M.L. 2011 **Project Abstract**
For the Period Ending June 30, 2014

PROJECT TITLE: Trout Stream Springshed Mapping in Southeast Minnesota – Phase III
PROJECT MANAGER: Jeff Green
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2011, First Special Session, Chp. 2, Art.3, Sec. 2, Subd. 05b1

APPROPRIATION AMOUNT: $ 220,000

Overall Project Outcome and Results

Trout streams depend on a steady supply of clean, cold water which comes from groundwater springs. These trout springs are under increasing pressure from changing land use, climate change, and groundwater withdrawals for domestic use, mining, agriculture, and energy production. Delineation of the recharge areas or springsheds of trout springs using dye tracing is a necessary first step in the conservation and protection of the trout stream coldwater supplies. This project focused on delineating groundwater springsheds both in the Galena Group limestone karst areas of Fillmore and Olmsted counties, where this work has been done for over 30 years, and in the Cambrian St. Lawrence Formation and Tunnel City Group bedrock across southeast Minnesota. Prior to this project, no springsheds had been delineated in the St. Lawrence or Tunnel City bedrock units. We demonstrated that springs discharging from these units receive surface water recharge from sinking streams and that this recharge moves hundreds of feet per day through the bedrock. This has rewritten our understanding of the hydrology of southeast Minnesota and has demonstrated that these springs, which we formerly believed to be well-protected from land surface activities, are much more vulnerable than we previously realized. Overall, during this project we mapped 41 groundwater springsheds (delineated by dye tracing) and 54 surface water springsheds (surface watersheds sending water to a point where it sinks underground into a groundwater springshed). Twelve of the groundwater springsheds and sixteen of the surface water springsheds are in the St. Lawrence Formation and Tunnel City Group. The groundwater springshed delineated areas total 50,708 acres and the surface water delineated areas total 124,447 acres. Prior to this project there was a total of 54,091 acres of both springshed types delineated. Springsheds were delineated in Dakota, Dodge, Fillmore, Goodhue, Houston, Mower, Olmsted, Wabasha and Winona counties.

Project Results Use and Dissemination

Information from this project was widely disseminated. A map of the delineated springsheds and a document on Spring Assessment Protocols were produced and submitted to the LCCMR and will be published by the Minnesota Geological Survey. The springshed coverage is being used by state and local governments to target areas for conservation efforts and for Clean Water Fund project ranking. The springshed mapping will be used by the DNR for Silica Sand Mining Trout Stream Setback permitting and in Water Appropriation permit review.

Project information was presented to numerous groups including the SE MN Water Resources Board, Root River Technical Advisor Group, Fillmore County Local Water Planning committee, Southeast Minnesota County and State Feedlot officers, Midwest Federal Agency Senior Managers, and at Silica Sand mining forums in Red Wing, Lewiston, La Crescent, and Winona.

On the ground information was presented during tours of the southeast; groups that went “on tour” include Minnesota Groundwater Association, MPCA/DNR field staff, SE Minnesota water advocacy groups, Geological Society of America, Minnesota Association of Professional Soil Scientists, and state and federal agency staff from Minnesota, Iowa, and Wisconsin.

A paper on the St. Lawrence tracing work has been was published in the journal Carbonates and Evaporites. The springshed mapping work was the subject of two stories on Minnesota Public Radio. Project results were presented at numerous scientific meetings including the 11th and 12th Multidisciplinary Conference on Sinkholes and the Environmental and Engineering Aspects of Karst, the Minnesota Groundwater Association, the Midwest Groundwater Conference, the Geological Society of America, The Driftless area Symposium, and at a Winona State University Geology Department seminar.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2011 Final Report

Date of Status Update: 9/15/2014
Date of Next Status Update: Final Report
Date of Work Plan Approval: 6/23/2011
Project Completion Date: 6/30/2014 **Is this an amendment request?** Yes

Project Title: Trout Stream Springshed Mapping in Southeast Minnesota – Phase III

Project Manager: Jeff Green
Affiliation: MN DNR
Address: 3555 9th St NW
City: Rochester **State:** MN **Zipcode:** 55901

Telephone Number: (507) 206-2853
Email Address: jeff.green@state.mn.us
Web Address:

Location:

Counties Impacted: Dakota, Dodge, Fillmore, Goodhue, Houston, Mower, Olmsted, Rice, Wabasha, Washington, Winona

Ecological Section Impacted: Paleozoic Plateau (222L)

Total ENRTF Project Budget:		
	ENRTF Appropriation $:	220,000
	Amount Spent $:	218,341
	Balance $:	1,659

Legal Citation: M.L. 2011, First Special Session, Chp. 2, Art.3, Sec. 2, Subd. 05b1

Appropriation Language: $250,000 the first year and $250,000 the second year are from the trust fund to continue to identify and delineate water supply areas and springsheds for springs serving as cold water sources for trout streams and to assess the impacts from development and water appropriations. Of this appropriation, $140,000 each year is to the Board of Regents of the University of Minnesota and $110,000 each year is to the commissioner of natural resources.

