B.C. COBB GENERATING FACILITY

BOTTOM ASH POND INFLOW DESIGN FLOOD CONTROL SYSTEM PLAN

Muskegon, 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 **1652598**

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

Table of Contents

List of Tables

List of Figures

List of Appendices

1.0 INTRODUCTION

1.1 Background

B.C. Cobb Generating Facility (BC Cobb) is a coal-fired power generation facility located in Muskegon, Michigan as presented on Figure 1 – Site Location Map. BC Cobb formerly operated two coal-burning baseload units but ceased electrical generation on April 15, 2016. Prior to stopping electrical generation, bottom ash was sluiced from BC Cobb to the Bottom Ash Pond. Stored bottom ash was mechanically removed from the pond as needed to maintain storage capacity. The Bottom Ash Pond discharged water via two corrugated metal outflow pipes that were reported to be in good to fair condition in the Barr Triennial Ash Dike Risk Assessment Report – Spring 2014 (Barr 2014). The pipes discharge to an internal pond network (Ponds 0-8) and then to the permitted National Pollutant Discharge Elimination System (NPDES) outfall to Muskegon Lake as provided on Figure 2 – General Site Plan. Currently, BC Cobb is being decommissioned. The Bottom Ash Pond is no longer receiving coal combustion residual (CCR) from an active power generating plant. The Bottom Ash Pond is anticipated to accept negligible amounts of CCR contact wash water and other low-volume miscellaneous wastewaters until the expiration of the BC Cobb NPDES permit (October 1, 2018) or a date earlier when the BC Cobb NPDES permit is administratively discharged by the Michigan Department of Environmental Quality (MDEQ) after satisfaction that all permitted potential polluting streams have been addressed. It is anticipated that the Bottom Ash Pond's final receipt of waste will occur on October 1, 2018; and resulting subsequent closure activities will commence within regulated timeframes.

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 CCR Surface Impoundments). The Bottom Ash Pond has been rated a significant hazard potential as determined under 40 CFR 257.73(a)(2). 40 CFR 257.82(a) requires the owner or operator of a significant hazard potential CCR surface impoundment to design, construct, operate, and maintain an inflow flood control system as follows:

- Adequately manage the flow into the CCR unit during and following the peak discharge of the inflow of the 1000-year flood event
- Adequately manage the flow from the CCR unit to collect and control the peak discharge resulting from the 1000-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 (1000-year event) for two cases: 1) floodwater from outside the unit from Muskegon Lake, and 2) controlling internal water levels within the unit.

2.1 External Floodwater Protection

The Bottom Ash Pond is surrounded by a perimeter dike that provides external floodwater protection. One potential inflow source to the Bottom Ash Pond was identified and evaluated; Muskegon Lake.

A publicly available 1000-year flood elevation for Muskegon Lake has not been determined by Federal Emergency Management Agency (FEMA). As a result, Golder Associates Inc. (Golder) has estimated the 1000-year flood elevation by extrapolation of the FEMA data and verification with a hydraulic model. The FEMA Flood Insurance Study (FIS) (FEMA 2015) reported Muskegon Lake levels for the 10-, 50-, 100- and 500-year recurrence intervals. The 100- and 500-year levels are 584.4 and 585.3 feet (NAVD88), respectively. Based on a logarithmic best fit curve extrapolation, the 1000-year Muskegon Lake level is approximately 585.7 feet (NAVD88). The lowest elevation along the perimeter dike is 595.0 feet (NAVD88), which allows for 9.3 feet of freeboard during the 1000-year flood event. Therefore, Muskegon Lake was determined to not be an inflow source to the Bottom Ash Pond.

2.2 Internal Flood Control

The only inflow will be precipitation directly falling on the Bottom Ash Pond from a 1000-year 24-hour storm event of 11.6 inches, as provided in Appendix B - Rainfall Data. There are two discharge structures in the perimeter berm: one 15-inch and one 18-inch corrugated metal pipe (CMP). These pipes flow from the Bottom Ash Pond to Pond 6.

Table 2.2.1 - Discharge Structure Summary

Discharge Structure	Type	Size (Inches)	Length (Feet)	Upstream Invert (NAVD88)	Downstream Invert (NAVD88)	Slope (%)
15-inch	CMP	15	250.0	592.12	588.01	1.64
18-inch	CMP	18	250.0	591.05	588.05	1.20

Given the negligible amount of CCR contact wash water draining to the Bottom Ash Pond, it is expected that the static water elevation in the Bottom Ash Pond will equalize with Muskegon Lake's (Lake Michigan) normal water elevation of 579.40 feet (NAVD88), as reported by the National Oceanic and Atmospheric Administration (NOAA) and provided in Appendix A - FEMA Flood Elevation and Lake Michigan Normal Elevation. Given the pond bottom is approximately 589.0 (NAVD88), the pond was assumed to be dry at the start of the rain event. Table 2.2.2 below provides a storm flow summary that indicates that the Bottom

Ash Pond is contained with 3.08 feet of freeboard, a peak discharge rate of 2.32 cubic feet per second (cfs) and total outflow volume of 0.789 acre-feet to Pond 6 during the design storm event (1000-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 (1000-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 (NAVD88)	Pond Elevation 1000-year 24-hour (NAVD88)	Peak Outflow (cfs)	Volume of Outflow (acre-feet)
Bottom Ash Pond	595.00	591.92	2.32	0.789

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 §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 §257.105(g)(4).”

