Springs in Forestville Mystery Cave State Park, MN: Inventory, Chemistry and Flow Systems

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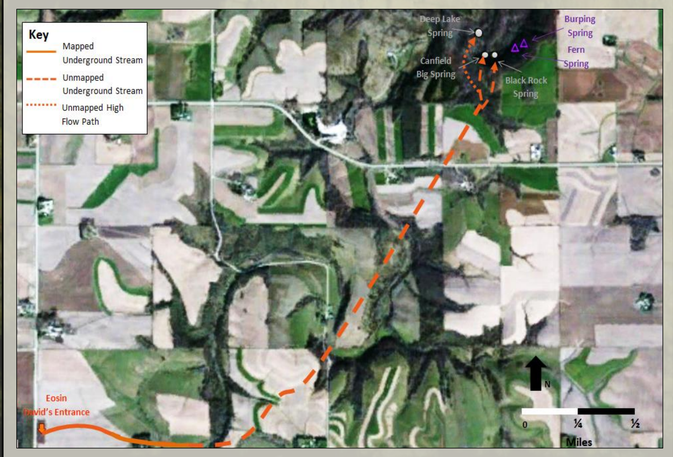
Introduction

Forestville Mystery Cave State Park is 3,583 acres of karst topography in which the water can move up to miles per day before coming out springs in various places[1]. The ground and surface waters in this area are polluted with high concentrations of nitrate, primarily from agricultural fertilizer. Row crop agriculture is the dominant land use in the springsheds surrounding the Park. This project provides new information that can help manage and improve water quality not only for the trout and other organisms in the streams but also for the region's drinking water.

During the studies, five new springs were located. Those springs and four previously mapped springs were monitored for dissolved ions. Dye traces, along with the chemistry, were used to identify groups of the springs which drain common springsheds.



Map 2. Blowup of Canfield Creek springs containing the dye trace from David's Entrance. An example of a fluorescent spectra from this trace is shown in Figure 1.

Dye Tracing

Three fluorescent dyes were poured in different locations (see Map 1) to help define the springshed data in the area. The charcoal bugs absorb the fluorescent dyes at the mouths of springs. The bugs were then collected and analyzed for dyes. The dyes become excited at different wavelengths that are emitted as part of the fluorescent spectra from the samples (see Figure 1). When dye is present, its general path through the conduit system is mapped. In Map 2, the eosin flowed through Goliath cave and emerged from Canfield Big and Black Rock Springs.

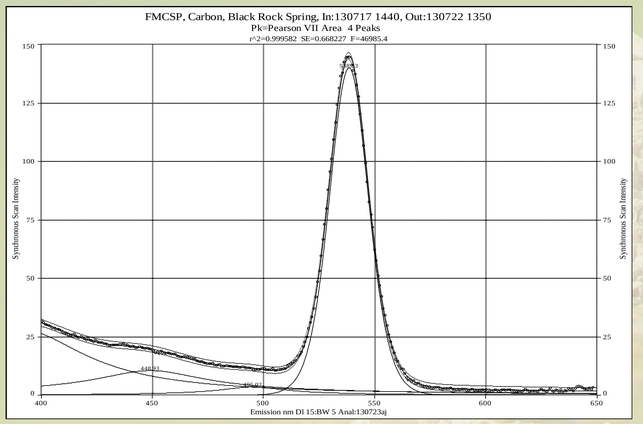


Figure 1. Peak Fit® analysis of the fluorescent spectrum of a Black Rock Spring charcoal sample from 22 July 2013. The peak centered at 538 nm from eosin[2].

Map 1. Map of Forestville Mystery Cave State Park and surrounding area containing new and old springs studied during this project. Triangles represent newly located springs and circles represent previously discovered springs. The springs that come from the same source are represented by the same color. The small white circles represent seeps.

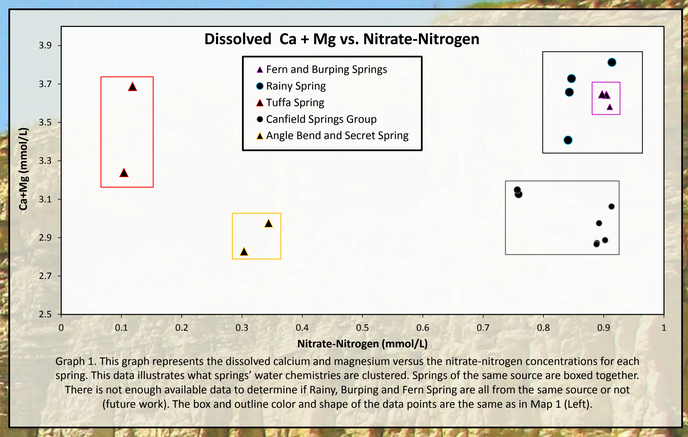
New Springs Located	North UTM	East UTM
Secret Spring	4,830,383	562,978
Angle Bend Spring	4,830,546	563,088
Tuffa Spring	4,831,192	563,249
Burping Spring	4,828,341	562,706
Fern Spring	4,828,335	562,710

Table 1 (Left). UTM locations of five new springs located in Forestville Mystery Cave State Park. See Map 1 for their locations relative to the four previously discovered springs monitored in this research.

