Maple Grove, MN | HEI No. 8866_0001
January 13, 2020

Bakers Lake Outlet - drone photo captured on May 30, 2019

BAKERS LAKE OUTLET STRUCTURE

Feasibility Report

High Island Creek Watershed District

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January 13, 2020

Prepared for:
High Island Creek Watershed District

Houston Engineering, Inc.
7550 Meridian Cir N, Suite 120
Maple Grove, MN 55369
Phone # 763.493.4522

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

Chris Otterness
License No. 41961

January 13, 2020
Date

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

Bret T. Zimmerman
License No. 53178

January 13, 2020
Date

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EXECUTIVE SUMMARY

Bakers Lake is located within the High Island Creek Watershed District in McLeod County, Minnesota. The lake is a 546 acre basin and High Island Creek flows through the lake. The watershed upstream of Bakers Lake is approximately 109.9 square miles and is extensively drained by public and private drainage systems. The outlet of Bakers Lake has deteriorated, and a replacement structure been a topic of discussion since the 1970s. The purpose of this study is to conceptualize and evaluate alternatives for replacement of the Bakers Lake outlet and repair of the High Island Creek channel through Bakers Lake to address these concerns.

A field assessment was completed as part of this study in order to develop existing conditions hydrologic and hydraulic models. The assessment included topographic field survey and capturing aerial photographs and video with a drone. After the field survey was completed, a hydrologic (HEC-HMS) model was developed for 147 square miles of the High Island Creek Watershed. The hydrologic model develops synthetic event runoff hydrographs. The runoff hydrographs are then simulated through a hydraulic (HEC-RAS) model that was developed for 24 miles of High Island Creek. These two models were used to evaluate existing conditions and to develop outlet structure replacement alternatives.

A project team meeting was held to develop design criteria for a successful project. Present at the meeting were stakeholders from High Island Creek Watershed District, Houston Engineering, Inc., Minnesota DNR, McLeod County SWCD, Sibley County SWCD, McLeod County Commissioners, and two adjacent landowners. The design criteria are considered a measuring stick to determine if a specific alternative meets the project goals

A total of nine alternatives were analyzed for this study. The alternatives include various geometric configurations for replacement of the Bakers Lake outlet structure. A cleanout of the High Island Creek channel through Bakers Lake was also analyzed along with the outlet configurations. The alternatives were evaluated against the design criteria in order to determine if the alternatives meet the project goals. One alternative passed all design criteria and is recommended to carry forward for detailed review and design.

The recommended alternative includes; a 56-foot weir at 1014.91 feet, raising the embankment to the southeast of the outlet structure to reduce breakout flows, and a channel cleanout of the High Island Creek channel through Bakers Lake. The alternative is described in Section 3.8. Discussion on the performance of this alternative is included in Section 4 and Section 5 of this report. The estimated project cost for this alternative is $352,400.

This purpose of this study was for conceptual planning and was not intended to establish a final design. Final dimensions and elevations of the Bakers Lake outlet structure will need to be determined during final design and plan development.

1 PROJECT BACKGROUND

Bakers Lake is located within the High Island Creek Watershed in Sections 7, 8, 17, 18, 19, and 20, Penn Township, McLeod County, Minnesota as shown on **Figure 1a**. Bakers Lake is approximately 4 miles south of Brownton, MN, and approximately 5.5 miles west of New Auburn, MN. Bakers Lake is designated as a Minnesota Public Water Basin, # 43-048P. The ordinary high water level (OHW) for the lake is 1016.91 (NAVD88).

Bakers Lake is a 546 acre basin and is divided into two portions. The north basin is 313 acres, is mainly open water, and drains into the south basin. The south basin is 233 acres and predominantly heavily vegetated with a small open channel through the middle of the lake. High Island Creek flows through the south basin of Bakers Lake. The High Island Creek channel through the south basin, as well as the channel from the north basin into the south basin, have been prone to clogging due to excessive cattail growth and deposition of bog material. The clogging of the channels has likely been exacerbated by the condition of the outlet, which has increased the magnitude and frequency of water level bounce in the south basin. Photos taken in 2019 of Bakers Lake are shown on **Figure 1b** through **Figure 1e**.

The upstream watershed consists of approximately 109.9 square miles (70,366 acres) and is primarily agricultural land. The watershed is extensively drained by both public and private drainage systems and High Island Creek.

The current outlet structure of Bakers Lake was constructed as a sheet pile weir. The outlet has deteriorated over time and now mainly consists of rock riprap with a few portions of sheet pile remaining. Photos taken in 2019 of the outlet structure are shown on **Figure 1f** through **Figure 1i**.

The condition of the lake outlet and the channel through the lake's south basin have generated a number of concerns for stakeholders including the High Island Creek Watershed District (HICWD), DNR, and adjacent landowners. The concerns include:

a) Water levels in High Island Creek providing an inadequate outlet for drainage;
b) More frequent and/or higher duration flooding of crop land
c) Unpredictable outlet for management of habitat within the Bakers Lake Wildlife Management Area
d) Insufficient flood storage; and
e) Downstream sediment delivery due to scour at the outlet and downstream channel.

The purpose of this study is to conceptualize and evaluate alternatives for replacement of the Bakers Lake outlet and repair of the High Island Creek channel through Bakers Lake to address these concerns.

1.1 FEMA FLOODPLAIN

There is a defined FEMA floodplain for Bakers Lake and High Island Creek in McLeod County, MN. Based on the McLeod County Flood Insurance Study (FIS), Effective July 7, 2014, (FEMA, 2014) the lake and creek are mapped as FEMA Flood Zone A with no associated flood elevation or delineated floodway. Minnesota Law regulates the allowable increase in flood stage for any proposed alternative to 6 inches or 0.5 feet.

1.2 PREVIOUS STUDIES

The replacement of the Bakers Lake outlet structure has been a topic of discussion since the late 1970s. Over the past 25 years, two studies have been completed by the DNR related to Bakers Lake and High Island Creek.

The DNR first completed a study related to the replacement of the Bakers Lake Dam (outlet structure) in 1994. Findings from that study were published in August of 1994 in a report titled *Bakers Lake (43-48) McLeod County, Hydrologic and Hydraulic Study for Replacement of the Outlet Dam* (MNDNR, Bakers Lake (43-48) McLeod County, Hydrologic and Hydraulic Study for Replacement of the Outlet Dam, 1994). This study focused on replacing the outlet structure, and three different outlet elevations were considered. These elevations were:

a) the existing (1994) runout at 1013.41;
b) the DNR Divisions of Fish and Wildlife preferred elevation of 1015.71; and
c) adjacent landowners' preferred elevation of 1014.91.

The conclusion of the study was that the goals of the DNR and adjacent landowners could not be achieved through the design of a new outlet structure.

In 2017, the DNR completed a study that focused on the reduction in floodplain area with varying peak flow reductions. The results were published in a memo titled *RE: High Island Creek Flow Rate Reduction Study* on February 21, 2017 (MNDNR, High Island Creek Flow Rate Reduction Study, 2017). This study utilized the 1-dimensional, steady state, HEC-RAS model developed for the McLeod County FIS but extended it downstream to High Island Lake. The study reported reductions in floodplain area based on flow reductions of 20%, 30%, and 40%. The study did not focus on changes to the Bakers Lake outlet structure.

1.3 VERTICAL DATUM

All elevations in this report are in reference to the North American Vertical Datum of 1988 (NAVD88). Previous reports reference elevations in the National Geodetic Vertical Datum of 1929 (NGVD29). The conversion between the two datums varies spatially throughout North America. The conversion between the two datums at Bakers Lake was determined using the National Geodetic Survey VERTCON conversion calculator (NGS, 2019).

$$NGVD29\ elevation + 0.41\ feet = NAVD88\ elevation$$
$$Example\!:\ 1016.5'\ (NVGD29) + 0.41' = 1016.91'\ (NAVD88)$$

1.4 PROJECT TEAM MEETING

A project team meeting was held on August 26, 2019 in Glencoe, MN. Present at the meeting were stakeholders from High Island Creek Watershed District, Houston Engineering, Inc. (HEI), Minnesota DNR, McLeod County SWCD, Sibley County SWCD, McLeod County Commissioners, and two adjacent landowners. The purpose of the meeting was to discuss the scope of the project and to develop design criteria for a successful project. The design criteria are considered a measuring stick to determine if a specific alternative meets the project goals. The design criteria were further subdivided into mandatory objectives and secondary objectives. The criteria that were agreed upon by the project stakeholders are:

Mandatory Objectives:

- No increase in peak water surface elevation greater than 0.5-feet upstream or downstream of Bakers Lake during the 100-year event
- No increase in peak water surface elevation greater than 0.5-feet upstream of downstream of Bakers Lake during the 2-year event
- The north and south basins maintain an identical normal water level (within 0.1')
- No increase in normal water level in High Island Creek upstream or downstream of Bakers Lake
- Meet local, state, and federal regulatory requirements
- Have a stable lake outlet structure

Secondary Objectives:

- Reduction in total flooded acres for the 2-year event
- Reduction in upstream elevations by 1.5-feet for the 2-year event
- Flow reduction downstream of Bakers Lake by 20% for the 2-year event
- Reduction in peak water surface elevations downstream of Bakers Lake by 0.5-feet during the 10-year event
- Minimize long term maintenance

2 EXISTING CONDITIONS MODEL DEVELOPMENT

The HEC-RAS model developed for the McLeod County FIS, that was later updated during the DNR 2017 study, was used as a base model for this study. The HEC-RAS model needed to be updated to adequately evaluate the outlet structure. The following subsections describe updates that were made to the model.

2.1 FIELD INVESTIGATION

A topographic field survey was conducted by HEI on May 30, 2019, in order to refine the hydraulic model. The field survey included topographic survey of roadway crossings near Bakers Lake and channel cross sections near the crossings. Water surface elevations were also recorded at the crossings. The topographic field survey that was collected is shown on **Figure 2.1a**.

The watershed to Bakers Lake experienced approximately 2-inches of rainfall from May 28 to May 29, 2019. When the field survey was conducted, the watershed was experiencing high water conditions. Due to the high flows across the Bakers Lake outlet structure, the crest of the outlet structure could not be surveyed. However, the McLeod County SWCD surveyed the crest of the outlet structure in January of 2019, as shown on **Figure 2.1b**. This profile was used to represent the existing condition in the hydraulic model.

During the field survey, an Unmanned Aircraft System (UAS), or drone, was used to capture video and photos of the project area. The flight path was above the north and south basins of Bakers Lake, and approximately 1 mile upstream and downstream of the lake along High Island Creek. The photos shown on **Figures 1b-1i** were collected during the drone flight.

2.2 HYDROLOGIC (HEC-HMS) MODEL

The base HEC-RAS model was a steady state hydraulic model. In order to simulate a full synthetic rainfall event in the hydraulic model, a hydrologic model needed to be developed for the study area. A HEC-HMS model (USACE, HEC-HMS, 2018) was developed for approximately 147 square miles of the High Island Creek Watershed above Kirby Lake.

LiDAR elevation data for this study was acquired from the DNR topographic data viewer, MNTopo (MNDNR, MnTOPO, 2019). The LiDAR data was used to delineated subbasins for the hydrologic model and was also used for elevation data in the hydraulic model. The HEC-HMS model has a total of 35 subbasins with an average size of 4.2 square miles. The modeling extent and subbasins are shown on **Figure 2.2**.

The HEC-HMS hydrologic model uses the SCS Curve Number runoff method. This method uses curve numbers, that are developed based on land cover and soil types, to determine the amount of runoff generated during a specific rainfall event. The average Curve Number for the hydrologic model area is 79. Due to the amount of public and private tile systems and the delay in tile systems contributing during the peak of a synthetic storm, a noncontributing analysis was completed using the 50-year rainfall.

The hydrologic model was simulated using NOAA Atlas 14 rainfall depths. The rainfall depths were applied with a nested distribution. The model was used to simulate synthetic 24-hour rainfall events. The runoff hydrographs from these events were then simulated through the hydraulic model.

2.3 HYDRAULIC (HEC-RAS) MODEL

The DNR model for High Island Creek that was updated for the 2017 study was updated with the topographic field survey available LiDAR data. The model extends from the western Sibley/McLeod County Line at Zane Avenue downstream to Kirby Lake, or downstream of 216th Street near High Island Lake. The HEC-RAS modeling schematic is shown on **Figure 2.3a**.