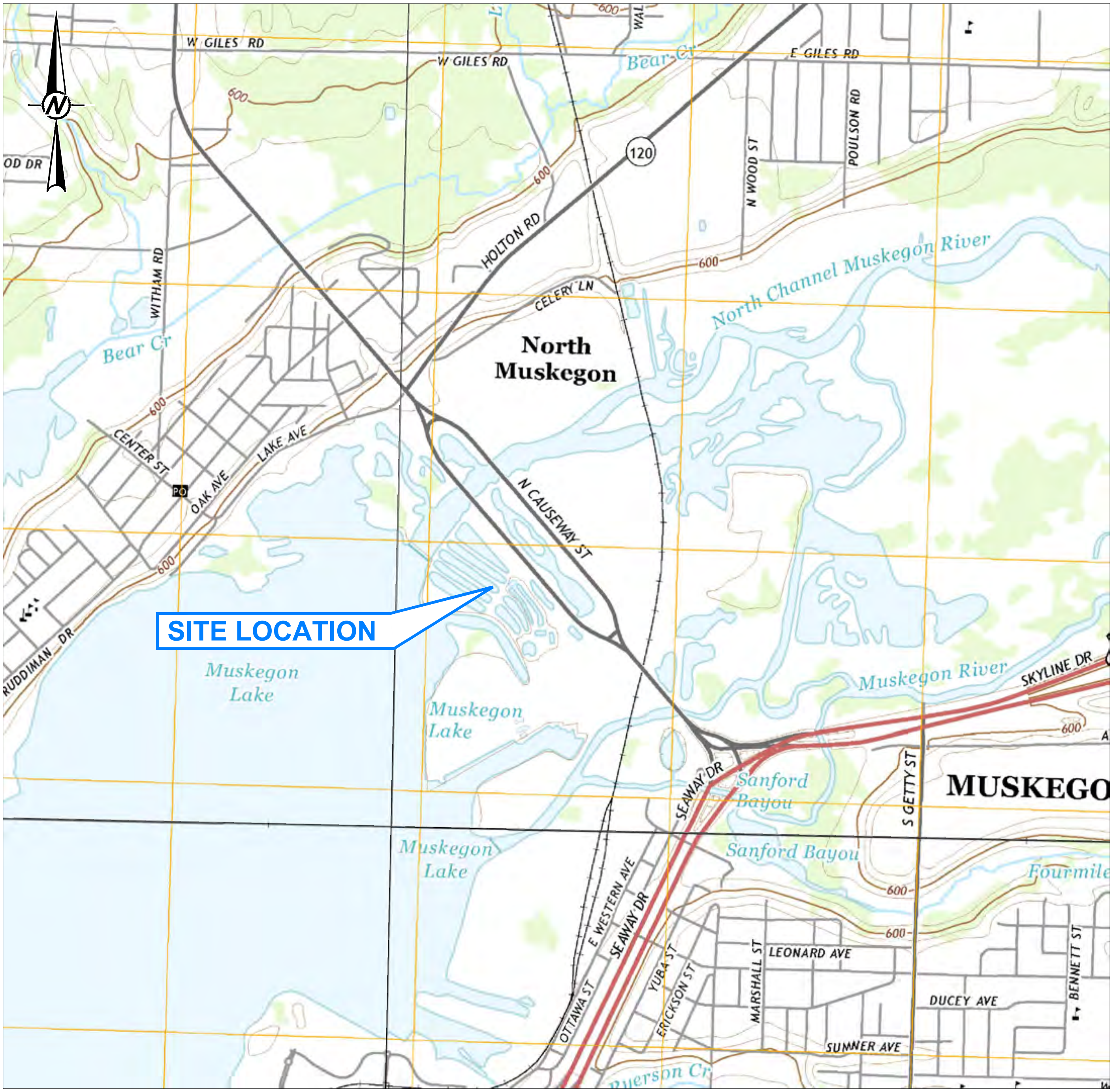
4.0 REFERENCES

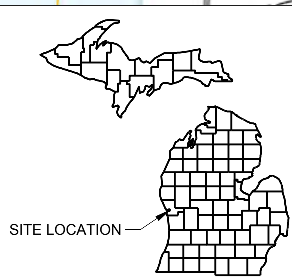
Barr Engineering Company, 2014. B.C. Cobb Ash Disposal Area: Triennial Ash Dike Risk Assessment Report – Spring 2014.

FEMA (Federal Emergency Management Agency). 2015. Flood Insurance Study, Muskegon County, Michigan. Effective July 6, 2015. Flood Insurance Study Number 26121CV000A.

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)

1. BASE MAP TAKEN FROM 7.5 MINUTE U.S.G.S. □UADRANGLES OF DALTON, TWIN LAKE, MUSKEGON EAST, AND MUSKEGON WEST, MICHIGAN, DATED 2014.

0 1000 2000

1" = 2000' FEET

CLIENT

CONSUMERS ENERGY COMPANY
151 N. CAUSEWAY
MUSKEGON, MI 49445

PROJECT

B.C. COBB PLANT
BOTTOM ASH POND FLOOD CONTROL PLAN
MUSKEGON, MI 49445

CONSULTANT

Golder Associates

YYYY-MM-DD	2016-06-14
DESIGNED	JRP
PREPARED	AM
REVIEWED	JRP
APPROVED	MAB

TITLE

SITE LOCATION MAP

PROJECT NO.	CONTROL	REV.	FIGURE
1652598	B001	0	1

Path: \\mtlaurel\cadd\Projects\2016\1652598\B Consumers - BC Cobb\PRODUCTION\B - Ponds 0-8 Closure Plan\ | File Name: 1652598B001 - SITE LOCATION MAP.dwg

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

0 1 in

LEGEND

GROUNDWATER MONITORING WELL

REFERENCE(S)

1. TOPOGRAPHIC SURVEY PROVIDED BY SUMMIT SURVEYING, INC.; DATED JANUARY 28, 2015.

CLIENT CONSUMERS ENERGY COMPANY 151 N. CAUSEWAY MUSKEGON, MI 49445		PROJECT B.C. COBB PLANT BOTTOM ASH POND FLOOD CONTROL PLAN MUSKEGON, MI 49445	
CONSULTANT Golder Associates	YYYY-MM-DD: 2016-06-14 DESIGNED: JRP PREPARED: AM REVIEWED: JRP APPROVED: JDP	TITLE **GENERAL SITE PLAN**	
		PROJECT NO. 1652598	CONTROL C002
		REV. 0	FIGURE 2

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

APPENDIX A
FEMA FLOOD ELEVATION AND LAKE MICHIGAN 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 Farm Services Administration. This information was photogrammetrically compiled at a scale of 1:12,000 from aerial photography dated 2005.

