Technical Memorandum

To: Jennifer Saran and Christie Kearney, Poly Met Mining, Inc.
From: Cory Anderson and Melisa Pollak, Barr Engineering Co.
Subject: Time to Flush Legacy Water from Wetlands at the NorthMet Plant Site
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Project: 23/69-0862.12 100 001
c: Keith Hanson and Tina Pint, Barr Engineering Co.

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1.0 Introduction

Water quality in the wetlands and creeks downgradient of the existing LTV Steel Mining Company (LTVSMC) tailings basin has been affected by ferrous (legacy) seepage. Baseline monitoring in Unnamed (Mud Lake) Creek, Trimble Creek, and Unnamed Creek has documented exceedances of surface water quality standards for several parameters associated with the former ferrous operations, namely total dissolved solids (TDS), specific conductance, and hardness. When the NorthMet Project (Project) begins operating, the legacy seepage (and future nonferrous seepage) will be collected by a seepage containment system around the Tailings Basin and will no longer flow to the downstream wetlands and creeks. In the Trimble and Unnamed creek watersheds, the collected seepage will be replaced with treated water from the Waste Water Treatment Plant (WWTP), which will meet all surface water quality standards. In the separate Unnamed (Mud Lake) Creek watershed, the seepage will be replaced by additional background runoff routed through a drainage swale, which will meet surface water quality standards for TDS, specific conductance, and hardness amongst other surface water quality standards. From a permitting perspective, the question is when will water quality at the Project NPDES/SDS surface water monitoring stations on Unnamed (Mud Lake) Creek, Trimble Creek, and Unnamed Creek meet applicable water quality standards for the parameters of concern in legacy water: TDS, specific conductance, and hardness.

For certain parameters, namely aluminum and mercury, exceedances of surface water quality standards are due to background conditions, not the legacy water. Exceedances of these parameters have been documented in the Embarrass River both upstream and downstream of the confluences of Unnamed (Mud Lake) Creek, Trimble Creek, and Unnamed Creek. The WWTP effluent, which will meet all surface water quality standards, is expected to decrease the loading of these parameters to the surface water monitoring stations on Trimble Creek and Unnamed Creek. Likewise, for sulfate, the WWTP effluent is expected to lower the concentration from the baseline values measured at the surface water monitoring stations on Trimble Creek and Unnamed Creek. In Unnamed (Mud Lake) Creek, dilution of the legacy water with increased watershed runoff is expected to lower the concentration of sulfate from the baseline concentration. With the exception of aluminum and mercury concentrations in Unnamed (Mud Lake) Creek, which will become more representative of background conditions, the overall effect of the Project will be to improve water quality for aluminum, mercury, and sulfate in the wetlands and creeks downgradient of the Tailings Basin.

Barr evaluated the time it will take for Project water (i.e., WWTP discharge) to move through the wetlands to the monitoring stations. This time is referred to as the 'time to flush' or 'residence time'. WWTP effluent will be discharged to the wetlands at the toe of the Tailings Basin, and will flush out the legacy water as it flows through the wetlands to the creeks. There will be a time-lag after WWTP discharge begins before water quality at the NPDES/SDS surface water monitoring locations reflects Project water quality (WWTP discharge to Trimble Creek and Unnamed Creek, and increased watershed runoff to Unnamed (Mud Lake) Creek), because it will take time for the Project water to flush the legacy water out of the wetlands.

Water quality improvements are expected before the legacy water is flushed from the wetlands, as Project water dilutes the legacy water; however, estimating the time-lag between commencement of WWTP discharge and compliance with standards for TDS, specific conductance, and hardness at surface water monitoring stations is beyond the scope of this analysis. Residence time can be used as a proxy for the time to meet water quality standards, with the caveat that the residence time calculations did not directly assess parameter concentrations. The time it will take to meet water quality standards at these surface water monitoring stations will vary by constituent, depending on factors such as the relative concentrations in the legacy water and the Project discharge, and the actual flow paths through the wetlands. Estimated residence times presented in this memo represent reasonable bounds for the time it may take for values of TDS, specific conductance, and hardness to meet water quality standards at NPDES/SDS surface water monitoring locations. However, even before water quality is representative of Project discharge quality, exceedances caused by legacy water may resolve. In other words, the time necessary to reach surface water quality standards at these locations could be shorter than the residence time.

