be designed to convey at least the 25-year, 24-hour storm event. This report documents that the engineering structures for run-off and run-on control have been sized appropriately to meet this condition.

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1 Introduction

This Run-On and Run-Off Control System (ROROCS) Plan was prepared for the existing A.B. Brown Generating Station Type III Restricted Waste Landfill (Fig. 1) in accordance with 40 CFR 257.81 (Run-on and run-off controls for CCR landfills). This ROROCS Plan documents that the facility control systems have been designed and constructed to meet the CCR rule following specified engineering calculations for the 24-hour, 25-year design storm. This ROROCS Plan will be placed in the facility's operating record as required by 40 CFR 257.105(g)(3).

2 Regulatory Requirements

2.1 Federal CCR Rule

As required by 40 CFR 257.81, the owner or operator of a coal combustion residuals (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; and

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.

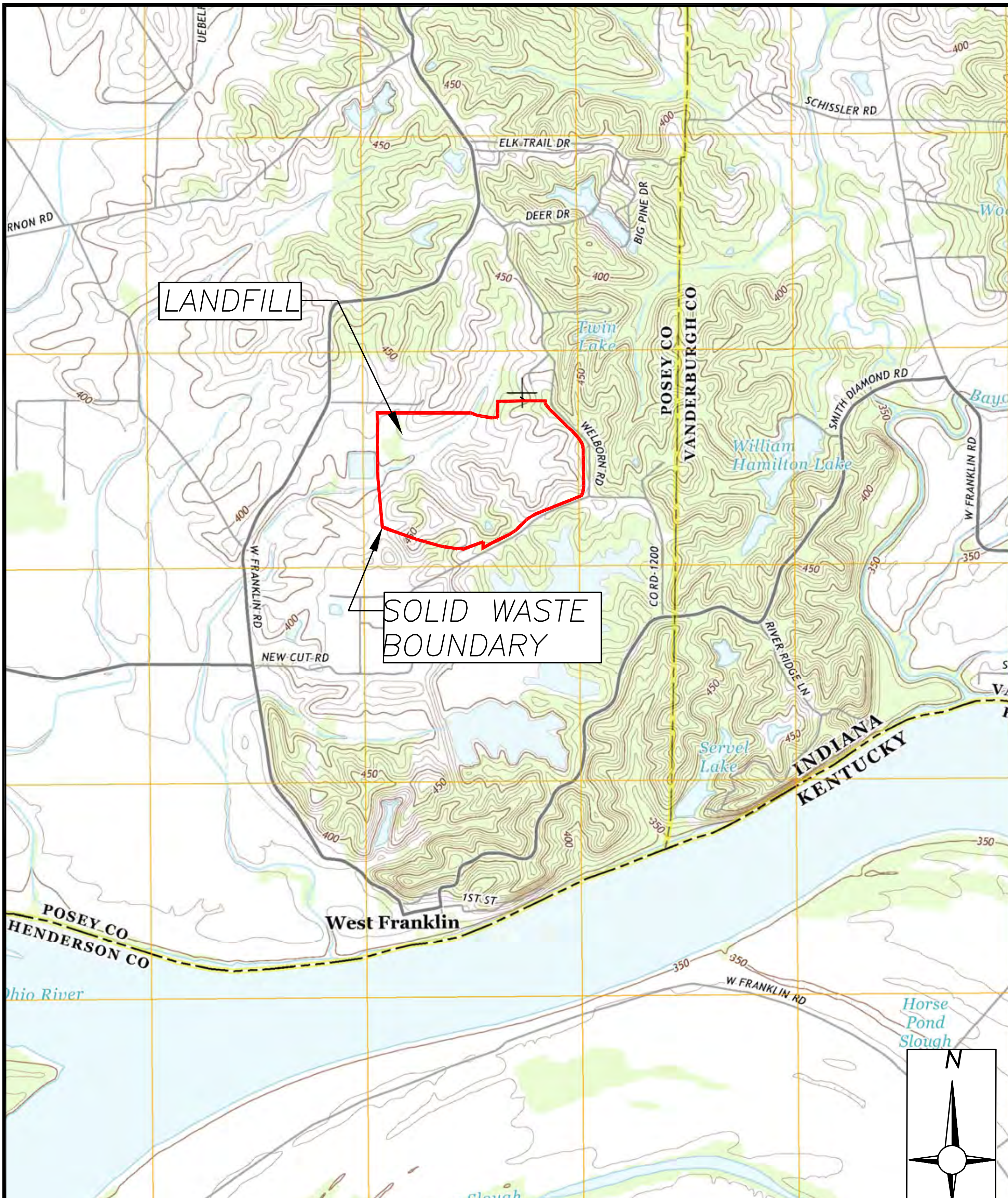
Additional requirements of the CCR Rule state that the ROROCS Plan must be updated and submitted once every five years as long as the landfill continues to be active.

The original permit and subsequent minor modification applications reviewed and approved by IDEM include sedimentation and erosion control systems that meet these requirements.

2.2 Preamble to the Federal CCR Rule

The preamble to the federal CCR Rule provides additional description regarding the intent of the requirements. Regarding run-off control, the following quotation from the preamble is relevant.

> *The owner or operator must design, construct, operate, and maintain the CCR landfill in such a way that any runoff generated from at least a 24-hour, 25-year storm must be collected through hydraulic structures, such as drainage ditches, toe drains, swales, or other means, and controlled so as to not adversely affect the condition of the CCR landfill. EPA has promulgated these requirements to minimize the detention time of run-off on the CCR landfill and minimize infiltration into the CCR landfill, to dissipate storm water run-off velocity, and to minimize erosion of CCR landfill slopes. An additional concern with run-off from CCR landfills is the water quality of the run-off, which may collect suspended solids from the landfill slopes.*



A.B. BROWN GENERATING STATION TYPE III RWS LANDFILL

8511 WELBORN ROAD
MOUNT VERNON, INDIANA 47620
POSEY COUNTY, INDIANA

Project Number: 170lf00271			Drn. By: WS
Drawing File: SEE LEFT			Ckd. By: CD
Date: 8/16	Scale: AS SHOWN		App'd By:
ATC			Figure: 1

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A description of the run-on and run-off control systems is included in the following sections of this report.

3 Design Methodology

3.1 Design Storm

The 24-hour, 25-year design storm is the mandatory protection standard for run-on and run-off control systems. The A.B. Brown Landfill was designed to handle run-off flow from this event. The 25-year design storm was derived from the National Oceanic and Atmospheric Administration (NOAA) TP 40 data for Posey County, Indiana. The storm generates 5.4 inches of precipitation for this location. The rainfall hyetograph for this storm event is included in Appendix A. All run-on and run-off control systems were designed for this capacity.

3.2 Rainfall Abstractions

Losses in rainfall volume are accounted for in abstractions (losses). The SCS Method was applied to calculate the correct curve number for the land use and soil types of the site. This curve number was then applied to calculate the losses and the actual runoff. SCS equations are below:

$S = 1000/CN - 10$ [Equation 1]

$I_a = 0.2*S$ [Equation 2]

Where:
S = potential maximum retention after runoff begins (in.);
CN = curve number; and
I_a = initial abstraction (in.)

The initial abstraction is a function of the land use conditions as represented by the composite curve number for the tributary drainage area. For example, the initial abstraction for run-off from CCR material having a curve number of 79 is calculated as follows:

$I_a = 200/79 - 2 = 0.53$ *inches*

3.3 Runoff and Routing Methodology

Both the SEDCAD 4 and HydroCAD programs were used to generate the flow velocities and flow depths for each of the run-on / run-off control measures. The SEDCAD4 Model was developed by Civil Software Design & Warner of the University of Kentucky, and emulates the NRCS TR55 Model. The SEDCAD4 program was used for designing runoff control measures of the western half of the landfill in the 2007 IDEM Minor Modification Permit Application.

The HydroCAD model was developed by HydroCAD Software Solutions LLC and was used for designing runoff control measures of the eastern half of the landfill in the 2012 IDEM Minor Modification Permit Application.

The routing calculations from both programs used SCS Curve Number method. All erosion control measures were linked to drainage channels and reservoir areas using the modelling programs. The routing flow paths are included with the modelling results in Appendix B and Appendix C.

4 Run-On Control

4.1 Topography

The site of the A.B. Brown Landfill is located north of the Ohio River and west of Bayou Creek. The surrounding area is mostly flat and the landfill is the highest feature in this area. The landfill is protected from run-on flow by Franklin Road to the west, Welborn Road to the east, and also by natural drainage relief around the landfill perimeter.

4.2 Perimeter Roadway

The landfill area is bounded by Welborn Road to the east and an access road for the generating station to the south. West Franklin Road is also present approximately 1,000 feet west of the landfill. The roadway embankment heights generally vary between 3 and 5 feet above natural grade preventing run-on flow to the landfill area (see Appendix B). Furthermore the minimum road grade sits well above the 100-year backwater elevation of the Ohio River, ensuring insulation of the A.B. Brown Landfill during the Interim and Final Cover conditions

5 Run-Off Control

5.1 Erosion Control Measures

A series of diversion berms and slope terraces have been constructed on the landfill to direct run-off flow through the conveyance system. These berms prevent disturbance of the CCR materials during the design storm event. All berms typically have 2H:1V to 3H:1V sideslopes with seeding and erosion control mats as needed. Berm height is 2 feet which adequately protects from the approximately 1-foot calculated flow depth of the design storm.

5.2 Flow Conveyance and Capture Measures

Flow from diversion berms is directed into riprapped downchutes or pipe downdrains which discharge into the perimeter ditch system at various locations. The encircling landfill perimeter ditch system is divided into two reaches beginning at a high ground split point on the south side of the landfill. The first reach flows clockwise from the split until flow reaches the Landfill Settling Basin. The Landfill Settling Basin outlets to the Capital Pond through a gravity-fed barrel culvert. Both the Landfill Settling Basin and Capital Pond direct flow to the NPDES outfall area.

The second ditch reach flows counter-clockwise from the south split wrapping around the eastern and northern perimeters before routing to the Stormwater Surge Basin at the northwest corner of the landfill. The Stormwater Surge Basin, built from a former borrow area, captures water coming from partially closed and covered portions of the landfill. The Stormwater Surge Basin, Capital Pond and Landfill Settling Basin together have enough storage to handle the 25-year, 24-hour design storm runoff from the entire A.B. Brown Landfill Solid Waste Boundary area during both Interim and Final Cover Conditions.

6 Conclusions

As required by 40 CFR 257.81, the A.B. Brown Landfill run-on control system is designed to prevent flow onto the active portion of the CCR unit during the peak discharge from a 24-hour, 25-year storm, and the A.B. Brown Landfill run-off control system is designed to collect and control at least the water volume resulting from a 24-hour, 25-year storm.

Appendices

Appendix A: Design Storm and Structure Overview

Appendix B: Calculations for Run-On Control System

Section 1: Run-On Control System Summary
Section 2: References

Appendix C: Calculations for Run-Off Control System

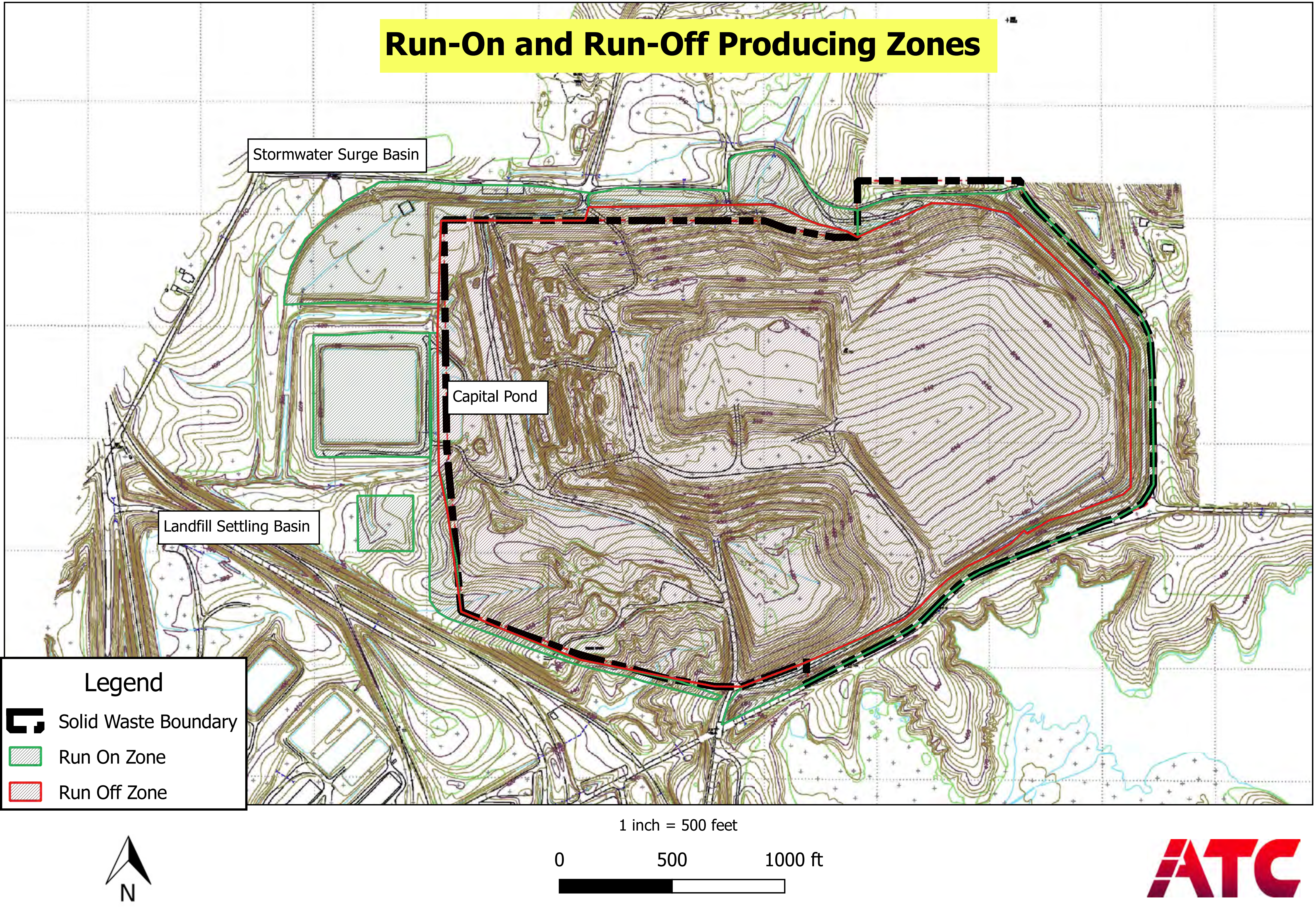
Section 1: Run-Off Control System Interim Conditions Summary
Section 2: Run-Off Control System Final Cover Conditions Summary
Section 3: References

Appendix D: Surface Water Control and Design Plan Sheets

Appendix A: Design Storm and Structure Overview

FLOW CONTROL STRUCTURE CONVEYANCE TABLE

FLOW CONTROL STRUCTURE	FLOW TYPE CONVEYED
Perimeter Channels	Run-On & Run-Off
Downdrains (Inlet & Pipe)	Run-Off
Erosion Control Berms	Run-Off
Outlets to Retention Pond	Run-On & Run-Off
Retention Ponds	Run-On & Run-Off



Run-On and Run-Off Producing Zones
Stormwater Surge Basin
Capital Pond
Landfill Settling Basin
Legend
Solid Waste Boundary
Run On Zone
Run Off Zone
1 inch = 500 feet
0
500
1000 ft
N
ATC

Appendix B: Calculations for Run-On Control System

Section 1:	Run-On Control System Summary
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Appendix B: Calculations for Run-On Control System

Section 1: Run-On Control System Summary

OBJECTIVE:

The objective of this calculation is to demonstrate that the perimeter stormwater controls for the A.B. Brown Type III Restricted Waste Landfill have capacity to control run-on flow from the 24-hour, 25-year storm. According to EPA, run-on is defined as

"…Any liquid that drains over land onto any part of a CCR landfill or any lateral expansion of a CCR landfill. In surface water hydrology, run-on is a quantity of surface run-off, or excess rain, snowmelt, or other sources of water, which flows from an upstream catchment area onto a specific downstream location."

Although perimeter ditches and retention pond systems handle *both* run-on and run-off flow, the hydraulic capacities of these structures will be evaluated under this run-on section since the structures are located in the run-on producing zone of the landfill and adjoining area.

METHOD:

The capacity of the perimeter stormwater controls will be evaluated using the SCS method and Manning's equation. For this design the 25-year design storm [Ref. 4] will be used which exceeds the minimum standards.

DEFINITION OF VARIABLES:

A = area;
b = bottom width of flow through channel;
d = flow depth through channel;
CN = curve number;
D = channel depth;
i = rainfall depth;
n = Manning's roughness coefficient for flow through channel;
Q = discharge flow;
S = longitudinal slope of the channel flow;
T = top width of flow through channel;
V = velocity of flow through channel; and
Z = channel side slope.

CALCULATIONS:

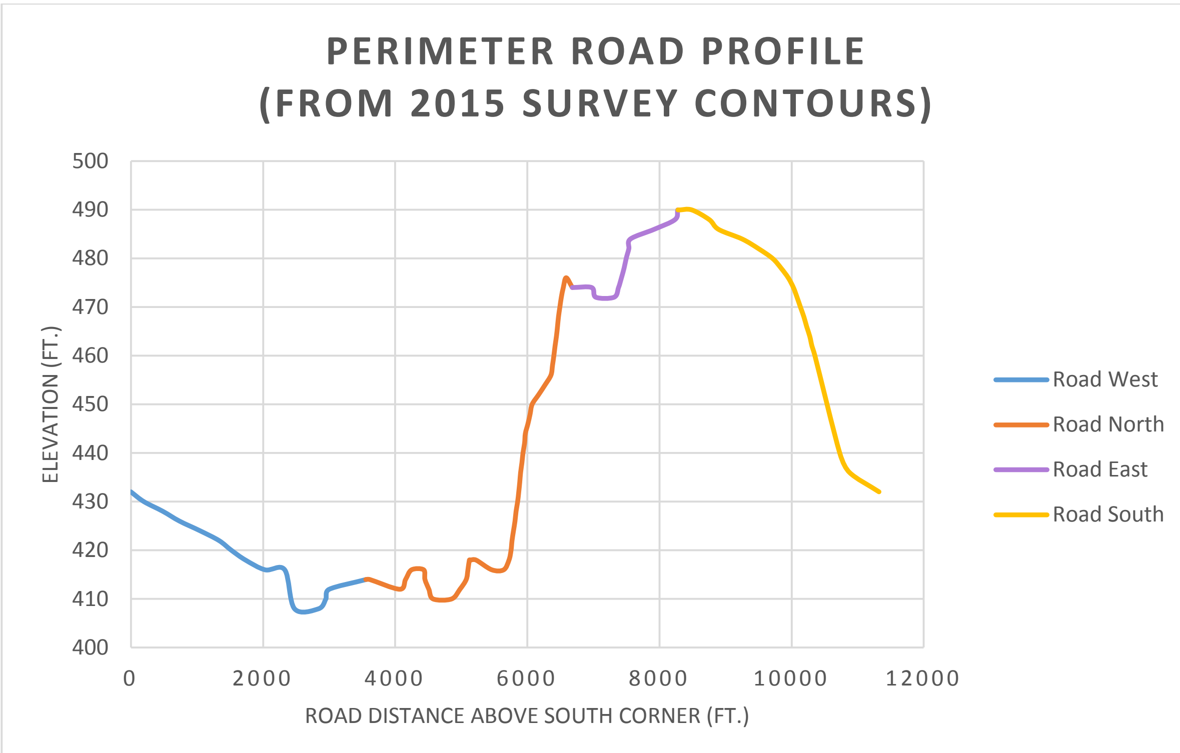
1.0 Perimeter Road

Drainage from the encompassing watershed of the landfill flows in the southwest direction. The natural gradient of the watershed is high on the northeast side of the landfill to low on the northwest side of the landfill where flow joins the unnamed tributary to the Ohio River (see USGS Streamstats watershed maps [Ref. 2]).

Run-on flow divides around the landfill as it reaches the perimeter road embankment of Welborn Road at the eastern edge of the solid waste boundary. This road prevents run-on stormwater from reaching the final closure landfill area. The design of the perimeter haul road system allows for insular protection of the landfill because the road grade is 3-5 feet above natural ground which is greater than the depth of overland flow. The embankment of the haul road, in addition to the final cover grade, together act as an effective means to divert run-on flow from the outside subbasin areas.

The 100-year flood backwater elevation of the nearby Ohio River is approximately 373.5’ NAVD [Ref. 5]. By comparison the lowest grade of the perimeter road system is 408 feet (Fig. 1). This indicates that in addition to protection from the upstream catchment run-on flow, the final cover area would also be protected from backwater of the Ohio River.

Figure 1 – Perimeter Road Profile



2.0 Perimeter Stormwater Channels

Two joining reaches of a perimeter ditch system are located outside the base of the A.B. Brown Type III Restricted Waste Landfill. The first reach of the perimeter ditch begins at the southern end of the landfill and conveys stormwater in a clockwise direction to the lined Landfill Settling Basin at the southwest corner of the landfill.

The second perimeter ditch reach conveys flow in a counterclockwise direction to the northwest corner of the landfill through a former borrow area that was converted to the Stormwater Surge Basin. The Stormwater Surge Basin ranges in depth from five (5) to eight (8) feet and covers an area of approximately five (5) acres.

Design criteria for the perimeter ditch channels were evaluated by first estimating the peak flow to the channels using the SCS method [Ref. 3], and then evaluating the channel capacity using Manning’s equation. The channels were designed for capacity of the 24-hour, 25-year storm.

2.1 Channel peak flow rates

The landfill perimeter and final cover were both assumed to contribute flow to the channel reaches. The time of concentration for the storm water runoff was calculated as the cumulative sum of upstream contributing berm and downdrain subwatersheds. Peak flow rates to the channels were estimated using the 2007 SEDCAD4 model [Ref. 1] and are summarized in the following table:

Table 1: Channel Peak Flow Rate						
Rainfall			Contribution of Flow from Landfill (Run-Off)			
SEDCAD Channel Reach	Design Storm Event (years)	Rainfall 24-Hour {i} (in.)	Land Use	Curve Number {CN}	Drainage Area {A} (ac.)	Peak Runoff {Q} (cfs)
#12	25	5.4	Vegetated	78	221.2	353.0
#20	25	5.4	Vegetated	78	2.8	8.9
#21	25	5.4	Vegetated	78	18.9	52.2
#22	25	5.4	Vegetated	78	41.5	113.0
#28	25	5.4	Vegetated	78	50	80.6
#29	25	5.4	Vegetated	78	60.3	85.9
#30	25	5.4	Vegetated	78	204.3	342.7
#31	25	5.4	Vegetated	78	64.4	182.0

2.2 Channel Capacity

The stormwater perimeter channels consist of trapezoidal channels with dimensions presented in the following table:

Table 3: Channel Dimensions						
SEDCAD ID	Bottom Width {b}	Depth {D}	Left Side Slope {Z_1 H:V}	Right Side Slope {Z_2 H:V}	Top Width {T}	Approximate Longitudinal Slope {S}
	(ft)	(ft)			(ft)	(ft/ft)
#12	12	4	3	3	36	0.007
#20	12	4	3	3	36	0.020
#21	12	4	3	3	36	0.033
#22	12	4	3	3	36	0.019
#28	12	4	3	3	36	0.020
#29	12	4	3	3	36	0.067
#30	12	4	3	3	36	0.007
#31	12	4	3	3	36	0.013

The capacity of both ditches was evaluated using Manning's equations as presented in the following equations:

$V = 1.49/n\ R^{2/3}\ S^{1/2}$
$Q = VA$

The flow cross-section area “A” and wetted perimeter “P” were calculated based on the geometry of a trapezoidal channel with a flow depth “d”, bottom width “b”, left side slope “Z1”, and right side slope “Z2”, using the following relationships:

$$A = b*d + 0.5*Z1*d^2 + 0.5*Z2*d^2$$

$$P = b + sqrt[(Z1*d)^2 + d^2] + sqrt[\{Z2*d)^2 + d^2]$$

The channel was assumed to have grass lining and flow capacity was evaluated for the design slope condition subject to the 25-year, 24-hour design storm event. Channel capacity calculated for the selected grade and runoff is shown in the following tables:

Table 4: Channel Capacity for Perimeter Ditch Reaches Flowing Clockwise

SEDCAD ID	Storm Recurrence Interval (years)	Channel Lining	Manning's n {n}	Flow Depth {d} (ft.)	Flow Area {A} (ft^2)	Velocity {V} (ft/s)	Channel Capacity {Q} (cfs)	Peak Runoff {Q} (cfs)	Channel Capacity > Peak Runoff?	Freeboard (in.)
#20	25	Grass	0.0680	0.41	5.50	1.6	557.2	8.9	YES	43.1
#21	25	Grass	0.0517	0.70	16.52	3.2	941.4	52.2	YES	39.6
#22	25	Grass	0.0373	0.99	22.66	5.0	990.0	113.0	YES	36.1
#31	25	Grass	0.0340	1.35	34.20	5.3	898.4	182.0	YES	31.8

Table 5: Channel Capacity for Perimeter Ditch Reaches Flowing Counter-Clockwise

SEDCAD ID	Storm Recurrence Interval (years)	Channel Lining	Manning's n {n}	Flow Depth {d} (ft.)	Flow Area {A} (ft^2)	Velocity {V} (ft/s)	Channel Capacity {Q} (cfs)	Peak Runoff {Q} (cfs)	Channel Capacity > Peak Runoff?	Freeboard (in.)
#28	25	Grass	0.0354	1.66	14.36	5.6	1070.3	80.6	YES	28.1
#29	25	Grass	0.0440	1.58	10.62	8.1	1576.0	85.9	YES	29.0
#30	25	Grass	0.0284	2.51	55.16	6.2	789.3	342.7	YES	17.9
#12	25	Grass	0.0270	2.60	51.54	6.9	830.2	353.0	YES	16.8

Modeling results show that the perimeter ditches have enough capacity to meet the design storm with considerable freeboard leftover.

3.0 Ponds

Run-on and run-off flow from the perimeter ditch system is routed to three (3) different basins. The ditch reaches which flow counterclockwise route to the Stormwater Surge Basin at the northwest corner of the landfill. The Stormwater Surge Basin occupies an area of approximately 5 acres in size. The Stormwater Surge Basin handles only non-contact water. This energy dissipating area allows for sedimentation to occur before eventual discharge to an NPDES outfall area.

Ditch reaches which flow clockwise route to the Landfill Settling Basin at the southwest corner of the landfill. According to 2015 construction plans submitted as part of the Storm Water Pollution Prevention Plan (SWP3), the marked (Normal) 'Pool Elevation' is 397.5' leaving 3.5 feet of available storage during typical operating conditions. This storage sedimentation space is used for treatment of contact waters produced from the active cell portions of the landfill. A pipe connecting the Landfill Settling Basin to the Capital Pond has an upstream invert (overflow) elevation of 400.0' allowing for additional storage before treatment occurs at the treatment facility of the generating station.

Combined storage available in the Stormwater Surge Basin, Landfill Settling Basin, and Capital Pond is sufficient to handle the 25-year storm volume from the landfill and adjacent contributing areas.

DISCUSSION:

The perimeter stormwater controls for the A.B. Brown Type III Restricted Waste Landfill have capacity to control both run-on and non-contact water run-off for the 24-hour, 25-year storm.

REFERENCES:

1. SEDCAD 4 by Civil Software Design, LLC.
2. StreamStats in Indiana. U.S. Geological Survey. <http://streamstats.usgs.gov/>.
3. United States Department of Agriculture, "Urban Hydrology for Small Watersheds", Technical Release 55, June 1986.
4. Hershfield, David M., "Technical Paper No. 40 Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years", NOAA National Weather Service, obtained January 14, 2005.
5. Indiana Floodplain Information Portal (INFIP). <http://dnrmaps.dnr.in.gov/appsphp/fdms/>.

