INFLOW DESIGN FLOOD CONTROL SYSTEM PLAN

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Bremo Power Station CCR Surface Impoundment: North Ash Pond

Dominion

Submitted To: Bremo Power Station
1038 Bremo Bluff Road
Bremo Bluff, VA 23022

Submitted By: Golder Associates Inc.
2108 W. Laburnum Avenue, Suite 200
Richmond, VA 23227

October 2016 **Project No. 15-20347**

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Appendices

1.0 CERTIFICATION

This Inflow Design Flood Control System Plan for the Bremo Power Station's North Ash Pond was prepared by Golder Associates Inc. (Golder). The document and Certification/Statement of Professional Opinion are based on and limited to information that Golder has relied on from Dominion and others, but not independently verified, as well as work products produced by Golder.

On the basis of and subject to the foregoing, it is my professional opinion as a Professional Engineer licensed in the Commonwealth of Virginia that this document 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 document was prepared consistent with the requirements in §257.82 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 §257.82)

The use of the word "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.

James R. DiFrancesco, P.E.
Print Name

Principal and Practice Leader
Title

Signature

10/13/2016
Date

COMMONWEALTH OF VIRGINIA
JAMES R. DIFRANCESCO
Lic. No. 025260
10-13-16
PROFESSIONAL ENGINEER

Golder Associates

2.0 INTRODUCTION

This Inflow Design Flood Control System (FCS) Plan was prepared for the Bremo Power Station's (Station) existing Coal Combustion Residuals (CCR) surface impoundment known as the North Ash Pond (NAP). This FCS Plan was prepared in accordance with 40 CFR Part §257, Subpart D and is consistent with the requirements of 40 CFR §257.82.

The Station, owned and operated by Virginia Electric and Power Company d/b/a Dominion Virginia Power (Dominion), is located in Fluvanna County at 1038 Bremo Road, east of Route 15 (James Madison Highway) and north of the James River. The Station includes an existing CCR surface impoundment, the NAP, as defined by the Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule (40 CFR §257; the CCR rule).

3.0 INFLOW DESIGN FLOOD CONTROL SYSTEM PLAN

3.1 Hazard Potential Classification

As indicated in Golder's *Hazard Potential Classification Assessment*, the NAP is assigned a "Significant" hazard potential rating per 40 CFR §257.73.

3.2 Inflow Design Flood

According to 40 CFR §257.82(a)(3)(ii), a hazard potential rating of Significant requires an evaluation of the 1000-year storm event. Per the NOAA Atlas-14, provided in Appendix A, the 1000-year event rainfall totals for the 6-, 12-, and 24-hour durations are 7.04, 9.41, and 12.1 inches, respectively.

3.3 Inflow and Outflow Control

In anticipation of closure, the NAP's primary spillway, an intake tower and 24-inch diameter pipe, has been plugged to route the surface water to the Centralized Source Water Treatment System for treatment prior to discharge. Surface water and pore water within the NAP are pumped to the on-site treatment plant for treatment and discharge. The emergency spillway, located on the west side of the NAP, is available for discharge should the water accumulate to the crest of the spillway.

The NAP stormwater system was modeled in the U.S. Army Corps of Engineers Hydrologic Engineering Center's Hydraulic Modeling System (HEC-HMS), and the analysis is included in Appendix B. The analysis was conducted using the 6-, 12-, and 24-hour Probable Maximum Flood (PMF) events, which consist of 27, 30.6, and 30.6 inches of rain, respectively. The NAP inflow design flood control system is capable of adequately managing the inflow from a PMF event without overtopping the embankment, and has adequate spillway capacity to manage the resulting outflow.

4.0 CONCLUSIONS

Through work performed by Golder, both field inspection and document review, it is our opinion that the NAP inflow design flood control system has sufficient capacity for the 1000-year storm event, as required by 40 CFR §257.82.

Established in 1960, Golder Associates is a global, employee-owned organization that helps clients find sustainable solutions to the challenges of finite resources, energy and water supply and management, waste management, urbanization, and climate change. We provide a wide range of independent consulting, design, and construction services in our specialist areas of earth, environment, and energy. By building strong relationships and meeting the needs of clients, our people have created one of the most trusted professional services organizations in the world.

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Appendix A

NOAA Atlas 14

NOAA Atlas 14, Volume 2, Version 3 BREMO BLUFF PWR
Station ID: 44-0993
Location name: Bremo Bluff, Virginia, USA*
Latitude: 37.7092°, Longitude: -78.2886°
Elevation:
Elevation (station metadata): 225 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

