

2006-1008 Project Abstract

For the Period Ending June 30, 2010

PROJECT TITLE: Lake Superior Research
PROJECT MANAGER: Steven M. Colman
AFFILIATION: Large Lakes Observatory, UMD
MAILING ADDRESS: 2205 E. 5th St.
CITY/STATE/ZIP: Duluth, MN 55812
PHONE: 218-726-6979
FAX: 218-726-6979
E-MAIL: scolman@d.umn.edu
WEBSITE: www.d.umn.edu/llo
FUNDING SOURCE: Environment and Natural Resources Trust Fund and Great Lakes Protection Fund
LEGAL CITATION: M.L. 2006, Chap. 243, Sec. 20, Subd. 6
M.L. 2008, Chap. 367, Sec. 2, Subd. 4(i)
APPROPRIATION AMOUNT: 2006: \$295,000
2008: \$68,000

Overall Project Outcome and Results

There is a surprising lack of study and understanding of the ecosystems of the Great Lakes and their properties, especially in the deepwater basins. We know more about many marine systems than we know about the Great Lakes. With current concerns about the environmental health of the Great Lakes, studies supported through this project aimed to contribute to alleviating some of the unknowns. A series of studies were conducted that research the condition, functioning, and processes of Lake Superior, its sediments, and its ecosystem including:

- Studies related to the entire living ecosystem, from top predator fish down to picoplankton.
- Studies of the circulation of the lake using numerical models and oceanographic instrumentation.
- Studies of the water column including the balance between CO₂ production and oxygen consumption, the processes related to the fate of organic matter and nutrients, and the effect of these and other water column processes on primary producers.
- Studies of the transport and delivery of organic and inorganic materials to the lake floor as sediments that accumulate in deep waters of the lake and the erosion, transport, and storage of coarse-grained sediment in coastal waters.

In all of these studies, we took a holistic, “physics to fish” approach, examining the interactions between physical and biological processes.

We conducted a total of 24 field projects, with project funds going primarily to the cost of using of our research ship for an aggregate of 53 days at sea. Project funds leveraged other funding as most of these studies were small pilot projects, extensions to projects funded from other sources, and projects to collect preliminary data often required for proposals to the national science agencies. The projects have a common theme of understanding the dynamics of Lake Superior, its sediments, and its ecosystem. Through these studies, we hope to provide Minnesotans, from lay citizens to environmental managers, a better understanding of how Lake Superior works and how it might change in response to climate change and human activity.

Project Results Use and Dissemination

We have now collected a wealth of environmental data for Lake Superior. A significant part of those data have already been used for larger research proposals to the National Science Foundation and other agencies, some of which have already been successful in bringing new federal funding into the state. Plans are for the results of studies supported through this project to be published in peer-reviewed journals where they will be available to Minnesota managers and regulators. With other funding, we are in the process of developing a system called the Global Great Lakes Data and Modeling Center, which will allow incorporation and assimilation of existing data, new data like those collected in this project, and ongoing real-time observational data. The Data and Modeling Center will allow numerical models to be run and compared in real time using the different data sets and make all data readily available through an internet interface.

Trust Fund 2006 and 2008 Final Report

Date of Report: April 16, 2010
Trust Fund 2006 and 2008 Final Report
Date of Work program Approval: June 13, 2006
Project Completion Date: Oct. 31, 2009

I. PROJECT TITLE: Lake Superior Research

Project Manager: Steven M. Colman
Affiliation: Large Lakes Observatory, UMD
Mailing Address: 2205 E. 5th St.
City / State / Zip : Duluth, MN 55812
Telephone Number: 218-726-8522
E-mail Address: scolman@d.umn.edu
FAX Number: 218-726-6979
Web Page address: www.d.umn.edu/llo

Location: Western Lake Superior, map attached to original work plan.

Total ENRT Project Budget:	ENRT 2006 Appropriation: \$ 295,000
	ENRT 2008 Appropriation: \$ 86,000
	Minus Amount Spent: <u>\$ 381,000</u>
	Equal Balance: \$ 0

Budget detail: Included in text of Results and Budget Spreadsheet.

