Inflow Design Flood Control System Plan

D.E. KARN GENERATING FACILITY

BOTTOM ASH POND INFLOW DESIGN FLOOD CONTROL SYSTEM PLAN

Essexville, Michigan

Pursuant to 40 CFR 257.82

Submitted To: Consumers Energy Company
1945 W. Parnall Road
Jackson, Michigan 49201

Submitted By: Golder Associates Inc.
15851 South US 27, Suite 50
Lansing, Michigan 48906

October 2016 **1655284**

Golder Associates

CERTIFICATION

Professional Engineer Certification Statement [40 CFR 257.82(c)]

I hereby certify that, having reviewed the attached documentation and being familiar with the provisions of Title 40 of the Code of Federal Regulations Section 257.82 (40 CFR Part 257.82), I attest that this Inflow Design Flood Control System Plan is accurate and has been prepared in accordance with good engineering practices, including the consideration of applicable industry standards, and with the requirements of 40 CFR Part 257.82.

Golder Associates Inc.

Signature

October 14, 2016

Date of Report Certification

John D. Puls, PE

Name

6201055787

Professional Engineer Certification Number

STATE OF MICHIGAN
JOHN D. PULS
ENGINEER
No.
6201055778
10-14-16
LICENSED PROFESSIONAL ENGINEER

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1.0 INTRODUCTION

1.1 Background

D.E. Karn Generating Facility (DE Karn) is a coal-fired power generation facility located near Essexville, Michigan as presented on Figure 1 – Site Location Map. Bottom ash is sluiced from the DE Karn Unit 1&2 electrical generating units to the Bottom Ash Pond. An elevated trestle and pipe system hydraulically conveys bottom ash to the pond system. Stored bottom ash is removed via mechanical equipment from the ponds as required to maintain storage capacity on a yearly basis. Water is discharged from the ponds via one 24-inch diameter steel pipe into an internal ditch that conveys the flow to the permitted National Pollutant Discharge Elimination System (NPDES) outfall as provided on Figure 2 - Site Plan.

1.2 Purpose

The purpose of the Inflow Design Flood Control System Plan (Plan) is to provide a basis for the certification required by 40 CFR 257.82 Hydrologic and Hydraulic Capacity Requirements for Coal Combustion Residual (CCR) Surface Impoundments. The Bottom Ash Pond has been rated a low hazard potential as determined under 40 CFR 257.73(a)(2). 40 CFR 257.82(a) requires the owner or operator of the low hazard potential CCR surface impoundment to design, construct, operate, and maintain an inflow design flood control system as follows:

- Adequately manage the flow into the CCR unit during and following the peak discharge of the inflow of the 100-year flood event
- Adequately manage the flow from the CCR unit to collect and control the peak discharge resulting from the 100-year flood event
- Handle discharge from the CCR unit in accordance with the surface water requirements under 40 CFR 257.3-3

2.0 FLOOD CONTROL SYSTEM

To meet the requirements of 40 CFR 257.82(a), the flood control system must provide flood protection to the CCR unit during the inflow design flood (100-year event) for two cases: 1) floodwater from outside the unit from the Saginaw River and from Saginaw Bay, and 2) controlling internal water levels within the unit.

2.1 External Floodwater Protection

The Bottom Ash Pond is surrounded by a perimeter berm that provides external flood water protection. Based on borings completed in 2016, the berm is generally constructed of sand and CCR.

A publicly available 100-year flood elevation for Saginaw Bay has been determined by Federal Emergency Management Agency (FEMA). Based on FEMA Firm Map Numbers 26017C0239E, both Saginaw River and Saginaw Bay have 100-year flood elevations of 585.00 feet (NAVD88) as provided in Appendix A – FEMA Flood Elevation and Lake Huron Normal Elevation. The lowest elevation along the perimeter berm is 598.17 feet (NAVD88), which allows for 13.17 feet of freeboard during the 100-year flood event. Therefore, the Saginaw Bay and Saginaw River should not to be an inflow source to the Bottom Ash Pond.

2.2 Internal Flood Control

The only inflow other than process water will be precipitation directly falling on the Bottom Ash Pond and surrounding drainage areas from a 100-year 24-hour storm event of 5.99 inches, as provided in Appendix B - Rainfall Data. The discharge structure in the perimeter berm includes one 24-inch steel pipe. Table 2.2.1 below provides a summary of the outflow structures as surveyed in June 2016.

Table 2.2.1 - Discharge Structure Summary

Discharge Structure	Type	Size (Inches)	Length (Feet)	Upstream Invert (NAVD88)	Downstream Invert (NAVD88)	Slope (%)
Bottom Ash Pond	Steel	24	60	591.60	591.00	1.00

Table 2.2.2 below provides a storm flow summary that indicates that the Bottom Ash Pond is contained with 4.20 feet of freeboard and a peak discharge rate of 17.07 cubic feet per second (cfs) during the design storm event (100-year 24-hour). The modeled results indicate that:

- The inflow design flood control system adequately manages flow from the CCR unit to collect and control the peak discharge resulting from the inflow design flood (100-year 24-hour storm event)

The hydrologic and hydraulic model output is provided in Appendix C - Hydrologic and Hydraulic Model Output. It should be noted that the pond elevations presented in Table 2.2.2 were used to assess the maximum storage pool loading condition pursuant to 40 CFR 257.73(e)(1)(i).

Table 2.2.2 – Storm Flow Data

Area	Perimeter Berm Elevation (NAVD 88)	Pond Elevation 100-year,24-hour (NAVD 88)	Peak Outflow (cfs)
Bottom Ash Pond	598.17	593.97	17.07

3.0 PLAN REVISION AND RECORDKEEPING

Per 40 CFR 257.82(c)(2); "The owner or operator of the CCR unit may amend the written inflow design flood control system plan at any time provided the revised plan is placed in the facility's operating record as required by Section 257.105(g)(4). The owner or operator must amend the written inflow design flood control system plan whenever there is a change in conditions that would substantially affect the written plan in effect."

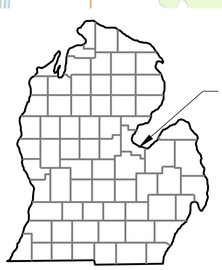
Per 40 CFR 257.82(c)(4); "The owner or operator must prepare periodic inflow design flood control system plans required by paragraph (c)(1) of this section every five years. The date of completing the initial plan is the basis for establishing the deadline to complete the first periodic plan. The owner or operator may complete any required plan prior to the required deadline provided the owner or operator places the completed plan into the facility's operating record within a reasonable amount of time. In all cases, the deadline for completing a subsequent plan is based on the date of completing the previous plan. For purposes of this paragraph (c)(4), the owner or operator has completed an inflow design flood control system plan when the plan has been placed in the facility's operating record as required by Section 257.105(g)(4)."