The model includes High Island Creek and portions of two small tributaries that drain into Bakers Lake. The south basin of Bakers Lake was modeled with cross sections and the north basin of Bakers Lake was modeled with the HEC-RAS Storage Area element. Bathymetry data for Bakers Lake was not available at the time of this study. LiDAR elevations for the lake are at approximately 1014.5 feet, which was the water surface elevation in the lake when the LiDAR was flow. Bathymetry data was extrapolated between 1012 and 1014.5 in the HEC-RAS model. Three overflow locations from Bakers Lake were included in the model. The overflow locations and approximate elevations are shown on **Figure 2.3b** and include:

- Bakers Lake North Portion overflow at approximately 1019.0’
- Bakers Lake Outlet northwest embankment at approximately 1020.0’
- Bakers Lake Outlet southeast embankment at approximately 1018.0’

The HEC-RAS model was used to simulate 24-hour synthetic rainfall events. The model is an unsteady model, meaning that a full event hydrograph is simulated through the model (not just one static discharge).

2.4 MODEL VALIDATION

The HEC-RAS modeling results were validated based on USGS regression flows. USGS regression flows were calculated using StreamStats (USGS, 2019) at three locations; McLeod County Highway 7 (approximately 6 miles upstream of Bakers Lake), MN Highway 15 (approximately 1.3 miles upstream of Bakers Lake), and near the eastern McLeod/Sibley County Line at Leaf Avenue (approximately 4 miles downstream of Bakers Lake). The HEC-RAS modeled flows for the 2-year through 100-year events were within the confidence limit flows at all three locations. The 10-year event was within 10-percent of the regression flows at all three locations.

The HEC-RAS model was also validated using water surface elevations collected during the May 30, 2019 field survey. Prior to the field survey, the watershed received approximately 2-inches of rainfall in the prior 2-days, and the watershed had been in a very wet period for the entire 2019 spring. Water surface elevations were compared with the 2-year event to validate model parameters.

3 ALTERNATIVE ANALYSIS

A total of nine alternatives were analyzed for this study. The alternatives include various geometric configurations for replacement of the Bakers Lake outlet structure and a cleanout of the High Island Creek channel through the lake. The alternatives are described in the following subsections. Existing and alternative profiles for the crest of the outlet structure are shown on **Figure 3a** and **Figure 3b**.

Some of the alternatives used the same elevations as the 1994 DNR study (MNDNR, Bakers Lake (43-48) McLeod County, Hydrologic and Hydraulic Study for Replacement of the Outlet Dam, 1994). These elevations are shown in **Table 1**. These elevations were selected because they represent a range from a low runout elevation to a high runout elevation.

Table 1: Runout Elevations

Source	Alternative Nomenclature	Elevation
Existing Runout	Low Outlet	1013.41
Surrounding Landowners[1]	Mid Outlet	1014.91
DNR Division of Fish and Wildlife[1]	High Outlet	1015.71

[1] Elevations as published in the 1994 report and converted to NAVD 88 datum. Preferences may have changed since 1994.

3.1 ALTERNATIVE 1 – CHANNEL CLEANOUT

The rationale for this alternative is to determine the maximum achievable reduction in normal water level upstream of Bakers Lake. The cleanout alternative would remove cattails, debris, and sediment along the High Island Creek channel through the south basin of the lake. The cleanout assumed a 40-foot wide section would be free of obstructions. The cleanout also includes sediment removal near the outlet of the north portion of Bakers Lake that is shown on **Figure 1c**. No restoration of the existing dam is included in this alternative, as it is solely designed to evaluate the effectiveness of a clean channel

3.2 ALTERNATIVE 2 – LOW OUTLET W CHANNEL CLEANOUT

The rational for this alternative is to determine the effectiveness of restoring the outlet of Bakers Lake at the lowest practicable elevation. The outlet would consist of a 50-foot weir at 1013.41 feet with 2:1 side slopes until tying into existing ground. This alternative also includes the channel cleanout in Alternative 1.

3.3 ALTERNATIVE 3 – MID OUTLET W/ CHANNEL CLEANOUT

The rational for this alternative is to determine the relative effectiveness of a mid-level outlet elevation. The outlet would consist of a 56-foot weir at 1014.91 feet with 2:1 side slopes until tying into existing ground. This alternative would also include the channel cleanout in Alternative 1.

3.4 ALTERNATIVE 4 – HIGH OUTLET W/ CHANNEL CLEANOUT

The rational for this alternative is to determine the effectiveness and potential impacts of raising the outlet to a relatively high elevation, 1.2 feet below the Ordinary High Water Elevation. The outlet would consist of a 59-foot weir at 1015.71 feet with 2:1 side slopes tying into existing ground. This alternative also includes the channel cleanout in Alternative 1.

3.5 ALTERNATIVE 5 – HIGH OUTLET (NO CLEANOUT)

The rational for this alternative is to evaluate the impacts of restoring the outlet structure without restoring the High Island Creek channel through the south basin. This alternative is identical to Alternative 4 except that it does not include the channel cleanout. Comparing Alternative 5 and Alternative 4 demonstrates the utility and need of a functioning channel through the into and through the south basin.

3.6 ALTERNATIVE 6 – 2-STAGE OUTLET AT 1013.5 W/ CHANNEL CLEANOUT

The rational for this alternative is to create a shorter low stage outlet with a longer second stage outlet to reduce or eliminate the increases in peak water surface elevation. The outlet would consist of a 2-stages. The first stage is a 30-foot weir at 1013.5 feet, and the second stage is an 85-foot weir at 1016.0 feet. The 2-stage outlet allows for a smaller amount of flow at low elevations and a larger amount of flow at the higher elevations. This alternative also includes the channel cleanout in Alternative 1.

3.7 ALTERNATIVE 7 – 2-STAGE OUTLET AT 1013.5, RAISE EMBANKMENT TO 1019.0 W/ CHANNEL CLEANOUT

The earthen embankment to the southeast of the outlet structure currently overtops at approximately 1018.0 feet. This allows for uncontrolled breakout flows to bypass the outlet structure and inundate downstream farm land. This alternative raises the embankment to the southeast to an elevation of 1019.0 feet in order to reduce the recurrence and amount of uncontrolled breakout flow. The 2-stage outlet configuration is the same as the one described in Alternative 6. The first stage is a 30-foot weir at 1013.5 feet, and the second stage is an 85-foot weir at 1016.0 feet. This alternative also includes the channel cleanout in Alternative 1.

3.8 ALTERNATIVE 8 – MID OUTLET, RAISE EMBANKMENT TO 1019.0 W/ CHANNEL CLEANOUT

The rational for this alternative is to determine the impacts of raising the embankment to the southeast along with a constant elevation outlet structure. The outlet configuration is similar to Alternative 3 and consists of a 56-foot weir at 1014.91 feet with 2:1 side slopes until tying into existing ground. This Alternative includes the raised embankment described in Alternative 7 and the channel cleanout described in Alternative 1.

3.9 ALTERNATIVE 9 – LOW OUTLET, 80-FOOT WEIR W/ CHANNEL CLEANOUT

The rational for this alternative is to demonstrate the results of a long and wide outlet that would significantly reduce the attenuation of floodwaters within Bakers Lake. The outlet consists of an 80-foot weir at 1013.41 feet with vertical side slopes. This alternative would also include the channel cleanout in Alternative 1. This alternative provides the lowest and widest outlet of all of the alternatives.

4 MODELING RESULTS

The results from the simulated alternatives were evaluated against the design criteria discussed in Section 1.4 to determine the impacts of the alternatives. Reporting locations were selected in order to assess the impacts against the design criteria. The reporting locations are shown on **Figure 4** and include:

- MN State Highway 15 – road crossing approximately 1.3 miles upstream (west) of Bakers Lake
- North Bakers Lake Basin
- South Bakers Lake Basin
- Oday Avenue / County Highway 13 – road crossing approximately 1.2 miles downstream (east) of Bakers Lake
- Leaf Avenue – road crossing near the county line approximately 4 miles downstream (east) of Bakers Lake

In additional to the mandatory and secondary criteria, four other results are shown in the table. These additional data, which may provide additional context to the function of the alternatives, include:

- The bounce on south portion of Bakers Lake during the 2-year event
- The normal water level on the north and south portions of Bakers Lake
- Reduction in the frequency of breakout flow over the southeast embankment of the outlet during the 10-year event (results are based on depth of breakout flow at the peak flood elevation for the 10-year event).
- Reduction in breakout or overflow from the north portion of Bakers Lake

The effectiveness of each alternative in meeting project objectives is shown in **Table 2**. For the mandatory objectives, results shaded in green indicate that the alternative meets the design criteria, and results shaded in red indicated failure to achieve the design criteria. The same shading applies to the secondary objectives with the additional of yellow representing the design criteria is partially met. Under the other results section, green text represents reductions and red text represents increases. **Table 2** only quantifies the change relative to existing conditions. An expanded table showing the full results is shown in the **Appendix**.

Table 2: Alternative Results – Design Criteria

Mandatory Objectives	Location	Event	Existing Conditions	Alternative 1 Channel Cleanout	Alternative 2 Low Outlet w/ Cleanout	Alternative 3 Mid Outlet w/ Cleanout	Alternative 4 High Outlet w/ Cleanout	Alternative 5 High Outlet (No Cleanout)	Alternative 6 2-stage Outlet w/ Cleanout	Alternative 7 2-stage Outlet, Raise Embankment w/ Cleanout	Alternative 8 Mid Outlet, Raise Embankment w/ Cleanout	Alternative 9 Low Outlet, 80-ft weir w/ Cleanout
100-year event No increase in Peak WSE greater than 0.5-feet upstream or downstream of Bakers Lake	MN State Highway 15	100-year	1,025.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Oday Ave / County Highway 13		1,018.96	-0.05	-0.15	0.00	0.09	0.10	-0.09	-0.06	0.05	-0.19
2-year event No increase in peak WSE of greater than 0.5-feet upstream or downstream of Bakers Lake	MN State Highway 15	2-year	1,021.64	-0.02	-0.03	-0.01	0.03	0.03	-0.02	-0.02	-0.01	-0.03
	Oday Ave / County Highway 13		1,014.40	-0.22	0.06	-0.12	-0.22	-0.22	-0.10	-0.10	-0.12	0.01
North and South basins maintain the same peak WSE for the 2-year rainfall event (0.05-foot tolerance) (Results shown are actual results not the change from Existing)	Difference between north/south basin	2-year	0.08	0.03	0.12	0.02	0.01	0.03	0.05	0.05	0.02	0.14
No increase in Normal Water Level upstream or downstream of Bakers Lake (more than 0.1')	MN State Highway 15	N/A	1,018.08	0.00	-0.01	0.02	0.12	0.12	-0.01	-0.01	0.02	-0.01
	Oday Ave / County Highway 13		1,011.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stable Outlet Structure	Qualitative		-	NO	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Meet local, state, and federal regulatory requirements	Qualitative		-									
Secondary Objectives												
2-year Event Decrease flooded acreages	Project Area	2-year	1,409 acres	1,334 acres (-5%)	1,332 acres (-5%)	1,383 acres (-2%)	1,412 acres (0%)	1,412 acres (0%)	1,344 acres (-5%)	1,383 acres (-2%)	1,343 acres (-5%)	1,290 acres (-8%)
2-year Event Reduction in upstream elevations by 1.5-feet	MN State Highway 15	2-year	1,021.64	-0.02	-0.03	-0.01	0.03	0.03	-0.02	-0.02	-0.01	-0.03
2-year Event Flow reduction downstream of Bakers Lake by 20%	Oday Ave / County Highway 13	2-year	572	-7%	2%	-4%	-7%	-7%	-3%	-3%	-4%	0%
10-year Event Reduction in flood elevations downstream of Bakers Lake by 0.5-feet	Oday Ave / County Highway 13	10-year	1,016.36	-0.13	-0.24	0.04	0.25	0.24	-0.10	-0.10	-0.03	-0.27
Minimize long term maintenance	Qualitative		Poor	Poor	Good	Good	Good	Poor	Good	Best	Best	Good
Other Results												
2-year event Bounce on South Bakers Lake	South Bakers Lake	2-year	1.88	-0.13	-0.19	-0.50	-0.61	-0.61	-0.12	-0.12	-0.50	-0.12
Normal Water Level on the North and South basins (OHW = 1016.91')	North Bakers Lake	NWL	1,016.44	-1.18	-1.83	-0.51	0.24	0.25	-1.33	-1.33	-0.51	-2.05
	South Bakers Lake	NWL	1,015.24	-0.01	-0.73	0.67	1.44	1.44	-0.18	-0.18	0.67	-0.99
Reduce frequency of breakout flow around the outlet. Based on the depth of breakout flow at peak flood elevations. (depths are shown)	South Bakers Lake	10-year	0.51	0.44	0.00 No Breakout	0.56	0.89	0.90	0.20	0.00 No Breakout	0.00 No Breakout	0.00 No Breakout
Breakout flow from North Bakers Lake (No breakout flow for 2- or 10-year)	North Breakout	100-year	279	-16%	-32%	-10%	6%	17%	-23%	-12%	7%	-37%

Ordinary high water level (OHW) = 1016.91
Existing overflow south of the existing outlet ~ 1018.0
Existing overflow north of the existing outlet ~ 1020.0
North Bakers Lake overflow ~1019.0

Formatting Legend – Design Criteria

- Met
- Partially Met
- Not Met

Formatting Legend – Other Results

- Decrease
- Increase

5 CONCLUSION AND RECOMMENDATIONS

The results indicate that only Alternative 7 and Alternative 8 meet all mandatory objectives, provide improvement for the secondary objectives, and provide the best conditions to minimize long term maintenance. These two alternatives provide the best conditions for long term maintenance due to the reduction in recurrence and the rate of breakout flow over the embankment southeast of the outlet. Alternative 8 will result in an increase to the normal water level of the south basin by 0.67 feet (8 inches). The increase in normal water level will enable improved habitat management, while keeping the permanent pool within the confines of the existing wetland complex. The outlet configuration results in a decrease in the bounce on the south basin during a 2-year event by 0.5 feet (6 inches). The decrease in bounce will reduce the frequency of cattails and bog material from detaching. **Alternative 8 is the recommended alternative to carry forward for detailed review and design.**

Additional results comparing Existing Conditions and Alternative 8 have been provided in the **Appendix**. Stage and discharge hydrographs for the 2-year, 10-year, and 100-year events are shown at MN State Highway 15, South Bakers Lake Basin, Oday Avenue / County Highway 13, and Leaf Avenue.

