Mapped Paleozoic Karst Springsheds in Southeast Minnesota

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September 2014

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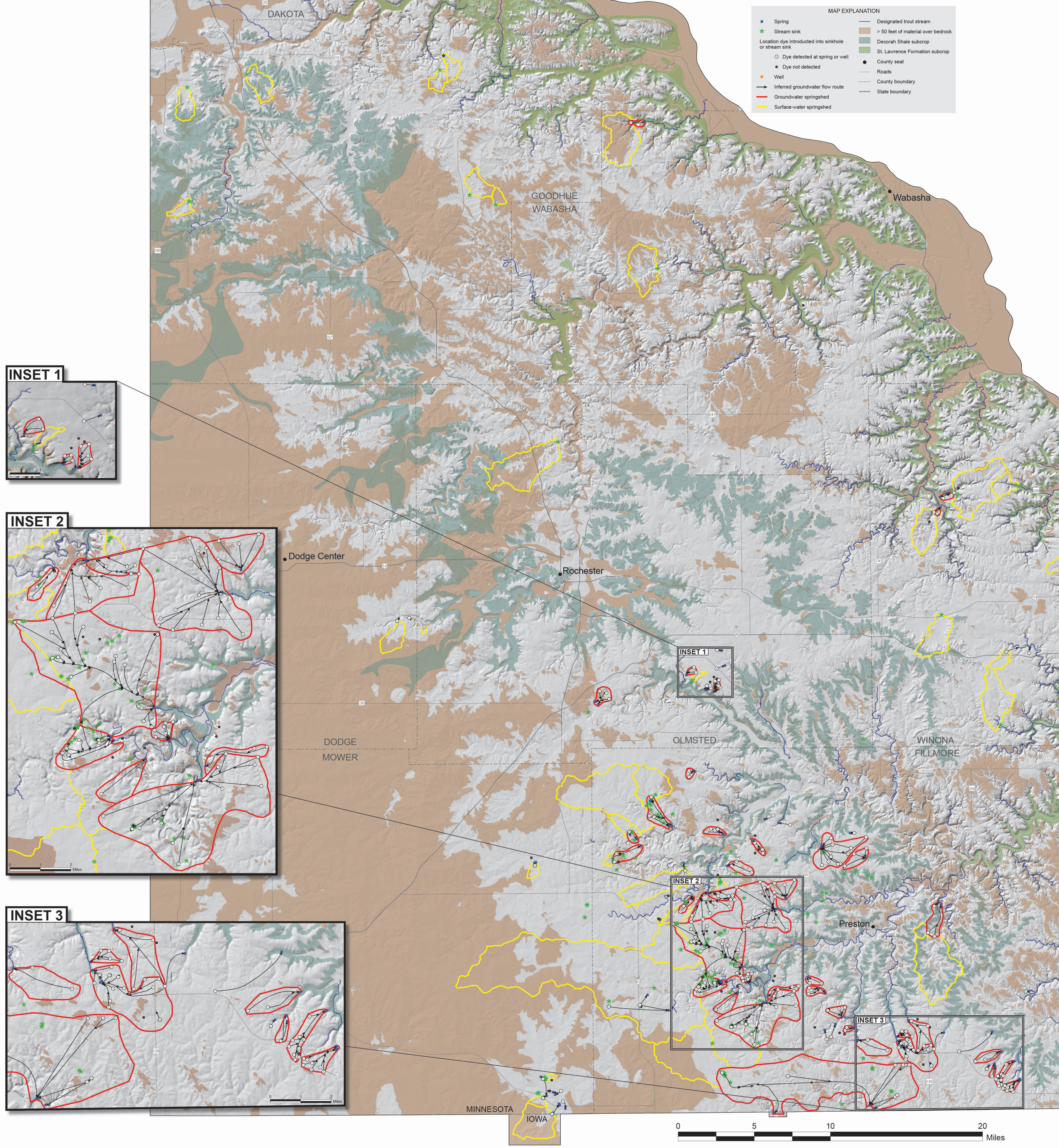
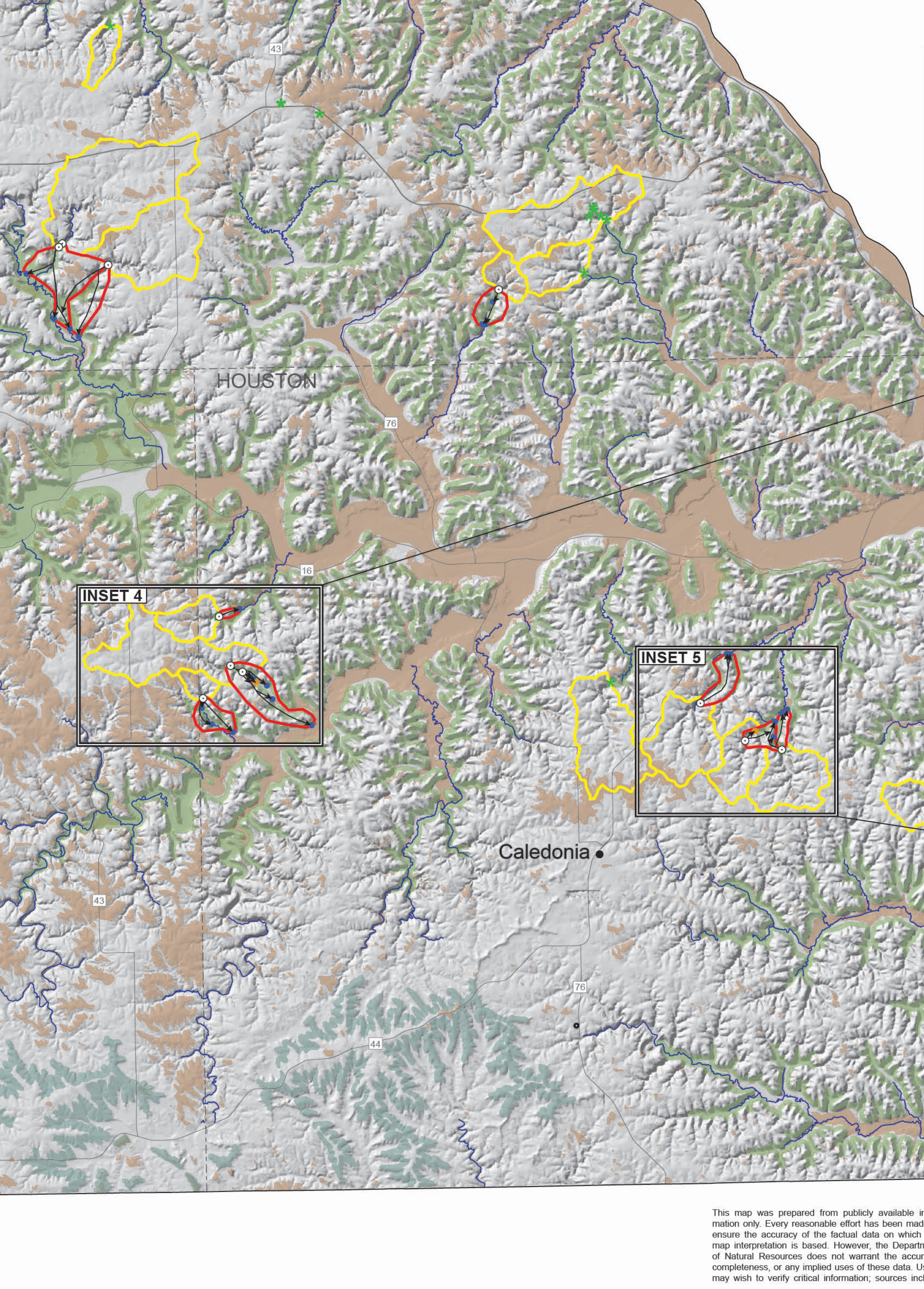
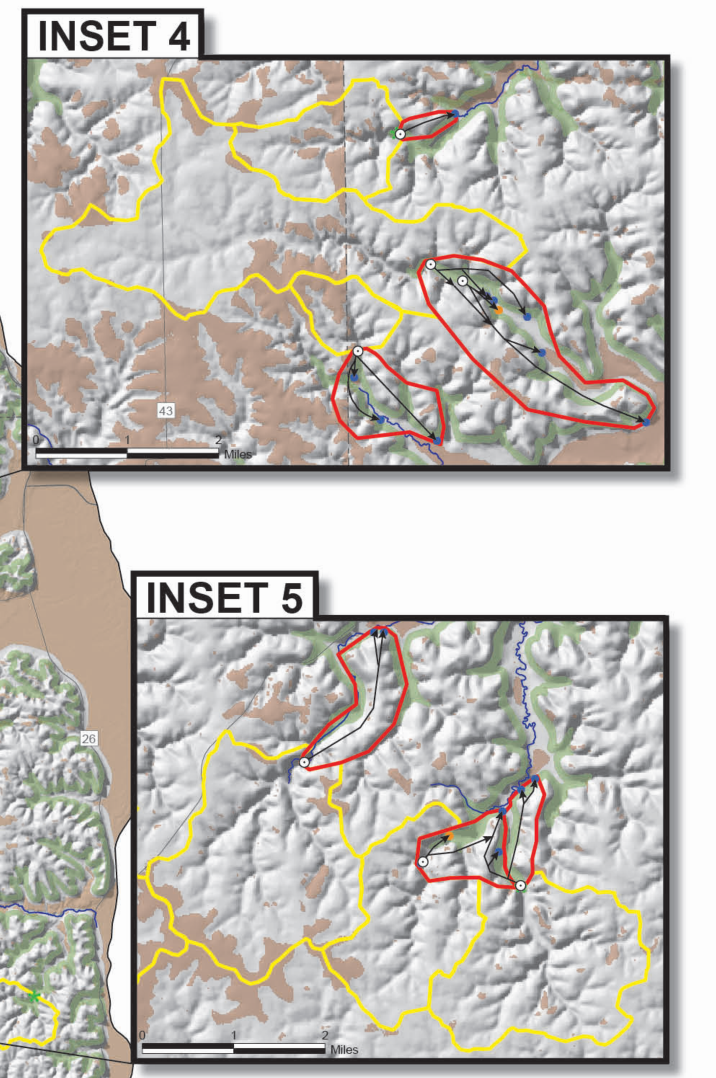
Map to accompany the LCCMR report:
Springshed Assessment Methods for Paleozoic Bedrock Springs of Southeastern Minnesota
Project Title: Trout Stream Springshed Mapping in Southeast Minnesota, Phase III
Legal Citation: M.L. 2011, First Special Session, Chp. 2, Art. 3, Sec. 2, Subd. 05b1







