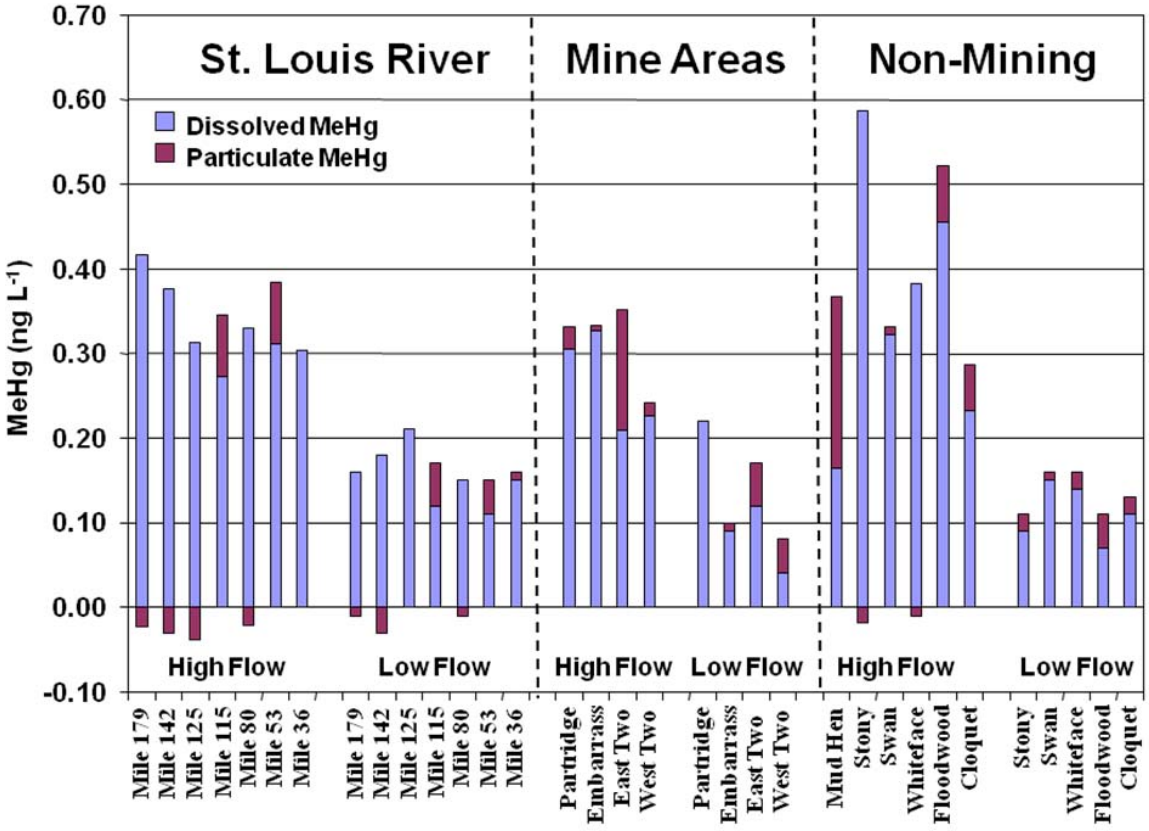

Figure 3. Dissolved and particulate MeHg concentrations for samples collected from the St. Louis River and its tributaries during May and September/October 2008. Negative values for particulate MeHg indicates samples where the MeHg concentration measured in filtered samples was slightly higher than that in unfiltered samples. Figure is from Berndt and Bavin (2009).

