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External Memorandum

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From: Katie Wenigmann, Greg Williams, Miguel Wong

Subject: Changes to the Tailings Basin Flows in the Embarrass River Watershed – PolyMet RS-74

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1.0 Introduction

This memo presents additional deterministic predictions of surface water quality in the Embarrass River that corresponds to changes in the seepage from the Tailings Basin (Cells 1E & 2E and Cell 2W) and discharges from Babbitt WWTP and Pit 5NW during low flows under PolyMet's NorthMet Project for both Tailings Basin-Proposed Action and Tailings Basin-Geotechnical Mitigation. At the meeting between the Agencies (MDNR, MPCA), PolyMet, Tribes, and Barr held at Barr's Minneapolis Office on September 23, 2008, questions were raised regarding the accuracy of low flow estimates in the Embarrass River and the associated amount of seepage coming from the Tailings Basin Area. This memo was formally promised as a result of the meeting on October 9, 2008 between Barr, MDNR and the Tribes at Barr's Minneapolis Office. The information presented here does not supersede the information presented in the RS74B Draft-02 report submitted on September 13, 2008 (henceforth referred to as RS74B, Draft-02). This memo further analyzes the impacts to the Embarrass River during low flow conditions and confirms that even with the changes described, the deterministically predicted water quality in the Embarrass River does not exceed any Minnesota surface water quality standards other than those already represented in RS74B, Draft-02. Only changes with respect to RS74B, Draft-02 are presented; and the table and figure numbering follows RS74B, Draft-02.

2.0 Changes in Modeling Inputs

2.1 Changes in Tailings Basin Seepage

There are two inputs from the Tailings Basin included in the Embarrass River model: seepage from Cell 2W and seepage from Cells 1E/2E. Under existing conditions (i.e., prior to PolyMet Operations) the estimated seepage from LTVSMC Cell 2W was 4,123 gpm (9.2 cfs) and from Cells 1E/2E was 900 gpm (2.01 cfs) in RS74B, Draft-02. However, the lowest monitored total flow in the river at PM-13 was 7.2 cfs in July 2004, which is less than the calculated seepage from the existing LTVSMC Tailings Basin, indicating that not all of the estimated seepage is reaching the Embarrass River. Therefore in RS74B, Draft-02 during dry conditions, only 1.2 cfs of total seepage flow of the Tailings Basin was added to the model (because baseflow in the Embarrass River at PM-13 is approximately 5 cfs). The effective seepage value of 1.2 cfs was determined based on calibration of the Embarrass River model using sulfate as a sample parameter during low flow events. Therefore, not all of the load from the Tailings Basin was accounted for in the model during low flow conditions.

The existing 4,123 gpm seepage from LTVSMC Cell 2W was calibrated against 2001 data, which was when LTVSMC was shut-down and pond on Cell 2W started to dry up. It is expected that seepage from Cell 2W would decrease over time; hence it is probable that the actual seepage from LTVSMC Cell 2W is less than 4,123 gpm in 2008. The final steady state condition has been estimated at 610 gpm. However, all the groundwater flow models of the Tailings Basin are steady-state. It was never intended to predict transient seepage losses from Cell 2W.

It is possible that the instantaneous flow measurements taken during the water quality monitoring measurements in the Embarrass River are not extremely accurate. Accurate flow measurements require a detailed rating curve that can be difficult to develop for low flows or a well-calibrated measurement device such as an ACDP. Therefore, it is possible that the actual low flow in the Embarrass River is different from the estimate of 7.2 cfs based on the July 2004 measurement.

Therefore, it was decided to calibrate the existing conditions model to obtain the total LTVSMC Tailings Basin seepage. The calibration was completed focusing on low flow conditions using a variety of parameters: calcium, chloride, copper, fluoride, iron, magnesium, sodium, and sulfate. Calibrations were performed based on the average of parameter concentrations at PM-13 observed during two flow conditions: 1) flows less than 10 cfs (occurring in July 2004, August 2004, and October 2006), and 2) flows between 10 and 20 cfs (occurring in June 2004, August 2006, November 2006, and July 2007). These calibrations are presented in Appendix I of this memo.

Under the first flow conditions, calibration was performed by assuming no surface runoff to PM-12 or PM-13. The total seepage from the Tailings Basin was then varied in order to match the model-predicted parameter concentration at PM-13 to the average of the concentrations observed at that location on the dates listed above. Groundwater inflows to the Embarrass River were held constant. The total flow in the river at PM-13 was allowed to differ from that recorded during sampling; total flow as calculated in the calibration is the sum of the Babbitt WWTP inflow, the groundwater inflow (i.e., the natural groundwater recharge), and the seepage from the Tailings Basin. This process was performed both assuming no discharge from the Pit 5NW as well as a discharge of 0.26 cfs from the Pit 5NW (the minimum observed flow based on NTS sampling data).

Calibration to the periods of flow between 10 and 20 cfs differs slightly from the method used for flows less than 10 cfs. For these flows, the flow in the Embarrass River at PM-13 was held constant at 16.5 cfs (the average of the flows observed on the dates listed above, which vary from 15.2 to 17.9 cfs). Again, groundwater inflow was held constant. Surface runoff into the Embarrass River was calculated as the remainder of the 16.5 cfs total flow less the groundwater inflow, Babbitt WWTP discharge, Pit 5NW discharge, and Tailings Basin seepage. The seepage from the Tailings Basin was varied in order to match the model-predicted parameter concentration at PM-13 to the average of the concentrations observed at that location on the dates listed above. This process was performed both assuming no discharge from the Pit 5 NW as well as a discharge of 0.26 cfs from the Pit 5NW (the minimum observed flow based on NTS sampling data).

