2010 Project Abstract
For the Period Ending June 30, 2014

PROJECT TITLE: County Geologic Atlases and Related Hydrogeologic Research
PROJECT MANAGER: Dale R. Setterholm
AFFILIATION: Regents of the University of Minnesota; Minnesota Geological Survey
MAILING ADDRESS: 2642 University Ave. W.
CITY/STATE/ZIP: St. Paul, MN 55114
PHONE: 612-627-4780
E-MAIL: sette001@umn.edu
WEBSITE: http://www.mngs.umn.edu/index.html
FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2010, Chp. 362, Sec. 2, Subd. 3a; M.L. 2013, Chapter 52, Section 2, Subdivision 17

APPROPRIATION AMOUNT: $1,130,000

Overall Project Outcome and Results
The Minnesota Geological Survey maps sediment and rock because these materials control where water can enter the subsurface (recharge), where and how much water can reside in the ground (aquifers), where the water re-emerges (discharge), and at what rates this movement occurs. This information is essential to managing the quality of our water and the quantity that can be sustainably pumped. This project completed geologic atlases for Sherburne and Morrison counties, and contributed to atlas work in Anoka, Wright, Hennepin, Hubbard, Becker, Wadena, St. Louis, and Lake counties. Information about the geology is gleaned from the records of domestic wells, and from drilling conducted for this project. In Sherburne County we used 14,450 wells and 5 cores and in Morrison County we used 6,400 wells and 21 cores, and soil borings and geophysical surveys. From the data we created maps of the geology immediately beneath the soil; the aquifers within the glacial sediment; and the shape, elevation, and rock types of the bedrock surface. These maps and data support monitoring, wellhead protection, water appropriation, clean-ups, and supply management.

The deep bedrock aquifers in southeastern Minnesota are in most places not yet significantly impacted by pollution and presumed to be protected by low permeability overlying geologic layers, called aquitards. Even though aquitards are an important control on recharge and contaminant transport, their hydrologic characteristics are poorly understood compared to aquifers. This subproject investigated the St. Lawrence Formation through existing data, new data on fracturing, and by constructing an instrumented borehole to test the water-bearing characteristics. We learned that the St. Lawrence acts to retard vertical water flow where it is buried by more than 50 feet of overlying rock, but fails to do so in more shallow settings. Parts of the formation convey water horizontally in either setting.

A third subproject traced ground water movement in the Rochester area by examining the chemistry of the water. We learned that flow patterns are changing, apparently in response to high capacity pumping.

Project Results Use and Dissemination
County geologic atlases are distributed in print and digital formats. The digital format allows us to include all the data that support the maps and the ability to change the maps or create new ones. The products are available from the MGS web site (http://www.mngs.umn.edu/index.html). We also conduct post-project workshops in the map area to familiarize users with the products and their applications. The products are also distributed to libraries. Products of the Morrison County Geologic Atlas have been applied to finding new municipal water supplies in Little Falls and Motley. We expect both these atlases will be applied to understanding the widespread distribution of nitrate in ground water in this part of Minnesota.

Additional funding from DNR has allowed us to continue to collect data from the instrumented borehole constructed for the St. Lawrence subproject. This additional data will be combined with what we have in

a formal MGS Report of Investigations. The Rochester study is likely to improve computer simulations of water flow and influence decisions about the distribution and pumping rates of the wells that supply the city.

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

Date of Report: 8/7/14
Final Report
Date of Work Program Approval: 6/09/10
Project Completion Date: 6/30/14

I. PROJECT TITLE: County Geologic Atlases and Related Hydrogeologic Research

Project Manager: Dale R. Setterholm
Affiliation: Regents of the University of Minnesota; Dept: Minnesota Geological Survey
Mailing Address: Regents: 450 McNamara Center
200 Oak Street SE
Minneapolis MN 55455
Mailing Address: Geological Survey: 2642 University Ave. W.
St. Paul MN 55114
Telephone Number: 612-627-4780
E-mail Address: sette001@umn.edu
Fax Number: 612-627-4778
Web Site Address: http://www.geo.umn.edu/mgs/

Location: Result 1: Sherburne County and Morrison County; Result 2: that part of Minnesota where the St. Lawrence Formation exists (southeastern third of MN); Result 3: Greater Rochester area

Total ENRTF Project Budget:	**ENRTF Appropriation**	**$ 1,130,000**
	Minus Amount Spent:	**$ 1,130,000**
	Equal Balance:	**$ 0**

Legal Citation: M.L. 2010, Chp. 362, Sec. 2, Subd. 3a; M.L. 2013, Chapter 52, Section 2, Subdivision 17

Appropriation Language:
$1,130,000 is from the trust fund to the Board of Regents of the University of Minnesota for the Geologic Survey to initiate and continue the production of county geologic atlases, establish hydrologic properties necessary to water management, and investigate the use of geochemical data in water management. This appropriation represents a continuing effort to complete the county geologic atlases throughout the state. This appropriation is available until June 30, 2013, by which time the project must be completed and final products delivered. The availability of the appropriations for the following projects are extended to June 30, 2014: (10) Laws 2010, chapter 362, section, subdivision 3, paragraph (a), County Geologic Atlases and Related Hydrogeologic Research;

