Groundwater Tracing in Orion, Marion and Eyota Townships of Olmsted County, Minnesota

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ABSTRACT

Orion, Marion, Eyota and Pleasant Grove Townships are located in Olmsted County southeast of Rochester, Minnesota and host a significant number of mapped karst features including the Orion Sinkhole Plain. The area is intensively farmed and is increasingly residential as part of Rochester’s exurbs. The area bedrock is composed of a relatively flat upland underlain by limestone, dolomite, and silty limestone of the Middle Ordovician Stewartville, Prosser and Cummingsville Formations. The carbonates are underlain by the Decorah Shale, which forms a partial aquitard; though the Decorah is truncated by incised stream valleys. Numerous karst springs emerge just above the Decorah and form tributaries which flow to the Zumbro and North Branch Root Rivers. These regional base level rivers are incised into the St. Peter Formation and Prairie du Chien Group. Thin, discontinuous glacial sediments and loess overlie the bedrock. Groundwater is the sole source of potable water in the area.

Groundwater tracing research was initiated in the area due to environmental issues related to the presence of confined animal feedlots. Dye tracing has been successfully used to define connections between water running into sinkholes or losing streams and water emerging from springs, wells or along gaining reaches of streams in the karst of southeast Minnesota for 75 years. Dye traces have proven to be singularly effective tools in helping elevate discussions among communities, landowners and farmers about surface water-groundwater interactions. Information gained helps landowners implement strategies to minimize nutrient and bacteria losses into vulnerable karst aquifers.

We initiated nine traces between 2014 and 2016. Eight of the traces were positive, in that at least one connection was confirmed between the sinkhole input of the dye and a monitored spring or creek. The positive results are drawn as springshed maps illustrating these connections, and are overlain on a base map of the previous dye tracing work. The base springsheds map will be updated as new traces are completed and the map is available on-line at: http://files.dnr.state.mn.us/waters/groundwater_section/mapping/springshed/springshed_map.pdf

BACKGROUND

A collaborative partnership between the Minnesota Department of Natural Resources, University of Minnesota and the Olmsted County Feedlot Technician began in 2014 to delineate springsheds in Olmsted County. The partnership has been useful in facilitating field work, sharing expertise and educating landowners about groundwater sensitivity. Protection of groundwater quality in a karst geologic region can be enhanced by detailed knowledge of the local hydrogeologic properties such as recharge areas, discharge points, connections between inputs and emergences and point-to-point travel times. Only in the rare situation where a cave can be entered and surveyed, can the actual geometry and location of conduits be accurately determined. The delineation of springsheds helps to define water contribution areas to springs, which, in turn, aids in identifying pollution source points and potential environmental impact. Mill Creek and Kinney Creek are Designated Trout Streams. They rely upon high water quality to maintain sport fishing, which is an important economic resource to the state of Minnesota.

STUDY AREA

A large array of sinkholes known as the Orion Sinkhole Plain (Picture 1) is located south of Interstate 90 and north of the North Branch of the Root River (see Alexander and Maki, 1988). The area is bordered to the west by Kinney Creek and on the east by Mill Creek, which are two Designated Trout Streams, as defined by the Minnesota Department of Natural Resources (DNR). Surface geology of the Orion Sinkhole Plain is dominated by sinkholes with limited soil cover over carbonate bedrock of the Ordovician Stewartville and Prosser Formations (see Olsen, 1988). Dye trace studies completed by previous research have demonstrated that a significant portion of the groundwater from the sinkhole plain discharges into springs that feed these two trout streams.

To the north of the Orion Sinkhole Plain is Eyota Township. The topography of the township is slightly rolling with an array of sinkholes which trends from west to east, and is located north of US Interstate 90. Limited soil cover exists over the carbonate bedrock of the Prosser Formation. Historic Bear Spring (Picture 5) emerges near the western township boundary. No previous dye tracing had taken place in Eyota Township prior to 2014 and little was known about the groundwater flow paths.

Specific injection points were chosen based on known contamination events or where previous dye traces had not been conducted. Seven dye injection points are in locations where the Prosser Formation of the Galena Group is the first bedrock. Two dye injection points in Orion Township were selected where the Stewartville Formation occurs as the uppermost bedrock. All of the sample points are connected to springs that emanate from the lower Prosser and upper Cummingsville Formations above the Decorah Shale Formation.

Picture 1. Orion Sinkhole Plain (Photo by Martin Larsen.)

Figure 1. Groundwater Flow Paths and Dye Trace Vectors.

METHODS

Dye tracing uses the injection of fluorescent dyes into karst surface features such as sinkholes to track groundwater flow directions and travel times. Dye type and mass were chosen based on previous dye use, spring geometry and potential travel distances. Primarily three dyes were used in these studies: Rhodamine WT, Eosine, and Uranine HS.

Prior to injection, charcoal packet detectors (bugs) were placed in the identified springs, or in spring runs downstream of the identified springs, to determine background conditions. Both direct water samples and passive dye detectors were used for sample collection. All samples were analyzed at the University of Minnesota, Department of Earth Sciences laboratory using a scanning spectrofluorophotometer.

Dyes were flushed into the conduit system with between 500-1,000 gallons (1,900-3,800 liters) of water or utilizing snow meltwater running into the sinkholes (Pictures 2 and 3). The dyes flowed through the underground conduit system until they re-emerged and were adsorbed onto the charcoal in the bugs.

Picture 2. Dye flushed into the Vrieze sinkhole on November 16, 2015 (Photo by Martin Larsen.)

Picture 3. Calvin Alexander dumping dye into the Campion sinkhole during snowmelt on March 7, 2016 (Photo by Martin Larsen.)

Picture 4. Devil's Den Spring Complex: The springs, A16, A117, and A118 are visible in this picture, at a time when flow was running high. The springs were separately monitored during some traces. (Photo by Martin Larsen.)

Picture 5. Bear Spring: One of the springs monitored during some of the dye traces, emanates from the hillside within the old spring house. (Photo by Martin Larsen.)

RESULTS

Nine separate dye injections were conducted since 2014 with eight positive connections made. Thirty-two sites, including springs (such as Devil's Den Springs Complex shown in Picture 4), spring runs, creeks, streams etc. were monitored. Dye from at least one injection was recovered at or downstream of seven different monitored springs. Six positive traces were pioneer connections. Two springs with positive dye detections were discovered during the fieldwork prior to tracing, and were previously unknown and un-mapped in the statewide spring survey. Results of the three years of research are shown in Figure 1.

Groundwater flow velocities in the Galena Group can be extremely rapid. In the first Bear Spring trace initiated on April 21, 2015, the land owner reported that Bear Spring (Picture 5) turned visibly bright red in less than six hours after the dye input in the sinkhole. This corresponds to a minimum groundwater velocity of 22,700 feet/day (7km / day).

Through the study, numerous new karst features were identified including a total of twelve new springs. All of the eight successful traces have identified new groundwater flow paths and springsheds in areas that had not been studied and little information was available. This partnership and research has elevated discussion among communities, landowners and farmers about surface water – groundwater interactions. It has already resulted in implementing many best management practices near surface karst features including setbacks, buffers and runoff control systems.

REFERENCES

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