Appendix B: Calculations for Run-On Control System

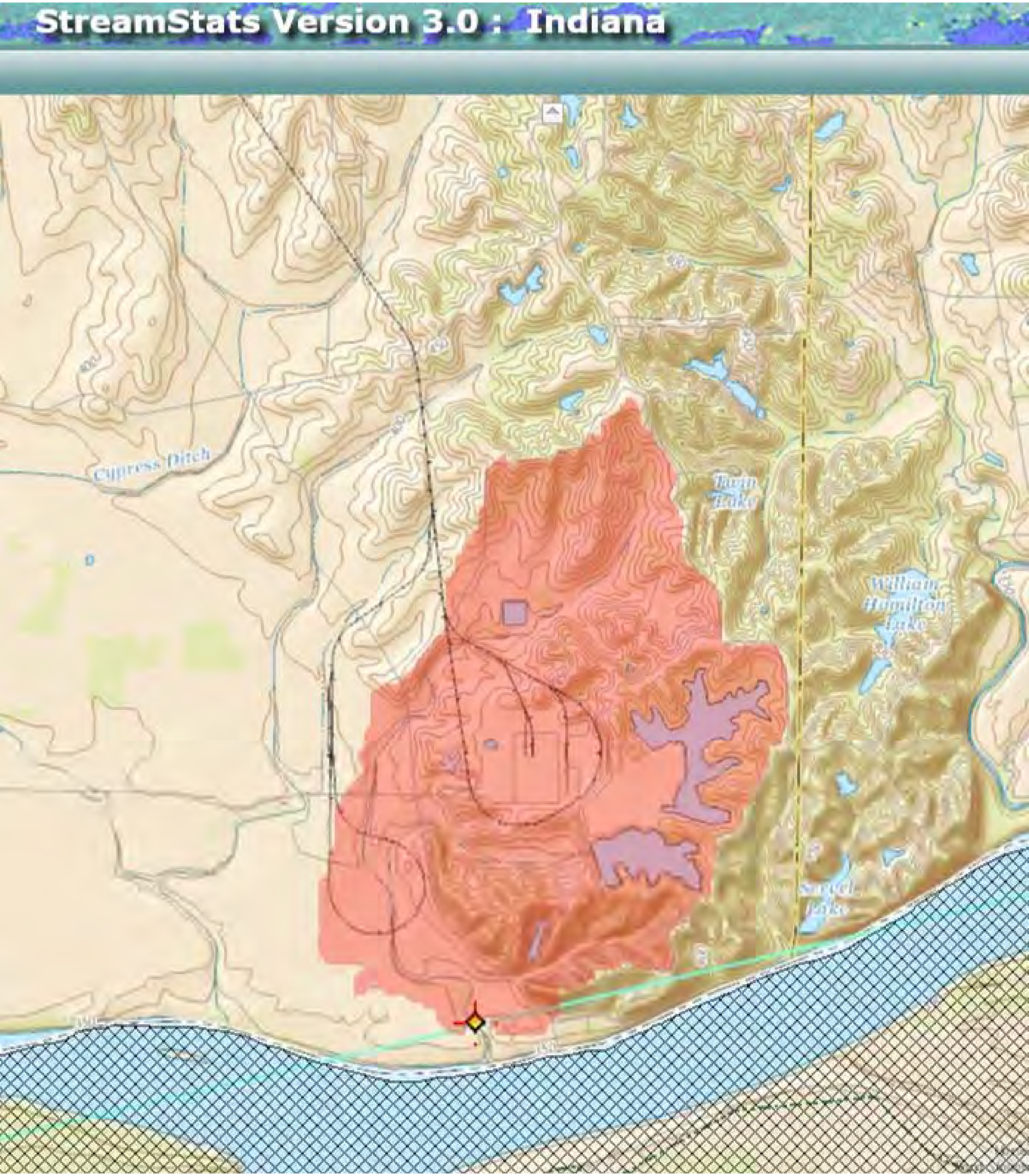
Section 2: References

REFERENCE NO.	DESCRIPTION
1	SEDCAD 4
2	USGS Streamstats – Drainage Areas
3	USDA TR-55
4	NOAA Technical Paper No. 40
5	INFIP Report

Reference 1: SEDCAD 4

[See Appendix C – Section 3, Reference 1 for Combined Run-On and Run-Off Modeling Results]

Reference 2: USGS Streamstats – Drainage Areas


StreamStats Version 3.0 : Indiana
Cypress Ditch
Twin Lake
William Hamilton Lake

Reference 3: USDA TR-55

United States
Department of
Agriculture

Natural
Resources
Conservation
Service

Conservation
Engineering
Division

Technical
Release 55

June 1986

Urban Hydrology for Small Watersheds

TR-55

Chapter 2 Estimating Runoff

SCS runoff curve number method

The SCS Runoff Curve Number (CN) method is described in detail in NEH-4 (SCS 1985). The SCS runoff equation is

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad \text{[eq. 2-1]}$$

where

- Q = runoff (in)
- P = rainfall (in)
- S = potential maximum retention after runoff begins (in) and
- I_a = initial abstraction (in)

Initial abstraction (I_a) is all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration. I_a is highly variable but generally is correlated with soil and cover parameters. Through studies of many small agricultural watersheds, I_a was found to be approximated by the following empirical equation:

$$I_a = 0.2S \qquad \text{[eq. 2-2]}$$

By removing I_a as an independent parameter, this approximation allows use of a combination of S and P to produce a unique runoff amount. Substituting equation 2-2 into equation 2-1 gives:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad \text{[eq. 2-3]}$$

S is related to the soil and cover conditions of the watershed through the CN. CN has a range of 0 to 100, and S is related to CN by:

$$S = \frac{1000}{CN} - 10 \qquad \text{[eq. 2-4]}$$

Figure 2-1 and table 2-1 solve equations 2-3 and 2-4 for a range of CN's and rainfall.

Factors considered in determining runoff curve numbers

The major factors that determine CN are the hydrologic soil group (HSG), cover type, treatment, hydrologic condition, and antecedent runoff condition (ARC). Another factor considered is whether impervious areas outlet directly to the drainage system (connected) or whether the flow spreads over pervious areas before entering the drainage system (unconnected). Figure 2-2 is provided to aid in selecting the appropriate figure or table for determining curve numbers.

CN's in table 2-2 (*a* to *d*) represent average antecedent runoff condition for urban, cultivated agricultural, other agricultural, and arid and semiarid rangeland uses. Table 2-2 assumes impervious areas are directly connected. The following sections explain how to determine CN's and how to modify them for urban conditions.

Hydrologic soil groups

Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. Soils are classified into four HSG's (A, B, C, and D) according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting. Appendix A defines the four groups and provides a list of most of the soils in the United States and their group classification. The soils in the area of interest may be identified from a soil survey report, which can be obtained from local SCS offices or soil and water conservation district offices.

Most urban areas are only partially covered by impervious surfaces: the soil remains an important factor in runoff estimates. Urbanization has a greater effect on runoff in watersheds with soils having high infiltration rates (sands and gravels) than in watersheds predominantly of silts and clays, which generally have low infiltration rates.

Any disturbance of a soil profile can significantly change its infiltration characteristics. With urbanization, native soil profiles may be mixed or removed or fill material from other areas may be introduced. Therefore, a method based on soil texture is given in appendix A for determining the HSG classification for disturbed soils.

Manning's equation is:

$$V = \frac{1.49 r^{\frac{2}{3}} s^{\frac{1}{2}}}{n} \quad \text{[eq. 3-4]}$$

where:

V = average velocity (ft/s)
r = hydraulic radius (ft) and is equal to a/p_w
a = cross sectional flow area (ft^2)
p_w = wetted perimeter (ft)
s = slope of the hydraulic grade line (channel slope, ft/ft)
n = Manning's roughness coefficient for open channel flow.

Manning's n values for open channel flow can be obtained from standard textbooks such as Chow (1959) or Linsley et al. (1982). After average velocity is computed using equation 3-4, T_t for the channel segment can be estimated using equation 3-1.

Reservoirs or lakes

Sometimes it is necessary to estimate the velocity of flow through a reservoir or lake at the outlet of a watershed. This travel time is normally very small and can be assumed as zero.

Limitations

- Manning's kinematic solution should not be used for sheet flow longer than 300 feet. Equation 3-3 was developed for use with the four standard rainfall intensity-duration relationships.

- In watersheds with storm sewers, carefully identify the appropriate hydraulic flow path to estimate T_c. Storm sewers generally handle only a small portion of a large event. The rest of the peak flow travels by streets, lawns, and so on, to the outlet. Consult a standard hydraulics textbook to determine average velocity in pipes for either pressure or nonpressure flow.

- The minimum T_c used in TR-55 is 0.1 hour.

- A culvert or bridge can act as a reservoir outlet if there is significant storage behind it. The procedures in TR-55 can be used to determine the peak flow upstream of the culvert. Detailed storage routing procedures should be used to determine the outflow through the culvert.

Example 3-1

The sketch below shows a watershed in Dyer County, northwestern Tennessee. The problem is to compute T_c at the outlet of the watershed (point D). The 2-year 24-hour rainfall depth is 3.6 inches. All three types of flow occur from the hydraulically most distant point (A) to the point of interest (D). To compute T_c, first determine T_t for each segment from the following information:

Segment AB: Sheet flow; dense grass; slope (s) = 0.01 ft/ft; and length (L) = 100 ft. Segment BC: Shallow concentrated flow; unpaved; s = 0.01 ft/ft; and L = 1,400 ft. Segment CD: Channel flow; Manning's n = .05; flow area (a) = 27 ft^2; wetted perimeter (p_w) = 28.2 ft; s = 0.005 ft/ft; and L = 7,300 ft.

See figure 3-2 for the computations made on worksheet 3.

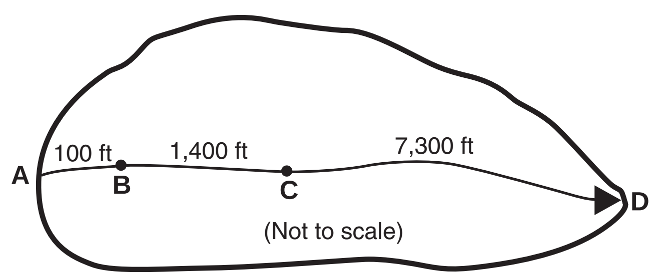


Table 7–4 Classification of vegetation cover as to degree of retardance

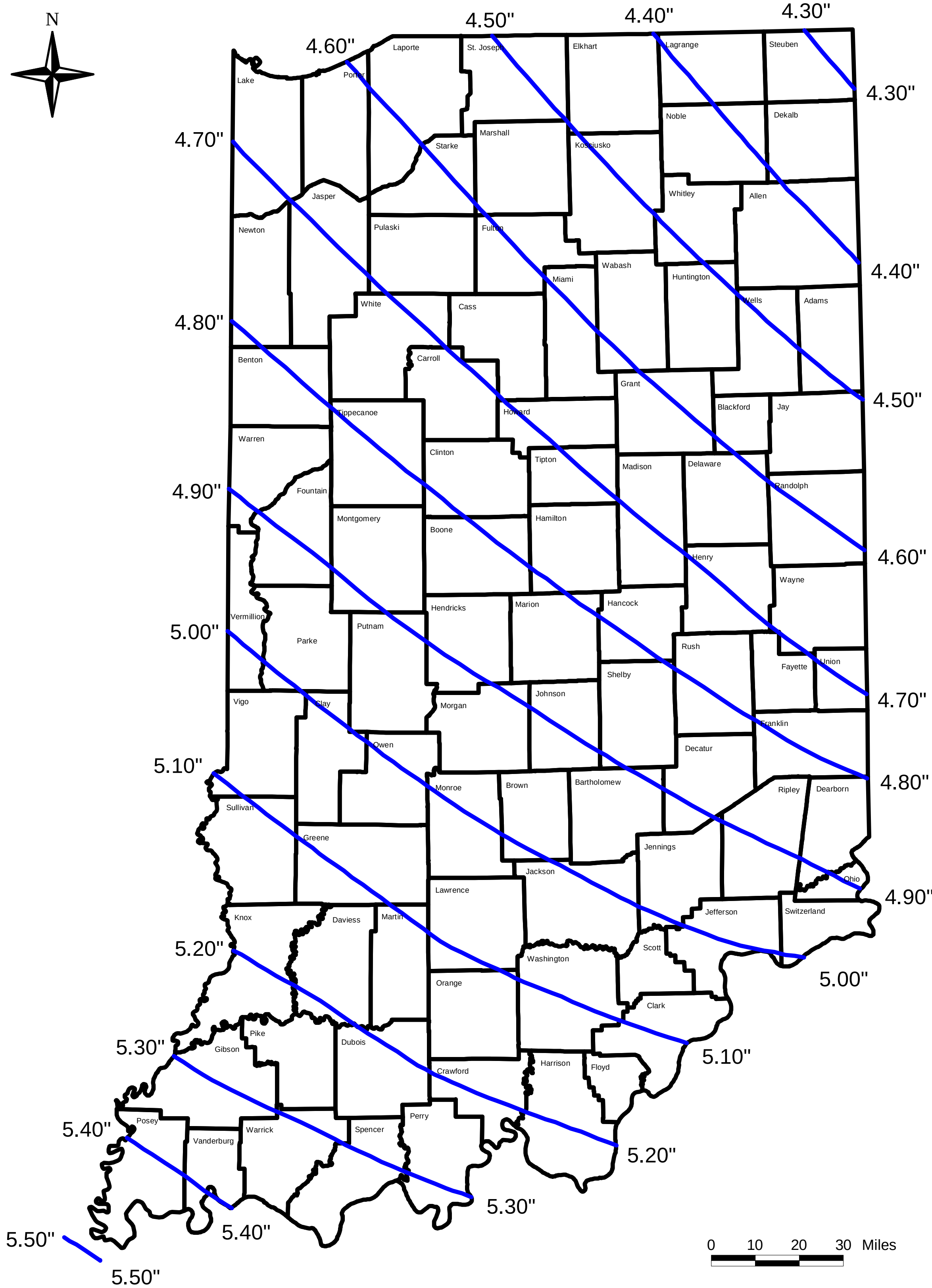
Retardance	Cover	Condition
A	Weeping lovegrass	Excellent stand, tall (average 30 in)
	Reed canarygrass or Yellow bluestem ischaemum	Excellent stand, tall (average 36 in)
B	Smooth bromegrass	Good stand, mowed (average 12 to 15 in)
	Bermudagrass	Good stand, tall (average 12 in)
	Native grass mixture (little bluestem, blue grama, and other long and short midwest grasses	Good stand, unmowed
	Tall fescue	Good stand, unmowed (average 18 in)
	Sericea lespedeza	Good stand, not woody, tall (average 19 in)
	Grass-legume mixture—Timothy, smooth bromegrass, or orchardgrass	Good stand, uncut (average 20 in)
	Reed canarygrass	Good stand, uncut (average 12 to 15 in)
	Tall fescue, with birdsfoot trefoil or ladino clover	Good stand, uncut (average 18 in)
	Blue grama	Good stand, uncut (average 13 in)
C	Bahiagrass	Good stand, uncut (6 to 8 in)
	Bermudagrass	Good stand, mowed (average 6 in)
	Redtop	Good stand, headed (15 to 20 in)
	Grass-legume mixture—summer (orchardgrass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6 to 8 in)
	Centipedegrass	Very dense cover (average 6 in)
	Kentucky bluegrass	Good stand, headed (6 to 12 in)
D	Bermudagrass	Good stand, cut to 2.5-in height
	Red fescue	Good stand, headed (12 to 18 in)
	Buffalograss	Good stand, uncut (3 to 6 in)
	Grass-legume mixture—fall, spring (orchardgrass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (4 to 5 in)
	Sericea lespedeza or Kentucky bluegrass	Good stand, cut to 2-in height. Very good stand before cutting
E	Bermudagrass	Good stand, cut to 1.5-in height
	Bermudagrass	Burned stubble

Table 7–5 Retardance curve index by retardance class

SCS retardance class	Retardance curve index C_I
A	10.0
B	7.64
C	5.60
D	4.44
E	2.88

Reference 4: NOAA Technical Paper No. 40

RAINFALL - 25 YEAR FREQUENCY - 24 HOUR DURATION



REFERENCE
TECHNICAL PAPER NO. 40
NATIONAL WEATHER SERVICE

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

Reference 5: Indiana Floodplain Information Portal (INFIP) Report

Indiana Floodplain Information Portal Report

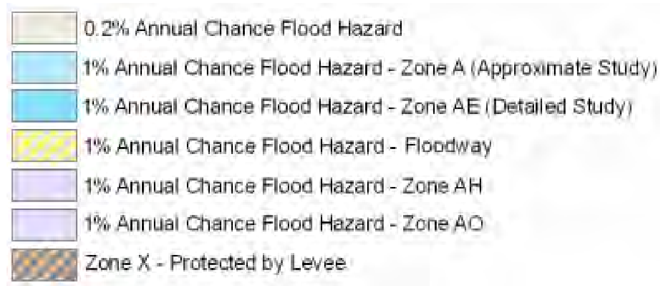
Point of Interest

Effective Flood Zone:
X
Preliminary Flood Zone:
N/A
Best Available Flood Zone:
X
Approximate Flood Elevation:
373.5ft NAVD88
Source:
Zone AE Profile Conversion
Nearest Stream:
OHIO RIVER

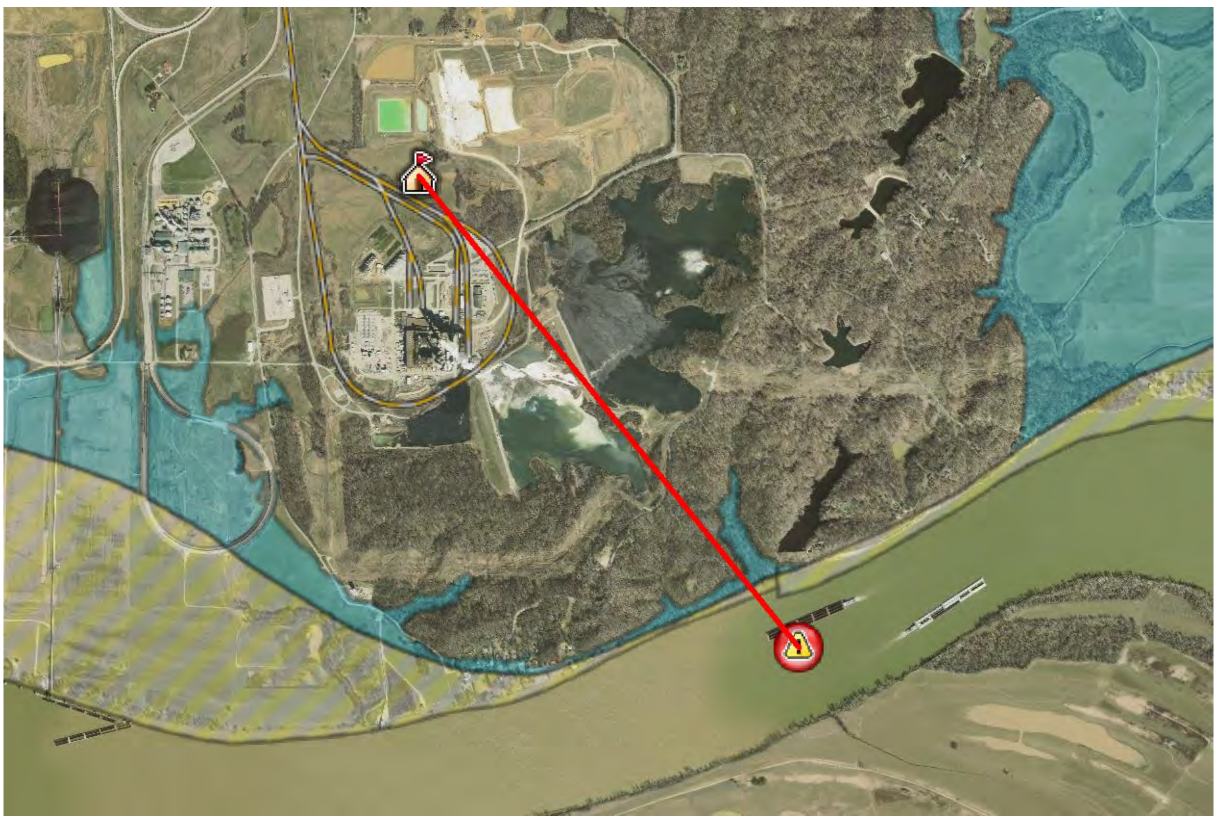
Map Legend

Point of Interest
Nearest Point on Stream

Effective Flood Zone



Site Map with Effective Flood Zone



Approximate scale 1:36,000

Disclaimer

This data is a digital representation of the former paper Flood Insurance Rate Maps (FIRMs) for counties that have completed the Map Modernization Initiative. The data on counties derived from the official FEMA digital products (DFIRM) represent official FEMA designations of the Special Flood Hazard Areas. This data can be used for official National Flood Insurance Program (NFIP) purposes in accordance with the FEMA Mitigation Directorate Policy document tiled "Use of Digital Flood Hazard Data" dated November 29, 2007. For the non-modernized counties, the Effective is enhanced by the addition of the floodplain data from digitized paper copies of the FIRMs and the information should be considered advisory only. For these non-modernized counties, the paper maps are the official FEMA documents for regulatory and insurance purposes. Once the NFHL is official, the Effective is updated with the newly published information. For the status of counties published by FEMA please see http://www.floodmaps.fema.gov/NFHL/status.shtml.

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Appendix C: Calculations for Run-Off Control System

Section 1: Run-Off Control System Interim Conditions Summary
Section 2: Run-Off Control System Final Cover Conditions Summary
Section 3: References

Appendix C: Calculations for Run-Off Control System

Section 1: Run-Off Control System Interim Conditions Summary

OBJECTIVE:

The objective of this calculation is to evaluate the temporary run-off control measures inside the A.B. Brown Landfill to provide capacity to control contact water run-off for the 25-year, 24-hour storm during interim conditions. The temporary run-off control measures for interim phase cells include a temporary collection sump, perimeter ditch system, the Landfill Settling Basin, and the Capital Pond.

METHOD:

The required sizing of run-off control measures was evaluated using the Soil Conservation Service (SCS) method for calculating runoff.

DEFINITION OF VARIABLES:

A = area;
CN = curve number;
Q = flow;

CALCULATIONS:

1.0 Contact water run-off for interim conditions

Prior to closure of the landfill and installation of final cover run-off control measures, operations of interim cell areas utilize interim run-off control measures. In many cases the interim run-off control measures overlap or are the same as those used during final cover conditions but since the active area (interim cells) and final cover area (entire landfill) differ in size, grading, and configuration, different routing procedures are followed for control of stormwater.

The Eastern Landfill Area, which is closed and inactive, already has installed the final cover berms, downdrains, and perimeter ditch segments which will operate during both interim and final cover conditions. The Western Landfill Area, northern half, is also closed with run-off controls (terrace berms and riprap downchutes) already installed. Development of the Western Landfill Area, southern and eastern portions is considered the Interim (active) Area. The approximate 2016 Interim Area is detailed in Appendix D of this report. Conveyance of run-off water from these areas to the Landfill Settling Basin and Capital Pond via a temporary holding sump is described below.

1.1 Estimate run-off volume for interim conditions

The 25-year run-off volume was evaluated assuming the tributary drainage area is CCR material, which was assumed to be consistent with a hydric soil class B based on engineering experience. SCS Method [Ref. 1] was used to calculate the runoff from each interim cell during the 25-year storm event which was used to size the runoff control measures. The hydrologic conditions and 25-year runoff volume for interim conditions were calculated (See Computation Sheet) and are summarized as shown in the following table:

Table 1: Runoff Volume per Cell for Interim Conditions					
Interim Cell ID	Storm Recurrence Interval (years)	Rainfall for 24-Hour Storm {i} (in.)	Curve Number {CN}	Drainage Area {A} (ac.)	25-Year Run-Off Volume per Cell {V} (ac-ft)
17 North	25	5.4	79	3.10	0.81
17 South	25	5.4	79	2.67	0.70
18 North	25	5.4	79	3.97	1.04
18 South	25	5.4	79	4.28	1.12
TOTAL INTERIM CELL RUNOFF VOLUME					3.67

1.2 Describe typical runoff control measures

Sizing of all interim runoff control measures was done for the 24-hour, 25-year storm [Ref. 2]. Cells 17 and 18 North and South are graded to flow west to the temporary collection sump. This sump then routes to the Landfill Settling Basin.

The sump volume is estimated based on sideslopes of approximately 1.5H:1V, bottom width of approximately twelve (12) feet, and total sump length approximately equal to 740 feet. At a height of 14 vertical feet, the sump volume provided is approximately 341,880 cubic feet or 7.85 acre-feet.

1.3 Evaluate hydraulic performance of control measures

Based on the stated assumptions for the interim storage sump, the storage capacity of 7.85 acre-feet is greater than the 25-year storm runoff volume from the interim cells which generates approximately 3.67 acre-feet. Therefore the interim sump is adequately sized to handle design runoff.

The capacity of the typical interim structure is summarized in the table below:

Table 2: Capacity of Interim Sump					
Design Storm Event (years)	Sump Bottom Width (ft.)	Flow Area (ft2)	Sump Length (ft)	Storage Capacity (ac-ft)	Storage Capacity > Runoff Volume?
25	12.0	462	740	7.85	YES

The results of SCS calculations for the runoff storm volume of interim cells is summarized in the following reference pages.

DISCUSSION:

The interim storage sump for the A.B. Brown Landfill interim cells has capacity to control the runoff from the 24-hour, 25-year storm.

REFERENCES:

1. United States Department of Agriculture, “Urban Hydrology for Small Watersheds”, Technical Release 55, June 1986.
2. Hershfield, David M., “Technical Paper No. 40 Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years”, NOAA National Weather Service, obtained January 14, 2005.

Appendix C: Calculations for Run-Off Control System

Section 2: Run-Off Control System Final Cover Conditions Summary

OBJECTIVE:

The objective of this calculation is to evaluate the size of run-off control measures within the A.B. Brown Type III Restricted Waste Landfill to provide capacity to control non-contact water run-off for the 24-Hour, 25-Year storm during final cover conditions.

METHOD:

Diversion berm, downdrain, perimeter ditch, and retention pond designs were evaluated using SEDCAD4 and HydroCAD modeling softwares and the Soil Conservation Service (SCS) method for calculating runoff.

DEFINITION OF VARIABLES:

A = area;
CN = curve number;
Q = flow;
Tc = time of concentration

CALCULATIONS

1.0 Contact water run-off for final cover conditions

After placement of the CCR to achieve a consistent grade across the landfill footprint, the landfill closure area will be covered in protective soil and a vegetative layer. The Western Landfill Area will be graded to drain towards several levels of terrace berms which will outlet to downdrain riprap channels and perimeter ditches. The Eastern Landfill Area will drain into tack-on berms and downdrain pipes which will also outlet to the perimeter ditch system. Run-off from the final cover landfill area will be captured by these design features and conveyed to the west Landfill Settling Basin and northwest Stormwater Surge Basin.

SEDCAD4 and HydroCAD computer softwares [Ref. 1, 2] were used to model the hydraulic performance of the berms, downdrains, perimeter ditches, and ponds for the 24-Hour, 25-Year storm event [Ref. 4].

1.1 Estimate flow to a typical diversion berm

Two types of diversion berms exist as part of the final cover design of the West Landfill Area. The first type of berm is a side-slope terrace channel berm which coveys run-off flow generated by the steeper (25%) side slopes of the final cover. The second type of berm is a top-of-slope diversion berm which conveys run-off flow generated by the longer, flatter (2.5%) side slope of the final cover running south.

The drainage area to any individual side-slope terrace berm and top-of-slope diversion berm in the West Landfill Area during final cover conditions will be limited to approximately 2.3 acres and 18 acres, respectively. The tributary drainage area is CCR material, which was assumed to be consistent with a hydric soil class B based on engineering experience. Time of concentration was calculated using TR-55 Methodology [Ref. 3]. Below are the SEDCAD4 calculated runoff amounts from both the side-slope terrace diversion berm and top-of-slope diversion berm assuming the maximum drainage area.

Design Feature	SEDCAD Model ID	Storm Frequency	Drainage Area (ac.)	Curve Number	Time of Concentration (hr)	Peak Discharge (cfs)
West End Side-Slope (Terrace) Berm	#10	25yr, 24hr	2.3	78	0.194	6.8
West End Top-of-Slope Berm	#12	25yr, 24hr	18	78	0.339	49

For the East Landfill Area, the HydroCAD calculated run-off amount for the tack-on diversion berm with the greatest drainage area is shown below:

Design Feature	HydroCAD Model ID	Storm Frequency	Drainage Area (ac.)	Curve Number	Time of Concentration (hr)	Peak Discharge (cfs)
East End Tack-On Diversion Berm	West Portion of NW D.A. 2R	25yr, 24hr	6.4	78	0.338	21.3

1.2 Describe typical berm and downdrain outlet

<u>West Landfill Area</u>

On the West Landfill Area the terrace diversion berms are 2 feet high with a 5H:1V side slope on the contact (intercept) face of the berm. The width of each terrace is approximately 10 feet. Terrace berm channels are graded at a 2% slope and route towards riprap channel downdrain structures which feed into the north and south reaches of the perimeter ditch.

The top-of-slope diversion berms on the West Landfill Area are also 2 feet high with 2% channel slopes. These berms have a 4H:1V side slope on both faces of the berm mound.

An average of five (5) terrace berm levels outlet flow to a typical receiving downdrain channel. Downdrain outlets that discharge to the perimeter ditch service (receive flow from) an average of ten (10) terrace runoff areas. There are a total of five (5) downdrain outlets to the perimeter ditch system along the western half of the landfill. The largest drainage area received by any one of these downdrain channels is approximately 23 acres.

<u>East Landfill Area</u>

The East Landfill Area is designed during final cover conditions to convey flow through a series of tack-on diversion berms and 18”-diameter downdrain pipes. The tack-on berms typically have 3H:1V side slopes with 2% channel slope and the berm height varies from 2 feet (minimum) to 4 feet (maximum) at the end nearest to the downdrain. The increased height of the berm at the downstream end allows for a small temporary ponding buffer zone to form should the downdrains become backed up due to exceedance of design capacity during severe storm events.

