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Coal Combustion Residuals Unit
Inflow Design Flood Control System Plan

Richmond Power & Light
Whitewater Valley Station
Surface Impoundment
Wayne County, Indiana

GAI Project Number: C151119.07

April 2018

Revised April 2023

RICHMOND POWER & LIGHT

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Certification/Statement of Professional Opinion

The Coal Combustion Residuals Inflow Design Flood Control System Plan (Plan) for the Whitewater Valley Station (Station) Surface Impoundment was prepared by GAI Consultants, Inc. (GAI). The Plan may contain findings and determinations that are based on certain information that, other than for information GAI originally prepared, GAI has relied on, but not independently verified. This Certification/Statement of Professional Opinion is therefore limited to the information available to GAI at the time the Plan was written. On the basis of and subject to the foregoing, it is my professional opinion as a Professional Engineer licensed in the State of Indiana that the Plan has been prepared in accordance with good and accepted engineering practices as exercised by other engineers practicing in the same discipline(s), under similar circumstances, at the same time, and in the same locale. It is my professional opinion that the Plan is accurate and has been prepared consistent with the requirements of § 257.82(c) of the United States Environmental Protection Agency's "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments," published in the Federal Register on April 17, 2015 with an effective date of October 19, 2015 (40 CFR 257 Subpart D), and meeting the provisions of the "Extension of Compliance Deadlines for Certain Inactive Surface Impoundments: Response to Partial Vacatur," effective October 4, 2016.

The use of the words "certification" and/or "certify" in this document shall be interpreted and construed as a Statement of Professional Opinion and is not and shall not be interpreted or construed as a guarantee, warranty, or legal opinion.

GAI Consultants, Inc.

John R. Klamut, P.E.
Senior Engineering Manager

Date 4/14/2023

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REGISTERED
PE11800468
4/14/23
STATE OF
INDIANA
PROFESSIONAL ENGINEER

Acronyms

CCR	Coal Combustion Residuals
CCR Rule	"Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments" 40 CFR 257 Subpart D (2015)
CFR	Code of Federal Regulations
cfs	Cubic feet per second
EPA	United States Environmental Protection Agency
GAI	GAI Consultants, Inc.
IDFCS	Inflow Design Flood Control System
Impoundment	Surface Impoundment
IN	Indiana
Plan	Coal Combustion Residuals Inflow Design Flood Control System Plan
RP&L	Richmond Power & Light
Station	Whitewater Valley Station
SWM	Stormwater Management

1.0 Introduction

The Whitewater Valley Station (Station) is owned by Richmond Power & Light (RP&L) and is located in Richmond, Indiana (IN). The Station includes a Surface Impoundment (Impoundment), which is used for the long term storage of Coal Combustion Residuals (CCR).

The Impoundment is located on RP&L property at the Whitewater Valley Station in Wayne County, Indiana (coordinates 39° 48' 12.9" North and 84° 53' 54.8" West). The Impoundment is located in the northwestern corner of the property.

The Impoundment is currently inactive and is regulated as an existing CCR Surface Impoundment under the United States Environmental Protection Agency's (EPA's) "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments" [40 CFR 257 Subpart D] published in the Federal Register on April 17, 2015 with an effective date of October 19, 2015 (CCR Rule), and meeting the provisions of the "Extension of Compliance Deadlines for Certain Inactive Surface Impoundments: Response to Partial Vacatur," effective October 4, 2016.

The initial CCR Unit Inflow Design Flood Control System Plan was prepared in April 2018. This periodic update is being prepared as required by § 257.82(c)(4) of the CCR Rule [40 CFR § 257.82(c)(4)]

2.0 Purpose

This CCR Unit Inflow Design Flood Control System Plan (Plan) is prepared pursuant to § 257.82(c) of the CCR Rule [40 CFR § 257.82(c)].

3.0 Initial Inflow Design Flood Control System Plan

In accordance with § 257.73(a)(2), an Initial Hazard Potential Classification was prepared for the Impoundment under current conditions. The Impoundment was determined to be a "significant hazard potential" CCR surface impoundment (GAI Consultants, 2018). As required by § 257.82(a)(3), the inflow design flood for a significant hazard potential CCR surface impoundment is a 1,000-year flood.

As required by § 257.82(c)(1), this Plan includes:

- Documentation of how the inflow design flood control system (IDFCS) has been designed, constructed, operated, and maintained to adequately manage flow into the Impoundment during and following the peak discharge of the inflow design flood [§ 257.82(a)(1)];
- Documentation of how the IDFCS has been designed, constructed, operated, and maintained to adequately manage flow from the Impoundment so as to collect and control the peak discharge resulting from the inflow design flood [§ 257.82(a)(2)]; and
- Documentation of how the IDFCS has been designed, constructed, operated, and maintained to adequately address the requirements of § 257.3-3 [§ 257.82(b)].

3.1 Site Configuration

The Impoundment consists of earthen embankments and stored CCR contained within an area bounded by the embankments. The Impoundment crest is at approximately elevation 984.0 feet above mean sea level. On the north, west, and northeast sides, the crest is approximately 15 feet above the surrounding ground elevation. On the south and southeast, the Impoundment sits at a lower elevation than surrounding ground and receives stormwater runoff from the upgradient areas.

Stormwater runoff into and from the Impoundment is conveyed to a settling/stormwater management (SWM) pond, known as Pond P1-P3, situated at the north end of the Impoundment within the embankment perimeter. The SWM Pond discharges via culvert spillway to Pond P4, which ultimately discharges through an outfall permitted as a non-categorical discharge. Figure 1 depicts existing conditions at the Surface Impoundment.

3.2 Flow Into the Impoundment

Stormwater flows into the Impoundment from upgradient areas through a series of collection channels and culverts from adjacent areas, including the coal field situated to the south. The drainage areas to the Impoundment, including the Impoundment itself, comprise approximately 26 acres. The calculations for contributing watersheds to the Impoundment are included in Appendix A.

All upgradient runoff is capable of being conveyed into the Impoundment or safely around the Impoundment during the inflow design flood. Runoff from the coal field area is conveyed to the Impoundment via a culvert; when discharge exceeds the capacity of the culvert, excess runoff is directed to the west and downslope along the toe of the Impoundment embankment. Calculations included in Appendix A show that, when fully vegetated, the natural swale formed by the interface between the embankment and natural ground is capable of conveying the inflow design flood flow while meeting shear stress requirements. This swale is currently mulched and seeded to provide vegetation growth.

3.3 Flow From the Impoundment

Flow within and from the Impoundment is managed by interior discharge structures (gravel drains within the embankment defining the southern edge of the SWM Pond, and overflow of this embankment into the SWM Pond) and a spillway from the SWM Pond to Pond P4. These structures comprise the IDFCS for the Impoundment. Figure 1 depicts existing conditions and identifies the discharge structures.

The overall Impoundment embankment is at approximate elevation 984.0 feet, with the internal embankment defining the SWM Pond set slightly lower so that overflow occurs into the SWM Pond. The combined maximum discharge of the gravel drains is approximately 40 cubic feet per second (cfs) at maximum depth in the Impoundment. Flow to the SWM Pond via overtopping of the internal embankment has a maximum discharge rate of approximately 372 cfs at maximum potential depth in the Impoundment. Discharge from the gravel drains and embankment overtopping is conveyed directly to the SWM Pond, which has established vegetation to reduce the potential for erosion.

The SWM Pond was modeled for its performance during a 1,000-year flood. Appendix A contains calculations and results of the modeling. The model shows that the pool in the SWM Pond from a 1,000-year flood would attain an estimated peak water surface of 975.8 feet above mean sea level. The SWM Pond crest provides containment to approximate elevation 976.0 feet.

In this Plan, management of the inflow design flood is defined as having the capacity to convey the peak discharge resulting from the flood through and from the Impoundment without overtopping or otherwise discharging uncontrolled from the Impoundment. The capacity of each component of the IDFCS was evaluated and compared to the peak discharge resulting from the inflow design flood (1,000-year flood). Information for the components of the IDFCS was obtained from site topographic mapping, aerial photography, and site observations. Hydrologic and hydraulic calculations to support the IDFCS analysis are contained in Appendix A. The analysis indicates that interior components of the IDFCS and the spillway to Pond P4 are capable of passing the peak discharge from the 1,000-year flood.

3.4 Surface Water Requirements

Title 40 CFR § 257.3-3 states that "a facility shall not cause a discharge of pollutants into waters of the United States that is in violation of the National Pollutant Discharge Elimination System under section 402 of the Clean Water Act, as amended." The Impoundment discharges to Pond P4, from which water is conveyed to a publicly-operated treatment works operated by the Richmond Sanitary District. The Impoundment is regulated under a non-categorical discharge permit. Discharges are limited in accordance with the discharge permit, and are monitored for compliance with the permit, which functions to satisfy the requirements of the CCR Rule § 257.82(b).

The Impoundment also conveys the inflow design flood without overtopping or discharging uncontrolled, reducing the risk of breach, erosion, or similar failure of the Impoundment during the event. Once discharge is directed to Pond P4, releases from the pond are not anticipated to adversely affect the Impoundment.

4.0 Periodic Update

As required by § 257.82(c)(4), a periodic update to the Plan is required within five years of the completion of the initial Plan. No changes to the Impoundment or its discharge mechanism have occurred since the completion of the initial Plan.

The upgradient watershed to the Impoundment has been modified since the initial Plan. A coal field settling basin has been installed to intercept runoff from the coal field, provide for settlement, and pre-treat the runoff before discharging to the Richmond Sanitary District sewer system. While extreme runoff events will still be discharged through the coal field basin’s emergency spillway towards the Impoundment, the basin will tend to dampen the peak flow and prevent inflow towards the Impoundment during events up to the 100-year storm. As a result, the runoff from this area towards the Impoudment is expected to be less than that analyzed during the development of the initial Plan. Since the Impoundment was considered to be in compliance with CCR Rule requirements in the initial Plan, this finding will not change due to the presence of the settling basin. No new analyses are included in this periodic Plan.

Figure 1 has been revised and updated to reflect current conditions at the Impoundment.

5.0 Conclusion

It is GAI’s opinion, based on a review of available material and additional analyses performed for this Plan, that the existing Impoundment Inflow Design Flood Control System is in compliance with the requirements in § 257.82 of the CCR Rule for a significant hazard impoundment.