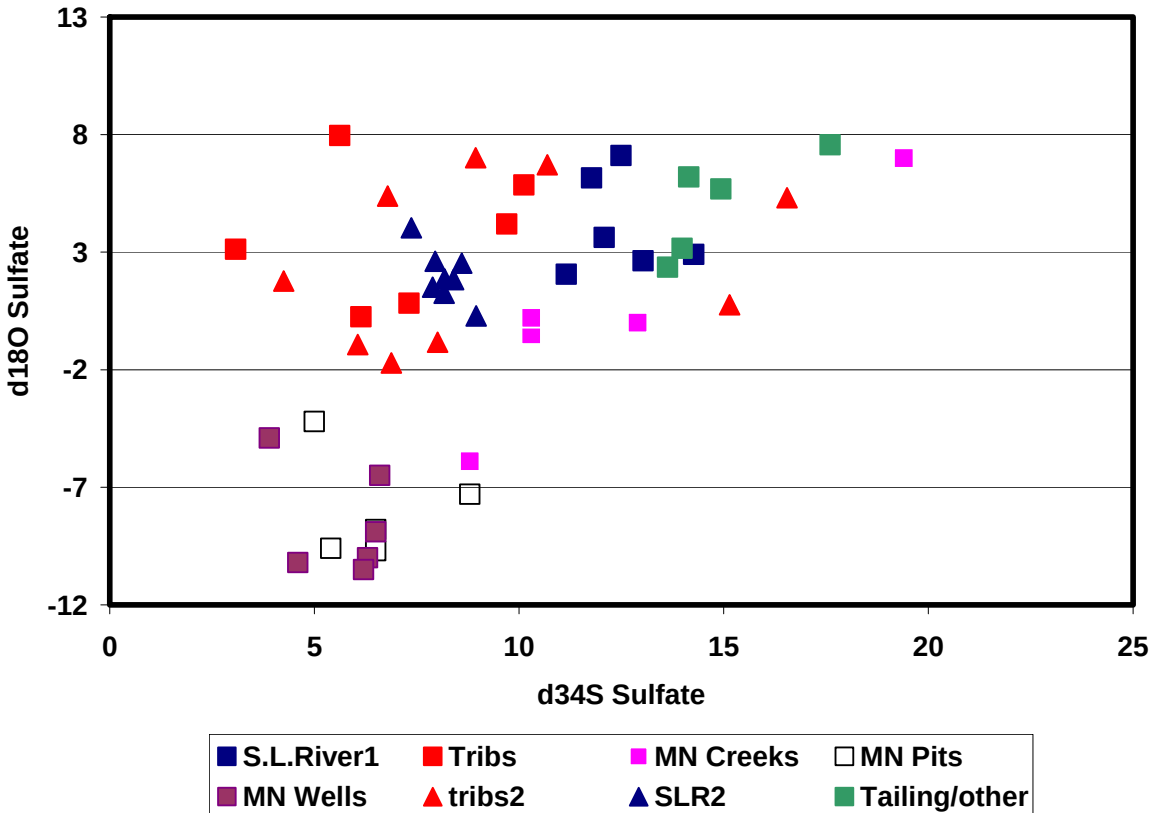

Figure 4: $\delta^{34}S_{SO4}$ and $\delta^{18}O_{SO4}$ for waters in the St. Louis River watershed. Data include published and unpublished data from DNR studies and from environmental studies conducted by mining companies. There is local and seasonal variation in the isotopic composition of dissolved SO_4 in the St. Louis River, but data needed for full interpretation of this variation is lacking.

5. Results and Deliverables –

There are, essentially, five separate deliverables in the proposed study. There are three independent studies that will be completed during the first year, followed by the production of an interim report that will be circulated to scientists and stakeholders as a means of gathering additional input. This interim report will contain a brief update and available preliminary results for each of the three studies that comprise the overall project and is considered the first deliverable. This document will be used to inform stakeholders of the progress that has been made and to help determine the relative emphasis needed in each subject area during the second year. Ultimately, a final report will be generated for each of the three project areas containing final data and interpretation by the end of the second year. These will be accompanied by a summary report linking the three studies together and providing overall interpretations regarding the controllability of SO_4 loading from mining (cost and effectiveness) and the likely impact such SO_4 controls would have on improving the environment.

6. Timetable –

Deliverable or Result	Begin	Complete
Sulfide Mineral and Stream Sampling Survey	July 1, 2010	June 30, 2012
St. Louis River Sediment Study	July 1, 2010	June 30, 2012
In-Pit Treatment Study	July 1, 2010	June 30, 2012
Interim Report	June 1, 2011	June 30, 2011
Final Reports	March 31, 2012	June 30, 2012

7. Budget –

This is a multi-component project involving a team of investigators and multiple sources of funding. For this research, Dr. Berndt will be assisted by research efforts of Dr. James Miller and Dr. Nathan Johnson at the University of Minnesota Duluth. The LCCMR funding will serve as core funding for an overall project that ties these research efforts together. Managing the research projects necessarily requires an adaptive approach whereby funding decisions for the second year are based partially on findings from the first year. However, most of the field and laboratory work and associated chemical analysis will be conducted during the first 1.5 years of the study. The last half year is reserved for consolidation of results, literature research, and writing of final reports.

