

Dye Trace Report on the Groundwater Springsheds of Roaring Spring and Frego Creek near Canton, Minnesota

Traces: September 2009, March 2010, and February 2011

Fillmore County, Minnesota

Jeffrey A. Green¹, Andrew Luhmann^{2,3}, Scott Alexander²,
Betty Wheeler², and E. Calvin Alexander, Jr.²

¹ Minnesota Department of Natural Resources
Ecological and Water Resources Division
3555 9th St. NW Suite 350
Rochester MN 55901

² University of Minnesota
Earth Sciences Department
310 Pillsbury Dr. SE
Minneapolis MN 55455

³ Current address:
New Mexico Institute of Mining & Technology
Earth & Environmental Science Department
801 Leroy Place
Socorro, NM 87801

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Introduction

Dye traces were conducted in and around the area of Canton, MN in southern Fillmore County as part of the Environmental and Natural Resources Trust Fund (ENRTF) funded Springshed Mapping project. This report covers traces done in September 2009, March 2010, and February 2011. Tracing had been done in the area previously in the spring of 2008 (Green et al., 2008) and 2009 (Green et al., 2009) under the auspices of the ENRTF-Springshed Project, spring of 2007 for the South Fork Root River watershed project (Green, 2007), in 1993 and 1994 during the Fillmore County Geologic Atlas Project and earlier work summarized in Alexander et al. (1995) and by Kingston and Janssen (1941).

Green et al. (2014) discuss and define three components to Minnesota Karst Springsheds: Groundwater Springsheds (GwS), Surface Water Springsheds (SWS) and Regional Groundwater Springsheds (RGS). Figure 1 is a section of the Alexander et al. (1995) Fillmore County Springsheds Map around Canton, MN. Figure 1 shows only two groundwater springsheds (groundwater basins that feed to springs) near Canton, MN. The Boiling Sand Springshed (#18) drains water from within the city of Canton northward to Springs 23A420* and 23A631. About a mile further southeast along US 52 in the Frego Springshed (#17), two sinkholes drain northeast to Spring 23A400. Both of these springsheds contribute water to Frego Creek, a designated Trout Stream. But both springsheds were defined at that time by only two traces each and there are several significant springs contributing to flow in Frego Creek between 23A400 and 23A420/23A631. This area is underlain by Ordovician Galena Group limestone and is characterized by surface karst features. The predominant karst features are sinkholes and springs.

The traces described in this report were conducted to find and improve the delineation of the groundwater springsheds that feed the springs and are the water sources for Frego Creek. In karst areas like the Frego Creek watershed, it is common for the groundwater springsheds to have different boundaries than surface water watersheds.

* “23A420” and “A420” are shorthand versions of the Karst Features Database (KFD) ID number (Tipping et al., 2014) for that feature, English Spring in this case. For example, MN23:A00420 is the full ID number for English Spring.

Methods

Dye tracing entails using fluorescent dyes to track groundwater flow directions and travel times. The dye is poured into a sinkhole or sinking stream. From there it flows through the karst conduit system until it re-emerges at a spring or springs. For this project, the dyes used were Uranine C (Color Index # 45350, Chem. Abs. # 518-47-8), Eosine Y (Color Index # 45380, Chem. Abs. # 17372-87-1) and Rhodamine WT (Acid Red 388, Chem. Abs. # 37299-86-8). Both direct water samples and passive dye detectors were used and all the samples were analyzed at the University of Minnesota Earth Sciences Department using a scanning spectrofluorophotometer. The dye trace methods and springshed delineation protocols used in the Canton/Frego Creek dye traces are detailed in Green et al. (2014). These traces were designed and executed by Jeff Green of MNDNR Waters. E. Calvin Alexander, Jr., Andrew Luhmann, Scott Alexander and Betty Wheeler of the University of Minnesota Earth Sciences Department performed the sample analyses and interpretation.

The September 2009 traces were dry sinkhole traces, meaning that an external water source was needed to wash the dye down into the karst groundwater flow system. The city of Canton delivered water by the city fire truck to flush the dye into the sinkholes. The March 2010 and February 2011

traces were conducted using snowmelt runoff to wash the dye into the karst groundwater system. The locations of the dye input points and the monitoring points are listed in Table 1. The locations of the monitoring points are shown in Figure 2. The monitoring points are often located varying distances down the surface stream from the actual springs for logistical and redundancy reasons.

Roaring Spring, 23A455, and several smaller springs and seeps (springs 23A632 & 633 and seeps 23A446 & 447) were collectively monitored by bugs and water samples at 23X55.

