# Inflow Design Flood Control System Plan

For Compliance with the Coal Combustion Residuals Rule (40 CFR Part 257)

Valmont Station - CCR Surface Impoundments
*Public Service Company of Colorado*
*Denver, Colorado*

October 17, 2016

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# Table of Abbreviations and Acronyms

| Abbreviation | Definition |
|---|---|
| CCR | Coal Combustion Residuals |
| CFR | Code of Federal Regulations |
| cfs | cubic feet per second |
| CN | Curve Number |
| EPA | Environmental Protection Agency |
| HSG | Hydrologic Soil Group |
| NOAA | National Oceanic and Atmospheric Administration |
| PSCo | Public Service Company of Colorado |
| RCRA | Resource Conservation and Recovery Act |
| SCS | Soil Conservation Service |
| TR-20 | Technical Release 20 |
| TR-55 | Technical Release 55 |

# 1.0 Introduction

On April 17, 2015 the U.S. Environmental Protection Agency (EPA) published regulations under Subtitle D of the Resource Conservation and Recovery Act (RCRA) meant to control the safe disposal of coal combustion residuals (CCR) generated by coal fired electric utilities. The rule defines a set of requirements for the disposal and handling of CCR within CCR units (defined as either landfills or surface impoundments). The requirements include preparation of an Inflow Design Flood Control System Plan to evaluate the inflow design flood control system for active surface impoundments.

This Inflow Design Flood Control System Plan was prepared for the active CCR surface impoundments at the Valmont Station, operated by Public Service Company of Colorado (PSCo), an Xcel Energy Company, in accordance with the requirements of 40 Code of Federal Regulations (CFR) 257.82. The regulation requires an initial Inflow Design Flood Control System Plan be prepared no later than October 17, 2016.

## 1.1 Facility Description

The Valmont Station is located approximately 4 miles east of Boulder, Colorado. The Valmont Station CCR surface impoundments are located northeast of the power plant and are surrounded by Leggett Reservoir to the north, Valmont Reservoir to the east, and Hillcrest Reservoir to the south. A location map is included as **Figure 1**.

The Valmont Station currently manages its bottom ash through two active surface impoundments identified as 3A and 3B. The bottom ash is pumped from the coal-fired boiler to the surface impoundments as a slurry. The ponds are then periodically dewatered, excavated and the bottom ash is disposed in the on-site ash disposal facility (ADF).

Per 40 CFR 257.53, the active impoundments are defined as incised CCR surface impoundments because they were constructed by excavation and hold an accumulation of CCR entirely below the natural ground surface.

## 1.2 Regulatory Requirements

40 CFR 257.82 requires that an owner or operator of an existing or new CCR surface impoundment or any lateral expansion of a CCR surface impoundment to design, construct, operate, and maintain an inflow design flood control system per the requirements below:

1) The inflow design flood control system must adequately manage flow into the CCR unit during and following the peak discharge of the inflow design flood specified in item 3) below; and
2) The inflow design flood control system must adequately manage flow from the CCR unit to collect and control the peak discharge resulting from the inflow design flood specified in item 3) below.
3) The inflow design flood is the 25-year flood for incised CCR surface impoundments.
4) Discharge from the CCR surface impoundment must not cause a discharge of pollutants to waters of the United States that is in violation of the requirements of the National Pollutant Discharge Elimination System (NPDES) under Section 402 of the Clean Water Act.

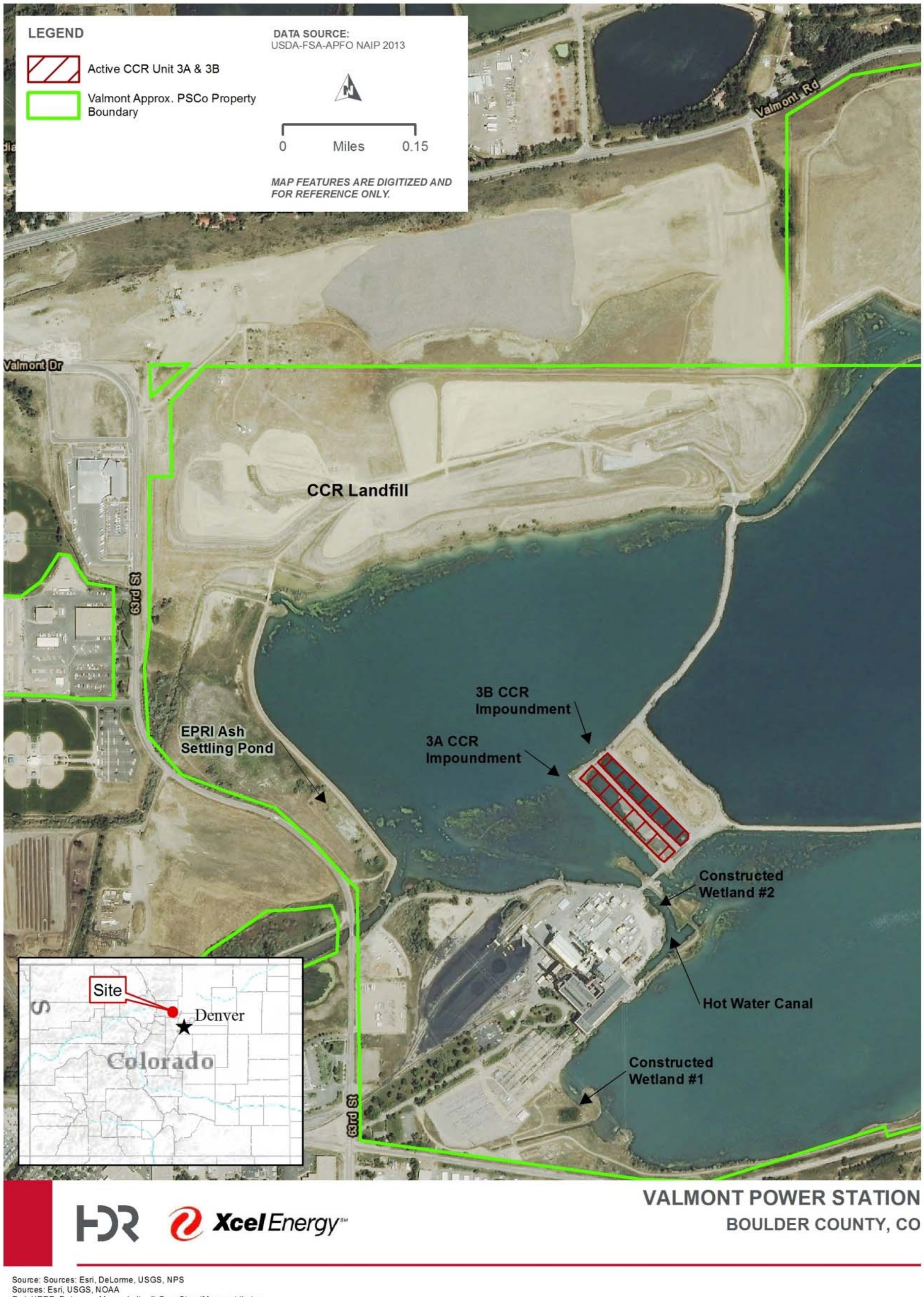



**Figure 1. Valmont Power Station Location Map**

# 2.0 Hydrologic and Hydraulic Analysis for CCR Impoundments

A hydrologic and hydraulic analysis was completed for the two active surface impoundments at Valmont Station identified as Impoundments 3A and 3B. The evaluation was completed in accordance with 40 CFR 257.82 and identified the drainage basin for each impoundment and evaluated the capacity of the outfalls to ensure safe passage of the 25-year 24-hour storm events.

The evaluation included preparation of a surface water run-off model using HydroCAD® 10.00-11 to determine whether existing flood control systems meet the required criteria for controlling inflow from the 25-year flood.

The evaluation was completed based on the best available information provided by PSCo at the time of this report. There was no current survey of the impoundments. Estimates were made on the grade elevations of the impoundments and outfall structures based on historic drawings and site visits conducted by HDR personnel on August 26 and 29, 2016. Assumptions used to develop the hydraulic model are discussed in further detail below.

## 2.1 Description of CCR Impoundments and Drainage Area

To develop the HydroCAD® model, physical information regarding on the two surface impoundments was taken from the Valmont Closure Plan, prepared by Tetra Tech, dated April 23, 2014 and last revised September 26, 2014. According to this report, surface impoundments 3A and 3B were originally constructed as 20-feet deep below grade earth embankments using a 2 horizontal to 1 vertical (2H:1V) side slope. Following their original construction, sheet pile walls were installed around the ponds to a depth of approximately 30 feet to provide additional stability (HDR was unable to confirm this depth as no as-built documentation was reviewed).The report goes on to estimate the current depth of ash to be approximately 25 feet below grade (HDR confirmed the depth of ash to be 20-25 feet below grade via soil borings). According to the closure report, the impoundments are approximately 680 feet long with a width of 65 feet and a surface area of 1.02 acres. During site visits conducted by HDR the water level in both ponds was observed to be approximately 4 to 5 feet below the top of the sheet pile wall.

CCR surface impoundments 3A and 3B are surrounded by water on all sides with three separate access roads connecting them to the main land to the northeast, southeast, and southwest. Northeast of the impoundments is a former fuel oil tank yard which is level with the impoundments at the surface and gradually slopes down to form a depression. As a result, the area draining into the CCR impoundments 3A and 3B is limited to the adjoining tank yard berm and the water entering from direct precipitation into the impoundments. The CCR surface impoundments and delineated drainage basins for each impoundment are shown on **Figure 2**.

## 2.2 Existing Inflow Design Flood Controls

As a result of the location of the CCR surface impoundments no inflow flood controls are necessary. The only storm water entering the impoundments is a result of precipitation that falls directly into them and a minimal amount from the adjoining tank yard berm.


**Figure 2. Stormwater Drainage Map**

## 2.3 Existing Outflow Design Controls

No as-built information was available on the configuration of the existing outfalls. Based on HDR's observations, the outfalls for both ponds are similar and constructed out of sheet pile. The outfalls consist of a low slotted weir followed by an upper weir and an overflow structure. Pictures of the outfall structure are provided in **Appendix A**. Elevations for the outfall structures were estimated using an assumed top elevation of 5,230.75 feet and measurements taken by HDR.

The outfalls from both surface impoundments discharge water to the Leggett Reservoir under a water discharge permit from the Colorado Department of Public Health and Environment.