1.3 Evaluate hydraulic performance of a typical diversion berm

<u>West Landfill Area</u>

Based on the stated assumptions, runoff from the 25-Year storm event produces a flow depth of approximately 1.4 feet in the terrace channel. The planned terrace diversion berm height of 2 feet is capable of conveying the storm flow without the berm overtopping.

Design Feature	SEDCAD Model ID	Storm Frequency	Flow Area Design (sq. ft.)	Flow Area Available (sq. ft.)	Flow Depth Design Flow (ft.)	Depth Channel (ft.)	Freeboard (ft.)
West End Side-Slope (Terrace) Berm	#10	25yr, 24hr	8.8	20	1.40	2	0.60

Based on the stated assumptions, runoff from the 25-Year storm event produces a flow depth of approximately 1.7 feet in the top-of-slope diversion berm channel. The planned top-of-slope diversion berm height of 2 feet is capable of conveying the storm flow without the berm overtopping.

Design Feature	SEDCAD Model ID	Storm Frequency	Flow Area Design (sq. ft.)	Flow Area Available (sq. ft.)	Flow Depth Design Flow (ft.)	Depth Channel (ft.)	Freeboard (ft.)
West End Top-of-Slope Berm	#12	25yr, 24hr	35.7	48	1.70	2	0.30

<u>East Landfill Area</u>

Based on the stated assumptions, runoff from the 25-Year storm event produces a maximum flow depth of approximately 0.76 feet in the tack-on diversion berm channel. The modeled channel depth is produced based on the maximum drainage area received by a typical berm on the East Landfill Area. The planned diversion berm height of 2-4 feet is capable of conveying the storm flow without the berm overtopping.

Design Feature	HydroCAD Model ID	Storm Frequency	Flow Area Design (sq. ft.)	Flow Area Available (sq. ft.)	Flow Depth Design Flow (ft.)	Depth Channel (ft.)	Freeboard (ft.)
East End Tack-On Diversion Berm	West Portion of NW D.A. 2R	25yr, 24hr	13.2	184	0.76	2	1.24

1.4 Evaluate hydraulic performance of a typical downdrain

West Landfill Area

The downdrain structures for the A.B. Brown West Landfill Area, final cover design are riprapped stormwater channels. The downdrain channels run downhill at the same grade as the landfill. The downdrain channel design has a 2-foot bottom with 1.5-foot depth and 4H:1V side slopes. The downdrain channels use Type I Riprap. Capacity calculations for a typical riprap downdrain are shown below:

Table 5A: Structure Capacity for Riprap Open Channel Downdrains

SEDCAD ID	Design Storm Event (years)	Channel Bottom (ft.)	Channel Area (ft2)	Velocity (fps)	Design Discharge (cfs)	Flow Capacity (cfs)	Flow Capacity > Design Flow?
#25	25yr, 24hr	2.0	12	10.0	63.8	86.2	YES

East Landfill Area

The downdrain structures for the A.B. Brown East Landfill Area, final cover design are 18"-diameter corrugated polyethylene pipes. Discharges from the subbasins of the East Landfill Area, routed through the downdrains, are calculated below:

Table 5B: Structure Capacity for Pipe Downdrains

HydroCAD ID	Design Storm Event (years)	Pipe Diameter (ft.)	Pipe Area (ft2)	Velocity (fps)	Design Discharge (cfs)	Flow Capacity (cfs)	Flow Capacity > Design Discharge?
NW – 2R	25yr, 24hr	1.3	1.33	23.6	16.0	31.1	YES
NE – 2R	25yr, 24hr	1.3	1.33	23.2	14.8	31.1	YES
SE – 2R	25yr, 24hr	1.3	1.33	23.2	15.0	31.1	YES
SW – 2R	25yr, 24hr	1.3	1.33	23.5	15.8	31.1	YES

DISCUSSION:

Run-off control measures for the A.B. Brown Type III Restricted Waste Landfill have capacity to control non-contact water run-off for the 24-Hour, 25-Year storm during final cover conditions.

REFERENCES:

1. SEDCAD4 by Civil Software Design LLC.
2. HydroCAD by HydroCAD Software Solutions LLC.
3. United States Department of Agriculture, “Urban Hydrology for Small Watersheds”, Technical Release 55, June 1986.
4. Hershfield, David M., “Technical Paper No. 40 Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years”, NOAA National Weather Service, obtained January 14, 2005.

Appendix C: Calculations for Run-Off Control System

Section 3: References

REFERENCE NO.	DESCRIPTION
1	SEDCAD 4 Modeling Results
2	HydroCAD Modeling Results
3	USDA TR-55
4	NOAA Technical Paper No. 40

Reference 1: SEDCAD 4 - Modeling Results

STORM WATER RUNOFF CALCULATIONS

The erosion and stormwater control structures described in this section have been designed, as required, to limit soil erosion to less than 5 tons-per-acre-per-year and adequately convey the 25-year/24-hour storm event (5.43", IDNR 1994, attached). It is our understanding that the existing sedimentation basins are adequate. Soil erosion estimates are attached in a separate calculations section.

Stormwater flows from seven sub-drainage areas routed through perimeter channels and road-crossing culverts (see attached figure) were determined for the proposed modification area (NW, NE, SE, S, SW, and W), the completed landfill (E), and an undeveloped area (N) using the SEDCAD4 computer model developed by R.C. Warner of the University of Kentucky and P.J. Schwab of Civil Soft Design. These sub-drainage area flows are based on drainage area, elevation change across the drainage area, flow path length, and soil cover characteristics. These flows were input into the SEDCAD model at their respective locations along the north and south perimeter channels. The model then routed these flows through the north and south perimeter channels which then joined at a location near the southwest corner of the existing retention basin. Because the peak flows from the various sub-drainage areas occur at different times, the model accounts for the timing of these peaks and adjusts the peaks of combined flows accordingly. An output from the model of this drainage system is attached and shows that:

The south perimeter channel conveys 25-year/24-hour stormwater flows from the

SE area (3 acres at 9 cfs peak) which flows west through the
South perimeter channel at 9 cfs peak and 1.7 fps to an
18-inch-diameter culvert which flows to the

S area (16 acres at 46 cfs peak) which joins the SE area and flows west through the
South perimeter channel at 52 cfs peak and 3.2 fps to the

SW area (23 ac. at 64 cfs peak) which joins the SE and S areas and flows through the
South perimeter channel at 113 cfs peak and 5.0 fps to the

W area (23 acres at 72 cfs peak) joins SE, S, and SW areas and flows through a
60-inch-diameter culvert with a 72-inch-dia.drop-inlet and flows west through the

South perimeter channel at 172 cfs peak at 5.2 fps to join the
North perimeter channel and flow west through the
Combined north/south channel at 411 cfs peak and 5.9 fps.

The north perimeter channel conveys 25-year/24-hour stormwater flows from the

E area (50 acres at 81 cfs peak) which flows through the
North perimeter channel at 81 cfs peak and 5.6 fps to the

NE area (10 acres at 31 cfs peak) which joins the E area and flows west through the
North perimeter channel at 86 cfs peak and 8.1 fps to the

N area (144 acres at 264 cfs) which joins the E and NE areas to flow west through the
North perimeter channel at 343 cfs peak and 6.2 fps to the

NW area (17 ac. at 48 cfs) which joins the E, NE, and N areas and flows through the
North perimeter channel with a 353 cfs peak and 6.8 fps to join the
South perimeter channel and flow west through the
Combined north/south channel at 411 cfs peak and 5.9 fps.

The perimeter channels that transport flows at velocities greater than 5 fps typically require more erosion protection than normal vegetation can provide. Sheet 6 shows a riprap channel downstream from the NE sub-drainage area and turf-reinforcement mats downstream from the N sub-drainage area.

Maximum design flows within stormwater conveyance structures of a

- Side-slope terrace channel with a site-maximum area of 2.3 acres, a
- Top-of-slope diversion berm with a site-maximum area of 18 acres, and a
- Riprap-lined downdrain channel with a site-maximum area of 23 acres.

were individually determined by the SEDCAD4 computer model and were found to adequately convey their portions of the 25-year/24-hour storm. Outputs from these models are attached and described below.

Side-slope terrace channels lie between 90-ft lengths of 4H:1V, grass-covered, final cover slopes. The 90-ft terrace spacings are based on erosion control calculations provided in the "Final Cover Soil Loss Estimates" section of this minor permit modification application. The terrace channels have 2% slopes, are v-shaped with 4H:1V and 5H:1V sideslopes, and are up to 1,000 ft in length. These channels are drained into riprap-lined downdrain channels at the northeast, northwest, west, and the south sides of the proposed final cover modifications.

The attached SEDCAD4 output shows that at the maximum length of 1,000 feet and a maximum area of 2.3 acres, this proposed channel adequately handles the 25-year/24-hour storm flow of 7 cfs.

Top-of-final-cover diversion berms have been placed at selected locations on the 5%-sloped top of the final cover. These channels have 2% to 2.7% slopes, are v-shaped with 4H:1V and 20H:1V sideslopes, are up to 1,100 ft in length, and collect runoff from up to 18 acres of 5%-sloped final cover. These channels are drained into riprap-lined downdrain channels at the northeast, northwest, west, and south sides of the proposed final cover modifications.

The attached SEDCAD4 output shows that at the maximum area of 18 acres, this proposed berm adequately diverts the 25-year/24-hour storm flow of 49 cfs.

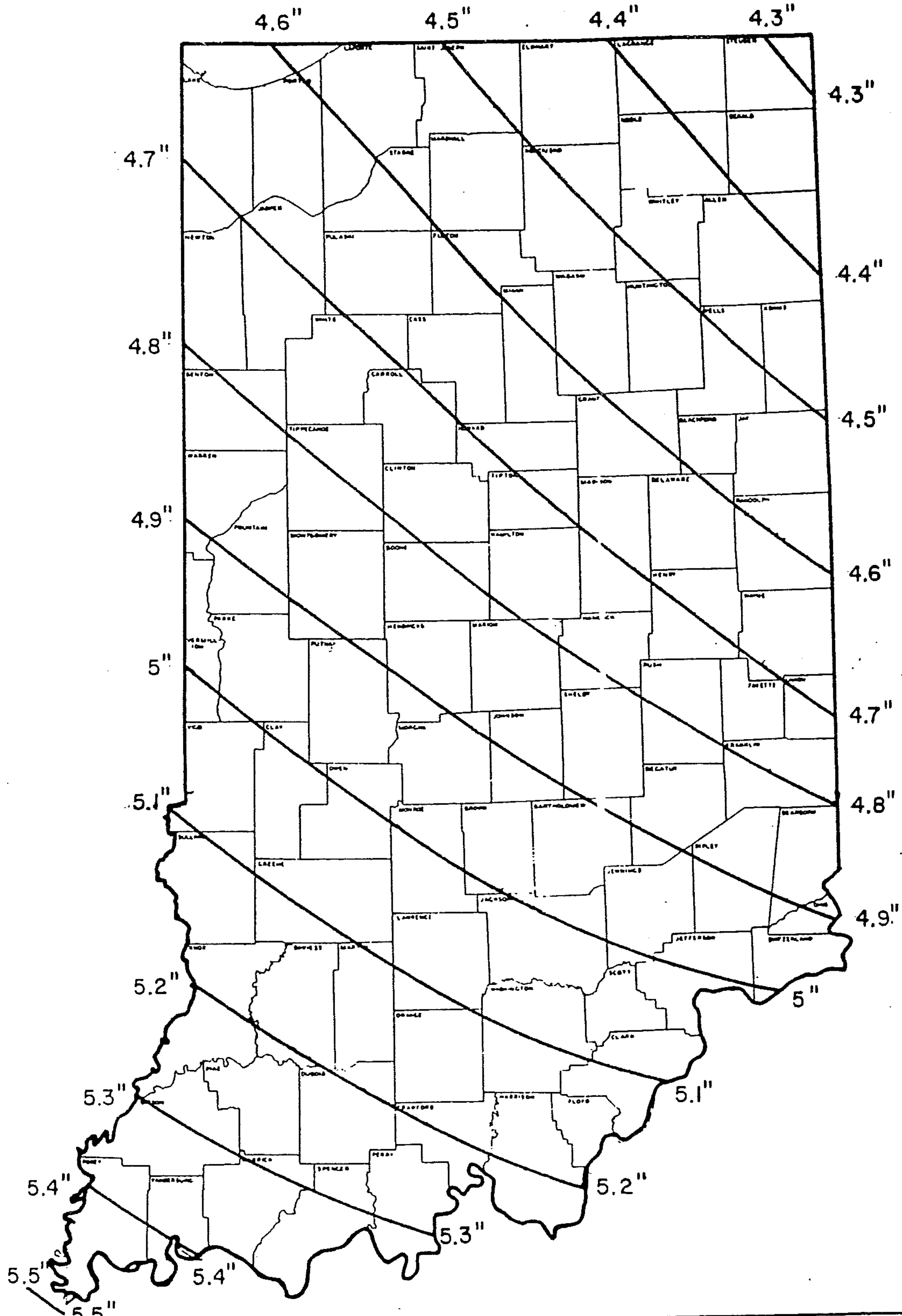
Riprap-lined downdrain channels have 2-ft bottoms, 4H:1V sideslopes, are generally sloped at 25% grades, and flow into the north and south perimeter channels. At the terraces, the riprap is extended an additional 6 feet past the top of the 3H:1V sideslopes.

The attached SEDCAD4 output shows that at the maximum area of 23 acres, the proposed downdrain adequately handles the 25-year/24-hour storm flow of 73 cfs. This model also shows the design features for a riprap-lined plunge pool for dissipation of flow energy. A detail of this plunge pool is shown on Sheet 6 of the engineering drawings.

Documentation

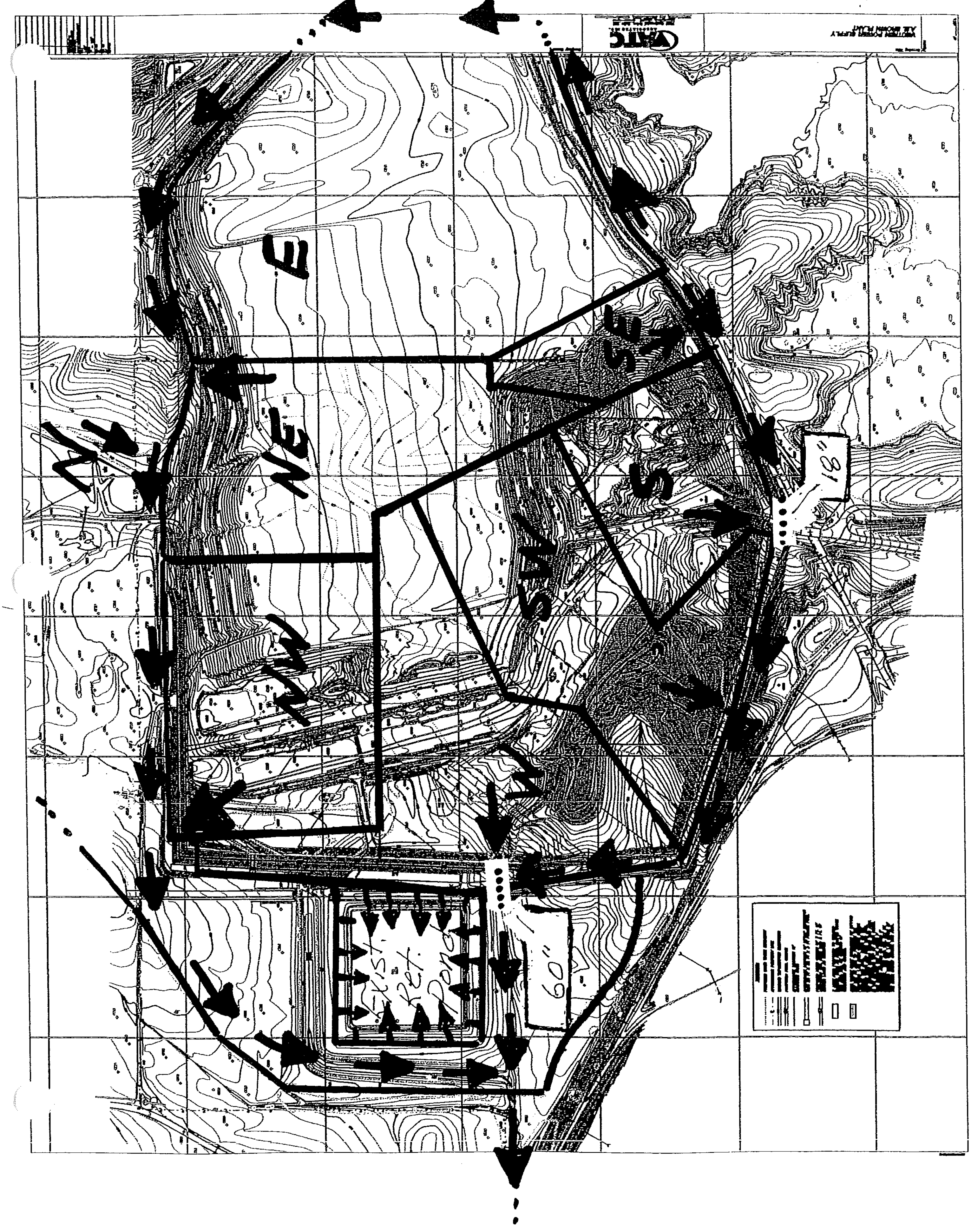
5/6

RAINFALL - 25 YEAR FREQUENCY - 24 HOUR DURATION



REFERENCE TECHNICAL PAPER NO. 40 NATIONAL WEATHER SERVICE	STATE OF INDIANA DEPARTMENT OF NATURAL RESOURCES DIVISION OF WATER

APRIL 1979


E
NE
N
NW
SE
S
SW
18"
60"

Runoff Flows from the NW, N, NE, E, SE, S, SW, and W Sub-Drainage Areas

AB Brown Type III Landfill January 2007 Minor Modification

Using a 25-year/24-hour design storm, this site's sub-drainage areas NW, N, NE and E have been routed through the north perimeter channel while the W, SW, S, and SE drainage areas have been routed through the south perimeter channel which includes a road-crossing culvert upstream of the S drainage area outlet and a road-crossing culvert downstream of the W drainage area outlet. These north and south perimeter channels meet near the west side of the existing retaining pond and then drain west to the site's existing sedimentation pond.

General Information

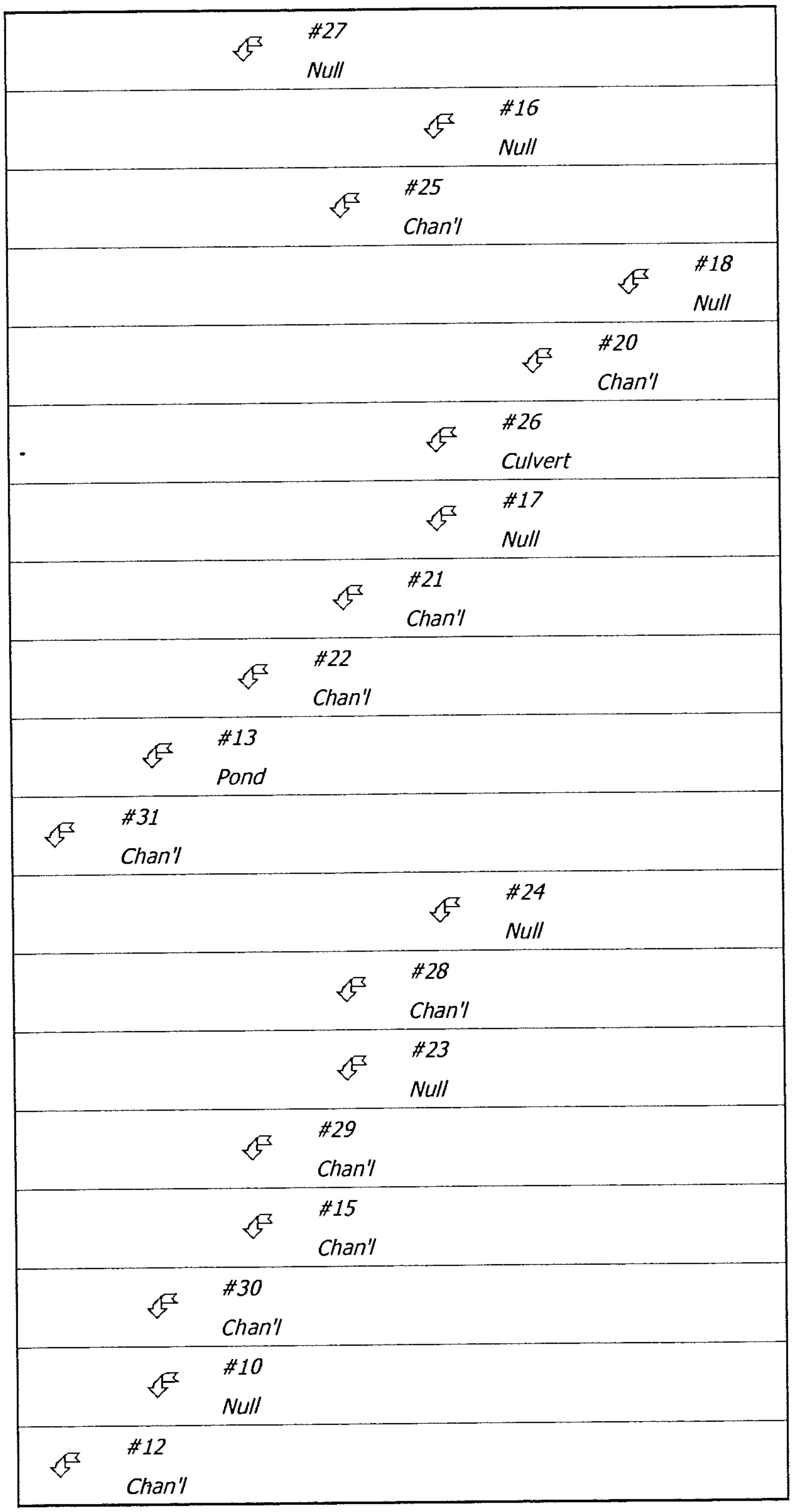
Storm Information:

Storm Type:	NRCS Type II
Design Storm:	25 yr - 24 hr
Rainfall Depth:	5.430 inches

Structure Networking:

Type	Stru #	(flows into)	Stru #	Musk. K (hrs)	Musk. X	Description
Null	#10	==>	#12	0.000	0.000	NW drainage area
Channel	#12	==>	#14	0.056	0.406	North perimeter channel from NE drainage area to junction with south perimeter channel drains NW, N, NE, and N drainage areas
Pond	#13	==>	#31	0.000	0.000	Headwater of 60-inch diameter culvert that drains the south perimeter channel under the perimeter road
Channel	#14	==>	End	0.000	0.000	Channel at southwest corner of existing retention pond that drains the north perimeter and south perimeter channels
Channel	#15	==>	#30	0.000	0.000	N drainage area
Null	#16	==>	#25	0.000	0.000	SW drainage area
Null	#17	==>	#21	0.000	0.000	S drainage area
Null	#18	==>	#20	0.000	0.000	SE drainage area
Channel	#20	==>	#26	0.000	0.000	South perimeter channel from SE to S drainage areas - drains SE area
Channel	#21	==>	#22	0.000	0.000	South perimeter channel from S to SW drainages areas - drains SE and S areas
Channel	#22	==>	#13	0.000	0.000	South perimeter channel from SW drainage area to the 60-inch diameter culvert - drains SW, S, and SE areas
Null	#23	==>	#29	0.000	0.000	NE drainage area
Null	#24	==>	#28	0.000	0.000	E drainage area
Channel	#25	==>	#22	0.000	0.000	SW drainage area - riprap downdrain for the SW drainage area
Culvert	#26	==>	#21	0.000	0.000	South perimeter channel culvert under road between drainage areas SE and S
Null	#27	==>	#13	0.000	0.000	W drainage area
Channel	#28	==>	#29	0.098	0.357	North perimeter channel - existing perimeter channel from E drainage area to NE drainage area - drains E area
Channel	#29	==>	#30	0.010	0.410	North perimeter channel - existing perimeter channel from NE drainage area and N drainage area - drains NE and E areas
Channel	#30	==>	#12	0.022	0.406	North perimeter channel - widened existing perimeter channel from N drainage area to NE drainage area - drains N, NE, and E areas

Type	Stru #	(flows into)	Stru #	Musk. K (hrs)	Musk. X	Description
Channel	#31	==>	#14	0.008	0.430	South perimeter channels from the 60-inch diameter culvert to the junction between the north and south perimeter channels



#14
Chan'l

Structure Routing Details:

Stru #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#12	9. Small streams flowing bankfull	0.67	10.00	1,500.00	7.34	0.056
#12	**Muskingum K:**					**0.056**
#16	8. Large gullies, diversions, and low flowing streams	0.00	0.00	0.00	0.00	0.000
#16	**Muskingum K:**					**0.000**
#28	8. Large gullies, diversions, and low flowing streams	2.00	30.00	1,500.00	4.24	0.098
#28	**Muskingum K:**					**0.098**
#29	8. Large gullies, diversions, and low flowing streams	6.67	20.00	300.00	7.74	0.010
#29	**Muskingum K:**					**0.010**
#30	9. Small streams flowing bankfull	0.67	4.00	600.06	7.34	0.022
#30	**Muskingum K:**					**0.022**
#31	9. Small streams flowing bankfull	1.33	4.00	300.00	10.39	0.008
#31	**Muskingum K:**					**0.008**

Structure Summary:

		Immediate Contributing Area (ac)	Total Contributing Area (ac)	Peak Discharge (cfs)	Total Runoff Volume (ac-ft)
#27		22.900	22.900	72.35	5.88
#16		22.600	22.600	63.78	5.80
#25		0.000	22.600	63.78	5.80
#18		2.800	2.800	8.85	0.72
#20		0.000	2.800	8.85	0.72
#26		0.000	2.800	8.85	0.72
#17		16.100	16.100	45.59	4.13
#21		0.000	18.900	52.22	4.85
#22		0.000	41.500	112.98	10.65
#13	In	0.000	64.400	185.33	16.53
	Out			182.03	16.53
#31		0.000	64.400	182.03	16.53
#24		50.000	50.000	80.57	12.83
#28		0.000	50.000	80.57	12.83
#23		10.300	10.300	30.90	2.64
#29		0.000	60.300	85.92	15.48
#15		144.000	144.000	263.85	36.96
#30		0.000	204.300	342.72	52.44
#10		16.900	16.900	47.64	4.34
#12		0.000	221.200	353.02	56.78
#14		0.000	285.600	411.02	73.31

Structure Detail:

Structure #27 (Null)

W drainage area

Structure #16 (Null)

SW drainage area

Structure #25 (Riprap Channel)

SW drainage area - riprap downdrain for the SW drainage area

Trapezoidal Riprap Channel Inputs:

Material: Riprap

Bottom Width (ft)}	Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)
2.00	3.0:1	3.0:1	25.0	0.50		

Riprap Channel Results:

PADER Method - Steep Slope Design

	w/o Freeboard	w/ Freeboard
Design Discharge:	63.78 cfs	
Depth:	1.16 ft	1.66 ft
Top Width:	8.99 ft	11.99 ft
Velocity:	9.96 fps	
X-Section Area:	6.40 sq ft	
Hydraulic Radius:	0.683	
Froude Number:	2.08	
Manning's n:	0.0580	
Dmin:	5.00 in	
D50:	9.00 in	
Dmax:	12.00 in	

Structure #18 (Null)

SE drainage area

Structure #20 (Vegetated Channel)

South perimeter channel from SE to S drainage areas - drains SE area

Trapezoidal Vegetated Channel Inputs:

Material: Grass mixture

Bottom Width (ft)	Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Retardance Classes	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)	Limiting Velocity (fps)
12.00	3.0:1	3.0:1	2.0	D, B				5.0

Vegetated Channel Results:

	Stability Class D w/o Freeboard	Stability Class D w/ Freeboard	Capacity Class B w/o Freeboard	Capacity Class B w/ Freeboard
Design Discharge:	8.85 cfs		8.85 cfs	
Depth:	0.41 ft		0.81 ft	
Top Width:	14.49 ft		16.84 ft	
Velocity:	1.61 fps		0.76 fps	
X-Section Area:	5.50 sq ft		11.62 sq ft	
Hydraulic Radius:	0.376		0.680	
Froude Number:	0.46		0.16	
Roughness Coefficient:	0.0680		0.2138	

Structure #26 (Culvert)

South perimeter channel culvert under road between drainage areas SE and S

Culvert Inputs:

Length (ft)	Slope (%)	Manning's n	Max. Headwater (ft)	Tailwater (ft)	Entrance Loss Coef. (Ke)
130.00	2.30	0.0240	2.20	1.00	0.90

Culvert Results:

Design Discharge = 8.85 cfs

Minimum pipe diameter: 1 - 18 inch pipe(s) required

Structure #17 (Null)