Legal Citation: M.L. 2006, Chap. 243, Sec. 20, Subd. 6
M.L. 2008, Chap. 367, Sec. 2, Subd. 4(i)

2006 Appropriation Language:

\$133,000 in fiscal year 2006 and \$134,000 in fiscal year 2007 are appropriated to the Board of Regents of the University of Minnesota for the Large Lakes Observatory for research on Lake Superior waters. \$28,000 in fiscal year 2007 from the Great Lakes protection account under Minnesota Statutes, section 116Q.02, is appropriated to the Board of Regents for the same purpose. This appropriation is available until June 30, 2009, at which time the project must be completed and final products delivered, unless an earlier date is specified in the work program.

2008 Appropriation Language:

\$86,000 is from the Great Lakes protection account to the Board of Regents of the University of Minnesota for the Large Lakes Observatory for research on Lake Superior waters. This appropriation is added to Laws 2006, chapter 243, section 20, subdivision 6, Lake Superior research. This appropriation is available until June 30, 2011, at which time the project must be completed and final products delivered, unless an earlier date is specified in the work program.

II. and III. FINAL PROJECT SUMMARY AND RESULTS:

Overall Project Outcome and Results

There is a surprising lack of study and understanding of the ecosystems of the Great Lakes and their properties, especially in the deepwater basins. We know more about many marine

systems than we know about the Great Lakes. With current concerns about the environmental health of the Great Lakes, studies supported through this project aimed to contribute to alleviating some of the unknowns. A series of studies were conducted that research the condition, functioning, and processes of Lake Superior, its sediments, and its ecosystem including:

- Studies related to the entire living ecosystem, from top predator fish down to picoplankton.
- Studies of the circulation of the lake using numerical models and oceanographic instrumentation.
- Studies of the water column including the balance between CO₂ production and oxygen consumption, the processes related to the fate of organic matter and nutrients, and the effect of these and other water column processes on primary producers.
- Studies of the transport and delivery of organic and inorganic materials to the lake floor as sediments that accumulate in deep waters of the lake and the erosion, transport, and storage of coarse-grained sediment in coastal waters.

In all of these studies, we took a holistic, “physics to fish” approach, examining the interactions between physical and biological processes.

We conducted a total of 24 field projects, with project funds going primarily to the cost of using of our research ship for an aggregate of 53 days at sea. Project funds leveraged other funding as most of these studies were small pilot projects, extensions to projects funded from other sources, and projects to collect preliminary data often required for proposals to the national science agencies. The projects have a common theme of understanding the dynamics of Lake Superior, its sediments, and its ecosystem. Through these studies, we hope to provide Minnesotans, from lay citizens to environmental managers, a better understanding of how Lake Superior works and how it might change in response to climate change and human activity.

Project Results Use and Dissemination

We have now collected a wealth of environmental data for Lake Superior. A significant part of those data have already been used for larger research proposals to the National Science Foundation and other agencies, some of which have already been successful in bringing new federal funding into the state. Plans are for the results of studies supported through this project to be published in peer-reviewed journals where they will be available to Minnesota managers and regulators. With other funding, we are in the process of developing a system called the Global Great Lakes Data and Modeling Center, which will allow incorporation and assimilation of existing data, new data like those collected in this project, and ongoing real-time observational data. The Data and Modeling Center will allow numerical models to be run and compared in real time using the different data sets and make all data readily available through an internet interface.

IV. OUTLINE OF PROJECT RESULTS:

As noted above, project results to date include data collection activities aimed at a better understanding of the condition, functioning, and processes of Lake Superior, its sediments, and its ecosystem. The original three Results were part of funding in FY 2006, and they have been completed for more than a year. In early 2008, a new project, listed below as Result 4, was proposed and planned as described in that Result section. This Result has also been completed, as described below.

