Water Quality of Heath Creek

An Assessment of Transparency, Conductivity and Anion Concentrations

Lindsey Stoddard
Markael Luterra
Eric Udelhofen

Carleton College Geology Department
November, 2004

ABSTRACT

Heath Creek drains an agricultural area in Rice County, Minnesota. Previous studies on the Heath Creek watershed found water quality problems typical of agricultural areas. In this study, we analyzed transparency, conductivity, and anion concentrations for four weeks in October 2004. We found that dissolved anions fell within acceptable limits and that a wetland on the creek significantly increased water quality during periods of low stream stage. Our findings suggest that the maintenance of this wetland and riparian or grassy buffer strips along the creek are crucial to sustaining the current level of water quality. We recommend continuous monitoring to better understand seasonal water quality variations, and the relation between water quality variations and stream stage.

INTRODUCTION

The Heath Creek drainage basin covers 103.61 square kilometers in Rice County, Minnesota, of which 90% is cropland (Berger et al. 2000) (Fig. 1). Four streams, collecting water from 75% of the total drainage basin, flow into Union Lake, which is then drained by Heath Creek. Heath Creek flows 21.5 kilometers through wetland, farmland, and residential areas to its mouth at the Cannon River near Dundas. It flows slowly with a gradient of less than one percent over wetland and sandy loam soils underlain by Ordovician dolomite, though stream velocity increases as it nears its mouth.

Heath Creek is classified as an impaired waterway, containing high levels of nitrogen and other dissolved substances (Berger et al. 2000). Such nutrient levels result in eutrophication (excessive plant growth), which can lead to a decrease in dissolved oxygen content and a reduction in overall habitat quality. As these dissolved nutrients travel down the Mississippi River, they contribute to the pollution of municipal water supplies and to the hypoxic “dead zone” in the Gulf of Mexico, an area where dissolved oxygen is insufficient for marine organisms to survive (Kroening and Andrews 1997).

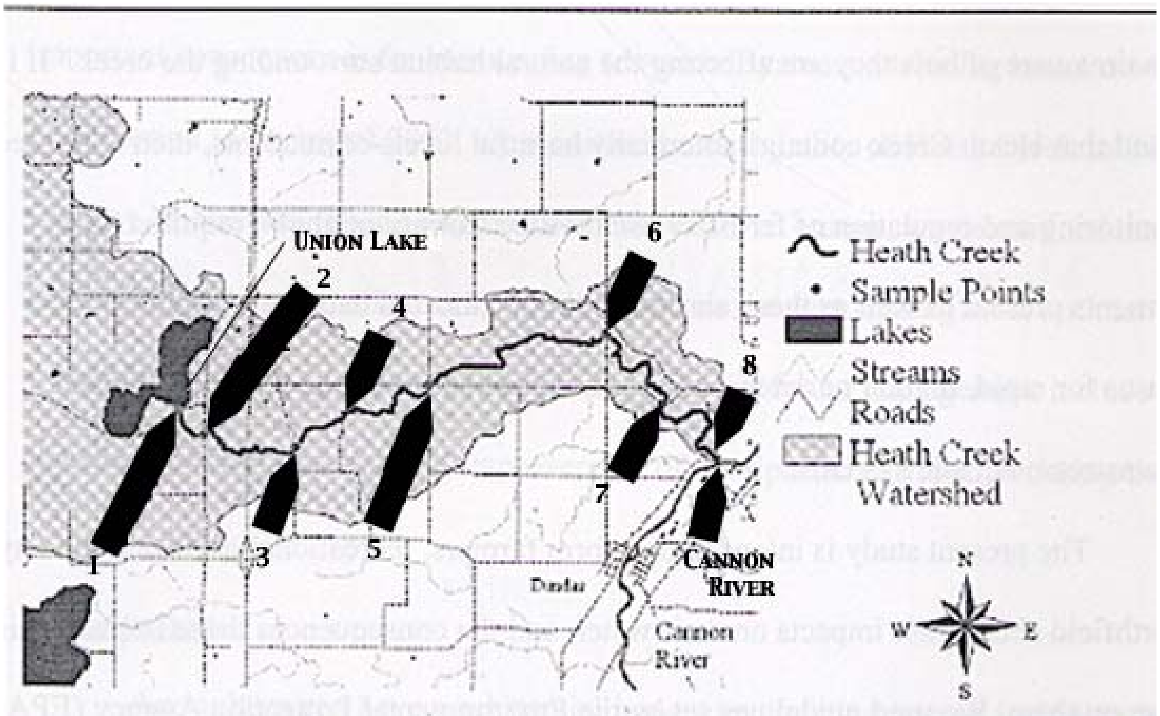

Figure 1. Map of Heath Creek watershed showing ten sampling sites: eight at road bridges over Heath Creek, one on Union Lake, and one on the Cannon River.