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	0.341 (0.306-0.380)	0.389 (0.350-0.432)	0.435 (0.391-0.483)	0.512 (0.459-0.568)	0.574 (0.515-0.635)	0.633 (0.564-0.699)	0.681 (0.605-0.752)	0.724 (0.639-0.799)	0.767 (0.673-0.848)	0.813 (0.707-0.899)
10-min	0.545 (0.490-0.607)	0.621 (0.560-0.691)	0.696 (0.627-0.774)	0.818 (0.735-0.908)	0.914 (0.820-1.01)	1.01 (0.899-1.11)	1.08 (0.961-1.20)	1.15 (1.01-1.27)	1.21 (1.06-1.34)	1.28 (1.11-1.42)
15-min	0.682 (0.612-0.758)	0.781 (0.704-0.869)	0.881 (0.793-0.979)	1.03 (0.929-1.15)	1.16 (1.04-1.28)	1.28 (1.14-1.41)	1.37 (1.21-1.51)	1.45 (1.28-1.60)	1.53 (1.34-1.69)	1.61 (1.40-1.78)
30-min	0.934 (0.839-1.04)	1.08 (0.972-1.20)	1.25 (1.13-1.39)	1.50 (1.35-1.66)	1.72 (1.54-1.90)	1.92 (1.71-2.12)	2.10 (1.86-2.31)	2.25 (1.99-2.49)	2.43 (2.13-2.69)	2.60 (2.27-2.88)
60-min	1.17 (1.05-1.30)	1.35 (1.22-1.51)	1.60 (1.44-1.78)	1.95 (1.75-2.17)	2.29 (2.05-2.53)	2.60 (2.32-2.88)	2.88 (2.56-3.19)	3.16 (2.79-3.49)	3.48 (3.06-3.85)	3.80 (3.31-4.20)
2-hr	1.39 (1.24-1.56)	1.61 (1.44-1.81)	1.91 (1.71-2.15)	2.35 (2.10-2.63)	2.78 (2.47-3.11)	3.21 (2.83-3.59)	3.60 (3.15-4.01)	3.99 (3.48-4.45)	4.47 (3.87-4.98)	4.94 (4.23-5.51)
3-hr	1.50 (1.33-1.69)	1.74 (1.55-1.96)	2.06 (1.84-2.33)	2.53 (2.25-2.85)	2.99 (2.65-3.37)	3.45 (3.03-3.87)	3.87 (3.38-4.34)	4.29 (3.73-4.81)	4.80 (4.13-5.38)	5.30 (4.52-5.94)
6-hr	1.84 (1.63-2.11)	2.14 (1.90-2.44)	2.53 (2.24-2.89)	3.10 (2.74-3.54)	3.70 (3.24-4.21)	4.31 (3.76-4.89)	4.88 (4.22-5.54)	5.49 (4.70-6.22)	6.25 (5.29-7.08)	7.03 (5.87-7.95)
12-hr	2.25 (2.00-2.58)	2.61 (2.32-2.99)	3.09 (2.74-3.54)	3.81 (3.37-4.36)	4.60 (4.02-5.24)	5.42 (4.70-6.15)	6.22 (5.34-7.04)	7.09 (6.00-7.98)	8.22 (6.86-9.25)	9.39 (7.71-10.6)
24-hr	2.63 (2.41-2.92)	3.19 (2.92-3.54)	4.08 (3.71-4.52)	4.83 (4.38-5.33)	5.93 (5.35-6.54)	6.87 (6.16-7.57)	7.91 (7.03-8.69)	9.05 (7.97-9.91)	10.7 (9.31-11.7)	12.1 (10.4-13.3)
2-day	3.09 (2.81-3.41)	3.73 (3.40-4.13)	4.75 (4.31-5.23)	5.58 (5.06-6.14)	6.79 (6.12-7.45)	7.79 (6.99-8.54)	8.87 (7.91-9.71)	10.0 (8.89-11.0)	11.7 (10.3-12.9)	13.1 (11.4-14.4)
3-day	3.27 (2.99-3.60)	3.95 (3.61-4.35)	5.02 (4.58-5.51)	5.90 (5.37-6.47)	7.17 (6.50-7.85)	8.23 (7.42-9.00)	9.37 (8.39-10.2)	10.6 (9.42-11.6)	12.4 (10.9-13.5)	13.8 (12.0-15.2)
4-day	3.45 (3.16-3.78)	4.17 (3.82-4.58)	5.30 (4.85-5.80)	6.22 (5.68-6.80)	7.55 (6.88-8.25)	8.67 (7.85-9.46)	9.87 (8.86-10.8)	11.2 (9.95-12.2)	13.0 (11.5-14.2)	14.5 (12.7-15.9)
7-day	3.95 (3.65-4.29)	4.75 (4.39-5.17)	5.93 (5.47-6.45)	6.91 (6.35-7.50)	8.30 (7.59-8.99)	9.45 (8.61-10.2)	10.7 (9.66-11.6)	12.0 (10.8-13.0)	13.9 (12.3-15.0)	15.4 (13.5-16.7)
10-day	4.46 (4.14-4.82)	5.35 (4.96-5.79)	6.60 (6.12-7.13)	7.62 (7.04-8.22)	9.05 (8.33-9.76)	10.2 (9.37-11.0)	11.4 (10.4-12.3)	12.7 (11.6-13.7)	14.5 (13.1-15.7)	16.0 (14.2-17.3)
20-day	6.01 (5.62-6.43)	7.17 (6.71-7.67)	8.66 (8.09-9.26)	9.83 (9.18-10.5)	11.4 (10.6-12.2)	12.7 (11.8-13.5)	13.9 (12.9-14.9)	15.2 (14.0-16.3)	17.0 (15.5-18.2)	18.3 (16.6-19.6)
30-day	7.41 (6.97-7.88)	8.78 (8.27-9.34)	10.4 (9.77-11.0)	11.6 (10.9-12.3)	13.2 (12.4-14.0)	14.4 (13.5-15.3)	15.6 (14.5-16.5)	16.7 (15.5-17.7)	18.2 (16.8-19.3)	19.3 (17.7-20.5)
45-day	9.32 (8.79-9.87)	11.0 (10.4-11.7)	12.9 (12.1-13.6)	14.2 (13.4-15.1)	16.0 (15.1-16.9)	17.3 (16.3-18.3)	18.6 (17.4-19.7)	19.8 (18.5-20.9)	21.3 (19.9-22.6)	22.4 (20.8-23.8)
60-day	11.1 (10.4-11.7)	13.0 (12.3-13.7)	15.0 (14.2-15.8)	16.5 (15.6-17.4)	18.4 (17.4-19.4)	19.8 (18.6-20.9)	21.1 (19.9-22.3)	22.4 (21.0-23.6)	24.0 (22.4-25.3)	25.1 (23.3-26.6)

