Report

Inflow Design Flood Control System Plan James DeYoung Power Plant Holland, Michigan

Holland Board of Public Works
Holland, MI

October 17, 2016
NTH Project No. 73-160017-01

NTH Consultants, Ltd.
41780 Six Mile Road
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INTRODUCTION

The Holland Board of Public Works (BPW) owns and operates the James DeYoung (JDY) plant located in Holland, Michigan, on the eastern end of Lake Macatawa. JDY was initially built in 1939 with a generating capacity of 15 MW; between 1953 and 1968, three new boilers were added. Since the late 1970's, the plant has consisted of three coal-fired boilers capable of producing up to 62.5 MW (Unit 3 is 11.5 MW; Unit 4 is 22 MW; and Unit 5 is 29 MW). BPW has discontinued the use of Unit 3, and coal is no longer utilized in Units 4 and 5 as of May 20, 2016. Units 4 and 5 are now operating only on natural gas.

BPW historically sluiced bottom ash from these boiler units with water to three incised surface impoundments located to the south of the plant throughout operations of the plant when Units 3-5 were operating on coal. Sluice water moved in series through each of three connected surface impoundments to allow solids to settle, into a weir and box structure for flow control, and to a site storm water conveyance network of manholes and pipes, eventually discharging to Lake Macatawa via an outfall with other site storm water effluent authorized under a National Pollution Discharge Elimination System (NPDES) permit. An overall site plan is included as Figure 1

These surface impoundments are considered CCR units and regulated under the recently promulgated rules regulating ash disposal from coal-fired power plants (40 CFR Part 257). In June 2016, BPW initiated removal of CCR material from the CCR units and closure of the CCR units will be completed in accordance with 40 CFR 257.101. Therefore, due to the closure of the plant, the ponds are being analyzed only for the stormwater inflow when there is a design flood event, since process flow operations have ceased.

While BPW has ceased use of the CCR units, NTH Consultants, Ltd. (NTH), in conjunction with our partner, Engineering & Environmental Solutions, LLC (EES), along with personnel from BPW, has completed an Inflow Design Flood Control System plan consistent with the requirements contained in 40 CFR 257.82 for the CCR surface impoundments at the JDY plant. This plan details the hydraulic and hydrologic capacity of the CCR impoundments and downstream hydraulic structures. The intent of the plan is to ensure that the CCR impoundment system has the capacity to manage the specified design flood event, referred to as the “inflow design flood”. The inflow design flood event for this analysis is the 25-year flood event as required in 40 CFR 257.82(a)(3)(iv) as the ash pond system at JDY is considered an incised surface impoundment..

Regulatory Basis

This Inflow Design Flood Control System plan demonstrates and documents the hydrologic and hydraulic capacity and performance capacity of the CCR surface impoundments in accordance with 40 CFR Part 257.82. Specifically, this plan details how the CCR surface impoundments collect and control the peak discharge from a 25-year flood event in accordance with 40 CFR 257.82(a)(3)(iv). The plan also includes:

- Characterization of the design storm, catchment area, run-on and run-off routing models;
- Characterization of the intake, decant, and spillway structures and their capacity;
- Characterization of the downstream hydraulic structures which receive the discharge from the CCR surface impoundments; and
- Supporting engineering calculations and analysis results.

MODELING OF CCR IMPOUNDMENT SYSTEM

NTH evaluated the CCR surface impoundment system using the Autodesk® Storm and Sanitary Analysis 2017 computer modeling software. We used this software to develop runoff hydrographs, or temporal flow distribution models, for the watersheds contributing to the system, as well as to route the inflow hydrographs through the CCR surface impoundment and conveyance structures.

Methodology

NTH and EES conducted several investigative activities in order to compile the data necessary for input into the model, including:

- Performed a site visit to meet with BPW personnel and observe the existing system conditions;
- Reviewed historic site information and drawings provided by Holland BPW; and
- Developed ground surface topographical information. Prior to the topographical survey, the ponds were partially dredged so that EES could obtain topographic information on the bottom of the ponds to allow for accurate capacity calculations (see Figure 2 for the detailed survey information).

NTH performed the analysis using design precipitation data adopted from the National Oceanic Atmospheric Administration (NOAA) Atlas 14, Volume 8, Version 2 (2013). We evaluated the CCR surface impoundment system for a 25-year flood event and utilized the Rational Method to calculate the storm water runoff generated from each of the sub-watersheds. The Rational Method determines the peak discharge rate from each sub-watershed based on the following equation:

$$\mathbf{Q = CiA}$$

Where:

Q = Peak discharge rate (cubic feet per second (CFS))

C = Runoff coefficient (Table 1)

i = Rainfall intensity from IDF curves based on design storm return period and Tc (in/hr)

A = Sub-watershed drainage area (Acres)

We divided the CCR surface impoundment system into sub-watersheds based on existing ground topography to determine the contributing runoff amount for each pond and the downstream conveyance system which ultimately receives the discharge from the impoundments. We determined the contributing area, time of concentration, and runoff coefficient for each watershed area. These input parameters are used to determine both the amount and intensity of runoff generated in each watershed during the design storm and the overall amount of runoff collected and conveyed by the storm water system (see Figure 3 for depiction of drainage areas).