Comprehensive studies of water quality in Heath Creek were conducted in July 2000 and April-May 2003 (Berger et al., 2001 Hendrix et al., 2003). Our study seeks to continue monitoring the Heath Creek watershed in an attempt to evaluate seasonal variability and potential long-term alterations in water quality due to changing land use patterns. The area around Heath Creek is seeing increasing residential development due to the expansion of the Twin Cities and Northfield. This could bring not only a change in the chemical composition of creek water, but also an increased interest in improving water quality for aesthetic and health reasons.

Between 3.7 and 5.5 kilometers from Union Lake, Heath Creek runs slowly through a marshy wetland covering several hundred acres. Such wetlands often have a beneficial effect on water quality, as slow water movement and nutrient extraction by plants allow for a reduction in dissolved nutrient content and increase in transparency (EPA: Wetlands). In our study, we will assess the impact of this feature on Heath creek by comparing anion concentrations and transparency from opposite sides of the wetland.

In addition, we will compare water samples from Heath Creek to samples from the Cannon River above the creek mouth. Through this comparison, we will attempt to evaluate Heath Creek relative to other area streams. The priority assigned to improvement of creek water quality will ultimately depend more on this comparison than on the actual composition of the water. If Heath Creek, while impaired, is above average, then it would seem a more effective use of resources to concentrate on other streams first.

METHODS

Data was collected from eight points along Heath Creek between its source in Union Lake and its mouth at the Cannon River, a distance of 21.5 kilometers. Data was also collected from Union Lake near the creek source and from the Cannon River just above the creek mouth (Fig. 1). Each site was sampled twice during the month of October 2004.

At each site, a Model 85 Yellow Springs Instrument multi-meter was used to measure conductivity. Transparency was measured using a Secchi transparency tube.

Water samples were taken at each site for further analysis. Using an ion chromatograph, samples were tested for the presence of seven anions: fluoride, chloride, bromide, nitrite, nitrate, phosphate, and sulfate.

RESULTS

Transparency increased as distance from the lake increased. This trend held true even when overall transparency increased between sampling dates. On the October 25 sampling date, increasing transparency was not constant along the creek course, but occured primarily in particular creek segments (Fig. 2).

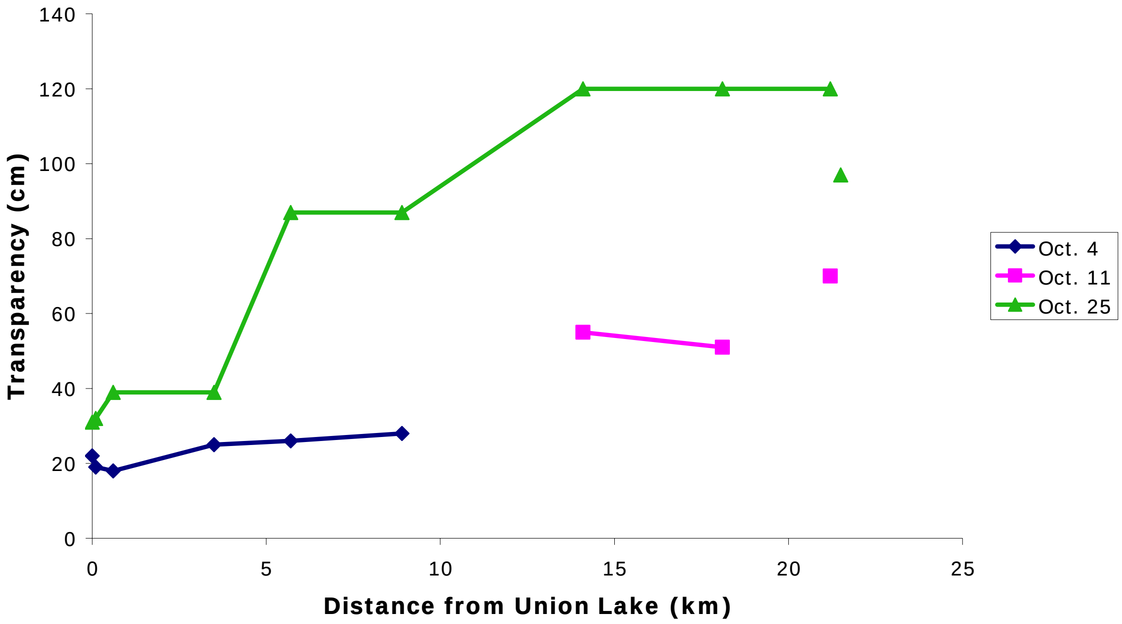

Figure 2. Transparency of Heath Creek. An increasing trend is apparent on all sampling dates, though high rainfall resulted in low overall transparency on Oct. 4 and 11. The final red point represents transparency of the Cannon River at the mouth of Heath Creek on October 25.

