Permit Application 2017-2077

Public Waters Work Permit Application

Date Submitted to DNR: May 16, 2017 at 6:34 AM	**Application Reference Name:** NorthMet Project Dunka Road Upgrade: Unnamed Tributary to Wyman Creek Culvert Extension

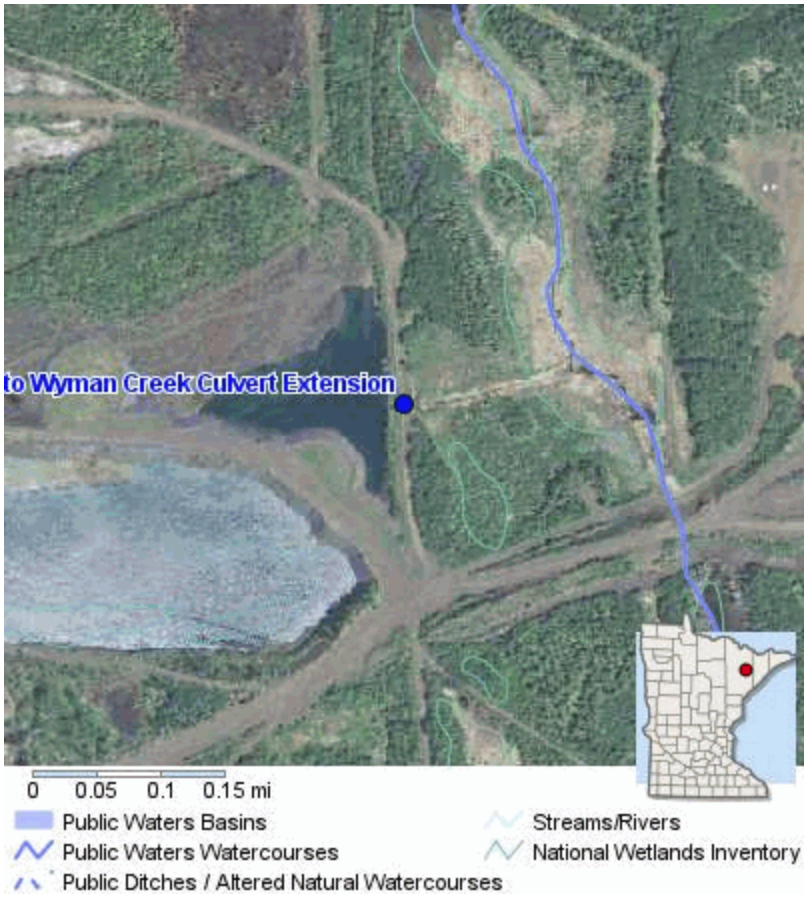
Parties (*Individuals and Organizations associated with the permit application*)

Cliffs Erie LLC - Landowner or Government Unit	**Address:** P.O. Box 900, Hoyt Lakes, MN 55750-0900 **Phone:** 218-225-3127
Poly Met Mining, Inc. - Lessee	**Address:** 6500 Co Rd 666, PO Box 475, Hoyt Lakes, MN 55750 **Phone:** 218-471-2150
Christie Kearney - Contact (*representing Poly Met Mining, Inc.*) (*submitted application*)	**Address:** 6500 County Road 666, Hoyt Lakes, MN 55750 **Phone:** 218-471-2163 **Email:** ckearney@polymetmining.com
Andrea Hayden - Contact (*representing Cliffs Erie LLC*)	**Address:** 10 Outer Dr, Silver Bay, MN 55614 **Phone:** 218-226-6032
Andrea Hayden - Agent	**Address:** 10 Outer Drive, Silver Bay, MN 55614 **Phone:** 218-226-6032 **Email:** andrea.hayden@cliffsnr.com

Proposed Activity

Culvert Construction/Modification/Replacement

Location and Water Resources (*within 50 meters*)



Site Name: Dunka Road Upgrade: Unnamed Tributary to Wyman Creek Culvert Extension
(Culvert Construction/Modification/Replacement)

Counties: St. Louis
Watersheds: St. Louis River
PLS: T59N-R14W-S14 NESE
UTM: X:569269 Y:5271389
Water Resources: Wetlands: National Wetland Inventory (quantity = 1), Stream/River

Project Overview

1	Please assign a reference/project name to this application.	NorthMet Project Dunka Road Upgrade: Unnamed Tributary to Wyman Creek Culvert Extension
2	What is the main type of work you are proposing to do?	Work in or near a lake, wetland, or river/stream (e.g., excavate, place fill, install a structure in a waterbody, modify a dam)
3	When is the anticipated start date for the project?	11/01/2017
4	When is the expected completion date for the entire project?	12/01/2018
5	Briefly describe the overall project purpose and need.	PolyMet plans to upgrade the existing Dunka Road to accommodate vehicle access between the NorthMet Mine and Plant Sites. This includes construction of safety berms on either side of the road. The Dunka Road corridor will also be widened in some areas to support construction of three pipelines between the Mine and the Plant Sites. This construction results in a need to extend the east end of the existing culvert to maintain the flow of the unnamed tributary to Wyman Creek. Although the unnamed tributary to Wyman Creek is not a Public Water, Wyman Creek is a designated trout stream (located approximately 700 feet east of the existing culvert; refer to attached Large Figure 1 and Hydraulic Analysis).
6	Has any portion of the proposed work in wetlands or water areas already started?	No

Project Overview (*Continued*)

7	Is this a transportation project sponsored by a government unit?	No
8	Will the project require any dewatering (the deliberate removal of water through the use of a pump, ditch, etc. to lower water levels to allow work to be accomplished)?	Yes
9	Will the removed water remain within its original source at all times (e.g., only pumped over the side of a coffer dam and never pumped off site to a holding pond)?	Yes
10	Has an Environmental Assessment Worksheet (EAW) or Environmental Impact Statement (EIS) been completed for the project, or will it be required?	Yes
11	If yes, please provide the DNR tracking number, if known. (optional)	NorthMet Mining Project and Land Exchange EIS – Record of Decision, March 3, 2016
12	Has the project gone through a Natural Heritage (endangered species) review?	Yes