The results of the calibrations are presented in Table 1 of this memo. The results indicate that the seepage from the Tailings Basin to the Embarrass River upstream of PM-13 is less than the estimated seepage in RS74B, Draft-02 of 11.2 cfs during average and high flow conditions. However, the seepage from the Tailings Basin to the Embarrass River upstream of PM-13 is greater than the estimated seepage in RS74B, Draft-02 of 1.2 cfs during low flow conditions. The results of the calibration in Table 1 average about 2.1 cfs for the seepage from the Tailings Basin. The calibration of sulfate, calcium, and magnesium suggest a greater seepage flow as flows in the river at PM-13 increase from less than 10 cfs to values between 10 and 20 cfs. Chloride and sodium demonstrated the opposite trend. These contrasting trends prevent the development of a relationship between Tailings Basin seepage flow and flows in the Embarrass River. High concentrations of sulfate in the Pit 5NW prevented accurate calibration when flow in the river was less than 10 cfs and flows from Pit 5NW were considered (see Table 1). It is likely that the Pit 5NW discharge is insignificant during periods of very low flow or the load is being stored somewhere upstream in the watershed.

As seen in Table 1, the LTVSMC Tailings Basin seepage ranged from 1 to 4 cfs. When calibrated against chloride, a non-reactive solute, the estimated LTVSMC Tailings Basin seepage was 4 cfs during very low flows and with zero discharge from Pit 5NW. This is the highest value calibrated, and it was chosen to be used in the surface water quality model. Therefore, it was assumed that existing conditions seepage from Cells 1E/2E is 900 gpm (2.01 cfs). The remaining seepage (895 gpm or 1.99 cfs) is from Cell 2W and is assumed to be constant until PolyMet Tailings Basin closure. Seepage from PolyMet Tailings Basin Cells 1E/2E during operations and closure remain the same as in RS74B, Draft-02. Table 4-1 presents the seepage from the Tailings Basin-Proposed Action design and Table 4-4 presents the seepage from the Tailings Basin-Geotechnical Mitigation design for low, average and high flow conditions (i.e., the seepage rates used in modeling in this memo are the same for low, average and high flows). For comparison, Table 4-1 and Table 4-4 also provide the values used in RS74B, Draft-02.

2.2 Changes in Discharges from Babbitt WWTP & Pit 5NW

In RS74B, Draft-02 the discharges from Babbitt WWTP and Pit 5NW were assumed to be zero during low flow conditions. In this memo, the discharge from Babbitt WWTP was assumed to be 0.33 cfs under all flow conditions. The discharge from Pit 5NW is assumed to be 0.26 cfs during low flow conditions, which corresponds to the lowest measured discharge during the monitoring period of June 2001 to December 2007. The average monitored discharge from Pit 5NW of 1.99 cfs was assumed during average and high flow conditions. Table 2-1 has been updated to reflect the changes in modeled discharges from Babbitt WWTP and Pit 5NW during low flow conditions.

2.3 Changes in Input Water Quality

There are no changes in water quality from RS74B, Draft-02 except for the surface runoff, which was recalibrated for existing conditions (i.e., no PolyMet Tailings Basin and Hydrometallurgical Residue Facility inputs) using a seepage rate of 4 cfs from the existing LTVSMC Tailings Basin. Table 5-2 displays the recalibrated surface runoff water quality.

3.0 Modeling Results

3.1 Tailings Basin-Proposed Action

3.1.1 Deterministic Water Quality Predictions at PM-12 of Tailings Basin-Proposed Action

Results at surface water quality monitoring location PM-12 are not presented in this memo because this location is upstream of the Tailings Basin and the water quality of all inputs to this location are below the Minnesota surface water quality standards. However, for reference the results are presented in Tables 5-4 to 5-6.

3.1.2 Deterministic Water Quality Predictions at PM-13 of Tailings Basin-Proposed Action

Deterministic water quality predictions of each constituent of analysis during Years 1, 5, 8, 9, 15, 20, Closure, and Post-Closure at surface water monitoring location PM-13 along with the most stringent of the chronic aquatic toxicity-based Minnesota surface water quality standards are presented in Tables 5-7 to 5-9 for low, average and high flows under Tailings Basin-Proposed Action. The maximum deterministic water quality predictions of some key water quality parameters are summarized below:

- Antimony. The highest deterministic water quality prediction of antimony is 0.00509 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Proposed Action vs. 0.00209 mg/L at PM-13 in Year 20 during low flow conditions in RS74B, Draft-02. This new predicted highest value is about one-sixth of the Minnesota surface water quality standard of 0.031 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00150 mg/L.

- Arsenic. The highest deterministic water quality prediction of arsenic is 0.00779 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Proposed Action vs. 0.00393 mg/L at PM-13 in Post-Closure during low flow conditions in RS74B, Draft-02. This new predicted highest value is about one-sixth of the Minnesota surface water quality standard of 0.053 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00100 mg/L.

- Cobalt. The highest deterministic water quality prediction of cobalt is 0.00414 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Proposed Action vs. 0.00172 mg/L at PM-13 in Year 20 during low flow conditions in RS74B, Draft-02. This new predicted highest value is about 80 percent of the Minnesota surface water quality standard of 0.005 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00050 mg/L.

