Minnesota
Cave Preserve

2017 York Blind Valley Dye Trace

Fillmore County, MN

John Barry Pouring Dye into the disappearing stream at the York Blind Valley. Photo by Martin Larsen

Upstream view of the disappearing stream at the York Blind Valley. Photo by Martin Larsen

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Introduction

York Blind Valley in southern Fillmore County is the largest blind valley in Minnesota. Blind valleys are landscape features that abruptly end with surface water disappearing into the subsurface. The York Blind Valley accepts 7,520 acres of Canfield Creek's surface watershed, draining into the longest subsurface conduit system documented by dye tracing in Minnesota. Water that disappears in the York Blind Valley resurges approximately 10.5 miles away at Minnesota's largest spring, Odessa Spring near the town of Granger. Other blind valleys in Minnesota have extensive cave systems associated with them; therefore the caving and karst community long sought an entry into this subterranean system.

In August 2008, the long desired connection was revealed. Holy Grail Cave was discovered in August 2008 after a June rain storm in southern Fillmore County delivered nearly 12 inches of precipitation. A new sinkhole, (23D5160) in the Karst Feature Database (KFD), opened in a grassed waterway during the storm event and created a window into the cave system below. Since Holy Grail Cave's discovery, over 4.2 miles of passageways have been explored and surveyed by members of the Minnesota Caving Club (Figure 1).

Holy Grail Cave is a joint controled, maze cave. Most of the passages are formed within the Galena group's Dubuque limestone although many deep pits cut through the underlying Stewartville limestone and encounter a water table roughly 40 feet below its upper level passages. In June of 2009, a dye trace was conducted by John Ackerman from within the cave at the Grand Central Station, pictured in Figure 1. The trace documented that cave drips within Holy Grail are connected to Odessa Spring (Figure 2).

The purpose of the 2017 York Blind Valley Dye trace was to establish a connection from the York Blind Valley to water flowing in the lower levels of Holy Grail Cave.

Figure 1. *Minnesota Caving Club members in Grand Central Station within Holy Grail Cave. A dye trace was conducted in 2009 documenting a connection from cave drips to Odessa Spring. Photo by Martin Larsen*