The Frego Creek GwS was monitored with varying combinations of bugs and water samples from 23A402, 23A403 and 23X245. Three mapped springs are upstream of 23X245 – 23A399, 23A400 and 23A401. These three springs could not be sampled directly because they are on private property to which were not granted access.

The locations of the dye input points are shown in Figure 3.

Results and Discussion

The results of these traces are listed in the “Dye Detects” column of Table 1 and in more detail in the results for the individual charcoal detector analyses in Table 2. The dye trace connections are shown, diagrammatically, by the white arrows in Figure 4.

The Frego Creek Groundwater Springshed: Six dye trace vectors from this work, when added to the two vectors reported in Alexander et al. (1995), expand and more clearly define the Frego Creek GwS as shown on Fig. 4. The Frego Creek GwS drains about a mile along US Hwy 52 in section 27 and the east side of section 28 of Canton Township. The water that infiltrates the soil or drains into sinkholes in that area quickly flows to a cluster of five springs which are the headwaters of the protected tributary to Frego Creek running under 120th Street in the northeast corner of section 17 of Canton Township.

That cluster includes Spring 23A402 which is on the west side of the valley just upstream (south) of the 120th Street culvert. Spring 23A403 actually squirts out of the joints between the precast culvert sections under 120th Street and is sometimes inaccessible during high flow. Springs 23A400 and A401 are about 200 meters upstream, south of the culverts and 23A399 is further upstream. We were unable to sample these three springs directly. Therefore a sampling point, 23X245, was monitored which is upstream of both 23A402 and 23A403. Depending on flow conditions and changing debris piles left by high flows, the location of 23X245 varied by several meters from trace to trace. Dyes from the various traces clearly reached 23A402, 23A403 and to one or more of the springs south of 23A402. On Fig. 4 the dye trace vectors are drawn connecting to Springs 23A402 and 23A403 with a side branch to Spring 23A400 based on the topography of the spring cluster. However, the Frego Creek GwS may also feed 23A399 and or 23A401. Dye from the Frego Creek GwS was also detected at 23X112. 23X112 was on the main stream of Frego Creek at 134th Street – over a mile downstream from the 120th Street culvert and is presumed to be the surface flow in Frego Creek.

The Roaring Spring Groundwater Springshed: Three dye trace vectors from this work, five traces from Green et al. (2008 and 2009) and two earlier traces define a new Roaring Spring GwS. These dye traces were all detected at 23X55. Field observations indicate that Roaring Spring, 23A445, is the main resurgence of this group of springs and the dye trace vectors in Fig. 4 are so drawn. The Roaring Spring GwS may also be feeding the other springs and seeps in the cluster. This cluster is the headwaters of a second Protected Tributary to Frego Creek.

In the 12 March 2010 uranine trace, uranine was detected in both the Roaring Spring and Frego Creek GwSs. In several past Fillmore County dye traces we have observed a single dye injection traveling to two different GwSs. Such traces define a GwS divide between the two adjacent springsheds. Such divides can move as the groundwater table fluctuates due to recharge events.

The southwestern edges of the Frego Creek GwS and Roaring Spring GwS essentially touch the northeastern edge of the Coldwater Spring SWS to the south. Any SWS contributions to springs 23A445 and 23A400/23A403 are probably quite small. The contribution of regional groundwater flow has not been quantified but is also probably small.

Both the Frego Creek GwS and Roaring Spring GwS feed springs that head Protected Tributaries to Frego Creek. The nominal headwaters of the State-Designated Trout Stream reach of Frego Creek, however, is a complex of six springs and seeps, 23A393 thru 23A398, in the northern part of section 27 and the southern part of section 22 of Canton Township between the Frego Creek GwS and the Roaring Spring GwS. The springsheds of these springs has yet to be defined.

Conclusions

These successful traces expanded and refined the boundaries of the GwSs feeding springs 23A445 and 23A400, 402 & 403 as is shown in Fig. 4. The edges of these GwSs are not sharp boundaries and can and do move horizontally and vertically in response to recharge events. These springs are major cold water sources for Protected Tributaries to Frego Creek, a state-designated trout stream. The results of these traces are included in the 2014 Springshed Map (Green and Alexander, 2014) and papers (Green et al., 2014, 2015).