S drainage area

Structure #21 (Vegetated Channel)

South perimeter channel from S to SW drainages areas - drains SE and S areas

Trapezoidal Vegetated Channel Inputs:

Material: Grass mixture

Bottom Width (ft)	Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Retardance Classes	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)	Limiting Velocity (fps)
12.00	3.0:1	30.0:1	3.3	D, B	0.50			5.0

Vegetated Channel Results:

	Stability Class D w/o Freeboard	Stability Class D w/ Freeboard	Capacity Class B w/o Freeboard	Capacity Class B w/ Freeboard
Design Discharge:	52.22 cfs		52.22 cfs	
Depth:	0.70 ft	1.20 ft	1.15 ft	1.65 ft
Top Width:	35.13 ft	51.63 ft	50.05 ft	66.55 ft
Velocity:	3.16 fps		1.46 fps	
X-Section Area:	16.52 sq ft		35.77 sq ft	
Hydraulic Radius:	0.470		0.714	
Froude Number:	0.81		0.30	
Roughness Coefficient:	0.0517		0.1480	

Structure #22 (Vegetated Channel)

South perimeter channel from SW drainage area to the 60-inch diameter culvert - drains SW, S, and SE areas

Trapezoidal Vegetated Channel Inputs:

Material: Grass mixture

Bottom Width (ft)	Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Retardance Classes	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)	Limiting Velocity (fps)
20.00	3.0:1	3.0:1	1.9	D, B				5.0

Vegetated Channel Results:

	Stability Class D w/o Freeboard	Stability Class D w/ Freeboard	Capacity Class B w/o Freeboard	Capacity Class B w/ Freeboard
Design Discharge:	112.98 cfs		112.98 cfs	
Depth:	0.99 ft		1.47 ft	
Top Width:	25.92 ft		28.80 ft	
Velocity:	4.99 fps		3.16 fps	
X-Section Area:	22.66 sq ft		35.77 sq ft	
Hydraulic Radius:	0.864		1.222	
Froude Number:	0.94		0.50	
Roughness Coefficient:	0.0373		0.0743	

Structure #13 (Pond)

Headwater of 60-inch diameter culvert that drains the south perimeter channel under the perimeter road

Pond Inputs:

Initial Pool Elev:	401.00
Initial Pool:	0.03 ac-ft

Drop Inlet

Riser Diameter (in)	Riser Height (ft)	Barrel Diameter (in)	Barrel Length (ft)	Barrel Slope (%)	Manning's n	Spillway Elev
72.00	4.00	60.00	80.00	0.10	0.0240	401.00

Pond Results:

Peak Elevation:	403.17
Dewater Time:	0.52 days

Dewatering time is calculated from peak stage to lowest spillway

Elevation-Capacity-Discharge Table

Elevation	Area (ac)	Capacity (ac-ft)	Discharge (cfs)	Dewater Time (hrs)	
395.00	0.001	0.000	0.000		
395.50	0.001	0.001	0.000		
396.00	0.002	0.001	0.000		
396.50	0.002	0.002	0.000		
397.00	0.003	0.004	0.000		
397.50	0.004	0.005	0.000		
398.00	0.004	0.007	0.000		
398.50	0.005	0.010	0.000		
399.00	0.006	0.013	0.000		
399.50	0.007	0.016	0.000		
399.70	0.007	0.017	0.000		
399.75	0.007	0.018	0.000		
399.80	0.007	0.018	0.000		
400.00	0.008	0.019	0.000		
400.50	0.009	0.024	0.000		
401.00	0.010	0.028	0.000		Spillway #1
401.50	0.031	0.038	20.659	11.45	
402.00	0.062	0.061	58.434	0.70	
402.50	0.105	0.102	107.349	0.10	

Elevation	Area (ac)	Capacity (ac-ft)	Discharge (cfs)	Dewater Time (hrs)	
403.00	0.159	0.168	165.275		
403.17	0.184	0.200	182.028	0.20	Peak Stage
403.50	0.224	0.263	215.257		
404.00	0.300	0.393	224.165		
404.50	0.394	0.566	231.945		
405.00	0.500	0.789	239.473		

Detailed Discharge Table

Elevation	Drop Inlet (cfs)	Combined Total Discharge (cfs)
395.00	0.000	0.000
395.50	0.000	0.000
396.00	0.000	0.000
396.50	0.000	0.000
397.00	0.000	0.000
397.50	0.000	0.000
398.00	0.000	0.000
398.50	0.000	0.000
399.00	0.000	0.000
399.50	0.000	0.000
399.70	0.000	0.000
399.75	0.000	0.000
399.80	0.000	0.000
400.00	0.000	0.000
400.50	0.000	0.000
401.00	0.000	0.000
401.50	20.659	20.659
402.00	58.434	58.434
402.50	107.349	107.349
403.00	165.275	165.275
403.50	215.257	215.257
404.00	224.165	224.165
404.50	231.945	231.945
405.00	239.473	239.473

Structure #31 (Vegetated Channel)

South perimeter channels from the 60-inch diameter culvert to the junction between the north and south perimeter channels

Trapezoidal Vegetated Channel Inputs:

Material: Tall fescue

Bottom Width (ft)	Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Retardance Classes	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)	Limiting Velocity (fps)
20.00	4.0:1	4.0:1	1.3	D, B				7.0

Vegetated Channel Results:

	Stability Class D w/o Freeboard	Stability Class D w/ Freeboard	Capacity Class B w/o Freeboard	Capacity Class B w/ Freeboard
Design Discharge:	182.03 cfs		182.03 cfs	
Depth:	1.35 ft		1.92 ft	
Top Width:	30.78 ft		35.33 ft	
Velocity:	5.32 fps		3.43 fps	
X-Section Area:	34.20 sq ft		53.01 sq ft	
Hydraulic Radius:	1.099		1.481	
Froude Number:	0.89		0.49	
Roughness Coefficient:	0.0340		0.0642	

Structure #24 (Null)

E drainage area

Structure #28 (Vegetated Channel)

North perimeter channel - existing perimeter channel from E drainage area to NE drainage area - drains E area

Trapezoidal Vegetated Channel Inputs:

Material: Tall fescue

Bottom Width (ft)	Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Retardance Classes	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)	Limiting Velocity (fps)
2.00	4.0:1	4.0:1	2.0	D, B				7.0

Vegetated Channel Results:

	Stability Class D w/o Freeboard	Stability Class D w/ Freeboard	Capacity Class B w/o Freeboard	Capacity Class B w/ Freeboard
Design Discharge:	80.57 cfs		80.57 cfs	
Depth:	1.66 ft		2.26 ft	
Top Width:	15.29 ft		20.06 ft	

	Stability Class D w/o Freeboard	Stability Class D w/ Freeboard	Capacity Class B w/o Freeboard	Capacity Class B w/ Freeboard
Velocity:	5.61 fps		3.24 fps	
X-Section Area:	14.36 sq ft		24.89 sq ft	
Hydraulic Radius:	0.915		1.208	
Froude Number:	1.02		0.51	
Roughness Coefficient:	0.0354		0.0738	

Structure #23 (Null)

NE drainage area

Structure #29 (Riprap Channel)

North perimeter channel - existing perimeter channel from NE drainage area and N drainage area - drains NE and E areas

Trapezoidal Riprap Channel Inputs:

Material: Riprap

Bottom Width (ft)}	Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)
2.00	3.0:1	3.0:1	6.7			

Riprap Channel Results:

PADER Method - Steep Slope Design

	w/o Freeboard	w/ Freeboard
Design Discharge:	85.92 cfs	
Depth:	1.58 ft	
Top Width:	11.46 ft	
Velocity:	8.09 fps	
X-Section Area:	10.62 sq ft	
Hydraulic Radius:	0.887	
Froude Number:	1.48	
Manning's n:	0.0440	
Dmin:	3.00 in	
D50:	6.00 in	
Dmax:	9.00 in	

Structure #15 (Vegetated Channel)

N drainage area

Trapezoidal Vegetated Channel Inputs:

Material: Grass mixture

Bottom Width (ft)	Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Retardance Classes	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)	Limiting Velocity (fps)
20.00	3.0:1	3.0:1	0.3	D, B				5.0

Vegetated Channel Results:

	Stability Class D w/o Freeboard	Stability Class D w/ Freeboard	Capacity Class B w/o Freeboard	Capacity Class B w/ Freeboard
Design Discharge:	263.85 cfs		263.85 cfs	
Depth:	2.58 ft		3.56 ft	
Top Width:	35.50 ft		41.37 ft	
Velocity:	3.68 fps		2.41 fps	
X-Section Area:	71.68 sq ft		109.26 sq ft	
Hydraulic Radius:	1.973		2.570	
Froude Number:	0.46		0.26	
Roughness Coefficient:	0.0318		0.0579	

Structure #30 (Vegetated Channel)

North perimeter channel - widened existing perimeter channel from N drainage area to NE drainage area - drains N, NE, and E areas

Trapezoidal Vegetated Channel Inputs:

Material: Tall fescue

Bottom Width (ft)	Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Retardance Classes	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)	Limiting Velocity (fps)
12.00	4.0:1	4.0:1	0.7	D, B				7.0

Vegetated Channel Results:

	Stability Class D w/o Freeboard	Stability Class D w/ Freeboard	Capacity Class B w/o Freeboard	Capacity Class B w/ Freeboard
Design Discharge:	342.72 cfs		342.72 cfs	
Depth:	2.51 ft		3.24 ft	
Top Width:	32.04 ft		37.90 ft	
Velocity:	6.21 fps		4.24 fps	
X-Section Area:	55.16 sq ft		80.79 sq ft	
Hydraulic Radius:	1.689		2.088	

	Stability Class D w/o Freeboard	Stability Class D w/ Freeboard	Capacity Class B w/o Freeboard	Capacity Class B w/ Freeboard
Froude Number:	0.83		0.51	
Roughness Coefficient:	0.0284		0.0480	

Structure #10 (Null)

NW drainage area

Structure #12 (Vegetated Channel)

North perimeter channel from NE drainage area to junction with south perimeter channel drains NW, N, NE, and N drainage areas

Trapezoidal Vegetated Channel Inputs:

Material: Tall fescue

Bottom Width (ft)	Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Retardance Classes	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)	Limiting Velocity (fps)
12.00	3.0:1	3.0:1	0.7	D, B	1.00			7.0

Vegetated Channel Results:

	Stability Class D w/o Freeboard	Stability Class D w/ Freeboard	Capacity Class B w/o Freeboard	Capacity Class B w/ Freeboard
Design Discharge:	353.02 cfs		353.02 cfs	
Depth:	2.60 ft	3.60 ft	3.31 ft	4.31 ft
Top Width:	27.61 ft	33.61 ft	31.86 ft	37.86 ft
Velocity:	6.85 fps		4.86 fps	
X-Section Area:	51.54 sq ft		72.59 sq ft	
Hydraulic Radius:	1.811		2.204	
Froude Number:	0.88		0.57	
Roughness Coefficient:	0.0270		0.0434	

Structure #14 (Vegetated Channel)

Channel at southwest corner of existing retention pond that drains the north perimeter and south perimeter channels

Trapezoidal Vegetated Channel Inputs:

Material: Tall fescue

Bottom Width (ft)	Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Retardance Classes	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)	Limiting Velocity (fps)
20.00	3.0:1	3.0:1	0.5	D, B				7.0

Vegetated Channel Results:

	Stability Class D w/o Freeboard	Stability Class D w/ Freeboard	Capacity Class B w/o Freeboard	Capacity Class B w/ Freeboard
Design Discharge:	411.02 cfs		411.02 cfs	
Depth:	2.52 ft		3.27 ft	
Top Width:	35.15 ft		39.63 ft	
Velocity:	5.90 fps		4.21 fps	
X-Section Area:	69.63 sq ft		97.52 sq ft	
Hydraulic Radius:	1.936		2.397	
Froude Number:	0.74		0.47	
Roughness Coefficient:	0.0277		0.0448	

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#27	1	22.900	0.102	0.000	0.000	78.000	TR55	72.35	5.878
	Σ	**22.900**						**72.35**	**5.878**
#16	1	22.600	0.252	0.000	0.000	78.000	TR55	63.78	5.801
	Σ	**22.600**						**63.78**	**5.801**
#25	Σ	**22.600**						**63.78**	**5.801**
#18	1	2.800	0.088	0.000	0.000	78.000	TR55	8.85	0.719
	Σ	**2.800**						**8.85**	**0.719**
#20	Σ	**2.800**						**8.85**	**0.719**
#26	Σ	**2.800**						**8.85**	**0.719**
#17	1	16.100	0.249	0.000	0.000	78.000	TR55	45.59	4.133
	Σ	**16.100**						**45.59**	**4.133**
#21	Σ	**18.900**						**52.22**	**4.852**
#22	Σ	**41.500**						**112.98**	**10.653**
#13	Σ	**64.400**						**185.33**	**16.531**
#31	Σ	**64.400**						**182.03**	**16.531**
#24	1	50.000	1.017	0.000	0.000	78.000	TR55	80.57	12.835
	Σ	**50.000**						**80.57**	**12.835**
#28	Σ	**50.000**						**80.57**	**12.835**
#23	1	10.300	0.160	0.000	0.000	78.000	TR55	30.90	2.644
	Σ	**10.300**						**30.90**	**2.644**
#29	Σ	**60.300**						**85.92**	**15.479**
#15	1	144.000	0.818	0.000	0.000	78.000	TR55	263.85	36.964
	Σ	**144.000**						**263.85**	**36.964**
#30	Σ	**204.300**						**342.72**	**52.443**
#10	1	16.900	0.253	0.000	0.000	78.000	TR55	47.64	4.338
	Σ	**16.900**						**47.64**	**4.338**
#12	Σ	**221.200**						**353.02**	**56.781**
#14	Σ	**285.600**						**411.02**	**73.313**

Subwatershed Time of Concentration Details:

Stru #	SWS #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#10	1	3. Short grass pasture	7.50	150.00	2,000.00	2.190	0.253
#10	**1**	**Time of Concentration:**					**0.253**
#15	1	3. Short grass pasture	1.43	40.00	2,800.14	0.950	0.818
#15	**1**	**Time of Concentration:**					**0.818**
#16	1	3. Short grass pasture	6.84	130.00	1,900.00	2.090	0.252
#16	**1**	**Time of Concentration:**					**0.252**
#17	1	3. Short grass pasture	4.40	66.00	1,500.00	1.670	0.249
#17	**1**	**Time of Concentration:**					**0.249**
#18	1	3. Short grass pasture	10.00	80.00	800.00	2.520	0.088
#18	**1**	**Time of Concentration:**					**0.088**
#23	1	3. Short grass pasture	9.29	130.00	1,400.00	2.430	0.160
#23	**1**	**Time of Concentration:**					**0.160**
#24	1	3. Short grass pasture	1.62	60.00	3,700.00	1.010	1.017
#24	**1**	**Time of Concentration:**					**1.017**
#27	1	6. Grassed waterway	8.97	148.00	1,650.00	4.490	0.102
#27	**1**	**Time of Concentration:**					**0.102**

Maximum-Flow Design for the Side-Slope Terrace Channel

AB Brown Type III Landfill January 2007 Minor Modification

Using the 25-year/24-hour design storm, the following calculations show that the maximum flows produced by this site are allowable for the size and configuration of the proposed side-slope terrace channels.

DS

General Information

Storm Information:

Storm Type:	NRCS Type II
Design Storm:	25 yr - 24 hr
Rainfall Depth:	5.430 inches

Structure Networking:

Type	Stru #	(flows into)	Stru #	Musk. K (hrs)	Musk. X	Description
Channel	#10	==>	End	0.000	0.000	Side-slope terrace channel with a site-maximum length of 1000 feet at 2%

#10
Chan'l

Structure Summary:

	Immediate Contributing Area (ac)	Total Contributing Area (ac)	Peak Discharge (cfs)	Total Runoff Volume (ac-ft)
#10	2.300	2.300	6.81	0.59

Structure Detail:

Structure #10 (Vegetated Channel)

Side-slope terrace channel with a site-maximum length of 1000 feet at 2%

Triangular Vegetated Channel Inputs:

Material: Grass mixture

Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Retardance Classes	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)	Limiting Velocity (fps)
4.0:1	5.0:1	2.0	D, B	0.50			5.0

Vegetated Channel Results:

	Stability Class D w/o Freeboard	Stability Class D w/ Freeboard	Capacity Class B w/o Freeboard	Capacity Class B w/ Freeboard
Design Discharge:	6.81 cfs		6.81 cfs	
Depth:	0.88 ft	1.38 ft	1.40 ft	1.90 ft
Top Width:	7.93 ft	12.43 ft	12.60 ft	17.10 ft
Velocity:	1.95 fps		0.77 fps	
X-Section Area:	3.49 sq ft		8.82 sq ft	
Hydraulic Radius:	0.430		0.683	
Froude Number:	0.52		0.16	
Roughness Coefficient:	0.0615		0.2117	

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#10	1	2.300	0.194	0.000	0.000	78.000	TR55	6.81	0.590
	$\sum$	**2.300**						**6.81**	**0.590**

Subwatershed Time of Concentration Details:

Stru #	SWS #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#10	1	3. Short grass pasture	3.86	42.50	1,100.00	1.570	0.194
#10	**1**	**Time of Concentration:**					**0.194**

Maximum Flow Design for the Top-of-Slope Diversion Berm

AB Brown Type III Landfill January 2007 Minor Modification

Using the 25-year/24-hour design storm, the following calculations show that the maximum flows produced by this site are allowable for the size and configuration of the proposed top-of-slope diversion berms.

DS

General Information

Storm Information:

Storm Type:	NRCS Type II
Design Storm:	25 yr - 24 hr
Rainfall Depth:	5.430 inches

Structure Networking:

Type	Stru #	(flows into)	Stru #	Musk. K (hrs)	Musk. X	Description
Channel	#12	==>	End	0.000	0.000	2% top-slope diversion berm assuming a site-maximum of 18 acres for the 5%-sloped final cover

#12
Chan'l

Structure Summary:

	Immediate Contributing Area (ac)	Total Contributing Area (ac)	Peak Discharge (cfs)	Total Runoff Volume (ac-ft)
#12	18.000	18.000	49.02	4.62

Structure Detail:

Structure #12 (Vegetated Channel)

2% top-slope diversion berm assuming a site-maximum of 18 acres for the 5%-sloped final cover

Triangular Vegetated Channel Inputs:

Material: Grass mixture

Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Retardance Classes	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)	Limiting Velocity (fps)
4.0:1	20.0:1	2.0	D, B				5.0

Vegetated Channel Results:

	Stability Class D w/o Freeboard	Stability Class D w/ Freeboard	Capacity Class B w/o Freeboard	Capacity Class B w/ Freeboard
Design Discharge:	49.02 cfs		49.02 cfs	
Depth:	1.17 ft		1.72 ft	
Top Width:	28.08 ft		41.38 ft	
Velocity:	2.98 fps		1.37 fps	
X-Section Area:	16.43 sq ft		35.67 sq ft	
Hydraulic Radius:	0.583		0.859	
Froude Number:	0.69		0.26	
Roughness Coefficient:	0.0492		0.1385	

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#12	1	18.000	0.339	0.000	0.000	78.000	TR55	49.02	4.621
	Σ	**18.000**						**49.02**	**4.621**

Subwatershed Time of Concentration Details:

Stru #	SWS #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#12	1	3. Short grass pasture	2.69	43.00	1,600.00	1.310	0.339
#12	**1**	**Time of Concentration:**					**0.339**

Maximum Flow Design for the Riprap-Lined Downdrain and Riprap-Lined Plunge Pool

AB Brown Type III Landfill January 2007 Minor Modification

Using the 25-year/24-hour design storm, the following calculations show that the maximum flows produced by this site are allowable for the size and configuration of the proposed riprap-lined downdrains and the riprap-lined plung pool at the base of each downdrain.

DS

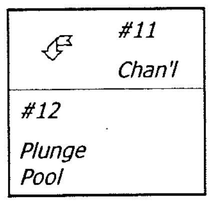
General Information

Storm Information:

Storm Type:	NRCS Type II
Design Storm:	25 yr - 24 hr
Rainfall Depth:	5.430 inches

Structure Networking:

Type	Stru #	(flows into)	Stru #	Musk. K (hrs)	Musk. X	Description
Channel	#11	==>	#12	0.000	0.000	25%-sloped riprap downdrain downdrain for a site-maximum 25yr/24hr- peak flow of 72 cfs that is developed in the W sub-drainage area
Plunge Pool	#12	==>	End	0.000	0.000	Plunge pool located at end of riprap-lined downdrain - note that the velocity of downdrain at 10 fps used for the plunge pool design and also that the INDOT Class I riprap will have a conservative D50 size of abot 12 inches



Structure Summary:

	Immediate Contributing Area (ac)	Total Contributing Area (ac)	Peak Discharge (cfs)	Total Runoff Volume (ac-ft)
#11	22.900	22.900	72.35	5.88
#12	0.000	22.900	72.35	5.88

Structure Detail:

Structure #11 (Riprap Channel)

25%-sloped riprap downdrain downdrain for a site-maximum 25yr/24hr- peak flow of 72 cfs that is developed in the W sub-drainage area

Trapezoidal Riprap Channel Inputs:

Material: Riprap

Bottom Width (ft)}	Left Sideslope Ratio	Right Sideslope Ratio	Slope (%)	Freeboard Depth (ft)	Freeboard % of Depth	Freeboard Mult. x (VxD)
2.00	4.0:1	4.0:1	25.0			

Riprap Channel Results:

PADER Method - Steep Slope Design

	w/o Freeboard	w/ Freeboard
Design Discharge:	72.35 cfs	
Depth:	1.14 ft	
Top Width:	11.11 ft	
Velocity:	9.69 fps	
X-Section Area:	7.47 sq ft	
Hydraulic Radius:	0.655	
Froude Number:	2.08	
Manning's n:	0.0580	
Dmin:	5.00 in	
D50:	9.00 in	
Dmax:	12.00 in	

Structure #12 (Plunge Pool)

Plunge pool located at end of riprap-lined downdrain - note that the velocity of downdrain at 10 fps used for the plunge pool design and also that the INDOT Class I riprap will have a conservative D50 size of abot 12 inches

Plunge Pool Inputs:

Pipe Diameter (in)	Pipe Slope (%)	Pipe Outlet Elevation	Tailwater Elevation	Channel Outlet Elevation	D50 (ft)
36.00	25.00	404.20	404.10	404.00	0.63

Plunge Pool Results:

Plunge Pool Length:	19.76 ft
Plunge Pool Width:	18.09 ft
Plunge Pool Depth (to top of rock):	4.46 ft
Froude Number:	2.47
Horiz Distance from Pipe Outlet to Center of Jet:	2.41 ft
Horiz Distance from Pipe Outlet to Center of Pool:	7.78 ft
Velocity at Pipe Outlet:	10.24 fps
Velocity at Jet Impingement:	14.32 fps

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#11	1	22.900	0.000	0.000	0.000	78.000	72.35	5.878	
	Σ	**22.900**						**72.35**	**5.878**
#12	Σ	**22.900**						**72.35**	**5.878**

Reference 2: HydroCAD Modeling Results

STORM WATER RUNOFF CALCULATIONS

The erosion and stormwater control structures described in this section have been designed, as required, to limit soil erosion to less than 5 tons-per-acre-per-year and adequately convey the 25-year/24-hour storm event (5.43", IDNR 1994, attached). Soil erosion estimates are attached in a separate calculations section.

Stormwater flows from sub-drainage areas SW, SE, NW, and NE are drained through downdrain pipes to perimeter channels. Flows were determined for each of these proposed sub-drainage areas (SW, SE, NW, and NE - see attached figure) using the HydroCAD model developed by HydroCAD Software Solutions LLC. These sub-drainage area flows are based on drainage area, elevation change across the drainage area, flow path length, and soil cover characteristics. The resulting flows from the 25-year/24-hour storm are:

- NW area (9.4 acres at 16.0 cfs peak) drains through two 18-inch diameter drop inlets and flows through a single 18-inch diameter downdrain pipe (at about one-half full) to a riprap-lined splash pad placed in an existing channel.

- SW area (9.2 acres at 15.8 cfs peak) drains through two 18-inch diameter drop inlets and flows through a single 18-inch diameter downdrain pipe (at about one-half full) to a riprap-lined splash pad placed in an existing channel.

- SE area (8.3 acres at 15.0 cfs peak) drains through two 18-inch diameter drop inlets and flows through a single 18-inch diameter downdrain pipe (at about one-half full) to a riprap-lined splash pad placed in an existing channel.

- NE area (8.2 acres at 14.8 cfs peak) drains through two 18-inch diameter drop inlets and flows through a single 18-inch diameter downdrain pipe (at about one-half full) to a riprap-lined splash pad placed in an existing channel.

The maximum design flows within a top-of-final-cover diversion berm occurs with sub-drainage area NW. The top-of-final-cover diversion berms have been placed near the perimeter of the 5%-sloped top of the final cover. These channels are:

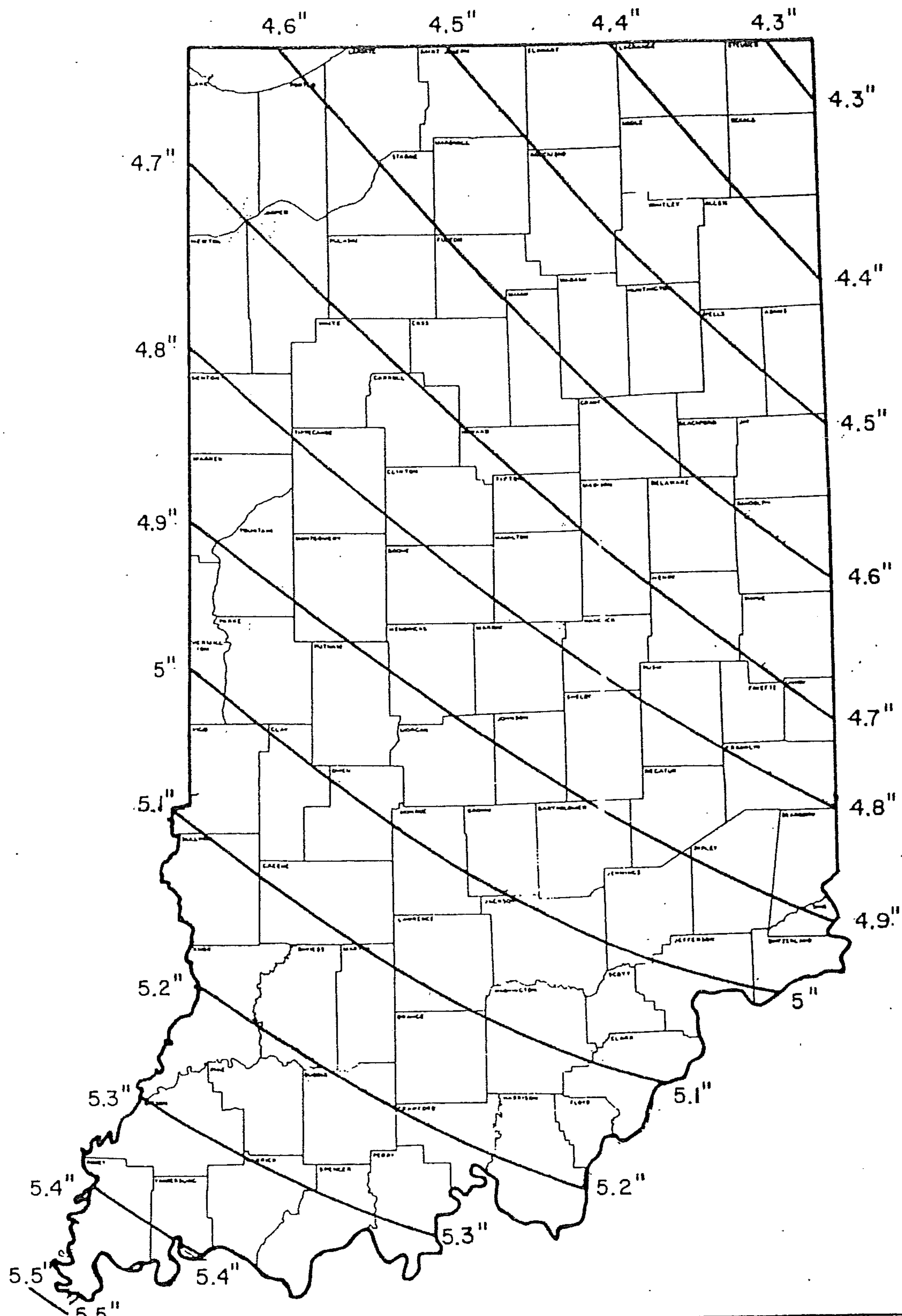
- Slopes of 2%,
- Sideslopes of 4H:1V and 20H:1V with v-shaped bottoms,
- Lengths up to 640 ft,

- Berm heights of 2 feet at more than 200 feet from the downdrain,
- Berm heights of 4 feet within 200 feet of the downdrains, and
- Drainage Areas of up to 6.4 acres with 5% slopes.