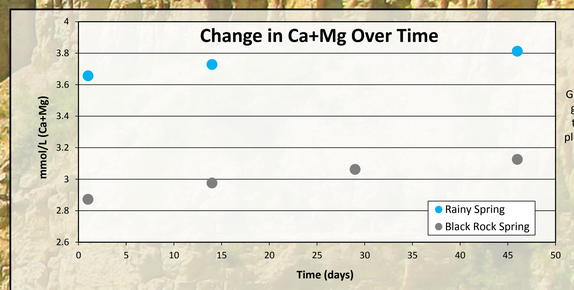
Table 2 (Below). Water chemistry data from the nine springs tested. Color coding matches Map 1 (above) with the same colors representing groups of springs from the same source.

Picture 1. Depicts Deep Lake Spring under high flow conditions on 5 June 2013 (left) and dry under base flow conditions on 29 July 2013 (right).

Spring	KFDB #	Date	Temp (ºC)	Conductivity (µS/cm)	pH	R.D.O (mg/L)	Alkalinity (as $CaCO_3$)	Nitrate Concentration (ppm)	Chloride (ppm)	Ca + Mg (mmol/L)
Deep Lake	MN23:A00032	5-Jun-13	9.2	563	7.65	9.83	207.5	12.44	17.85	2.87
Canfield Big	MN23:A00033	5-Jun-13	9.2	559	7.56	9.78	212.7	12.64	18.14	2.89
		22-Jul-13	9.8	586	7.3	9.48	254.2	10.6	17.02	3.15
Black Rock	MN23:A00034	5-Jun-13	9.1	559	7.71	9.85	207.3	12.45	17.9	2.87
		18-Jun-13	9.7	562	7.36	9.73	214	12.5	18.61	2.97
		5-Jul-13	9.5	573	7.49	9.3	223.7	12.79	17.82	3.06
		22-Jul-13	9.8	593	7.33	9.71	247.14	10.63	17	3.13
Fern	MN23:A00897	22-Jul-13	9.1	674	7.21	9.22	305.7	12.57	16.9	3.65
Burping	MN23:A00893	5-Jul-13	8.8	658	7.23	8.95	290.9	12.75	17.53	3.58
		22-Jul-13	9.1	675	7.21	9.59	302.7	12.67	17.05	3.64
Rainy North	MN23:A00031	5-Jun-13	8.9	674	7.38	9.89	292.2	11.81	12.79	3.66
		18-Jun-13	8.7	684	7.94	9.12	303.33	11.86	13.2	3.73
		22-Jul-13	9	699	7.16	8.78	314.1	12.8	14.7	3.81
Secret	MN23:A00888	18-Jun-13	7.1	519	7.66	9.55	251	4.82	7.86	2.98
Angle Bend	MN23:A00889	18-Jun-13	8	503	7.4	10.33	249.6	4.25	4.5	2.82
Tuffa	MN23:A00892	5-Jul-13	8.4	555	7.6	8.94	311.9	1.46	1.99	3.24
		22-Jul-13	8.9	620	7.56	9.07	340.2	1.66	2.32	3.69



Graph 1. This graph represents the dissolved calcium and magnesium versus the nitrate-nitrogen concentrations for each spring. This data illustrates what springs' water chemistries are clustered. Springs of the same source are boxed together. There is not enough available data to determine if Rainy, Burping and Fern Spring are all from the same source or not (future work). The box and outline color and shape of the data points are the same as in Map 1 (Left).



Graph 2 (Left). This graph represents the change in Ca plus Mg ions of two springs as the water flow decreases over time.

Water Chemistry

As water samples were collected, the pH, conductivity, temperature and dissolved oxygen were measured in the field. Back in the lab the cations were determined by ICP-AES, the anions by IC, and the alkalinity by digital titration to a colorimetric endpoint.

Water running through karst terrain is dominated by calcium, magnesium and bicarbonate ions. These ions are formed through the dissolution of the soluble limestone and dolomite. The conduit systems formed through the carbonates carry water at high speeds and emerge from one or multiple springs. The longer the water is in the karst system, the more Ca and Mg ions it will dissolve (until the water is saturated) as seen in Graph 2. Under high flow, water travels more quickly, spends less time underground and has dissolved fewer ions. Under base flow conditions the opposite occurs (see Picture 1).

Conclusion

During this project, five new springs were located in addition to four previously mapped springs (see Table 1). Based on chemistry, four groups of springs were identified. Each group appeared to drain a different springshed (see Graph 1). Six out of the nine springs tested have nitrate concentration levels above the drinking water standard of 10 ppm. The springsheds of these six springs are dominated by anthropogenic runoff that is contaminated with fertilizer and other agricultural chemicals. One flow system was verified based on a dye trace.

Acknowledgements

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