2010 Project Abstract
For the Period Ending June 30, 2013

PROJECT TITLE: Sulfate Release from Mining in the St. Louis River Watershed
PROJECT MANAGER: Michael E. Berndt
AFFILIATION: Minnesota Department of Natural Resources
MAILING ADDRESS: 500 Lafayette Rd
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WEBSITE: dnr.state.mn.us
FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2010, Chp. 362, Sec. 2, Subd. 5b
APPROPRIATION AMOUNT: $270,000.00

Overall Project Outcome and Results

Taconite mining on the Iron Range sends an average of approximately 35 tons of sulfate per day down the St. Louis River. Another 15 tons per day arises from non-mining sources. Loading from both sources is episodic and depends on hydrologic conditions in the watershed. Most mining-related sulfate arises from the oxidative weathering of minor iron sulfide minerals present in the mined rocks. The predominant pathway for sulfate introduction into the streams is through pumping and overflow of water from taconite pits.

In some source regions, a large percentage of sulfate released near the mines was removed by natural reactions that convert sulfate back to insoluble sulfides ("sulfate reduction"). However, once the sulfate reached the open channel ways in streams, little, if any, additional sulfate was removed by sulfate reduction. Laboratory experiments demonstrated that sulfate reduction can also be stimulated artificially in mine waters by adding organic compounds and iron minerals and eliminating oxygen. However, water hardness and the production of hydrogen sulfide were difficult to control using the methods that were tested.

Methylmercury is a toxic compound that can form as a byproduct of biologic sulfate reduction. Widespread sampling and measurement of methylmercury reveal that its concentration is minimally impacted by sulfate concentration in the main stream or river channels. The dominant source of methylmercury to streams involves the slow passage of water falling on the land through reduced, organic rich materials that surround streams in this area. Except in a few instances, sulfate from mining, added directly to streams, has limited ability to access and impact methylmercury formed in this source region. Laboratory experiments conducted on estuary sediments also indicated that the rate of methylmercury addition to the water column is not directly controlled by sulfate concentration in the overlying water.

Project Results Use and Dissemination

1. *Three reports and two MS theses were produced directly as a result of this research. Several reports were placed on the DNR's website in late October 2012. This website will be updated to reflect more recent reports by October 2013:*

Beck, B., 2013 Geochemical Controls on Production and Transport of Methylmercury in the St. Louis River Estuary, Civil Engineering. University of Minnesota, Duluth Minnesota, 100 p.

Berndt, M.E., Bavin, T.K., 2012. On the cycling of sulfur and mercury in the St. Louis River watershed, Northeastern Minnesota. Minnesota Department of Natural Resources, St. Paul, Minnesota, 91 p.

Johnson, N., Beck, B., 2013. Sulfur and carbon controls on methyl mercury in St. Louis River Estuary sediment, Report Submitted to the Minnesota Department of Natural Resources, 48 p.

Johnson, N., Zhu, X., 2012. Carbon and iron additions to stimulate in-pit sulfate reduction and removal, Report to the Minnesota Department of Natural Resources, 24 p.

Theriault, S.A., 2011. Mineralogy, Spatial Distribution, and Isotope Geochemistry of Sulfide Minerals in the Biwabik Iron Formation, Geology. University of Minnesota, 165 p.

An additional report is being readied for publication in a journal: Berndt, ME, Jeremiason, J, Bavin, T., and Von Korff, B., Hydrologic and Geochemical Controls on St. Louis River Composition with Implications for Regulating Sulfate to Control Methylmercury Concentrations. Currently in draft form.

Four professional abstracts referencing work from this project were presented during FY 2013:

Beck, B. F., and Johnson, N. W. (2013) Sulfate and Carbon Controls on the Production of Methyl mercury in Freshwater Estuary Sediments. Brian F. Beck and Nathan W. Johnson, February 2013. Seventh International Conference on Remediation of Contaminated Sediments, Dallas, TX.

Berndt, M. E. and Bavin, T. (2012) Impacts of sulfate and hydrology on the methylmercury inventory of the St. Louis River, NE Minnesota. Geological Society of America National Meeting, Charlotte, North Carolina, Nov. 5, 2012.

Bendt, M. E. , Bavin, T., and Johnson, N. W, (2012) Is MeHgHS and important methylmercury transport agent in H_2S-bearing waters? Geological Society of America National Meeting, Charlotte, North Carolina, Nov. 6, 2012.