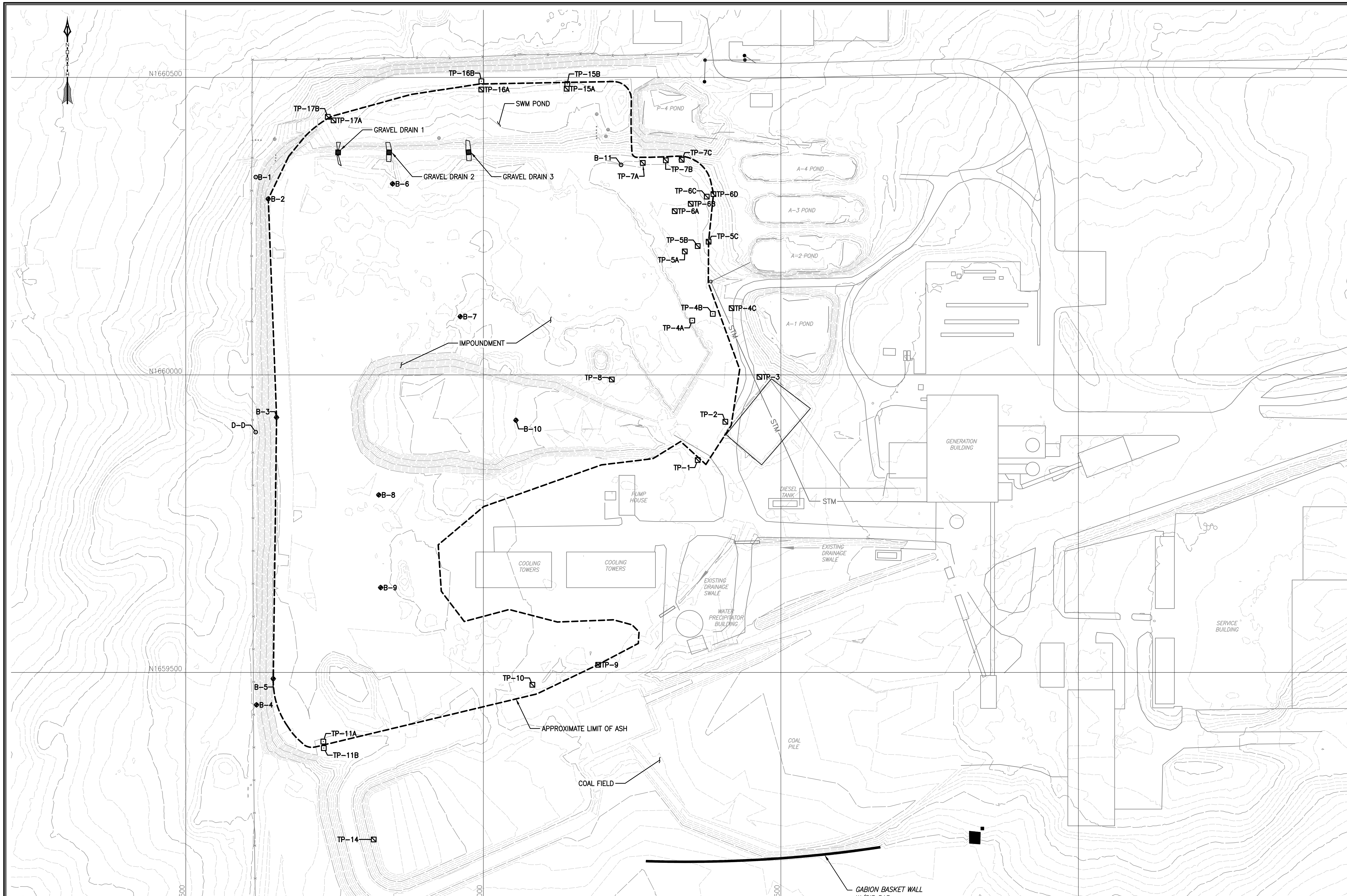
6.0 References

United States Environmental Protection Agency. *40 CFR Parts 257 and 261 Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule.* April 17, 2015 and subsequent updates

GAI Consultants, Inc. *Initial Hazard Potential Classification Assessment Report, Whitewater Valley Station Surface Impoundment*, April 2018.

GAI Consultants, Inc. *Inflow Design Flood Control System Plan, Whitewater Valley Station Surface Impoundment*, April 2018.

FIGURE



REFERENCE:
2012 INDIANA STATEWIDE IMAGERY AND LIDAR PROGRAM
1-FOOT PIXEL RESOLUTION ORTHOIMAGERY; AND
2-FOOT CONTOUR INTERVALS LINES DEVELOPED FROM 1.5 METER NPS BARE EARTH LIDAR.

SURVEY PROVIDED BY BEALS-MOORE & ASSOCIATES, INC.
DATED JANUARY 17, 2016, SEPTEMBER 27, 2016, JUNE 06, 2022

LEGEND:

---	APPROXIMATE LIMIT OF ASH
TP-2	SURVEYED TEST PIT LOCATION
TP-11	APPROXIMATE TEST PIT LOCATION
B-3	SURVEYED BORING LOCATION
B-1	APPROXIMATE BORING LOCATION

SCALE: 1" = 80'
80 0 80 160

NO.:	DATE:	DWN:	CHK:	APV:	DESCRIPTION:
1	04/14/2023	EJM	KMB	KMB	UPDATED TO INCLUDE COAL PILE RUNOFF POND

REVISION RECORD

GAI FILE NUMBER: C151119-07-002-C-D1-001
SHEET NO.: 1 OF 1
ALT./CLIENT DRAWING NUMBER:
REVISION 1

DRAWING TITLE
FIGURE 1 - IMPOUNDMENT PLAN VIEW

CLIENT
RICHMOND POWER AND LIGHT
RICHMOND, INDIANA

PROJECT
CCR RULE COMPLIANCE-RP&L
WHITEWATER VALLEY STATION
WAYNE COUNTY
RICHMOND, INDIANA 47374

gai consultants

ISSUING OFFICE: Murrysville | 4200 Triangle Lane, Export, PA 15632-1358

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DRAWN BY:	CHECKED BY:	APPROVED BY:
DOYLEMP	WALLAMJ	BORTZKM
DWG TYPE:	SCALE:	ISSUE DATE:
	AS SHOWN	04/16/2018

GAI DRAWING NUMBER:

GAI CAD FILE PATH: Z:\Energy\2015\C151119.07 - RPL Impound Closure Spt\CAD\Production Drawings\C151119-07-002-C-D1-001.dwg PLOTTED ON: 4/14/2023 9:32:42 AM PLOTTED BY: Ed Mayhood PLOT FILE: GAI.stb

APPENDIX A
Hydrologic and Hydraulic Analysis/Capacity Estimate

OBJECTIVE

The purpose of this calculation is to determine the hydraulic and hydrologic capacity of flow into and from the existing coal combustion residuals (CCR) Surface Impoundment (Impoundment) at the Whitewater Valley Power Station in Richmond, Indiana during the Impoundment's inflow design flood event.

METHODOLOGY

Runoff from the contributing watersheds was calculated using methodology from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Urban Hydrology for Small Watersheds Technical Release 55 (TR-55) Type II Soil Conservation Service (SCS) 24-hour storm. Peak flow rates and hydrologic routing were calculated using Hydraflow Hydrographs 2004.

Flow through the Impoundment's internal gravel drains was calculated using Hazen's empirical formula for coefficient of permeability based on the effective grain size, and Darcy's law for flow through porous media.

REFERENCES

1. Beals-Moore and Associates, Inc. *Beals and Moore Survey*; 2016.
2. United States Department of Agriculture. *Urban Hydrology for Small Watersheds Technical Release 55*; June 1986.
3. United States Department of Agriculture. *Web Soil Survey - Hydrologic Soil Group Report*; retrieved March 6, 2018.

BACKGROUND

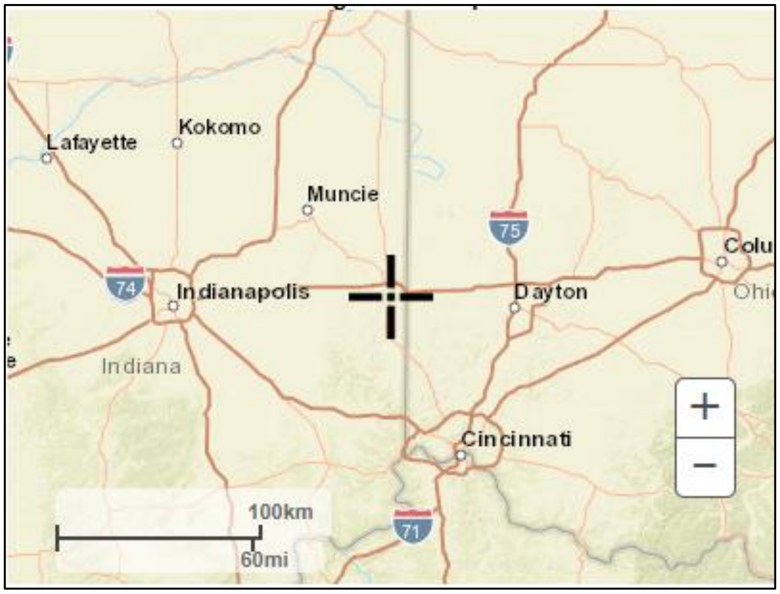
Section 257.82 of the Coal Combustion Residuals (CCR) Rule requires an Inflow Design Flood Control Plan that documents that the Impoundment adequately manages the peak discharge of the inflow design flood event. The Impoundment is classified as a significant hazard, and is therefore assigned an inflow design flood event of the 1,000-year flood by the CCR Rule.

In addition to direct rainfall within the Impoundment area, the Impoundment is incised on the southeastern side, and therefore stormwater runoff is conveyed to the Impoundment via grass swales and culverts from adjacent surfaces including vegetated areas, impervious areas, and a coal field. The Impoundment discharges to a stormwater management (SWM) pond (SWM Pond) at the northern end of the Impoundment, and ultimately to an outfall permitted as a non-categorical discharge. See Appendix A for a Watershed Map.

CALCULATIONS

Precipitation

From the National Oceanic and Atmospheric Administration (NOAA) Atlas 14, the Impoundment is located at approximately the marked location:



Precipitation data for this location is as follows:

NOAA Precipitation Data

PDS-based point precipitation frequency estimates with 90% confidence interval (in inches)						
Duration (in hours)	Average recurrence intervals (in years)					
	2	5	10	25	100	1000
24	2.82	3.44	3.92	4.56	5.56	7.26

Site Soils and Curve Numbers

Hydrologic soil groups were determined using data from the Web Soil Survey (USDA). The soil map is shown here:

Based on the Hydrologic Soil Group report, the "Or" symbol indicates loamy orthents, and the hydrologic soil group was not rated by the USDA. The coal field is the only area evaluated outside of the loamy orthents, and the curve number is not dependent on the hydrologic soil group. Based on the USDA's description of the Orthents in the area, the soil is well-drained. The hydrologic soil group C was assigned to vegetated areas based on the USDA drainage description combined with the overall industrial site designation.

The curve number (CN) for the watersheds was determined by using:

- CN = 98 for impervious areas
- CN = 88 for the coal field area (equivalent to "raw spoils" for disturbed surface mine areas)
- CN = 74 for good condition open vegetated space (grass cover greater than 75%) in fully developed urban areas (hydrologic soil group C)
- CN = 65 for the Impoundment and SWM Pond, approximately equivalent to poor condition brush (hydrologic soil group B) and used due to the visual observation of infiltration within the Impoundment and SWM Pond area

Watershed Analysis

Contributing watersheds to the Impoundment include:

- Grassy Swale (Eastern): Runoff from the coal field, grassy, and impervious areas conveyed via a grass swale to the western portion of the grassy swale;
- Grassy Swale (Western): Grassy and impervious areas runoff;
- Coal field runoff conveyed via a culvert which discharges into the Impoundment;
- Grassy and impervious areas runoff conveyed directly into the Impoundment; and
- Runoff conveyed directly into the SWM pond.

The sub-watersheds are evaluated individually. The collection swale is split into two sections, eastern and western: the eastern section collects runoff from the coal field, grassy areas, and impervious areas, and discharge via a culvert to the western section, which collects additional runoff from grassy and impervious areas and discharges via a culvert to the Impoundment.

The composite curve numbers are shown here:

	Drainage Area	Grassy Swale (Eastern)		Grassy Swale (Western)		Coal Field		Impoundment (Direct Runoff)		SWM Pond (Direct Runoff)	
Cover Description	Runoff CN	Area (Acres)	Product of CN x Area	Area (Acres)	Product of CN x Area	Area (Acres)	Product of CN x Area	Area (Acres)	Product of CN x Area	Area (Acres)	Product of CN x Area
Impervious Surfaces	98	0.46	44.83	0.13	12.98	0.00	0.00	1.66	162.75	0.00	0.00
Coal Field	88	1.23	108.04	0.00	0.00	5.34	469.91	0.00	0.00	0.00	0.00
Vegetated Space (Soil Group C)	74	0.70	51.79	0.32	23.47	0.00	0.00	2.10	155.59	0.00	0.00
Impoundment	65	0.00	0.00	0.00	0.00	0.00	0.00	12.47	810.83	1.53	99.24
	TOTALS	**2.39**	**204.66**	**0.45**	**36.45**	**5.34**	**469.91**	**16.24**	**1129.18**	**1.53**	**99.24**
	CN (WEIGHTED)	**85.8**		**81.1**		**88.0**		**69.5**		**65.0**	

Time of Concentration (Flow Path)

For the sub-watersheds that are relatively small, assume a time of concentration of 5 minutes, the minimum required for the TR-55 method. The calculated times of concentration for the coal field and impoundment sub-watersheds are shown on the following pages. The approximate physical dimensions of the channel is based on aerial photography.