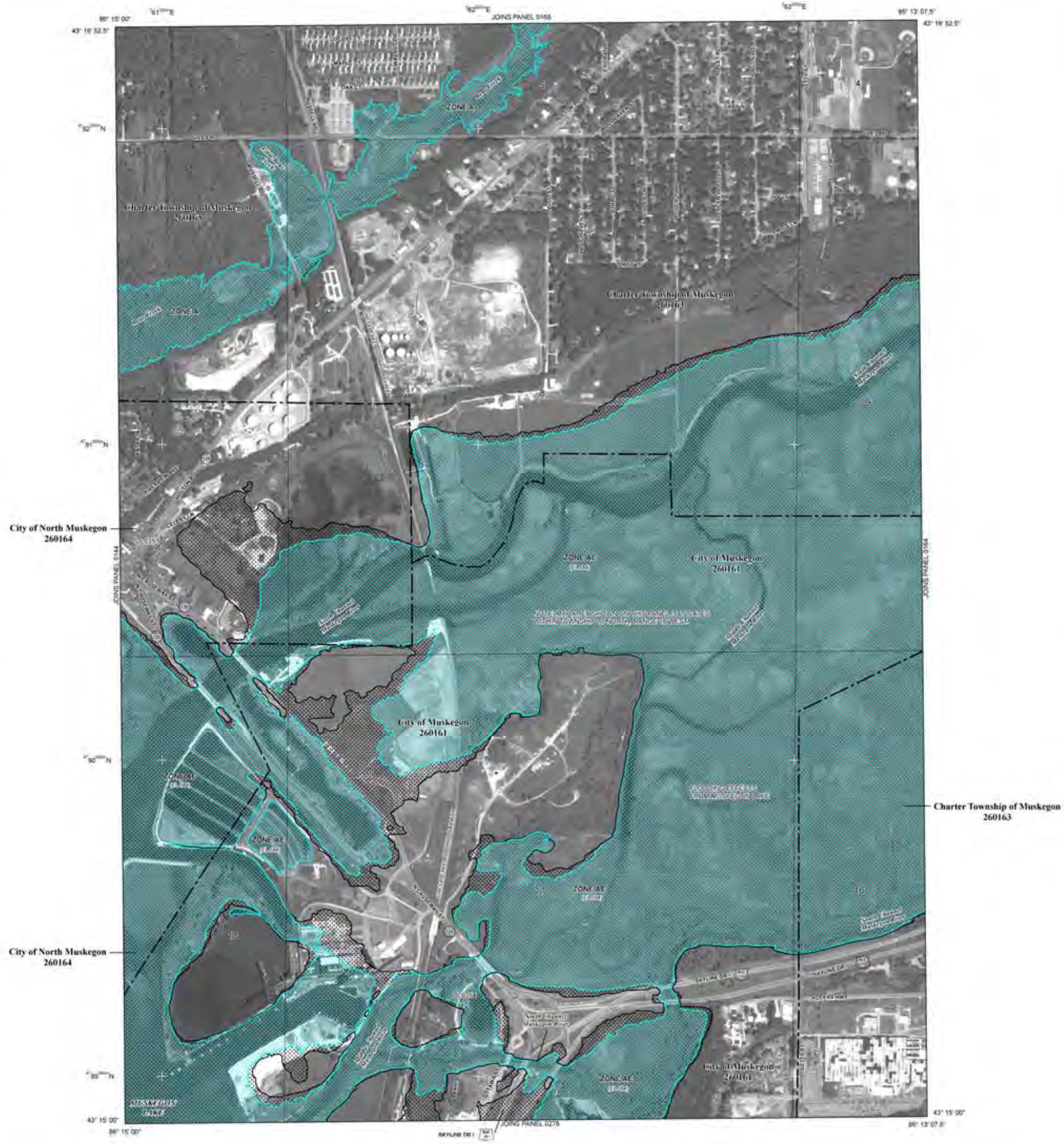
The **profile baselines** depicted on this map represent the hydraulic modeling baselines that match the flood profiles in the FIS report. As a result of improved topographic data, the **profile baseline**, in some cases, may deviate significantly from the channel centerline or appear outside the SFHA.

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.

For information on available products associated with this FIRM visit the **Map Service Center (MSC)** website at http://msc.fema.gov. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the MSC website.

If you have **questions about this map**, how to order products, or the National Flood Insurance Program in general, please call the **FEMA Map Information eXchange (FMIX)** at **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