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. These 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 blufland 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.

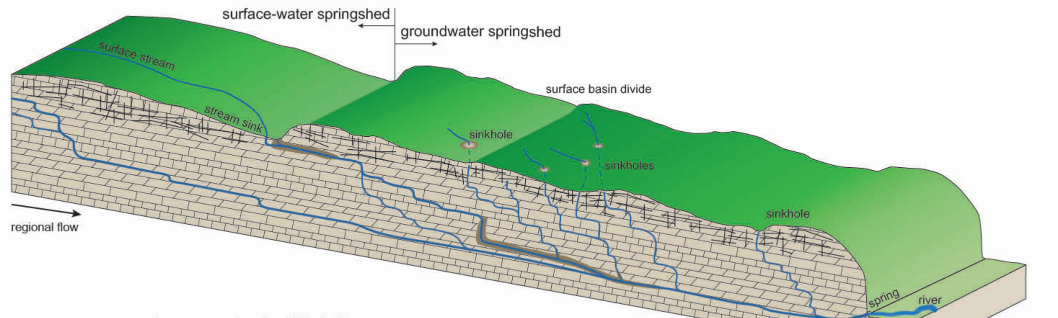


Figure 1. Springshed block diagram

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 infiltratration 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.

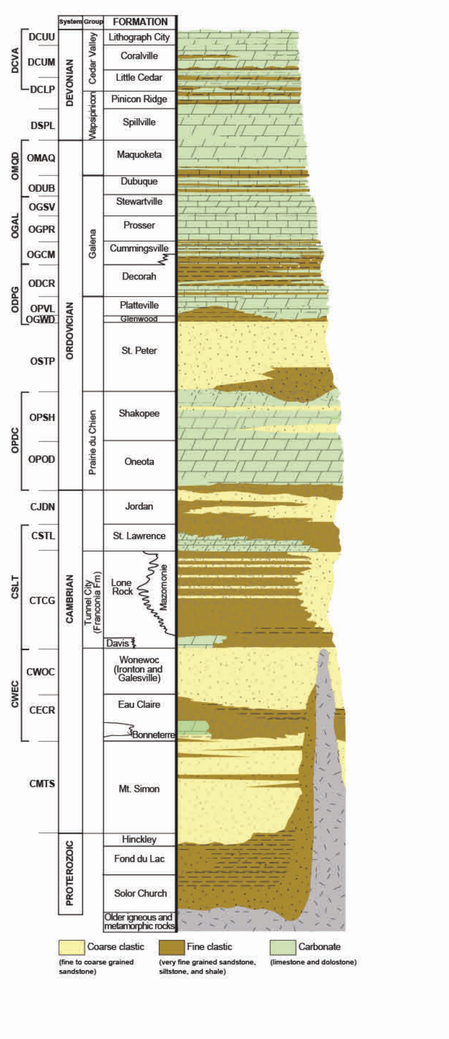


Figure 2. Stratigraphic column

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 stores 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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Acknowledgements

Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR).

This project would not have been possible without the work of many people. Scott Alexander of the University of Minnesota provided oversight and analysis of the dye trace samples. Donna Rasmussen of Fillmore County provided staff to assist in dye tracing and obtained property access for many traces. Other individuals who contributed much to this project include Tony Runkel of the Minnesota Geological Survey, Betty Wheeler, Kelsi Ustipak, and Andrew Luhmann of the University of Minnesota, Mark White (DNR), Andrew Peters (formerly DNR), the Harmony and Chatfield Fire Departments, and the many landowners who allowed access to their springs, sinking streams and sinkholes. Without their cooperation this work would not have been possible.

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. Edited by Carrie Jennings and Ruth MacDonald.