## 2.4 Hydrologic and Hydraulic Model

A surface water run-off model was prepared using HydroCAD® which utilizes procedures outlined in the Soil Conservation Service (SCS) Technical Release 55 (TR-55) for computing curve numbers and times of concentration and SCS TR-20 for calculating and generating runoff hydrographs and modeling the existing outfall structures. The model is included as **Appendix B**. A detailed discussion of the information inputted into the model is provided below.

### 2.4.1 Rainfall Data

Rainfall data was taken from the National Oceanic and Atmospheric Administration (NOAA) Precipitation Frequency Data Server. Rainfall data inputted into the model included the 2-year and 25-year, 24-hour storm events. The precipitation amounts are summarized below and the information from the NOAA Precipitation Frequency Data Server is included as **Appendix C**.

**Table 1. Rainfall Data**

| 24 Hour Rainfall Event | Precipitation (inches) |
|---|---|
| 2- year | 1.93 |
| 25-year | 3.88 |

### 2.4.2 Weighted Curve Number

The weighted curve number (CN) is determined according to a hydrologic soil group (HSG) and ground cover for a delineated drainage basin. As discussed above, the drainage area consists of the surface impoundments and surrounding berms (refer to **Figure 2**). The area surrounding the impoundments is all paved and the impoundments themselves are filled with water. The CN value for water and impervious surfaces is 98.

### 2.4.3 Time of Concentration

The time of concentration is defined as the time required for runoff to travel from the most hydrologically distant point of a sub-catchment to the point of collection. It is determined by summing the travel time for consecutive flow segments along the sub-catchment's hydraulic path. The time of concentration was calculated based on the distance from the outer edge of the drainage basin area to the estimated edge of the surface water in the impoundment and the slope of the path. For both drainage areas the time of concentration was estimated to be 0.2 minute.

### 2.4.4 Pond Model Inputs

As previously discussed, no current survey was available to provide data for input into HydroCAD® to model the existing impoundments. Assumptions on the existing impoundments' shape and side slopes were made based on the survey drawing included in the Closure Report and historic as-built drawings of the original impoundments. The top elevation of the berm surrounding the impoundments was assumed to be 5,231' based on the survey drawing included in the Closure Report. A copy of this drawing is included as **Figure 3**. The remaining elevations were based on field measurements taken by HDR personnel during site visits held in August.

As of the date of this report, the southern portion of impoundment 3B was completely filled with ash. There was no visible ash present in impoundment 3A. The water level in impoundment 3B was observed just above the culvert inlet. The water level for impoundment 3A was observed approximately 6 inches below the culvert invert.

The pond outfalls are constructed of steel sheet pile. The information inputted into the model for the outfall structure is summarized in **Table 2**. Pictures of the existing outlet structure for impoundment 3A are provided in **Appendix A**.

**Table 2. Outfall Structure Information**

| Outfall Structure Type | Elevation | Dimensions & Description |
|---|---|---|
| Lower Rectangular Weir | 5225.92' | 0.5 ft high x 4.56 ft long |
| Upper Rectangular Weir | 5229.25' | 1.5 ft high x 3.21 ft long |
| Overflow Grate | 5230.75' | 4 ft wide x 4 ft long |
| Concrete Outlet Pipe | 5225.92' | 4 ft x 4 ft box culvert |

## 2.5 Evaluation of Existing Inflow/Outflow Design Controls

To comply with 40 CFR 257.82, the inflow and outflow design flood control systems must adequately manage flow into and out of the CCR unit during the 25-year storm event. The CCR surface impoundments are located in an area that prevents any surface water from up-gradient catchment areas draining into the impoundments. The areas surrounding both impoundments are paved and the pond sides are covered by the sheet pile which prevents any erosion from surface water from directly adjacent areas eroding the sides of the impoundment. The inflow design system meets the requirements of 40 CFR 257.82(a)(1).

The HydroCAD® model was used to evaluate the inflow, outflow and peak elevations observed for the 25-year, 24-hour storm events. The model results for surface impoundments 3A and 3B are summarized below in **Table 3**.

**Table 3. Model Results Summary Table**

| 24 Hour Storm Event | CCR Surface Impoundment | Inflow cfs | Outflow cfs | Peak Elevation feet |
|---|---|---|---|---|
| 25-year | Impoundment 3A | 6.85 | 0.49 | 5,228.48 |
| | Impoundment 3B | 6.92 | 6.33 | 5,226.74 |

Based on the model results, the outflow design control systems for both impoundments are capable of managing flows from the 25-year, 24-hour storm event and meet the requirements of 40 CFR 257.82(a)(2).

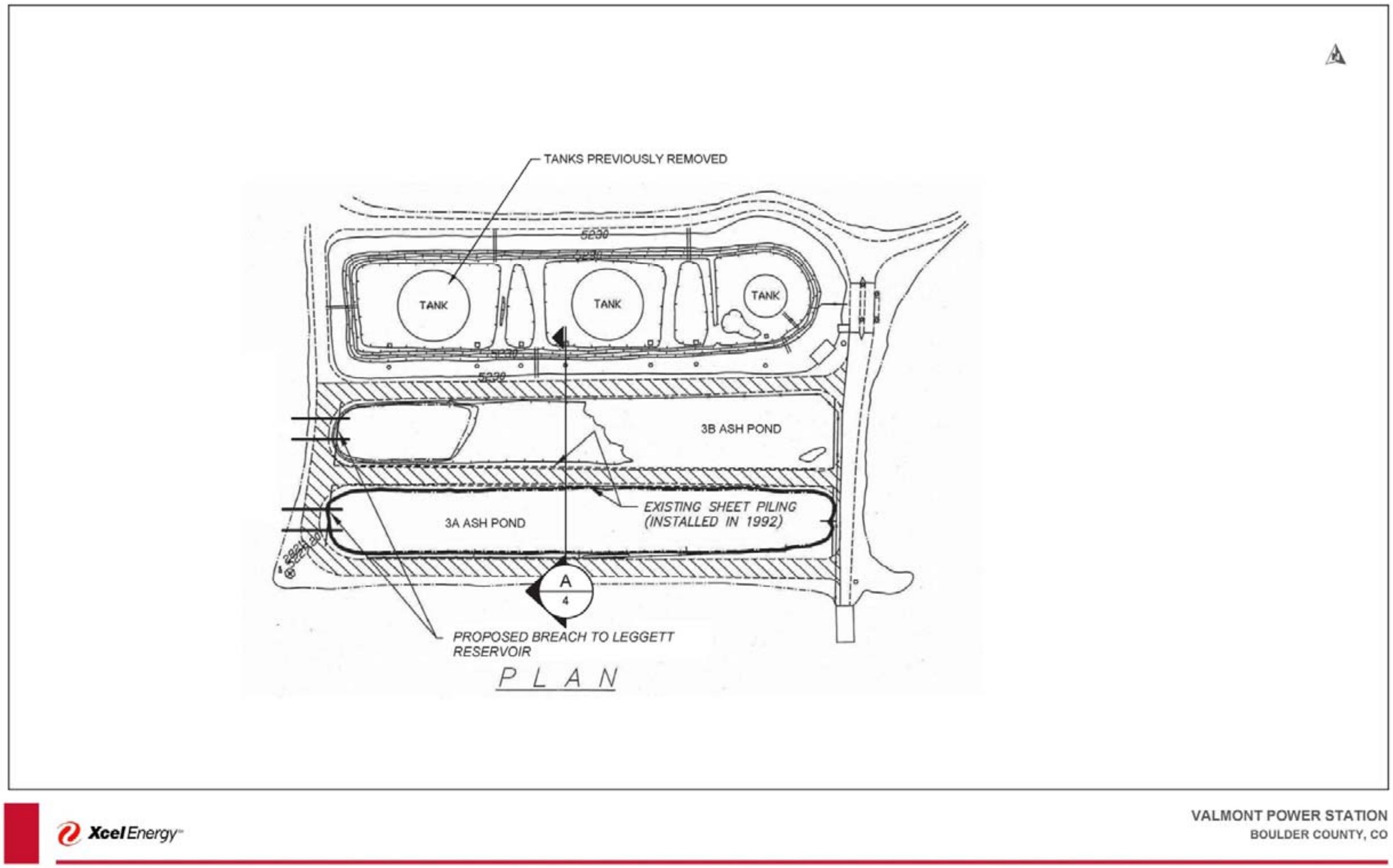



**Figure 3. EDOP Closure Plan 3A & 3B Ash Ponds**

## 2.6 Improvements to Existing Inflow/Outflow Design Controls

Based on the available information and the model results, the existing inflow design flood control systems in place for the surface impoundments 3A and 3B meet the requirements of 40 CFR 257.82. At this time there are no improvements proposed for the existing inflow design flood control systems.

# 3.0 Professional Engineer Certification

**Valmont Station CCR Unit 2016 Initial Hydrologic and Hydraulic Capacity Requirements for CCR Surface Impoundments Compliance with the Federal Coal Combustion Residuals Rule**

The undersigned Registered Professional Engineer is familiar with the requirements of Part 257 of Title 40 of the Code of Federal Regulations (40 CFR Part 257) and has visited and examined the facility, or has supervised examination of the facility by appropriately qualified personnel. The undersigned Registered Professional Engineer attests that this Run-on and Run-off Controls System Plan has been prepared in accordance with good engineering practice, including consideration of applicable industry standards and the requirements of 40 CFR Part 257.

This Plan is valid only to the extent that the facility owner or operator maintains existing inflow design flood control system described in this Plan.

