BURNS McDONNELL

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Inflow Design Flood Control System Plan

KANSAS CITY BPU
THE POWER OF COMMUNITY

Kansas City Board of Public Utilities

Nearman Creek Power Station
Project No. 87813

Revision 0
October 17, 2016

Inflow Design Flood Control System Plan

prepared for

Kansas City
Board of Public Utilities
Nearman Creek Power Station
Kansas City, Kansas

Project No. 87813

Revision 0
October 17, 2016

prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

INDEX AND CERTIFICATION

Kansas City
Board of Public Utilities
Inflow Design Flood
Control System Plan
Project No. 87813

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Certification

I hereby certify, as a Professional Engineer in the state of Kansas, that the information in this document was assembled under my direct supervisory control. This report is not intended or represented to be suitable for reuse by the Kansas City Board of Public Utilities or others without specific verification or adaptation by the Engineer.

JASON C. EICHENBERGER LICENSED 20601 KANSAS PROFESSIONAL ENGINEER

This document has been digitally signed and sealed. October 17, 2016

Jason C. Eichenberger, P.E.
Kansas License #20601

Date: 10/17/2016

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LIST OF ABBREVIATIONS

Abbreviation	Term/Phrase/Name
ac	acre
BMcD	Burns & McDonnell
Nearman Creek	Nearman Creek Power Station
CCR	Coal Combustion Residual
CFR	Code of Federal Regulations
cfs	cubic feet per second
KCBPU	Kansas City Board of Public Utilities
CY	cubic yard
ELG	Effluent Limitations Guidelines
EPA	Environmental Protection Agency
ft	feet
GPM	Gallons per Minute
HEC-HMS	Hydrologic Engineering Center's Hydrologic Modeling System
hr	hour
in	inch
MGD	Million Gallons per Day
min	minute
MW	Megawatts
NAD 27	North American Datum of 1927
NGVD 29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration

Abbreviation	Term/Phrase/Name
NRCS	Natural Resources Conservation Service
PFDS	Precipitation Frequency Data Server
RCRA	Resource Conservations and Recovery Act
SCS	Soil Conservation Service
U.S.C.	United States Code
USDA	US Department of Agriculture

1.0 INTRODUCTION

On April 17, 2015, the Environmental Protection Agency (EPA) issued the final version of the federal Coal Combustion Residual (CCR) Rule to regulate the disposal of CCR materials generated at coal-fired units. The rule will be administered as part of the Resource Conservation and Recovery Act [RCRA, 42 United States Code (U.S.C.) §6901 et seq.], using the Subtitle D approach.

The surface impoundment at the Kansas City Board of Public Utilities (KCBPU) Nearman Creek Power Station (Nearman Creek) is subject to the CCR Rule. As such, KCBPU must meet the hydrologic and hydraulic capacity requirements outlined in 40 Code of Federal Regulations (CFR) §257.82. This report serves as the inflow design flood control system plan for the Bottom Ash Pond at Nearman Creek.

This inflow design flood control system plan is in addition to, not in place of, any other applicable site permits, environmental standards, or work safety practices.

2.0 PLAN OBJECTIVES

Per §257.82, the inflow design flood control system plan must contain documentation (including supporting engineering calculations) that the inflow design flood control system has been designed and constructed to:

- Adequately manage flow into the CCR unit during and following the peak discharge of the inflow design flood,
- Adequately manage flow from the CCR unit to collect and control the peak discharge resulting from the inflow design flood, and
- Handle discharge from the CCR surface impoundment in accordance with the surface water requirements described in §257.3-3.

Per §257.82(c)(5), KCBPU must obtain certification from a qualified professional engineer that the inflow design flood control system plan, and subsequent updates to the plan, meet the requirements of §257.82. This sealed document serves as that certification.

3.0 EXISTING CONDITIONS

Nearman Creek is a single, coal-fired unit nameplated at 261 megawatts (MW) located on the south bank of the Missouri River in Wyandotte County, Kansas. The facility operates one CCR surface impoundment, The Bottom Ash Pond, which is used as a settling pond for wet-sluiced bottom ash. The Bottom Ash Pond is hydraulically connected to the adjacent clear water pond via a 24-inch reinforced concrete pipe. The clear water pond is used to store "clean water" which is eventually recycled back to the plant. In this way, the pond system operates in a closed loop.