Activity Detail

Activity: Culvert Construction/Modification/Replacement

How many different sites will have culvert construction/modification work (i.e., the number of individual stream/river, ditch, lake, pond, pit, and/or wetland crossings or impact areas)? 1

Site Name: Dunka Road Upgrade: Unnamed Tributary to Wyman Creek Culvert Extension

1	Briefly describe the impact to the water resource(s) at this particular site:	Per the attached plans and analysis, PolyMet proposes to extend the outlet of the culvert within the unnamed tributary of Wyman Creek by 26 linear feet, respectively. The extended culvert will not result in any significant changes to the hydrology of the existing structure. In addition, per the attached plans, PolyMet plans to construct a safety berm on both sides of the improved road surface and install three Mine to Plant Pipelines along the east side of the road. Construction of these features on the east side requires placing earthen or rock fill over the culvert extension extending up to the road surface. This will result in a 2:1 (horizontal to vertical) slope along the east side (downstream end) of Dunka Road and no change to the west side. Depending on the conditions at the time of installation, the contractor may need to construct a cofferdam (earthen berm, sandbags, or similar) upstream of the culvert inlet and pump the water over the road and discharge back into the stream to maintain flow during construction of the culvert extension. The pump intake will be covered with a screen, and the discharge will include a dissipation device to prevent scour. The contractor will install and maintain erosion and sediment control best management practices in accordance with the attached plan and the National Pollutant Discharge Elimination System and State Disposal System (NPDES/SDS) Construction Stormwater Permit to minimize impacts to the stream during construction.
2	If applicable, what is the size of the area to be filled?	0.04
3	Please choose units:	acres

Activity Detail (*Continued*)

4	If applicable, is the fill permanent or temporary?	Not applicable
5	If applicable, is the excavation permanent or temporary?	Not applicable
6	Will you be removing any vegetation from an aquatic resource that is not already associated with excavation/filling?	No
7	Will work at this site result in the draining of any water resources?	No
8	Select the resource(s) below that describes the type of water bodies that could be impacted at this site.	wetland, stream/river
9	Counties	St. Louis
10	Watersheds	St. Louis River
11	PLS	T59N-R14W-S14 NESE
12	UTMXY	X:569269 Y:5271389
13	Water resources	Wetlands: National Wetland Inventory (quantity = 1), Stream/River

Attachment(s): PolyMet_Work_in_Public_Waters_Full_Application_5-16-2017.pdf

Acknowledgment (*By the party who submitted the permit application*)

☑ **I attest that:**

·The information submitted and the statements made concerning this application are true and correct to the best of my knowledge.

PRINTED: 05/16/2017 at 6:34 AM

POLYMET
MINING

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May 16, 2017

Mike Liljegren
Supervisor – Mine Permitting and Coordination Unit
Minnesota Department of Natural Resources
500 Lafayette Road
St. Paul, MN 55155-4040

RE: Poly Met Mining, Inc.'s Work in Public Waters Permit Application for the NorthMet Project Dunka Road Upgrade: Unnamed Tributary to Wyman Creek Culvert Extension

Dear Mr. Liljegren:

Please find enclosed Poly Met Mining, Inc.'s (PolyMet) application to the Minnesota Department of Natural Resources (DNR) for a Work in Public Waters Permit (Application) for its NorthMet Project Dunka Road upgrade, specifically to extend a culvet in an unnamed tributary to Wyman Creek. This Application contains the following materials:

- Documentation of the application in the DNR's MPARS
- Large Figure 1 – Site Location Map
- Hydraulic Analysis of Proposed Modifications to the Dunka Road Culvert (Unnamed Tributary to Wyman Creek)

Pursuant to Minnesota Rules, part 6115.0240, subpart 3(E), PolyMet is also sending a copy of this Application to the mayor of Hoyt Lakes and the secretary of the North St. Louis County Soil and Water Conservation District. This culvert replacement is within the Hoyt Lakes municipal boundary in north St. Louis county. A copy of the cover letters submitted to Mayor Skelton and Secretary Charles Bainter are also attached to this submittal.

Based on PolyMet's review of the applicable laws and content of this Application, PolyMet believes that this Application is complete and satisfies the state requirements relating to the content of a work in public waters permit application. PolyMet recognizes that the MDNR may request additional information during the course of its review.

Thank you in advance for your review this Application. If any questions or concerns arise during MDNR's review of this Updated Application, please do not hesitate to contact me at 218-461-7746 or ckearney@polymetmining.com.

Sincerely,

Christie M. Kearney, P.E.
Environmental Site Director

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100 King Street West, Suite 5700, Toronto, Ontario, Canada, M5X 1C7
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May 16, 2017

Mayor Mark Skelton
City of Hoyt Lakes
Municipal Building
206 Kennedy Memorial Drive
Hoyt Lakes, MN 55750

RE: Poly Met Mining, Inc.'s Work in Public Waters Permit Application for the NorthMet Project Dunka Road Upgrade: Unnamed Tributary to Wyman Creek Culvert Extension

Dear Mayor Skelton:

Please find enclosed Poly Met Mining, Inc.'s (PolyMet) application to the Minnesota Department of Natural Resources (DNR) for a Work in Public Waters Permit (Application) for its NorthMet Project Dunka Road upgrade, specifically to extend a culvet in an unnamed tributary to Wyman Creek. This Application contains the following materials:

- Documentation of the application in the DNR's MPARS
- Large Figure 1 – Site Location Map
- Hydraulic Analysis of Proposed Modifications to the Dunka Road Culvert (Unnamed Tributary to Wyman Creek)

We are submitting a copy of this Application for your review, pursuant to Minnesota Rules 6115.0240, subpart 3(E), as this culvert replacement is within the Hoyt Lakes municipal boundary. PolyMet does not expect this culvert extension to have an impact on your municipal area water resources.

If any questions or concerns arise during your review of this Application, please do not hesitate to contact me at 218-461-7746 or ckearney@polymetmining.com.