[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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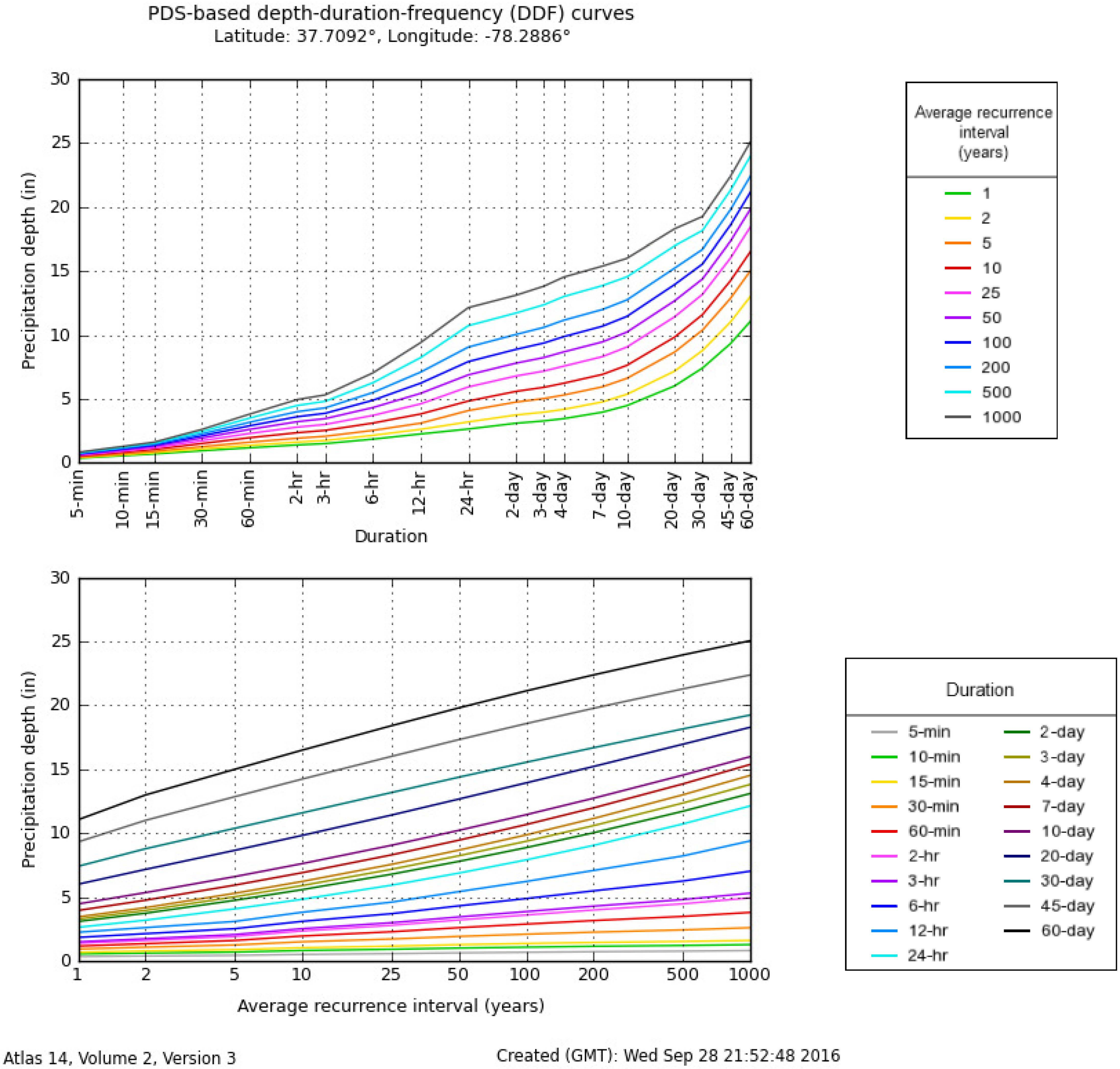
PF graphical



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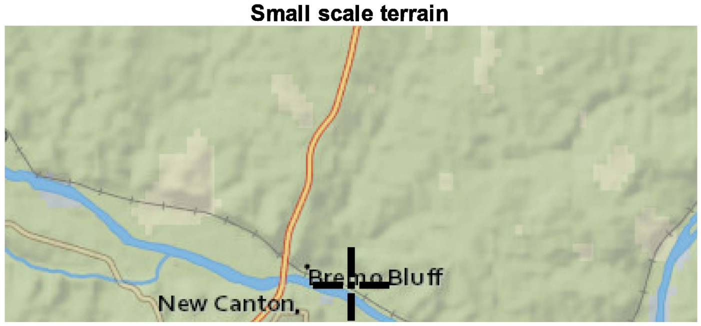
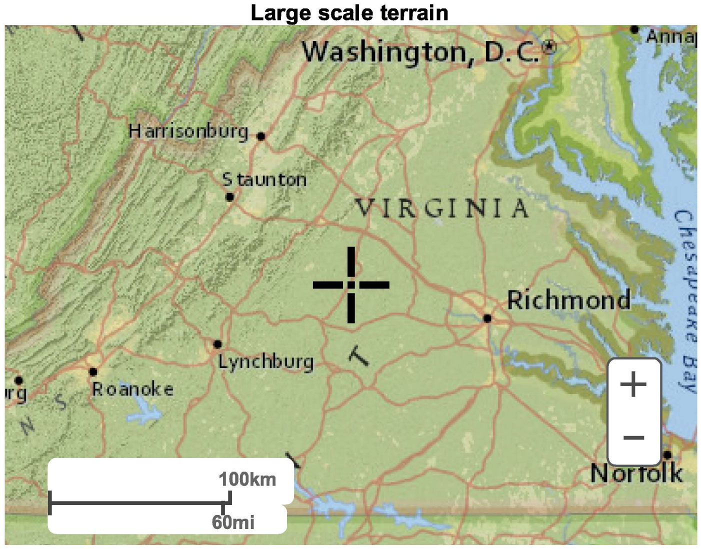
Maps & aerials