Conductivity showed a similar relationship, increasing as distance from the lake increased. A stream-wide increase in conductivity between sampling dates did not affect this trend (Fig. 3). Similar conductivity readings were observed in 2003 (Hendrix et al. 2003).

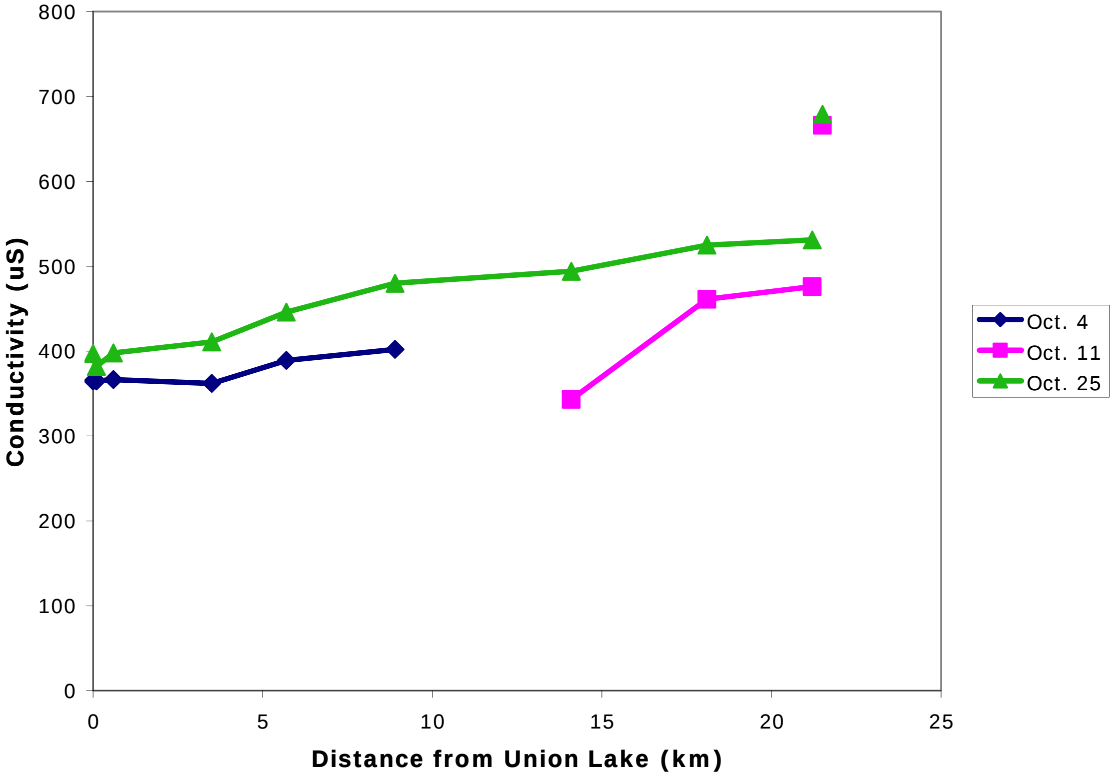

Figure 3. Conductivity of Heath Creek. On all sampling dates, an increasing trend was observed as distance from the lake increased. A similar trend was observed in the spring of 2003. The disconnected final points represent conductivity of the Cannon River on Oct. 11 and 25.

Of the seven anions tested, bromide and phosphate were not present in detectable amounts at any of our sample sites. Fluoride was present at levels between 0.1 mg/L and 0.12 mg/L in Heath Creek, showing no noticeable trend. Slightly higher amounts (0.146 mg/L) were detected in the Cannon River. Chloride exhibited a drop near Union Lake, then rose steadily for the remainder of the creek's course. Concentrations were higher on October 25, but the overall trend remained the same (Fig. 4).