I. PROJECT TITLE: Innovative Springshed Mapping for Trout Stream Management-Continuation (DNR)

II. FINAL PROJECT STATEMENT:
Trout streams depend on a steady supply of clean, cold water which comes from groundwater springs. These trout springs are under increasing pressure from changing land use, climate change, and groundwater withdrawals for domestic use, mining, agriculture, and energy production. Delineation of

the recharge areas or springsheds of trout springs using dye tracing is a necessary first step in the conservation and protection of the trout stream coldwater supplies. This project focused on delineating groundwater springsheds both in the Galena Group limestone karst areas of Fillmore and Olmsted counties, where this work has been done for over 30 years, and in the Cambrian St. Lawrence Formation and Tunnel City Group bedrock across southeast Minnesota. Prior to this project, no springsheds had been delineated in the St. Lawrence or Tunnel City bedrock units. We demonstrated that springs discharging from these units receive surface water recharge from sinking streams and that this recharge moves hundreds of feet per day through the bedrock. This has rewritten our understanding of the hydrology of southeast Minnesota and has demonstrated that these springs, which we formerly believed to be well-protected from land surface activities, are much more vulnerable than we previously realized. Overall, during this project we mapped 41 groundwater springsheds (delineated by dye tracing) and 54 surface water springsheds (surface watersheds sending water to a point where it sinks underground into a groundwater springshed). Twelve of the groundwater springsheds and sixteen of the surface water springsheds are in the St. Lawrence Formation and Tunnel City Group. The groundwater springshed delineated areas total 50,708 acres and the surface water delineated areas total 124,447 acres. Prior to this project there was a total of 54,091 acres of both springshed types delineated. Springsheds were delineated in Dakota, Dodge, Fillmore, Goodhue, Houston, Mower, Olmsted, Wabasha and Winona counties.

III. PROJECT STATUS UPDATES:

Project Status as of 15 January 2012
Work began in July after the end of the government shutdown. GIS and field reconnaissance has identified numerous locations that are potential dye trace targets. Landowners are being contacted and there are several areas where traces are being planned. Six dye traces were run in three different springsheds. These traces have resulted in expanded boundaries of one springshed and the identification of a previously unmapped springshed. The spring-temperature/conductivity effort is being reviewed & adjusted to use sites with better access. This will allow us to check the sites more frequently to verify that the equipment is working adequately.

Project Status as of 15 July 2012
During the winter months, work was started on producing 1:100000 scale springshed maps to be published by the Minnesota Geological Survey. This would allow for wider dissemination of the project's mapping efforts. Numerous requests came in from counties for information and assistance on frac sand mining issues. This was an opportunity to apply the work from the ENRTF- Hydraulic Impacts of Quarries and Pits project report and discuss the impacts of frac sand mining on springs and springsheds. The lack of snow precluded snowmelt dye tracing in the spring. This was a serious setback as we normally do 4-6 snowmelt traces in several different springsheds. The snowmelt traces also can be run from sinkholes that are inaccessible to water tanker trucks. GIS and field reconnaissance has identified numerous locations that are potential dye trace targets. A triple trace was run to refine springshed boundaries and identify a new springshed. Temperature/conductivity sensors were deployed in eleven springs.

Amendment Request 9/20/2012
This is a request to move funds from fleet expenses into the equipment category. We need to purchase equipment for measuring spring temperature, conductivity, and discharge. This equipment is needed to characterize springs. The equipment will be used going forward in this project and in our future springshed mapping and spring assessment work. Funds are available in the fleet budget since the drought has cut down on our field work.

Amendment Approved 10/8/2012

Project Status as of 15 January 2013

The project moved forward with significant time spent on field work and data management. The on-going drought is having a very negative impact on our ability to do dye tracing. The low flows in springs and lack of recharge events made it difficult to run traces and it kept background dye levels elevated in springsheds where we had planned to do additional traces. In spite of these obstacles, one dual and four single dye traces were run to identify new springsheds. GIS and field recon identified additional sites for dye traces in the St. Lawrence formation. The temperature and conductivity spring monitoring network was maintained and several springs were also measured for flow volume. The St. Lawrence dye tracing work was presented at the Midwest Groundwater Conference in Minneapolis in October.

Amendment Request 4/15/2013:
To extend the project completion date one year, from June 30, 2013 to June 30, 2014, to coincide with the availability of the appropriation under M.L. 2011, First Special Session, Chp. 2, Art.3, Sec. 2, Subd. 11 and to extend outcome completion dates accordingly. Extension of deadlines is needed, as project activities have not been completed and project funds have not been expended at the rate anticipated in the original work program due to the state shutdown. The extensions will not change any of the project outcomes.

Amendment Approved 4/30/2013

Project Status as of 15 July 2013
Field, office and GIS work continued on the project. Seven dye traces (two triple traces and one single trace) were run to refine or expand springshed boundaries and identify new springsheds. The single trace was our first attempt at dye introduction into the Cambrian Tunnel City Group. Sampling for these traces and traces started in November and December 2012 was a high priority. GIS and field recon identified additional sites for dye traces in the St. Lawrence and Tunnel City. The temperature and conductivity spring monitoring network was maintained and several springs were also measured for flow volume. The first draft of the Spring Assessment Protocols (project deliverable) was completed and is in the editing/revision phase. A method to delineate surface springsheds (land surface areas that contribute water to sinkholes and stream sinks) was developed with support from DNR GIS staff. This methodology was used to delineate surface springsheds across southeast Minnesota.

Amendment Request 10 Sept. 2013
In order to continue doing field work, this is a request to move funds from Equipment into Supplies to purchase dyes and sampling materials and to move funds from Vehicle Costs into Meals and Lodging.

Amendment Approved 9/9/2013

Project Status as of 15 January 2014
Field, office and GIS work continued on the project. A major focus was a dual dye trace that was run to delineate new springshed boundaries and focus in on characterizing flow in the Cambrian St. Lawrence Formation and Cambrian Tunnel City Group. This trace was conducted with automatic water samplers to provide greater detail on groundwater travel times. GIS and field recon identified additional sites for dye traces in the St. Lawrence and Tunnel City. The temperature and conductivity spring monitoring network was maintained and flow monitoring continued at our long-term spring flow monitoring site in southern Winona County. The editing and revising of the Spring Assessment Protocols continued with the goal of releasing them as a MGS publication.

Final Report Summary: 15 September 2014
A dual dye trace was conducted in the Galena karst of Olmsted County in cooperation with the Olmsted County SWCD. The focus of work was the production of the Spring Assessment Protocols and a springshed map of southeast Minnesota. The end-of-project final documents were prepared.

