



## Mercury Overview

*A summary of potential mercury releases from the NorthMet Project and potential effects on the environment*

Prepared for  
Poly Met Mining Inc.

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## Acronyms, Abbreviations and Units

Acronym	Description
AERA	Air Emissions Risk Analysis
BAF	Bioaccumulation Factor
BWCA	Boundary Waters Canoe Area (Wilderness)
DAT	Deposition Analysis Threshold
DEIS	Draft Environmental Impact Statement
EAW	Environmental Assessment Worksheet
EIS	Environmental Impact Statement
EPRI	Electric Power Research Institute
FTB	Flotation Tailings Basin
H <sub>2</sub> S	Hydrogen Sulfide
Hg	Mercury
HQ	Hazard Quotient
HRF	Hydrometallurgical Residue Facility
IAP	Impact Assessment Planning
LSDP	Large Scale Demonstration Plant, Mesabi Nugget
LTVSMC	LTV Steel Mining Company
MDH	Minnesota Department of Health
MDNR	Minnesota Department of Natural Resources
MMREM	MPCA's Mercury Risk Estimation Method
MPCA	Minnesota Pollution Control Agency
NADP	National Atmospheric Deposition Program
NPDES	National Pollutant Discharge Elimination System
OSP	Ore Storage Pile
P50	median or 50th percentile GoldSim water quality model result
PM	Particulate Matter
PM <sub>2.5</sub>	Particulate Matter (Fine) (less than 2.5 microns in aerodynamic diameter)
PM <sub>10</sub>	Particulate Matter (Coarse and Fine) (less than 10 microns in aerodynamic diameter)
PSD	Prevention of Significant Deterioration
RO	Reverse Osmosis
SAM	Sulfuric Acid Mist
SDEIS	Supplemental Draft Environmental Impact Statement
SER	Significant Emission Rate
SO <sub>2</sub>	Sulfur Dioxide
SO <sub>4</sub> or SO <sub>4</sub>	Sulfate
TMDL	Total Maximum Daily Load

TRS	Total Reduced Sulfur
UCL	Upper Confidence Level
UNESCO	United Nations Educational, Scientific and Cultural Organization
USEPA	U.S. Environmental Protection Agency
WARMF	Watershed Analysis Risk Management Framework
WHO	World Health Organization
WWTF	Waste Water Treatment Facility, Mine Site
WWTP	Waste Water Treatment Plant, Plant Site

Unit	Description
cfs	cubic feet per second
cm/yr	centimeters per year
cm/sec	centimeters per second
gpm	gallons per minute
grams/day	grams per day
g/m <sup>2</sup>	grams per square meter
g/m <sup>2</sup> /yr	grams per square meter per year
g/m <sup>3</sup>	grams per cubic meter
g/yr	grams per year
kg/ha/yr	kilograms per hectare per year
km	kilometer
L/yr	liters per year
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mg/m <sup>2</sup> /yr	milligrams per square meter per year
µg/L	micrograms per liter
µg/m <sup>2</sup> /yr	micrograms per square meter per year
µg/m <sup>3</sup>	micrograms per cubic meter
ng/L	nanograms per liter
pounds/year	pounds per year
ppm	parts per million
tpy	tons per year

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## Executive Summary

Technical assessments related to mercury have been submitted to the Co-Lead Agencies in support of the draft environmental impact statement, supplemental draft environmental impact statement, and the environmental permitting required for Poly Met Mining Inc.'s (PolyMet) NorthMet Project (Project). This document collects and summarizes information from those previously submitted reports with the goal of providing a comprehensive discussion of the potential effects from the Project's potential releases of mercury to the environment.

Because of the role of sulfate reducing bacteria in the mercury methylation process and the uptake of methylmercury by aquatic biota, this document also includes a discussion of potential sulfur releases from the Project, most of which is drawn from Project-related reports that did not directly address mercury issues.

Mercury may enter Minnesota's ecosystems indirectly through deposition of air emissions and directly through water/wastewater discharges. A total facility mass balance evaluation of the Project indicates that most of the mercury input to the process will be sent to the Flotation Tailings Basin (FTB) and Hydrometallurgical Residue Facility and sequestered from the general environment. There will be a small amount of mercury (approximately 4.6 pounds per year) released to air and to surface water.

### Potential Effects from Air Emissions

The potential local deposition of mercury from the Project's air emissions is estimated to be small. Potential changes in fish mercury concentrations are not likely to be measureable. Changes are not anticipated to existing fish consumption advisories, or existing risks to consumers of fish from lakes near the Project.

The potential cumulative local deposition of mercury emitted to air from the Project and the Mesabi Nugget Large Scale Demonstration Plant (LSDP) is also estimated to be small. Again, because potential changes in fish mercury concentrations are not likely to be measureable, no changes are anticipated to existing fish consumption advisories or existing risks to consumers of fish from lakes near the Project.

The potential additional sulfur that might be added from Plant Site SO<sub>2</sub> air emissions is estimated to be negligible, and is not expected to have any effect on mercury methylation or fish mercury concentrations.

The actual potential for deposition of fugitive dust to wetlands, and the potential release of sulfur in that dust, is uncertain. The fugitive dust control plan for the both the Mine Site and the Plant Site (including the FTB) should minimize such deposition, and the sulfur from any rock dust particles that are deposited may not be released or only released slowly through weathering. Ignoring those mitigating factors and using a conservative assumption that all sulfur in the deposited dust is both released and transformed to sulfate within the wetland, no statistically measurable increase in methylmercury concentrations is expected because available data indicates methylation is relatively insensitive to sulfate additions in the

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range likely to be experienced (potential incremental sulfate increase of 0.005 to 4 milligrams per liter (mg/L)).

## Potential Effects from Water Releases

At the Plant Site, the discharge water from the Waste Water Treatment Plant (WWTP) is estimated to meet a mercury concentration of 1.3 nanograms per liter (ng/L) and mass balance calculations indicate an overall small increase in mercury loading to the Embarrass River, but no measurable increase in mercury concentrations.

At the Mine Site, the discharge water from the West Pit lake after closure is estimated to have mercury concentrations less than 1.3 ng/L and mass balance calculations indicate an overall small reduction in mercury loading to the upper Partridge River, but no measurable decrease in mercury concentrations.

In the St. Louis River, assuming the Project discharge occurs at Forbes, and also at Cloquet, the Project is estimated to result in a reduced load of mercury to these respective evaluation points, but with no measurable decrease in total mercury concentrations.

Potential downstream effects from sulfate in discharge water are not expected because the Project will result in a reduction in sulfate loading to the Embarrass River at the monitoring site (PM13), and only a small increase in sulfate loading to the upper Embarrass River. The WWTP will discharge water at a lower sulfate concentration (~9 mg/L) than that in the current FTB seepage (~100-300 mg/L). In both cases, Project-related sulfur in water discharges is not expected to have any effect on mercury in aquatic environments, either immediately adjacent to the Project or in downstream areas.

The potential additional mercury load that might be added to the Embarrass River and the Partridge River from Plant Site air emissions is not expected to be statistically measurable when compared to the variability in background mercury concentrations. It also would not be expected to have any effect on the loading estimates from permitted discharges to the Embarrass River, Partridge River or the lower St. Louis River. The potential loading of mercury to the receiving waters meets the definition of non-degradation.

## Conclusion

Overall, based on agency-approved evaluations of air emissions and water discharges, the Project will not have any reasonably foreseeable effects on surface water mercury concentrations, fish mercury concentrations, methylation of mercury, nor will it have any potential additional risk to people consuming fish from lakes near the Project.

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# 1.0 Introduction

## 1.1 Purpose of this Document

Technical assessments related to mercury have been submitted to the Co-Lead Agencies in connection with the draft environmental impact statement (DEIS, October 2009), supplemental draft environmental impact statement (SDEIS, December 2013) and the environmental permitting for Poly Met Mining Inc.'s (PolyMet) NorthMet Project (Project). Some of the information in these assessments was discussed in the DEIS and the SDEIS, but some information was not explicitly referenced. This document collects and summarizes additional information from those previously submitted technical reports and memoranda that is intended to provide a single, comprehensive discussion of the potential effects from the Project's potential releases of mercury to the environment.

Because of the role of sulfate reducing bacteria in the mercury methylation process and the uptake of methylmercury by aquatic biota, a discussion of potential sulfur releases from the Project are summarized from other Project-related reports and also included in this document.

## 1.2 Project Reports and Documents Assessing Mercury

Mercury information for the Project is contained in the following documents, which provide the primary bases for this information summary.

### **General**

- 2007, Facility Mercury Mass Balance (RS66) (March 2007)

### **Air Emissions and Potential to Affect Human Health (fish consumption pathway)**

#### ***Project only***

- 2005, Air Emissions Risk Analysis (February 2005)
- 2007, Air Emissions Risk Analysis (AERA) – Plant Site (RS38) (March 2007)
  - Addendum 01 Supplemental Information to the March 2007 Air Emissions Risk Analysis (AERA) – Plant Site (October 2007)
- 2012, Mercury Emission Control Technology Review for NorthMet Project Processing Plant (February 2012)
- 2013, Supplemental Air Emissions Risk Analysis (AERA) – Plant Site (March 2013)

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### **Cumulative Effects**

- 2006, Cumulative Impacts Analysis: Minnesota Iron Range Industrial Development Projects: Mercury Deposition and Evaluation of Bioaccumulation in Fish in Northeast Minnesota (RS70) (November 2006)
  - 2007, Addendum 01 Supplemental Information to the November 2006 Air Quality Cumulative Assessment Report on Mercury Deposition and Evaluation of Bioaccumulation in Fish in Northeast Minnesota (August 2007)
- 2012, Cumulative Impacts Analysis: Local Mercury Deposition and Bioaccumulation in Fish (July 2012)
  - 2013, Cumulative Impacts Analysis: Local Mercury Deposition and Bioaccumulation in Fish, Addendum (March 2013)

### **Discharges to Surface Water and Compliance with Surface Water Standard (1.3 ng/L)**

- 2004, Flotation Pilot Plant Products Environmental Investigation and Air Testing (SGS Lakefield Research Limited, 2004)
- 2007, Technical Design Evaluation Report – Wastewater Treatment Technology. Appendix B: Laboratory Study of Mercury Adsorption to LTV Taconite and NorthMet Tailings (March 2007)
- 2008, Revisions to Technical Design Evaluation Report – Wastewater Treatment Technology. Technical Memorandum (August 28, 2008)
- 2013, NorthMet Project: Estimate of Mercury Loading to the Lower St. Louis River, Technical Memorandum, Version 2 (February 12, 2013)
- 2013, Water Modeling Data Package Volume 1 – Mine Site Version 12 (March 2013)
- 2013, Water Modeling Data Package Volume 2 – Plant Site, Version 9 (March 2013)
- 2014, Water Modeling Data Package Volume 1 – Mine Site, Version 13 (December 2014)
- 2015, Water Modeling Data Package Volume 2 – Plant Site, Version 10 (January 2015)
- 2015, NorthMet Project: Estimate of Mercury Loading to the Lower St. Louis River, Technical Memorandum, Version 3 (January 2015)

### **Special Assessments: Sulfate and/or Methylmercury**

- 2008, NorthMet Project: Assessing Potential Impacts from Sulfate in Seepage and Discharge Water on Total Mercury and Methylmercury Concentrations in Offsite Receiving Waters, Technical Memorandum (April 25, 2008)

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- 2008, NorthMet Project: Initial Comparison of Fish Mercury Concentrations from Hoyt Lakes Area Lakes with Fish Mercury Concentrations from Selected Lakes in Northeast Minnesota, Technical Memorandum (July 3, 2008)
    - Update to the July 3 Tech Memo on Fish Hg; Table 1 and Table 2 (August 18, 2008)
  - 2010, Results from the Additional Baseline Monitoring for Sulfate and Methylmercury in the Embarrass River Watershed (July – November 2009), Technical Memorandum (April 9, 2010)
  - 2013, Screening analysis for fugitive dust emissions at the Mine Site and Tailings Basin. Wetlands data package, version 7, March 1, 2013.

Other technical reports are referenced at appropriate places in the discussion where information is used from those reports. For example, because sulfate reducing bacteria have a role in mercury methylation and the uptake of methylmercury by aquatic biota, a summary of potential sulfur releases from other Project-related reports is also included in this document.

## 2.0 Background

### 2.1 Sources of Mercury to Ecosystems

Mercury may be input to Minnesota's ecosystems indirectly through deposition of air emissions and directly through water/wastewater discharges. The atmosphere is the main source of mercury to most surface waters, with anthropogenic sources estimated to contribute about 70% of the mercury deposition in Minnesota.<sup>1</sup> Minnesota air emission sources are estimated to contribute about 10% of the deposition occurring in Minnesota, with about 90% from out-of-state sources.<sup>2</sup>

Because of the nature of mercury and its stability in elemental form, local, regional and global emissions all may affect the mercury concentrations found in local ecosystems. Given the predominance of elemental mercury emissions from the Project (Section 3.1) and the transport and mixing of the elemental mercury in the atmosphere, the specific contribution of mercury from the Project to deposition at any location is not expected to be statistically significant or measurable.

#### 2.1.1 Atmospheric Deposition and Loading

Background total deposition of mercury (wet + dry) in Minnesota is estimated to be 12.5 micrograms per square meter per year ( $\mu\text{g}/\text{m}^2/\text{yr}$ ).<sup>3</sup> This rate is based on data and calculations from Swain et al.<sup>4</sup> and is the rate used in both the Minnesota TMDL<sup>5</sup> and project-specific local deposition analysis.<sup>6</sup> The deposition rate of 12.5  $\mu\text{g}/\text{m}^2/\text{yr}$  is assumed to be uniform across the state of Minnesota.<sup>7</sup>

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<sup>1</sup> Engstrom, D. R. and E. B. Swain, *Recent declines in atmospheric mercury deposition in the Upper Midwest*. *Environmental Science and Technology* 31:960-967 (2007).

<sup>2</sup> MPCA, *Minnesota Statewide Mercury Total Maximum Daily Load*, Minnesota Pollution Control Agency (March 2007). See also: Jackson, A.M., E.B. Swain and C.A. Andrews and D.Rae, *Minnesota's Mercury Contamination Reduction Initiative*, Fuel Processing Technology 65-66 (2000):79-99 (2000)

<sup>3</sup> Id. *Minnesota Statewide Mercury Total Maximum Daily Load*, Minnesota Pollution Control Agency (March 2007) [MPCA 2007].

<sup>4</sup> Swain, E.B., D.R. Engstrom, M.E. Brigham, T.A. Henning, and P.L. Brezonik, *Increasing rates of atmospheric deposition in midcontinental North America*, *Science*, 257:784-787.

<sup>5</sup> MPCA 2007

<sup>6</sup> MPCA, *MPCA Mercury Risk Estimation Method (MMREM) for the Fish Consumption Pathway: Impact Assessment of a Nearby Emission Source* (Dec. 2006), version 1 [MPCA 2006a].

<sup>7</sup> MPCA 2007.

Speciation of air emissions plays a major role in determining where the mercury will go after it is released to air from a facility and the potential for local impacts or partitioning to the global atmospheric pool of elemental mercury.<sup>8</sup> The following characteristics will affect the fate and transport of mercury:

- Elemental mercury typically is relatively inert, is not captured by air pollution control equipment and is a long-range transport pollutant, having a residence time in the atmosphere of several months to a year.<sup>9</sup>
- Divalent (oxidized) mercury is water soluble and has a relatively high potential to be captured by air pollution control systems. If oxidized mercury is emitted from a facility, the propensity for the oxidized mercury to adsorb to water and particles tends to result in the oxidized mercury being deposited relatively close to an emission source.<sup>10</sup>
- Particle-bound mercury also has a relatively high potential to be captured by air pollution control systems. If particle-bound mercury is emitted from a facility, there also is a tendency for these particles to be deposited locally.<sup>11</sup>

A portion of the mercury deposited on surface waters is removed from circulation through sediment burial and another small portion enters the food chain through methylation, but as identified by the U.S. Environmental Protection Agency (USEPA)<sup>12</sup> the majority of deposited mercury is re-emitted back into the atmosphere. How much mercury enters the aquatic food web and is found in fish is highly variable and depends on a number of factors. Watershed characteristics, land use, water chemistry and nutrients are among some of the variables that influence bioaccumulation. Wetlands are of particular interest as they

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<sup>8</sup> USEPA 1997a, *Mercury Study, Report to Congress*, Volume III: Fate and Transport of Mercury in the Environment, EPA-452/R-97-005, December 1997 [USEPA 1997a]; as summarized by MPCA 2007 (“Mercury cycles in the environment as a result of natural and human (anthropogenic) activities. Most of the mercury in the atmosphere is elemental mercury vapor, which is relatively inert and circulates in the atmosphere for up to a year and can be widely dispersed and transported long distances from an air emission source. Elemental mercury may be oxidized in the atmosphere and deposit to aquatic and terrestrial landscapes as divalent mercury. The inorganic form of mercury, when either bound to airborne particles or in a gaseous form, is readily removed from the atmosphere by precipitation and is also dry deposited. Most of the mercury in water, soil, sediments, or plants and animals is in the form of inorganic mercury salts and organic forms of mercury (e.g., methylmercury). Once deposited, divalent mercury may methylate and move through the food chain or convert back to elemental mercury and volatilize back to the atmosphere. Methylated mercury may also alkylate to form dimethyl mercury which may also volatilize to the atmosphere. Volatilization of mercury back to the atmosphere is a major loss mechanism for aquatic and terrestrial ecosystems. Divalent, methyl mercury and particulate bound mercury may also form complexes with suspended particulate matter or sediments or be buried in sediments. As it cycles between the atmosphere, land, and water, mercury undergoes a series of complex chemical and physical transformations, many of which are not completely understood or able to be incorporated mathematically into environmental simulation models”).

<sup>9</sup> USEPA 1997a; MPCA 2007.

<sup>10</sup> USEPA 1997a.

<sup>11</sup> USEPA 1997a.

<sup>12</sup> USEPA 1997a.

are an important land cover in Minnesota and because they host sulfate-reducing bacteria that are the primary mercury methylating agents.<sup>13</sup>

### 2.1.2 Point Source Discharges to Surface Water

The Minnesota Pollution Control Agency (MPCA)<sup>14</sup> identified 67 permitted point source discharges of mercury to surface waters in the northeast TMDL region which includes the Project area (National Pollutant Discharge Elimination System (NPDES) permits). Most of these point source discharges are wastewater treatment plants and are publicly owned treatment works (POTW), but also include discharges from one electric generating power plant, 4 paper mills and 7 taconite processing facilities.<sup>15</sup> These point source discharges of mercury to surface water are estimated to account for about 2.2% of the total mercury load in the northeast TMDL region.<sup>16</sup> Modeling of the St. Louis River watershed using the Watershed Analysis Risk Management Framework (WARMF), a model developed by the Electric Power Research Institute (EPRI), identified that atmospheric deposition is the primary input of mercury to the St. Louis River and that wastewater dischargers represented about 0.8% of the total mercury loading to the St. Louis River.<sup>17</sup>

Although wastewater point sources are minor contributors to the total mercury load, the MPCA will continue to pursue mercury reductions from these sources through mercury minimization plans and other permit conditions.<sup>18</sup>

## 2.2 Mercury Methylation

Methylation of mercury under anoxic conditions and the role of sulfate-reducing bacteria in the methylation process are well documented.<sup>19</sup> The importance of wetlands in providing an enhanced environment for mercury methylation is also well documented.<sup>20</sup>

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<sup>13</sup> MPCA 2007.

<sup>14</sup> *Id.*

<sup>15</sup> *Id.*

<sup>16</sup> *Id.*

<sup>17</sup> EPRI (Electric Power Research Institute), *Enhancement of Watershed Analysis Risk Management Framework (WARMF) for Mercury Watershed Management and Total Maximum Daily Loads (TMDLs)*, EPRI Report # 1005470, EPRI, Palo Alto, CA and Minnesota Power, Duluth MN (2006).

<sup>18</sup> MPCA 2007.

<sup>19</sup> Gilmour C., E.A. Henry and R. Mitchell, *Sulfate stimulation of mercury methylation in freshwater sediments*, *Environ. Sci. Technol.* 26(1): 2281-2287 (1992); *see also* Branfireun, B.A., N.T. Roulet, C.A. Kelly and J.W.M. Rudd, *In situ sulphate stimulation of mercury methylation in a boreal peatland: toward a link between acid rain and methylmercury contamination in remote environments*, *Global Biogeochemical Cycles* 13: 743-750 (1999); *see also* Benoit, J.M., C.C. Gilmour, R.P. Mason and A. Heyes, *Sulfide controls on mercury speciation and bioavailability to methylating bacteria in sediment pore waters*, *Environ. Sci. Technol.* 33: 951-957 (1999).

<sup>20</sup> St. Louis VL, Rudd JWM, Kelly CA, Beaty KG, Bloom NS & Flett RJ, *Importance of wetlands as sources of methyl mercury to boreal forest ecosystems*, *Can. J. Fish. Aquat. Sci.* 51: 1065-1076 (1994); Monson, *Effectiveness of Stormwater Ponds/Constructed Wetlands in the Collection of Total Mercury and Production of Methylmercury*, Final Project Report: Minnesota Pollution Control Agency, St. Paul, MN (2007); USGS (U.S. Geological Survey),

Background wet sulfate deposition in northeast Minnesota in calendar year 2013 is estimated at 3.4 kilograms per hectare per year (kg/ha/yr) (most current data from the National Atmospheric Deposition Program, Ely-Fernberg Road, Site MN18) and represents about a 70% reduction from the early to mid-1980s. Average background surface water sulfate concentrations in lakes and streams in northern Minnesota range from 0.5 milligrams per liter (mg/L) to approximately 5.0 mg/L.<sup>21</sup> Based on findings from Gilmour, background sulfate surface water concentrations are sufficient to stimulate the mercury methylation process.<sup>22</sup>

Several investigations have identified that a large increase in loading of sulfate can further increase mercury methylation.<sup>23</sup> For example, the dosing experiment by Jeremiason and others increased sulfate deposition to about 32 kg/ha/yr, approximately 4 times higher than background at that time.<sup>24</sup> The results from the various dosing experiments led the MPCA to develop a strategy to investigate the potential for elevated sulfate loading to sensitive environments, such as wetlands, to affect methylmercury concentrations in wetland streams and downstream water bodies.<sup>25</sup> As described by the MPCA the research findings will be used to inform the environmental review and NPDES permitting processes with regard to the need for additional controls to minimize sulfate loading to sensitive environments.<sup>26</sup>

The Minnesota Department of Natural Resources (MDNR) has also been investigating the effects of elevated sulfate loading on mercury methylation. As described by Berndt and Bavin:

*In the St. Louis River basin, situations that have the potential to increase Hg methylation might include SO<sub>4</sub> discharge to wetlands that drain to a river, discharge to streams where flooding may result in inundation of high organic wetlands, or SO<sub>4</sub> loading to lakes or impoundments in which anoxic conditions are produced within the water column or at the sediment/water interface. Until*

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*Mercury in wetlands at the Glacial Ridge National Wildlife Refuge, Northwestern Minnesota, 2007-9, Scientific Investigations Report 2013-5068 (2013).*

<sup>21</sup> Goldstein, R.M., M.E. Brigham, L. Steuwe, and M.A. Menheer, *Mercury Data from Small Lakes in Voyageurs National Park, Northern Minnesota, 2000-02*. U.S. Geological Survey, Open File Report 03-480; *see also* Berndt, M. and T. Bavin, *Sulfate and Mercury Chemistry of the S. Louis River in Northeastern Minnesota: A Report to the Minerals Coordinating Committee*, Minnesota Department of Natural Resources, Division of Lands and Minerals (Dec. 15, 2009); *see also* SDEIS Table 4.2.2-15.

<sup>22</sup> Gilmour *et al.* 1992.

<sup>23</sup> Gilmour *et al.* 1992; Jeremiason JD, Engstrom DR, Swain EB, Nater EA, Johnson B, Almendinger JE, Monson BA & Kolka RK, *Sulfate Addition Increases Methylmercury Production in an Experimental Wetland*. *Environ, Sci. Tech.* 40: 3800-3806 (2006); *see also* Mitchell, C., B. Branfireun, and R. Kolka, *Assessing sulfate and carbon controls on net methylmercury production in peatlands: An in situ mesocosm approach*, *Applied Geochemistry* 23: 503-518 (2008).

<sup>24</sup> Jeremiason *et al.* 2006.

<sup>25</sup> MPCA: *MPCA Strategy to Address Indirect Effects of Elevated Sulfate on Methylmercury Production and Phosphorus Availability*, Minnesota Pollution Control Agency, (Oct. 19, 2006) [MPCA 2006b].

<sup>26</sup> MPCA 2006b.

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*more detailed studies are conducted, virtually all SO<sub>4</sub> releases within the St. Louis River basin can be considered high risk because wetlands, flood plains, and lakes are common in the region.*<sup>27</sup>

Sensitive environments for methylmercury have been identified adjacent to the Project, including the wetlands to the north of the existing LTVSMC tailings basin. Sensitive environments downstream of the Project area have also been identified such as the Embarrass River chain of lakes, Colby Lake and the St. Louis River.