The two ponds are operated to maintain a normal pool elevation of 758.8 feet, as noted in the Dam Assessment Report prepared by Dewberry & Davis, LLC in April of 2011. Each pond is bounded by earthen dikes which crest at an elevation of 763 feet. A site plan is included in Appendix A.

4.0 DESIGN BASIS

4.1 Hazard Potential Classification

Per 40 CFR §257.73, KCBPU obtained certification from a qualified professional engineer who determined the Nearman Creek Bottom Ash Pond to be a low hazard potential CCR surface impoundment.

4.2 Inflow Design Flood System Criteria

4.2.1 Capacity Criteria

The CCR Rule requires CCR surface impoundments to have adequate hydrologic and hydraulic capacity to manage flows during the inflow design flood. For this analysis, the surface impoundment should be able to accept inflows during the design flood event without overtopping.

4.2.2 Freeboard Criteria

The CCR Rule further discusses that operating freeboard must be adequate to meet performance standards, but a specific freeboard is not defined. For the purposes of this analysis, it was assumed a 2-foot minimum freeboard shall be maintained during the inflow design flood event.

4.2.3 Flood Routing Design Criteria

The inflow design flood for this analysis is a 100-year flood event per §257.82(a)(3)(iii).

4.3 Project Mapping

Project mapping for this analysis consisted of an inventory of stormwater assets that contribute to the surface impoundment. Three primary sources of information were utilized: construction record drawings, plant operational information, and survey data. Construction record drawings of the surface impoundment are included in Appendix B.

4.3.1 Mapping Sources

Survey data utilized included bathymetric and topographic survey retrieved in October of 2010.

4.3.2 Vertical Datum

Mapping sources referenced are in the National Geodetic Vertical Datum of 1929 (NGVD 29).

4.3.3 Horizontal Coordinate System

Survey which was utilized as the basis for mapping and modeling efforts is in the Kansas State Plane North Zone, North American Datum of 1927 (NAD 27) coordinate system.

5.0 HYDROLOGIC AND HYDRAULIC CAPACITY

The United States Army Corps of Engineers Hydrologic Engineering Center developed a Hydrologic Modeling Software (HEC-HMS) which was used to model reservoir characteristics under the design storm event. Inputs to the HEC-HMS model were assumed to be as follows.

5.1 Pond Inflows

5.1.1 Runoff

5.1.1.1 Recurrence Interval and Rainfall Duration

The inflow flood design event for this study, as determined by the low hazard potential classification, is a 100-year flood event. Because a storm duration is not specified under §257.82 or other pertinent inflow flood design sections within the CCR Rule, a 24-hour storm duration was utilized.

5.1.1.2 Rainfall Distribution and Depth

The Soil Conservation Service (SCS) Type II rainfall distribution was used for computations associated with this evaluation. Precipitation data was acquired from the National Oceanic and Atmospheric Administration (NOAA) Precipitation Frequency Data Server (PFDS). Precipitation depth for the inflow design flood event is 8.67 inches.

5.1.1.3 Subbasin Characteristics

Calculations were determined based on the watershed parameters shown in Table 5-1. For the purposes of this analysis, it was assumed that the southwest portion of the Bottom Ash Pond is full of ash (unavailable for runoff storage) over the duration of the storm event period. Refer to Appendix C for more detailed calculations.

Table 5-1: Watershed Runoff Calculated Data for Nearman Creek Bottom Ash Pond

Component	Value	Unit
Watershed Area	17.8	ac
SCS Storm Depth: 100-yr, 24-hr	8.67	in
Weighted Curve Number	94	-
Initial Abstraction	0.128	in
Time of Concentration	14.62	min
Basin Lag Time	8.77	min

5.1.2 Pond Inflows / Outflows

When conducting the hydraulic analysis, it was assumed that the ponds are maintained at the normal operating level (758.8 feet) prior to the start of the storm event. Due to the closed-loop operation of the pond, it was assumed that there would be no net increase in water level within the pond system due to process flows, and therefore process inflows and outflows were not modeled as part of this calculation. All runoff into the pond is considered to be additional flow above the normal operating level.