4.0 REFERENCES

FEMA (Federal Emergency Management Agency). 2010. Flood Insurance Study, Bay County, Michigan. Effective September 17, 2010. Flood Insurance Study Number 26017CV000A.

USEPA (US Environmental Protection Agency). 2015. Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule. 40 CFR Part 257. Effective Date October 19, 2015.

FIGURES



MICHIGAN COUNTIES
NOT TO SCALE

REFERENCE(S)
BASE MAP TAKEN FROM USGS 7.5 MINUTE QUADRANGLE
BAY CITY NE, MICHIGAN
DATED 2014

0 1000 2000 3000
SCALE FEET

CLIENT
CONSUMERS ENERGY COMPANY
2742 NORTH WEADOCK HIGHWAY
ESSEXVILLE, MI. 48732

PROJECT
D.E. KARN UNITS #1 AND #2
BOTTOM ASH POND

CONSULTANT

Golder Associates

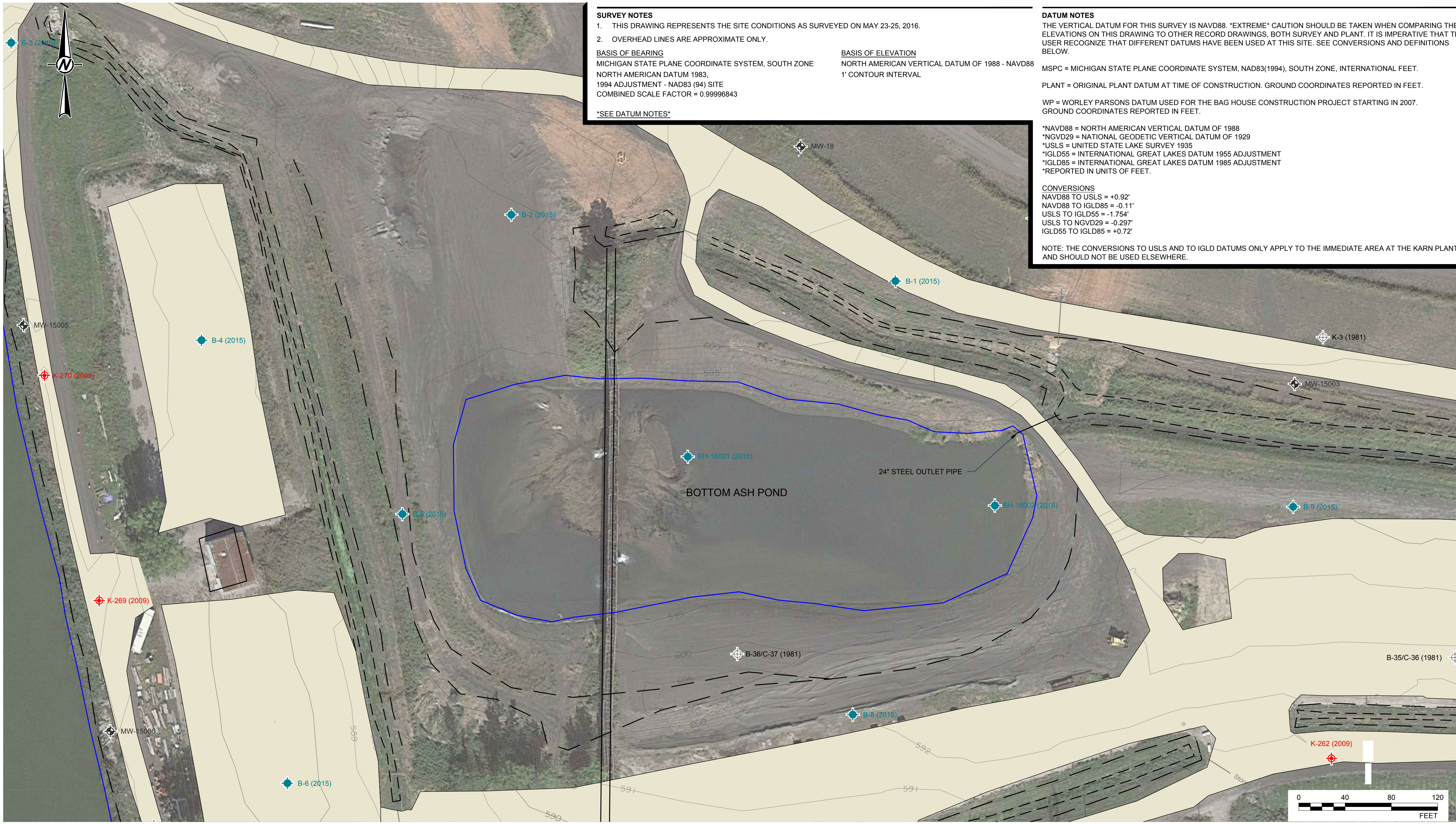
YYYY-MM-DD	2016-08-22
DESIGNED	MAL
PREPARED	MAL
REVIEWED	JRP
APPROVED	MAB

TITLE
SITE LOCATION MAP

PROJECT NO.	REV.	FIGURE
1655284	0	1

Path: \\sacramento\acad\Sites_Work for Other Offices\Karn & Weadock\PRODUCTION\ | File Name: 1655284_Karn Location Map.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
1 in
0



SURVEY NOTES

1. THIS DRAWING REPRESENTS THE SITE CONDITIONS AS SURVEYED ON MAY 23-25, 2016.
2. OVERHEAD LINES ARE APPROXIMATE ONLY.

BASIS OF BEARING
MICHIGAN STATE PLANE COORDINATE SYSTEM, SOUTH ZONE
NORTH AMERICAN DATUM 1983,
1994 ADJUSTMENT - NAD83 (94) SITE
COMBINED SCALE FACTOR = 0.99996843

BASIS OF ELEVATION
NORTH AMERICAN VERTICAL DATUM OF 1988 - NAVD88
1' CONTOUR INTERVAL

SEE DATUM NOTES

DATUM NOTES

THE VERTICAL DATUM FOR THIS SURVEY IS NAVD88. *EXTREME* CAUTION SHOULD BE TAKEN WHEN COMPARING THE ELEVATIONS ON THIS DRAWING TO OTHER RECORD DRAWINGS, BOTH SURVEY AND PLANT. IT IS IMPERATIVE THAT THE USER RECOGNIZE THAT DIFFERENT DATUMS HAVE BEEN USED AT THIS SITE. SEE CONVERSIONS AND DEFINITIONS BELOW.