- Copper. The highest deterministic water quality prediction of copper is 0.01110 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Proposed Action vs. 0.00579 mg/L at PM-13 in Post-Closure during low flow conditions in RS74B, Draft-02. This new predicted highest value is about two-thirds of the Minnesota surface water quality standard of 0.0172 mg/L, based on a hardness of 246.7 mg/L. (The corresponding Minnesota surface water quality standard in RS74B, Draft-02 is 0.0116 mg/L based on a hardness of 130.7 mg/L). The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00200 mg/L.

- Nickel. The highest deterministic water quality prediction of nickel is 0.06689 mg/L at PM-13 in Year 15 during low flow conditions under Tailings Basin-Proposed Action vs. 0.01829 mg/L at PM-13 in Year 20 during low flow conditions in RS74B, Draft-02. This new predicted highest value is less than two-thirds the Minnesota surface water quality standard of 0.1086 mg/L based on a hardness of 238.0 mg/L. (The corresponding Minnesota surface water quality standard in RS74B, Draft-02 is 0.0804 mg/L based on a hardness of 166.7 mg/L). The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00207 mg/L.

- Sulfate. The highest deterministic water quality prediction of sulfate is 156.1 mg/L at PM-13 in Year 15 during low flow conditions under Tailings Basin-Proposed Action vs. 63.4 mg/L at PM-13 in Year 20 during low flow conditions in RS74B, Draft-02. There is no Minnesota surface water quality standard for sulfate applicable to the Use Classification of the Embarrass River. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 36.1 mg/L.

Identical to RS74B, Draft-02, all constituents meet minimum in-stream Minnesota water quality standards at PM-13 during low, average and high flow conditions for all modeled scenarios under the

Tailings Basin-Proposed Action except for aluminum (see Tables 5-7 to 5-9). See Section 5.2.3.1 of RS74B, Draft-02 for discussion.

The deterministic model predicts sulfate concentrations at PM-13 that are above the average measured concentration of 36.1 mg/L. The high concentrations of sulfate in the Pit 5NW discharge (1,046 mg/L) result in a significant load to the Embarrass River, as the deterministic model assumes conservation of mass. During low flow conditions, seepage from Cells 1E/2E of the PolyMet Tailings Basin also results in a significant load in the Embarrass River (the highest predicted concentration of seepage from Cells 1E/2E is 241.9 mg/L in Year 15). Although the model calibration works well under average flow conditions, it does not under low flow conditions. Including the load from the Pit 5NW discharge and a flow of 4 cfs from the existing LTVSMC Tailings Basin, the model calibration resulted in predicted sulfate concentrations (95.9 mg/L for low flow conditions) that are higher than the measured concentrations during low flow conditions (41.30 mg/L) even without any additional mining inputs. When using the existing conditions model to obtain the total LTVSMC Tailings Basin seepage using sulfate, it was found that a LTVSMC Tailings Basin seepage flow rate of approximately 1.6 cfs provided the best fit calibration for flows less than 10 cfs and with no Pit 5NW discharge. It is possible that sulfate is being stored in wetlands, banks or ice during low flow conditions.

3.1.3 Culpability Analysis of Tailings Basin-Proposed Action

The culpability analysis (i.e., the degree of a particular Plant Site facility's or natural feature's impact on the overall deterministic water quality predictions in the Embarrass River) for the six water quality parameters of importance (antimony, arsenic, cobalt, copper, nickel and sulfate) and under low, average and high flow conditions are presented in Appendix G of this memo. All upstream impacts, including those from both natural features (i.e., groundwater recharge and surface runoff from areas that will not be disturbed by the Plant Site facilities) and Tailings Basin facilities (e.g., hydrometallurgical residue cell liner leakage, Cells 1E/2E seepage) were investigated for all scenarios and flow conditions at the PM-13 surface water quality monitoring stations.

The culpability analysis is completed for two sets of graphs which are presented in Appendix G of this memo for Tailings Basin-Proposed Action:

- Mass flux of upstream impacts (concentration of the feature multiplied by the flow of the feature).
- Percent contributions at PM-13 (mass flux of each feature divided by total mass flux at a certain location).

In Appendix G, "-" indicates that the mass flux is zero (e.g., there is no surface runoff during low flow conditions), whereas "0.00" indicates that the mass flux is very small. The figures in Appendix G present the full set of results of the culpability analysis for the Tailings Basin-Proposed Action. The main results of this analysis are presented below. If a result is different from RS74B, Draft-02, the RS74B, Draft-02 result is presented in a sub-bullet for comparison.

<u>Low Flow Conditions – Tailings Basin-Proposed Action</u>

- Seepage from Cells 1E/2E of the Tailings Basin in all years, followed by natural groundwater recharge from the watershed in Years 1, 5, 8, 9, Closure and Post-Closure, represents the main input determining concentrations of arsenic.
    - In RS74B, Draft-02, natural groundwater recharge from the watershed, followed by seepage from Cell 2W in Year 1 and seepage from Cells 1E/2E of the Tailings Basin in all other years, represents the main input determining concentrations of arsenic.
- Seepage from Cells 1E/2E of the Tailings Basin in Years 5, 8, 9, 15 and 20, followed by natural groundwater recharge from the watershed in Years 5, 8, and 9, represents the main input determining concentrations of cobalt. Natural groundwater recharge from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin and seepage from Cell 2W, represents the main input determining concentrations of cobalt in Years 1, Closure and Post-Closure.
    - In RS74B, Draft-02, natural groundwater recharge from the watershed, followed by seepage from Cell 2W in Year 1 and seepage from Cells 1E/2E of the Tailings Basin in all other years, represents the main input determining concentrations of cobalt.
- Natural groundwater recharge from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin and seepage from Cell 2W, represents the main input determining concentrations of copper and nickel in Years 1.
    - In RS74B, Draft-02, natural groundwater recharge from the watershed, followed by seepage from Cell 2W in Year 1 and seepage from Cells 1E/2E of the Tailings

  - Basin in all other years, represents the main input determining concentrations of copper.