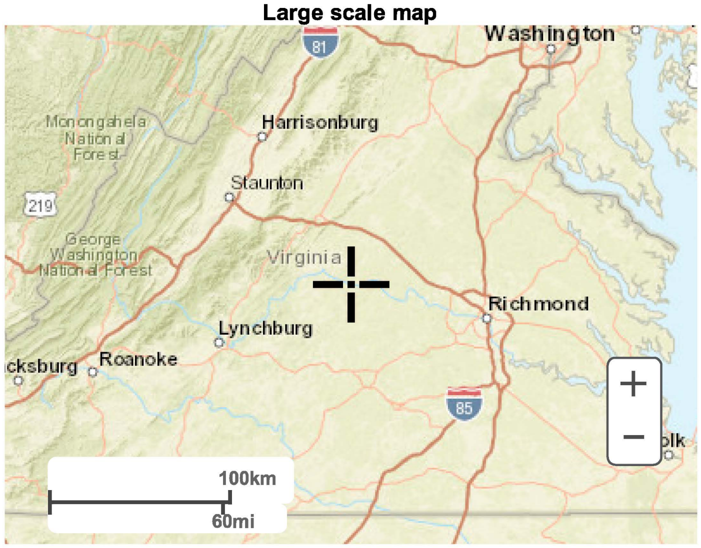
Small scale terrain



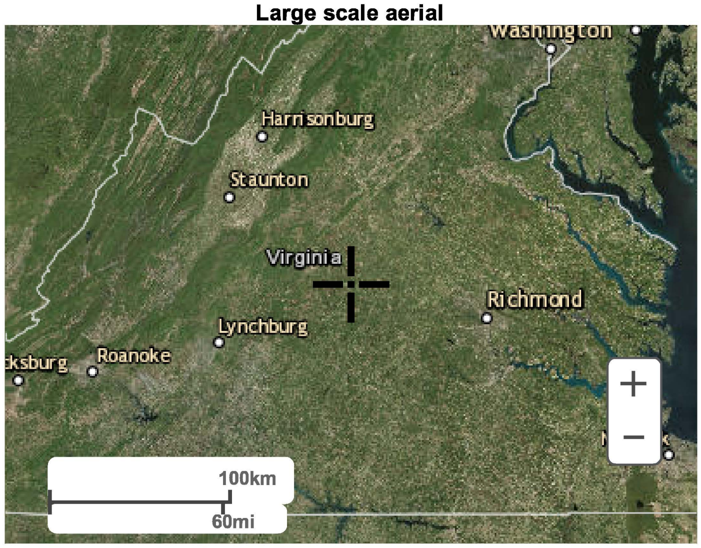
Large scale terrain



Large scale map



Large scale aerial



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US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Appendix B

North Ash Pond Hydraulic Modeling Analysis

CALCULATIONS

Date:	October 13, 2016	**Made by:**	DPM
Project No.:	15-20347	**Checked by:**	KAL
Subject:	North Ash Pond Hydraulic Modeling Analysis	**Reviewed by:**	JRD
Project:	**BREMO POWER STATION**		

The purpose of this evaluation is to verify the design and hydraulic performance of the North Ash Pond (NAP) coal combustion residuals (CCR) surface impoundment in its pre-closure interim state. As required by 40 CFR §257.82, the owner or operator of a CCR impoundment must design, construct, operate, and maintain an inflow design flood control system that:

- Adequately manages flow into the CCR unit during and following the peak discharge of the inflow design flood; and,
- Adequately manages flow from the CCR unit to collect and control the peak discharge resulting from the inflow design flood.

1.0 HYDRAULIC MODEL ANALYSIS

1.1 Drainage Area

The direct drainage area for the NAP is approximately 103 acres. Roughly 56 acres of the drainage area consists of the surface area of the pond, and the remaining acreage consists of small run-on areas south of Bremo Road that are wooded and in good condition. A composite curve number (CN) of 75 was computed for the drainage area. The predominant soil types in the area are Hydrologic Soil Group (HSG) 'B' soils. Attachment 1 shows the extents of the drainage area for the NAP.

1.2 Pond Storage Rating

The pond storage volumes were computed based on August 2016 aerial topographic survey. Volumes were computed as available water storage from the top of the previously impounded CCR at elevation 317 feet above mean sea level (ft amsl) to the top of the embankment at elevation 333 ft amsl. The available volume in the NAP is approximately 180 acre-feet (ac-ft) to the crest of the emergency spillway. Attachment 2 contains the rating table.

1.3 Probable Maximum Precipitation

Probable Maximum Precipitation (PMP) storm rainfall totals for the Bremo Power Station area were computed using the November 2015 "Probable Maximum Precipitation Study for Virginia" PMP Calculation Worksheet. The 6-, 12-, and 24-hour events based on the "local" storm data produced controlling PMP values of 27.0, 30.6, and 30.6 inches, respectively, for the watershed. The PMP worksheet is included as Attachment 3.

1.4 Probable Maximum Flood

Per the Virginia Impounding Structure Regulations, the probable maximum flood (PMF) was calculated for the 6-, 12-, and 24-hour PMP events. The resulting inflow from each event was then routed into the hydrologic model. Table 1 outlines the magnitude of each PMP event as modeled.