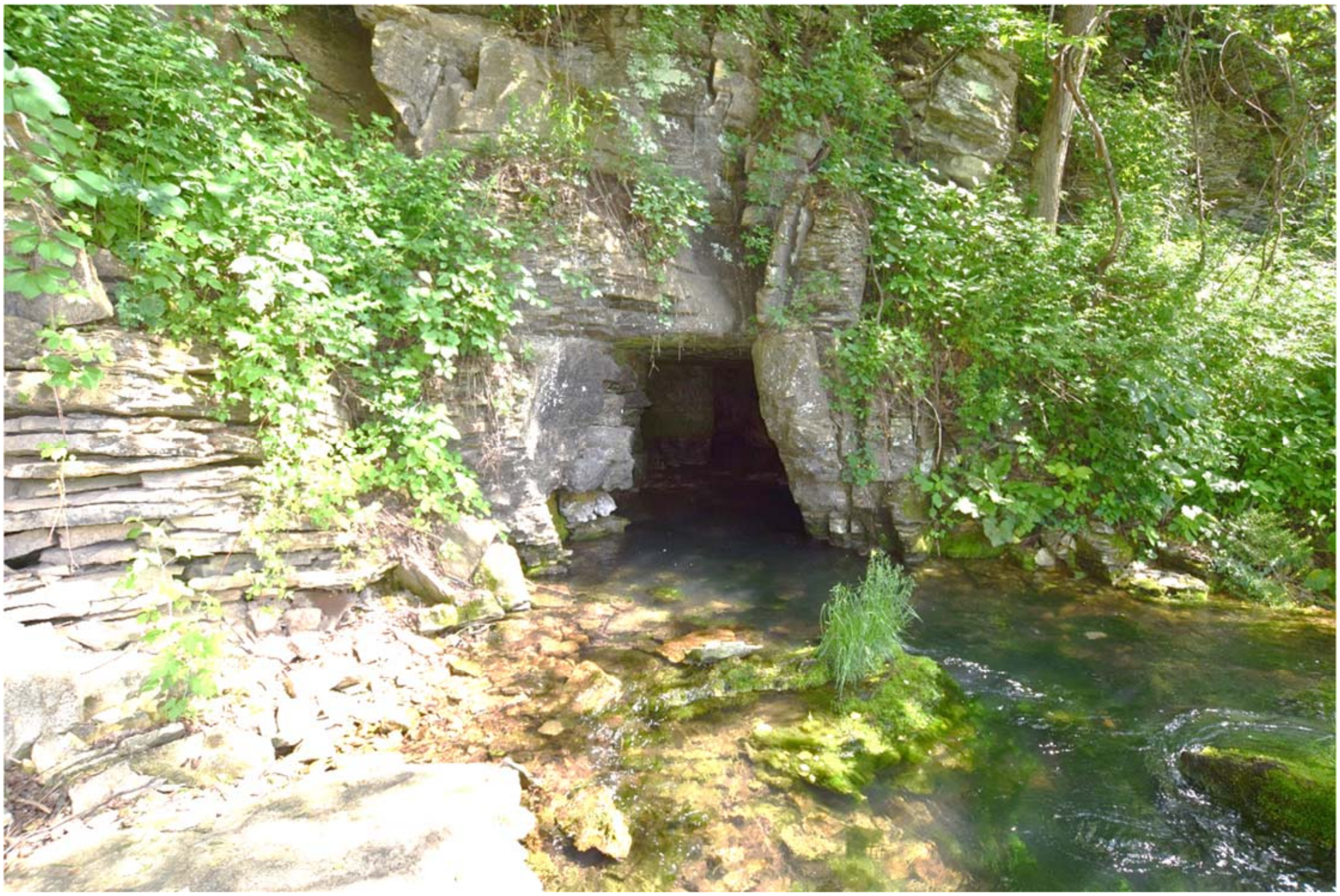

Figure 2. *Odessa Spring. Photo by Martin Larsen*

Participating Agencies

The dye trace was conducted by Martin Larsen of the Minnesota Cave Preserve, Jeff Green and John Barry of the Minnesota Department of Natural Resources and Calvin Alexander of the University of Minnesota Earth Sciences Department. The University supplied dye, charcoal detectors and logistical support. Analysis of the charcoal detectors was completed at the University of Minnesota by Scott Alexander and Sophie Kasahara. Betty Wheeler assisted with analytical results tracking (Appendix A).

Dye Trace Methods

Dye tracing uses the introduction of fluorescent dyes into karst surface and subsurface features such as sinkholes, stream sinks and caves to track groundwater flow directions and travel times. Dye type and mass were chosen based on previous dye use in the project vicinity, trace geometry and potential travel distances.

On 24 May 2017 at 15:43, 2.401 kg of Uranine HS (20 weight % solution) was poured into the York Blind Valley sinking stream at KFD point 23X319. The dye was carried into the conduit system by utilizing the stream flow immediately upstream of the York Blind Valley terminal sinking point located at 23B67. The stream flow was estimated at 25 cubic feet per second where it disappeared into channels in the base of a limestone cliff.

Passive charcoal detectors, referred to as bugs, were deployed in the cave to record the presence of dye that may flow through the system. They were located in previously determined locations within Holy Grail Cave and were secured within the cave by using nylon mason's line with a weight attached. The detectors were lowered into water flowing in lower level passages, nearly 40 feet below the upper level dry passage floor.

Area Geology and Hydrogeology

Underlying the relatively thin veneer of unconsolidated sediments, such as glacial till, loess, sand, and colluvium, in Fillmore County is a thick stack of Paleozoic bedrock units that range from middle Ordovician to Cambrian (Mossler, 1995). Ordovician rocks are generally dominated by carbonates, whereas the Cambrian rocks are generally siliciclastic (Figure 3).