II. FINAL PROJECT SUMMARY AND RESULTS:

The Minnesota Geological Survey maps sediment and rock because these materials control where water can enter the subsurface (recharge), where and how much water can reside in the ground (aquifers), where the water re-emerges (discharge), and at what rates this movement occurs. This information is essential to managing the quality of our water and the quantity that can be sustainably pumped. This project completed geologic atlases for Sherburne and Morrison counties, and contributed to atlas work in Anoka, Wright, Hennepin, Hubbard, Becker, Wadena, St. Louis, and Lake counties. Information about the geology is gleaned from the records of domestic wells, and from drilling conducted for this project. In Sherburne County we used 14,450 wells and 5 cores and in Morrison County we used 6,400 wells and 21 cores, and soil borings and geophysical surveys. From the data we created maps of the geology immediately beneath the soil; the aquifers within the glacial sediment; and the shape, elevation, and rock types of the bedrock surface. These maps and data support monitoring, wellhead protection, water appropriation, clean-ups, and supply management.

The deep bedrock aquifers in southeastern Minnesota are in most places not yet significantly impacted by pollution and presumed to be protected by low permeability overlying geologic layers, called aquitards. Even though aquitards are an important control on recharge and contaminant transport, their hydrologic characteristics are poorly understood compared to aquifers. This subproject investigated the St. Lawrence Formation through existing data, new data on fracturing, and by constructing an instrumented borehole to test the water-bearing characteristics. We learned that the St. Lawrence acts to retard vertical water flow where it is buried by more than 50 feet of overlying rock, but fails to do so in more shallow settings. Parts of the formation convey water horizontally in either setting.

A third subproject traced ground water movement in the Rochester area by examining the chemistry of the water. We learned that flow patterns are changing, apparently in response to high capacity pumping.

Project Results Use and Dissemination

County geologic atlases are distributed in print and digital formats. The digital format allows us to include all the data that support the maps and the ability to change the maps or create new ones. The products are available from the MGS web site (http://www.mngs.umn.edu/index.html). We also conduct post-project workshops in the map area to familiarize users with the products and their applications. The products are also distributed to libraries. Products of the Morrison County Geologic Atlas have been applied to finding new municipal water supplies in Little Falls and Motley. We expect both these atlases will be applied to understanding the widespread distribution of nitrate in ground water in this part of Minnesota.

Additional funding from DNR has allowed us to continue to collect data from the instrumented borehole constructed for the St. Lawrence subproject. This additional data will be combined with what we have in a formal MGS Report of Investigations. The Rochester study is likely to improve computer simulations of water flow and influence decisions about the distribution and pumping rates of the wells that supply the city.

III. A. PROGRESS SUMMARY AS OF 8/12/10:

Amendment Request (8/12/10):

We are requesting an amendment to support the purchase of geophysical equipment that will increase our efficiency in geologic mapping. This equipment requires fewer people and much less time to acquire bedrock elevation data than the methods we have used in the past and anticipated using in this project. We believe much of the cost will be offset by reduced labor costs within this project, and will certainly be covered when the equipment is deployed on current and future county geologic atlases. We have tested equipment owned by others to confirm its accuracy and cost of deployment.

Amendment Approved (8/13/2010)

Amendment Request (9/26/11):

We would like to change the work plan for Result 2 – Investigation of the hydrologic properties of the St. Lawrence Formation, to redirect resources towards the drilling of a scientific borehole near the city of Lakeville, Minnesota. The original work plan contains funds for drilling. The Lakeville hole we propose to drill is deeper and requires more specialized equipment than was originally planned, and therefore costs more than the current drilling budget.

In order to cover this additional cost, we would like to move sub award funds related to dye tracing ($3,000 in non-capital supplies; $30,000 in capital equipment; $10,000 in professional salary, $2,000 in travel) to expenses related to the Lakeville scientific borehole. The dye-tracing sub award was with the University of Minnesota Department of Geology and Geophysics, and the MNDNR. Dr. E. Calvin Alexander – University of Minnesota (612-624-3517) and Jeff Green – MN DNR (507-285-7430) agree to the work plan change. While the dye tracing results would have been useful, we believe the goals of the project are best met with data collected from the Lakeville site.

Amendment Approved (9/26/11)

III. B. PROGRESS SUMMARY AS OF 12/31/10:

Geologic Atlases have been initiated in Sherburne and Morrison counties. The County Well Index database (CWI) for Sherburne County now has nearly 16,000 well records including 10,000 wells that the county staff established locations for. In Morrison County the staff located 4,425 wells and the database now contains more than 7,000 wells. Work has begun on the surficial geologic maps for each county. The investigation of the St. Lawrence Formation has been initiated with field work that included analysis of fracture patterns in outcrops across southeastern Minnesota, and dye-tracing in collaboration with the Minnesota DNR (in conjunction with the LCCMR funded “Innovative Springshed Mapping” project). We have now conducted 10 dye traces, which have provided insight into groundwater flow through the St Lawrence aquitard. Planning for borehole drilling and testing of the St Lawrence aquitard has also progressed. We have selected a site at Lakeville Minnesota, and in collaboration with the USGS are working with Lakeville city officials and the Minnesota Department of Health in an effort to proceed with the drilling and testing operation, scheduled for late

summer or fall, 2011. The Rochester water chemistry work will begin later in the grant period.