Amendment Request 15 September 2014

In order to balance final total expenditures, this is a request to move funds from Equipment into DNR Fleet Vehicle Costs and Meals & Lodging for Fieldwork.

Amendment Request Approved retroactively by the LCCMR 9-25-2014

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Innovative Trout Springshed Maps and Reports

Description: Springsheds that feed source springs of trout streams will be delineated in the Galena, Prairie du Chien, and St. Lawrence karst lands. Maps of the springsheds will be transferred to the U of M for web posting and will be linked to the DNR web site. The existing temperature-monitoring network will be maintained and expanded as equipment and sites are available. The results of our dye tracing, spring monitoring, and hydrostratigraphy investigations will be used to develop spring assessment protocols. This is a cooperative project with the U of M Geology Dept. DNR is the lead on dye tracing investigations and spring temperature and conductivity monitoring. The U of M is the lead on dye trace analysis and spring turbidity monitoring. U of M staff will be doing dye traces in selected areas and both DNR and U of M staff will be developing the spring assessment protocols.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 220,000
Amount Spent: $ 218,341
Balance: $ 1,659

Activity Completion Date:

Outcome	Completion Date	Budget
1. Innovative Trout Springshed Maps and Reports (Conduct dye traces and field investigations for springshed map production, maps and reports of completed traces and spring parameter monitoring including spring assessment protocol development).	30 June 2014	$220,000

(See also the companion U of M project work program Activity 1)

Activity Status as of 15 January 2012

Extensive GIS and field reconnaissance work has resulted in the identification of several promising areas for dye tracing. These areas are in the counties of Fillmore, Goodhue, Houston, Wabasha and Winona. Six dye traces have been conducted in three separate springshed areas in Winona and Fillmore. A single trace was conducted near the Crystal Springs State Fish Hatchery operated by the DNR. The hatchery is supplied by two springs emanating from the Cambrian St. Lawrence formation. A stream southeast of the hatchery has been identified as a sinking stream. In August, it was sinking at or near the top of the St. Lawrence at a point ½ mile from the hatchery. A dye trace was done from this sinking point. In less than three weeks, the dye was detected at one of the hatchery springs; this is a newly identified springshed. The knowledge that one of their springs is connected to surface runoff will be used by hatchery staff for emergency planning. Five dye traces were conducted in the Galena karst of Fillmore County. A dual trace north of Wykoff expanded the boundaries of two existing springsheds. This work is supporting the watershed management efforts of local governments in the Watson Creek watershed. A triple trace was conducted in the Crystal Creek watershed west of Harmony. This work is expanding the boundaries of three springsheds. These trace results will be used by MDA as they work with farmers in the watershed to investigate runoff & tillage practices. Field recon emphasized finding St. Lawrence sites in Goodhue, Houston, Wabasha and Winona. Several sites with high potential for tracing were identified. The spring monitoring work (part of spring assessment methodology development) is continuing.

Activity Status as of 15 July 2012

A triple dye trace was run near Fountain in the Galena karst of Fillmore County. This work expanded the boundaries of two known springsheds and we identified one new springshed. Field and GIS recon work has been continuing in the Galena karst in Fillmore for the purposes of springshed boundary refinement and identification of new springsheds. A significant amount of time has been spent on GIS and field recon work to locate St. Lawrence sites in the counties of Wabasha, Winona and Houston. Five sites have been identified that are strong candidates for running dye traces. A potential site for a Prairie du Chien limestone dye trace was identified near Caledonia, MN in Houston County. Prairie du Chien traces have historically been problematic due to the chance of long (6-12 months) flow times; this site has the advantage of being quite accessible which cuts down on the time required for sampling. A St. Lawrence dye trace in the South Branch of the Whitewater River was designed and set-up; this trace is being run to determine if the South Branch is leaking into the St. Lawrence Formation and builds on two previous St. Lawrence traces conducted in tributaries to the South Branch. The temperature & conductivity loggers were deployed at springs discharging from the Prairie du Chien, St. Lawrence and Franconia formations. Six of the loggers were deployed at the three DNR Fish Hatcheries in southeast MN. The dye trace planning work and logger deployment has been coordinated with the U of M project partners. At the various frac sand meetings, detailed results from the ENRTF- Hydraulic Impacts of Quarried and Pits project were presented. The section in that report which gives guidance to local governments on information requirements for site review was highlighted as being of particular relevance to the frac sand mining debate. The potential for mines to effect springs was discussed as was the potential for mines to alter groundwater quantity and quality in springsheds.

Activity Status as of 15 January 2013

A dual dye trace was run northeast of Wykoff in the Galena karst of Fillmore County. These traces were run in the Shady Creek watershed. Shady Creek is a designated trout stream where no previous springshed mapping had been done. Both traces were recovered and two new springsheds were identified. This work will be used to design snowmelt traces this spring (assuming we receive adequate snow to provide runoff) to expand and refine the springshed boundaries. A significant amount of time has been spent on GIS and field recon work to locate St. Lawrence sites in the counties of Wabasha, Winona and Houston. As a result of that work, four dye traces were performed in the St. Lawrence during this reporting period. Three other sites that hold strong potential for St. Lawrence dye tracing were also identified. A St. Lawrence dye trace in the South Branch of the Whitewater River was run to determine if the South Branch is leaking into the St. Lawrence Formation. No dye was detected at any springs; this fits with previous work done on Rush Creek and demonstrates that the St. Lawrence is not being recharged from main-stem streams. A dye trace was run on Gilbert Creek in far northern Wabasha County. Gilbert Creek does not disappear totally into the St. Lawrence Formation but we believed it was leaking into it. Dye was detected at a spring tributary to the creek. This trace extends the geographic range of the St. Lawrence conduit flow/valley recharge phenomena significantly. A St. Lawrence trace was begun in late December at Bridge Creek in Houston County. No samples have yet been analyzed. The most significant dye trace was run at Campbell Valley Creek in southern Winona County. Dye was poured into a small pool that sinks into the top of the St. Lawrence Formation. Dye was recovered one month later at basal St. Lawrence springs and from springs discharging from the Tunnel City Formation. This is the first time we have recovered dye from the Tunnel City. This trace demonstrates that conduit flow exists in the Tunnel City and that it can be hydraulically connected to the St. Lawrence. This is highly significant as we believed the Tunnel City had some measure of separation (and protection) from surface sources. Spring monitoring and spring flow measurement is an on-going part of the project. This work will be incorporated into the spring assessment methodology which is under development. In September of 2012, the project budget was amended to provide additional money for equipment purchases. With those funds, a field-grade temperature/conductivity meter was purchased for use in spring characterization.

