Run-On and Run-Off Control System Plan Hunter Power Plant

PacifiCorp, Hunter Power Plant

Coal Combustion Residual Landfill

Revision 2
September 2016

Run-On and Run-Off Control System Plan Hunter Power Plant

Prepared for

PacifiCorp, Hunter Power Plant
Coal Combustion Residual Landfill
Castle Dale, Utah

Revision 2
September 2016

Prepared by

URS
Salt Lake City, Utah

INDEX AND CERTIFICATION

PacifiCorp, Hunter Power Plant
Run-On and Run-Off
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Certification

I hereby certify, as a Professional Engineer in the State of Utah, that the information in this document was assembled under my direct personal charge. This report is not intended or represented to be suitable for reuse by the PacifiCorp, Hunter Power Plant or others without specific verification or adaptation by the Engineer.

I hereby certify, as a Professional Engineer in the State of Utah that the initial run-on and run-off control system plans provided herein meet the requirements of 40 Code of Federal Regulations 257.81.

PROFESSIONAL ENGINEER
No. 8846769
BENJAMIN C. ROOD
STATE OF UTAH

Ben Rood, P.E. (UT #8846769-2202)

Date: 9/30/16

Ben Rood
License Number 8846769-2202

My license renewal date is 3/31/2017

Pages or sheets covered by this seal: As noted above.

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LIST OF ABBREVIATIONS

Abbreviation	**Term/Phrase/Name**
AF	acre-feet
AMSL	above mean sea level
CCR	Coal Combustion Residual
CFS	cubic feet per second
CN	Curve Number
FT	feet
MCY	million cubic yards
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
RRCS	Run-on and Run-off Control System
RRCSP	Run-on and Run-off Control System Plan
USEPA	United States Environmental Protection Agency

1.0 INTRODUCTION

The Hunter Coal Combustion Residuals (CCR) Landfill will include deposition of approximately 44.5 million cubic yards (MCY) of CCR within the current landfill footprint prior to closure, as described in the Basis of Design Memorandum (URS, 2015a). This plan describes how the run-on and run-off control systems have been designed and constructed to meet the requirements of the United States Environmental Protection Agency (USEPA) regulations for CCR (USEPA 2015, Disposal of Coal Combustion Residuals from Electric Utilities – 40 CFR §257, Federal Register 80, no. 74, April 17, 2015, hereinafter referred to as the “Rule”.).

1.1 Purpose of Design

The purpose of run-on control features is to prevent offsite stormwater flows from running on to the CCR landfill in order to minimize infiltration of moisture into the CCR material, to prevent erosion of the cover material, and to prevent transport of CCR material. The purpose of the run-off control features is to collect run-off from the CCR landfill and direct it to the zero-discharge stormwater retention basin.

This Run-on and Run-off Control System Plan (RRCSP) describes the design approach for features used to control run-on and run-off from the CCR Landfill, as provided in the Hunter Plant PacifiCorp CCR Landfill Design Documents (URS, 2015b). Key features of the RRCSP include positive slopes, down drain rock chutes, culverts, stilling basins and channels, connections to the existing perimeter ditch, and ultimately the stormwater retention basin.

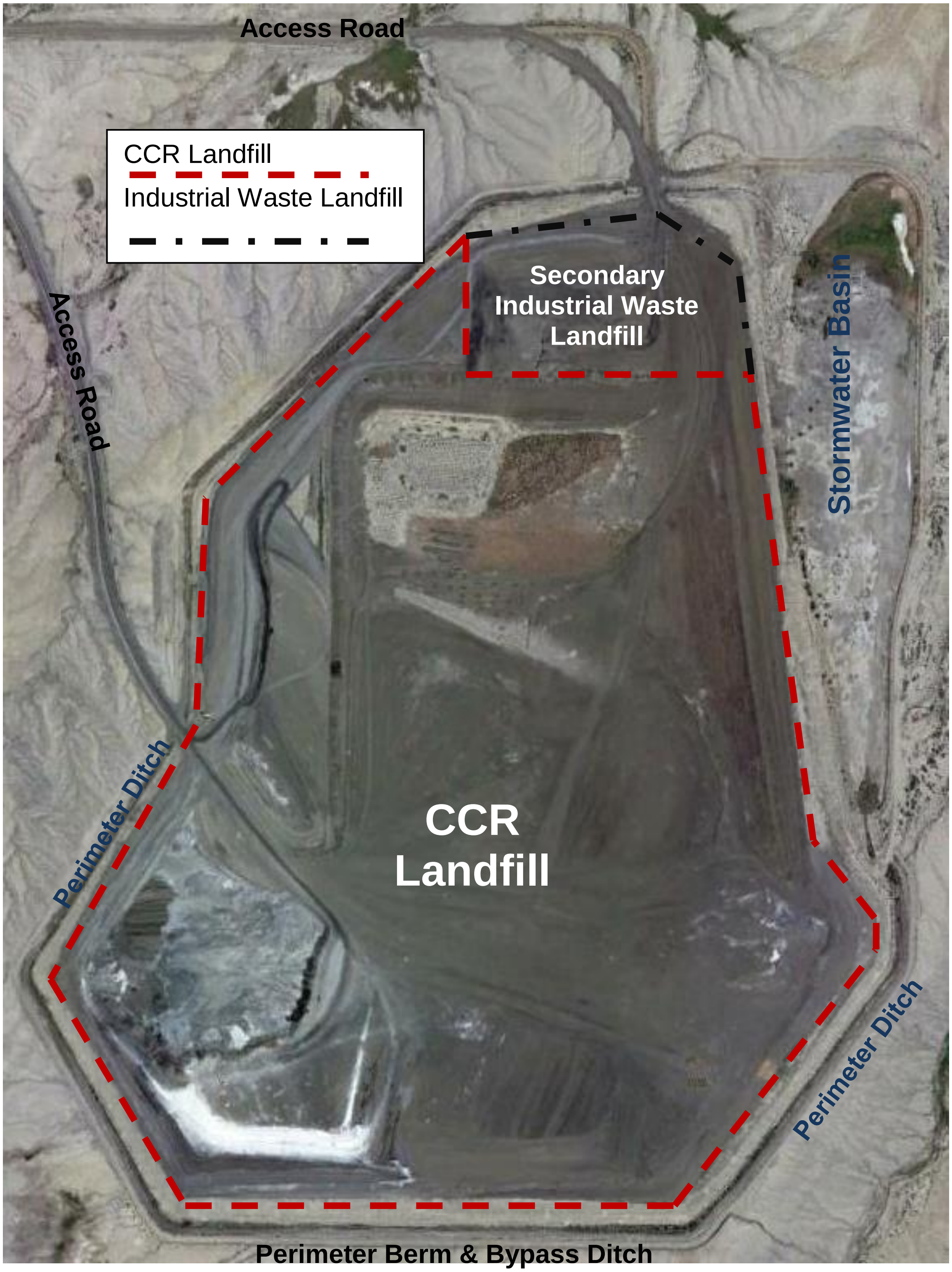
Elements of the completed CCR Landfill will include north and south (primary) access roads, industrial access road, the perimeter ditch, and the zero-discharge stormwater retention basin, which has a volume of 104 acre-feet (AF). Immediately north of the CCR Landfill, but within the boundary of the perimeter ditch, is a permitted class IIIb industrial waste landfill, which PacifiCorp manages in parallel with the CCR Landfill.

1.2 Existing Conditions

The Hunter Power Plant, located 2.5 miles south of Castle Dale, Utah, is a coal-fired power generation facility.

The CCR Landfill occupies approximately 230 acres southeast of the power plant, as shown in Figure 1-1. Elements of the existing CCR Landfill include the existing access road, the perimeter ditch, and the zero-discharge stormwater retention basin (104 AF capacity). The CCR landfill will be closed upon closure of the Hunter Plant (estimated 2042). The design documents include a total landfill capacity of 44.5 MCY.

Figure 1-1. Hunter Power Plant CCR Landfill Site Overview
(image created using *GoogleEarth Pro* and its partners, copyright protected)



2.0 BASIS FOR DESIGN

2.1 Data Sources

Data sources used for the development of this RRCSP include:

- Existing topographic survey of the CCR Landfill site, based on 2015 digital database
  - Source: Aero-Graphics, http://www.aero-graphics.com/
- Existing offsite watershed topography
  - Source: Utah Automated Geographic Reference Center, via GIS portal, http://gis.utah.gov/
- Hydrologic soil groups
  - Source: National Resource Conservation Service (NRCS) Web Soil Survey, http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
- Rainfall data (duration/intensity)
  - Source: National Oceanic and Atmospheric Administration (NOAA), Atlas 14, http://www.nws.noaa.gov/oh/hdsc/currentpf.htm

These data sources allow confirmation of the existing topography of the CCR Landfill, the perimeter ditch, and the stormwater retention basin. They are also used to determine soil types and applicable rainfall data to develop stormwater run-off calculations.

2.2 Design Storms

The stormwater controls discussed in this RRSCP were designed at different times during the CCR landfill history. Below is a summary of the design criteria used for each component.

CCR Landfill downdrains, stilling basins, culverts, roadways, and benches: 25-year, 24-hour storm as required by the USEPA Final Coal Combustion Residual Rule (40 C.F.R. §257 and 261 (2015)).

- Existing stormwater retention basin: 100-year, 24-hour storm
- Existing perimeter ditch: 100-year, 24-hour storm

The zero-discharge basin and perimeter ditch are not permitted to allow run-off from the site. The ditch has berms to prevent run-on of off-site stormwater.

3.0 DESIGN APPROACH

3.1 Project Assumptions

The Hunter CCR Landfill design includes the following general assumptions based on PacifiCorp operation procedures:

- Additional detention or retention basins are not required.
- The existing stormwater basin outlet structure meets the design requirements for the life of the power plant and the CCR Landfill.

Appendix 1 includes the Hydraulic and Hydrologic calculations used in design.

3.2 Hydrology

The hydrology and run-off were determined for the CCR Landfill design using the NRCS Technical Release 55 (TR-55), which employs the Soil Conservation Service Curve Number (CN) method. The NOAA Atlas 14 (NOAA 2012) was used to determine the rainfall depths specific to the Hunter landfill site. These rainfall depths are shown in Table 3-1 for the 25-year and 100-year recurrence intervals with a 24-hour duration storm event.

Table 3-1. Hunter CCR Landfill Site-Specific Rainfall Depths

		25-yr			100-yr		
Watershed ID	Runoff Area*	Rainfall Depth	Runoff	Volume	Rainfall Depth	Runoff	Volume
	Acre	inch	cfs	af	inch	cfs	af
North	33.05	1.86	36.10	2.15	2.28	50.73	3.03
North West	27.41	1.86	29.94	1.78	2.28	42.07	2.51
West	20.09	1.86	21.94	1.31	2.28	30.83	1.84
South West	35.97	1.86	39.30	2.34	2.28	55.21	3.30
South	27.03	1.86	29.53	1.76	2.28	41.49	2.48
South East	26.84	1.86	29.32	1.75	2.28	41.20	2.46
East	17.40	1.86	19.01	1.13	2.28	26.71	1.59
North East	31.10	1.86	33.97	2.02	2.28	47.73	2.85
North Add-on	5.08	1.86	5.55	0.33	2.28	7.80	0.47

3.3 Run-on Controls

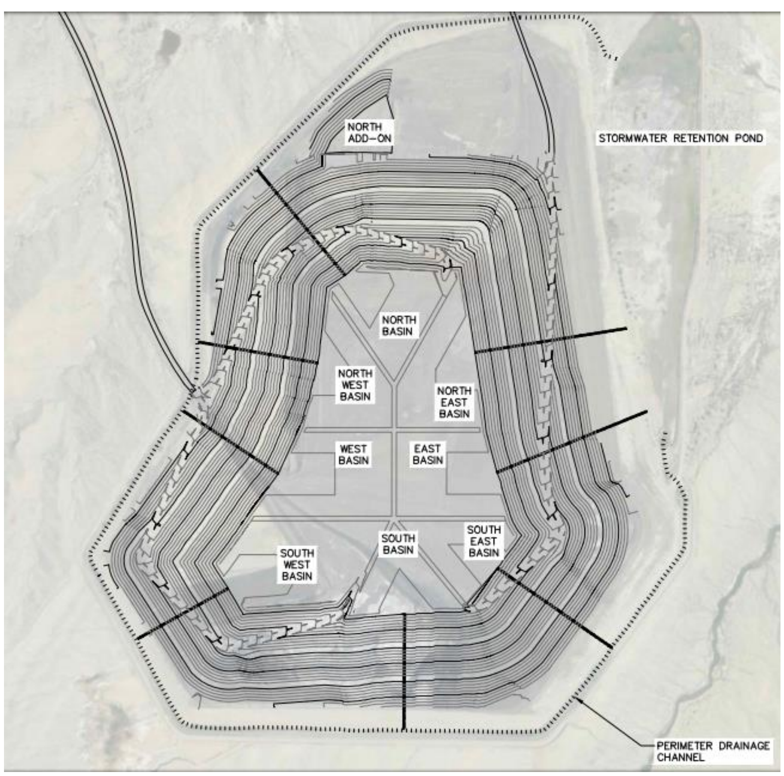
A run-on control system is required for all operating CCR landfills to prevent flow onto the landfill from offsite sources during the peak discharge from a 25-year storm. At the Hunter CCR Landfill, the run-on control system consists of a perimeter berm and bypass ditches that route offsite stormwater around the site. Therefore, no additional run-on controls are required.

3.4 Run-off Controls

A run-off control system is required for all operating CCR landfills to collect and control, at a minimum, the water volume resulting from a 24-hour, 25-year storm (see Table 1). Run-off control will prevent ponding and infiltration of water into the CCR Landfill, erosion of the cover and CCR material, destabilization of the landfill structure, and damage to access roads. Without controls, run-off could eventually develop gullies and ravines that compromise the integrity of the structure and cover.

At the Hunter CCR Landfill, the design approach is to control the direction and velocity of run-off to prevent erosion. This is achieved by sloping the CCR Landfill surface to maintain a positive slope toward the edges, and collecting the water into channels that then feed into downdrains designed to dissipate the energy without being eroded. The run-off is then conveyed to the perimeter ditch. In order to manage the water volume and flow rates, the CCR landfill was divided into eight small watersheds, as shown in Figure 3-1.

Figure 3-1. Watershed Delineations of the CCR Landfill



During each phase of the CCR Landfill construction, each watershed surface will be graded to prevent ponding of stormwater (in order to minimize infiltration into the landfill), and the positive slopes for each watershed will be used to convey this run-off to channels that then feed water to the downdrains and the perimeter ditch. The downdrains consist of rock-lined chutes to dissipate energy, underlain by a geotextile liner and an impermeable bedding layer to prevent erosion of the underlying cover and CCR materials.

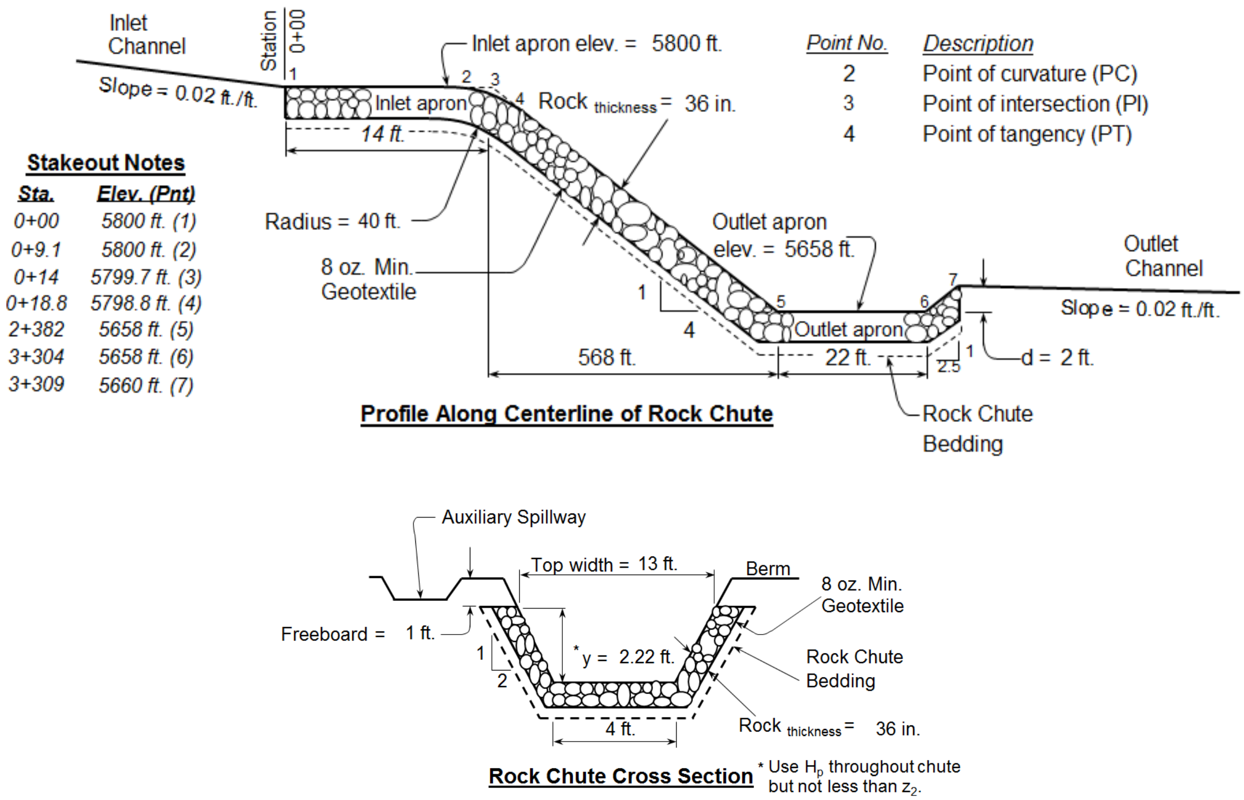
The CCR Landfill will include two 20-foot wide benches, one at elevation 5700 ft above mean sea level (amsl) and one at 5750 ft amsl, to collect side slope drainage. The benches will be sloped inwards towards the landfill. The run-off from the benches and from upstream slopes will be collected in rock lined ditches and routed to the downdrains.

Each downdrain will be equipped with stilling basins at the benches and at the connections to the perimeter ditch. The rock-lined stilling basins are designed to create a hydraulic jump to dissipate energy from the water. Figure 3-2 shows a detail of the chute and stilling basin design.

Culverts will be installed where downdrains cross haul roads. Culverts and channels are designed to convey water at low velocity and will have an impermeable liner. Where slopes require, culverts and channels will include rock material to dissipate energy and prevent erosion or transport of materials as detailed in the Design Documents (URS, 2015b).

The approach employed for rip-rap design of down drains and stilling basins is found in Design of Rock Chutes (1998).

Figure 3-2. Typical Chute and Stilling Basin from Design of Rock Chutes (1998)



3.5 Existing Perimeter Ditch and Stormwater Retention Basin

A minimum depth, width, and sideslopes are required to meet capacity for the design flows in the perimeter ditch. Wherein the existing perimeter ditch does not have required minimum depth, width and sideslopes, the ditch should be expanded to provide design flow capacity.

The existing stormwater retention basin will not be modified or improved as ample storage is provided.

4.0 CONCLUSIONS

This RRCSP consists of a comprehensive plan to manage stormwater run-on and run-off at the Hunter CCR Landfill. Elements of the RRCSP include the following:

- Existing perimeter ditch and stormwater retention basin
- Grading of the landfill to establish positive slopes
- Collection of run-off from watersheds and benches
- Conveyance of run-off via down drains to the perimeter ditch
- Surface drainage into culverts at the access roads.

This RRCSP is designed to manage run-off from a minimum 25-year 24-hour event as required by the United States Environmental Protection Agency (USEPA) Final Coal Combustion Residual Rule (40 CFR Part 257, Subtitle D) Section VI.G.

5.0 REFERENCES

Design of Rock Chutes, 1998. Robinson, Rice, Kadavy, ASAE.

National Oceanic and Atmospheric Administration, 2012. National Climate Data Center – Interactive Map. Version 2.4.4. http://gis.ncdc.noaa.gov/map/cdo/?thm=themeAnnual

URS, 2015a, Hunter Power Plant, "CCR Landfill Draft Basis of Design Memorandum," November 2015.

URS, 2015b, Hunter Plant PacifiCorp CCR Landfill Design Documents (December 2015).

U.S. Environmental Protection Agency, 2015. "Disposal of Coal Combustion Residuals from Electric Utilities" – 40 CFR §257. Federal Register 80, No. 74, April 17, 2015.

Appendix A - HYDROLOGIC AND HYDRAULIC CALCULATIONS

URS CALCULATION SHEET	Calculation No. 1
	Project No. 60439980
Project Title: Hunter Landfill	Sheet No. 1 of 6
Subject/Feature: General Hydrologic Data	Rev: A

SUMMARY

The analysis and design of the Landfill Hydrology are summarized in these calculations. The NRCS method was used and modelled using HydroCAD. The modelled results are included, summarizing the generated runoff volumes and flows. The hydrology was used to support the calculations for the proposed downdrains, culverts, and benches.