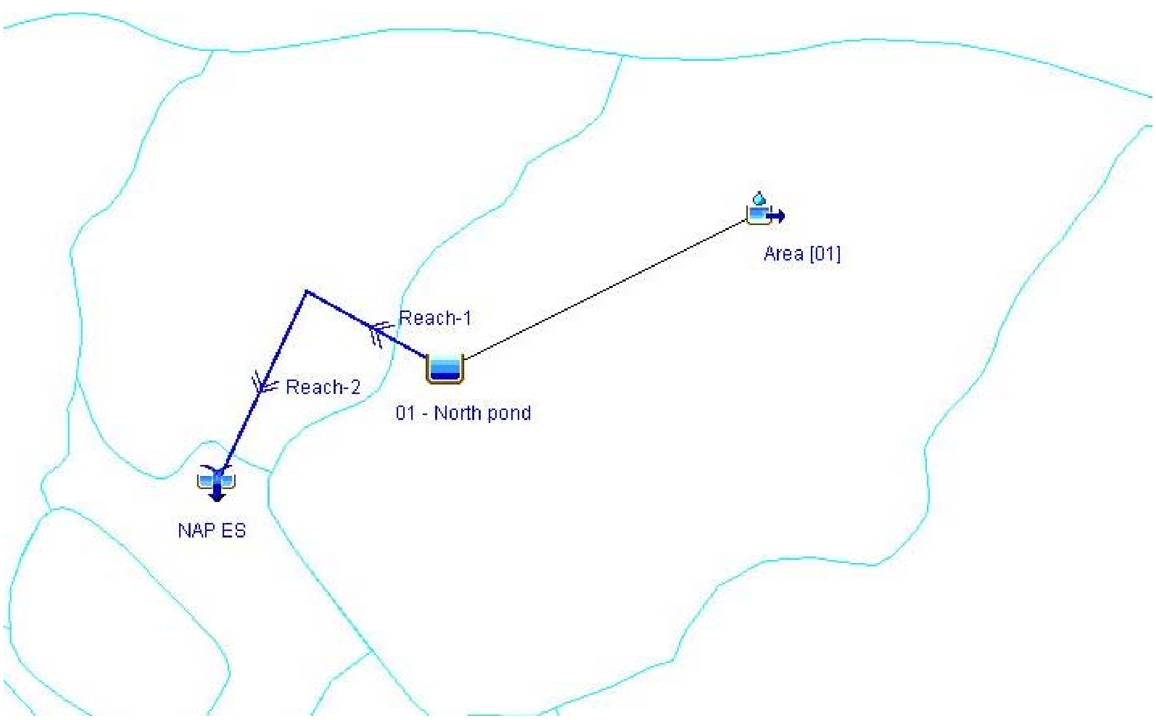
Table 1: Calculated PMF Inflows to NAP

Event	Rainfall, inches (in)	Q_{peak}, cubic feet per second (cfs)	Volume, Ac-ft
6-Hour	27.0	1,459	217.5
12-Hour	30.6	795	248.2
24-Hour	30.6	751	247.5

1.5 Model Input

Analysis of the NAP stormwater system was performed using the U.S. Army Corps of Engineers Hydrologic Engineering Center's Hydraulic Modeling System (HEC-HMS) release 4.1 software package. The NAP's primary spillway, an intake tower and a 24-inch diameter pipe, has been plugged. The emergency spillway is available for discharge should there be a significant enough storm event. Figure 1 illustrates the connectivity of the stormwater elements, as modeled in HEC-HMS.

Figure 1 – North Ash Pond HEC-HMS Model



1.6 Inflow and Outflow Control

The existing emergency spillway is an approximately trapezoidal-shaped, broad-crested spillway that is built into the road surface along the top of the embankment. Its original design crest width of 200 feet has been reduced to a width of approximately 153 feet due to operations and road maintenance over the years. The embankment has an effective depth of 2.6 feet and is surfaced with well-compacted gravel. The spillway capacity was computed from the August 2016 survey. Attachment 4 contains the emergency spillway rating table.

The 6-, 12-, and 24-hour PMP events were modeled to determine the resulting high water elevation and outflow. Two initial pond elevations were considered: a dry pond with a water level elevation of 317.0 ft amsl, and a full pond with a water level elevation of 330.0 ft amsl. The following table summarizes the results of the HEC-HMS analysis.

Table 2: HEC-HMS Results

		Dry Pond Start			Full Pool Start		
PMP Event	**Rainfall, (in)**	**Peak Water Surface Elevation (WSE)**	**Q_{out}**	**Freeboard, feet (ft)**	**Peak WSE**	**Q_{out}**	**Freeboard, ft**
6-Hour	27.0	330.66	71.79	2.34	331.64	729.96	1.36
12-Hour	30.6	330.82	135.32	2.18	331.41	528.85	1.59
24-Hour	30.6	330.80	125.56	2.20	331.38	508.90	1.62

Note: Spillway crest elevation is 330.4 ft amsl, and top of embankment is 333.0 ft amsl.

The emergency spillway adequately conveys the largest PMF flow in both scenarios. At peak flow conditions, the average flow velocity through the spillway is approximately 3.5 feet per second (ft/s). Appendix 7D-6 in the Virginia Department of Transportation (VDOT) Drainage Manual lists a maximum permissible velocity of 4.0 to 6.0 ft/s for a coarse gravel channel lining. The gravel lining of the emergency spillway should not experience significant erosion during a short-term flow event such as the PMF.