Coal Field

Check one:	■ Present	❑ Developed	❑ Developed (Undist
Sheet Flow			
	Segment ID	A	
Surface Description (Table 3-1)........		Gravel	
Manning's Roughness Coefficient, n (table 3-1)........		0.011	
Flow Length, L (max. 100 feet), (ft)........		100	
Two-year 24-hour Rainfall, P_2 (in)........		2.82	
Land Slope, s (ft/ft)........		0.04	
Travel Time, $T_t = (0.007*(n*L)^{0.8}) / (P_2^{0.5}*s^{0.4})$, (hrs)........		**0.0163**	
Shallow Concentrated Flow			
	Segment ID	B	
Surface Description (Paved (P) / Unpaved (U))........		Unpaved	
Surface Description Coefficient, C (P: 20.3282, U: 16.1345		16.1345	
Flow Length, L (ft)........		229	
Watercourse Slope, s (ft/ft)........		0.01	
Average Velocity, V = C*s^0.5 (ft/sec)........		1.85	
Travel Time, Tt = (L) / (3600*V), (hrs)........		**0.0345**	
Channel Flow			
	Segment ID	C	
Section Base, b........		1	
Section Depth, d........		1	
Section Side Slope, z........		1.5	
Cross Sectional Flow Area, $a = b*d + z*d^2$........		2.5	
Wetted Perimeter, $p_w = b + (2*d)*(z^2 + 1)^{0.5}$........		4.61	
Hydraulic Radius, $r = a / p_w$........		0.54	
Channel Slope, s........		0.01	
Manning's Roughness Coefficient, n........		0.033	
Average Velocity, $V = (1.49*r^{2/3}*s^{1/2}) / (n)$, (ft/sec)........		3.02	
Flow Length, L (ft)........		605	
Travel Time, $T_t = (L) / (3600*V)$, (hrs)........		**0.0558**	
Time of Concentration			
Sheet Flow T_t........		0.0163	hrs
Shallow Concentrated Flow T_t........		0.0345	hrs
Channel Flow T_t........		0.0558	hrs
Time of Concentration, T_c........		**0.1066**	**hrs**
		6.4	**mins**

For the impoundment, the time of concentration is taken using an existing, observed drainage path within the impoundment. The path is assumed to be a channelized flow feature split into two segments due to changes in channel slope: Segment A conveys stormwater into and through a small pool area, and Segment B conveys stormwater from the pool area to the gravel drains. The approximate physical dimensions of the channels are based on aerial photography.

Impoundment

Check one:	■ Present	❑ Developed	❑ Developed (Undist

Sheet Flow

Segment ID	-	
Surface Description (Table 3-1)........	Gravel	
Manning's Roughness Coefficient, n (table 3-1)........	0	
Flow Length, L (max. 100 feet), (ft)........	0	
Two-year 24-hour Rainfall, P_2 (in)........	2.82	
Land Slope, s (ft/ft)........	0.00	
Travel Time, $T_t = (0.007*(n*L)^{0.8}) / (P_2^{0.5}*s^{0.4})$, (hrs).....	**0.0000**	

Shallow Concentrated Flow

Segment ID	-	
Surface Description (Paved (P) / Unpaved (U))........	Unpaved	
Surface Description Coefficient, C (P: 20.3282, U: 16.1345	16.1345	
Flow Length, L (ft)........	0	
Watercourse Slope, s (ft/ft)........	0.00	
Average Velocity, V = C*s^0.5 (ft/sec)........	0.00	
Travel Time, Tt = (L) / (3600*V), (hrs)........	**0.0000**	

Channel Flow

Segment ID	A	B
Section Base, b........	1.5	4
Section Depth, d........	1	1
Section Side Slope, z........	1.5	1.5
Cross Sectional Flow Area, $a = b*d + z*d^2$........	3	5.5
Wetted Perimeter, $p_w = b + (2*d)*(z^2 + 1)^{0.5}$........	5.11	7.61
Hydraulic Radius, $r = a / p_w$........	0.59	0.72
Channel Slope, s........	0.003	0.012
Manning's Roughness Coefficient, n........	0.05	0.05
Average Velocity, $V = (1.49*r^{2/3}*s^{1/2}) / (n)$, (ft/sec)........	1.10	2.63
Flow Length, L (ft)........	1471	322
Travel Time, $T_t = (L) / (3600*V)$, (hrs)........	**0.3710**	**0.0340**

Time of Concentration

Sheet Flow T_t........	0.0000	hrs
Shallow Concentrated Flow T_t........	0.0000	hrs
Channel Flow T_t........	0.4050	hrs
Time of Concentration, T_c........	**0.4050**	**hrs**
	24	**mins**

Coal Field Conveyance

Flow from the majority of the coal field is conveyed to the Impoundment through a culvert, with flow in excess of the culvert capacity directed both into the Impoundment and to a slope to the southwest. A natural swale/channel is formed along this slope by the existing ground/Impoundment embankment and shown below:

The capacity of this channel was assessed to determine its ability to convey stormwater without eroding. The existing channel dimensions (area, wetted perimeter) were taken from survey data provided by Beals-Moore and Associates, Inc. (2016) and used to determine capacity and shear stress at the 1000-year storm depth:

Channel	Southwest Channel
Design Storm	1000-year, 24-hour
Protective Lining	Grass
Flow Depth (ft)	0.37
Area (square feet)	18.9
Wetted Perimeter (ft)	85.1
Hydraulic Radius (ft)	0.22
Slope	0.034
Vegetative Lining Retardance	N/A
Manning's n	0.0350
Velocity at Flow Depth (ft/s)	2.87
Flow at Flow Depth (cfs)	54.2
Required Capacity (cfs)	53.2
Minimum Required Freeboard (ft)	0.00
Total Depth Required (ft)	0.37
Actual Depth (ft)	0.34
Allowable Velocity (ft/s)	5.00
Actual Velocity (ft/s)	2.87
Shear Stress at Flow Depth (lb /sf)	0.78
Safety Factor	1.00
Shear Stress with SF (lb/sf)	0.78
Max. Allowable Shear Stress (lb/sf)	1.00
Froude Number	0.47
Lining OK?	YES

The channel is capable of conveying the overflow from the coal field within the allowable velocity and shear stress, and therefore is not anticipated to erode during the 1000-year storm event.

For the purposes of modeling the Impoundment, it is assumed all stormwater collected within the coal field is conveyed to the Impoundment by overtopping the road.

Impoundment Storage and Conveyance

The Impoundment stage-storage is based on survey data provided by Beals-Moore and Associates, Inc. (2016). Stage-storage is as follows:

Impoundment			
Elevation (ft)	Area (sq ft)	Incremental Volume (cu ft)	Cumulative Volume (cu ft)
978	150	-	-
979	200	175	175
980	1,656	928	1,103
981	4,757	3,207	4,310
982	16,416	10,587	14,896
983	58,854	37,635	52,531
984	132,936	95,895	148,426

The Impoundment drains to the SWM Pond through three gravel drains in the northern embankment. The crest at the northern embankment is lower than at the rest of the Impoundment, allowing runoff overtopping the drains to be controlled and conveyed to the SWM Pond.

The calculations for conveyance through the gravel drains are included below. The coefficient of permeability for the stone for all gravel drains is based on the equation by Hazen for relating coefficient of permeability to effective grain size. For constant C, the average value was used (1), and based on photographs of the area, gradation is assumed to be similar to AASHTO No. 8:

Coefficient of Permeability - Stone			
Equation:	k = C * (D10)^2		
Values:	C (constant)	1	-
	D10 (10% particles less than this diameter)	4.76	mm
Result:	k (Permeability)	22.7	cm/s

The flow through the gravel drains is based on Darcy's law for flow through porous media. The length is measured from the upstream midpoint to the downstream midpoint (except for Gravel Drain 1, where gravel is washed out upstream and the point is from the grate location to the downstream midpoint). The width of the drains is based on the width at the narrowest location as delineated by the surveyors. No discharge is assumed at the lowest elevation of the gravel drain as observed on the mapping.

Gravel Drain 1 - Flow

Flow Through Gravel Drain			
Equation:	q = k * (delta H)/L * A		
Values:	k (Permeability)	22.7	cm/s
	L (length of french drain)	14	ft
	Width of french drain	2.6	ft
	Downstream invert (elevation)	975.9	el. (ft)
Results:			
Elevation (ft)	Head over invert (ft)	Area (sq ft)	Flow (cfs)
978	2.1	5.5	0.6
979	3.1	8.1	1.3
980	4.1	10.7	2.3
981	5.1	13.3	3.6
982	6.1	15.9	5.1
983	7.1	18.5	7.0
983.2	7.3	19.0	7.4
983.4	7.5	19.5	7.8
983.6	7.7	20.0	8.2
983.8	7.9	20.5	8.6
984	8.1	21.1	9.1

Gravel Drain 2 - Flow

Flow Through Gravel Drain			
Equation:	q = k * (delta H)/L * A		
Values:	k (Permeability)	22.7	cm/s
	L (length of french drain)	20	ft
	Width of french drain	7	ft
	Downstream invert (elevation)	975.67	el. (ft)
Results:			
Elevation (ft)	Head over invert (ft)	Area (sq ft)	Flow (cfs)
978	2.3	16.3	1.4
979	3.3	23.3	2.9
980	4.3	30.3	4.9
981	5.3	37.3	7.4
982	6.3	44.3	10.4
983	7.3	51.3	14.0
983.2	7.5	52.7	14.8
983.4	7.7	54.1	15.5
983.6	7.9	55.5	16.4
983.8	8.1	56.9	17.2
984	8.3	58.3	18.1

Gravel Drain 3 - Flow

Flow Through Gravel Drain			
Equation:	q = k * (delta H)/L * A		
Values:	k (Permeability)	22.7	cm/s
	L (length of french drain)	21	ft
	Width of french drain	7	ft
	Downstream invert (elevation)	976.2	el. (ft)
Results:			
Elevation (ft)	Head over invert (ft)	Area (sq ft)	Flow (cfs)
978	1.8	12.6	0.8
979	2.8	19.6	1.9
980	3.8	26.6	3.6
981	4.8	33.6	5.7
982	5.8	40.6	8.3
983	6.8	47.6	11.5
983.2	7.0	49.0	12.1
983.4	7.2	50.4	12.8
983.6	7.4	51.8	13.6
983.8	7.6	53.2	14.3
984	7.8	54.6	15.1

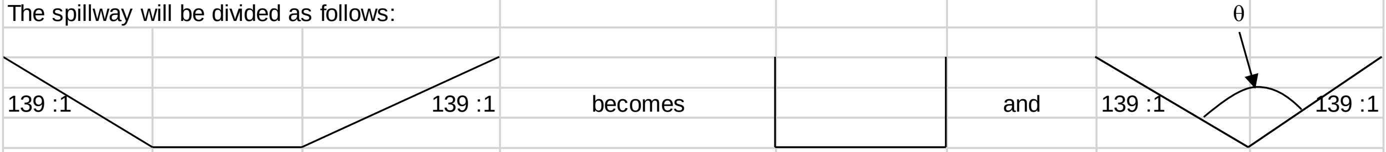
The northern embankment acts as a spillway between the Impoundment and the SWM Pond. The embankment has a low elevation 983 and extends at a shallow slope to the east (276:1), and provides containment up to elevation 984. The calculations for overflow of the northern embankment are as follows:

Evaluate the stage-discharge characteristics of the emergency spillway for the Surface Impoundment.