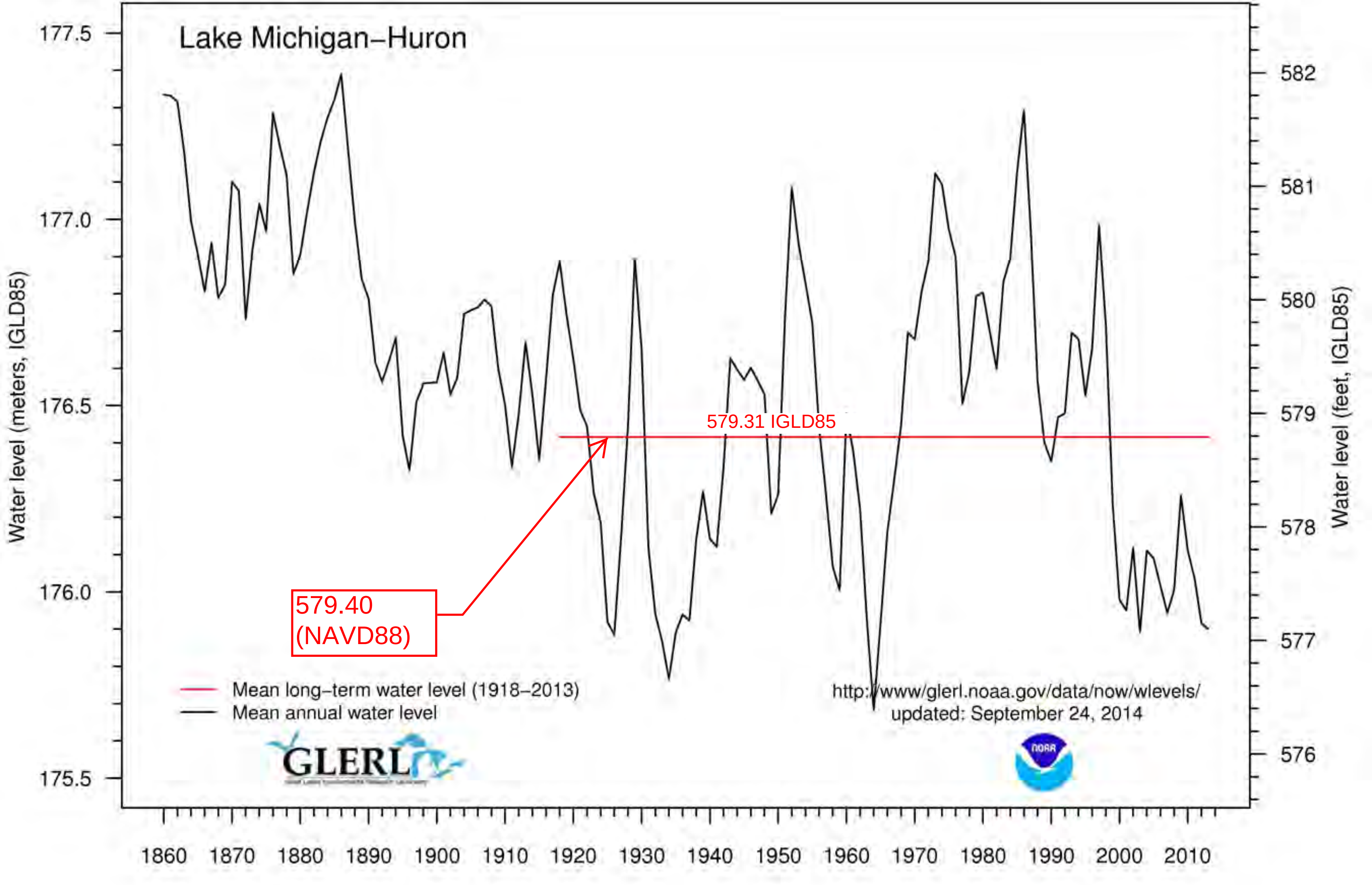
Floodway boundary

Zone D boundary

CBRS and OPA boundary

Boundary dividing Special Flood Hazard Area Zones and 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

$^{47}89^{000m}$ N 1000-meter Universal Transverse Mercator grid values, zone 16

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
July 6, 2015

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

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 0163D

FIRM
FLOOD INSURANCE RATE MAP
MUSKEGON COUNTY, MICHIGAN
(ALL JURISDICTIONS)

PANEL 163 OF 475
(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
MUSKEGON, CHARTER TOWNSHIP OF	260163	0163	D
MUSKEGON, CITY OF	260161	0163	D
NORTH MUSKEGON, CITY OF	260164	0163	D