## 2.3 Existing Conditions

### 2.3.1 Project Area

Background (baseline) concentrations of total mercury, methylmercury and sulfate for the Project area and water bodies specifically assessed for potential effects from the Project are provided in Table 2-1. As shown in Table 2-1, mining-related waters from the former LTVSMC tailings basin are lower in total mercury concentrations and higher in sulfate concentrations than background streams. In comparison, background surface waters such as the upper Embarrass River, Bear Creek and the upper Partridge River have higher total mercury concentrations and lower sulfate concentrations. These findings for mining and non-mining waters are consistent with other data from northern Minnesota.<sup>28</sup>

Existing NPDES-permitted discharges of mining-related water at the Plant Site contain total mercury and sulfate: SD033 (discharge from Area 5 Pit N), SD026 (south side of the LTVSMC tailings basin), and several locations on the north side of the LTVSMC tailings basin (Table 2-1). Monitored concentrations for these NPDES discharges indicate relatively low mercury concentrations compared to background streams and elevated sulfate concentrations (Table 2-1). Project operations will not affect the discharge (flow, concentrations) at SD033, but is expected to decrease seepage (flow) and sulfate concentrations at SD026 and to the north of the former LTVSMC tailings basin. Because the Mine Site is currently undeveloped, there are no existing point source discharges of mine-related water from that area.

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<sup>27</sup> Berndt and Bavin 2009.

<sup>28</sup> Barr Engineering Company, *Technical Memorandum, NorthMet Project: Assessing Potential Impacts from Sulfate in Seepage and Discharge Water* (Apr. 25, 2008), Appendix C [Barr 2008a]; see also Berndt and Bavin 2009.

**Table 2-1 Baseline Concentration for Total Mercury, Methylmercury and Sulfate in Precipitation and Selected Surface Waters Evaluated for Potential Effects from the Project**

Location	Mercury (total) (ng/L)	Mercury (methyl) (ng/L)	Percent MeHg (%) <sup>[1]</sup>	Sulfate (mg/L)	Reference
Precipitation	12-13 10 - 11	0.1 – 0.2	~1	0.5	PolyMet 2014a. NADP, MN 18, 2010-11 Halla et al., 2005 NADP, MN18, 2009-13 NADP, MN 18, 2010 – 2013, (precipitation-weighted average)
Plant Site					
<i>LTVSMC tailings seepage (toe of basin, Site PM10)</i>	1.4	0.2	14.3	105.2	Barr Eng. 2008, App. D, Table 2
<i>LTVSMC tailings seepage (SD001, SD002, SD004, SD005, and SD006)</i>	1.4			304	SDEIS Table 4.2.2.-4, SD004 & SD005. Barr Eng. 2011c [9] PolyMet 2015a. Large Table 5.
<i>Wetland Stream Unnamed Creek (PM11)</i>	1.5 1.9	0.2	14.1 <sup>[2]</sup>	152.0	Barr Eng. 2010. Table 1 (filtered) Barr Eng. 2010, Table 3 PolyMet 2015a, Section 4.4.4.2 (2004-2013) (unfiltered samples)
<i>Wetland Stream Trimble Creek (PM19)</i>	1.6 1.7	0.45	20.4 <sup>[2]</sup>	17.6	Barr Eng. 2010. Table 1. (filtered) Barr Eng. 2010, Table 3. PolyMet 2015a, Section 4.4.4.2 (2004-2013) (unfiltered samples)
<i>SD033</i>	0.9			953 1,060	PolyMet 2014a, Table 6-14 [10] Barr Eng. 2011a [10] PolyMet 2015a, Section 4.4.4.3 (2004-2013)
<i>SD026</i>	1.0			159	PolyMet 2015a. Table 6-6. Barr Eng. 2011b [11].
Embarrass River					
<i>PM12 (upstream of Plant Site)</i>	3.5 4.3	0.7	19.5 <sup>[2]</sup>	1.1 7.1	Barr Eng. 2010. Table 1 Barr Eng. 2010. Table 3 PolyMet 2015a, Section 4.4.4.1 (2004-2013)
<i>Wetland Stream (Bear Creek, PM20) [3]</i>	2.5	0.29	13.1 <sup>[2]</sup>	1.3	Barr Eng. 2010. Table 1 Barr Eng. 2010. Table 3
<i>PM13 (downstream of Plant Site)</i>	3.1 3.3	0.41	13.4 <sup>[2]</sup>	38.4 49.0	Barr Eng. 2010. Table 1 Barr Eng. 2010, Table 3 PolyMet 2015a, Section 4.4.4.1 (2004-2013)
<i>Sabin Lake (PM21)</i>	3.1	0.23	7.6	25.0 14.2,10.6	Barr Eng. 2010. Table 5 PolyMet 2015a, Section 4.4.4.4 (2010, 2011)

Location	Mercury (total) (ng/L)	Mercury (methyl) (ng/L)	Percent MeHg (%) <sup>[1]</sup>	Sulfate (mg/L)	Reference
Wynne Lake (PM22)	3.1	0.21	6.7	22.8 21.4,16.5	Barr Eng. 2010. Table 5 PolyMet 2015a, Section 4.4.4.4 (2010, 2011)
Esquagama Lake	3.1 <sup>[7]</sup>			14-27	SDEIS Table 4.2.2-3
Embarrass Lake	3.1 <sup>[7]</sup>			14-27 23.6	SDEIS Table 4.2.2-3 PolyMet 2015a, Section 4.4.4.4 (2010)
Heikkilla Lake	2.1 <sup>[8]</sup>				
Partridge River (PM16) <sup>[4]</sup>	3.5	0.31	8.9	14.9 5 – 21	Barr Eng. 2008, App. D, Table 2. SDEIS Table 4.2.2-3, P. 4-37.
Colby Lake	5.4 6.0	--	--	37 - 42	SDEIS Table 4.2.2-4, P. 4-41 SDEIS Table 4.2.2-3, P. 4-37. PolyMet 2014a, Section 4.4.4.3 (2008, 2013)
St. Louis River <sup>[5]</sup> (Headwaters, river mile 179)	7.8	0.35	4.5	3.3	Berndt and Bavin 2009
St. Louis River, Cloquet <sup>[6]</sup>	4.2	0.22	5.2	16.5 13.7 (5 – 32)	Berndt and Bavin 2009 Berndt and Bavin 2012

Note: a single value denotes an average concentration.

- 1] MeHg = methylmercury. Percent MeHg = methylmercury conc. as a percent of total mercury conc.
- 2] Streams: Percent methylmercury is from Table 1 in Barr Eng., 2010 and represents the average for 8 samples. Lakes: Percent methylmercury is from Table 5 in Barr Eng., 2010 and represents the average for 5 samples.
- 3] Bear Creek is a non-mining sub- watershed and enters the Embarrass R. between monitoring site PM13 and PM12.
- 4] Monitoring site PM16 on the upper Partridge is also referred to as monitoring site SW004 in other documents.
- 5] Mercury and methylmercury concentrations are from filtered samples (May, July, October 2008).
- 6] Mercury and methylmercury concentrations are from filtered samples (May, October 2008).
- 7] Surrogate total mercury concentration based on upstream measured concentrations in Sabin and Wynne lakes
- 8] Surrogate total mercury concentration based on the average concentration from small lakes in Voyageurs National Park (Goldstein et al. 2003).
- 9] Seepage from the LTVSMC tailings basin, north side, toward the Embarrass River via SD001, SD002, SD004, SD005 and SD006 (covered under Minnesota Pollution Control Agency (MPCA) NPDES Permit MN0054089).  
Average mercury concentration = 1.4 ng/L (range = <0.25 – 4.5 ng/L) (SDEIS Table 4.2.2-4, SD004 and SD005).  
Average sulfate concentration = 304 mg/L (range = 33 – 525 mg/L (Barr Eng. 2011c; wells GW001, GW006, GW012)
- 10] Outflow from the Area 5 Pit that forms the headwaters of Spring Mine Creek (SD033) (MPCA NPDES Permit MN0042536).  
Average mercury concentration = 0.9 ng/L (range = 0.7 – 1.1 ng/L) (PolyMet 2014a, Table 6-14, Pit 5N)  
Average sulfate concentration = 953 mg/L (range = 629 – 1140 mg/L) (Barr Eng. 2011a)
- 11] Seepage from the LTVSMC tailings basin, south side, to SD026 and then to Second Creek (MPCA NPDES Permit MN0042536).  
Average mercury concentration = 1.0 ng/L (range = <0.5 to <4 ng/L) (SDEIS Table 4.2.2-20)  
Average sulfate concentration = 159 mg/L (range = 150 – 170 mg/L (Barr Eng. 2011b)

Annual background deposition of mercury in northern Minnesota is estimated to be about 12.5 µg/m<sup>2</sup>.<sup>29</sup> Estimated annual background total mercury loadings to lakes within 10 kilometers of the Project are as follows:<sup>30</sup>

<b><u>Water Body</u></b>	<b><u>Mercury Loading</u></b>
Colby Lake	1,339 grams
Heikkilla Lake	24 grams
Sabin Lake	1,611 grams
Whitewater Lake	102 grams
Wynne Lake	1,640 grams

These background loading estimates form the basis for assessing the potential changes to fish mercury concentrations due to the Project's air emissions in Section 4.0.

### 2.3.2 Sources of Sulfate and Methylmercury to the St. Louis River

Sources of sulfate have existed in the St. Louis River watershed for at least 50 years, with the majority of sulfate in the St. Louis River is primarily from the iron mining district, which includes the Project area.<sup>31</sup> As further discussed by Berndt and Bavin:

*SO<sub>4</sub> added in the upstream portion of the St. Louis River is generally diluted downstream by waters from larger watersheds containing high percentages of wetlands. SO<sub>4</sub>, magnesium (Mg), calcium (Ca), sodium (Na), and chloride (Cl) concentrations all increase in the river, especially in the mining region, during periods of low-flow when groundwater inputs dominate chemistry of dissolved components.*<sup>32</sup>

However, mercury and methylmercury concentrations in the St. Louis River are predominantly contributed from non-mining watersheds such as the Whiteface River and the Cloquet River and have a high percentage of wetlands.<sup>33</sup> Methylmercury concentrations were found to be elevated during storm events, similar to the findings from other rivers in Minnesota, with flooded wetlands the most likely primary source.<sup>34</sup> As discussed by Berndt and Bavin<sup>35</sup> other investigations have concluded that benthic, in channel, production of MeHg was insignificant, compared to that delivered to the river during runoff from connected wetlands. Therefore, very little methylmercury is expected to be produced within the banks of the St. Louis River.

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<sup>29</sup> MPCA 2007.

<sup>30</sup> Barr Engineering, *NorthMet Project Supplemental Air Emissions Risk Analysis (AERA) – Plant Site* (Mar. 2013), version 3, attachment F [Barr 2013a].

<sup>31</sup> Berndt and Bavin 2009.

<sup>32</sup> *Id.*

<sup>33</sup> *Id.*; see also Berndt, M., Jeremiason, J., and Von Korff, B., *Hydrologic and Geochemical Controls on St. Louis River Chemistry with Implications for Regulating Sulfate to Control Methylmercury Concentrations*, Minnesota Department of Natural Resources Research Report (November 3, 2014).

<sup>34</sup> Berndt and Bavin 2009

<sup>35</sup> *Id.*

### 2.3.3 Mercury in Fish

Methylmercury is the predominant form of mercury in fish. Fish consumption advisories in Minnesota are based on the following fish mercury concentrations (parts per million, ppm).

<b><u>Fish Consumption</u></b>	<b><u>Fish Mercury Concentrations</u></b>
Unlimited consumption	Fish Hg < 0.05 ppm
1 meal per week	Fish Hg 0.05 to 0.2 ppm
1 meal per month	Fish Hg > 0.2 to 1.0 ppm
Do not eat	Fish Hg > 1.0 ppm

Minnesota lists surface waters as being impaired if the mercury fish concentrations exceed 0.2 ppm. Waters in the Lake Superior Basin, where the Project is located, are also listed as impaired if the mercury concentration in surface water exceeds the water quality standard of 1.3 ng/L.<sup>36</sup> Background fish mercury concentrations are available for lakes/streams in the Project Area from the State's Fish Contaminant Monitoring Program.<sup>37</sup> Fish mercury concentrations presented below represent either the average concentration or the 95% upper confidence level of the mean (95% UCL) for walleye.

<b><u>Water Body</u></b>	<b><u>Fish Mercury Concentrations</u></b>	<b><u>Bioaccumulation Factor</u></b>
Colby Lake	0.93 ppm (95% UCL; walleye);	BAF = 172,200
Embarrass Lake	0.93 ppm (average; walleye);	BAF = 300,000
Esquagama Lake	1.2 ppm (average; walleye);	BAF = 387,100
Heikilla Lake	0.65 ppm (95%UCL; walleye);	BAF = 309,500
Sabin Lake	1.02 ppm (95%UCL; walleye);	BAF = 329,000
Whitewater Lake	0.35 ppm (95%UCL; walleye);	BAF = 166,700
Wynne Lake	1.34 ppm (95%UCL; walleye);	BAF = 432,300

The bioaccumulation factor (BAF) for each lake is calculated from the following equation:

$$\text{BAF} = \text{Tissue Concentration (ppm)} / \text{Water Column Concentration (ppm)}.$$

Total mercury concentrations used in the BAF calculation are taken from Table 2-1 and converted from ng/L to mg/L (mg/L = ppm).

The above lakes are impaired for mercury in fish tissue.<sup>38</sup> Because these lakes are considered to represent a sensitive environment for mercury methylation, they were included in one or more assessments of potential effects from the Project operations.

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<sup>36</sup> MPCA 2007.

<sup>37</sup> MPCA 2008: *Minnesota's Fish Contaminant Monitoring Program, Fact Sheet* (July 2008) [MPCA 2008]; see also database from 2008 and updated as of 2010 for use in assessing potential NorthMet Project impacts.

<sup>38</sup> SDEIS Table 4.2.2-2.

## 3.0 Project Potential Releases of Mercury and Sulfur

Potential releases of mercury and sulfur from the Project are related to ore processing, hydrometallurgical extraction of the ore and water management/treatment. Water management plays an important role in the potential release of mercury and sulfur from the Project.

### 3.1 Project Water Management

During mining operations PolyMet will implement an integrated water recycle/reuse system for the Mine Site and the Plant Site, with process water collected by and distributed from the pond at the Plant Site Flotation Tailings Basin (FTB). The FTB will be constructed atop cells 1E and 2E of the existing LTVSMC tailings basin: the combined facility is referred to as the Tailings Basin. Seepage from the Tailings Basin will be collected by the FTB Containment System and the FTB South Seepage Management System (collectively referred to as the FTB seepage capture systems). Water collected by the FTB seepage capture systems will be returned to the FTB Pond or sent to the Waste Water Treatment Plant (WWTP) for treatment then discharged at permitted locations.

At the Mine Site, all process water will be collected and treated at the Waste Water Treatment Facility (WWTF) and then routed to the Plant Site. As described in the Adaptive Water Management Plan,<sup>39</sup> during mining operations the WWTF at the Mine Site will treat process water from the waste rock stockpiles, haul roads, OSP and mine pits. For the first approximately 10 years of mining operations, all WWTF effluent will be pumped to the FTB Pond for reuse in the beneficiation process. The purpose of treatment during this period will be to maintain the water quality in the FTB Pond at concentrations that do not have an adverse impact on beneficiation operations or future reclamation of the FTB. Beginning in Mine Year 11, some WWTF effluent will be sent to the East Pit to augment flooding as the pit is backfilled, with the remainder of the effluent continuing to be routed to the FTB. During active mining there will be no discharge of treated water to the Partridge River and contributions from groundwater flow paths will generally not have reached the Partridge River.<sup>40</sup> Overall, the Project during active mining operations is expected to reduce sulfate loading to the upper Partridge River due to a decrease in flow from the Mine Site.

At the Plant Site, during ore processing operations the primary source of process water will be the FTB Pond. Water in the FTB Pond will mostly contain return water from the flotation process, water treated at the Mine Site by the WWTF, and seepage water collected from the FTB and the LTVSMC tailings by the FTB seepage capture systems. Direct precipitation and stormwater runoff from the process areas at the Plant Site will also be directed to the FTB Pond for use as process water.<sup>41</sup> If necessary, additional makeup water will be provided by pumping from Colby Lake. Excess water that cannot be stored is expected to be

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<sup>39</sup> Poly Met Mining, *NorthMet Project Adaptive Water Management Plan*, Version 7, February 2015 [PolyMet Mining 2015b]

<sup>40</sup> Poly Met Mining, *NorthMet Project Water Modeling Data Package Volume 1 – Mine Site*, Version 12, March 2013 [PolyMet 2013a]; *see also* updated version 13 (December 2014) of this data package [PolyMet 2014a].

<sup>41</sup> Poly Met Mining, *NorthMet Project, Water Management Plan – Plant* (v4), February 2015 [PolyMet 2015c].

treated and discharged. Water will also be discharged from the WWTP to augment flow in Second Creek, Unnamed Creek and Trimble Creek. Overall, operations are expected reduce the flow of water and sulfate to the wetlands and streams to the north of the Tailings Basin and to Second Creek and sulfate loading will be reduced from current conditions.

After mine closure, the seepage from the Tailings Basin will continue to be collected and routed to the WWTP along with excess FTB pond water. Effluent from the WWTP will continue to be routed to Second Creek, Unnamed Creek and Trimble Creek.

In post-mining, following the completion of mining activities in approximately Mine Year 21, flooding will be allowed to commence in the West Pit. After approximately 35 years, by about Mine Year 55, the West Pit lake is estimated to approach overflow levels and the pit water will be pumped to the reverse osmosis (RO) WWTF. The treated water from the WWTF will be discharged to an unnamed creek that flows to the Partridge River during the long-term closure<sup>42</sup> time period for the Project.<sup>43</sup>

For both the WWTF and the WWTP, the treated water will be required to meet a total mercury concentration of 1.3 ng/L and a total sulfate concentration of 10 mg/L.

## 3.2 Mercury

### 3.2.1 Total Facility Mass Balance to Identify Potential Releases

A screening total facility mercury mass balance was constructed for the Project to identify the potential releases to the environment.<sup>44</sup> The original mass balance included two autoclaves associated with the hydrometallurgical process. The total facility mass balance for the Project followed the MPCA's requirements and was similar to mass balances conducted for other recent mining projects in Minnesota. Similar to other mining operations about 95% of the mercury in the process is expected to stay with the solids, reporting to the FTB or to the Hydrometallurgical Residue Facility (HRF). Also similar to other mining projects, air emissions are a small component of the total mass of mercury associated with ore processing.<sup>45</sup>

While there have been changes to the Project since the total facility mass balance was submitted to the Co-Lead Agencies in 2007, those changes do not affect the routing of mercury associated with ore processing. The majority of the mercury, about 95%, is expected to be routed to the FTB or the HRF where available information indicates it should remain sequestered and not be released to air, surface waters or groundwater. Because the main inputs of mercury to the process (ore) and the major loss/sequestering

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<sup>42</sup> "Long-term closure" is defined as the time period when the West Pit has flooded with water and the West Pit water level is maintained below the natural overflow elevation by discharging treated water from the WWTF to a small watercourse south of the West Pit that flows to the Partridge River. (Poly Met Mining: *NorthMet Project, Water Management Plan – Mine, Version 4* (Dec. 2014) [PolyMet 2014c]).

<sup>43</sup> Poly Met Mining: *NorthMet Project Water Modeling Data Package Volume 2 – Plant Site* Version 10, January 2015 [PolyMet 2015a].

<sup>44</sup> Barr Engineering: *Facility Mercury Mass Balance Analysis (RS66)* (Mar. 2007) [Barr 2007a].

<sup>45</sup> *Id.*

mechanism (i.e., solids, tailings and Hydrometallurgical Residue) have not changed appreciably, the screening total facility mass balance<sup>46</sup> is still appropriate as a means of identifying the potential releases of mercury to the environment from Project operations.

As with all mass balances, even for facilities that have been in operation for several years, there is uncertainty in the various data available to estimate the mass of mercury in specific components. Most mass balances typically do not have 100% closure (i.e., inputs do not equal outputs). Because the mass balance estimates about 107 pounds per year (pounds/year) input of mercury in ore, with 16 pounds/year routed to the FTB and 164 pounds/year being sent to the HRF, additional data collection during operations would likely include collecting samples of ore, tailings and the Hydrometallurgical Residue to refine the mercury mass balance for these components.

No significant amount of mercury is expected to be lost from the FTB and the HRF through seepage. Data for seepage water from tailings basins indicates that mercury associated with solids remains sequestered with the solids,<sup>47</sup> similar to mercury behavior in the natural environment.<sup>48</sup> No seepage is expected from HRF, which will be a double-lined facility with a leakage collection system.<sup>49</sup> Therefore, based on available data, any loss of mercury from seepage is expected to be small, if any.

### 3.2.2 Air Emissions

Mercury in the ore is the primary source of mercury at the Plant Site and air emissions of mercury are primarily associated with the hydrometallurgical plant (4.1 pounds/year). A small amount of mercury emissions are estimated to potentially be emitted from natural gas combustion associated with a package boiler and a natural gas fired process heater and space heaters (0.4 pounds/year). In addition, a small amount of particle-bound mercury is associated with mining, ore crushing, milling processes, flotation concentrate handling and fugitive dust emissions from the Tailings Basin (less than 0.1 pounds/year). A relatively small amount of mercury is estimated to be associated with diesel fuel combustion in mine vehicles.

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<sup>46</sup> *Id.*

<sup>47</sup> Poly Met Mining: *NorthMet Project Water Modeling Data Package Volume 2 – Plant Site* Version 9 [PolyMet 2013b]. *see also* updated version 10 (January 2015) of this data package [PolyMet 2015a].

<sup>48</sup> *See* Grigal, D, *Inputs and outputs of mercury from terrestrial watersheds: a review*, Environ. Rev. (10), 1-39 (2002), DOI: 10.1139/A01-01; *see also* Harris, R. C, John W. M. Rudd, Marc Amyot, Christopher L. Babiarz, Ken G. Beaty, Paul J. Blanchfield, R. A. Bodaly, Brian A. Branfireun, Cynthia C. Gilmour, Jennifer A. Graydon, Andrew Heyes, Holger Hintelmann, James P. Hurley, Carol A. Kelly, David P. Krabbenhoft, Steve E. Lindberg, Robert P. Mason, Michael J. Paterson, Cheryl L. Podemski, Art Robinson, Ken A. Sandilands, George R. Southworth, Vincent L. St. Louis, and Michael T. Tate, *Whole-ecosystem study shows rapid fish-mercury response to changes in mercury deposition*, Proc. National Academy of Sciences (PNAS), 42, Vol. 104: 16586-16591. doi 10.1073 PNAS.0704186104 (2007); *see also* Watras, C.J. and K.A. Morrison, *The response of two remote, temperate lakes to changes in atmospheric mercury deposition, sulfate, and the water cycle*, Can. J. Fish. Aquat. Sci. 65:100-116 (2008).

<sup>49</sup> Poly Met Mining: *NorthMet Project, Residue Management Plan*, Version 4 [PolyMet 2014b].

Overall, total potential emissions of mercury from the Project are estimated to be 4.6 pounds/year from the Plant Site, a maximum of 0.17 pounds/year from Tailings Basin construction vehicles (diesel fuel combustion emissions) and approximately 0.6 pounds/year from diesel fuel combustion at the Mine Site.<sup>50</sup> In comparison, Minnesota’s statewide mercury emissions in 2005 were estimated to be 3,011 pounds and in 2011 about 2,835 pounds.<sup>51</sup> The TMDL target emissions are set at 789 pounds/year by 2025.<sup>52</sup> The Project air emissions are about 0.16% of 2011 estimated statewide emissions and about 0.6% of the TMDL statewide target emissions. The MPCA has conducted a review of the Project Proposed Action mercury emissions and has determined that it will not impede the TMDL reduction goals.<sup>53</sup>

The speciation of mercury air emissions from the autoclave is uncertain, but expected to be primarily in elemental form. The two stage scrubber system proposed for the autoclave vents is expected to be effective at controlling particulate and oxidized mercury.<sup>54</sup> Therefore, mercury air emissions from the Plant Site are expected to be primarily elemental mercury. Because there is some uncertainty in the exact speciation of the emissions associated with autoclave operations, a second, more conservative speciation scenario was used for assessing potential effects that uses a higher percentage of oxidized mercury and is considered to provide a worst-case emissions scenario for the local impacts assessment.

<b><u>Mercury Species</u></b>	<b><u>Scenario 1 Conservative Speciation</u></b>	<b><u>Scenario 2 More Likely Speciation</u></b>
Elemental Hg	25%	80%
Oxidized Hg	50%	10%
Particle-bound Hg	25%	10%

### 3.2.3 Permitted Discharges to Surface Water

During ore processing, wastewater discharge from the WWTP will be limited to the amount needed to maintain flow levels in the streams located downstream of the FTB seepage capture systems. Because of the demonstrated ability of both taconite tailings and copper nickel tailings to rapidly absorb mercury,<sup>55</sup> seepage water from the FTB is expected to have a low concentration of mercury, less than 1.3 ng/L.<sup>56</sup> The FTB seepage water will be collected and routed to the WWTP. The WWTP will use greensand filtration followed by reverse osmosis (RO) or similar membrane technology, which is expected to remove some additional mercury, although removal efficiency at low concentrations is not established. Because of the

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<sup>50</sup> Barr Engineering 2012a: Mercury Emission Control Technology Review for NorthMet Project Processing Plant (Feb. 2012), version 2 [Barr 2012a].