Result 1: Field research 2006

Description: A portfolio of research activity was conducted on Lake Superior in the summer of 2006. As mentioned in the Project Summary, these studies are small pilot studies, extensions to projects funded from other sources (see section VI-B), and activities to collect preliminary data often required for proposals to the National Science Foundation. The studies have a common theme of understanding the dynamics of Lake Superior, its sediments, and its ecosystem. All studies have been peer reviewed either by a funding agency or by a committee of scientists that use the RV Blue Heron, commonly both.

Costs paid for with Environment and Natural Resources Trust (ENRT) funds were entirely for field activities, observations, and data collection on board the RV Blue Heron, accounted for at the ship's day rate of \$4654. The day rate includes crew, technician and ship manager salaries; insurance; and operational costs (fuel, food, garbage, dock fees, etc.). Total of cost of activities listed above was \$65,156. Other sources of project funding (in some case, the main funding for the project) are listed with the individual projects.

Summary Budget Information for Result 1:	ENRT Budget	\$ 65,156
	Expended	\$ 65,156
	Balance	\$ 0

Completion Date: Oct. 31, 2006

Final Report Summary: Research activities included:

1. (Wattrus, PI) June 4th-6th, in conjunction with an NSF-funded cruise. An acoustic survey of the western arm of Lake Superior to image the paleo-shorelines associated with earlier (Minong/Houghton) lowstands of the lake. Two days of ship time (\$9,308) were paid with ENRT funds, and the National Science Foundation (NSF paid for an additional day, along with support for equipment usage and data analyses. Results: The paleo-shoreline features were located and imaged. The data are also being used to map the size and dimensions of the sediment fan associated with the Nemadji River.
2. (Hrabik, PI) July 26th – August 1st, in conjunction with a MN DNR-funded cruise for fish stock assessments. Four days of ship time (\$18,616) were paid with ENRT funds. Two additional days were paid for by MN DNR. Results: These fish stock assessments, in cooperation with the MN DNR, are part of a long term monitoring program; this operation provided the monitoring data for 2006. In addition, with the additional ship time, Dr. Hrabik used both traditional trawling gear as well as hydroacoustic equipment to test the ability of hydroacoustic survey tools to accurately assess fisheries stock when compared to more traditional survey methods (trawls). Results of the comparison are being analyzed.
3. (Wattrus, PI) August 17th-18th. An acoustic survey of the distal sediment fan associated with the Silver Bay mine-tailings delta. Two days of ship time (\$9,308) were paid with ENRT funds. Results: This was a pilot study to prepare for a future Sea Grant proposal. Data were collected to determine where the finer sediments derived from the delta turbidity currents have been deposited. These sediments have been mapped and will provide the necessary preliminary data for the Sea Grant proposal.
4. (Hrabik, PI) August 23rd-24th. Mysis nocturnal migration study. Two days of ship time (\$9,308) were paid for with ENRT. This study was designed to collect preliminary data for a future NSF grant proposal. Results: The project used trawling to collect fish during the day, at night, and at dusk (for acoustic target id and diet information). The project also collected mysis using plankton tows at a variety of depths to

establish their density at depth during the day and at night. These data are now being analyzed to clarify some of the mysteries related to mysis migrations and the extent to which cisco feed on them during the day, dawn and dusk, as well as night periods.

5. (Brown, PI) October 5th. Supplemental operations for Brown's Sea Grant project. His project uses data from moored instruments to develop a more detailed understanding of biological gas cycling on daily as well as seasonal timescales. One day of ship time (\$4,654) paid with ENRT funds. Results: This project supplemented a full two year Sea Grant project and allowed additional limnological data to be collected. These data have been analyzed and are being compiled for an MS thesis and eventual publication in a scientific journal.
6. (Colman, PI) Research activities and training for a variety of graduate, undergraduate, and minority students, using real world problems on Lake Superior. Cruises occurred on July 7th, September 14th and 16th, and October 2nd, 3rd, and 4th. Faculty in charge of the cruise included Drs. Branstrator, Johnson, and Shannon, and Ms. Hardwig and Sharp. Three days of ship time, \$13,962. Results: Successful training a research experiences for a variety of students, some of whom are training as future researchers on Lake Superior.

