Memorandum

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August 30, 2024

TO: Stephen Bourn – Rio Tinto

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Ashley Romero – GEI Consultants, Inc.

RE: Stream C Evaluation Work Plan – Revision 2
Reclaimed Flambeau Mine – Ladysmith, Wisconsin

1. Introduction

The Flambeau mine was an open-pit copper sulfide mine located just south of Ladysmith in Rusk County, Wisconsin (WI) (Figure 1). From 1994 through 1997, Flambeau Mining Company (Flambeau) mined 1.8 million tons from an ore body adjacent to the Flambeau River using an open-pit method. Reclamation, which included backfilling the pit and the demolition of most of the site infrastructure, commenced in earnest in 1998. Reclamation was completed in 2001.

Flambeau petitioned for a Certificate of Completion (COC) in January 2007. A public hearing was held, and a COC was received in August 2007 for the entire site except for a 32-acre parcel known as the Industrial Outlot. The Reclamation Plan for the Industrial Outlot included leaving certain structures intact. These include a building that serves as a Wisconsin Department of Natural Resources (Department/WDNR) service center and a laydown area for Excel Energy. Elevated levels of copper and zinc have historically been observed in the Industrial Outlot area, so it was excluded from the 2007 COC. The 2007 COC signified that Flambeau had fulfilled the requirements of the Reclamation Plan for the mining site, except for the Industrial Outlot. Since 2004, there have been numerous remedial actions taken to reduce residual copper and zinc in the soils of the Industrial Outlot.

Subsequently, on November 4, 2021, Flambeau submitted a petition seeking the issuance of the COC for the Industrial Outlot area of the Reclaimed Flambeau Mine. The Department issued a public notice on June 6, 2022, announcing the request and providing the public with a comment period. The public hearing was held on July 6, 2022. The COC for the Industrial Outlot portion of the mining site was issued on December 20, 2022. As a result, the 2022 COC, considered together with the 2007 COC, signifies Flambeau has fulfilled the requirements of reclamation for the entire mine site.

1.1 Study Objective

Public comments were received during the 2022 COC request related to the elevated copper and zinc levels observed in Stream C. The Department incorporated some of these comments in its *Findings of Fact, Conclusions of Law and Revised Mining Permit – Flambeau Mining Company* (*Findings of Fact*) (WDNR, 2022b). As stated in Number 27 of the *Findings of Fact*, “The Department has been engaged with Flambeau on a study of Stream C to determine if Stream C is attaining its designated uses.”

This Stream C Evaluation Work Plan (Work Plan) has been prepared on behalf of Flambeau to address this and complete a study to evaluate current copper and zinc levels in Stream C.

The objective of the Stream C evaluation is to determine if 1) Stream C is meeting its designated use and 2) it can be removed from the Clean Water Act (CWA) 303d impaired waters list.

1.2 Stream C Setting

Stream C is approximately 0.75 miles long and passes through the southeast corner of the Industrial Outlot. It is located entirely on Flambeau property. The Stream C sub-watershed is shown on Figure 1. Stream C was not monitored prior to mining; therefore, a pre- and post-mining comparison is not possible.

Stream C headwaters begin in an area east of Highway (Hwy) 27. It is generally agreed that Stream C begins west of Hwy 27 near the culvert. The watershed is the composite of the areas within the outline shown on Figure 1. The largest area of drainage upstream of Flambeau is located east of Hwy 27. This area drains to a culvert underneath Hwy 27 and then through Wetland 7 to Copper Park Lane. The watershed also includes the roadside ditch area west of Hwy 27. Water from this area drains to a former rail spur and then flows west to a series of constructed basins. Runoff from the asphalted area of the Industrial Outlot drains east into the basins. The flow converges just north of Copper Park Lane, and all water flows to a culvert underneath Copper Park Lane and drains to the Flambeau River. There is also an unnamed tributary shown on Figure 1 that converges with Stream C before it enters the Flambeau River.

The area east of Hwy 27 is comprised mainly of undeveloped woods and wetlands and includes ditch runoff from Hwy 27. The area west of Hwy 27 is comprised of wetland grasses and semi-aquatic vegetation and includes runoff from Hwy 27, Wetland 7, and the storm water basins located west of Hwy 27.

The area north of Copper Park Lane has been altered on several occasions, including the ditching and installation of a culvert when it was in agricultural use, the construction of Copper Park Lane and multiple culverts during active mining, and the installation of the 0.9-acre bio-filter and subsequent storm water basins since reclamation. The area south of Copper Park Lane is mainly undeveloped woods and wetlands. There is an equestrian trail system in the woods south of Copper Park Lane.

As indicated in the Department’s February 16, 2023, email, Stream C, by default, has a Designated Use of a full fish and aquatic life use, as it is not otherwise listed in Wisconsin

Administrative Code (Wis. Admin. Code) NR 104 as a limited forage fish or limited aquatic life. However, also indicated in that email, Stream C has a Natural Community designation as Macroinvertebrate. This Work Plan does not propose a bioassessment. If one is conducted in the future, it will focus exclusively on macroinvertebrates (no fish) and proceed under a separate work plan.

1.3 Stream C 303d Listing History

Water quality monitoring completed between 2002 and 2018 showed that Stream C and its contributing drainage ways contained copper and zinc concentrations that frequently exceeded the Wis. Admin. Code NR 105 Table 2 acute toxicity criteria (ATC). In 2010 and 2011, the Department (Craig Roesler) conducted a study of Stream C. The study (WDNR, 2012) concluded that there were no significant changes in copper and zinc in the Flambeau River in response to mining activities. While water quality frequently exceeded the ATC, there was no significant acute or chronic toxicity found in the sample collected from Stream C.