<sup>51</sup> MPCA: *Mercury State of the Knowledge*, Minnesota Pollution Control Agency (Oct. 29, 2013[MPCA 2013].

<sup>52</sup> MPCA: *Statement of Needs and Reasonableness: Proposed Amendments to Rules Relating to Air Emissions Permits, Minnesota Rules Chapter 7005, 7007, 7011, and 7019* [MPCA 2014].

<sup>53</sup> SDEIS, Section 5.2.7, P. 5-395.

<sup>54</sup> Barr 2012a.

<sup>55</sup> Barr Engineering: *Technical Design Evaluation Report – Wastewater Treatment Technology. Laboratory Study of Mercury Adsorption to LTV Taconite and NorthMet Tailings*. March 2007. [Barr 2007e]. Appendix B.

<sup>56</sup> PolyMet 2013b; 2015a.

low concentrations of mercury in FTB and LTVSMC tailings seepage and greensand filtration followed by RO or similar membrane technology, the WWTP is expected to meet the numeric water quality standard of 1.3 ng/L.<sup>57</sup> Additional discussion is provided in Section 4.3.2 regarding the screening mass balance non-degradation analysis conducted for the Plant Site wastewater discharges.

At the Mine Site, because of the low concentrations of mercury in pit lakes and the membrane treatment process at the WWTF, the permitted discharge from the Mine Site is expected to meet the Lake Superior Basin water quality standard of 1.3 ng/L.<sup>58</sup> Section 4.3 provides a summary of the screening mass balance non-degradation analysis conducted for the Mine Site discharge.

## 3.3 Sulfur

Because of the potential for sulfate to affect mercury methylation, additional information on the potential for the Project to release sulfur and/or sulfate are provided here and will be used or referenced in Section 4.0 (Potential for Effects).

### 3.3.1 Air Emissions

#### 3.3.1.1 Stacks and Mobile Sources

Sulfur related emissions include sulfur dioxide (SO<sub>2</sub>), sulfuric acid mist (SAM), reduced sulfur compounds and sulfur in particulate (e.g., sulfur in the mineral matrix of the ore). Each pollutant is discussed below.

#### *Sulfur Dioxide*

Potential SO<sub>2</sub> emissions from stacks, after air streams are passed through control equipment, are estimated to be 7 tons per year (tpy) at the Plant Site and 1.93 tpy at the Mine Site.<sup>59</sup> Additional SO<sub>2</sub> emissions from mobile sources were estimated to be 0.12 tpy at the Plant Site and 0.42 tpy at the Mine Site. In total, potential SO<sub>2</sub> emissions are estimated to 7.12 tpy from the Plant Site and 2.4 tpy from the Mine Site.

The estimated Plant Site and Mine Site SO<sub>2</sub> emissions are well below the Prevention of Significant Deterioration (PSD) air permitting thresholds and Significant Emission Rate (SER; 40 tpy)). However, as described in SDEIS Section 5.2.7:

*"... the NorthMet Project Proposed Action has been designed so that it is considered a synthetic minor source for air permitting purposes. However, the evaluation of the NorthMet Project Proposed Action in this SDEIS has treated it as a major source due to its sensitive nature. ..."*<sup>60</sup>

Modeling results for SO<sub>2</sub> are from the impact assessments conducted for the SDEIS.<sup>61</sup> Because the Project SO<sub>2</sub> air emissions are below the PSD SER, by definition these emissions are considered insignificant with

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<sup>57</sup> *Id.*

<sup>58</sup> PolyMet 2013a; 2014a.

<sup>59</sup> SDEIS Table 5.2.7-4.

<sup>60</sup> SDEIS Section 5.2.7 (Air Quality, P. 5-395).

regard to potential air quality impacts and potential impacts on soils, vegetation and visibility. Therefore, no further consideration of this source of sulfur is required for environmental impact purposes. However, because of the potential for sulfate to affect mercury methylation and because Plant Site SO<sub>2</sub> air emissions were modeled to demonstrate compliance with air quality standards, the potential deposition of sulfur from modeled SO<sub>2</sub> air emissions is included in Section 4.0 for this evaluation of potential effects of the Project on mercury concentrations in the local environment.

### *Sulfuric Acid Mist (SAM)*

Potential emissions of SAM are estimated to be 5 tpy from the Plant Site. The Mine Site is not expected to have SAM emissions. The PSD SER for SAM emissions is 7 tpy. Because the Project SAM air emissions are below the PSD SER, by definition these emissions are considered insignificant with regard to potential air quality impacts and potential impacts on soils, vegetation and visibility. No modeling of SAM emissions was required for ambient air quality purposes. Potential SAM emissions were included in the Class I Areas assessment (modeled as sulfate), with potential sulfur deposition modeled to be below the Deposition Analysis Threshold (DAT) of 0.01 kg/ha/yr and no adverse impacts to air quality related values identified for any of Class I areas evaluated.<sup>62</sup> Therefore, no further consideration of this source of sulfur is required for environmental impact purposes.

A potential SAM air concentration was estimated for the 2007 Plant Site AERA<sup>63</sup> and included in the 2013 Plant Site AERA after adjustment for changes in the potential SAM emissions in the latest version of the emission inventory (11.5 tpy in 2007 and 5 tpy current estimate; 56% decrease in potential emissions)<sup>64</sup> (adjusted air concentration = 0.12 µg/m<sup>3</sup>). Because of the potential for sulfate to affect mercury methylation and because a potential SAM air concentration was estimated for the Plant Site AERA,<sup>65</sup> the potential deposition of sulfur from SAM air emissions is included in Section 4.0 for this evaluation of potential effects of the Project on mercury concentrations in the local environment.

### *Reduced Sulfur Compounds*

Reduced sulfur compounds are a complex family of substances and are defined by the presence of sulfur in a reduced state and are generally characterized by strong odors at relatively low concentrations. Hydrogen sulfide is one member of the reduced sulfur compounds. Potential Project emissions of total reduced sulfur (TRS) compounds, which include hydrogen sulfide (1.88 tpy) and carbon disulfide (5.1 tpy), are estimated to be 6.98 tpy.<sup>66</sup> The PSD SER for TRS compounds is 10 tpy. Because the Project TRS air emissions are below the PSD SER, by definition these emissions are considered insignificant with regard to potential air quality impacts and potential impacts on soils, vegetation and visibility. No modeling of TRS

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<sup>61</sup> Class I and Class II modeling results; summarized in SDEIS Section 5.2.7.1.4 starting at P. 5-406.

<sup>62</sup> Barr Engineering: *Class I Area Dispersion Modeling*, NorthMet Project (May 2012), Version 2 [Barr 2012d].

<sup>63</sup> Barr 2007b.

<sup>64</sup> Barr Engineering: *NorthMet Project Supplemental Air Emissions Risk Analysis (AERA) – Plant Site* (Mar. 2013), version 3 [Barr 2013a].

<sup>65</sup> Barr Engineering: *Air Emissions Risk Analysis (AERA) – Plant Site (RS38)* (Mar. 2007) [Barr 2007b]; *see also* Barr 2013a.

<sup>66</sup> Poly Met Mining: *NorthMet Project Air Data Package*, Version 4 (January 2015) [PolyMet 2015e]. Attachment J.

emissions was required for ambient air quality purposes. Therefore, no further consideration of this source of sulfur is required for environmental impact purposes.

Air emissions of TRS compounds represent an uncertain source of sulfur to the local environment. A qualitative discussion is provided in Section 4.0 as no air dispersion or deposition modeling was conducted for TRS compounds.

### *Sulfur in Particulate*

Sulfur in particulate is primarily associated with fine particles from ore processing operations. The concentration of sulfur in ore that has been used in Project air emission calculations<sup>67</sup> and air modeling<sup>68</sup> is estimated to be 8700 ppm. Potential air emissions of sulfur in particulate have not been calculated, as it is not a criteria pollutant or a hazardous air pollutant (HAP).

Potential sulfur deposition from sulfur in particulate can be estimated from the potential deposition of fine particles from the maximum modeled PM<sub>2.5</sub> air concentration for the annual averaging time period (5.8 µg/m<sup>3</sup> at the Plant Site property boundary)<sup>69</sup> and then partitioning the deposited particles by the potential sulfur concentration in the ore (8700 ppm). In this analysis, it is assumed that ore processing is responsible for all of the modeled PM<sub>2.5</sub> air concentration. The results of the screening calculations are provided in Section 4.0.

#### **3.3.1.2 Fugitive Dust**

Fugitive dust represents about 60% of the Project PM<sub>10</sub> air emissions (about 320 tpy) and about 17% of PM<sub>2.5</sub> air emissions (43 tpy).<sup>70</sup> Some of the fugitive dust emissions from the Mine Site and the FTB may contain sulfur. Sulfur associated with fugitive dust is part of the mineral matrix of the rock particles (sulfide). Therefore, weathering of the particle must occur before any of the sulfur would be released to soil, soil water or surface water. As identified in the Wetlands Data Package<sup>71</sup> and consistent with the Wetlands impacts assessment planning (IAP) Work Group request and approved work plan, potential fugitive dust emissions at the Mine Site and the Tailings Basin were evaluated for potential deposition, as well as speciating the dust deposition for sulfur and metals, to identify potential future monitoring sites. Potential additions of sulfur from fugitive dust emissions from the FTB and the Mine Site are discussed in Section 4.0 with regard to their potential effect on mercury methylation in wetland environments.

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<sup>67</sup> Poly Met Mining: *NorthMet Project Wetland Data Package*, Version 7 (Mar. 2013) [PolyMet 2013c]. *see also* updated version 9 (January 2015) of this data package [PolyMet 2015d].

<sup>68</sup> Barr Engineering: *Plant Site Class II Air Quality Air Dispersion Modeling Report*, Version 2 (Nov. 2012) [Barr 2012c]; *see also* Barr Engineering 2013b: *Cumulative Impacts Analysis: Local Mercury Deposition and Bioaccumulation in Fish, Addendum*, Revised Table 4 (Mar. 2013).

<sup>69</sup> Barr 2012c.

<sup>70</sup> Barr 2013b.

<sup>71</sup> PolyMet 2013c; 2015d.

### 3.3.2 Permitted Discharges to Surface Water

As previously discussed, process water will be treated at the Mine Site WWTF to maintain the quality of the water to be re-used in the processing of ore at the Plant Site. Also, during mining operations, FTB seepage will be collected by the FTB seepage capture systems and routed to the FTB Pond to the extent possible, and any excess water will be sent to the Plant Site WWTP.<sup>72</sup> During active mining and ore processing, direct discharges of water are expected to occur at the Plant Site.<sup>73</sup>

After mine closure, the FTB seepage will be continue to be collected and routed to the WWTP along with excess FTB pond water. The WWTP will use greensand filtration followed by RO or similar membrane technology, which is expected to remove sulfates to a concentration of 10 mg/L or lower.<sup>74</sup> Overall, the Project during active mining operations and in long-term closure is expected to reduce sulfate concentrations in NPDES permitted discharges from the Plant Site and reduce the loading of sulfate to wetlands to the north of the FTB. Overall, a 45% reduction in sulfate load (P50 modeling results) at monitoring site PM13 is estimated to be associated with the Project.<sup>75</sup>

During active mining, process water will be treated at the Mine Site WWTF to maintain a quality of water that can be routed to the FTB Pond for use in ore processing at the Plant Site. No direct discharge of water from the Mine Site is expected during active operations.

In post-mining, following the completion of mining activities in approximately Mine Year 21, flooding will be allowed to commence in the West Pit. Approximately 35 years after closure (Mine Year 55), the West Pit lake will approach overflow levels and lake water will be pumped to the reverse osmosis (RO) WWTF. The treated water from the WWTF will be discharged to an unnamed creek that flows to the Partridge River. The NPDES permitted discharge from the Mine Site in long-term closure is expected to meet the 10 mg/L surface water quality standard for wild rice based on pilot-testing of the RO process.<sup>76</sup>

In Mine Years 20 to 40, groundwater flow paths will not have reached the Partridge River.<sup>77</sup> After Mine Year 40, groundwater flow paths are estimated to reach the Partridge River. In addition, by approximately Mine Year 55, the West Pit is estimated to be full and water will be treated at the WWTF and then discharged to an existing waterway (the West Pit Outlet Creek) that connects to the upper Partridge River. The sulfate concentration in the treated West Pit water is estimated to be 9 mg/L. Modeling results indicate that sulfate loading in the Partridge River may increase by about 0.1% above background conditions.<sup>78</sup> However, this potential increase in sulfate loading to the upper Partridge River is very small

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<sup>72</sup> PolyMet 2015b.

<sup>73</sup> Barr 2007a; PolyMet 2014c; Poly Met Mining: *NorthMet Project, Water Management Plan – Plant*, Version 4 (Feb. 2015) [PolyMet 2015c].

<sup>74</sup> Barr Engineering: *Final Pilot-testing Report, Plant Site Wastewater Treatment Plant Pilot-testing Program* (June 2013) [Barr 2013d].

<sup>75</sup> PolyMet 2015a.

<sup>76</sup> Barr 2013d.

<sup>77</sup> PolyMet 2013a; 2014a.

<sup>78</sup> SDEIS, pg. 6-18.

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compared to existing conditions (about 652,000 kilograms per year calculated from average streamflow of  $4.1E+10$  liters per year and sulfate concentration of 15.9 mg/L) and is not expected to be statistically measurable given the small potential change compared to the variability in background conditions (e.g., variability in streamflow; variability in monitored sulfate concentrations, range from 5 to 21 mg/L, Table 2-1).

## 4.0 Assessments of Potential Project Effects on Mercury Methylation and Fish Concentrations

Two aspects of potential effects from the Project are described below: potential effects on fish mercury concentrations and potential effects on mercury methylation. As discussed in this section, a potential change in mercury methylation may not result in a statistically measurable change in fish mercury concentrations.

### 4.1 Assessments Using Mass-balance Models

#### 4.1.1 Local Deposition Assessment

To assess the potential effects of the Project's air emissions on fish mercury concentrations in local lakes, the MPCA's Mercury Risk Estimation Method (MMREM) was used. The MMREM has been the MPCA's assessment tool for projects with more than 3 pounds/year of mercury emissions since its development in 2006.<sup>79</sup>

The MPCA's method estimates the potential loading of mercury to a local lake from a project and the potential incremental change in fish mercury concentration based on the following:

- a project's air emissions and potential deposition of those emissions based on known or reasonably expected speciation
- lake surface area and watershed area
- total mercury loading to the surface water and to the terrestrial watershed; from the project and from background
- estimated contribution of mercury from the watershed to the lake based on research data
- estimated background concentration of mercury in fish using available monitoring data (Minnesota Fish Contaminant Database)
- estimated incremental change in fish mercury concentration based on the assumption of proportionality between mercury loading and fish mercury concentration (a change in mercury loading will result in a proportional change in fish mercury concentration)

As noted by the MPCA:

*The purpose of this risk estimation method for the local impacts of a particular emission source is to provide a practical way to implement the principle of proportionality between mercury deposition and fish contamination for surface water that is not subject to a uniform change in atmospheric mercury. ... MMREM is not a mechanistic model of mercury methylation and bioaccumulation, but*

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<sup>79</sup> MPCA 2006a.

*rather combines empirical fish contamination data with the premise that mercury concentrations in fish will achieve a steady state in relation to atmospheric mercury deposition (USEPA 2001). MMREM can be used to estimate the noncancer oral hazard quotients associated with fish tissue consumption based on increases in mercury deposition. MMREM can provide an answer to the question, "If fish in this lake already have a given mercury concentration, how much would that concentration increase if more mercury were added?"<sup>80</sup>*

As formulated by the MPCA, the MMREM is the state of Minnesota's preferred methodology to assess the potential effects of a project's air emissions on fish mercury concentrations in a nearby lake. The assessment of potential local deposition and changes in fish mercury conducted for the Project are consistent with the assessments conducted for other recent mining projects requiring environmental review.

#### 4.1.2 Non-Degradation Assessments for Wastewater Discharges

To assess the Project's ability to comply with the surface water quality standard of 1.3 ng/L, the model selection was predicated on mass balance methodology. As described by UNESCO:

*The basic principle of water quality models is that of mass balance. A water system can be divided into different segments or volume elements, also called 'computational cells'. For each segment or cell, there must be a mass balance for each water quality constituent over time. Most water quality simulation models simulate quality over a consecutive series of discrete time periods,  $\Delta t$ . Time is divided into discrete intervals  $t$  and the flows are assumed constant within each of those time period intervals. For each segment and each time period, the mass balance of a substance in a segment can be defined. Components of the mass balance for a segment include: first, changes by transport ( $Tr$ ) into and out of the segment; second, changes by physical or chemical processes ( $P$ ) occurring within the segment; and third, changes by sources/discharges to or from the segment ( $S$ ).<sup>81</sup>*

The choices of mass balance models ranged from simpler (spreadsheet -based but not "simple") to complex, with the GoldSim model being considered a complex mass balance model. Other detailed models that could have been used for assessing potential effects from mercury air emissions include the Dynamic Mercury Cycling Model (D-MDM),<sup>82</sup> TRIM.fate model<sup>83</sup> and WARMF.<sup>84</sup> An important consideration in the selection of a water quality model is the complexity of the chemical being assessed and the available data. Another important consideration is that a complex situation may not require a complex water quality model.<sup>85</sup> In particular, models that require large amounts of monitoring data

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<sup>80</sup> MPCA 2006a.

<sup>81</sup> UNESCO: *Water Resources Systems Planning and Management*, Chapter 12. ISBN 92-3-103998-9, available at [http://ecommons.library.cornell.edu/bitstream/1813/2804/9/12\\_chapter12.pdf](http://ecommons.library.cornell.edu/bitstream/1813/2804/9/12_chapter12.pdf) [UNESCO 2005].

<sup>82</sup> EPRI (Electric Power Research Institute), *Dynamic Mercury Cycling Model for Windows XP/Vista – A Model for Mercury Cycling in Lakes*. D-MCM Version 3.0 (Dec. 2009) [EPRI 2009].

<sup>83</sup> USEPA: *Total Risk Integrated Methodology (TRIM)*, TRIM.fate User's Guide. Office of Air Quality Planning and Standards. Modules 1 – 16 [USEPA 2005].

<sup>84</sup> EPRI 2006, Watershed Analysis Risk Management Framework (WARMF).

<sup>85</sup> UNESCO 2005.

should not be used in situations where such data are not available as this likely creates a need to use surrogate data or to make numerous assumptions.<sup>86</sup>

The screening spreadsheet-based mass balance models that were employed in this case have been developed to represent the movement of various chemicals through the environment, including mercury. The screening models track mercury through various parts of the ecosystem based on Minnesota data and/or empirical relationships developed from Minnesota data. The MPCA's spreadsheet-based model allows reviewers to focus on key inputs and their impact on model behavior and results. Furthermore, the use of a separate spreadsheet model for mercury enabled the specification of assumptions that were specifically conservative for mercury but that were not necessarily conservative for other contaminants. For example, the spreadsheet-based mass balance model for the West Pit lake assumed a 30-foot deep mixing zone, which was conservative for mercury, because it allowed for less dilution of atmospherically-deposited mercury. On the other hand, the GoldSim model assumed full mixing of the mine pit, which was conservative for non-mercury solutes because it allowed high concentrations of metals in the deep waters to be cycled to the surface, which typically does not occur in deep pit lakes due to density stratification that prevents the mixing of surface (0-30 feet) water with deeper waters (60 – 300 feet). Therefore, developing a spreadsheet-based model optimized for mercury was both more efficient and more conservative than reprogramming and recalibrating the GoldSim model to account for mercury-specific features.

When considering the need to demonstrate compliance with the 1.3 ng/L water quality standard and demonstrating non-degradation in the receiving waters (Embarrass River, upper Partridge River) and in the St. Louis River, PolyMet and the Co-Lead Agencies determined that modifying GoldSim to accommodate mercury was a low priority and that a spreadsheet-based mass balance model would provide defensible results for use in the SDEIS review and water permitting processes. Therefore, the spreadsheet-based mass balance modeling was undertaken to demonstrate compliance of the 1.3 ng/L surface water standard in receiving water at the Plant Site and the Mine Site.

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<sup>86</sup> With regard to GoldSim in particular, the model would have required adjustments and specific programming for assessing mercury. Some adjustments for input data to GoldSim would have been required and they would have likely been similar to those documented in the modeling of the St. Louis River watershed. EPRI 2006. As identified for the WARMF modeling of the St. Louis River watershed, a large number of input values were estimated from available data and extrapolated or surrogate data were used where data were missing. EPRI 2006. For example, mercury is unique in that significant interaction and transport occurs between the watershed and atmosphere via the wet and dry deposition of mercury and the volatilization (i.e., evasion) of mercury from surface waters and the terrestrial watershed into the atmosphere. In addition, mercury has a noted biological component in both the terrestrial watershed, wetlands, sediments and surface water (bioaccumulation). Other pollutants modeled with GoldSim do not have these special modeling requirements. Any modifications to GoldSim would then have required additional testing to demonstrate the model was providing representative results.

Also, as noted by UNESCO:

*A simple but useful modelling approach that may be used in the absence of monitoring data is 'dilution calculations'. In this approach the rate of pollutant loading from point sources in a water body is divided by the streamflow to give a set of estimated pollutant concentrations that may be compared to the standard. Simple dilution calculations assume conservative movement of pollutants. Thus, the use of dilution calculations will tend to be conservative and predict higher than actual concentrations for decaying pollutants.<sup>87</sup>*

Therefore, the mass balance approach used for the Project to assess potential changes in loading and surface water concentrations in the St. Louis River can be considered a conservative analysis because it does not account for the loss of mercury from the system due to volatilization or burial to the sediment, nor does it account for the decay (dilution) of mercury as it moves downstream from the Project to the assessment points at Forbes and at Cloquet.<sup>88</sup>

Section 4.3 provides a summary of the results from the mass balance modeling for the Plant Site (Embarrass River and Second Creek), the Mine Site (upper Partridge River) and the St. Louis River.

## 4.2 Mercury Air Emissions and Potential for Local Deposition

### 4.2.1 Potential Changes in Fish Mercury Concentrations

Potential mercury releases to air from the Plant Site were quantitatively assessed for potential local and cumulative effects within about 12 kilometers of the Plant Site in accordance with the approved work plan. Again, the methodology used to evaluate potential effects from Plant Site mercury air emissions was the MPCA MMREM. The analysis focused on the Autoclave Scrubber Stack, because this is the main source of mercury emissions for the Project.

The MMREM uses the concept of proportionality to estimate potential changes in fish mercury concentrations in nearby lakes due to a project's air emissions. The MMREM calculation spreadsheet calculates an estimated potential increase in fish tissue concentration based on existing fish tissue concentration data, estimated background deposition to a lake's water surface and watershed and the model-estimated ambient air concentrations related to a project's air emissions.

Mine Site air emissions are estimated to be approximately 0.7 pounds/year primarily related to the combustion of diesel fuel, but include some contribution from fugitive dust. This small amount of particle-bound mercury is not expected to have any statistically measureable effect on local deposition and is below the MPCA's level of concern.

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<sup>87</sup> UNESCO 2005.

<sup>88</sup> Barr Engineering: *NorthMet Project: Estimate of Mercury Loading to the Lower St. Louis River*, Technical Memorandum, Version 2 (Feb. 12, 2013) [Barr 2013c]. *see also* updated version 3 (January 2015) of this Technical Memorandum [Barr 2015] .

#### 4.2.1.1 Potential for Project-Only Effects

Potential changes in fish mercury concentrations and the potential human health risks from fish consumption were evaluated for 5 lakes within 12 kilometers of the Plant Site: Heikkillla, Colby, Whitewater, Wynne and Sabin.<sup>89</sup> Two mercury air emission scenarios were evaluated. Scenario 1 is a conservative overestimation of oxidized mercury and Scenario 2 is considered to be a conservative but more likely mercury speciation for the air emissions associated with the Project given the two-staged scrubbing system proposed for the autoclave:

- Scenario 1: 25% elemental mercury; 50% oxidized mercury; 25% particle bound mercury
- Scenario 2: 80% elemental mercury; 10% oxidized mercury; 10% particle bound mercury

Potential incremental increases in fish mercury concentrations were estimated to be between 0.002 ppm (Whitewater Lake) and 0.016 ppm (Wynne Lake) (0.6-1.6% increase) for emissions Scenario 1 and between 0.001 ppm (Whitewater Lake) and 0.004 ppm (Wynne Lake) (0.2-0.4% increase) for emission Scenario 2 (Table 4-1). The estimated incremental change in fish mercury concentration is small compared to background fish mercury concentrations in these lakes that range from 0.35 (Whitewater Lake) to 1.34 ppm (Wynne Lake) (95% upper confidence limit (UCL)). In particular, background fish tissue concentrations in Sabin and Wynne Lakes range from 0.44-1.62 and 0.35-2.06 ppm, respectively (Table 4-1). The estimated small potential incremental increases in fish mercury concentrations due to the Project are not likely statistically measurable given the variation in background fish mercury concentration in these lakes and current laboratory analytical methods. The potential small changes in fish mercury concentrations are not expected to change the background bioaccumulation factors for these lakes.

