Water Tracing in the Crystal Creek Watershed in Minnesota

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Introduction
The Root River Field to Stream Partnership is a multi-agency effort led by the Minnesota Department of Agriculture (MDA). The primary goal is to characterize nutrient losses by agriculture to surface water and groundwater, and to apply sustainable best management practices (BMPs) to reduce those losses. One of the three study areas is the Crystal Creek Watershed (CCW), a 15 km² (3,700 ac) watershed located in the east region of southern Minnesota. In the CCW, 78% of the watershed land area is devoted to cropland with corn and soybeans making up 76% of the crop acres.

Beginning in 2010, the Partnership has collaborated with the University of Minnesota—Department of Earth and Environmental Science and the Minnesota Department of Natural Resources to conduct dye tracing within and around the CCW. Tracing was employed to approximate the land area which supplies groundwater to springs (groundwater-springshed) that discharge directly to Crystal Creek.

Methods
Dye tracing was accomplished with the use of fluorescent dye to determine groundwater flow directions and estimates of travel times. The dyes were flushed into sinkholes with either 3,780 liters (1,000 gallons) of water or utilizing snow melt running into sinkholes (Pictures 2 and 3). The dye flowed through the least bedrock system until they re-emerged at a spring, multiple springs or streams. Chemicals and dyes were placed at various spring and stream locations to absorb the fluorescent dye. Once present, dye was removed from charcoal and evaluated using a spectrometer, which is then scanned with a spectrophotometer. Each dye is characterized by a unique emission wavelength. Sample analysis was completed by the University of Minnesota—Department of Earth Sciences Hydrochemistry Laboratory. Figure 3 shows the fluorescent spectrum results of a positive Uranine recovery from a chemical spring in the spring run of Twin Springs from Nov. 15 to Nov. 19, 2010.

Results and Discussion
Results from the dye traces are shown in Figure 4. From 2010 through 2015, a total of 14 dye traces were conducted in the CCW. In 10 of 14 traces, a positive connection was confirmed between the sinkhole dye input and a monitored spring or creek. These traces help approximate the boundaries for five springshed: Crystal River, Crystal Spring, Twin Springs, Trout Pond and Willow Pond. The size of the delineated springsheds range from 25 ha (82 ac) to over 63,920 ha (183,000 acres).

Groundwater Flow Velocities and Pathways - Groundwater velocities in the Callera group can be extremely rapid and conduit pathways can extend for several miles. Groundwater velocities for the Twin Springs springshed during a 2015 trace exceeded 1 mile/day (1.6 km/day). This velocity is consistent with the range of peak groundwater flow velocities (1.6-4.6 km/day, 1-3 miles/day) from previous traces conducted in the Springfield-Galena Karst (Green and others, 2014). The longest flow path in this set of traces was 8.0 km (5 miles), while the shortest was 24 km (30 miles).

Springhead Boundaries Cross Surface Watershed Divides - As expected, springhead boundaries were found to cross the surface divides. However, for Trout Pond the springhead boundary is located outside of the CCW surface watershed boundary. Conversely, solutions for Willow Pond outlined three springhead flowpaths originating in CCW that do not connect to CCW springs. This suggests that infiltration in this particular area (covering about 10 ha [25 ac]) may not be contributing to the nitrate loading in CCW as monitored at the Crystal Creek outlet. The flow paths from the southeast part of CCW may also serve as recharge areas for springs outside of CCW, but more traces are needed to confirm the springhead boundaries.

Implications - Springhead maps will help improve nitrate-nitrogen yield loss computations and computer models used to measure the effectiveness of nitrogen practices. It will also inform where nitrogen management survey and BMPs should be concentrated. When discussing the importance of strategies to minimize nitrate-nitrogen losses from agricultural activities, the dye tracings have proven to be effective in helping evaluate nitrogen BMP discussions with area farmers and crop advisors. The information has been shared at numerous one to one meetings and watershed field days at local farms. Additional dye trace studies scheduled for future years will further refine springhead boundaries and help improve the understanding of complex surface-water-groundwater interactions in the CCW.

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References

Nitrates, Springs, and Streams
Baseflow-nitrate-nitrogen concentrations highlight a strong relationship between nitrites in springs and those measured in the receiving stream (Figure 1). This suggests the land area connected to the springs is vulnerable to nitrite leaching from cropland aid profiles. Therefore, defining the drainage area to these springs is an important step in evaluating the effectiveness of nitrogen BMPs.

Bedrock Geology of Crystal Creek Watershed Area
This figure illustrates the bedrock geology and land topology in the study area. It also shows how water soluble contaminents due nitrate may easily end up groundwater.