Summary of Alternative 8 performance:

- The peak flow and stage reductions for the 2-year and 10-year events will extend downstream to the McLeod/Sibley county line and to High Island Lake (see **Appendix**).
- Slight increase in peak flow and stage for the 100-year event downstream of Bakers Lake. Peak stage increases are less than 0.05 feet.
- Function of the outlet will be stable and predictable, enabling improved habitat management in the wildlife management area.
- The recurrence and volume of breakout flow from the north basin will be reduced, resulting in a reduction of crop inundation and erosion.
- The recurrence and volume of breakout flow over the embankment southeast of the outlet structure will be reduced, resulting in a reduction of crop inundation and erosion.
- The normal water level in the south basin of Bakers Lake will be increased. by 0.67 feet (8 inches).
- The north and south basins of Bakers Lake will more closely function like a single basin, enabling more consistent habitat management.
- Bounce in the south basin will be reduced. This will reduce the frequency of bog detachment and clogging of the High Island Creek channel through the basin.
- Downstream velocities will decrease for the 2-year rainfall event. This will reduce scour and sediment and nutrient delivery downstream.
- Peak water surface elevations upstream of the lake will not increase.

For future planning purposes, an opinion of probable cost (OPC) was developed for Alternative 8. The estimate includes removal of the existing structure, construction costs associated with the construction of the new sheet pile outlet weir and southeast embankment earthwork, engineering and project management costs, and a 20% contingency. The estimated project cost is **$352,400**. A detailed breakdown of cost is provided in the **Appendix**.

This purpose of this study was for conceptual planning and was not intended to establish a final design. Final dimensions and elevations of the Bakers Lake outlet structure would need to be determined during final design and plan development.

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FIGURES

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Figure 1b:	Bakers Lake North Portion
Figure 1c:	Bakers Lake North/South Connection
Figure 1d:	Bakers Lake South Portion (1 or 2)
Figure 1e:	Bakers Lake South Portion (2 of 2)
Figure 1f:	Bakers Lake Outlet (1 of 4)
Figure 1g:	Bakers Lake Outlet (2 of 4)
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Figure 1i:	Bakers Lake Outlet (4 of 4)
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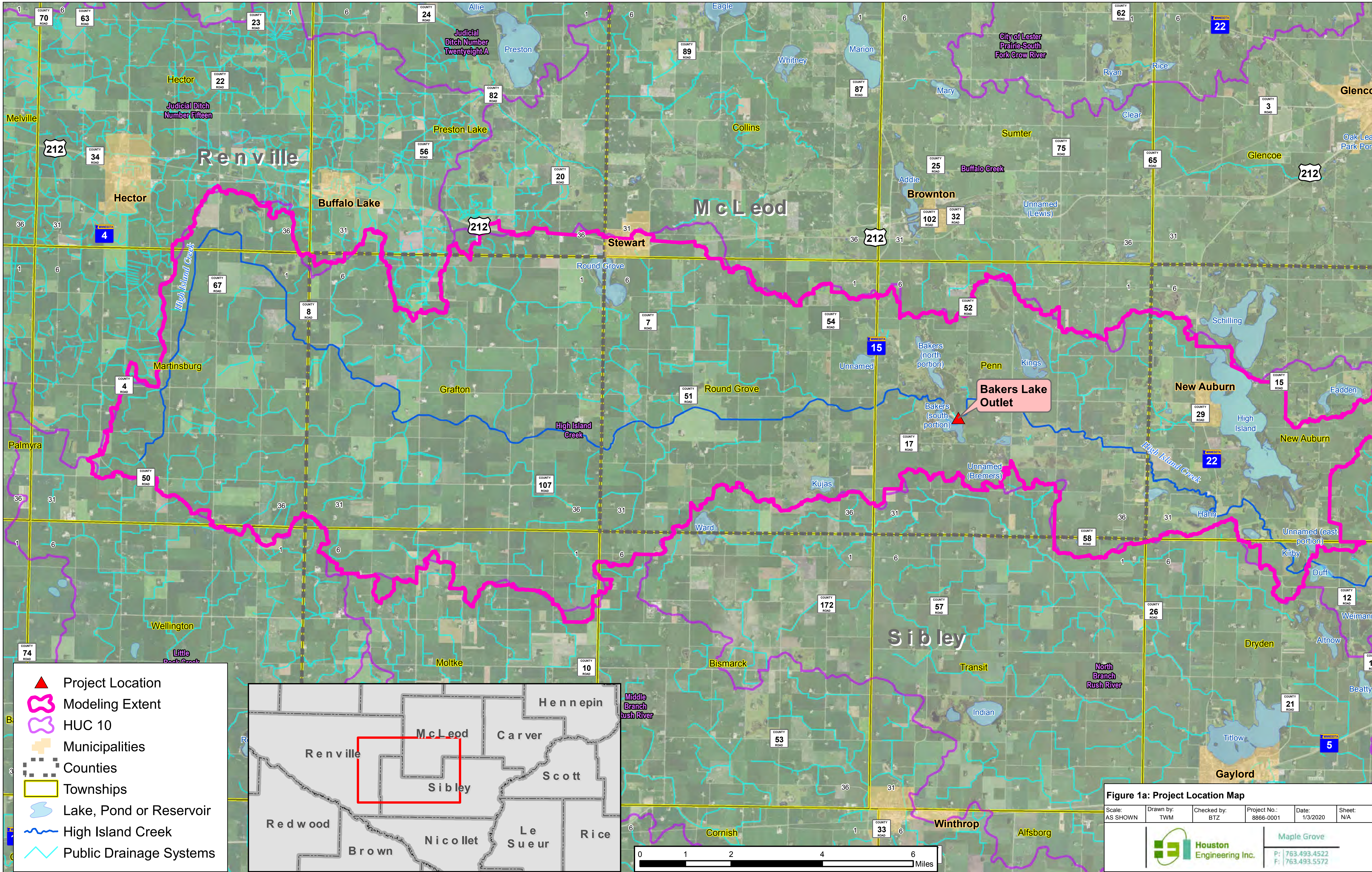

Figure 1a: Project Location Map

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AS SHOWN	TWM	BTZ	8866-0001	1/3/2020	N/A

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Figure 1b: Bakers Lake North Portion

Taken near the north/south connection looking north at the outlet of the north portion.

Figure 1c: Bakers Lake North/South Connection

Taken above the north portion near the north/south connection looking south.

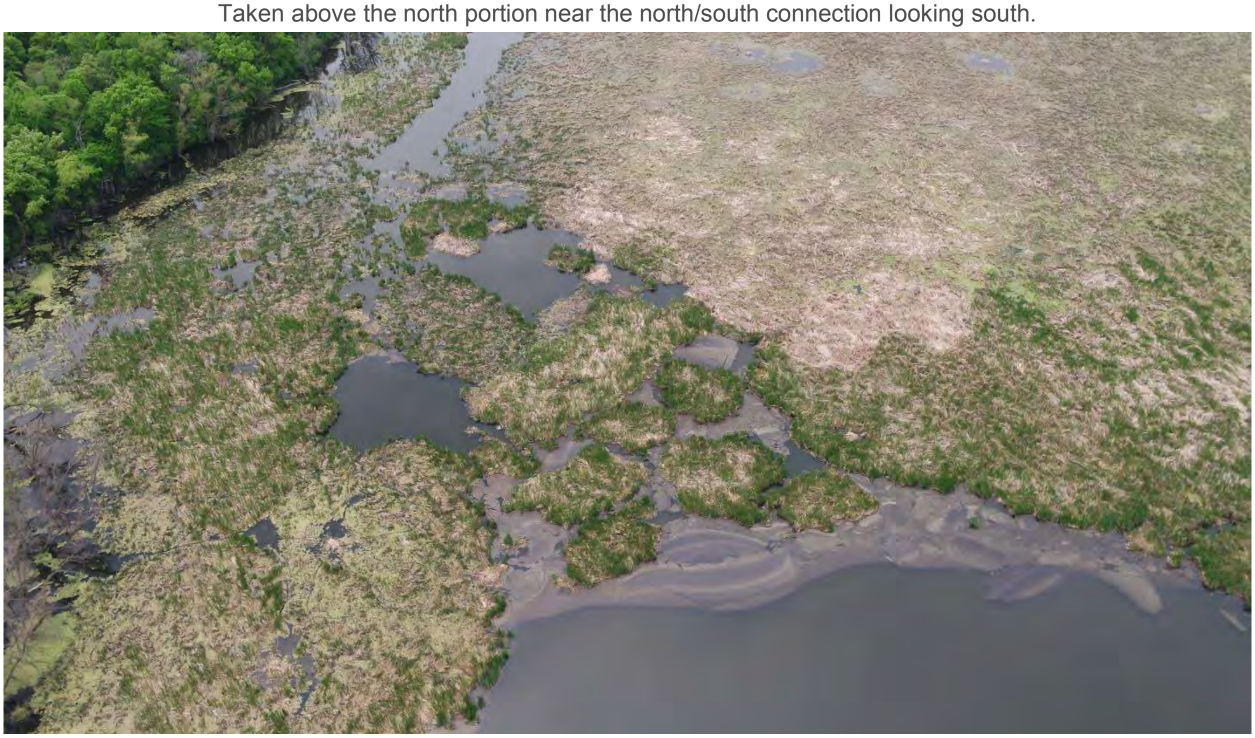

Figure 1d: Bakers Lake South Portion (1 or 2)

Taken above the south portion looking north. High Island Creek inflow on the top left. Outlet structure is to the right.

Figure 1e: Bakers Lake South Portion (2 of 2)

Taken near the south end of the south portion looking north. Outlet structure is to the right.

Figure 1f: Bakers Lake Outlet (1 of 4)
Taken above the south portion looking east at the outlet.

Figure 1g: Bakers Lake Outlet (2 of 4)
Taken above the outlet looking northeast.

Figure 1h: Bakers Lake Outlet (3 of 4)
Taken above the outlet looking east.

Figure 1i: Bakers Lake Outlet (4 of 4)
Taken above the outlet looking west.