Johnson, N. W., Bailey, L. T., Engstrom, D. R., Mitchell, C., Jeremiasson, J., Coleman-Wasik, J. Sulfide's effect on methyl mercury production and transport in sulfate-impacted lakes and wetlands (2013). Eleventh International Conference on Mercury as a Global Pollutant, Edinburgh Scotland. August 2013.

2. *The work by our group has been widely presented to outside groups including scientists and stakeholders. Plans are in works to publish all or parts of the above reports in peer reviewed journals over the next year.*

Environment and Natural Resources Trust Fund (ENRTF)
2010 Work Program Final Report

Date of Report: Aug 15, 2013
Date of Next Progress Report: June 30, 2013 – final report.
Date of Work Program Approval: June 9, 2010
Project Completion Date: June 30, 2013

I. PROJECT TITLE: Sulfate Release from Mining in the St. Louis River Watershed

Project Manager: Michael Berndt
Affiliation: Minnesota Department of Natural Resources
Mailing Address: 500 Lafayette Road
City / State / Zip: St. Paul, MN 55455
Telephone Number: 651-259-5378
E-mail Address: mike.berndt@state.mn.us
FAX Number: 651-259-5939
Web Site Address:

Location: *St. Louis County, Minnesota – St. Louis River watershed*

Total ENRTF Project Budget:	**ENRTF Appropriation**	**$270,000**
	Minus Amount Spent:	**$270,000**
	Equal Balance:	**$ 0**

Legal Citation: M.L. 2010, Chp. 362, Sec. 2, Subd. 5b

Appropriation Language:
$270,000 is from the trust fund to the commissioner of natural resources to map current sulfate sources and assess treatment options to minimize potential impacts of mercury on fish and wildlife from sulfate releases in the St. Louis River Basin. This appropriation is available until June 30, 2013, by which time the project must be completed and final products delivered.

II. and III Final Project Summary:

Taconite mining on the Iron Range sends an average of approximately 35 tons of sulfate per day down the St. Louis River. Another 15 tons per day arises from non-mining sources. Loading from both sources is episodic and depends on hydrologic conditions in the watershed. Most mining-related sulfate arises from the oxidative weathering of minor iron sulfide minerals present in the mined rocks. The predominant pathway for sulfate introduction into the streams is through pumping and overflow of water from taconite pits.

In some source regions, a large percentage of sulfate released near the mines was removed by natural reactions that convert sulfate back to insoluble sulfides ("sulfate reduction"). However, once the sulfate reached the open channel ways in streams, little, if any, additional sulfate was removed by sulfate reduction. Laboratory experiments demonstrated that sulfate reduction can also be stimulated artificially in mine waters by adding organic compounds and iron minerals and eliminating oxygen. However, water hardness and the production of hydrogen sulfide were difficult to control using the methods that were tested.

Methylmercury is a toxic compound that can form as a byproduct of biologic sulfate reduction. Widespread sampling and measurement of methylmercury reveal that its concentration is minimally impacted by sulfate concentration in the main stream or river channels. The dominant source of methylmercury to streams involves the slow passage of water falling on the land through reduced, organic rich materials that surround streams in this area. Except in a few instances, sulfate from mining, added directly to streams, has limited ability to access and impact methylmercury formed in this source region. Laboratory experiments conducted on estuary sediments also indicated that the rate of methylmercury addition to the water column is not directly controlled by sulfate concentration in the overlying water.

IV. OUTLINE OF PROJECT RESULTS*:*

RESULT 1: Interim Report on Source and Fate of Sulfate in the St. Louis River Watershed

Description: This report will summarize work completed in the first year on three primary sub-projects described in Results 2 through 4, below. These three studies overlap with each other and this document will serve as a reference document when evaluating where more specific emphasis is needed during the second year of the overall study. It will be distributed to stakeholders for comment and will help make the final report for the whole project a more inclusive, complete document.

Summary Budget Information for Result 1:	**ENRTF Budget:**	**$5,000**
	Amount Spent:	**$5,000**
	Balance:	**$0,000**

Deliverable/Outcome	Completion Date	Budget
1. *Interim Report*	June 30, 2011	$5,000

Final Report Summary: The interim report contained all sulfate concentration and isotopic data as well as stream flow information for samples collected through the end of March 2011. It was distributed and discussed with stakeholders and helped to guide later efforts. This result was superseded in final reports for the project and so is not discussed further.