SIGNATURE: 


Christopher M. Koehler, PE — Colorado PE 0051359

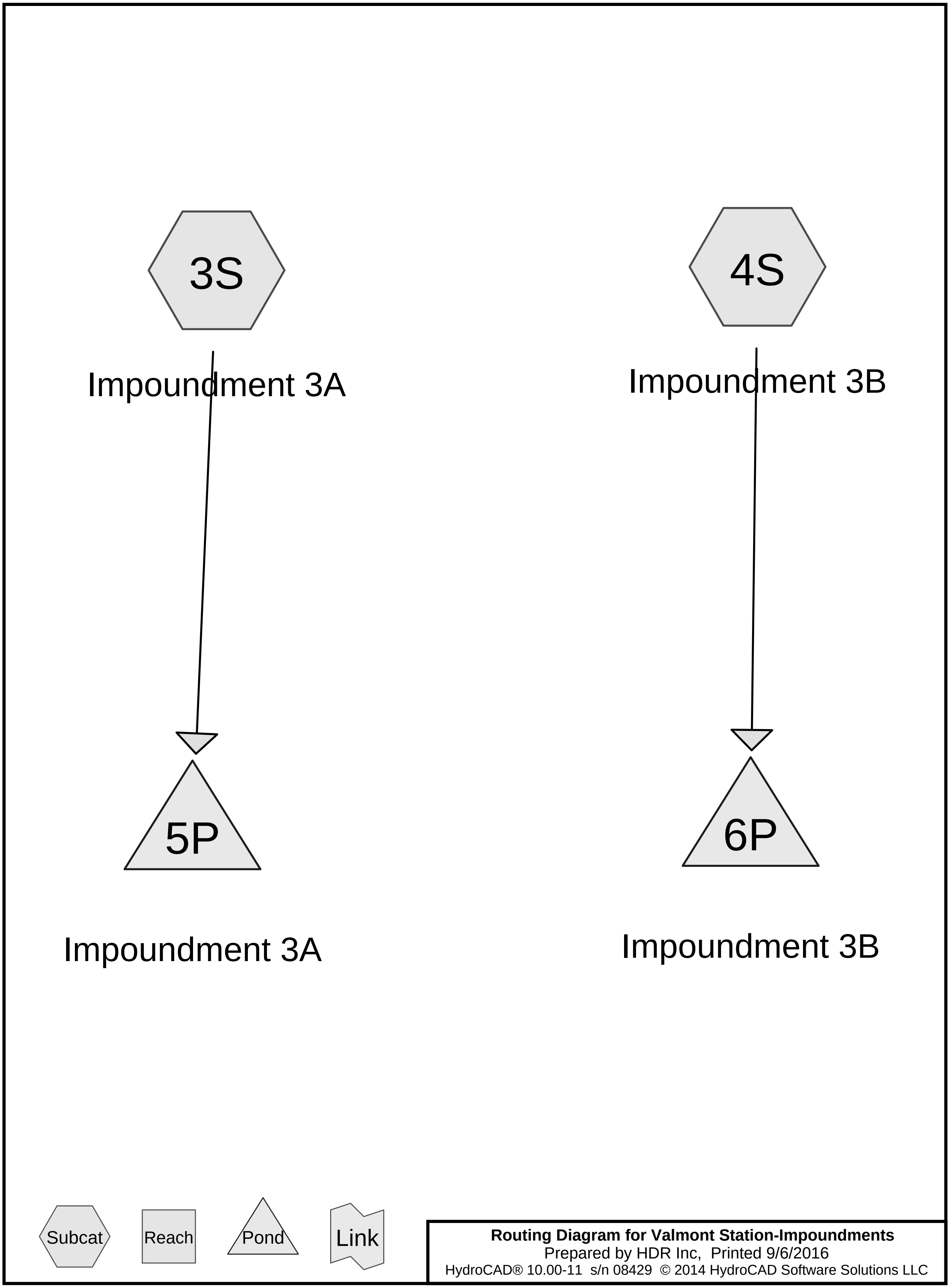
DATE: October 14, 2016

# APPENDIX A - PHOTOGRAPHS OF EXISTING IMPOUNDMENT OUTFALLS

5230.75’
4”
18”
3.21’
5229.25’
34”
4.56’
5225.92’
6”
5225.42’


4”
3.21’
4.0’
4.0’

# APPENDIX B - HYDROCAD® MODEL RESULTS




**Routing Diagram for Valmont Station-Impoundments**
Prepared by HDR Inc, Printed 9/6/2016
HydroCAD® 10.00-11 s/n 08429 © 2014 HydroCAD Software Solutions LLC

## Area Listing (all nodes)

| Area (acres) | CN | Description (subcatchment-numbers) |
|---|---|---|
| 3.980 | 98 | (3S, 4S) |
| **3.980** | **98** | **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 | |
| 3.980 | Other | 3S, 4S |
| **3.980** | | **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 | 3.980 | 3.980 | | 3S, 4S |
| **0.000** | **0.000** | **0.000** | **0.000** | **3.980** | **3.980** | **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 | 5P | 5,225.92 | 5,225.92 | 57.0 | 0.0000 | 0.011 | 4.0 | 4.0 | 0.0 |
| 2 | 6P | 5,225.92 | 5,225.92 | 47.0 | 0.0000 | 0.011 | 50.5 | 50.5 | 0.0 |

Time span=0.01-90.00 hrs, dt=0.25 hrs, 361 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

**Subcatchment 3S: Impoundment 3A** Runoff Area=1.980 ac 100.00% Impervious Runoff Depth=5.01"
Flow Length=20' Slope=0.1700 '/' Tc=0.2 min CN=98 Runoff=9.32 cfs 0.827 af

**Subcatchment 4S: Impoundment 3B** Runoff Area=2.000 ac 100.00% Impervious Runoff Depth=5.01"
Flow Length=20' Slope=0.1700 '/' Tc=0.2 min CN=98 Runoff=9.42 cfs 0.835 af

**Pond 5P: Impoundment 3A** Peak Elev=5,229.75' Storage=0.568 af Inflow=9.32 cfs 0.827 af
Outflow=0.62 cfs 0.770 af

**Pond 6P: Impoundment 3B** Peak Elev=5,226.92' Storage=0.023 af Inflow=9.42 cfs 0.835 af
Outflow=8.67 cfs 0.836 af

**Total Runoff Area = 3.980 ac Runoff Volume = 1.663 af Average Runoff Depth = 5.01"**
**0.00% Pervious = 0.000 ac 100.00% Impervious = 3.980 ac**

## Summary for Subcatchment 3S: Impoundment 3A

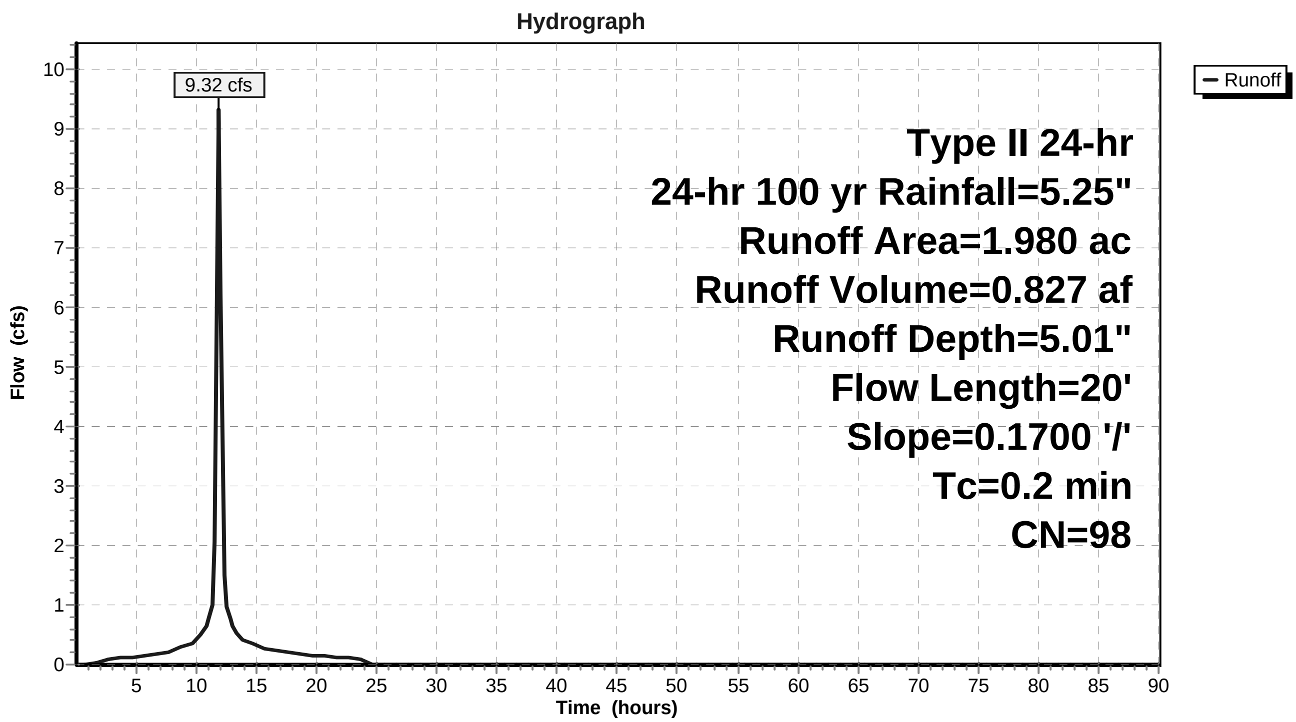
Runoff = 9.32 cfs @ 11.81 hrs, Volume= 0.827 af, Depth= 5.01"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.01-90.01 hrs, dt= 0.25 hrs
Type II 24-hr 24-hr 100 yr Rainfall=5.25"

| | Area (ac) | CN | Description |
|---|---|---|---|
| * | 1.980 | 98 | |
| | 1.980 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 0.2 | 20 | 0.1700 | 1.82 | | **Sheet Flow, sheet flow**<br>Smooth surfaces n= 0.011 P2= 1.93" |