Spillway elevation	983
Bottom width	0
Weir coefficient C	2.8
Coefficient of discharge C_d	0.622
Side Slopes	139 :1
θ (degrees)	179.18

Note: 276H:1V on the east; assume 2H:1V on the west.

The spillway will be divided as follows:



Flor through the rectangular section can be defined by the rectangular weir equation: $Q = C\ L\ H^{3/2}$

Flor through the triangular section can be defined by the triangular weir equation: $Q = C_d\ (8/15)\ (2g)^{1/2} \tan(\theta/2)\ h^{5/2}$

Elevation (ft)	Head over spillway (ft)	Rectangular section flow (cfs)	Triangular section flow (cfs)	Total flow (cfs)	Flow Area (sf)	Spillway Velocity (ft/s)
983	0	0	0	0	0.0	0.0
983.2	0.2	0	7	7	5.6	1.2
983.4	0.4	0	38	38	22.2	1.7
983.6	0.6	0	104	104	50.0	2.1
983.8	0.8	0	213	213	89.0	2.4
984	1	0	372	372	139.0	2.7

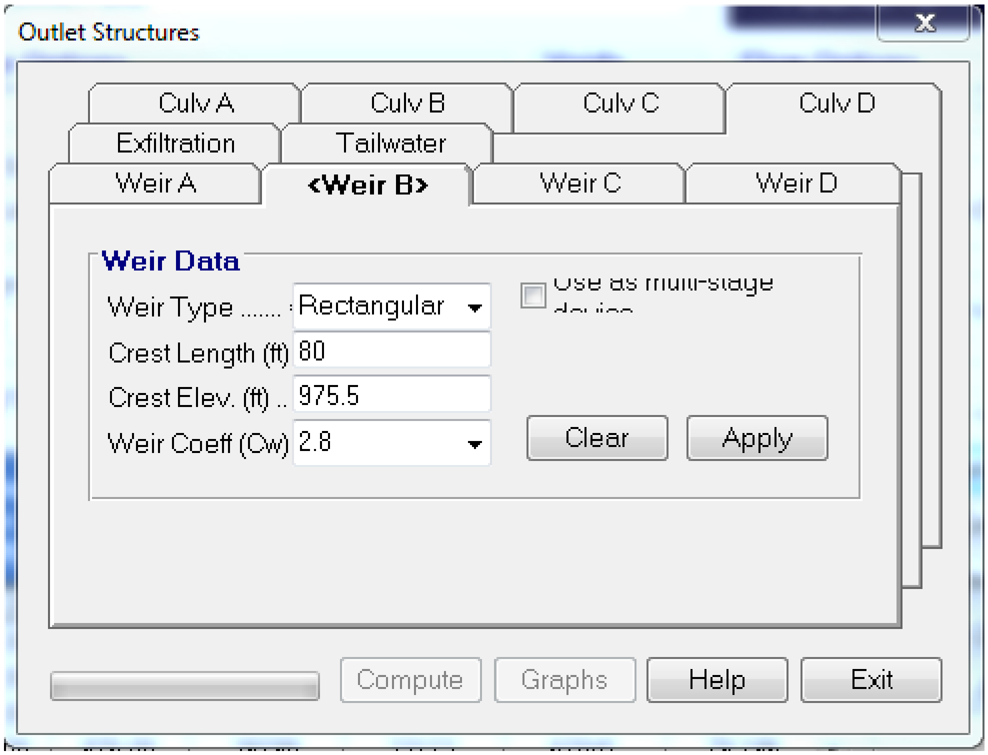
The discharge rate from the Impoundment will consist of the three gravel drains and embankment overflow.

SWM Pond Storage and Conveyance

The SWM Pond stage-storage is based on survey data provided by Beals-Moore and Associates, Inc. (2016). Stage-storage is as follows:

SWM Pond (P Pond)			
Elevation (ft)	Area (sq ft)	Incremental Volume (cu ft)	Cumulative Volume (cu ft)
972	118	-	-
973	2,731	1,424	1,424
974	12,654	7,693	9,117
975	26,948	19,801	28,918
976	39,298	33,123	62,041

The SWM Pond discharges into site Pond P4 via an overflow spillway. The spillway is approximately 80 feet wide at elevation 975.5 feet:



The SWM Pond spillway was evaluated in Hydrographs 2004 as a rectangular weir.

The SWM Pond is downstream of the gravel drain discharge, and the embankment height surrounding the SWM Pond (elevation 976.0 feet) is lower than the main Impoundment area. The maximum water level contained within the SWM Pond is not anticipated to affect the main Impoundment.

Routing

Hydrographs 2004 was used to model the stormwater runoff based on precipitation, watershed areas and curve numbers, times of concentration, calculated stage-storage, and discharge. Based on results from Hydrographs 2004, the peak flows are as follows:

Watershed	Peak Flow, 1000-Year Storm (cfs)
Grassy Swale (Eastern)	23.1
Grassy Swale (Western)	27.2
Coal Pile	53.2
Impoundment Discharge	65.1
SWM Pond Discharge	65.5

The pool levels for the 1,000-year storm are:

Pond Name	Pool Level, 1000-Year Storm (feet above mean sea level)
Impoundment	983.4
SWM Pond	976.0

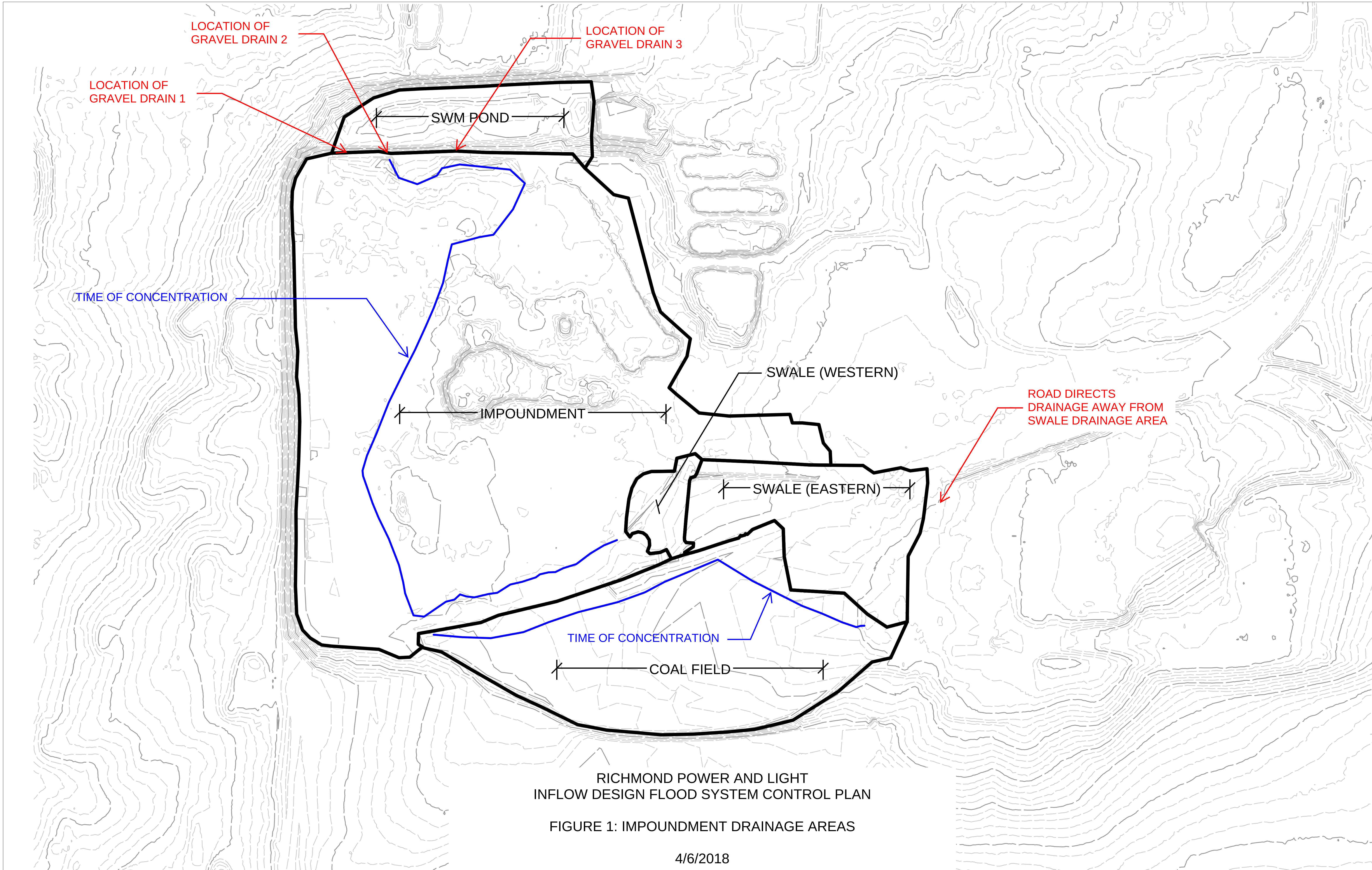
The Hydrographs 2004 report is attached.

CONCLUSIONS

The Impoundment is capable of conveying and controlling runoff collected from the contributing watersheds through the spillway and SWM Pond. The hydraulic ratings of conveyance structures including spillways have adequate capacity to control the peak flow from the runoff without overtopping.

gai consultants

FIGURE 1
WATERSHED MAP



RICHMOND POWER AND LIGHT
INFLOW DESIGN FLOOD SYSTEM CONTROL PLAN

FIGURE 1: IMPOUNDMENT DRAINAGE AREAS

4/6/2018

gai consultants

ATTACHMENT 1
HYDROGRAPHS 2004 REPORT

Hydrograph Summary Report

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to peak (min)	Volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Maximum storage (cuft)	Hydrograph description
1	SCS Runoff	23.13	1	717	50,040	----	------	------	Swale-E
2	SCS Runoff	4.04	1	717	8,522	----	------	------	Swale-W
3	Combine	27.18	1	717	58,562	1, 2	------	------	Swale
4	SCS Runoff	53.20	1	717	116,868	----	------	------	Coal Pile
5	SCS Runoff	62.55	1	728	222,946	----	------	------	Impoundment
6	Combine	119.08	1	718	398,375	3, 4, 5	------	------	Impoundment Combine
7	Reservoir	65.12	1	733	398,375	6	983.35	77,723	Impound Route
8	SCS Runoff	9.41	1	718	18,929	----	------	------	SWM Pond
9	Combine	66.42	1	733	417,304	7, 8	------	------	SWM Pond Combine
10	Reservoir	65.53	1	736	371,824	9	975.94	60,036	SWM Pond Route