RESULT 2: Environmental Effect of Sulfate in the Lower Saint Louis River and Estuary

Description: This portion of the study evaluates the total amount of sulfate from the mineland regions that reach the lower St. Louis River and enters the estuary on Lake Superior. It also determines how this sulfate behaves once it reaches the estuary and the degree to which it promotes methylation of mercury. Sulfur isotope ratios and sulfate concentrations are measured weekly at Scanlon Dam to quantify the sulfate source specifically from the mining regions. Examination of multiple cores collected from the estuary will be performed to determine the degree to which the sulfate is being reduced and affecting chemical processes within the sediments and estuary.

Summary Budget Information for Result 2:	**ENRTF Budget:**	**$86,847**
	Amount Spent:	**$ 86,847**
	Balance:	**$ 0**

Deliverable/Outcome	Completion Date	Budget
1.Water Chemistry and Sediment Results Year 1	June 30,2011	$45,000
2. Final Report and Results for Years 1 and 2	June 30,2012	$41,847

Final Report Summary: (Aug 15, 2012)
The average daily mining and non-mining $SO_4^=$ contributions to the St. Louis River, as determined from measurements at the Scanlon Dam site, are about 35 and 15 metric tons, respectively. Flow versus concentration plots for sulfate and other dissolved components indicated that this loading is highly episodic, rarely reaching a steady state. Rather, the sulfate accumulates relatively slowly in the watershed during winter and dry

periods, and is then flushed rapidly downstream, into the estuary, during snowmelt and precipitation events. The non-mining waters that flush the St. Louis River during summer high-flow periods have low sulfate, but elevated dissolved aluminum, iron, and manganese. The presence of these dissolved components is consistent with river recharge through oxygen-depleted, organic-rich, soils and sediments. Sulfate concentrations in the river during dry periods becomes elevated. These flushing periods will create wide shifts in estuary sulfate, Fe, and Al concentrations over time.

Laboratory sulfate addition experiments were performed to evaluate potential impacts of water column sulfate on estuary methylmercury levels. These experiments used 20 cm intact sediment cores obtained from three characteristic sites in the St. Louis River Estuary. The intact cores from each site were exposed to a high (50 mg/L), medium (15 mg/L), and low (5 mg/L) overlying water sulfate treatment for incubation periods of six months. Results from the six month study indicated that production of sediment methyl mercury in the surface sediments were insensitive to sulfate addition, but were sensitive to the quantity of inorganic mercury and the type of organic carbon present in the core. In the 4 to 10 cm interval of one of the cores, methylmercury production was sensitive to sulfate concentration in the overlying column, but this level is thought to be too deep to impact methylmercury in the overlying water column.

Methylmercury concentrations are elevated in the St. Louis River during wet periods when flow rates in the St. Louis River are high and lowest when flow rates are depressed. Experimental data obtained from the experiments on the rate at which methylmercury is released from sediments suggest that diffusion of methylmercury from sediments will only impact methylmercury concentrations in the estuary during relatively dry periods, when the flow rates in the St. Louis River is low. However, the experimental data also show that the actual transfer rate of methylmercury from sediment into the water column should be insensitive to sulfate concentration. This affects the strategies that might be used or considered when the state issues mining permits.

RESULT 3: Source and Fate of SO4 in the Upper St. Louis River Watershed

Description: This report will evaluate primary sources of sulfate and identify local areas of sulfate reduction in the Iron Mining Region using isotope geochemistry and measurements of dissolved organic carbon, major dissolved cations and anions, and water flow measurements in the mining region. These surveys will be conducted during four seasons throughout the year representing dry and wet summer periods, spring runoff, and winter base flow conditions. The observed variability in each of these parameters will be used as an input for Result 2 (above) to specifically help quantify the sources of sulfate to the lower St. Louis River region.

Summary Budget Information for Result 3:	**ENRTF Budget:**	**$97,320**
	Amount Spent:	**$ 97,320**
	Balance:	**$ 0**

Deliverable/Outcome	Completion	Budget

	Date	
1. Water Chemistry and Source Rock data from upper St. Louis River in Year 1.	June 30, 2011	$50,000
2. Final Report and Results for Years 1 and 2	June 30, 2012	$47,320

Final Report Summary: (August 15, 2013)

Stephanie Theriault, UMD, completed her MS Thesis on sulfur isotopes in the Biwabik Iron Formation. The wide variation in isotopic composition that she observed for the secondary sulfides are interpreted as arising during low temperature oxidation of the formation.