Hazard quotients (HQs) that provide an estimate of potential incremental risk for a subsistence fisher (199 grams per day (grams/day), 160 pounds/year), a subsistence tribal fisher (224 grams/day, 180 pounds/year) and a recreational fisher (30 grams/day, 24 pounds/year) are estimated by the MMREM based on background mercury fish tissue concentrations and the potential increase in fish mercury concentration associated with the Project's air emissions.<sup>90</sup> Potential incremental HQs were estimate to be between 0.01 (recreational fisher at Whitewater Lake) and 0.55 (tribal subsistence fisher at Wynne Lake) for air emissions scenario 1 (a conservative estimate of potential speciation) and between <0.01 (recreational fisher at Whitewater Lake) and 0.14 (tribal subsistence fisher at Wynne Lake) for air emissions scenario 2 (reasonably expected speciation) (Table 4-2). All incremental HQs are less than the guideline value of 1 which is used by both the Minnesota Department of Health (MDH) and MPCA as one piece of information to consider in the risk management decision for a project.

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<sup>89</sup> Barr 2013a.

<sup>90</sup> *Id.*

**Table 4-1 Estimated Potential Change in Fish Mercury Concentrations in Nearby Lakes Using the MPCA's Mercury Risk Estimation Method (MMREM)**

Lake	Existing Ambient Fish Hg Concentration (mg/kg) <sup>[1]</sup>	Existing BAF <sup>[2]</sup>	Mercury Air Emissions Speciation Scenario <sup>[3]</sup>	Potential Change in Fish Hg Concentration (mg/kg)	Potential % Increase In Conc.
Colby Lake	95% UCL = 0.93 Range: 0.49-1.23 St. Dev. = 0.22	172,200	Scenario 1	0.010	1.1%
			Scenario 2	0.003	0.3%
			Average	0.006	0.6%
Heikkillä Lake	95% UCL = 0.65 Range: 0.12-2.06 St. Dev. = 0.34	309,500	Scenario 1	0.010	1.6%
			Scenario 2	0.003	0.4%
			Average	0.006	0.9%
Sabin Lake	95% UCL = 1.02 Range: 0.44-1.62 St. Dev. = 0.39	329,000	Scenario 1	0.012	1.2%
			Scenario 2	0.003	0.3%
			Average	0.007	0.7%
Whitewater Lake	95% UCL = 0.35 Range: 0.12-0.90 St. Dev. = 0.13	166,700	Scenario 1	0.002	0.6%
			Scenario 2	0.0006	0.2%
			Average	0.001	0.3%
Wynne Lake	95% UCL = 1.34 Range: 0.35-2.06 St. Dev. = 0.57	432,300	Scenario 1	0.016	1.2%
			Scenario 2	0.004	0.3%
			Average	0.01	0.7%

(From Barr Eng. 2013a, Section 10)

- [1] Background fish mercury concentration data obtained from the Minnesota Fish Mercury database. The 95% upper confidence limit of the background fish mercury concentration is used per the MPCA's (2006a) guidance for their Mercury Risk Estimation Method (MMREM).  
Background concentration for Heikkillä Lake is the 95% UCL for data from Colby, Whitewater, Wynne, Sabin and Bear Island Lakes.
- [2] Bioaccumulation Factor, BAF = Tissue Concentration (ppm) / Water Column Concentration (ppm).  
Water column total mercury concentrations (ng/L) obtained from Table 2-1 of this report (ng/L converted to mg/L (mg/L = ppm). BAF rounded to nearest hundred.  
The potential percent change in BAF reflects the potential percent change in fish Hg concentration, and is not reported here.
- [3] NorthMet Plant Site Mercury Air Emission Speciation (%)
- |            | Elemental | Oxidized | Particle-bound |
|------------|-----------|----------|----------------|
| Scenario 1 | 25        | 50       | 25             |
| Scenario 2 | 80        | 10       | 10             |

**Table 4-2 Estimated Potential Incremental Hazard Quotients (HQ) for a Recreational, Subsistence Tribal Fisher and Subsistence Fisher using the MPCA’s Mercury Risk Estimation Method (MMREM)**

Lake	NorthMet Air Emissions Scenario <sup>[2]</sup>	Recreational Angler <sup>[1]</sup> (30 grams/day)		Subsistence or Tribal Angler <sup>[1]</sup> (224 grams/day)		Subsistence Fisher <sup>[1]</sup> (199 grams/day)	
		Existing HQ	Modeled Potential Increase in HQ <sup>[3]</sup>	Existing HQ	Modeled Potential Increase in HQ <sup>[3]</sup>	Existing HQ	Modeled Potential Increase in HQ <sup>[3]</sup>
Heikkillia	#1	3.0	0.05	22.3	0.4	19.8	0.3
	#2		0.01		0.1		0.08
Colby	#1	4.3	0.05	32.0	0.4	28.4	0.3
	#2		0.01		0.1		0.08
Whitewater	#1	1.6	0.01	11.9	0.1	10.6	0.07
	#2		0.003		0.02		0.02
Wynne	#1	6.2	0.07	46.2	0.6	41.0	0.5
	#2		0.02		0.1		0.1
Sabin	#1	4.7	0.06	35.1	0.4	31.2	0.4
	#2		0.01		0.1		0.09

(From Barr Eng. 2013a, Section 10)

- [1] Exposure Scenarios (fish consumption):  
 Recreational Fisher: general population; 1 meal per week  
 Subsistence Fisher consumption rate is 95th percentile of the general population (USEPA 1997b)  
 Subsistence Tribal Fisher consumption rate assumes the Treaty protected catch rate of 180 pounds/year per member.
- [2] Emissions Scenario 1: 25% elemental Hg, 50% oxidized Hg, 25% particle-bound Hg  
 Emissions Scenario 2: 80% elemental Hg, 10% oxidized Hg, 10% particle-bound Hg.
- [3] Modeled incremental increase from the Plant Site using AERMOD dispersion modeling and the MPCA’s MMREM spreadsheet model.

The HQ calculation in the MMREM spreadsheet model relies in part on the estimated change in fish mercury concentration to estimate the potential incremental change in the HQ for the three fish consumption scenarios. It is noted that Table 4-1 identifies that the potential change in fish mercury concentrations for each lake is small and is not likely to be statistically measurable. In addition, the estimated potential change in fish mercury concentration for each lake will have no effect on the existing fish consumption advisories (i.e., no expected change to current advisories). Because there is no reasonably foreseeable change in fish mercury concentrations or fish advisories, the estimated HQs for the three fish consumption scenarios in Table 4-2 are considered a conservative estimate of the potential incremental change.

Overall, the Project's mercury air emissions will have no reasonably foreseeable effect on fish mercury concentrations, existing fish consumption advisories and the existing background risks to people consuming fish from nearby lakes.<sup>91</sup>

#### 4.2.1.2 Potential for Cumulative Effects with Nearby Projects

Previous assessments for the DEIS<sup>92</sup> took a semi-quantitative approach to the evaluation of potential cumulative mercury impacts in northeastern Minnesota from potential atmospheric deposition (Table 4-3). These assessments examined potential impacts on a larger scale (northeast Minnesota; 6-county project area) that included nine proposed Iron Range projects (i.e., reasonably foreseeable and in the environmental review or permitting process), including the Project. Conservative screening-level calculations, including a netting analysis of project increases and known emission reduction projects, were conducted to judge the significance of the proposed cumulative project mercury emissions with regard to potential changes in bioaccumulation of mercury in fish. These previous analyses identified a net decrease in mercury air emissions and it was concluded that the small amount of mercury potentially contributed by the proposed projects to Minnesota lakes was not expected to result in a measurable increase in fish mercury concentrations.

Since its development, the MPCA has required project proposers to use the MMREM spreadsheet model to evaluate potential cumulative impacts from multiple projects. Because other cumulative analyses have identified that local impacts from mercury deposition are small and likely not measureable in terms of fish mercury concentration within 10 kilometers of a single project (e.g., Keetac Expansion Project), therefore it is expected that impacts at greater distances would be even lower. Thus, the maximum extent of the quantitative cumulative impact assessments using the MMREM is about 25 kilometers from the specific project of interest. Consistent with evaluations conducted for other mining projects, the quantitative evaluation of cumulative impacts from mercury air emissions was limited to local effects and sources within 25 kilometers of the Project.<sup>93</sup> Only the Mesabi Nugget Large Scale Demonstration Plant (LSDP) is within 25 kilometers of the Project. One emission scenario was evaluated for the Mesabi Nugget LSDP which is estimated to emit primarily elemental mercury (99.3% elemental mercury) while two emission scenarios for the Project were evaluated (Table 4-1). The 5 lakes included in the "Project only" evaluation (Section 4.2.1) were also assessed for potential cumulative effects.

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<sup>91</sup> Barr Engineering: *Cumulative Impacts Analysis: Local Mercury Deposition and Bioaccumulation in Fish* July 2012 [Barr 2012b]; Barr 2013a; Barr 2013b.

<sup>92</sup> Barr Engineering: *Cumulative Impacts Analysis Minnesota Iron Range Industrial Development Projects: Mercury Deposition and Evaluation of Bioaccumulation in Fish in Northeast Minnesota* (Nov. 2006) [Barr 2006]; see also Barr Engineering: *Addendum 01: Supplemental Information to the November 2006 Air Quality Cumulative Impact Assessment Report on Mercury Deposition and Evaluation of Bioaccumulation in Fish in Northeast Minnesota* (Aug. 2007) [Barr 2007d].

<sup>93</sup> Barr 2012b.

**Table 4-3 Summary Results for the Cumulative Mercury Deposition Impact Assessments Conducted for the Project**

<b>Project Information</b>	<b>2012/2013 Assessment <sup>[1]</sup></b>	<b>2006 Assessment and 2007 Addendum <sup>[1]</sup></b>
Other reasonable foreseeable projects included <sup>[1]</sup>	PolyMet NorthMet Project Mesabi Nugget Large Scale Demonstration Plant (LSDP)	NorthMet Project Excelsior Energy Mesabi Nugget Large Scale Demonstration Plant (LSDP) Minnesota Steel Industries (now Essar Steel) Northshore Mining Co. Furnace 5 Reactivation United Taconite Emissions and Energy Reduction US Steel Keewatin Taconite Fuel Diversification UPM/Blandin Paper Mill Expansion Laurentian Wood Fired Energy Project
Estimated emissions evaluated	79 pounds/year	221 pounds/year
NorthMet Project emissions <sup>[2]</sup>	4.1 pounds/year	8 pounds/year
Type of analysis	Quantitative: MMREM	Semi-quantitative: emissions analysis
Background deposition rate <sup>[3]</sup>	12.5 µg/m <sup>2</sup> /yr	12.5 µg/m <sup>2</sup> /yr
Zone of impact assessed	Local impacts within 25 km: Heikkill Lake Colby Lake Sabin Lake Wynne Lake Whitewater Lake	Regional impacts (4 county area): Itasca county St Louis county Lake county Cook county (includes BWCAW and VNP)
Estimated potential maximum increase to background mercury deposition rate <sup>[4]</sup>	Scenario 1: 0.23 µg/m <sup>2</sup> /yr Scenario 2: 0.06 µg/m <sup>2</sup> /yr	Scenario 1: 0.2 µg/m <sup>2</sup> /yr Scenario 2: 0.02 µg/m <sup>2</sup> /yr
		0.08 µg/m <sup>2</sup> /yr (based on MPCA methodology used for statewide mercury TMDL)
Estimated potential incremental cumulative increase in mercury fish concentrations <sup>[4]</sup>	Scenario 1: 0.003-0.018 ppm (0.8-1.8% change) Scenario 2: 0.001-0.005 ppm (0.3-0.5% change)	

MMREM = MPCA's Mercury Risk Estimation Method (MPCA 2006a)

- [1] The 2006 cumulative assessment included all proposed Iron Range projects engaged in the environmental review and/or air permitting process. The 2012 assessment only included two projects, NorthMet and the Mesabi Nugget LSDP. The Mesabi Nugget LSDP was the only project within 20 to 25 kilometers of the Project. Information and data for the 2012/2013 assessment from Barr Eng. 2012b and Barr Eng. 2013b. Information and data for the 2006 assessment from Barr Eng. 2006 and Barr Eng. 2007d.
- [2] Only the Plant Site Autoclave emissions modeled per the approved work plan (IAP process)  
Emissions Scenario 1, overestimate of oxidized species: 25% elemental, 50% oxidized, 25% particle-bound  
Emissions Scenario 2, more likely speciation: 80% elemental, 10% oxidized, 10% particle-bound
- [3] Background deposition= 12.5 µg/m<sup>2</sup>/yr (MPCA 2007).
- [4] Modeling results for the Project as reported in Barr Eng. 2013b, Revised Table 4.

The cumulative MMREM analysis indicated that for the worst case Project emissions scenario (50% oxidized mercury), fish mercury concentrations in nearby lakes could potentially increase by about 0.003 to 0.018 ppm (about 0.5-1.8%) above background concentrations (Table 4-3)<sup>94</sup>. For the more likely Project emissions scenario (10% oxidized mercury), potential incremental fish mercury concentrations are estimated to be about 0.001 to 0.005 ppm (about 0.3-0.5%) (Table 4-3).<sup>95</sup>

The small potential increase in fish mercury concentrations from the two projects is likely not measurable given the variability in background concentrations for the 5 lakes (Table 4-1). Overall, the potential cumulative changes in fish mercury concentrations is expected to have no effect on existing fish consumption advisories and are not reasonably foreseen to have an effect on potential consumers of locally caught fish.

## 4.2.2 Conservatism in the Local Deposition Assessment Methodology

The MMREM tool is a screening method to estimate the potential incremental increase in fish tissue mercury concentrations from a nearby single source. It assumes the principle of proportionality applies to the relationship between total mercury loading and empirical fish tissue concentration data such that an increase in loading to a lake (including the direct drainage watershed) results in a proportional increase in fish mercury concentration.<sup>96</sup> The MMREM allows a project proposer to estimate potential changes in fish mercury concentrations from local deposition with a minimum of site-specific data,<sup>97</sup> however, it should not be considered predictive of any actual outcome.

Consistent with other analyses conducted for the Project, the inputs to the MMREM spreadsheet model were chosen to overestimate rather than underestimate potential impacts as is appropriate for a model used in a screening analysis. In addition to the conservatism in potential air emissions Scenario 1 (50% oxidized mercury), three additional examples of conservatism in the MMREM analysis are discussed below.

### 4.2.2.1 Background Fish Mercury Concentrations

The background fish tissue concentration is calculated as the 95% UCL of the arithmetic mean based on available predator (northern pike and/or walleye) fish tissue data. Bass and panfish have lower concentrations of mercury than do northern pike and walleye because of their diet.<sup>98</sup> While many people have an interest in catching and eating walleye and northern pike, many sport fishers probably eat more bass and panfish than they do walleye and northern pike.<sup>99</sup> Therefore, a likely more representative fish mercury concentration for a lake, and more representative background and incremental risks, would be calculated if it included bass and panfish. However, to provide a conservative estimate of background fish

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<sup>94</sup> Barr 2013b.

<sup>95</sup> *Id.*

<sup>96</sup> MPCA 2006a.

<sup>97</sup> MPCA 2006a.

<sup>98</sup> MPCA (Minnesota Pollution Control Agency), 2010. Bruce Monson, personal communication for the Essar Steel Cumulative Mercury Impacts Assessment (Apr. 2010) [MPCA 2010].

<sup>99</sup> MDNR 2014, available at <http://www.dnr.state.mn.us/faq/mnfacts/fishing.html>.

mercury concentrations, only the data from predator fish species are used to calculate the background fish mercury concentration per the MMREM guidance.

#### 4.2.2.2 Assumption of Proportionality

The MMREM model assumes that the mercury concentration in the fish in a specific lake is directly proportional to the amount of mercury deposition and loading to the lake. This is only true, however, if the other chemical, physical, and biological factors that can affect the formation of methylmercury remain unchanged. Research indicates that the increase in fish mercury concentration in their study lake was not proportional to the increased mercury loading.<sup>100</sup> Based on the work of Harris and others, the assumption of proportionality is interpreted to provide for a conservative assessment and likely overestimates the potential incremental increase in fish mercury concentrations from the potential local deposition of a specific project's air emissions.<sup>101</sup>

The current MPCA-estimated mercury deposition rate is 12.5  $\mu\text{g}/\text{m}^2/\text{yr}$  for northeast Minnesota.<sup>102</sup> This means that about 250 pounds of mercury currently deposits onto the St. Louis River Watershed (~3600 square miles) every year due to background deposition. Even assuming that the maximum modeled deposition rate from the Project's potential air emissions (0.2  $\mu\text{g}/\text{m}^2/\text{year}$  at Heikilla Lake for emissions scenario 1) occurred over the entire potentially affected Project area of 150 square miles, the potential total annual deposition in the watershed from the Project is estimated to be about 0.17 pounds/year.<sup>103</sup> This is less than 0.1% of the estimated 250 pounds/year of mercury already being deposited to the St. Louis River watershed due to background deposition. Because the change in mercury concentration in fish is thought to be ultimately proportional to the percent increase in mercury load,<sup>104</sup> this potential 0.1% increase in annual mercury deposition is not likely to result in a measureable change in the mercury concentration in the fish in water bodies of the St. Louis River watershed or in the St. Louis River itself.

#### 4.2.2.3 Deposition of New Mercury and Potential for Uptake by Fish

The current version of MMREM assumes that 26% of the total mercury deposited to a watershed is contributed to the lake and is available to be methylated and then taken up by fish. Harris identifies that only new mercury deposited directly to the lake's surface has the potential to be methylated and taken up by fish while new mercury deposited on the terrestrial watershed is retained in the watershed.<sup>105</sup> Because the MMREM spreadsheet model estimates that new mercury from a project that is deposited on the terrestrial watershed is also contributed to the lake water column, the local deposition assessment provides a conservative overestimate of the potential change in fish mercury.

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<sup>100</sup> Harris et al. (2007).

<sup>101</sup> *Id.*

<sup>102</sup> MPCA 2007.

<sup>103</sup> Barr 2012b.

<sup>104</sup> MPCA 2006a.

<sup>105</sup> Harris et al. (2007).

## 4.2.3 Uncertainty Analysis

### 4.2.3.1 Fish Consumption Rates

Consistent with other recent mining projects (since about 2006), three fish consumption scenarios were included in the local mercury deposition assessment for the Project.

- Recreational fisher consuming 30 grams/day (~0.5 pounds/week; 1 meal/week)
- Subsistence fisher consuming 199 grams/day (~3 pounds/week; 6 meals/week)
- Tribal subsistence fisher consuming 224 grams/day (~3.5 pounds/week; 7 meals/week)

These fish consumption scenarios were included in the Project-only local deposition assessment and the cumulative local deposition assessment (NorthMet + Mesabi Nugget LSDP), respectively. The local deposition assessment also assumes that all of the fish being consumed by a fisher come from the lake being evaluated, and that the fisher is consuming only predator species such as walleye or northern pike.

There is uncertainty in estimating the background HQ and the incremental HQ as to whether Tribal members consume fish the 5 lakes included in this analysis. If Tribal members do consume fish from the 5 lakes included in this analysis, there is no data on the amount of fish consumed.

Overall, there is no specific data on Native American fish consumption rates in Minnesota. A fish consumption rate of 180 pounds/year (approximately 224 grams per day) has been used in negotiating Treaty rights. But there is uncertainty in whether this fish consumption rate applies to all Native Americans who consume fish or is a best estimate for the general population that may be a low estimate for specific individuals who may consume more fish. There is also uncertainty in whether fish consumption rates from other locations in the United States, such as neighboring Wisconsin or the Pacific Northwest, could apply to Native Americans in Minnesota. To date, the Tribes in Minnesota have relied on the 224 grams/day fish consumption rate to derive method detection limits for fish contaminant analyses and for communicating fish consumption guidance.<sup>106</sup>

If one conservatively assumes that the fisher receptor at Wynne Lake (highest background risk of the 5 lakes evaluated and highest potential incremental HQ, Table 4-2) has approximately double the fish consumption rate, from 224 grams/day to 400 grams/day (0.88 pounds/day) to account for a potential higher-end consumer of fish, then estimated incremental fish pathway risk as calculated by the MMREM spreadsheet would increase by about 80%. The subsistence fisher incremental HQ would increase from 0.6 to 1.1 for the worst case emissions scenario (Scenario 1, 50% oxidized mercury air emissions), while for the reasonably expected emissions scenario (Scenario 2, 10% oxidized mercury air emissions) the subsistence fisher HQ would increase from 0.1 to 0.2.

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<sup>106</sup> J. Persell letter to M. Watkins, January 19, 2004; *see also* original reference for the Keetac Expansion Project; *see also* Barr Engineering Company 2009, *Human Health Screening Level Risk Assessment, U.S. Steel Keetac Expansion Project* (Feb. 2009) [Barr 2009a].

For both emissions scenarios the estimated incremental HQs are considered conservative estimates. Given the overall conservatism in the local mercury deposition assessment and the fact that the Project will have no statistically measurable change in fish mercury concentrations (Table 4-1) and therefore no measurable effect on background fish consumption advisories or background HQs, no effects to consumers of locally caught fish are reasonably expected to occur from potential deposition related to the Project's mercury air emissions.

#### **4.2.3.2 Potential for Additional Project Related Mercury from Wastewater Discharges to Affect Fish Mercury Concentrations**

As discussed in Section 3.1, during mining operations PolyMet has proposed a water recycle/reuse system for both the Mine Site and the Plant Site. However, there will be some wastewater discharged from the Plant Site during active operations (Mine Years 1 to 20). As a result of the planned water management strategy, during active mining and ore processing when mercury air emissions will occur from the Plant Site, there is likely some additional mercury to be added to the 5 study lakes from the Project's treated wastewater.

Any treated wastewater that is released from the Plant Site during active mining and ore processing is expected to be low in mercury, 1.3 ng/L or lower. As demonstrated by recent mining projects, and as identified by Berndt and Bavin,<sup>107</sup> mining influenced waters are low in mercury, much lower than background surface water concentrations from non-mining watersheds. Therefore, if there are releases of treated wastewater from the Plant Site during ore processing, there is likely to be a dilution (i.e., lowering) of the background concentration of mercury. Overall, during mining and ore processing, the potential additional mercury from treated wastewater discharges is expected to be small in comparison to the mercury load from the non-mining portions of the Embarrass River watershed and the Partridge River watershed and is not expected to change the results of the local deposition analysis for the 5 lakes.

#### **4.2.3.3 Previous Assessments of the Relationship between Sulfate and Methylmercury**

Several assessments have been conducted to investigate the relationship of sulfate and methylmercury in surface waters at the Mine Site, Plant Site and the wetlands to the north of the existing LTVSMC tailings basin.

- 2008, NorthMet Project: Assessing Potential Impacts from Sulfate in Seepage and Discharge Water on Total Mercury and Methylmercury Concentrations in Offsite Receiving Waters, Technical Memorandum (April 25, 2008)
- 2008, NorthMet Project: Initial Comparison of Fish Mercury Concentrations from Hoyt Lakes Area Lakes with Fish Mercury Concentrations from Selected Lakes in Northeast Minnesota, Technical Memorandum (July 3, 2008)
- Update to the July 3 Tech Memo on Fish Hg; Table 1 and Table 2 (August 18, 2008)

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<sup>107</sup> Berndt and Bavin (2009).

- 2010, Results from the Additional Baseline Monitoring for Sulfate and Methylmercury in the Embarrass River Watershed (July – November 2009, Technical Memorandum (April 9, 2010)

These assessments have been provided to the Co-Lead Agencies in support of the development of the DEIS and the SDEIS. To date, the studies conducted in support of the DEIS and SDEIS identified that surface waters from watersheds with mining features having higher sulfate concentrations did not have significantly different concentrations of methylmercury compared to non-mining background watersheds.<sup>108</sup> Some of the highest methylmercury concentrations are associated with lower sulfate concentrations in background streams that do not have mining features in their watershed.<sup>109</sup> Results from additional baseline monitoring identified that methylmercury concentrations in wetland streams to the north of the LTVSMC tailing basin were not statistically different from non-mining background streams, methylmercury concentrations decreased with distance downstream of PM13 and that methylmercury concentrations in Sabin and Wynne Lakes were similar to concentrations in the Embarrass River and did not show any trend with depth in the water column (i.e., in-lake methylation not important).<sup>110</sup> Appendix A provides additional discussion on the additional baseline monitoring study.<sup>111</sup>

In addition, fish mercury concentrations from the lakes near the Project (e.g., Wynne and Sabin lakes; dark water systems with wetland influence) are considered to be similar to fish mercury concentrations from other lakes in the BWCAW and Voyageurs National Park with lower sulfate concentrations.<sup>112</sup> These findings are consistent with other research<sup>113</sup> that indicates wetlands have a significant effect on surface water methylmercury concentrations and higher fish mercury concentrations tend to be associated with wetland dominated systems (i.e., dark water systems) even though background sulfate concentrations are low and average about 2 to 5 mg/L.<sup>114</sup>

While the existing LTVSMC tailings basin may be contributing sulfate to what is considered by the MPCA/MDNR to be a high risk environment (i.e., wetlands to the north/northwest of the basin that contribute their water to the Embarrass River and the downstream chain of lakes), the 2009 additional baseline monitoring data does not indicate that the elevated sulfate concentrations are resulting in elevated methylmercury concentrations or in elevated “% that is methylmercury” compared to

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<sup>108</sup> Barr 2008a; Barr Engineering Company, *Technical Memorandum, NorthMet Project: Results from the Additional Baseline Monitoring for Sulfate and Methylmercury in the Embarrass River Watershed* (Apr. 9, 2010) [Barr 2010].