  - In RS74B, Draft-02, natural groundwater recharge from the watershed represents the main input determining concentrations of nickel in Year 1.

- Seepage from Cells 1E/2E of the Tailings Basin in Years 5, 8, 9, 15, 20, Closure and Post-Closure, followed by natural groundwater recharge from the watershed in Years 5, 8, 9, Closure and Post-Closure, represents the main input determining concentrations of copper.

  - In RS74B, Draft-02, natural groundwater recharge from the watershed, followed by seepage from Cell 2W in Year 1 and seepage from Cells 1E/2E of the Tailings Basin in all other years, represents the main input determining concentrations of copper.

- Seepage from Cells 1E/2E of the Tailings Basin in Years 5, 8, 9, 15, 20, Closure and Post-Closure, followed by natural groundwater recharge from the watershed in Years 5, Closure and Post-Closure, represents the main input determining concentrations of nickel.

  - In RS74B, Draft-02, seepage from Cells 1E/2E of the Tailings Basin, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of nickel in Years 15 and 20.

  - In RS74B, Draft-02, natural groundwater recharge from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of nickel in Years 5, 8, 9, Closure and Post-Closure.

- Seepage from Cells 1E/2E of the Tailings Basin in all years, followed by natural groundwater recharge from the watershed in Years 1, 5, Closure and Post-Closure, represents the main input determining concentrations of antimony.

  - In RS74B, Draft-02, natural groundwater recharge from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of antimony in all years.

- Seepage from Cells 1E/2E of the Tailings Basin, followed by seepage from Cell 2W and discharge from Pit 5NW, represents the main input determining concentrations of sulfate in Years 1, 5, 8 and 9.

  - In RS74B, Draft-02, seepage from Cell 2W, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Year 1.

    - In RS74B, Draft-02, seepage from Cell 2W, followed by liner leakage from the Hydrometallurgical Residue Cells and seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Years 5, 8 and 9.

- Seepage from Cells 1E/2E of the Tailings Basin represents the main input determining concentrations of sulfate in Years 15 and 20.

    - In RS74B, Draft-02, liner leakage from the Hydrometallurgical Residue Cells, followed by seepage from Cells 1E/2E of the Tailings Basin and from Cell 2W, represents the main input determining concentrations of sulfate in Years 15 and 20.

- Discharge from Pit 5NW, followed by seepage from Cells 1E/2E of the Tailings Basin and from Cell 2W, represents the main input determining concentrations of sulfate in Closure and Post-Closure.

    - In RS74B, Draft-02, seepage from Cell 2W, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Closure.

    - In RS74B, Draft-02, seepage from Cells 1E/2E of the Tailings Basin, followed by seepage from Cell 2W, represents the main input determining concentrations of sulfate in Post-Closure.

Average Flow Conditions – Tailings Basin-Proposed Action

- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of arsenic in Years 15 and 20. This is the same as in RS74B, Draft-02.

- Natural surface water runoff from the watershed, followed by Seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of arsenic in Years 1, 5, 8, 9, Closure and Post-Closure.

    - In RS74B, Draft-02, natural surface water runoff from the watershed, followed by seepage from Cell 2W, represents the main input determining concentrations of arsenic in Year 1.

    - In RS74B, Draft-02, natural surface water runoff from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of arsenic in Years 5, 8, 9, Closure and Post-Closure.

- Natural surface water runoff from the watershed represents the main input determining concentrations of cobalt in Years 1, 5, 8, 9, Closure and Post-Closure.
    - In RS74B, Draft-02, natural surface water runoff from the watershed, followed by seepage from Cell 2W, represents the main input determining concentrations of cobalt in Year 1.
    - In RS74B, Draft-02, natural surface water runoff from the watershed represents the main input determining concentrations of cobalt in Years 5, 8, 9, Closure and Post-Closure.
- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of cobalt in Years 15 and 20. This is the same as in RS74B, Draft-02.
- Natural surface water runoff from the watershed represents the main input determining concentrations of copper in Year 1.
    - In RS74B, Draft-02, natural surface water runoff from the watershed, followed by seepage from Cell 2W, represents the main input determining concentrations of copper in Year 1.
- Natural surface water runoff from the watershed, followed by Seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of copper in Years 5, 8, 9, Closure and Post-Closure. This is the same as in RS74B, Draft-02.
- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of copper in Years 15 and 20. This is the same as in RS74B, Draft-02.
- Natural surface water runoff from the watershed, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of nickel in Year 1.
    - In RS74B, Draft-02, natural surface water runoff from the watershed, followed by seepage from Cell 2W, represents the main input determining concentrations of nickel in Year 1.
- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of nickel in Years 5, 8, and 9. This is the same as in RS74B, Draft-02.
- Seepage from Cells 1E/2E of the Tailings Basin represents the main input determining concentrations of nickel in Years 15 and 20. This is the same as in RS74B, Draft-02.

- Natural surface water runoff from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of nickel in Closure and Post-Closure. This is the same as in RS74B, Draft-02.

- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of antimony in Years 1 and 5, and in Closure and Post-Closure.