The time of concentration (Tc) is the time required for the entire sub-watershed to contribute runoff to the system and is dependent on flow path, slope, and ground type. In general, Tc for each sub-area was very small due to the small nature of the watersheds. Based on state-of-the-practice engineering standards, we utilized a minimum Tc of 15 minutes for each sub-watershed, which is the minimum amount of time used in a typical analysis, even though the actual flow time may be much less. The model was allowed to run for a 2-hour duration to allow enough time for all of the storm water runoff from the design storm to contribute to the CCR impoundment and the downstream structures.

The runoff coefficient (C) is a function of land use and ground condition. We adopted runoff coefficients from our past experience and generally-acceptable industry standards. The runoff coefficients used for this study are summarized in Table 1.

Table 1: Runoff Coefficients

Ground Type	Runoff Coefficient (C)
Grass	**0.30**
Pavements/Parking Lots	**0.90**
Compacted Gravel Covered Areas	**0.85**

We selected the hydrodynamic routing method in Storm and Sanitary Analysis software program due to its sophistication and because it produces the most theoretically accurate results. It solves the one-dimensional Saint-Venant flow equations, which consist of continuity and momentum equations for pipes and a volume continuity equation at the storage nodes and junctions. This routing method can represent pressurized flows when the piping becomes full and can model the amount of flooding in storage nodes and junctions.

Figure 3 depicts the CCR system and contributing drainage areas based on the results of our field survey and investigation, and review of historical site information. Refer to the model output results in the attachments for additional input information.

Model Input Assumptions

NTH utilized information obtained from topographic surveys, historical information, and field investigations to build the model of the CCR impoundment and conveyance network. When available, we used items such as pipe/manhole diameter, inverts, material of construction, and inlet/cover type to accurately model the conveyance network.

As the plant no longer operates on coal, process water is neither produced nor discharged into the basins from the plant; the only contributing flow into the ponds are the result of storm water inflows from sub-watershed contributions during rainfall events.

To develop a complete system model, reasonable assumptions for some of the input parameters were made, due to absence of detailed information from historical documents for many components of the system. In general, these assumptions related to piping length, orientation of the impoundment discharge, and watershed topographic information that could not be confirmed during the field investigation or review of historical information provided by BPW.

While every attempt was made to accurately model the existing system, assumptions introduce unknown parameters into the model. If any of these assumptions are incorrect, the results of the model will be impacted. Should actual conditions vary from the assumptions utilized in the model, the predicted model results, and subsequent recommendations to correct any deficiencies identified, may be impacted. Given this fact, it is expected that the model for the CCR impoundment and conveyance structures depicts the most conservative anticipated conditions during the modeled flood event.

Existing System Components

There are three CCR surface impoundments at the JDY plant, Ash Ponds 1, 2, and 3. The ponds consist of excavated side slopes of 2H:1V inclination without a compacted soil liner (according to topographic survey information and soil borings performed on-site). Storm water sheet flows into each pond and the ponds are connected with 24-inch diameter overflow culverts. We estimated the capacity of each pond based on an analysis of the topographic survey information provided by EES. The capacity of each pond and associated peak flow is summarized in Table 2.

Table 2: Capacity and Peak Flow for JDY Ash Pond System

Pond	Capacity (gal)	Peak Flow (cfs)
Pond 1	407,000	2.95
Pond 2	203,330	1.30
Pond 2	260,300	3.23

The Coal Pile Runoff (CPRO) ditch, which collects storm water from surrounding areas of the adjacent coal pile, is manually pumped into Pond 1, as necessary. Since this operation is manually controlled by site personnel, for this analysis NTH has assumed that the contributing storm water from the CPRO area is not pumped into the pond system during the 25-year storm event, but is reasonably assumed to be pumped into Pond 1 after the peak storm event has passed through the ponds.

Pond 3 discharges through a 6-inch orifice into a sheet pile-lined weir box structure on the south side of the pond. The box structure flows into a 24-inch pipe that is located beneath the coal pile area. The pipe is routed to a below-grade junction structure where it combines with other on-site stormwater from different areas of the facility prior to discharge through Outfall 1 and to Lake Macatawa. Based on a review of historical drawings provided by BPW, additional storm water flow from different areas of the facility includes a portion of the power plant roof drainage as well as runoff from portions of the facility's access drive/parking areas. Also, given the location of the outfall pipe in relation to Lake Macatawa water surface elevation, the outfall pipe is in a completely submerged condition (i.e. the water surface elevation exceeds the crown of the pipe). This was assumed as the outfall boundary condition in the model.