Acknowledgments

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References

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Tables

TABLE 1

Canton-Frego Summary Data Points

30 September 2009: 2 Dye Traces

KFD #	Site Name	Feature	Easting	Northing	Dye Detects	Description
MN23:X00245	X245 (aka, Frego Creek Bug Set); (aka, "A400" spring run)	Monitoring Point	589,558	4,820,192	Uran	Bug located in spring boil, left side, downstream.
MN23:A00403	A403	Monitoring Point	589,561	4,820,239	Uran	Bug located upstream about 20 ft from debris tangle, wired to branch in stream.
MN23:X00055	X55 (aka, "A445" spring run)	Monitoring Point	589,316	4,822,196	RhWT	Bug located on west side of county road 23 along the north side of the culvert. (A445 is at 589,000 E; 4,822,192 N)
MN23:A00631	A631	Monitoring Point	586,914	4,821,825	nd	Bug located on north side of spring. Accessed through farm.
MN23:X00050	X50	Monitoring Point	584,873	4,819,376	nd	
MN23:X00051	X51	Monitoring Point	584,894	4,818,567	nd	
MN23:X00052	X52	Monitoring Point	584,337	4,816,942	nd	
MN23:X00053	X53	Monitoring Point	586,518	4,818,341	nd	
MN23:X00112	X112	Monitoring Point	589,422	4,822,118	Uran	Bug located on the south side of the road (134th St.) tied to small tree on the west side of the east culvert.
MN23:X00242	X242 (aka, "Canton Sec 25") (aka, "Schoolhouse Crossing")	Monitoring Point	591,767	4,820,315	nd	Schoolhouse crossing, south side of Co. Rd. (from loop) culvert under 120th Street in sec 24 of Canton Twp.
MN23:X00246	X246 (aka, "Canton Community Center")	Monitoring Point	586,461	4,820,136	nd	Bug was placed in a toilet tankin the Canton Community Center to monitor water from the city well.
MN23:D07481	D7481	Dye Input - Uranine	588,726	4,819,082		30 Sep 2009, Uranine dye input, 535.8 g 35 wt % solution. Flushed with 1500 gal from Canton F.D. Poned, drained in less than 2.5 hours.
MN23:D10171	D10171	Dye Input - Rhodamine WT	587,052	4,820,187		30 Sep 2009, Rhodamine WT, 523.1 g 17.7 wt % solution. Flushed with 1500 gal from Canton F.D. No ponding. Swallow hole 1 ft diameter in road ditch.

TABLE 1 (continued)

Canton-Frego Summary Data Points (continued)

12-15 March 2010: 3 Dye Traces

KFD #	Site Name	Feature	Easting	Northing	Dye Detects	Description
MN23:A00396	A396	Monitoring Point	588,960	4820367	nd	
MN23:A00398	A398	Monitoring Point	589,042	4,820,482	nd	
MN23:X00112	X112	Monitoring Point	589,422	4,822,118	RhWT	Bug located on the south side of the road (134th St.) tied to small tree on the west side of the east culvert.
MN23:A00403	X245 and A403 monitored together	Monitoring Point	589,561	4,820,239	RhWT, Uran	Bug located upstream about 20 ft from debris tangle, wired to branch in stream.
MN23:X00055	X55 (aka, "A445" spring run)	Monitoring Point	589,316	4,822,196	Uran, Eos	Bug located on west side of county road 23 along the north side of the culvert. (A445 is at 589,000 E; 4,822,192 N)
MN23:D07317	D7317	Dye Input - Uranine	587,600	4,819,812		12 Mar 2010, Uranine dye input, 654.52 g 35 wt % solution. Snow packed into swallet.
MN23:D07967	D7967	Dye Input - Eosin	587,594	4,819,626		12 Mar 2010, Eosin dye input, 885.63 g 33 wt % solution. Snow covered swallet, audible flow under snow pack.
MN23:D07638	D7638	Dye input - Rhodamine WT	587,844	4,819,543		15 Mar 2010, Rhodamine WT input, 829.58 g 17.7 wt % solution. Snow packed into sinkhole around dye pour point. Water trickling below snow.