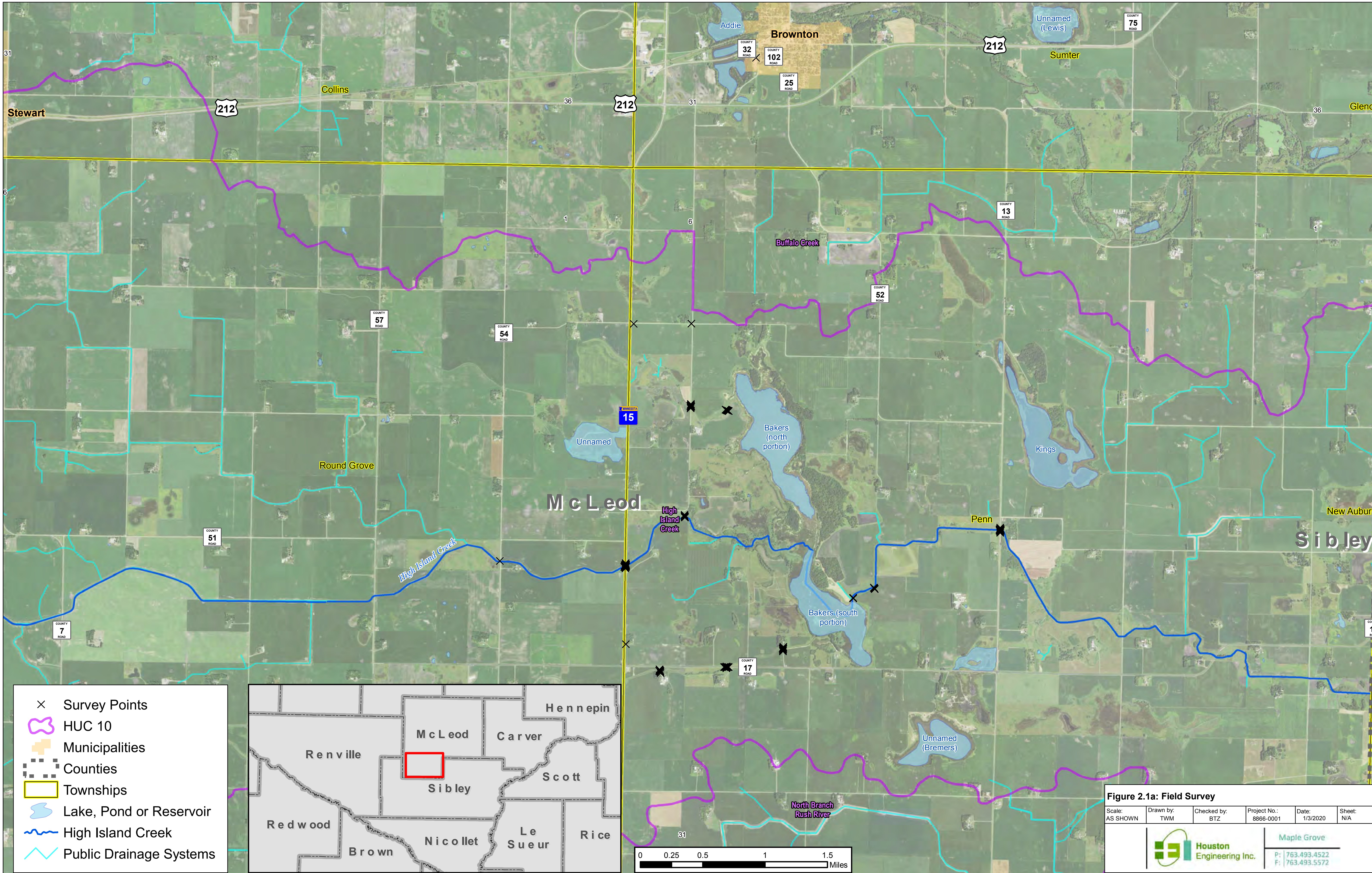

Figure 2.1a: Field Survey

Scale:	Drawn by:	Checked by:	Project No.:	Date:	Sheet:
AS SHOWN	TWM	BTZ	8866-0001	1/3/2020	N/A

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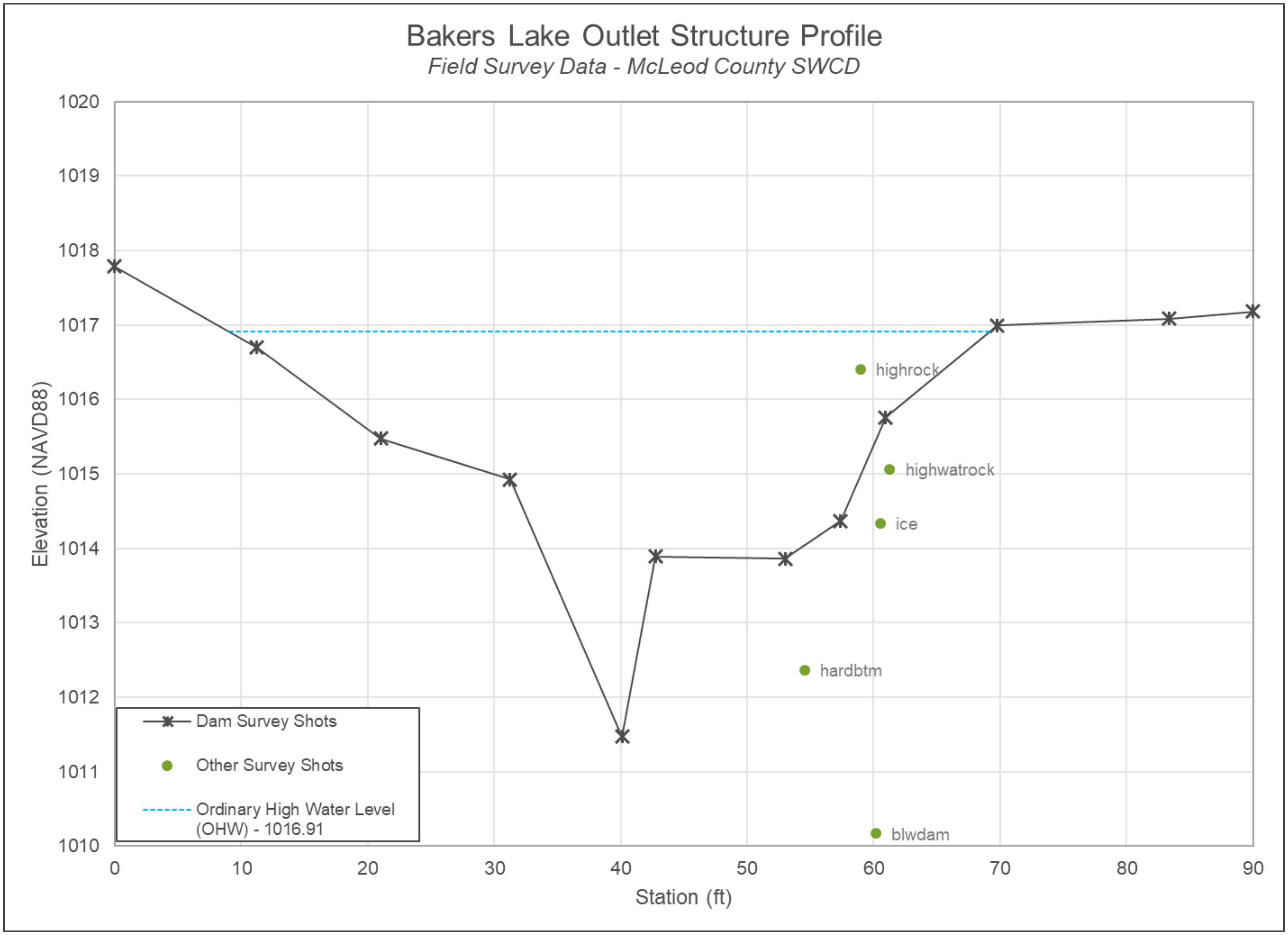
Figure 2.1b: Existing Bakers Lake Outlet Profile