Inflow-RPL_P4 berm.gpw	Return Period: 1 Year	Tuesday, Apr 17 2018, 12:32 PM

Hydrograph Plot

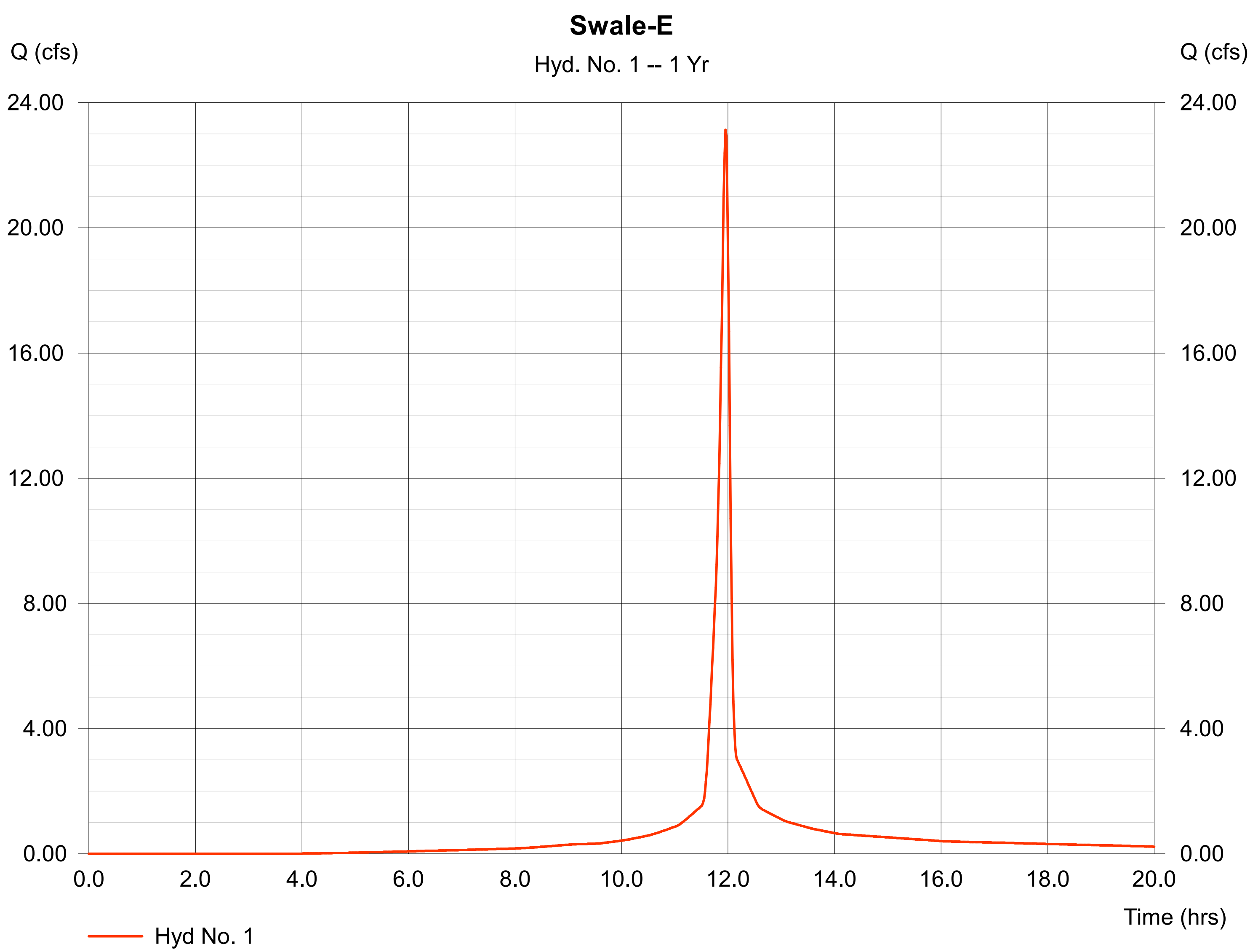
Hydraflow Hydrographs by Intelisolve — Tuesday, Apr 17 2018, 12:32 PM

Hyd. No. 1

Swale-E

Hydrograph type	= SCS Runoff	Peak discharge	= 23.13 cfs
Storm frequency	= 1 yrs	Time interval	= 1 min
Drainage area	= 2.390 ac	Curve number	= 85.8
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= USER	Time of conc. (Tc)	= 5.00 min
Total precip.	= 7.26 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

Hydrograph Volume = 50,040 cuft



Hydrograph Plot

Hydraflow Hydrographs by Intelisolve

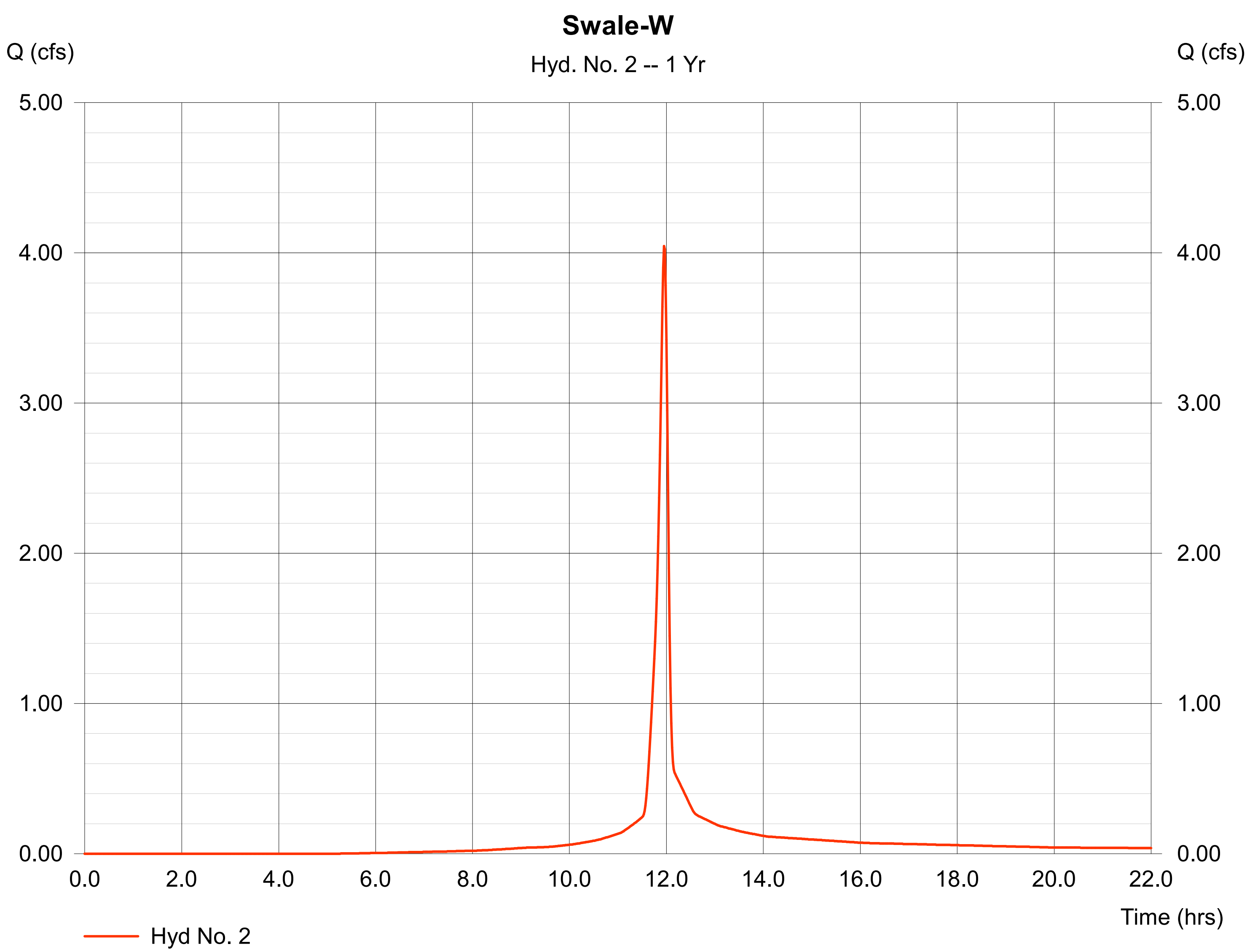
Tuesday, Apr 17 2018, 12:32 PM

Hyd. No. 2

Swale-W

Hydrograph type	= SCS Runoff	Peak discharge	= 4.04 cfs
Storm frequency	= 1 yrs	Time interval	= 1 min
Drainage area	= 0.450 ac	Curve number	= 81.1
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= USER	Time of conc. (Tc)	= 5.00 min
Total precip.	= 7.26 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

Hydrograph Volume = 8,522 cuft



Hydrograph Plot

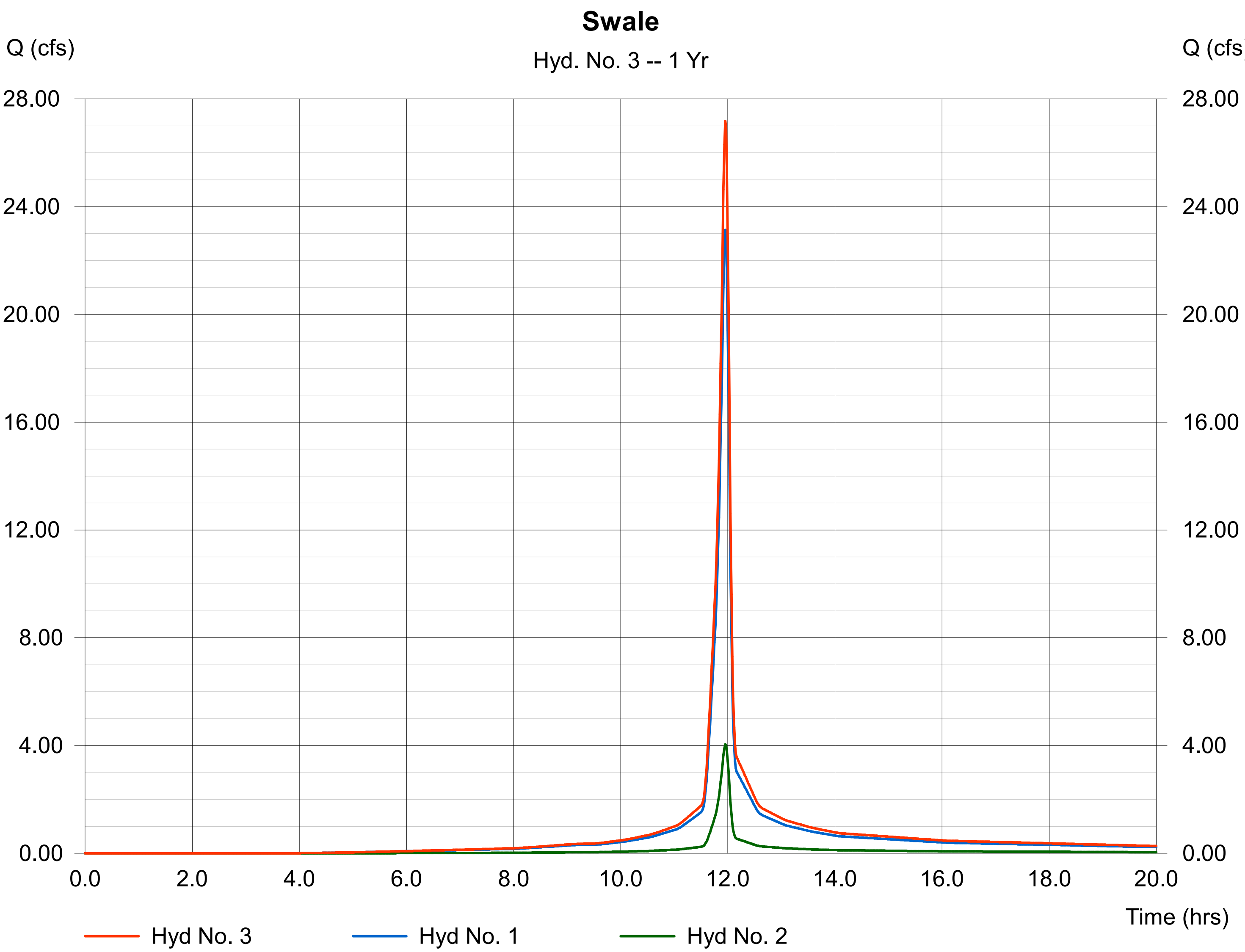
Hydraflow Hydrographs by Intelisolve — Tuesday, Apr 17 2018, 12:32 PM

Hyd. No. 3

Swale

Hydrograph type	= Combine	Peak discharge	= 27.18 cfs
Storm frequency	= 1 yrs	Time interval	= 1 min
Inflow hyds.	= 1, 2		