A Research Scientist II, located at the Minnesota Department of Natural Resources and funded by LCCMR, will be dedicated to this project half-time during the first year to assist primarily with field and laboratory work. The other half of this researcher's employment will be provided by other research grants received by the DNR. This scientist's responsibility and funding during the second year of this project will be increased to full-time as he or she will be expected to conduct up-to-date literature searches, consolidate findings from the new studies, and

write reports that summarize the new data in the context of existing literature on the subject. A summer intern will also be employed to assist with sampling duties during the both summers. In addition, the project will require part-time assistance from a Chemist-1 or equivalent level field assistant. Dr. Berndt will contribute up to 40% of his time throughout the study at no cost to the project.

	Year 1	Year 2	Total (2 years)
Research Scientist II	$35,000	$70,000	$105,000
Chemist 1	$10,000	$10,000	$20,000
Student Summer Employment	$2,500	$2,500	$5,000
UMD Contracts	$35,000	30,000	$65,000
Stream Gaging	$5,000	$5,000	$10,000
Field Expense – Travel, meals, Lodging	$2,500	$2,500	$5000
Chemical Analysis	$37,500	$12,500	$50,000
Supplies	$7,500	$2,500	$10,000
Total	$135,000	$135,000	$270,000

8. Credentials –

8.1.Michael E. Berndt: Vita –November 2009

Research Interests:
Aqueous geochemistry, both low and high temperature. Economic geology as it relates to the origin of ore deposits and the distribution of minerals in the Earth's crust. Applying knowledge of mineral distributions and aqueous geochemistry to help evaluate environmental effects of mining in Northeastern Minnesota.

Education:

1980: BS Geology, University of Minnesota
BS Geophysics, University of Minnesota
1983: MS Geology, University of Wisconsin
1987: PhD Geology, University of Minnesota

Work Experience: (last position held at each employer)
2001-present: Research Scientist III at Minnesota Department of Natural Resources – Division of Lands and Minerals (DNR-LAM). Adjunct Faculty - University of Minnesota Department of Geology and Geophysics.

1987-2001: Senior Research Associate - University of Minnesota, Department of Geology and Geophysics.

Recent Reports and Publications (reverse chronological):

Bavin, T. K. and Berndt M. E. (2009) Chloride and Methylmercury Chemistry of the St. Louis River in NE Minnesota: A Report to the Minnesota Pollution Control Agency CFMS Contract No. B15507. 30 pages.

Berndt M. E. and Bavin T. K. (2009) Sulfate and Mercury Chemistry of the St. Louis River in Northeastern Minnesota: A Report to the Minerals Coordinating Committee. Minnesota Department of Natural Resources, Division of Lands and Minerals. St. Paul, MN. 83 pages, in review.

Lapakko, K. A. and Berndt, M. (2009). Laboratory dissolution of tailings under three different test conditions. *In* Proc. Securing the Future and 8thICARD, June 22-26, 2009, Skellefteå, Sweden (CD ROM). 11 p.

Bavin, T. K. and Berndt, M. E. (2008) Sources and fate of sulfate in NE Minnesota watersheds: A Minerals Coordinating Committee progress report. Minnesota Department of Natural Resources Division of Lands and Minerals, St. Paul, MN, 23p. plus figures, tables, and appendices.

Berndt, M. E. and Brice, W. (2008) The Origins of Public Concern with Taconite and Human Health: Reserve Mining and the Asbestos Case**.** *Regulatory Toxicology and Pharmacology.* 52, S31-S39.

Berndt, M. E. and Engesser, J. (2007) Mercury Transport in Taconite Processing Facilities: (III) Control Method Test Results. Iron Ore Cooperative Research Final Report. Minn. Dept. of Nat. Resources. 38 pages plus appendices.

Berndt, M. E. and Leibfried, R. (2007), A Geochemical Tracer Study of Minnesota's First In-Pit Disposal Facility for Taconite Tailings, Minn. Dept. Nat. Resources Reports, Div. of Minerals, St. Paul, MN. 36 p.

Berndt, M. E., Engesser, J., and Berquó, T. S. (2005) Mercury Chemistry and Mössbauer Spectroscopy of Iron Oxides During Taconite Processing on Minnesota's Iron Range. In Proceedings Air Quality V, International Conference on Mercury, Trace Elements, SO3, and Particulate Matter. Washington, DC, Sept. 2005. 15 p.

Berndt, M. E. and Engesser, J. (2005) Mercury Transport in Taconite Processing Facilities: (I) Release and Capture During Induration. Iron Ore Cooperative Research Final Report. Minnesota Department of Natural Resources. 31 pages plus appendices.