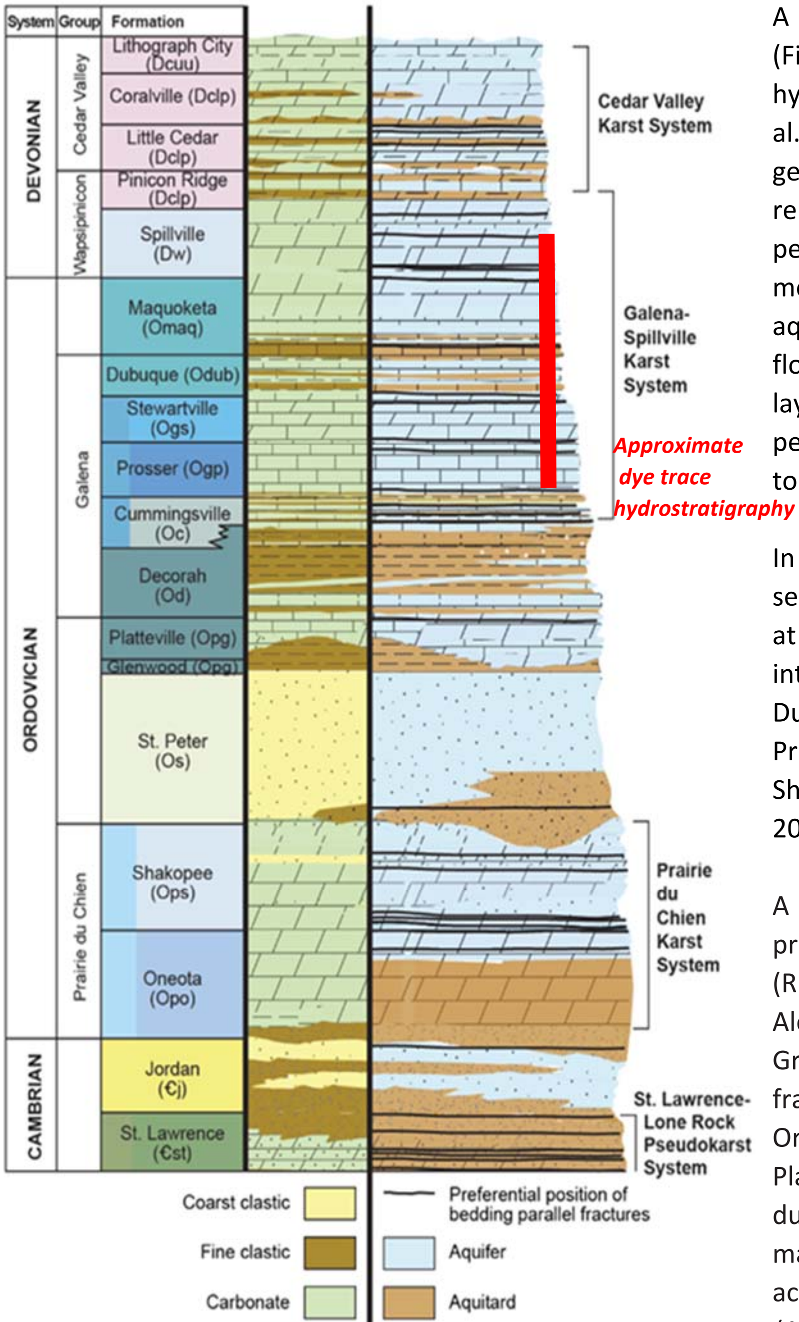

***Figure 3**. Geologic and hydrogeologic attributes of Paleozoic rocks in southeastern Minnesota. Modified from Runkel et al. 2013.*

A generalized stratigraphic column for Fillmore County (Figure 3) shows lithostratigraphic and generalized hydrostratigraphic properties (modified from Runkel et. al. 2013). Hydrostratigraphic attributes have been generalized into either aquifer or aquitard based on their relative permeability. Layers assigned as aquifers are permeable and easily transmit water through porous media, fractures or conduits. Layers assigned as aquitards have lower permeability that vertically retards flow, hydraulically separating aquifer layers. However, layers designated as aquitards may contain high permeability bedding plane fractures conductive enough to yield large quantities of water.

In southeast Minnesota, springs and groundwater seepage frequently occurs at the toe of bluff slopes and at specific hydrostratigraphic intervals. Common intervals include near the contact of Maquoketa-Dubuque, Dubuque-Stewartville, Stewartville-Prosser, Prosser-Cummingsville, Decorah-Platteville, St. Peter-Shakopee, and Shakopee-Oneota (Steenberg and Runkel, 2018).

A hydrogeologic framework that describes four prominent karst systems for southeastern Minnesota (Runkel et al., 2013) is based largely on the work of Alexander and Lively (1995), Alexander et al. (1996), and Green et al. (1997, 2002). The systems described in this framework include the Devonian Cedar Valley, the Upper Ordovician Galena-Spillville, the Upper Ordovician Platteville Formation, and the Lower Ordovician Prairie du Chien Group. Karst characterization and sinkhole mapping in Fillmore County has delineated areas of active karst processes and high sinkhole probability (Alexander and Lively, 1995, Witthuhn and Alexander 1995).

The dye tracing presented in this report occurred across multiple hydrostratigraphic units. Dye was introduced into the a terminal sink in York Blind Valley located in the Devonian Spillville Formation and emerged at Odessa Spring in the lower Prosser Formation of the Galena Galena Group (Figure 3).