III. C. PROGRESS SUMMARY AS OF 7/21/11

The combined efforts of MGS and county staff have established the locations of nearly 10,000 wells in Sherburne County and more than 4,000 wells in Morrison County. There is some follow-up work underway to resolve problems with about 200 additional wells. Surficial geologic mapping begins with a compilation of existing data (soils maps, air photos, borings) and a preliminary map is drafted. This has been accomplished in both counties. Field work to drill additional borings, and to find, describe, and sample outcrops is currently underway for both counties. The bedrock mapping has been started in Sherburne County, and will begin soon in Morrison County. The Sherburne bedrock map will be cost-shared by the USGS STATEMAP program (federal contribution of $38,266). The investigation of the St. Lawrence Formation is still conducting dye traces, and an agreement has been reached on a site for the borehole in Lakeville. The Rochester water chemistry work will begin later in the grant period.

III. D. PROGRESS SUMMARY AS OF 12/5/11

The database of water well construction records for Sherburne County is complete, and mapping based on that data is underway. A total of 14,367 records are entered with digital locations. Surficial geologic mapping started this field season and a compilation of accessory data is complete (air photos, soils, cuttings, core). Bedrock geologic mapping is well along, and is being cost-shared ($38,266 federal share) by STATEMAP. The bedrock topography map is also under construction.

The well database for Morrison County is nearly done and the county is resolving remaining location problems. The surficial map is underway with some field work completed and data sets interpreted. The bedrock geologic map and topography are about 60% complete and are being cost-shared ($33,787 federal share) under STATEMAP.

III. E. PROGRESS SUMMARY AS OF 7/17/12

The databases are compiled for both counties and have been used to support both surficial and bedrock geologic maps. In the Sherburne County database there are more than 14,000 wells with almost 10,000 of them added for this project. In the Morrison County database there are nearly 6,500 wells with more than 5,000 added for this project. The surficial geology maps for both counties are in the review process. The bedrock geology maps for both counties are completed, having been accepted for STATEMAP USGS cost-sharing ($65,070). The focus for this year is creating the subsurface Quaternary products, and production and editing of finished products. The subsurface work for both counties is receiving cost-share from the USGS Great Lakes Geologic Mapping Coalition ($44,428). Drilling was completed last winter and Clean Water Funds augmented the drilling budget to allow us to drill additional holes ($51,548).

III. F. PROGRESS SUMMARY AS OF 1/12/13

Progress in Sherburne and Morrison counties is nearly parallel. In both cases the database work is done, the surficial maps are either complete or in editing, and the bedrock geologic and topographic maps are complete. The stratigraphy of the glacial

materials and mapping of sand bodies within them is underway and on schedule. That work is receiving cost-share from the USGS Great Lakes Geologic Mapping Coalition ($44,428).

A borehole was constructed in Afton State Park to test the hydrologic performance of the St. Lawrence Formation. The St. Lawrence formation was tested by several means including a Flute test (transmissivity test), a thermal profile, packer and pump testing and borehole geophysics by USGS, and Westbay multiport instrumentation has provided 5 rounds of head profiling. We will continue the head profiling as long as possible. We are trying to identify funds outside this grant that would allow us to continue collecting data from the borehole. If none are found we will have the borehole sealed in accordance with regulations prior to the project end date. We continue to collaborate with DNR personnel in interpreting dye traces across the St. Lawrence Formation. A report of our findings will be written.

The Rochester project has collected water chemistry data from Rochester Public Utilities and analysis of the data is underway. A report will be written.

Amendment Request (4/13):
A request is made to extend availability of project funds to June 30, 2014.

Amendment Approved (5/9/13)

III. G. PROGRESS SUMMARY AS OF 8/22/13
The geologic atlases of Sherburne and Morrison counties are nearly complete, with Sherburne slightly farther along. For both counties the database, bedrock geology, depth-to-bedrock, bedrock topography, and surficial geology plates are complete. The products that describe the distribution of sand (aquifers) within the glacial deposits are the only remaining products and they are 80 to 90% complete.

The St. Lawrence project continues to compile information on the hydrologic performance of this formation from the Afton borehole, from “wells of opportunity” that intersect this formation, and from springs and dye traces in southeastern Minnesota. DNR has included funds to continue operating the Afton borehole for two more years and then seal the well. Analysis of current data is underway and report writing will start as the field season winds down.

The Rochester project has completed acquisition of data (much from Rochester Public Utilities), analysis of the data, and report writing is about 60% complete. A draft of the report will be ready for technical review in the very near future.

Funds from this grant have been used to complete projects initiated under earlier grants. Specifically, the Anoka County Geologic Atlas was completed ($11,889), and the Wright County Geologic Atlas ($35,864) wrap-up is utilizing these funds.

Funds from this grant have also been used to start new atlas projects. Pilot studies in Lake and St. Louis counties ($16,780) are underway to determine costs, and methods appropriate to this part of the state where data density driven by population and mineral

exploration vary widely, and the paucity of roads for access, especially equipment access, is a problem. Funds have also been used to initiate atlases in Becker, Hubbard, and Wadena counties ($1,747). These atlases are now being funded by our 2013 ENRTF grant, but funds from this grant allowed us to provide training and support for county efforts to establish well locations. Waiting for the new grant would have caused them to miss the first half of the field season.

Amendment Request (08/22/2013):

As the project enters its last year, there is a need to shift funds among the three results, and within each result. This is caused by normal uncertainty inherent to investigating new terrains, drilling (which is conducted because we don't know what we will encounter), and not knowing how long it will take to compile and analyze results and create a useful report.