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
26121C0163D

EFFECTIVE DATE
JULY 6, 2015

Federal Emergency Management Agency
~~~

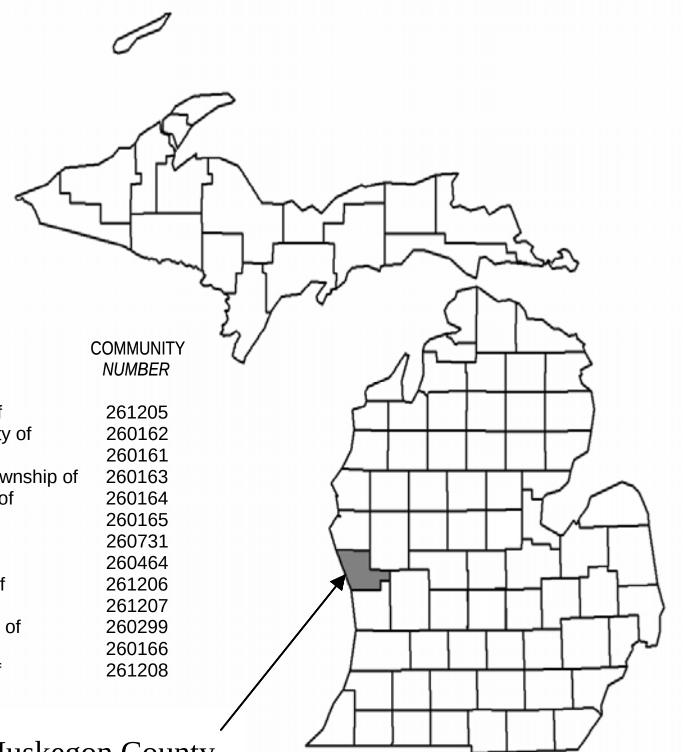


Lake Michigan−Huron
Water level (meters, IGLD85)
Water level (feet, IGLD85)
177.5
177.0
176.5
176.0
175.5
582
581
580
579
578
577
576
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
579.31 IGLD85
579.40
(NAVD88)
Mean long−term water level (1918−2013)
Mean annual water level
http://www.glerl.noaa.gov/data/now/wlevels/
updated: September 24, 2014
GLERL

FLOOD INSURANCE STUDY

MUSKEGON COUNTY, MICHIGAN

(ALL JURISDICTIONS)



COMMUNITY *NAME*	COMMUNITY *NUMBER*	COMMUNITY *NAME*	COMMUNITY *NUMBER*
*Blue Lake, Township of	261196	Moorland, Township of	261205
*Casnovia, Township of	261197	Muskegon Heights, City of	260162
Cedar Creek, Township of	261198	Muskegon, City of	260161
*Dalton, Township of	261199	Muskegon, Charter Township of	260163
Egelston, Township of	260680	North Muskegon, City of	260164
Fruitland, Township of	260265	Norton Shores, City of	260165
Fruitport, Charter Township of	261200	Ravenna, Township of	260731
*Fruitport, Village of	261201	Ravenna, Village of	260464
*Holton, Township of	261203	*Roosevelt Park, City of	261206
Laketon, Township of	260159	Sullivan, Township of	261207
*Lakewood Club, Village of	261204	White River, Township of	260299
Montague, City of	260160	Whitehall, City of	260166
Montague, Township of	261240	Whitehall, Township of	261208

*No Special Flood Hazard Areas Identified

Effective: July 6, 2015

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
26121CV000A

Table 3 - Summary of Stillwater Elevations

Water Surface Elevations (NAVD[1])

Flooding Source	10-Percent-Annual-Chance	2-Percent-Annual-Chance	1-Percent-Annual-Chance	0.2-Percent-Annual-Chance
Bear Lake	582.9	584.0	584.4	585.3
Black Lake	599.1	600.0	600.3	601.4
Lake Michigan	582.9	584.0	584.4	585.3
Mona Lake	582.9	584.0	584.4	585.3
Muskegon Lake	582.9	584.0	584.4	585.3
White Lake	582.9	584.0	584.4	585.3

[1] North American Vertical Datum of 1988

This Countywide Analysis

Flood Elevations for Lake Michigan along Muskegon County were obtained from the Revised Report on Great Lakes Open-Coast Flood Levels (USACE, 1988). The Bear Lake, Mona Lake, Muskegon Lake, and White Lake elevations were based on the Lake Michigan elevations from the 1988 report.