Dye Trace Setting

The York Bind Valley dye trace took place in Fillmore County, Minnesota (Figure 4). The study area is located in a gently rolling karst interfluve between the Canfield and Willow Creek drainage to the north and the Upper Iowa River to the south. Land use in the study area is comprised primarily of row crop agriculture. Dye was injection at a location where the Spillville Formation of the Wapsipinicon Group is the first bedrock encountered from the surface (Mossler, 1995). Figure 4 shows the location of Fillmore County within the State of Minnesota and highlights the locations of Holy Grail Cave and Odessa Spring.

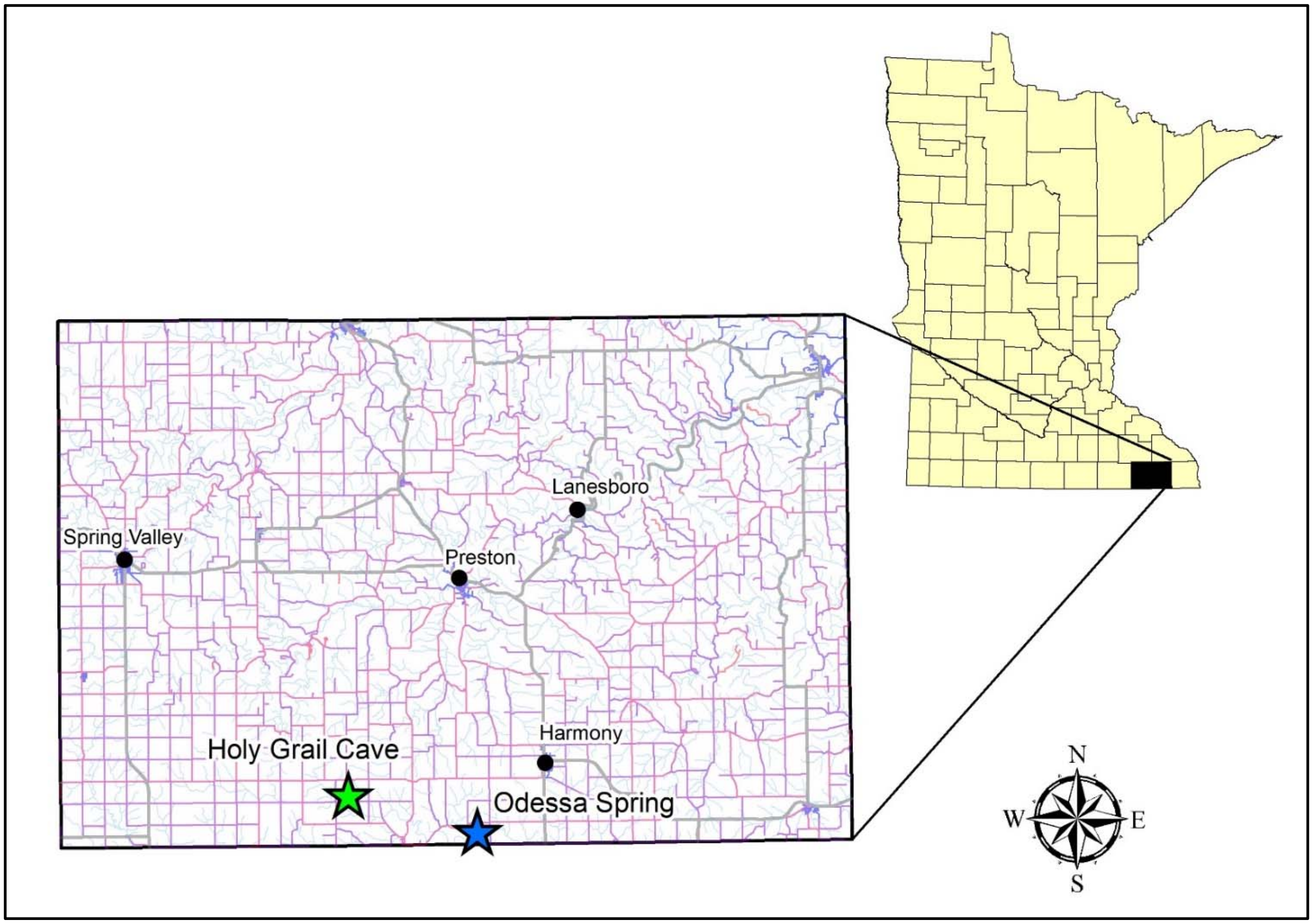

Figure 4. *Dye trace location*

The Holy Grail cave monitoring points were located at the water table within the Stewartville Member of the Galena Group (Figure 6). An additional monitoring point located in Canfield Creek was added shortly after dye injection. Dye trace pour and monitoring locations and their corresponding Karst Feature Database numbers are summarized in Table 1.