OBJECTIVE

The NRCS method was then used to look at the watershed as a whole to generate appropriate peak flows and total volumes of runoff to be routed through the downdrains, ditches and ultimately the existing storm water retention pond. This conservative approach allows dimensioning of the ditches for the fully-reclaimed condition of the landfill.

DESIGN BASIS

The hydrology and runoff were determined for the CCR Landfill design using the NRCS Technical Release 55 (TR-55), which employs the Soil Conservation Service Curve Number (CN) method. The National Oceanic and Atmospheric Administration (NOAA) Atlas 14 was used to determine the rainfall depths specific to the Hunter landfill site. These rainfall depths are shown for the 25-year and 100-year recurrence intervals with a 24-hour duration storm event.

DATA

Of particular note for this design is the 25-year, 24-hour rainfall depth of 1.86 inches and the 100-year, 24-hour rainfall depth of 2.28 inches. The rainfall depth estimates were derived from North Horn Mountain, which resides directly West of the landfill, at an elevation of 5825 ft in order to capture the orthographic effect that will influence the landfill.

To account for rainfall loss during the storm through infiltration, initial abstraction, or evaporation that does not result in runoff, the curve number (CN) method was used as outlined in the NRCS method. Since all the drainages will have similar vegetation cover at closure, the CN used in the hydrologic models for undisturbed areas in all basins was 88, since the cover material will have low-permeability.

A time of concentration (TOC) of 15 minutes was used for all basins.

URS

CALCULATION SHEET

Calculation No. 1	
Project No. 60439980	
Project Title: Hunter Landfill	Sheet No. 1 of 6
Subject/Feature: General Hydrologic Data	Rev: A

METHODS

In order to manage the water volume and flow rates, the CCR landfill was divided into eight small watersheds. The area for each watershed was delineated. A hydrologic rainfall/runoff analysis for each watershed was performed using HydroCAD. HydroCAD generates rainfall/runoff hydrographs using the NRCS methodologies and routes the runoff through the proposed systems. HydroCAD calculates storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for storm water reservoirs.

RESULTS

Summary of the HydroCAD results are seen in the table below. HydroCAD generated reports are attached.

Watershed ID	Runoff Area*	25-yr			100-yr		
		Rainfall Depth	Runoff	Volume	Rainfall Depth	Runoff	Volume
	Acre	inch	cfs	af	inch	cfs	af
North	33.05	1.86	36.10	2.15	2.28	50.73	3.03
North West	27.41	1.86	29.94	1.78	2.28	42.07	2.51
West	20.09	1.86	21.94	1.31	2.28	30.83	1.84
South West	35.97	1.86	39.30	2.34	2.28	55.21	3.30
South	27.03	1.86	29.53	1.76	2.28	41.49	2.48
South East	26.84	1.86	29.32	1.75	2.28	41.20	2.46
East	17.40	1.86	19.01	1.13	2.28	26.71	1.59
North East	31.10	1.86	33.97	2.02	2.28	47.73	2.85
North Add-on	5.08	1.86	5.55	0.33	2.28	7.80	0.47

***Note**: This area is the watershed area going into the perimeter ditch, not all this area will be sent through the downdrains. However, the downdrains were consrvatively modelled to contain the full watershed area of the largest basin.

Form 356-02 (MM) dated 7 Oct 2011

Summary for Subcatchment E: East

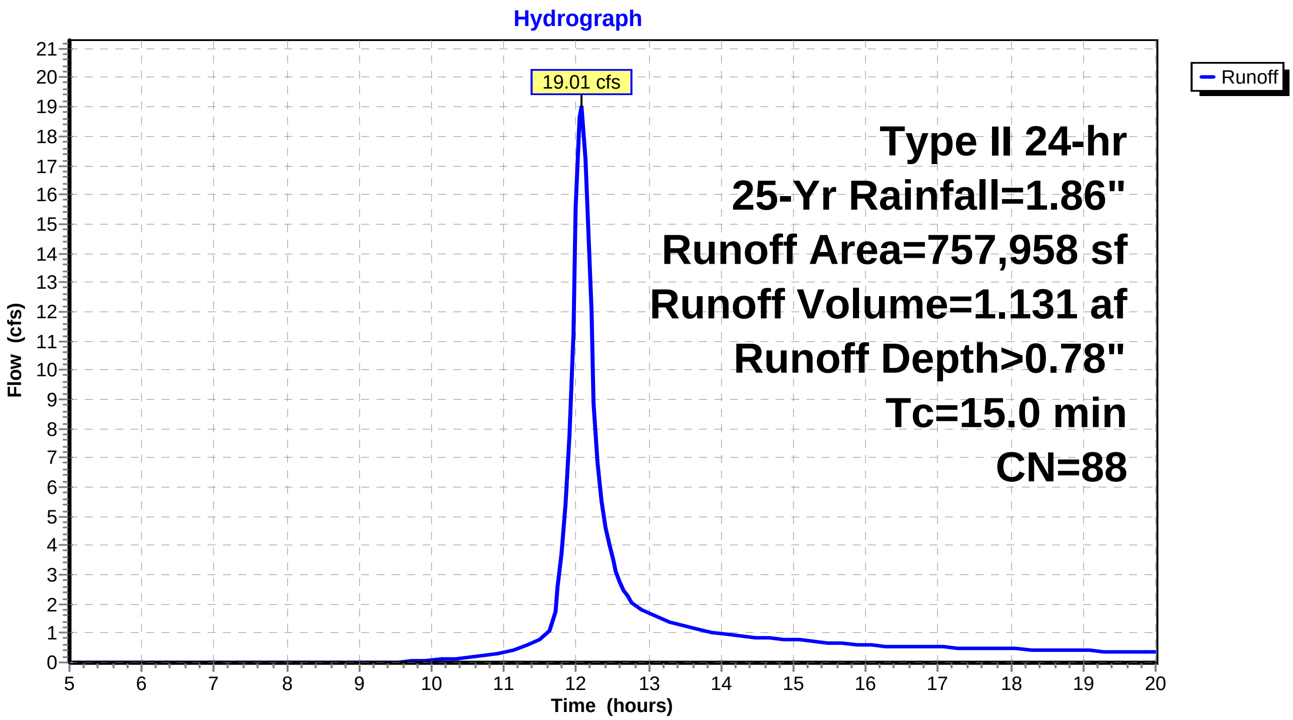
Runoff = 19.01 cfs @ 12.07 hrs, Volume= 1.131 af, Depth> 0.78"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-Yr Rainfall=1.86"

	Area (sf)	CN	Description
*	757,958	88	
	757,958		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment E: East



Summary for Subcatchment N: North

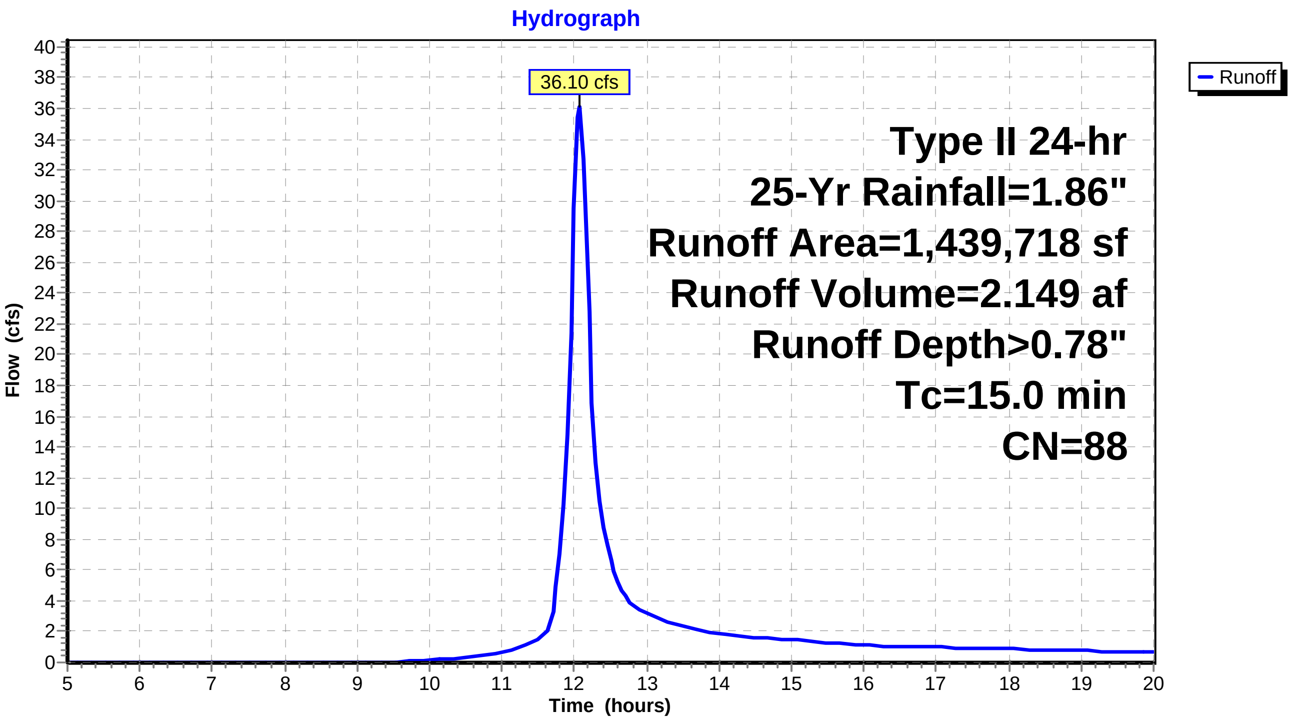
Runoff = 36.10 cfs @ 12.07 hrs, Volume= 2.149 af, Depth> 0.78"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-Yr Rainfall=1.86"

	Area (sf)	CN	Description
*	1,439,718	88	
	1,439,718		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment N: North



Summary for Subcatchment NA: North Add-on

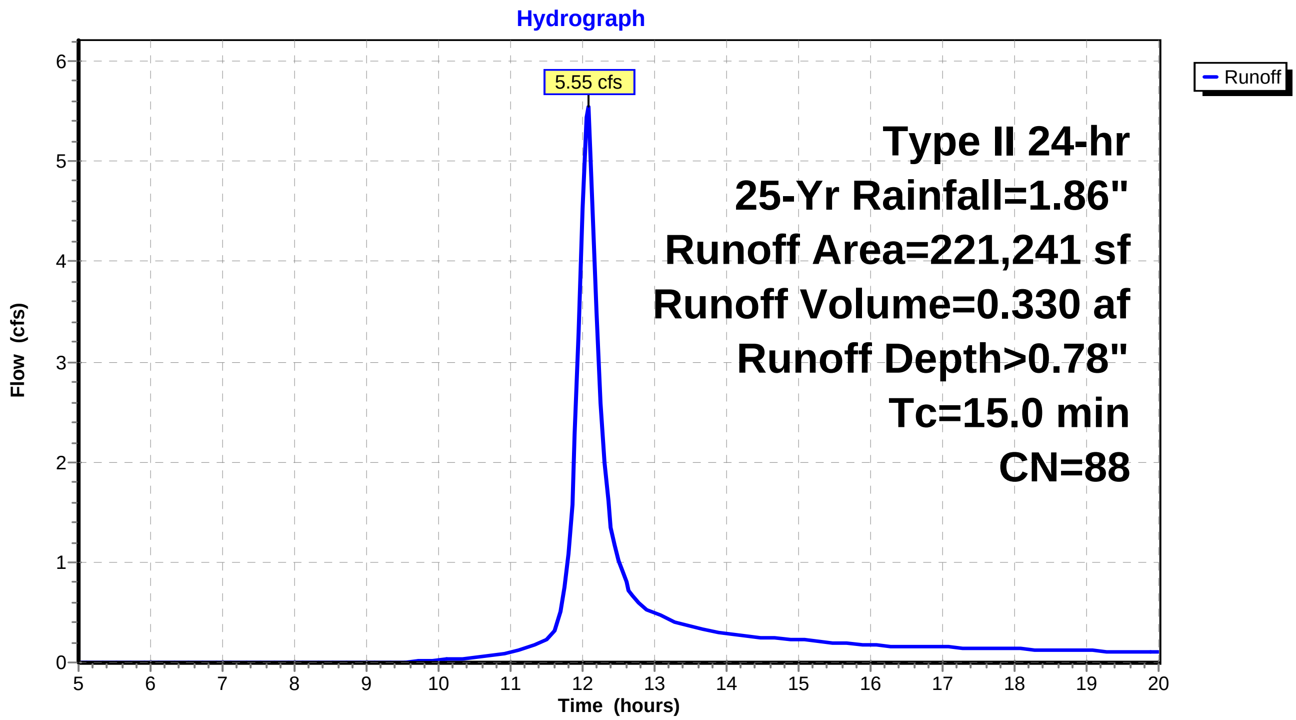
Runoff = 5.55 cfs @ 12.07 hrs, Volume= 0.330 af, Depth> 0.78"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-Yr Rainfall=1.86"

	Area (sf)	CN	Description
*	221,241	88	
	221,241		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment NA: North Add-on



Summary for Subcatchment NE: North East

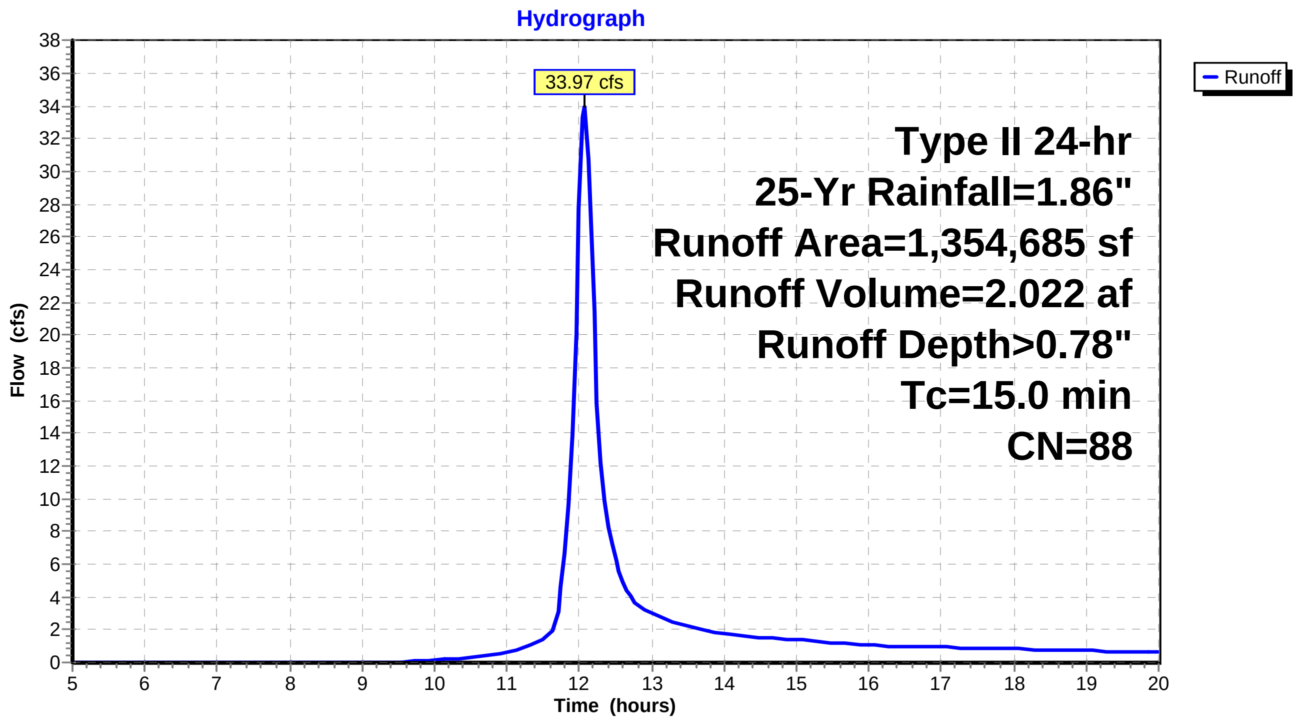
Runoff = 33.97 cfs @ 12.07 hrs, Volume= 2.022 af, Depth> 0.78"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-Yr Rainfall=1.86"

	Area (sf)	CN	Description
*	1,354,685	88	
	1,354,685		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment NE: North East



Summary for Subcatchment NW: North West

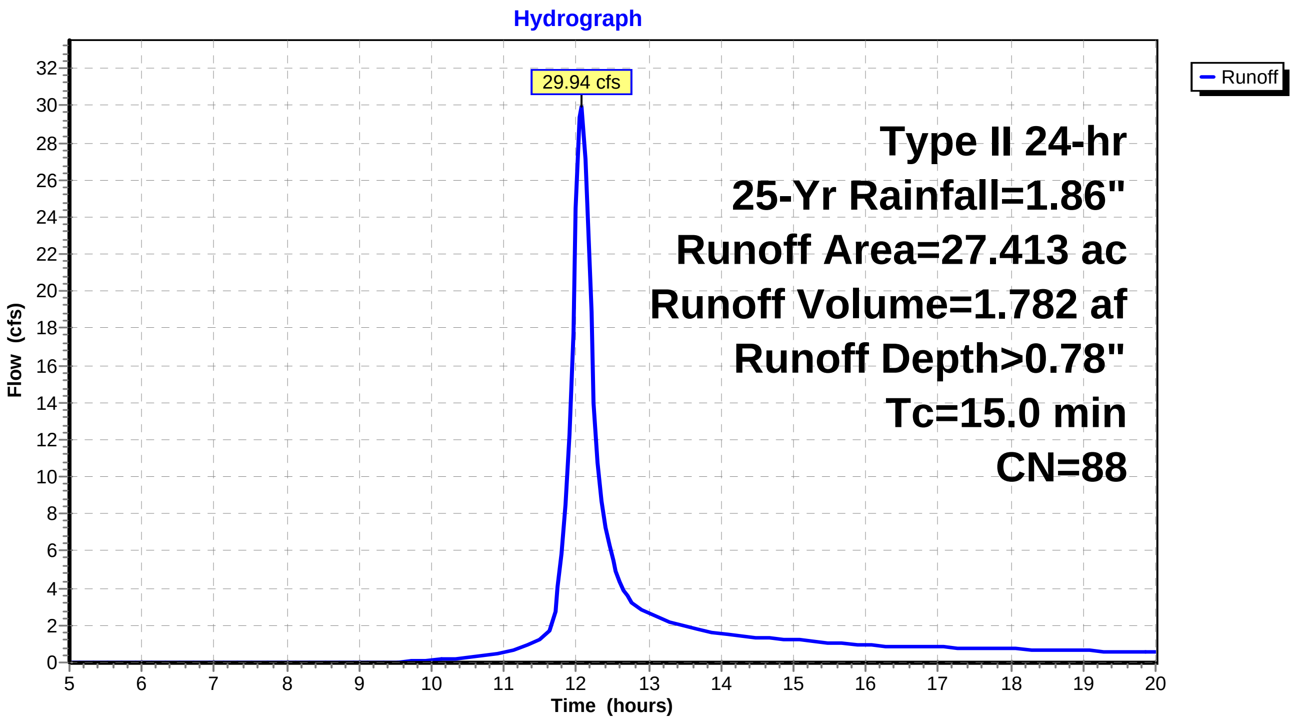
Runoff = 29.94 cfs @ 12.07 hrs, Volume= 1.782 af, Depth> 0.78"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-Yr Rainfall=1.86"

	Area (ac)	CN	Description
*	27.413	88	
	27.413		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment NW: North West



Summary for Subcatchment S: South

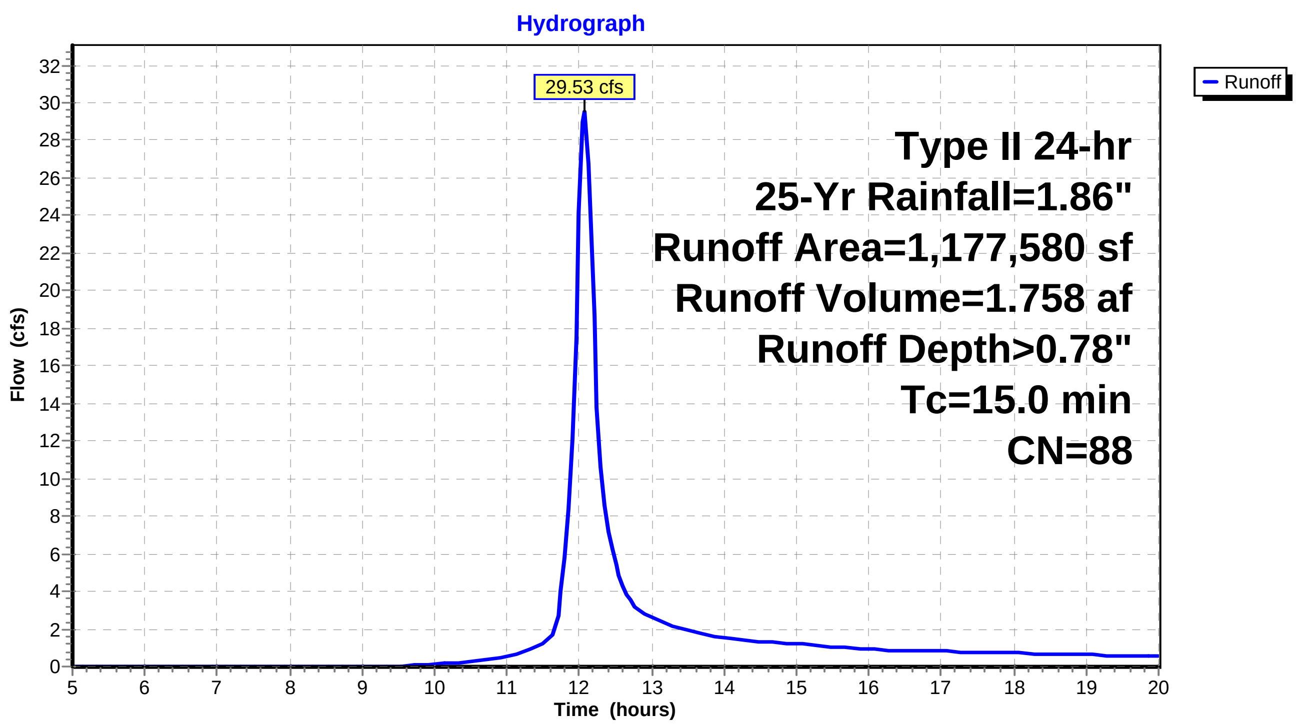
Runoff = 29.53 cfs @ 12.07 hrs, Volume= 1.758 af, Depth> 0.78"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-Yr Rainfall=1.86"