Model Output

The model produces output from the pond watersheds that includes inflow, outflow, peak outflow rate, and total runoff inflow/outflow volumes. The model also provides output from the CCR impoundment and conveyance structures including peak flow rates/velocities, maximum hydraulic grade lines, flow depths, and flooding/surcharged structures. To determine where system deficiencies exist, the results were analyzed for:

1. Locations where the modeled water surface elevation exceeded the rim/ground surface elevation at the ponds, ditches, and manholes (i.e. Flooding);
2. Locations were the modeled water surface exceeded the crown of the pipes within the manholes (i.e. Surcharging); or
3. Locations where the anticipated flow in a conveyance structure was greater than its design capacity (i.e. flow is > capacity).

While items noted as surcharging or below capacity identify a system deficiency, this does not necessarily warrant upgrades or improvements. These system deficiencies show that the system is still operating, but as a pressure flow system instead of a gravity flow system. If no flooding is observed, the flow is still contained within the conveyance system, and the model calculates theoretically accurate downstream and upstream system results based on the operating condition of these components.

Analysis of Design Flood Event –Existing Conditions

The modeled results show that the CCR surface impoundments conveyance system at the JDY is operating as a pressure flow system. During the 25-year flood event, the depth of the water within Pond 1 rises 0.12 feet above minimum water elevation in the pond (outlet pipe invert at elevation 585.17 feet), which still provides approximately 1.9 feet of freeboard to the top elevation of the pond, more than the industry standard. The water level in Pond 2 rises 0.12 above minimum water elevation of the pond (elevation 584.22), which provides 1.8 feet of freeboard in the pond, more than the industry standard. Pond 3's water level rises 0.16 feet above minimum water elevation in the pond (elevation 582.85) providing 1.4 feet of freeboard in the pond, more than the industry standard. The 6-inch orifice has a maximum calculated capacity of 1.8 cfs (see Orifice Capacity Calculation for details).

Historically, the basins have performed well according to JDY Plant personnel. There is an adequate amount of freeboard in the basins to account for a reasonable level of unforeseen incidents in the event additional flow into or restricted flow downstream of the basins occurs. JDY Plant staff also inspects the CCR surface impoundment system weekly and after significant rain or storm events to remediate any observed issues as soon as practical.

The model output result file provides additional information regarding the output and results. Refer to Figure 3 for additional information on the existing CCR surface impoundment components.

CONCLUSIONS

NTH has prepared this inflow design flood control system plan to demonstrate and document the hydrologic and hydraulic capacity and performance requirements for the CCR surface impoundments of the JDY Plant in accordance with 40 CFR 257.82.

The existing CCR surface impoundment system at JDY currently conveys only stormwater contributing to each basin. The overall hydraulic system comprises the three CCR surface impoundments, outfall orifice/weir box, and downstream conveyance piping and structures.

Our analysis indicates that there are no current deficiencies for the CCR surface impoundments or downstream conveyance structures at the JDY that warrant upgrades or improvements to the CCR surface impoundments or downstream conveyance structures.

STATEMENT OF CERTIFICATION

I, David R. Lutz and Blaine A. Litteral, Professional Engineers licensed in the State of Michigan, certify[1] that NTH Consultants, Ltd. and Engineering & Environmental Solutions, LLC, have reviewed available historical information, conducted a field visit, and performed engineering and hydraulic/hydrologic analysis, modeling, and calculations on the inflow design flood control system for the CCR surface impoundments at the Holland Board of Public Works, James DeYoung Power Plant, located in Holland, Michigan. To the best of my knowledge and belief, the analysis and documentation presented in this report for the CCR surface impoundments at the aforementioned facility is accurate and has been developed in substantial conformance with the requirements stipulated in 40 CFR Part 257.82.

STATE OF MICHIGAN
DAVID R. LUTZ
ENGINEER
No. 57487
LICENSED PROFESSIONAL ENGINEER

10/17/16

David R. Lutz, P.E.
State of Michigan Professional Engineer
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BLAINE A. LITTERAL
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10/17/16

Blaine A. Litteral, P.E.
State of Michigan Professional Engineer
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([1]) I am rendering my professional opinion based on the information available to me at the time of this report writing. This certification does not comprise a guarantee or warranty that certain conditions exist, nor does it relieve any other party of their requirements to abide by all applicable local, state, and federal regulations, and to honor all express or customary guarantees and warranties associated with their work.