6.0 RESULTS

The pond was modeled for a 100-year, 24-hour storm event with initial elevation set at normal operating level. While not normally operated in such a manner, it was conservatively assumed that 50% of the Bottom Ash Pond is full up to the top of the dike elevation and this portion of the pond is not available for stormwater storage capacity at the time of the storm event.

Under the assumed conditions, the pond system was able to contain runoff from the 100-year, 24-hour storm with at least 2 feet of freeboard. The results of the modeled storm event are as follows:

Table 6-1: Modeled Pond Design

Component	Property	Value	Unit
Subbasin Watershed	Peak Discharge	150.9	cfs
	Runoff Volume	7.95	in
Reservoir Bottom Ash Pond - 50% full of ash	Initial Elevation	758.8	ft
	Peak Inflow	150.9	cfs
	Peak Discharge	0.0	cfs
	Peak Elevation	760.1	ft
	Peak Storage (above normal operating level)	11.9	ac-ft

After a significant storm event, excess water collected in the Bottom Ash Pond and clear water pond will be pumped back to the plant for reuse, similar to current operations.

7.0 PERIODIC ASSESSMENT AND AMENDMENT

KCBPU must place the initial plan in the CCR Operating Record by October 17, 2016. After the initial plan is published in the Operating Record, periodic inflow design flood control system plans will be required every five years. KCBPU may publish revised plans at shorter intervals, noting the deadline for publishing the next revision will be maintained as five years after the publish date of the previous revision. KCBPU may amend the plan at any time, and is required to do so whenever there is a change in conditions which would affect the current plan. All amendments and revisions must be placed on the CCR publicly accessible internet site. A record of revisions made to this document is included in Section 8.0.

8.0 RECORD OF REVISIONS AND UPDATES

Revision Number	Date	Revisions Made	By Whom
0	10/17/2016	Initial Issue	Burns & McDonnell