### Subcatchment 3S: Impoundment 3A



## Summary for Subcatchment 4S: Impoundment 3B

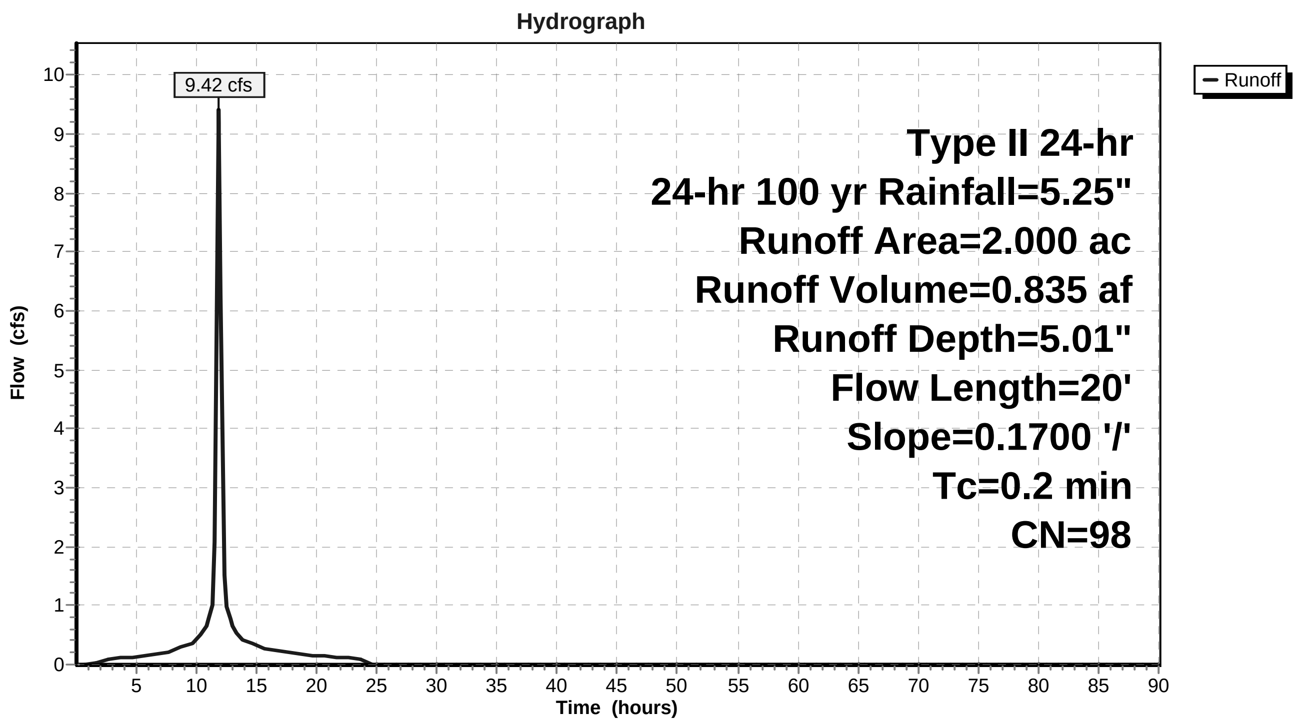
Runoff = 9.42 cfs @ 11.81 hrs, Volume= 0.835 af, Depth= 5.01"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.01-90.01 hrs, dt= 0.25 hrs
Type II 24-hr 24-hr 100 yr Rainfall=5.25"

| | Area (ac) | CN | Description |
|---|---|---|---|
| * | 2.000 | 98 | |
| | 2.000 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 0.2 | 20 | 0.1700 | 1.82 | | **Sheet Flow, overland flow** Smooth surfaces n= 0.011 P2= 1.93" |

### Subcatchment 4S: Impoundment 3B



## Summary for Pond 5P: Impoundment 3A

Inflow Area = 1.980 ac,100.00% Impervious, Inflow Depth = 5.01" for 24-hr 100 yr event
Inflow = 9.32 cfs @ 11.81 hrs, Volume= 0.827 af
Outflow = 0.62 cfs @ 13.10 hrs, Volume= 0.770 af, Atten= 93%, Lag= 76.9 min
Primary = 0.62 cfs @ 13.10 hrs, Volume= 0.770 af

Routing by Dyn-Stor-Ind method, Time Span= 0.01-90.01 hrs, dt= 0.25 hrs / 2
Starting Elev= 5,225.42' Surf.Area= 1.065 ac Storage= 0.044 af
Peak Elev= 5,229.75' @ 13.10 hrs Surf.Area= 1.358 ac Storage= 0.568 af (0.524 af above start)

Plug-Flow detention time= 564.5 min calculated for 0.726 af (88% of inflow)
Center-of-Mass det. time= 468.0 min ( 1,205.8 - 737.8 )

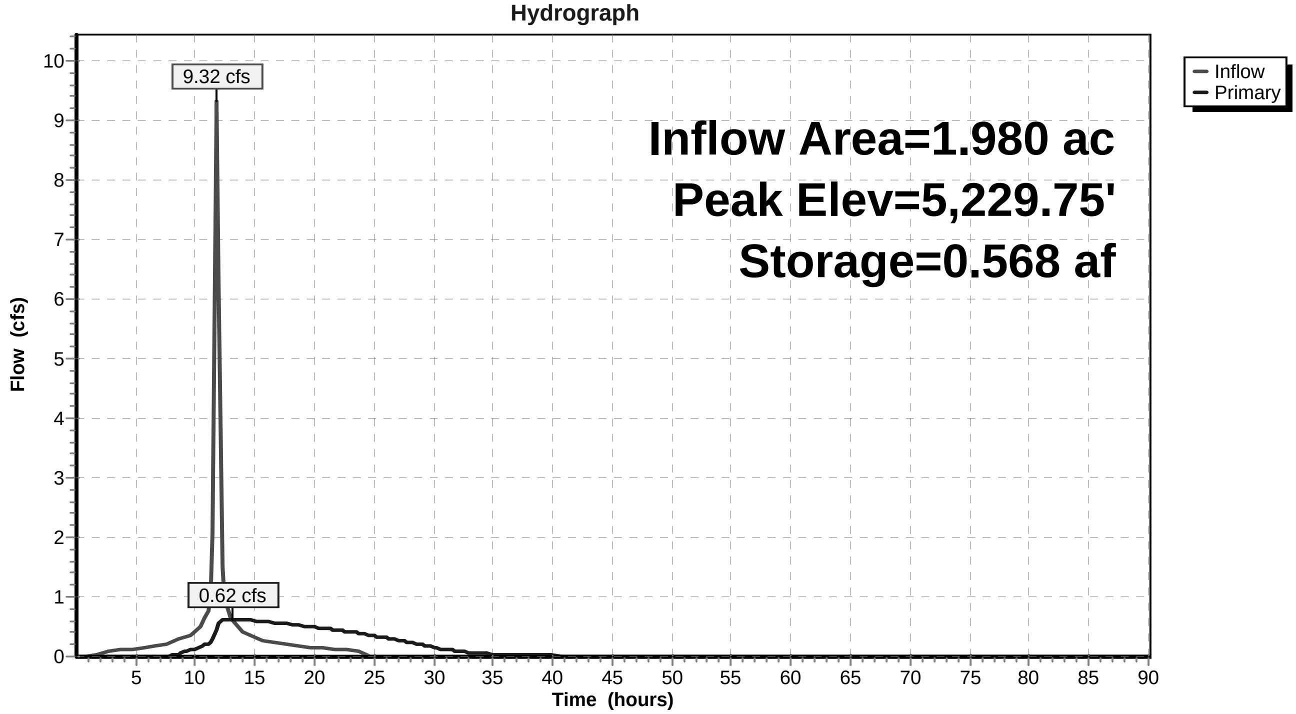
| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 5,225.00' | 0.753 af | **Custom Stage Data (Irregular)** Listed below (Recalc)<br>7.533 af Overall x 10.0% Voids |

| Elevation (feet) | Surf.Area (acres) | Perim. (feet) | Inc.Store (acre-feet) | Cum.Store (acre-feet) | Wet.Area (acres) |
|---|---|---|---|---|---|
| 5,225.00 | 1.038 | 1,435.0 | 0.000 | 0.000 | 1.038 |
| 5,226.00 | 1.104 | 1,447.8 | 1.071 | 1.071 | 1.113 |
| 5,227.00 | 1.171 | 1,460.6 | 1.137 | 2.208 | 1.189 |
| 5,228.00 | 1.238 | 1,473.4 | 1.204 | 3.413 | 1.265 |
| 5,229.00 | 1.306 | 1,486.2 | 1.272 | 4.684 | 1.342 |
| 5,230.00 | 1.375 | 1,499.0 | 1.340 | 6.025 | 1.420 |
| 5,231.00 | 1.646 | 1,562.4 | 1.508 | 7.533 | 1.776 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 5,225.92' | **4.0" W x 4.0" H Box Culvert**<br>L= 57.0' Box, 0° wingwalls, square crown edge, Ke= 0.700<br>Inlet / Outlet Invert= 5,225.92' / 5,225.92' S= 0.0000 '/' Cc= 0.900<br>n= 0.011 Concrete pipe, straight & clean, Flow Area= 0.11 sf |
| #2 | Device 1 | 5,225.92' | **54.7" W x 6.0" H Vert. Orifice/Grate** C= 0.600 |
| #3 | Device 1 | 5,229.25' | **3.2' long x 1.80' rise Sharp-Crested Rectangular Weir**<br>2 End Contraction(s) |
| #4 | Device 1 | 5,230.75' | **4.0" x 2.0" Horiz. Orifice/Grate**<br>X 12 rows C= 0.600 in 48.0" x 48.0" Grate<br>Limited to weir flow at low heads |

**Primary OutFlow** Max=0.62 cfs @ 13.10 hrs HW=5,229.75' (Free Discharge)
└─**1=Culvert** (Barrel Controls 0.62 cfs @ 5.58 fps)
  ├─**2=Orifice/Grate** (Passes < 20.76 cfs potential flow)
  ├─**3=Sharp-Crested Rectangular Weir** (Passes < 3.57 cfs potential flow)
  └─**4=Orifice/Grate** ( Controls 0.00 cfs)

## Pond 5P: Impoundment 3A



## Summary for Pond 6P: Impoundment 3B

Inflow Area = 2.000 ac,100.00% Impervious, Inflow Depth = 5.01" for 24-hr 100 yr event
Inflow = 9.42 cfs @ 11.81 hrs, Volume= 0.835 af
Outflow = 8.67 cfs @ 11.86 hrs, Volume= 0.836 af, Atten= 8%, Lag= 3.1 min
Primary = 8.67 cfs @ 11.86 hrs, Volume= 0.836 af

Routing by Dyn-Stor-Ind method, Time Span= 0.01-90.01 hrs, dt= 0.25 hrs / 2
Peak Elev= 5,226.92' @ 11.87 hrs Surf.Area= 0.256 ac Storage= 0.023 af

Plug-Flow detention time= 2.6 min calculated for 0.833 af (100% of inflow)
Center-of-Mass det. time= 2.8 min ( 740.6 - 737.8 )