MSPC = MICHIGAN STATE PLANE COORDINATE SYSTEM, NAD83(1994), SOUTH ZONE, INTERNATIONAL FEET.

PLANT = ORIGINAL PLANT DATUM AT TIME OF CONSTRUCTION. GROUND COORDINATES REPORTED IN FEET.

WP = WORLEY PARSONS DATUM USED FOR THE BAG HOUSE CONSTRUCTION PROJECT STARTING IN 2007. GROUND COORDINATES REPORTED IN FEET.

*NAVD88 = NORTH AMERICAN VERTICAL DATUM OF 1988
*NGVD29 = NATIONAL GEODETIC VERTICAL DATUM OF 1929
*USLS = UNITED STATE LAKE SURVEY 1935
*IGLD55 = INTERNATIONAL GREAT LAKES DATUM 1955 ADJUSTMENT
*IGLD85 = INTERNATIONAL GREAT LAKES DATUM 1985 ADJUSTMENT
*REPORTED IN UNITS OF FEET.

CONVERSIONS
NAVD88 TO USLS = +0.92'
NAVD88 TO IGLD85 = -0.11'
USLS TO IGLD55 = -1.754'
USLS TO NGVD29 = -0.297'
IGLD55 TO IGLD85 = +0.72'

NOTE: THE CONVERSIONS TO USLS AND TO IGLD DATUMS ONLY APPLY TO THE IMMEDIATE AREA AT THE KARN PLANT AND SHOULD NOT BE USED ELSEWHERE.

LEGEND

- INCLINOMETER
- MONITORING WELL
- OBSERVATION WELL
- PIEZOMETER
- ELECTRIC BOX
- CATCH BASIN
- GAS VALVE
- LIGHT POLE
- POWER POLE
- POST (WOOD/METAL)
- GRAVEL SURFACE / TRAVELED PATHWAY
- ASPHALT SURFACE
- CONCRETE SURFACE
- Elec — OVERHEAD ELECTRIC LINE
- GAS — ABOVE GROUND GAS LINE
- Storm — UNDERGROUND STORM LINE
- TOP OF BANK
- TOE OF SLOPE

CLIENT
CONSUMERS ENERGY COMPANY
2742 NORTH WEADOCK HIGHWAY
ESSEXVILLE, MI. 48732

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-07-01
DESIGNED	MMJ
PREPARED	MAL
REVIEWED	JRP
APPROVED	JDP

PROJECT
D.E. KARN BOTTOM ASH POND

TITLE
SITE PLAN

PROJECT NO.	REV.	FIGURE
1655284	----	2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

Path: \\sacramento\cad\Sites_Work for Other Offices\1655284_DE Karn Bottom Ash Pond\CIVIL 3D\ | File Name: 1655284_2016-06 Survey.dwg

APPENDIX A
FEMA FLOOD ELEVATION AND LAKE HURON NORMAL ELEVATION

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) Report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS Report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study Report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study Report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study Report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) zone 16. The **horizontal datum** was NAD 83, GRS 1980 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713- 3242**, or visit its website at http://www.ngs.noaa.gov.

Base Map information shown on this FIRM was provided in digital format by Bay County, Michigan. This information was photogrammetrically compiled at a scale of 1200 from aerial photography dated 2005.

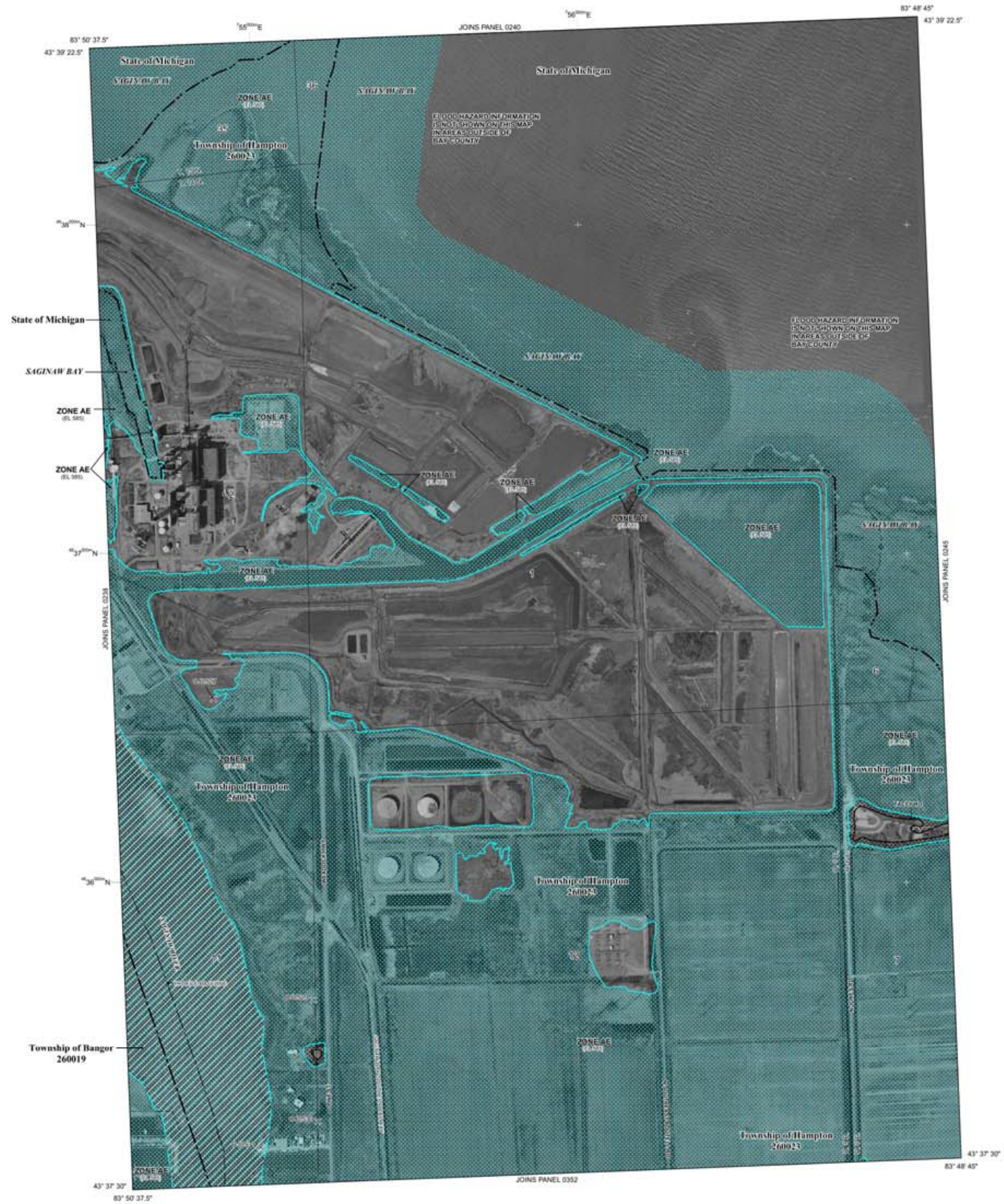
The **profile baselines** depicted on this map represent the hydraulic modeling baselines that match the flood profiles in the FIS report. As a result of improved topographic data, the **profile baseline**, in some cases, may deviate significantly from the channel centerline or appear outside the SFHA.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