Hydrograph Volume = 58,562 cuft



Hydrograph Plot

Hydraflow Hydrographs by Intelisolve

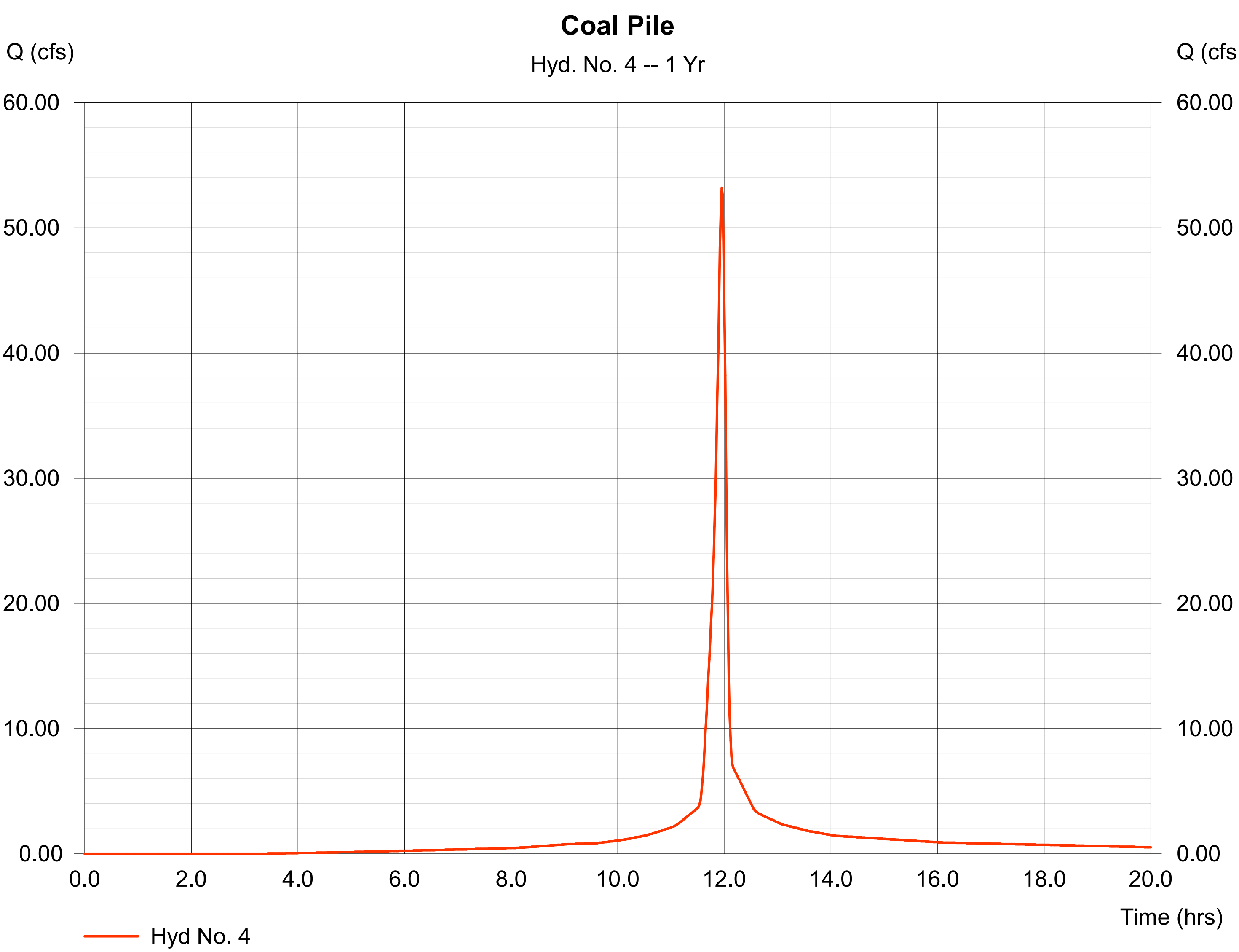
Tuesday, Apr 17 2018, 12:32 PM

Hyd. No. 4

Coal Pile

Hydrograph type	= SCS Runoff	Peak discharge	= 53.20 cfs
Storm frequency	= 1 yrs	Time interval	= 1 min
Drainage area	= 5.340 ac	Curve number	= 88
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= USER	Time of conc. (Tc)	= 6.40 min
Total precip.	= 7.26 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

Hydrograph Volume = 116,868 cuft



Hydrograph Plot

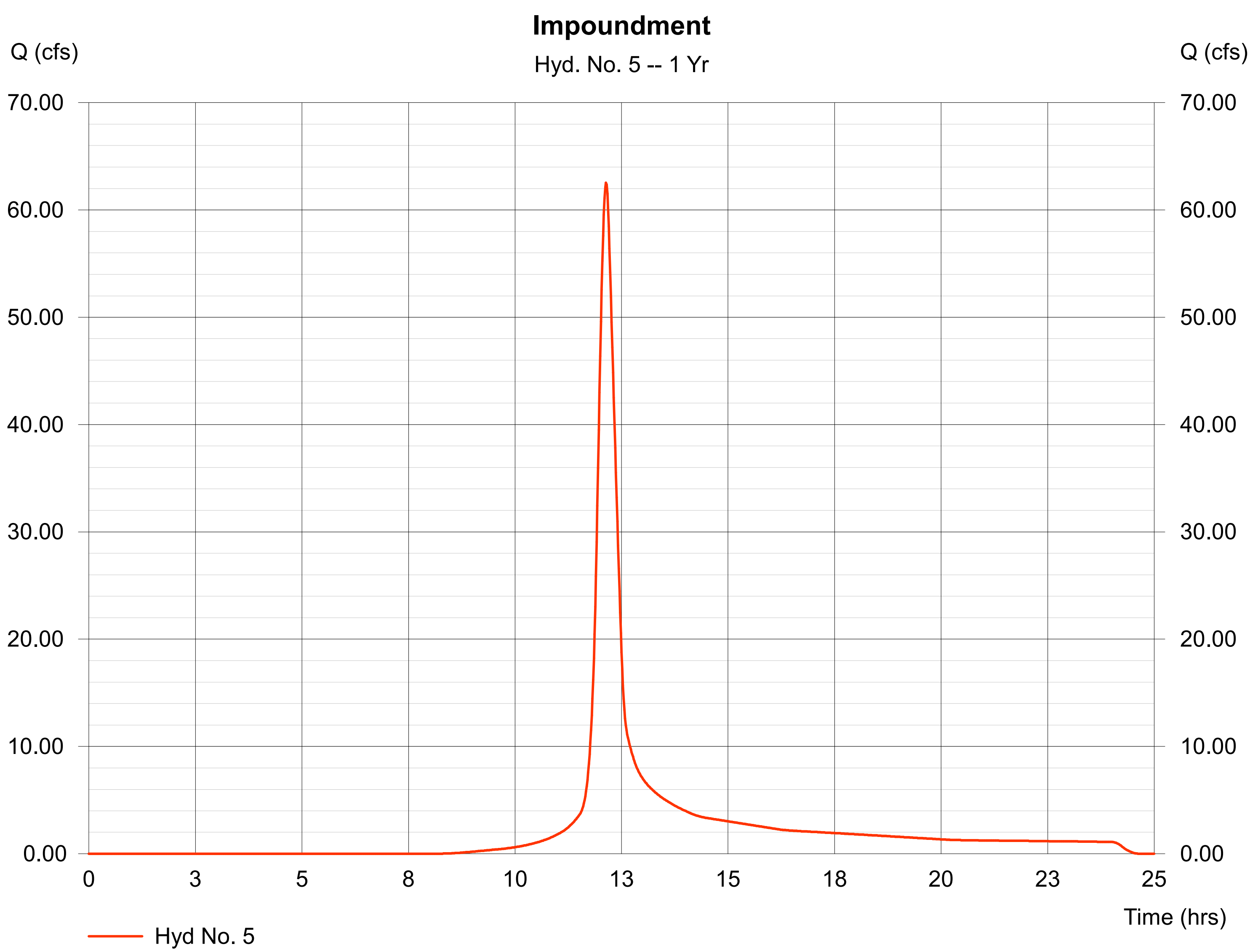
Hydraflow Hydrographs by Intelisolve | Tuesday, Apr 17 2018, 12:32 PM

Hyd. No. 5

Impoundment

Hydrograph type	= SCS Runoff	Peak discharge	= 62.55 cfs
Storm frequency	= 1 yrs	Time interval	= 1 min
Drainage area	= 16.240 ac	Curve number	= 69.5
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= USER	Time of conc. (Tc)	= 24.00 min
Total precip.	= 7.26 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

Hydrograph Volume = 222,946 cuft



Hydrograph Plot

Hydraflow Hydrographs by Intelisolve

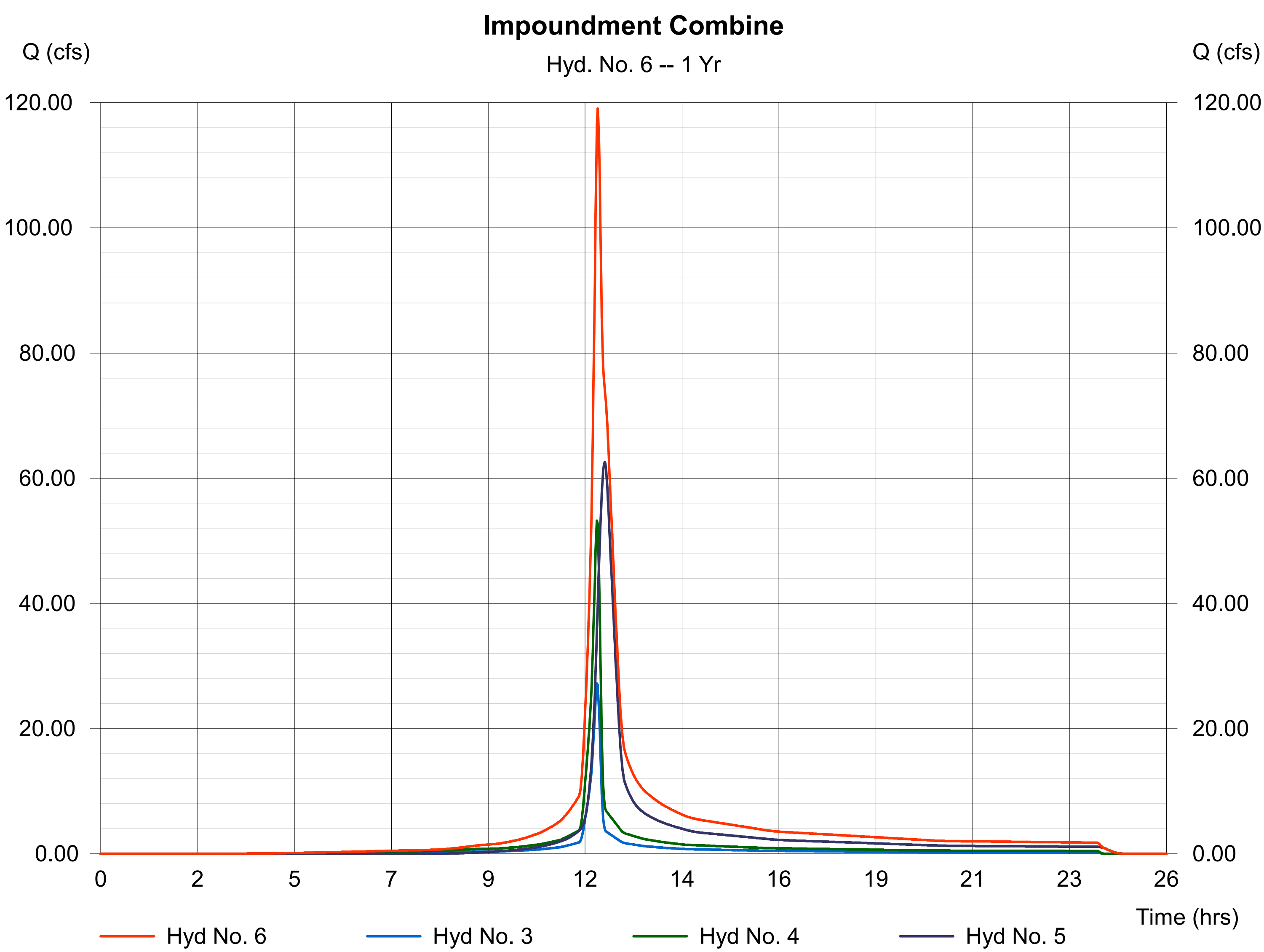
Tuesday, Apr 17 2018, 12:32 PM

Hyd. No. 6

Impoundment Combine

Hydrograph type	= Combine	Peak discharge	= 119.08 cfs
Storm frequency	= 1 yrs	Time interval	= 1 min
Inflow hyds.	= 3, 4, 5		