	Area (sf)	CN	Description
*	1,177,580	88	
	1,177,580		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment S: South



Summary for Subcatchment SE: South East

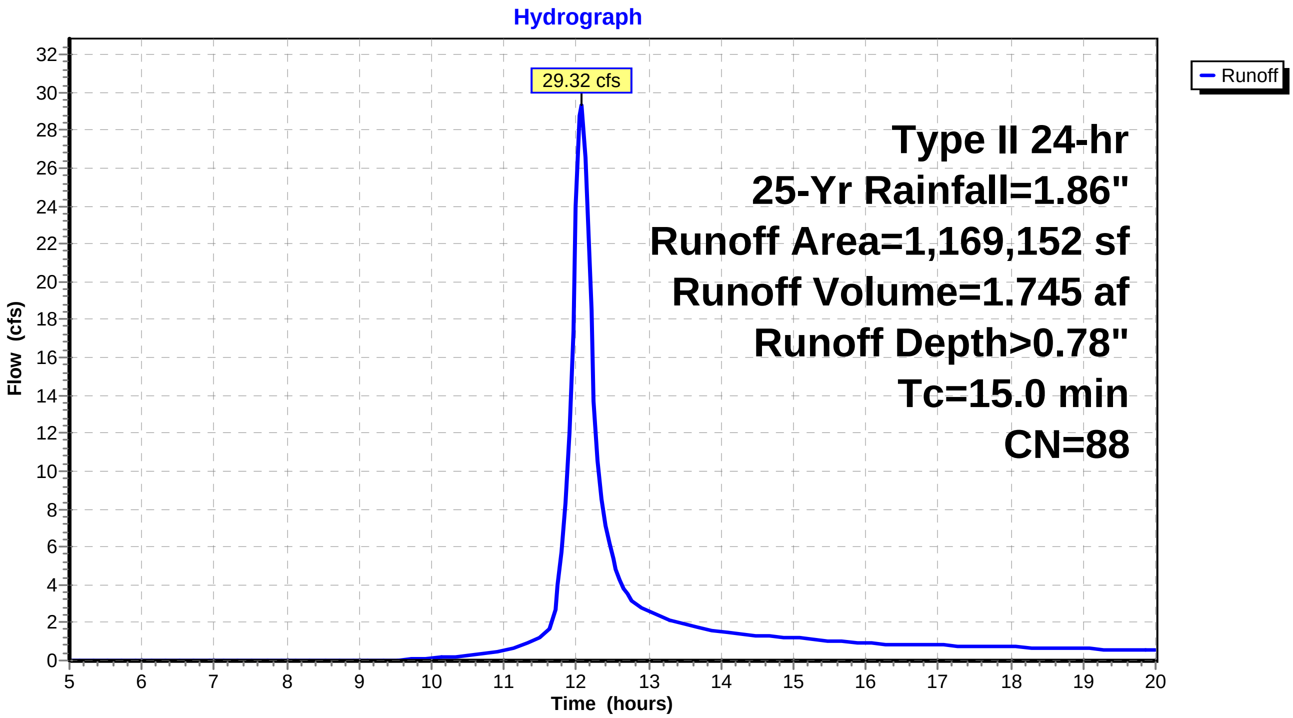
Runoff = 29.32 cfs @ 12.07 hrs, Volume= 1.745 af, Depth> 0.78"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-Yr Rainfall=1.86"

	Area (sf)	CN	Description
*	1,169,152	88	
	1,169,152		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment SE: South East



Summary for Subcatchment SW: South West

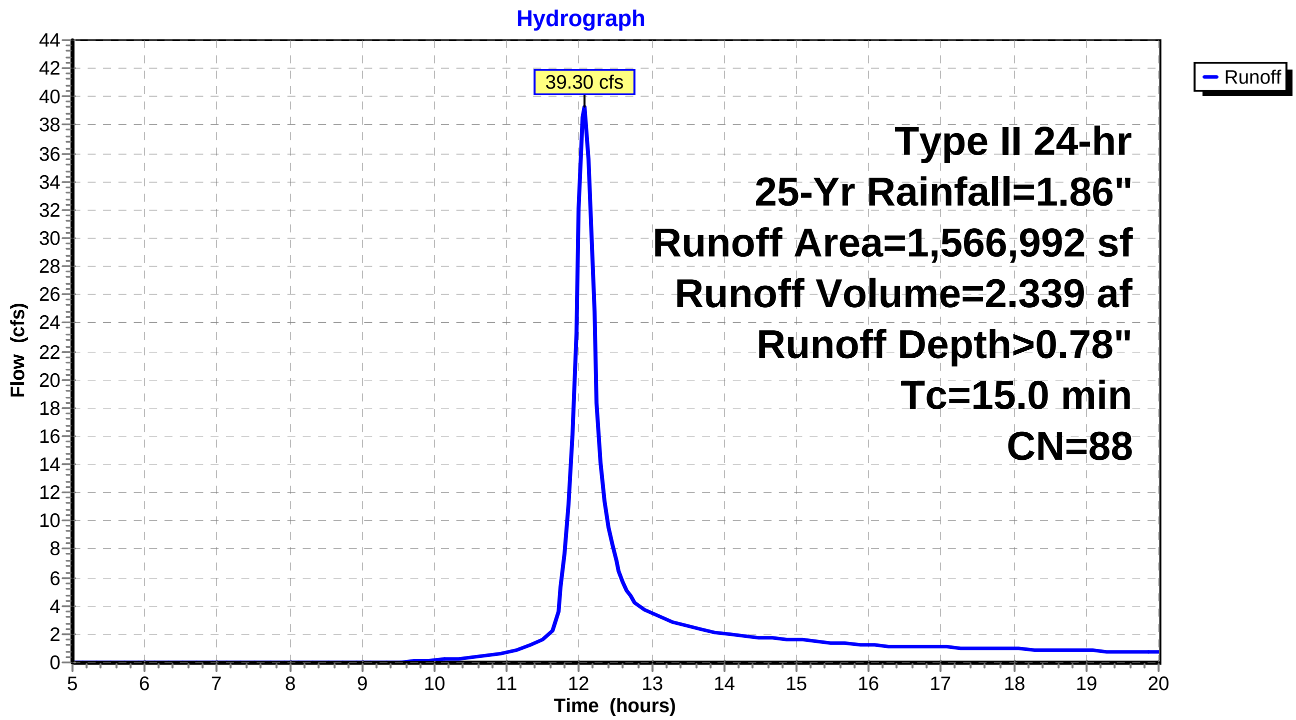
Runoff = 39.30 cfs @ 12.07 hrs, Volume= 2.339 af, Depth> 0.78"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-Yr Rainfall=1.86"

	Area (sf)	CN	Description
*	1,566,992	88	
	1,566,992		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment SW: South West



Summary for Subcatchment W: West

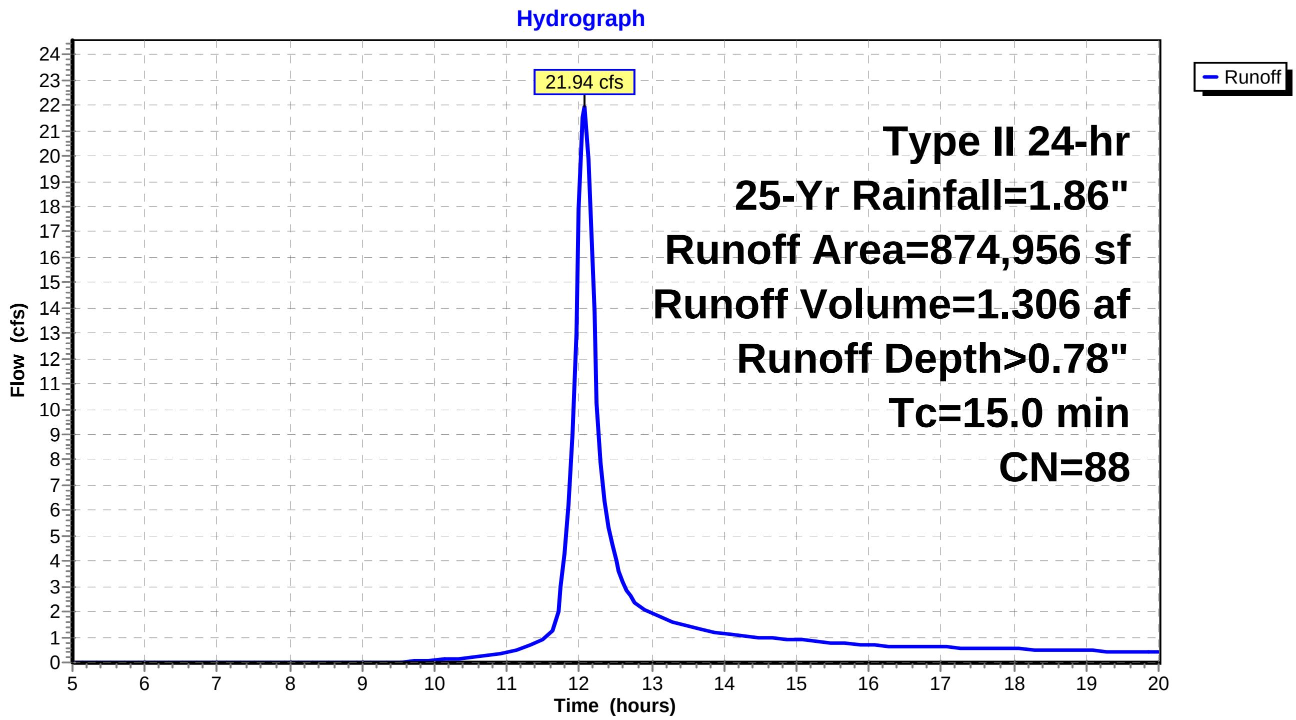
Runoff = 21.94 cfs @ 12.07 hrs, Volume= 1.306 af, Depth> 0.78"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-Yr Rainfall=1.86"

	Area (sf)	CN	Description
*	874,956	88	
	874,956		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment W: West



Summary for Subcatchment E: East

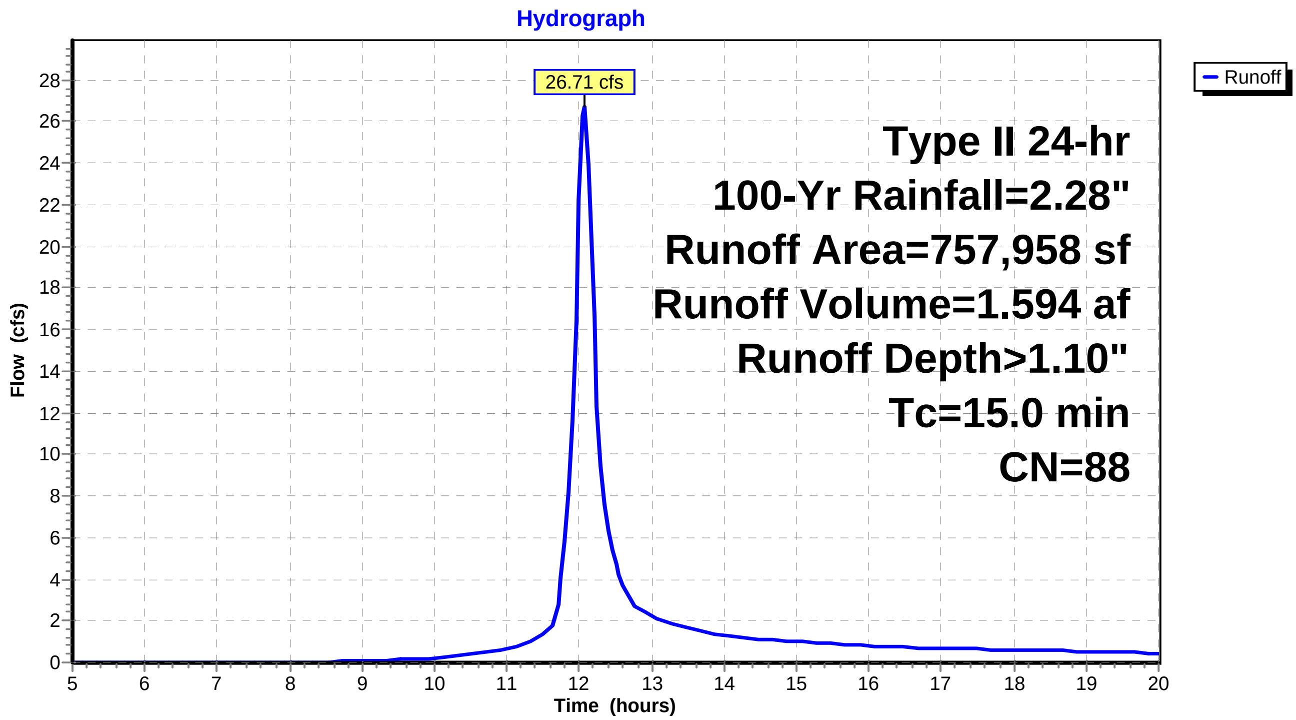
Runoff = 26.71 cfs @ 12.07 hrs, Volume= 1.594 af, Depth> 1.10"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-Yr Rainfall=2.28"

	Area (sf)	CN	Description
*	757,958	88	
	757,958		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment E: East



Summary for Subcatchment N: North

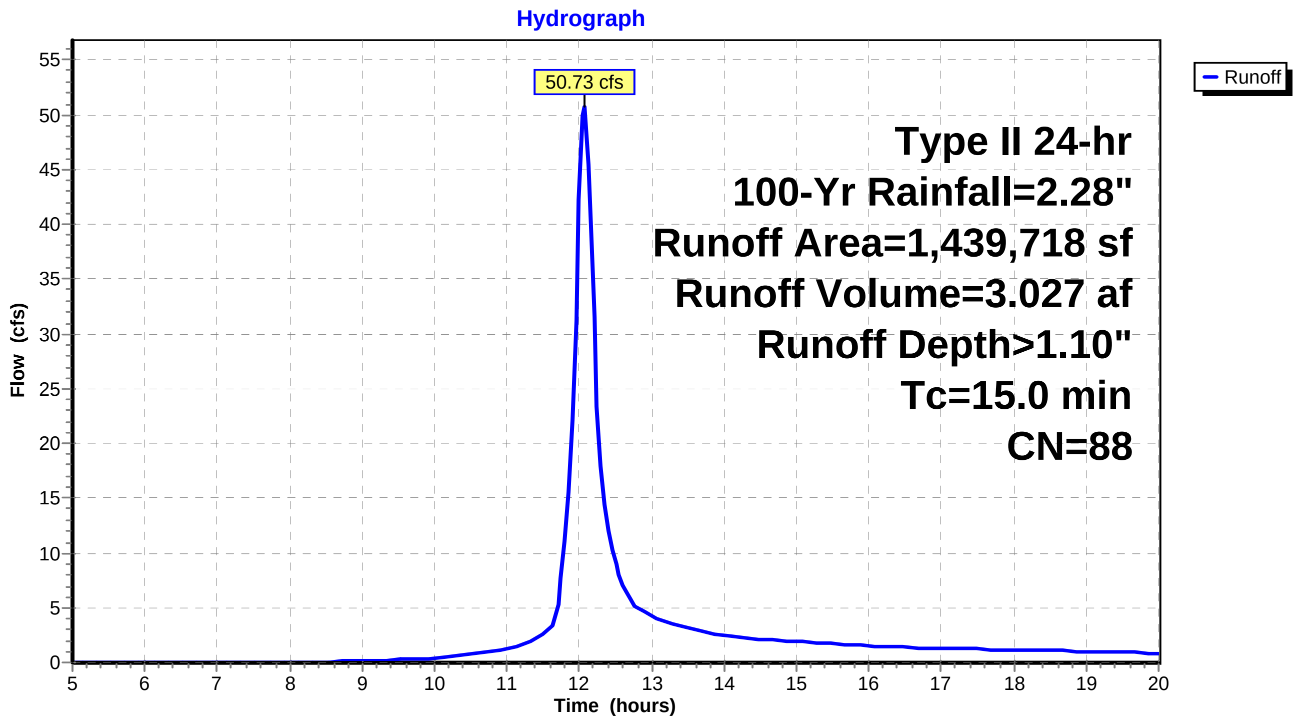
Runoff = 50.73 cfs @ 12.07 hrs, Volume= 3.027 af, Depth> 1.10"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-Yr Rainfall=2.28"

	Area (sf)	CN	Description
*	1,439,718	88	
	1,439,718		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment N: North



Summary for Subcatchment NA: North Add-on

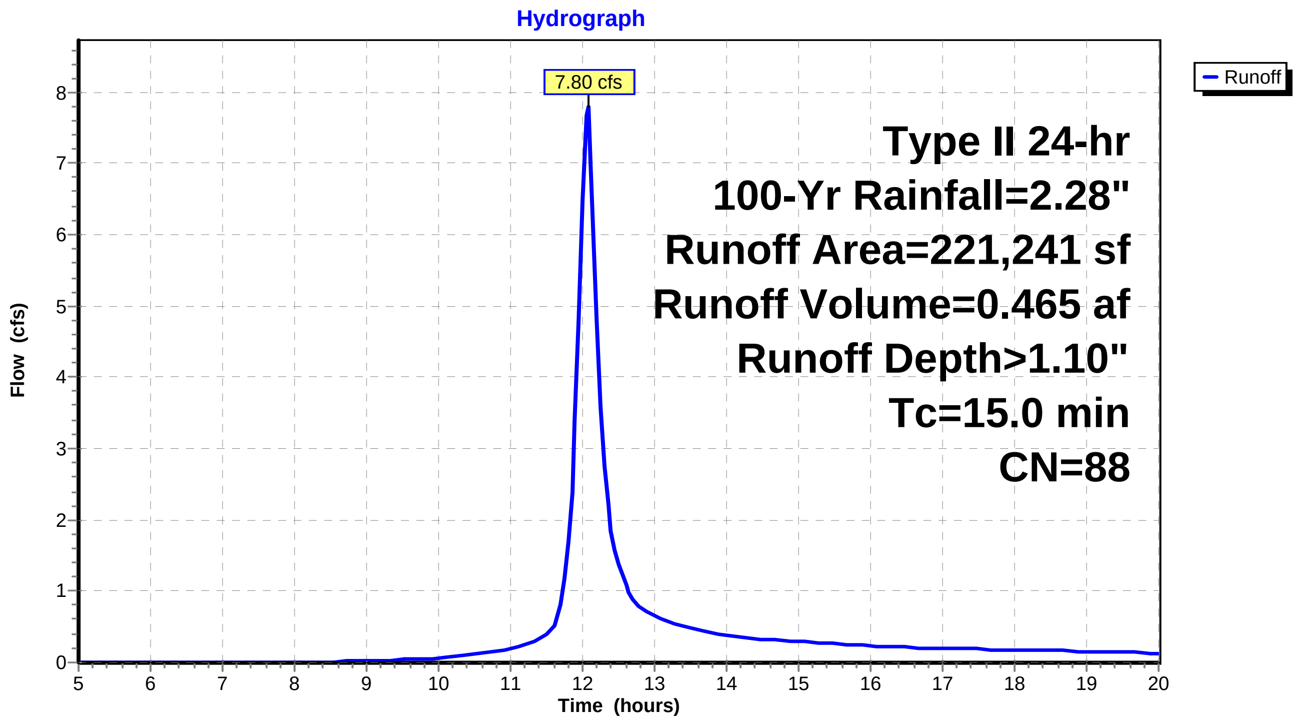
Runoff = 7.80 cfs @ 12.07 hrs, Volume= 0.465 af, Depth> 1.10"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-Yr Rainfall=2.28"

	Area (sf)	CN	Description
*	221,241	88	
	221,241		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment NA: North Add-on