<sup>109</sup> Barr 2008a; Barr 2010.

<sup>110</sup> Barr 2010.

<sup>111</sup> Barr 2010.

<sup>112</sup> Barr Engineering Company 2008b, *Technical Memorandum, NorthMet Project: Initial comparison of fish mercury concentrations from Hoyt Lakes Area Lakes with fish mercury concentrations from selected lakes in northeast Minnesota* (July 3, 2008) [Barr 2008b].

<sup>113</sup> Swain, E. B. and D.D. Helwig, *Mercury in Fish from Northeastern Minnesota Lakes: Historic Trends, Environmental Correlates, and Potential Sources*, J. Minn. Acad. Science, 55(1): 103-109 (1989); Hurley, J.P., J.M. Benoit, C.L. Babiarz, M.M. Shafer, A.W. Andren, J.R. Sullivan, R. Hammond, and D.A. Webb, *Influences of Watershed Characteristics on Mercury Levels in Wisconsin Rivers*, Environmental Science and Technology 29: 1867-1875 (1995).

<sup>114</sup> Goldstein et al. 2003, Voyageurs National Park lakes; Berndt and Bavin 2009, St. Louis River and tributaries.

background conditions.<sup>115</sup> Based on these findings, and noting that the existing LTVSMC tailings basin has been a watershed feature for some 40+ years, it is highly unlikely that Project operations will have an effect on the sulfate and methylmercury dynamics in the Embarrass River watershed.

#### **4.2.3.4 Supplemental Assessment: Potential Additional Sulfur from Wastewater Discharges**

As discussed in Section 3.1, during mining operations PolyMet has proposed a water recycle/reuse system for both the Mine Site and the Plant Site. In addition, there will be a seepage capture system that will limit the amount of water reaching the wetlands to the north of the FTB. There will be some wastewater, discharged from the Plant Site during active operations (Mine Years 1 to 20). As a result of the planned water management strategy, during active mining and ore processing when mercury air emissions will occur from the Plant Site, there is likely some sulfate added to downstream lakes (Colby Lake, Whitewater Lake, Sabin Lake and Wynne Lake) from the Project's treated wastewater.

Overall, there will be a reduction in water releases during Project operations from both the Mine Site and the Plant Site compared to existing conditions. For the Plant Site, the reduction in sulfate loading to nearby surface waters is estimated to result in a 45% reduction (P50 water modeling results) in sulfate loading to the Embarrass River at site PM13.<sup>116</sup> This also means that sulfate loading will be reduced to downstream lakes (e.g., Sabin and Wynne Lakes). For the Mine Site, there is a small estimated increase in sulfate loading to the Partridge River (0.1% increase) that is not expected to be statistically measurable given the small potential change compared to the variability in background conditions (e.g., variability in streamflow; variability in monitored sulfate concentrations that range from 5 to 21 mg/L, Table 2-1). Therefore, there is likely to be no measureable change in sulfate loading to water bodies downstream of the Mine Site (Colby and Whitewater Lakes) and it is reasonably concluded that Project-related sulfate will have no effect on methylmercury concentrations in nearby surface waters or on fish mercury concentrations in the 5 lakes assessed for local mercury deposition

#### **4.2.3.5 Supplemental Assessment: Potential Additional Sulfur from Stack and Fugitive Dust Air Emissions**

The local mercury deposition analysis in the SDEIS does not include potential indirect effects on mercury methylation from the potential deposition of sulfur associated with the Project's sulfur air emissions (SO<sub>2</sub>, SAM, reduced sulfur compounds (as TRS) and sulfur in particulate) from stacks. In light of the public comments on Project sulfate potentially affecting mercury methylation and fish concentrations in downstream areas, a screening estimate of potential sulfate additions to Colby Lake and Sabin Lake from the Plant Site stack SO<sub>2</sub> air emissions (SO<sub>2</sub>, SAM, and sulfur in fine particulate) and potential sulfate additions to wetlands from Plant Site and Mine Site fugitive dust emissions from Plant Site and Mine (~7 tpy) is provided here. Potential additional sulfur from estimated stack and fugitive air emissions is discussed below and includes a qualitative discussion for TRS. Calculation details are provided in Appendix B.

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<sup>115</sup> Barr 2010.

<sup>116</sup> PolyMet 2015a.

## *Sulfur Dioxide*

Potential Plant Site stack SO<sub>2</sub> air emissions are estimated to be ~7 tpy. Stack emissions of SO<sub>2</sub> at the Mine Site were estimated to be about 1.9 tpy and are de minimis for PSD air permitting and therefore were not required to be modeled. PSD regulations are designed to “protect public health and welfare from any adverse effect which might occur even at air pollution levels better than the national ambient air quality standards.”<sup>117</sup> The protection of “public welfare” includes soil and vegetation effects. Therefore, Mine Site SO<sub>2</sub> emissions are not considered to have potential significant impacts as determined under the PSD program.

Air concentrations of SO<sub>2</sub> were modeled for the Plant Site Class II Air Quality Air Dispersion Modeling Report<sup>118</sup> and can be used to estimate a potential deposition of sulfur related to SO<sub>2</sub> air emissions. The average watershed SO<sub>2</sub> air concentrations are based on Class II modeling and reflect the Class II modeling receptor grid.<sup>119</sup> Because SO<sub>2</sub> emissions are in the gas phase and emitted from a taller stack, they will tend to disperse further, and the average concentration over the watershed is therefore considered a more reasonable approximation of a potential air concentration. Because the receptor grid has very dense spacing in some areas over the Partridge River watershed, the watershed average SO<sub>2</sub> concentration is an area-weighted average. In comparison, the Embarrass River watershed average SO<sub>2</sub> concentration represents the average of all receptors over the Embarrass River watershed. Because of the denseness of receptors at the Plant Site boundary, the average SO<sub>2</sub> concentrations for both watersheds are considered to be slightly overestimated.

Additional information required for estimating potential deposition includes a deposition velocity, lake surface area, and the water mixing zone due to wind and wave actions. Summary information used to estimate a potential sulfate surface water concentration from Plant Site SO<sub>2</sub> air emissions is provided below, along with summary results.

### Colby Lake (Partridge River watershed)

- Average SO<sub>2</sub> air concentration over Partridge River watershed = 0.05 µg/m<sup>3</sup> (~8% of background)
- SO<sub>2</sub> Deposition Velocity = 0.46 cm/sec.<sup>120</sup>
- Background sulfur deposition rate (2007-2013 NADP data) = 0.12 g/m<sup>2</sup>/yr.
- Potential sulfur deposition over Partridge River watershed = 0.003 g/m<sup>2</sup>/yr (~2% of background)
- Colby Lake surface area = 502 acres; mixing zone = surface water layer = 1 foot.

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<sup>117</sup> USEPA. *New Source Review Workshop Manual: Prevention of Significant Deterioration and Nonattainment Area Permitting*. Draft October 1990, [USEPA 1990].

<sup>118</sup> Barr 2012c.

<sup>119</sup> *Id.*

<sup>120</sup> EPCM, *Estimation of Dry Acid Deposition at TEEM Passive Monitoring Sites*. Submitted to Wood Buffalo Environmental Association Terrestrial Environmental Effects Monitoring Committee Fort McMurray, Alberta (Apr. 2002) [EPCM 2002].

- Potential surface water concentration from deposition to lake surface (as sulfate) = 0.03mg/L
- Background sulfate concentration in Colby Lake (range = 37 – 42 mg/L) (Table 2-1).
- Background sulfate concentration in upper Partridge River (PM16), representing runoff water = 14.9 mg/L (range = 5 – 21 mg/L) (Table 2-1)

#### Sabin Lake (Embarrass River watershed)

- Average SO<sub>2</sub> air concentration over Embarrass River watershed = 0.02 µg/m<sup>3</sup> (~3% of background)
- SO<sub>2</sub> Deposition Velocity = 0.46 cm/sec<sup>121</sup>
- Background sulfur deposition rate (2007-2013 NADP data) = 0.12 g/m<sup>2</sup>/yr
- Potential sulfur deposition over Embarrass River watershed = 0.002 g/m<sup>2</sup>/yr (~2% of background)
- Sabin Lake surface area = 299 acres; mixing zone = surface water layer = 1 foot.
- Potential surface water concentration from deposition to lake surface (as sulfate) = 0.02 mg/L
- Background sulfate concentration in Sabin Lake (mean = 17 mg/L; range = 10 – 25 mg/L Table 2-1) (also, range = 15 - 16 mg/L).<sup>122</sup>
- Background sulfate concentration in the St. Louis River headwaters (River Mile 179), upper Embarrass River (PM12) and Bear Creek (PM20), representing runoff water = 1.1 to 3.3 mg/L (Table 2-1)

Even considering the conservative estimate of potential air concentrations over the respective watersheds and the general overestimate of potential deposition associated with screening equations, potential sulfur deposition from SO<sub>2</sub> emissions is a small percent of background sulfur deposition for both the Embarrass River and Partridge River watersheds. In addition, the estimated potential surface water concentration of sulfate from Plant Site SO<sub>2</sub> air emissions is small and well within the variability of background concentrations and is not be expected to be statistically measurable.

#### *Sulfuric Acid Mist (SAM)*

The available modeled air concentration for SAM for the annual averaging time is the maximum estimate at the Plant Site property boundary and is from the 2007 Plant Site AREA and is based on estimated emissions of 11.5 tpy (0.28 µg/m<sup>3</sup>).<sup>123</sup> As done for the 2013 Plant Site AERA,<sup>124</sup> the 2007 modeled air concentration was adjusted for the current estimate of SAM emissions of 5.02 tpy, a standard adjustment

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<sup>121</sup> EPCM 2002.

<sup>122</sup> SDEIS Table 4.2.2-3.

<sup>123</sup> Barr 2007b.

<sup>124</sup> Barr 2013a.

technique. The revised air concentration is estimated to be  $0.12 \mu\text{g}/\text{m}^3$ , about a 56% reduction, and is used to estimate potential sulfur deposition to both Colby Lake and Sabin Lake.

Additional information required for estimating potential deposition includes a deposition velocity, lake surface area, and the water mixing zone due to wind and wave actions. Summary information used to estimate a potential sulfate surface water concentration from Plant Site SAM air emissions is provided below, along with summary results.

#### Colby Lake (Partridge River watershed)

- Maximum modeled SAM air concentration at Plant Site boundary; applied to entire lake surface and watershed =  $0.12 \mu\text{g}/\text{m}^3$
- SAM Deposition Velocity =  $0.04 \text{ cm}/\text{sec}$ .<sup>125</sup>
- Background sulfur deposition rate (2007-2013 NADP data) =  $0.12 \text{ g}/\text{m}^2/\text{yr}$ .
- Potential sulfur deposition to watershed and lake surface =  $0.0005 \text{ g}/\text{m}^2/\text{yr}$  (~0.4% of background)
- Colby Lake surface area = 502 acres; mixing zone = surface water layer = 1 foot.
- Potential surface water concentration from deposition to lake surface (as sulfate) =  $0.005 \text{ mg}/\text{L}$
- Background sulfate concentration in Colby Lake (range = 37 – 42 mg/L) (Table 2-1).
- Background sulfate concentration in upper Partridge River (PM16), representing runoff water =  $14.9 \text{ mg}/\text{L}$  (range = 5 – 21 mg/L) (Table 2-1)

The estimated potential incremental sulfate concentration for Sabin Lake is also  $0.005 \text{ mg}/\text{L}$  and details are provided in Appendix B.

Even considering the conservative estimate of using a maximum modeled air concentration at the Plant Site property boundary as representing an air concentration over the respective watersheds and the general overestimate of potential deposition associated with screening equations, potential sulfur deposition from SAM emissions is a small percent of background sulfur deposition for both the Embarrass River and Partridge River watersheds. In addition, the estimated potential surface water concentration of sulfate from estimated Plant Site SAM air emissions is small and well within the variability of background concentrations and is not be expected to be statistically measurable.

#### *Reduced Sulfur Compounds*

Potential Project emissions of total reduced sulfur (TRS) compounds, which include hydrogen sulfide (1.88 tpy) and carbon disulfide (5.1 tpy), are estimated to be 6.98 tpy, all from the Plant Site.<sup>126</sup> No modeling of

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<sup>125</sup> Xu and Carmichael 1997, *Modeling the dry deposition velocity of sulfur dioxide and sulfate in Asia*, J. of Ap. Meteorology Vol. 37. p.1084

TRS emissions was required for ambient air quality purposes or the Supplemental Plant Site AERA. However, the potential deposition of sulfur from TRS compounds is likely small due to the following:

- Because both H<sub>2</sub>S and carbon disulfide tend to remain as gases under normal environmental conditions<sup>127</sup> they have the potential to be dispersed more than 10 kilometers from an emission source.<sup>128</sup>
- H<sub>2</sub>S in air is oxidized by molecular oxygen and hydroxyl radicals, ultimately forming SO<sub>2</sub> or sulfate compounds,<sup>129</sup> which takes time, on the order of hours to days, therefore allowing more transport away from an emission source and more dispersion to occur before any sulfur would potentially deposit out.
- The residence times of H<sub>2</sub>S in air range from one day in summer to 40 days in winter, with behavior like other gaseous pollutants that are dispersed and eventually removed.<sup>130</sup>
- Other research has shown that H<sub>2</sub>S tends to volatilize rather than be deposited out of the atmosphere.<sup>131</sup>
- Carbon disulfide (CS<sub>2</sub>), which makes up 73% of the Project's TRS emissions, occurs in the gas phase at ambient temperatures and reacts with photochemically produced hydroxyl radicals, with the half-life of this process estimated to be 5.5 days.<sup>132</sup>

Overall, the potential local deposition of sulfur from TRS compounds, which are emitted in the gas-phase, is uncertain, but is not likely to be a significant contributor to potential local sulfur deposition.

### *Sulfur in Particulate*

To estimate the potential deposition of sulfur from sulfur in particulate, the maximum modeled PM<sub>2.5</sub> air concentration for the annual averaging time period (5.8 µg/m<sup>3</sup> at the Plant Site property boundary)<sup>133</sup> was used as the starting point for the screening evaluation. In this analysis, it is assumed that ore processing is responsible for all of the modeled PM<sub>2.5</sub> air concentration (potential sulfur concentration in the ore = 8700 ppm). This approach is used to estimate potential sulfur deposition to both Colby Lake and Sabin Lake.

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<sup>126</sup> Barr 2013j.

<sup>127</sup> WHO (World Health Organization) 2003, *Hydrogen Sulfide: Human Health Aspects. Concise International Chemical Assessment Document (CICAD) 53* (2003) [WHO 2003].

<sup>128</sup> Schnoor J.L., P.S. Thorne, and W. Powers, *Fate and Transport of Air Pollutants from CAFOs, in "Iowa Concentrated Animal Feeding Operations, Air Quality Study", Final Report* (Feb. 2002).

<sup>129</sup> WHO 2003.

<sup>130</sup> Alberta Environment: *Assessment report on reduced sulphur compounds for developing ambient air quality objectives*, Prepared by AMEC Earth and Environmental Limited and the University of Calgary (Nov. 2004).

<sup>131</sup> WHO 2003.

<sup>132</sup> Alberta Environment 2004.

<sup>133</sup> Barr 2012c.

Additional information required for estimating potential deposition includes a deposition velocity, lake surface area, and the water mixing zone due to wind and wave actions. Summary information used to estimate a potential sulfate surface water concentration from Plant Site sulfur in particulate air emissions is provided below, along with summary results.

#### Colby Lake (Partridge River watershed)

- Maximum modeled PM<sub>2.5</sub> air concentration at Plant Site boundary; applied to entire lake surface and watershed = 5.8 µg/m<sup>3</sup>
- Fine Particle Deposition Velocity = 0.281 cm/sec
- Background sulfur deposition rate (2007-2013 NADP data) = 0.12 g/m<sup>2</sup>/yr.
- Potential sulfur deposition to watershed and lake surface = 0.0045 g/m<sup>2</sup>/yr (~4% of background)
- Colby Lake surface area = 502 acres; mixing zone = surface water layer = 1 foot.
- Potential surface water concentration from deposition to lake surface (as sulfate) = 0.04 mg/L
- Background sulfate concentration in Colby Lake (range = 37 – 42 mg/L) (Table 2-1).
- Background sulfate concentration in upper Partridge River (PM16), representing runoff water = 14.9 mg/L (range = 5 – 21 mg/L) (Table 2-1)

The estimated potential incremental sulfate concentration for Sabin Lake is also 0.04 mg/L and details are provided in Appendix B.

Even considering the conservative estimate of using a maximum modeled air concentration at the Plant Site property boundary as representing an air concentration over the respective watersheds and the general overestimate of potential deposition associated with screening equations, potential sulfur deposition from sulfur in particulate stack emissions is a small percent of background sulfur deposition for both the Embarrass River and Partridge River watersheds. In addition, the estimated potential surface water concentration of sulfate from estimated Plant Site particle air emissions is small and well within the variability of background concentrations and would not be expected to be statistically measurable.

#### *Potential Additional Sulfur from Fugitive Dust*

The potential for indirect effects to wetlands water quality due to potential deposition of metals and sulfur associated with fugitive dust was evaluated in the March 2013 Wetland Data Package<sup>134</sup> as a screening analysis to identify potential areas for future monitoring. Only wetlands that are not directly impacted by the Project were considered in the analysis.<sup>135</sup> Following the approved work plan developed in conjunction with the Wetlands IAP Work Group and approved by the Co-Lead Agencies, the screening criterion to

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<sup>134</sup> PolyMet 2013c. *see also* updated version 9 (January 2015) of this data package [PolyMet 2015d]

<sup>135</sup> SDEIS, Pp 5-299 to 5-302.

determine potentially impacted areas for future monitoring was estimated Project-related deposition greater than background rates.

Deposition modeling was conducted using the AERMOD model. Mine Site fugitive dust sources included rail car loading of ore, and handling activities outside the pit associated with ore, category 2/3 waste rock and category 4 waste rock including loading and unloading and stockpiles.<sup>136</sup> FTB fugitive dust sources included loading and unloading of tailing from former LTVSMC operations and the construction of tailings dams. Both the maximum sulfide content of Project materials and the background deposition of sulfate were evaluated on an elemental sulfur basis to provide a direct comparison.<sup>137</sup>

The highest model-estimated annual dust deposition at the Mine Site was 75 grams per square meter ( $\text{g}/\text{m}^2$ ) (less than 25% of the background effects level) and at the FTB was about  $183 \text{ g}/\text{m}^2$  (about 50% of the background effects level) (background effects level dust deposition =  $365 \text{ g}/\text{m}^2$ ). In comparison, the highest estimated annual total sulfur deposition on the receptor grid, as speciated from dust deposition modeling results, was  $0.42 \text{ g}/\text{m}^2$ . In comparison, model-estimated annual sulfur deposition to Heikkilla Lake just north of the FTB was estimated to be about  $0.002 \text{ g}/\text{m}^2$  while background annual total sulfur deposition was estimated to be  $0.16 \text{ g}/\text{m}^2$  based on NADP data from 2007 to 2011.

The Wetlands Data Package provided a discussion on conservatism and uncertainty in the analysis, including a discussion that the estimated sulfur deposition was as particle-bound sulfur, with the sulfur being inherent to the mineral matrix of the dust and not readily available for dissolution in soils or surface waters.<sup>138</sup> Some SDEIS commenters have gone further and assumed 100% of the sulfide in fugitive dust will be liberated to the environment as sulfate. Under the conservative assumption that all of the sulfur in fugitive dust converts to sulfate and mix with surface water in a wetland, the following information was used to estimate a potential incremental increase in sulfate concentration.

- Potential maximum sulfur deposition =  $0.42 \text{ g}/\text{m}^2$  (maximum anywhere on the receptor grid; assuming all converted to sulfate =  $1.26 \text{ g}/\text{m}^2$ )
- $1.26 \text{ g sulfate}/\text{m}^2 = 1,260 \text{ mg sulfate}/\text{m}^2$ ;
- Assume this mass of sulfate mixes with the surface 12 inches of water (30 cm = 0.3 meters; average depth of water in a typical "wetland" as defined by the MDNR (2014)); volume = 0.3 cubic meters ( $\text{m}^3$ ) = 300 Liters.
- Potential incremental sulfate concentration =  $1,260 \text{ mg} / 300 \text{ L} = 4.2 \text{ mg}/\text{L}$
- Potential incremental sulfate concentration if mixed with annual precipitation ( $\sim 76 \text{ cm}/\text{yr}$ ) =  $1.7 \text{ mg}/\text{L}$

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<sup>136</sup> PolyMet 2013c. *see also* updated version 9 (January 2015) of this data package [PolyMet 2015d]

<sup>137</sup> *Id.*

<sup>138</sup> *Id.*

Other calculations based on Project test data that account for the potential release of sulfate inherent to the mineral matrix of deposited rock/dust particles indicate potential incremental surface water sulfate concentrations that range from 0.19 mg/L to 0.26 mg/L at the FTB and from 0.07 mg/L to 0.13 mg/L at the Mine Site.

Background sulfate concentrations in streams draining wetlands range from 1 to 3 mg/L. A potential maximum incremental increase of 4 mg/L sulfate from potential sulfur associated with fugitive dust at the FTB likely warrants future monitoring, as initially identified in the Wetlands Data Package.<sup>139</sup> However, based on the findings from Benoit<sup>140</sup> and Barr Engineering,<sup>141</sup> an incremental increase in sulfate concentration of 4 mg/L is not likely to have any statistically measurable effect on methylmercury concentrations in surface water or fish mercury concentrations. As shown in Table 2-1 and in Table A-1, and as discussed in several Project reports,<sup>142</sup> higher sulfate concentrations in the streams draining the wetlands to the north of the LTSMC tailings basin (sites PM11 and PM19) and in lakes downstream of the Project (Sabin and Wynne lakes) have methylmercury concentrations not significantly different from (i.e., considered here to be similar to) non-mining background surface waters with sulfate concentrations ranging from 1 to 5 mg/L. These results and conclusions are consistent with the findings by Berndt and Bavin<sup>143</sup> that indicate methylmercury concentrations from mining influenced watersheds are not elevated above the concentrations found in non-mining watershed (e.g., the Cloquet River or Floodwood River watersheds). There is no data for the Project area or from the St. Louis River watershed that indicates a potential incremental surface water sulfate concentration of 4 mg/L will result in increased surface water methylmercury concentrations.

In summary, the initial fugitive dust deposition assessment identified several wetland areas near the FTB and the Mine Site for potential future monitoring of sulfur. But because the sulfur is inherent to the mineral matrix of the dust particles, it is likely that less than 100% of the sulfur would be weathered from the particles and be available to go into solution if deposited to soils or water. For a worst-case sulfate release scenario, the potential incremental surface water concentration is estimated to be 4 mg/L. While this potential incremental change may warrant future monitoring, it is not expected to have an effect on methylmercury concentrations in surface water based on available data that indicates a relative insensitivity of wetlands to additional sulfate.<sup>144</sup>

### ***Summary of Potential Additional Sulfur from Project Air Emissions***

A screening assessment of potential additional sulfur deposition from the Project's air emissions that includes stack emissions of SO<sub>2</sub>, SAM, and sulfur in particulate, and fugitive dust from the FTB and the Mine Site, was conducted. Estimated potential depositions of sulfur from SO<sub>2</sub>, SAM and sulfur in particulate are small and the potential incremental sulfate concentrations in surface water ranged from

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<sup>139</sup> PolyMet 2013c. *see also* updated version 9 (January 2015) of this data package [PolyMet 2015d].

<sup>140</sup> Benoit et al (1999).

<sup>141</sup> Barr (2008a; 2010).

<sup>142</sup> Barr 2008a; 2008b; 2010.

<sup>143</sup> Berndt and Bavin (2009).

<sup>144</sup> Benoit *et al.* 1999; Jeremiason *et al.* 2006; Barr 2010.

0.0005 mg/L to 0.04 mg/L. Under a conservative and reasonable representation of the potential release of sulfur from fugitive dust, potential incremental sulfate concentrations in surface water ranged from 0.0007 mg/L to 0.13 mg/L. Under a worst case assumption that all sulfur associated with fugitive dust would be converted to sulfate, a potential incremental concentration of 4.2 mg/L was estimated.

If the potential additional sulfate concentrations are added together, the following is obtained:

- Conservative and reasonable representation:  
Sum (mg/L) = 0.03 mg/L + 0.005 + 0.04 + 0.26 = 0.34 mg/L
- Worst case potential increase:  
Sum (mg/L) = 0.03 mg/L + 0.005 + 0.04 + 4.2 = 4.3 mg/L

Baseline data and evaluations have not identified that methylmercury concentrations in surface waters adjacent to or downstream of the Plant Site that receive waters with elevated sulfate concentrations are statistically different from background concentrations in non-mining watersheds.<sup>145</sup> Berndt and Bavin<sup>146</sup> have identified that sulfate is primarily contributed to the St. Louis River from mining-influenced watersheds while methylmercury in the St. Louis River watershed is primarily contributed by non-mining watersheds. The additional sulfate in mining-influenced watersheds does not seem to be resulting in elevated methylmercury in surface waters.