Berndt and Bavin completed a major report on sulfur and oxygen isotopes and concentrations of sulfate, mercury, methylmercury, and many other dissolved components found in waters of the St. Louis River watershed. Mine-waters in taconite pits and wells near the mines were found to contain dissolved sulfate with sulfur and oxygen isotope ratios distinct from those observed in waters collected in the rest of the watershed. Changes in isotope ratios were observed in streams leading from the mines revealing that considerable biologic reduction of the sulfate occurs in some, but not all, of the mining watersheds. This sulfate reduction was most clearly evident for wetlands or small lakes closest to the mines. An additional unidentified exchange process, also likely biologically controlled, modified oxygen isotope ratios of dissolved sulfate without changing the sulfur isotope ratios as the mine waters move downstream and mix with low-sulfate non-mining waters in tributaries leading to the St. Louis River. Sulfur and oxygen isotopes in dissolved sulfate for waters collected near Scanlon Dam were consistent with the simple mixing of waters (with no further sulfate reduction in the river) containing sulfate from mining and non-mining tributaries.

Methylmercury, total mercury (THg), and dissolved organic carbon (DOC) concentrations for mining and non-mining streams, measured following a major storm event, were compared to similar non-event data reported for 2007 to 2009. THg/DOC ratios following the event were similar to the previously measured values but MeHg/DOC and DOC concentrations were elevated. These chemical trends are interpreted as a natural consequence of stream recharge through oxygen-depleted, organic rich materials. MeHg/DOC and THg/DOC ratios of waters recharging the rivers is established initially under reducing conditions where methylation and demethylation reactions both occur and create a steady-state balance between inorganic and organic (MeHg) concentrations. Subsequent demethylation processes decreases MeHg/DOC, but preserve the THg/DOC values. Similarity in MeHg, THg, and DOC relationships for mining and non-mining streams, respectively, suggest that mercury cycling processes are insensitive to sulfate concentration in the central stream. However, elevated MeHg/DOC ratios have been found locally in some wetlands and lakes that directly receive mining waters, particularly when sulfate reduction leads to H_2S generation in amounts that upset the cycling of iron or when sulfate addition takes place in wetlands or peatlands prone to flooding.

The above results are highly significant because they provide a means for the DNR and other state agencies to determine where sulfate reduction takes place and whether it is impacting methylmercury inventories. This affects the strategies that might be used or considered when the state issues mining permits.

RESULT 4: Treatment and Reclamation Options for reducing SO_4 release from the Iron Range Mining Region

Description: This portion of the study will evaluate mitigation and control options for SO_4 from mineland areas. Small scale experiments will be conducted on naturally occurring high sulfate waters in mine-pits, which is where sulfate derived from waste rock piles is most often pooled. The primary method that will be evaluated involves reducing the sulfate in the deepest waters of pits that are in the process of filling and/or that do not turn over yearly (meromictic). Results from this study will be compared to other known methods of sulfate mitigation and control in an effort to determine how best to control sulfate release from mineland areas.

Summary Budget Information for Result 4:	**ENRTF Budget:**	**$ 61,622**
	Amount Spent:	**$ 61,622**
	Balance:	**$ 0**

Deliverable/Outcome	Completion Date	Budget
1. Experimental Results from Year 1 Study	June 30, 2011	$35,000
2. Final Report and Results for Years 1 and 2	June 30, 2012	$26,622

Result Completion Date: *(June 30, 2012)*

Final Report Summary: (August 15, 2012)

Large volumes of water containing elevated concentrations of sulfate and other dissolved solids are present in abandoned mine pits on the Mesabi Iron Range. The release of water with elevated sulfate and, to a lesser extent hardness, is an environmental concern owing to its potential effects on wild rice, mercury, and phosphorus. Using conventional technology for treatment of mine pit waters is a challenge owing to the large volumes of water present and discharge patterns which can be driven by natural hydrologic processes. Biological sulfate reduction is used in both engineered and natural sulfate treatment systems in a process whereby carbon provides the fuel to drive the transformation of sulfate to sulfide, and iron provides a means to remove sulfide from water.