APPENDIX A – SITE PLAN AND WATERSHED PARAMETERS

BURNS McDONNELL

date 9/22/2016

designed A. MYERS

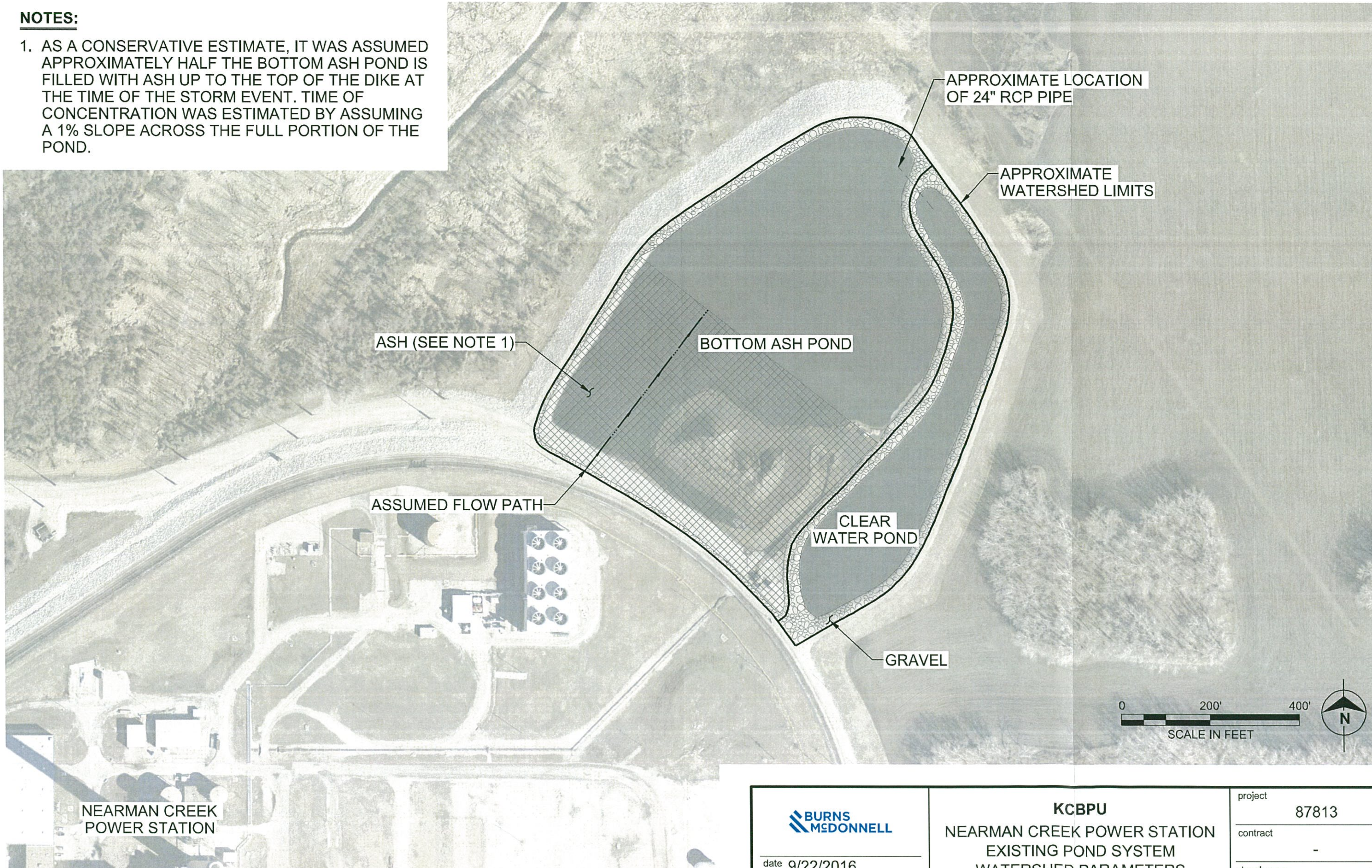
KCBPU

NEARMAN CREEK POWER STATION
EXISTING POND SYSTEM
SITE PLAN

project	87813
contract	-
drawing no.	SK - CIVIL - 001
rev.	0

NOTES:

1. AS A CONSERVATIVE ESTIMATE, IT WAS ASSUMED APPROXIMATELY HALF THE BOTTOM ASH POND IS FILLED WITH ASH UP TO THE TOP OF THE DIKE AT THE TIME OF THE STORM EVENT. TIME OF CONCENTRATION WAS ESTIMATED BY ASSUMING A 1% SLOPE ACROSS THE FULL PORTION OF THE POND.



BURNS McDONNELL	KCBPU NEARMAN CREEK POWER STATION EXISTING POND SYSTEM WATERSHED PARAMETERS	project 87813
date 9/22/2016		contract -
designed A. MYERS		drawing no. SK - CIVIL - 002 rev. 0

APPENDIX B – EXISTING DRAWINGS


47th STREET
EXIST. RIVER ACCESS ROAD
℄ EXIST. RAILROAD
℄ BOTTOM ASH POND DIKE
TOE OF SLOPE
℄ BOTTOM ASH POND INTERIOR DIKE
℄ BOTTOM ASH POND DIKE
EXIST. RIVER ACCESS ROAD
℄ EXIST. RAILROAD
BEGIN PLACEMENT OF RIPRAP AT END OF EXISTING RIPRAP E 2,936,800±
BEGIN PLACEMENT OF RIPRAP AT END OF EXISTING RIPRAP
LEGEND
(ALL DRAWINGS EXCEPT 72-2P-AP-1)
LOCATION OF SOIL BORING
EXISTING CONTOUR
FINISH CONTOUR BY THIS CONTRACT
TOP OF SLOPE
TOE OF SLOPE
EXISTING TOP OF SLOPE (MAY BE DASHED)
EXISTING TOE OF SLOPE
RIPRAP BY THIS CONTRACT
SURFACING BY THIS CONTRACT
SCALE IN FEET
JUL 09 1982
JACK F. DAILY LICENSED 2693 KANSAS PROFESSIONAL ENGINEER
NOTE THIS DRAWING CONFORMS TO CONSTRUCTION RECORDS DATE 12/81
BOARD OF PUBLIC UTILITIES
KANSAS CITY, KANSAS
NEARMAN CREEK POWER STATION
CONTRACT NUMBER 75A
POWER PLANT ASH PONDS
ASH POND GRADING PLAN
LUTZ, DAILY & BRAIN CONSULTING ENGINEERS
P.O. BOX 718 SHAWNEE MISSION, KANSAS 66201
CONFORMED TO CONST. REC. 12-81
REVISED AS INDICATED 1-9-80
REVISED PER ADDENDUM #1 10-75
REV DESCRIPTION
DRAWING NUMBER 72-2P-AP-2
SHEET 3 OF 12

