HYDROLOGY AND GEOCHEMISTRY OF HEATH CREEK, RICE COUNTY, MINNESOTA

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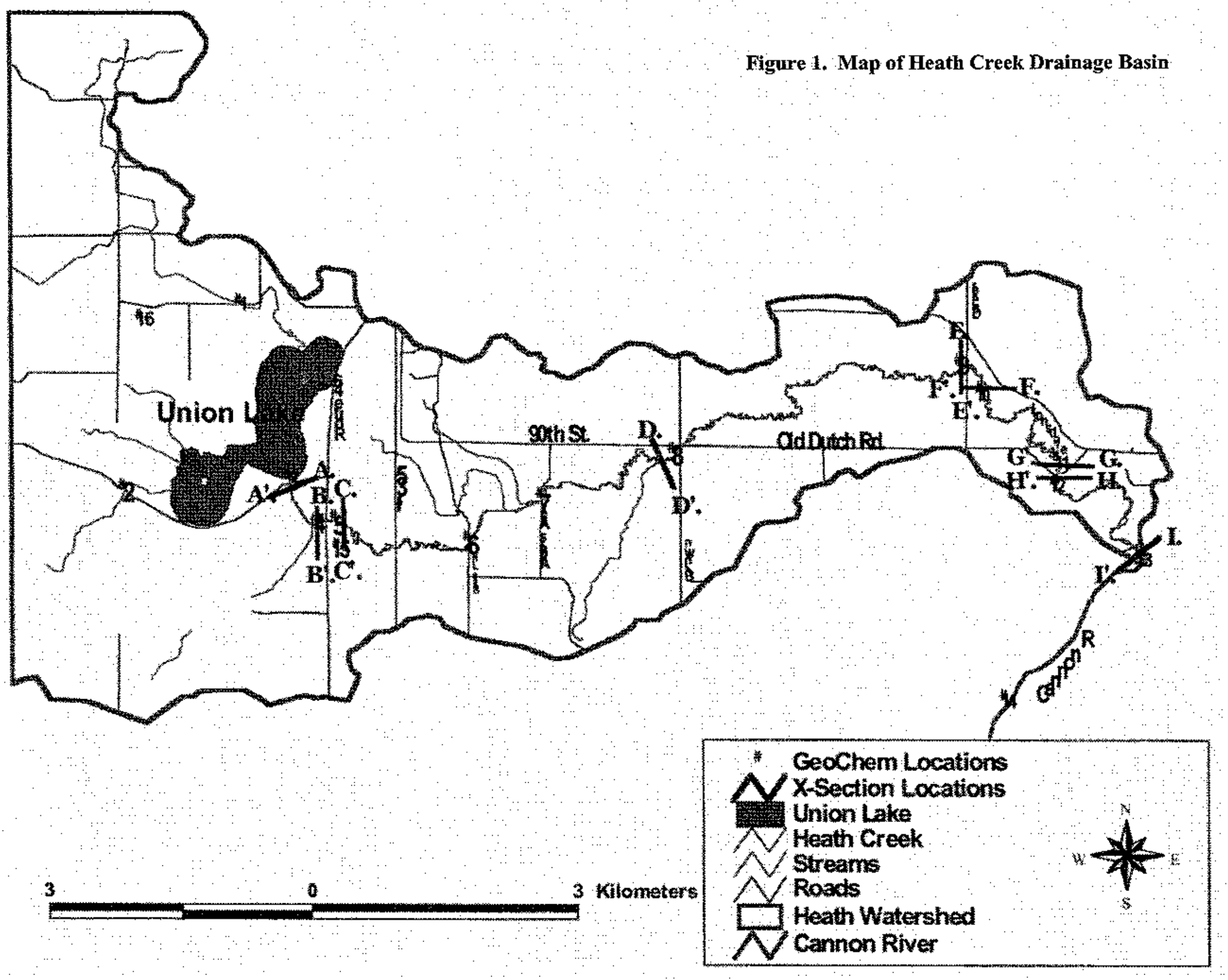

Figure 1. Map of Heath Creek Drainage Basin

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INTRODUCTION

The Heath Creek drainage basin (Figure 1) covers 103.61 km^3. It is part of the Cannon River Watershed in Rice County, MN, 40 miles southeast of the Twin Cities Metropolitan Area. The Cannon River drainage basin encompasses 3733.6 km^2 and drains east into the Mississippi River near Red Wing, MN. Landuse in the Heath Creek drainage basin is representative of the Cannon River watershed as a whole with 90% of the study area occupied as cropland.