The primary objective of this study was to determine whether the artificial addition of iron and carbon can be used to stimulate biological sulfate reduction and remove high sulfate and hardness from mine pit waters on the Mesabi Iron Range. Towards this end, short term, batch laboratory studies tested the effectiveness of different carbon and iron sources at both room temperature and 4^0C under mixed and unmixed conditions. The effectiveness of carbon and iron sources was evaluated based on the rate at which

sulfate was removed and the ability of added iron to keep hydrogen sulfide, a toxin to the sulfate reduction process, concentrations low. The ability to simultaneously remove hardness through precipitation with carbonate was also evaluated.

Of the carbon sources tested, ethanol was the most effective in driving biological sulfate reduction. While >90% sulfate reduction was observed after only 3 weeks in well-mixed ethanol-amended waters at room temperature, the reaction occurred 10-20 times slower at 4^0C. Iron materials were not added in great excess; however, of the two iron sources tested, iron carbonate was most effective at keeping hydrogen sulfide concentrations low. No combinations of iron and carbon amendments were able to remove hardness effectively. Due to the high cost and non-local source of commercial iron carbonate, future investigations should further consider the ability of locally available minerals to effectively provide iron for in-situ sulfate reduction and removal processes.

RESULT 5: Summary Report and Recommendations for the Management of Sulfate Release from Mineland Areas

Description: This report will provide a less technical summary of the work completed and results for the three largely independent studies listed above (Results 2 through 4). The purpose of this report is to provide an overview and summary of recommendations that can be understood by less technically inclined individuals. The more technical documents on which this report will be based will be available for those interested in the full details of the studies that were conducted during the project period. No update will be provided during the first year of the study because results from the full study will need be nearly completed before work on this report can begin.

Summary Budget Information for Result 5:	**ENRTF Budget:**	**$ 19,211**
	Amount Spent:	**$ 19,211**
	Balance:	**$ 0**

Deliverable/Outcome	Completion Date	Budget
5. Final Reporting	June 30, 2013	$19,211

Result Completion Date: *(June 30, 2013)*

Final Report Summary: (August 15, 2013)
No separate document was completed because the present report serves that purpose. The other projects were completed early and under-budget. Permission was sought and granted to use residual funds from other parts of the project to publicize the results from the those studies.

The most relevant findings in terms of mineland management strategies include the following:

(1) Decreasing the sulfate concentrations in mineland streams would have little or no impact on MeHg in the St. Louis River, at least above Scanlon Dam where the

samples for this study were collected. This is because almost all of the methylmercury found in the river is generated outside of the areas impacted by mining sulfate.

(2) In smaller streams or lakes where enhanced methylmercury production and transport are found, elimination of sulfate is only one of several options that might be considered when a reduction in methylmercury concentrations is desired or required. Iron addition, elimination of nutrients, or strategies to promote demethylation or to avoid methylmercury transport to open water may be more effective and less costly. If a decrease in methylmercury concentration is needed at a location, separate studies would be required to determine the most effective means to reach the desired levels. This is because methylmercury generation and transport processes may be insensitive to sulfate concentration and much more sensitive to other chemical and physical parameters.

(3) Decreasing sulfate added to the estuary would likely have little impact on methylmercury in sites similar to those from which the cores from our experiments were collected (upper estuary flats, lower estuary flats, and sheltered bay). Methylmercury generation in the upper few centimeters was insensitive to sulfate level in the overlying water column. Sulfate reduction and methylmercury generation increased with sulfate in the 4 to 10 cm depth interval of cores from one of the sites. However, increased methylmercury production at this depth is likely too deep to impact methylmercury concentrations in the estuary.

(4) Laboratory results suggest that biologic sulfate reduction may provide a rapid means to reduce sulfate concentrations in pit waters. However, it was also found that H_2S and HS^- generation was difficult to control as was water hardness.

The following technical reports were prepared as a part of this project:

Beck, B., 2013 Geochemical Controls on Production and Transport of Methylmercury in the St. Louis River Estuary, Civil Engineering. University of Minnesota, Duluth Minnesota, 100 p.

Berndt, M.E., Bavin, T.K., 2012. On the cycling of sulfur and mercury in the St. Louis River watershed, Northeastern Minnesota. Minnesota Department of Natural Resources, St. Paul, Minnesota, 91 p.

Johnson, N., Beck, B., 2013. Sulfur and carbon controls on methyl mercury in St. Louis River Estuary sediment, Report Submitted to the Minnesota Department of Natural Resources, 48 p. (Error in 2012 report was found and corrected)

Johnson, N., Zhu, X., 2012. Carbon and iron additions to stimulate in-pit sulfate reduction and removal, Report to the Minnesota Department of Natural Resources, 24 p.