    - In RS74B, Draft-02, seepage from Cells 1E/2E of the Tailings Basin, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of antimony in Year 1 and in Closure and Post-Closure.

- Seepage from Cells 1E/2E of the Tailings Basin represents the main input determining concentrations of antimony in Years 8, 9, 15 and 20.

    - In RS74B, Draft-02, seepage from Cells 1E/2E of the Tailings Basin represents the main input determining concentrations of antimony in Years 5, 8, 9, 15 and 20.

- Discharge from Pit 5NW in all years, followed by seepage from Cells 1E/2E of the Tailings Basin in Years 8, 9, 15 and 20, represents the main input determining concentrations of sulfate.

    - In RS74B, Draft-02, discharge from Pit 5NW, followed by seepage from Cell 2W and seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Years 1, 5, 8, and 9.

    - In RS74B, Draft-02, discharge from Pit 5NW, followed by seepage from Cells 1E/2E of the Tailings Basin and seepage from Cell 2W, represents the main input determining concentrations of sulfate in Years 15 and 20.

    - In RS74B, Draft-02, discharge from Pit 5NW represents the main input determining concentrations of sulfate in Closure and Post-Closure.

<u>High Flow Conditions – Tailings Basin-Proposed Action</u>

- Natural surface water runoff from the watershed represents the main input determining concentrations of arsenic, cobalt and copper in all years. This is the same as in RS74B, Draft-02.

- Natural surface water runoff from the watershed represents the main input determining concentrations of nickel in Years 1, 5, 8, 9, Closure and Post-Closure. This is the same as in RS74B, Draft-02.

- Natural surface water runoff from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of nickel in Years 15 and 20. This is the same as in RS74B, Draft-02.

- Natural surface water runoff from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of antimony in Years 1, 5, Closure and Post-Closure.

    - In RS74B, Draft-02, Natural surface water runoff from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of antimony in Years 1, Closure and Post-Closure.

- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of antimony in Years 8, 9, 15 and 20.

    - In RS74B, Draft-02, Seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of antimony in Years 5, 8, 9, 15, and 20.

- Natural surface water runoff from the watershed, followed by discharge from Pit 5NW, represents the main input determining concentrations of sulfate in all years. This is the same as in RS74B, Draft-02.

3.1.4 Factor to Exceed of Tailings Basin-Proposed Action

This section presents the analysis conducted to determine what increase in NorthMet Project's Tailings Basin seepage chemical concentrations would cause the deterministic water quality predictions in the Embarrass River watershed to exceed Minnesota surface water quality standards under Tailings Basin-Proposed Action.

The predicted chemical concentrations for the leachate from the PolyMet Tailings Basin (Cells 1E/2E) and Hydrometallurgical Residue Facility were multiplied concurrently by a factor. The determination of the factor for a given parameter (antimony, arsenic, cobalt, copper and nickel) and flow condition (low, average or high) was based on deterministic water quality predictions in the Embarrass River that exceed Minnesota surface water quality standards for that parameter at PM-13 and a given stage of the Tailings Basin development or closure under the Tailings Basin- Proposed Action.

Table 5-10 presents the smallest factors, along with the location and scenario that would cause the deterministic water quality predictions to exceed Minnesota surface water quality standards in the Embarrass River at PM-13. There is no applicable Minnesota surface water quality standard for sulfate given the use classification of the Embarrass River. However, there is emerging interest in sulfate, and so the corresponding sulfate concentration for the smallest factors referred to above is also presented in Table 5-10.

Table 5-11 compares the concentrations of leachate from PolyMet Tailings Basin (Cells 1E/2E) and Hydrometallurgical Residue Facility (all occurring concurrently) that would cause Embarrass River deterministic water chemistry predictions to exceed Minnesota surface water quality standards and the “base case” concentrations of these Tailings Basin features. “Base Case” concentrations are those reasonable worst case concentrations presented in Tables 4-2 and 4-3 of RS74B, Draft-02.

The main results of this analysis are presented below:

- Antimony. The smallest factor to exceed the corresponding standard is 6.4 under the Tailings Basin- Proposed Action vs. 33.0 in RS74B, Draft-02.
- Arsenic. The smallest factor to exceed the corresponding standard is 7.9 under the Tailings Basin- Proposed Action vs. 34.0 in RS74B, Draft-02.
- Cobalt. The smallest factor to exceed the corresponding standard is 1.2 under the Tailings Basin- Proposed Action vs. 5.7 in RS74B, Draft-02.
- Copper. The smallest factor to exceed the corresponding standard is 1.7 under the Tailings Basin- Proposed Action vs. 3.6 in RS74B, Draft-02.
- Nickel. The smallest factor to exceed the corresponding standard is 1.8 under the Tailings Basin- Proposed Action vs. 6.1 in RS74B, Draft-02.

3.2 Tailings Basin-Geotechnical Mitigation

3.2.1 Deterministic Water Quality Predictions at PM-12 of Tailings Basin-Geotechnical Mitigation

Results at surface water quality monitoring location PM-12 are not presented in this memo because this location is upstream of the Tailings Basin and the water quality of all inputs to this location are below the Minnesota surface water quality standards. However, for reference the results are presented in Tables 7-1 to 7-3.