NAME	KFDB #	Classification	UTM E	UTM N
York Sinking Stream	23X319	Sinking Stream Injection Point	558389	4820635
Falling Floor Bug Set	23X324	Cave Pool	565183	4820528
Breezeway Bug Set	23X325	Cave Pool	564890	4820597
Canfield Creek South	23X091	Spring Run Sample Point	562734	4828497

Table 1. *York Blind Valley Dye trace features and locations*

Sampling Schedule

Prior to injection, passive charcoal detectors (bugs) were placed in the cave sampling locations. The Canfield Creek South bug set did not include a background sample. Background charcoal detectors were deployed on 20 May 2017 and then removed and replaced on 24 May 2017 before the introduction of dye. The second set of bugs were changed and replaced on 4 June 2017 and removed on 10 June 2017 (Appendix A). By consensus agreement among participants, sampling was terminated thereafter.

All samples were analyzed at the University of Minnesota, Department of Earth Sciences laboratory using a scanning spectrofluorophotometer.

Trace Results

The results of the analysis of the charcoal detectors are summarized in Appendix A and are shown as inferred groundwater flow directions in Figures 5, 6 & 7. Uranine HS was successfully traced from the York sinking stream (23X319) to the Falling Floor Bug Set (23X324) as shown in Figure 7. Uranine HS was only detected in the first bug collection on 4 June 2017 and was not detected at any other monitored location. The passive monitoring bugs were not changed until June 4, 2017, limiting the resolution of a time of travel calculation for this trace. Dye likely arrived very quickly to Odessa Spring, as groundwater velocity in the Galena-Spillville karst can reach up to 1-3 miles/day (Green et al. 2014).

This trace and a previous trace from the York Blind Valley elegantly illustrate the complexities of karst hydrology. The surface watershed that drains to the York Blind Valley is in the Root River watershed. The York Blind Valley pirates that surface water flow and re-distributes it to the Upper Iowa River watershed. This is the most dramatic example of watershed piracy in southeast Minnesota.