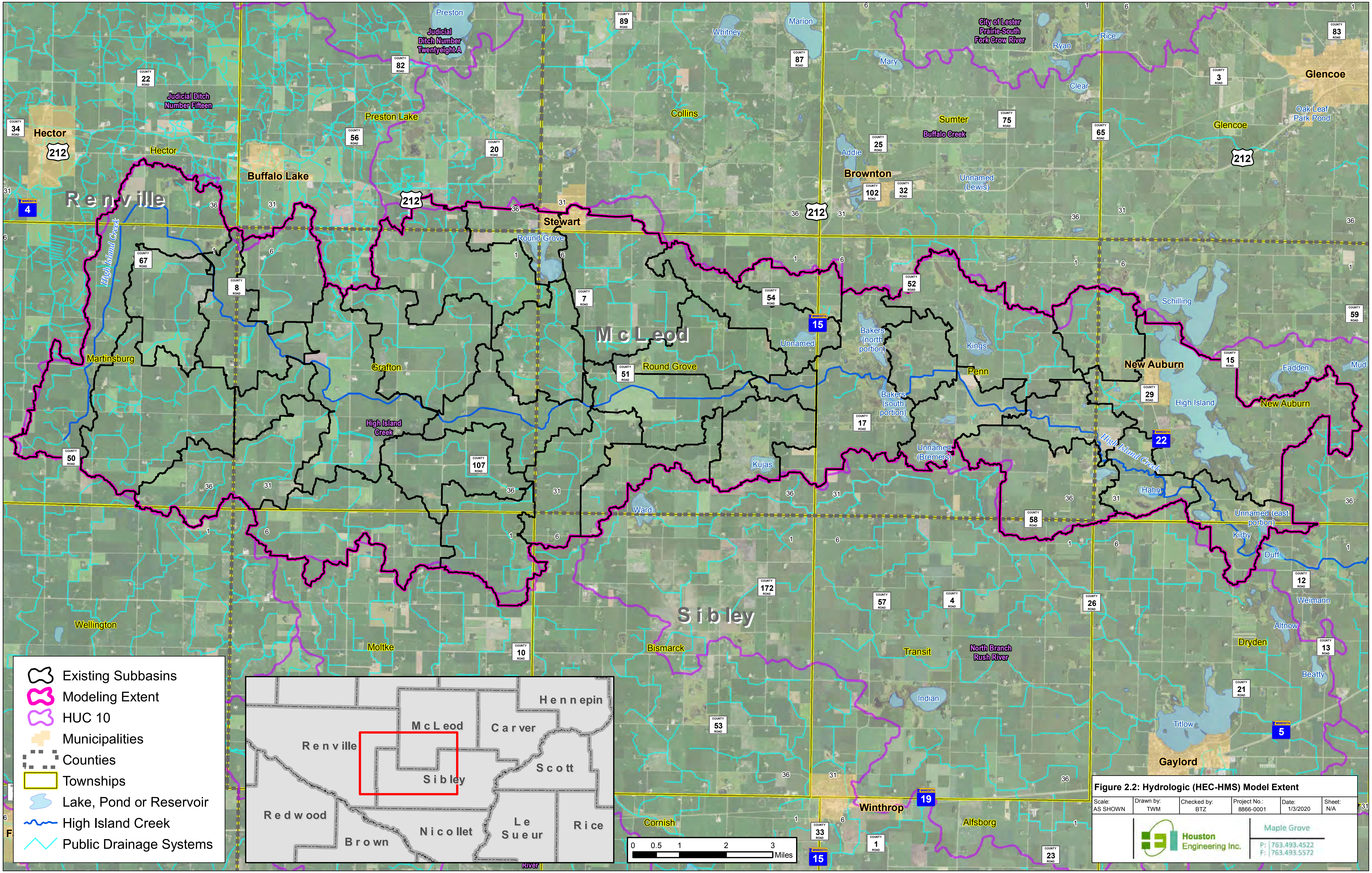


Figure 2.2: Hydrologic (HEC-HMS) Model Extent

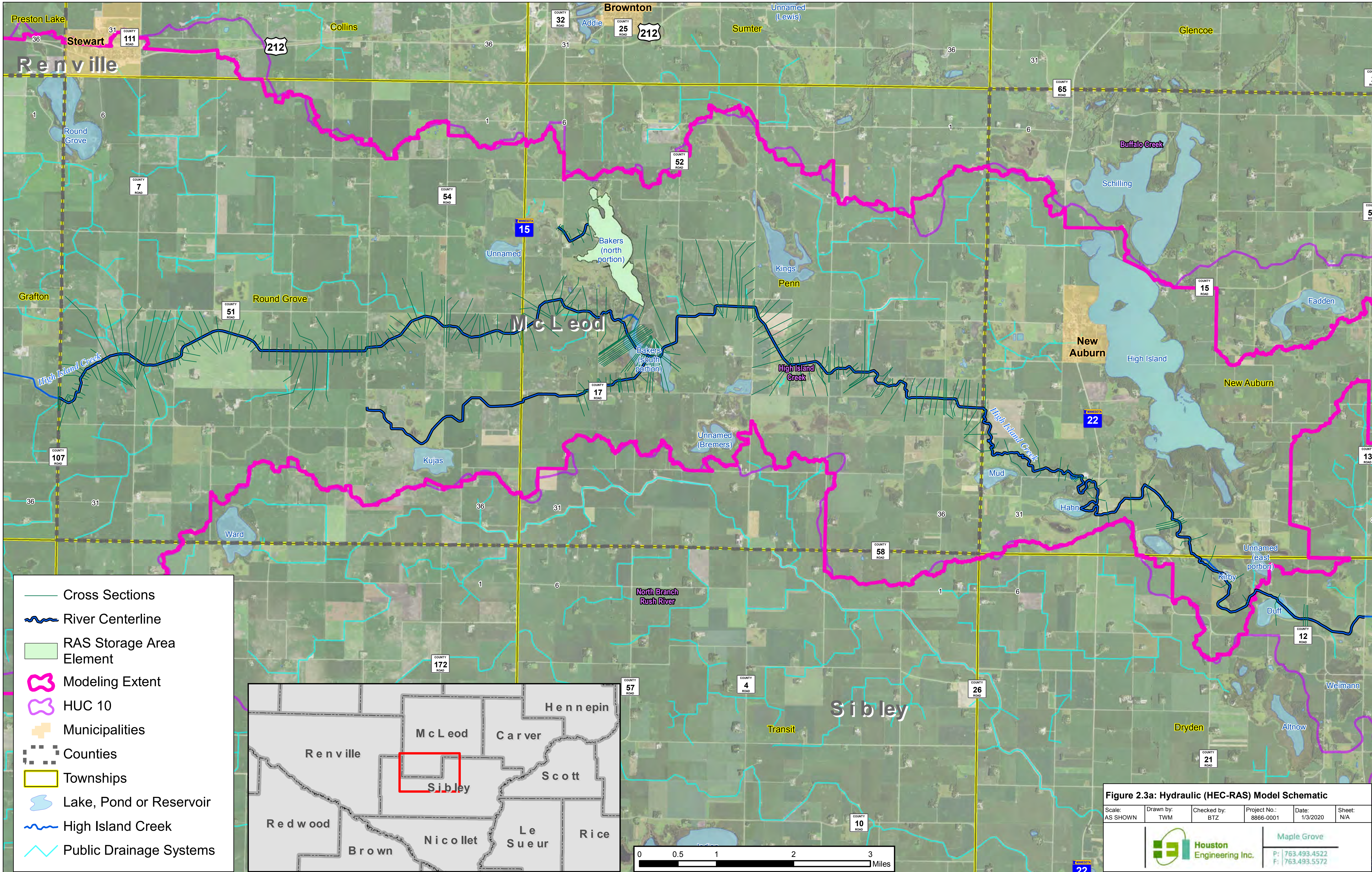
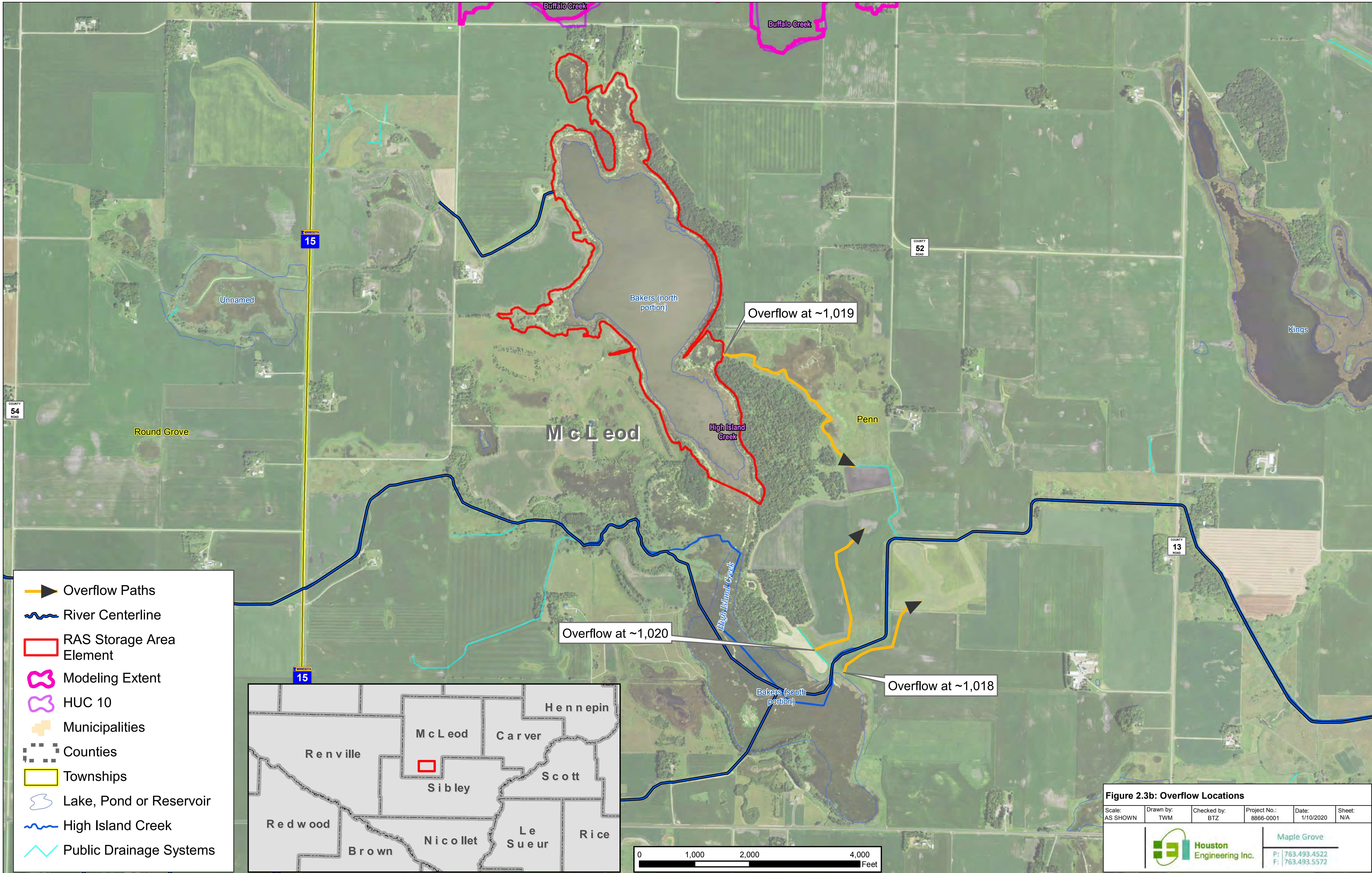


Figure 2.3a: Hydraulic (HEC-RAS) Model Schematic



Buffalo Creek
Buffalo Creek
Bakers (north portion)
Overflow at ~1,019
Overflow at ~1,020
Overflow at ~1,018
Bakers (south portion)
High Island Creek
High Island Creek
Unnamed
Kings
Penn
Round Grove
McLeod
15
15
52
54
13
Overflow Paths
River Centerline
RAS Storage Area Element
Modeling Extent
HUC 10
Municipalities
Counties
Townships
Lake, Pond or Reservoir
High Island Creek
Public Drainage Systems
Hennepin
McLeod
Carver
Renville
Sibley
Scott
Redwood
Le Sueur
Rice
Nicollet
Brown
0
1,000
2,000
4,000
Feet
Figure 2.3b: Overflow Locations
Scale: AS SHOWN
Drawn by: TWM
Checked by: BTZ
Project No.: 8866-0001
Date: 1/10/2020
Sheet: N/A
Houston Engineering Inc.
Maple Grove
P: 763.493.4522
F: 763.493.5572

Figure 3a: Outlet Structure Alternative Profiles

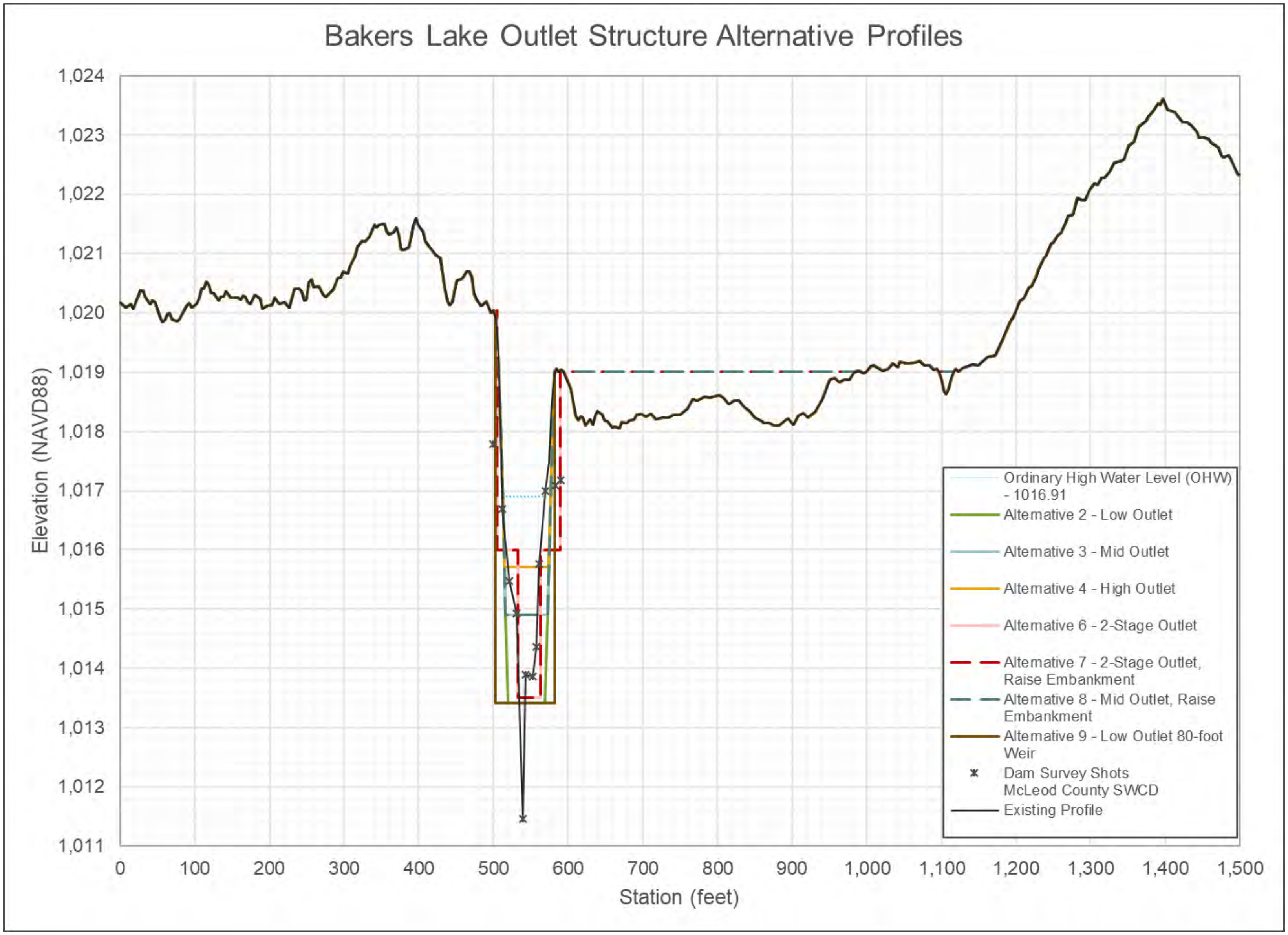
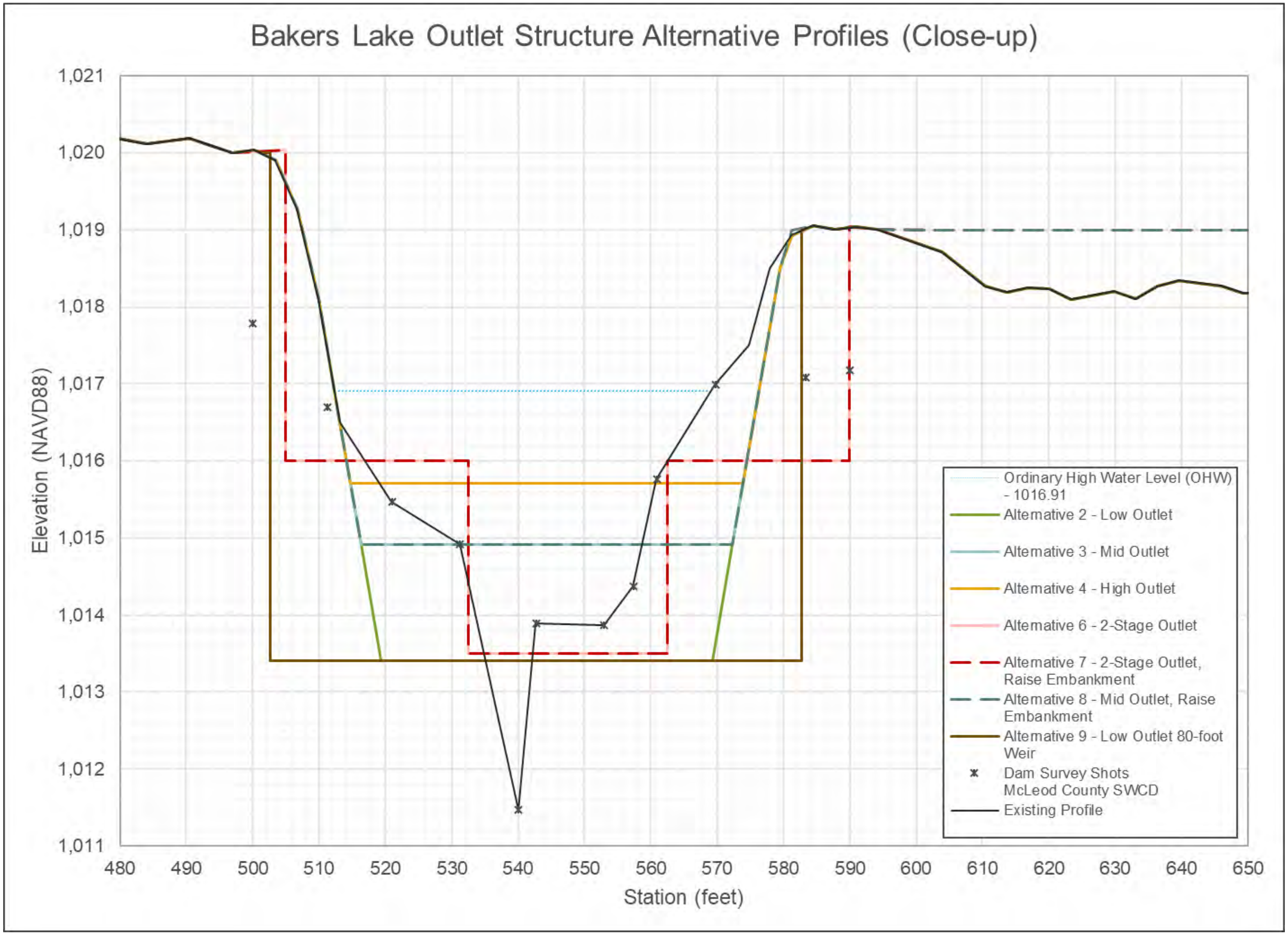
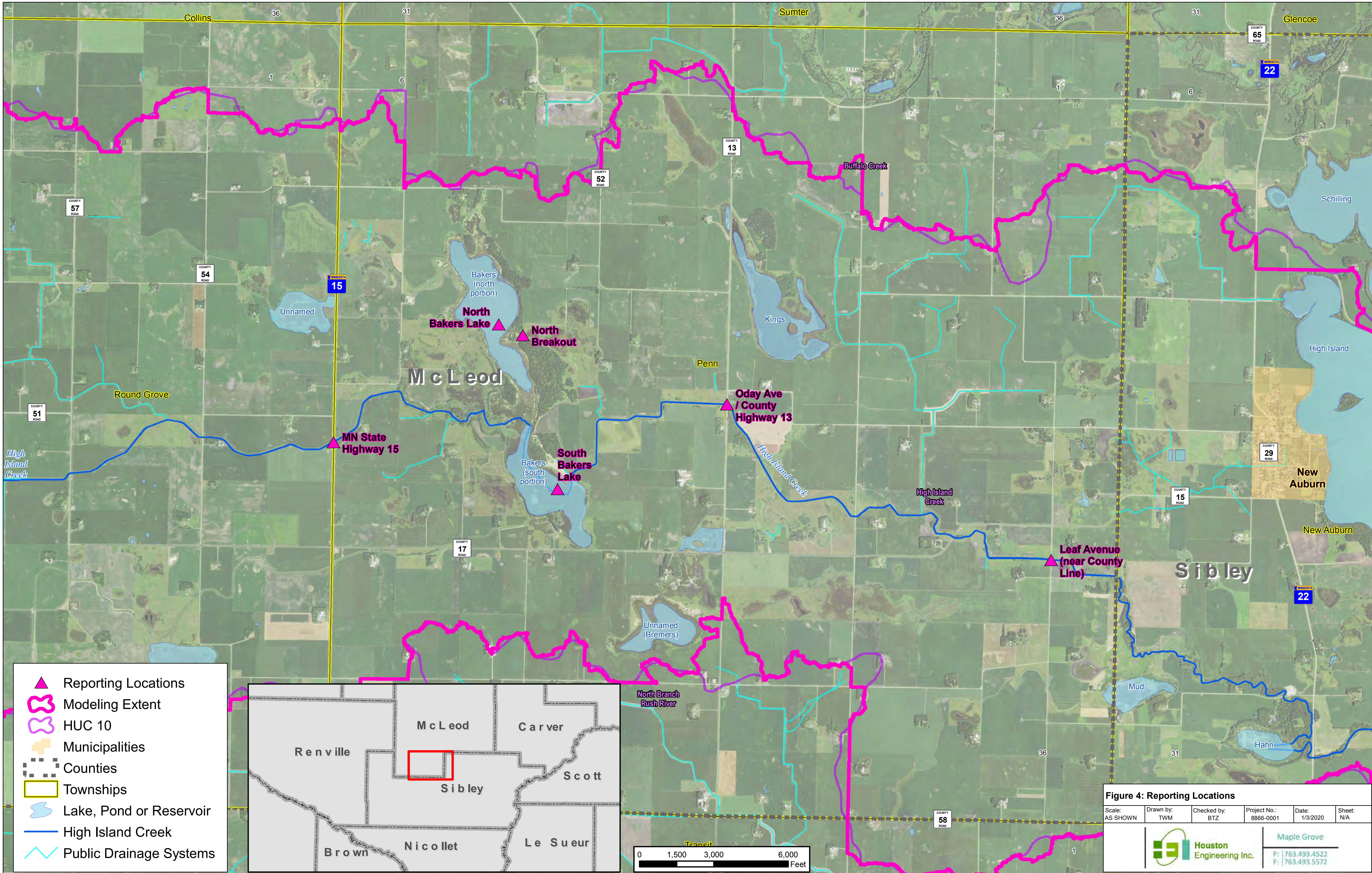