3.2.2 Deterministic Water Quality Predictions at PM-13 of Tailings Basin-Geotechnical Mitigation

Deterministic water quality predictions of each constituent of analysis during Years 1, 5, 10, 15, 20, Closure, and Post-Closure at surface water monitoring location PM-13 along with the most stringent of the chronic aquatic toxicity-based Minnesota surface water quality standards are presented in Tables 7-4 to 7-6 for low, average and high flows under Tailings Basin-Geotechnical Mitigation. The maximum deterministic water quality predictions of some key water quality parameters are summarized below:

- Antimony. The highest deterministic water quality prediction of antimony is 0.00555 mg/L at PM-13 in Year 10 during low flow conditions under Tailings Basin-Geotechnical Mitigation vs. 0.00217 mg/L at PM-13 in Year 10 during low flow conditions in RS74B, Draft-02. This new predicted highest value is about one-sixth of the Minnesota surface water quality standard of 0.031 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00150 mg/L.

- Arsenic. The highest deterministic water quality prediction of arsenic is 0.00762 mg/L at PM-13 in Post-Closure during low flow conditions under Tailings Basin-Geotechnical Mitigation vs. 0.00545 mg/L at PM-13 in Post-Closure during low flow conditions in RS74B, Draft-02. This new predicted highest value is about one-sixth of the Minnesota surface water quality standard of 0.053 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00100 mg/L.

- Cobalt. The highest deterministic water quality prediction of cobalt is 0.00164 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Geotechnical Mitigation vs. 0.00131 mg/L at PM-13 in Post-Closure during low flow conditions in RS74B, Draft-02. This new predicted highest value is about one-third of the Minnesota surface water quality standard of 0.005 mg/L. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00050 mg/L.

- Copper. The highest deterministic water quality prediction of copper is 0.00740 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Geotechnical Mitigation vs. 0.00513 mg/L at PM-13 in Post-Closure during low flow conditions in RS74B, Draft-02. This new predicted highest value is less than one-half the Minnesota surface water quality standard of 0.0162 mg/L, based on a hardness of 223.5 mg/L. (The corresponding Minnesota surface water quality standard in RS74B, Draft-02 is 0.01278 mg/L based on a hardness of 152.8 mg/L). The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00200 mg/L.

- Nickel. The highest deterministic water quality prediction of nickel is 0.01451 mg/L at PM-13 in Year 20 during low flow conditions under Tailings Basin-Geotechnical Mitigation vs. 0.00868 mg/L at PM-13 in Year 20 during low flow conditions in RS74B, Draft-02. This new predicted highest value is about one-sixth the Minnesota surface water quality standard of 0.1030 mg/L based on a hardness of 223.5 mg/L. (The corresponding Minnesota surface water quality standard in RS74B, Draft-02 is 0.07829 mg/L based on a hardness of 161.6 mg/L). The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 0.00207 mg/L.

- Sulfate. The highest deterministic water quality prediction of sulfate is 150.1 mg/L at PM-13 in Year 10 during low flow conditions under Tailings Basin-Geotechnical Mitigation vs. 61.6 mg/L at PM-13 in Year 10 during low flow conditions in RS74B, Draft-02. There is no Minnesota surface water quality standard for sulfate applicable to the Use Classification of the Embarrass River. The average concentration from surface water quality monitoring in 2004, 2006 and 2007 at PM-13 is 36.1 mg/L.

Identical to RS74B, Draft-02, all constituents meet minimum in-stream Minnesota water quality standards at PM-13 during low, average and high flow conditions for all modeled scenarios under the Tailings Basin-Geotechnical Mitigation except for aluminum (see Tables 7-4 to 7-6). See Section 7.2.3.1 of RS74B, Draft-02 for discussion.

The deterministic model predicts sulfate concentrations at PM-13 that are above the average measured concentration of 36.1 mg/L. The high concentrations of sulfate in the Pit 5NW discharge (1,046 mg/L) result in a significant load to the Embarrass River, as the deterministic model assumes conservation of mass. During low flow conditions, seepage from Cell 1E/2E of the PolyMet Tailings Basin also results in a significant load in the Embarrass River (the highest predicted concentration of seepage from Cell 1E/2E is 223.1 mg/L in Year 10). Although the model calibration works well under average flow conditions, it does not under low flow conditions. Including the load from the Pit 5NW discharge and a flow of 4 cfs from the LTVSMC Tailings Basin, the model calibration resulted in predicted sulfate concentrations (95.9 mg/L for low flow conditions) higher than the measured concentrations during low flow conditions (41.30 mg/L) even without any additional mining inputs. When using the existing conditions model to obtain the total LTVSMC Tailings Basin seepage using sulfate, it was found that a LTVSMC Tailings Basin seepage flow rate of approximately 1.6 cfs provided the best fit calibration for flows less than 10 cfs and with no Pit 5NW discharge. It is possible that sulfate is being stored in wetlands, banks or ice during low flow conditions.

3.2.3 Culpability Analysis of Tailings Basin-Geotechnical Mitigation

The culpability analysis (i.e., the degree of a particular Plant Site facility's or natural feature's impact on the overall deterministic water quality predictions in the Embarrass River) for the six water quality parameters of importance (antimony, arsenic, cobalt, copper, nickel and sulfate) and under low, average and high flow conditions are presented in Appendix G of this memo. All upstream impacts, including those from both natural features (i.e., groundwater recharge and surface runoff from areas that will not be disturbed by the Plant Site facilities) and Tailings Basin facilities (e.g., hydrometallurgical residue cells liner leakage, Cells 1E/2E seepage) were investigated for all scenarios and flow conditions at the PM-13 surface water quality monitoring stations.