Result 2: Field research 2007

Description: A portfolio of research activity was conducted on Lake Superior in the summer of 2007. As mentioned in the Project Summary, these studies are small pilot studies, extensions to projects funded from other sources (see section VI-B), and activities to collect preliminary data often required for proposals to the National Science Foundation. The studies have a common theme of understanding the dynamics of Lake Superior, its sediments, and its ecosystem. All studies have been peer reviewed either by a funding agency or by a committee of scientists that use the RV Blue Heron, commonly both.

Costs were entirely for field activities, observations, and data collection on board the RV Blue Heron, accounted for at the ship's day rate of \$5385. The day rate includes crew, technician and ship manager salaries; insurance; and operational costs (fuel, food, garbage, dock fees, etc.). Total of cost of activities listed above was \$110,390.

Summary Budget Information for Result 2:	ENRT Budget	\$ 110,390
	Expended	\$ 110,390
	Balance	\$ 0

Completion Date: Oct. 31, 2007

Final Report Summary: Research activities for 2007 included:

1. Austin, PI, June 5th-7th and September 17th-19th – Deployment of a large meteorological buoy off of the North Shore. Six days of ship time, \$32,310. Results: four months of data were collected including standard meteorological parameters as well as CO₂ content of the atmosphere and the water column. The fact that the LLO meteorological buoy has been successfully deployed and recovered was noted in a recently submitted National Science Foundation proposal and the buoy's data will be used in the funded project. Additionally, LLO's meteorological buoy was highlighted in a recently submitted GLOS (Great Lakes Observing System) proposal to NOAA (National Oceanic & Atmospheric Administration).
2. Hrabik, PI, May 15th-17th, July 24th – 26th and October 21st-23rd – ENRT funds paid for supplemental operations for Hrabik's SeaGrant project: a study of diurnal vertical

- migration of Mysis, prey fish and predatory fish. Four and one-half days of ship time, \$24,232, paid by ENRT funds with the remaining time paid by the Minnesota SeaGrant program. Results: Data were collected by trawling, plankton tows, hydroacoustic surveys and surveys using the Triaxus underwater towed vehicle. Hrabik obtained funding through SeaGrant using data collected during his 2006 ENRT funded cruise. This study will help clarify some of the mysteries related to mysis migrations and their interactions with prey and predatory fish during the day, dawn and dusk as well as night periods.
3. Hrabik, PI, August 4th-10th– Fish stock assessment in cooperation with the MN & WI DNR: additional operations in a cooperative project using funds from ENRT, the MN DNR and the WI DNR. Using traditional trawling gear as well as hydroacoustic equipment, Dr. Hrabik tests the ability of hydroacoustic survey tools to accurately assess fisheries stock when compared to more traditional survey methods (trawls). Three days of ship time, \$16,155, paid by ENRT funds with the remaining time paid by the MN and WI DNR. Results: These fish stock assessments, in cooperation with the MN and WI DNR, are part of a long term monitoring program. This operation provided the monitoring data for 2007.
 4. Minor, PI, August 26th – Preliminary sampling of dissolved organic carbon (DOC), dissolved inorganic carbon (DIC), and particulate organic carbon (POC) from the Lake Superior water column. One day of ship time, \$5,385. Results: Dr. Minor collected a water column profile of DOC, DIC and POC and is undertaking radiocarbon analyses to investigate Lake Superior's carbon cycle. The data support a currently funded Grant-in-Aid award and will be used in a February, 2008, National Science Foundation proposal.
 5. Sterner, PI , July 30th-August 1st, October 5th-7th, November 7th-9th – ENRT paid for supplemental operations for Sterner's Sea Grant project: a study of primary production and grazing dynamics in Lake Superior. Two days of ship time, \$10,770, paid by ENRT with the remaining time paid by the Minnesota SeaGrant program and the University of Minnesota's Office of the Vice President for Research. Results: Data were collected using our CTD/water sampling system and by using a free-floating buoy system. Ultimately, this study will improve estimates of lake wide primary productivity and make the first estimates of grazing on phytoplankton and bacterioplankton. The resulting data will be used in subsequent proposals to the National Science Foundation and SeaGrant.
 6. Wattrus, PI, October 12th – Geophysical survey of underwater (drowned) beach ridges formed during the Houghton Lowstand. One half-day of ship time, \$2,693. Results: This work was a continuation of the 2006 Wattrus ENRT/NSF funded survey of the paleo-shorelines associated with a previous lowstand of Lake Superior. The survey was used to identify likely sediment coring sites to collect sediment to help date the lowstands. The resulting data will be used as preliminary results for an NSF proposal that will seek funding to further delineate paleo-shorelines for Lake Superior.
 7. Colman, PI - Research activities and training for a variety of graduate and undergraduate students using real world problems on Lake Superior. Cruises occurred on May 1st and 19th, July 6th, September 11th, and October 8th, 9th and 10th. Faculty in charge of the cruises included Drs. Branstrator, Danz, Gallup, Little, Morton and Ricketts and Ms. Sharp. Three and a half days of ship time, \$18,848. Results: Successful training and research experiences for a variety of students, some of whom are training as future researchers on Lake Superior.