Theriault, S.A., 2011. Mineralogy, Spatial Distribution, and Isotope Geochemistry of Sulfide Minerals in the Biwabik Iron Formation, Geology. University of Minnesota, 165 p.

V. TOTAL ENRTF PROJECT BUDGET:

Personnel: $ 130,000
Research Scientist II: $105,000.00
Chemist 1: $20,000.00
Student summer assistant: $5000.00
Funds will not be used for classified state employees unless the funded portions of their salaries are backfilled with unclassified staff.

Contracts: $ 125,000
University of Minnesota-Duluth Research Support ($65,000)

Dr. James Miller, University of Minnesota, Duluth: $35,000.00. Doctor Miller is an associate professor at the University of Minnesota-Duluth and he will contribute his time at no cost to the project. These funds will be used to fund the salary of a graduate student assistant and to provide supplies and expenses needed for the research, particularly during the first year of the study (Results 1 and 2 above). See peer review addendum for more complete explanation of Dr. Miller's role.

Dr. Nathan Johnson, University of Minnesota, Duluth: $30,000.00. Dr. Nathan Johnson is an assistant professor at the University of Minnesota- Duluth. Doctor Johnson is a professor at the University of Minnesota-Duluth and he will contribute his time at no cost to the project. These funds will be used to fund the salary of a graduate student assistant and to provide supplies and expenses needed for the research, particularly during the second year of the study (Results 1 and 2 above). See peer review addendum for more complete explanation of Dr. Johnson's role.

Chemical Analyses and Stream Gaging ($50,000)

- Sulfate Isotope measurements: Waterloo Isotope Laboratory ($22,500): The Minnesota Department of health has established a long relationship and has an existing contract with this Canadian laboratory. Few laboratories and no Minnesota state facilities provide sulfate isotopic measurement.
- DOC, Hg and MeHg: Minnesota Department of Health: $8,500.
- Dissolved Cations and Anions, including SO4: Contract Laboratories $19,000.00
- Stream gaging: DNR Division of Waters or, if necessary, contracted using the RFP process ($10,000)

Equipment/Tools/Supplies: $ 10,000

- 100s of sample bottles and specialized sampling equipment (disposable filters, rubber gloves, clean pipettes, and tubing) are required for the large number of samples that will be collected during the course of stream sampling in the mineland region (Result 2) and at the Scanlon Dam (Result 3) as well as sampling of waters produced in laboratory experiments (Result 4). Numerous vacutainers and several specially constructed tube-reactors are required for the construction of equipment needed for conducting the larger scale experiments later in the study.

Travel: $ 5000

Sampling trips in Minnesota. It is estimated that there will be 50 overnight stays in Northeastern Minnesota required for sampling trips. Per diem, transportation, and lodging were estimated at $100.00 per night.

Additional Budget Items: none

TOTAL ENRTF PROJECT BUDGET: $270,000

Explanation of Capital Expenditures Greater Than $3,500: none

VI. PROJECT STRATEGY:

A. Project Partners:

Funds from this appropriation:

Dr. James Miller, University of Minnesota, Duluth: $35,000.00

Dr. Nathan Johnson, University of Minnesota, Duluth: $30,000.00 (Estuary sediment experiments)

Dr. Nathan Johnson, University of Minnesota, Duluth: $40,000.00 (Biologic sulfate reduction in pits)

B. Project Impact and Long-term Strategy:

The MPCA in 2006 provided new guidance that discourages SO_4 loading into streams and lakes where it may promote formation Hg of MeHg, the kind of Hg that accumulates in fish tissues. The result of this research will be a consistent and comprehensive series of recommendations and supporting documents that state agencies, industry, and other stake holders can use to help manage mining-related sulfate releases to the St. Louis River and its estuary in Lake Superior.

C. Other Funds Proposed to be Spent during the Project Period:

An estimated $22,000 in DNR shared services.

DNR Lands and Minerals will also contribute up to 40% of Dr. Berndt's time to this project. Funds from the ENRTF will not be used for this salary.

Dr. Nathan Johnson has applied for funding through a non-state entity (US Geological Survey) which would permit the DNR to provide a $35,000.00 matching grant through its Environmental Cooperative Research fund. His research proposal is pending and so is not listed specifically elsewhere.