Summary for Subcatchment NE: North East

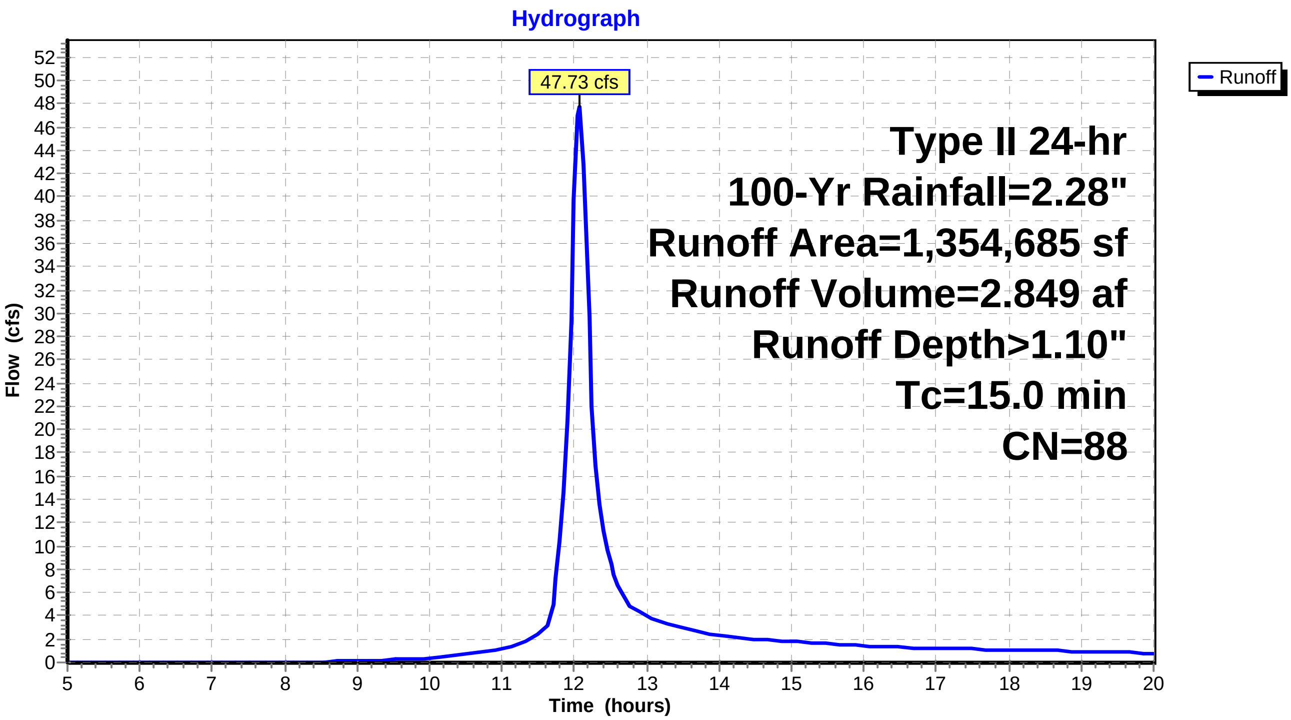
Runoff = 47.73 cfs @ 12.07 hrs, Volume= 2.849 af, Depth> 1.10"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-Yr Rainfall=2.28"

	Area (sf)	CN	Description
*	1,354,685	88	
	1,354,685		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment NE: North East



Summary for Subcatchment NW: North West

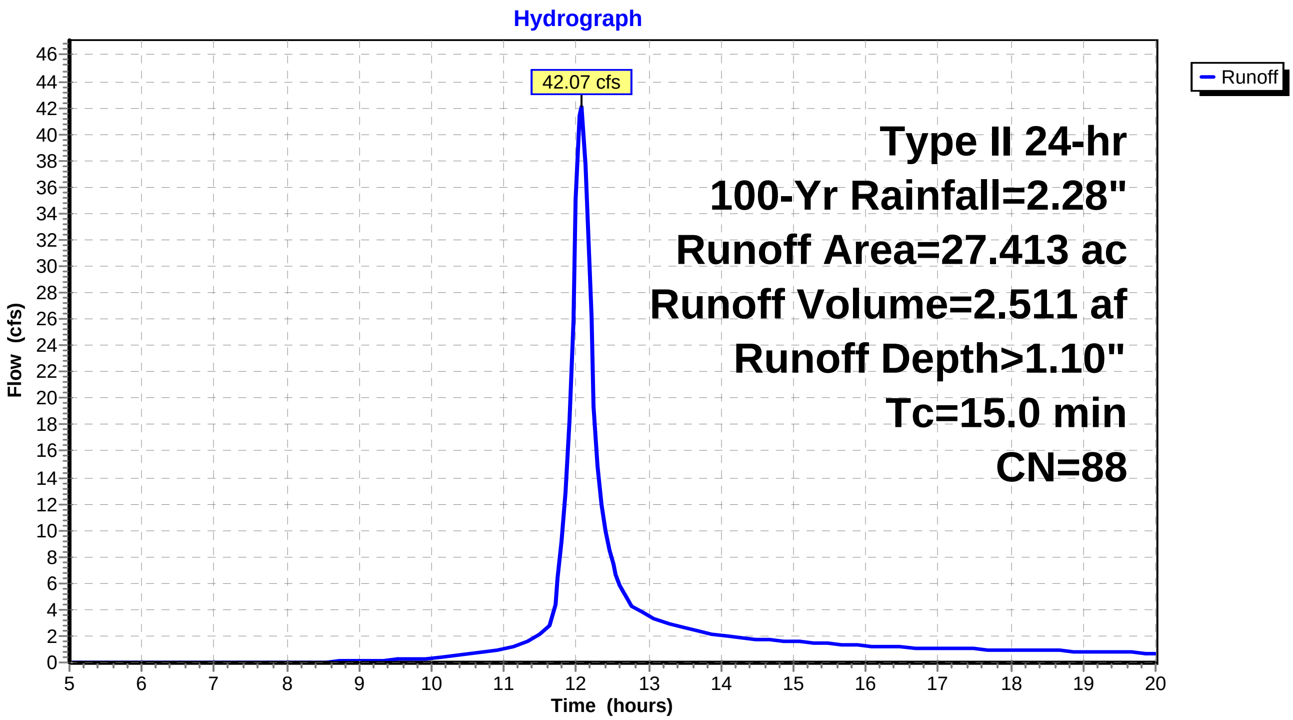
Runoff = 42.07 cfs @ 12.07 hrs, Volume= 2.511 af, Depth> 1.10"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-Yr Rainfall=2.28"

	Area (ac)	CN	Description
*	27.413	88	
	27.413		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment NW: North West



Summary for Subcatchment S: South

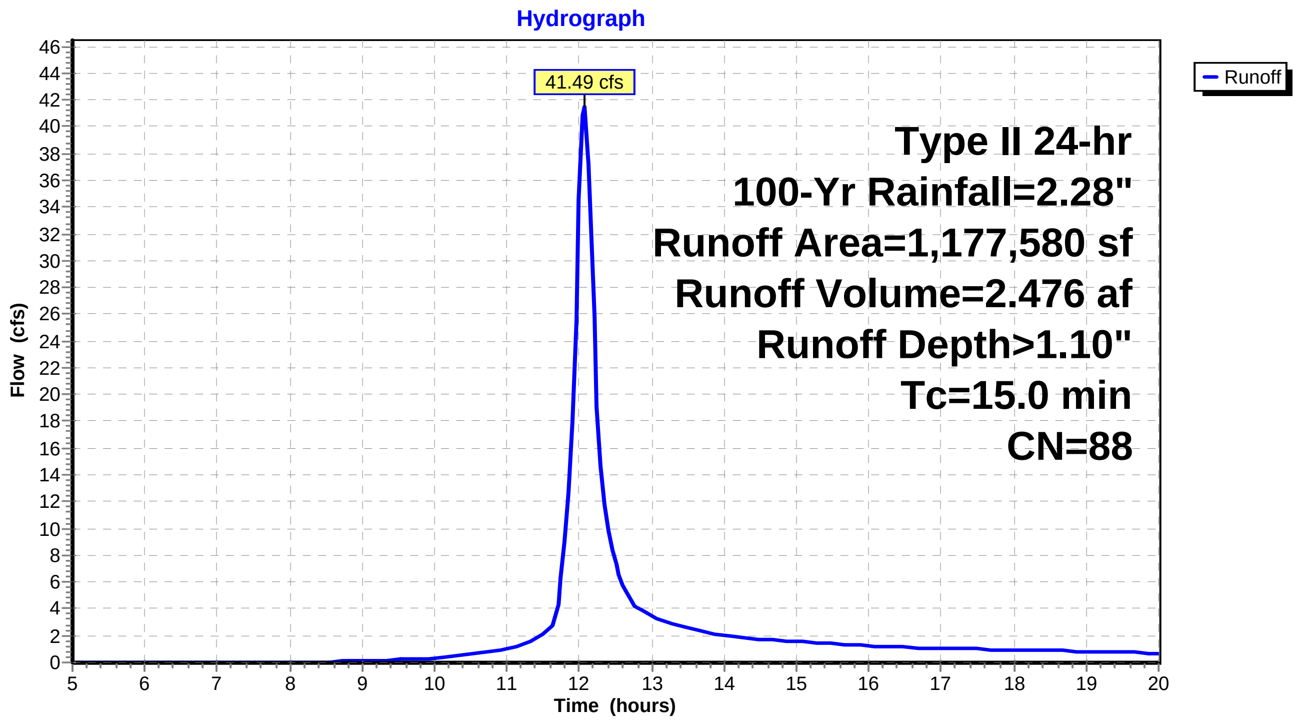
Runoff = 41.49 cfs @ 12.07 hrs, Volume= 2.476 af, Depth> 1.10"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-Yr Rainfall=2.28"

	Area (sf)	CN	Description
*	1,177,580	88	
	1,177,580		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment S: South



Summary for Subcatchment SE: South East

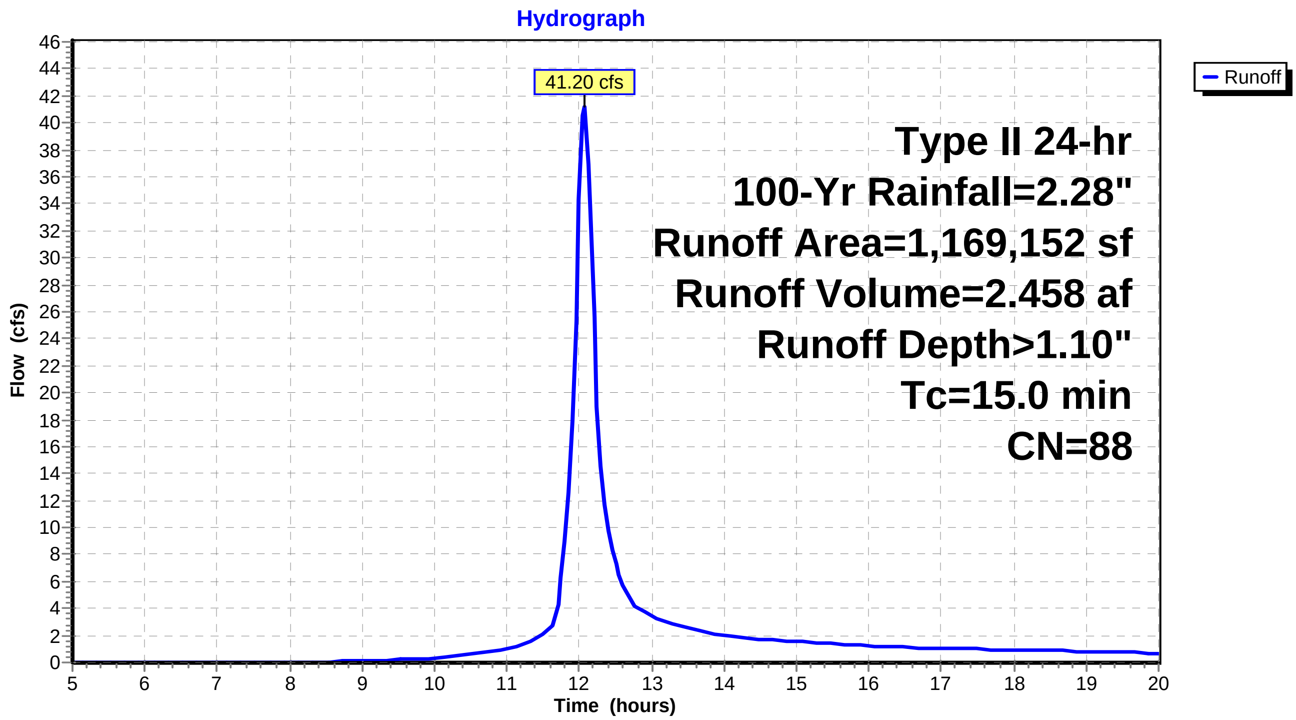
Runoff = 41.20 cfs @ 12.07 hrs, Volume= 2.458 af, Depth> 1.10"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-Yr Rainfall=2.28"

	Area (sf)	CN	Description
*	1,169,152	88	
	1,169,152		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment SE: South East



Summary for Subcatchment SW: South West

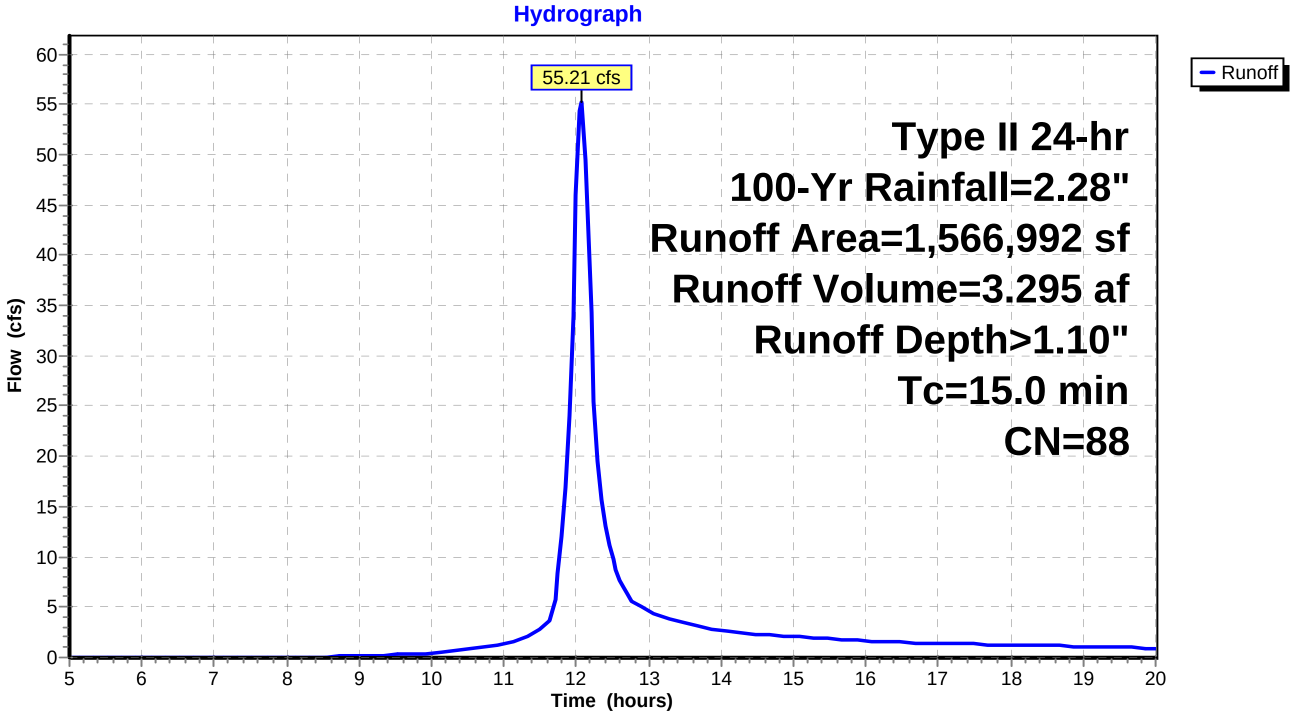
Runoff = 55.21 cfs @ 12.07 hrs, Volume= 3.295 af, Depth> 1.10"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-Yr Rainfall=2.28"

	Area (sf)	CN	Description
*	1,566,992	88	
	1,566,992		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment SW: South West



Summary for Subcatchment W: West

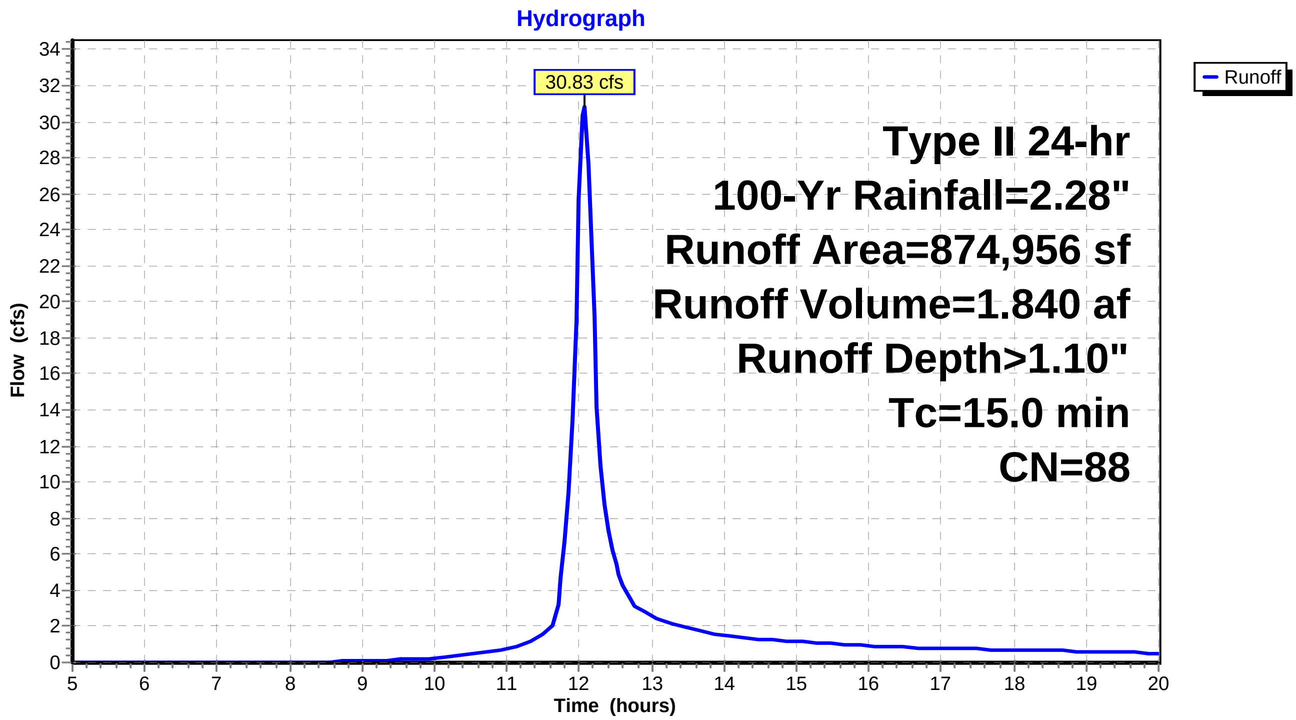
Runoff = 30.83 cfs @ 12.07 hrs, Volume= 1.840 af, Depth> 1.10"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-Yr Rainfall=2.28"

	Area (sf)	CN	Description
*	874,956	88	
	874,956		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
15.0					**Direct Entry,**

Subcatchment W: West



URS

CALCULATION SHEET

Calculation No. 1	Project No. 60439980
Project Title: Hunter Landfill	Sheet No. 2 of 6
Subject/Feature: Bench Ditch	Rev: A

SUMMARY

The analysis and design of the Landfill Bench Ditches are summarized in these calculations.

OBJECTIVE

Runoff from the landfill will sheet flow off the surface and collected in ditches built into 20 foot benches which are spaced every 50 feet of elevation of the landfill. These ditches will convey the storm water runoff to the nearest down drain.

DESIGN BASIS

The collection system was designed to adequately collect and convey storm water runoff during the 25-year, 24-hour storm event while minimizing erosion of the reclaimed surface. Consolidation should be considered so that flow continues to move laterally to the next down drain even after final consolidation at a 0.50% slope. This positive drainage will avoid ponding or "short-circuiting" of storm water flows. Open channel reach flow is based on Manning's Equation.

DATA

The following flows were calculated in HydroCAD (see hydrology calcs) and used for downdrain design.

		25-yr			100-yr		
Watershed ID	Runoff Area*	Rainfall Depth	Runoff	Volume	Rainfall Depth	Runoff	Volume
	Acre	inch	cfs	af	inch	cfs	af
North	33.05	1.86	36.10	2.15	2.28	50.73	3.03
North West	27.41	1.86	29.94	1.78	2.28	42.07	2.51
West	20.09	1.86	21.94	1.31	2.28	30.83	1.84
South West	35.97	1.86	39.30	2.34	2.28	55.21	3.30
South	27.03	1.86	29.53	1.76	2.28	41.49	2.48
South East	26.84	1.86	29.32	1.75	2.28	41.20	2.46
East	17.40	1.86	19.01	1.13	2.28	26.71	1.59
North East	31.10	1.86	33.97	2.02	2.28	47.73	2.85
North Add-on	5.08	1.86	5.55	0.33	2.28	7.80	0.47

*Note: This area is the watershed area going into the perimeter ditch, not all this area will be sent through the downdrains. However, the downdrains were consrvatively modelled to contain the full watershed area of the largest basin.