We would like to shift funds from Result 1 to Results 2 and 3. Result 1 will achieve all its goals, but at a lower cost than we estimated. We would decrease the cost of Result 1 by $46,252 and redistribute those funds to wages and benefits for Result 2 ($38,062) and wages and benefits for Result 3 ($8,190).
The surplus funds in Result 1 come from lower than expected drilling costs, slightly lower effort levels (wages and benefits), and lower than expected travel costs. Some of that is offset by increased printing costs that will include printing of the Sherburne, Morrison, and Anoka CGAs, and by higher than expected costs for field and lab supplies and repairs.
The funds transferred to Results 2 and 3 would be reassigned to wages and benefits to allow completion of reports for those results.
Amendment Request Approved (8/22/13)

III. H. PROGRESS SUMMARY AS OF 12/26/13
The geologic atlases of Anoka, Sherburne, and Wright counties are complete, and the atlas of Morrison counties is nearly complete. The database, bedrock geology, depth-to-bedrock, bedrock topography, and surficial geology plates are complete. The products that describe the distribution of sand (aquifers) within the glacial deposits are the only remaining products and they are 90% complete.

The St. Lawrence project continues to compile information on the hydrologic performance of this formation from the Afton borehole, from "wells of opportunity" that intersect this formation, and from springs and dye traces in southeastern Minnesota. DNR has included funds to continue operating the Afton borehole for two more years and then seal the well. Analysis of current data is underway and report writing is underway.

The Rochester project has completed acquisition of data (much from Rochester Public Utilities), analysis of the data, and report writing is about 90% complete. A draft of the report will be ready for technical review in the very near future.

Funds from this grant have been used to complete projects initiated under earlier grants. Specifically, the Anoka County Geologic Atlas was completed ($20,188), and

the Wright County Geologic Atlas ($40,559) was completed. Funds were also used to prepare the County Well Index data for a Geologic Atlas Update for Hennepin County ($915) anticipated to start in the new year.

Funds from this grant have also been used to start new atlas projects. Pilot studies in Lake and St. Louis counties ($45,755) are underway to determine costs, and methods appropriate to this part of the state where data density driven by population and mineral exploration vary widely, and the paucity of roads for access, especially equipment access, is a problem. Funds have also been used to initiate atlases in Becker, Hubbard, and Wadena counties ($1,747). These atlases are now being funded by our 2013 ENRTF grant, but funds from this grant allowed us to provide training and support for county efforts to establish well locations. Waiting for the new grant would have caused them to miss the first half of the field season.

Amendment Request 2/4/14:

As this grant nears its completion, the inevitable inaccuracies in our estimations have resulted in some categories of spending having a surplus of funds, and some categories in need of funds. Attachment A is a suggested solution in which the budget has been amended to conform to the expected spending outcomes. In this solution a small surplus in Results 1 and 3 (less than $3,000) has been transferred to Result 2, and rebalancing among spending categories within each result has eliminated any deficits. The project outcomes are unchanged- atlases will be completed for Sherburne and Morrison counties, additional atlas progress has been achieved in Anoka (completed), Wright (completed), Hennepin, Lake, St. Louis, Hubbard, Becker, and Wadena counties, and the St. Lawrence and Rochester research projects will be completed by the end of the grant period. The suggested amendment would result in all remaining funds being allocated to salary and fringe costs for the St. Lawrence project. I would appreciate having permission to spend no more than $2,000 on other kinds of spending (travel, equipment, services) if an unexpected need for such arises before the project end.

Amendment Request Approved 2/5/14

III. I. PROGRESS SUMMARY AS OF 6/30/14

The geologic atlases of Sherburne and Morrison counties are complete and printed. Digital versions are available on the MGS web site. This project also contributed to completion of the Anoka and Wright CGAs, initiation of the Hennepin, Wadena, Becker, and Hubbard CGAs, and pilot studies in St. Louis and Lake counties.

Amendment Request 8/7/14:

In the final execution of the project there was an imbalance of $2,180 between the costs for results 2 and 3, and a need to reallocate some of the funds intended for salary and fringe costs to cover expenses in other categories. Attachment A is a suggested solution in which staffing funds not utilized for result 2 ($5,145) are redistributed to cover $2,710 of professional contract costs, $40 of noncapital equipment, and $216 of travel costs for result 2, and $2,179 of staffing costs for result 3. The overall budget is balanced.

IV. OUTLINE OF PROJECT RESULTS*:*

RESULT/ACTIVITY 1: Geologic Atlas Projects- Initiate 2 new County Geologic Atlas Part A projects (Sherburne County and Morrison County), complete earlier LCCMR supported geologic atlas projects as necessary. Note: all components listed below may not be completed within the time frame and budget of this project, but substantial progress in both counties is anticipated.

Description:

- create geologic maps, illustrations, and databases in print and GIS formats (files made available on our web site).
- map location, boundaries, size, and hydrologic characteristics of aquifers and the materials that confine them in these counties as essential information in efforts to protect and wisely allocate ground water and support these related activities and programs:
    - ground water monitoring, wellhead protection, ground water allocation, well construction, well field design, facility siting, permitting, application of agricultural best management practices, remediation, and management of ground water dependent surface water features (springs, fens, lakes, rivers).
- products:
    - maps of bedrock geology, surficial geology, subsurface Quaternary geology, bedrock topography, and thickness of glacial deposits
    - database of well construction records to support the mapping, describe water use, and to help resolve well problems; scientific test drilling as necessary

Summary Budget Information for Result/Activity 1: **ENRTF Budget: $ 752,270**
Amount Spent: $ 752,270
Balance: $ 0

Deliverable/Outcome	Completion Date	Budget
1. County Well Index databases	6/30/2011	$ 18,000
2. geologic maps and associated data	6/30/2014	$734,270

Result Completion Date: 6/30/2014

Result Status as of: 12/31/2010 Locations have been established for the wells to be included in the CWI databases, and data entry and digitizing are underway. The data sets to support the surficial geologic maps (air photos, soils, previous mapping, etc.) have been compiled in GIS projects. Existing samples are being examined and existing analyses added to the project. A reconnaissance field excursion (2 days) was also made.