Activity Status as of 15 July 2013

A single dye trace was run at Bridge Creek in Houston County in late December in cooperation with the MN Dept. of Agriculture (MDA). Bridge Creek is one of their watershed study sites. The sampling for

that trace began during this reporting period. The creek was sinking into the middle part of the St. Lawrence formation. The dye was detected at several sites. The strongest dye signal (indicating the most direct connection) was at a Tunnel City spring 2.5 miles from the sinking point. This spring discharges from the upper part of the Tunnel City and is on the opposite side of a prominent ridge from the sinking point. The dye traveled the 2.5 miles in 20-40 days. Dye was also detected in a domestic well ½ mile from the sinking point. This trace is the second example of dye from a St. Lawrence stream sink moving through the St. Lawrence into the Tunnel City. At Campbell Valley in southern Winona County, the first St. Lawrence to Tunnel City trace, sampling continued. We also ran a second trace from a point upstream of where Campbell Valley creek disappears into what we believe is the Tunnel City formation. Based on this second trace, and the sampling from the St. Lawrence trace, the dye we introduced into the St. Lawrence is moving all the way through it and down through the Tunnel City to springs that discharge from the lower part of the formation. The Campbell Valley trace and the Bridge Creek trace are highly significant. They are the first traces ever done that demonstrate a connection between surface water and Tunnel City springs. We know now that these springs are much more vulnerable than previously believed and this work furthers our understanding of their hydrology.

Two triple traces were run using snowmelt runoff in the Crystal Creek watershed and the Watson/Forestville creek watershed in the Galena karst of Fillmore County. One of the traces at Crystal Creek was the first to the headwater spring of the creek so we have now begun to delineate that springshed. The other traces there and at Watson/Forestville refined known springshed boundaries. The Crystal Creek traces were run in cooperation with the MDA and the Watson/Forestville trace was run in cooperation with the Fillmore SWCD to support their watershed management activities. The spring monitoring network of Solinst level-temperature conductivity loggers captured several runoff events of significance at Crystal Spring state Fish Hatchery and at several sites in Houston and Fillmore County. These data are still being reviewed. Flow measurements at several springs were obtained to continue our work of comparing flow volumes to spring geology and springshed type and size. The first draft of the Spring and Springshed Assessment protocols (project deliverable) was completed and sent to the project partners for review and editing. A GIS method was developed using the DNR catchment tool to delineate surface (allogenic) springsheds. These springsheds contribute surface flow to stream sinks and sinkholes. The tool was used to delineate these areas that feed runoff water to the sinking points that are tied to subsurface basins that have yet to be mapped. This information will help future mapping efforts and will be useful for state and local resource managers.

Activity Status as of 15 January 2014

A dual dye trace was run at Bridge Creek and Girl Scout Camp Creek in western Houston County. The Bridge Creek trace was built upon a previous trace from a sinking point in the creek and was run in cooperation with the MN Dept. of Agriculture (MDA). Bridge Creek is one of their watershed study sites. At the time of the second Bridge Ck. trace, the stream was sinking 0.5 miles upstream from the point of our previous trace. At the first Bridge Creek trace, the dye went into the middle portion of the St. Lawrence Formation and went under a broad ridge to an upper Tunnel City Group spring. In order to learn more about groundwater flow times and the conduit system carrying the flow, the second trace was done using programmable automatic water samplers. The automatic samplers allowed us to construct a breakthrough curve and determine that the groundwater was moving at a horizontal rate of 1,024 ft. /day. This speed is consistent with flow through karst conduits and is another data point in our characterization of the St. Lawrence and Tunnel City as karst-conduit aquifers in valley settings. The dye trace on Girl Scout Camp Creek was also a St. Lawrence sinking stream investigation. Girl Scout Camp Creek has a remnant population of native brook trout and thus is of high interest to our DNR Fisheries staff. A tributary to the main stem of the creek sinks into the top of the St. Lawrence Formation; that was where we introduced dye. The dye was recovered at a St. Lawrence a spring and at an upper Tunnel City spring making this the third place where have documented the connection between Tunnel City springs and surface stream recharge. GIS and field work identified several additional St. Lawrence/Tunnel City sinking points. Those points are potential dye tracing locations. Flow measurement data continued to be collected. Considerable time and effort was spent on editing and expanding the Spring Assessment Protocols and on doing basic work for the development of dye trace reports for the many dye traces done during the life of this project.