A Manning's Number of 0.030 was used for the rip rap lined ditch.

METHODS

HydroCAD was used to model flow through a ditch with 2:1 side slopes dug into a 20 foot wide bench that slopes inward at a 20:1 slope. Models were run to ensure that both a SCS 25-yr and 100-yr, 24 hour storm would be captured within the bench.

RESULTS

HydroCAD report summaries are attached.

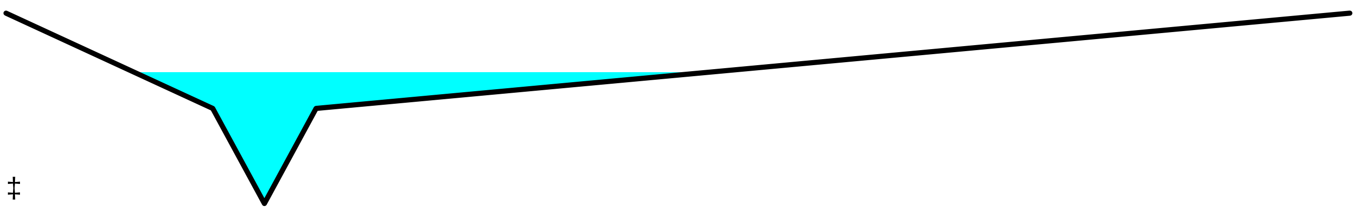
Summary for Reach 7R: Bench Drain

Inflow Area = 6.390 ac, 0.00% Impervious, Inflow Depth > 0.78" for 25-Yr event
Inflow = 11.23 cfs @ 11.89 hrs, Volume= 0.418 af
Outflow = 5.23 cfs @ 12.20 hrs, Volume= 0.411 af, Atten= 53%, Lag= 18.4 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.74 fps, Min. Travel Time= 13.4 min
Avg. Velocity = 1.02 fps, Avg. Travel Time= 22.8 min

Peak Storage= 4,873 cf @ 11.97 hrs
Average Depth at Peak Storage= 1.38'
Bank-Full Depth= 2.00' Flow Area= 15.0 sf, Capacity= 35.60 cfs

Custom cross-section, Length= 1,394.0' Slope= 0.0050 '/'
Constant n= 0.030
Inlet Invert= 7.00', Outlet Invert= 0.00'

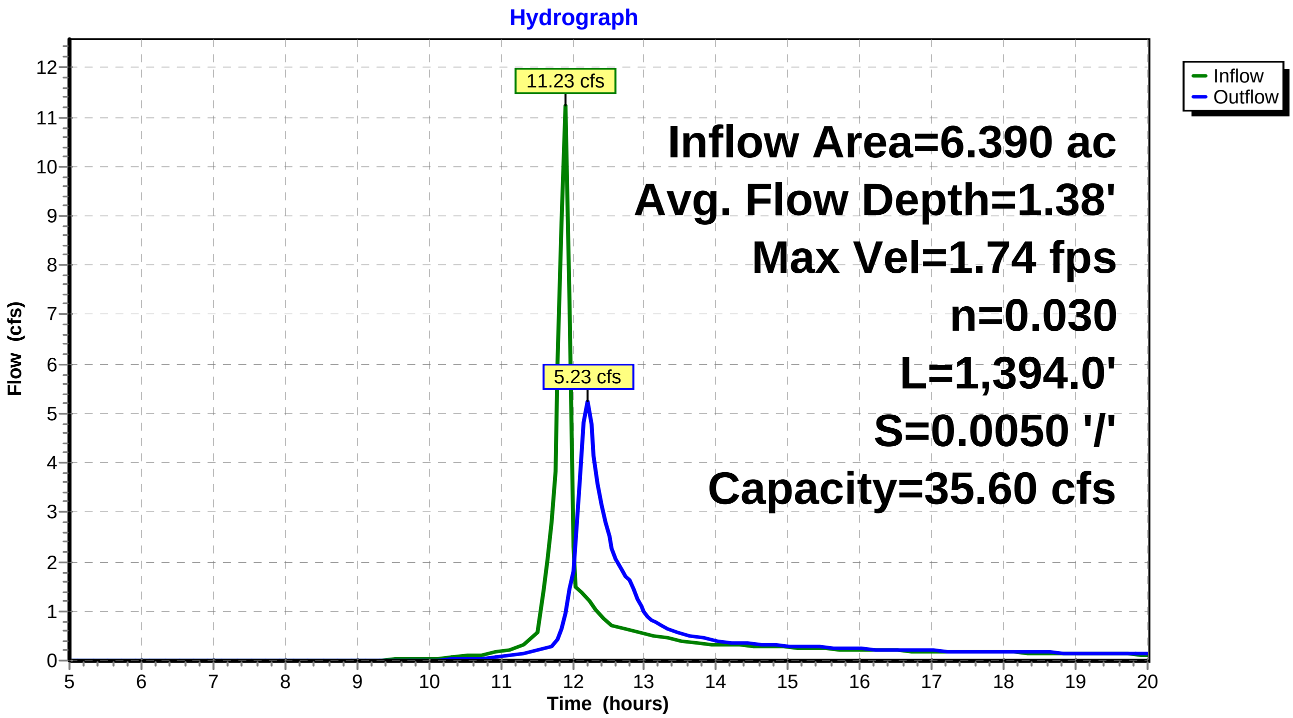


‡

Offset (feet)	Elevation (feet)	Chan.Depth (feet)
-5.00	4.00	0.00
-1.00	3.00	1.00
0.00	2.00	2.00
1.00	3.00	1.00
21.00	4.00	0.00

Depth (feet)	End Area (sq-ft)	Perim. (feet)	Storage (cubic-feet)	Discharge (cfs)
0.00	0.0	0.0	0	0.00
1.00	1.0	2.8	1,394	1.76
2.00	15.0	27.0	20,910	35.60

Reach 7R: Bench Drain



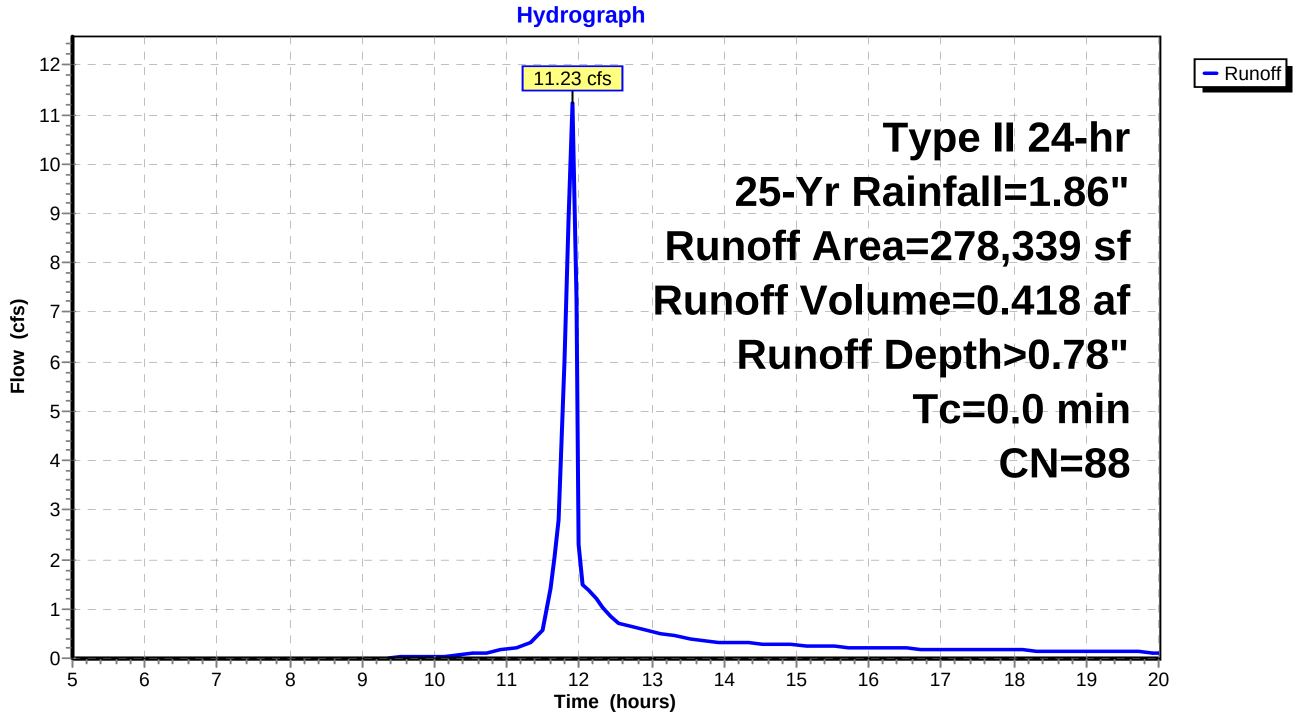
Summary for Subcatchment 9S: Bench

Runoff = 11.23 cfs @ 11.89 hrs, Volume= 0.418 af, Depth> 0.78"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 25-Yr Rainfall=1.86"

	Area (sf)	CN	Description
*	278,339	88	
	278,339		100.00% Pervious Area

Subcatchment 9S: Bench



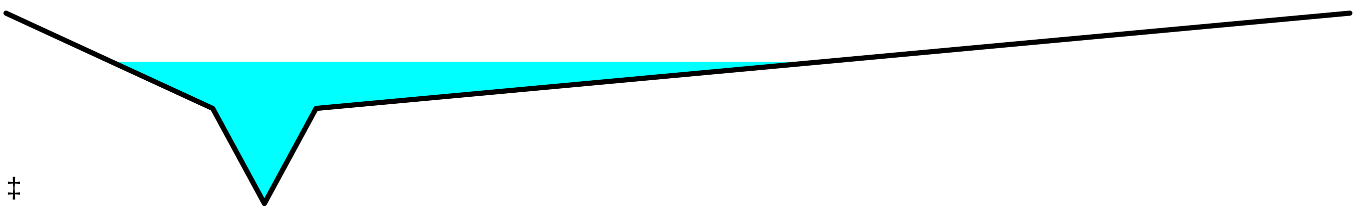
Summary for Reach 7R: Bench Drain

Inflow Area = 6.390 ac, 0.00% Impervious, Inflow Depth > 1.10" for 100-Yr event
Inflow = 15.57 cfs @ 11.89 hrs, Volume= 0.588 af
Outflow = 7.82 cfs @ 12.19 hrs, Volume= 0.580 af, Atten= 50%, Lag= 18.1 min

Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.73 fps, Min. Travel Time= 13.4 min
Avg. Velocity = 1.06 fps, Avg. Travel Time= 21.9 min

Peak Storage= 6,719 cf @ 11.97 hrs
Average Depth at Peak Storage= 1.49'
Bank-Full Depth= 2.00' Flow Area= 15.0 sf, Capacity= 35.60 cfs

Custom cross-section, Length= 1,394.0' Slope= 0.0050 '/'
Constant n= 0.030
Inlet Invert= 7.00', Outlet Invert= 0.00'

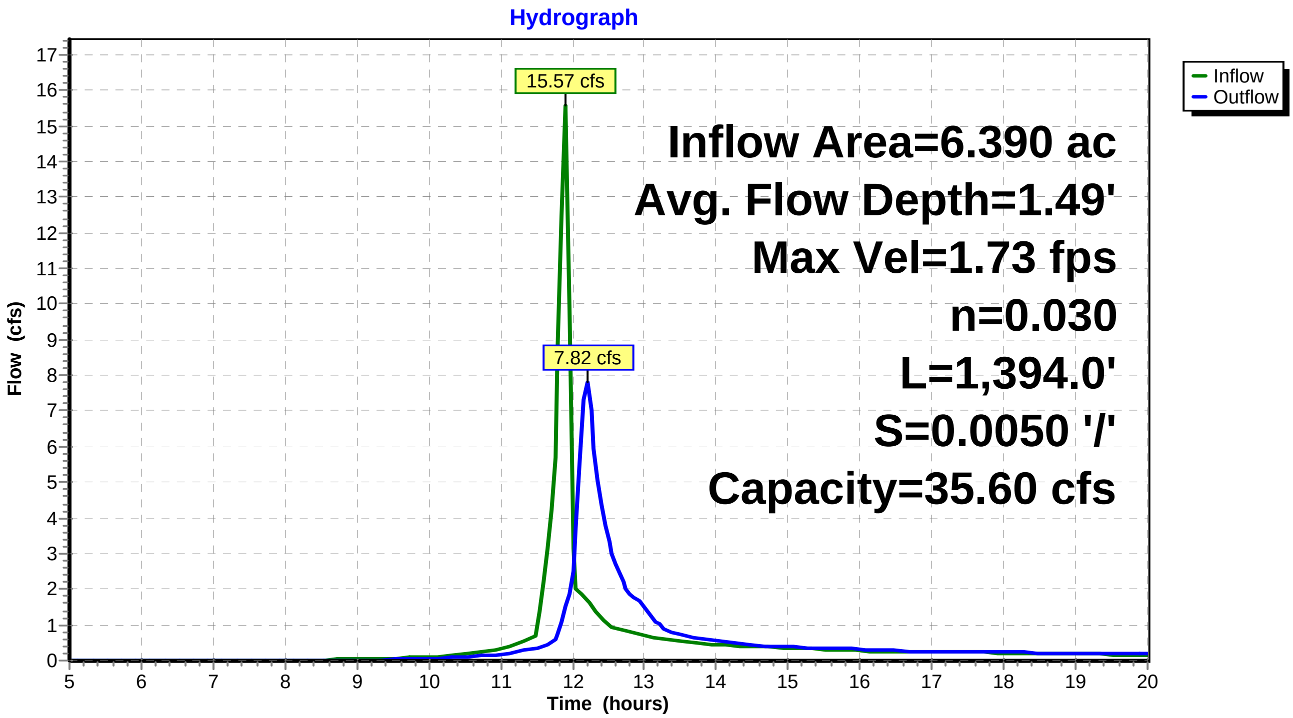


‡

Offset (feet)	Elevation (feet)	Chan.Depth (feet)
-5.00	4.00	0.00
-1.00	3.00	1.00
0.00	2.00	2.00
1.00	3.00	1.00
21.00	4.00	0.00

Depth (feet)	End Area (sq-ft)	Perim. (feet)	Storage (cubic-feet)	Discharge (cfs)
0.00	0.0	0.0	0	0.00
1.00	1.0	2.8	1,394	1.76
2.00	15.0	27.0	20,910	35.60

Reach 7R: Bench Drain



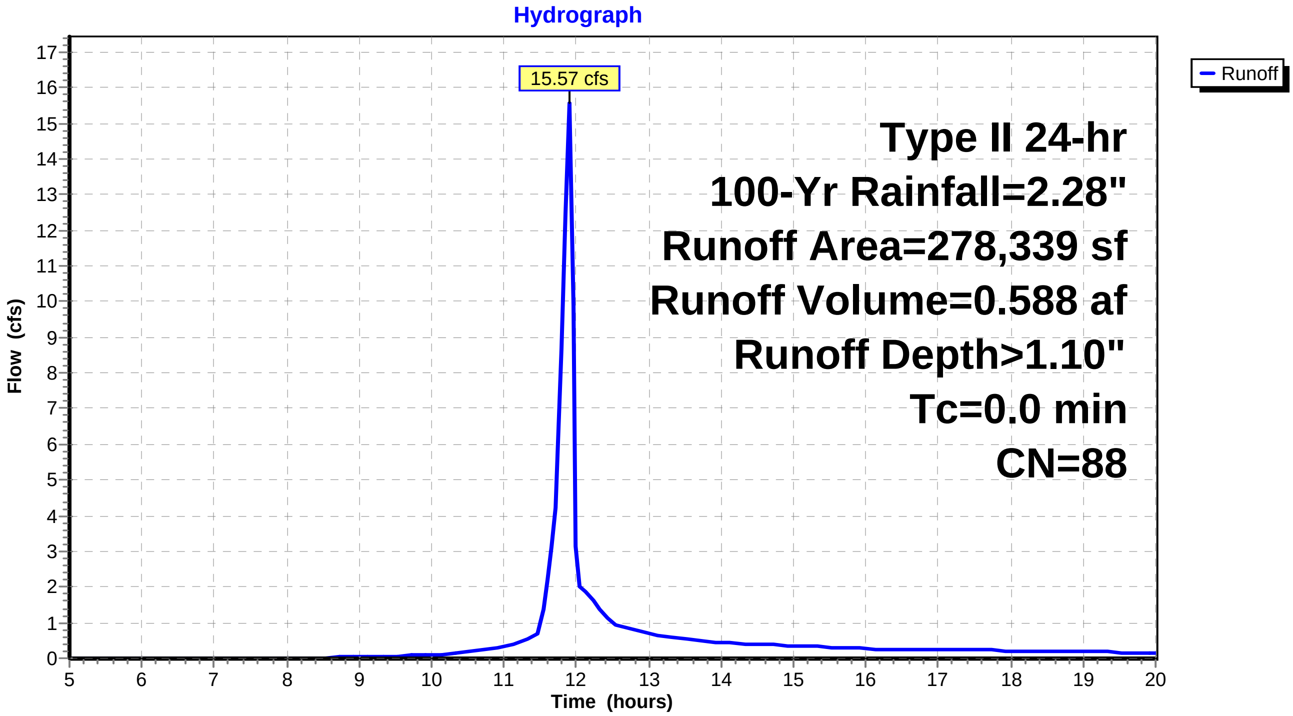
Summary for Subcatchment 9S: Bench

Runoff = 15.57 cfs @ 11.89 hrs, Volume= 0.588 af, Depth> 1.10"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-Yr Rainfall=2.28"

	Area (sf)	CN	Description
*	278,339	88	
	278,339		100.00% Pervious Area

Subcatchment 9S: Bench



SUMMARY

The analysis and design of haul road crossing culverts are summarized in these calculations. Culvert geometry is calculated and summarized. Design figures and HY-8 outputs are included summarizing findings.

OBJECTIVE

Temporary culverts are required for passing downdrain flows under proposed haul roads. New CCR rules outline required flows drainage features must pass. These calculations analyze culvert sizing requirements for the culverts that will convey downdrain flows under proposed Haul Roads.

DESIGN BASIS

Proposed haul road crossing culverts are analyzed based on the 24-hr, 100 year flow from the downdrains that they convey.

DATA

The west culvert needs to meet capacity from a 55 cfs flow.

METHODS

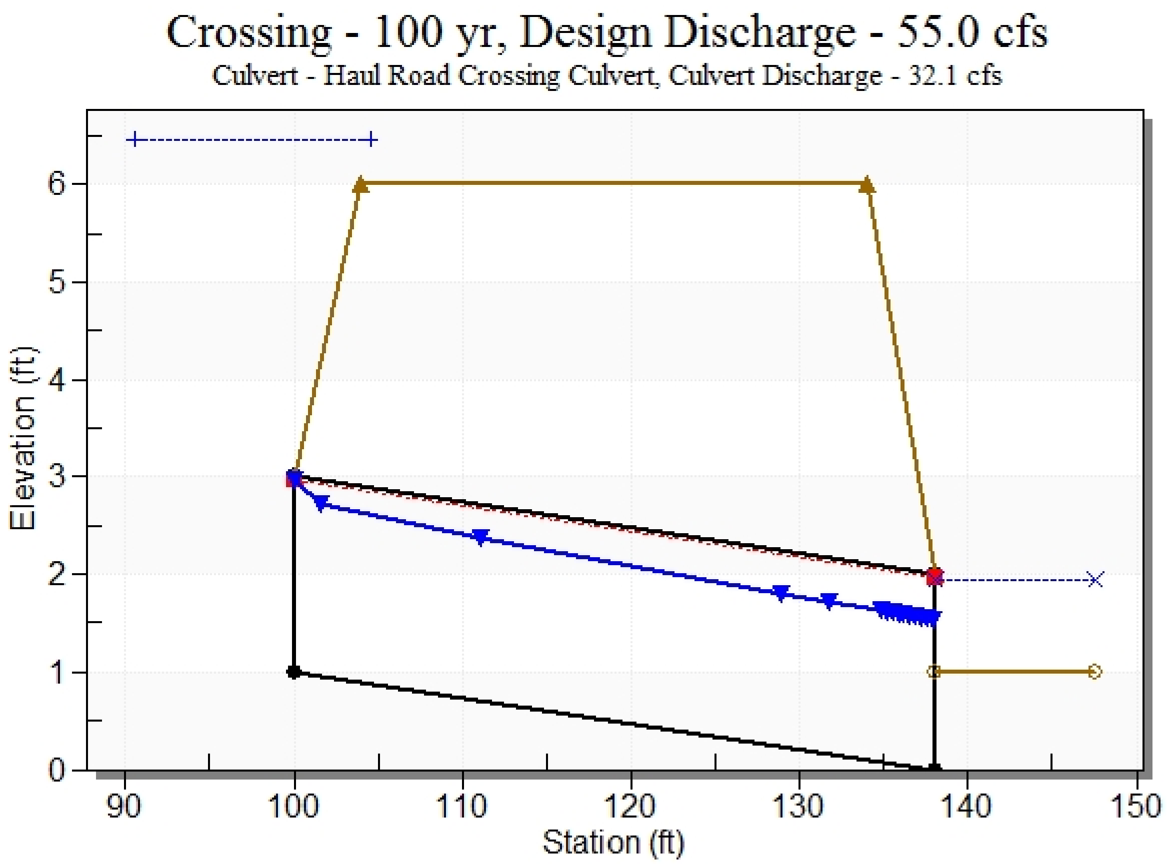
Flows were calculated in Hydrocad. Culvert analysis was done using HY-8.