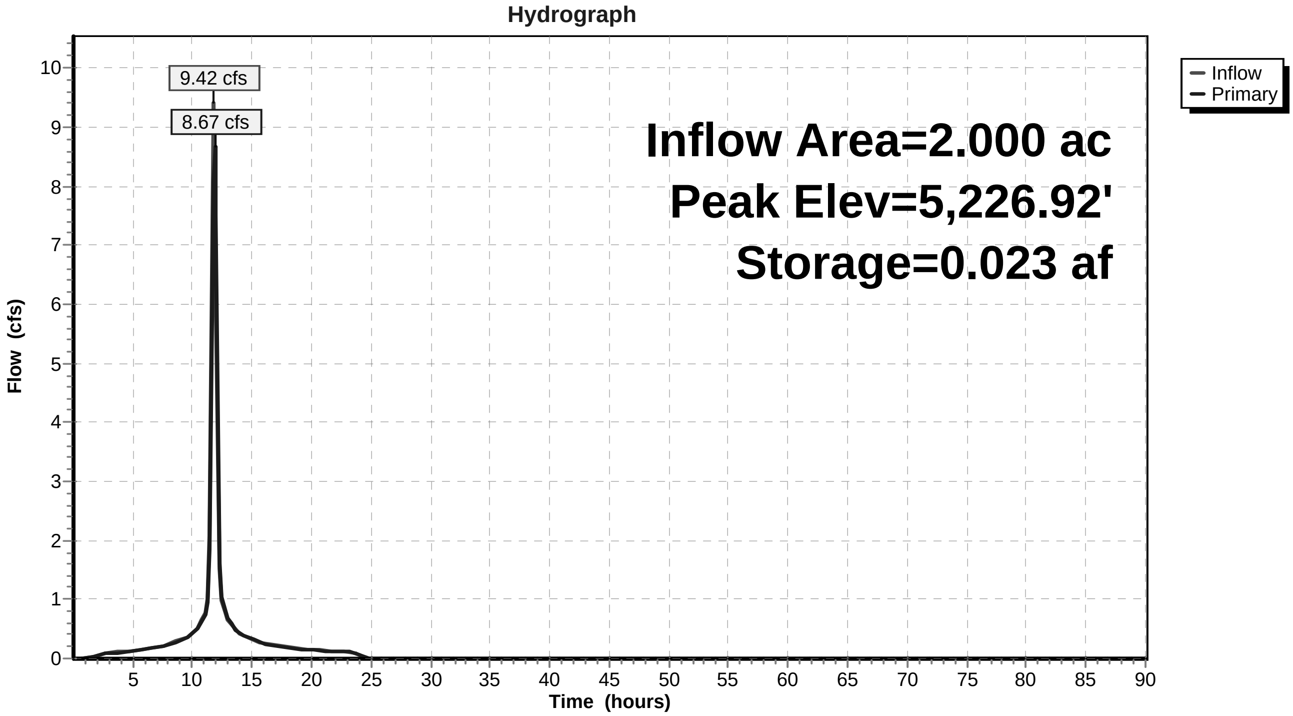
| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 5,226.00' | 0.220 af | **Custom Stage Data (Irregular)** Listed below (Recalc)<br>2.200 af Overall x 10.0% Voids |

| Elevation (feet) | Surf.Area (acres) | Perim. (feet) | Inc.Store (acre-feet) | Cum.Store (acre-feet) | Wet.Area (acres) |
|---|---|---|---|---|---|
| 5,226.00 | 0.238 | 428.2 | 0.000 | 0.000 | 0.238 |
| 5,227.00 | 0.258 | 440.9 | 0.248 | 0.248 | 0.260 |
| 5,228.00 | 0.279 | 453.5 | 0.268 | 0.516 | 0.284 |
| 5,229.00 | 0.135 | 483.4 | 0.203 | 0.719 | 0.336 |
| 5,230.00 | 0.690 | 924.0 | 0.377 | 1.096 | 1.469 |
| 5,231.00 | 1.580 | 1,546.4 | 1.105 | 2.200 | 4.278 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 5,225.92' | **50.5" W x 50.5" H Box Culvert**<br>L= 47.0' Box, 0° wingwalls, square crown edge, Ke= 0.700<br>Inlet / Outlet Invert= 5,225.92' / 5,225.92' S= 0.0000 '/' Cc= 0.900<br>n= 0.011 Concrete pipe, straight & clean, Flow Area= 17.71 sf |
| #2 | Device 1 | 5,225.92' | **54.7" W x 6.0" H Vert. Orifice/Grate** C= 0.600 |
| #3 | Device 1 | 5,229.25' | **3.2' long x 1.83' rise Sharp-Crested Rectangular Weir**<br>2 End Contraction(s) |
| #4 | Device 1 | 5,230.75' | **2.0" x 4.0" Horiz. Orifice/Grate**<br>X 12 rows C= 0.600 in 48.0" x 48.0" Grate<br>Limited to weir flow at low heads |

**Primary OutFlow** Max=7.84 cfs @ 11.86 hrs HW=5,226.85' (Free Discharge)
└─**1=Culvert** (Barrel Controls 7.84 cfs @ 2.67 fps)
  ├─**2=Orifice/Grate** (Passes 7.84 cfs of 8.99 cfs potential flow)
  ├─**3=Sharp-Crested Rectangular Weir** ( Controls 0.00 cfs)
  └─**4=Orifice/Grate** ( Controls 0.00 cfs)

# Pond 6P: Impoundment 3B



Time span=0.01-90.00 hrs, dt=0.25 hrs, 361 points x 2
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

**Subcatchment 3S: Impoundment 3A** Runoff Area=1.980 ac 100.00% Impervious Runoff Depth=3.65"
Flow Length=20' Slope=0.1700 '/' Tc=0.2 min CN=98 Runoff=6.85 cfs 0.601 af

**Subcatchment 4S: Impoundment 3B** Runoff Area=2.000 ac 100.00% Impervious Runoff Depth=3.65"
Flow Length=20' Slope=0.1700 '/' Tc=0.2 min CN=98 Runoff=6.92 cfs 0.608 af

**Pond 5P: Impoundment 3A** Peak Elev=5,228.69' Storage=0.428 af Inflow=6.85 cfs 0.601 af
Outflow=0.52 cfs 0.545 af

**Pond 6P: Impoundment 3B** Peak Elev=5,226.74' Storage=0.018 af Inflow=6.92 cfs 0.608 af
Outflow=6.33 cfs 0.608 af

**Total Runoff Area = 3.980 ac Runoff Volume = 1.209 af Average Runoff Depth = 3.65"**
**0.00% Pervious = 0.000 ac 100.00% Impervious = 3.980 ac**

## Summary for Subcatchment 3S: Impoundment 3A

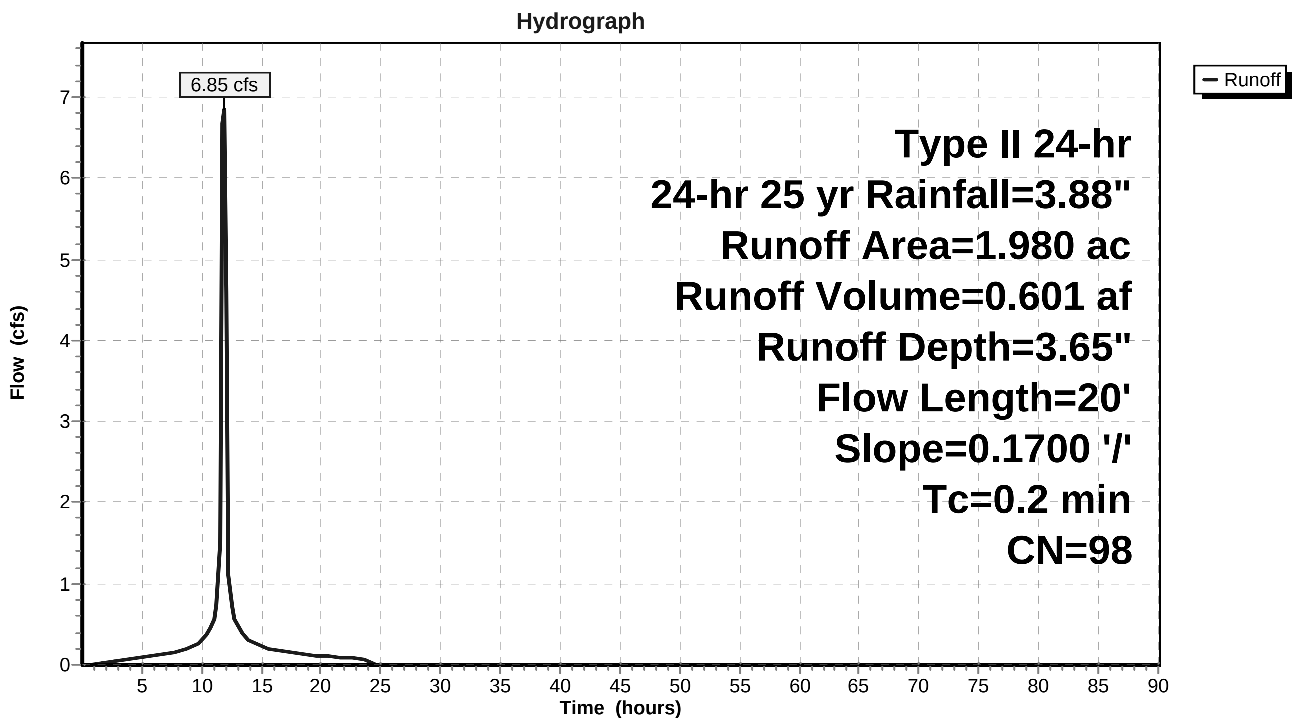
Runoff = 6.85 cfs @ 11.81 hrs, Volume= 0.601 af, Depth= 3.65"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.01-90.01 hrs, dt= 0.25 hrs
Type II 24-hr 24-hr 25 yr Rainfall=3.88"

| | Area (ac) | CN | Description |
|---|---|---|---|
| * | 1.980 | 98 | |
| | 1.980 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 0.2 | 20 | 0.1700 | 1.82 | | **Sheet Flow, sheet flow**<br>Smooth surfaces n= 0.011 P2= 1.93" |