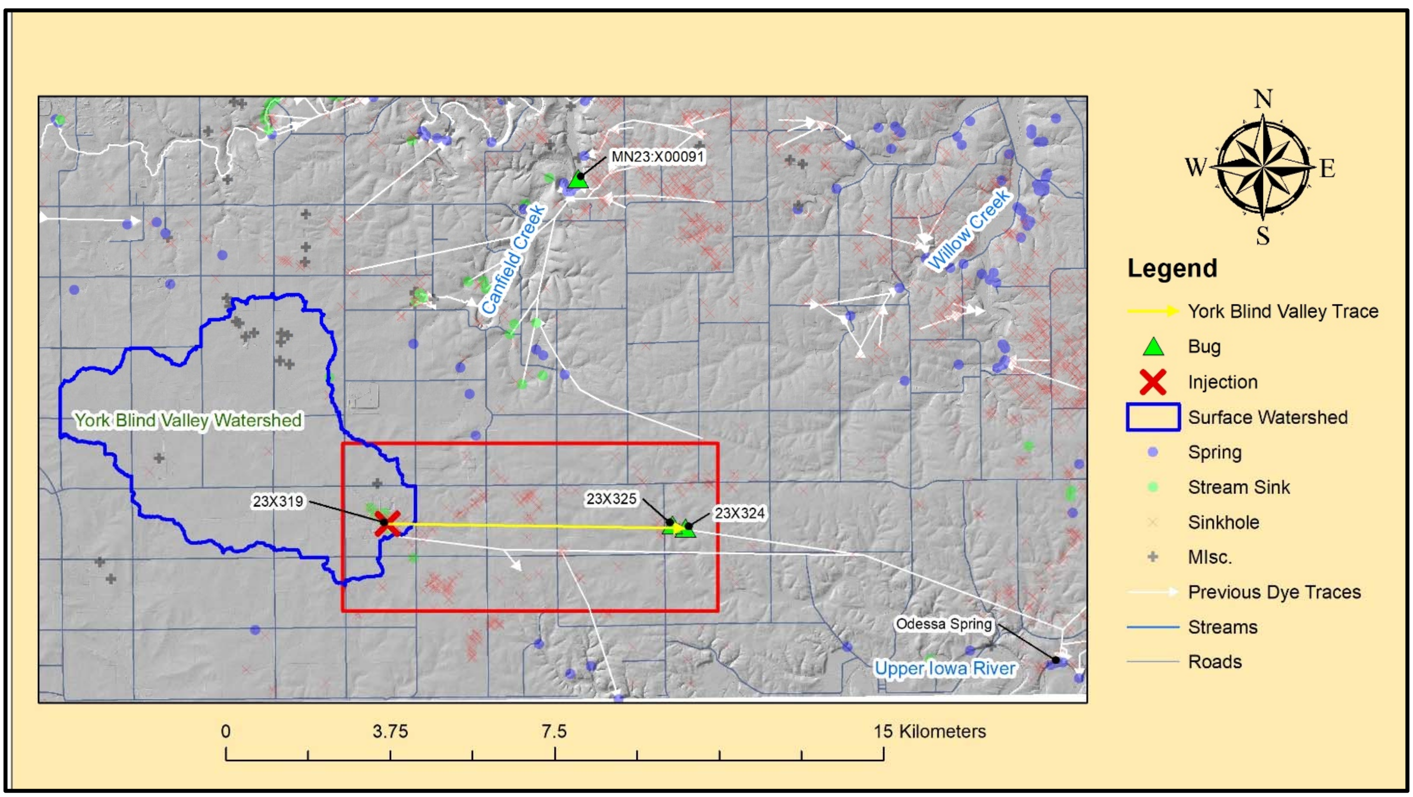

Figure 5. *2017 York Blind Valley trace study area. Dye input points, monitoring points, white dye vectors from previous traces in the study area. The rectangle outlined in red is the extent of Figure 6.*