Result Status as of: 6/30/2011 The well locating is complete except for resolution of some conflicting data. Preliminary versions of the surficial geologic maps have been made and further sampling, drilling, and analysis of samples in the lab is underway to

improve the maps. The bedrock map is underway for Sherburne County (with federal cost-sharing) and the bedrock map for Morrison County will start soon.

Result Status as of: 12/31/2011 The database of water well construction records for Sherburne County is complete, and mapping based on that data is underway. A total of 14,367 records are entered with digital locations. Surficial geologic mapping started this field season and a compilation of accessory data is complete (air photos, soils, cuttings, core). Bedrock geologic mapping is well along, and is being cost-shared ($38,266 federal share) by STATEMAP. The bedrock topography map is also under construction. The well database for Morrison County is nearly done and the county is resolving remaining location problems. The surficial map is underway with some field work completed and data sets interpreted. The bedrock geologic map and topography are about 60% complete and are being cost-shared ($33,787 federal share) under STATEMAP.

Result Status as of: 6/30/2012 The databases are compiled for both counties and have been used to support both surficial and bedrock geologic maps. In the Sherburne County database there are more than 14,000 wells with almost 10,000 of them added for this project. In the Morrison County database there are nearly 6,500 wells with more than 5,000 of those added for this project. The surficial geology maps for both counties are in the review process. The bedrock geology maps for both counties are completed, having been accepted for STATEMAP USGS cost-sharing ($65,070). The focus for this year is creating the subsurface Quaternary products, and production and editing of finished products. The subsurface work for both counties is receiving cost-share from the USGS Great Lakes Geologic Mapping Coalition ($44,428). Drilling was completed last winter and Clean Water Funds augmented the drilling budget to allow us to drill additional holes ($51,548).

Result Status as of: 12/31/2012 Progress in Sherburne and Morrison counties is nearly parallel. In both cases the database work is done, the surficial maps are either complete or in editing, and the bedrock geologic and topographic maps are complete. The stratigraphy of the glacial materials and mapping of sand bodies within them is underway and on schedule. That work is receiving cost-share from the USGS Great Lakes Geologic Mapping Coalition ($44,428).

Result Status as of: 7/25/2013 Geologic atlases of Sherburne and Morrison counties are nearly complete, with only the glacial subsurface products as yet incomplete (85%). Work to complete an earlier atlas (Anoka) and to work toward completion of another (Wright) was also undertaken. New projects were initiated in St. Louis and Lake counties (pilot study) and in Becker, Hubbard, and Wadena counties.

Result Status as of: 12/26/13 Geologic atlases of Anoka, Sherburne, and Wright counties are complete, and the atlas of Morrison County is nearly complete. The products that describe the occurrence of sand bodies (aquifers) in the glacial deposits are the last to be completed and they are well-along.

Final Report Summary: The geologic atlases of Sherburne and Morrison counties are complete, including printing. Workshops to familiarize users with the products are

planned. Digital versions and databases for these atlases are available at the MGS web site. We are aware that the cities of Little Falls and Motley are guiding efforts to establish new municipal water supplies with these products. They will also be helpful in understanding the causes and potential solutions to nitrate contamination of ground water in these counties.

RESULT/ACTIVITY 2: Investigation of the hydrologic properties of the St. Lawrence Formation

Description:
Result 2: Investigation of the hydrologic properties of the St. Lawrence Formation at the regional scale – *MGS $267,542*

- Conduct field measurements, outcrop investigations and collect data throughout southeastern Minnesota that will be used characterize the range of primary and secondary porosity and permeability of the St. Lawrence Formation over regional scales.
- Drill and collect data from a scientific borehole to characterize the horizontal and vertical hydraulic conductivity of the St. Lawrence Formation at the borehole scale.

Result 2: Investigation of the hydrologic properties of the St. Lawrence Formation at the borehole scale – *$80,377 from Trust Fund to USGS; USGS will provide $52,485 in goods and services at no cost.*

- Drill and collect data from scientific boreholes that characterize the horizontal and vertical hydraulic conductivity of the St. Lawrence Formation at the borehole scale. Specific tasks include the installation of packers to measure hydraulic head at discrete intervals, and the installation of real-time monitoring equipment for continuous data collection.