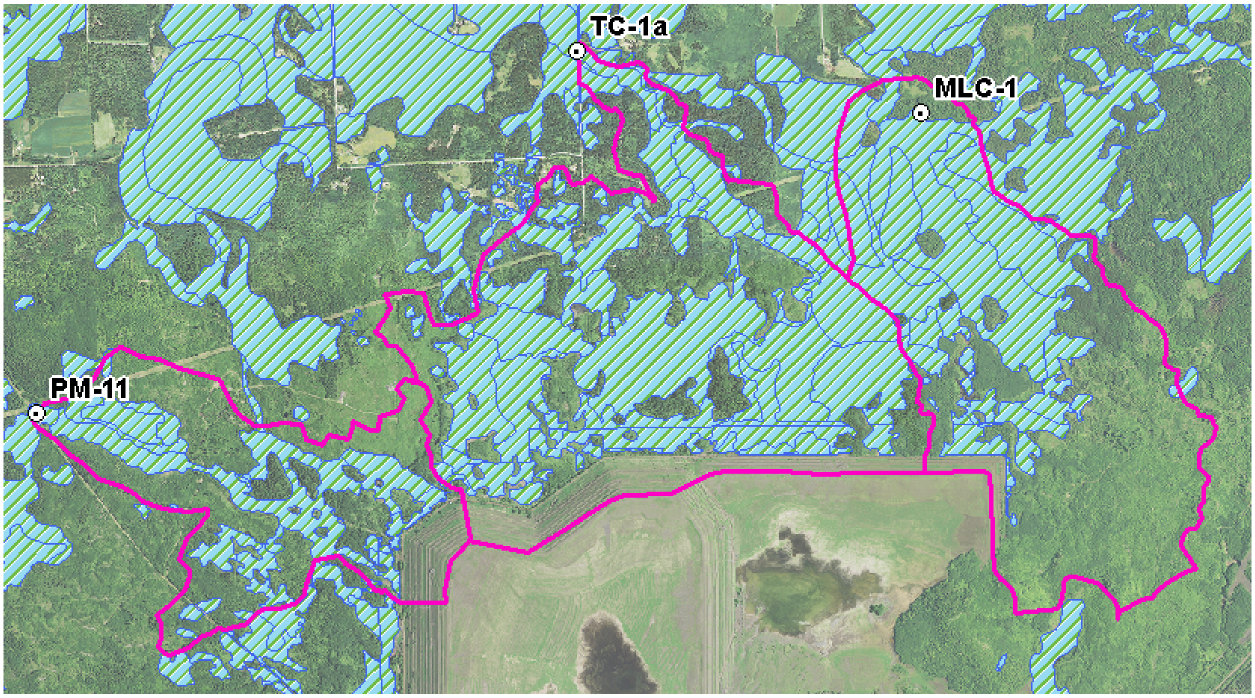

Figure 1 Delineated wetlands north and west of the existing LTVSMC tailings basin

2.0 Method

The residence time was calculated based on the proposed NPDES/SDS surface water monitoring locations: PM-11 on Unnamed Creek, TC-1a on Trimble Creek, and MLC-1 on Unnamed (Mud Lake) Creek (Figure 1). Calculations take into account the total amount of water in the wetland complexes between the FTB Seepage Containment System and these monitoring locations. The actual flow paths and mixing conditions in the wetlands are complex. Two simplifying assumptions were used for the residence time calculations; one that represents the system more like a stream (plug flow conditions), and one that represents the system more like a pond (completely mixed conditions). These two conditions provide low and high estimates, respectively, of the time to flush legacy water out of the wetlands upstream of the monitoring locations.

- Plug flow type conditions are most representative of a stream-type system (T_{pf}, Equation 1). This simulates the pulse of Project water to the monitoring location.
- Completely mixed conditions are most representative of a pond-type system (T_{cm}, Equation 2). This simulates the condition where Project water and legacy water are uniformly mixed throughout the wetlands, so water quality gradually improves at the same rate at all points in the system, including the monitoring location. For this analysis Barr calculated the residence time to flush 90% of legacy water from the wetlands.

$$T_{pf} = \frac{V}{Q}$$ Equation 1 (Plug Flow)

$$T_{cm} = \left[-\ln\left(\frac{C_t}{C_o}\right)\right] * \left(\frac{V}{Q}\right)$$ Equation 2 (Completely Mixed)

where

T_{pf} = residence time for plug flow conditions (pulse of Project water to monitoring location)

V = average volume of water in the wetlands

Q = average annual flows through each wetland complex to PM-11, TC-1a, and MLC-1

T_{cm} = residence time for completely mixed conditions (water at monitoring location, and throughout the wetland complex, is 90% Project water and 10% legacy water, in other words, 90% of legacy water has been flushed from wetlands)

C_t = concentration at time t at the evaluation location

C_o = initial concentration at the evaluation location

The flows (Q) used for the residence time calculations were the flows modeled for the FEIS under Project conditions (i.e., with the FTB Seepage Containment System in place and with WWTP discharge for stream augmentation).