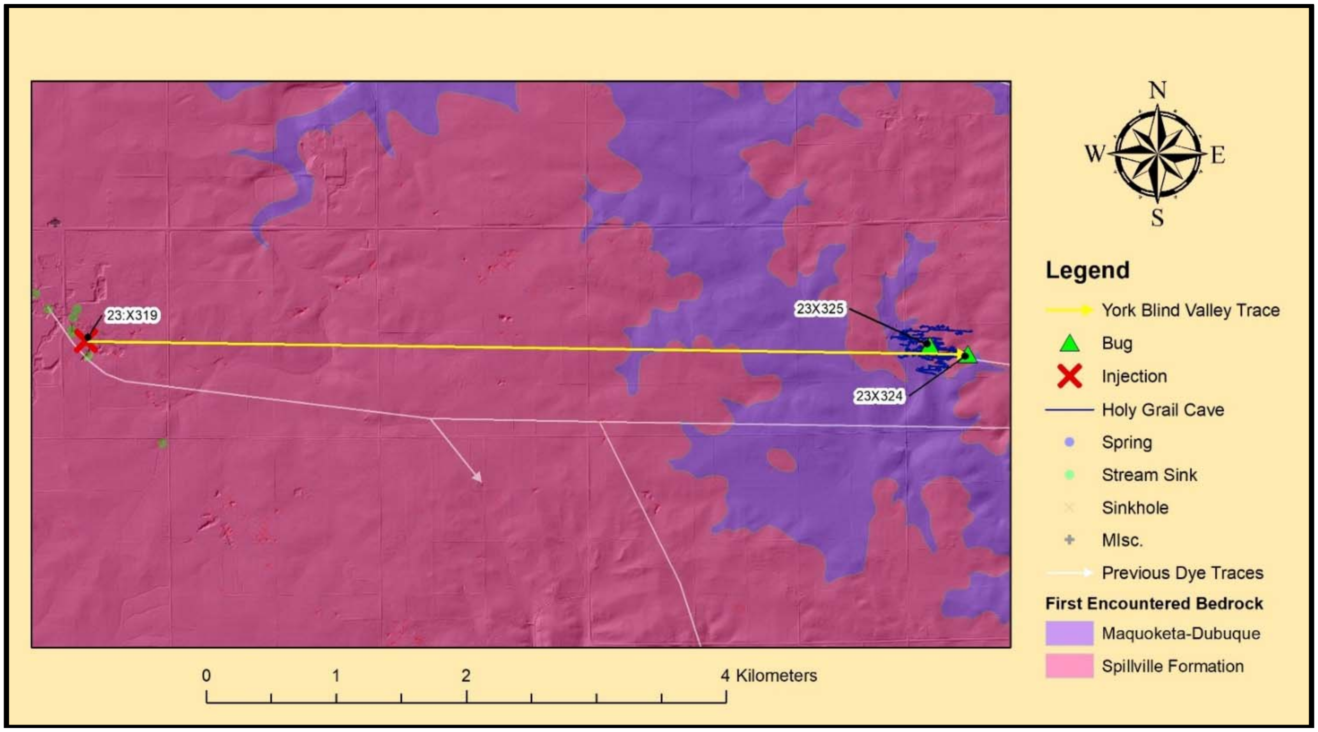

Figure 6. *2017 Monitored locations within Holy Grail Cave*

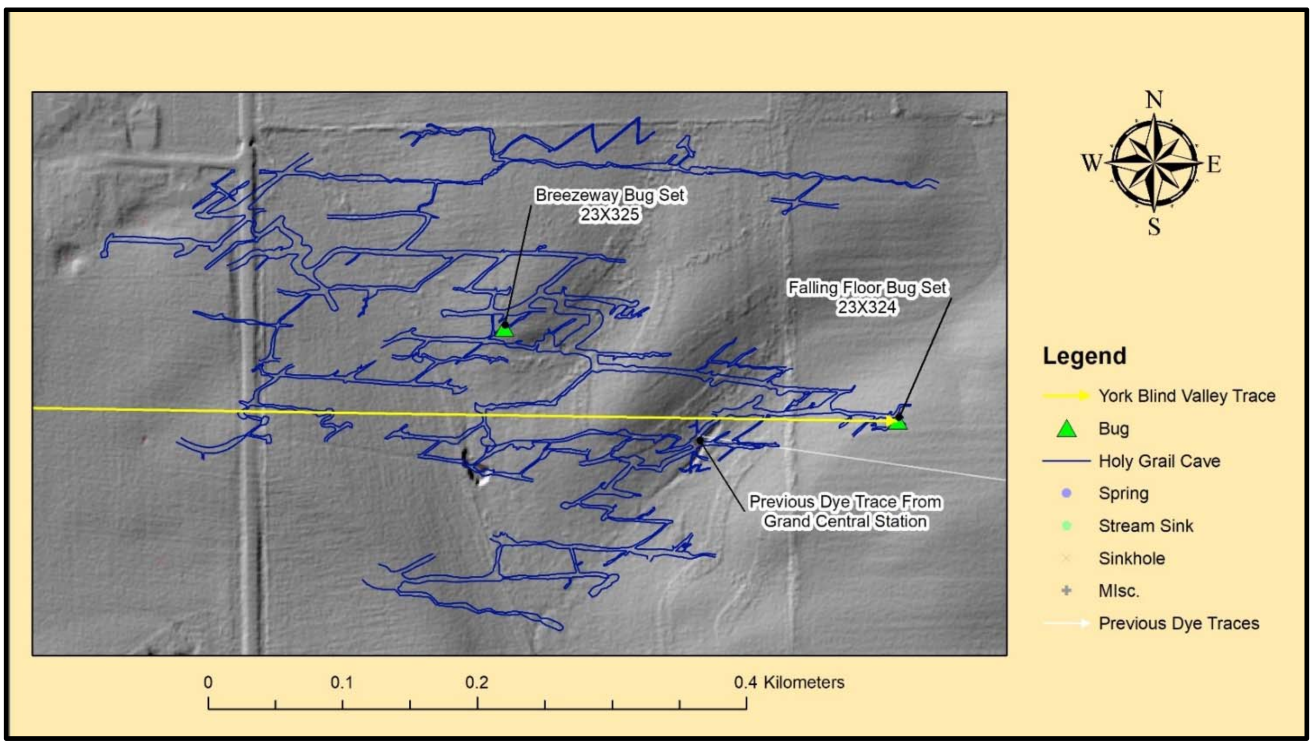

Figure 7. *Inferred groundwater flow path determined for the 2017 York Blind Valley Trace*

Acknowledgments

This project would not have been possible without the cooperation of John Ackerman and the Minnesota Cave Preserve. Funding for this project was provided by the Minnesota Clean Water Land and Legacy Amendment and the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR). Scott Alexander at the University of Minnesota Department of Earth Sciences analyzed samples and performed peak fitting.