It is recognized that some sulfate is needed to stimulate the methylation process, but that need seems to be satisfied from background sulfate deposition. As shown by Benoit et al. and Jeremiason et al.,<sup>147</sup> a high dose of sulfate can stimulate the methylation process and increase methylmercury concentrations. But it has also been shown that aquatic systems have similar methylmercury concentrations when sulfate concentrations range from about 2 to greater than 100 mg/L (order of magnitude difference).<sup>148</sup> Therefore, an increase in sulfate does not necessarily result in more methylmercury being produced. Because the potential additional deposition of sulfur from the Project's air emissions is estimated to be small, including the potential release of sulfur from potential fugitive dust emissions, the findings and conclusions of the local mercury deposition analysis do not require changes or adjustments and no changes to current surface water methylmercury concentrations or fish mercury concentrations are reasonably expected.

### 4.3 Mercury in Wastewater Discharges and Loading Estimates (Screening Non-degradation Analysis)

The Project will have permitted wastewater discharges from both the Plant Site and the Mine Site. National Pollutant Discharge Elimination System (NPDES) permitting requires that new discharges in the Lake Superior Basin meet the 1.3 ng/L surface water quality standard. In addition, a non-degradation

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<sup>145</sup> Barr 2008a, 2010.

<sup>146</sup> Berndt and Bavin (2009).

<sup>147</sup> Benoit *et al* (1999); Jeremiason *et al* (2006); Barr 2008a.

<sup>148</sup> Barr 2008a.

analysis is required for a new or expanded wastewater discharge. The following subsections provide details from reports and technical memoranda that have been submitted to the Co-Lead Agencies in support of the SDEIS.

### 4.3.1 Demonstrating Compliance with Surface Water Quality Standards

Three separate but related evaluations were performed for water discharges from the Project in long-term closure to demonstrate compliance with the surface water quality standard of 1.3 ng/L. Mercury mass balances were prepared for both the Plant Site<sup>149</sup> and Mine Site<sup>150</sup> in order to determine whether the point source discharges comply with mercury discharge standards and to demonstrate non-degradation with regard to mercury concentrations in the respective rivers and in the St. Louis River (i.e., demonstrate that the Project does not increase mercury concentrations or loading to the St. Louis River).<sup>151</sup>

In order to assess whether discharges from the Project in long-term closure meet the Lake Superior Basin's 1.3 ng/L discharge standard, the potential mercury concentrations associated with respective water management at the Mine Site and the Plant Site were analyzed using a spreadsheet-based mass balance model. This estimation method was preferred over a detailed mechanistic model because it incorporated the important input and removal processes for mercury, it was transparent with regard to data inputs and it allowed for easy assessment of the effects of changing parameter values on mercury concentrations. The mass balance approach proposed by PolyMet was approved by the MPCA and the MDNR because it is a scientifically valid and defensible method. All initial assumptions and parameter input values to the respective mass balances were reviewed by agency staff. The final assumptions, parameter input values and final results and conclusions were also reviewed by the MPCA and MDNR staff prior to their acceptance.

Each non-degradation assessment is discussed in the following sections.

### 4.3.2 Potential Mercury Load from the Plant Site to the Upper Embarrass River

In order to assess whether discharges from the Project's WWTP meet the Lake Superior Basin's 1.3 ng/L discharge standard, the potential mercury concentration in the FTB at the Plant Site in long-term closure was analyzed using a spreadsheet-based mass balance model. The mass balance model for the Project was used to demonstrate the anticipated fate of the mercury associated with the processing of NorthMet ore. This estimation method was preferred over a detailed mechanistic model because it incorporated the important input and removal processes for mercury, it was transparent with regard to data inputs and it allowed for easy assessment of the effects of changing parameter values on mercury concentrations. The proposed approach and data inputs were presented in a work plan to MDNR and MPCA technical staff, which provided a thorough review in two rounds of comments in October and November of 2011.

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<sup>149</sup> PolyMet 2013b. *see also* updated version 10 (January 2015) of this data package [PolyMet 2015a]

<sup>150</sup> PolyMet 2013a. *see also* updated version 12 (December 2014) of this data package [PolyMet 2014a]

<sup>151</sup> Barr 2013c. *see also* updated version 3 (January 2015) of this Technical Memorandum [Barr 2015]

Based on the agreed upon approach and inputs, Barr completed the Plant Site mercury analysis, which was submitted to the MDNR and MPCA as a part of the Plant Site Water Modeling Data Package (version 9).<sup>152</sup> MDNR and MPCA provided written and oral comments in January and February of 2013. Key assumptions addressed in the agency dialog included the ability of tailings to reduce the mercury content of the seepage and the equilibrium concentration of mercury in a shallow, oligotrophic, clear water system like the FTB in long-term closure. After the analysis was revised to address these comments, the MDNR and MPCA provided final acceptance in March of 2013. The same approach and methodology for the mass balance assessment was used in Version 10 submitted in January 2015.<sup>153</sup>

The analysis concluded that, given the available information and data, the total mercury concentration of WWTP discharge water during long-term closure is expected to meet the applicable water quality standard of 1.3 ng/L.<sup>154</sup> The assessment indicates a potential small increase in mercury loading to the upper Embarrass River (0.2 grams per year, about a 0.1% increase above existing conditions) (Table 4-4).

Some water from the WWTP will be routed to NPDES discharge SD026. The assessment indicates a potential small increase to the lower Partridge River (0.1 grams per year increase) (Table 4-4). The average flow at the USGS 04015500 gaging station on Second Creek was 22.4 cfs (equal to 20 billion L/yr). Baseline water quality sampling indicated an average total mercury concentration of approximately 3.4 ng/L at site MNSW8, near the USGS gaging station.<sup>155</sup> Therefore, current mercury loading at this point is estimated to be 68 g/yr, and the potential increased load resulting from the Project at this point is negligible (a potential increase of about 0.1%), with no measurable change in the total mercury water column concentration.

Additional mercury removal by the WWTP's greensand filtration and reverse osmosis processes are expected to reduce mercury concentrations further. This potential additional removal of mercury is not accounted for in the mass balance calculations, however, which adds a level of overestimation to the mass balance results. Overall, the screening analysis indicates that the potential change in mercury loading to the upper Embarrass River and the lower Partridge River from the Project in long-term closure is small, and does not constitute degradation of the existing surface waters.

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<sup>152</sup> PolyMet 2013b.

<sup>153</sup> PolyMet 2015a.

<sup>154</sup> Barr 2015.

<sup>155</sup> Barr Engineering. *Sulfate, Mercury, and Methyl Mercury in Second Creek. Mesabi Nugget Phase II Project Report*. May 2009. [Barr 2009b]

**Table 4-4 Summary of Mercury Mass Balance Modeling Results for Wastewater Discharges from the Project in Long-term Closure to the Upper Embarrass River and Upper and Lower Partridge River and the Overall Potential Loading to the Lower St. Louis River**

Project Discharge (Long-term Closure [1])	Estimated Concentration in Discharge Water [2]	Receiving Water (Evaluation Point)	Estimated Potential Change in Evaluation Point Receiving Water Due to Project			
			Load	% Change	Concentration [3]	% Change [3]
Plant Site WWTP	< 1.3 ng/L	Upper Embarrass River, PM13	+ 0.2 g/yr	0.1%	0.05 ng/L	ND
Plant Site WWTP	< 1.3 ng/L	Lower Partridge River via Second Creek	+ 0.1 g/yr	0.2%	< 0.05 ng/L	ND
Mine Site WWTF (West Pit discharge)	< 1.3 ng/L	Upper Partridge River, SW004a	-1.4 g/yr	-0.9%	< 0.05 ng/L	ND
Total Project (Plant Site + Mine Site)	< 1.3 ng/L	St. Louis River EP-1, Forbes (Hwy 7 Bridge)	- 1.0 g/yr	-0.05%	< 0.05 ng/L	ND
Total Project (Plant Site + Mine Site)	< 1.3 ng/L	St. Louis River EP-2, Cloquet (Hwy 33 Bridge)	- 1.0 g/yr	-0.01%	< 0.05 ng/L	ND

(From Barr Eng. 2015.)

[1] "Long-term closure" is defined as being the time period when the West Pit has filled with water and the WWTF is discharging water to the outlet channel to the Upper Partridge River. This will likely occur during the post-closure maintenance period of reclamation.

[2] Lake Superior Basin water quality standard = 1.3 ng/L

[3] Given the variability of total mercury concentrations and the current analytical method (USEPA Method 1631E), it is unlikely that any of the estimated potential changes in concentration would be statistically significant or detectable from existing conditions. Therefore, "Non-Detect", ND, is used in this column.

### 4.3.3 Potential Mercury Load from the Mine Site to the Upper Partridge River

In order to assess whether discharges from the Project's WWTF in long-term closure will meet the Lake Superior Basin's 1.3 ng/L discharge standard, the potential mercury concentration in the West Pit lake at the Mine Site was analyzed using a spreadsheet-based mass balance model. This estimation method was preferred over a detailed mechanistic model because it incorporated the important input and removal processes for mercury, it was transparent with regard to data inputs and it allowed for easy assessment of the effects of changing parameter values on mercury concentrations. The proposed approach and data inputs were presented in a work plan to MDNR and MPCA technical staff. Based on the agreed upon approach and inputs, Barr completed the Mine Site mercury analysis, which was submitted to the MDNR and MPCA. MDNR and MPCA provided written and oral comments in January and February of 2013. Key assumptions addressed in the agency dialog included the wet and dry mercury deposition rates and the estimated rate of mercury burial and evasion in the West Pit lake. After the analysis was revised to address these comments, the MDNR and MPCA provided notice of final acceptance in March of 2013. The details

of the assessment were included as a part of the Mine Site Water Modeling Data Package (Version 12).<sup>156</sup> The same approach and methodology for the mass balance assessment was used in Version 13 submitted in December 2014.<sup>157</sup>

Based on conservative assumptions, the mass balance analysis estimated the average mercury concentration of the West Pit during flooding (Mine Year 20 to about Mine Year 55) to be about 0.3 ng/L. At the time of overflow, the mercury concentration was estimated to be about 0.5 ng/L, which then reached an equilibrium concentration near 0.9 ng/L. Overall, the Mine Site permitted discharge is expected to meet the applicable water quality standard of 1.3 ng/L.<sup>158</sup> The assessment also indicates a potential small decrease in mercury loading to the upper Partridge River (decrease of 1.4 grams per year, about a 0.9% decrease from existing conditions) (Table 4-4).

The WWTF will include a reverse osmosis treatment process that is expected to provide additional mercury removal if needed. The mercury mass balance did not account for any additional mercury removal by the WWTF, however, which adds a level of overestimation to the potential mercury concentration in water discharged from the West Pit.

Overall, the screening analysis indicates that the potential change in mercury loading to the upper Partridge River is likely to be less than current background loading and is interpreted to be non-degradation of the existing surface waters.

#### **4.3.4 Potential Mercury Load from the Project to the St. Louis River**

A mercury loading assessment to estimate the potential effects of the Project on the average annual concentration of total mercury in the lower St. Louis River was conducted. This analysis compared pre-Project (Existing Conditions) to post-Project (long-term closure) mercury concentrations and loading, taking into account Project discharges as well as changes to the watershed flows and mercury concentrations resulting from the Project. The analysis conservatively did not account for mercury loss mechanisms in the watershed, instead assuming that all mercury discharged from the Project was delivered to the evaluation points in the St. Louis River (Forbes, Highway 7 bridge; Cloquet, Highway 33 bridge). The mercury loading analysis was submitted to the MDNR and MPCA as a stand-alone technical memorandum. MDNR and MPCA staff provided written and oral comments in February 2013. Key assumptions addressed in the agency dialog included the background concentration and flow data. After the analysis was revised to address these comments, the MDNR and MPCA provided notice of final acceptance in February of 2013.

Results indicate that under existing conditions, and assuming the Project discharge water is delivered to an Evaluation Point without evaporative or other losses, average annual flows from the Project area contribute approximately 2.7% of the flow in the lower St. Louis River at Evaluation Point 1 (Forbes) and approximately 0.6 % at Evaluation Point 2 (Cloquet). The effect of the Project in long-term closure is

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<sup>156</sup> PolyMet 2013a.

<sup>157</sup> PolyMet 2014a.

<sup>158</sup> Barr 2015.

estimated to slightly decrease average annual flow from the Project area, which is expected because of evaporative losses associated with the Plant Site and Mine Site water treatment plants.

With the Project in long-term closure, there is an estimated slight decrease in average annual mercury loading (-1.0 g/yr) (Table 4-4).<sup>159</sup> This estimated small change in loading is not expected to result in a detectable change in total mercury concentrations at the Evaluation Points given the variability in concentrations and the current laboratory analytical method ((USEPA Method 1631E). Overall, the Project is not reasonably expected to increase loading of mercury nor have any measurable effect on total mercury concentrations in the St. Louis River.

#### **4.3.5 Uncertainty Analysis: Potential Additional Mercury Deposition to the Embarrass River and Partridge River from Project Air Emissions**

The screening non-degradation analysis of potential point source discharges of mercury to receiving waters, as described in the Estimate of Mercury Loading to the Lower St. Louis River Technical Memorandum,<sup>160</sup> followed MPCA guidance and recommendations. It served the dual purpose of providing an impact assessment for the SDEIS, and of informing the future NPDES permitting process. Thus, it did not include atmospheric deposition related to the Project's estimated mercury air emissions.

Because of the planned reuse/recycle water management plan, during mining operations (Mine Years 1 to 20), no treated water is expected to be discharged from the Mine Site, and treated water is expected to be discharged from the Plant Site WWTP to augment flow in tributaries at rates slightly lower than current flow. As a result, during active mining, the majority of potential inputs of mercury to the upper Embarrass River or the upper Partridge River watersheds from the Project will be from the potential deposition of the Project's air emissions. After mining operations end, at the end of Mine Year 20, there will be no air emissions from ore processing. Therefore, the screening non-degradation analyses for long-term closure were technically correct as submitted (i.e., they did not include the Project's mercury air emissions).<sup>161</sup>

However, as a conservative approach, the following screening analysis of Project mercury loading to the upper Embarrass River and the upper Partridge River in long-term closure includes potential local deposition of the Project's air emissions even though no air emissions from ore processing will occur during this period.

##### **4.3.5.1 Calculation Approach for Estimating Potential Additional Mercury from Deposition of the Project's Air Emissions**

The potential local deposition of the Project's mercury air emissions to the upper Embarrass River and the upper Partridge River were calculated for two emission scenarios and the respective mercury species deposition velocity over the estimated water surface area for the two water bodies. The two air emission

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<sup>159</sup> *Id.*

<sup>160</sup> Barr 2013c; 2015.

<sup>161</sup> PolyMet 2013a, 2014a; 2013b, 2015a; 2013c, 2015d.

scenarios and the respective mercury deposition velocities are consistent with the local deposition analysis conducted for the Plant Site<sup>162</sup> and the cumulative mercury deposition analysis.<sup>163</sup>

Two Project air emission scenarios were evaluated for potential mercury deposition:<sup>164</sup>

- Scenario 1: 25% elemental mercury; 50% oxidized mercury; 25% particle bound mercury
- Scenario 2: 80% elemental mercury; 10% oxidized mercury; 10% particle bound mercury

The first emissions scenario is more conservative due to the higher percent of oxidized mercury which has the highest potential to deposit locally.<sup>165</sup> The oxidized mercury deposition velocity is two orders of magnitude (1.10 cm/sec) larger than elemental and particulate bound, 0.01 cm/sec and 0.05 cm/sec, respectively.<sup>166</sup> Scenario 2 is considered to be a conservative but more likely mercury speciation for the air emissions associated with the Project given the two-staged scrubbing system proposed for the autoclave.

The calculation approach to estimate potential Project-related mercury deposition for this analysis deviates from the MPCA's guidance<sup>167</sup> and follows the work of Harris et al.<sup>168</sup> As described by Harris et al., their 3-year mercury study added high mercury doses to a lake and watershed and the findings indicate that *"essentially all of the increase in fish methylmercury concentrations came from mercury deposited directly to the lake surface. In contrast, <1% of the mercury isotope deposited to the watershed was exported to the lake."*<sup>169</sup> Therefore, the estimates of potential additional mercury to the Embarrass River and the Partridge River from the potential deposition of the Project's air emissions are based on the findings from Harris et al. that only "new" mercury deposited directly to the water surface will show up in the water and any "new" mercury deposited to the terrestrial watershed will be retained in the watershed.<sup>170</sup>

The surface area of open water for each river was calculated using an estimate of the upstream river miles and the average river width estimated for multiple points along the river. For the Partridge River, upstream river miles (upstream of monitoring location SW004) were estimated using the National Hydrography dataset flow lines (56 miles), and the average river width at sites SW004b, SW003, and SW002 (43.3 feet). The estimated upstream river length of 56 miles includes upstream tributaries. The average stream width was then applied to the 56 mile stream length and the calculation resulted in an estimate of 294 acres of river surface water area.

For the Embarrass River, upstream river miles (upstream of monitoring location PM13) were also estimated using the National Hydrography dataset flow lines (78 miles) and the average river width at

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<sup>162</sup> Barr 2013a.

<sup>163</sup> Barr 2012b.

<sup>164</sup> Barr 2012b; Barr 2013a.

<sup>165</sup> MPCA 2006a.

<sup>166</sup> *Id.*

<sup>167</sup> *Id.*

<sup>168</sup> Harris *et al.* (2007).

<sup>169</sup> *Id.*

<sup>170</sup> *Id.*

PM13 and PM12 (30.5 feet). The estimated upstream river length of 78 miles includes the upstream tributaries. The river width at PM13 and PM12 were estimated using 2013 aerial photos and the MDNR's 2010 2-ft LiDAR data. The average river width of the main river (average of widths estimated at PM13 and PM12) is conservatively applied to upstream tributaries and the calculations resulted in an estimate of 288 acres of river surface water area.

#### 4.3.5.2 Project's Estimated Potential Total Loading of Mercury (Surface Water Discharge and Atmospheric Deposition)

As previously identified, the potential loading of mercury to the upper Partridge River and the upper Embarrass River as a result of the Project in closure is from point source discharges to surface water from the Plant Site WWTP and the Mine Site WWTF. During active mining operations (Mine Years 1 to 20), the potential mercury loading to the two rivers is from potential deposition of the Project's air emissions from the Hydrometallurgical Plant (air emissions of about 4.6 pounds/year). By combining these two separate operating scenarios into one, a conservative estimate of potential loading to the upper Embarrass River and the upper Partridge River is created.

As previously reported,<sup>171</sup> the Project in closure is estimated to potentially increase mercury loading to the upper Embarrass River by about 0.2 grams per year, with a potential change in mercury concentration of approximately 0.05 ng/L. For the upper Partridge River, the Project in closure is estimated to potentially decrease mercury loading by about 1.4 grams per year, with a potential reduction in mercury concentration of less than 0.05 ng/L.<sup>172</sup> As shown in Table 4-5 and Table 4-6, under the assumption that wastewater discharges and air emissions from hydrometallurgical operations occur at the same time, the additional potential loading to each river from the Project's air emissions is small, ranging from about 0.02 to 0.1 grams per year. For both rivers, the potential increase in loading due to atmospheric deposition is very small, and no change in the surface water total mercury concentration of either river is expected to change.

As shown in Table 4-5, the estimated potential atmospheric deposition loading of new mercury to the upper Partridge River due to the Project air emissions represents a small portion (0.02% to 0.09%) of the measured background total mercury loading rate. Overall, when conservatively accounting for both potential deposition of Project mercury air emissions and discharges to surface water, there is a potential decrease in loading to the upper Partridge River from existing conditions. This potential change is not expected to be statistically significant or measureable given the variability in mercury loading and surface water concentrations that occur in the river and does not constitute degradation of the receiving water.

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<sup>171</sup> Barr 2013c; 2015.

<sup>172</sup> *Id.*

**Table 4-5 Background and Estimated Potential Change in Mercury Loading to the Upper Partridge River from Project Surface Water Discharges and Potential Deposition of Plant Site Air Emissions**

Emissions Scenario	Background <sup>[1]</sup>		Project <sup>[2]</sup>				Estimated Potential Change in Total Mercury Loading as a % of Background
	Total Mercury Loading Rate <sup>[5]</sup> (g/yr)	Total Mercury Conc. (SW004) (ng/L)	Estimated Potential Atmospheric Deposition Rate <sup>[6]</sup> (to surface water) (g/yr)	Potential Change in Mercury Loading Rate From Water Discharges due to Mine Site in Long-term Closure <sup>[7]</sup> (g/yr)	Potential Total Change in Mercury Loading Rate <sup>[8]</sup> (g/yr)	Potential Change in Total Mercury Conc. (ng/L)	
Scenario 1 <sup>[3]</sup>	150	3.6	0.13	-1.4	-1.27	< 0.05	-0.85%
Scenario 2 <sup>[4]</sup>	150	3.6	0.04	-1.4	-1.36	< 0.05	-0.91%

- [1] Background represents the existing background mercury loading without influence from the Project.
- [2] Project represents the mercury loading as a result of the Project (air emissions from ore processing and discharges to surface water during long-term closure).
- [3] Emissions Scenario 1: speciation of air concentrations = 50% oxidized, 25% elemental, and 25% particulate bound.
- [4] Emissions Scenario 2: speciation of air concentrations = 14% oxidized, 77% elemental, and 10% particulate bound.
- [5] The background (existing conditions) mercury loading value to the river is from Large Table 4 of the January 2015 Barr Engineering Technical Memorandum (Barr 2015).
- [6] The atmospheric deposition rate due to the Project was determined using a deposition velocity for each mercury species (from MPCA 2006a), the modeled ambient mercury concentration due to the Project for the annual averaging time for the Colby Lake watershed (Barr 2013a), and the surface area of the Partridge River upstream of monitoring location SW004b. The surface area of the Partridge River upstream of monitoring location SW004b was calculated by the following equation:  
 Surface area of open water (acres) = (river length (feet) x width (feet)) / 43,560 ft<sup>2</sup> per acre  
 River length in miles upstream of monitoring location site SW004b was estimated using the National Hydrography dataset flow lines (56 miles) and includes tributary streams. The average river width at sites SW004b, SW003, and SW002 was estimated using 2013 aerial photos and the MDNR's 2010 2-ft LiDAR data (average width = 43.3 feet) and conservatively applied to the entire 56 miles of river upstream of monitoring location SW004b.
- [7] The potential change in mercury loading due to the Mine Site in long-term closure is from the last row in Large Table 4 of the January 2015 Barr Engineering Technical Memorandum (Barr 2015).  
 Potential Change = ((Adjusted Evaluation Point + Project) – Existing Evaluation Point)
- [8] Calculated as the sum of the Project's potential atmospheric deposition to surface area of the river (an increase) and potential change in mercury loading to the river due to the Mine Site in long-term closure.

As shown in Table 4-6, the estimated potential atmospheric deposition loading of new mercury to the upper Embarrass River due to the Project air emissions represents a small portion (0.009% to 0.03%) of the measured background total mercury loading rate. Overall, when conservatively accounting for both potential deposition of Project mercury air emissions and discharges to surface water, there is a potential small increase in loading to the upper Embarrass River from existing conditions. This potential change is insignificant when compared to background total mercury loading rate (potential change of 0.12% and 0.10%). This potential change is not expected to be statistically significant or measureable given the variability in mercury loading and surface water concentrations that occur in the river and does not constitute degradation of the receiving water.

**Table 4-6 Background and Estimated Potential Change in Mercury Loading to the Upper Embarrass River from Project Surface Water Discharges and Potential Deposition of Plant Site Air Emissions**

Emissions Scenario	Background <sup>[1]</sup>		Project <sup>[2]</sup>				Estimated Potential Change in Total Mercury Loading Rate as a % of Background
	Total Mercury Loading Rate <sup>[5]</sup> (g/yr)	Total Mercury Conc. (PM13) (ng/L)	Estimated Potential Atmospheric Deposition Rate <sup>[6]</sup> (to surface water) (g/yr)	Potential Change in Mercury Loading Rate From Water Discharges Due To Plant Site in Long-term Closure <sup>[7]</sup> (g/yr)	Potential Total Change in Mercury Loading Rate <sup>[8]</sup> (g/yr)	Potential Change in Total Mercury Conc. (ng/L)	
Scenario 1 <sup>[3]</sup>	230	3.1	0.08	0.2	0.28	0.05	0.12%
Scenario 2 <sup>[4]</sup>	230	3.1	0.02	0.2	0.22	0.05	0.10%

- [1] Background represents the existing mercury loading to the stream without influence from the Project.
- [2] Project represents the mercury loading to the surface area of the river as a result of the Project (air emissions from ore processing and discharges to surface water during long-term closure).
- [3] Emissions Scenario 1, speciation of air concentration = 50% oxidized, 25% elemental, and 25% particulate bound.
- [4] Emissions Scenario 2, speciation of air concentration = 14% oxidized, 77% elemental, and 10% particulate bound.
- [5] The background (existing conditions) mercury loading value to the river is from Large Table 6 of the January 2015 Barr Engineering Technical Memorandum (Barr 2015).
- [6] The atmospheric deposition rate due to the Project was determined using a deposition velocity for each mercury species (MPCA 2006a), the modeled ambient air mercury concentration due to the Project for the annual averaging time period for the Sabin Lake watershed (Barr 2013a), and the surface area of the Embarrass River upstream of monitoring location PM13. The surface area of the Embarrass River upstream from monitoring location PM13 was calculated by the following equation:  

$$\text{Surface area (acres)} = (\text{river length (feet)} \times \text{width (feet)}) / 43,560 \text{ ft}^2 \text{ per acre}$$
 River miles upstream of monitoring location PM13 were estimated using the National Hydrography dataset flow lines (river miles = 78 miles). The 78 miles of river upstream of monitoring location PM13 includes tributary streams. The average river width at monitoring locations PM13 and PM12 was estimated using 2013 aerial photos and the MDNR's 2010 2-ft LiDAR data (average width = 30.5 feet) and conservatively applied to the entire 78 miles of river upstream of monitoring location PM13.
- [7] The potential change in mercury loading due to the Plant Site in long-term closure is from the last row of Large Table 6 of the January 2015 Barr Engineering Technical Memorandum (Barr 2015).  

$$\text{Potential change} = ((\text{Adjusted Evaluation Point} + \text{Project}) - \text{Existing Evaluation Point})$$
- [8] Calculated as the sum of the Project's potential atmospheric deposition to the surface area of the river (an increase) and potential change in mercury loading due to the Plant Site in long-term closure.