Result 3: Field research 2008

Description: A portfolio of research activity was conducted on Lake Superior in the summer of 2008. As mentioned in the Project Summary, these studies are small pilot studies, extensions to projects funded from other sources (see section VI-B), and activities to collect preliminary data often required for proposals to the National Science Foundation. The studies have a common theme of understanding the dynamics of Lake Superior, its sediments, and its ecosystem. All studies have been peer reviewed either by a funding agency or by a committee of scientists that use the RV Blue Heron, commonly both.

Costs are entirely for field activities, observations, and data collection on board the RV Blue Heron, accounted for at the ship's day rate of \$5,556. The day rate includes crew, technician and ship manager salaries; insurance; and operational costs (fuel, food, garbage, dock fees, etc.). Total of cost of activities listed above is \$119,454, which was charged during the field season.

Summary Budget Information for Result 3:	ENRT Budget	\$ 119,454
	Expended	\$ 119,454
	Balance	\$ 0

Completion Date: Oct. 31, 2008

Final Report Summary: Research activities for 2008 included:

1. Austin, PI, June 13th-16th – Deployment of a meteorological buoy off of the North Shore and three subsurface buoys throughout the rest of Lake Superior. One day of ship time, \$5,556. Results: five months of data were collected including standard meteorological data as well as fluctuations in water column temperature. On the basis of data from 2008 and previously years (also ENRT supported), Austin was recently funded by the National Science Foundation (NSF) for three more years of data collection using the meteorological buoy and the subsurface buoys. Data from the North Shore meteorological buoy was available to the public online while the buoy was deployed.
2. Brown, PI, August 28th-29th – Preliminary sampling of waters in the western arm of Lake Superior to determine dissolved oxygen content for calculations of deep water respiration. Two days of ship time, \$11,112. Results: Brown was able to determine that coastal deep water oxygen content is higher than off-shore deep water oxygen content in late summer. This indicates that near shore deep water respiration is higher than off-shore deep water respiration, which brings into question previous calculations of Lake Superior primary productivity. These data will be used in future proposals submitted to NSF and the Sea Grant program.
3. Hrabik, PI, May 28th-30th, July 23rd-25th, and October 23rd-25th – ENRT paid for supplemental operations for Hrabik's Sea Grant study of diurnal vertical migration of Mysis, prey fish, and predatory fish.. The project required nine days on board the Blue Heron during 2008, of which ENRT paid for 3.5 days. The remaining ship time necessary for the project were paid by the Minnesota Sea Grant program. Three and one-half days of ship time, \$19,446. Results: data were collected by trawling, plankton tows, hydroacoustic surveys and surveys using the Triaxus underwater towed vehicle. Hrabik obtained funding through Sea Grant on the basis of data collected during his 2006 ENRT-funded cruise. This study will help clarify some of the mysteries related to mysis migrations and their interactions with prey and predatory fish during the day, dawn and dusk, as well as night periods.