Stream C has been listed on the CWA 303d impaired waters list since 2012. The following summarizes the CWA 303d listing of Stream C:

- In 2012, the Department listed Stream C as having its fish and aquatic life designation use impaired, with copper and zinc being the listed pollutants. This listing was based on copper and zinc ATC determined over 10 years of monitoring data.
  - Originally the Department considered Stream C to begin south of Copper Park Lane and to be approximately 0.55 miles in length. The 0.2-mile section above Copper Park Lane was treated as “not navigable” and considered as a wetland complex.
- In 2020, the Department removed zinc as an impairment based upon subsequent monitoring conducted by Flambeau pursuant to its Chapter 30 permits that were required due to reconfigurations of its stormwater management systems in 2011, 2012, and 2015.
- In 2022, the Department changed the status of the upper reach of Stream C (section above Copper Park Lane) to navigable and listed the upper reach as impaired for copper and zinc ATC. This listing was based on the Flambeau monitoring conducted pursuant to the same Chapter 30 permits.

2. Scope of Proposed Study for 2024

Table 1 summarizes locations to be monitored for flow, water chemistry, and toxicity as described in this Section.

2.1 Flow

Flow monitoring will consist of visual observations and flow rate determination. Visual observations of Stream C will occur once per week from July 2024 through November 2024. Visual observations will be documented using a combination of field notes, pictures, and videos. It should be noted that visual observations were conducted at a frequency of twice per month from April 2024 through June 2024, prior to the increase in frequency being defined within this revised Work Plan.

Flow rate will be monitored on a continuous basis at the Hwy 27 and Copper Park Lane culverts. This will be accomplished with a combination of continuous depth monitoring and with known flow hydraulics associated with the culvert characteristics. A pressure transducer will be installed in the existing staff gauge brackets at each culvert and will record water depth every 15 minutes. The culvert material type, diameter, length/slope, and any head/tailwater conditions will be recorded at the time of transducer installation. The transducer data will then be periodically downloaded (manually), and the recorded water depths will be used with established culvert hydraulic equations to calculate flow rate. The procedure to translate the transducer data into a flow rate is provided in Attachment 1.

Flow rate will also be monitored twice per month (April 2024 through November 2024) near the mouth of Stream C manually with a hand-held velocimeter unit (one velocity measurement collected at the deepest point within the stream). The exact location of flow monitoring near the mouth of Stream C (SW-STM) was determined during initial site observations in April 2023 and will be utilized during subsequent flow monitoring events. This location is shown on Figure 2.

2.2 Water Chemistry

Water quality monitoring shall occur at 10 locations at a frequency of twice per month from spring through fall of 2024, dependent on flow existing within Stream C. The proposed water quality monitoring locations are shown on Figure 2 and summarized in Table 1. Depending on flow conditions within Stream C, an attempt will be made to conduct sampling events approximately 14 days apart. Samples will be collected only when visible surface water flow at the water quality monitoring locations is present. One duplicate sample will be collected during each sampling event.

Water quality sampling protocols consist of two subsections:

- Collecting a surface water sample
- Measuring the field parameters

Field and analytical laboratory analysis will be utilized to assess the quality of surface water for the parameters summarized in Table 2 and Table 3. As defined within Table 1, four locations (SW-C9, SW-C5, SW-C1, and SW-STM) will be analyzed for parameters summarized in Table 2, and the remaining six locations will be analyzed for parameters summarized in Table 3. The analytical laboratory water sample is collected first. This assures the sample is clean and no residual contamination could occur from the field instrumentation. Field parameters are measured and recorded using a water quality meter. Water samples will be collected using a peristaltic pump and new tubing for each sample to minimize the potential for sediment disturbance and cross-contamination between samples. The Standard Operating Procedure for this sampling is provided in Attachment 1.

Laboratory analytical activities will be performed by Pace Analytical Services (Pace), located in Green Bay, Wisconsin. Pace is a Wis. Admin. Code NR 149-certified laboratory. Analytical analysis will be conducted using the methods defined in Table 2.

Where appropriate, elements of the 2020 *Quality Assurance Project Plan* (*QAPP*) (Foth, 2020) will be utilized to manage quality through all phases of each sampling event including sample collection, sample custody and transportation, and data validation and management.

2.3 Toxicity

2.3.1 ATC

Surface water quality data collected under Section 2.2 will be used to calculate the ATC, which is based on water hardness, as prescribed in Wis. Admin. Code NR 105 Table 2. ATC is defined within Wis. Admin. Code NR 105 as "the maximum daily concentration of a substance which ensures adequate protection of sensitive species of aquatic life from the acute toxicity of that substance and will adequately protect the designated fish and aquatic life use of the surface water if not exceeded more than once every 3 years." ATC will be assessed for both copper and zinc. For instances where measured hardness is below the copper and zinc ATC applicable range (Wis. Admin. Code NR 105 Table 2A), the lower bound of the range will be utilized for hardness within the calculation.

2.3.2 BLM

Surface water quality data collected under Section 2.2 for locations SW-C9, SW-C5, SW-C1, and SW-STM will be further assessed for copper toxicity through the use of the U.S. Environmental Protection Agency (USEPA) Biotic Ligand Model (BLM), as described in the USEPA water quality criteria for copper (USEPA, 2007). Output from the BLM based on water quality inputs will be compared to the copper ATC described in Section 2.3.1.

The BLM uses the dissolved chemistry of the receiving water body to develop site-specific water quality criteria based on predicted metal bioavailability. The BLM generates a set of site-specific surface water copper criteria, including the Criterion Maximum Concentration (CMC), and the Criterion Continuous Concentration (CCC). The CMC is the applicable criteria to be utilized for comparison to the ATC at the site.

2.3.3 Toxicity Testing

Toxicity testing will occur once during the spring and once during the fall of 2024 on water samples collected at four locations. Water sample collection will coincide with water quality sampling events described in Section 2.2. A summary of toxicity testing locations is provided in Table 1 and shown on Figure 2. Toxicity tests will be conducted using two standard testing species, the water flea *Ceriodaphnia dubia*, and the fathead minnow *Pimephales promelas*. All toxicity testing methods will follow the State of Wisconsin's *Aquatic Life Toxicity Testing Methods Manual* (WDNR, 2004), whole-effluent toxicity (WET) Program Guidance Document (WDNR, 2022a), and the Wis. Admin. Code NR 149-certified laboratory's standard operating procedures (SOPs). While this study does not entail toxicity testing in waters collected from a regulated effluent outfall, standard WET testing methods are widely used and recommended for conducting reliable tests in ambient waters.