This study focuses on a 21.5 kilometer length of Heath Creek, from slightly upstream of the two source streams of Union Lake, downstream to the Cannon River. The purpose of the study is twofold: first, to establish a baseline of hydrologic, physical, and geochemical characteristics of Heath Creek and its floodplains, and second, to correlate these characteristics to the surrounding land use.

METHODOLOGY

Cross-Sections and Discharge. Cross section measurements of the stream channel and floodplain were taken at nine locations along the creek, from the Union Lake outlet and to the Cannon River confluence. Locations were chosen according to accessibility and surrounding land use. Elevation measurements were taken along transects perpendicular to stream flow with a CST/Berger automatic level and a stadia rod at distances determined by changes in topography. Velocity measurements were taken with a Marsh-Birney Flo-Meter 2000 at 60% of stream depth at each point.

Floodplain Stratigraphy. Seven core samples of the floodplains along the creek were taken for stratigraphic analysis. The locations were chosen based on accessibility, riparian cover, and variability of channel morphology. The augering was done on the point bar of each location approximately 10 feet from the water-bank contact. A three inch auger head with extensions was used to core to depths between 0.82-1.5 meters. A two meter pole was used to determine depth of hole and water table elevation.

Geochemical Analysis. Heath Creek runs through wooded and grassy riparian zones, open wetlands, pastures, agricultural land, and residential areas. In order to determine the effect, if any, of surrounding land use on the water chemistry of the creek, sample sites were chosen to include a variety of environments. Eleven water samples from Heath Creek, and one each from the two source streams, a gravel pit above the lake, a private well, and the Cannon River were analyzed for geochemical and biological water quality indicators. Temperature, pH, salinity, conductivity, nutrient levels and cation concentrations were studied as geochemical indicators of water quality. GPS points were taken with a Trimble GeoExplorer II at each sampling site, and downloaded onto a GIS map of the area.

Biological analyses. Benthic and Integrated Depth Samples were taken at three locations of differing riparian cover to determine the presence and general abundance of macro-invertebrate specimens. Samples were collected in a low velocity stretch buffered by marshland 50 meters upstream of Country 46, in the low velocity wooded riparian zone downstream of County 46, and in a high velocity zone buffered by grassland upstream of Decker Bridge.

Kick sampling, integrated depth sampling of organisms throughout the entire water column, and streambed sediment sampling were three methods of benthic invertebrate collection used in this study. The invertebrates were identified using a dichotomous key within four hours of collection.

RESULTS AND DISCUSSION

Channel morphology. There are two distinct cross-sectional channel shapes along Heath Creek: Cross sections A and B, taken in wetlands, have a wider channel with more sloping banks. At cross sections F-H, where the riparian buffer is wooded, the channel banks are steeper and often have cutbanks on both sides of the creek. Stream banks were generally less stable in regions where there is pasture or reeds but no woods.

The increase in discharge and velocity downstream is a potential cause of the downcutting and steeper banks in the residential reach between Baldwin Ave. and Sechler Park. The runoff contributing to discharge in these residential areas seems to have increased significantly due to the removal of natural buffers, the addition of landscaped lawns, and the installation of tile drains and culverts. As a result of these human interferences with the natural drainage system, the hydrograph of Heath Creek experiences a high flux in stage for a short time after a storm, eroding banks, and causing possible bank instability.

Floodplain Stratigraphy. As the distance from Union Lake increases there is an overall downstream coarsening of floodplain sediments. The substrate changes from silt upstream to sands and gravel in intermediate reaches, and finally gravel and cobbles near the mouth of the Cannon River (Figure 2). This change in sediment size is due to the increased competence of the stream as the velocity and gradient increase.

The two auger sites below Union Lake show thick fine-grained layers, indicative of a low velocity wetland depositional environment. Decker Ave., with a meter-thick post-settlement layer of organic rich silts is an example of excessive erosion of topsoils due to agriculture at sites upstream in the basin. Augering in some downstream reaches revealed thick layers of recently deposited silt, suggesting that there is a significant amount of sediment erosion either from upstream locations or from historic removal of forests and introduction of agriculture in the region. The two auger sites lowest in the basin just above the mouth of Heath Creek at the Cannon have sediments from silts and clays to thick layers of fine and coarse grained sands at the bottom of section. Several thin layers within the core at these two sites may be indicative of individual flood events.