Final Report Summary: 15 September 2014
Much significant work was accomplished during this project. The existing springshed mapping in the Galena Group limestone karst of Fillmore and Olmsted counties was expanded significantly. Dye traces were run and springsheds identified in the Prairie du Chien Group karst of Dakota and Winona counties. Fourteen dye traces were conducted in the St. Lawrence Formation and Tunnel City Group bedrock units in Houston, Winona and Wabasha counties. This work has radically altered our understanding of springs and springsheds in southeast Minnesota. Prior to this project there had been no planned dye traces in these units. While it was known that many springs emanated from them, it was assumed that they were not directly connected to the land surface by sinkholes or sinking streams. In this project we documented that springs discharging from the St. Lawrence Formation and Tunnel City Group bedrock units receive surface water recharge from sinking streams in the upper St. Lawrence Formation and that this recharge moves hundreds of feet per day through bedrock. We demonstrated that this phenomena is regional, occurring from the north edge of Wabasha county to southern Houston County, showing that the thousands of springs in southeast Minnesota that discharge from these bedrock units are far more vulnerable to human impact than previously believed. During this project we have monitored spring temperature and conductivity. That information, along with our dye tracing observations, field investigations, and GIS investigations was used to guide the development of Spring Assessment Protocols for the Paleozoic Bedrock Springs of Southeast Minnesota. This document is the first of its kind in the upper Midwest and is a compilation of the state of our knowledge on the dynamics of groundwater flow to Paleozoic bedrock springs. A map, “Mapped Paleozoic Bedrock Springsheds in Southeast Minnesota” was produced to show all of the springshed mapping that has been done in southeast Minnesota.

V. DISSEMINATION:

Description: GIS-based maps and written reports of the springsheds will be prepared and disseminated to the LCCMR, interested residents and to local, regional and state resource managers and regulators interested in specific targeted areas. Interim dye trace results will be available as GIS shape files and derived products on a dye trace by dye trace basis. Data tables of discharge and chemistry will be available as developed. Spring assessment protocols will be published and made available to local and state agency staff.

Status as of 15 January 2012
Springshed information & results were presented as part of three tours in southeast Minnesota. They were karst tours for the Geological Society of America, Minnesota Association of Professional Soil Scientists and state and federal agency staff from Minnesota, Wisconsin and Iowa. The St. Lawrence tracing work was presented at the national Geological Society of America meeting in Minneapolis in October. Springshed information and results from the ENRTF-funded “Hydraulic Impacts of Quarries and Pits” was presented at silica sand mining forums in Goodhue and Winona counties.

Status as of 15 July 2012
The St. Lawrence tracing work was presented at the Minnesota Groundwater Association spring conference. Springshed information and results from the ENRTF-funded “Hydraulic Impacts of Quarries and Pits” was presented at silica sand mining meetings in Fillmore, Houston and Olmsted counties. A coalition of southeast MN water advocacy groups and local governments sponsored a karst and hydrology tour. Springshed information & results were presented as part of that tour.

Status as of 15 January 2013
The St. Lawrence tracing work and results from the ENRTF-funded “Hydraulic Impacts of Quarries and Pits” were presented at the Midwest Groundwater Conference at the Earle Brown Center. Springshed information was discussed with NRCS/NGO and Environmental Defense Fund staff as part of a new, federally-funded Root River watershed project.

Status as of 15 July 2013

The springshed mapping work was presented at a Winona State Geology department seminar in February and at a DNR GIS users group meeting in March. Springshed mapping results, spring inventory methods and springshed assessment techniques were presented to county and state feedlot program staff at a MPCA sponsored training event in Oronoco, MN in April.

Status as of 15 January 2014
In October, the springshed mapping work was presented at a DNR groundwater training seminar for field staff, at the EcoWaters all division meeting and as part of the MGWA/AIPG fall field trip in southeast MN. An update on the work was presented at the Root River Technical Advisor Group meeting in Preston, MN November 2013.

Final Report Summary: 15 September 2014
Information from this project was widely disseminated. A map of the delineated springsheds and a document on Spring Assessment Protocols were produced and submitted to the LCCMR and will be published by the Minnesota Geological Survey. The springshed coverage is being used by state and local governments to target areas for conservation efforts and for Clean Water Fund project ranking. The springshed mapping will be used by the DNR for Silica Sand Mining Trout Stream Setback permitting and in Water Appropriation permit review.

Project information was presented to numerous groups including the SE MN Water Resources Board, Root River Technical Advisor Group, Fillmore County Local Water Planning committee, Southeast Minnesota County and State Feedlot officers, Midwest Federal Agency Senior Managers, and at Silica Sand mining forums in Red Wing, Lewiston, La Crescent, and Winona. On the ground information was presented during tours of the southeast; groups that went “on tour” include Minnesota Groundwater Association, MPCA/DNR field staff, SE Minnesota water advocacy groups, Geological Society of America, Minnesota Association of Professional Soil Scientists, and state and federal agency staff from Minnesota, Iowa, and Wisconsin.

A paper on the St. Lawrence tracing work has been was published in the journal Carbonates and Evaporites. The springshed mapping work was the subject of two stories on Minnesota Public Radio. Project results were presented at numerous scientific meetings including the 11th and 12th Multidisciplinary Conference on Sinkholes and the Environmental and Engineering Aspects of Karst, the Minnesota Groundwater Association, the Midwest Groundwater Conference, the Geological Society of America, The Driftless area Symposium, and at a Winona State University Geology Department seminar.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget:

Budget Category	$ Amount	Explanation
Personnel:	$ 201,200	Hydrologist 3
Equipment/Tools/Supplies:	$ ~~6,100~~ $3,900	Field equipment, dye, sampling supplies
Travel Expenses in MN:	~~$12,700~~ $14,900	Mileage and expenses
TOTAL ENRTF BUDGET:	**$ 220,000**	

Explanation of Use of Classified Staff- The Hydrologist 3-Southeast Minnesota Regional Groundwater Specialist has been assigned to work on the springshed project. The activities performed by this position have been assigned to other staff.