Figure 3b: Outlet Structure Alternative Profiles (Close-up)





Collins
Sumter
Glencoe
Buffalo Creek
Schilling
Bakers (north portion)
North Bakers Lake
North Breakout
Unnamed
Kings
High Island
McLeod
Penn
Round Grove
Oday Ave / County Highway 13
MN State Highway 15
South Bakers Lake
Bakers (south portion)
High Island Creek
New Auburn
Leaf Avenue (near County Line)
Sibley
Unnamed (Bremers)
North Branch Rush River
Mud
Hahn
Transit
Reporting Locations
Modeling Extent
HUC 10
Municipalities
Counties
Townships
Lake, Pond or Reservoir
High Island Creek
Public Drainage Systems
Renville
McLeod
Carver
Sibley
Scott
Brown
Nicollet
Le Sueur
0 1,500 3,000 6,000 Feet
Figure 4: Reporting Locations
Scale: AS SHOWN
Drawn by: TWM
Checked by: BTZ
Project No.: 8866-0001
Date: 1/3/2020
Sheet: N/A
Houston Engineering Inc.
Maple Grove
P: 763.493.4522
F: 763.493.5572

APPENDIX

Table A.1: Expanded Results Alternative Results – Design Criteria
Figure A.1: Stage Hydrograph at MN State Highway 15
Figure A.2: Discharge Hydrograph at MN State Highway 15
Figure A.3: Stage Hydrograph at South Bakers Lake Basin
Figure A.4: Discharge Hydrograph at South Bakers Lake Basin
Figure A.5: Stage Hydrograph at Oday Avenue / County Highway 13
Figure A.6: Discharge Hydrograph at Oday Avenue / County Highway 13
Figure A.7: Stage Hydrograph at Leaf Avenue
Figure A.8: Discharge Hydrograph at Leaf Avenue
Table A.2: Opinion of Probable Cost (OPC)

Table A.1: Expanded Alternative Results – Design Criteria

Mandatory Objectives	Location	Event	Existing Cond.	Alternative 1 Channel Cleanout		Alternative 2 Low Outlet w/ Cleanout		Alternative 3 Mid Outlet w/ Cleanout		Alternative 4 High Outlet w/ Cleanout		Alternative 5 High Outlet (No Cleanout)		Alternative 6 2-stage Outlet w/ Cleanout		Alternative 7 2-stage Outlet, Raise Embankment w/ Cleanout		Alternative 8 Mid Outlet, Raise Embankment w/ Cleanout		Alternative 9 Low Outlet, 80-ft weir w/ Cleanout	
				Result	Change	Result	Change	Result	Change	Result	Change	Result	Change	Result	Change	Result	Change	Result	Change	Result	Change
100-year event No increase in Peak WSE greater than 0.5-feet upstream or downstream of Bakers Lake	MN State Highway 15	100-year	1,025.77	1,025.77	0.00	1,025.77	0.00	1,025.77	0.00	1,025.77	0.00	1,025.77	0.00	1,025.77	0.00	1,025.77	0.00	1,025.77	0.00	1,025.77	0.00
	Oday Ave / County Highway 13		1,018.96	1,018.91	-0.05	1,018.81	-0.15	1,018.96	0.00	1,019.05	0.09	1,019.06	0.10	1,018.87	-0.09	1,018.90	-0.06	1,019.01	0.05	1,018.77	-0.19
2-year event No increase in peak WSE of greater than 0.5-feet upstream or downstream of Bakers Lake	MN State Highway 15	2-year	1,021.64	1,021.62	-0.02	1,021.61	-0.03	1,021.63	-0.01	1,021.67	0.03	1,021.67	0.03	1,021.62	-0.02	1,021.62	-0.02	1,021.63	-0.01	1,021.61	-0.03
	Oday Ave / County Highway 13		1,014.40	1,014.18	-0.22	1,014.46	0.06	1,014.28	-0.12	1,014.18	-0.22	1,014.18	-0.22	1,014.30	-0.10	1,014.30	-0.10	1,014.28	-0.12	1,014.41	0.01
North and South basins maintain the same peak WSE during all events (0.05-foot tolerance)	Difference between north/south basin	2-year	0.08	0.03	-0.05	0.12	0.04	0.02	-0.06	0.01	-0.07	0.03	-0.05	0.05	-0.03	0.05	-0.03	0.02	-0.06	0.14	0.06
No increase in Normal Water Level upstream or downstream of Bakers Lake (more than 0.1')	MN State Highway 15	N/A	1,018.08	1,018.08	0.00	1,018.07	-0.01	1,018.10	0.02	1,018.20	0.12	1,018.20	0.12	1,018.07	-0.01	1,018.07	-0.01	1,018.10	0.02	1,018.07	-0.01
	Oday Ave / County Highway 13		1,011.19	1,011.19	0.00	1,011.19	0.00	1,011.19	0.00	1,011.19	0.00	1,011.19	0.00	1,011.19	0.00	1,011.19	0.00	1,011.19	0.00	1,011.19	0.00
Stable Outlet Structure	Qualitative		-	NO		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Meet local, state, and federal regulatory requirements	Qualitative		-	-		-		-		-		-		-		-		-		-	
Secondary Objectives																					
2-year Event Decrease flooded acreages	Project Area	2-year	1,409	1,334	-5%	1,332	-5%	1,383	-2%	1,412	0%	1,412	0%	1,344	-5%	1,383	-2%	1,345	-5%	1,290	-8%
2-year Event Reduction in upstream elevations by 1.5-feet	MN State Highway 15	2-year	1,021.64	1,021.62	-0.02	1,021.61	-0.03	1,021.63	-0.01	1,021.67	0.03	1,021.67	0.03	1,021.62	-0.02	1,021.62	-0.02	1,021.63	-0.01	1,021.61	-0.03
2-year Event Flow reduction downstream of Bakers Lake by 20%	Oday Ave / County Highway 13	2-year	572	534	-7%	583	2%	552	-4%	534	-7%	534	-7%	555	-3%	555	-3%	552	-4%	574	0%
10-year Event Reduction in flood elevations downstream of Bakers Lake by 0.5-feet	Oday Ave / County Highway 13	10-year	1,016.36	1,016.23	-0.13	1,016.12	-0.24	1,016.40	0.04	1,016.61	0.25	1,016.60	0.24	1,016.26	-0.10	1,016.26	-0.10	1,016.33	-0.03	1,016.09	-0.27
Minimize long term maintenance	Qualitative		Poor	Poor		Good		Good		Good		Poor		Good		Best		Best		Good	
Other Results																					
2-year event Bounce on South Bakers Lake	South Bakers Lake	2-year	1.88	1.75	-0.13	1.69	-0.19	1.38	-0.50	1.27	-0.61	1.27	-0.61	1.76	-0.12	1.76	-0.12	1.38	-0.50	1.76	-0.12
Normal Water Level on the North and South basins (OHW = 1016.91')	North Bakers Lake	NWL	1,016.44	1,015.26	-1.18	1,014.61	-1.83	1,015.93	-0.51	1,016.68	0.24	1,016.69	0.25	1,015.11	-1.33	1,015.11	-1.33	1,015.93	-0.51	1,014.39	-2.05
	South Bakers Lake	NWL	1,015.24	1,015.23	-0.01	1,014.51	-0.73	1,015.91	0.67	1,016.68	1.44	1,016.68	1.44	1,015.06	-0.18	1,015.06	-0.18	1,015.91	0.67	1,014.25	-0.99
Reduce frequency of breakout flow around the outlet. Based on depth of breakout flow at peak flood elevations.	South Bakers Lake	10-year	0.51 1,018.51	0.44 1,018.44	-0.07	0.00 1,017.95	-0.56	0.56 1,018.56	0.05	0.89 1,018.89	0.38	0.90 1,018.90	0.39	0.20 1,018.20	-0.31	0.00 1,018.20	-0.31	0.00 1,018.64	0.13	0.00 1,017.84	-0.67
Breakout flow from North Bakers Lake (No breakout flow for 2- or 10-year)	North Breakout	100-year	279	233	-16%	189	-32%	251	-10%	295	6%	326	17%	214	-23%	244	-12%	298	7%	175	-37%