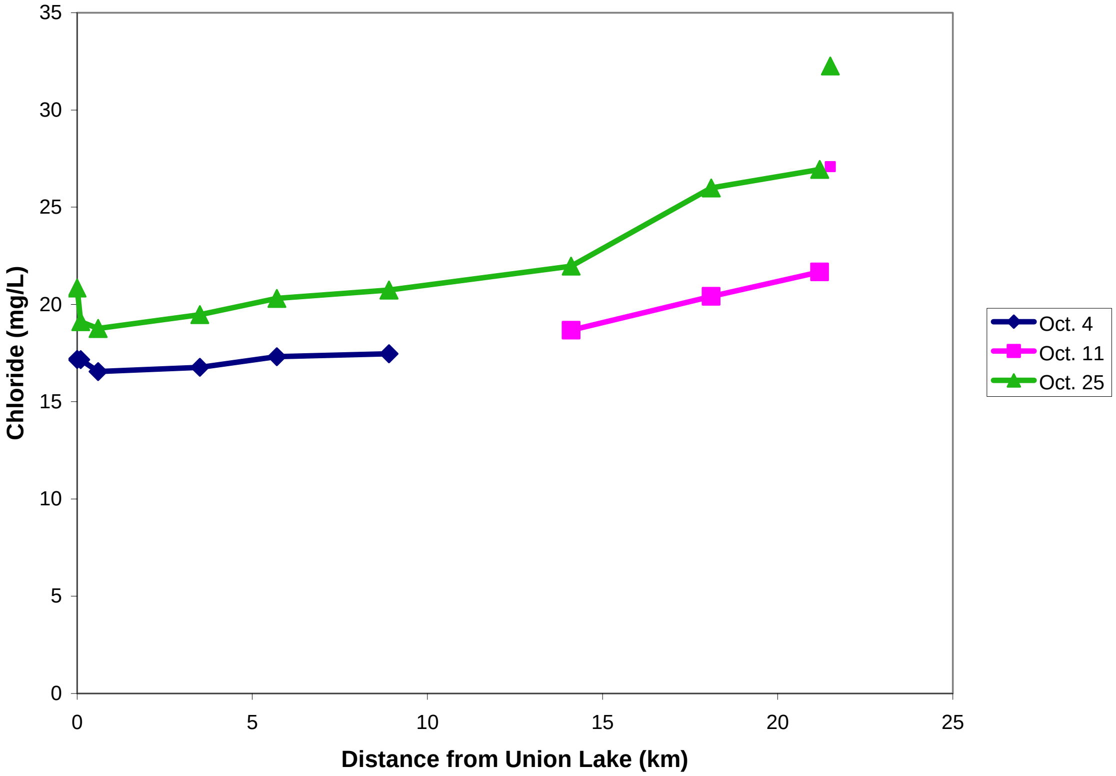

Figure 4. Chloride concentration in Heath Creek. After the first kilometer, a marked, steady increasing trend is apparent, approaching the higher levels found in the Cannon River.

With the exception of a very low amount (0.08 mg/L as nitrogen) near Union Lake on one sampling date, no detectable nitrate was found in the first six kilometers of Heath Creek. Over the rest of the creek, nitrate levels became detectable and increased significantly to 0.8 mg/L at its confluence with the Cannon River. The Cannon River contained a high level of dissolved nitrate (6.1 mg/L) (Fig. 5).

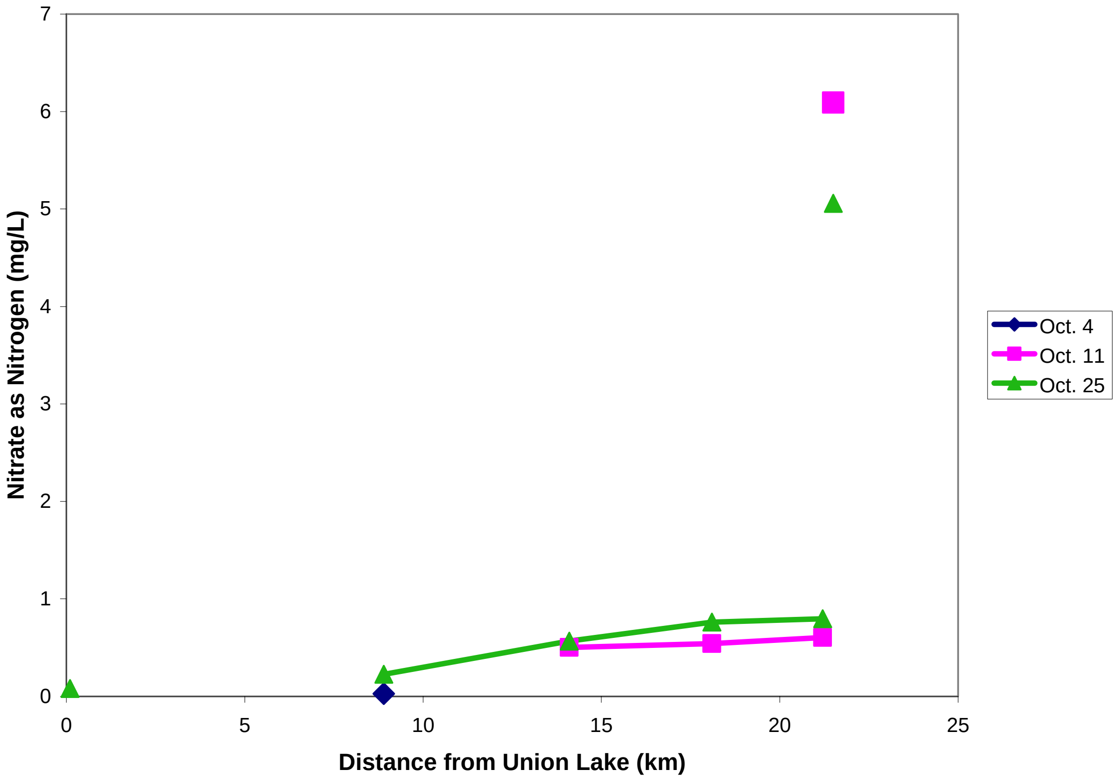

Figure 5. Nitrate levels in Heath Creek. Significant concentrations were only detected in the lower part of the creek, where nitrate exhibited an increasing trend. Cannon River nitrate levels were comparably much higher.