APPENDIX C – ENGINEERING CALCULATIONS

BURNS & McDONNELL

Kansas City Board of Public Utilites
Inflow Design Flood Control System Plan
Nearman Creek - Bottom Ash Pond
BMcD Project Number : 87813

WORKSHEET TITLE:	Inflow Design Flood - Nearman Creek Bottom Ash Pond	CALCULATION NO.:	87813 - C - 001
CREATED:	9/14/2016	REVISION:	0
PERFORMED BY:	A. MYERS	REVIEWED BY:	J. Eichenberger
OBJECTIVE:	Determine capacity of pond to maintain a 100-year, 24-hour storm event using SCS Curve Number Method		

REFERENCES:

1 Lindeburg, M. (2008). Civil engineering reference manual for the PE exam. 11th ed. Belmont, CA: Professional Publications, Inc.

2 US Department of Agriculture. (no date). Custom soils resouces report for Wyandotte County, KS. Retrieved from http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

3 National Oceanic and Atmospheric Administration. (2015). NOAA Atlas 14, Volume 9, Version 2. [Point precipitation frequency estimates for Kansas City, KS, US (39.172379, -94.691958)]. Retrieved from http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ks (copy of data is included in Appendix C)

4 United States. Department of Agriculture. Natural Resources Conservation Service. National Engineering Handbook: Part 630 Hydrology, Chapter 15 Time of Concentration. N.p., n.d. Web. 9 Feb. 2016. Retrieved from http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

SOFTWARE:

1 Bentley® FlowMaster® V8i (SELECTseries 1)

Bentley Systems, Inc
27 Siemon Company Drive Ste 200W
Watertown, CT 06795 USA

Phone: +1-203-755-1666
Fax: +1-203-597-1488
Web: http://www.bentley.com
Contact Technical Support

Registered To:
User Name
Company:
Serial Number
License: Commercial
Is Checked Out: False
Expiration Date

SELECT Server Name: selectserver.bentley.com
Activation Key: VS-E254C09D30C24FFB881E3218676F8
Site ID:

2 **Hydrologic Modeling System (HEC-HMS)**
Version: 4.0 Build: 1542 Date: 31Dec2013 Java: 1.6.0_65

This software is developed primarily to meet the needs of the U.S. Army Corps of Engineers, though we provide a copy free on our website. Funding comes from the Corps' Civil Works Research and Development program and from special projects. To provide feature suggestions, report errors, or request additional information, write to the development team at:

U.S. Army Corps of Engineers
Institute For Water Resources
Hydrologic Engineering Center
609 Second Street
Davis, CA 95616-4620

You can also contact the development team through our website at:

www.hec.usace.army.mil

ASSUMPTIONS:

1 Design storm is 100 years (low hazard classification per 2016 hazard potential classification)
2 Max intensity duration is 5 minutes
3 Soils are generally silty clay loam, Hydrologic Soil Group D — Reference 2
4 Bottom Ash Pond is 50% full of sediment up to the top of dike at the time of the storm event. Initial water level is equal to normal operating level maintained in the pond.
5 Ash modeled as Hydrologic Soil Group C

EQUATIONS:

1	Rational Method	$Q = CIA_d$	Reference 1, p. 20-13, eq. 20.36
2	Sheet Flow Travel Time	$t_{sheet} = 0.007*(nL)^{0.8}/\sqrt{(P_2)}*S_{decimal}^{0.4}$	Reference 1, p. 20-3, eq. 20.6
3	Shallow Flow Travel Time	$t_{shallow} = L/v_{shallow}$	Reference 1, p. 20-3, section 5
4	Velocity of Shallow Flow	$v_{shallow} = 16.1345\sqrt{(S_{decimal})}$	Reference 1, p. 20-3, eq. 20.7, [unpaved]
5	Channel Flow Travel Time	$t_{channel} = L/v_{channel}$	Reference 1, p. 20-3, section 5
6	Time of Concentration	$t_c = t_{sheet} + t_{shallow} + t_{channel}$	Reference 1, p. 20-3, eq. 20.5
7	Lag Time	$t_{lag} = 0.6*t_c$	Reference 1, p.20-11, eq. 20.27
8	Soil Water Storage Capacity	$S = (1000/CN) - 10$	Reference 1, p. 20-19, eq. 20.43
9	Initial Abstraction	$I_a = 0.2*S$	Reference 1, p. 20-15, eq. 20.38