2.3.3.1 Sample Collection and Shipment

The chosen Wis. Admin. Code NR 149-certified laboratory will provide the necessary supplies for sample collection at least one week prior to test initiation. Typically, new, clean Cubitainers® are used for sampling and are made of a proprietary blend of U.S. Food and Drug Administration (FDA)-compliant low-density polyethylene (PE) and linear low-density polyethylene (LLDPE). The appropriate number of Cubitainers® with lids are placed in a cooler and all chain-of-custody forms and volume requirements are also included and shipped to the facility.

Following the provided volume requirements, grab samples from each location will be collected with clean containers, rinsing the containers with the samples several times prior to collection. It is important to minimize the amount of air in the Cubitainers® (i.e., headspace) and ensure that a sufficient amount of water is collected. Therefore, the Cubitainers® will be filled as fully as possible, and any air in the Cubitainers® will be expelled by compressing the container before reclosing. Sample temperature will be maintained at less than or equal to (≤) 4 degrees Celsius (°C) (without freezing) immediately after sample collection and prior to shipment. In addition, the appropriate areas of the chain of custody will be completed.

When packing coolers for shipment, samples will be placed in a heavy-duty plastic bag filled with ice to ensure that the sample temperature does not exceed 10° C upon arrival at the laboratory. The plastic bag with samples and ice will then be placed in another heavy-duty plastic bag and tied securely to prevent leakage if any ice melts. The laboratory chain-of-custody form will be placed in a Ziploc® bag in the cooler and taped to the inside of the lid of cooler before it is closed. A custody seal, filled out with the sampler's signature and date, will be placed over the seam of the closed cooler, a shipping label will be affixed to the top of the cooler, and the cooler will be thoroughly taped closed. Depending on the delivery service, samples may need to be delivered priority overnight (FedEx) or Next Day Air (UPS) to ensure samples are received by the testing laboratory and used within the 36-hour hold time. Upon receipt at the laboratory, the temperature and pH will be taken immediately on each sample and will be written on the chain-of-custody form, along with the signature of the recipient at the lab and the date/time of sample receipt. Standard WET chemistry analyses (i.e., at a minimum, conductivity, alkalinity, and hardness) will be performed on each sample prior to test initiation.

2.3.3.2 Static Renewal Acute Toxicity Testing

Toxicity testing will be conducted in accordance with the laboratory’s SOPs for conducting WET tests. Static renewal acute toxicity testing will be conducted using the *C. dubia* and *P. promelas* species for 48 and 96 hours, respectively. Testing will be conducted on each undiluted sample and a synthetic (standard) laboratory water control. To control potential pH drift, testing under carbon dioxide (CO_2) atmosphere is required by the *Aquatic Life Toxicity Testing Methods Manual* (WDNR, 2004). The pH will be maintained at a level no lower than the measured pH of the samples at the time of collection. Table 4 summarizes the acute testing conditions and test acceptability criteria for *C. dubia* and *P. promelas* static renewal tests.

3. Data Reporting Plan

Approximately, monthly status emails will be provided to the Department to indicate if flow was recorded and if samples were collected during the preceding month. Data will then be provided via two data submittals. The first submittal will be a data memorandum prepared to document implementation of this Work Plan and any potential Work Plan deviations during the spring and summer sampling events. The first data memorandum will be prepared and submitted to the Department in mid-September 2024. The objective of the data memorandum will be the following:

- Document Work Plan implementation and any potential Work Plan deviations; and
- Document spring and summer collected data, including field visualization, flow, and analytical data.

The second submittal will be an assessment memorandum prepared to document the implementation of this Work Plan and any potential Work Plan deviations during the fall sampling events, and to assess the data collected across all sampling events. The objective of the assessment memorandum will be the following:

- Document Work Plan implementation and any potential Work Plan deviations;
- Document fall collected data, including field visualization, flow, and analytical data;
- Assess if Stream C is meeting its designated use; and
- Describe next steps.

4. Schedule and Notifications

The anticipated schedule for executing this Work Plan is as follows:

- Flow, water quality, WET testing, and visual monitoring began in the spring of 2024.
- Spring and summer 2024 data will be reported in mid-September 2024, and the fall 2024 data will be reported in late-January 2025 within an assessment memorandum.

The Department will be notified when the toxicity testing will occur and with as much advance notice as possible for water quality sampling events. The Department will be kept informed of the Work Plan's progress, site conditions, and sampling event outcomes as work progresses.

5. References

Foth Infrastructure & Environment, LLC (Foth), 2020. *Quality Assurance Project Plan*: *Long Term Care Monitoring for the Reclaimed Flambeau Mine*. August 10, 2020.

Wisconsin Department of Natural Resources (WDNR), 2004. *Aquatic Life Toxicity Testing Methods Manual*, 2nd Edition. November 2004.

WDNR, 2012. *Surface Water Quality Assessment of the Flambeau Mine Site*. April 2012.

WDNR, 2022a. Whole Effluent Toxicity (WET) Program Guidance Document, Edition No. 13. October 13, 2022.

WDNR, 2022b. *Findings of Fact, Conclusions of Law and Revised Mining Permit – Flambeau Mining Company.* December 20, 2022.

U.S. Environmental Protection Agency (USEPA), 2007. "Aquatic Life Ambient Freshwater Quality Criteria – Copper"; EPA/822/R-07/001; 544 USEPA, Office of Water: Washington, D.C., 545 2007; p 204 pp. February 2007.