Contact the **FEMA Map Service Center** at 1-800-358-9616 for information on available products associated with this FIRM. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. The FEMA Map Service Center may also be reached by Fax at 1-800-358-9620 and its website at http://msc.fema.gov.

If you have **questions about this map** or questions concerning the National Flood Insurance Program in general, please call **1- 877- FEMA MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/business/nfip/.



LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Areas formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X — Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X — Areas determined to be outside the 0.2% annual chance floodplain.

ZONE D — Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

1% Annual Chance Floodplain Boundary

0.2% Annual Chance Floodplain Boundary

Floodway boundary

Zone D boundary

CBRS and OPA boundary

Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.

~~~ 513 ~~~ Base Flood Elevation line and value; elevation in feet*

(EL 987) Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

(A)——(A) Cross section line

(23) - - - - (23) Transect line

45° 02' 08", 93° 02' 12" Geographic coordinates referenced to the North American Datum of 1983 (NAD 83) Western Hemisphere

[89]000m N 1000-meter Universal Transverse Mercator grid values, zone 16N

DX5510 × Bench mark (see explanation in Notes to Users section of this FIRM panel)

• M1.5 River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
June 16, 1998

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

September 17, 2010 – to add Special Flood Hazard Areas and roads and road names; to change Special Flood Hazard Areas, to update corporate limits and map format; to incorporate previously issued Letters of Map Revision; and to reflect updated topographic information.

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 500'

250 0 500 1000 FEET

150 0 150 300 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0239E

FIRM
FLOOD INSURANCE RATE MAP

BAY COUNTY, MICHIGAN
ALL JURISDICTIONS

PANEL 239 OF 450
(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BANGOR, TOWNSHIP OF	260019	0239	E
HAMPTON, TOWNSHIP OF	260023	0239	E

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
26017C0239E

MAP REVISED
SEPTEMBER 17, 2010

Federal Emergency Management Agency
~~~

APPENDIX B
RAINFALL DATA

NOAA Atlas 14, Volume 8, Version 2
Location name: Essexville, Michigan, US*
Latitude: 43.6433°, Longitude: -83.8376°
Elevation: 585 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	0.281 (0.221–0.364)	0.333 (0.262–0.432)	0.421 (0.331–0.548)	0.497 (0.388–0.651)	0.606 (0.458–0.829)	0.693 (0.510–0.963)	0.783 (0.556–1.12)	0.877 (0.595–1.30)	1.01 (0.655–1.54)	1.11 (0.700–1.72)
10-min	0.411 (0.324–0.533)	0.487 (0.384–0.632)	0.617 (0.484–0.803)	0.728 (0.568–0.953)	0.887 (0.670–1.21)	1.02 (0.747–1.41)	1.15 (0.814–1.64)	1.28 (0.872–1.90)	1.47 (0.959–2.25)	1.62 (1.03–2.52)
15-min	0.501 (0.396–0.649)	0.594 (0.469–0.771)	0.752 (0.591–0.979)	0.888 (0.693–1.16)	1.08 (0.817–1.48)	1.24 (0.911–1.72)	1.40 (0.992–2.00)	1.57 (1.06–2.32)	1.80 (1.17–2.75)	1.98 (1.25–3.07)
30-min	0.722 (0.570–0.936)	0.859 (0.678–1.12)	1.09 (0.856–1.42)	1.29 (1.01–1.69)	1.57 (1.19–2.15)	1.80 (1.32–2.49)	2.03 (1.44–2.90)	2.27 (1.54–3.35)	2.60 (1.69–3.97)	2.86 (1.81–4.44)
60-min	0.940 (0.742–1.22)	1.11 (0.877–1.44)	1.41 (1.11–1.84)	1.67 (1.31–2.19)	2.05 (1.56–2.82)	2.37 (1.74–3.30)	2.69 (1.91–3.87)	3.04 (2.07–4.51)	3.52 (2.30–5.40)	3.91 (2.47–6.07)
2-hr	1.16 (0.925–1.48)	1.36 (1.09–1.75)	1.73 (1.38–2.22)	2.05 (1.62–2.65)	2.54 (1.95–3.45)	2.94 (2.19–4.05)	3.36 (2.42–4.78)	3.81 (2.62–5.60)	4.45 (2.94–6.76)	4.96 (3.17–7.63)
3-hr	1.29 (1.04–1.63)	1.51 (1.21–1.91)	1.90 (1.52–2.42)	2.26 (1.80–2.90)	2.81 (2.18–3.81)	3.28 (2.47–4.51)	3.78 (2.74–5.36)	4.33 (3.00–6.33)	5.10 (3.39–7.72)	5.73 (3.69–8.77)
6-hr	1.52 (1.24–1.90)	1.75 (1.43–2.20)	2.19 (1.78–2.75)	2.61 (2.11–3.30)	3.28 (2.59–4.42)	3.86 (2.95–5.27)	4.50 (3.31–6.33)	5.21 (3.66–7.57)	6.24 (4.20–9.37)	7.09 (4.61–10.7)
12-hr	1.78 (1.47–2.20)	2.02 (1.67–2.50)	2.50 (2.06–3.10)	2.98 (2.43–3.71)	3.75 (3.01–5.02)	4.44 (3.45–6.02)	5.22 (3.89–7.28)	6.09 (4.34–8.78)	7.36 (5.02–11.0)	8.43 (5.54–12.6)
24-hr	2.05 (1.71–2.49)	2.31 (1.93–2.81)	2.85 (2.37–3.48)	3.40 (2.81–4.17)	4.29 (3.49–5.67)	5.09 (4.00–6.81)	5.99 (4.53–8.27)	7.01 (5.05–10.0)	8.51 (5.87–12.6)	9.77 (6.49–14.5)
2-day	2.33 (1.97–2.78)	2.64 (2.23–3.16)	3.25 (2.74–3.91)	3.87 (3.25–4.69)	4.88 (4.02–6.37)	5.79 (4.61–7.64)	6.80 (5.20–9.26)	7.94 (5.79–11.2)	9.62 (6.70–14.0)	11.0 (7.39–16.2)
3-day	2.55 (2.17–3.02)	2.86 (2.44–3.40)	3.50 (2.97–4.17)	4.14 (3.49–4.96)	5.18 (4.29–6.69)	6.11 (4.90–7.99)	7.15 (5.50–9.66)	8.32 (6.11–11.7)	10.1 (7.05–14.6)	11.5 (7.76–16.8)
4-day	2.74 (2.35–3.23)	3.06 (2.63–3.61)	3.70 (3.16–4.39)	4.35 (3.69–5.18)	5.39 (4.49–6.91)	6.33 (5.10–8.22)	7.37 (5.70–9.90)	8.55 (6.30–11.9)	10.3 (7.24–14.8)	11.7 (7.95–17.0)
7-day	3.23 (2.81–3.76)	3.59 (3.11–4.19)	4.28 (3.70–5.01)	4.94 (4.24–5.82)	6.00 (5.03–7.55)	6.93 (5.62–8.86)	7.95 (6.20–10.5)	9.09 (6.75–12.5)	10.7 (7.63–15.3)	12.1 (8.29–17.4)
10-day	3.67 (3.20–4.23)	4.07 (3.56–4.71)	4.83 (4.20–5.60)	5.54 (4.79–6.47)	6.64 (5.59–8.26)	7.59 (6.19–9.60)	8.63 (6.76–11.3)	9.77 (7.29–13.3)	11.4 (8.14–16.1)	12.8 (8.78–18.2)
20-day	4.91 (4.35–5.58)	5.49 (4.86–6.25)	6.50 (5.73–7.43)	7.40 (6.48–8.52)	8.75 (7.42–10.6)	9.86 (8.12–12.2)	11.0 (8.73–14.2)	12.3 (9.27–16.5)	14.1 (10.1–19.6)	15.5 (10.8–22.0)
30-day	6.02 (5.37–6.78)	6.73 (6.01–7.59)	7.95 (7.07–9.00)	9.01 (7.95–10.3)	10.5 (8.97–12.6)	11.8 (9.75–14.4)	13.0 (10.4–16.6)	14.4 (10.9–19.0)	16.2 (11.8–22.4)	17.7 (12.4–24.9)
45-day	7.49 (6.75–8.36)	8.38 (7.54–9.36)	9.84 (8.82–11.0)	11.1 (9.84–12.5)	12.7 (10.9–15.1)	14.1 (11.7–17.0)	15.4 (12.3–19.3)	16.7 (12.7–21.9)	18.5 (13.5–25.3)	19.9 (14.0–27.8)
60-day	8.81 (7.99–9.77)	9.84 (8.90–10.9)	11.5 (10.3–12.8)	12.8 (11.5–14.4)	14.6 (12.5–17.0)	15.9 (13.3–19.0)	17.2 (13.8–21.4)	18.5 (14.1–24.0)	20.1 (14.7–27.2)	21.3 (15.1–29.7)