Berndt, M. E. and Engesser, J. (2005) Mercury Transport in Taconite Processing Facilities: (II) Fate of Mercury Captured by Wet Scrubbers. EPA: Great Lakes National Program Office Report. 32 pages.

Selected Other Publications/reports:

Berndt, M. E., Allen, D. E., and Seyfried, W. E., Jr. (1996) Reduction of CO_2 during serpentinization of olivine at 300C and 500 bars. *Geology* 24, 351-354.

Berndt, M. E., and Seyfried, W. E. Jr. (1999) Rates of aragonite conversion to calcite in dilute aqueous fluids at 50 to 100C: experimental calibration using Ca-isotope attenuation. *Geochim. Cosmochim. Acta*. 63, 373-382.

Berndt, M. E. and Seyfried, W. E., Jr., (1997) Calibration of Br/Cl fractionation during subcritical phase separation of seawater. *Geochim. Cosmochim. Acta.* 61, 2849-2854.

Berndt, M. E., Seyfried, W. E., and Person, M. A. (2001) SaltTherm- an integrated numerical (finite volume) flow model for predicting two phase flow near magma chambers at mid-ocean ridges. V. W. Goldschmidt Conference Proceedings, Warm Springs, Va.

Berndt, M. E., Seal, R. R., II., Shanks, W. C., III, and Seyfried, W. E., Jr. (1996) Hydrogen isotope systematics of phase separation in submarine hydrothermal systems: experimental calibration and theoretical models. *Geochim. Cosmochim. Acta*. 60, 1595-1604.

Berndt, M. E. and Soule, R. (2000) Minnesota Arsenic Study: Report on Geochemistry, in Messing, R. B. et al., The Minnesota Arsenic Study (MARS), Minnesota Department of Health, St. Paul, MN. 30 p.

Berndt, M. E., Soule, R. G., and Erickson, M. (2000) The Minnesota Arsenic Study (MARS). Possible Roll Front Mechanism to account for high arsenic in western Minnesota drinking water. Minnesota Groundwater Association Newsletter. 4p.

Foustoukos, D.I., James R.H., Berndt M.E. and Seyfried W.E.Jr. (2004) Lithium isotopic systematics of hydrothermal vent fluids at the Main Endeavour Field, Northern Juan de Fuca Ridge. *Chemical Geology* 212 (1-2), 17-26

Horita, J. K. and Berndt, M. E. (1999) Abiogenic methane formation and isotopic fractionation under hydrothermal conditions. *Science*, 285, 1055-1057.

Seyfried W.E.Jr., Seewald J.S., Berndt M.E., Ding K. and Foustoukos D.I. (2003) Chemistry of hydrothermal vent fluids from the Main Endeavour Field, Northern Juan de Fuca Ridge: Geochemical controls in the aftermath of June 1999 seismic events. *Journal of Geophysical Research* 108(B9).

8.2. Nathan W. Johnson: Vita-November, 2009

Department of Civil Engineering, University of Minnesota-Duluth
1305 Ordean Ct., 229 Voss-Kovach Hall, Duluth, MN 55812
nwjohnso@d.umn.edu; ofc: 218-726-8063; cell: 512-636-9779; fax: 218-726-8581

EDUCATION

PhD Civil Engineering (2009)
The University of Texas at Austin, Austin, TX

M.S. Environmental and Water Resources Engineering (2005)
The University of Texas at Austin, Austin, TX

B.S.E. Civil and Environmental Engineering (2003, Cum Laude)
Princeton University, Princeton, NJ

RESEARCH AREAS

Environmental biogeochemistry & aquatic chemistry
Mathematical modeling of complex environmental systems
Fate and transport of environmental contaminants in aquatic sediments
GIS, hydrologic, and water quality modeling

EXPERIENCE

08/09 – Present Assistant Professor, University of Minnesota Duluth

08/05 – 08/09 PhD Research, The University of Texas at Austin
Dissertation Topic: Mercury Biogeochemistry in Aquatic Sediments

09/07 – 11/07 Visiting Researcher, Norwegian Water Research Institute, Oslo, Norway
Research Topic: Mercury Methylation in Sandefjord, Norway

09/03 – 09/05 Master's Research, The University of Texas at Austin
Thesis Topic: ArcGIS and Hydrologic/Water Quality Modeling

PUBLICATIONS

A Model for Methyl Mercury-Related Biogeochemical Processes in Aquatic Sediments. N. W. Johnson, D. D. Reible, L. E. Katz, [in preparation] Research Paper.