The culpability analysis is completed for two sets of graphs which are presented in Appendix G for Tailings Basin-Geotechnical Mitigation:

- Mass flux of upstream impacts (concentration of the feature multiplied by the flow of the feature).
- Percent contributions at PM-13 (mass flux of each feature divided by total mass flux at a certain location).

In Appendix G, "-" indicates that the mass flux is zero (e.g., there is no surface runoff during low flow conditions), whereas "0.00" indicates that the mass flux is very small. The figures in Appendix G present the full set of results of the culpability analysis for the Tailings Basin-Geotechnical Mitigation. The main results of this analysis are presented below. If a result is different from RS74B, Draft-02, the RS74B, Draft-02 result is presented in a sub-bullet for comparison.

Low Flow Conditions – Tailings Basin-Geotechnical Mitigation

- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of arsenic in all years.
    - In RS74B, Draft-02, natural groundwater recharge from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of arsenic in Years 1, 5, 10, 15, 20 and Closure.
    - In RS74B, Draft-02, seepage from Cells 1E/2E of the Tailings Basin, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of arsenic in Post-Closure.
- Natural groundwater recharge from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin and seepage from Cell 2W, represents the main input determining concentrations of cobalt in Years 1, Closure and Post-Closure.
- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of cobalt in Years 5, 10, 15 and 20.
    - In RS74B, Draft-02, natural groundwater recharge from the watershed, followed by seepage from Cell 2W, represents the main input determining concentrations of cobalt in Years 1, 5, 10, 15 and Closure.
    - In RS74B, Draft-02, natural groundwater recharge from the watershed, followed seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of cobalt in Years 20 and Post-Closure.
- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of copper in all years.
    - In RS74B, Draft-02, natural groundwater recharge from the watershed in all years, followed by seepage from Cells 1E/2E of the Tailings Basin in Years 20 and Post-Closure, represents the main input determining concentrations of copper.

- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of nickel in all years.
    - In RS74B, Draft-02, natural groundwater recharge from the watershed in all years, followed by seepage from Cells 1E/2E of the Tailings Basin in Years 1, 5, 10, 15, and 20, represents the main input determining concentrations of nickel.
- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of antimony in Year 1.
- Seepage from Cells 1E/2E of the Tailings Basin represents the main input determining concentrations of antimony in Years 5, 10, 15 and 20.
- Natural groundwater recharge from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of antimony in Closure and Post-Closure.
    - In RS74B, Draft-02, natural groundwater recharge from the watershed in all years, followed by seepage from Cells 1E/2E of the Tailings Basin in Years 1, 5, 10, 15, and 20, represents the main input determining concentrations of antimony.
- Seepage from Cells 1E/2E of the Tailings Basin, followed by seepage from Cell 2W and discharge from Pit 5NW, represents the main input determining concentrations of sulfate in Year 1.
    - In RS74B, Draft-02, seepage from Cell 2W, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Years 1 and Closure.
- Seepage from Cells 1E/2E of the Tailings Basin represents the main input determining concentrations of sulfate in Years 5, 10, 15, and 20.
    - In RS74B, Draft-02, seepage from Cell 2W, followed by liner leakage from the Hydrometallurgical Residue Cells and seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Year 5.
    - In RS74B, Draft-02, liner leakage from the Hydrometallurgical Residue Cells, followed by seepage from Cells 1E/2E of the Tailings Basin and seepage from Cell 2W, represents the main input determining concentrations of sulfate in Years 10, 15 and 20.

- Seepage from Cells 1E/2E of the Tailings Basin, followed by discharge from Pit 5NW and by seepage from Cell 2W, represents the main input determining concentrations of sulfate in Closure and Post-Closure.
    - In RS74B, Draft-02, seepage from Cells 1E/2E of the Tailings Basin, followed by seepage from Cell 2W, represents the main input determining concentrations of sulfate in Post-Closure.

<u>Average Flow Conditions – Tailings Basin-Geotechnical Mitigation</u>

- Natural surface water runoff from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of arsenic in all years. This is the same as in RS74B, Draft-02.
- Natural surface water runoff from the watershed represents the main input determining concentrations of cobalt in all years. This is the same as in RS74B, Draft-02. However, in the updated modeling, seepage from Cells 1E/2E of the Tailings Basin is an important secondary input determining concentrations of cobalt in Year 20.
- Natural surface water runoff from the watershed in all years, followed by seepage from Cells 1E/2E of the Tailings Basin in Years 10, 15 and 20 only, represents the main input determining concentrations of copper. This is the same as in RS74B, Draft-02.
- Natural surface water runoff from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of nickel in Year 1.
    - In RS74B, Draft-02, natural surface water runoff from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin and seepage from Cell 2W, represents the main input determining concentrations of nickel in Year 1.
- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of nickel in Years 5, 10, 15 and 20.
    - In RS74B, Draft-02, seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed and seepage from Cell 2W, represents the main input determining concentrations of nickel in Years 5, 10, 15 and 20.
- Natural surface water runoff from the watershed, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of nickel in Closure and Post-Closure. This is the same as in RS74B, Draft-02.

- Seepage from Cells 1E/2E of the Tailings Basin represents the main input determining concentrations of antimony in Years 1, 5, 10, 15 and 20. This is the same as in RS74B, Draft-02.

- Natural groundwater recharge from the watershed, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of antimony in Closure and Post-Closure.

    - In RS74B, Draft-02, natural groundwater recharge from the watershed represents the main input determining concentrations of antimony in Closure and Post-Closure.

- Discharge from Pit 5NW, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Years 1, 5, 10, 15 and 20.