[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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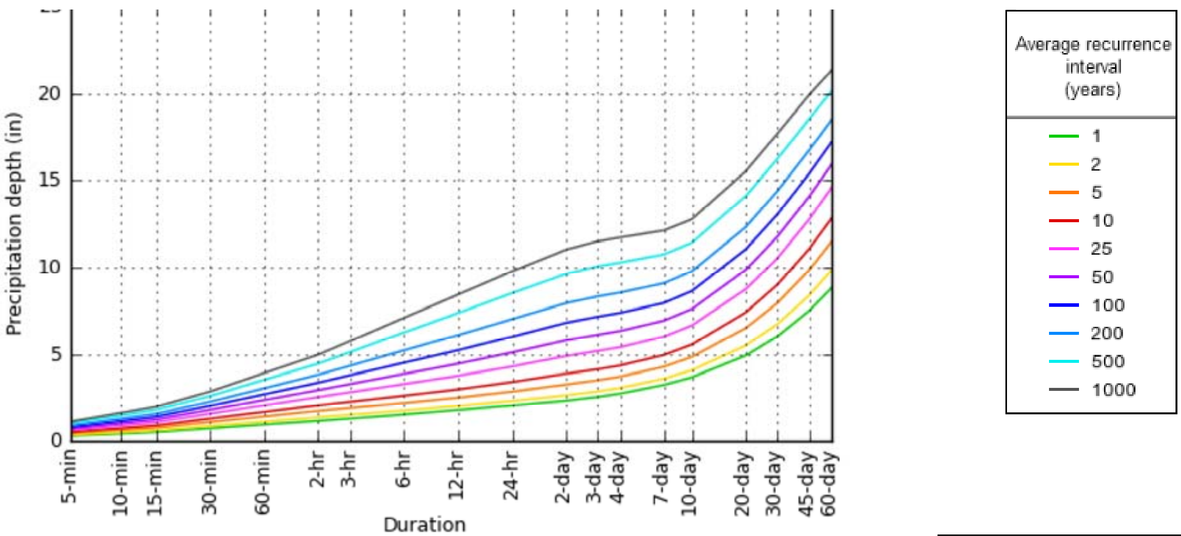
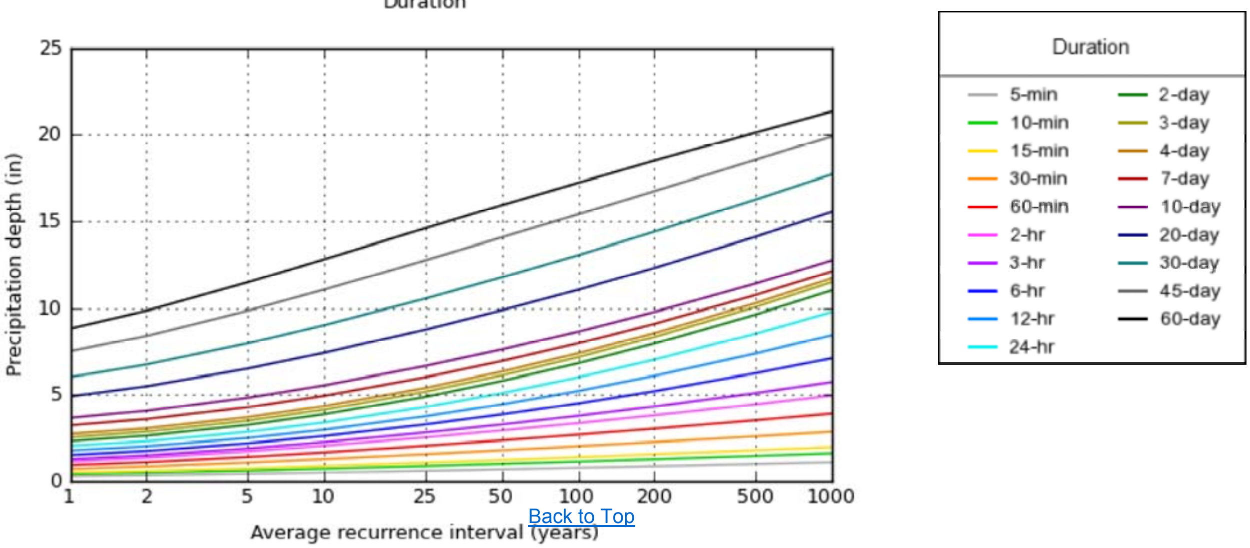
PF graphical