Sincerely,

Christie Kearney

Christie M. Kearney, P.E.
Environmental Site Director

POLYMET
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May 16, 2017

Charles Bainter, Secretary of the Board
North St. Louis Soil and Water Conservation District
Northland Office Building
307 1st Street South, Suite 114
Virginia, MN 55792

RE: Poly Met Mining, Inc.'s Work in Public Waters Permit Application for the NorthMet Project Dunka Road Upgrade: Unnamed Tributary to Wyman Creek Culvert Extension

Dear Mr. Bainter:

Please find enclosed Poly Met Mining, Inc.'s (PolyMet) application to the Minnesota Department of Natural Resources (DNR) for a Work in Public Waters Permit (Application) for its NorthMet Project Dunka Road upgrade, specifically to extend a culvet in an unnamed tributary to Wyman Creek. This Application contains the following materials:

- Documentation of the application in the DNR's MPARS
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- Hydraulic Analysis of Proposed Modifications to the Dunka Road Culvert (Unnamed Tributary to Wyman Creek)

We are submitting a copy of this Application for your review, pursuant to Minnesota Rules 6115.0240, subpart 3(E), as this culvert replacement is in North St. Louis County, although it is located in the Hoyt Lakes munipal boundary. PolyMet does not expect this culvert extension to have an impact on area water resources.

If any questions or concerns arise during your review of this Application, please do not hesitate to contact me at 218-461-7746 or ckearney@polymetmining.com.

Sincerely,

Christie M. Kearney, P.E.
Environmental Site Director

Proposed 2-Foot Contours and Features
Mine to Plant Pipelines
Railroad
Culvert Extension
10-Foot Contour
2-Foot Contour
Dunka Road
Existing Culvert
Public Waters Inventory (PWI) Watercourses
Wetlands
St. Louis County PLS Quarter Quarter Boundaries

*Wyman Creek is a Designated Trout Stream.

0 125 250 500
Feet

BARR

Large Figure 1
SITE LOCATION
PROPOSED CULVERT EXTENSION - UNNAMED TRIBUTARY TO WYMAN CREEK
NorthMet Project
Poly Met Mining, Inc.

Barr Footer: ArcGIS 10.4, 2017-05-10 14:59, File: I:\Client\PolyMet_Mining\Work_Orders\Permitting\Water_Appropriations\Maps\ReportWork_in_PublicWatersLarge Figure 1 Site Location Proposed Culvert Extension.mxd User: amn2

resourceful. naturally.
engineering and environmental consultants

BARR

Technical Memorandum

To: Christie Kearney, Poly Met Mining, Inc.
From: Paul Swenson, Greg Williams
Subject: Hydraulic Analysis of Proposed Modifications to Dunka Road Culvert (Unnamed Tributary to Wyman Creek)
Date: May 15, 2017
Project: 23690862.12-200-002
c: File

This memorandum summarizes the hydraulic analysis of proposed modifications to an existing culvert under Dunka Road within an unnamed tributary of Wyman Creek. Wyman Creek is a Minnesota Department of Natural Resources (DNR) public water and a designated trout stream. The analysis described herein is intended to demonstrate that there would be no significant impact to the hydrology of the unnamed tributary to Wyman Creek resulting from the proposed culvert modification.

1.0 Description of Location

The existing culvert in this unnamed tributary under Dunka Road is a round, 36-inch diameter corrugated metal pipe located approximately 700 feet west of the perennial channel of Wyman Creek (see Large Figure 1 and Figure 1). The existing culvert is approximately 107 feet in length with upstream and downstream invert elevations of 1587.18 feet and 1584.68 feet, respectively. Downstream (east) of the Dunka Road crossing, water flows approximately 450 feet before reaching a wide, wetland area adjacent to Wyman Creek at approximate elevation 1580 feet.

The culvert drains a watershed of 556 acres and includes 468 acres of vegetated and barren ground and 88 acres of open water comprised of two basins, both of which are considered Pit 3. Because the tributary area is much less than 2 square miles, which is the drainage area required to define a public water, it is expected that the unnamed tributary is an intermittent stream. The normal water level of the pond upstream from the culvert was therefore assumed to be at to the invert elevation of the culvert. The majority of the watershed drains to the larger, southwest basin before reaching the culvert, which drains the smaller, northeast basin. The basins are assumed to be hydrologically connected through the railroad embankment that separates them, although no other culverts were found during the site reconnaissance, based on identical observed water surface elevations.

The existing culvert is in good condition based on review of its structural integrity and hydraulic function based on visual inspection. It passes through the embankment of Dunka Road at approximately Station 214 + 70. The embankment is stable and provides an excellent foundation for the driving surface. At the culvert location, the existing Dunka Road driving surface on the embankment is approximately 18 feet

above the invert of the culvert, with embankment slopes of 1.4+/- H:1V on the west side and 1.5+/- H:1V on the east side. The toe of the embankment on either side is located approximately at the end of the culvert.

2.0 Alternatives Analysis

Several alternatives were considered in the process of selecting the preferred design to extend the culvert and widen the Dunka Road embankment to support the NorthMet Project. An analysis of each of the alternatives considered is provided below.

2.1 Replace the Culvert

This alternative would include removing and replacing the culvert with a new, longer culvert to optimize placement and hydraulics. Such a replacement would require the closure of Dunka Road while the existing culvert is excavated and removed, and a new culvert is installed. The new culvert would be long enough to accommodate the widened Dunka Road embankment, as needed for the Project. The overall length of the new culvert would be about 150 feet. The longer culvert would allow for a 1.5H:1V slope on the west side of the embankment, which, if armored with riprap or other surface stabilization, will provide a stable slope, and a 2H:1V slope on the east side. Approximately 3,550 square feet of stream channel and wetlands would be disturbed or filled under this alternative. A complete removal would be disruptive to other operations and construction because Dunka road is the primary route between the Plant Site and the Mine Site, and, due to limited access to this area, the shortest detour would be about three miles. A visual inspection indicated that the culvert is in good condition and should serve its intended purpose for the life of the Project. Excavation and filling needed to remove and replace the culvert would result in disturbance to the channel and wetlands on either side of Dunka Road and would result in high erosion potential to an already stable embankment. Therefore, this alternative was dismissed.