A small amount of nitrite (as nitrogen), around 0.16 mg/L, was detected in the lower half of Heath Creek on October 4 and 11. Samples from October 25 revealed no detectable nitrite. Nitrite concentrations in the Cannon River remained relatively constant around 0.2 mg/L across all of our sampling dates (Fig. 6).

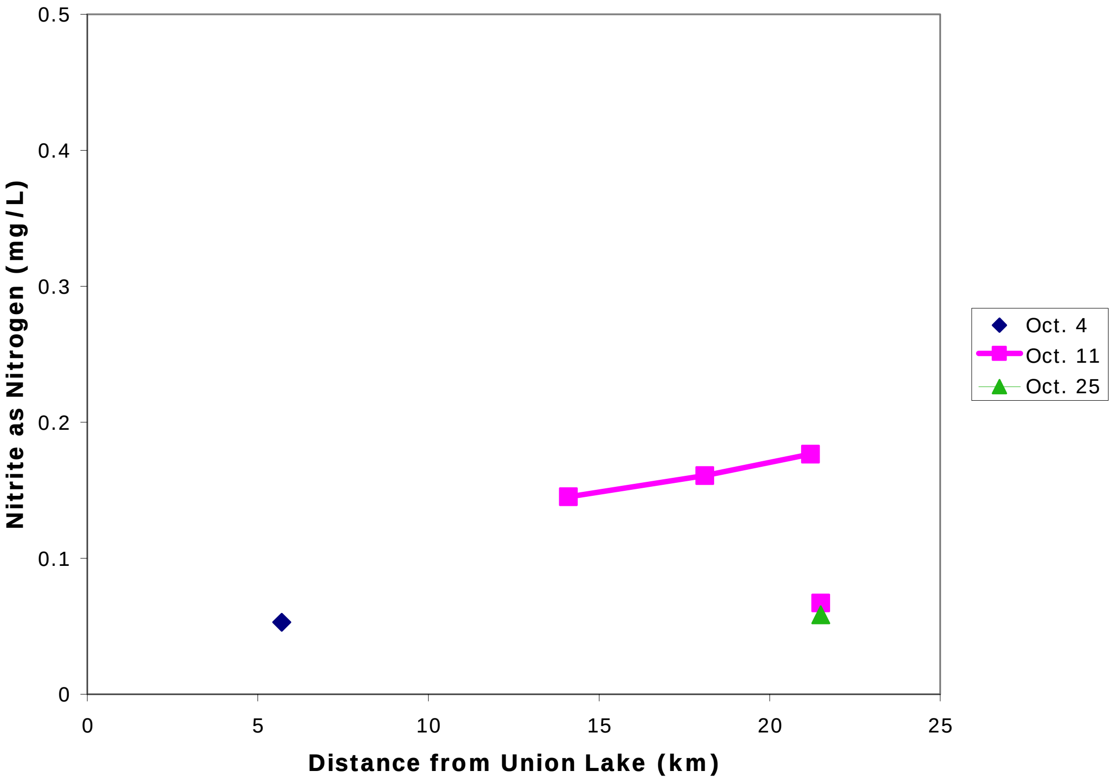

Figure 6. Nitrite levels in Heath Creek. Nitrite was only detected on October 4 and 11 when it showed an increasing trend in the lower half of the creek.

Sulfate levels remained remarkably constant throughout the course of Heath Creek. Levels on October 25 were consistently slightly higher than levels on October 4 and 11, while following the same general pattern. The only exception to this stable pattern was a slight drop in the first half-kilometer and another between four and six kilometers from Union Lake observed on October 25 (Fig. 7).