Residence times were calculated under three scenarios – average flow, low-flow conditions (10th percentile flow), and high-flow conditions (90th percentile flow). Low- and high-flow conditions would be due primarily to differences in precipitation, because the stream augmentation flow rate is expected to be relatively constant during the first few years of operations. Stream augmentation flow during this time period is expected to be close to the minimum rate established under permit terms; stream augmentation may be slightly higher during wet periods. Flow rates used for the calculations are shown in Table 1.

Table 1 Hydraulic characteristics for the three subwatersheds

Parameter	PM-11, Unnamed Creek	TC-1a, Trimble Creek	MLC-1, Unnamed (Mud Lake) Creek
Average Annual Flow Rate[1] (gpm)	1,240	1,820	870
Low-Flow Conditions (10th percentile) Flow Rate[1] (gpm)	440	1,270	140
High-Flow Conditions (90th percentile) Flow Rate[1] (gpm)	2,270	2,550	1,810
Estimated Wetland Volume[2] (acre-ft)	590	510	280
Estimated Average Wetland Depth[2] (ft)	1.7	0.8	0.9

[1] Rates from FEIS modeling as presented in the Water Modeling Data Package – Plant Site v11 (Reference (1))
[2] Calculated as described above

The volume of water within the wetlands was calculated using the delineated wetland areas in each subwatershed and the estimated depths of those wetlands. The polygons of the delineated wetlands (shown in Figure 1) were assumed to be the areas inundated with water. The depth of water within the wetlands was analyzed with GIS using the following steps:

1. The elevation of the wetland polygon boundaries was extracted from the 2012 DNR LiDAR surface. Along the boundaries of the wetland polygons, the water surface elevation is assumed to be equal to the ground elevation.
2. A TIN surface was created within the wetland polygon boundaries to represent the water surface elevation of each of the delineated wetland areas. The TIN surface was converted to a raster or grid surface.
3. The LiDAR surface, representing the ground elevation, was subtracted from the wetland water surface raster. The difference between the LiDAR surface and the wetland water surface represents water depth in the delineated wetland areas (i.e., a water depth raster).

The water depth raster (Figure 2) was used to calculate the total volume of water within the footprint of the delineated wetlands. This total volume was used to calculate the residence time of the water. The volume calculation was restricted to the wetland areas tributary to PM-11, TC-1a, and MLC-1 shown in Figure 1. Wetland areas downstream or outside of the watersheds tributary to PM-11, TC-1a, and MLC-1 were not included. The resulting total volume and average water depth in the wetlands are shown in Table 1.