The attached HydroCAD output shows that at the maximum area of 6.4 acres (the west portion of the NW sub-drainage area - see attached figure), this proposed berm adequately carries the 25-year/24-hour storm flow to the inlets of a pipe downdrain.

Documentation

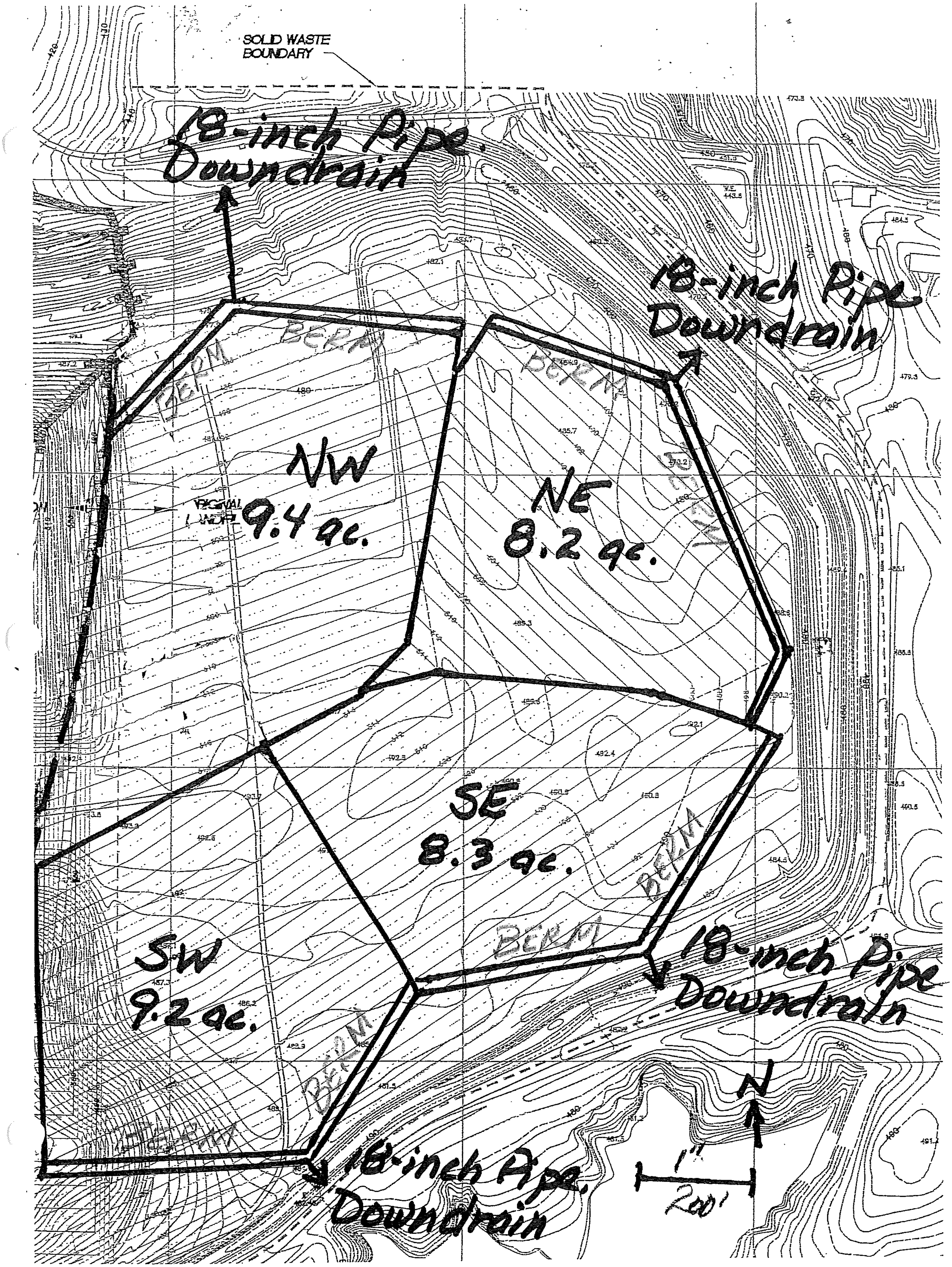
RAINFALL - 25 YEAR FREQUENCY - 24 HOUR DURATION



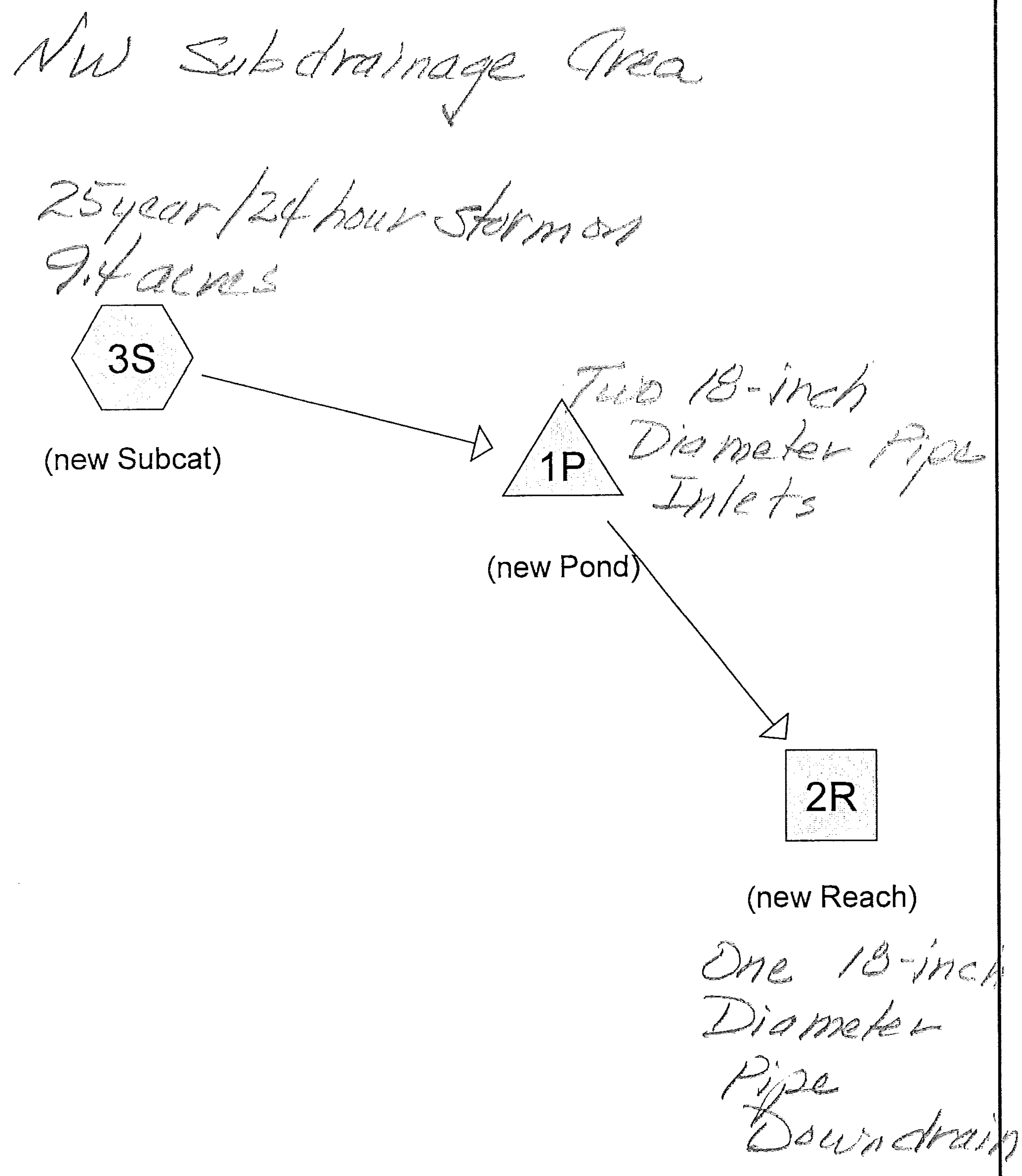
REFERENCE
TECHNICAL PAPER NO. 40
NATIONAL WEATHER SERVICE

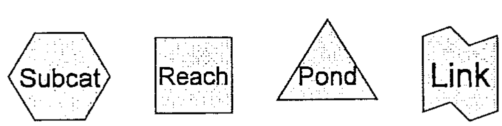
STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

APRIL 19?9



SOLID WASTE BOUNDARY
18-inch Pipe Downdrain
18-inch Pipe Downdrain
NW 9.4 ac.
NE 8.2 ac.
SE 8.3 ac.
SW 9.2 ac.
BERM
18-inch Pipe Downdrain
18-inch Pipe Downdrain
N
1" 200'





Routing Diagram for ABB 9.4

Prepared by HydroCAD SAMPLER 1-800-927-7246 www.hydrocad.net, Printed 3/20/2012

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Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
9.400	78	(3S)
9.400	**78**	**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
0.000	HSG B	
0.000	HSG C	
0.000	HSG D	
9.400	Other	3S
9.400		**TOTAL AREA**

Ground Covers (all 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	9.400	9.400		3S
0.000	**0.000**	**0.000**	**0.000**	**9.400**	**9.400**	**TOTAL AREA**	

Pipe Listing (all nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)	Inside-Fill (inches)
1	2R	0.00	-5.00	20.0	0.2500	0.015	15.6	0.0	0.0

Time span=5.00-35.00 hrs, dt=0.10 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 3S: (new Subcat) Runoff Area=9.400 ac 0.00% Impervious Runoff Depth=3.08"
Flow Length=300' Slope=0.0500 '/' Tc=20.3 min CN=78 Runoff=31.23 cfs 2.413 af

Reach 2R: (new Reach) Avg. Flow Depth=0.66' Max Vel=23.56 fps Inflow=16.02 cfs 2.413 af
15.6" Round Pipe n=0.015 L=20.0' S=0.2500 '/' Capacity=31.08 cfs Outflow=16.02 cfs 2.413 af

Pond 1P: (new Pond) Peak Elev=2.22' Storage=19,265 cf Inflow=31.23 cfs 2.413 af
Outflow=16.02 cfs 2.413 af

Total Runoff Area = 9.400 ac Runoff Volume = 2.413 af Average Runoff Depth = 3.08"
100.00% Pervious = 9.400 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 3S: (new Subcat)

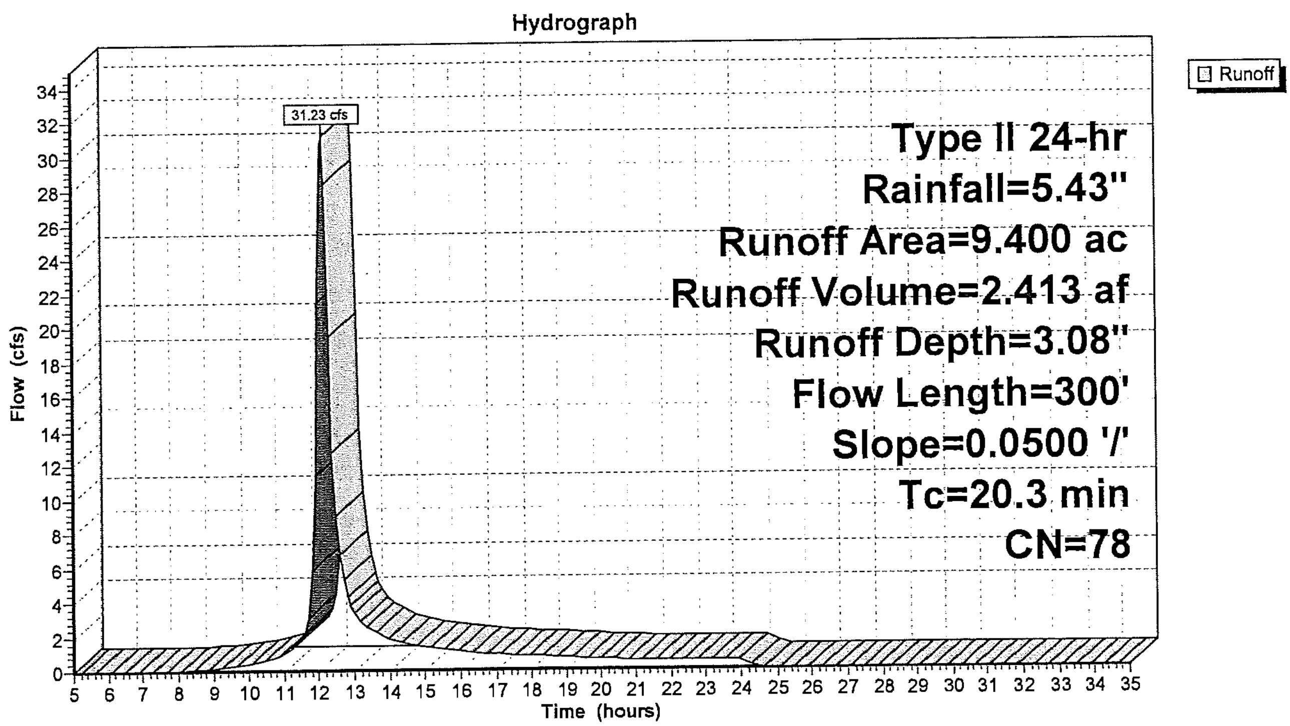
Runoff = 31.23 cfs @ 12.13 hrs, Volume= 2.413 af, Depth= 3.08"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-35.00 hrs, dt= 0.10 hrs
Type II 24-hr Rainfall=5.43"

	Area (ac)	CN	Description
*	9.400	78	
	9.400		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.3	300	0.0500	0.25		**Sheet Flow,** n= 0.200 P2= 3.30"

Subcatchment 3S: (new Subcat)



Summary for Reach 2R: (new Reach)

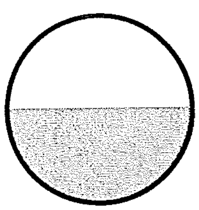
[52] Hint: Inlet/Outlet conditions not evaluated
[65] Warning: Inlet elevation not specified
[90] Warning: Qout>Qin may require Finer Routing or smaller dt

Inflow Area = 9.400 ac, 0.00% Impervious, Inflow Depth = 3.08"
Inflow = 16.02 cfs @ 12.35 hrs, Volume= 2.413 af
Outflow = 16.02 cfs @ 12.35 hrs, Volume= 2.413 af, Atten= 0%, Lag= 0.0 min

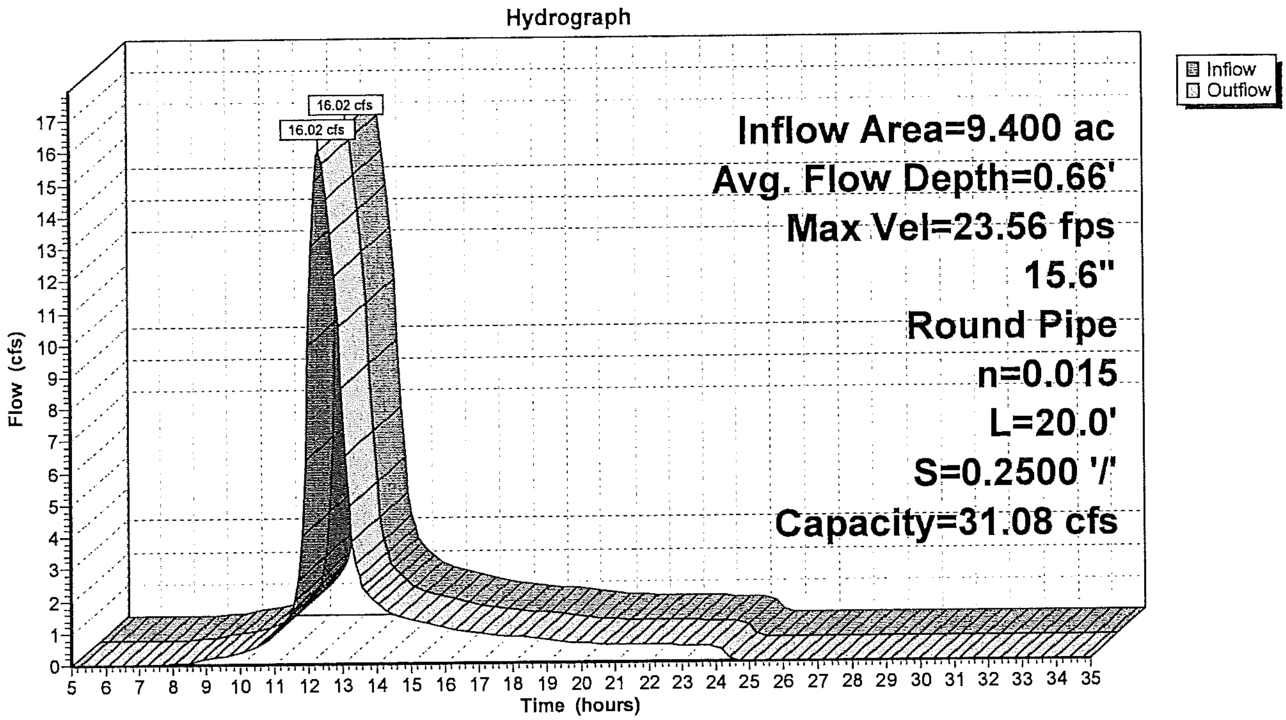
Routing by Dyn-Stor-Ind method, Time Span= 5.00-35.00 hrs, dt= 0.10 hrs
Max. Velocity= 23.56 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 10.10 fps, Avg. Travel Time= 0.0 min

Peak Storage= 14 cf @ 12.35 hrs
Average Depth at Peak Storage= 0.66'
Bank-Full Depth= 1.30' Flow Area= 1.3 sf, Capacity= 31.08 cfs

15.6" Round Pipe
n= 0.015 Corrugated PE, smooth interior
Length= 20.0' Slope= 0.2500 '/'
Inlet Invert= 0.00', Outlet Invert= -5.00'



Reach 2R: (new Reach)



Summary for Pond 1P: (new Pond)

Inflow Area = 9.400 ac, 0.00% Impervious, Inflow Depth = 3.08"
Inflow = 31.23 cfs @ 12.13 hrs, Volume= 2.413 af
Outflow = 16.02 cfs @ 12.35 hrs, Volume= 2.413 af, Atten= 49%, Lag= 13.0 min
Primary = 16.02 cfs @ 12.35 hrs, Volume= 2.413 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-35.00 hrs, dt= 0.10 hrs
Peak Elev= 2.22' @ 12.35 hrs Surf.Area= 17,380 sf Storage= 19,265 cf

Plug-Flow detention time= 9.4 min calculated for 2.405 af (100% of inflow)
Center-of-Mass det. time= 9.4 min (843.0 - 833.6)

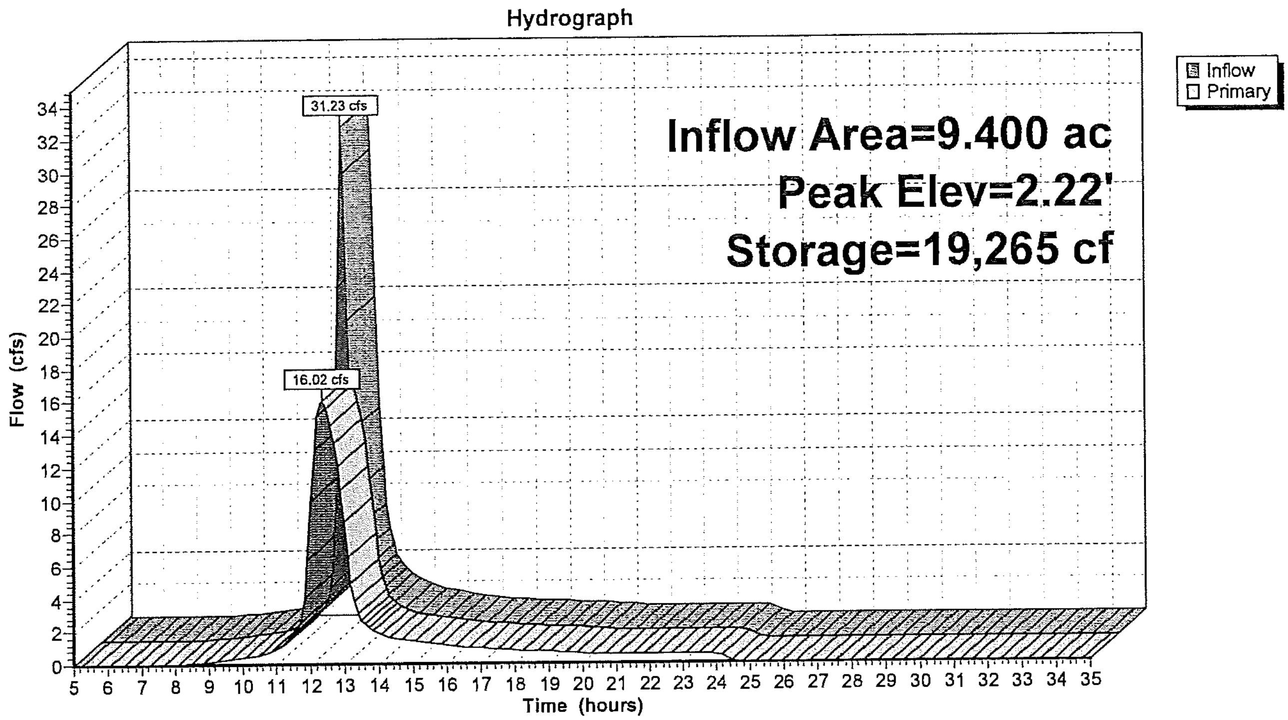
Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	62,724 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

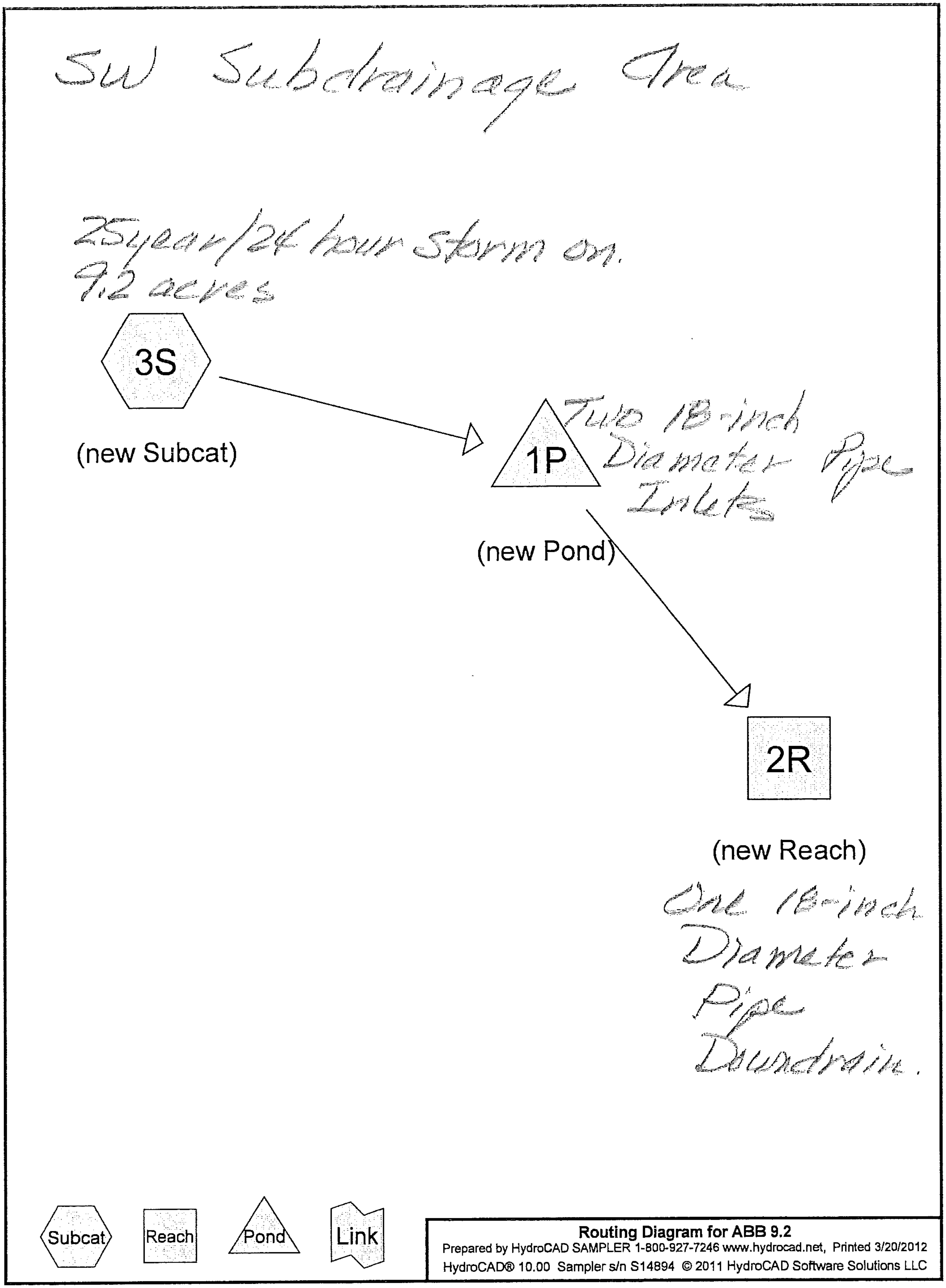
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
0.00	2	0	0
4.00	31,360	62,724	62,724

Device	Routing	Invert	Outlet Devices
#1	Primary	0.01'	**15.6" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	0.01'	**15.6" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=15.88 cfs @ 12.35 hrs HW=2.20' TW=0.66' (Dynamic Tailwater)
├─**1=Orifice/Grate** (Orifice Controls 7.94 cfs @ 5.98 fps)
└─**2=Orifice/Grate** (Orifice Controls 7.94 cfs @ 5.98 fps)

Pond 1P: (new Pond)





Routing Diagram for ABB 9.2
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Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
9.200	78	cayuga (3S)
9.200	**78**	**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
0.000	HSG B	
0.000	HSG C	
0.000	HSG D	
9.200	Other	3S
9.200		**TOTAL AREA**

Ground Covers (all 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	9.200	9.200	cayuga	3S
0.000	**0.000**	**0.000**	**0.000**	**9.200**	**9.200**	**TOTAL AREA**	

Pipe Listing (all nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)	Inside-Fill (inches)
1	2R	0.00	-5.00	20.0	0.2500	0.015	15.6	0.0	0.0

Time span=5.00-35.00 hrs, dt=0.10 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 3S: (new Subcat) Runoff Area=9.200 ac 0.00% Impervious Runoff Depth=3.08"
Flow Length=300' Slope=0.0500 '/' Tc=20.3 min CN=78 Runoff=30.57 cfs 2.362 af

Reach 2R: (new Reach) Avg. Flow Depth=0.66' Max Vel=23.50 fps Inflow=15.84 cfs 2.362 af
15.6" Round Pipe n=0.015 L=20.0' S=0.2500 '/' Capacity=31.08 cfs Outflow=15.84 cfs 2.362 af

Pond 1P: (new Pond) Peak Elev=2.18' Storage=18,630 cf Inflow=30.57 cfs 2.362 af
Outflow=15.84 cfs 2.362 af

Total Runoff Area = 9.200 ac Runoff Volume = 2.362 af Average Runoff Depth = 3.08"
100.00% Pervious = 9.200 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 3S: (new Subcat)

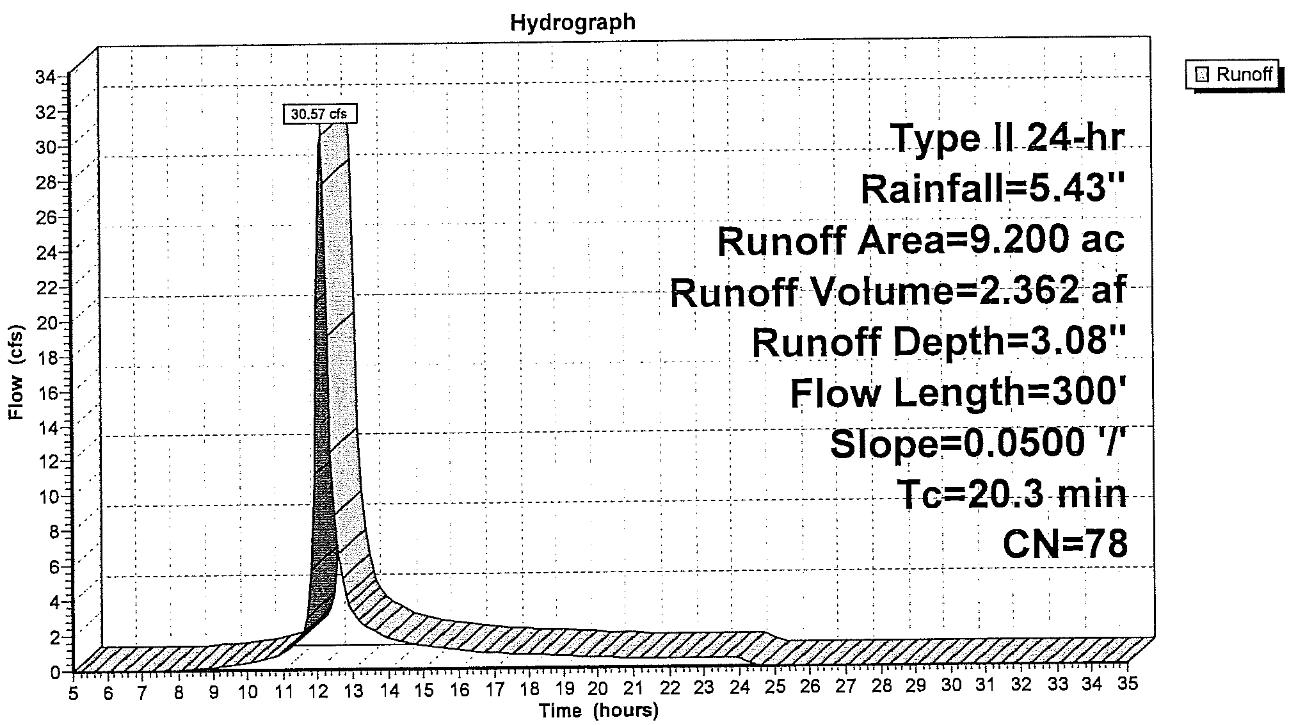
Runoff = 30.57 cfs @ 12.13 hrs, Volume= 2.362 af, Depth= 3.08"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-35.00 hrs, dt= 0.10 hrs
Type II 24-hr Rainfall=5.43"