Summary Budget Information for Result/Activity 2:	**ENRTF Budget:**	**$ 345,741**
	Amount Spent:	**$ 345,741**
	Balance:	**$ 0**

Deliverable/Outcome	**Completion Date**	**Budget**
1. Peer-reviewed report on the hydraulic properties of the St. Lawrence Formation, borehole to regional scales.	June 30, 2013	$345,741

Result Completion Date: 6/30/2013

Result Status as of: 12/31/2010 Initiated with field work that included analysis of fracture patterns in outcrops across southeastern Minnesota, and dye-tracing in collaboration with the Minnesota DNR (in conjunction with the LCCMR funded "Innovative Springshed Mapping" project). We have now conducted 10 dye traces, which have provided insight into groundwater flow through the St. Lawrence aquitard. Planning for borehole drilling and testing of the St Lawrence aquitard has also progressed. We have selected a site at Lakeville Minnesota, and in collaboration

with the USGS are working with Lakeville city officials and the Minnesota Department of Health in an effort to proceed with the drilling and testing operation, scheduled for late summer or fall, 2011.

Result Status as of: 6/30/2011 Additional dye tracing is being conducted in Houston and Winona counties to test the properties of the St. Lawrence Formation. The scientific borehole will be constructed in Lakeville with cooperation from the city, and the logistics of the drilling contract and scheduling all the parties involved (including the USGS) are being resolved. Drilling should take place this fall.

Result Status as of: 12/31/2011 Costs from a competitive bidding process for the drilling were too high to proceed. MGS is now looking for a geologic setting where the St. Lawrence Formation is less deeply buried and costs will be lower. This has affected our schedule, but we anticipate drilling next spring and completing the work within the project deadline. We are also considering other sources to augment funding for this work. We continue to participate in dye traces that provide insight into the hydrologic performance of the St. Lawrence Formation. This work cooperates with the LCCMR Innovative Springshed project.

Result Status as of: 6/30/2012 A borehole has been drilled at Afton State Park to test the hydrologic properties of the St. Lawrence Formation. The conditions at the Lakeville site would have caused drilling costs to be prohibitively high. A profile of transmissivity across the St. Lawrence Formation has been conducted using a flexible liner inside the borehole. In less than two weeks a thermal profile of the hole will be recorded, and then borehole geophysical investigations and packer tests will be conducted by the USGS. This will be followed by instrumentation of the borehole and a period of data recording. Negotiations are under way to keep this borehole instrumented and providing data beyond the period of this grant. If this is not possible the hole will be abandoned according to code.

Result Status as of: 12/31/2012 A borehole was constructed in Afton State Park to test the hydrologic performance of the St. Lawrence Formation. The St. Lawrence formation was tested by several means including a Flute test (transmissivity test), a thermal profile, packer and pump testing and borehole geophysics by USGS, and Westbay multiport instrumentation has provided 5 episodes of head profiling. We will continue the head profiling as long as possible. We are trying to identify funds outside this grant that would allow us to continue collecting data from the borehole. If none are found we will have the borehole sealed in accordance with regulations prior to the project end date. We continue to collaborate with DNR personnel in interpreting dye traces across the St. Lawrence Formation. A report of our findings will be written.

Result Status as of: 7/25/2013 We continue to collect information on the hydrologic performance of the St. Lawrence Formation from the Afton borehole, from “holes of opportunity”, and from springs and dye traces. Data analysis is underway and report writing will take place after the field season.

Result Status as of: 12/26/13 In cooperation with the USGS and the University of Guelph, two rounds of water sampling were completed at the Afton multiport site.

Samples were analyzed for general chemistry and field parameters, stable isotopes, sulfur hexafluoride and dissolved gas analysis, and tritium content. Well cuttings samples were submitted for general chemistry analysis. Eight rounds of pressure profile measurements were conducted, along with hydraulic conductivity measurements made using pulse testing methods. At the regional scale, representative hydrogeologic cross sections are being prepared that characterize the St. Lawrence formation under near surface and buried-bedrock conditions. Data assimilation and report writing for both the Afton site and for the southeastern Minnesota regional assessment have begun.

Final Report Summary: Compilation of data from the Afton multiport instrumented well, dye traces in southeastern Minnesota, existing data, and outcrop examination provides a robust data set to determine the effect of the St. Lawrence Formation on ground water flow. A final report that organizes the data sets, analyzes them, and provides conclusions has been delivered. Those conclusions are that the St. Lawrence does impede vertical flow in those settings where the St. Lawrence is overlain by at least 50 feet of other strata. Where overlying strata are thinner than that the ability of the St. Lawrence to limit vertical flow is compromised. In both settings parts of the St. Lawrence allow horizontal flow at rates similar to aquifers. We also conclude that some of the ability to limit vertical flow is attributable to strata within the overlying Jordan Sandstone. Other factors that can affect the confining ability of the St. Lawrence include faults, and high capacity pumping. Additional funding from DNR will allow us to continue to collect data at the Afton borehole, and then properly abandon it. This is a particularly useful site as it allows us to study the effects of high capacity pumping at a nearby snow-making operation, and the effects of water injection at a nearby observation well. The current report will be augmented with this additional data, and then a formal MGS Report of Investigations will be published.

RESULT/ACTIVITY 3: Evaluation of using chemical and isotopic data to trace ground-water flow pathways in an urban area - Rochester Minnesota

Description:

- Assemble historic ground-water chemical and isotopic data for the city of Rochester and surrounding area.
- Analyze data in the context of revised hydrogeological framework for the Paleozoic rocks in southeastern Minnesota.
- Report on results using cross sections, fence diagrams or other means that best illustrate the three-dimensional distribution of ground-water chemical types.