ATTACHMENTS

- Figure 1: Overall Site Plan
- Figure 2: Topographic Survey
- Figure 3: Existing System Component Plan
- Orifice Capacity Calculation
- Time of Concentration Calculation
- Autodesk Storm and Sanitary Analysis Model Outputs

REFERENCE DOCUMENTS

- Storm Water Site Map

ATTACHMENTS

- FIGURE 1: OVERALL SITE PLAN
- FIGURE 2: TOPOGRAPHIC SURVEY
- FIGURE 3: EXISTING SYSTEM COMPONENT PLAN
- ORIFICE CAPACITY CALCULATION
- TIME OF CONCENTRATION CALCULATION
- AUTODESK STORM AND SANITARY ANALYSIS MODEL OUTPUTS

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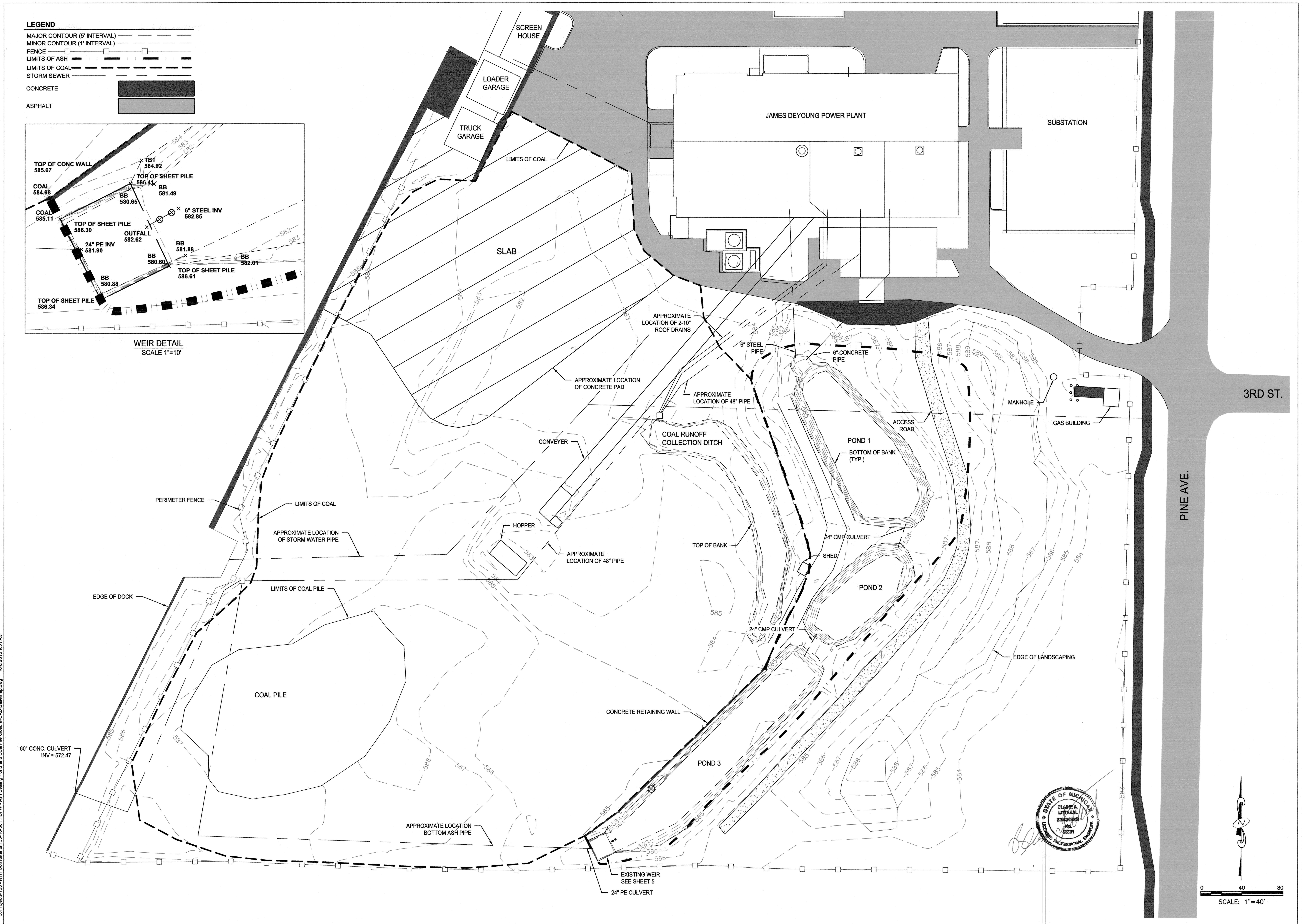
NTH PROJECT No.: 62-160017	CAD FILE NAME: 160017-JDY	NTH Consultants, Ltd. Infrastructure Engineering and Environmental Services	SITE LOCATION PLAN	FIGURE: 1
DESIGNED BY: SLG	PLOT DATE: 10/4/2016		JAMES DEYOUNG POWER PLANT HOLLAND, MI	
DRAWN BY: SLG	DRAWING SCALE: 1" = 200'			
CHECKED BY: DRL	INCEPTION DATE: 9/7/2016			