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Maps & aerials

Small scale terrain

Large scale terrain

Large scale map

Large scale aerial

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Disclaimer

APPENDIX C
HYDROLOGIC AND HYDRAULIC MODEL OUTPUT

Project Description

File Name .... Karn BaseFLow Pond.SPF

Project Options

Flow Units .... CFS
Elevation Type .... Elevation
Hydrology Method .... SCS TR-55
Time of Concentration (TOC) Method .... SCS TR-55
Link Routing Method .... Hydrodynamic
Enable Overflow Ponding at Nodes .... YES
Skip Steady State Analysis Time Periods .... NO

Analysis Options

Start Analysis On	Aug 04, 2016	00:00:00
End Analysis On	Aug 06, 2016	00:00:00
Start Reporting On	Aug 04, 2016	00:00:00
Antecedent Dry Days	0	days
Runoff (Dry Weather) Time Step	0 01:00:00	days hh:mm:ss
Runoff (Wet Weather) Time Step	0 00:05:00	days hh:mm:ss
Reporting Time Step	0 00:05:00	days hh:mm:ss
Routing Time Step	10	seconds

Number of Elements

	Qty
Rain Gages	1
Subbasins...	1
Nodes...	2
Junctions	0
Outfalls	1
Flow Diversions	0
Inlets	0
Storage Nodes	1
Links...	1
Channels	0
Pipes	1
Pumps	0
Orifices	0
Weirs	0
Outlets	0
Pollutants	0
Land Uses	0

Rainfall Details

SN	Rain Gage ID	Data Source	Data Source ID	Rainfall Type	Rain Units	State	County	Return Period (years)	Rainfall Depth (inches)	Rainfall Distribution
1	Rain Gage-01	Time Series	TS-100	Cumulative	inches	Michigan	None	100	5.99	SCS Type II 24-hr

Subbasin Summary

SN	Subbasin ID	Area (ac)	Weighted Curve Number	Total Rainfall (in)	Total Runoff (in)	Total Runoff Volume (ac-in)	Peak Runoff (cfs)	Time of Concentration (days hh:mm:ss)
1	Sub-01	4.99	98.00	5.99	5.75	28.70	39.26	0 00:05:00

Node Summary

SN	Element ID	Element Type	Invert Elevation (ft)	Ground/Rim (Max) Elevation (ft)	Initial Water Elevation (ft)	Surcharge Elevation (ft)	Ponded Area (ft^2)	Peak Inflow (cfs)	Max HGL Elevation Attained (ft)	Max Surcharge Depth Attained (ft)	Min Freeboard Attained (ft)	Time of Peak Flooding Occurrence (days hh:mm)	Total Flooded Volume (ac-in)	Total Time Flooded (min)
1	Out-01	Outfall	591.00					17.07	592.49					
2	Stor-01	Storage Node	591.00	598.00	591.00		0.00	59.16	593.97				0.00	0.00

Link Summary

SN	Element ID	Element Type	From (Inlet) Node	To (Outlet) Node	Length (ft)	Inlet Invert Elevation (ft)	Outlet Invert Elevation (ft)	Average Slope (%)	Diameter or Height (ft)	Manning's Roughness	Peak Flow (cfs)	Design Flow Capacity (cfs)	Peak Flow/ Design Flow Ratio	Peak Flow Velocity (ft/sec)	Peak Flow Depth (ft)	Peak Flow Depth/ Total Depth Ratio	Total Time Surcharged (min)	Reported Condition
1	Link-01	Pipe	Stor-01	Out-01	60.00	591.60	591.00	1.0000	2.000	0.0160	17.07	18.38	0.93	5.87	1.74	0.87	0.00	Calculated

Subbasin Hydrology

Subbasin : Sub-01

Input Data

Area (ac) 4.99
Weighted Curve Number 98.00
Rain Gage ID .... Rain Gage-01

Composite Curve Number

Soil/Surface Description	Area (acres)	Soil Group	Curve Number
-	4.99	-	98.00
Composite Area & Weighted CN	4.99		98.00

Time of Concentration

TOC Method : SCS TR-55

Sheet Flow Equation :

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

Where :

Tc = Time of Concentration (hr)
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 (hr)
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 :