2.2 Extend East and West Ends of Culvert

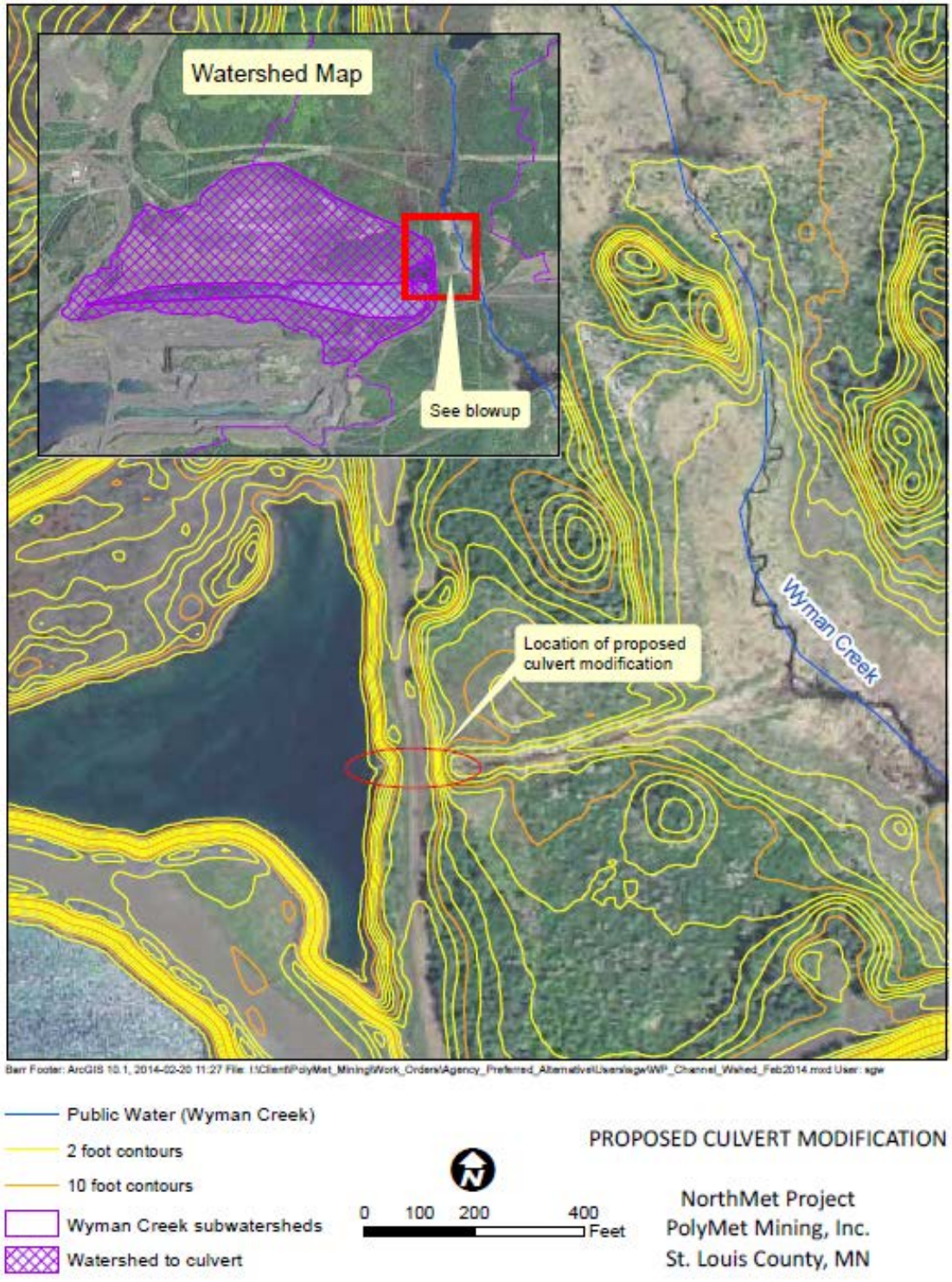
This alternative would include extending both ends of the culvert: the east extension would be about 26 feet and the west extension would be about four feet. Both extensions would be constructed with no slope (i.e., the extension would be installed flat). Constructing the culvert extension with no slope on the west end would minimize any change to the normal water elevation of Pit 3. The east culvert extension would be constructed with no slope to match the downstream channel profile. The west extension would allow for the culvert to extend about one foot beyond the planned toe of slope and would allow construction of the embankment with a 1.7H:1V slope, which, if armored with riprap or other surface stabilization, will provide a stable slope. Extending the east end of the culvert would allow constructing an embankment slope of 2H:1V, which would provide a stable slope. Approximately 2,750 square feet of stream channel and wetlands would be disturbed or filled under this alternative. Extending the west end of the culvert and regrading the west embankment would result in more impacts than benefit. The west

embankment is stable and the culvert is functioning properly in its current condition. Therefore, this alternative was dismissed.

2.3 Extend Only East End of Culvert

This alternative would include extending only the east end of the culvert by about 26 feet. The extension would be constructed with no slope (i.e., the extension would be installed flat) to match the downstream channel profile. Extending the east end of the culvert would allow constructing an embankment slope of 2H:1V, which will provide a stable slope. Approximately 2,750 square feet of stream channel and wetlands would be disturbed or filled under this alternative. The west embankment is stable and the culvert is functioning properly in its current condition, so the west end of the culvert and the west embankment would not be modified. This alternative results in the least disturbance to wetlands, the least amount of fill in the channel, and meets the needs of the Project. Therefore, this alternative was selected for implementation.

Figure 1 Site Location



3.0 Hydraulic Evaluation

A combination of HydroCAD modeling and hydraulic computations were performed to evaluate potential impacts to peak flow and velocity through the culvert and the maximum water surface elevation in the basins upstream of the culvert resulting from Alternative 2.3 (see Section 2.3).