2.0 CONCLUSIONS

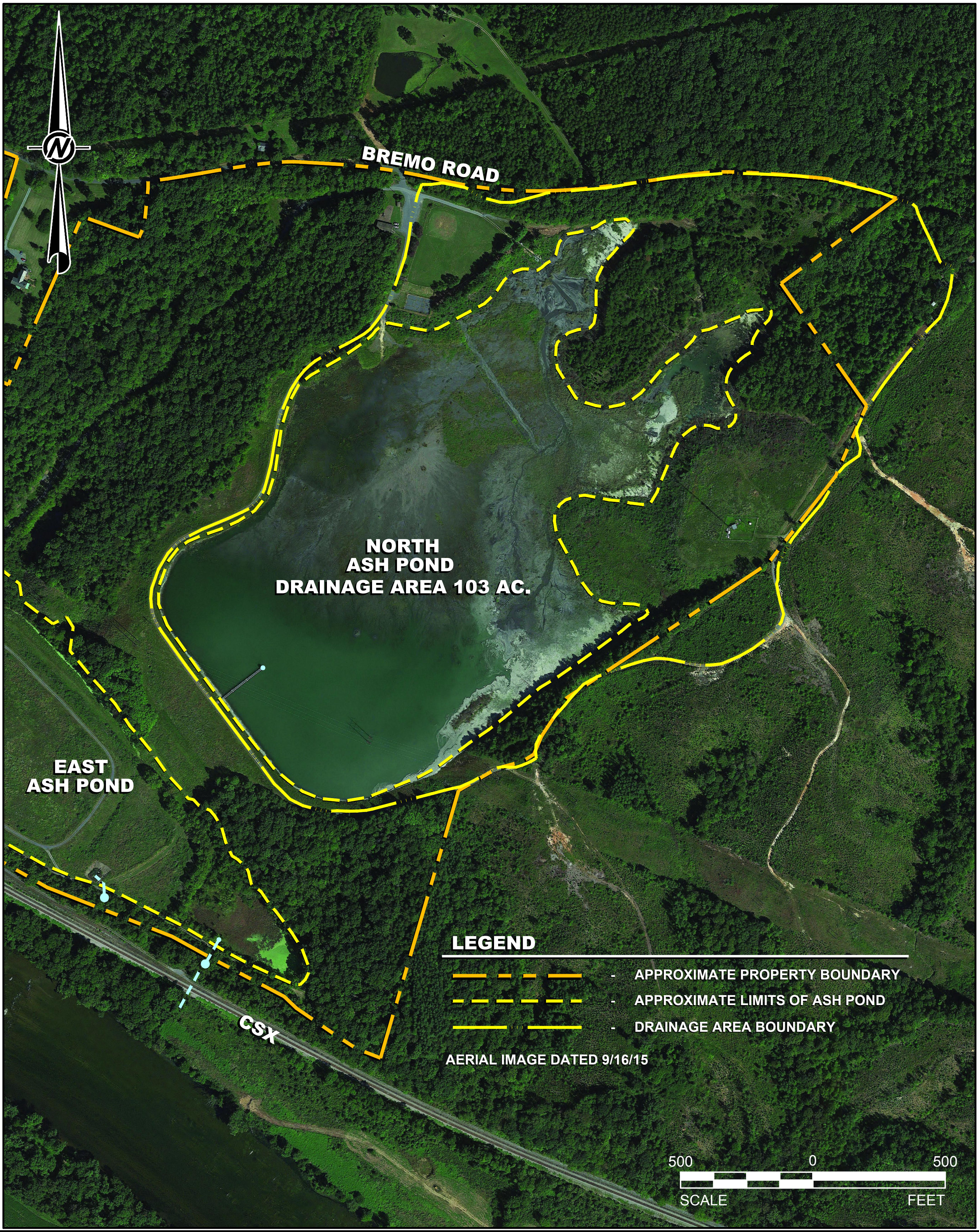
Based on the calculations presented herein, the NAP adequately manages the flow during and following the inflow design flood from the PMF event. The size and capacity of the NAP's emergency spillway is adequate to discharge the runoff from the 6-, 12-, and 24-hour PMP storm events without overtopping the embankment or eroding the spillway.

3.0 ATTACHMENTS

1) North Ash Pond Drainage Area Map
2) North Ash Pond Stage-Storage Table
3) PMP Calculation Worksheet
4) Emergency Spillway Rating Table

Attachment 1

North Ash Pond Drainage Area Map



Golder Associates, Richmond, Virginia	DATE 09/21/16	TITLE	
	DESIGN DPM	**NORTH ASH POND DRAINAGE AREA MAP**	
	CADD DPM		
PROJECT No. 152-0347	CHECK		
SCALE AS SHOWN / REV. 0	REVIEW	**BREMO POWER STATION**	FIGURE 1

Attachment 2

North Ash Pond Stage-Storage Table

Bremo North Pond (8/12/16 Aerial Survey)

Elevation	Area, ft^2	Area, Ac	Volume, Ft^3	Volume, CY	Cumulative CY	Cumulative Ac-ft
333	2,477,161	56.868	2,464,954.5	91,294.6	555,052.2	344.04
332	2,452,773	56.308	2,440,590.9	90,392.3	463,757.6	287.45
331	2,428,434	55.749	2,253,534.1	83,464.2	373,365.4	231.42
330	2,083,052	47.820	1,689,610.6	62,578.2	289,901.1	179.69
329	1,324,660	30.410	1,127,466.9	41,758.0	227,323.0	140.90
328	941,172	21.606	889,598.6	32,948.1	185,564.9	115.02
327	839,005	19.261	783,802.3	29,029.7	152,616.8	94.60
326	729,868	16.755	679,314.6	25,159.8	123,587.1	76.60
325	629,987	14.463	594,776.6	22,028.8	98,427.3	61.01
324	560,249	12.862	534,588.4	19,799.6	76,398.6	47.35
323	509,333	11.693	478,290.2	17,714.5	56,599.0	35.08
322	447,906	10.283	399,939.8	14,812.6	38,884.5	24.10
321	353,821	8.123	301,354.4	11,161.3	24,072.0	14.92
320	251,775	5.780	198,392.3	7,347.9	12,910.7	8.00
319	149,434	3.431	108,058.0	4,002.1	5,562.8	3.45
318	71,427	1.640	42,138.2	1,560.7	1,560.7	0.97
317	18,569	0.426	-	-	-	-