RESULTS

Given geometric constraints on the culverts, the 24-hr, 100 year flows cannot be conveyed through the culverts. As such, stilling basins were designed to armor the haul road surface. Culverts are to remain to drain smaller flows as a freeze prevention.

HY-8 Culvert Analysis Report

Water Surface Profile Plot for Culvert: Haul Road Crossing Culvert



Site Data - Haul Road Crossing Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 100.00 ft

Inlet Elevation: 1.00 ft

Outlet Station: 138.00 ft

Outlet Elevation: 0.00 ft

Number of Barrels: 1

Culvert Data Summary - Haul Road Crossing Culvert

Barrel Shape: Circular

Barrel Diameter: 2.00 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: Yes

Table 1 - Downstream Channel Rating Curve (Crossing: 100 yr)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
55.00	1.94	0.94	10.00	14.61	2.09
55.00	1.94	0.94	10.00	14.61	2.09
55.00	1.94	0.94	10.00	14.61	2.09
55.00	1.94	0.94	10.00	14.61	2.09
55.00	1.94	0.94	10.00	14.61	2.09
55.00	1.94	0.94	10.00	14.61	2.09
55.00	1.94	0.94	10.00	14.61	2.09
55.00	1.94	0.94	10.00	14.61	2.09
55.00	1.94	0.94	10.00	14.61	2.09
55.00	1.94	0.94	10.00	14.61	2.09
55.00	1.94	0.94	10.00	14.61	2.09

Tailwater Channel Data - 100 yr

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 4.00 ft

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.2500

Channel Manning's n: 0.0570

Channel Invert Elevation: 1.00 ft

Roadway Data for Crossing: 100 yr

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 28.00 ft

Crest Elevation: 6.00 ft

Roadway Surface: Gravel

Roadway Top Width: 30.00 ft

SUMMARY

The analysis and design of the Landfill Drainage Downdrains are summarized in these calculations. Required downdrain geometry and armoring are calculated and summarized. Design figures and associated drawings are included summarizing findings.

OBJECTIVE

Run-off from the top of the landfill, benches and landfill sideslopes will be routed to the downdrains. Each downdrain will be equipped with stilling basins at the benches and connections to the perimeter ditch. The rock-lined stilling basins are designed to create a hydraulic jump to dissipate energy from the flowing water.

DESIGN BASIS

The 24-hour, 25 year storm is used to calculate the design flow for each of the downdrains. The largest of the delineated basins is used as the tributary area to calculate a standardized flow to each downdrain. Flows are calculated in HydroCAD (see hydrology calcs).

DATA

The following flows were calculated in HydroCAD (see hydrology calcs) and used for downdrain design.

		25-yr			100-yr		
Watershed ID	Runoff Area*	Rainfall Depth	Runoff	Volume	Rainfall Depth	Runoff	Volume
	Acre	inch	cfs	af	inch	cfs	af
North	33.05	1.86	36.10	2.15	2.28	50.73	3.03
North West	27.41	1.86	29.94	1.78	2.28	42.07	2.51
West	20.09	1.86	21.94	1.31	2.28	30.83	1.84
South West	35.97	1.86	39.30	2.34	2.28	55.21	3.30
South	27.03	1.86	29.53	1.76	2.28	41.49	2.48
South East	26.84	1.86	29.32	1.75	2.28	41.20	2.46
East	17.40	1.86	19.01	1.13	2.28	26.71	1.59
North East	31.10	1.86	33.97	2.02	2.28	47.73	2.85
North Add-on	5.08	1.86	5.55	0.33	2.28	7.80	0.47

*Note: This area is the watershed area going into the perimeter ditch, not all this area will be sent through the downdrains. However, the downdrains were consrvatively modelled to contain the full watershed area of the largest basin.

From these rainfall depths, the maximum flow (24-hour, 25 year storm) to a downdrain was calculated to be 39.37 cfs.

METHODS

This excel spreadsheet is included as a tool to design rock chutes. Median size for angular rock is determined along with the chute hydraulics and dimensions. The spreadsheet is based on “Design of Rock Chutes” by Robinson, Rice and Kadavy, ASAE Vol 41(3), pp.621-626, 1998 (Ref. 1).

RESULTS

See attached calculations.

Rock Chute Design Data

(Version 4.01 - 04/23/03, Based on Design of Rock Chutes by Robinson, Rice, Kadavy, ASAE, 1998)

Project: *Hunter Landfill* **County:** *Emery*
Designer: *Michael Guymon* **Checked by:** Nikki Comber
Date: 12/17/2015 **Date:** 12/17/15

Input Channel Geometry

Inlet Channel	Chute	Outlet Channel
Bw = 4.0 ft.	Bw = 4.0 ft.	Bw = 4.0 ft.
Side slopes = 2.0 (m:1)	Factor of safety = 1.50 (F_s)	Side slopes = 2.0 (m:1)
n-value = 0.050	Side slopes = 2.0 (m:1) → **2.0:1 max.**	n-value = 0.050
Bed slope = 0.2500 ft./ft.	Bed slope (4:1) = 0.250 ft./ft. → **2.5:1 max.**	Bed slope = 0.2500 ft./ft.
Freeboard = 1.0 ft.	Outlet apron depth, d = 2.0 ft.	Base flow = 0.0 cfs

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

Drainage area = 38.0 acres Rainfall = ◉ 0 - 3 in. ○ 3 - 5 in. ○ 5+ in.

Apron elev. --- Inlet = 5800.0 ft. --- Outlet = 5658.0 ft. --- (H_{drop} = 140 ft.)

Chute capacity = Q25-year
Total capacity = Q100-year
Minimum capacity (based on a 5-year, 24-hour storm with a 0 - 3 inch rainfall)

Q_{high} = 39.4 cfs High flow storm through chute → Tw (ft.) = *Program*

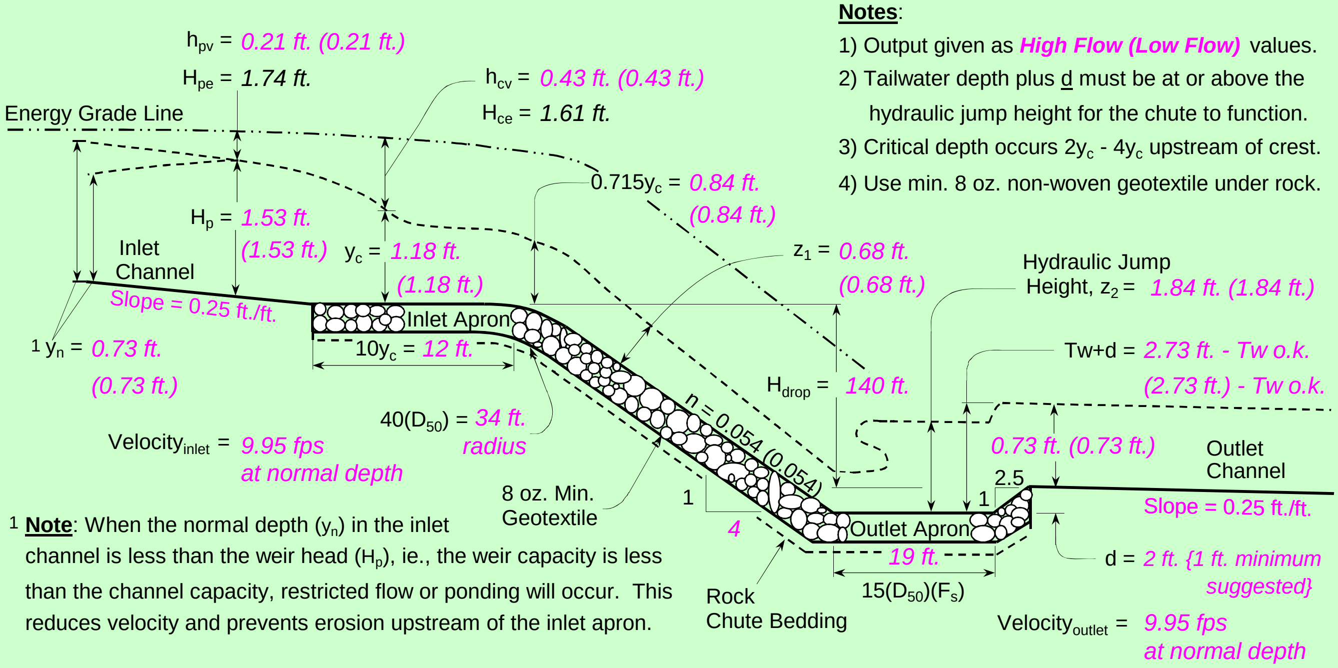
Q_{low} = 39.4 cfs Low flow storm through chute → Tw (ft.) = *Program*

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

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

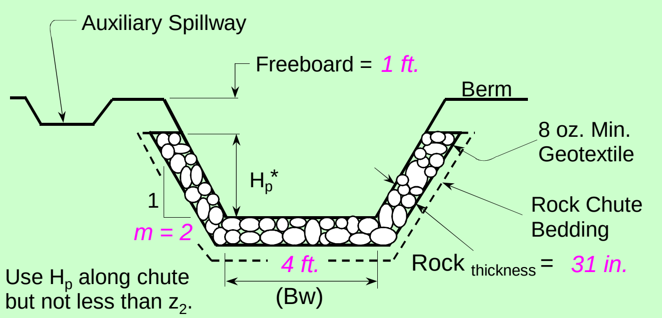
Profile and Cross Section (Output)

Notes:
1) Output given as ***High Flow (Low Flow)*** values.
2) Tailwater depth plus d must be at or above the hydraulic jump height for the chute to function.
3) Critical depth occurs $2y_c$ - $4y_c$ upstream of crest.
4) Use min. 8 oz. non-woven geotextile under rock.



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

Profile Along Centerline of Chute



* Use H_p along chute but not less than z_2.

Typical Cross Section

q_t =	7.25 cfs/ft.	Equivalent unit discharge
F_S =	1.50	Factor of safety (multiplier)
z_1 =	0.68 ft.	Normal depth in chute
n-value =	0.054	Manning's roughness coefficient
$D_{50}(F_s)$ =	15.5 in. (272 lbs. - 50% round / 50% angular)	
$2(D_{50})(F_s)$ =	31 in.	Rock chute thickness
Tw + d =	2.73 ft.	Tailwater above outlet apron
z_2 =	1.84 ft.	Hydraulic jump height
****** The outlet***	***will***	***function adequately***

High Flow Storm Information

Rock Chute Design - Plan Sheet

(Version 4.0 - 07/10/00, Based on Design of Rock Chutes by Robinson, Rice, Kadavy, ASAE, 1998)

Project: Hunter Landfill **County:** Emery
Designer: Michael Guymon **Checked by:** ______
Date: 12/17/2015 **Date:** ______

Design Values

Angular D_{50} dia. = 15.5 in.
$Rock_{chute}$ thickness = 31.0 in.
Inlet apron length = 12 ft.
Outlet apron length = 19 ft.
Radius = 34 ft.
Will bedding be used? Yes ---------- Depth (in.) = 12.0

Rock Gradation Envelope

% Passing		Diameter, in. (weight, lbs.)
D_{100}	---------	23 - 31 (916 - 2171)
D_{85}	---------	20 - 28 (596 - 1583)
D_{50}	---------	16 - 23 (271 - 916)
D_{10}	---------	12 - 20 (139 - 596)

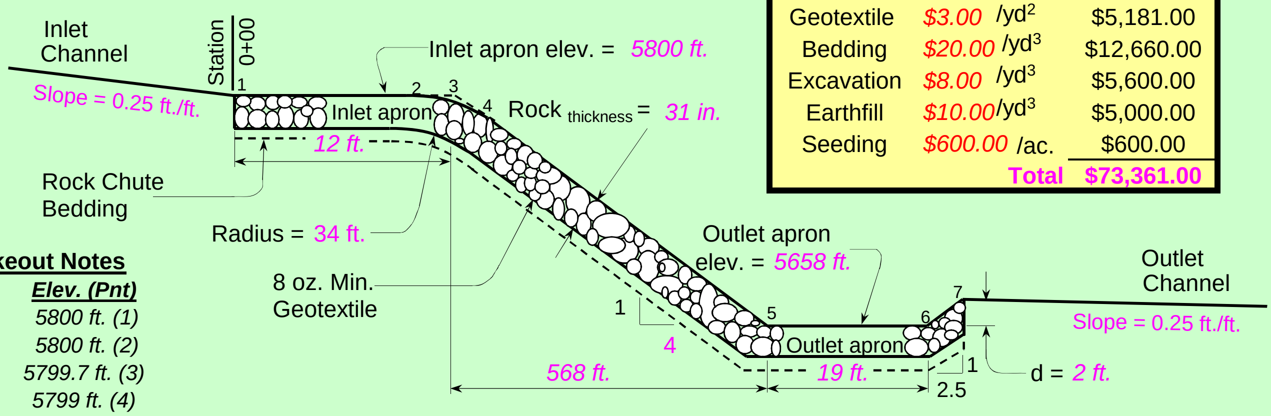
Quantities [a]

Angular Rock = 1108 yd^3
Geotextile (8 oz.)[b] = 1727 yd^2
Bedding (12 in.) = 633 yd^3
Excavation = 700 yd^3
Earthfill = 500 yd^3
Seeding = 1.0 acres

Notes: [a] Rock, bedding, and geotextile quantities are determined from the x-section below (neglect radius).
[b] Geotextile shall be overlapped (18-in. min.) and anchored (18-in. min. along sides and 24-in. min. on the ends).

Rock Chute Cost Estimate

Unit	Unit Cost	Cost
Rock	\$40.00 /yd^3	\$44,320.00
Geotextile	\$3.00 /yd^2	\$5,181.00
Bedding	\$20.00 /yd^3	\$12,660.00
Excavation	\$8.00 /yd^3	\$5,600.00
Earthfill	\$10.00/yd^3	\$5,000.00
Seeding	\$600.00 /ac.	\$600.00
	Total	**\$73,361.00**

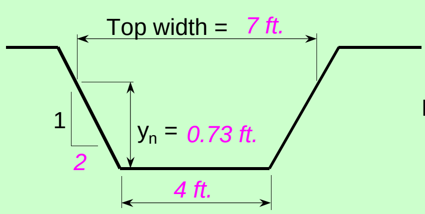


Profile Along Centerline of Rock Chute

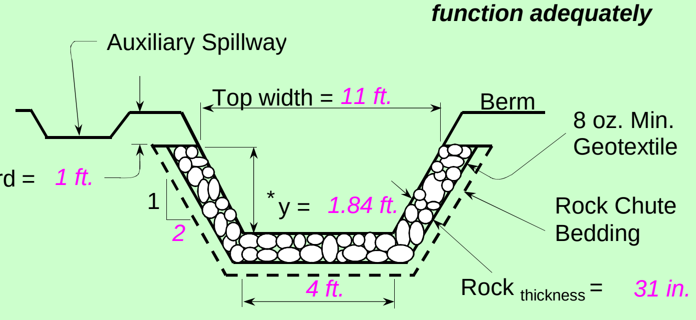
Stakeout Notes

Sta.	Elev. (Pnt)
0+00	5800 ft. (1)
0+7.8	5800 ft. (2)
0+12	5799.7 ft. (3)
0+16.1	5799 ft. (4)
2+380	5658 ft. (5)
3+299	5658 ft. (6)
3+304	5660 ft. (7)

**** Note : The outlet will function adequately**

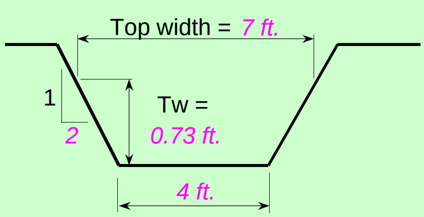


Inlet Channel Cross Section



Rock Chute Cross Section

* Use H_p throughout chute but not less than z_2.



Outlet Channel Cross Section

Profile, Cross Sections, and Quantities

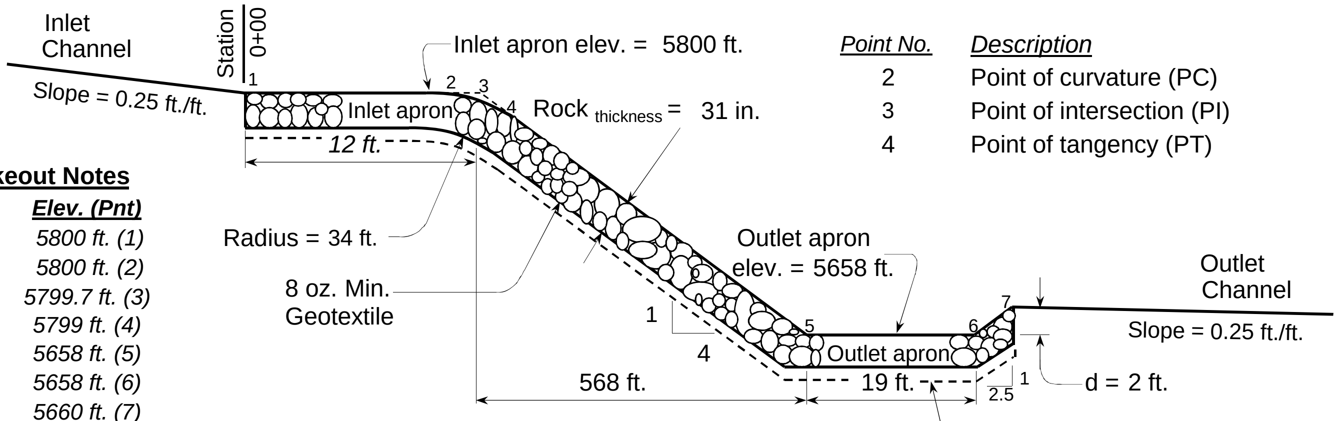
Project: Hunter Landfill
Location: Emery County

U.S. Department of Agriculture
Natural Resources Conservation Service

Designed: Michael Guymon	Approved by: ______
Drawn: NRCS Standard Dwg.	Title: ______
	Title: ______
Traced: ______	Sheet No. ______ of ______ / Drawing No.
Checked: ______	

Design Values		***Rock Gradation Envelope***		***Quantities*** [a]
Angular D_{50} dia. = 15.5 in.	*% Passing*	*Diameter, in. (weight, lbs.)*		***Angular*** Rock = 1108 yd^3
$Rock_{chute}$ thickness = 31.0 in.	D_{100} ---------	23 - 31 (916 - 2171)		Geotextile (8 oz.)[b] = 1727 yd^2
Inlet apron length = 12 ft.	D_{85} ---------	20 - 28 (596 - 1583)		Bedding (12 in.) = 633 yd^3
Outlet apron length = 19 ft.	D_{50} ---------	16 - 23 (271 - 916)		Excavation = 700 yd^3
Radius = 34 ft.	D_{10} ---------	12 - 20 (139 - 596)		Earthfill = 500 yd^3
Will bedding be used? Yes	*Coefficient of Uniformity, $(D_{60})/(D_{10}) \leq 2.0$*			Seeding = 1.0 acres

Notes: [a] *Rock, bedding, and geotextile quantities are determined from x-section below (neglect radius).*
[b] *Geotextile shall be overlapped (18-in. minimum) and anchored (18-in. minimum along sides and 24-in. minimum on the ends) --- <u>quantity not included</u>.*

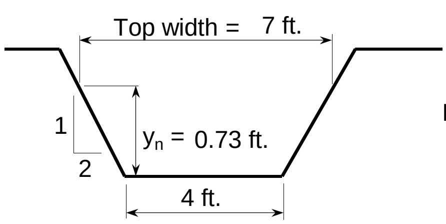


Point No.	*Description*
2	Point of curvature (PC)
3	Point of intersection (PI)
4	Point of tangency (PT)

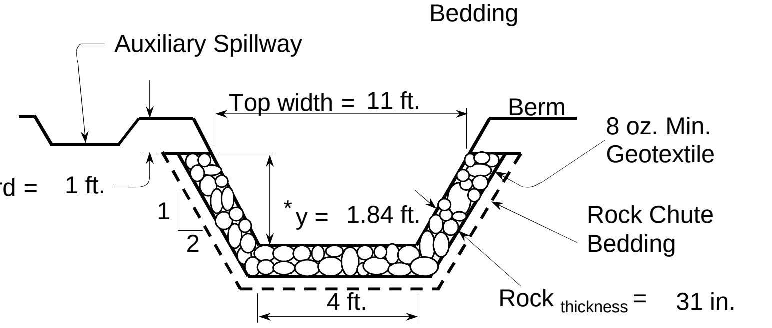
Stakeout Notes

Sta.	***Elev. (Pnt)***
0+00	*5800 ft. (1)*
0+7.8	*5800 ft. (2)*
0+12	*5799.7 ft. (3)*
0+16.1	*5799 ft. (4)*
2+380	*5658 ft. (5)*
3+299	*5658 ft. (6)*
3+304	*5660 ft. (7)*

Profile Along Centerline of Rock Chute

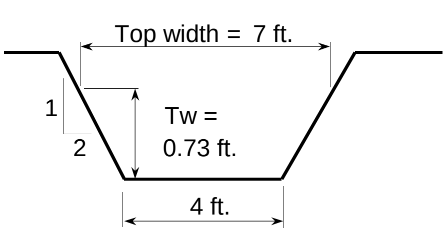


Inlet Channel Cross Section



Rock Chute Cross Section

* Use H_p throughout chute but not less than z_2.