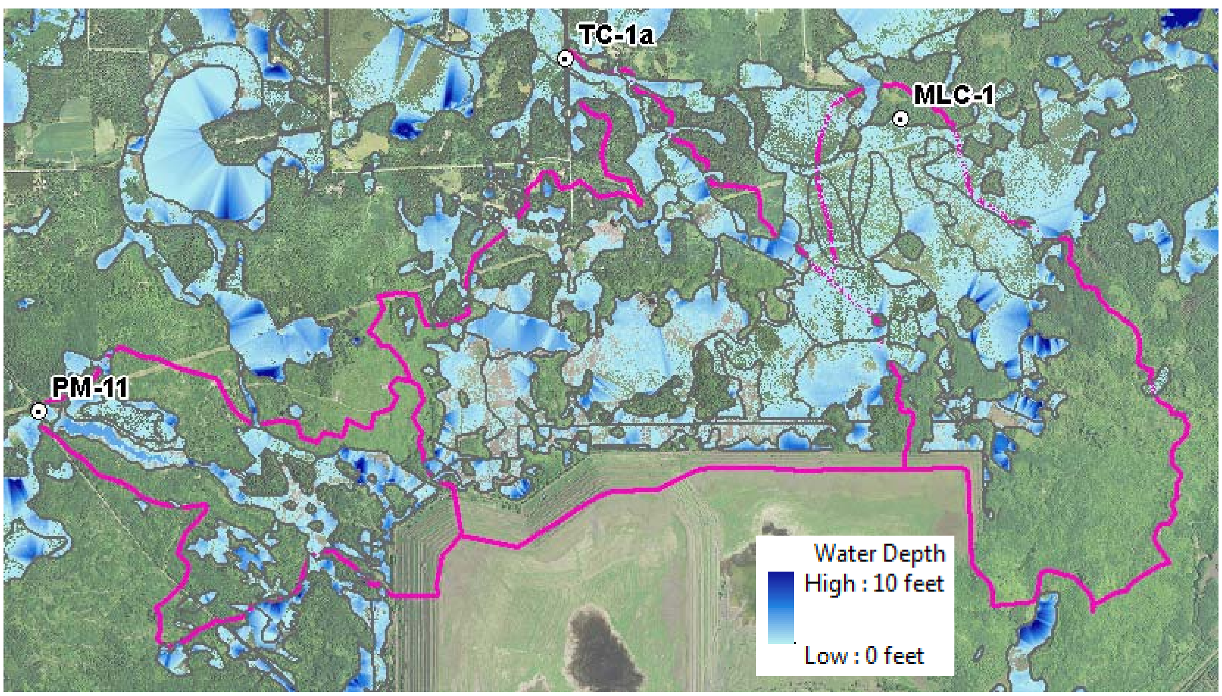

Figure 2 Estimated water depths in wetlands located around the north and west sides of the LTVSMC tailings basin

3.0 Results

Calculated residence times are presented in Table 2. Given average annual flow conditions, the residence time ranges from approximately 2 months (stream-type system) to 8 months (pond-type system). These values provide reasonable bounds for the time to flush legacy water from wetlands upstream of the surface water monitoring locations. Given the wetland types and hydrologic characteristics, these wetlands will likely perform more similarly to a stream-type system than a pond-type system, meaning the upper limit is likely conservative. Further, water quality will gradually improve as the cleaner WWTP effluent dilutes the legacy water in the wetlands. The residence times represent reasonable bounds of the time expected to elapse before values of TDS, specific conductance, and hardness at the monitoring points meet surface water quality standards.

Flow conditions will also influence the time to flush legacy water from wetlands in the headwater areas of the creeks. Legacy water will be flushed more quickly by high-flow conditions and more slowly by low-flow conditions, as shown in Table 2. Given high-flow conditions, the residence times range from approximately 1 month (stream-type system) to 4.5 months (pond-type system). Given low-flow conditions, the residence times range from approximately 3 months (stream-type system) to 34 months (pond-type system).

Residence times are generally shortest and least variable in the Trimble Creek subwatershed, where flow will be dominated by the steady WWTP discharge rather than watershed runoff. Residence times are most variable in the Unnamed (Mud Lake) Creek subwatershed, which will not receive WWTP discharge, and instead be flushed entirely by precipitation and runoff.

The season in which the WWTP discharge starts will also influence the time to flush. If operations begin in early winter, with limited runoff and essentially only WWTP discharge, the time to flush will be longer. If operations begin during spring snowmelt or during wetter times of the year, the WWTP discharge will be in addition to runoff, and the flushing of water in the wetlands will be expedited.

Table 2 Estimated residence time for water in the wetlands within the three subwatersheds

Hydrologic Scenario	Monitoring Location, Subwatershed	Plug Flow Residence Time Estimate (months)	Completely Mixed Residence Time Estimate[1] (months)
Average Conditions	PM-11, Unnamed Creek	3.5	8
	TC-1a, Trimble Creek	2	5
	MLC-1, Unnamed (Mud Lake) Creek	2.5	5.5
Low-Flow Conditions[2]	PM-11, Unnamed Creek	10	23
	TC-1a, Trimble Creek	3	7
	MLC-1, Unnamed (Mud Lake) Creek	15	34
High-Flow Conditions[3]	PM-11, Unnamed Creek	2	4.5
	TC-1a, Trimble Creek	1.5	3.5
	MLC-1, Unnamed (Mud Lake) Creek	1	2.5

[1] Based on a goal of flushing 90% of the legacy water out
[2] Based on the 10^{th} percentile modeled flow rate through the watershed from the FEIS modeling of the Plant Site
[3] Based on the 90th percentile modeled flow rate through the watershed from the FEIS modeling of the Plant Site

4.0 Summary

This analysis demonstrates that given average flow conditions, values of TDS, specific conductance, and hardness are expected to meet water quality standards at Project NPDES/SDS surface water monitoring locations within approximately one year after WWTP discharge begins. If weather during the first year of flushing is significantly drier than average, creating low-flow conditions, the ongoing effect of legacy water should be considered when interpreting monitoring results during subsequent years.

5.0 References

Barr Engineering Co. 2015. *NorthMet Project Water Modeling Data Package Volume 2 - Plant Site, Version 11.* 2015.