## Subcatchment 3S: Impoundment 3A



## Summary for Subcatchment 4S: Impoundment 3B

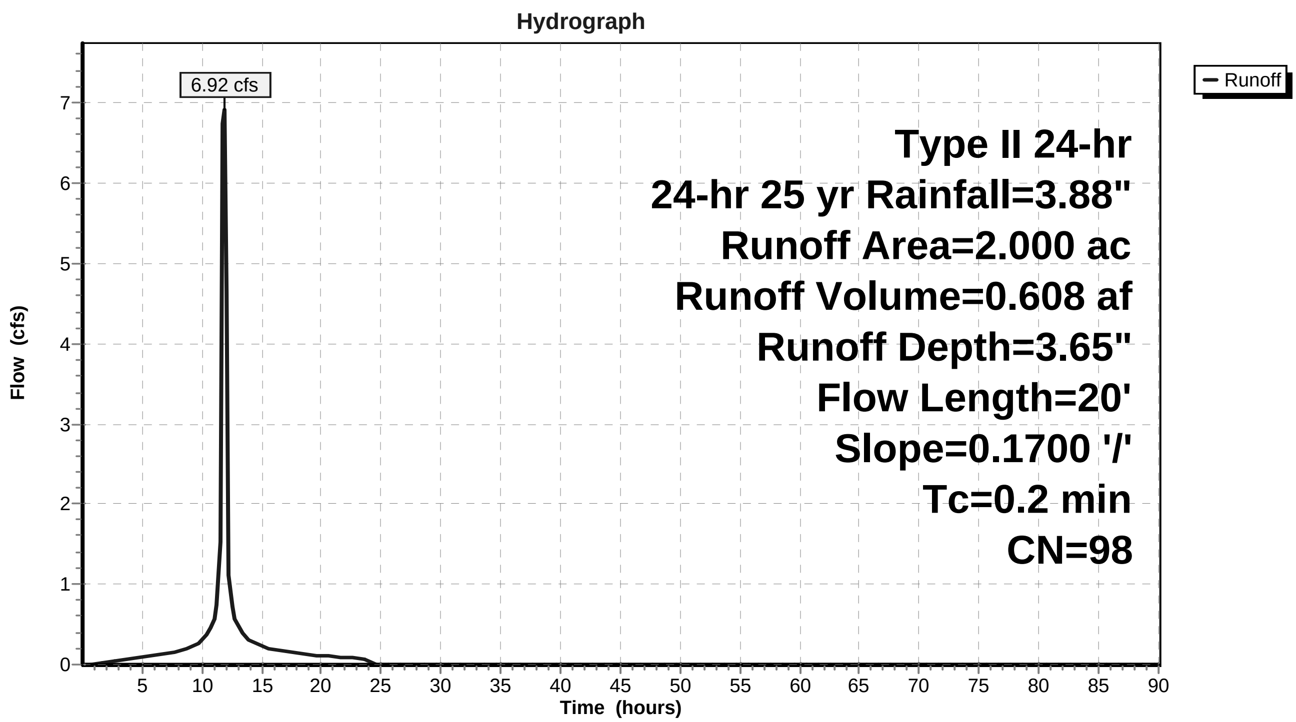
Runoff = 6.92 cfs @ 11.81 hrs, Volume= 0.608 af, Depth= 3.65"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.01-90.01 hrs, dt= 0.25 hrs
Type II 24-hr 24-hr 25 yr Rainfall=3.88"

| | Area (ac) | CN | Description |
|---|---|---|---|
| * | 2.000 | 98 | |
| | 2.000 | | 100.00% Impervious Area |

| Tc (min) | Length (feet) | Slope (ft/ft) | Velocity (ft/sec) | Capacity (cfs) | Description |
|---|---|---|---|---|---|
| 0.2 | 20 | 0.1700 | 1.82 | | **Sheet Flow, overland flow**<br>Smooth surfaces n= 0.011 P2= 1.93" |

## Subcatchment 4S: Impoundment 3B



## Summary for Pond 5P: Impoundment 3A

Inflow Area = 1.980 ac,100.00% Impervious, Inflow Depth = 3.65" for 24-hr 25 yr event
Inflow = 6.85 cfs @ 11.81 hrs, Volume= 0.601 af
Outflow = 0.52 cfs @ 12.90 hrs, Volume= 0.545 af, Atten= 92%, Lag= 65.1 min
Primary = 0.52 cfs @ 12.90 hrs, Volume= 0.545 af

Routing by Dyn-Stor-Ind method, Time Span= 0.01-90.01 hrs, dt= 0.25 hrs / 2
Starting Elev= 5,225.42' Surf.Area= 1.065 ac Storage= 0.044 af
Peak Elev= 5,228.69' @ 12.90 hrs Surf.Area= 1.285 ac Storage= 0.428 af (0.384 af above start)

Plug-Flow detention time= 541.7 min calculated for 0.501 af (83% of inflow)
Center-of-Mass det. time= 425.6 min ( 1,168.9 - 743.2 )

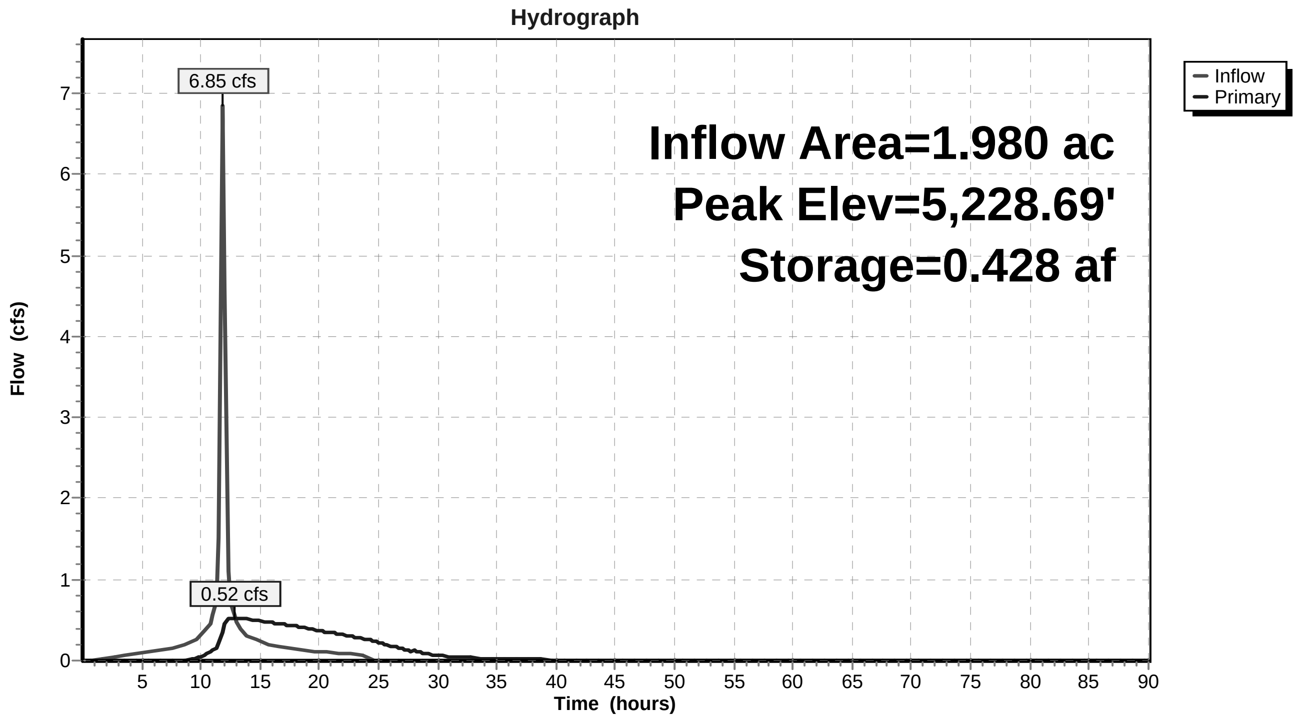
| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 5,225.00' | 0.753 af | **Custom Stage Data (Irregular)**Listed below (Recalc)<br>7.533 af Overall x 10.0% Voids |

| Elevation (feet) | Surf.Area (acres) | Perim. (feet) | Inc.Store (acre-feet) | Cum.Store (acre-feet) | Wet.Area (acres) |
|---|---|---|---|---|---|
| 5,225.00 | 1.038 | 1,435.0 | 0.000 | 0.000 | 1.038 |
| 5,226.00 | 1.104 | 1,447.8 | 1.071 | 1.071 | 1.113 |
| 5,227.00 | 1.171 | 1,460.6 | 1.137 | 2.208 | 1.189 |
| 5,228.00 | 1.238 | 1,473.4 | 1.204 | 3.413 | 1.265 |
| 5,229.00 | 1.306 | 1,486.2 | 1.272 | 4.684 | 1.342 |
| 5,230.00 | 1.375 | 1,499.0 | 1.340 | 6.025 | 1.420 |
| 5,231.00 | 1.646 | 1,562.4 | 1.508 | 7.533 | 1.776 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 5,225.92' | **4.0" W x 4.0" H Box Culvert**<br>L= 57.0' Box, 0° wingwalls, square crown edge, Ke= 0.700<br>Inlet / Outlet Invert= 5,225.92' / 5,225.92' S= 0.0000 '/' Cc= 0.900<br>n= 0.011 Concrete pipe, straight & clean, Flow Area= 0.11 sf |
| #2 | Device 1 | 5,225.92' | **54.7" W x 6.0" H Vert. Orifice/Grate** C= 0.600 |
| #3 | Device 1 | 5,229.25' | **3.2' long x 1.80' rise Sharp-Crested Rectangular Weir**<br>2 End Contraction(s) |
| #4 | Device 1 | 5,230.75' | **4.0" x 2.0" Horiz. Orifice/Grate**<br>X 12 rows C= 0.600 in 48.0" x 48.0" Grate<br>Limited to weir flow at low heads |

**Primary OutFlow** Max=0.52 cfs @ 12.90 hrs HW=5,228.69' (Free Discharge)
└─**1=Culvert** (Barrel Controls 0.52 cfs @ 4.65 fps)
  ├─**2=Orifice/Grate** (Passes 0.52 cfs of 17.41 cfs potential flow)
  ├─**3=Sharp-Crested Rectangular Weir** ( Controls 0.00 cfs)
  └─**4=Orifice/Grate** ( Controls 0.00 cfs)

## Pond 5P: Impoundment 3A



## Summary for Pond 6P: Impoundment 3B

Inflow Area = 2.000 ac,100.00% Impervious, Inflow Depth = 3.65" for 24-hr 25 yr event
Inflow = 6.92 cfs @ 11.81 hrs, Volume= 0.608 af
Outflow = 6.33 cfs @ 11.87 hrs, Volume= 0.608 af, Atten= 9%, Lag= 3.5 min
Primary = 6.33 cfs @ 11.87 hrs, Volume= 0.608 af

Routing by Dyn-Stor-Ind method, Time Span= 0.01-90.01 hrs, dt= 0.25 hrs / 2
Peak Elev= 5,226.74' @ 11.87 hrs Surf.Area= 0.253 ac Storage= 0.018 af

Plug-Flow detention time= 2.5 min calculated for 0.606 af (100% of inflow)
Center-of-Mass det. time= 2.5 min ( 745.7 - 743.2 )