Outlet Channel Cross Section

Profile, Cross Sections, and Quantities

Project: Hunter Landfill
Location: Emery County

U.S. Department of Agriculture
Natural Resources Conservation Service

Designed: Michael Guymon	Approved by:
Drawn: NRCS Standard Dwg.	Title:
	Title:
Traced:	Sheet No. / Drawing No.
Checked:	of

Rock Chute Design Calculations

(Version 4.0 - 07/10/00, Based on Design of Rock Chutes by Robinson, Rice, Kadavy, ASAE, 1998)

Project: Hunter Landfill **County:** Emery
Designer: Michael Guymon **Checked by:**
Date: ######## **Date:**

I. Calculate the normal depth in the inlet channel.

High Flow			Low Flow			
y_n =	**0.73**	**ft.**	**y_n =**	**0.73**	**ft.**	(Normal depth)
Area =	4.0	ft^2	Area =	4.0	ft^2	(Flow area in channel)
Q_{high} =	39.4	cfs	Q_{low} =	39.4	cfs	(Capacity in channel)

II. Calculate the critical depth in the chute.

High Flow			Low Flow			
y_c =	**1.18**	**ft.**	**y_c =**	**1.18**	**ft.**	(Critical depth in chute)
Area =	7.5	ft^2	Area =	7.5	ft^2	(Flow area in channel)
Q_{high} =	39.4	cfs	Q_{low} =	39.4	cfs	(Capacity in channel)
H_{ce} =	1.61	ft.	H_{ce} =	1.61	ft.	(Total minimum specific energy head)
h_{cv} =	0.43	ft.	h_{cv} =	0.43	ft.	(Velocity head corresponding to y_c)
$10y_c$ =	**11.78**	**ft.**	---	---		(Required inlet apron length)
$0.715y_c$ =	**0.84**	**ft.**	**$0.715y_c$ =**	**0.84**	**ft.**	(Depth of flow over the weir crest or brink)

III. Calculate the tailwater depth in the outlet channel.

High Flow			Low Flow				
Tw =	**0.73**	**ft.**	**Tw =**	**0.73**	**ft.**	(Tailwater depth)	
Area =	4.0	ft^2	Area =	4.0	ft^2	(Flow area in channel)	
Q_{high} =	39.4	cfs	Q_{low} =	39.4	cfs	(Capacity in channel)	140.00 = H_{drop}
H_2 =	0.00	ft.	H_2 =	0.00	ft.	(Downstream head above weir crest, H_2 = 0, if H_2 < 0.715*y_c, neglect velocity head)	

IV. Calculate the head for a trapezoidal shaped broad-crested weir.

C_d = 1.00 C_{vn} = 0.581 (Discharge coefficient for rectangular & v-notch broad-crested weirs, respectively)

High Flow					
H_p =	1.61	ft.	**1.53**	**ft.**	(Weir head)
Area =	11.6	ft^2	10.8	ft^2	(Flow area in channel)
V_i =	0.00	fps	**3.65**	**fps**	(Approach velocity)
h_{pv} =	0.00	ft.	0.21	ft.	(Velocity head corresponding to H_p)
Q_{high} =	39.4	cfs	39.4	cfs	(Capacity in channel)

Trial and error procedure solving simultaneously for velocity and head

Low Flow					
H_p =	1.61	ft.	**1.53**	**ft.**	(Weir head)
Area =	11.6	ft^2	10.8	ft^2	(Flow area in channel)
V_i =	0.00	fps	**3.65**	**fps**	(Approach velocity)
h_{pv} =	0.00	ft.	0.21	ft.	(Velocity head corresponding to H_p)
Q_{low} =	39.4	cfs	39.4	cfs	(Capacity in channel)

Trial and error procedure solving simultaneously for velocity and head

Rock Chute Design Calculations

(Version 4.0 - 07/10/00, Based on Design of Rock Chutes by Robinson, Rice, Kadavy, ASAE, 1998)

Project: Hunter Landfill **County:** Emery
Designer: Michael Guymon **Checked by:** ______
Date: ######## **Date:** ______

V. Calculate the rock chute parameters (w/o a factor of safety applied).

High Flow			Low Flow			
q_t =	0.67	cms/m	q_t =	0.67	cms/m	(Equivalent unit discharge)
D_{50} (mm) =	262.59 → ***(10.34 in.)***		D_{50} =	262.68	mm	(Median ***angular*** rock size)
n =	0.054		n =	0.054		(Manning's roughness coefficient)
z_1 =	0.68	ft.	z_1 =	0.68	ft.	(Normal depth in the chute)
A_1 =	3.7	ft^2	A_1 =	3.7	ft^2	(Area associated with normal depth)
Velocity =	10.78	fps	Velocity =	10.78	fps	(Velocity in chute slope)
z_{mean} =	0.54	ft.	z_{mean} =	0.54	ft.	(Mean depth)
F_1 =	2.58		F_1 =	2.58		(Froude number)
$L_{rock\ apron}$ =	12.92	ft.	----	----		(Length of rock outlet apron = 15*D_{50})

VI. Calculate the height of hydraulic jump height (conjugate depth).

High Flow			Low Flow			
z_2 =	**1.84**	**ft.**	**z_2 =**	**1.84**	**ft.**	(Hydraulic jump height)
Q_{high} =	39.4	cfs	Q_{low} =	39.4	cfs	(Capacity in channel)
A_2 =	14.1	ft^2	A_2 =	14.1	ft^2	(Flow area in channel)

VII. Calculate the energy lost through the jump (absorbed by the rock).

High Flow			Low Flow			
E_1 =	2.49	ft.	E_1 =	2.49	ft.	(Total energy before the jump)
E_2 =	1.96	ft.	E_2 =	1.96	ft.	(Total energy after the jump)
R_E =	21.15	%	R_E =	21.16	%	(Relative loss of energy)

Calculate Quantities for Rock Chute

-------Rock Riprap Volume-------

Area Calculations	Length @ Rock CL
h = 1.84	Inlet = 11.84
x_1 = 5.78	Outlet = 19.41
L = 4.11	Slope = 585.48
A_s = 10.63	2.5:1 Lip = 5.12
x_2 = 5.17	**Total = 621.85 ft.**
A_b = 26.83	**Rock Volume**
A_b+2*A_s = 48.09 ft^2	**1107.55 yd^3**

-------Bedding Volume-------

Area Calculations	
h = 4.42	**Bedding Thickness**
x_1 = 2.24	t_1, t_2 = ***12.00*** in.
L = 9.88	
A_s = 9.88	**Length @ Bed CL**
x_2 = 2.00	**Total = 621.82 ft.**
A_b = 7.69	**Bedding Volume**
A_b+2*A_s = 27.46 ft^2	**632.38 yd^3**

-------Geotextile Quantity-------

Width	Length @ Bot. Rock
2*Slope = 19.77	**Total = 621.83 ft.**
Bottom = 5.22	**Geotextile Area**
Total = 24.99 ft.	**1726.37 yd^2**

Note: 1) The radius is not considered when calculating quantities of riprap, bedding, or geotextile.
2) The geotextile quantity does not include over-overlapping (18-in. min.) or anchoring material (18-in. min. along sides, 24-in. min. on ends).

Instructions - Rock Chute Design Program

This Excel spreadsheet is included as a tool to design rock chutes for conservation practices. Median size for **angular** rock is determined along with the chute hydraulics and dimensions. This spreadsheet is based on "Design of Rock Chutes" by Robinson, Rice, and Kadavy, ASAE Vol. 41(3), pp. 621-626, 1998 (Ref. 1). One Spreadsheet version is included. Rock_Chute.xls is intended for Excel in Microsoft Office 97. The Excel file (.xls) is password protected. A ***Glossary*** is included below. All equations are available from the Iowa NRCS Design Staff by request.

Glossary

A_1 (ft^2) = *Area of flow corresponding to normal depth in the chute.*

A_2 (ft^2) = *Area of flow corresponding to the hydraulic jump height in the chute.*

Bw (ft.) = *Designates the bottom width for the inlet channel, the chute, and the outlet channel sections.*

d (ft.) = *Lower the outlet apron a depth d to submerge the hydraulic jump (1-ft. suggested minimum).*

D_{50} (ft.) = *Median **angular** **(cubical)** rock size (angular rock is stable at a unit discharge approximately 40% greater than that for rounded (spherical) stone of the same diameter).*

E_1 (ft.) = *Total energy before the jump.*

E_2 (ft.) = *Total energy after the jump.*

F_1 = *Froude number corresponding to normal chute depth.*

Freeboard = *The berm (or embankment) height above the top of rock in feet.*

F_s = *Factor of safety (multiplier) applied to the median angular rock size,* $D_{50.}$ *The designer may use Minnesota Technical Release 3 , Loose Riprap Protection, July 1989, page 17, Table 2-1 for help.*

H_2 (ft.) = *Downstream head above weir crest, affects weir flow if* H_2 *is greater than* $0.715y_c$ *or the brink depth (When* $H_2>0$ *submerged weir flow exists and normal depth (*z_1*) will not occur in the chute slope, and the program may over-estimate the* D_{50} *size for this condition.)*

H_{ce} (ft.) = *Total minimum specific energy head (sum of critical depth and velocity head).*

h_{cv} (ft.) = *Velocity head (*$V^2/2g$*) corresponding to velocity at critical depth.*

H_{drop} (ft.) = *The difference in elevation between the inlet apron and outlet channel.*

H_p (ft.) = *Head upstream of the weir crest required to force flow through the weir.*

H_{pe} (ft.) = *Total energy head (sum of* H_p *and the velocity head).*

h_{pv} (ft.) = *Velocity head (*$V^2/2g$*) corresponding to velocity at depth* $H_{p.}$

m = *Horizontal component of the side slope ratio (m:1).*

n = *Manning's roughness coefficient measured in the middle 1/3 of the chute calculated by Equation 7 in Ref. 1, and also used to designate the inlet and outlet channel roughness.*

Q_{high} (cfs) = *High flow storm*

Q_{low} (cfs) = *Low flow storm*

(The user shall make sure that tailwater depths are at the hydraulic jump height or greater for high and low flow conditions.)

q_t (cfs/ft.) = *Equivalent unit discharge in the rock chute.*

R_E (%) = *Relative loss of energy =* $(1-E_2/E_1)*100$.

Tw (ft.) = *Tailwater depth above the outlet channel (determined by Manning's equation or input by user).*

Tw+d (ft.) = *Tailwater depth above the outlet apron (must be* z_2 *or greater).*

V_i (fps) = *Approach velocity upstream of weir crest (trial and error procedure solving simultaneously for approach velocity and head).*

y (ft.) = *Height of riprap (vertically) along the rock chute side slope, the greater of* H_p *or* $z_{2.}$

y_c (ft.) = *Critical depth occurs* $2y_c$ *to* $4y_c$ *upstream of the rock chute crest (*$0.715y_c$ *occurs at the crest).*

y_n (ft.) = *Normal depth in the inlet channel determined by using Manning's equation (accelerated flow continues upstream of the weir crest approximately* $10y_c$*).*

Instructions - Rock Chute Design Program

z_1 (ft.) = Normal depth in the middle 1/3 of the chute, calculated by Equation 6 in Ref. 1.
z_2 (ft.) = Conjugate depth or hydraulic jump height due to the transition from supercritical to subcritical flow at the base of chute slope.
z_{mean} (ft.) = Mean depth in the rock chute.

Factor of Safety - The factor of safety (or multiplier, F_s) is used to safeguard against possible undersizing of the rock chute's median rock size (D_{50}). ***F_s adjusts the D_{50} rock size, the rock chute thickness, and the outlet apron length*** . The Iowa NRCS Design Staff also considered modifying (with F_s) the unit discharge (cfs/ft.), Q_{high}, and the bed slope (hydraulic grade line) instead of the D_{50}. Applying a F_s to the D_{50} will give a more conservative (larger) median rock size than applying the same F_s to the other above mentioned parameters. The user must decide what value of F_s to use. See Minnesota Technical Release 3 , Loose Riprap Protection, July 1989, page 17, Table 2-1.

Maximum values (or limits) were not considered in the spreadsheet. Only values that were outside the scope of the research were limited (chute bed slope and chute side slope). Each designer should consider what limits or maximum values they want for various parameters, such as the height of drop (H_{drop}), high flow storm (Q_{high}), bottom width (Bw), etc.

The program has 2 sheets, (Rock Chute Design Data and Rock Chute Design - Plan Sheet) that are available to the user by selecting the appropriate icon, besides the **Instructions** sheet. They are described below.

1) Rock Chute Design Data

The **Instructions** button (in the upper right) switches the user to this page (select the **Back to Design** button to return). The **Plan Sheet** button takes the user to the Profile, Cross Sections, and Quantities sheet (see below). The **Solve Spreadsheet** button (in the center of the sheet) must be selected after changing the design information. The **Tailwater from Program** button will enter the word "Program" in the tailwater cells (or the user may specify a tailwater by typing the value corresponding to high and low discharge). There are three main areas in the Design Data sheet: **1) Input Channel Geometry**, **2) Design Storm Data**, **3) Profile and Cross Section (Output)**. No print button is available on this sheet. The user should refer to the Rock Chute Design - Plan Sheet for print buttons. *The user should not print with the print icons (standard icons) or menus in Excel, **not all the design information will print**.*

Input Channel Geometry

This is the major input area for setting channel geometry. All red, italicized values and text can be entered (or changed) by the user. The user should note the **Solve Spreadsheet** button in the center of the spreadsheet. Changing any value, with the exception of *Freeboard* under the inlet channel column, *Outlet apron depth, d,* and the *Factor of safety (multiplier)* under the chute column will blank the output values in the Profile and Cross Section area (see below). The user must select the **Solve Spreadsheet** button when finished inputting. The program sets a limit on the steepest side slope allowed in the chute (2:1) and the steepest bed slope (2.5:1). Values steeper than these will blank the output area and the program can not be solved or printed (just to the right of these cells will indicate *Too Steep)* . Also, the user should input a 1.0-foot "suggested" minimum for d (always make sure that T_w + d is greater than or equal to z_2).

Instructions - Rock Chute Design Program

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

Here the user is prompted to input the *Drainage area* and the *Inlet and Outlet apron elevation*. The program will determine the NRCS minimum capacity (storm frequency year) for a full-flow open structure (chute and auxiliary spillway). The user must select the rainfall amount (0-3 in., 3-5 in., or 5+ in.) for a 5-year frequency, 24-hour duration storm. Input the high and low frequency storm (in cfs) flowing through the chute portion of the structure (this program does not design the auxiliary spillway). The tailwater must be adequate for both high and low flow events. The tailwater can be entered by the user or computed by the program for corresponding high and low flow storms. The **Tailwater from Program** button enters the word "Program" in the tailwater cells indicating that the spreadsheet will calculate the tailwater. The user should note that changing Q_{high} or Q_{low} will require the **Solve Spreadsheet** button to be selected.

Profile and Cross Section (Output)

No values need to be input. These results display chute hydraulics and dimensions for both high and low flow conditions. Low flow results are given in parenthesis and units are listed with the value. The user should make sure that T_w + d is greater than or equal to z_2 as indicated by T_w *o.k.* in the output. If output values give a dashed line or say "Not Solved" the user must select the **Solve Spreadsheet** button. If this doesn't work check the chute *Bed Slope* and *Side Slope* values and make sure they are not too steep. The High Flow Storm Information shows the D_{50} rock size by diameter (inches) and weight (pounds) for 50% angular and 50% round rock with a specific gravity (Gs) of 2.65. The weight comes from Minnesota Technical Release 3 (MN TR-3), Loose Riprap Protection, July 1989, page 18, Figure 2-2.

2) Rock Chute Design - Plan Sheet

This sheet gives the Profile, Cross Sections, and Quantities (along with a cost estimate) for the design. The user may input all red, italicized values and text. The design values can be changed by the user to make them more appropriate for construction *(we strongly discourage reducing the design values below what the program calculated)*. The user must enter the quantity of Excavation, Earthfill, and Seeding (if needed). Input the unit cost for each item in the cost estimate box. There are two print buttons in the upper left: **Print Documentation** will print this page as it appears on the screen (in addition to 3 pages of design information), and **Print Plan** will print a modified page that is a copy of the Plan Sheet (without the cost estimate). This page can then be pasted on the plan and includes stakeout notes for the finished rock chute grade. Use the **Back to Design** button to return to the design data sheet. The **Instructions** button (in the upper right) switches the user to this page. A uniform rock riprap size is required. Uniformly sized materials remained stable at higher flow rates than non-uniform (well
A coefficient of uniformity (D_{60}/D_{10}) of 2.0 or less was used to define the D_{10} size. The remainder of the values (D_{100}, D_{85}, and D_{50}) came from MN TR-3, Loose Riprap Protection, July 1989, page 21, Table 2-2.

Any questions or comments please contact:

NRCS
Iowa Design Staff
693 Federal Building
210 Walnut Street
Des Moines, IA 50309-2180

URS CALCULATION SHEET	Calculation No. 5
	Project No. 60439980
Project Title: Hunter Landfill	Sheet No. 5 of 6
Subject/Feature: Perimeter Ditches	Rev: A

SUMMARY

The perimeter ditch collects flow from downdrains and any run-on offsite flow. The perimeter ditch outlets into the Stormwater Retention Pond. These calculations analyze required capacity of the ditches.

OBJECTIVE

Two existing perimeter ditches circumnavigate the landfill. Runoff from the landfill and offsite flows will be sent to the perimeter ditches and distributed to the nearby Stormwater Retention Pond.

DESIGN BASIS

Perimeter ditches were designed based on the 24-hr, 100 year flow from the tributaries that feed them. All the runoff from the landfill should be able to flow to the retention pond without flooding. Existing ditches were modeled to determine if adequate to support the flow.

DATA

An SCS 24-hr, 100 yr storm of 2.28" was acquired from NOAA Atlas 14 to produce the runoff captured in the downdrain design. A slope of 1.5% and a Manning's number of 0.018 was used for both ditches.

METHODS

HydroCAD was used to model the flow through the existing ditch. Since the ditch varies in sizes due to sediment build up, the shallowest section was used to model the greatest flow. This section had a left side of 3.3:1 a right side of 35:1 a bottom of 8.8 ft and a depth of 0.4 ft. This cross-section failed and the model flooded. An iterative process was used in HydroCAD to determine a typical cross section that could be used to safely capture and transport the water to the Stormwater Retention Pond.

RESULTS

An iterative process in HydroCAD determined that a typical cross section of a trapezoidal ditch with 3:1 side slopes, a 4 ft bottom width and a 2 ft channel depth. Flows for both ditches can be seen in the table.

HydroCAD report summaries are attached.