Conic Method for Reservoir Volume:

$$V = \tfrac{1}{3}(EL2 - EL1) * (Area1 + Area2 + \sqrt{Area1 * Area2})$$

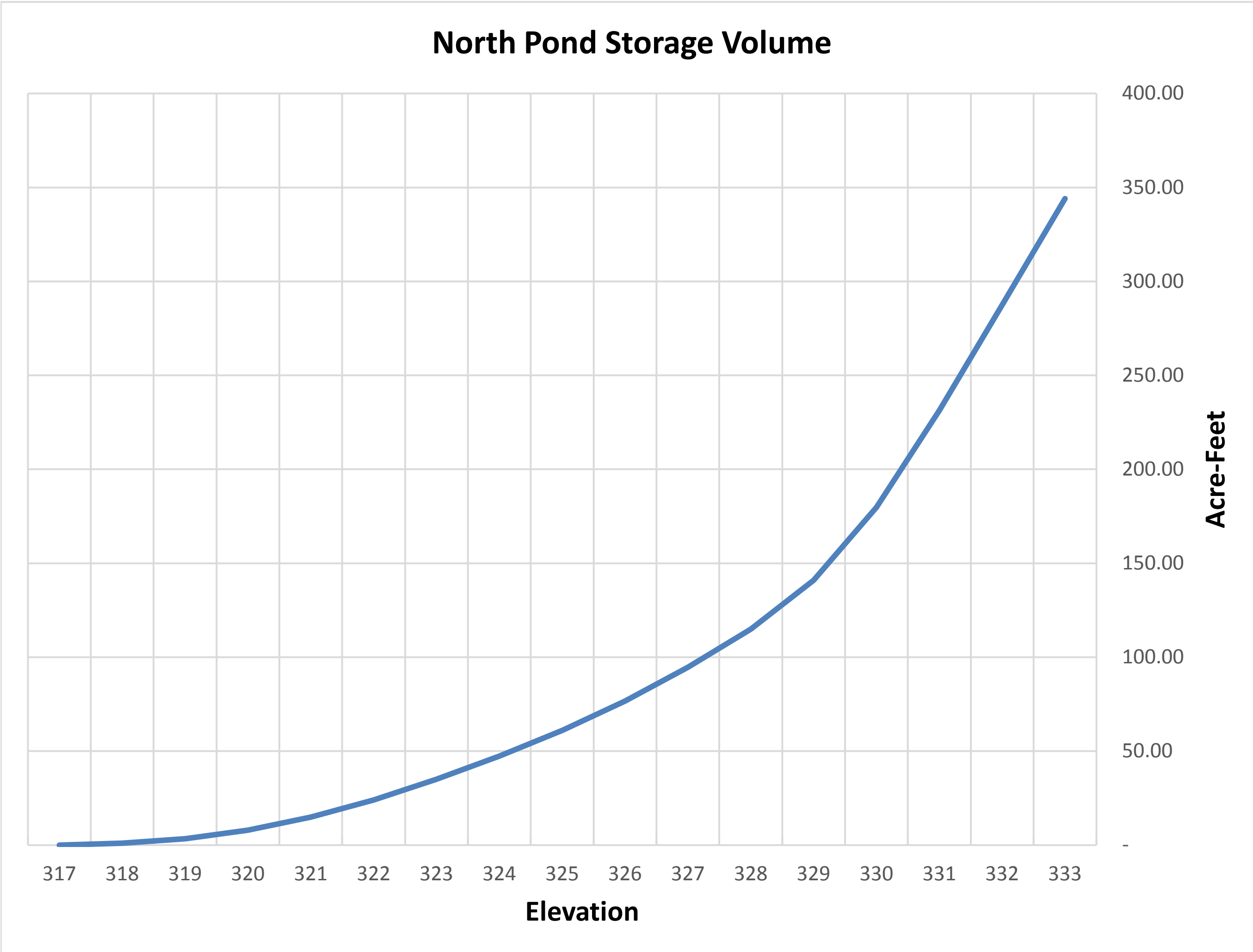
Where: EL2, EL1 = Upper and Lower elevations of the increment
Area2, Area1 = Areas computed for EL2 and EL1, sq. ft.
V = Incremental volume between EL2 and EL1

Area Interpolation:

$$IA = (\sqrt{Area1} + ((Ei - E1)/(E2 - E1) * (\sqrt{Area2} - \sqrt{Area1})))^2$$

Where: E2, E1 = Closest Elevations with known area data
Area2, Area1 = Areas computed for E2 and E1, sq. ft.
Ei = Elevation at which to interpolate the area
IA = Interpolated Area for Ei

Made By: DPM 9/16/16
Checked:
Reviewed:



Made By: DPM 9/16/16
Checked:
Reviewed:

Attachment 3

PMP Calculation Worksheet

Virginia 2015 PMP Calculation Worksheet

Project: Bremo North Ash Pond Dam #06520

Date: 2/16/2016

Agency Golder Associates Inc.

Engineer: Daniel McGrath, P.E.

	User Defined Variable

Drainage Area to Dam

Information obtained from GIS Shapefile / Watershed Boundary Analysis

Drainage Area	103.00	0.161
	Acres	Sq. Miles

General Storm Events

Grid Pts	Point X	Point Y	Zone	6 Hr. PMP	12 Hr. PMP	24 Hr. PMP	Controlling 6 Hr. Storm	Controlling 12 Hr. Storm	Controlling 24 Hr. Storm
1	-78.3	37.9	6	15.6	18.1	19.3	SPAS_1339_1	SPAS_1339_1	SPAS_1201_1
2	-78.55	37.5	6	16	18.6	20.6	SPAS_1339_1	SPAS_1339_1	SPAS_1201_1
3	-78.575	37.675	6	16	18.6	20.8	SPAS_1339_1	SPAS_1339_1	SPAS_1201_1