4. Hrabik, PI, August 6th-12th – Fish stock assessment in cooperation with the DNR: additional operations in a cooperative project using funds from ENRT, the MN DNR and the WI DNR. Using traditional trawling gear as well as hydroacoustic equipment, Dr. Hrabik is testing the ability of hydroacoustic survey tools to accurately assess fisheries stock when compared to more traditional survey methods (trawls). Three days of ship time, \$16,668. Four additional days of ship time were paid by MN and WI DNR. Results: These fish stock assessments, in cooperation with the MN and WI DNR, are part of a long term monitoring program. This operation provided the monitoring data for 2008.
5. McNeill, PI, August 26th - Supplemental operations for McNeill's NSF project: 'Singlet oxygen's role in the photochemical-biochemical degradation of dissolved organic carbon.' The study intends to determine the impact of oxygen on microbial use of organic matter in Lake Superior. One half-day of ship time, \$2,778. Results: McNeill was able to extend the data set he has collected over the last six years. His current NSF grant has ended so this cruise was extremely valuable for maintaining continuity in his data set, strengthening any future proposals.
6. Minor, PI, May 20th-23rd and September 23rd-26th- Undertook preliminary sampling of the Lake Superior water column to determine dissolved organic carbon (DOC), dissolved inorganic carbon (DIC) and particulate organic carbon (POC) content. Minor is undertaking radiocarbon analyses of these various forms of carbon to investigate Lake Superior's carbon cycle. Two days of ship time, \$11,112. Results: Dr. Minor used data from this and previously ENRT-funded cruises in a successful NSF proposal to continue these measurements throughout the lake through 2010.
7. Sterner, PI, April 29th-May 1st, July 30th-August 1st and September 16-18th - ENRT paid for supplemental operations for Sterner's Sea Grant project: a study of primary production and grazing dynamics in Lake Superior. Two and one half days of ship time, \$13,890, paid by ENRT, with the remaining time paid by the Minnesota Sea Grant program and the University of Minnesota's Office of the Vice President for Research. Results: Data were collected using our CTD/water sampling system and by using a free-floating buoy system. Ultimately, this study will improve estimates of lake wide primary productivity and make the first estimates of grazing on phytoplankton and bacterioplankton. The resulting data will be used in subsequent proposals to the National Science Foundation and Sea Grant.
8. Werne, PI, May 20th-23rd and September 23rd-26th – Supplemental operations for Werne's NSF project: 'Linking archaeal membrane lipids and ecology in great lakes: Understanding the TEX86 paleotemperature proxy'. Werne's project proposes to better understand crenarchaeota, an aquatic organism that is poorly understood, but whose membrane structures might be useful in reconstructing past lake temperature. Four and one half days of ship time, \$25,002. Results: ENRT funding allowed for an extension of this NSF funded project. By allowing Werne to extend his project by deploying and recovering moorings during 2008, additional data were collected which may be useful in getting additional funding from NSF.
9. Colman, PI - Research activities and training for a variety of graduate and undergraduate students using real world problems on Lake Superior. Cruises occurred on May 6th, September 11th, 13th, 20th, and October 1st. Faculty in charge of the cruises were Drs. Gallup, Johnson and Werne and Ms. Sharp. Two and half days of ship time, \$13,890. Results: Successful training and research experiences for a variety of students, some of whom are training as future researchers on Lake Superior.