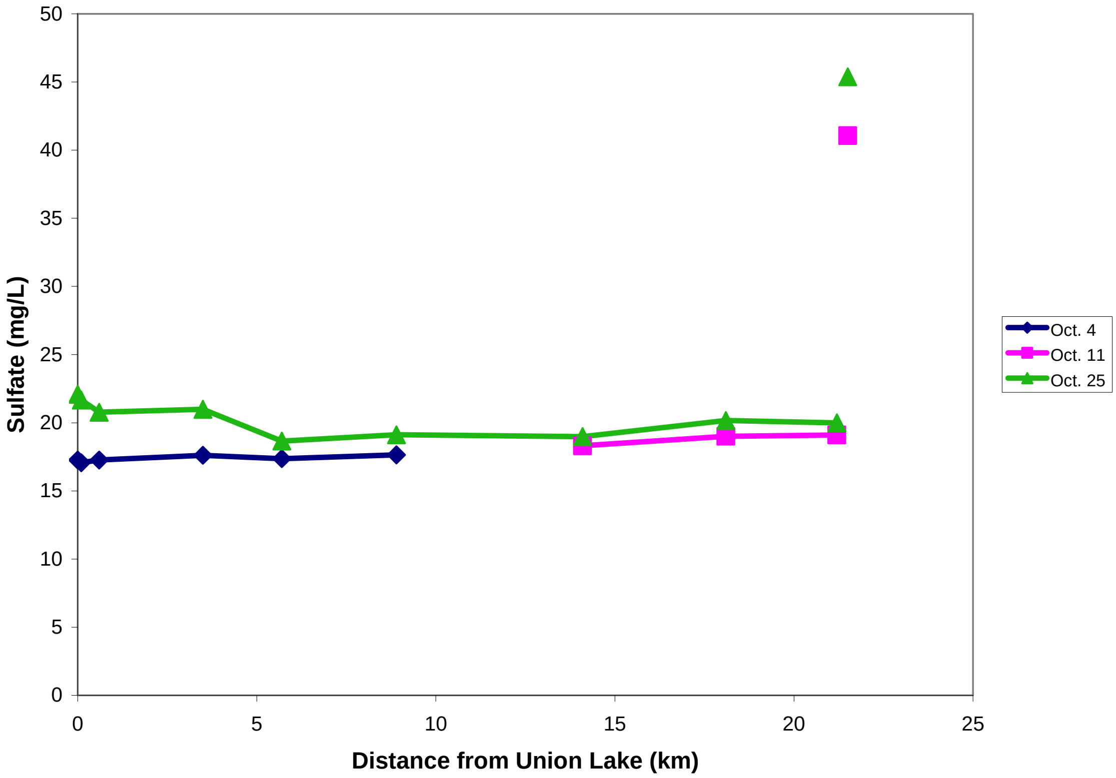

Figure 7. Sulfate concentration in Heath Creek. Levels remained generally constant along the creek, with slight drops near the source and slight increases later. Sulfate levels in the Cannon River were more than twice levels in Heath Creek.

DISCUSSION

Heath Creek, while not exceeding safety guidelines, exhibits many traits characteristic of streams in agricultural areas. Transparency shows a marked decrease after precipitation events, and nitrate levels increase as the creek flows past cultivated land. Other dissolved substances, such as fluoride and sulfate, appear less directly related to human activities.

In the three weeks prior to our first sampling date, a series of rainfall events totaling 4.2 inches resulted in a high stream stage. Another half inch fell between October 4 and 11, yielding a similar or slightly lower stream stage on October 11. In the two weeks preceding October 25, only 0.4 inches of rain fell, allowing stream stage to fall.

On all sampling dates, the creek became more transparent as distance from Union Lake increased. This is likely because the creek environment is less conducive to algal growth than the lake, resulting in a gradual decrease in suspended algae (and a corresponding increase in transparency) along the creek. Algae grow best in stagnant waters exposed to sunlight, characteristics of Union Lake but not of the flowing, often shaded creek. Transparency showed a larger increase on October 25, when creek level was significantly lower. Lower flow rates correspond with lower stream velocity, allowing algae and sediment more time to settle out.

On October 25, a large increase in transparency was observed between 3.5 and 5.7 kilometers from Union Lake. In this area, Heath Creek flows through a marshy wetland comprising several hundred acres. Previous studies have shown that wetlands are effective stream cleansers, reducing sediment and dissolved nutrient levels as velocity is reduced and plants absorb nutrients from the water (EPA Wetlands). On October 4, higher stream flow probably reduced water dwell time in the wetland and reduced its filtration capacity.

Fluoride concentrations in Heath Creek remained steady at around 0.1-0.12 mg/L on all sampling dates. This is well below the EPA drinking water standard of 4.0 mg/L. Sources of fluoride include natural geology and pesticides. Because few pesticides are applied in the fall, it is possible that fluoride in Heath Creek represents a low level of residual fluoride left from earlier pesticide application. In any case, current fluoride levels are of little concern, as this ion is often added to drinking water in much larger concentrations for dental reasons (EPA).

After an initial drop, chloride levels exhibited a steady, gradual increase. Sources of chloride include fertilizers, road salt, animal waste and industrial applications (MPCA, Have), as well as natural chloride minerals. In this case, fertilizer and road salt appear the most likely sources. The largest rate of chloride increase occurs where Heath Creek parallels State Highway 19 and receives runoff from Northfield, lending support to the possibility of road salt or other human sources. Lower levels on October 4 and 11, when stream stage was higher, suggest that chloride is not concentrated in runoff. A higher volume of water thus results in a more dilute chloride concentration. Chloride is only harmful at very high concentrations, far above levels found in Heath Creek.