D. Spending HIstory:

The Minnesota Department of Natural Resources conducted a previous preliminary study on sulfate and methyl mercury reactions in the upper St. Louis River region north of Cloquet. The project was directed by Dr. Berndt and funded through the Minerals Coordinating Committee and the draft report was completed in June 2009 and updated to address comments on Dec. 30, 2009 (Berndt and Bavin, 2009). The cost of this project, not including Dr. Berndt's time, which was donated to the project, was $150,000.00. This previous research was also supplemented by a grant from the

MPCA for $20,077.00 and a separate report generated from that contract (Bavin and Berndt, 2009) was produced in June 2009.

VII. DISSEMINATION:

All reports from the Minnesota Department of Natural Resources are public documents. The documents prepared in connection with this study will all be published as official DNR reports, available free to citizens in electronic format via a searchable public Web site.

Moreover, the data and interpretations are being reworked into papers that will go through a more rigorous and formal peer review process over the upcoming years.

VIII. REPORTING REQUIREMENTS: Periodic work program progress reports will be submitted not later than Dec. 31, 2010, June 30, 2011, Dec. 31 2011, and June 30, 2012**. A final work program report and associated products will be submitted between June 30 and August 1, 2011 as requested by the LCCMR. (Completed)**

IX. RESEARCH PROJECTS: Additional research is currently underway that is testing and extending some of the interpretations that were made during this study. These research projects are being funded through a cooperative research agreement between the Minnesota Department of Natural Resources and a consortium of mining companies on the Iron Range.

Attachment A: Budget Detail for 2010 Projects - Summary and a Budget page for each partner (if applicable)

Project Title: *Sulfate Release from Mining in the St. Louis River Watershed*

Project Manager Name: *Michael E. Berndt*

Trust Fund Appropriation: $ *270,000*

1) See list of non-eligible expenses, do not include any of these items in your budget sheet

2) Remove any budget item lines not applicable

2010 Trust Fund Budget	**Result 1 Budget:**	**Amount Spent** *(8/15/13)*	**Balance** *(8/15/13)*	**Result 3 Budget:**	**Amount Spent** *(8/15/13)*	**Balance** *(8/15/13)*	**Result 2 Budget:**	**Amount Spent** *(8/15/13)*	**Balance** *(8/15/13)*	**Result 4 Budget:**	**Amount Spent** *(8/15/13)*	**Balance** *(8/15/13)*	**Result 5 Budget:**	**Amount Spent** *(8/15/13)*	**Balance** *(8/15/13)*	**TOTAL BUDGET**	**TOTAL BALANCE (8/15/13)**
	Interim Report			*Upper St. Louis River*			*Lower St. Louis River and Estuary*			*Treatment and Reclamation*			*Final Report*				
BUDGET ITEM																	
PERSONNEL: wages and benefits Research Scientist II	5000	5000	0	33456	33456	0	37850	37850	0	21622	21622	0	5000	5000	0	102928	0
Student Worker								0	0							0	0
Chemist 1					0	0		0	0		0	0				0	0
Preapproved 2012/2013 Transfer													14211	14211	0	14211	0
Contracts																0	0
University of Minnesota Duluth - Contracts to Dr. James Miller and Dr. Nathan Johnson who are collaborating in this effort. (See work program and peer review adendum for more detail)				25000	25000	0	40000	40000	0	40000	40000	0				105000	0
																0	0
																0	0
Other contracts																0	0
Waterloo Isotope Laboratory, Canada (Sulfate isotopes)				17210	17210	0	4568	4568	0							21778	0
Stream Gaging Contract or DNR Division of Waters or other contract laboratory				7835	7835	0										7835	0
Minnesota Department of Health (DOC and Hg analysis)				5088	5088	0	1440	1440	0							6528	0
Cation and Anion Analysis Contracts (Either U of M specialty lab or other contract laboratory selected through competitive contract)				5458	5458	0	1767	1767	0	0	0	0				7225	0
																	0
Non-capital Equipment / Tools *(what equipment? Give a general description and cost)*																0	0
Supplies																0	0
laboratory supplies (see work program for more detail)				1555	1555	0	1000	1000	0	0	0	0				2555	0
Travel expenses in Minnesota				1718	1718	0	222	222	0							1940	0
COLUMN TOTAL	**$5,000**	**$5,000**	**$0**	**$97,320**	**$97,320**	**$0**	**$86,847**	**$86,847**	**$0**	**$61,622**	**$61,622**	**$0**	**$19,211**	**$19,211**	**$0**	**$270,000**	**$0**