Hydrograph Volume = 398,375 cuft



Hydrograph Plot

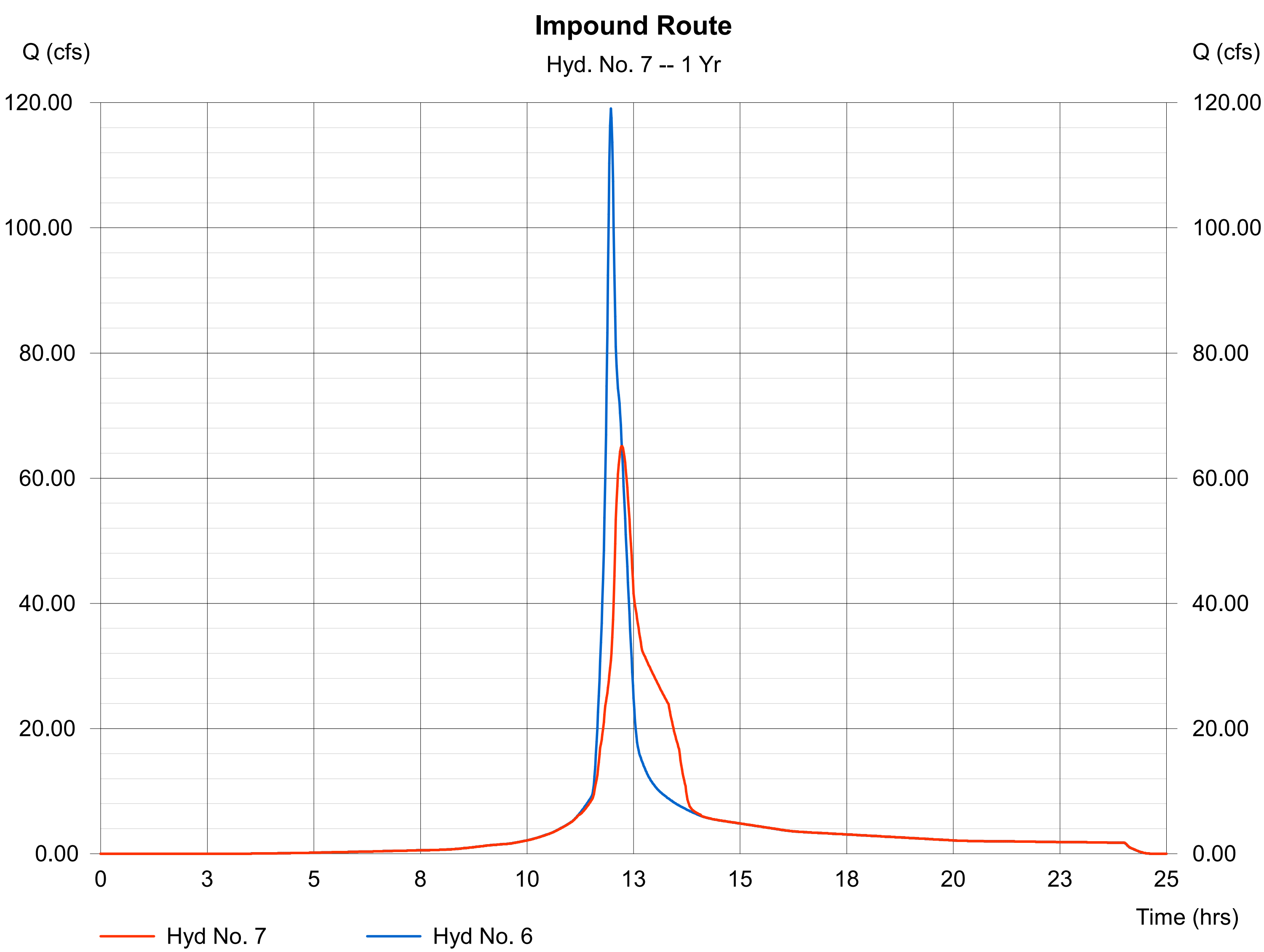
Hydraflow Hydrographs by Intelisolve | Tuesday, Apr 17 2018, 12:32 PM

Hyd. No. 7

Impound Route

Hydrograph type	= Reservoir	Peak discharge	= 65.12 cfs
Storm frequency	= 1 yrs	Time interval	= 1 min
Inflow hyd. No.	= 6	Max. Elevation	= 983.35 ft
Reservoir name	= Impoundment	Max. Storage	= 77,723 cuft

Storage Indication method used. | Hydrograph Volume = 398,375 cuft



Pond Report

Hydraflow Hydrographs by Intelisolve — Tuesday, Apr 17 2018, 12:32 PM

Pond No. 1 - Impoundment

Pond Data

Pond storage is based on known contour areas. Average end area method used.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	978.00	150	0	0
1.00	979.00	200	175	175
2.00	980.00	1,656	928	1,103
3.00	981.00	4,757	3,207	4,310
4.00	982.00	16,416	10,587	14,896
5.00	983.00	58,854	37,635	52,531
5.20	983.20	73,670	13,252	65,783
5.40	983.40	88,487	16,216	81,999
5.60	983.60	103,303	19,179	101,178
5.80	983.80	118,120	22,142	123,320
6.00	984.00	132,936	25,106	148,426

Culvert / Orifice Structures

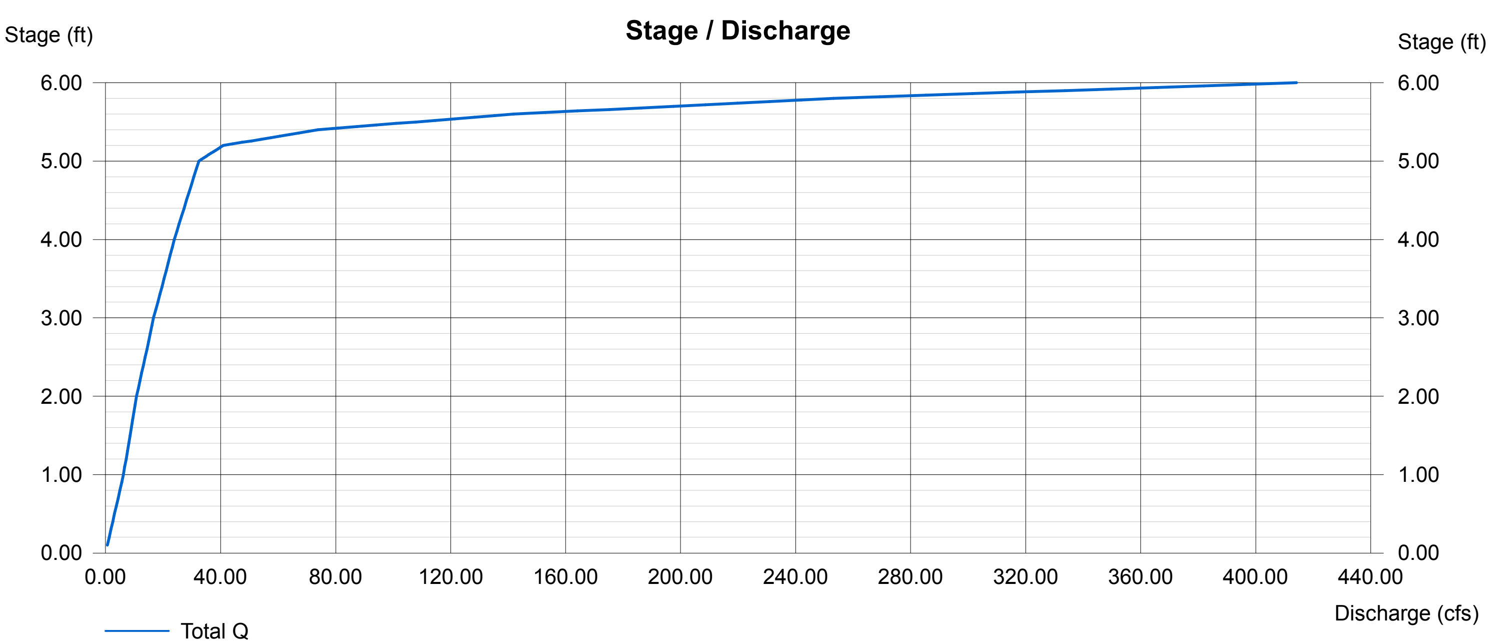
	[A]	[B]	[C]	[D]
Rise (in)	= 0.00	0.00	0.00	0.00
Span (in)	= 0.00	0.00	0.00	0.00
No. Barrels	= 0	0	0	0
Invert El. (ft)	= 0.00	0.00	0.00	0.00
Length (ft)	= 0.00	0.00	0.00	0.00
Slope (%)	= 0.00	0.00	0.00	0.00
N-Value	= .000	.000	.000	.000
Orif. Coeff.	= 0.00	0.00	0.00	0.00
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 0.00	0.00	0.00	0.00
Crest El. (ft)	= 0.00	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= ---	---	---	---
Multi-Stage	= No	No	No	No

Exfiltration = 0.000 in/hr (Contour) Tailwater Elev. = 0.00 ft

Note: Culvert/Orifice outflows have been analyzed under inlet and outlet control.



Hydrograph Plot

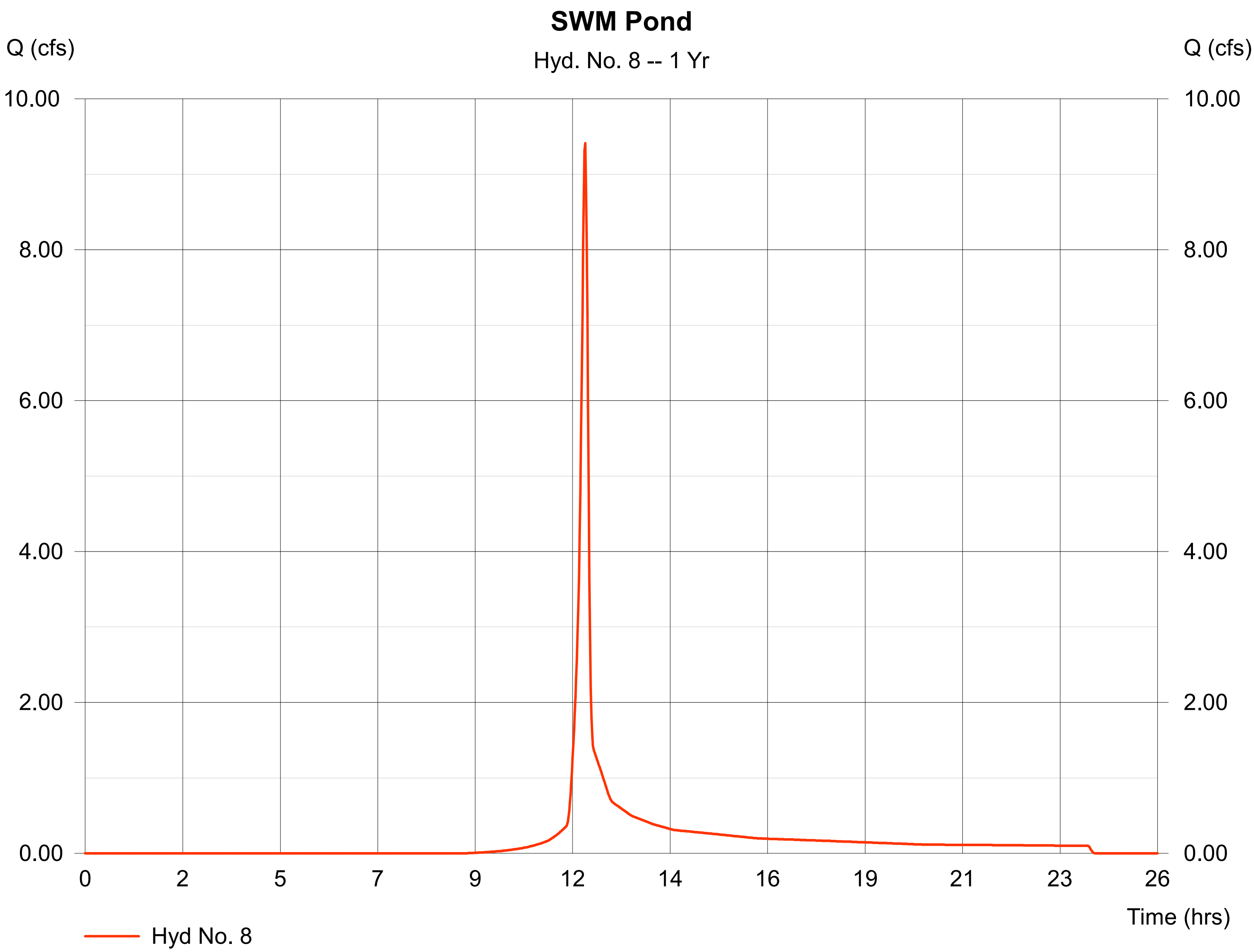
Hydraflow Hydrographs by Intelisolve — Tuesday, Apr 17 2018, 12:32 PM