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BOTTOM ASH POND INVESTIGATION
HOLLAND BOARD OF PUBLIC WORKS
SECTION 30 T. 5 N., R. 15 W., CITY OF HOLLAND, OTTAWA COUNTY
64 PINE AVE.
HOLLAND, MICHIGAN

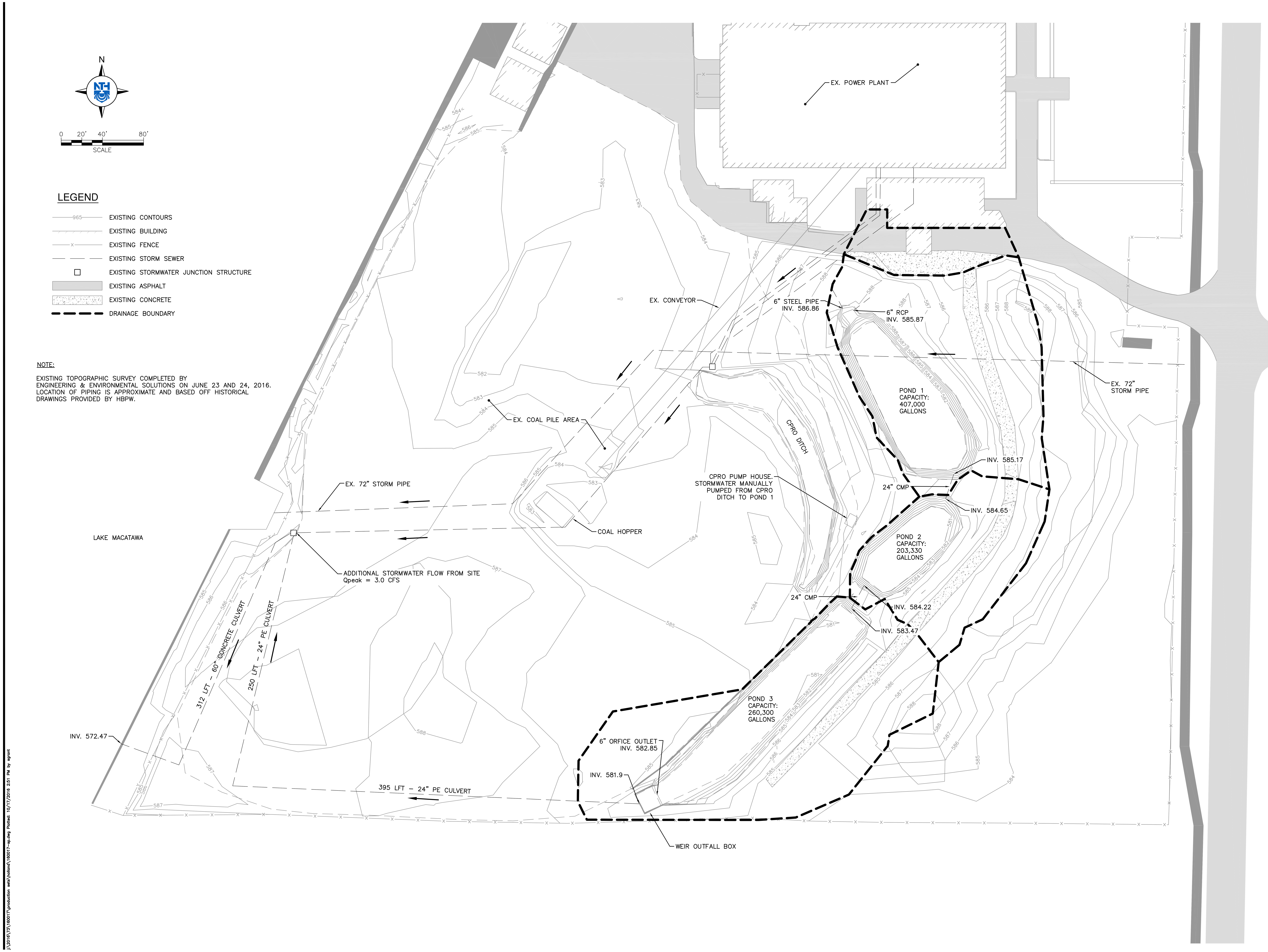
MARK	DATE	DESCRIPTION

DESIGNED BY:	--
DRAWN BY:	AM
CHECKED BY:	BL
PROJECT NO:	133-16-001
SHEET TITLE	

EXSITING CONDITIONS

FIGURE 2

S:\Projects\133 - NTH Consultants\133-16-001 HBPW - Ash Settling Pond and Coal Pile Closure\CAD\Basemap.dwg 10/6/2016 9:51 AM



NTH Consultants, Ltd.