TABLE 1 (continued)

Canton-Frego Summary Data Points (continued)

17 Feb 2011: 3 Dye Traces

KFD #	Site Name	Feature	Easting	Northing	Dye Detects	Description
MN23:A00402	X245 and A402 monitored together	Monitoring Point	589,524	4,820,191	Uran, RhWT, Eos*	Tied to tree above culvert. (UTMs are the location of A402). * This Eosin positive is based on a single bug.
MN23:X00242	X242 (aka, "Canton Sec 25") (aka, "Schoolhouse Crossing")	Monitoring Point	591,767	4,820,315	nd	Schoolhouse crossing, south side of Co. Rd. (from loop) culvert under 120th Street in sec 24 of Canton Twp.
MN23:X00055	X55 (aka, "A445" spring run)	Monitoring Point	589,316	4,822,196	nd	Bug located on east side of county road 23 at the culvert. (A445 is at 589,000 E; 4,822,192 N)
MN23:X00053	X53	Monitoring Point	586,518	4,818,341	nd	
MN23:D07636	D7636	Dye Input - Eosin	587,815	4,819,225		17 Feb 2011, Eosin dye input, 525 g 33 wt % solution, 1+ cfs snow melt run off running uder the snow, no ponding.
MN23:D07473	D7473	Dye Input - Uranine	588,247	4,818,961		17 Feb 2011, Uranine dye input, 581 g 35 wt % solution, ~0.25-0.50 cfs snow melt run off runing under the snow pack, no ponding.
MN23:D07475	D7475	Dye Input - Rhodamine WT	588,889	4,818,865		17 Feb 2011, Rhodamine WT input, 507 g, 17.7 wt % solution, ~0.25 cfs snow melt run off runding under snow pack, no ponding.

TABLE 2

Canton-Frego Creek Dye Trace Results (30 Sep 2009, 12/15 Mar 2010 and 11 Feb 2011)

KFD #s	Site Name	4 May-27 Aug 2009	27 Aug-30 Sep 2009	30 Sep 2009 Dye Input	30 Sep - 6 Oct 2009	6 Oct-14 Oct 2009	14 Oct-26 Oct 2009	26 Oct 2009-13 Jan 2010	12 + 15 Mar 2010 Dye Input	8 Mar-22 Mar 2010	22 Mar-8 Apr 2010	17 Feb 2011 Dye Inputs	17 Feb-24 Feb 2011	24 Feb-4 Mar 2011
MN23:A00403	A403	nd			Uran (106 σ) Eos* (15 σ)	Uran (106 σ)	Uran	Uran		Uran (24 σ) RhWT (377 σ) (12-22 Mar 2010) (Note: same bug for both MN23:X00245 and MN23:A00403)	Uran RhWT (Note: same bug for both MN23:X00245 and MN23:A00403)			
MN23:X00245	X245 (aka, Frego Creek Bug Set); (aka, "A400" spring run)	nd			Uran	Uran		lost					Uran (125 σ) Eos* (21 σ) RhWT (30 σ) (Note: the same bug for both MN23:X00245 and MN23:A00402)	Uran (95 σ) RhWT (3 σ) (Note: the same bug for both MN23:X00245 and MN23:A00402)
MN23:A00402	A402													
MN23:X00112	X112	nd	nd		Uran	Uran	Uran			RhWT (101 σ) (12-22 Mar 2010)	Uran* (9 σ) Eos* (4 σ) RhWT (63 σ)			
MN23:X00055	X55 (aka, "A445" spring run)	Uran (7 σ) Eos (8 σ) RhWT (9 σ) (from 6 Mar 2009 dye pour)			Uran* (4 σ) RhWT (3 σ) (from 6 Mar 2009 dye pour)	RhWT (109 σ)	RhWT (21 σ)	RhWT (5 σ)		Uran (364 σ) Eos (100 σ) (12-22 Mar 2010)	Uran (269 σ) Eos (34 σ)		Uran* (3 σ)	Uran* (5 σ)
MN23:A00396	A396									nd	nd			
MN23:A00398	A398									nd	nd			
MN23:A00631	A631	nd	nd		nd	RhWT* (3 σ)	nd							

TABLE 2 (continued)

Canton-Frego Creek Dye Trace Results (continued)

KFD #s	Site Name	4 May-27 Aug 2009	27 Aug-30 Sep 2009	30 Sep 2009 Dye Input	30 Sep-6 Oct 2009	6 Oct-14 Oct 2009	14 Oct-26 Oct 2009	26 Oct 2009-13 Jan 2010	12 + 15 Mar 2010 Dye Input	8 Mar-22 Mar 2010	22 Mar-8 Apr 2010	17 Feb 2011 Dye Inputs	17 Feb-24 Feb 2011	24 Feb-4 Mar 2011			
MN23:X00242	X242 (aka, "Canton Sec 25") (aka, "Schoolhouse Crossing")				nd								Uran* (4 σ)	nd			
MN23:X00246	X246 (aka, "Canton Community Center")				nd		nd										
MN23:X00050	X50		empty		nd	nd	nd										
MN23:X00051	X51				empty	nd											
MN23:X00052	X52		nd (4 May-30 Sep 2009)		nd	nd											
MN23:X00053	X53				nd	nd	nd									Uran* (3 σ)	nd

Uran = Uranine dye detected

Eos = Eosin dye detected

RhWT = Rhodamine WT dye detected

Eos* = Eosin dye detected in 1 bug.