Biogeochemical Changes and Mercury Methylation beneath a Sediment Cap. N. W. Johnson, D. D. Reible, L. E. Katz, in review at Environ. Sci. Technol. Research Paper.

Development of HSPF Interface Data Model for Regional Watershed Modeling. Y. C. Su, P. Zardo, T. Brink, N. W. Johnson, D. R. Maidment, GIS and Water Resources AWRA Spring Specialty Conference. Proceedings Paper. June 2006.

The ArcGIS HSPF Preprocessing Methodology. N. W. Johnson, D. R. Maidment, Report to the San Antonio River Authority. Tools & Documentation. September 2005.

PRESENTATIONS

Mercury Methylation beneath an in-situ Sediment Cap. N. W. Johnson, D. D. Reible, L. E. Katz, ACS Annual Meeting, Washington, DC. Platform Presentation. August 2009.

Mercury Methylation beneath an in-situ Sediment Cap. N. W. Johnson, D. D. Reible, L. E. Katz, SETAC North American 21st Annual Meeting, Tampa Bay, FL. Platform Presentation. November 2008.

Transport and transformation of mercury in forest–wetland–lake ecosystems. L. E. Katz, N. W. Johnson, TCEQ Mercury Impaired Waters Advisory Group. Invited Talk. November 2008.

Availability of Organic and Inorganic Contaminants. N. W. Johnson, D. D. Reible, Y. S. Hong, D. Lampert, Geological Society of America Joint Meeting. Invited Talk. October 2008.

Mercury Fate Beneath a Sediment Cap. N. W. Johnson, D. D. Reible, L. E. Katz J. Liu. BATTELLE Conference on Remediation of Contaminated Sediments. Platform Presentation. January 2007.

ArcGIS to HSPF: A Practical Application to TMDLs of Texas Waterbodies. J. L. Watts, D. R. Maidment, ESRI 2005 GIS Hydro Preconference Seminar. Online Document and Presentation. June 2005. http://www.crwr.utexas.edu/gis/gishydro05/

Considerations for Interacting with HSPF in ArcGIS. N. W. Johnson, D. R. Maidment, ESRI 2004 GIS Hydro Preconference Seminar. Online Document and Presentation. June 2004. http://www.crwr.utexas.edu/gis/gishydro04/

PROFESSIONAL AFFILIATIONS

American Chemical Society (ACS)

Society of Environmental Toxicology and Chemistry (SETAC)

American Geophysical Union (AGU)

HONORS AND AWARDS

Graduate Dean's Prestigious Fellowship Supplement, 2007-Present

EPA STAR Graduate Research Fellow (US Environmental Protection Agency), 2006-Present

THRUST 2000 Fellowship (The University of Texas at Austin), 2005-Present

Honors at Graduation, Dept. of Civil and Environ. Eng. (Princeton University), 2003

Elected Sigma Xi (2003)

8.3. James Miller: Vita – November 2009

Department of Geological Sciences, University of Minnesota-Duluth
mille066@d.umn.edu; Phone: 218-726-6582 (UMD) 218-720-4355(NRRI)

EDUCATION

PhD Geology (1986)
University of Minnesota-Twin Cities

BS Geology (1977)
University of Illinois-Urbana Champaign

RESEARCH AREAS

- Bedrock geologic mapping of Precambrian terrains in northeastern Minnesota
- Petrologic and metallogenic studies of mafic layered intrusions of the Duluth Complex

PROFESSIONAL EXPERIENCE

1/08-pres. Department of Geological Sciences, University of Minnesota Duluth
Position: Associate Professor

6/06-pres. Precambrian Research Center, University of Minnesota Duluth
Position: Administrative Director

7/83-1/08 Minnesota Geological Survey, UM-TC
Positions: Senior Scientist (6/90-present)
Scientist (7/85 - 6/90)
Research Assistant (7/83 - 7/85)

SELECTED PUBLICATIONS

Journal Articles and Reports

Miller, J.D., Jr. **1999**, Geochemical evaluation of platinum group element (PGE) mineralization in the Sonju Lake intrusion, Finland, Minnesota. Minnesota Geological Survey Information Circular 44, 32 p.

Miller, J.D. Jr., Green, J.C., Severson, M.J., Chandler, V.W., Hauck, S.A., Peterson, D.E., and Wahl, T.E., **2002**, Geology and mineral potential of the Duluth Complex and related rocks of northeastern Minnesota. Minnesota Geological Survey Report of Investigations 58, 207p. w/ CD-ROM

Park, Y-R., Ripley, E.M., Miller, J.D., Li, C., Mariga, J., and Shafer, P., **2004**, Stable isotopic constraints on fluid-rock interaction and Cu-PGE-S redistribution in the Sonju Lake Intrusion, Minnesota. Economic Geology, v. 99, no. 2, p. 325-338.