Result 4: Buoy observations on Lake Superior in 2008-09

Description: This result was added to the Project in January, 2008, as a result of a supplemental application for funds from the Great Lakes Protection Account (see supplemental appropriation language). Jay Austin, the PI, deployed a large meteorological buoy off of the North Shore as well as three subsurface moorings in Eastern, Central and Western Lake Superior. The meteorological buoy measures standard meteorological parameters (humidity, wind speed, air temperature, cloudiness), as well as water temperature at multiple depths in the water column. The subsurface moorings measure water temperature at multiple depths. Using this information, in conjunction with satellite data (indicating, for example, the extent of ice cover) Austin will, among other things, gain a better understanding of the relationship between ice cover and water temperature in Lake Superior. This, in turn, will give us a better understanding of the effect of regional climate on lake temperature and lake level. Data collected from this buoy and moorings will be used to augment a NSF-funded project Austin currently is conducting and a GLOS (Great Lakes Observing System) project in which Austin is participating. Both of these related proposals are currently active, and the work described here is an extension of research that has been peer reviewed in two published scientific journal articles.

Costs are for 12 days of ship time for field activities, observations, and data collection on board the RV Blue Heron, accounted for at the ship's day rate of \$5,556, totaling \$66,672. The day rate includes crew, technician and ship manager salaries; insurance; and operational costs (fuel, food, garbage, dock fees, etc.). An additional cost is approximately 16 weeks of technician salary and benefits (\$19,328), before and after the field operations, for mobilizing and demobilizing the buoys. Total of cost of activities listed above is \$86,000.

Summary Budget Information for Result 4:	ENRT Budget	\$ 86,000
	Expended	\$ 86,000
	Balance	\$ 0

Result Status as of March 1, 2010: Completed.

Final Report Summary:

During 2008 the supplemental funds paid for ship time on June 13-16th (three days), September 3rd-6th (four days) and October 30th (one half day). Seven and one half ship days: \$41,670. Five months of data were collected including standard meteorological data as well as fluctuations in water column temperature. Data from the North Shore meteorological buoy was available for five months to the public online while the Meteorological buoy was deployed. The subsurface buoys were redeployed in September and will be collecting data under the ice during the winter. In addition, technician salary and benefits (\$19,328) were accrued for mobilization and demobilization of the buoys.

During 2009, we used four and one half additional ship days (\$25,002) on this project to deploy and recover the meteorological buoys and a total of seven subsurface buoys. As a result of these two seasons of data collection on Lake Superior, we now have an unparalleled set of observations of physical properties of the water column through the changing seasons. This is especially true of the temperature field of the water column, which drives the overall circulation of the lake. We also have some of the first continuous measurements of in-situ ice extent and thickness anywhere in the world. These data are currently being analyzed and promise to lead to a new understanding of seasonal changes in Lake Superior.

V. TOTAL ENRT PROJECT BUDGET:

All Results: Personnel: \$19,328

All Results: Equipment: \$ 0

All Results: Development: \$ 0

All Results: Acquisition: \$ 0

All Results: Other: Field observations and data collection costs \$ 361,672

TOTAL ENRT PROJECT BUDGET: \$381,000

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

VI. OTHER FUNDS & PARTNERS:

A. Project Partners:

1. Several partners from the Large Lakes observatory at the University of Minnesota Duluth, including Steven Colman, Nigel Wattrus, Jay Austin, Elizabeth Minor, Thomas Johnson, Erik Brown, and Josef Werne.
2. Several partners from science Departments at the University of Minnesota Duluth, including Donn Branstrator, Thomas Hrabik, Timothy Demko, James Miller, Angela Sharp Nick Nanz, Christina Gallup, and Amanda Little.
3. Several partners from science departments at the University of Minnesota Twin Cities, including Robert Sterner, James Cotner, Christopher McNeill

The partners are involved with different projects at different times. The distribution of funds to the project Principle Investigator is listed with each project above.