Peak discharges for the approximate study in Muskegon County were derived using either the published USGS regional regression equations, the MDNRE SCS procedures, or the Natural Resource Conservation Service (NRCS) Technical Release 55 methodology (NRCS, 1986).

For the majority of the approximate analyses, peak discharges were estimated using the published USGS regional regression equations (USGS, 1984). Regression equations estimate peak discharges for ungaged streams based on characteristics of nearby gaged streams.

Several streams in Muskegon County that were previously studied using approximate methods have drainage areas that do not fall within the allowable range for use with the USGS regression equations. For these streams, the MDNRE has published a guidance document on small ungaged watersheds that outlines procedures to determine peak discharges (Sorrell, 2008).

3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding from the sources studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals. Users should be aware that flood elevations shown on the FIRM represent rounded whole-foot elevations and may not exactly reflect the elevations shown on the Flood Profiles or in the Floodway Data Table in the FIS report. Flood elevations shown on the FIRM are primarily intended for flood

APPENDIX B
RAINFALL DATA

NOAA Atlas 14, Volume 8, Version 2
Location name: Muskegon, Michigan, US*
Latitude: 43.2588°, Longitude: -86.2463°
Elevation: 587 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	0.308 (0.262–0.371)	0.365 (0.309–0.439)	0.463 (0.391–0.559)	0.550 (0.462–0.668)	0.680 (0.550–0.868)	0.787 (0.617–1.02)	0.899 (0.676–1.20)	1.02 (0.728–1.41)	1.19 (0.810–1.69)	1.33 (0.871–1.91)
10-min	0.452 (0.384–0.543)	0.534 (0.453–0.643)	0.678 (0.573–0.818)	0.806 (0.676–0.978)	0.995 (0.806–1.27)	1.15 (0.904–1.49)	1.32 (0.990–1.76)	1.49 (1.07–2.06)	1.74 (1.19–2.48)	1.94 (1.28–2.80)
15-min	0.551 (0.468–0.662)	0.651 (0.552–0.784)	0.827 (0.698–0.998)	0.983 (0.825–1.19)	1.21 (0.983–1.55)	1.41 (1.10–1.82)	1.61 (1.21–2.14)	1.82 (1.30–2.51)	2.12 (1.45–3.02)	2.37 (1.56–3.41)
30-min	0.749 (0.637–0.901)	0.890 (0.755–1.07)	1.14 (0.960–1.37)	1.36 (1.14–1.65)	1.68 (1.36–2.15)	1.95 (1.53–2.53)	2.23 (1.68–2.98)	2.54 (1.81–3.50)	2.97 (2.02–4.22)	3.31 (2.18–4.77)
60-min	0.964 (0.819–1.16)	1.14 (0.967–1.37)	1.46 (1.23–1.76)	1.75 (1.46–2.12)	2.18 (1.77–2.80)	2.56 (2.01–3.32)	2.95 (2.22–3.95)	3.39 (2.42–4.68)	4.00 (2.73–5.71)	4.50 (2.96–6.48)
2-hr	1.18 (1.01–1.41)	1.39 (1.19–1.66)	1.78 (1.51–2.13)	2.14 (1.80–2.57)	2.69 (2.20–3.44)	3.16 (2.50–4.09)	3.67 (2.78–4.89)	4.23 (3.05–5.82)	5.03 (3.46–7.14)	5.69 (3.77–8.14)