Hyd. No. 8

SWM Pond

Hydrograph type	= SCS Runoff	Peak discharge	= 9.41 cfs
Storm frequency	= 1 yrs	Time interval	= 1 min
Drainage area	= 1.530 ac	Curve number	= 65
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= USER	Time of conc. (Tc)	= 5.00 min
Total precip.	= 7.26 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

Hydrograph Volume = 18,929 cuft



Hydrograph Plot

Hydraflow Hydrographs by Intelisolve

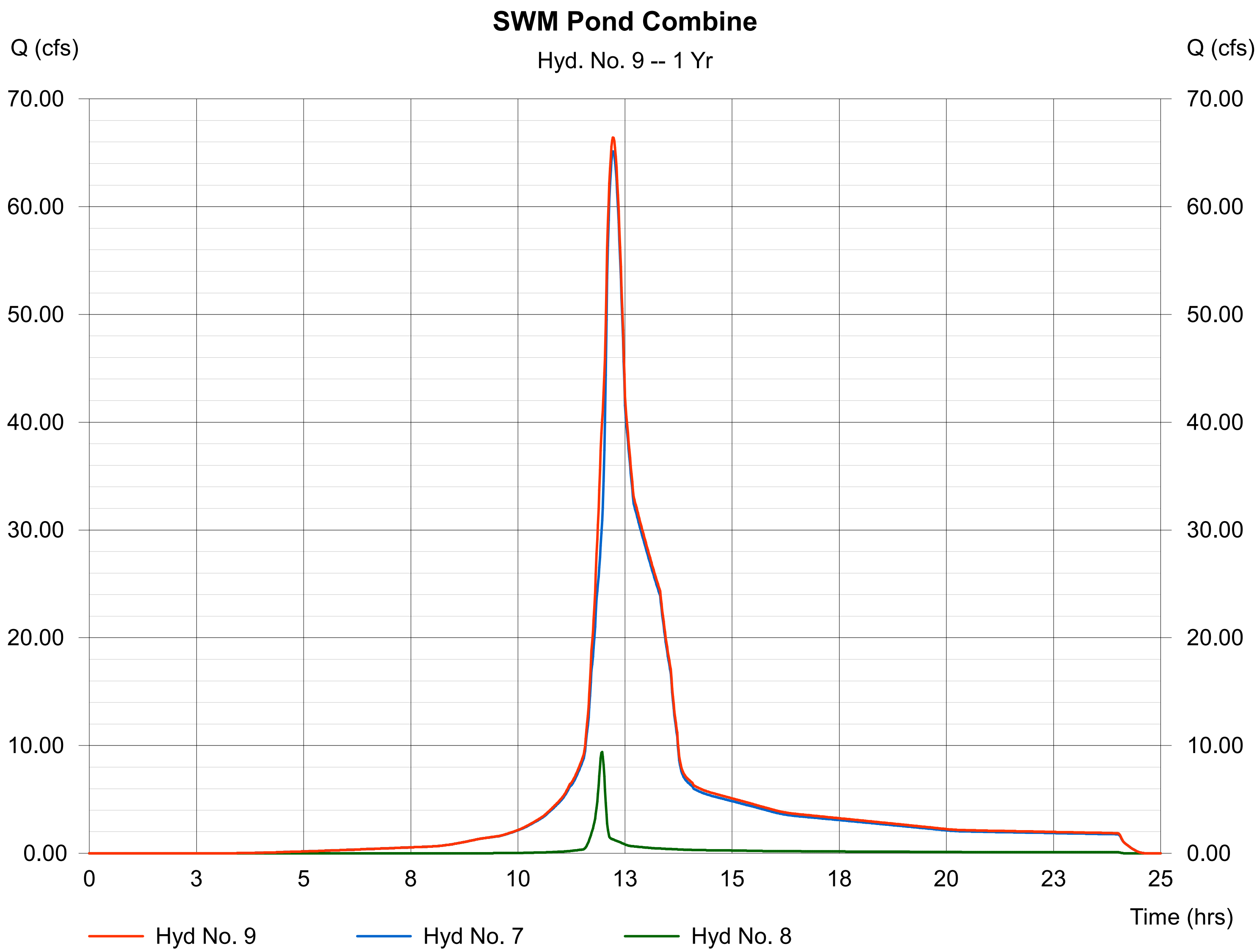
Tuesday, Apr 17 2018, 12:32 PM

Hyd. No. 9

SWM Pond Combine

Hydrograph type	= Combine	Peak discharge	= 66.42 cfs
Storm frequency	= 1 yrs	Time interval	= 1 min
Inflow hyds.	= 7, 8		

Hydrograph Volume = 417,304 cuft



Hydrograph Plot

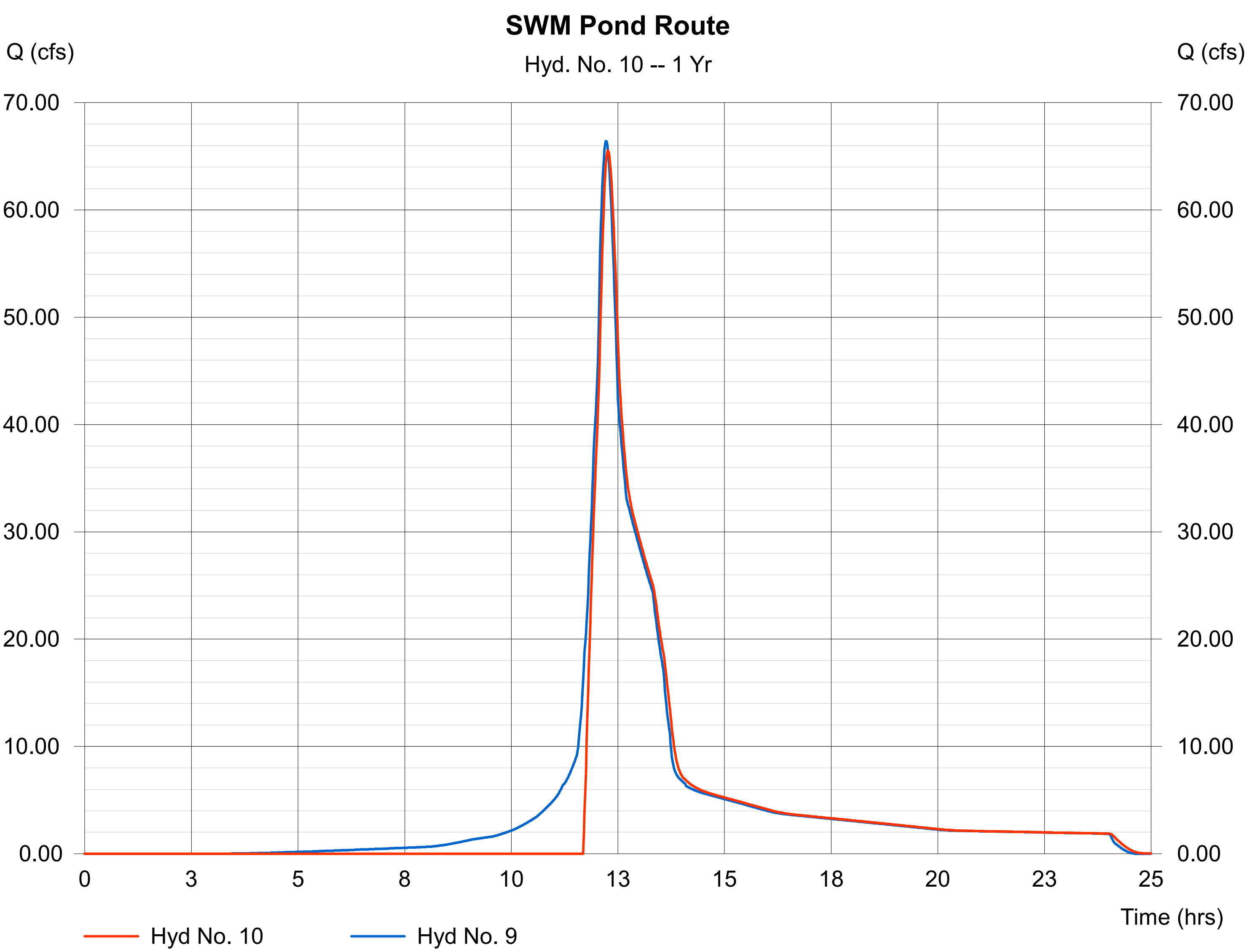
Hydraflow Hydrographs by Intelisolve | Tuesday, Apr 17 2018, 12:32 PM

Hyd. No. 10

SWM Pond Route

Hydrograph type	= Reservoir	Peak discharge	= 65.53 cfs
Storm frequency	= 1 yrs	Time interval	= 1 min
Inflow hyd. No.	= 9	Max. Elevation	= 975.94 ft
Reservoir name	= SWM Pond	Max. Storage	= 60,036 cuft

Storage Indication method used. | Hydrograph Volume = 371,824 cuft



Pond Report

Pond No. 2 - SWM Pond

Pond Data

Pond storage is based on known contour areas. Average end area method used.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	972.00	118	0	0
1.00	973.00	2,731	1,425	1,425
2.00	974.00	12,654	7,693	9,117
3.00	975.00	26,948	19,801	28,918
4.00	976.00	39,298	33,123	62,041

Culvert / Orifice Structures

	[A]	[B]	[C]	[D]
Rise (in)	= 0.00	0.00	0.00	0.00
Span (in)	= 0.00	0.00	0.00	0.00
No. Barrels	= 0	0	0	0
Invert El. (ft)	= 0.00	0.00	0.00	0.00
Length (ft)	= 0.00	0.00	0.00	0.00
Slope (%)	= 0.00	0.00	0.00	0.00
N-Value	= .013	.013	.013	.000
Orif. Coeff.	= 0.60	0.60	0.60	0.00
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 0.00	80.00	0.00	0.00
Crest El. (ft)	= 0.00	975.50	0.00	0.00
Weir Coeff.	= 3.33	2.80	0.00	0.00
Weir Type	= ---	Rect	---	---
Multi-Stage	= No	No	No	No

Exfiltration = 0.000 in/hr (Contour) Tailwater Elev. = 0.00 ft

Note: Culvert/Orifice outflows have been analyzed under inlet and outlet control.