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SUBMITTAL

REV	DESCRIPTION	DATE	BY

PROJECT NAME:

HOLLAND BPW
JAMES DEYOUNG
POWER PLANT

PROJECT LOCATION:

JAMES DEYOUNG
POWER PLANT
HOLLAND, MICHIGAN

NTH PROJECT NO.: 62-160047	CAD FILE NAME: 160017-SP
DESIGNED BY: SLG	INCEP DATE: 9/7/2016
DRAWN BY: SLG	DRAWING SCALE: 1" = 40'
CHECKED BY: DRL	SUBMITTED DATE: 10/17/2016

SHEET TITLE:

JAMES DEYOUNG
POWER PLANT
BOTTOM ASH BASIN

EXISTING SYSTEM
COMPONENT PLAN

SHEET REFERENCE NUMBER:

3

NTH Consultants, Ltd.

Infrastructure Engineering
and Environmental Services

Job	Holland BPW H/H Analysis	Project No.	73-160017	Sheet No.	1
Subject	Orifice Capacity	By	SLG	Date	10/11/16
		Checked By	KDD	Date	10/11/16

Orifice Capacity for Holland BPW CCR Impoundment

$$V = C_v\sqrt{2gh}$$

$C_d = 0.98 \rightarrow$ sharp-edged orifice (coefficient of velocity)

h = pond max elev − orifice centerline $= 584.44 - 583.1$

$= 1.34$ ft

$$V = 0.98 \cdot \sqrt{2 \cdot 32.2\ \text{ft/s}^2 \cdot 1.34\ \text{ft}}$$

$$V = 9.1\ \text{ft/s}$$

$$Q = VA = 9.1\ \frac{\text{ft}}{\text{s}} \cdot \pi (0.25\ \text{ft})^2$$

$$\boxed{Q = 1.8\ \text{cfs}}$$

Holland BPW James DeYoung Power Plant
Drainage Areas
73-160017

L = distance in feet
S = slope in %
T = time of travel in hours = L / (V * 3600)
V=0.48*sqrt(S)-Sheet Flow<300'
V=2.1*sqrt(S)-Channel Flow

Area #	Overland Flow		Channel Flow	Tc (hrs.)	**Tc (min.)**
Pond 1	L (ft)	49			
	S (%)	8.00			
	V (ft/s)	1.36			
	T (hrs)	0.010		0.010	**0.6**
	L (ft)	16			
	S (%)	0.60			
	V (ft/s)	0.37			
	T (hrs)	0.012		0.012	**0.7**
	L (ft)	67			
	S (%)	2.00			
	V (ft/s)	0.68			
	T (hrs)	0.027		0.027	**1.6**
	L (ft)	12			
	S (%)	0.30			
	V (ft/s)	0.26			
	T (hrs)	0.013		0.013	**0.8**
			Tc		**3.7**
Pond 2	L (ft)	32.00			
	S (%)	7.60			
	V (ft/s)	1.32			
	T (hrs)	0.007		0.007	**0.4**
	L (ft)	66.00			
	S (%)	0.90			
	V (ft/s)	0.46			
	T (hrs)	0.040		0.040	**2.4**
	L (ft)	44.00			
	S (%)	0.01			
	V (ft/s)	0.05			
	T (hrs)	0.255		0.255	**15.3**
			Tc		**18.1**
Pond 3	L (ft)	72.00			
	S (%)	1.60			
	V (ft/s)	0.61			
	T (hrs)	0.033		0.033	**2.0**
	L (ft)	22.00			
	S (%)	0.01			
	V (ft/s)	0.05			
	T (hrs)	0.127		0.127	**7.6**
	L (ft)	8.00			
	S (%)	4.90			
	V (ft/s)	1.06			
	T (hrs)	0.002		0.002	**0.1**
			Tc		**9.7**

```
Autodesk® Storm and Sanitary Analysis 2016 - Version 11.1.55 (Build 1)
-----------------------------------------------------------------------------------------

*******************
Project Description
*******************
File Name ................. Holland Ash Ponds.SPF


****************
Analysis Options
****************
Flow Units ................ cfs
Subbasin Hydrograph Method. Rational
Time of Concentration...... SCS TR-55
Return Period.............. 25 years
Link Routing Method ....... Hydrodynamic
Storage Node Exfiltration.. None
Starting Date ............. AUG-23-2016 00:00:00
Ending Date ............... AUG-23-2016 02:00:00
Report Time Step .......... 00:00:10


*************
Element Count
*************
Number of subbasins ....... 4
Number of nodes ........... 6
Number of links ........... 5


****************
Subbasin Summary
****************
Subbasin                 Total
                          Area
ID                         ft²
------------------------------
Sub-01                43893.01
Sub-02                20530.53
Sub-03                44720.87
Sub-04                  402.49


************
```

Node Summary
****

Node ID	Element Type	Invert Elevation ft	Maximum Elev. ft	Ponded Area ft²	External Inflow
Jun-1	JUNCTION	572.59	586.42	0.00	Yes
Outfall-1	OUTFALL	572.47	577.47	0.00	
Pond-1	STORAGE	581.37	587.22	0.00	
Pond-2	STORAGE	580.26	586.14	0.00	
Pond-3	STORAGE	580.50	584.44	0.00	
Pond-4	STORAGE	580.50	585.00	0.00	