Summary Budget Information for Result/Activity 3:	**ENRTF Budget:**	**$ 31,990**
	Amount Spent:	**$ 31,990**
	Balance:	**$ 0**

Deliverable/Outcome	**Completion Date**	**Budget**
1. Report describing the three-dimensional distribution of ground-water chemical faces for the city of Rochester	June 30, 2012	$31,990

Result Completion Date: 6/30/2013

Result Status as of: 12/31/2010 This work is scheduled to begin later in the grant period.

Result Status as of: 6/30/2011 This work is scheduled to begin later in the grant period.

Result Status as of: 12/31/2011 This work is scheduled to begin later in the grant period.

Result Status as of: 6/30/2012 This work is scheduled to begin later in the grant period.

Result Status as of: 12/31/2012 The Rochester project has collected water chemistry data from Rochester Public Utilities and analysis of the data is underway. A report will be written.

Result Status as of: 7/25/2013 Data compilation is complete, analysis is 90% complete, and a draft report for technical review is imminent. Review, revision, and editing follow. This report will explain ground water flow patterns based on the chemical changes to water as it flows through various materials.

Result Status as of: 12/31/13 Water chemistry data have been compiled and analyzed. Report figures, tables and statistical analysis are completed. Final draft report text is 70 percent complete.

Final Report Summary: A final report summarizing the distribution of groundwater chemical types in the Rochester area has been delivered. The compilation and analysis of water chemistry data demonstrates that the flow paths of ground water in the vicinity of Rochester have changed over time, and that this change is largely attributable to high capacity pumping. The data indicate that flow rates and residence times are in some cases different than those commonly used to simulate the ground water system in this area, with more water moving vertically through aquifers than indicated by numeric modeling. In addition, the data indicate that over the last 20 years, the amount of water reaching the Jordan aquifer in the Rochester Central metropolitan area from the Upper Carbonate Plateau has increased. The distribution of chemical types we have generated will be useful in recalibrating current groundwater flow models. In turn, our work and updated models can guide decisions about the location and rates of pumping and expectations regarding the quality of water produced. We anticipate eventually publishing this work in a peer reviewed journal. In the meantime we will produce an MGS Open-File version for distribution through our web site.

V. TOTAL ENRTF PROJECT BUDGET:

Personnel: $ 817,357 These are MGS salaries and fringes.

Contracts: $ 260,129 Includes $79,000 to USGS, 2 drilling contracts (competitive bids), and a printing contract (competitive bid)
Equipment/Tools/Supplies: $ 25,322
Acquisition (Fee Title or Permanent Easements): $ 0
Travel: $ 27,191
Additional Budget Items:

TOTAL ENRTF PROJECT BUDGET: $1,130,000

Explanation of Capital Expenditures Greater Than $3,500:
The Minnesota Geological Survey has purchased passive seismic geophysical equipment and a dedicated field-rugged computer to enable measurement of the elevation of the bedrock surface. This is necessary for those places where well data doesn't exist, or the wells are finished in glacial materials and don't reach the bedrock surface. We have tested this equipment and find it to be accurate, and requiring fewer people and much less time to deploy and operate. We expect the labor cost savings to cover much of the acquisition cost within this project, and it will certainly be cost effective when deployed on current and future geologic atlases.

The seismic equipment has been purchased and deployed with great success.

VI. PROJECT STRATEGY:

A. Project Partners: Result 1 and result 3 will be conducted entirely by MGS. The work under Result 2 involves MGS and USGS. The USGS will conduct borehole scale testing of the hydrologic properties of the St. Lawrence Formation ($79,000).

B. Project Impact and Long-term Strategy: County geologic atlases support water and mineral resource management as carried out by state and local government. They increase the value and efficiency of most water programs (allocation, wellhead protection, well construction, monitoring, modeling, sustainability evaluation) and are also used by businesses and private citizens. We intend to complete county geologic atlases statewide.

The St. Lawrence research will strengthen these same activities in any part of Minnesota where the St. Lawrence Formation exists. Understanding its hydrologic properties and effects on flow are essential to managing ground water above, below, or within it. This information will affect modeling of ground water flow and well construction practices.

Mapping the distribution of water chemistry in the Rochester area will establish the value of this type of work to understanding ground water flow paths. Flow paths are critical for understanding recharge, ground water and surface water interaction, and ground water sensitivity. This may be a less expensive and quicker method of obtaining this kind of information.

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

The MGS has successfully proposed elements of the county geologic atlases for cost-sharing under the USGS STATEMAP Program. Two cost-sharing projects have brought in $72,053 in federal funds from the STATEMAP program.

The USGS Water Resources Center (Mounds View) will provide unbilled services in the amount of $52,485 in result 2B.

The USGS Great Lakes Geologic Mapping Coalition is cost-sharing work on the subsurface Quaternary products for both atlases for $44,428.

Clean Water Funds augmented the drilling costs associated with the atlases for $51,548.

D. Spending History:
M.L. 2007, Chapter 30, Subd 5(j) County Geologic Atlas Program Acceleration (Chisago and Benton counties)
M.L. 2008, Chapter 367, Sec.2, Subd.4(h). South-Central MN Groundwater Monitoring and County Geologic Atlases (Blue Earth, Nicollet, and Sibley counties)
M.L. 2009, Chapter 143, Sec. 2, Subd. 3(b) County Geologic Atlas Acceleration (Anoka and Wright counties)

VII. DISSEMINATION: MGS will make all products available at its web page http://www.geo.umn.edu/mgs/. Any completed county geologic atlas products will also be available in print from MGS, or from the host county. Interim results of the St. Lawrence Project were presented in the Minnesota Ground Water Association newsletter and in a poster at the MGWA Spring Conference. Draft versions of maps from the Morrison CGA have been sent to the City of Little Falls to support well field planning, and to the county to support a feedlot decision.