Ordinary high water level (OHW) = 1016.91
Existing overflow south of the existing outlet ~ 1018.0
Existing overflow north of the existing outlet ~ 1020.0
North Bakers Lake overflow ~1019.0

Formatting Legend – Design Criteria Status
- Met
- Partially Met
- Not Met

Formatting Legend – Other Results
- Decrease
- Increase

Figure A.1: Stage Hydrograph at MN State Highway 15

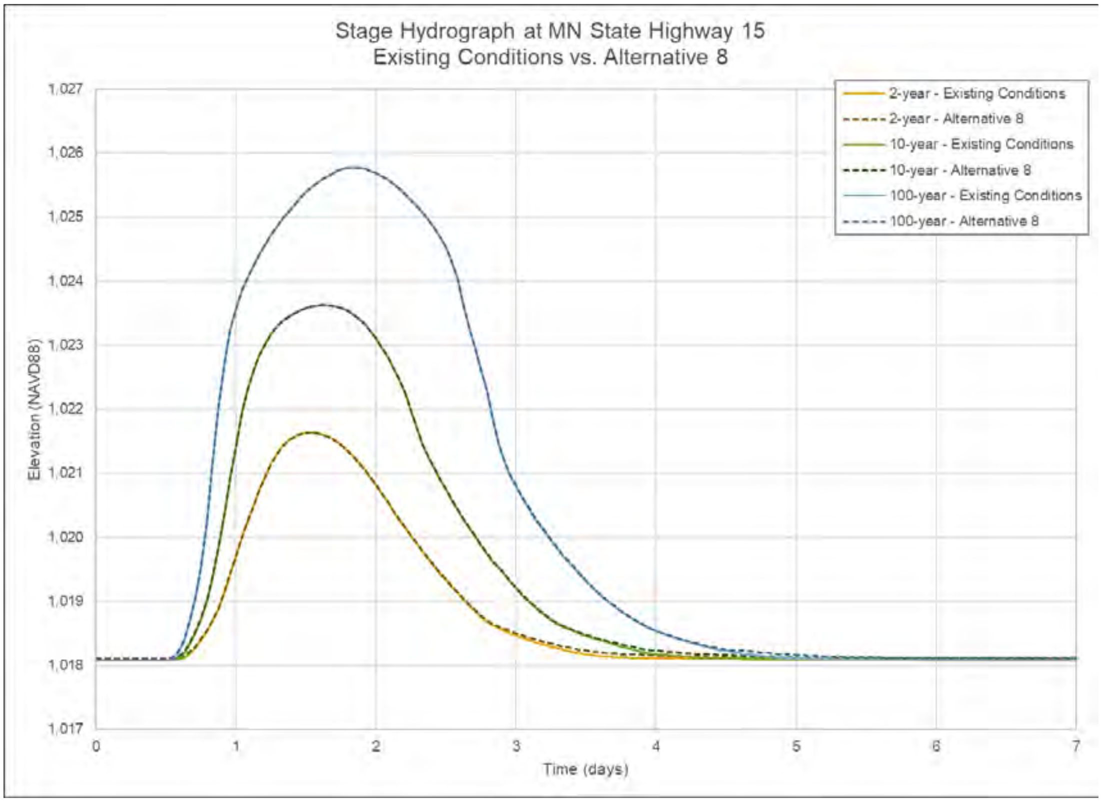


Figure A.2: Discharge Hydrograph at MN State Highway 15

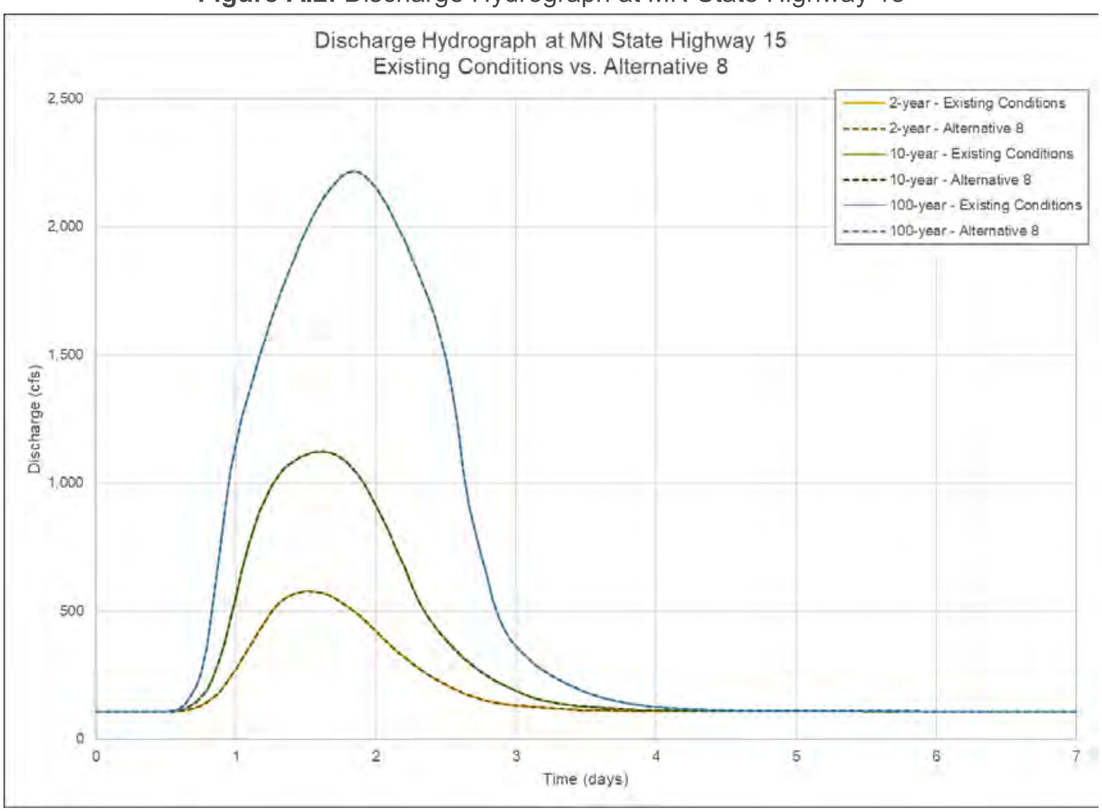


Figure A.3: Stage Hydrograph at South Bakers Lake Basin

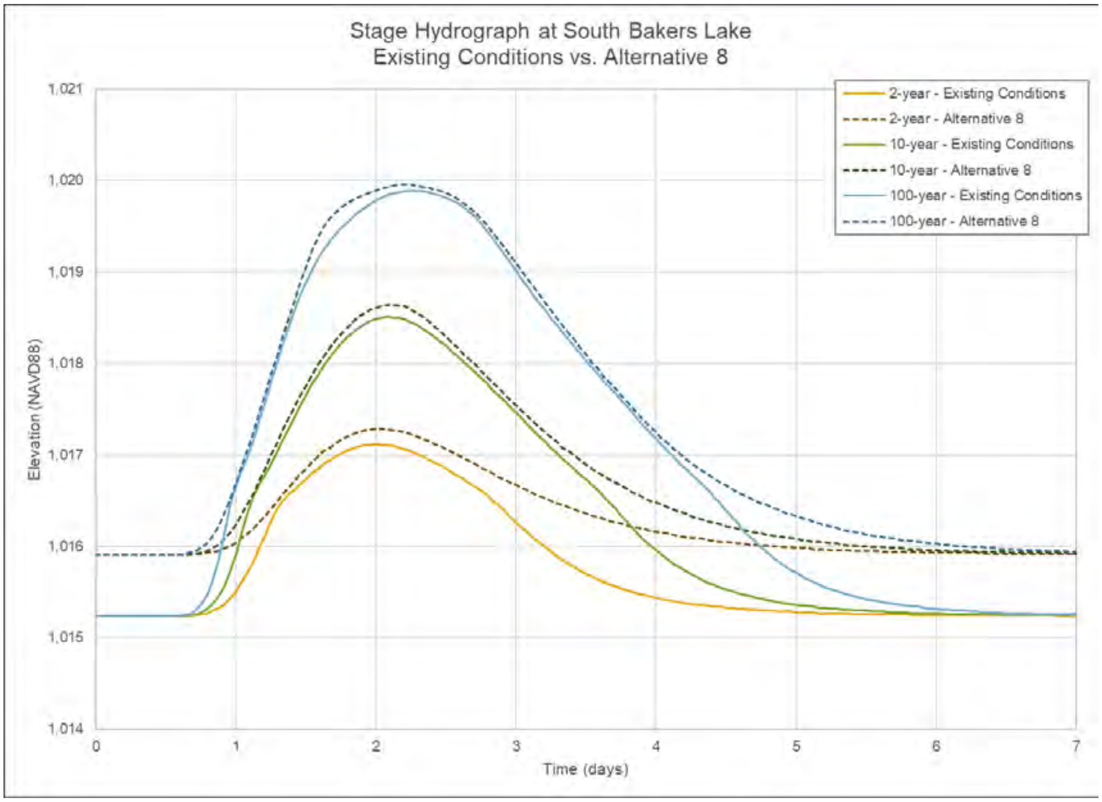


Figure A.4: Discharge Hydrograph at South Bakers Lake Basin

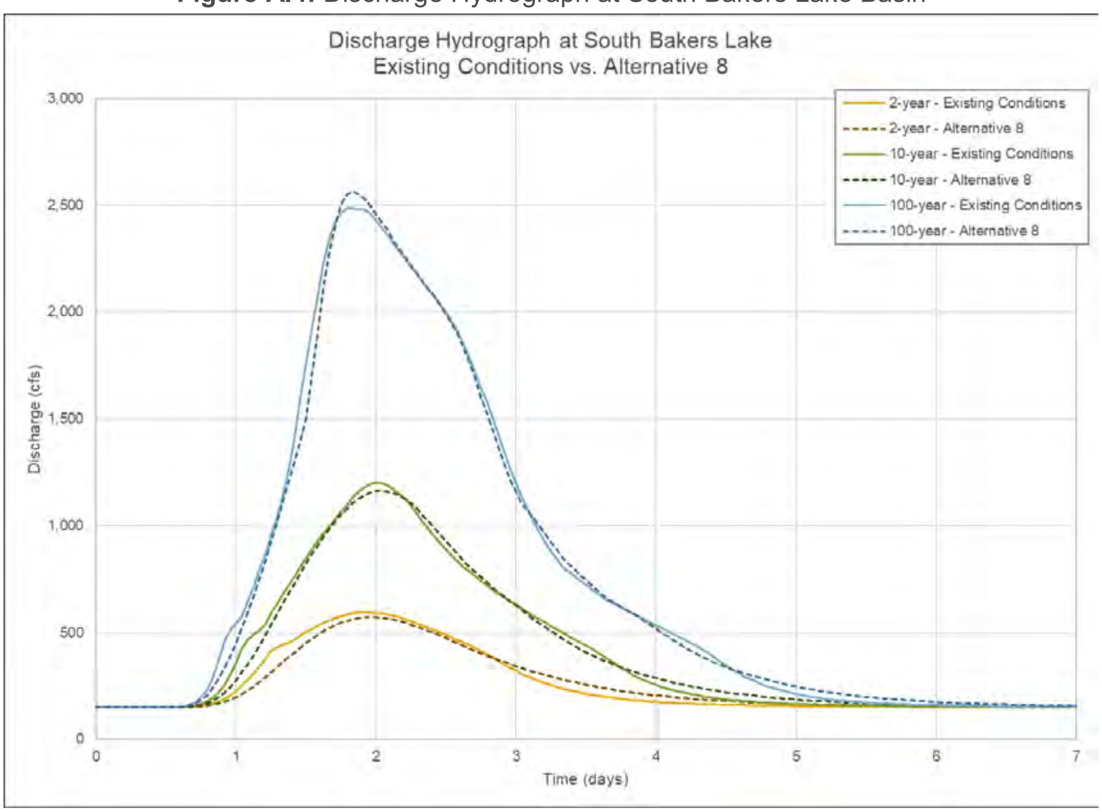


Figure A.5: Stage Hydrograph at Oday Avenue / County Highway 13

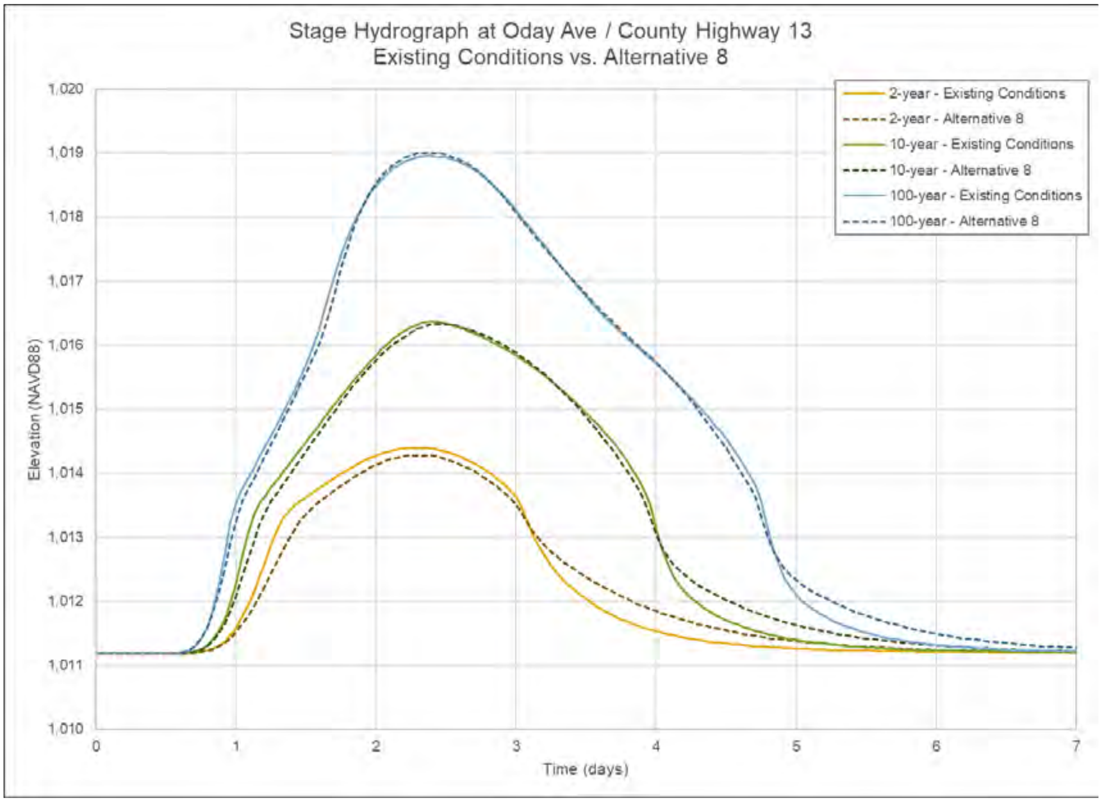


Figure A.6: Discharge Hydrograph at Oday Avenue / County Highway 13

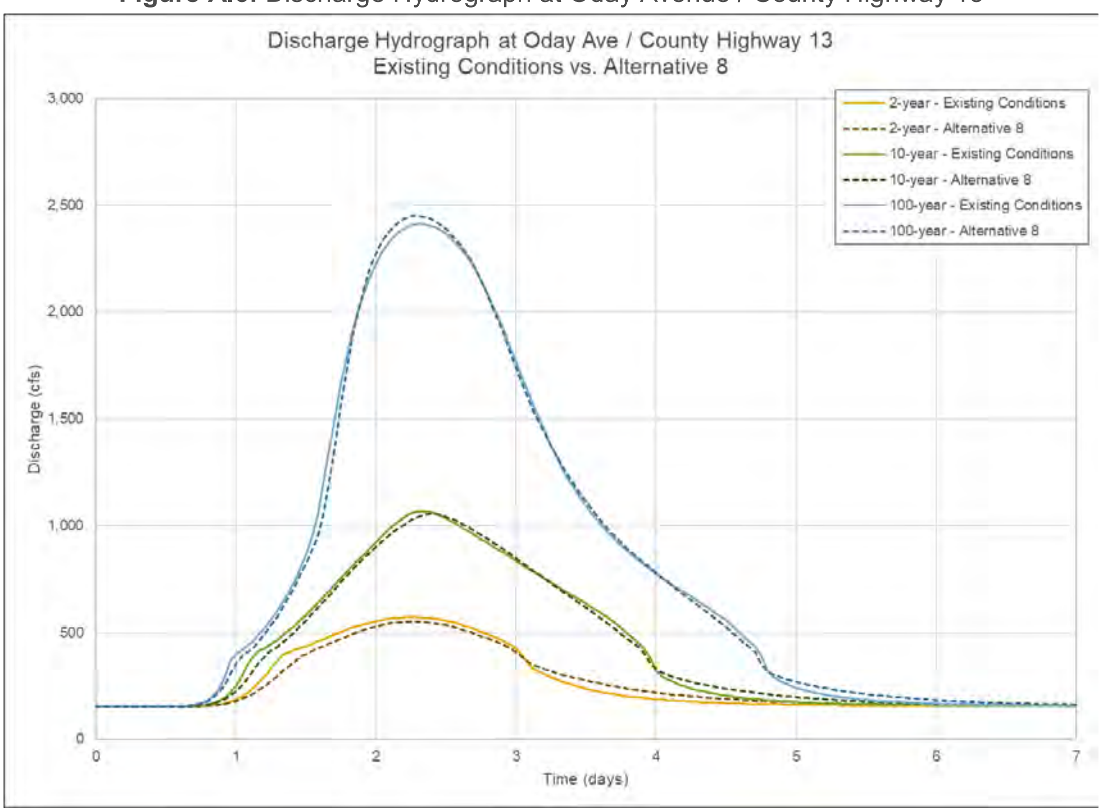


Figure A.7: Stage Hydrograph at Leaf Avenue