****
Link Summary
****

Link ID	From Node	To Node	Element Type	Length ft	Slope %	Manning's Roughness
Link-1	Pond-1	Pond-2	CONDUIT	25.0	2.0817	0.0130
Link-2	Pond-2	Pond-3	CONDUIT	25.2	2.9774	0.0130
Link-3	Pond-4	Jun-1	CONDUIT	645.0	0.1240	0.0130
Link-4	Jun-1	Outfall-1	CONDUIT	312.4	0.0384	0.0130
Orifice-1	Pond-3	Pond-4	ORIFICE			

****
Cross Section Summary
****

Link ID	Shape	Depth/ Diameter ft	Width ft	No. of Barrels	Cross Sectional Area ft²	Full Flow Hydraulic Radius ft	Design Flow Capacity cfs
Link-1	CIRCULAR	2.00	2.00	1	3.14	0.50	32.64
Link-2	CIRCULAR	2.00	2.00	1	3.14	0.50	39.04
Link-3	CIRCULAR	2.00	2.00	1	3.14	0.50	7.97
Link-4	CIRCULAR	5.00	5.00	1	19.63	1.25	51.04

****
Runoff Quantity Continuity
****

	Volume acre-ft	Depth inches
Total Precipitation	0.256	1.223
Continuity Error (%)	0.384	

Flow Routing Continuity	Volume acre-ft	Volume Mgallons
External Inflow	0.496	0.162
External Outflow	0.502	0.164
Initial Stored Volume	3.770	1.229
Final Stored Volume	3.921	1.278
Continuity Error (%)	0.000	

Runoff Coefficient Computations Report

Subbasin Sub-01

Soil/Surface Description	Area (ft²)	Soil Group	Runoff Coeff.
Grass	21467.81	-	0.30
Pavement/pondarea	22425.21	-	0.90
Composite Area & Weighted Runoff Coeff.	43893.01		0.61

Subbasin Sub-02

Soil/Surface Description	Area (ft²)	Soil Group	Runoff Coeff.
Grass	11088.59	-	0.30
Pond	9441.94	-	0.90
Composite Area & Weighted Runoff Coeff.	20530.53		0.58

Subbasin Sub-03

Soil/Surface Description	Area (ft²)	Soil Group	Runoff Coeff.
Grass	18899.87	-	0.30
Pond	25821.00	-	0.90
Composite Area & Weighted Runoff Coeff.	44720.87		0.65

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Subbasin Sub-04
------------------
                                                          Area          Soil       Runoff
Soil/Surface Description                                  (ft²)         Group      Coeff.
-----------------------------------------------------------------------------------------
-                                                        402.49           -          0.90
Composite Area & Weighted Runoff Coeff.                  402.49                      0.90


***************************************************
SCS TR-55 Time of Concentration Computations Report
***************************************************

Sheet Flow Equation
-------------------

        Tc = (0.007 * ((n * Lf)^0.8)) / ((P^0.5) * (Sf^0.4))

        Where:

        Tc = Time of Concentration (hrs)
        n  = Manning's Roughness
        Lf = Flow Length (ft)
        P  = 2 yr, 24 hr Rainfall (inches)
        Sf = Slope (ft/ft)

Shallow Concentrated Flow Equation
----------------------------------

        V  = 16.1345 * (Sf^0.5) (unpaved surface)
        V  = 20.3282 * (Sf^0.5) (paved surface)
        V  = 15.0 * (Sf^0.5) (grassed waterway surface)
        V  = 10.0 * (Sf^0.5) (nearly bare & untilled surface)
        V  = 9.0 * (Sf^0.5) (cultivated straight rows surface)
        V  = 7.0 * (Sf^0.5) (short grass pasture surface)
        V  = 5.0 * (Sf^0.5) (woodland surface)
        V  = 2.5 * (Sf^0.5) (forest w/heavy litter surface)
        Tc = (Lf / V) / (3600 sec/hr)

        Where:

        Tc = Time of Concentration (hrs)
        Lf = Flow Length (ft)
        V  = Velocity (ft/sec)
        Sf = Slope (ft/ft)
```

```
Channel Flow Equation
---------------------

        V  = (1.49 * (R^(2/3)) * (Sf^0.5)) / n
        R  = Aq / Wp
        Tc = (Lf / V) / (3600 sec/hr)

        Where:

        Tc = Time of Concentration (hrs)
        Lf = Flow Length (ft)
        R  = Hydraulic Radius (ft)
        Aq = Flow Area (ft²)
        Wp = Wetted Perimeter (ft)
        V  = Velocity (ft/sec)
        Sf = Slope (ft/ft)
        n  = Manning's Roughness