	Area (ac)	CN	Description
*	9.200	78	cayuga
	9.200		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.3	300	0.0500	0.25		**Sheet Flow,** n= 0.200 P2= 3.30"

Subcatchment 3S: (new Subcat)



Summary for Reach 2R: (new Reach)

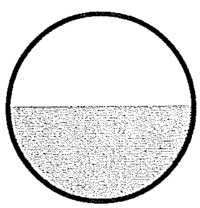
[52] Hint: Inlet/Outlet conditions not evaluated
[65] Warning: Inlet elevation not specified
[90] Warning: Qout>Qin may require Finer Routing or smaller dt

Inflow Area = 9.200 ac, 0.00% Impervious, Inflow Depth = 3.08"
Inflow = 15.84 cfs @ 12.34 hrs, Volume= 2.362 af
Outflow = 15.84 cfs @ 12.34 hrs, Volume= 2.362 af, Atten= 0%, Lag= 0.0 min

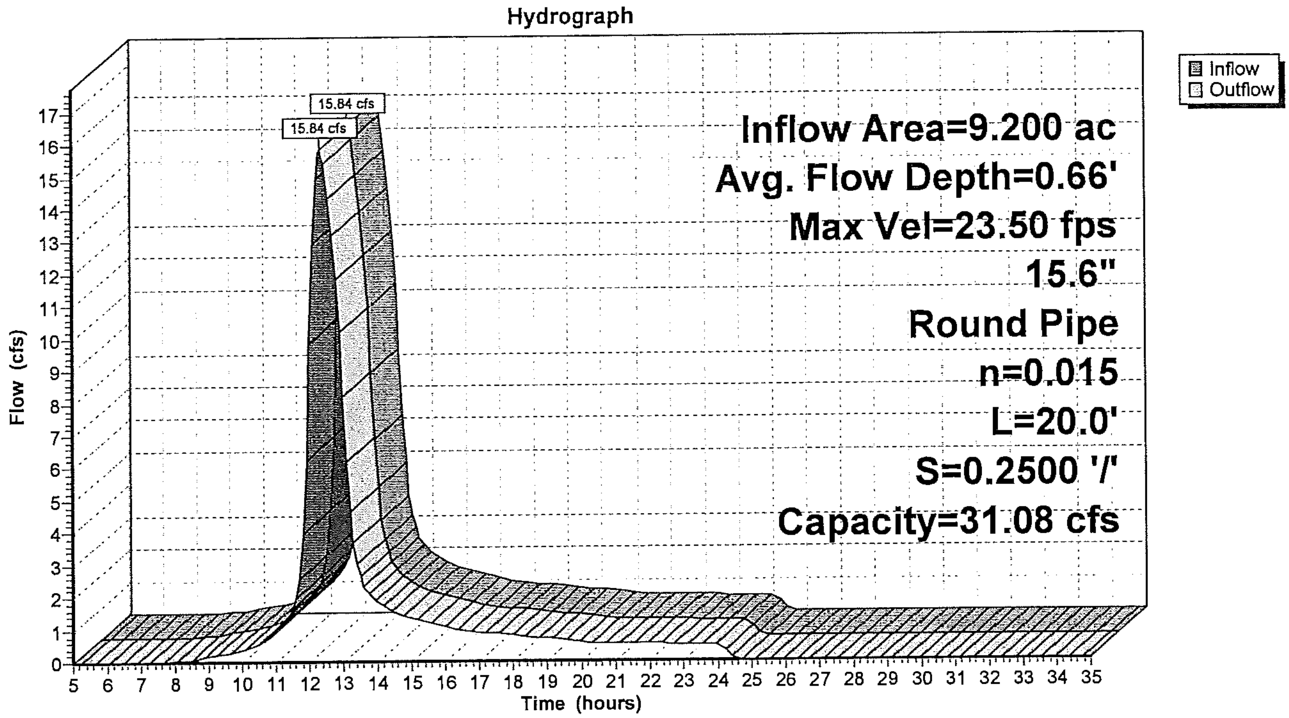
Routing by Dyn-Stor-Ind method, Time Span= 5.00-35.00 hrs, dt= 0.10 hrs
Max. Velocity= 23.50 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 10.08 fps, Avg. Travel Time= 0.0 min

Peak Storage= 13 cf @ 12.34 hrs
Average Depth at Peak Storage= 0.66'
Bank-Full Depth= 1.30' Flow Area= 1.3 sf, Capacity= 31.08 cfs

15.6" Round Pipe
n= 0.015 Corrugated PE, smooth interior
Length= 20.0' Slope= 0.2500 '/'
Inlet Invert= 0.00', Outlet Invert= -5.00'



Reach 2R: (new Reach)



Summary for Pond 1P: (new Pond)

Inflow Area = 9.200 ac, 0.00% Impervious, Inflow Depth = 3.08"
Inflow = 30.57 cfs @ 12.13 hrs, Volume= 2.362 af
Outflow = 15.84 cfs @ 12.34 hrs, Volume= 2.362 af, Atten= 48%, Lag= 12.8 min
Primary = 15.84 cfs @ 12.34 hrs, Volume= 2.362 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-35.00 hrs, dt= 0.10 hrs
Peak Elev= 2.18' @ 12.35 hrs Surf.Area= 17,089 sf Storage= 18,630 cf

Plug-Flow detention time= 9.2 min calculated for 2.354 af (100% of inflow)
Center-of-Mass det. time= 9.2 min (842.8 - 833.6)

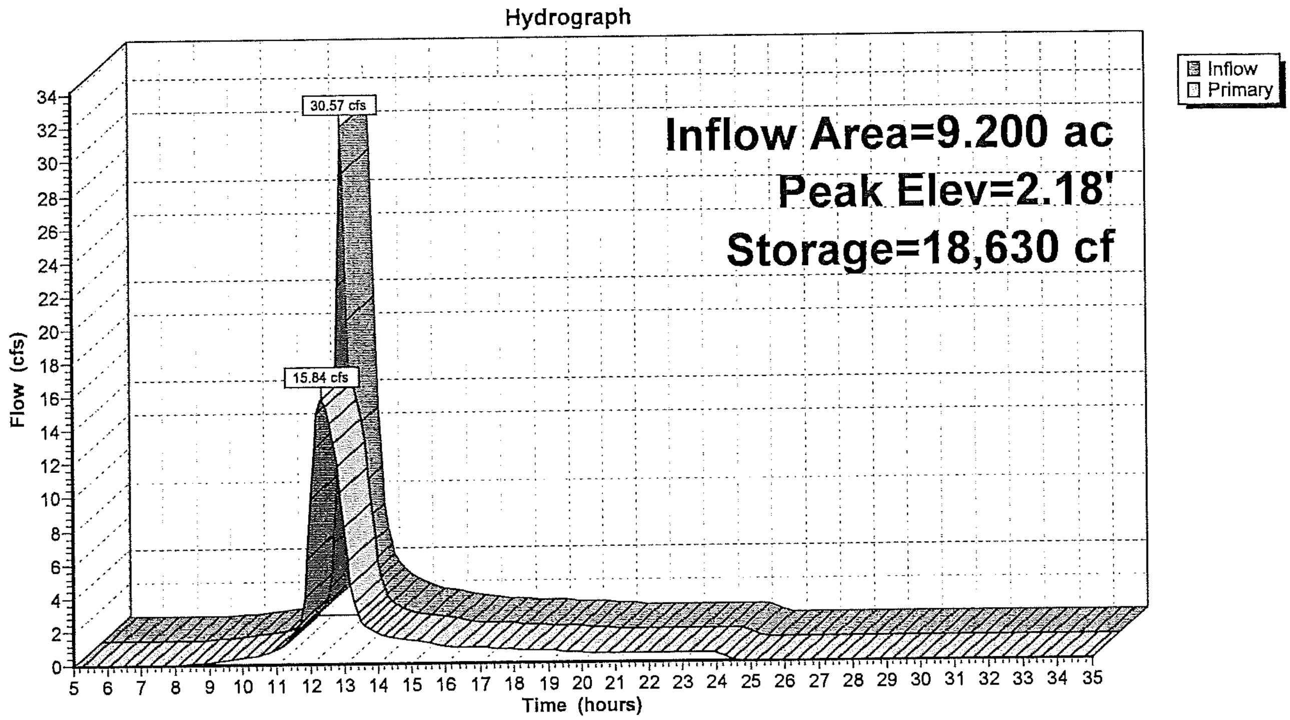
Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	62,710 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

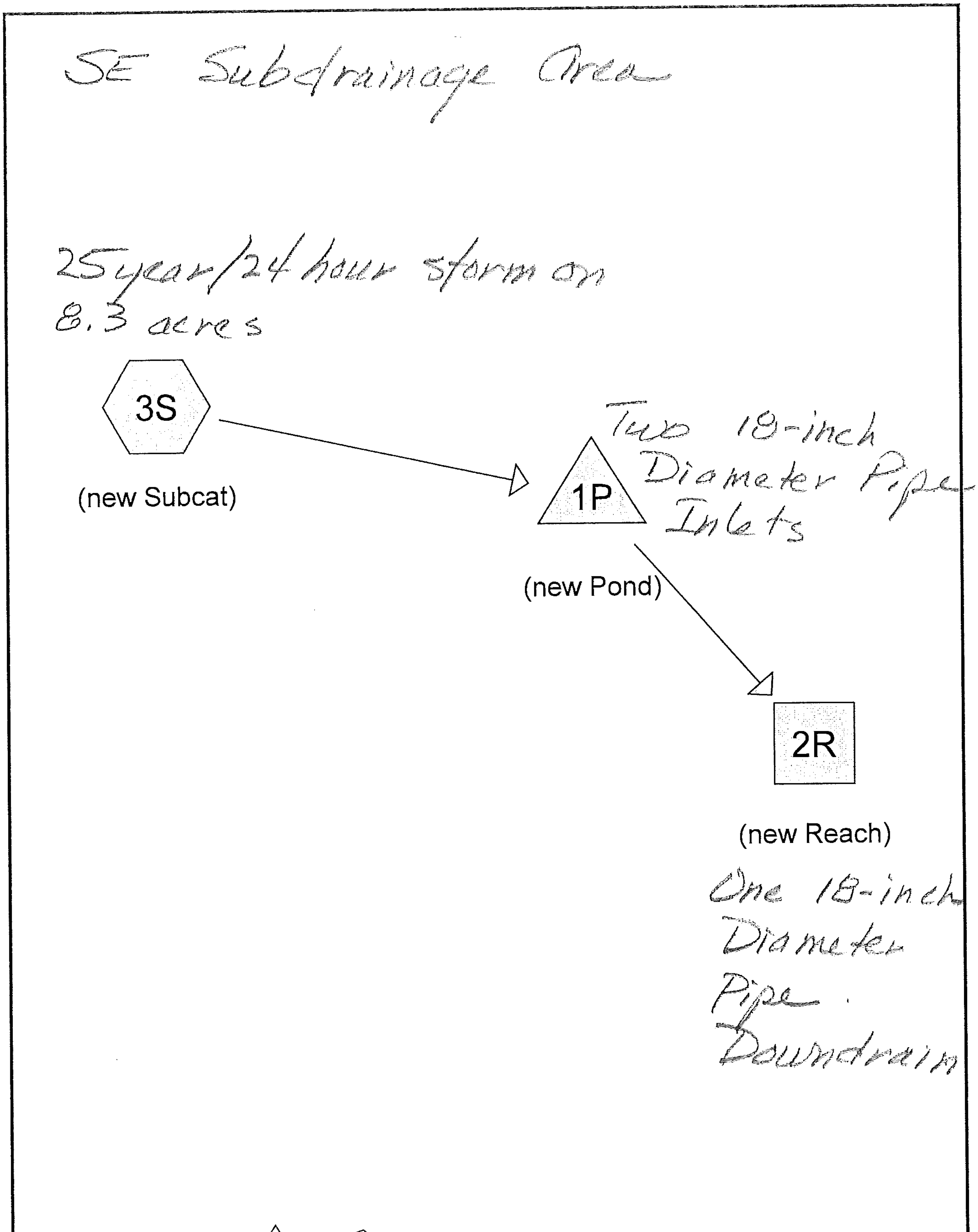
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
0.00	2	0	0
4.00	31,353	62,710	62,710

Device	Routing	Invert	Outlet Devices
#1	Primary	0.01'	**15.6" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	0.01'	**15.6" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=15.70 cfs @ 12.34 hrs HW=2.17' TW=0.65' (Dynamic Tailwater)
—**1=Orifice/Grate** (Orifice Controls 7.86 cfs @ 5.92 fps)
—**2=Orifice/Grate** (Orifice Controls 7.85 cfs @ 5.91 fps)

Pond 1P: (new Pond)





Routing Diagram for ABB 8.3

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Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
8.300	78	cayuga (3S)
8.300	**78**	**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
0.000	HSG B	
0.000	HSG C	
0.000	HSG D	
8.300	Other	3S
8.300		**TOTAL AREA**

Ground Covers (all 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	8.300	8.300	cayuga	3S
0.000	**0.000**	**0.000**	**0.000**	**8.300**	**8.300**	**TOTAL AREA**	

Pipe Listing (all nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)	Inside-Fill (inches)
1	2R	0.00	-5.00	20.0	0.2500	0.015	15.6	0.0	0.0

Time span=5.00-35.00 hrs, dt=0.10 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 3S: (new Subcat) Runoff Area=8.300 ac 0.00% Impervious Runoff Depth=3.08"
Flow Length=300' Slope=0.0500 '/' Tc=20.3 min CN=78 Runoff=27.58 cfs 2.131 af

Reach 2R: (new Reach) Avg. Flow Depth=0.64' Max Vel=23.19 fps Inflow=15.00 cfs 2.131 af
15.6" Round Pipe n=0.015 L=20.0' S=0.2500 '/' Capacity=31.08 cfs Outflow=15.00 cfs 2.131 af

Pond 1P: (new Pond) Peak Elev=2.02' Storage=15,997 cf Inflow=27.58 cfs 2.131 af
Outflow=15.00 cfs 2.131 af

Total Runoff Area = 8.300 ac Runoff Volume = 2.131 af Average Runoff Depth = 3.08"
100.00% Pervious = 8.300 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 3S: (new Subcat)

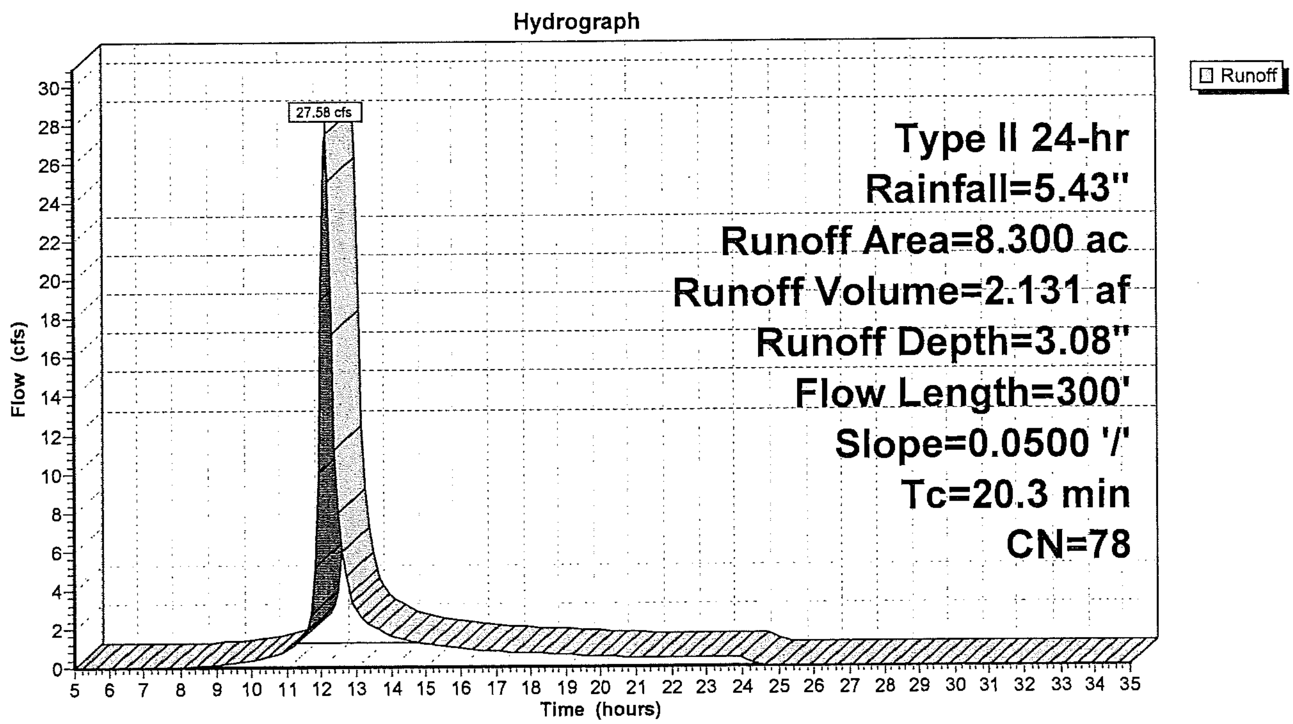
Runoff = 27.58 cfs @ 12.13 hrs, Volume= 2.131 af, Depth= 3.08"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-35.00 hrs, dt= 0.10 hrs
Type II 24-hr Rainfall=5.43"

	Area (ac)	CN	Description
*	8.300	78	cayuga
	8.300		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.3	300	0.0500	0.25		**Sheet Flow,** n= 0.200 P2= 3.30"

Subcatchment 3S: (new Subcat)



Summary for Reach 2R: (new Reach)

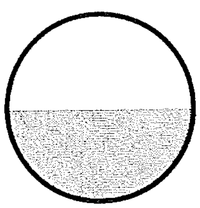
[52] Hint: Inlet/Outlet conditions not evaluated
[65] Warning: Inlet elevation not specified
[90] Warning: Qout>Qin may require Finer Routing or smaller dt

Inflow Area = 8.300 ac, 0.00% Impervious, Inflow Depth = 3.08"
Inflow = 15.00 cfs @ 12.34 hrs, Volume= 2.131 af
Outflow = 15.00 cfs @ 12.33 hrs, Volume= 2.131 af, Atten= 0%, Lag= 0.0 min

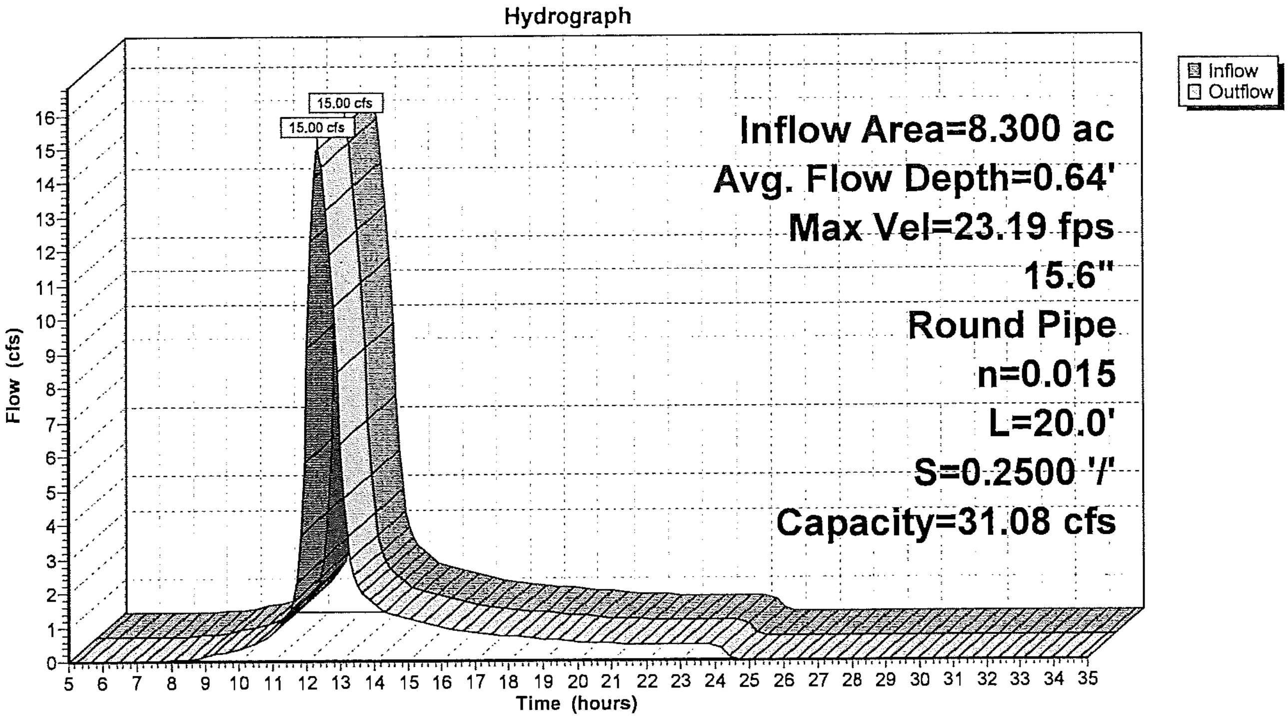
Routing by Dyn-Stor-Ind method, Time Span= 5.00-35.00 hrs, dt= 0.10 hrs
Max. Velocity= 23.19 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 9.72 fps, Avg. Travel Time= 0.0 min

Peak Storage= 13 cf @ 12.33 hrs
Average Depth at Peak Storage= 0.64'
Bank-Full Depth= 1.30' Flow Area= 1.3 sf, Capacity= 31.08 cfs

15.6" Round Pipe
n= 0.015 Corrugated PE, smooth interior
Length= 20.0' Slope= 0.2500 '/'
Inlet Invert= 0.00', Outlet Invert= -5.00'



Reach 2R: (new Reach)



Summary for Pond 1P: (new Pond)

```
Inflow Area =      8.300 ac,  0.00% Impervious,  Inflow Depth =  3.08"
Inflow      =     27.58 cfs @  12.13 hrs,  Volume=        2.131 af
Outflow     =     15.00 cfs @  12.34 hrs,  Volume=        2.131 af,  Atten= 46%,  Lag= 12.3 min
Primary     =     15.00 cfs @  12.34 hrs,  Volume=        2.131 af
```

Routing by Dyn-Stor-Ind method, Time Span= 5.00-35.00 hrs, dt= 0.10 hrs
Peak Elev= 2.02' @ 12.34 hrs Surf.Area= 15,835 sf Storage= 15,997 cf

Plug-Flow detention time= 8.4 min calculated for 2.131 af (100% of inflow)
Center-of-Mass det. time= 8.4 min (842.0 - 833.6)

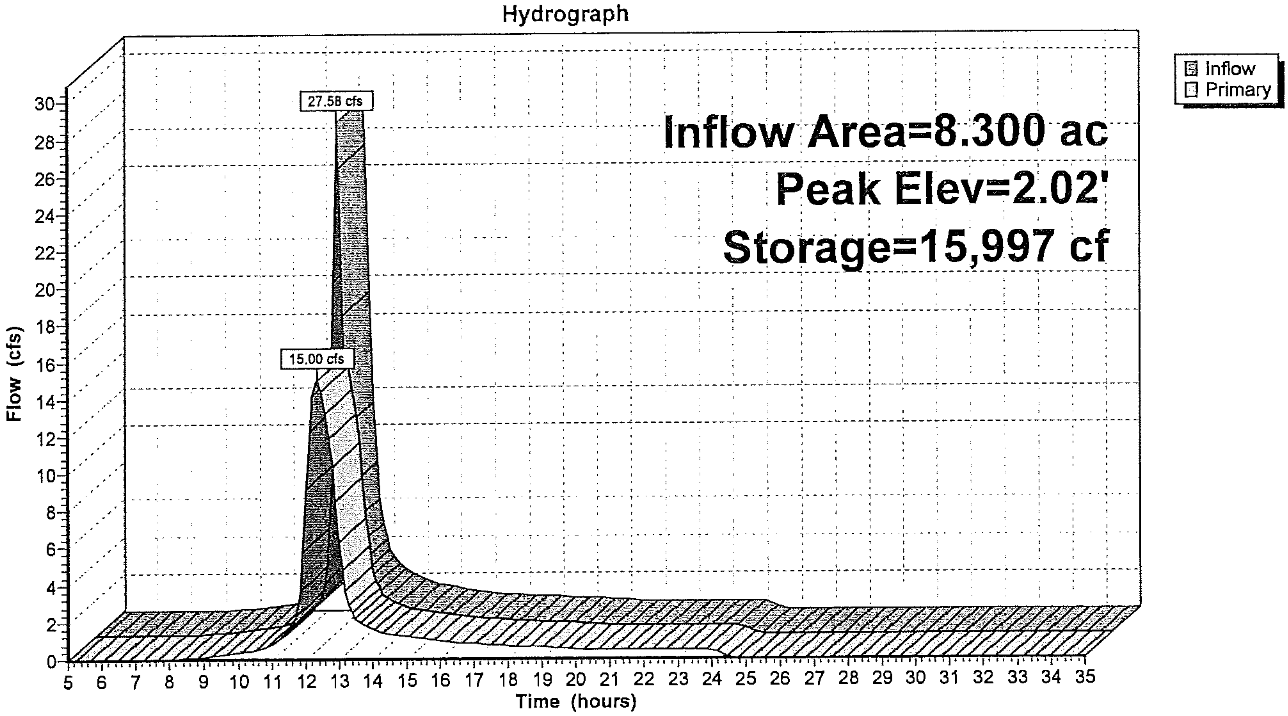
Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	62,710 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

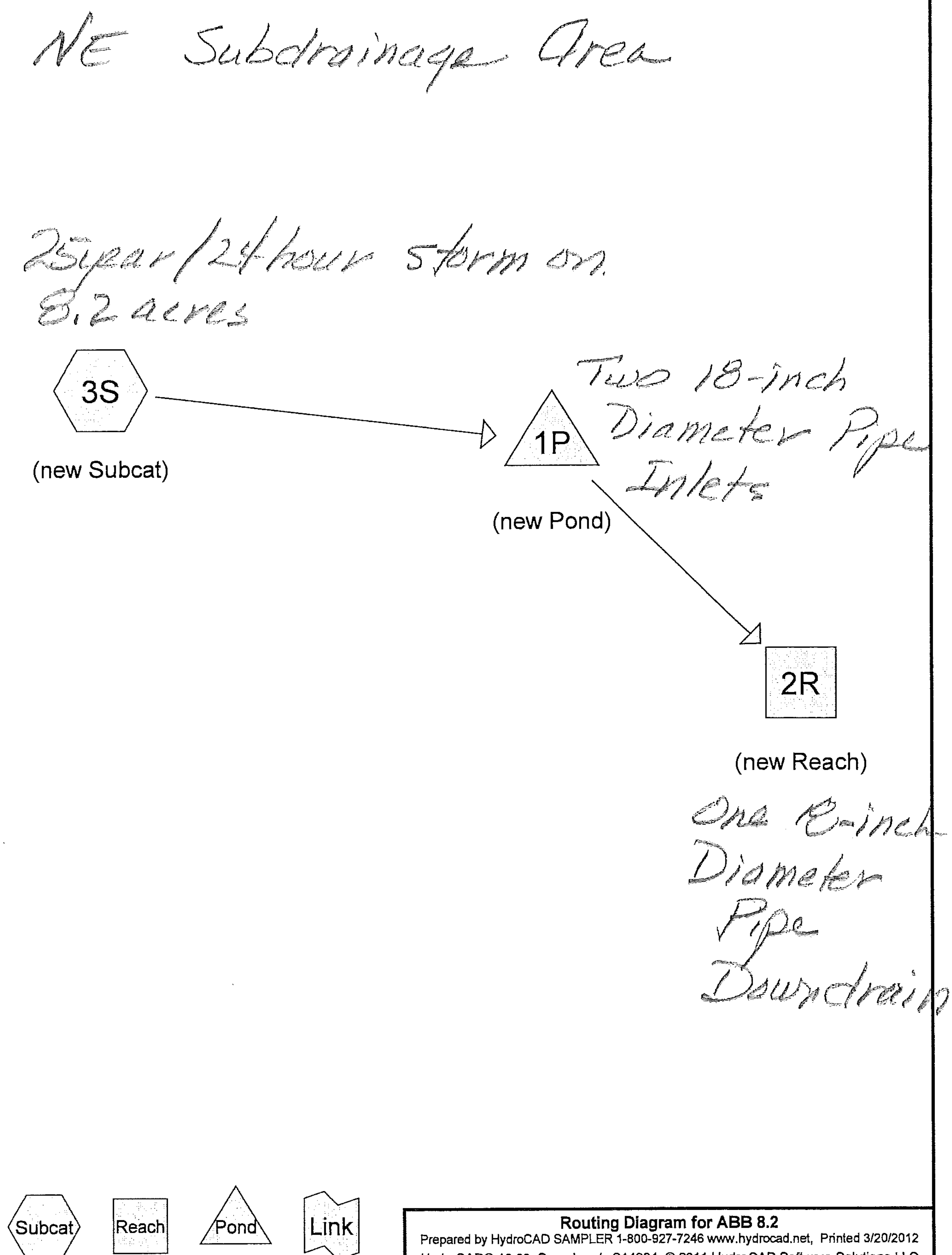
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
0.00	2	0	0
4.00	31,353	62,710	62,710