3-hr	1.33 (1.14–1.58)	1.55 (1.33–1.85)	1.98 (1.69–2.37)	2.39 (2.02–2.87)	3.03 (2.49–3.87)	3.58 (2.85–4.63)	4.19 (3.19–5.57)	4.86 (3.52–6.67)	5.83 (4.02–8.25)	6.62 (4.40–9.44)
6-hr	1.61 (1.39–1.90)	1.87 (1.61–2.21)	2.37 (2.03–2.81)	2.86 (2.44–3.41)	3.65 (3.04–4.66)	4.35 (3.49–5.61)	5.13 (3.94–6.80)	5.99 (4.38–8.20)	7.26 (5.05–10.2)	8.31 (5.56–11.8)
12-hr	1.93 (1.67–2.26)	2.22 (1.92–2.60)	2.80 (2.41–3.29)	3.38 (2.89–4.00)	4.32 (3.62–5.50)	5.17 (4.18–6.63)	6.11 (4.73–8.06)	7.17 (5.27–9.75)	8.73 (6.12–12.2)	10.0 (6.76–14.1)
24-hr	2.26 (1.97–2.63)	2.58 (2.25–3.01)	3.24 (2.80–3.78)	3.90 (3.35–4.58)	4.98 (4.20–6.30)	5.96 (4.85–7.60)	7.05 (5.50–9.25)	8.29 (6.14–11.2)	10.1 (7.14–14.1)	11.6 (7.90–16.3)
2-day	2.58 (2.26–2.98)	2.93 (2.57–3.39)	3.65 (3.18–4.24)	4.38 (3.79–5.11)	5.58 (4.74–7.00)	6.66 (5.45–8.43)	7.87 (6.18–10.3)	9.24 (6.89–12.4)	11.3 (8.01–15.6)	12.9 (8.85–18.0)
3-day	2.77 (2.43–3.18)	3.15 (2.76–3.63)	3.91 (3.42–4.52)	4.67 (4.06–5.43)	5.91 (5.03–7.37)	7.02 (5.77–8.84)	8.27 (6.50–10.7)	9.66 (7.23–12.9)	11.7 (8.36–16.1)	13.4 (9.22–18.6)
4-day	2.95 (2.60–3.38)	3.33 (2.93–3.82)	4.10 (3.59–4.72)	4.86 (4.23–5.63)	6.11 (5.21–7.59)	7.23 (5.95–9.07)	8.48 (6.69–10.9)	9.89 (7.42–13.2)	12.0 (8.56–16.4)	13.7 (9.43–18.9)
7-day	3.53 (3.13–4.02)	3.85 (3.41–4.40)	4.54 (3.99–5.20)	5.26 (4.59–6.05)	6.46 (5.55–7.98)	7.57 (6.27–9.45)	8.82 (7.01–11.3)	10.3 (7.75–13.6)	12.4 (8.92–16.9)	14.2 (9.81–19.4)
10-day	4.06 (3.60–4.61)	4.38 (3.88–4.97)	5.05 (4.46–5.76)	5.76 (5.05–6.60)	6.95 (5.98–8.52)	8.03 (6.68–9.97)	9.27 (7.39–11.8)	10.7 (8.09–14.1)	12.8 (9.24–17.4)	14.5 (10.1–19.9)
20-day	5.48 (4.89–6.17)	6.00 (5.35–6.77)	6.94 (6.16–7.85)	7.79 (6.86–8.86)	9.06 (7.75–10.8)	10.1 (8.41–12.3)	11.3 (8.99–14.1)	12.5 (9.50–16.2)	14.3 (10.4–19.1)	15.7 (11.0–21.3)
30-day	6.65 (5.96–7.46)	7.36 (6.59–8.27)	8.55 (7.61–9.63)	9.55 (8.45–10.8)	10.9 (9.32–12.9)	12.0 (9.99–14.4)	13.2 (10.5–16.3)	14.3 (10.9–18.3)	15.9 (11.5–21.0)	17.0 (12.0–23.1)
45-day	8.16 (7.33–9.11)	9.06 (8.12–10.1)	10.5 (9.37–11.8)	11.6 (10.3–13.1)	13.2 (11.2–15.4)	14.4 (11.9–17.1)	15.5 (12.4–19.0)	16.6 (12.6–21.1)	18.1 (13.1–23.8)	19.1 (13.5–25.8)
60-day	9.48 (8.53–10.5)	10.5 (9.41–11.7)	12.0 (10.8–13.5)	13.3 (11.8–15.0)	15.0 (12.8–17.4)	16.2 (13.5–19.2)	17.4 (14.0–21.3)	18.6 (14.2–23.6)	20.1 (14.7–26.4)	21.2 (15.0–28.5)

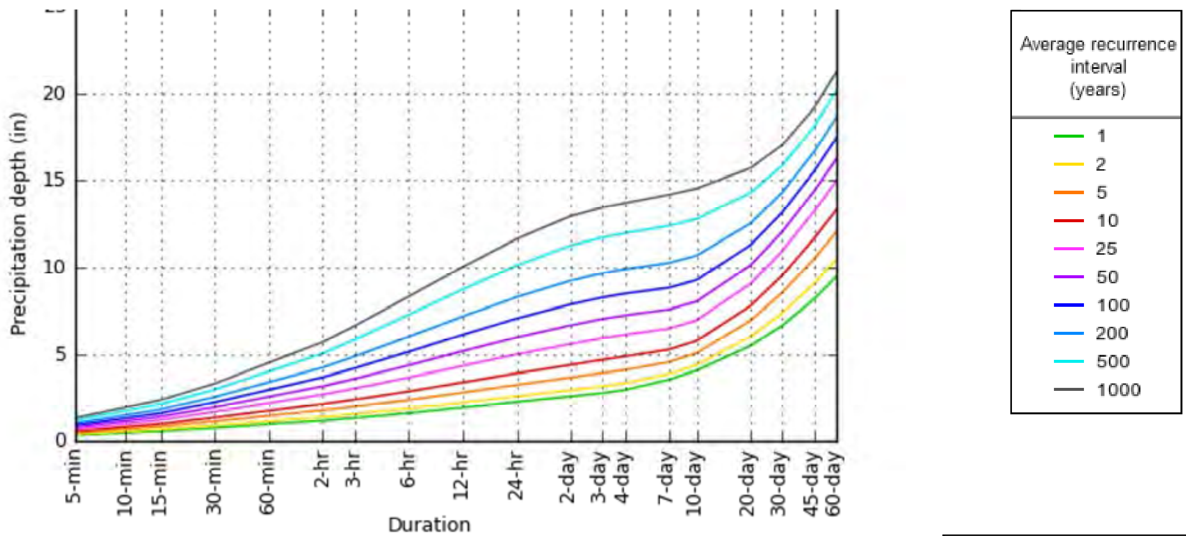
[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

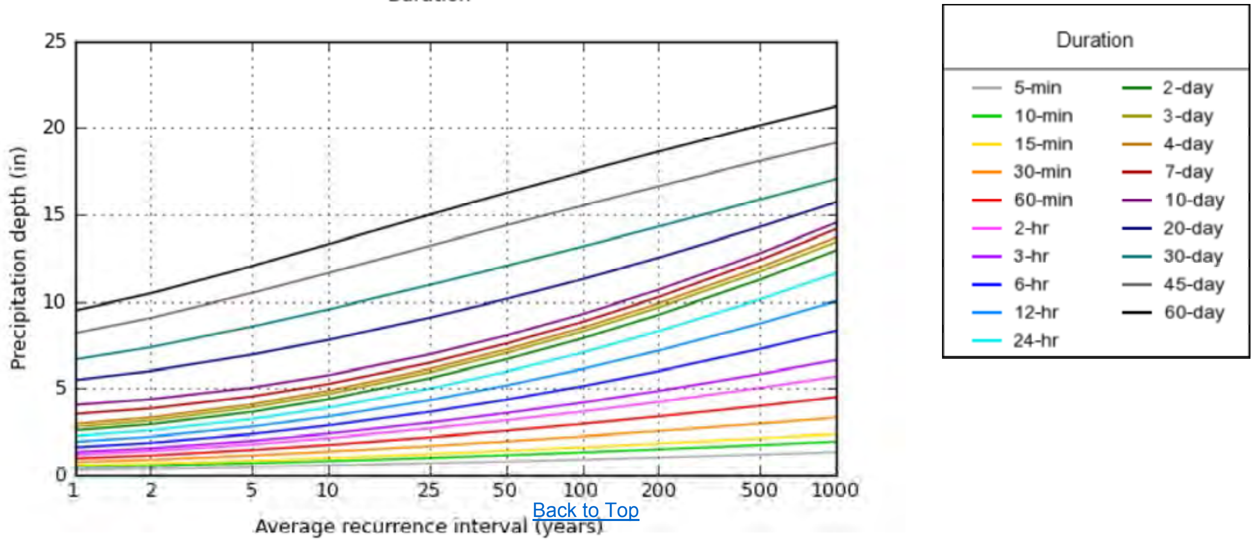