Attachments

Tables
Figures
Attachment 1 Standard Operating Procedures

Tables

Table 1
Location Monitoring Summary
Former Flambeau Mine Site - Ladysmith, WI

Monitoring Location	Flow	Visual Observation	Water Quality	WET Test
SW-C9 (west of Highway 27 culvert)	X[1]	X	X[3]	X[5]
SW-C5		X	X[3]	X[5]
SW-C1 (south of Copper Park Lane)	X[1]	X	X[3]	X[5]
SW-STM (mouth of Stream C)	X[2]	X	X[3]	X[5]
SW-EB		X	X[4]	
SW-NBOUT		X	X[4]	
SW-NB		X	X[4]	
SW-HWY27W		X	X[4]	
SW-HWY27E		X	X[4]	
CP-04 (Copper Park Lane Ditch)		X	X[4]	

Notes:
WET = whole effluent toxicity
[1] Flow data collection using transducer.
[2] Flow data collection using portable flow meter.

Prepared by: MCC2
Checked by: SVF

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Table 2
Water Quality Parameters - Locations Assessed with Biotic Ligand Model
Former Flambeau Mine Site - Ladysmith, WI

Parameters	Total/Dissolved	Units	Method	Limit of Detection	Container	Preservative	Hold Time
Field Parameters							
Color	--	None	Field Observation	--	--	--	--
Odor	--	None	Field Observation	--	--	--	--
Turbidity	--	None	Field Observation	--	--	--	--
Dissolved Oxygen	--	mg/L	Field Method	--	--	--	--
pH	--	s.u.	Field Method	--	--	--	--
Redox Potential	--	mV	Field Method	--	--	--	--
Specific Conductance	--	umhos/cm	Field Method	--	--	--	--
Temperature	--	° C	Field Method	--	--	--	--
General Chemistry and Metals							
Alkalinity	Total and Dissolved	mg/L	EPA 310.2	7.4	125 mL plastic	4° C	14 days
Calcium	Total and Dissolved	µg/L	EPA 6020B	76.2	250 mL plastic	HNO_3 to pH <2, 4° C	180 days
Chloride	Total and Dissolved	mg/L	EPA 300.0	0.43	125 mL plastic	4° C	28 days
Copper	Total and Dissolved	µg/L	EPA 6020B	1.9	250 mL plastic	HNO_3 to pH <2, 4° C	180 days
Dissolved Organic Carbon	Dissolved	mg/L	SM 5310C	0.14	125 mL amber glass	H_2SO_4 to pH <2, 4° C	28 days
Hardness	Total and Dissolved	mg/L	SM 2340B	0.32	250 mL plastic	HNO_3 to pH <2, 4° C	180 days
Iron	Total and Dissolved	µg/L	EPA 6020B	58.00	250 mL plastic	HNO_3 to pH <2, 4° C	180 days
Magnesium	Total and Dissolved	µg/L	EPA 6020B	31.2	250 mL plastic	HNO_3 to pH <2, 4° C	180 days
Manganese	Total and Dissolved	µg/L	EPA 6020B	1.2	250 mL plastic	HNO_3 to pH <2, 4° C	180 days
Potassium	Total and Dissolved	µg/L	EPA 6020B	237	250 mL plastic	HNO_3 to pH <2, 4° C	180 days
Sodium	Total and Dissolved	µg/L	EPA 6020B	42.0	250 mL plastic	HNO_3 to pH <2, 4° C	180 days
Sulfate	Total and Dissolved	mg/L	EPA 300.0	0.44	125 mL plastic	4° C	28 days
Total Suspended Solids	Total	mg/L	SM 2540D	0.48	2L plastic	4° C	7 days
Zinc	Total and Dissolved	µg/L	EPA 6020B	10.3	250 mL plastic	HNO_3 to pH <2, 4° C	180 days
Sulfide	Total and Dissolved	mg/L	SM 4500S2F	0.066	500 mL plastic	Zinc Acetate and NaOH, 4° C	7 days

Notes:

Prepared by: MCC2
Checked by: SVF

-- = not applicable
< = less than
° C = degrees Celsius
µg/L = micrograms per liter
HNO_3 = nitric acid
H_2SO_4 = sulfuric acid
L = liter
mg/L = milligrams per liter
mL = milliliter
mV = millivolts
NaOH = sodium hydroxide
s.u. = standard units
umhos/cm = microhoms per centimeter

Table 3
Water Quality Parameters
Former Flambeau Mine Site - Ladysmith, WI

Parameters	Total/Dissolved	Units	Method	Limit of Detection	Container	Preservative	Hold Time
Field Parameters							
Color	--	None	Field Observation	--	--	--	--
Odor	--	None	Field Observation	--	--	--	--
Turbidity	--	None	Field Observation	--	--	--	--
Dissolved Oxygen	--	mg/L	Field Method	--	--	--	--
pH	--	s.u.	Field Method	--	--	--	--
Redox Potential	--	mV	Field Method	--	--	--	--
Specific Conductance	--	umhos/cm	Field Method	--	--	--	--
Temperature	--	° C	Field Method	--	--	--	--
General Chemistry and Metals							
Copper	Total and Dissolved	µg/L	EPA 6020B	1.9	250 mL plastic	HNO_3 to pH <2, 4° C	180 days
Dissolved Organic Carbon	Dissolved	mg/L	SM 5310C	0.14	125 mL amber glass	H_2SO_4 to pH <2, 4° C	28 days
Hardness	Total and Dissolved	mg/L	SM 2340B	0.32	250 mL plastic	HNO_3 to pH <2, 4° C	180 days
Zinc	Total and Dissolved	µg/L	EPA 6020B	10.3	250 mL plastic	HNO_3 to pH <2, 4° C	180 days

Notes:

-- = not applicable
< = less than
° C = degrees Celsius
µg/L = micrograms per liter
HNO_3 = nitric acid
H_2SO_4 = sulfuric acid
L = liter

mg/L = milligrams per liter
mL = milliliter
mV = millivolts
s.u. = standard units
umhos/cm = microhoms per centimeter