VIII. REPORTING REQUIREMENTS: Periodic work program progress reports will be submitted not later than January 2011, July 2011, January 2012, July 2012, January 2013, July 2013, and January 2014. A final work program report and associated products will be submitted between June 30 and August 1, 2014 as requested by the LCCMR.

IX. RESEARCH PROJECTS:

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

Project Title: Minnesota Geological Survey County Geologic Atlases and Related Hydrogeologic Research

Project Manager Name: *Dale Setterholm*

Trust Fund Appropriation: $1,130,000

2010 Trust Fund Budget	**Revised Result 1 Budget 2/4/14**	**Amount Spent** *(date)*	**Balance** *(date)*	**Revised Result 2 Budget 2/4/14:**	**Revised Result 2 Budget 8/7/14**	**Amount Spent** *(date)*	**Balance** *(date)*	**Revised Result 3 Budget 2/4/14**	**Revised Result 3 Budget 8/7/14**	**Amount Spent** *(date)*	**Balance** *(date)*	**TOTAL BUDGET**	**TOTAL BALANCE**
	Geologic Atlas Projects	*6/30/2014*	*6/30/2014*	*St. Lawrence Project*	*St. Lawrence Project*	*6/30/2014*	*6/30/2014*	*Use of chemical and isotopic data to trace ground-water flow in an urban area - Rochester Minnesota*	*Use of chemical and isotopic data to trace ground-water flow in an urban area - Rochester Minnesota*	*6/30/2014*	*6/30/2014*		
BUDGET ITEM													
PERSONNEL: wages and benefits													
Overall Result 1 staffing: 5 to 15 MGS staff including mappers, editors, technicians, geophysicist, database managers- none at full time; 63% salary, 37% fringe	$655,114	$655,114	$0									$655,114	$0
Overall Result 2 staffing: Runkel, Tipping, Robinson, and others in smaller roles				~~$132,434~~	$127,289	$127,289	$0					$132,434	$0
Tony Runkel, MGS: 30% of full time, two years - borehole siting; on-site geologist during drilling; outcrop investigations; data compilation and report writing. 63% of total listed is salary, 37% is benefits [anticipate $61,254]												$0	$0
Bob Tipping, MGS: 10% of full time, two years - borehole siting, hydraulic testing, data compilation and report writing. 63% of total listed is salary, 37% is benefits [anticipate $17,443]												$0	$0
Lori Robinson, MGS: 4% of full time, one year - editor. 63% of total listed is salary, 37% is benefits [anticipate $2,610]												$0	$0
Julia Steenberg, MGS 1% of full time, one year - borehole siting, on-site geologist during drilling													$0
Griffin Williams, field technician													
Rachel Kane, student													
Matt Matko, student													
Overall Result 3 staffing:								~~$29,810~~	$31,990	$31,990	$0	$29,810	$0
Bob Tipping: 23% of full time, 1 year - database assembly and analysis; final report and database delivery. 63% of total listed is salary, 37% is benefits [anticipate $20,516]												$0	$0
Tony Runkel: 1% of full time, 1 year - scientific review. 63% of total listed is salary, 37% is benefits												$0	$0
Lori Robinson: 2% of full time, 1 year - editor. 63% of total listed is salary, 37% is benefits												$0	$0
Contracts													
Professional/technical *(Result 2 - scientific borehole drilling, southeastern MN, competitive bid) licenses, and fees*				~~$129,553~~	$132,263	$132,263	$0					$129,553	$0
Professional/technical (Result 2- USGS; personnel (Jones, Green, Menheer, Shapiro, geophysicist, 14.5 weeks) $40,385; travel $5,350; GIS support, IT support, report review, safety, and report preparation $15,745; equipment shipping $1,920; equipment to adapt packer system to drill rig, supplies for borehole surveys, pressure transducers and data loggers $15,600 -no item >$3,500)				~~$80,377~~	$80,377	$80,377	$0					$80,377	$0
Professional/technical *(Result 1 - scientific borehole drilling; competitive bid)*	$41,003	$41,003	$0									$41,003	$0
Professional/technical *(Result 1 - printing of atlas maps, competitive bid)*	$9,196	$9,196	$0									$9,196	$0
Non-capital Equipment / Tools *(Result 1 - expendable augers, core boxes, sample bags, lab supplies (chemicals, sieves, settling tubes, sample envelopes) services (repairs, age dating, analyses), fees, photocopy*	$15,435	$15,435	$0	~~$599~~	$639	$639	$0					$16,034	$0
Capital equipment over $3,500 Result 1: MGS-Seismic recorder and dedicated laptop with sunlight readable screen. Think Pad and DVD Burner for seismic recorder.	$9,288	$9,288	$0	$0	$0	$0	$0					$9,288	$0
Travel expenses in Minnesota MGS (trips to project areas to make observations and conduct tests)	$22,234	$22,234	$0	~~$4,957~~	$5,173	$5,173	$0	$0		$0	$0	$27,191	$0
COLUMN TOTAL	**$752,270**	**$752,270**	**$0**	**~~$347,920~~**	**$345,741**	**$345,741**	**$0**	**~~$29,810~~**	**$31,990**	**$31,990**	**$0**	**$1,130,000**	**$0**