## 5.0 Control Measures for Mercury

### 5.1 Air Emissions Control Technology

As early as 2004, in preparation for the Scoping EAW (May 2005) and the draft EIS, PolyMet began its evaluation of the Project air and wastewater discharges in relation to a potential statewide mercury TMDL and a potential TMDL for the St. Louis River watershed. Discussions with the MPCA and other co-lead agencies were initiated in 2007, and then discussions continued with the Air Impact Assessment Planning (IAP) work group and have continued to the current time period. Members of the IAP work group included the Tribes and USEPA Region 5 staff. An initial work plan was developed in May 2011 for IAP work group review and comment. Discussions on mercury air emissions and potential impacts were discussed with the co-lead agencies and contributing agencies through the IAP process.

Because the Plant Site will have annual emissions of approximately 4.6 pounds of total Hg, a control technology review was conducted.<sup>173</sup> The evaluation focused on the Plant Site where the majority of the emissions are expected to occur. Less than 1 pound/year of mercury is estimated to be emitted from the Mine Site related to diesel fuel combustion and particle-bound mercury as fugitive dust that will be controlled with an approved fugitive emission control plan.

The proposed mercury control system for the autoclave vents is a two stage scrubber system; a venturi scrubber is used for a first stage scrubber and a packed bed scrubber as the second stage. The venturi scrubber uses the autoclave exhaust pressure to enhance particulate control and the packed bed scrubber is the most effective method of removing gaseous pollutants. The control technology assessment information has been incorporated into the SDEIS. As stated in the SDEIS:

*The NorthMet Project Proposed Action selected a two-stage mercury control system that is expected to achieve 25 percent control for elemental mercury and 90 percent control for particle bound and oxidized mercury (Barr 2012r). Because the total mercury control is less than 90 percent, PolyMet moved forward with the remaining TMDL requirement. In addition, PolyMet has conducted a cumulative effects analysis on the local mercury deposition and bioaccumulation in fish (Barr 2012b) and the assessment of the cumulative effects is provided in Section 6.7.5. MPCA has conducted a review of the NorthMet Project Proposed Action mercury emissions and has determined that it will not impede the reduction goals (MPCA 2013b). Thus, no minimization and mitigation plan will be required for the NorthMet Project Proposed Action.<sup>174</sup>*

### 5.2 Water Discharges (wastewater treatment)

Both the WWTP at the Plant Site and the WWTF at the Mine Site will use greensand filtration followed by reverse osmosis (RO) or similar membrane technology. Membrane treatment systems are known to remove mercury, particularly when an RO system is preceded by pretreatment. Specific removal

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<sup>173</sup> Barr 2012a.

<sup>174</sup> SDEIS Section 5.2.7.2.5, P. 5-432.

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efficiencies when treating waters with low concentrations of mercury (i.e., concentrations less than 1.3 ng/L) are not yet well established in practice, although a recent evaluation<sup>175</sup> indicates that RO with pretreatment is capable of controlling mercury to meet the 1.3 ng/L limit. Additional mercury removal may occur by interactions of FTB pond water with tailings. Therefore, in the event that mercury concentrations in WWTP or WWTF influent flows exceed projections, it is likely that the WWTF and WWTP will effectively reduce mercury concentration below the 1.3 ng/L water quality standard. Monitoring of the WWTF and WWTP waters for constituents, including total mercury, will determine whether the treated water can be discharged to surface waters or whether additional treatment is needed.

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<sup>175</sup> Urgan-Demirtas et al., *Achieving very low mercury levels in refinery wastewater by membrane filtration*, Journal of Hazardous Materials, Vols. 215-216 (2009).

## 6.0 Summary and Conclusions

A total facility mass balance evaluation of the Project indicates that most of the mercury input to the process will be sent to the FTB and the HRF and sequestered from the general environment. There will be a small amount of mercury released to air (approximately 4.6 pounds/year) and to surface water. Baseline data collection and evaluations<sup>176</sup> of the potential effects from mercury and/or sulfate releases from the proposed facility were performed using standard screening tools and following MPCA guidance, and reflect MPCA, MDNR and Tribal input. These evaluations indicate the following:

### Related to Air Emissions

- The potential local deposition of mercury from the Project's air emissions is estimated to be small, with potential changes in fish mercury concentrations not likely to be measureable (Table 4-1) and changes to existing fish consumption advisories or existing risks to consumers of fish from lakes near the Project not reasonably foreseen (Table 4-2).
- The potential cumulative local deposition of mercury emitted to air from the Project and the Mesabi Nugget LSDP is also estimated to be small, with potential changes in fish mercury concentrations not likely to be measureable (Table 4-3) and changes to existing fish consumption advisories or existing risks to consumers of fish from lakes near the Project not reasonably foreseen.
- The potential additional sulfur that might be added from Plant Site stack air emissions is estimated to be negligible (Section 4.2.3.5) and likely not statistically measurable when compared to the variability in background conditions: it is not expected to have any effect on mercury methylation or fish mercury concentrations.
- The potential deposition of fugitive dust to wetlands and the potential release of sulfur is uncertain given the fugitive dust control plan for the both the Mine Site and the Plant Site (including the FTB) and the potential weathering of sulfur from the rock dust particles. Under a reasonably conservative assumption that some of the sulfide in the dust particles will be released and transformed to sulfate, the estimated additional sulfate is small compared to background (incremental sulfate of 0.07 mg/L to 0.26 mg/L; background ranges from 1 to 3 mg/L; Section 4.2.3.5). Under a conservative worst-case assumption that all sulfur in the deposited dust is released and transformed to sulfate (incremental sulfate ~ 4.2 mg/L), no statistically measurable increase in methylmercury concentrations is expected because available data indicates methylation is relatively insensitive to sulfate additions in the range likely to be experienced (incremental change < 1 to 4 mg/L).<sup>177</sup>

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<sup>176</sup> Barr 2010.

<sup>177</sup> Benoit *et al* 1999; Barr 2008a; Barr 2010.

- When considering the potential indirect effects of sulfate on atmospherically deposited mercury from the Project, potential downstream effects from sulfate in discharge water are not reasonably expected because the Project will result in a 45% reduction in sulfate loading to the Embarrass River at monitoring site PM13 and only about a 0.1% increase in sulfate loading to the upper Partridge River (Section 4.2.3.4). In both cases, Project-related sulfur in water discharges is not reasonably expected to have any effect on mercury in aquatic environments, either immediately adjacent to the Project or in downstream areas.

#### Related to Permitted Discharges to Surface Water

- A screening non-degradation analysis for permitted discharges was conducted (Section 4.3).
  - At the Mine Site, the discharge water from the West Pit lake after closure is estimated to have mercury concentrations less than 1.3 ng/L and mass balance calculations indicate an overall small reduction in mercury loading to the upper Partridge River (-1.4 g/yr; -0.9% decrease from current conditions) but no measurable decrease in mercury concentrations (Table 4-4).
  - At the Plant Site, the discharge water from the WWTP is estimated to meet a mercury concentration of 1.3 ng/L and mass balance calculations indicate an overall small increase in mercury loading to the Embarrass River (+ 0.2 g/yr; 0.1% increase), but no measurable increase in mercury concentrations (Table 4-4).
  - In the St. Louis River, assuming the Project discharge occurs at Forbes, and also at Cloquet, the Project is estimated to result in a reduced load of mercury to these respective evaluation points (- 1.0 g/yr; about a -0.01% to -0.05% change), but with no measurable decrease in total mercury concentrations (Table 4-4).
- When considering the potential additional mercury deposited to the respective rivers from Project air emissions in addition to the mercury in permitted water discharges (i.e., the potential cumulative load of mercury from the Project), the potential additional mercury load that might be added to the Embarrass River and the Partridge River from Plant Site air emissions is estimated to be negligible (Table 4-5, Table 4-6), is not expected to be statistically measurable when compared to the variability in background mercury concentrations, and is not expected to have any effect on the loading estimates for the Embarrass River, Partridge River, or the lower St. Louis River.
- Overall, the screening results indicate the potential loading of mercury to the receiving waters meets the definition of non-degradation.

Based on the evaluations conducted for air emissions and water discharges, the Project is not reasonably foreseen to have any effects on surface water mercury concentrations, fish mercury concentrations, methylation of mercury, or any potential additional risk to people consuming fish from lakes near the Project.

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## Appendices

## **Appendix A**

### **Sulfur and Mercury Methylation**

## **Appendix A Sulfur and Mercury Methylation**

### **Additional Discussion on the Potential for Project-Related Sulfur to Affect Mercury Methylation and Bioaccumulation in Fish**

#### **Overview of Assessments and Studies Conducted for the NorthMet Project**

During development of the Draft EIS in 2007 and 2008, the co-lead agencies identified an information gap with regard to the MPCA's guidance<sup>178</sup> on the discharge of sulfate to sensitive systems such as wetlands and downstream lakes and the potential effect of the NorthMet Project's discharge of sulfate to the small streams just north of the Tailings Basin. PolyMet provided an initial assessment of the potential for the NorthMet project's discharge of sulfate to surface waters to affect methylmercury concentrations.<sup>179</sup> This initial assessment of sulfate, total mercury and methylmercury concentrations in surface water (lakes and streams) using baseline monitoring data from the Minnesota Steel Industries project near Nashwauk on the west end of the Iron Range, the NorthMet Project and the Franconia project (near Birch Lake) indicated that it was unlikely that sulfate from the NorthMet Project would have any measurable effect on methylmercury concentrations in the upper Embarrass River, upper Partridge River or the headwaters of Second Creek, respectively.

An additional qualitative evaluation of fish mercury concentrations was also provided to the MDNR and the MPCA.<sup>180</sup> This screening evaluation indicates that fish mercury concentrations in low sulfate non-mining surface waters of northeast Minnesota are similar to fish mercury concentrations in the Embarrass River chain of lakes downstream of the Plant Site and that sulfate concentration in surface water is not a predictor or an indicator of fish mercury concentrations.<sup>181</sup> The conclusion was that sulfate concentrations in the Embarrass River and in the chain of lakes downstream of the Plant Site was not the cause of elevated fish mercury concentrations as remote lakes in the BWCAW and Voyageurs National Park had equivalent and sometimes higher fish mercury concentrations than did the chain of lakes. Because the information presented in the two technical memoranda<sup>182</sup> were different from the MPCA/MDNR paradigm on the relationship of sulfate and methylmercury, and because of the importance of the mercury issue to the overall environmental review and permitting processes, discussions with MPCA/MDNR staff and the EIS consultant (ERM) on sulfate and methylmercury continued through spring of 2009.

#### **Baseline Study for Sulfate and Methylmercury – Wetlands North of Tailings Basin**

In the early spring of 2009 the conclusion of the co-lead agencies was that additional information on sulfate and methylmercury in the small streams to the north of the Tailings Basin and the lakes downstream of the Tailings Basin was needed. Discussions were held with the MPCA and MDNR staff in May 2009 on the scope of the work, including study design, sample collection and laboratory analytical

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<sup>178</sup> MPCA 2006b.

<sup>179</sup> Barr 2008a.

<sup>180</sup> Barr 2008b.

<sup>181</sup> Barr 2008b.

<sup>182</sup> Barr 2008a; Barr 2008b.

methods, and reporting. A work plan was developed by Barr Engineering, reviewed by the MPCA and MDNR staff and finalized in early June 2009. Field work was initiated in June 2009. A conference call was held with the Tribes in August 2009 and a revised work plan was developed to address the Tribe's comments and interests. The revised work plan (August 2009) was followed for the remainder of the study. In early November 2009, MPCA, MDNR and Tribal staff toured the monitoring sites and provided additional technical input. Field work was completed in early November 2009.

A technical memorandum on the findings of the 2009 stream and lake study was prepared and submitted to the MPCA and MDNR for review in February 2010. The draft report identified the following for the current loading of sulfate from the Tailings Basin (summarized in Table A-1)

- Methylmercury concentrations in the streams draining the wetlands north of the Tailings Basin receiving elevated levels of sulfate were not statistically different from methylmercury concentrations in background streams.
- Methylmercury concentrations in the downstream lakes, Sabin and Wynne, reflected upstream methylmercury concentrations and there was no increase in methylmercury with depth in either lake indicating that in-lake methylation was not important.
  - Sabin Lake acts as a settling basin for methylmercury; methylmercury is lost to the sediment (i.e., loss of mercury to the sediment with subsequent burial) and methylmercury concentrations in Wynne Lake, downstream of Sabin, were less than the methylmercury concentrations in Sabin Lake.
- Overall, sulfate in the seepage/discharge water from the Tailings Basin was determined to not have a measurable effect on the methylmercury concentrations in the small streams to the north of the Tailings Basin or in the downstream lakes (Sabin, Wynne).
- In this case, the wetlands to the north of the Tailings Basin and the lakes downstream of the Plant Site are not sensitive systems with regard to sulfate additions.
- Based on the findings from the 2009 stream and lake study, and noting that the Tailings Basin has been a watershed feature for some 40+ years, it is unlikely that continued operation of the Tailings Basin by PolyMet will have an effect on the sulfate and methylmercury dynamics in the Embarrass River watershed.

A meeting was held with MPCA and MDNR staff to discuss the findings of the stream and lake study. Agency comments were incorporated into the final technical memorandum. The final technical memorandum was submitted to the MPCA in April 2010. This April 2010 Technical Memorandum, as well as the other mercury-related assessments listed at the beginning of this document, were forwarded to USEPA Region 5 staff as a follow-up to their comments on the DEIS. These collective reports continue as the support base for the SDEIS.

As currently stated in the SDEIS, the NorthMet Project will reduce the sulfate loading to the small streams to the north of the Tailings Basin, the Embarrass River and the downstream lakes. It is uncertain whether

this reduction in sulfate discharge from the Tailings Basin will reduce methylmercury concentrations. However, the NorthMet Project is not expected to increase methylmercury concentrations in any of the receiving waters and is in compliance with MPCA's guidance<sup>183</sup> on the discharge of sulfate to sensitive ecosystems.

**Table A-1 Summary of 2009 Baseline Methylmercury and Sulfate Concentrations in Background and Mining Influenced Wetland Streams in the Embarrass River Watershed and in Lakes (Sabin and Wynne) Downstream of the Tailings Basin Discharge**

Surface Water Monitoring Site	Average Methylmercury Concentration <sup>[2]</sup> (ng/L)	Methylmercury as a % of Total Mercury <sup>[2]</sup> (average)	Average Sulfate Conc. <sup>[2]</sup> (mg/L)	Findings Related to Methylmercury Concentrations <sup>[3]</sup>
Background – Embarrass River (site PM12) <sup>1</sup>	0.72	20%	1.1	PM12 significantly higher than PM11 and PM19
Background – Bear Creek (site PM20)	0.29	13%	1.3	PM20 not significantly different from PM11 or PM19
Mining influenced – Unnamed Creek (site PM11)	0.20	14%	152	PM11 significantly lower than PM12; not significantly different from PM20
Mining influenced – Trimble Creek (site PM19)	0.35	20%	17.6	PM19 significantly lower than PM12; not significantly different from PM20
Downstream – Embarrass River (site PM13) <sup>1</sup>	0.41	14%	38.4	PM13 not significantly different from PM12
Downstream – Sabin Lake (site PM21)	0.23	7.6%	25.0	Concentrations similar to Embarrass R.; no increase in concentration with depth
Downstream – Wynne Lake (site PM22) <sup>1</sup>	0.21	6.7%	22.8	Concentrations similar to Embarrass R.; no increase in concentration with depth

From: Barr Eng. 2010.

[1] Sites PM12, PM13, PM21 and PM22 represent a transect analysis from background (upstream at site PM12) to downstream of the tailings basin discharge area at site PM13 to Wynne Lake at site PM22.

[2] For streams, methylmercury concentration, methylmercury as a percent of total mercury and sulfate concentration obtained from Barr Eng. 2010, Table 3; for lakes, the data obtained from Table 5.

[3] Summary of statistical findings from Barr Eng. 2010, Table 2.

<sup>183</sup> MPCA 2006b.

## **Appendix B**

### **Potential Sulfur Deposition from Project Air Emissions (calculations)**

Lake BAF Estimates

NorthMet Project

12-Aug-14

Calculating Bioaccumulation Factors (BAF) for Lakes

Formula: BAF = Tissue Concentration (ppm) / Water column concentration (ppm)

EXISTING CONDITIONS

POTENTIAL CHANGE DUE TO PROJECT

Lake	Average Mercury fish Conc. (ppm)	Mercury (total)		BAF - Current rounded	Emissions Scenario	MMREM results; change in fish Hg Concentration (ppm)	Adjusted Fish Hg Concentration	Potential Change in BAF (assume no change in Hg surface water conc. )	
		Average Mercury (total) Water Column Conc. (ng/L) = ppm	Water Column Conc. (mg/L) (mg/L)					no change in Hg surface water conc. )	% Change in BAF
Colby	0.93	5.4	0.0000054	172,222	172,200 #1	0.01	0.94	174,074	1.1%
	0.93				#2	0.003	0.93	172,778	0.3%
	0.93				Ave	0.006	0.94	173,333	0.6%
Embarrass	0.93	3.1	0.0000031	300,000	300,000 #1				
					#2				
					Ave				
Esquagama	1.2	3.1	0.0000031	387,097	387,100 #1				
					#2				
					Ave				
Heikkillla	0.65	2.1	0.0000021	309,524	309,500 #1	0.01	0.66	314,286	1.5%
	0.65				#2	0.003	0.65	310,952	0.5%
	0.65				Ave	0.006	0.66	312,381	0.9%
Sabin	1.02	3.1	0.0000031	329,032	329,000 #1	0.012	1.03	332,903	1.2%
	1.02				#2	0.003	1.02	330,000	0.3%
	1.02				Ave	0.007	1.03	331,290	0.7%
Whitewater	0.35	2.1	0.0000021	166,667	166,700 #1	0.002	0.35	167,619	0.6%
	0.35				#2	0.0006	0.35	166,952	0.2%
	0.35				Ave	0.001	0.35	167,143	0.3%
Wynne	1.34	3.1	0.0000031	432,258	432,300 #1	0.016	1.36	437,419	1.2%
	1.34				#2	0.004	1.34	433,548	0.3%
	1.35				Ave	0.01	1.36	438,710	1.5%

Water column Hg concentration for Embarrass and Esquagama Lakes assumed to be represented by the average Hg (total) concentration in Sabin and Wynne Lakes (Embarrass River chain of lakes).

Water column Hg concentration for Heikkillla and Whitewater Lakes assumed to be represented by the average Hg (total) concentration for lakes in Voyageur Nat. Park. (Goldstein et al. 2003). (from Barr 2008, Appendix C, Table 1b)

H2SO4 dep to surface water

NorthMet Project

12-Aug-14

Calculating Potential Sulfur Deposition from Sulfuric Acid Mist (as H2SO4) Air Concentration

Potential Surface Water Conc. (mg/L)

S (mg/L) = Dep x mg/g x m2/ha x ha/acre x acres/ft2 x 1/mix zone in ft x ft3/Liter  
 SO4 (mg/L) = S/0.33

PARTRIDGE RIVER				<i>Estimated Potential Surface Water Concentration (Colby Lake)</i>	
Modeled H2SO4 air conc. <sup>[1]</sup>	Modeled S air con.	Dep Vel. <sup>[2]</sup>	Deposition	S (mg/L) =	0.0017
0.122662609 ug/m3		0.04 cm/sec		SO4 (mg/L) =	0.0050
1.22663E-07 g/m3	4.00531E-08 g/m3	0.0004 m/sec	0.0005 (grams/m2/yr)		
<b>Unit Conversions</b>				Information for calculating potential surface water conc.	
milligram to microgam	1000 1 mg = 1000 ug			1 hectare =	2.47 acres
gram to milligram	1000 1 g = 1000 mg			1 hectare =	10000 square meters
kilogram to gram	1000 1 kg = 1000 g			1 acre =	43560 square ft
				1 ft3 =	28.31625 liters
meters to centimeter	100 1 m = 100 cm			Colby Lake	502 acres
centimeters to meters	0.01 1 cm = 0.01 m			Mixing layer	1 ft (approximates the surface layer)
					Littoral zone (15 ft depth) = max mix zone
					For Colby Lake, 377 acres of littoral zone)
					Max depth = 30 ft.
S from H2SO4 S =	32			S from SO4 S =	32
H2SO4=	98			SO2 =	96
S =	0.33			S =	0.33
seconds per year	31536000				

EMBARRASS RIVER				<i>Estimated Potential Surface Water Concentration (Sabin Lake)</i>	
Modeled H2SO4 air conc. <sup>[1]</sup>	Modeled S air con.	Dep Vel. <sup>[2]</sup>	Dep.	S (mg/L) =	0.0017
0.122662609 ug/m3		0.04 cm/sec		SO4 (mg/L) =	0.0050
1.22663E-07 g/m3	4.00531E-08 g/m3	0.0004 m/sec	0.0005 (grams/m2/yr)		
<b>Unit Conversions</b>				Information for calculating potential surface water conc.	
milligram to microgam	1000 1 mg = 1000 ug			1 hectare =	2.47 acres
gram to milligram	1000 1 g = 1000 mg			1 hectare =	10000 square meters
kilogram to gram	1000 1 kg = 1000 g			1 acre =	43560 square ft
				1 ft3 =	28.31625 liters
meters to centimeter	100 1 m = 100 cm			Sabin	299 acres
centimeters to meters	0.01 1 cm = 0.01 m			Mixing layer	1 ft (approximates the surface layer)
					Littoral zone (15 ft depth) = max mix Zone
					For Sabin Lake, 135 acres of littoral zone)
					Max Depth = 40 ft.
S from SO2 S =	32			S from SO4 S =	32
SO2 =	98			SO2 =	96
S =	0.33			S =	0.33
seconds per year	31536000				

[1] Barr Eng., 2007 AERA for the Plant Site: H2SO4 emissions = 11.5 tpy and air conc. = 0.281 ug/m3. 2012 AERA: H2SO4 emissions = 5.02 tpy

[2] average of SO4 deposition velocity over "swamp" as found in 0.04 cm/s  
 Xu and Carmichael, 1997 "Modeling the dry deposition velocity of sulfur dioxide and sulfate in Asia", J. of Ap. Meteorology Vol 37. p.1084

SO2 dep to surface water

NorthMet Project

4-Aug-14

Calculating Potential Sulfur Deposition from SO2 Emissions based on SO2 air concentrations

Potential Surface Water Conc. (mg/L)

S (mg/L) = Dep x mg/g x m2/ha x ha/acre x acres/ft2 x 1/mix zone in ft x ft3/Liter  
 SO4 (mg/L) = S/0.33

PARTRIDGE RIVER				Estimated Potential Surface Water Concentration (Colby Lake)		
<b>Modeled SO2 air conc. [1]</b>	Modeled S air con.	Dep Vel.	S Dep.	S (mg/L) =	0.0111	
0.0465 ug/m3		0.46 cm/sec		SO4 (mg/L) =	0.033	
4.65E-08 g/m3	2.325E-08 g/m3	0.0046 m/sec	0.003 (grams/m2/yr)			
<b>Unit Conversions</b>				Information for calculating potential surface water conc.		
milligram to microgam	1000 1 mg = 1000 ug			1 hectare =	2.47 acres	
gram to milligram	1000 1 g = 1000 mg			1 hectare =	10000 square meters	
kilogram to gram	1000 1 kg = 1000 g			1 acre =	43560 square ft	
				1 ft3 =	28.31625 liters	
meters to centimeter	100 1 m = 100 cm			Colby Lake	502 acres	
centimeters to meters	0.01 1 cm = 0.01 m			Mixing layer	1 ft (approximates the surface layer)	
					Littoral zone(15 ft depth) = max mix zone	
					For Colby Lake, 377 acres of littoral zone)	
					Max depth = 30 ft.	
S from SO2	S =	32		S from SO4	S =	32
	O2 =	32			O4 =	64
	SO2 =	64			SO2 =	96
	S =	0.50			S =	0.33
seconds per year	31536000					

EMBARRASS RIVER				Estimated Potential Surface Water Concentration (Sabin Lake)		
<b>Modeled SO2 air conc. [1]</b>	Modeled S air con.	Dep Vel.	Dep.	S (mg/L) =	0.0054	
0.0226 ug/m3		0.46 cm/sec		SO4 (mg/L) =	0.016	
2.26E-08 g/m3	1.13E-08 g/m3	0.0046 m/sec	0.002 (grams/m2/yr)			
<b>Unit Conversions</b>				Information for calculating potential surface water conc.		
milligram to microgam	1000 1 mg = 1000 ug			1 hectare =	2.47 acres	
gram to milligram	1000 1 g = 1000 mg			1 hectare =	10000 square meters	
kilogram to gram	1000 1 kg = 1000 g			1 acre =	43560 square ft	
				1 ft3 =	28.31625 liters	
meters to centimeter	100 1 m = 100 cm			Sabin	299 acres	
centimeters to meters	0.01 1 cm = 0.01 m			Mixing layer	1 ft (approximates the surface layer)	
					Littoral zone (15 ft depth) = max mix zone	
					For Sabin Lake, 135 acres of littoral zone)	
					Max Depth = 40 ft.	
S from SO2	S =	32		S from SO4	S =	32
	O2 =	32			O4 =	64
	SO2 =	64			SO2 =	96
	S =	0.50			S =	0.33
seconds per year	31536000					

[1] Modeled SO2 air concentration from Barr Eng., 2012, Plant Site Class II Air Dispersion Modeling Report.