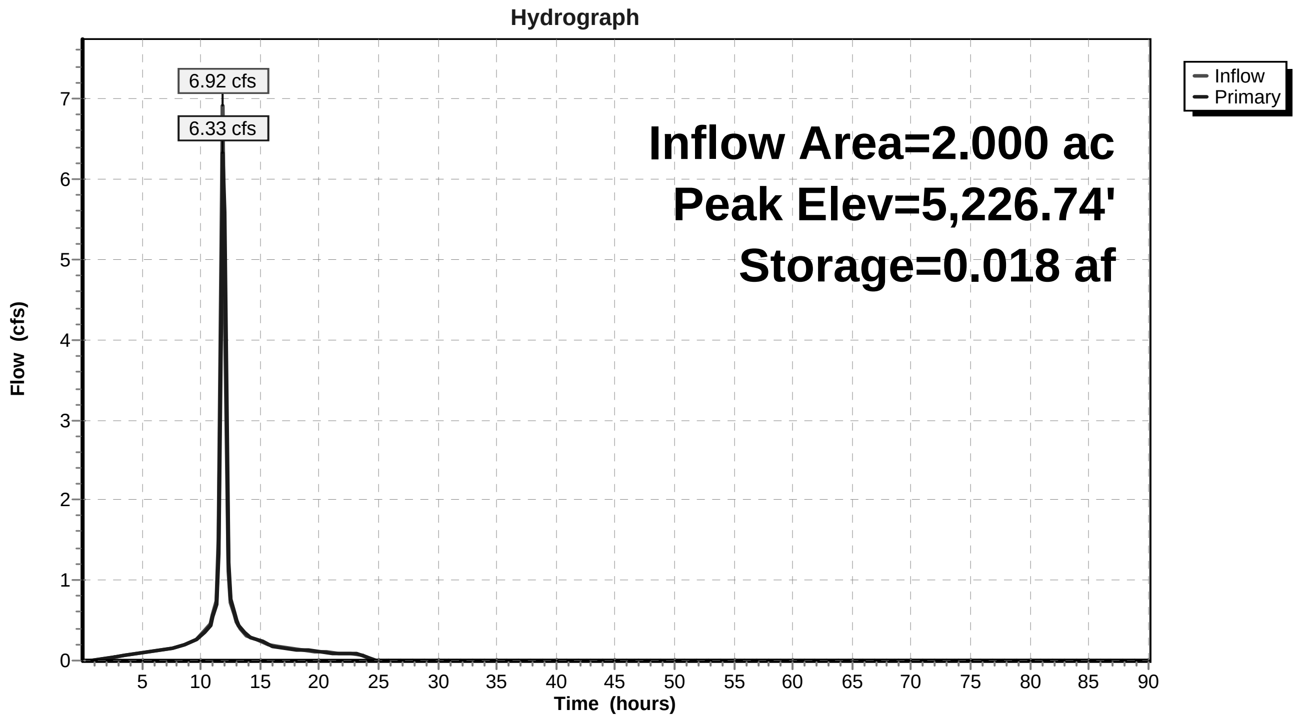
| Volume | Invert | Avail.Storage | Storage Description |
|---|---|---|---|
| #1 | 5,226.00' | 0.220 af | **Custom Stage Data (Irregular)** Listed below (Recalc)<br>2.200 af Overall x 10.0% Voids |

| Elevation (feet) | Surf.Area (acres) | Perim. (feet) | Inc.Store (acre-feet) | Cum.Store (acre-feet) | Wet.Area (acres) |
|---|---|---|---|---|---|
| 5,226.00 | 0.238 | 428.2 | 0.000 | 0.000 | 0.238 |
| 5,227.00 | 0.258 | 440.9 | 0.248 | 0.248 | 0.260 |
| 5,228.00 | 0.279 | 453.5 | 0.268 | 0.516 | 0.284 |
| 5,229.00 | 0.135 | 483.4 | 0.203 | 0.719 | 0.336 |
| 5,230.00 | 0.690 | 924.0 | 0.377 | 1.096 | 1.469 |
| 5,231.00 | 1.580 | 1,546.4 | 1.105 | 2.200 | 4.278 |

| Device | Routing | Invert | Outlet Devices |
|---|---|---|---|
| #1 | Primary | 5,225.92' | **50.5" W x 50.5" H Box Culvert**<br>L= 47.0' Box, 0° wingwalls, square crown edge, Ke= 0.700<br>Inlet / Outlet Invert= 5,225.92' / 5,225.92' S= 0.0000 '/' Cc= 0.900<br>n= 0.011 Concrete pipe, straight & clean, Flow Area= 17.71 sf |
| #2 | Device 1 | 5,225.92' | **54.7" W x 6.0" H Vert. Orifice/Grate** C= 0.600 |
| #3 | Device 1 | 5,229.25' | **3.2' long x 1.83' rise Sharp-Crested Rectangular Weir**<br>2 End Contraction(s) |
| #4 | Device 1 | 5,230.75' | **2.0" x 4.0" Horiz. Orifice/Grate**<br>X 12 rows C= 0.600 in 48.0" x 48.0" Grate<br>Limited to weir flow at low heads |

**Primary OutFlow** Max=5.74 cfs @ 11.87 hrs HW=5,226.69' (Free Discharge)
└─**1=Culvert** (Barrel Controls 5.74 cfs @ 2.38 fps)
  ├─**2=Orifice/Grate** (Passes 5.74 cfs of 7.80 cfs potential flow)
  ├─**3=Sharp-Crested Rectangular Weir** ( Controls 0.00 cfs)
  └─**4=Orifice/Grate** ( Controls 0.00 cfs)

## Pond 6P: Impoundment 3B



# APPENDIX C - NOAA RAINFALL DATA

**NOAA Atlas 14, Volume 8, Version 2**
**Location name: Boulder, Colorado, US***
**Latitude: 40.0280°, Longitude: -105.2050°**
**Elevation: 5290 ft***
* source: Google Maps

## POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

## PF tabular

**PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]**

| Duration | Average recurrence interval (years) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 5 | 10 | 25 | 50 | 100 | 200 | 500 | 1000 |
| 5-min | 0.210 (0.171-0.258) | 0.257 (0.210-0.317) | 0.349 (0.283-0.431) | 0.438 (0.353-0.544) | 0.582 (0.459-0.769) | 0.708 (0.538-0.939) | 0.848 (0.617-1.15) | 1.00 (0.694-1.39) | 1.23 (0.811-1.75) | 1.42 (0.900-2.02) |
| 10-min | 0.307 (0.251-0.378) | 0.376 (0.307-0.464) | 0.511 (0.415-0.631) | 0.642 (0.518-0.796) | 0.852 (0.671-1.13) | 1.04 (0.788-1.38) | 1.24 (0.903-1.68) | 1.47 (1.02-2.04) | 1.81 (1.19-2.56) | 2.08 (1.32-2.95) |
| 15-min | 0.375 (0.306-0.461) | 0.459 (0.374-0.566) | 0.623 (0.506-0.769) | 0.783 (0.631-0.971) | 1.04 (0.819-1.37) | 1.26 (0.961-1.68) | 1.52 (1.10-2.05) | 1.79 (1.24-2.49) | 2.20 (1.45-3.12) | 2.54 (1.61-3.60) |
| 30-min | 0.519 (0.423-0.639) | 0.633 (0.516-0.780) | 0.856 (0.695-1.06) | 1.07 (0.866-1.33) | 1.43 (1.12-1.89) | 1.74 (1.32-2.30) | 2.08 (1.51-2.82) | 2.46 (1.70-3.41) | 3.02 (1.99-4.29) | 3.49 (2.21-4.95) |
| 60-min | 0.644 (0.525-0.792) | 0.784 (0.639-0.966) | 1.06 (0.858-1.31) | 1.32 (1.07-1.64) | 1.75 (1.38-2.31) | 2.12 (1.61-2.82) | 2.54 (1.85-3.44) | 3.00 (2.07-4.16) | 3.68 (2.42-5.21) | 4.24 (2.68-6.01) |
| 2-hr | 0.769 (0.633-0.937) | 0.935 (0.769-1.14) | 1.26 (1.03-1.54) | 1.57 (1.28-1.93) | 2.07 (1.65-2.71) | 2.51 (1.93-3.30) | 3.00 (2.20-4.02) | 3.54 (2.47-4.86) | 4.33 (2.88-6.08) | 4.99 (3.20-7.01) |
| 3-hr | 0.845 (0.699-1.02) | 1.03 (0.847-1.24) | 1.37 (1.13-1.67) | 1.71 (1.39-2.08) | 2.24 (1.79-2.90) | 2.70 (2.08-3.52) | 3.22 (2.37-4.28) | 3.79 (2.66-5.16) | 4.62 (3.09-6.44) | 5.30 (3.42-7.41) |
| 6-hr | 1.03 (0.861-1.24) | 1.25 (1.04-1.50) | 1.64 (1.36-1.98) | 2.02 (1.67-2.45) | 2.62 (2.10-3.35) | 3.13 (2.44-4.04) | 3.70 (2.76-4.87) | 4.32 (3.06-5.83) | 5.23 (3.54-7.21) | 5.97 (3.89-8.26) |
| 12-hr | 1.31 (1.10-1.55) | 1.57 (1.32-1.87) | 2.05 (1.71-2.44) | 2.49 (2.07-2.98) | 3.18 (2.57-4.01) | 3.76 (2.95-4.78) | 4.40 (3.30-5.71) | 5.09 (3.64-6.78) | 6.09 (4.16-8.30) | 6.90 (4.55-9.45) |
| 24-hr | 1.59 (1.35-1.87) | 1.93 (1.64-2.27) | 2.54 (2.14-2.99) | 3.08 (2.58-3.65) | 3.88 (3.15-4.80) | 4.54 (3.58-5.68) | 5.25 (3.97-6.71) | 6.00 (4.33-7.87) | 7.06 (4.87-9.49) | 7.90 (5.28-10.7) |
| 2-day | 1.82 (1.55-2.11) | 2.26 (1.93-2.63) | 3.01 (2.56-3.51) | 3.65 (3.08-4.27) | 4.56 (3.71-5.54) | 5.29 (4.19-6.50) | 6.03 (4.60-7.60) | 6.82 (4.96-8.81) | 7.88 (5.49-10.5) | 8.72 (5.89-11.7) |
| 3-day | 1.98 (1.70-2.29) | 2.43 (2.08-2.81) | 3.19 (2.72-3.69) | 3.84 (3.26-4.47) | 4.77 (3.91-5.76) | 5.51 (4.40-6.74) | 6.28 (4.82-7.87) | 7.08 (5.19-9.10) | 8.18 (5.74-10.8) | 9.04 (6.15-12.1) |
| 4-day | 2.12 (1.82-2.44) | 2.56 (2.20-2.95) | 3.31 (2.84-3.82) | 3.95 (3.37-4.59) | 4.89 (4.02-5.88) | 5.63 (4.51-6.87) | 6.41 (4.94-8.00) | 7.22 (5.32-9.25) | 8.34 (5.88-11.0) | 9.22 (6.31-12.3) |
| 7-day | 2.46 (2.13-2.80) | 2.90 (2.51-3.31) | 3.65 (3.15-4.18) | 4.30 (3.69-4.94) | 5.23 (4.33-6.24) | 5.98 (4.83-7.22) | 6.75 (5.25-8.35) | 7.56 (5.62-9.60) | 8.68 (6.18-11.3) | 9.56 (6.60-12.6) |
| 10-day | 2.75 (2.40-3.12) | 3.21 (2.79-3.64) | 3.97 (3.45-4.53) | 4.63 (3.99-5.30) | 5.57 (4.64-6.60) | 6.32 (5.13-7.58) | 7.09 (5.54-8.71) | 7.90 (5.90-9.96) | 9.00 (6.44-11.7) | 9.86 (6.85-12.9) |
| 20-day | 3.59 (3.16-4.04) | 4.11 (3.61-4.62) | 4.97 (4.35-5.59) | 5.68 (4.94-6.43) | 6.68 (5.61-7.80) | 7.47 (6.11-8.83) | 8.26 (6.51-10.0) | 9.07 (6.84-11.3) | 10.2 (7.35-13.0) | 11.0 (7.73-14.3) |
| 30-day | 4.27 (3.78-4.77) | 4.88 (4.30-5.44) | 5.85 (5.15-6.55) | 6.66 (5.82-7.49) | 7.76 (6.54-8.97) | 8.61 (7.08-10.1) | 9.45 (7.49-11.3) | 10.3 (7.81-12.7) | 11.4 (8.30-14.5) | 12.2 (8.67-15.8) |
| 45-day | 5.11 (4.54-5.66) | 5.85 (5.19-6.49) | 7.04 (6.23-7.83) | 8.00 (7.03-8.94) | 9.29 (7.85-10.6) | 10.2 (8.46-11.9) | 11.2 (8.91-13.3) | 12.1 (9.23-14.8) | 13.3 (9.72-16.7) | 14.1 (10.1-18.1) |
| 60-day | 5.80 (5.17-6.40) | 6.69 (5.96-7.39) | 8.10 (7.18-8.96) | 9.22 (8.13-10.2) | 10.7 (9.05-12.2) | 11.8 (9.75-13.6) | 12.8 (10.2-15.2) | 13.8 (10.6-16.8) | 15.1 (11.1-18.8) | 15.9 (11.5-20.4) |