Eos* = Eosin dye detected from some other unknown source

RhWT* = Rhodamine WT dye detected at a level that is not quantifiable

Uran* = Uranine dye detected from some other unknown source

nd = no dye detected

empty = no charcoal in bug

yellow highlighted cell = no bug was received

lost = bug was lost

TABLE 2 (continued)

Canton -- Frego Creek Dye Inputs:

31 Mar 2008 --Eosin into MN23:D07460 and Rhodamine WT into MN23:D07667.

[See: Green, JA, Peters, AJ, Luhmann, AJ, Alexander, EC, Jr., and Alexander, SC. 2008. Frego Creek Dye Trace: March 11, 2008 to June 16, 2008. Unpublished DNR report.]

6 Mar 2009 -- Eosin into MN23:D07964, Rhodamine WT into MN23:D07648 and Uranine into MN23:D07963.

[See: Green, JA, Peters, AJ, Luhmann, AJ, Alexander, EC, Jr., and Alexander, SC. 2009. Frego Creek Spring 2009 Dye Trace: March 6, 2009 to May 5, 2009. Unpublished DNR report.]

30 Sept 2009 -- Uranine C into MN23:D07481 and Rhodamine WT into MN23:D10171.

12 and 15 Mar 2010 -- Uranine into MN23:D07317, Eosin into MN23:D07967, and Rhodamine WT into MN23:D07638.