Prepared by: MCC2
Checked by: SVF

Table 4
Summary of WET Test Conditions
Former Flambeau Mine Site - Ladysmith, WI

Parameter	Test Conditions	
Test species	*C. dubia*	*P. promelas*
Sample collection procedure	Grab	
Dilution water	Not Applicable	
Test duration	48 hours	96 hours
Age of organisms at start	<24 hours old	4 to 14 days old
Renewal frequency	Daily	Daily
Feeding	2 hours before start of test	0.20 mL *Artemia nauplii* before 48-hour solution renewal
End point	Mortality	Mortality
Test chamber size	30 mL	250 mL
Volume of exposure chamber (minimum)	15 mL	200 mL
Number of organisms exposed/chamber (minimum)	5	10
Number of replicates/treatment (minimum)	4	4
Temperature	20°C ± 1.0	20°C ± 1.0
Standard toxicant used for reference toxicant testing	NaCl	NaCl
Aeration	None, unless DO < 4.0 mg/L	None, unless DO < 4.0 mg/L
Recommended CO_2 atmosphere	2.5%	2.5%
Test acceptability	Survival > 90% in controls	Survival > 90% in controls

Notes
% = percent
< = less than
> = greater than
± = plus or minus
°C = degrees Celsius
CO_2 = carbon dioxide

DO = dissolved oxygen
mg/L = milligrams per liter
mL = milliliter
NaCl = sodium chloride
WET = whole effluent toxicity

Prepared by: MCC2
Checked by: SVF

Figures

NOTES:

1. Base imagery from esri.com, courtesy of the Microsoft Corporation and its data suppliers.
2. Horizontal datum based on NAD 1983. Horizontal coordinates based on Wisconsin State Plane North (Feet).

LEGEND

- Surface Water Sampling Locations
- Groundwater Wells - MONITORED FOR WATER LEVELS ONLY
- Groundwater Wells
- Flambeau River Surface Water Monitoring Location
- Approximate Culvert Location
- Approximate Rail Spur
- Intermittent Stream
- Flambeau Project Area
- Intermittent Stream C Drainage Area

Foth

Foth Infrastructure & Environment, LLC

REVISED	DATE	BY	DESCRIPTION

PREPARED BY:	MCC2	DATE:	MAR.'23
CHECKED BY:	SVF	DATE:	MAR.'23
APPROVED BY:	SVF	DATE:	MAR.'23

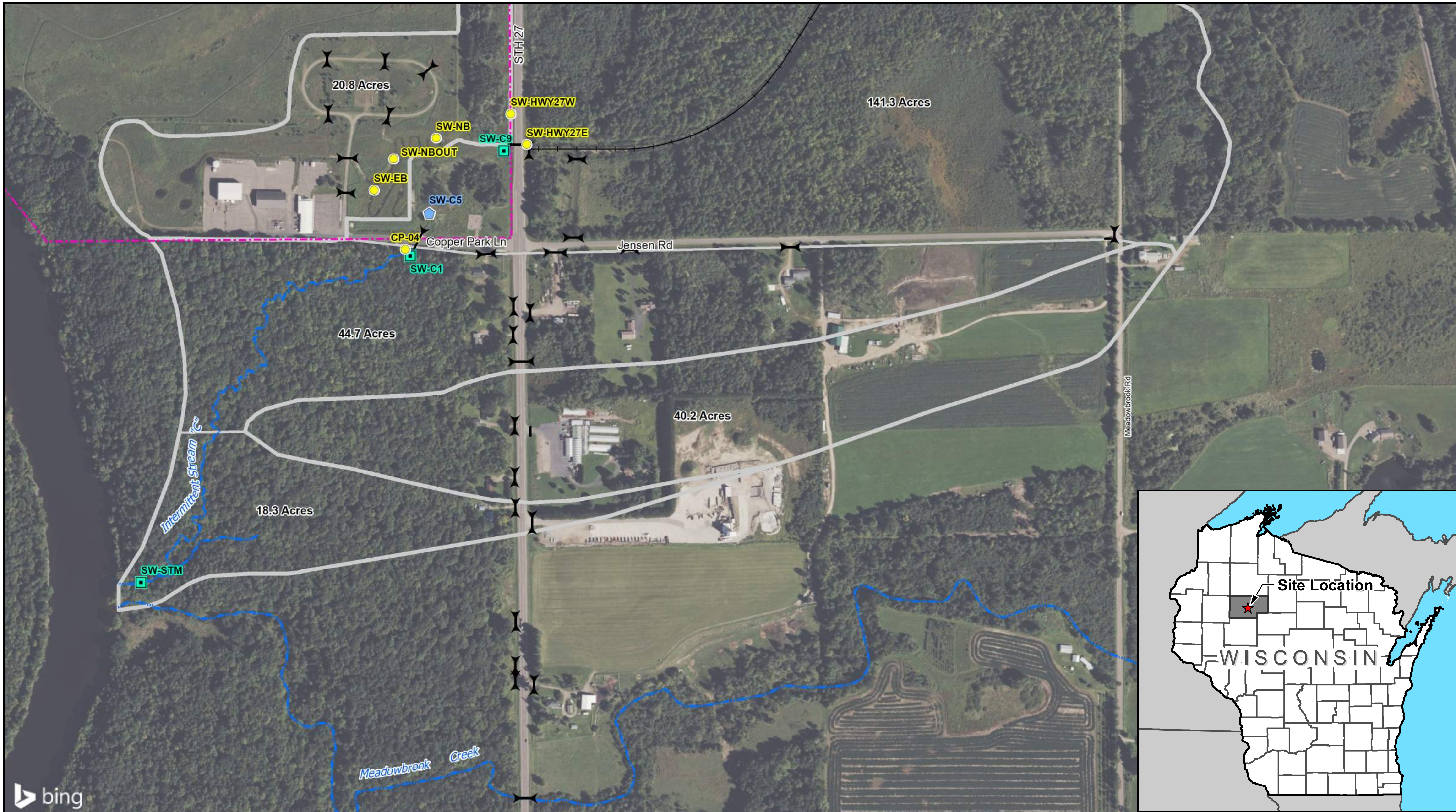
FLAMBEAU MINING COMPANY

FIGURE 1

SITE LAYOUT MAP
STREAM C EVALUATION WORK PLAN

Scale: 0 350 700 Feet		Date:	MARCH 2023
Drafted by:	DAT	Project No:	17F777.23

Path: Q:\Flambeau Mining Company\17F777\GIS\mxd\Stream C Evaluation Work Plan\Figure 1 - Site Location Map.mxd Date: 3/1/2023



NOTES:

1. Base imagery from esri.com, courtesy of the Microsoft Corporation and its data suppliers.
2. Horizontal datum based on NAD 1983. Horizontal coordinates based on Wisconsin State Plane North (Feet).