    - In RS74B, Draft-02, discharge from Pit 5NW, followed by seepage from Cell 2W and seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of sulfate in Years 1, 5, 10, 15 and 20.

- Discharge from Pit 5NW represents the main input determining concentrations of sulfate in Closure and Post-Closure. This is the same as in RS74B, Draft-02.

<u>High Flow Conditions – Tailings Basin-Geotechnical Mitigation</u>

- Natural surface water runoff from the watershed represents the main input determining concentrations of arsenic, cobalt, copper, and nickel in all years. This is the same as in RS74B, Draft-02.

- Natural surface water runoff from the watershed, followed by seepage from Cells 1E/2E of the Tailings Basin, represents the main input determining concentrations of antimony in Year 1.

    - In RS74B, Draft-02, seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of antimony in Year 1.

- Seepage from Cells 1E/2E of the Tailings Basin, followed by natural surface water runoff from the watershed, represents the main input determining concentrations of antimony in Years 5, 10, 15 and 20. This is the same as in RS74B, Draft-02.

- Natural surface water runoff from the watershed represents the main input determining concentrations of antimony in Closure and Post-Closure.

  - In RS74B, Draft-02, natural surface water runoff from the watershed, followed by natural groundwater recharge from the watershed, represents the main input determining concentrations of antimony in Closure.

  - In RS74B, Draft-02, natural surface water runoff from the watershed represents the main input determining concentrations of antimony in Post-Closure.

- Natural surface water runoff from the watershed, followed by discharge from Pit 5NW, represents the main input determining concentrations of sulfate in all years. This is the same as in RS74B, Draft-02.

3.2.4 Factor to Exceed of Tailings Basin-Geotechnical Mitigation

This section presents the analysis conducted to determine what increase in NorthMet Project's Tailings Basin seepage chemical concentrations would cause the deterministic water quality predictions in the Embarrass River watershed to exceed Minnesota surface water quality standards under Tailings Basin-Geotechnical Mitigation.

The predicted chemical concentrations for the leachate from the PolyMet Tailings Basin (Cells 1E/2E) and Hydrometallurgical Residue Facility were multiplied concurrently by a factor. The determination of the factor for a given parameter (antimony, arsenic, cobalt, copper and nickel) and flow condition (low, average or high) was based on deterministic water quality predictions in the Embarrass River that exceed Minnesota surface water quality standards for that parameter at PM-13 and a given stage of the Tailings Basin development or closure under the Tailings Basin-Geotechnical Mitigation.

Table 5-10 presents the smallest factors, along with the location and scenario that would cause the deterministic water quality predictions to exceed Minnesota surface water quality standards in the Embarrass River at PM-13. There is no applicable Minnesota surface water quality standard for sulfate given the use classification of the Embarrass River. However, there is emerging interest in sulfate, and so the corresponding sulfate concentration for the smallest factors referred to above is also presented in Table 5-10.

Table 5-11 compares the concentrations of leachate from PolyMet Tailings Basin (Cells 1E/2E) and Hydrometallurgical Residue Facility (all occurring concurrently) that would cause Embarrass River deterministic water chemistry predictions to exceed Minnesota surface water quality standards and the “base case” concentrations of these Tailings Basin features. “Base Case” concentrations are those reasonable worst case concentrations presented in Tables 4-3 and 4-5 of RS74B, Draft-02.

The main results of this analysis are presented below:

- Antimony. The smallest factor to exceed the corresponding standard is 6.2 under the Tailings Basin-Geotechnical Mitigation vs. 32.0 in RS74B, Draft-02.
- Arsenic. The smallest factor to exceed the corresponding standard is 9.3 under the Tailings Basin-Geotechnical Mitigation vs. 16.9 in RS74B, Draft-02.
- Cobalt. The smallest factor to exceed the corresponding standard is 4.4 under the Tailings Basin-Geotechnical Mitigation vs. 13.7 in RS74B, Draft-02.
- Copper. The smallest factor to exceed the corresponding standard is 2.7 under the Tailings Basin-Geotechnical Mitigation vs. 6.1 in RS74B, Draft-02.
- Nickel. The smallest factor to exceed the corresponding standard is 9.2 under the Tailings Basin-Geotechnical Mitigation vs. 31.1 in RS74B, Draft-02.

4.0 Conclusions

The deterministically predicted water quality in the Embarrass River does not exceed any additional Minnesota surface water quality standards than was presented in RS74B, Draft-02. (The only parameter to exceed Minnesota surface water quality standards in RS74B, Draft-02 was aluminum). However, there are increases in the concentrations of almost all parameters during low flow conditions when the seepage from the Tailings Basin (Cells 1E & 2E and Cell 2W) and discharges from Babbitt WWTP and Pit 5NW were increased. Under Tailings Basin-Proposed Action, the predicted concentrations at PM-13 of cobalt, copper and nickel are within two-thirds of the Minnesota surface water quality standard. The smallest factor to exceed the corresponding standard is 1.2, 1.7 and 1.8 for cobalt, copper, and nickel, respectively.

The predicted concentrations at PM-13 under the Tailings Basin-Geotechnical Mitigation are further below the Minnesota surface water quality standards than under the Tailings Basin-Proposed Action. The highest predicted concentration of copper is less than one-half the Minnesota surface water quality standard. The smallest factor to exceed the corresponding standard is 2.7 for copper under

Tailings Basin-Geotechnical Mitigation; factors for other parameters of interest are larger, indicating that the predicted concentrations are relatively much lower than the Minnesota surface water quality standard.