3.1 Modeling Approach

HydroCAD version 10 was used to evaluate potential impacts to peak flow and velocity through the culvert and the maximum water surface elevation in the basins upstream of the culvert. Modeling inputs are shown in Table 1. For this analysis, the following two assumptions were made:

- Assumption 1: The two basins are hydrologically connected and modeled as a single basin. This assumption may overestimate flow from the larger basin to the smaller basin containing the outlet, thereby overestimating the maximum water surface elevation in the smaller basin. This assumption is likely conservative for estimates of peak flow and velocity in the culvert and maximum water surface elevation in the smaller basin. This assumption may underestimate maximum water surface elevation in the larger basin.

- Assumption 2: The culvert is modeled with a free outfall tailwater. This assumption was made to simplify the analysis. Model results indicate critical flow conditions in the culvert under existing and proposed conditions, validating this assumption for anticipated tailwater conditions. Note that higher tailwater conditions may reduce the velocities that were estimated in this analysis; higher tailwater is not expected to significantly affect maximum water surface elevations in the pit lake due to the large surface area or the discharge rates through the culvert.

Table 1 HydroCAD Modeling Inputs

Model Feature	Parameter	Existing Condition	Proposed Condition
Subcatchment	Area	468 acres	468 acres
	Curve number	77[1]	77[1]
	Time of concentration	30 minutes	30 minutes
Pond	Area[2]	88 acres	88 acres
	Initial stage[3]	1587.18	1587.18
	Outlet type	Orifice (vertical)	Orifice (vertical)
	Outlet invert	1587.18	1587.18
	Outlet diameter	36 inches	36 inches
	Discharge coefficient	0.9	0.9
Pipe	Length	107 feet	107 feet[6]
	Shape	Round	Round
	Diameter	36 inch	36 inch
	Inlet elevation	1587.18	1587.18[6]
	Outlet elevation	1584.68	1584.68[6]
	Manning's number[4]	0.025	0.025
	Entrance	CMP projecting, no headwall	CMP projecting, no headwall
	Tailwater[5]	Free discharge	Free discharge

[1] Combination of brush and woods in poor condition, type C soils

[2] Stage-area curve assumes vertical side-walls for simplicity

[3] Water level set at outlet pipe invert as the initial condition

[4] Manning's coefficient based on typical corrugated metal closed conduits

[5] Tailwater condition of free outfall was assumed (see Section 3.1).

[6] Proposed conditions were modeled as two pipe segments, including a 107 foot segment with the inlet and outlet elevations shown, and a second 26 foot segment with a slope of 0 percent, over which the direct step method and hydraulic jump equations were used to estimate depth and velocity.

3.2 Modeling Results

The design storm event used in this analysis is the National Oceanic and Atmospheric Administration Atlas 14 100-year, 24-hour rainfall (5.69 inches rainfall depth) using an MSE3 distribution, modeled with HydroCAD. The output of the HydroCAD model is provided in Attachment A. For the existing condition, the modeling estimates a maximum water surface elevation in the basin is 1588.45 feet (Attachment A1, an increase of 1.27 feet over the initial stage), a peak discharge of 16.4 cubic feet per second (Attachment A1), and peak velocity of approximately 6.6 feet per second (Attachment A3) in the culvert.

For the proposed condition, the model returns similar flow and velocity results for the 107-foot segment with slope similar to the existing culvert. In the proposed condition, the maximum water surface elevation is unchanged from the existing condition at 1588.45 feet (Attachment A2) and the peak velocity remains at 6.6 feet per second (Attachment A4).

Model results were checked using Manning's equation and confirmed a steep, partially full (S2) water surface profile for the existing condition with maximum flow velocity similar to HydroCAD model results. An estimated flow velocity in the culvert using Manning's equation is approximately 7 feet per second.

3.3 Hydraulic Computations (Direct Step Method)

The flow within the existing culvert segment is estimated to be supercritical. Transition from a steep profile to a horizontal segment will decrease flow velocity. The direct step method was used to assess the change in depth and velocity over the length of the 26 foot zero slope portion of the proposed culvert. Results of the direct step computations are provided in Attachment A5.

Analysis of the 26 foot, zero slope segment using the direct step method suggests that a hydraulic jump will occur approximately within two feet of the beginning of that pipe segment, resulting in subcritical flow and reducing velocity. Using a best fit curve for sequential hydraulic jump depths (see Attachment A) and depth estimates from the HydroCAD analysis of the upstream pipe segment (1.14 feet depth and 16.4 cubic feet per second, respectively) the estimated depth downstream of the hydraulic jump is 1.71 feet, which corresponds to a flow velocity of approximately 3.9 feet per second in the zero slope culvert segment downstream of the jump.

The direct step method was also used, working backwards from an assumed free outfall at the culvert outlet, to determine if the zero slope segment is long enough for supercritical flow to jump to subcritical flow and accelerate back to critical flow by the outlet. This analysis (shown in Attachment A5) estimates that flow depth equal to the sequent depth of the hydraulic jump occurs about 20 feet upstream of the culvert outlet. Although the length of the hydraulic jump is unknown, this analysis suggests that a hydraulic jump will occur within the culvert and critical velocity of 5.6 feet per second will occur at the outlet. If higher tailwater conditions prevent a free discharge, outlet velocities may approach to those estimated immediately downstream of the hydraulic jump (about 3.9 feet per second).