------------------
Subbasin Sub-01
------------------

        User-Defined TOC override (minutes):      3.70

------------------
Subbasin Sub-02
------------------

        User-Defined TOC override (minutes):     18.10

------------------
Subbasin Sub-03
------------------

        User-Defined TOC override (minutes):      9.70

------------------
Subbasin Sub-04
------------------

        User-Defined TOC override (minutes):      0.00

***********************
Subbasin Runoff Summary
***********************
```

Subbasin ID	Accumulated Precip in	Rainfall Intensity in/hr	Total Runoff in	Peak Runoff cfs	Weighted Runoff Coeff	Time of Concentration days hh:mm:ss
Sub-01	1.20	4.80	0.73	2.95	0.610	0 00:15:00
Sub-02	1.32	4.37	0.77	1.20	0.580	0 00:18:06
Sub-03	1.20	4.80	0.78	3.20	0.650	0 00:15:00
Sub-04	1.20	4.80	1.08	0.04	0.900	0 00:15:00

****
Node Depth Summary
****

Node ID	Average Depth Attained ft	Maximum Depth Attained ft	Maximum HGL Attained ft	Time of Max Occurrence days	Time of Max Occurrence hh:mm	Total Flooded Volume acre-in	Total Time Flooded minutes	Retention Time hh:mm:ss
Jun-1	4.91	5.03	577.62	0	00:00	0	0	0:00:00
Outfall-1	5.03	5.03	577.50	0	00:00	0	0	0:00:00
Pond-1	3.89	3.92	585.29	0	00:29	0	0	0:00:00
Pond-2	4.05	4.08	584.34	0	00:35	0	0	0:00:00
Pond-3	2.48	2.51	583.01	0	02:00	0	0	0:00:00
Pond-4	1.52	1.59	582.09	0	02:00	0	0	0:00:00

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Node Flow Summary
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Node ID	Element Type	Maximum Lateral Inflow cfs	Peak Inflow cfs	Time of Peak Inflow Occurrence days	Time of Peak Inflow Occurrence hh:mm	Maximum Flooding Overflow cfs	Time of Peak Flooding Occurrence days	Time of Peak Flooding Occurrence hh:mm
Jun-1	JUNCTION	3.00	3.08	0	02:00	0.00		
Outfall-1	OUTFALL	0.00	5.93	0	00:00	0.00		
Pond-1	STORAGE	2.95	2.95	0	00:15	0.00		
Pond-2	STORAGE	1.19	1.30	0	00:18	0.00		
Pond-3	STORAGE	3.20	3.23	0	00:15	0.00		

Pond-4	STORAGE	0.04	0.09	0 02:00	0.00

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Storage Node Summary
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Storage Node ID	Maximum Ponded Volume 1000 ft³	Maximum Ponded Volume (%)	Time of Max Ponded Volume days hh:mm	Average Ponded Volume 1000 ft³	Average Ponded Volume (%)	Maximum Storage Node Outflow cfs	Maximum Exfiltration Rate cfm	Time of Max. Exfiltration Rate hh:mm:ss	Total Exfiltrated Volume 1000 ft³
Pond-1	74.434	66	0 00:29	73.796	65	0.21	0.00	0:00:00	0.000
Pond-2	43.678	70	0 00:35	43.378	70	0.24	0.00	0:00:00	0.000
Pond-3	46.741	62	0 02:00	45.998	61	0.09	0.00	0:00:00	0.000
Pond-4	0.837	28	0 02:00	0.788	26	0.08	0.00	0:00:00	0.000

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Outfall Loading Summary
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Outfall Node ID	Flow Frequency (%)	Average Flow cfs	Peak Inflow cfs
Outfall-1	100.00	3.04	5.93
System	100.00	3.04	5.93

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Link Flow Summary
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Link ID	Element Type	Time of Peak Flow Occurrence days hh:mm	Maximum Velocity Attained ft/sec	Length Factor	Peak Flow during Analysis cfs	Design Flow Capacity cfs	Ratio of Maximum /Design Flow	Ratio of Maximum Flow Depth	Total Time Surcharged minutes	Reported Condition
Link-1	CONDUIT	0 00:29	2.76	1.00	0.21	32.64	0.01	0.06	0	Calculated
Link-2	CONDUIT	0 00:35	3.28	1.00	0.24	39.04	0.01	0.06	0	Calculated
Link-3	CONDUIT	0 02:00	0.83	1.00	0.08	7.97	0.01	0.07	0	Calculated

Link-4	CONDUIT	0	00:00	0.30	1.00	5.93	51.04	0.12	1.00	1	SURCHARGED
Orifice-1	ORIFICE	0	02:00			0.09			0.32		

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Highest Flow Instability Indexes
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Link Link-4 (2)

Analysis began on: Tue Oct 04 21:00:37 2016
Analysis ended on: Tue Oct 04 21:00:37 2016
Total elapsed time: < 1 sec