B. Other Funds being Spent during the Project Period:

Summary of other funds related to the projects listed for Results 1-4, with sources and approximate amounts. These projects either (1) were funded as a result of pilot projects funded by the ENRT grant, (2) were enhanced and expanded by ENRT funding of field operations, or (3) are related to and ran concurrently with the ENRT project. They include:

1. National Science Foundation, \$ 3,100,000
2. Minnesota Sea Grant, \$380,000
3. Minnesota Dept. of Natural Resources, \$210,000
4. Great Lakes Observing System (GLOS), \$52,000

C. Required Match (if applicable): Not applicable

D. Past Spending: None

E. Time: Appropriation language extends project until June 30, 2011.

VII. DISSEMINATION:

Plans are for the results of all of these projects to be published in peer-reviewed journals and presented at national meetings. The results will also be presented to state environmental managers where appropriate. The results will also be available on the web site of the Large Lakes Observatory (www.d.umn.edu/llo).

VIII. REPORTING REQUIREMENTS:

Periodic work program progress reports will be submitted not later than:
Dec. 31, 2006 (submitted)

May 31, 2007 (submitted)
Dec. 31, 2007 (submitted)
May 31, 2008 (submitted)
Jan. 15, 2009 (submitted)
April 16, 2010 (this report, final)

IX. RESEARCH PROJECTS:

Research projects are listed along with a brief description in the Outline of Project Results (Section IV).

Attachment A: Budget Detail for 2005 Projects - Summary and a Budget page for each partner (if applicable)

Proposal Title: *Fill in your proposal title and Proposal # (A-01)*

Project Manager Name: *Fill in your name.*

LCMR Requested Dollars: \$ *Fill in the dollar amount you are requesting.*

- 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

2005 LCMR Proposal Budget	<u>Result 1 Budget:</u>	<u>Result 1 Budget, revised:</u>	<u>Amount Spent (12/31/06)</u>	<u>Balance (4/21/08)</u>	<u>Result 2 Budget:</u>	<u>Result 2 Budget, revised:</u>	<u>Amount Spent (12/31/07)</u>	<u>Balance (4/21/08)</u>	<u>Result 3 Budget:</u>	<u>Result 3 Budget, revised:</u>	<u>Amount Spent (10/31/08)</u>	<u>Balance (10/31/08)</u>	<u>Result 4 Budget:</u>	<u>Amount Spent (11/01/09)</u>	<u>Balance (6/25/09)</u>	
	<i>Field research 2006</i>				<i>Field research 2007</i>				<i>Field research 2008</i>				<i>Field research 2008-9</i>			TOTAL FOR BUDGET ITEM
BUDGET ITEM																
PERSONNEL: Staff Expenses, wages, salaries													14,496	14,496	0	14,496
PERSONNEL: Staff benefits –													4,832	4,832	0	4,832
Contracts																
Professional/technical (<i>with whom?, for what?</i>)																
Other contracts (<i>with whom?, for what?</i>) <i>list out: personnel, equipment,</i>																
Other direct operating costs (<i>for what? – be specific</i>)																
Equipment / Tools (<i>what equipment? Give a general description and cost</i>)																
Office equipment & computers - NOT ALLOWED <i>unless unique to the project</i>																
Other Capital equipment (<i>list specific items</i>)																
Land acquisition (<i>how many acres</i>)																
Land rights acquisition (<i>less than fee</i>)																
Printing																
Other Supplies (<i>list specific categories</i>)																
Travel expenses in Minnesota																
Travel outside Minnesota (<i>where?</i>)																
Construction (<i>for what?</i>)																
Other land improvement (<i>for what?</i>)																
Other: Field observations and data collection on board the RV Blue Heron at the ship's day rate of \$4654 (increasing after 1st yr). Includes crew, technician and ship manager salaries; insurance; and operational costs (fuel, food, garbage, dock fees, etc.)	67,483	65,156	65,156	0	113,759	110,390	110,390	0	113,758	119,454	119,454	0	66,672	66,672	0	361,672
COLUMN TOTAL	67,483	65,156	65,156	0	113,759	110,390	110,390	0	113,758	119,454	119,454	0	86,000	86,000	0	381,000