Number of Full-time Equivalent (FTE) funded with this ENRTF appropriation: 1.0

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
State			
0.05 FTE General Fund	$10,822		EcoWaters staff project support
Minnesota DNR's In-kind Contribution: $28,805 for shared services and governance	$28,805		General fund and other funds as appropriate
TOTAL OTHER FUNDS:	$ 39,627	**$**	

VII. PROJECT STRATEGY:

A. Project Partners: University of Minnesota, total from appropriation $280,000
B. Project Impact and Long-term Strategy: By delineating springsheds and making web-based maps available, this project will provide critical information for the protection and management of the springs that form the coldwater streams of southeast Minnesota. This information is critical for Total Maximum Daily Load (TMDL) implementation strategies, impaired waters remediation, ground water protection and allocation issues, and local land and water management decisions.

Karst ground water flow is the most complex hydrogeologic environment in Minnesota. Springs are the natural features that return groundwater to surface waters. Karst springs respond much faster to surface recharge than is expected from conventional hydrology theory. Karst springs exhibit a wide range of rapid responses to recharge events. Springs integrate all of the natural and anthropogenic processes that occur in their recharge areas – in their individual springsheds. Springshed mapping is critical component of karst aquifer characterization. Long-term resources are needed to gather and maintain the parameters necessary to realistically, effectively manage karst springs in Minnesota and to train staff and resource managers in the use of the available karst data. LCMR and LCCMR have played a leading role in the effort to understand and manage Minnesota's karst springs

The availability of high-resolution LiDAR maps has produced a flood of new information showing the locations of karst features. This new information is having a major impact on the springshed mapping project by identifying additional sinkholes and sinking streams as possible dye trace input points. LiDAR imagery has allowed us to identify the particular characteristics of St. Lawrence sinking streams; we are using that knowledge to identify additional sites to field check that are in remote valleys that are difficult to access.

C. Spending History:

Funding Source	M.L. 2005 or FY 2006-07	M.L. 2007	M.L. 2008 or FY 2009	M.L. 2009	M.L. 2010 or FY 2011
ENRTF via contract with U of M		125,000			
ENRTF appropriation to DNR				250,000	

VIII. ACQUISITION/RESTORATION LIST:

IX. MAP(S): Attached

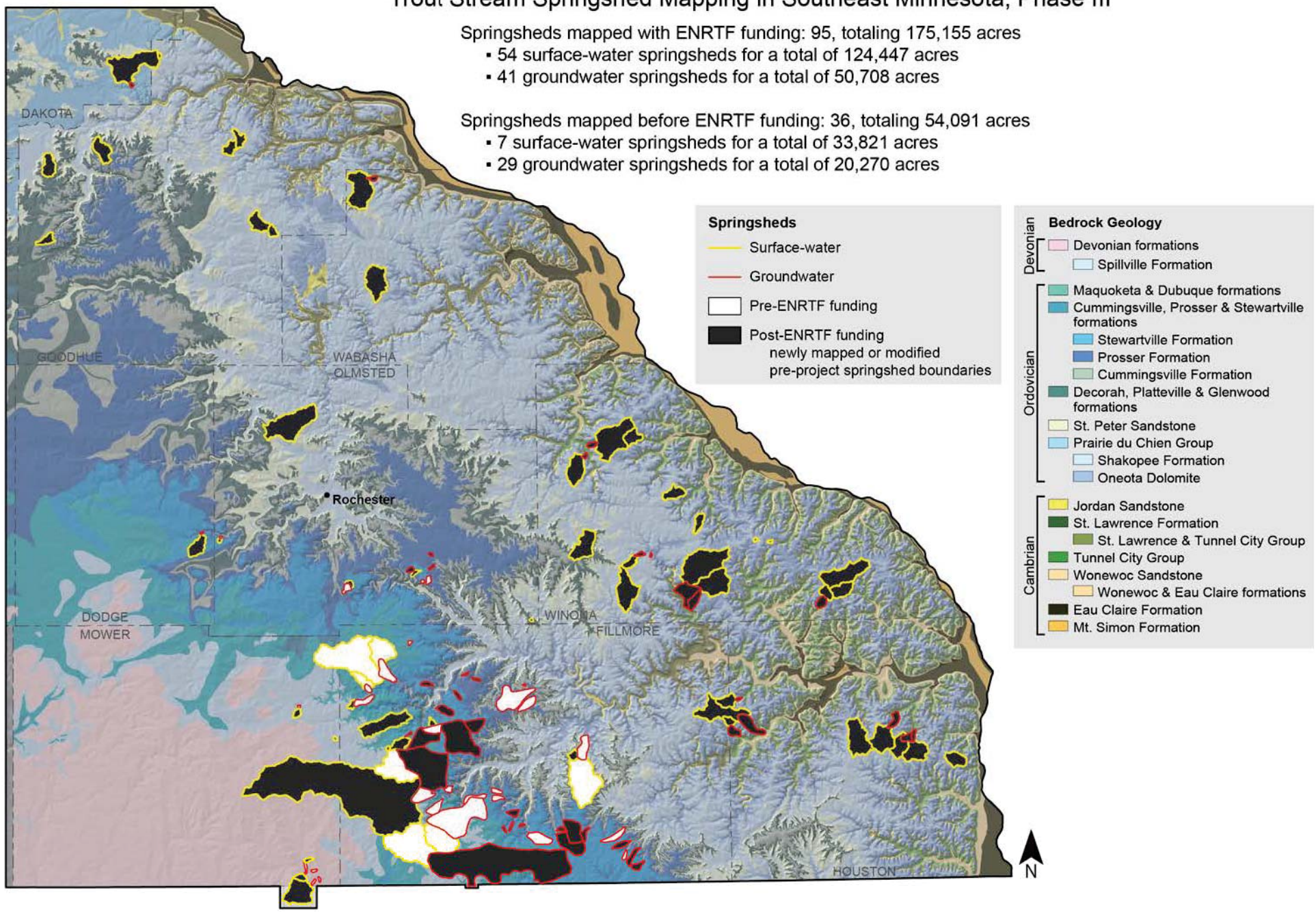
X. RESEARCH ADDENDUM:

XI. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted not later than *15 January 2012, 15 July 2012***,** *15 January 2013, 15 July 2013* **and** *15 January 2014.* **A final report and associated products will be submitted between June 30 and September 15, 2014 as requested by the LCCMR.**

Trout Stream Springshed Mapping in Southeast Minnesota, Phase III

Springsheds mapped with ENRTF funding: 95, totaling 175,155 acres
- 54 surface-water springsheds for a total of 124,447 acres
- 41 groundwater springsheds for a total of 50,708 acres

Springsheds mapped before ENRTF funding: 36, totaling 54,091 acres
- 7 surface-water springsheds for a total of 33,821 acres
- 29 groundwater springsheds for a total of 20,270 acres



Project Legal Citation: M.L. 2011, First Special Session, Chp. 2, Art.3, Sec. 2, Subd. 05b1

Attachment A: Budget Detail			
Project Title: *Trout Stream Springshed Mapping in Southeast Minnesota – Phase III*			
Legal Citation: *Laws MN 2011, 1st Sp. Session, Ch. 2, Art. 3, Sect. 2, Subd. 05b1*			
Project Manager: *Jeff Green*			
M.L. 2011, First Special Session, Chp. 2, Art.3, Sec. 2, Subd. 05b1 ENRTF Appropriation: $220,000			
Project Length and Completion Date: *June 30, 2014*			
Date of Update: *9/15/2014*			
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	**Revised Activity 1 Budget 9/15/2014**	**Amount Spent**	**Balance**
BUDGET ITEM			
Personnel (Wages and Benefits, Unemployment) *Hydrologist 3 (Jeff Green), 100%*	201,200	200,318	882
Equipment	1,800	1,474	326
Supplies	2,100	1,906	194
DNR Fleet Vehicle Costs	13,000	12,773	227
Meals & Lodging for Fieldwork	1,900	1,868	32
COLUMN TOTAL	**$220,000**	**$218,341**	**$1,659**

Mapped Paleozoic Karst Springsheds in Southeast Minnesota

Jeffrey A. Green[1] and E. Calvin Alexander, Jr.[2]

September 2014

1. Minnesota Department of Natural Resources, Ecological and Water Resources Division
2. University of Minnesota, Department of Earth Sciences

Map to accompany the LCCMR report:
Springshed Assessment Methods for Paleozoic Bedrock Springs of Southeastern Minnesota
Project Title: Trout Stream Springshed Mapping in Southeast Minnesota, Phase III
Legal Citation: M.L. 2011, First Special Session, Chp. 2, Art. 3, Sec. 2, Subd. 05b1

LOCATION DIAGRAM

MAP EXPLANATION

- Spring
- Stream sink
- Location dye introduced into sinkhole or stream sink
- Dye detected at spring or well
- Dye not detected
- Well
- Inferred groundwater flow route
- Groundwater springshed
- Surface-water springshed
- Designated trout stream
- < 50 feet of material over bedrock
- Cenomanian Shale subcrop
- St. Lawrence Formation subcrop
- County seat
- Roads
- County boundary
- State boundary

Introduction

Springs are the natural discharge points for groundwater systems. They provide baseflow for streams and are critical sources of constant-temperature water for cold water trout streams. In order to conserve and protect the source of water to a spring it is necessary to identify the springshed, the area that contributes water to the spring.

This map displays mapped springsheds as of June 2014 in the Paleozoic karst bedrock of southeast Minnesota. It also incorporates work done as part of the Fillmore County Geologic Atlas (Alexander and others, 1996, Plate 9).

Karst and Hydrogeology

Karst is a landscape-scale hydrologic system formed in soluble bedrock. Water chemically and mechanically enlarges passages resulting in integrated conduits through which it can travel rapidly, at speeds of up to several miles per day. Certain bedrock layers are more prone to karst formation (Figure 1).

The land surface may express the karst system through the presence of sinkholes and sinking streams, which are inlets or «windows to the bedrock aquifer. Even areas with few or none of these features at the surface may have water moving rapidly through subsurface conduits, especially in areas where water infiltrates through thin soil.

Some of the water that has entered the subsurface emerges at the surface in springs. A groundwater springshed includes three components: 1) water that has infiltrated from the land surface into the first karst aquifer even where there are no obvious karst features present, 2) surface water that entered at a specific karst feature, and 3) regional groundwater flow.

Springsheds are dynamic and their boundaries can change as groundwater levels rise and fall. The boundaries of groundwater springsheds and the surface watersheds do not necessarily correspond.

Regional Geology and Stratigraphy

The flat-lying Paleozoic sedimentary bedrock of southeastern Minnesota is Cambrian to Devonian in age (505 to 350 million years ago) (Mossler, 2008) and was deposited as a series of shallow, fluctuating seas advanced and retreated across what is now southeastern Minnesota (Figure 2). The Cambrian-age rocks are primarily sandstone, siltstone and shale while the Ordovician and Devonian rocks are primarily carbonate (limestone and dolostone) and shale.

Rock layers that serve as the source of water for the many springs found in southeast Minnesota are highlighted on the map and stratigraphic column (Figure 2). The Decorah Shale (blue on the map) is a regional aquitard and is the boundary between the Galena limestone karst system and the Prairie du Chien karst system. Many springs discharge from the lower Galena because the water cannot move through the relatively impervious, underlying shale. The St. Lawrence Formation (green on the map) is an important regional bedrock unit from which many springs discharge and where disappearing streams (stream sinks) contribute water to springs (Green and others, 2012).