Nitrate, not detectable in the upper third of Heath Creek, displayed an increasing trend as the creek approached the Cannon River. It is possible that algae growth in Union Lake and slower portions of upper Heath Creek effectively uses much of the available nitrate. Stream velocity increases in the lower portions, making conditions less favorable for algal proliferation. This could explain the observed pattern, as nitrate in runoff from farmland along the lower part of Heath Creek accumulates in the creek. While some nitrate occurs naturally, levels are generally very low. In the Upper Mississippi River

Basin, fertilizer is responsible for 49% of nitrogen in streams, and animal manure adds another 23% (Kroening and Andrews). All of the nitrate (as nitrogen) concentrations found in Heath Creek were under 0.8 mg/L, well below the EPA maximum contaminant level for drinking water of 10 mg/L.

Nitrite was only found in detectable levels in Heath Creek on October 4 and 11. On October 11, nitrite displayed a similar pattern to nitrate, but at lower overall concentrations (around 0.16 mg/L as nitrogen). These findings suggest that nitrite enters Heath Creek primarily through surface runoff, thus leading to higher levels following rainfall events. Also, it is possible that nitrite primarily enters Heath Creek during the growing season, when nitrogen fertilizers are applied. This could also help to explain the reduction in nitrite levels between October 11 and October 25. The maximum acceptable level of nitrite (as nitrogen) in drinking water is 1 mg/L. Given the large observed variability in nitrite levels during our sampling period, it is possible that acceptable levels are exceeded after significant rain events.

Sulfate levels remained relatively constant on all sampling dates, similar to a previous study (Hendrix et al.) and well below the maximum contaminant level for drinking water of 250 mg/L (EPA). Human activities can influence sulfate concentrations, but such fluctuations are generally small compared to large natural variations (0-1000 mg/L) resulting from dissolving of sulfate minerals. The constant level suggests a natural source for sulfate in Heath Creek. A slight decrease (from 21.0 to 18.7 mg/L) occurred between four and six kilometers from Union Lake on October 25 where the creek runs through a wetland. Studies have shown that microorganisms in wetlands reduce sulfate thus lowering sulfate concentrations (Volk, 2002). On October 4, when stream stage was higher, sulfate levels were lower overall, suggesting that sulfate is not concentrated in surface runoff. The wetland effect was also much less pronounced on this date, likely because a higher stage and velocity correspond to a decreased dwell time in the wetland.

Sources of experimental error are most likely to involve subjective measurement differences, contamination of samples, placement of sensors, and testing delay. Transparency readings are subject to judgment and eyesight of observers, the amount of available light, and glare. Consequently, some variation can be attributed to experimental error. Contamination of samples could have occurred in the transportation of non-sterile sampling vessels or during handling while sampling or testing. Conductivity readings are extremely sensitive to material on the sensor, and thus subject to error when the meter is near the stream bottom. Samples were tested 1-5 weeks after collection, possibly allowing for change in chemical composition.

CONCLUSION

None of the data we collected suggested that Heath Creek has a serious water quality problem at the moment. This could be due to the fact that the lower part of the creek is effectively isolated from direct contact with agriculture by buffer strips of grass or forest on both sides. Also, there are no large animal feedlots directly on or adjacent to the creek. However, past studies have revealed high concentrations of some chemicals, particularly nitrite, at certain times of the year (Barger et al., 2001). In addition, Union Lake, the source of Heath Creek, exhibits a high degree of eutrophication probably due primarily to high nitrate and phosphate levels from agricultural sources. Studies of other rural agricultural watersheds have found consistent variation in nitrate and phosphate concentrations with annual agricultural cycles (Kroening and Andrews). More consistent and long-term monitoring of Heath Creek could help to identify periods of serious contamination and suggest actions to limit this effect.

To provide a basis for comparison, we sampled the Cannon River above the mouth of Heath Creek. Most dissolved anions were found in higher concentrations in the river than in any part of Heath Creek, a finding which correlated with a correspondingly high conductivity. Primarily natural-sourced substances, such as sulfate, exhibited higher concentrations in the river, probably because of inflow of groundwater and dissolution of minerals from the riverbed. Nitrate (as nitrogen) levels in the Cannon River were around 6 mg/L. This would suggest either that many of the Cannon River's other tributaries are more highly contaminated than Heath Creek or that point sources on the river, likely towns and associated industries, are a major source of this pollution. Heath Creek shows many of the negative effects of agriculture on water quality, but it does not presently exceed allowable EPA standards. Despite draining a primarily agricultural watershed, intact wetlands and buffer strips allow Heath Creek to remain relatively uncontaminated during periods of low flow.