Miller, J.D., Jr., **2004**, Petrology and PGE potential of the Greenwood Lake Intrusion, Central Duluth Complex, Lake County, Minnesota. Minnesota Geological Survey Report of Investigations 62, 93p.

Jirsa, M.A., Miller, J.D., Jr., Severson, M.J., and Chandler, V.W., **2006**, Final report on the geology, geochemistry, and geophysical attributes of mafic to ultramafic

intrusions in Minnesota, excluding the Duluth Complex. Minnesota Geological Survey Open-file Report OF-06-3; on-line report

Li, C., Ripley, E.M., Oberthür, T., Miller, J.D., Jr., Gregory D. Joslin, G.D., **2007**, Textural, mineralogical and stable isotope studies of hydrothermal alteration in the main sulfide zone of the Great Dyke, Zimbabwe and the precious metals zone of the Sonju Lake Intrusion, Minnesota, USA. Miner Deposita, v. 42, in press.

Jirsa, M.A., Miller, J.D., Jr., and Morey, G.B., **2008**, Geology of the Biwabik Iron Formation. Regulartory Toxicology and Pharmacology v. 52, p. S5-S10.

Geological Maps

Miller, J.D., Jr. and Chandler, V.W., **1999**, Bedrock geologic map of the central Duluth Complex and western part of the Beaver Bay Complex, Lake and St. Louis Counties, Minnesota. Minnesota Geological Survey Miscellaneous Map Series, M-101, 1:100,000 scale.

Miller, J.D., Jr., Green, J.C., Severson, M.J., Chandler, V.W., and Peterson, D.E., **2001**, Geologic map of the Duluth Complex and related rocks, northeastern Minnesota. Miscellaneous Map Series, M-119, scale 1:200,000, 2 sheets.

Jirsa, M.A., and Miller, J.D., Jr., **2004**, Bedrock geology of the Ely and Basswood Lake 30' x 60' quadrangles, northeast Minnesota. Minnesota Geological Survey Miscellaneous Map M-148, scale 1:100,000.

Severson, M.A. and Miller, J.D., Jr., **2005**, Bedrock geology of the Babbitt quadrangle, St. Louis County, Minnesota. Minnesota Geological Survey Miscellaneous Map M-159, scale 1:24,000.

Miller, J.D., Jr., Severson, M.A. and Foose, M.P., **2005**, Bedrock geology of the Babbitt Northeast quadrangle, St. Louis and Lake Counties, Minnesota. Minnesota Geological Survey Miscellaneous Map M-160, scale 1:24,000.

Miller, J.D., Jr. and Severson, M.A., **2005**, Bedrock geology of the Babbitt Southwest quadrangle, St. Louis County, Minnesota. Minnesota Geological Survey Miscellaneous Map M-161, scale 1:24,000.

Miller, J.D., Jr., **2005**, Bedrock geology of the Babbitt Southeast quadrangle, St. Louis and Lake Counties, Minnesota. Minnesota Geological Survey Miscellaneous Map M-162, scale 1:24,000.

Miller, J.D., Jr., Green, J.C., and Jerde, E.A., **2006**, Bedrock geology of the Little Marais quadrangle, Lake and Cook Counties, Minnesota. Minnesota Geological Survey Miscellaneous Map M-172, scale 1:24,000.

Miller, J.D., Jr., and Green, J.C., 2008, Bedrock geology of the Duluth Heights and eastern portion of the Adolph quadrangles, St. Louis County, Minnesota. Minnesota Geological Survey Miscellaneous Map M-181, scale 1:24,000.

Green, J.C., and Miller, J.D., Jr., 2008, Bedrock geology of the Duluth quadrangle, St. Louis County, Minnesota. Minnesota Geological Survey Miscellaneous Map M-182, scale 1:24,000.

Miller, J.D., Jr., and Green, J.C., 2008, Bedrock geology of the West Duluth and eastern portion of the Esko quadrangles, St. Louis County, Minnesota. Minnesota Geological Survey Miscellaneous Map M-183, scale 1:24,000.

9. Dissemination and Use –

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 form and, depending on the number of requests received, either free or at-cost in hard-copy forms.

12/18/08