These rock units are covered by varying thicknesses of unconsolidated sediments. Areas with less than 50 feet of sediment cover have been the focus of springshed mapping efforts because sinkholes and disappearing streams are primarily found in those areas. Those features are not common where the cover is thicker than 50 feet (brown areas on the map), typically in three settings: isolated areas in the bluffland regions, along the alluvium deposits of the major rivers, and under deep glacial deposits to the west.

Methods

The surface-water springsheds were identified by analyzing LiDAR digital elevation models or topographic maps. The groundwater springsheds in southeastern Minnesota were mapped primarily through dye tracing done by the University of Minnesota, DNR, and private cavers.

The use of artificial additives (tracers) to track groundwater flow is common for karst aquifer investigations. A tracer is added to the groundwater system through a sinkhole, sinking stream, or cave stream. Then groundwater discharge locations, typically springs, are monitored for the arrival of the tracers. When input-to-discharge connections are established, the identified connection can be used to identify the area that contributes water to a spring (groundwater springshed). Frequent sampling during the tracing experiment allows the travel time of the groundwater to be calculated.

Fluorescent dyes are the preferred tracers because they are conservative (travel with water and are non-reactive), readily obtainable, non-toxic, relatively simple to analyze, detectable at very low concentrations and not naturally present in the groundwater. For this study, the dyes used were eosine (CAS 17372-87-1), Rhodamine WT (CAS 37299-86-8), and uranine C/fluorescein (CAS 518-47-8). Multiple dyes were used to trace from different sinkholes at the same time. The traces were carried out with 200–1200 grams of dye. The dyes were introduced into the groundwater systems through sinking streams, snow melt running into sinkholes, and dry sinkholes. In the latter case, the dyes were flushed with water from a tanker truck (typically 500–2000 gallons). Dye traces were conducted in the Lithograph City Formation, Spillville Formation, Galena Group, Prairie du Chien Formation, St. Lawrence Formation, and the Tunnel City Group.

Springs, streams, and wells were monitored to determine background levels both before and after dye inputs with a combination of integrating charcoal packets and direct water samples. The charcoal packets and water samples were analyzed using a scanning spectrofluorophotometer in the Earth Sciences Department of the University of Minnesota. All three dyes could be measured in parts per billion.

Results

This map displays mapped groundwater and surface-water springsheds across southeast Minnesota. The groundwater springshed boundaries are outlined in red and reflect groundwater levels in the first bedrock karst aquifer at the time that the dye traces were conducted. Surface-water springsheds are outlined in yellow. Common boundaries of neighboring springsheds represent surface-water or groundwater divides. Sinkholes or stream sinks that were used as dye-trace input points are symbolized differently depending on whether or not dye was later detected in the springs that were being monitored. The dye-trace vectors (black arrows) are the diagrammatic depiction of the groundwater flow route.

The five insets are enlargements of areas with a high density of dye trace points and vectors.

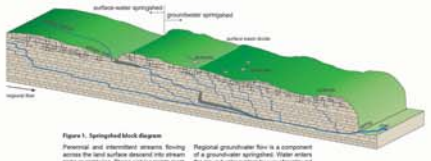


Figure 1. Springshed block diagram

Perennial and intermittent streams flowing across the land surface descend into stream sinks or sinkholes. Those sinking points mark the beginning of a groundwater springshed carrying groundwater flow to a spring. The black lines represent the general direction of groundwater flow through enlarged openings in the subsurface, such as vertical and horizontal joints and fractures. The gray-shaded linear features represent larger conduits carrying groundwater flow.

Regional groundwater flow is a component of a groundwater springshed. Water enters the groundwater system by way of continued infiltration from the surface and can come from areas far beyond the surface-water springsheds. Regional sources of water to groundwater springsheds have a significantly longer underground residence time and provide a large fraction of spring discharge from the St. Lawrence Formation and Tunnel City Group.

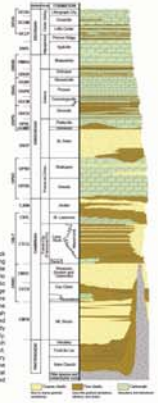


Figure 2. Stratigraphic column

This stratigraphic column shows bedrock of southeastern Minnesota highlighting lithostratigraphic attributes. The carbonate bedrock has been partially dissolved to form karst aquifers. The coarse clastic bedrock stones and transmits large volumes of water in the primary pore space in the sandstone matrix. Two fine clastic bedrock formations, the Decorah and the St. Lawrence, are highlighted on the map. Their lower primary porosity does not allow water to infiltrate readily, creating numerous springs which discharge laterally at their upper contact. These units have enhanced secondary porosity in the form of bedding plane fractures and conduits, which is a critical factor for spring occurrence. Adapted from Mossler (2008).

References

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INSET 1

INSET 2

INSET 3

INSET 4

INSET 5

Red Wing
DAKOTA
GOODHUE
WABASHA
Wabasha
Winona
Dodge Center
Rochester
DODGE
MOWER
OLMSTED
WINONA
FILLMORE
HOUSTON
Preston
Caledonia
MINNESOTA
IOWA

0 5 10 20 Miles

N

This map was prepared from publicly available information only. Every reasonable effort has been made to ensure the accuracy of the information shown on this map. Information is known, however, the Department of Natural Resources does not warrant the accuracy, completeness, or any implied uses of these data. Users may wish to verify critical information; sources include both the references here and information on file in the offices of the Minnesota Geological Survey and the Minnesota Department of Natural Resources. This map should not be used to establish legal title, boundaries, or locations of improvements.

Project data compiled from 2007 to 2014. Universal Transverse Mercator projection, grid zone 15, 1983 North American Datum. Vertical datum is mean sea level.

GIS and cartography by Jeff Green and Holly Johnson
Editorial by Carrie Jennings and Ruth MacDonald