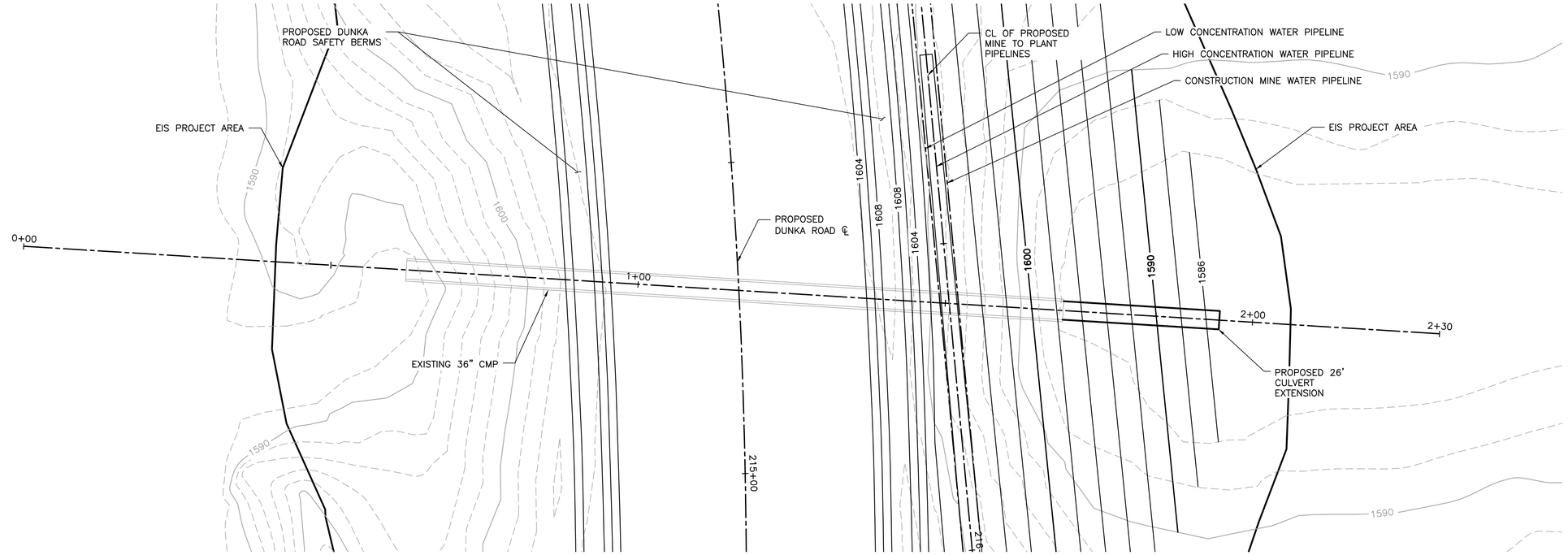
4.0 Culvert Extension Design

The culvert extension design is shown on Figure 2. The east culvert extension will be constructed with no profile slope so the culvert extension discharges at the same elevation as the existing culvert because there is little slope in the channel to the east. The short section of level pipe will also provide some energy dissipation before discharging to the earthen channel, limiting erosion potential.

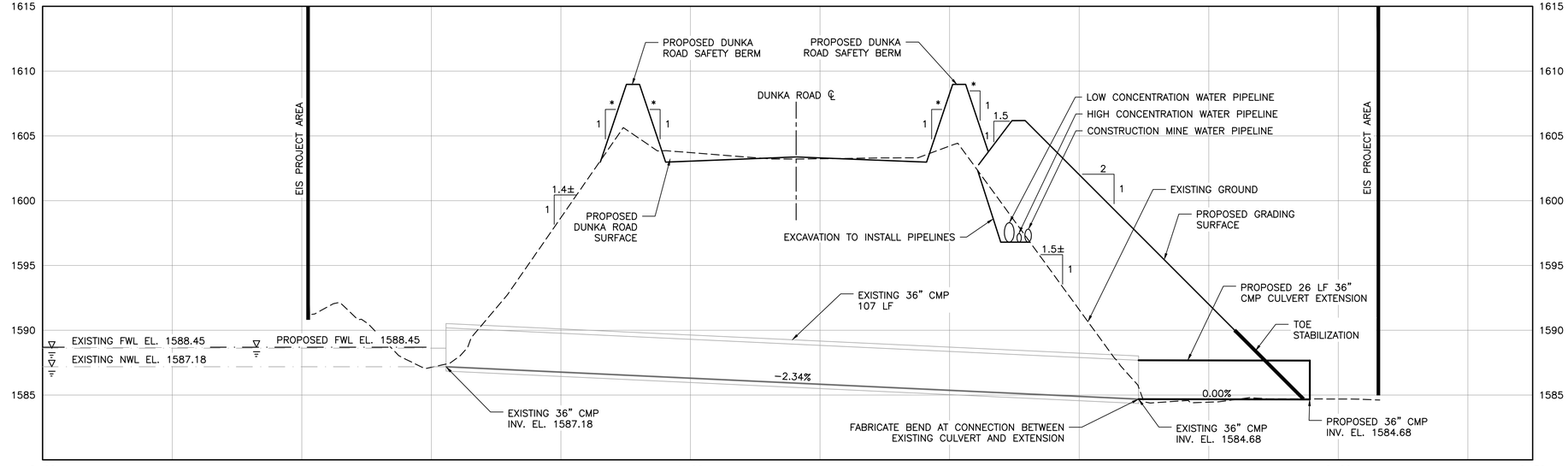
Due to the low flow velocities in the culvert (estimated at 3.9 feet per second at the downstream portion), downstream channel stabilization, such as riprap, is not planned.

5.0 Conclusions

HydroCAD modeling and hydraulic computations of the culvert extension in the unnamed tributary to Wyman Creek under Dunka Road show there would be no significant changes in hydrology as a result of the proposed culvert extension.



1 — PLAN: DUNKA ROAD 36" CMP CROSSING
1"=10'-0"
0 10 20
SCALE IN FEET



2 — PROFILE: DUNKA ROAD 36" CMP CROSSING
0 10 20
SCALE IN FEET

ABBREVIATIONS

NWL	NORMAL WATER LEVEL
FWL	FLOOD WATER LEVEL
*	ANGLE OF REPOSE
CMP	CORRUGATED METAL PIPE
EL.	ELEVATION

VER NO	DATE	DESCRIPTION
1	5/15/17	ISSUED FOR WORK IN PUBLIC WATERS PERMIT

ISSUE STATUS	VERSION	DATE
FOR PERMITTING	1	5/15/17
FOR CONSTRUCTION		
NOT APPROVED FOR CONSTRUCTION		

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.