LEGEND

Surface Water Sampling Type

- Flow, Visual Oberservation, Water Quality, WET Test
- Visual Oberservation, Water Quality, WET Test
- Visual Oberservation, Water Quality
- Approximate Culvert Location
- Intermittent Stream
- Flambeau Project Area
- Intermittent Stream C Drainage Area

Foth Infrastructure & Environment, LLC

REVISED	DATE	BY	DESCRIPTION

PREPARED BY:	MCC2	DATE:	MAR.'23
CHECKED BY:	SVF	DATE:	MAR.'23
APPROVED BY:	SVF	DATE:	MAR.'23

Foth

FLAMBEAU MINING COMPANY

FIGURE 2

STREAM C EVALUATION LOCATIONS
STREAM C EVALUATION WORK PLAN

Scale: 0 200 400 Feet		Date:	MARCH 2023
Drafted by:	DAT	Project No:	17F777.23

Path: Q:\Flambeau Mining Company\17F777\GIS\mxd\Stream C Evaluation Work Plan\Figure 2 - Stream C Evaluation Locations.mxd Date: 8/21/2023

Attachment 1

Standard Operating Procedures

Surface Water Sampling for Stream C (Wadeable Stream) Standard Operating Procedure (FMC-11)

Flambeau Culvert Flow Standard Operating Procedure

Standard Operating Procedure

Stream C Surface Water Sampling (Wadeable Stream)

Introduction

The purpose of this standard operating procedure (SOP) is to identify the site-specific procedures to be utilized in obtaining surface waters samples at Stream C.

References

Foth Infrastructure & Environment, LLC (Foth), 2020. Water Quality Meter Use with Field Calibration SOP FMC-01.

Foth, 2020. Sample Identification and Labeling SOP FMC-02.

Foth, 2020. Shipping and Packaging of Non-Hazardous Samples SOP FMC-06.

Foth, 2020. Sample Chain of Custody SOP FMC-07.

Foth, 2020. Field Log Book SOP FMC-08.

Personnel Qualifications

Qualifications of sampling personnel are as directed in the Project Planning Document (PPD) and Health & Safety Plan and appointed by the Project Manager:

- One person must be trained in this sampling technique.
- A minimum of one person is required to conduct sampling, but a second or third person is ideal for assistance depending on sample location.

Equipment and Supplies

- Multi-meter instrumentation for collecting field readings for pH, conductivity (microsiemens per centimeter [µS/cm] or micromhos per centimeter [µmhos/cm]), temperature (degrees Celsius [°C]), oxidation reduction potential (ORP), and dissolved oxygen (DO) (milligrams per liter [mg/L]).
- Peristaltic pump with disposable tubing and 0.45 micron-field filters (if necessary).
- Shipping container(s) for the sampling event to identify and protect bottles from possible sources of cross-contamination and breakage during storage and transportation.
- The correct quantity of properly cleaned and prepared sample bottles for parameters being collected. Note: Sample bottles will be pre-preserved in the laboratory.
- Gloves – Keep in mind water temperature where liner gloves and shoulder length gloves may be necessary.

- Provision for labeling samples (pre-labeled outer bags or other method). Refer to the Shipping and Packaging of Non-Hazardous Samples SOP FMC-06.

- Electronic data log book, Field Log Book, lab sheets, and chain of custody forms.

- Personal protective equipment (PPE) normally used when collecting samples at the sample collection site.

- Waders may be needed to enter Stream C to collect samples.

Procedures

This is the site-specific procedure for collecting surface water samples from Stream C. Samples will be collected at predetermined sample collection locations The sampling procedures will go as follows at each sample location:

1. Surface water sample will be collected.
2. Field instrumentation will be collected.

Contamination of samples or sample containers may originate from air, sampling personnel, or contacted surfaces. To avoid contamination and to properly collect representative samples for the persons obtaining the samples should have a good understanding of potential sources of contamination.

Stream C Samples

1. All team members carry the equipment near the sampling site.

2. Prepare the sampling area to minimize contamination. Lay plastic sheeting down if needed for clean work area. Check wind and weather conditions. In Field Logbook or electronic field book, note any other potential sources of contamination. If any of the above conditions affect sample collection, the sampling event shall cease until conditions permit accurate sample collection.

3. Assemble pump, install clean tubing, and attach filter for sampling.

4. If multiple team members, designate one member of the team as the sample collector to enter stream and the other to handle samples on shore.

5. Place tubing into the water or attach a pole to the tubing to facilitate consistent placement during sampling. If needing to enter stream, plan to enter the stream downstream from the sample location.

6. Pump water through tubing and filter for one to two minutes before filling bottles.

7. Fill bottles as required for dissolved analysis.

8. Remove filter from tubing and fill bottles as required for total analysis.

9. As bottles are filled, the sampler shall tightly screw the cap back onto the bottles. The sampler returns the sample bottles to a position which maintains contaminant-free sampling

while continuing additional sample bottle collection. Typically, a contaminant-free location would be inside a Ziploc® bag or something similar prior to being placed in the cooler.

At the end of the sampling event, document the above sampling procedure in the project Field Log Book or Field Form, including sampling team names. Note any possible sources of cross contamination that could affect the results during the sampling procedure.