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper 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.

Back to Top

PF graphical



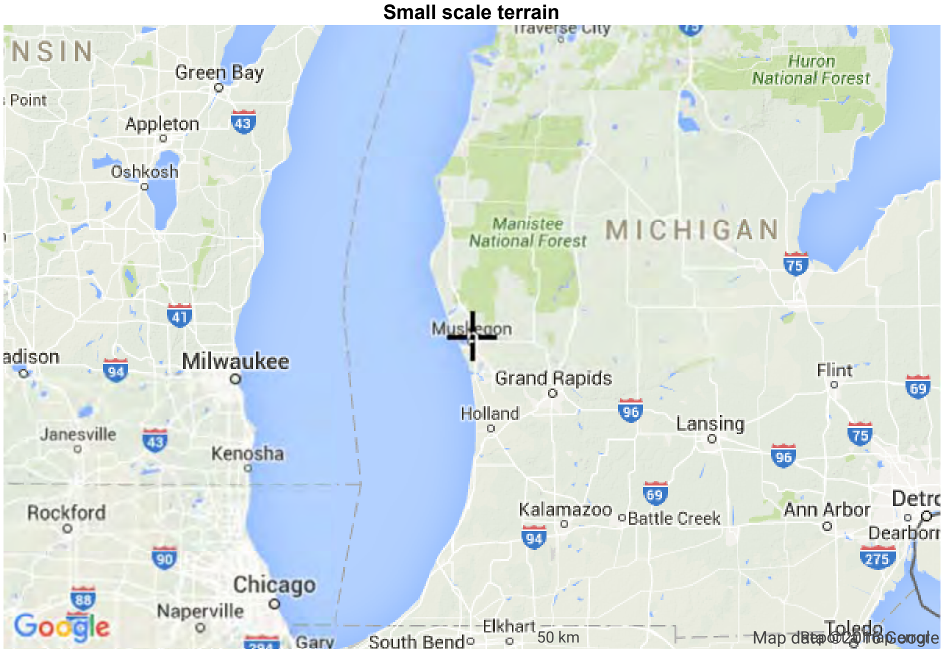


Back to Top

NOAA Atlas 14, Volume 8, Version 2 Created (GMT): Mon May 9 13:58:58 2016

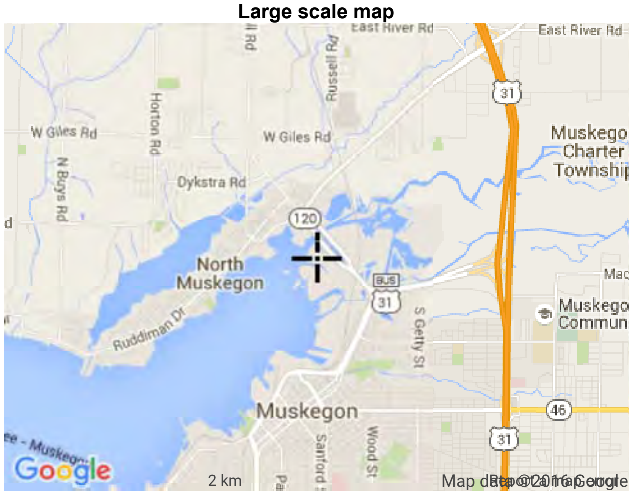
Maps & aerials

Small scale terrain



Large scale terrain

Large scale map



Large scale aerial

[Back to Top]

APPENDIX C
HYDROLOGIC AND HYDRAULIC MODEL OUTPUT

Pipe Listing (selected nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Diam/Width (inches)	Height (inches)
1	12P	592.12	588.01	250.0	0.0164	0.025	15.0	0.0
2	12P	591.05	588.05	250.0	0.0120	0.025	18.0	0.0

Summary for Pond 12P: PROPOSED BAP

Inflow Area = 1.700 ac, 27.06% Impervious, Inflow Depth > 10.26" for 1000-YEAR event
Inflow = 29.11 cfs @ 11.90 hrs, Volume= 1.453 af
Outflow = 2.32 cfs @ 12.38 hrs, Volume= 0.789 af, Atten= 92%, Lag= 28.7 min
Primary = 2.32 cfs @ 12.38 hrs, Volume= 0.789 af

Routing by Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs / 3
Peak Elev= 591.92' @ 12.38 hrs Surf.Area= 19,574 sf Storage= 40,092 cf

Plug-Flow detention time= 296.1 min calculated for 0.789 af (54% of inflow)
Center-of-Mass det. time= 180.9 min (937.5 - 756.6)

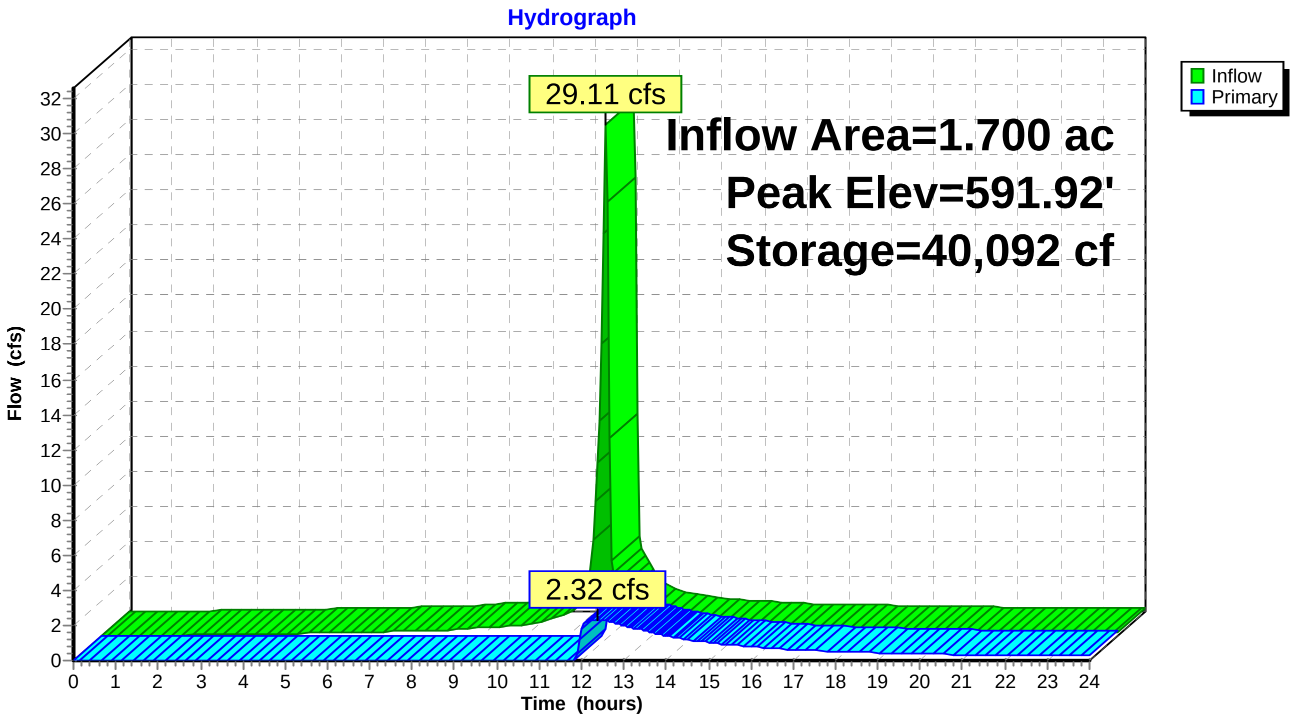
Volume	Invert	Avail.Storage	Storage Description
#1	589.00'	109,946 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
589.00	4,212	0	0
590.00	11,928	8,070	8,070
591.00	17,734	14,831	22,901
592.00	19,730	18,732	41,633
593.00	21,727	20,729	62,362
594.00	23,779	22,753	85,115
595.00	25,884	24,832	109,946

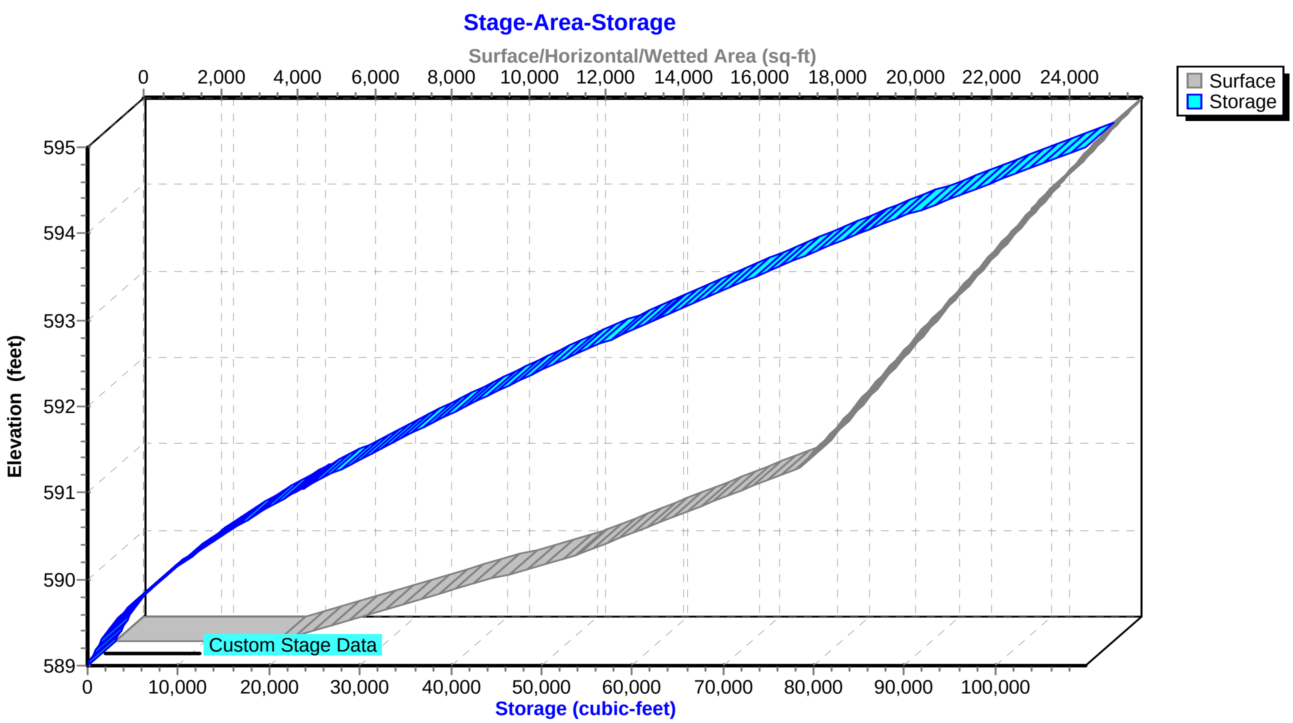
Device	Routing	Invert	Outlet Devices
#1	Primary	592.12'	**15.0" Round Culvert** L= 250.0' CMP, projecting, no headwall, Ke= 0.900 Outlet Invert= 588.01' S= 0.0164 '/' Cc= 0.900 n= 0.025 Corrugated metal
#2	Primary	591.05'	**18.0" Round Culvert** L= 250.0' CMP, projecting, no headwall, Ke= 0.900 Outlet Invert= 588.05' S= 0.0120 '/' Cc= 0.900 n= 0.025

Primary OutFlow Max=2.32 cfs @ 12.38 hrs HW=591.92' (Free Discharge)
├─**1=Culvert** (Controls 0.00 cfs)
└─**2=Culvert** (Barrel Controls 2.32 cfs @ 3.14 fps)

Pond 12P: PROPOSED BAP



Pond 12P: PROPOSED BAP



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.

Africa	+ 27 11 254 4800
Asia	+ 852 2562 3658
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Inc.
15851 South U.S. 27, Suite 50
Lansing, MI 48906 USA
Tel: (517) 482-2262
Fax: (517) 482-2460

Engineering Earth's Development, Preserving Earth's Integrity