Device	Routing	Invert	Outlet Devices
#1	Primary	0.01'	**15.6" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	0.01'	**15.6" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=14.87 cfs @ 12.34 hrs HW=2.00' TW=0.63' (Dynamic Tailwater)
├—**1=Orifice/Grate** (Orifice Controls 7.47 cfs @ 5.63 fps)
└—**2=Orifice/Grate** (Orifice Controls 7.40 cfs @ 5.57 fps)

Pond 1P: (new Pond)





Routing Diagram for ABB 8.2

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Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
8.200	78	cayuga (3S)
8.200	**78**	**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
0.000	HSG B	
0.000	HSG C	
0.000	HSG D	
8.200	Other	3S
8.200		**TOTAL AREA**

Ground Covers (all 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	8.200	8.200	cayuga	3S
0.000	**0.000**	**0.000**	**0.000**	**8.200**	**8.200**	**TOTAL AREA**	

Pipe Listing (all nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)	Inside-Fill (inches)
1	2R	0.00	-5.00	20.0	0.2500	0.015	15.6	0.0	0.0

Time span=5.00-35.00 hrs, dt=0.10 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 3S: (new Subcat) Runoff Area=8.200 ac 0.00% Impervious Runoff Depth=3.08"
Flow Length=300' Slope=0.0500 '/' Tc=20.3 min CN=78 Runoff=27.24 cfs 2.105 af

Reach 2R: (new Reach) Avg. Flow Depth=0.64' Max Vel=23.20 fps Inflow=14.79 cfs 2.105 af
15.6" Round Pipe n=0.015 L=20.0' S=0.2500 '/' Capacity=31.08 cfs Outflow=14.99 cfs 2.108 af

Pond 1P: (new Pond) Peak Elev=1.96' Storage=14,993 cf Inflow=27.24 cfs 2.105 af
Outflow=14.79 cfs 2.105 af

Total Runoff Area = 8.200 ac Runoff Volume = 2.105 af Average Runoff Depth = 3.08"
100.00% Pervious = 8.200 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 3S: (new Subcat)

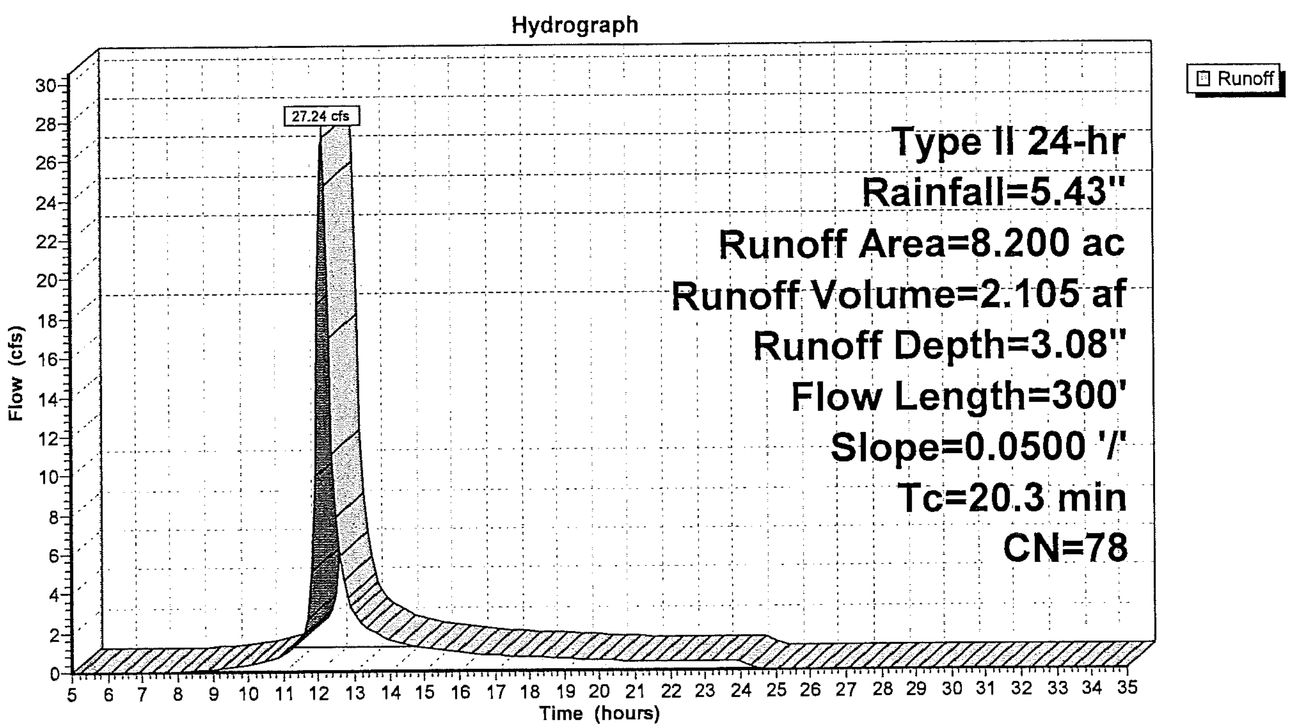
Runoff = 27.24 cfs @ 12.13 hrs, Volume= 2.105 af, Depth= 3.08"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-35.00 hrs, dt= 0.10 hrs
Type II 24-hr Rainfall=5.43"

	Area (ac)	CN	Description
*	8.200	78	cayuga
	8.200		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.3	300	0.0500	0.25		**Sheet Flow,** n= 0.200 P2= 3.30"

Subcatchment 3S: (new Subcat)



Summary for Reach 2R: (new Reach)

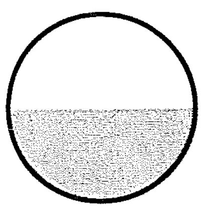
[52] Hint: Inlet/Outlet conditions not evaluated
[65] Warning: Inlet elevation not specified
[90] Warning: Qout>Qin may require Finer Routing or smaller dt
[80] Warning: Exceeded Pond 1P by 0.06' @ 18.40 hrs (1.58 cfs 0.403 af)

Inflow Area = 8.200 ac, 0.00% Impervious, Inflow Depth = 3.08"
Inflow = 14.79 cfs @ 12.33 hrs, Volume= 2.105 af
Outflow = 14.99 cfs @ 12.31 hrs, Volume= 2.108 af, Atten= 0%, Lag= 0.0 min

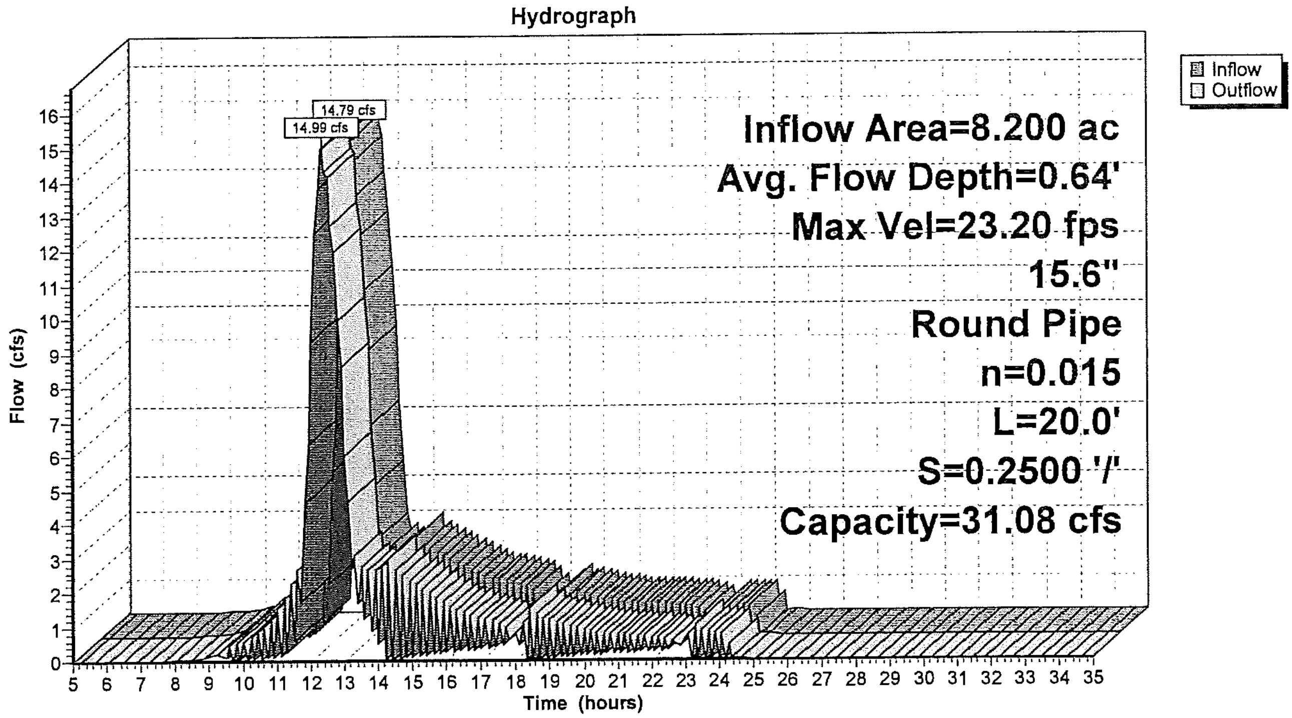
Routing by Dyn-Stor-Ind method, Time Span= 5.00-35.00 hrs, dt= 0.10 hrs
Max. Velocity= 23.20 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 9.29 fps, Avg. Travel Time= 0.0 min

Peak Storage= 13 cf @ 12.31 hrs
Average Depth at Peak Storage= 0.64'
Bank-Full Depth= 1.30' Flow Area= 1.3 sf, Capacity= 31.08 cfs

15.6" Round Pipe
n= 0.015 Corrugated PE, smooth interior
Length= 20.0' Slope= 0.2500 '/'
Inlet Invert= 0.00', Outlet Invert= -5.00'



Reach 2R: (new Reach)



Summary for Pond 1P: (new Pond)

[87] Warning: Oscillations may require Finer Routing or smaller dt

Inflow Area = 8.200 ac, 0.00% Impervious, Inflow Depth = 3.08"
Inflow = 27.24 cfs @ 12.13 hrs, Volume= 2.105 af
Outflow = 14.79 cfs @ 12.33 hrs, Volume= 2.105 af, Atten= 46%, Lag= 11.7 min
Primary = 14.79 cfs @ 12.33 hrs, Volume= 2.105 af

Routing by Dyn-Stor-Ind method, Time Span= 5.00-35.00 hrs, dt= 0.10 hrs
Peak Elev= 1.96' @ 12.34 hrs Surf.Area= 15,330 sf Storage= 14,993 cf

Plug-Flow detention time= (not calculated: outflow precedes inflow)
Center-of-Mass det. time= 7.6 min (841.2 - 833.6)

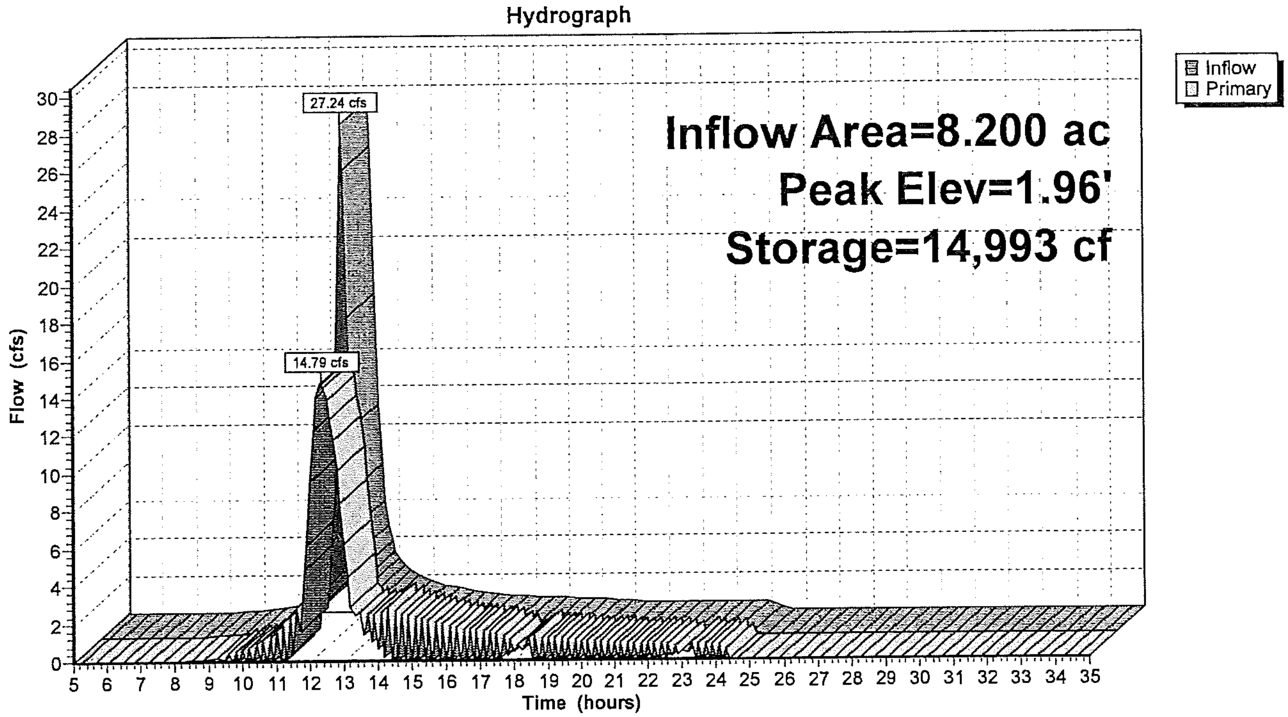
Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	62,710 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

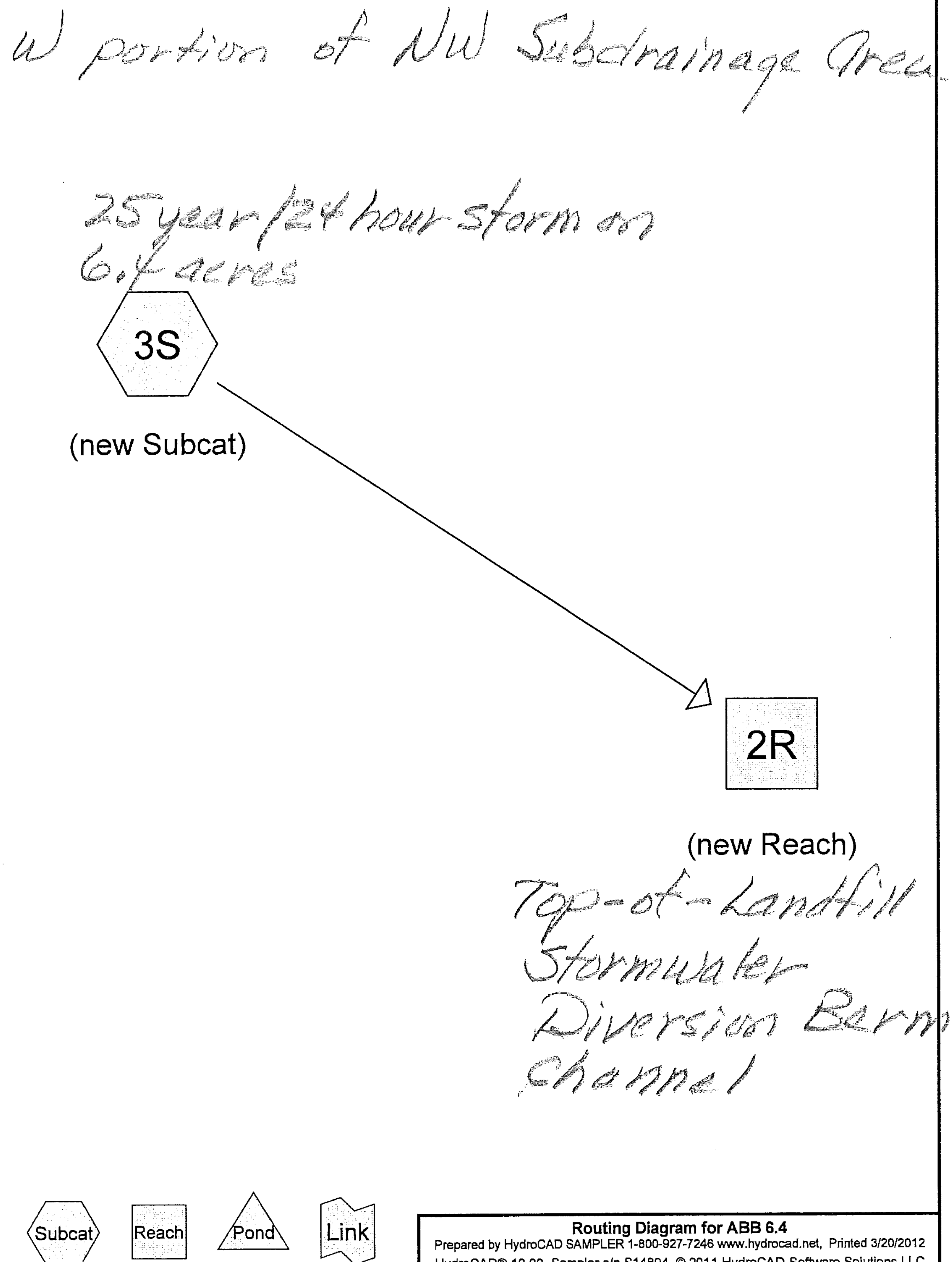
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
0.00	2	0	0
4.00	31,353	62,710	62,710

Device	Routing	Invert	Outlet Devices
#1	Primary	0.01'	**15.6" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads
#2	Primary	0.01'	**15.6" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Primary OutFlow Max=14.60 cfs @ 12.33 hrs HW=1.94' TW=0.63' (Dynamic Tailwater)
—**1=Orifice/Grate** (Orifice Controls 7.30 cfs @ 5.50 fps)
—**2=Orifice/Grate** (Orifice Controls 7.30 cfs @ 5.50 fps)

Pond 1P: (new Pond)





Routing Diagram for ABB 6.4

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Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
6.400	78	(3S)
6.400	**78**	**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
0.000	HSG B	
0.000	HSG C	
0.000	HSG D	
6.400	Other	3S
6.400		**TOTAL AREA**

Ground Covers (all 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	6.400	6.400		3S
0.000	**0.000**	**0.000**	**0.000**	**6.400**	**6.400**	**TOTAL AREA**	

Time span=5.00-35.00 hrs, dt=0.10 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 3S: (new Subcat) Runoff Area=6.400 ac 0.00% Impervious Runoff Depth=3.08"
Flow Length=300' Slope=0.0500 '/' Tc=20.3 min CN=78 Runoff=21.26 cfs 1.643 af

Reach 2R: (new Reach) Avg. Flow Depth=0.76' Max Vel=3.12 fps Inflow=21.26 cfs 1.643 af
n=0.035 L=540.0' S=0.0200 '/' Capacity=1,744.31 cfs Outflow=20.54 cfs 1.643 af

Total Runoff Area = 6.400 ac Runoff Volume = 1.643 af Average Runoff Depth = 3.08"
100.00% Pervious = 6.400 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 3S: (new Subcat)

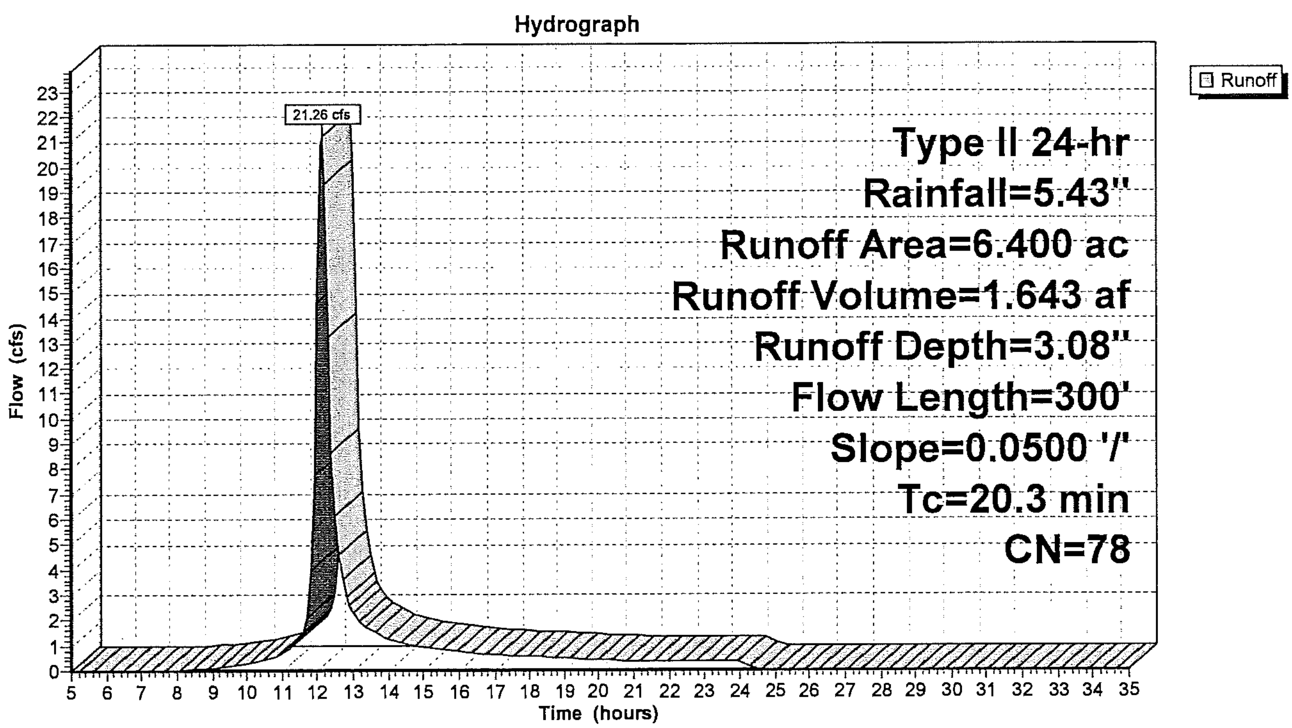
Runoff = 21.26 cfs @ 12.13 hrs, Volume= 1.643 af, Depth= 3.08"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-35.00 hrs, dt= 0.10 hrs
Type II 24-hr Rainfall=5.43"

	Area (ac)	CN	Description
*	6.400	78	
	6.400		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.3	300	0.0500	0.25		**Sheet Flow,** n= 0.200 P2= 3.30"

Subcatchment 3S: (new Subcat)



Summary for Reach 2R: (new Reach)

[65] Warning: Inlet elevation not specified

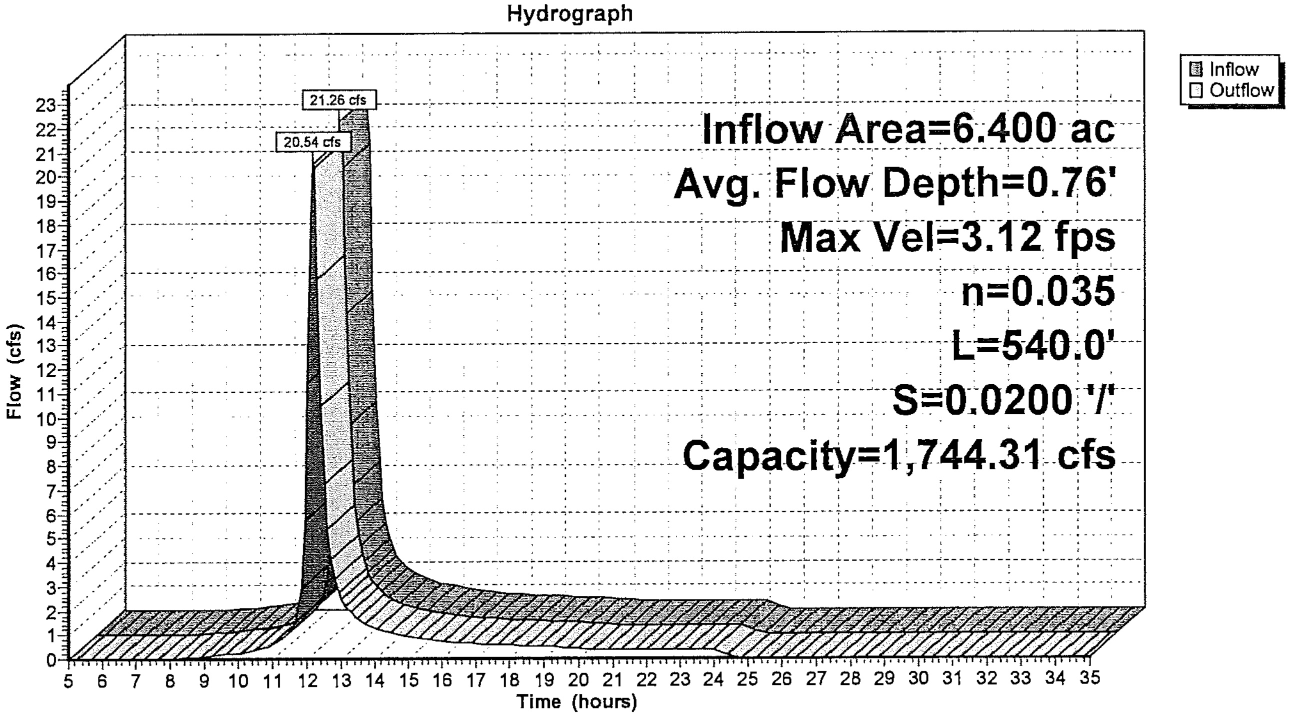
Inflow Area =	6.400 ac,	0.00% Impervious, Inflow Depth = 3.08"		
Inflow =	21.26 cfs @	12.13 hrs, Volume=	1.643 af	
Outflow =	20.54 cfs @	12.18 hrs, Volume=	1.643 af,	Atten= 3%, Lag= 2.9 min

Routing by Dyn-Stor-Ind method, Time Span= 5.00-35.00 hrs, dt= 0.10 hrs
Max. Velocity= 3.12 fps, Min. Travel Time= 2.9 min
Avg. Velocity = 1.19 fps, Avg. Travel Time= 7.5 min

Peak Storage= 3,552 cf @ 12.18 hrs
Average Depth at Peak Storage= 0.76'
Bank-Full Depth= 4.00' Flow Area= 184.0 sf, Capacity= 1,744.31 cfs

0.00' x 4.00' deep channel, n= 0.035 High grass
Side Slope Z-value= 20.0 3.0 '/' Top Width= 92.00'
Length= 540.0' Slope= 0.0200 '/'
Inlet Invert= 0.00', Outlet Invert= -10.80'

Reach 2R: (new Reach)



Reference 3: USDA TR-55

United States
Department of
Agriculture

Natural
Resources
Conservation
Service

Conservation
Engineering
Division

Technical
Release 55

June 1986

Urban Hydrology for Small Watersheds

TR-55

Chapter 2 Estimating Runoff

SCS runoff curve number method

The SCS Runoff Curve Number (CN) method is described in detail in NEH-4 (SCS 1985). The SCS runoff equation is

$$Q = \frac{\left(P - I_a\right)^2}{\left(P - I_a\right) + S} \qquad \text{[eq. 2-1]}$$

where

- Q = runoff (in)
- P = rainfall (in)
- S = potential maximum retention after runoff begins (in) and
- I_a = initial abstraction (in)

Initial abstraction (I_a) is all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration. I_a is highly variable but generally is correlated with soil and cover parameters. Through studies of many small agricultural watersheds, I_a was found to be approximated by the following empirical equation:

$$I_a = 0.2S \qquad \text{[eq. 2-2]}$$

By removing I_a as an independent parameter, this approximation allows use of a combination of S and P to produce a unique runoff amount. Substituting equation 2-2 into equation 2-1 gives:

$$Q = \frac{\left(P - 0.2S\right)^2}{\left(P + 0.8S\right)} \qquad \text{[eq. 2-3]}$$

S is related to the soil and cover conditions of the watershed through the CN. CN has a range of 0 to 100, and S is related to CN by:

$$S = \frac{1000}{CN} - 10 \qquad \text{[eq. 2-4]}$$

Figure 2-1 and table 2-1 solve equations 2-3 and 2-4 for a range of CN's and rainfall.