Field* Instrumentation *Readings

Instrumentation should be calibrated prior to use and anytime the batteries are replaced. Refer to the Water Quality Meter Use with Field Calibration SOP FMC-01 for calibration details. The instrumentation should be calibrated or spot-checked at any time the sampler questions any of the reading results to confirm accuracy.

1. The instrumentation should be placed in surface water where sensors are completely submerged but does not disturb sediment floor. If needing to enter stream, enter the stream downstream from the sample location to minimize sediment disturbance at the sample location.

2. Allow parameters to stabilize within 3% for a period of three consecutive one minute interval before recording readings.

3. Remove instrumentation from stream and decontaminate three times with distilled or de-ionized water.

Preservation and Shipping

Samples should be preserved on ice immediately after collection. In very cold weather, prevent samples for prolonged exposure to limit freezing potential.

Samples maybe transported to the lab in one of the following ways:

1. The sampler delivers the samples to laboratory upon leaving the site; or

2. The sampler arranges for the samples to be picked up by a courier service (laboratory or third party) within 24 hours of the completion of the sampling event. Refer to the Shipping and Packaging of Non-Hazardous Samples SOP FMC-06 for more information.

Note: Sample bottles that contain acid preservative may need to be shipped in accordance with the federal hazardous materials rules (49 CFR, Part 172).

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Standard Operating Procedure - Flambeau

Continuous Culvert Flow Monitoring - Manning's Equation

Introduction

The purpose of this Standard Operating Procedure (SOP) is to establish a standard procedure for automatically collecting and recording stream flow measurements in culverts under Highway 27 and Copper Park Lane at the Flambeau site.

The SOP covers the computation of discharge of water in the culverts using the culvert dimensions, slope, and roughness coefficient along with continuous water depth measurements recorded by pressure transducers. This information is then used along with Manning's equation to compute the stream flow. See Foth (2021) for details on procedures for collecting manual stream flow measurements in culverts.

References

Arcement, Jr., G.J., and Schneider, V.R., 1989, "Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains", United States Geological Survey Water Supply Paper 2339, US Department of the Interior, Washington, DC, 44p.

Bentley, 2009, Bentley FlowMaster, Bentley Systems, Inc., Watertown, CT.

CED, 2023, "Spreadsheet Use for Partially Full Pipe Flow Calculations", Course No C02-037, Continuing Education and Development, Inc., Stony Point, NY (www.cedengineering.com).

Foth, 2021, *Foth Standard Operating Procedure #2104*, Culvert Flow Rate Monitoring.

Personnel Qualifications

A minimum of one qualified person is required to complete measurements. A qualified person shall be someone who is formally trained in hydrology via an Accreditation Board for Engineering and Technology (ABET)-accredited engineering college or university and experienced in making open channel flow measurements. A qualified person may also be a technician lacking formal college training in hydrology but whom has been formally trained in open channel flow measurements using the procedures described in this SOP.

This measurement technique also requires knowledge of surveying techniques/equipment or ability to operate a high-accuracy GPS unit. Additional persons may be required to complete measurement protocols and should be trained in this measurement technique.

Personnel performing open-channel flow measurements shall have access to the project Health and Safety Plan (HASP). Note that the HASP may require a minimum of two people to be present when near water features such as rivers and streams.

Additional Health and Safety Training Requirements:

- Field personnel shall have current CPR (Cardiopulmonary Resuscitation) and First Aid training.

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- Field personnel shall have satisfied Occupational Safety and Health Administration (OSHA) training requirements (40 CFR 1910.120) if hazardous materials are known to be or may be present at the site.
- Field personnel shall have satisfied Mine Safety and Health Administration (MSHA) safety training requirements prior to making open channel flow measurements on a project site regulated by MSHA.

Equipment and Supplies

Required equipment will vary according to the measurement method and may include the following:

- Surveying equipment or high-accuracy GPS unit with sub-foot accuracy, such as the Trimble GeoExplorer® 6000 Series GeoXH Handheld
- Telescoping level rod
- Self-leveling level
- Pressure transducer/datalogger
- Flat tape measure
- Sharpie or waterproof marker
- Field Book
- Camera
- Hip waders
- Life jackets

Procedures

Field Measurement Procedures

1. *Preparation prior to field work*.

   a. Review the HASP and SOP with all field personnel.

   b. Check current weather conditions. Work in streams may be hazardous during extreme weather and icy conditions may require additional equipment.

   c. Perform any necessary calibration of surveying equipment.

   d. Perform any necessary calibration and formatting of pressure transducers.

   e. Review operation instructions for GPS unit. Set region and set up data files on GPS unit as necessary. Charge battery on GPS unit.

2. *Monitoring Location Selection*: The culvert flow conditions are critical for the flow calculation procedures in this SOP to be applicable. The Manning equation is not applicable when significant headwater or tailwater conditions exist, or when stagnant/ponded water conditions exist in the culvert. In these cases, a velocimeter should be installed, which measures both water depth and velocity.

   In the field, notes should be collected (and pictures taken) on the following:

   - Flow conditions (flowing, stagnant, flow depth) at inlet and outlet.
   - Presence of sedimentation on culvert bottom (and depth, if present).
   - Presence of obstructions and debris.

3. *Record Culvert Length, Slope, Diameter, and Material:*

   a. Record culvert length and diameter with measuring tape.

   b. Survey culvert invert elevations at inlet and outlet. Also survey elevation of highest ground elevation at upstream end of culvert (i.e. if culvert flows under road, this would be the road surface elevation).

   c. Record culvert material type (i.e. concrete, corrugated metal, high-density polyethylene, etc.)

4. *Install Pressure Transducer:* The pressure transducer should be capable of automatically recording and storing head measurements in units of feet, and should be programmed to do so every 15 minutes. Note that the transducers for the site are not vented, so a barometric pressure transducer will also be needed for pressure compensation – make sure to install this unit in a protected area, exposed to the atmosphere but not potential stream flow, and again record it to collect and store a reading every 15 minutes. The following installation procedures are recommended for the transducer measuring water depth:

   - The transducer should be installed on the upstream culvert end if tailwater conditions are anticipated, and on the downstream end if significant headwater conditions are expected. Note that a transducer could also be installed at both ends.