Ditch ID	Runoff Area*	100-yr Runoff	100-yr Volume	100-yr Flow Depth
	Acre	cfs	af	ft
North West	**116.50**	**175.36**	**10.66**	**1.59**
South East	53.87	80.72	4.929	1.05

Form 356-02 (MM) dated 7 Oct 2011

Summary for Reach D1: Ditch 1 North West

Inflow Area = 116.524 ac, 0.00% Impervious, Inflow Depth > 1.10" for 100-Yr event
Inflow = 175.36 cfs @ 12.09 hrs, Volume= 10.659 af
Outflow = 139.33 cfs @ 12.33 hrs, Volume= 10.499 af, Atten= 21%, Lag= 14.3 min

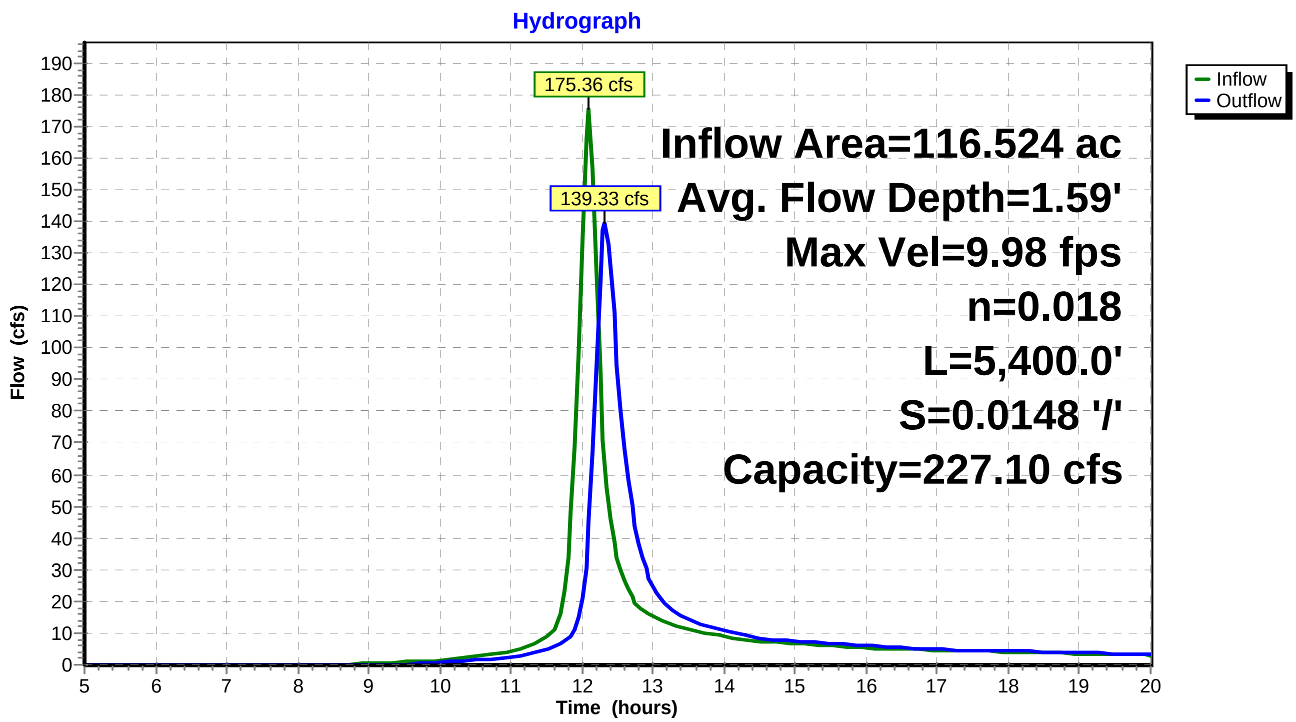
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 9.98 fps, Min. Travel Time= 9.0 min
Avg. Velocity = 3.81 fps, Avg. Travel Time= 23.6 min

Peak Storage= 75,304 cf @ 12.18 hrs
Average Depth at Peak Storage= 1.59'
Bank-Full Depth= 2.00' Flow Area= 20.0 sf, Capacity= 227.10 cfs

4.00' x 2.00' deep channel, n= 0.018
Side Slope Z-value= 3.0 '/' Top Width= 16.00'
Length= 5,400.0' Slope= 0.0148 '/'
Inlet Invert= 5,664.00', Outlet Invert= 5,584.00'

‡

Reach D1: Ditch 1 North West



Summary for Reach D2: Ditch 2 South East

Inflow Area = 53.874 ac, 0.00% Impervious, Inflow Depth > 1.10" for 100-Yr event
Inflow = 80.72 cfs @ 12.09 hrs, Volume= 4.929 af
Outflow = 55.56 cfs @ 12.45 hrs, Volume= 4.788 af, Atten= 31%, Lag= 21.5 min

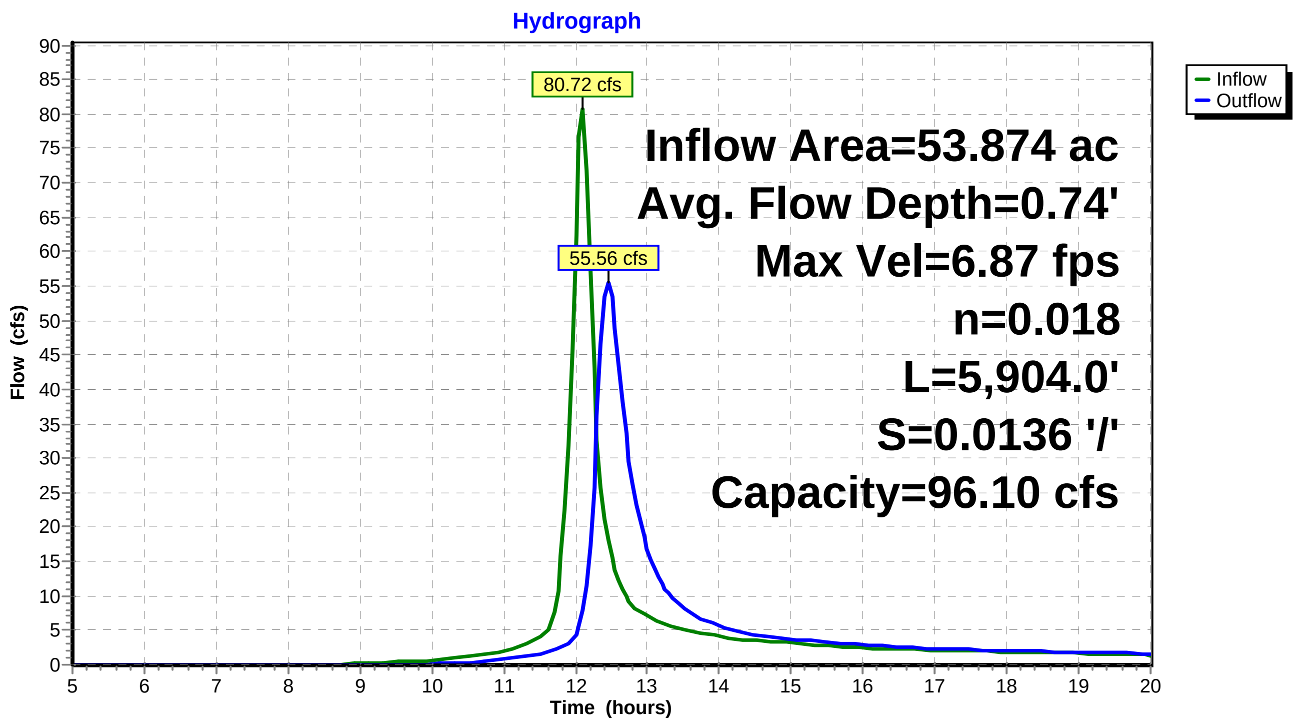
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 6.87 fps, Min. Travel Time= 14.3 min
Avg. Velocity = 2.29 fps, Avg. Travel Time= 43.0 min

Peak Storage= 48,098 cf @ 12.21 hrs
Average Depth at Peak Storage= 0.74'
Bank-Full Depth= 1.00' Flow Area= 11.8 sf, Capacity= 96.10 cfs

8.80' x 1.00' deep channel, n= 0.018
Side Slope Z-value= 3.0 '/' Top Width= 14.80'
Length= 5,904.0' Slope= 0.0136 '/'
Inlet Invert= 5,670.00', Outlet Invert= 5,590.00'

‡

Reach D2: Ditch 2 South East



URS **CALCULATION SHEET**	Calculation No. 5
	Project No. 60439980
Project Title: Hunter Landfill	Sheet No. 6 of 6
Subject/Feature: Perimeter Ditch Culverts	Rev: A

SUMMARY

The Perimeter ditch collects flow from downdrains and any run-on offsite flow. The perimeter ditch outlets into the Stormwater Retention Pond. There are two existing culverts. These calculations analyze required capacity of the culverts.

OBJECTIVE

New CCR rules outline required flows drainage features must pass. These calculations analyze existing and proposed culvert capacities.

DESIGN BASIS

Perimeter ditches are designed based on the 24-hr, 25 year flow from the tributaries that feed them. The west culvert needs to meet capacity from a 55 cfs flow. The north culvert needs to meet capacity from a 175 cfs flow.

DATA

The west culvert needs to meet capacity from a 55 cfs flow. The north culvert needs to meet capacity from a 175 cfs flow. The inverts of the culverts were verified from in-field survey done by Johansen & Tuttle.

METHODS

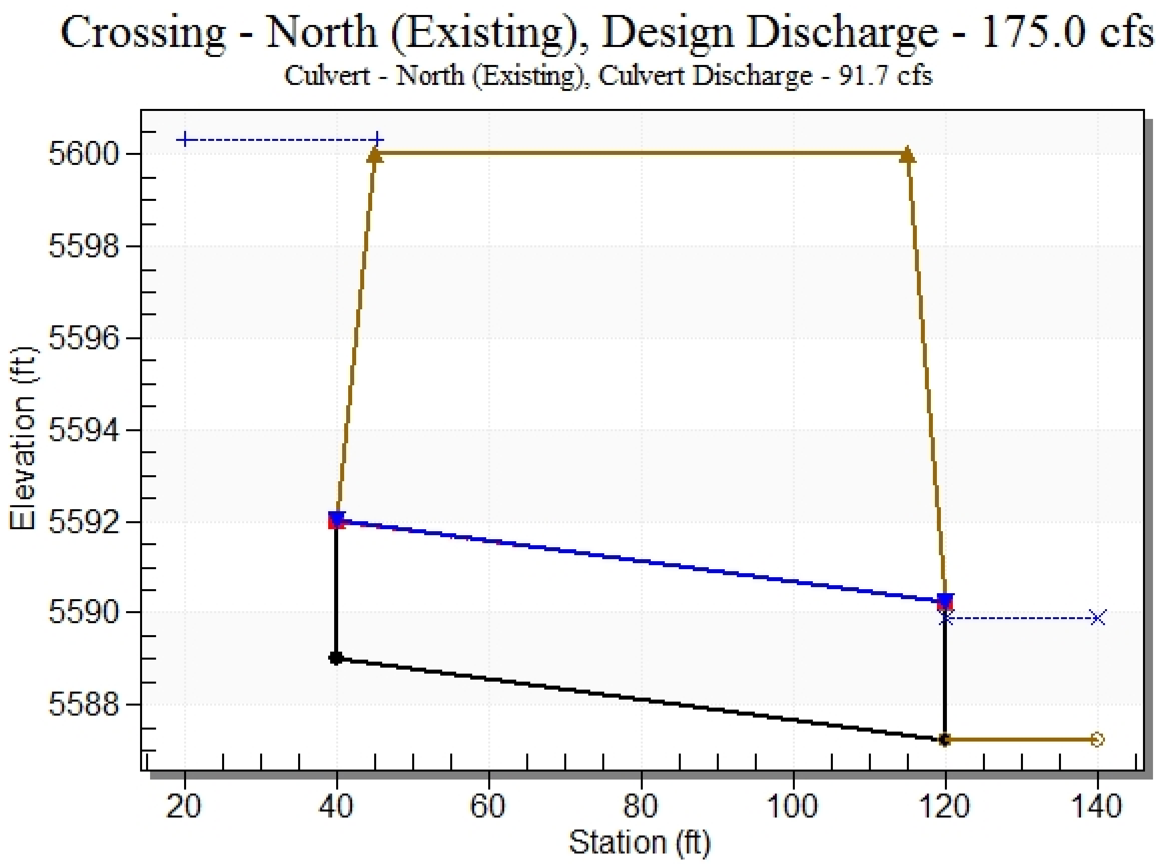
Flows were calculated in Hydrocad. Culvert analysis was done using HY-8.

RESULTS

The North culvert will need to be replaced with a new diameter of 4 feet. The existing north culvert overtops and flow routes offsite. As such, the north culvert will need to be replaced with a new diameter of 4 feet. Inverts are to be maintained. The west culvert will not need to be replaced despite overtopping because flow is contained on site.

HY-8 Culvert Analysis Report

Water Surface Profile Plot for Culvert: North (Existing)



Site Data - North (Existing)

Site Data Option: Culvert Invert Data

Inlet Station: 40.00 ft

Inlet Elevation: 5589.01 ft

Outlet Station: 120.00 ft

Outlet Elevation: 5587.25 ft

Number of Barrels: 1

Culvert Data Summary - North (Existing)

Barrel Shape: Circular

Barrel Diameter: 3.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Inlet Type: Conventional

Inlet Edge Condition: Thin Edge Projecting

Inlet Depression: NONE

Table 1 - Downstream Channel Rating Curve (Crossing: North (Existing))

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78

Tailwater Channel Data - North (Existing)

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 4.00 ft

Side Slope (H:V): 3.00 (_:1)

Channel Slope: 0.0200

Channel Manning's n: 0.0500

Channel Invert Elevation: 5587.25 ft

Roadway Data for Crossing: North (Existing)

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 160.00 ft

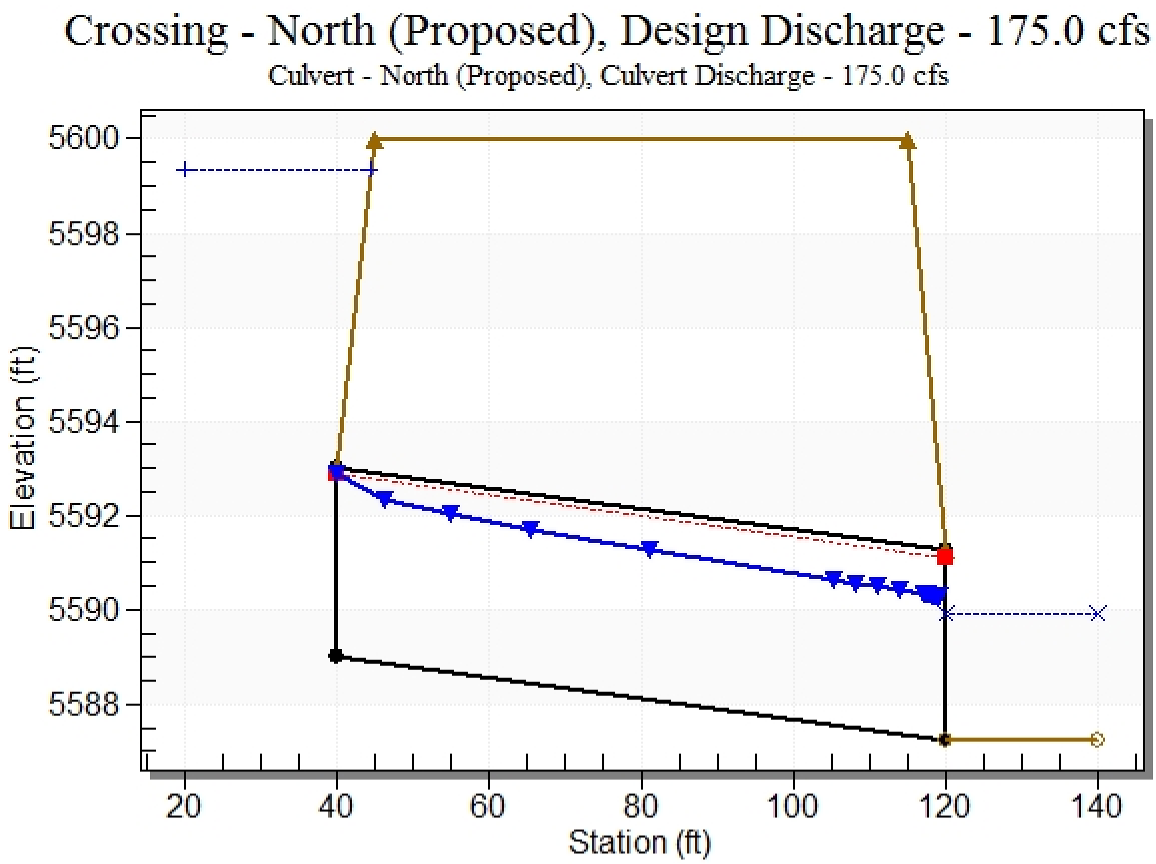
Crest Elevation: 5600.00 ft

Roadway Surface: Gravel

Roadway Top Width: 70.00 ft

HY-8 Culvert Analysis Report

Water Surface Profile Plot for Culvert: North (Proposed)



Site Data - North (Proposed)

Site Data Option: Culvert Invert Data

Inlet Station: 40.00 ft

Inlet Elevation: 5589.01 ft

Outlet Station: 120.00 ft

Outlet Elevation: 5587.25 ft

Number of Barrels: 1

Culvert Data Summary - North (Proposed)

Barrel Shape: Circular

Barrel Diameter: 4.00 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: NONE

Table 1 - Downstream Channel Rating Curve (Crossing: North (Proposed))

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78
175.00	5589.89	2.64	5.56	3.30	0.78

Tailwater Channel Data - North (Proposed)

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 4.00 ft

Side Slope (H:V): 3.00 (_:1)

Channel Slope: 0.0200

Channel Manning's n: 0.0500

Channel Invert Elevation: 5587.25 ft

Roadway Data for Crossing: North (Proposed)

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 160.00 ft

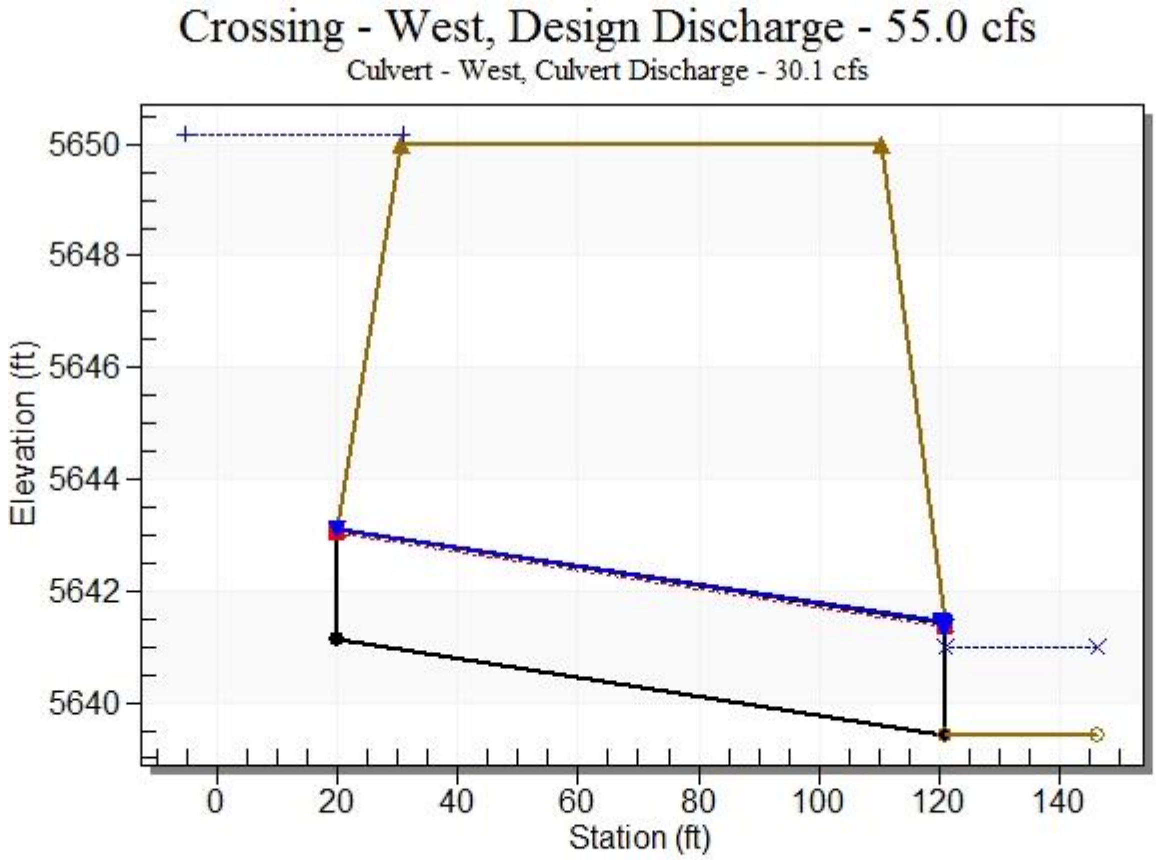
Crest Elevation: 5600.00 ft

Roadway Surface: Gravel

Roadway Top Width: 70.00 ft

HY-8 Culvert Analysis Report

Water Surface Profile Plot for Culvert: West



Site Data - West

Site Data Option: Culvert Invert Data

Inlet Station: 20.00 ft

Inlet Elevation: 5641.12 ft

Outlet Station: 121.00 ft

Outlet Elevation: 5639.43 ft

Number of Barrels: 1

Culvert Data Summary - West

Barrel Shape: Circular

Barrel Diameter: 2.00 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Inlet Type: Conventional

Inlet Edge Condition: Thin Edge Projecting

Inlet Depression: NONE

Table 1 - Downstream Channel Rating Curve (Crossing: West)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
55.00	5640.98	1.55	4.12	1.93	0.72
55.00	5640.98	1.55	4.12	1.93	0.72
55.00	5640.98	1.55	4.12	1.93	0.72
55.00	5640.98	1.55	4.12	1.93	0.72
55.00	5640.98	1.55	4.12	1.93	0.72
55.00	5640.98	1.55	4.12	1.93	0.72
55.00	5640.98	1.55	4.12	1.93	0.72
55.00	5640.98	1.55	4.12	1.93	0.72
55.00	5640.98	1.55	4.12	1.93	0.72
55.00	5640.98	1.55	4.12	1.93	0.72
55.00	5640.98	1.55	4.12	1.93	0.72

Tailwater Channel Data - West

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 4.00 ft

Side Slope (H:V): 3.00 (_:1)

Channel Slope: 0.0200

Channel Manning's n: 0.0500

Channel Invert Elevation: 5639.43 ft

Roadway Data for Crossing: West

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 120.00 ft

Crest Elevation: 5650.00 ft

Roadway Surface: Gravel

Roadway Top Width: 80.00 ft

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