10 Weighted Curve Number

$CN_W = (CN_i*A_i)/A_T$

11 Weighted Rational Runoff Coefficient

$C_W = (C_i*A_i)/A_T$

VARIABLES:

1	Q	peak runoff rate, cfs
2	C	rational runoff coefficient, unitless
3	I	rainfall intensity, in/hr
4	A_d	total drainage area, ac or mi^2
5	t_{sheet}	sheet flow travel time, min
6	n	Manning's roughness coefficient, unitless
7	L	hydraulic length of the watershed, ft
8	P_2	2yr 24hr rainfall, in
9	$S_{decimal}$	slope, ft/ft
10	$t_{shallow}$	shallow concentrated flow travel time, min
11	$V_{shallow}$	shallow velocity, ft/s
12	$t_{channel}$	channel flow travel time, min
13	$V_{channel}$	channel velocity, ft/s
14	t_c	time of concentration, min
15	t_{lag}	lag time, hrs
16	S	soil water storage capacity, in
17	CN	curve number, unitless
18	I_a	initial abstraction, in
19	CN_W	weighted curve number, unitless
20	A_i	total area, ac
21	C_W	weighted rational runoff coefficient, unitless
22	CN_{WT}	total weighted curve number, unitless
23	C_{WT}	weighted rational runoff coefficient, unitless

CALCULATIONS:

1 Establish drainage area

	Pond Area	
A_d (ac)	17.8	Measured in Microstation, see SK-CIVIL-001 in Appendix A.
A_d (mi^2)	0.028	Conversion from ac to mi^2

2 Establish rainfall data (assume SCS Type II distribution)

SCS Storm	Depth (in)	
100yr, 24hr	8.67	Reference 3

3 Establish CN, percent impervious cover, and initial abstraction. Assume antecedent moisture condition (AMC) II - average conditions.

	Pond Area			
Land Description	CN_i*	A_i** (ac)	CN_W	
Gravel	91	2.4	12	Equation 10
Open space, poor condition (ash)	86	6.5	31	Equation 10
Pond	100	8.9	50	Equation 10
A_i (ac)		17.8		Sum
CN_{WT}			94	Sum
S (in)			0.64	Equation 8
I_a (in)			0.128	Equation 9

*Reference 1, Table 20.4, p. 20-17. See Assumptions 3, 4, & 5.

**Measured in Microstation, see SK-CIVIL-002 in Appendix A. Ash area based on Assumption 4.

4 Establish Time of Concentration and Basin Lag time for SCS Unit Hydrograph Transform

Subbasin	Pond Area	
Sheet Flow		
n	0.05	Reference 1, p. 20-3, Table 20.1
L* (ft)	300	Measured in Microstation, see SK-CIVIL-002 in Appendix A
P_2 (in)	3.61	Reference 3, 2yr 24hr rainfall
$S^*_{decimal}$ (ft/ft)	0.01	Measured in Microstation, see SK-CIVIL-002 in Appendix A
t_{sheet} (hrs)	0.20	Equation 2
t_{sheet} (min)	12.17	Conversion from hrs to min
Shallow Flow		
$S^*_{decimal}$ (ft/ft)	0.01	Measured in Microstation, see SK-CIVIL-002 in Appendix A
$V_{shallow}$ (ft/s)	1.00	Reference 4, Figure 15-4
L* (ft)	187	Measured in Microstation, see SK-CIVIL-002 in Appendix A
$t_{shallow}$ (s)	147.0	Equation 3
$t_{shallow}$ (min)	2.45	Conversion from s to min
Time of Concentration		
t_c (min)	14.62	Equation 6 min is 0.1 hr per TR-55
Lag Time		
t_{lag} (min)	8.77	Equation 7

*Measured in Microstation

5 Run HEC-HMS with input parameters: all discharge into ponds (rainfall) is additional flow above normal operating level (EL 758.8).
Elevation-area data for the ponds is as noted below.