ACKNOWLEDGEMENTS

We extend our gratitude to Bereket Haileab for his assistance in our anion testing and guidance throughout the study, to the Carleton College Geology department for providing funding and equipment, and to our lab assistants Jake Gold and Rebecca Isaacson.

APPENDIX 1

Data collected from eight sites along Heath Creek, one from Union Lake and one from the Cannon River above the mouth of Heath Creek.

Distance from Union Lake (km)		Union Lake, 0	0.1	0.6	3.5	5.7
Fluoride (mg/L)	Oct. 4	0.10	0.12	0.10	0.1088	0.11
	Oct. 11					
	Oct. 25	0.10		0.11		
Chloride (mg/L)	Oct. 4	17.18	17.16	16.55	16.77	17.31
	Oct. 11					
	Oct. 25	20.85	19.12	18.76	19.47	20.31
Nitrate (mg/L)	Oct. 4					
	Oct. 11					
	Oct. 25		0.36			
Nitrite (mg/L)	Oct. 4					0.17
	Oct. 11					
	Oct. 25					
Sulfate (mg/L)	Oct. 4	17.27	17.07	17.26	17.62	17.37
	Oct. 11					
	Oct. 25	22.08	21.67	20.77	20.99	18.65
Transparency (cm)	Oct. 4	22	19	18	25	26
	Oct. 11					
	Oct. 25	31	32	39	39	87
Conductivity (uS)	Oct. 4	365	365	366.5	362	389
	Oct. 11					
	Oct. 25	397	382	398	411	446

Distance from Union Lake (km)		8.9	14.1	18.1	21.2	Cannon R., 21.5
Fluoride (mg/L)	Oct. 4	0.11				
	Oct. 11		0.15	0.12	0.11	0.18
	Oct. 25	0.12	0.11	0.10	0.11	0.15
Chloride (mg/L)	Oct. 4	17.46				
	Oct. 11		18.67	20.42	21.67	27.08
	Oct. 25	20.74	21.97	25.99	26.94	32.26
Nitrate (mg/L)	Oct. 4	0.12				
	Oct. 11		2.23	2.40	2.68	26.98
	Oct. 25	1.001	2.52	3.38	3.53	22.40
Nitrite (mg/L)	Oct. 4					
	Oct. 11		0.48	0.53	0.58	0.22
	Oct. 25					0.19
Sulfate (mg/L)	Oct. 4	17.64				
	Oct. 11		18.299	18.9939	19.102	41.0571
	Oct. 25	19.1222	18.9774	20.1665	19.9952	45.3766
Transparency (cm)	Oct. 4	28				
	Oct. 11		55	51	70	
	Oct. 25	87	120	120	120	97
Conductivity (uS)	Oct. 4	402				
	Oct. 11		343	461	476	666
	Oct. 25	480	494	525	531	679

REFERENCES

“An introduction to Wetland Restoration, Creation and Enhancement.” 25 May. 2004. U.S. Environmental Protection Agency. 7 Nov. 2004. http://www.epa.gov/owow/wetlands/restore/finalinfo/html.

Barger, S., M. Chen, E. Figueroa, B. Harris, B. Knight. “Hydrology and Geochemistry of Heath Creek, Rice County, Minnesota.” *KECK Geology Consortium: 14th Annual Undergraduate Research Symposium.* Keck Geology Consortium. Carleton College, Northfield, MN: 2001.

“Drinking Water Contaminants.” U.S. Environmental Protection Agency. Nov. 8. 2004. http://www.epa.gov/safewater/hfacts/html.

Have, M.R. “Selected Water-Quality Characteristics In the Upper Mississippi River Basin, Royalton to Hastings, Minnesota. U.S. Geological Survey. St. Paul, MN: 1991.

Hendrix, R., K. Lewis, B.Sandel, L. Sipher-Mann. “Water Quality of Heath Creek.” *Status of Lakes and Streams of Rice County, Minnestota.* Carleton College, Northfield, MN: 2003.

Kroening, S. and Anrdews, W. “Water Quality Assessment of Part of the Upper Mississippi River Basin, Minnesota and Wisconsin – Nitrogen and Phosphorous in Streams, Streambed Sediment, and Ground Water, 1971-94.” U.S. Geological Survey. Mounds, MN: 1997.

“Sulfate in Drinking Water.” 26 Nov. 2002. U.S. Environmental Protection Agency. 7 Nov. 2004. http://www.epa.gov/safewater/sulfate.html.

Volk, S. “Influence of Wetlands on Stream Nitrate and Sulfate Concentrations in the Broad Mouth Creek Watershed, South Carolina.” *2002 Abstracts with Programs. Vol.34, No.2.* The Geological Society of America: March 2002.