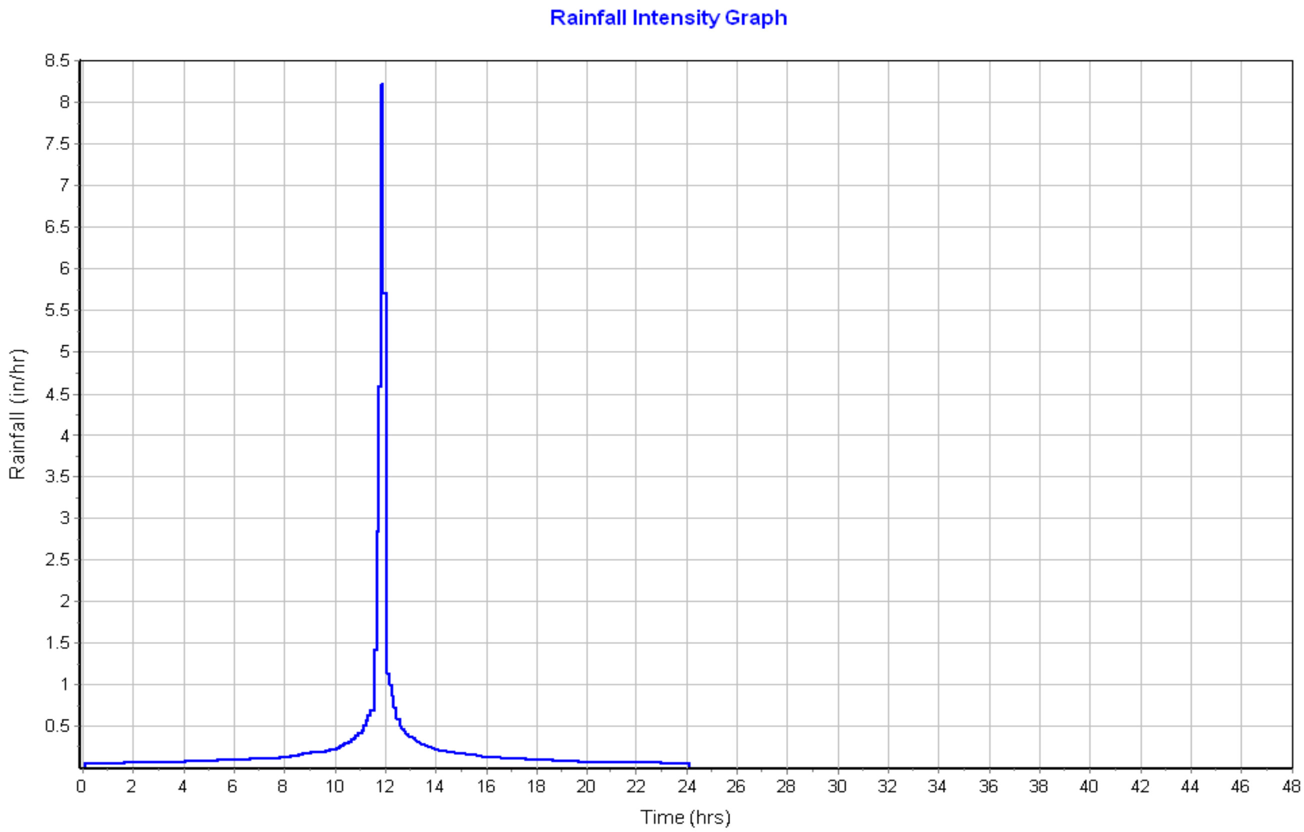
Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
R = Hydraulic Radius (ft)
Aq = Flow Area (ft²)
Wp = Wetted Perimeter (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)
n = Manning's roughness

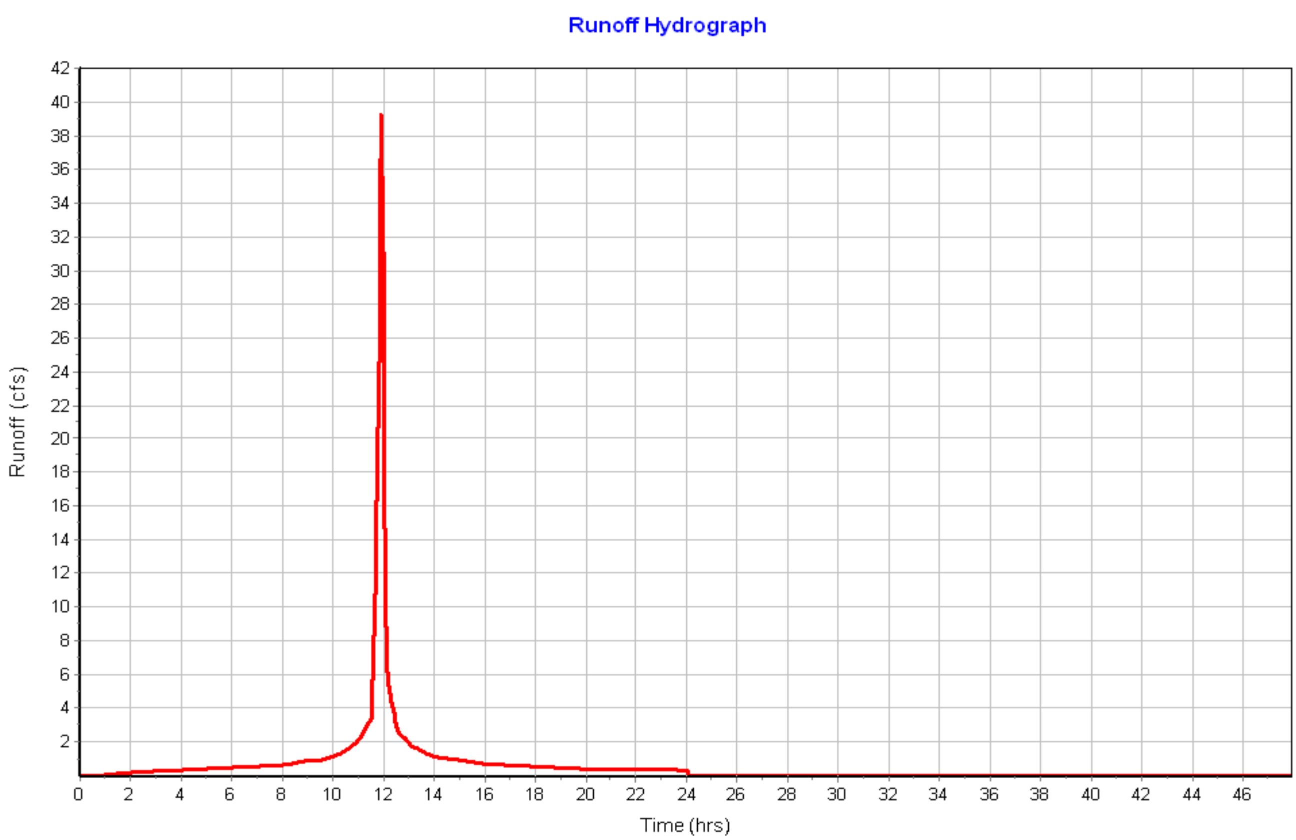
User-Defined TOC override (minutes): 5

Subbasin Runoff Results

Total Rainfall (in) 5.99
Total Runoff (in) 5.75
Peak Runoff (cfs) 39.26
Weighted Curve Number 98.00
Time of Concentration (days hh:mm:ss) 0 00:05:00