For the Partridge River, the air concentration is an area-weighted concentration to account for a large number of receptors on/near the property boundary.

For the Embarrass River, the concentration is an average of all receptors.

Calculating Potential Sulfur Deposition from Particulate Stack Emissions Based on PM2.5 Air Concentration

Potential Surface Water Conc. (mg/L)

S (mg/L) = Dep x mg/g x m2/ha x ha/acre x acres/ft2 x 1/mix zone in ft x ft3/Liter  
 SO4 (mg/L) = S/0.33

PARTRIDGE RIVER WATERSHED

Modeled annual PM2.5 air conc. [1]	Estimated PM2.5 deposition	S Dep.
5.8 ug/m3		
5.80E-06 g/m3	5.14E-01 g/m2/yr	0.004 (grams/m2/yr)

<b>Estimated Potential Surface Water Concentration (Colby Lake) (Case = A.)</b>	
S (mg/L) =	0.0147
SO4 (mg/L) =	0.044

Calculation Parameter	A. based on PM2.5 at the Plant Site (PolyMet boundary max conc.)	
	Value	
Deposition velocity	0.281 cm/s	
Deposition velocity	0.00281 m/s	
Max Modeled annual air concentration [1]	5.8 ug/m3	
Max annual air concentration	5.80E-06 g/m3	
seconds per year	3.15E+07	
Annual Project PM2.5 Deposition, maximum on the receptor	0.514 g/m2/yr	as PM2.5
Annual Project Sulfur Deposition	0.004 g/m2	as sulfur (uses sulfur content of ore)

B. based on PM2.5 at the Plant Site (LTVSMC boundary max conc.)		
	Value	
Deposition velocity	0.281 cm/s	
Deposition velocity	0.00281 m/s	
Max Modeled annual air concentration [1]	3.7 ug/m3	
Max annual air concentration	0.0000037 g/m3	
seconds per year	3.15E+07	
Annual Project PM2.5 Deposition, maximum on the receptor	0.328 g/m2/yr	as PM2.5
Annual Project Sulfur Deposition	0.003 g/m2	as sulfur (uses sulfur content of ore)

Sulfur content of ore (8,700 ppm; 0.87%; 95% UCL) 0.0087

0.0087

**Unit Conversions**

milligram to microgam	1000 1 mg = 1000 ug
gram to milligram	1000 1 g = 1000 mg
kilogram to gram	1000 1 kg = 1000 g

meters to centimeter	100 1 m = 100 cm
centimeters to meters	0.01 1 cm = 0.01 m

S from SO2	S =	32
O2	=	32
SO2	=	64
S	=	0.50

Information for calculating potential surface water conc.  
 1 hectare = 2.47 acres  
 1 hectare = 10000 square meters  
 1 acre = 43560 square ft  
 1 ft3 = 28.31625 liters  
 Colby Lake 502 acres  
 Mixing layer 1 ft (approximates the surface layer)  
 Littoral zone(15 ft depth) = max mix zone  
 For Colby Lake, 377 acres of littoral zone)  
 Max depth = 30 ft.

S from SO4	S =	32
	O4 =	64
	SO2 =	96
	S =	0.33

seconds per year 31536000

Calculating Potential Sulfur Deposition from Particulate Stack Emissions Based on PM2.5 Air Concentration

Potential Surface Water Conc. (mg/L)

EMBARRASS RIVER WATERSHED			Estimated Potential Surface Water Concentration (Sabin Lake)		
Modeled maximum annual PM2.5 air concentration [1]	5.8 ug/m3	Estimated PM2.5 deposition	S Dep.	S (mg/L) =	0.0147
	5.80E-06 g/m3	5.14E-01 g/m2/yr	0.004 (grams/m2/yr)	SO4 (mg/L) =	0.044
<b>A. based on PM2.5 at the Plant Site (PolyMet boundary max conc.)</b>			<b>B. based on PM2.5 at the Plant Site (LTVSMC boundary max conc.)</b>		
<b>Calculation Parameter</b>	<b>Value</b>		<b>Value</b>		
Deposition velocity	0.281 cm/s		0.281 cm/s		
Deposition velocity	0.00281 m/s		0.00281 m/s		
Max Modeld annual air concentration [1]	5.8 ug/m3		3.7 ug/m3		
Max annual air concentration	5.80E-06 g/m3		0.0000037 g/m3		
seconds per year	3.15E+07		3.15E+07		
Annual Project PM2.5 Deposition, maximum on the receptor grid	0.514 g/m2/yr	as PM2.5	0.328 g/m2/yr	as PM2.5	
Annual Project Sulfur Deposition	0.004 g/m2	as sulfur (uses sulfur content of ore)	0.003 g/m2	as sulfur (uses sulfur content of ore)	
Sulfur content of ore, 8700 ppm = 0.87%	0.0087		0.0087		
<b>Unit Conversions</b>			<b>Information for calculating potential surface water conc.</b>		
milligram to microgam	1000 1 mg = 1000 ug		1 hectare =	2.47 acres	
gram to milligram	1000 1 g = 1000 mg		1 hectare =	10000 square meters	
kilogram to gram	1000 1 kg = 1000 g		1 acre =	43560 square ft	
meters to centimeter	100 1 m = 100 cm		1 ft3 =	28.31625 liters	
centimeters to meters	0.01 1 cm = 0.01 m		Sabin	299 acres	
			Mixing layer	1 ft	(approximates the surface layer)
S from SO2	S =	32			Littoral zone (15 ft depth) = max mix zone
	O2 =	32			For Sabin Lake, 135 acres of littoral zone)
	SO2 =	64			Max Depth = 40 ft.
	S =	0.50	S from SO4	S =	32
				O4 =	64
				SO2 =	96
				S =	0.33
seconds per year	31536000				

[1] Modeled air concentration from Barr Eng., 2012, Plant Site Class II Air Quality Air Dispersion Modeling Report, Version 2, November 2012

Sulfate, PM2.5 stack - wetlands

NorthMet Project

1. Estimating the amount of Sulfur potentially released from Plant Site PM2.5 (includes stack emissions and tailings erosion as per Class II modeling results)

Background Information (from SDEIS, NorthMet Tailings Geochemistry; Pp. 5-61 to 5-68.

NorthMet: Humidity Cell Tests are the basis for the data presented in the SDEIS. 14 tests for course tailings 7 tests for fine tailings Range in sulfide concentrations: 0.06 to 0.14% S

Rate from "Calcs\_Sulfate Release Rate" tab: Rate: 240.61 mg SO4 per 1 kg waste rock 1 week

2. Estimating Potential Release of Sulfur

A. from PM2.5 at the Plant Site (PolyMet boundary max conc.)

B. from PM2.5 at the Plant Site (LTVSMC boundary max conc.)

Calculation Parameter

Calculation Parameter	Value		Value	
Deposition velocity	0.281 cm/s		0.281 cm/s	
Deposition velocity	0.00281 m/s		0.00281 m/s	
Max annual air concentration, PM2.5 (maximum on the receptor grid) [1]	5.8 ug/m3		3.7 ug/m3	
Max annual air concentration	5.80E-06 g/m3		3.7E-06 g/m3	
seconds per year	3.15E+07		3.15E+07	
Annual Project PM2.5 Deposition, maximum on the receptor grid	5.14E-01 g/m2/yr	as PM2.5	0.32788 g/m2/yr	as PM2.5
Annual Project Sulfur Deposition	4.47E-03 g/m2/yr	as sulfur (uses sulfur content of ore)	0.002853 g/m2/yr	as sulfur (uses sulfur content of ore)
Sulfur content of ore (8,700 ppm; 0.87%; 95% UCL)	0.0087		0.0087	

Estimated Sulfate from Deposited Dust Available to be dissolved in water;

Sulfate, mg/m2 = Estimated Deposition in g PM2.5 / m2 x Release Rate in mg SO4 / kg ore / week x 1 kg/1000 g x 52 wks = 6.43 mg/m2 4.10 mg/m2

Under worst case assumption that all S converts to SO4: 13.41 mg/m2 8.56 mg/m2

3. Estimating a Potential Sulfate Concentration in Soil Solution or Surface Water From Deposited Dust

Depth of wetland soil or water that dust assumed to mix with 0.3 meters 30 cm, ~ 12 inches  
 Volume of soil or water that dust would mix with (1 m2 x depth in m) = 0.3 cubic meters; m3 300 Liters

Sulfate concentration, mg/L = Sulfate available to mix, mg / 300 L = 0.02 mg/L 0.01 mg/L  
 Worst Case, all sulfur converts to sulfate, mg/L = sulfate available to mix, mg / 300 L 0.04 mg/L 0.03 mg/L

Note, Background concentrations of sulfate in surface waters ranges from about 1 to 3 mg/L.

Unit Conversions		Information for calculating potential surface water conc.	
milligram to microgam	1000 1 mg = 1000 ug	1 hectare =	2.47 acres
gram to milligram	1000 1 g = 1000 mg	1 hectare =	10000 square meters
kilogram to gram	1000 1 kg = 1000 g	1 acre =	43560 square ft
meters to centimeter	100 1 m = 100 cm	1 ft3 =	28.31625 liters
centimeters to meters	0.01 1 cm = 0.01 m		
1 cubic centimeter =	1 milliliter (ml)		
1 cubic meter (m3) =	1000000 cm3		
1 cubic meter (m3) =	1000000 milliliters (mls)	S from SO4	S = 32
1 liter (L) =	1000 milliliters (mls)		O4 = 64
1 cubic meter (m3) =	1000 liters (L)		SO2 = 96
			S = 0.33
S from SO2	S = 32		
	O2 = 32		
	SO2 = 64	seconds per year	31536000
	S = 0.50		

[1] Modeled air concentration from Barr Eng., 2012, Plant Site Class II Air Quality Air Dispersion Modeling Report, Version 2, November 2012.

Sulfate from Fugitive Dust, 1

NorthMet Project

Method 1: estimation based on particle sulfur deposition rate and theoretical sulfur release rate from PM10 sized particulate

1. Estimating the amount of Sulfur potentially released from fugitive dust at the Mine Site (waste rock) and the Plant Site (LTVSMC and NorthMet tailings)

Background Information (from SDEIS, NorthMet Tailings Geochemistry; Pp. 5-61 to 5-68.

NorthMet: Humidity Cell Tests are the basis for the data presented in the SDEIS.

14 tests for course tailings  
Cat. 1 rock = 432 ppm; Cat 2/3 rock = 2,361 ppm

7 tests for fine tailings  
Range in sulfide concentrations: 0.06 to 0.14% S  
Average for Cat. 1 and Cat. 2/3 rock = 0.14% S

Rate from "Calcs_Sulfate Release Rates" tab:	Rate:	9.68 mg SO4	per	1 kg S in waste rock	1 week	(for 10 micron particle size; 0.14% S)
	Rate:	8.30 mg SO4	per	1 kg S in tailings	1 week	(for 10 micron particle size; 0.12% S)

2. Estimating Potential Release of Sulfur

A. from Fugitive Wasterock Dust at the Mine Site

B. from Fugitive Tailings Dust at the Plant Site

Calculation Parameter

Value

Value

Annual Project Sulfur Deposition, maximum on the receptor grid [1]  
Sulfur content of dust at point of max S deposition (Max content = 9588 ppm at mine site ; in Wetlands Data Package)  
Annual Project Dust Deposition, at point of maximum sulfur on the receptor grid  
Annual Project SULFATE (SO4) Deposition

0.42 g/m2  
0.0096  
43.805 g/m2  
1.26 g/m2 as sulfate

(background S deposition from NADP Data used in this calculation; worst case assumption for the Plant Site)  
0.16 g/m2  
0.0012  
133.3333 g/m2  
0.48 g/m2 as sulfate

Estimated Sulfate from Deposited Dust Available to be dissolved in water;

Based on NorthMet Waste Rock Release Rate:

Sulfate, mg/m2 = Estimated Dep in g dust / m2 x Release Rate in mg SO4 / kg waste rock / week x 1 kg/1000 g x 52 wks = 22.05 mg/m2/yr

57.52 mg/m2/yr

3. Estimating a Potential Sulfate Concentration in Soil Solution or Surface Water From Deposited Dust

Depth of wetland soil or water that dust would mix with  
Volume of soil or water that dust would mix with (1 m2 x depth in m) =  
Sulfate concentration, mg/L = Sulfate available to mix in mg / 300 L =

0.3 meters 30 cm, ~ 12 inches  
0.3 cubic meters; m3 300 Liters

0.073 mg/L

0.1917 mg/L

Note: Background concentrations of sulfate in surface waters ranges from about 1 to 3 mg/L.

Unit Conversions		Information for calculating potential surface water conc.	
milligram to microgam	1000 1 mg = 1000 ug	1 hectare =	2.47 acres
gram to milligram	1000 1 g = 1000 mg	1 hectare =	10000 square meters
kilogram to gram	1000 1 kg = 1000 g	1 acre =	43560 square ft
		1 ft3 =	28.31625 liters
meters to centimeter	100 1 m = 100 cm		
centimeters to meters	0.01 1 cm = 0.01 m		
1 cubic centimeter =	1 milliliter (ml)	S from SO2	S from SO4
1 cubic meter (m3) =	1000000 cm3	S =	S =
1 cubic meter (m3) =	1000000 milliliters (mls)	O2 =	O4 =
1 liter (L) =	1000 milliliters (mls)	SO2 =	SO2 =
1 cubic meter (m3) =	1000 liters (L)	S =	S =
seconds per year	31536000		

[1] Modeled Sulfur dust deposition from work and data presented in Barr Eng., Wetlands Data Package, Version 7, March 2013

Sulfate from Fugitive Dust, 2

NorthMet Project

Method 2: estimation based on modeling results of total dust deposition rate and theoretical sulfur release rate from PM10 sized particulate

1. Estimating the amount of Sulfur potentially released from fugitive dust at the Mine Site (waste rock) and the Plant Site (LTVSMC and NorthMet tailings)

Background Information (from SDEIS, NorthMet Tailings Geochemistry; Pp. 5-61 to 5-68.

NorthMet: Humidity Cell Tests are the basis for the data presented in the SDEIS. 14 tests for course tailings 7 tests for fine tailings Range in sulfide concentrations: 0.06 to 0.14% S  
 Cat. 1 rock = 432 ppm; Cat 2/3 rock = 2,361 ppm

Rate from "Calcs_Sulfate Release Rates" tab:	Rate:	9.68 mg SO4	per	1 kg waste rock	1 week	(for 10 micron particle size; 0.14% S)
	Rate:	8.30 mg SO4	per	1 kg waste rock	1 week	(for 10 micron particle size; 0.12% S)

2. Estimating Potential Release of Sulfur

A. from Fugitive Waste Rock Dust at the Mine Site

B. from fugitive Tailings Dust at the Plant Site

Calculation Parameter

Annual Project maximum Dust Deposition on the receptor grid [1]

Value

74.6 g/m2

Value

182.5 g/m2

Estimated Sulfate from Deposited Dust Available to be dissolved in water;

Sulfate, mg/m2 = Estimated Dep in g dust / m2 x Release Rate in mg SO4 / kg dust / week x 1 kg/1000 g x 52 wks = 37.55 mg/m2/yr

78.73672 mg/m2/yr

3. Estimating a Potential Sulfate Concentration in Soil Solution or Surface Water From Deposited Dust

Depth of soil or water that dust would mix with

0.3 meters 30 cm, ~ 12 inches

Volume of soil or water that dust would mix with (1 m2 x 0.3 m) =

0.3 cubic meters; m3 0.3 m3 = 300 Liters

Sulfate concentration, mg/L = Sulfate available to mix in mg / 300 L =

0.13 mg/L

0.26 mg/L

Note: Background concentrations of sulfate in surface waters ranges from about 1 to 3 mg/L.

Unit Conversions		Information for calculating potential surface water conc.	
milligram to microgram	1000 1 mg = 1000 ug	1 hectare =	2.47 acres
gram to milligram	1000 1 g = 1000 mg	1 hectare =	10000 square meters
kilogram to gram	1000 1 kg = 1000 g	1 acre =	43560 square ft
		1 ft3 =	28.31625 liters
meters to centimeter	100 1 m = 100 cm	Colby Lake	502 acres
centimeters to meters	0.01 1 cm = 0.01 m	Mixing layer	15 ft
			(approximates the littoral zone)
			For Colby Lake, 377 acres of littoral zone)
			Max depth = 30 ft.
1 cubic centimeter =	1 milliliter (ml)		
1 cubic meter (m3) =	1000000 cm3		
1 cubic meter (m3) =	1000000 milliliters (mls)		
1 liter (L) =	1000 milliliters (mls)		
1 cubic meter (m3) =	1000 liters (L)		
S from SO2	S = 32	S from SO4	S = 32
	O2 = 32		O4 = 64
	SO2 = 64		SO2 = 96
	S = 0.50		S = 0.33
seconds per year	31536000		

[1] Modeled dust deposition from work and data presented in Barr Eng., Wetlands Data Package, Version 7, March 2013 (dust deposition)

Sulfate from Fugitive Dust,3

NorthMet Project

Method 3: estimation based on modeling results of sulfur deposition rate assuming all sulfate is available to be immediately dissolved in water

1. Estimating the amount of Sulfur potentially released from fugitive dust at the Mine Site (waste rock) and the Plant Site (LTVSMC and NorthMet tailings)

Background Information (from SDEIS, NorthMet Tailings Geochemistry; Pp. 5-61 to 5-68.

NorthMet: Humidity Cell Tests are the basis for the data presented in the SDEIS.

14 tests for course tailings      7 tests for fine tailings      Range in sulfide concentrations: 0.06 to 0.14% S  
 Cat. 1 rock = 432 ppm; Cat 2/3 rock = 2,361 ppm

2. Estimating Potential Release of Sulfur

Calculation Parameter

A. from Fugitive Wasterock Dust at the Mine Site

B. from Fugitive Tailings Dust at the Plant Site

Calculation Parameter	Value	Value
Annual Project Sulfur Deposition, maximum on the receptor grid [1]	0.42 g/m2	0.16 g/m2
Annual Project SULFATE (SO4) Deposition	1.26 g/m2 as sulfate	0.48 g/m2 as sulfate
Estimated Sulfate from Deposited Dust Available to be dissolved in water; <i>Assume all of the sulfide is released as sulfate to surface water</i>	1260.000 mg/m2	480 mg/m2

(background S deposition from NADP; worst case assumption for the Plant Site)

3. Estimating a Potential Sulfate Concentration in Soil Solution or Surface Water From Deposited Dust

Depth of wetland soil or water that dust would mix with      0.3 meters    30 cm, ~ 12 inches  
 Volume of soil or water that dust would mix with (1 m2 x 0.3 m depth) =      0.3 cubic meters; m3      300 Liters

Sulfate concentration, mg/L = Sulfate available to mix in mg / 300 L =      **4.20 mg/L**      **1.60 mg/L**

Alternative: larger volume of water for dust to mix in; annual precip      0.76 meter    76 cm; 30 inches  
 Alternative: volume of soil or water = 1 m2 x 1 m depth =      0.76 cubic meters; m3      760 Liters

Sulfate concentration, mg/L = Sulfate available to mix in mg / 760 L =      **1.66 mg/L**      **0.63 mg/L**

Note, Background concentrations of sulfate in surface waters ranges from about 1 to 3 mg/L.

Unit Conversions	Information for calculating potential surface water conc.
milligram to microgam      1000 1 mg = 1000 ug	1 hectare =      2.47 acres
gram to milligram      1000 1 g = 1000 mg	1 hectare =      10000 square meters
kilogram to gram      1000 1 kg = 1000 g	1 acre =      43560 square ft
	1 ft3 =      28.31625 liters
meters to centimeter      100 1 m = 100 cm	
centimeters to meters      0.01 1 cm = 0.01 m	
1 cubic centimeter =      1 milliliter (ml)	
1 cubic meter (m3) =      1000000 cm3	S from SO2 S =      32
1 cubic meter (m3) =      1000000 milliliters (mls)	O2 =      32
1 liter (L) =      1000 milliliters (mls)	SO2 =      64
1 cubic meter (m3) =      1000 liters (L)	S =      0.50
seconds per year      31536000	
	S from SO4 S =      32
	O4 =      64
	SO2 =      96
	S =      0.33

[1] Modeled Sulfur dust deposition from work and data presented in Barr Eng., Wetlands Data Package, Version 7, March 2013

Calcs - Sulfate Release Rates

NorthMet Project Estimated Sulfate Release Rates from Rock Particles

(Scale Factors based on Information from: Barr Eng., Waste Characterization Data Package, Version 10, March 7, 2013. )

Scale Factor, varies as a function of particle size

Particle size (µm)	Side length (m)	Surface area (m <sup>2</sup> )	Volume (m <sup>3</sup> )	Mass (kg)	Specific surface area (m <sup>2</sup> /kg)	Mean HCT specific surface area (m <sup>2</sup> /kg)	Mean Particle Size Factor	Mean Temperature Factor	Scale Factor
30	0.00003	5.4E-09	2.7E-14	7.91E-11	68.26	9.4	7.26	0.228	1.66
20	0.00002	2.4E-09	8E-15	2.34E-11	102.39	9.4	10.89	0.228	2.48
10	0.00001	6E-10	1E-15	2.93E-12	204.78	9.4	21.78	0.228	4.97
5	0.000005	1.5E-10	1.25E-16	3.66E-13	409.56	9.4	43.57	0.228	9.93
2.5	0.0000025	3.75E-11	1.56E-17	4.58E-14	819.11	9.4	87.14	0.228	19.87
2	0.000002	2.4E-11	8E-18	2.34E-14	1023.89	9.4	108.92	0.228	24.83

Sulfate release rate, assuming particle size is 20 microns

Sulfur Conc. (%)	Sulfate release rate (mg SO <sub>4</sub> /kg rock/week)	Sulfate release rate (mg SO <sub>4</sub> /kg rock/year)
0.02	0.69	35.95284003
0.04	1.38	71.90568005
0.06	2.07	107.8585201
0.08	2.77	143.8113601
0.1	3.46	179.7642001
0.12	4.15	215.7170402
0.14	4.84	251.6698802
0.236	8.16	424.2435123
0.6	20.74	1078.585201
0.87	30.08	1563.948541

Sulfate release rate, assuming particle size is 10 microns

Sulfur Conc. (%)	Sulfate release rate (mg SO <sub>4</sub> /kg rock/week)	Sulfate release rate (mg SO <sub>4</sub> /kg rock/year)
0.02	1.38	71.90568005
0.04	2.77	143.8113601
0.06	4.15	215.7170402
0.08	5.53	287.6227202
0.1	6.91	359.5284003
0.12	8.30	431.4340803
0.14	9.68	503.3397604
0.236	16.32	848.4870246
0.6	41.48	2157.170402
0.87	60.15	3127.897082

Cat. 1 waste rock = 432 ppm 95% UCL

0.12% sulfur in NorthMet tailings; 10 micron particles  
Average of Cat. 1 and Cat. 2/3 = 1396 ppm (Release rate for 0.14% S can represent Mine Site dust)  
Cat. 2/3 waste rock = 2361 ppm 95% UCL

ore conc = 8700 ppm 95% UCL  
Cat. 4 waste rock = 18,876 ppm 95% UCL

Calculation of depletion after a year, varies as a function of particle size

Particle size (µm)	Depletion (%)
30	4%
20	6%
10	12%
5	24%
2	60%

Added by Nadine Czoschke and Cliff Twaroski, 8/13/2014.

Sulfate Release Rate, assuming 2.5 microns

Sulfur Conc. %	Sulfate release rate (mg SO <sub>4</sub> /kg rock/week)	Sulfate release rate (mg SO <sub>4</sub> /kg rock/year)
0.87	240.61	12511.58833 for PM2.5