17 Feb 2011 -- Eosin into MN23:D07636, Uranine into MN23:D07473, and Rhodamine WT into MN23:D07475.

Figures

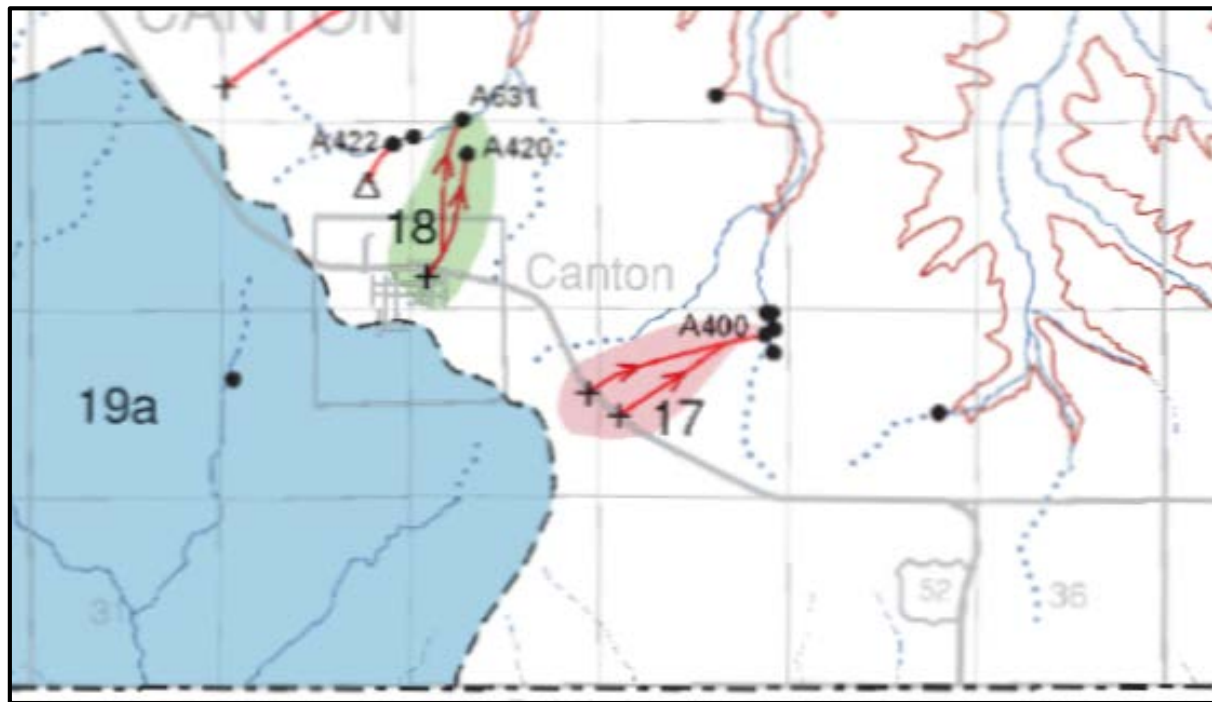


Figure 1. Canton Area Springsheds 1995. A section of the 1995 Fillmore County Springsheds map (Alexander et al., 1995). Black dots are springs, red arrows are dye trace connections. The shaded areas on the map enclose springsheds, as they were understood in 1995. The pink shaded area labeled “17” is the Frego Creek GwS. The green shaded area labeled “18” is the Boiling Sand GwS. The blue shaded area labeled “19a” is Coldwater Spring SWS that drains south into the Coldwater Cave and to Coldwater Springs, Iowa.

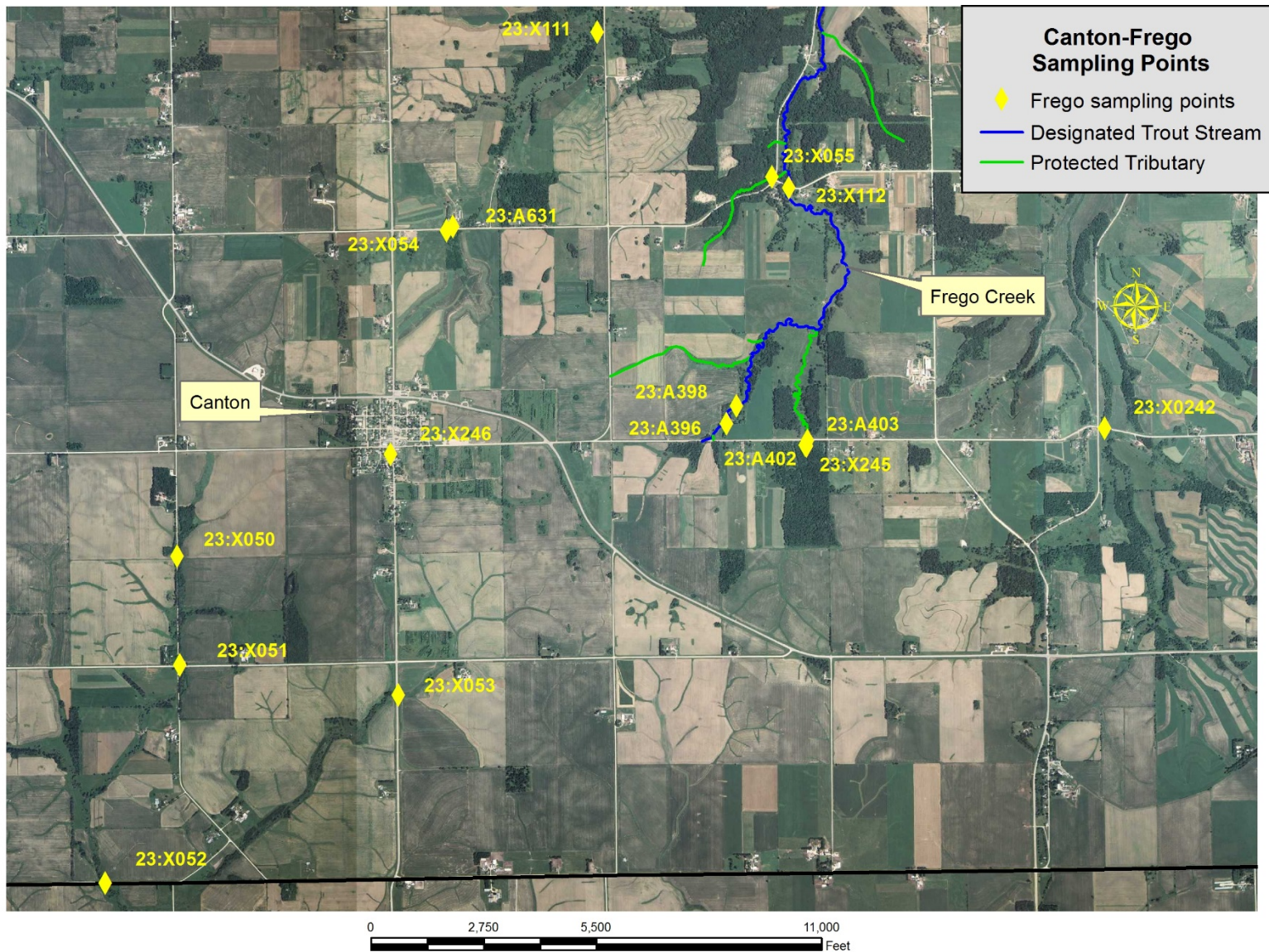


Figure 2. Monitoring locations. Yellow diamonds show the locations of the monitoring points. The adjacent yellow labels are the shorthand versions of the KFD ID numbers of each feature. “A” = a spring, “X” = surface spring run monitoring point. In this and subsequent figures, the dark blue line is the Designated Trout Stream reach of Frego Creek; and the green lines are Protected Trout Stream Tributaries. The black line is the Minnesota/Iowa state line.