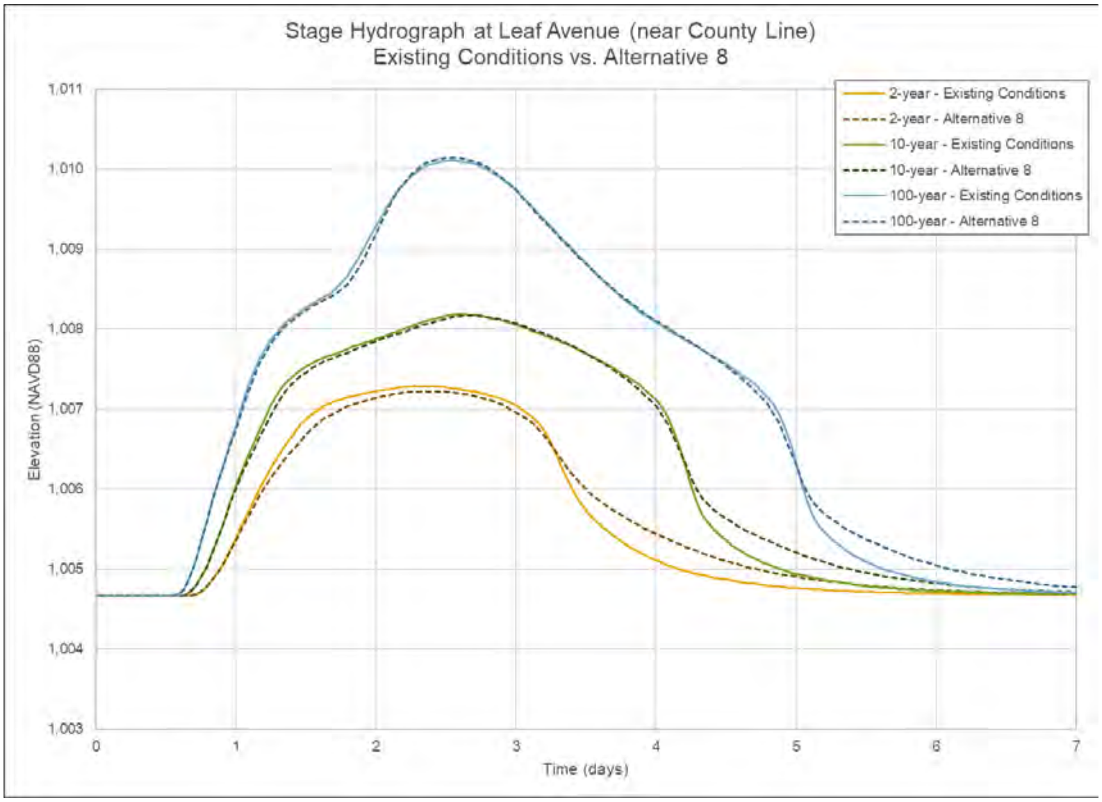


Figure A.8: Discharge Hydrograph at Leaf Avenue

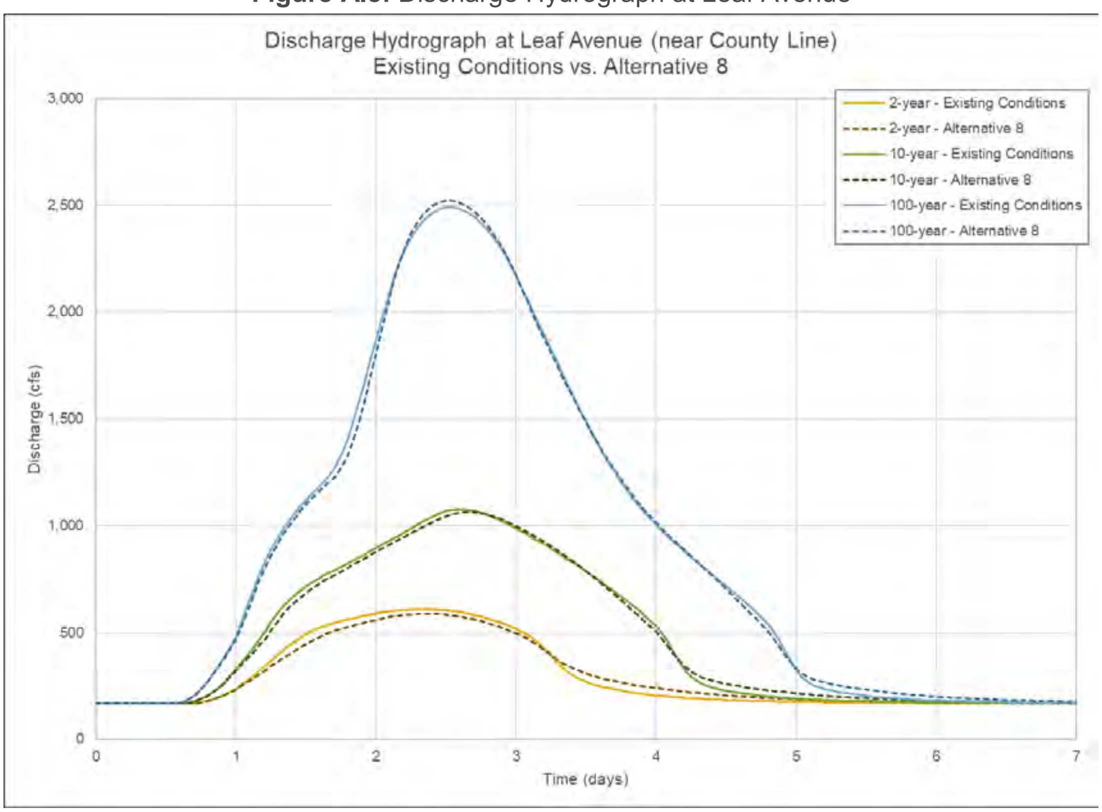


Table A.2: Opinion of Probable Cost

Alternative 8 Mid Outlet, Raise Embankment to 1019.0 w/ Channel Cleanout					
No.	***Item***	***Unit***	***Quantity***	***Unit Price***	***Total Price***
1	Mobilization	LS	1.0	$ 23,000.00	$ 23,000.00
2	Outlet Structure Removal	LS	1.0	$ 5,000.00	$ 5,000.00
3	Sheet Pile Weir	SF	1,000.0	$ 60.00	$ 60,000.00
4	Embankment Common Fill	CY	100.0	$ 20.00	$ 2,000.00
5	Riprap (Class III)	CY	125.0	$ 80.00	$ 10,000.00
6	Seeding and Mulching	LS	1.0	$ 2,000.00	$ 2,000.00
7	Channel Cleanout	LF	5,000.0	$ 30.00	$ 150,000.00
				Construction Subtotal	$ 252,000.00
				Contingencies (20%)	$ 50,400.00
				Total Construction Cost	$ 302,400.00
				Topographic Survey, Engineering, & Construction Administration	$ 50,000.00
				Non-Construction Cost	$ 50,000.00
				Total Estimated Project Cost	$ 352,400.00