EL	Area (ac)		
	Bottom Ash Pond*	Clearwater Pond	Total
758.8	5.7	2.9	8.6
760	6.0	3.1	9.1
762	6.5	3.4	9.9
763	7.0	3.9	10.9

*Measured in Microstation based on pond being 50% full of ash (see Assumption 4)

RESULTS:

Component	Subbasin		Reservoir				
Property	Peak Discharge (cfs)	Runoff Volume (in)	Initial EL*	Peak Inflow (cfs)	Peak Discharge (cfs)	Peak Elevation (ft)	Peak Storage (ac-ft)**
Combined Pond System	150.9	7.95	758.8	150.9	0.0	760.1	11.9

*Assumed based on pump operation info provided by Owner

**Represents storage volume above the initial EL

CONCLUSION:

Under the modeled conditions, the Bottom Ash Pond can accept inflows from the design flood event while still maintaining over 2-feet of freeboard based on a top of dike EL of 763 feet. Excess flow will be evaporated off the pond or pumped back to the plant for reuse.

NOAA Atlas 14, Volume 8, Version 2
Location name: Kansas City, Kansas, US*
Latitude: 39.1740°, Longitude: -94.6918°
Elevation: 757 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	0.397 (0.315-0.504)	0.466 (0.370-0.592)	0.584 (0.462-0.743)	0.686 (0.539-0.875)	0.832 (0.634-1.09)	0.949 (0.706-1.25)	1.07 (0.769-1.44)	1.20 (0.825-1.64)	1.37 (0.909-1.91)	1.51 (0.972-2.11)
10-min	0.581 (0.462-0.738)	0.682 (0.542-0.867)	0.855 (0.676-1.09)	1.00 (0.790-1.28)	1.22 (0.929-1.60)	1.39 (1.03-1.83)	1.57 (1.13-2.10)	1.75 (1.21-2.40)	2.01 (1.33-2.79)	2.21 (1.42-3.10)
15-min	0.708 (0.563-0.899)	0.832 (0.661-1.06)	1.04 (0.825-1.33)	1.22 (0.963-1.56)	1.49 (1.13-1.95)	1.70 (1.26-2.24)	1.91 (1.37-2.56)	2.14 (1.47-2.92)	2.45 (1.62-3.41)	2.70 (1.74-3.78)
30-min	0.998 (0.793-1.27)	1.18 (0.933-1.49)	1.48 (1.17-1.88)	1.74 (1.37-2.22)	2.11 (1.61-2.77)	2.42 (1.80-3.19)	2.73 (1.96-3.66)	3.06 (2.11-4.18)	3.52 (2.33-4.89)	3.88 (2.49-5.42)
60-min	1.31 (1.04-1.66)	1.55 (1.23-1.97)	1.97 (1.56-2.51)	2.34 (1.84-2.98)	2.86 (2.18-3.75)	3.28 (2.44-4.33)	3.71 (2.67-4.98)	4.17 (2.87-5.69)	4.80 (3.18-6.67)	5.30 (3.41-7.41)
2-hr	1.61 (1.29-2.04)	1.93 (1.54-2.44)	2.47 (1.97-3.12)	2.94 (2.33-3.72)	3.60 (2.77-4.69)	4.14 (3.10-5.43)	4.70 (3.40-6.25)	5.28 (3.67-7.15)	6.08 (4.06-8.39)	6.71 (4.36-9.32)
3-hr	1.82 (1.46-2.28)	2.19 (1.76-2.75)	2.82 (2.25-3.54)	3.36 (2.67-4.23)	4.14 (3.19-5.36)	4.76 (3.58-6.21)	5.41 (3.93-7.17)	6.09 (4.25-8.21)	7.02 (4.71-9.63)	7.75 (5.06-10.7)