PRINTED NAME PAUL T. SWENSON
SIGNATURE
DATE 5/15/17 LICENSE# 20533

DRAWN: KKB
CHECKED: ATS
BARR PROJECT NO.: 23/69-0C29
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

WORK IN PUBLIC WATERS PERMIT
DUNKA ROAD 36" CMP CROSSING STA 214+70
PLAN AND PROFILE

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. FIGURE 3
REV

Attachment A

Hydrologic and Hydraulic Calculations

Summary for Pond 20P: Existing Culvert

Inflow Area = 468.000 ac, 0.00% Impervious, Inflow Depth = 3.21"
Inflow = 1,350.83 cfs @ 12.43 hrs, Volume= 125.185 af
Outflow = 16.36 cfs @ 22.18 hrs, Volume= 39.295 af, Atten= 99%, Lag= 584.9 min
Primary = 16.36 cfs @ 22.18 hrs, Volume= 39.295 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
Starting Elev= 1,587.18' Surf.Area= 88.000 ac Storage= 15.840 af
Peak Elev= 1,588.45' @ 22.18 hrs Surf.Area= 88.000 ac Storage= 127.506 af (111.666 af above start)

Plug-Flow detention time= 1,438.8 min calculated for 23.455 af (19% of inflow)
Center-of-Mass det. time= 933.8 min (1,757.1 - 823.3)

Volume	Invert	Avail.Storage	Storage Description
#1	1,587.00'	440.000 af	**Custom Stage Data (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,587.00	88.000	0.000	0.000
1,588.00	88.000	88.000	88.000
1,589.00	88.000	88.000	176.000
1,590.00	88.000	88.000	264.000
1,592.00	88.000	176.000	440.000

Device	Routing	Invert	Outlet Devices
#1	Primary	1,587.18'	**36.0" Vert. Orifice/Grate** C= 0.900

Primary OutFlow Max=16.36 cfs @ 22.18 hrs HW=1,588.45' (Free Discharge)
└**1=Orifice/Grate** (Orifice Controls 16.36 cfs @ 5.75 fps)

Summary for Pond 37P: Proposed Culvert

Inflow Area = 468.000 ac, 0.00% Impervious, Inflow Depth = 3.21" for 100-approx event
Inflow = 1,350.83 cfs @ 12.43 hrs, Volume= 125.185 af
Outflow = 16.36 cfs @ 22.18 hrs, Volume= 39.295 af, Atten= 99%, Lag= 584.9 min
Primary = 16.36 cfs @ 22.18 hrs, Volume= 39.295 af

Routing by Stor-Ind method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
Starting Elev= 1,587.18' Surf.Area= 88.000 ac Storage= 15.840 af
Peak Elev= 1,588.45' @ 22.18 hrs Surf.Area= 88.000 ac Storage= 127.506 af (111.666 af above start)

Plug-Flow detention time= 1,438.8 min calculated for 23.455 af (19% of inflow)
Center-of-Mass det. time= 933.8 min (1,757.1 - 823.3)

Volume	Invert	Avail.Storage	Storage Description
#1	1,587.00'	440.000 af	**Custom Stage Data (Prismatic)**Listed below (Recalc)

Elevation (feet)	Surf.Area (acres)	Inc.Store (acre-feet)	Cum.Store (acre-feet)
1,587.00	88.000	0.000	0.000
1,588.00	88.000	88.000	88.000
1,589.00	88.000	88.000	176.000
1,590.00	88.000	88.000	264.000
1,592.00	88.000	176.000	440.000

Device	Routing	Invert	Outlet Devices
#1	Primary	1,587.18'	**36.0" Vert. Orifice/Grate** C= 0.900

Primary OutFlow Max=16.36 cfs @ 22.18 hrs HW=1,588.45' (Free Discharge)
└**1=Orifice/Grate** (Orifice Controls 16.36 cfs @ 5.75 fps)

Summary for Reach 19R: Existing Pipe

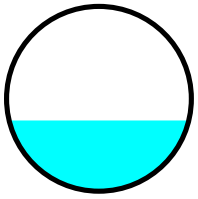
[52] Hint: Inlet/Outlet conditions not evaluated
[81] Warning: Exceeded Pond 20P by 0.01' @ 11.69 hrs

Inflow Area = 468.000 ac, 0.00% Impervious, Inflow Depth > 1.01" for 100-approx event
Inflow = 16.36 cfs @ 22.18 hrs, Volume= 39.295 af
Outflow = 16.36 cfs @ 22.19 hrs, Volume= 39.287 af, Atten= 0%, Lag= 0.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
Max. Velocity= 6.61 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 5.85 fps, Avg. Travel Time= 0.3 min

Peak Storage= 265 cf @ 22.18 hrs
Average Depth at Peak Storage= 1.14'
Bank-Full Depth= 3.00' Flow Area= 7.1 sf, Capacity= 53.01 cfs

36.0" Round Pipe
n= 0.025 Corrugated metal
Length= 107.0' Slope= 0.0234 '/'
Inlet Invert= 1,587.18', Outlet Invert= 1,584.68'



Summary for Reach 36R: Proposed Pipe

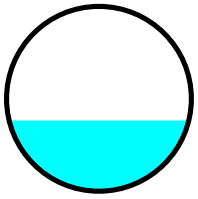
[52] Hint: Inlet/Outlet conditions not evaluated
[81] Warning: Exceeded Pond 37P by 0.01' @ 11.69 hrs

Inflow Area = 468.000 ac, 0.00% Impervious, Inflow Depth > 1.01" for 100-approx event
Inflow = 16.36 cfs @ 22.18 hrs, Volume= 39.295 af
Outflow = 16.36 cfs @ 22.19 hrs, Volume= 39.287 af, Atten= 0%, Lag= 0.5 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.01 hrs
Max. Velocity= 6.61 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 5.85 fps, Avg. Travel Time= 0.3 min

Peak Storage= 265 cf @ 22.18 hrs
Average Depth at Peak Storage= 1.14'
Bank-Full Depth= 3.00' Flow Area= 7.1 sf, Capacity= 53.01 cfs

36.0" Round Pipe
n= 0.025 Corrugated metal
Length= 107.0' Slope= 0.0234 '/'
Inlet Invert= 1,587.18', Outlet Invert= 1,584.68'