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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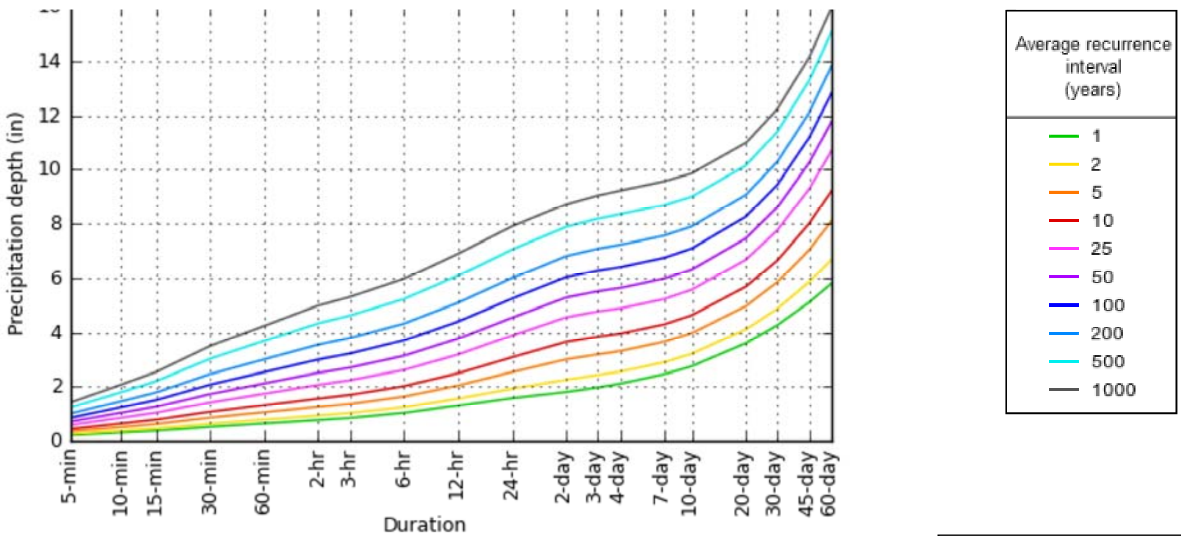
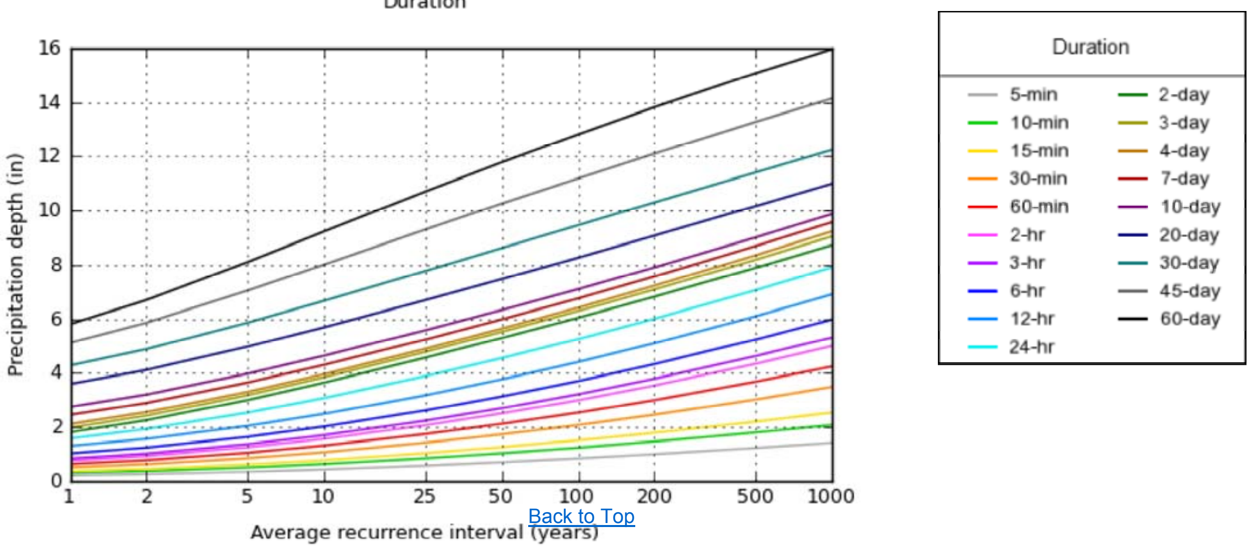
## PF graphical

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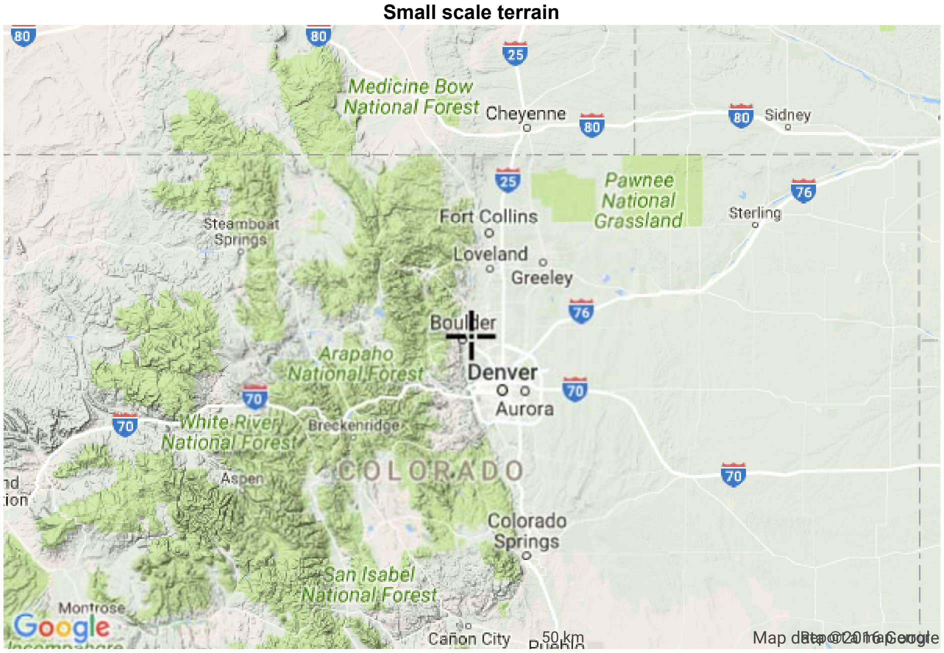
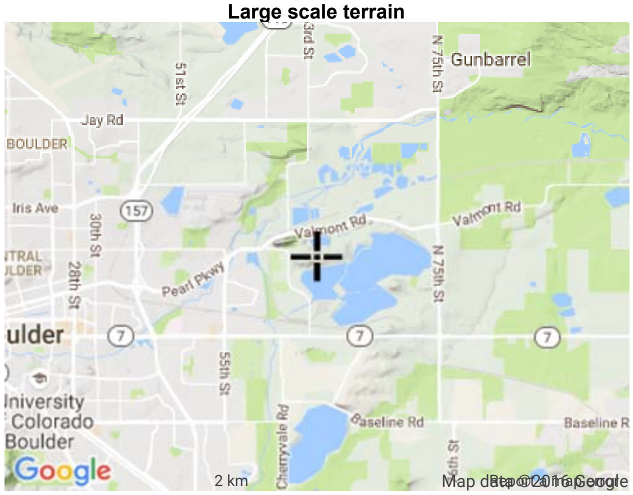
## Maps & aerials

**Small scale terrain**



**Large scale terrain**




**Large scale map**


**Large scale aerial**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