6-hr	2.19 (1.77-2.73)	2.65 (2.14-3.29)	3.42 (2.76-4.26)	4.09 (3.27-5.11)	5.05 (3.92-6.49)	5.82 (4.41-7.53)	6.62 (4.85-8.70)	7.46 (5.25-9.98)	8.61 (5.83-11.7)	9.52 (6.26-13.0)
12-hr	2.60 (2.12-3.21)	3.12 (2.54-3.85)	4.01 (3.25-4.96)	4.78 (3.86-5.93)	5.90 (4.62-7.52)	6.80 (5.20-8.73)	7.73 (5.72-10.1)	8.72 (6.19-11.6)	10.1 (6.88-13.6)	11.1 (7.40-15.2)
24-hr	3.04 (2.50-3.72)	3.61 (2.96-4.42)	4.58 (3.74-5.61)	5.42 (4.40-6.66)	6.64 (5.25-8.41)	7.63 (5.89-9.73)	8.67 (6.46-11.2)	9.76 (6.99-12.9)	11.3 (7.77-15.1)	12.5 (8.36-16.8)
2-day	3.54 (2.92-4.29)	4.12 (3.40-5.00)	5.13 (4.21-6.23)	6.00 (4.91-7.32)	7.28 (5.79-9.13)	8.31 (6.46-10.5)	9.39 (7.06-12.1)	10.5 (7.62-13.8)	12.1 (8.44-16.1)	13.4 (9.06-17.9)
3-day	3.89 (3.23-4.70)	4.47 (3.71-5.40)	5.47 (4.52-6.62)	6.35 (5.22-7.70)	7.63 (6.11-9.53)	8.68 (6.78-10.9)	9.77 (7.39-12.5)	10.9 (7.94-14.2)	12.5 (8.78-16.6)	13.8 (9.41-18.4)
4-day	4.19 (3.49-5.04)	4.77 (3.96-5.74)	5.77 (4.78-6.95)	6.65 (5.48-8.04)	7.93 (6.37-9.86)	8.98 (7.04-11.2)	10.1 (7.64-12.8)	11.2 (8.19-14.6)	12.8 (9.03-17.0)	14.1 (9.66-18.8)
7-day	4.96 (4.15-5.93)	5.57 (4.66-6.65)	6.61 (5.50-7.91)	7.51 (6.22-9.01)	8.81 (7.11-10.9)	9.87 (7.78-12.3)	11.0 (8.37-13.8)	12.1 (8.90-15.6)	13.7 (9.71-18.0)	15.0 (10.3-19.8)
10-day	5.63 (4.73-6.69)	6.30 (5.29-7.50)	7.44 (6.23-8.87)	8.42 (7.00-10.1)	9.81 (7.93-12.0)	10.9 (8.63-13.5)	12.1 (9.23-15.1)	13.2 (9.76-16.9)	14.9 (10.6-19.4)	16.1 (11.2-21.2)
20-day	7.48 (6.33-8.82)	8.46 (7.15-9.97)	10.0 (8.46-11.9)	11.3 (9.52-13.4)	13.1 (10.7-15.9)	14.5 (11.5-17.7)	15.9 (12.2-19.7)	17.2 (12.8-21.8)	19.1 (13.6-24.5)	20.4 (14.3-26.6)
30-day	9.05 (7.69-10.6)	10.3 (8.71-12.0)	12.2 (10.3-14.3)	13.7 (11.6-16.2)	15.8 (12.9-19.0)	17.4 (13.9-21.0)	18.9 (14.6-23.3)	20.4 (15.2-25.6)	22.3 (16.0-28.5)	23.7 (16.7-30.8)
45-day	11.1 (9.47-12.9)	12.5 (10.7-14.6)	14.8 (12.6-17.3)	16.6 (14.0-19.4)	18.9 (15.4-22.5)	20.6 (16.5-24.8)	22.3 (17.3-27.2)	23.8 (17.8-29.7)	25.8 (18.6-32.8)	27.1 (19.2-35.1)
60-day	12.9 (11.0-15.0)	14.5 (12.4-16.8)	16.9 (14.4-19.7)	18.9 (16.0-22.0)	21.3 (17.4-25.2)	23.1 (18.5-27.6)	24.8 (19.3-30.1)	26.3 (19.7-32.6)	28.2 (20.4-35.6)	29.5 (20.9-37.9)

[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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