Factors considered in determining runoff curve numbers

The major factors that determine CN are the hydrologic soil group (HSG), cover type, treatment, hydrologic condition, and antecedent runoff condition (ARC). Another factor considered is whether impervious areas outlet directly to the drainage system (connected) or whether the flow spreads over pervious areas before entering the drainage system (unconnected). Figure 2-2 is provided to aid in selecting the appropriate figure or table for determining curve numbers.

CN's in table 2-2 (*a* to *d*) represent average antecedent runoff condition for urban, cultivated agricultural, other agricultural, and arid and semiarid rangeland uses. Table 2-2 assumes impervious areas are directly connected. The following sections explain how to determine CN's and how to modify them for urban conditions.

Hydrologic soil groups

Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. Soils are classified into four HSG's (A, B, C, and D) according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting. Appendix A defines the four groups and provides a list of most of the soils in the United States and their group classification. The soils in the area of interest may be identified from a soil survey report, which can be obtained from local SCS offices or soil and water conservation district offices.

Most urban areas are only partially covered by impervious surfaces: the soil remains an important factor in runoff estimates. Urbanization has a greater effect on runoff in watersheds with soils having high infiltration rates (sands and gravels) than in watersheds predominantly of silts and clays, which generally have low infiltration rates.

Any disturbance of a soil profile can significantly change its infiltration characteristics. With urbanization, native soil profiles may be mixed or removed or fill material from other areas may be introduced. Therefore, a method based on soil texture is given in appendix A for determining the HSG classification for disturbed soils.

Manning's equation is:

$$V = \frac{1.49 r^{\frac{2}{3}} s^{\frac{1}{2}}}{n} \qquad \text{[eq. 3-4]}$$

where:

- V = average velocity (ft/s)
- r = hydraulic radius (ft) and is equal to a/p_w
  - a = cross sectional flow area (ft^2)
  - p_w = wetted perimeter (ft)
- s = slope of the hydraulic grade line (channel slope, ft/ft)
- n = Manning's roughness coefficient for open channel flow.

Manning's n values for open channel flow can be obtained from standard textbooks such as Chow (1959) or Linsley et al. (1982). After average velocity is computed using equation 3-4, T_t for the channel segment can be estimated using equation 3-1.

Reservoirs or lakes

Sometimes it is necessary to estimate the velocity of flow through a reservoir or lake at the outlet of a watershed. This travel time is normally very small and can be assumed as zero.

Limitations

- Manning's kinematic solution should not be used for sheet flow longer than 300 feet. Equation 3-3 was developed for use with the four standard rainfall intensity-duration relationships.
- In watersheds with storm sewers, carefully identify the appropriate hydraulic flow path to estimate T_c. Storm sewers generally handle only a small portion of a large event. The rest of the peak flow travels by streets, lawns, and so on, to the outlet. Consult a standard hydraulics textbook to determine average velocity in pipes for either pressure or nonpressure flow.
- The minimum T_c used in TR-55 is 0.1 hour.
- A culvert or bridge can act as a reservoir outlet if there is significant storage behind it. The procedures in TR-55 can be used to determine the peak flow upstream of the culvert. Detailed storage routing procedures should be used to determine the outflow through the culvert.

Example 3-1

The sketch below shows a watershed in Dyer County, northwestern Tennessee. The problem is to compute T_c at the outlet of the watershed (point D). The 2-year 24-hour rainfall depth is 3.6 inches. All three types of flow occur from the hydraulically most distant point (A) to the point of interest (D). To compute T_c, first determine T_t for each segment from the following information:

Segment AB: Sheet flow; dense grass; slope (s) = 0.01 ft/ft; and length (L) = 100 ft. Segment BC: Shallow concentrated flow; unpaved; s = 0.01 ft/ft; and L = 1,400 ft. Segment CD: Channel flow; Manning's n = .05; flow area (a) = 27 ft^2; wetted perimeter (p_w) = 28.2 ft; s = 0.005 ft/ft; and L = 7,300 ft.

See figure 3-2 for the computations made on worksheet 3.

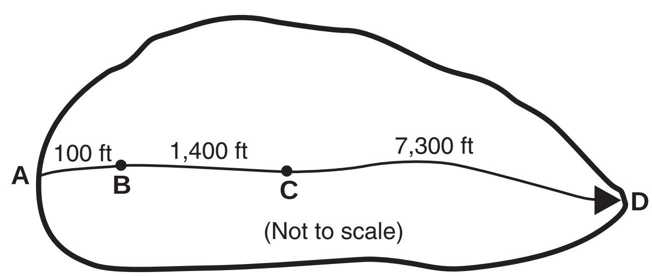


Table 7–4 Classification of vegetation cover as to degree of retardance

Retardance	Cover	Condition
A	Weeping lovegrass	Excellent stand, tall (average 30 in)
	Reed canarygrass or Yellow bluestem ischaemum	Excellent stand, tall (average 36 in)
B	Smooth bromegrass	Good stand, mowed (average 12 to 15 in)
	Bermudagrass	Good stand, tall (average 12 in)
	Native grass mixture (little bluestem, blue grama, and other long and short midwest grasses	Good stand, unmowed
	Tall fescue	Good stand, unmowed (average 18 in)
	Sericea lespedeza	Good stand, not woody, tall (average 19 in)
	Grass-legume mixture—Timothy, smooth bromegrass, or orchardgrass	Good stand, uncut (average 20 in)
	Reed canarygrass	Good stand, uncut (average 12 to 15 in)
	Tall fescue, with birdsfoot trefoil or ladino clover	Good stand, uncut (average 18 in)
	Blue grama	Good stand, uncut (average 13 in)
C	Bahiagrass	Good stand, uncut (6 to 8 in)
	Bermudagrass	Good stand, mowed (average 6 in)
	Redtop	Good stand, headed (15 to 20 in)
	Grass-legume mixture—summer (orchardgrass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6 to 8 in)
	Centipedegrass	Very dense cover (average 6 in)
	Kentucky bluegrass	Good stand, headed (6 to 12 in)
D	Bermudagrass	Good stand, cut to 2.5-in height
	Red fescue	Good stand, headed (12 to 18 in)
	Buffalograss	Good stand, uncut (3 to 6 in)
	Grass-legume mixture—fall, spring (orchardgrass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (4 to 5 in)
	Sericea lespedeza or Kentucky bluegrass	Good stand, cut to 2-in height. Very good stand before cutting
E	Bermudagrass	Good stand, cut to 1.5-in height
	Bermudagrass	Burned stubble

Table 7–5 Retardance curve index by retardance class

SCS retardance class	Retardance curve index C_I
A	10.0
B	7.64
C	5.60
D	4.44
E	2.88

Interim Runoff Calculations
A.B. Brown Landfill - Cell 17 North

<u>SCS Run-Off Equation</u>

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in) and
I_a = initial abstraction (in)

$$S = \frac{1000}{CN} - 10$$

S = 1000/79 – 10 = 2.658

$$Q = \frac{(5.4 - 0.2*2.658)^2}{5.4 + 0.8*2.658} \approx 3.15 \text{ in.}$$

[Amount of Runoff]

<u>SCS Runoff Volume</u>

Total Storm Volume
= (3.15 in./12in.) * (3.10 acres) = 0.81 ac-ft

<u>SCS Watershed Variables Defined</u>

CN = Curve Number = 79

P = Rainfall = 5.4 in. (25-Year, 24-Hour Storm)

A (Area of Watershed, Typical Interim Cell)
A = 3.10 acres

Interim Runoff Calculations
A.B. Brown Landfill - Cell 17 South

<u>SCS Run-Off Equation</u>

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in) and
I_a = initial abstraction (in)

$$S = \frac{1000}{CN} - 10$$

S = 1000/79 – 10 = 2.658

Q = (5.4 – 0.2*2.658)^2
----------------------- ~= 3.15 in.
5.4 + 0.8*2.658

[Amount of Runoff]

<u>SCS Runoff Volume</u>

Total Storm Volume
= (3.15 in./12in.) * (2.67 acres) = 0.70 ac-ft

<u>SCS Watershed Variables Defined</u>

CN = Curve Number = 79

P = Rainfall = 5.4 in. (25-Year, 24-Hour Storm)

A (Area of Watershed, Typical Interim Cell)
A = 2.67 acres

Interim Runoff Calculations
A.B. Brown Landfill - Cell 18 North

SCS Run-Off Equation

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in) and
I_a = initial abstraction (in)

$$S = \frac{1000}{CN} - 10$$

S = 1000/79 – 10 = 2.658

$$Q = \frac{(5.4 - 0.2*2.658)^2}{5.4 + 0.8*2.658} \approx 3.15 \text{ in.}$$

[Amount of Runoff]

SCS Runoff Volume

Total Storm Volume
= (3.15 in./12in.) * (3.97 acres) = 1.04 ac-ft

SCS Watershed Variables Defined

CN = Curve Number = 79

P = Rainfall = 5.4 in. (25-Year, 24-Hour Storm)

A (Area of Watershed, Typical Interim Cell)
A = 3.97 acres

Interim Runoff Calculations
A.B. Brown Landfill - Cell 18 South

SCS Run-Off Equation

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in) and
I_a = initial abstraction (in)

$$S = \frac{1000}{CN} - 10$$

S = 1000/79 – 10 = 2.658

$$Q = \frac{(5.4 - 0.2*2.658)^2}{5.4 + 0.8*2.658} \approx 3.15 \text{ in.}$$

[Amount of Runoff]

SCS Runoff Volume

Total Storm Volume
= (3.15 in./12in.) * (4.28 acres) = 1.12 ac-ft

SCS Watershed Variables Defined

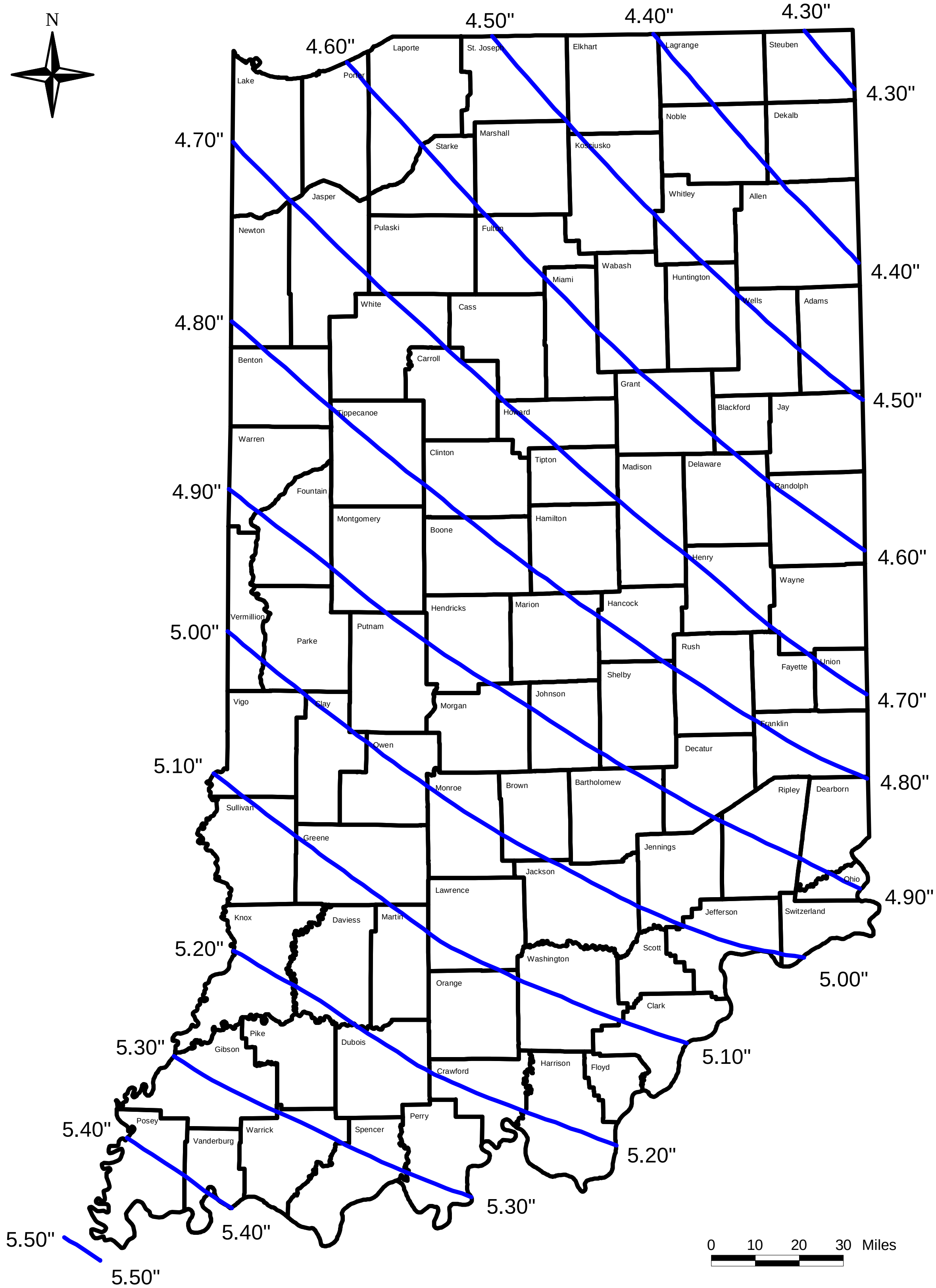
CN = Curve Number = 79

P = Rainfall = 5.4 in. (25-Year, 24-Hour Storm)

A (Area of Watershed, Typical Interim Cell)
A = 4.28 acres

Reference 4: NOAA Technical Paper No. 40

RAINFALL - 25 YEAR FREQUENCY - 24 HOUR DURATION



REFERENCE
TECHNICAL PAPER NO. 40
NATIONAL WEATHER SERVICE

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER

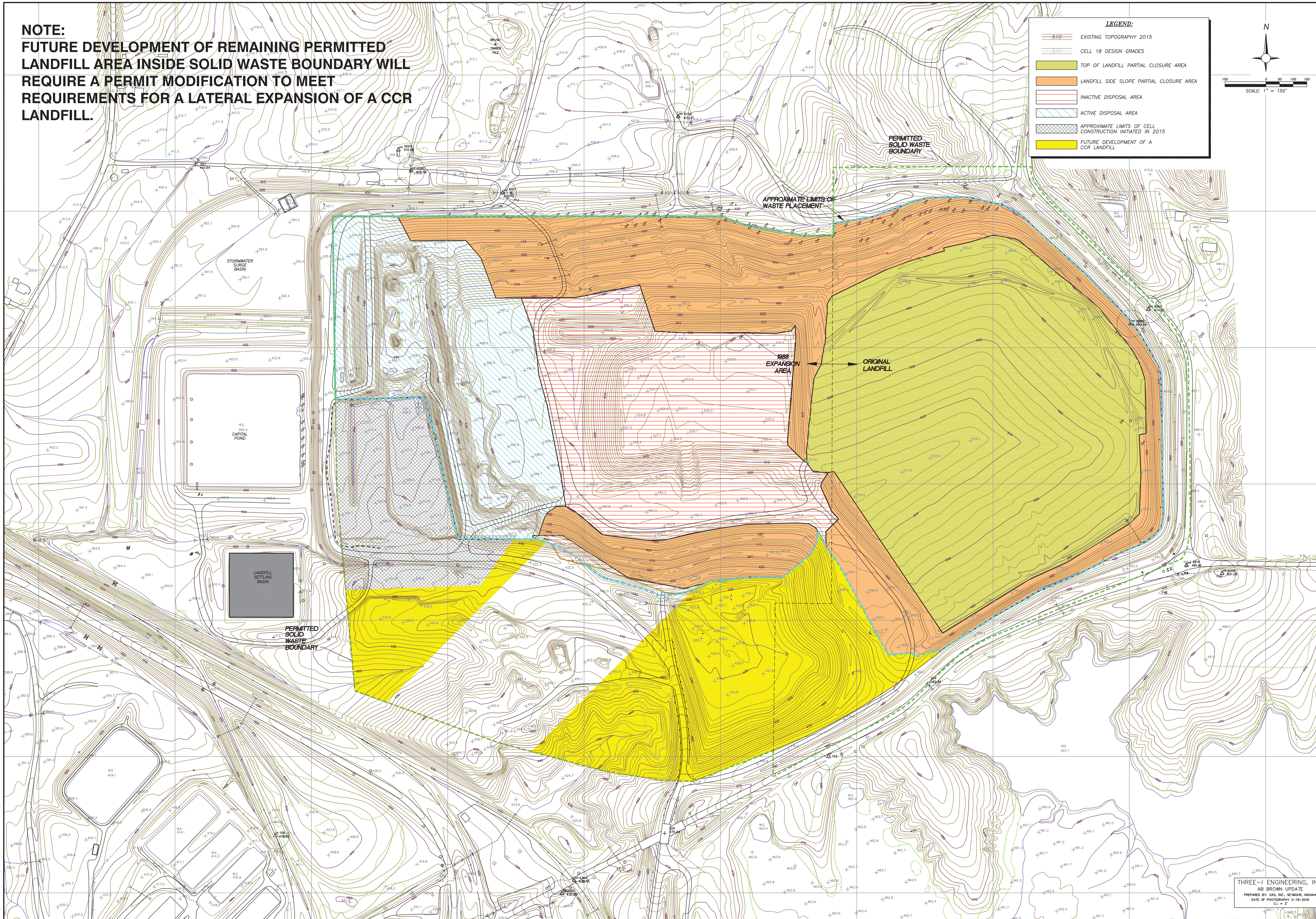
INDIANA DEPARTMENT OF NATURAL RESOURCES

Appendix D: Surface Water Control and Design Plan Sheets

SHEET NO.	DESCRIPTION
*1	Site Plan
*2	Final Cover Grades - Surface Water Control Plan
*3	Details – Terrace Berm and Perimeter Ditch

*Plan sheets from previously approved Indiana Department of Environmental Management (IDEM) Restricted Waste Type III Landfill 2007 and 2012 minor modification applications

NOTE:
FUTURE DEVELOPMENT OF REMAINING PERMITTED LANDFILL AREA INSIDE SOLID WASTE BOUNDARY WILL REQUIRE A PERMIT MODIFICATION TO MEET REQUIREMENTS FOR A LATERAL EXPANSION OF A CCR LANDFILL.



THREE-I ENGINEERING, INC.
AB BROWN UPDATE
PREPARED BY: OAS, INC., SEYMOUR, INDIANA
DATE OF PHOTOGRAPHY 2-18-2016
C.I. = 2'

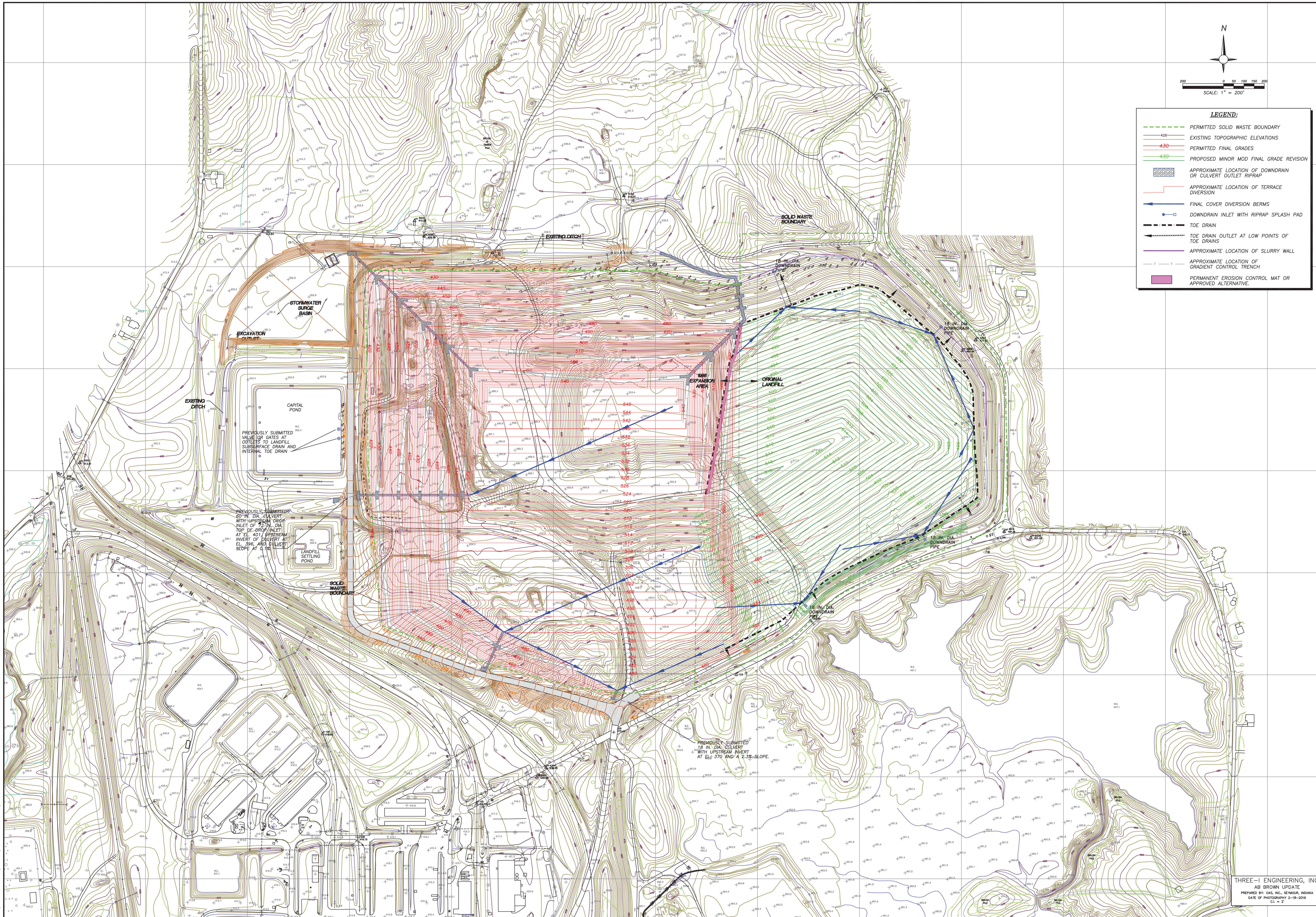
Project Number: 170LF00271
Drawing File: SEE LEFT
Date: 9/16
Scale: AS SHOWN
App'd By: | Ckd. By: CD | Drn. By: CR

Company Name:
SOUTHERN INDIANA GAS AND ELECTRIC COMPANY
A.B. BROWN GENERATING STATION
WEST FRANKLIN, INDIANA

ATC GROUP SERVICES LLC
7988 CENTERPOINT DR.
SUITE 100
INDIANAPOLIS, IN 46256
PHONE +1 317 849 4990
FAX +1 317 849 4278
WWW.ATCGROUPSERVICES.COM

Drawing Title:
SITE PLAN
A.B. BROWN GENERATING STATION

Sheet: 1



Revision:

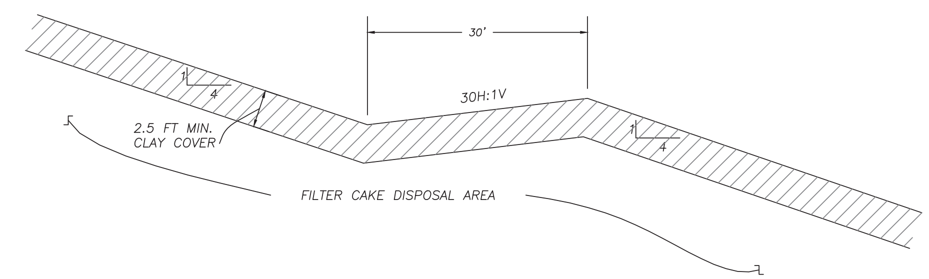
Project Number: 170LF00271
Drawing File: SEE LEFT
Date: 9/16
Scale: AS SHOWN
App'd By: | Ckd. By: CD | Drn. By: CR

Company Name:
SOUTHERN INDIANA GAS AND ELECTRIC COMPANY
A.B. BROWN GENERATING STATION
TYPE III RESTRICTED WASTE LANDFILL

ATC GROUP SERVICES LLC
7988 CENTERPOINT DR.
SUITE 100
INDIANAPOLIS, IN 46256
PHONE +1 317 849 4990
FAX +1 317 849 4278
WWW.ATCGROUPSERVICES.COM

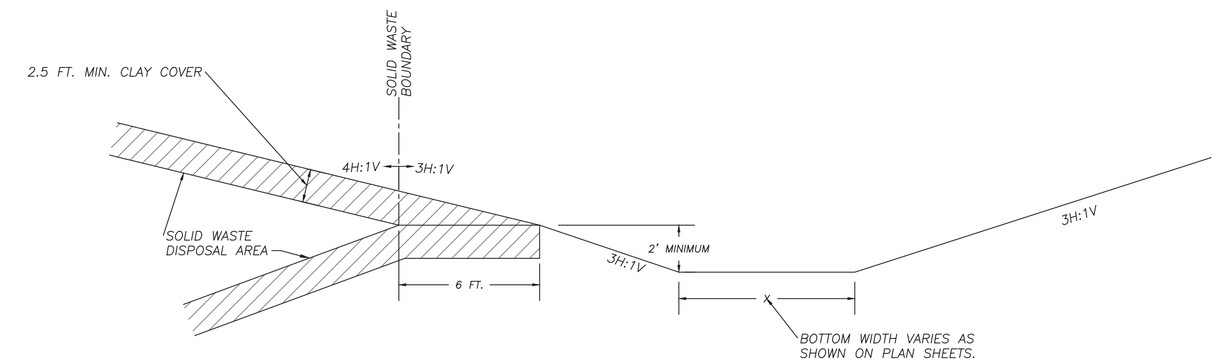
Drawing Title:
PROPOSED FINAL COVER GRADES
TYPE III RESTRICTED WASTE LANDFILL
A.B. BROWN GENERATING STATION

Sheet:
2



TYPICAL ROAD TERRACE DETAIL

(NOT TO SCALE)



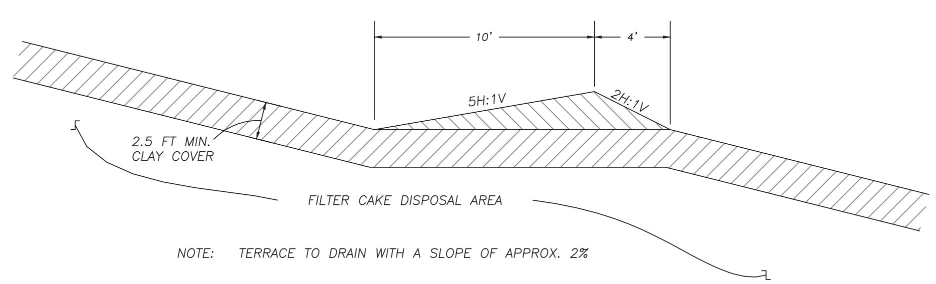
NOTE:

DITCH TO DRAIN WITH A SLOPE EQUAL TO THE GRADE SHOWN ON THE PLAN SHEETS, IN THE DIRECTION OF FLOW.

BASE AND SIDE SLOPES OF CHANNEL TO HAVE VEGETATIVE LINING UNLESS DESIGNATED OTHERWISE ON PLAN SHEETS.

TYPICAL TRAPEZOIDAL PERIMETER DITCH

(NOT TO SCALE)



NOTE: TERRACE TO DRAIN WITH A SLOPE OF APPROX. 2%

TYPICAL TERRACE DIVERSION BERM DETAIL

(NOT TO SCALE)

Revision:

Project Number: 170LF00271
Drawing File: SEE LEFT
Date: 9/16
Scale: AS SHOWN
App'd By: | Ckd. By: CD | Drn. By: CR

Company Name:
SOUTHERN INDIANA GAS AND ELECTRIC COMPANY
A.B. BROWN GENERATING STATION
TYPE III RESTRICTED WASTE LANDFILL

ATC GROUP SERVICES LLC
7988 CENTERPOINT DR.
SUITE 100
INDIANAPOLIS, IN 46256
PHONE +1 317 849 4990
FAX +1 317 849 4278
WWW.ATCGROUPSERVICES.COM

Drawing Title:
DETAIL SHEET (REVISED JANUARY 2007)
TYPE III RESTRICTED WASTE LANDFILL
A.B. BROWN GENERATING STATION

Sheet:
3