Subbasin : Sub-01





Pipe Input

SN	Element ID	Length (ft)	Inlet Invert Elevation (ft)	Inlet Invert Offset (ft)	Outlet Invert Elevation (ft)	Outlet Invert Offset (ft)	Total Drop (ft)	Average Slope (%)	Pipe Shape	Pipe Diameter or Height (ft)	Pipe Width (ft)	Manning's Roughness	Entrance Losses	Exit/Bend Losses	Additional Losses	Initial Flow (cfs)	Flap Gate	No. of Barrels
1	Link-01	60.00	591.60	0.60	591.00	0.00	0.60	1.0000	CIRCULAR	2.000	2.000	0.0160	0.5000	1.0000	0.0000	0.00	No	1

Pipe Results

SN	Element ID	Peak Flow (cfs)	Time of Peak Flow Occurrence (days hh:mm)	Design Flow Capacity (cfs)	Peak Flow/ Design Flow Ratio	Peak Flow Velocity (ft/sec)	Travel Time (min)	Peak Flow Depth (ft)	Peak Flow Depth/ Total Depth Ratio	Total Time Surcharged (min)	Froude Number	Reported Condition
1	Link-01	17.07	0 13:00	18.38	0.93	5.87	0.17	1.74	0.87	0.00		Calculated

Storage Nodes

Storage Node : Stor-01

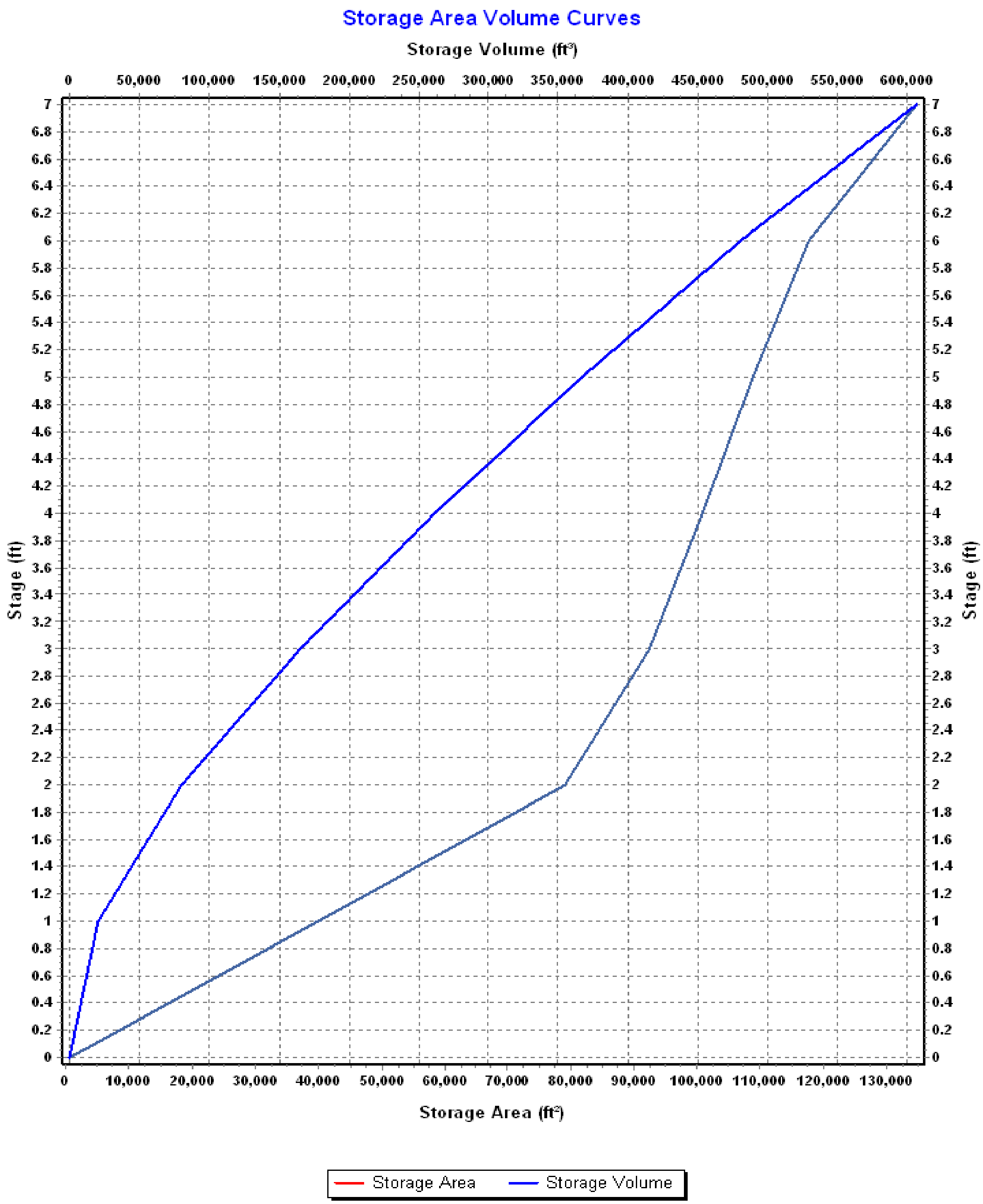
Input Data

Invert Elevation (ft) 591.00
Max (Rim) Elevation (ft) 598.00
Max (Rim) Offset (ft) 7.00
Initial Water Elevation (ft) 591.00
Initial Water Depth (ft) 0.00
Ponded Area (ft²) 0.00
Evaporation Loss 0.00

Storage Area Volume Curves

Storage Curve : Storage-01

Stage (ft)	Storage Area (ft²)	Storage Volume (ft³)
0	645.95	0.000
1	40027.96	20336.96
2	78931.05	79816.47
3	92303.24	165433.62
4	100810.40	261990.44
5	108844.27	366817.78
6	117750.88	480115.36
7	134728.97	606355.29



Storage Area Volume Curves
Storage Volume (ft³)
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
450,000
500,000
550,000
600,000
Stage (ft)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
4.8
5
5.2
5.4
5.6
5.8
6
6.2
6.4
6.6
6.8
7
Storage Area (ft²)
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
110,000
120,000
130,000
Storage Area
Storage Volume

Storage Node : Stor-01 (continued)

Output Summary Results

Peak Inflow (cfs) 59.16
Peak Lateral Inflow (cfs) 59.16
Peak Outflow (cfs) 17.07
Peak Exfiltration Flow Rate (cfm) 0.00
Max HGL Elevation Attained (ft) 593.97
Max HGL Depth Attained (ft) 2.97
Average HGL Elevation Attained (ft) 592.99
Average HGL Depth Attained (ft) 1.99
Time of Max HGL Occurrence (days hh:mm) 0 12:59
Total Exfiltration Volume (1000-ft³) 0.000
Total Flooded Volume (ac-in) 0
Total Time Flooded (min) 0
Total Retention Time (sec) 0.00

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