Collaboration between the Minnesota Department of Natural Resources, University of Minnesota-Department of Earth Sciences, Minnesota Department of Agriculture, Caving Clubs and Soil & Water Conservation Districts (SWCD) has led to many dye tracing investigations in southeastern Minnesota. The results of these investigations are available through an online *Minnesota Groundwater Tracing Database* application developed by the Minnesota Department of Natural Resources (https://www.dnr.state.mn.us/waters/programs/gw_section/springs/dtr-list.html).

References

Alexander, E.C., Jr., and Lively, R.S., 1995, Karst-aquifers, caves and sinkholes, *in* Lively, R.S., and Balaban, N.H., eds., Text supplement to the geologic atlas, Fillmore County, Minnesota: Minnesota Geological Survey, County Atlas Series C-8, Part C, p. 10-18.

Alexander, E.C., Green, J.A., Alexander, S.C., and Spong, R.C., 1996. Springsheds, pl.9 of Lively, R.S. , and Balaban, N.H., eds., Geological atlas of Fillmore County, Minnesota: Minnesota Department of Natural Resources, Division of Waters, County Atlas Series C-8, Part B, scale 1:100,000.

Green, J.A., Barry, J.D., and Alexander, E.C., Jr., 2014, Springshed Assessment Methods for Paleozoic Bedrock Springs of Southeastern Minnesota, Report to the LCCMR, Minnesota Department of Natural Resources, Sept. 2014, 48 pp.

Green, J.A., Alexander, E.C., Jr., Marken, W.G., and Alexander, S.C., 2002, Karst hydrogeomorphic units, pl. 10 *of* Falteisek,J., ed., Geologic atlas of Mower County, Minnesota: Minnesota Department of Natural Resources, Division of Waters,County Atlas Series C-11, Part B, scale 1:100,000.

Green, J.A., Mossler, J.H., Alexander, S.C., and Alexander, E.C., Jr., 1997, Karst hydrogeology of Le Roy Township, Mower County, Minnesota: Minnesota Geological Survey Open File Report 97-2, 2 pl., Scale 1:24,000.

Mossler, J.H., 1995. Bedrock Geology, plate 2, C-8 Geologic atlas of Fillmore County, Minnesota [Part A]: Minnesota Geological Survey. https://conservancy.umn.edu/handle/11299/58513.

Runkel, Anthony C.; Steenberg, Julia R.; Tipping, Robert G.; Retzler, Andrew J., 2014. OFR14-02, Geologic controls on groundwater and surface water flow in southeastern Minnesota and its impact on nitrate concentrations in streams. Minnesota Geological Survey. Retrieved from the University of Minnesota Digital Conservancy, http://hdl.handle.net/11299/162612.

Steenberg, J.R., Runkel, A.C., 2018, Stratigraphic Positions of Springs in Southeast Minnesota. Minnesota Geological Survey. Retrieved from the University of Minnesota Digital Conservancy. http://hdl.handle.net/11299/198183.

Witthuhn, Kathleen M. and Alexander, E. Calvin, Jr. 1995, Sinkholes and Sinkhole Probability. Plate 8 in Geological Atlas of Fillmore County, Minnesota, County Atlas Series, Atlas C-8, Part B, Minn. Dept. of Natural Resources, St. Paul.

Appendix A. Summary of analytical results for the 2017 York Blind Valley trace

Field Name	KFD	Site Type	UTM Easting NAD83 Zone 15	UTM Northing NAD83 Zone 15	Background May-20-17 to 24-May-17	Dye Input 24-May-2017 2.401 kg Uranine (20% wt. solution)	24-May-17 to 4 Jun 2017	4 Jun to 10 Jun 2017
Falling Floor Bug Set, HGC (in Holy Grail Cave)	23X324	cave drip	565,183	4,820,528	**nd**		Uran (228 σ)	**nd**
Breezeway Bug Set, HGC (in Holy Grail Cave)	23X325	cave drip	N	4,820,597	SrB * (2.96 σ)		**nd**	SrB * (2.92 σ)
Canfield Creek South Bug Set	23X91	creek	562,734	4,828,497	---		**nd** (In: 26 May Out: 30 May)	**nd** (In: 30 May Out: 13 Jun)

--- indicates no bug was received by the lab
Uran indicates **Uranine (fluorescein)** dye detected
nd indicates no dye detected
SrB * A small, complex fluorescent peak was observed in the laboratory spectra at the Sulforhodamine B position. This result indicates the presence of a sporadic interference of unknown origin at this spectral position in these samples.