   - A stilling well, comprised of a polyvinyl chloride (PVC) pipe with holes drilled in it, will protect the transducer and allow for a smoothed data set under high flow conditions. The PVC pipe should be installed firmly to a bracket mounted on the culvert, with the bottom of the PVC pipe resting on the culvert invert (ensure holes are drilled at the very bottom of the pipe).

Calculations

Flow/discharge calculations will be performed using Manning's equation, shown below (CED, 2023):

$$Q = \frac{1.486}{n} AR^{2/3}S$$

where:
Q = flow (cubic feet per second [cfs])
n = Manning roughness coefficient (-)
A = cross-section area (ft^2)
R = hydraulic radius (ft)
S = pipe slope (ft/ft)

The calculations can be performed manually or with the aid of various models or spreadsheets such as FlowMaster (Bentley, 2009) or others. A public-domain example of a Manning's Equation calculator can be found on the Natural Resources Conservation (NRCS) website at: Cross-Section Hydraulic Analyzer | NRCS (usda.gov). Inputs to the program include water surface (culvert) slope, water depth, culvert geometry, and culvert roughness coefficient.

Procedures to calculate flow using manual calculations are found below.

1. Select the roughness coefficient (n) (unitless) for the given pipe material. Information on n values can be found throughout the hydraulics literature, including Arcement & Schneider (1989).

2. Calculate pipe slope (S) (units of ft/ft) using the surveyed elevations of the culvert upstream and downstream inverts as well as the measured culvert length.

Slope (ft/ft) = (upstream invert elev – downstream invert elev) / culvert length

3. Compute the cross-section properties of area (A), wetted perimeter (P), and hydraulic radius (R). Use Figures 1 and 2 below for reference (CED, 2023).

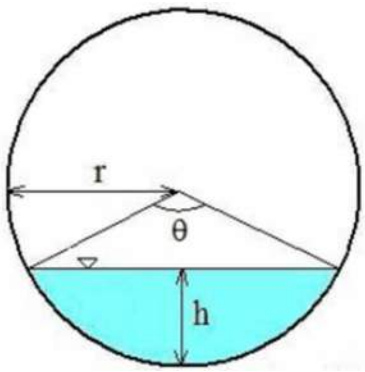

Figure 1. Pipe Flowing < Half Full

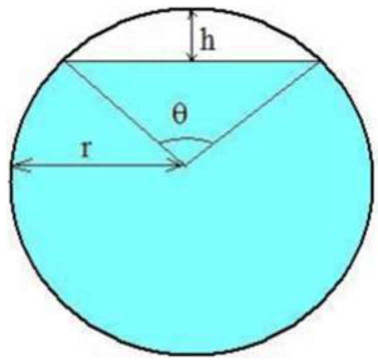

Figure 2. Pipe Flowing > Half Full

a. *Cross-section Area (A):* The cross-sectional area calculation differs whether the pipe is flowing less than or more than half full (see Figures 1 and 2, respectively; note that the "r" value in both figures is the pipe radius, or pipe diameter (D)/2) (CED, 2023).

For less than half-full conditions (expected to be the majority of readings), the area is found using Figure 1 and as follows:

$$\theta = 2\arccos\left(\frac{r-h}{r}\right)$$ (r&h in ft; Θ in radians)

$$A = \frac{r^2(\theta - \sin\theta)}{2}$$ (r in ft; Θ in radians; A in ft^2)

For more than half-full conditions, the area is found using Figure 2 and as follows:

$$\theta = 2\arccos\left(\frac{r-h}{r}\right)$$ (r&h in ft; Θ in radians)

$$A = \pi r^2 - \frac{r^2(\theta - \sin\theta)}{2}$$ (r in ft; Θ in rad; A in ft^2)

The flow depth used in the above equations will be obtained from the pressure transducer record. Note that the pressure transducer record must first be adjusted with the barometric pressure transducer record, using procedures provided with the transducer equipment/software. Also note that in the water flow scenario in Figure 1 (flowing < half full), the value "*h*" will be the flow depth values taken directly from the pressure transducer. In the flow scenario in Figure 2 (flowing > half full), the value "*h*" will be the pipe diameter (D) minus the flow depth value taken from the pressure transducer.

In any case, the pressure transducer depth record will first be plotted (depth vs time) to identify the flow events above background. Then select flow depths (likely one per hour, but will vary depending on storm intensity and duration, ensuring to capture hydrograph peak) will be used to calculate flow area (and ultimately flow rate).

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b. *Wetted Perimeter (P):* Wetted perimeter is the total length (in units of ft) of the boundary between the pipe and the water (in cross-section view), and the calculation differs whether the pipe is flowing less than or more than half full (CED, 2023).

For less than half-full conditions, the wetted perimeter is found using Figure 1 and as follows:

$$P = r\theta$$ (r & P in ft; Θ in radians)

For more than half-full conditions, the wetted perimeter is found using Figure 2 and as follows:

$$P = 2\pi r - r\theta$$ (r & P in ft; Θ in radians)

c. *Hydraulic Radius (R):* Hydraulic radius (in units of ft) is calculated as the area divided by the wetted perimeter (A/P) (CED, 2023).

4. Compute total discharge (Q) (units of cfs) using Manning's equation:

$$Q = \frac{1.486}{n} A R^{2/3} S$$

where:
Q = flow (cfs)
n = Manning roughness coefficient (-)
A = cross-section area (ft^2)
R = hydraulic radius (ft)
S = pipe slope (ft/ft)

Foth will use the FlowMaster (Bentley, 2009) software, which will calculate flowrate (cfs) given the inputs and procedures discussed above. An automated routine in an Excel spreadsheet will also be set up between the pressure transducer output (depth of flow, in feet) and the FlowMaster pipe hydraulics calculations, that will allow for flow to be calculated automatically at each transducer record.