Average PMP Values:	15.9	18.4	20.2

Local Storm Events

Grid Pts	Point X	Point Y	Zone	6 Hr. PMP	12 Hr. PMP	24 Hr. PMP	Controlling 6 Hr. Storm	Controlling 12 Hr. Storm	Controlling 24 Hr. Storm
1	-78.3	37.9	6	26.1	29.3	29.3	SPAS_1534_1	SPAS_1534_1	SPAS_1534_1
2	-78.55	37.5	6	27.7	31.4	31.4	SPAS_1534_1	SPAS_1534_1	SPAS_1534_1
3	-78.575	37.675	6	27.3	31	31	SPAS_1534_1	SPAS_1534_1	SPAS_1534_1

Average PMP Values:	27.0	30.6	30.6

Tropical Storm Events

Grid Pts	Point X	Point Y	Zone	6 Hr. PMP	12 Hr. PMP	24 Hr. PMP	Controlling 6 Hr. Storm	Controlling 12 Hr. Storm	Controlling 24 Hr. Storm
1	-78.3	37.9	6	17.6	27.6	27.6	SPAS_1491_1	SPAS_1491_1	SPAS_1491_1
2	-78.55	37.5	6	19.5	30	30	SPAS_1491_1	SPAS_1491_1	SPAS_1491_1
3	-78.575	37.675	6	19.9	30.6	30.6	SPAS_1491_1	SPAS_1491_1	SPAS_1491_1

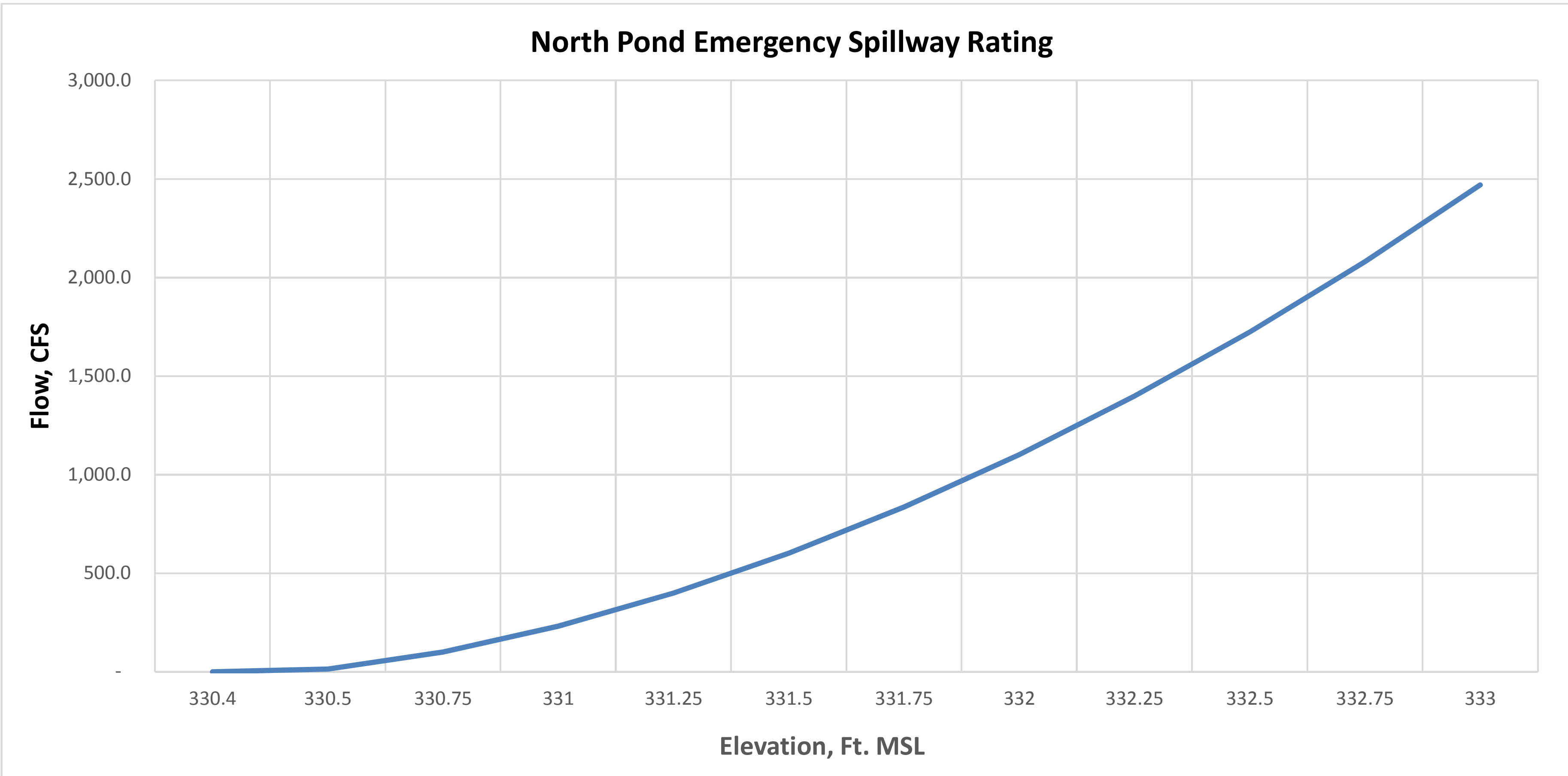
Average PMP Values:	19.0	29.4	29.4

Controlling PMP Values from Storm Events

	6 Hr. PMP	12 Hr. PMP	24 Hr. PMP
Controlling PMP Values for Watershed	**27.0**	**30.6**	**30.6**

Attachment 4

Emergency Spillway Rating Table


North Pond Emergency Spillway Rating
Flow, CFS
3,000.0
2,500.0
2,000.0
1,500.0
1,000.0
500.0
-
330.4
330.5
330.75
331
331.25
331.5
331.75
332
332.25
332.5
332.75
333
Elevation, Ft. MSL