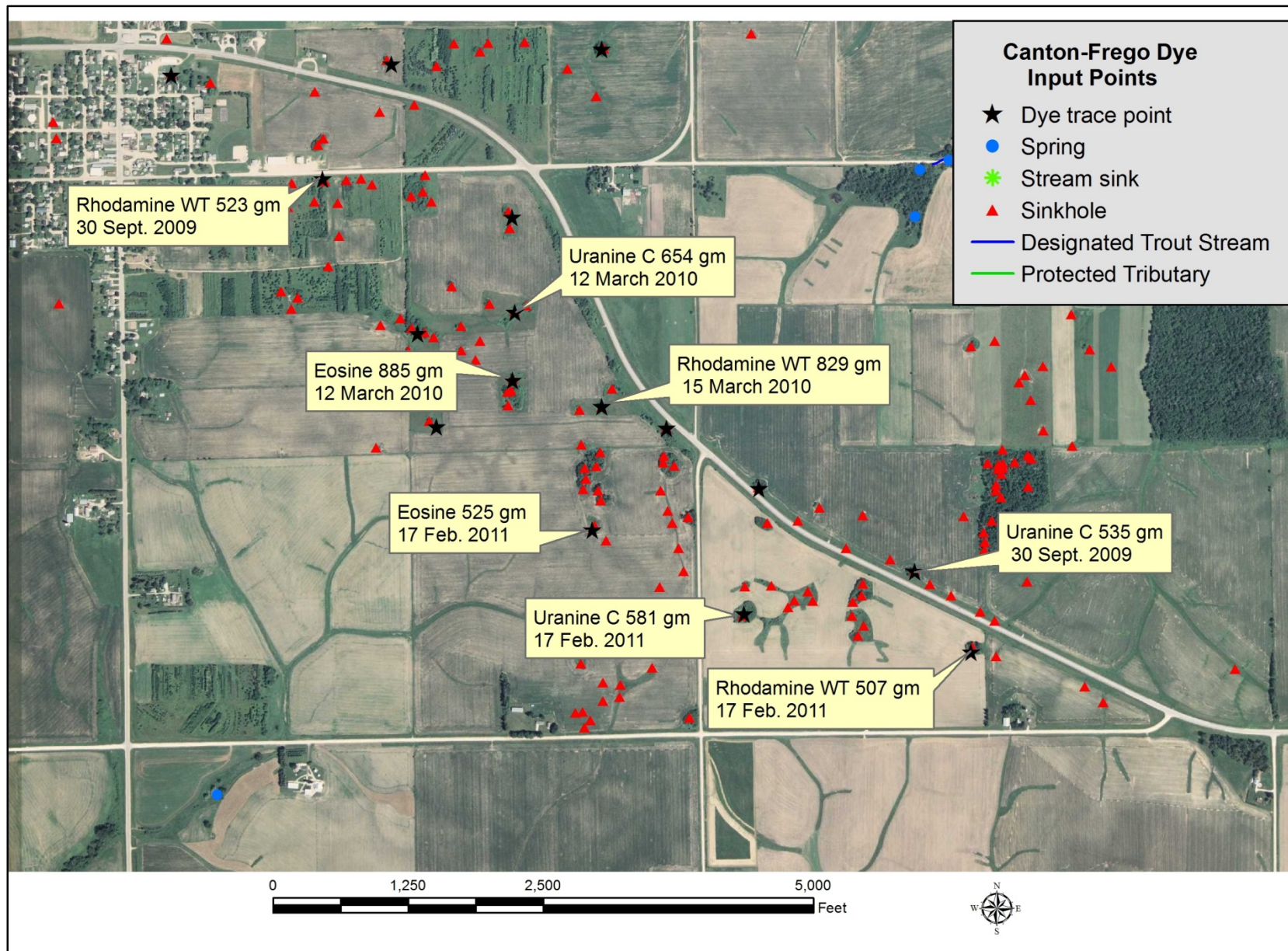
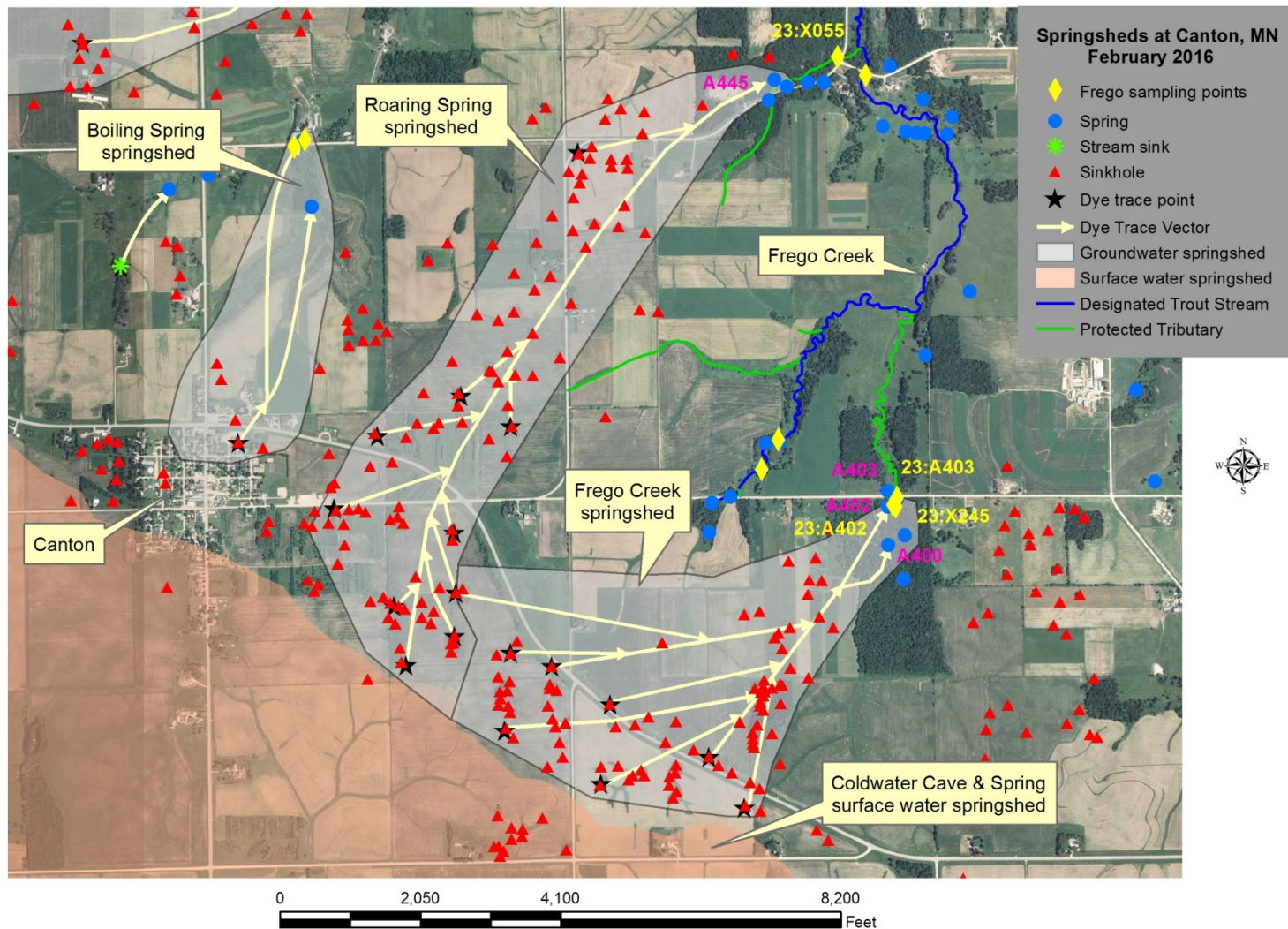


Figure 3. Dye trace input points. The small red triangles are sinkholes. The black stars are dye input points in this and Fig 4. The callout labels identify the eight traces covered in this report and show the date and dye amount used. The dark blue dots are springs.



Base 2009 FSA color aerial photo

Figure 4. Revised Springsheds including results from the Sept 2009, March 2010, February 2011 dye inputs. The white arrows show the diagrammatic connections between the dye input sinkholes (black stars) and the springs (blue dots) to which the dyes went. The magenta numbers identify the springs the dyes reached. The Boiling Spring, Frego Creek and the new Roaring Spring GwSs are shown as gray shaded areas.