Horizontal Pipe Segment - Direct Step Method and Hydraulic Jump Calculations

Parameter	Distance	Change in Distance	Flow	Depth	Velocity	Flow Area	Wet Perimeter	Hydraulic Radius	Theta	Pipe Diameter	Energy	Pipe Slope	Energy Slope	Average Slope	Assume Theta, solve for zero to get X
Symbol	X	Del X	Q	y	V	A	P	R	Θ	D	E	S_0	S_e	$S_{eAvg.}$	
Units	ft	ft	ft^3/sec	ft	ft/sec	ft^2	ft	ft	radians	ft	ft	ft/ft	--	--	
	0.00		16.4	1.14	6.64	2.471	3.99	0.619	2.660	3	1.8261	0	0.0235	0.0224	
	0.70	0.70	16.4	1.17	6.41	2.557	4.05	0.631	2.700	3	1.8104	0	0.0214	0.0202	0
	1.38	0.69	16.4	1.21	6.16	2.664	4.13	0.646	2.750	3	1.7965	0	0.0191	0.0181	-9.37028E-14
	1.85	0.46	16.4	1.25	5.91	2.773	4.20	0.660	2.800	3	1.7881	0	0.0171	0.0160	0
before jump	2.08	0.23	16.4	1.29	5.62	2.916	4.30	0.679	2.865	3	1.7844	0	0.0149	0.0149	5.6205E-14
after jump	2.08		16.4	1.72	3.92	4.179	5.15	0.812	3.430	3	1.9547				
Depth reaches critical depth (1.29 feet) at distance of about 2.1 feet, within the horizontal segment															
Use direct step to work back from theoretical free outfall at unknown distance downstream to theta (or depth) of flow after jump (see above)															
	0.00		16.4	1.29	5.62	2.916	4.30	0.679	2.865	3	1.7844	0	0.0149	0.0144	
	-0.07	-0.07	16.4	1.32	5.48	2.993	4.35	0.688	2.900	3	1.7854	0	0.0139	0.0133	-0.000542713
	-0.40	-0.34	16.4	1.36	5.28	3.105	4.43	0.702	2.950	3	1.7898	0	0.0126	0.0120	-0.000887966
	-1.05	-0.65	16.4	1.39	5.10	3.216	4.50	0.715	3.000	3	1.7976	0	0.0115	0.0110	-0.000565115
	-2.03	-0.98	16.4	1.43	4.93	3.328	4.58	0.728	3.050	3	1.8083	0	0.0104	0.0100	-0.000591287
	-3.35	-1.33	16.4	1.47	4.77	3.441	4.65	0.740	3.100	3	1.8216	0	0.0096	0.0092	-0.000386288
	-5.04	-1.69	16.4	1.51	4.62	3.553	4.73	0.752	3.150	3	1.8371	0	0.0088	0.0084	-0.00017512
	-7.12	-2.08	16.4	1.54	4.47	3.666	4.80	0.764	3.200	3	1.8546	0	0.0081	0.0078	1.54384E-05
	-9.60	-2.48	16.4	1.58	4.34	3.778	4.88	0.775	3.250	3	1.8739	0	0.0075	0.0072	-0.000642197
	-12.50	-2.90	16.4	1.62	4.22	3.890	4.95	0.786	3.300	3	1.8947	0	0.0069	0.0067	-0.000777997
	-15.83	-3.33	16.4	1.66	4.10	4.002	5.03	0.796	3.350	3	1.9169	0	0.0064	0.0062	-0.004828553
	-19.60	-3.77	16.4	1.69	3.99	4.112	5.10	0.806	3.400	3	1.9402	0	0.0060	0.0058	-0.006043986
	-22.08	-2.48	16.4	1.72	3.92	4.179	5.15	0.812	3.430	3	1.9547	0	0.0057	0.0057	-0.005199229

Approximately 22 feet upstream of free outfall (critical depth), the depth is approximate to the sequent depth following the hydraulic jump.
Total length to jump and from jump to critical depth is approximately 24 feet
Length of hydraulic jump is unknown.
Due to horizontal pipe segment length (26 feet) length estimated to be less than the sum of the the distance to jump, length of jump, and distance from jump to critical velocity, the velocity at the pipe outlet is expected to be critical (5.6 feet/sec) with a jump occuring within the zero slope pipe segment.

Direct Step Formulas:

$$E = y + \frac{V^2}{2g}$$

$$S_e = \frac{V^2 n^2}{K^2 R^{\frac{4}{3}}}$$

$$Delta\ X = \frac{E_{i+1} - E_i}{S_0 - \bar{S_e}}$$

Inputs for Hydraulic Jump Best fit (from Sturm Figure 3.3

1.14	y1
0.19	Z for hyraulic jump
0.38	y1/d
1.5	y2/y1 based on sturm fig 3.3
1.713	y2
3.925	V2

Hydraulic Jump Formulas:

$$Z_{circ} = \frac{Q}{g^{\frac{1}{2}} D^{\frac{5}{2}}}$$

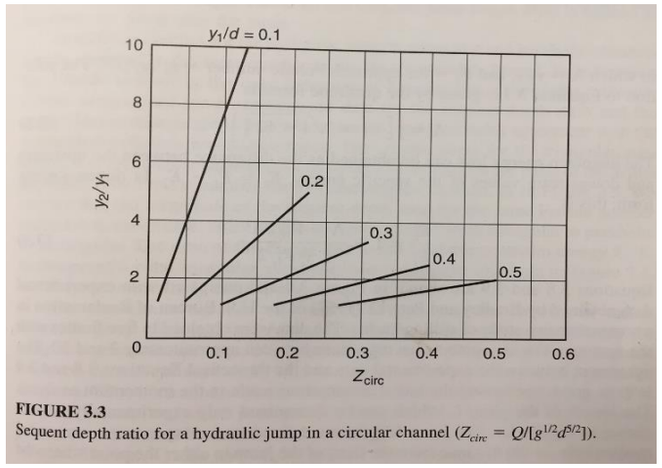


FIGURE 3.3
Sequent depth ratio for a hydraulic jump in a circular channel ($Z_{circ} = Q/[g^{1/2}d^{5/2}]$).