Sinuosity. The total sinuosity of Heath Creek is 1.529. The areas of residential development have the highest sinuosity, including the reach between cross-sections F and G, which has a sinuosity of 2.3, higher than any other reach. The reaches that run through the wetlands just downstream of Union Lake have the lowest sinuosity.

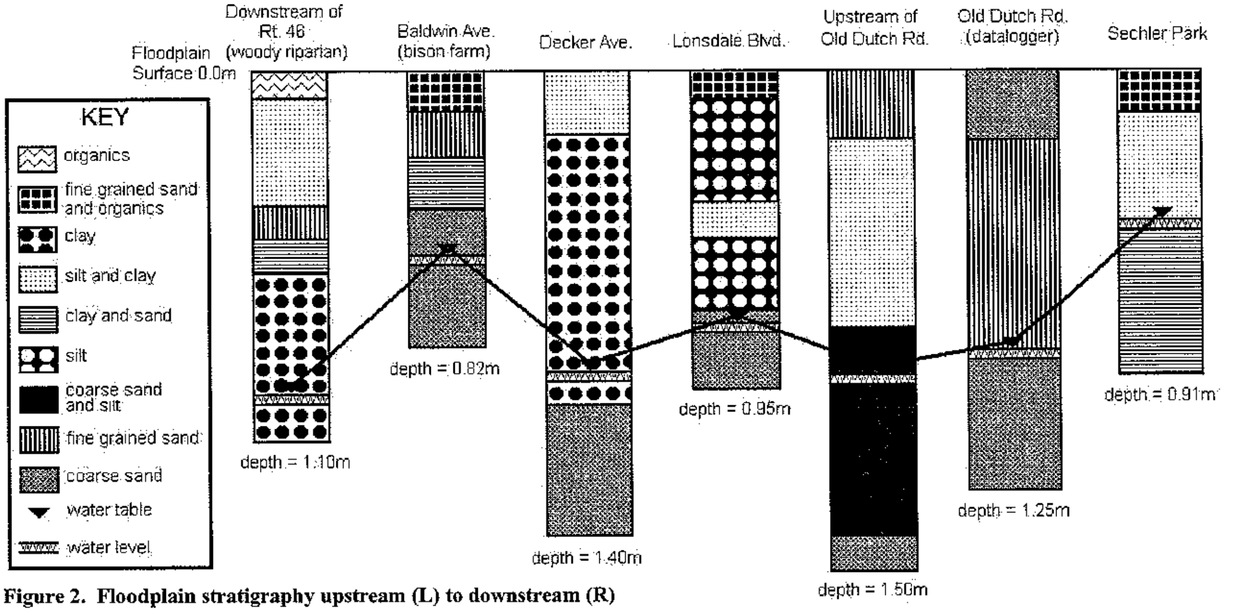

Figure 2. Floodplain stratigraphy upstream (L) to downstream (R)

Nutrients (NO_2^-, NO_3^-, PO_4^{3-}). Stream discharge from Union Lake is pea-green with low transparency due to algal blooms. At all locations sampled, the suspended sediments measured less than 0.1 grams per 0.4 liters. This further suggests that algal blooms, not the suspended sediment load, were a significant factor in the low transparency upstream. Transparency improves with distance from Union Lake, such that the creek is a clear reddish-brown at the Cannon Despite this visual improvement in water quality, nutrient levels remain elevated throughout the reach of the study site.

Nitrite concentrations in Heath Creek range from 4 mg/L to 11 mg/L, generally decreasing downstream. (Figure 3). NO_2^- levels are highest at sites 3-5, from Union Lake to the two wetland sites 1 km downstream of the lake. Nitrite levels are especially high at the headwaters of Heath Creek at Union Lake, suggesting that Union Lake is a low-oxygen environment. This is supported by the presence of invertebrates that are commonly found in areas with low dissolved oxygen. NO_3^- levels are constant, between 0.8-1.0 mg/L, from Union Lake to Baldwin Ave. Concentrations increase significantly from Decker Ave. to the Cannon River, peaking at 1.7 mg/L at Lonsdale Blvd.

Curious is the inverted nitrite-nitrate relationship in the reaches of the creek surrounded by wetland, shown in locations 3,

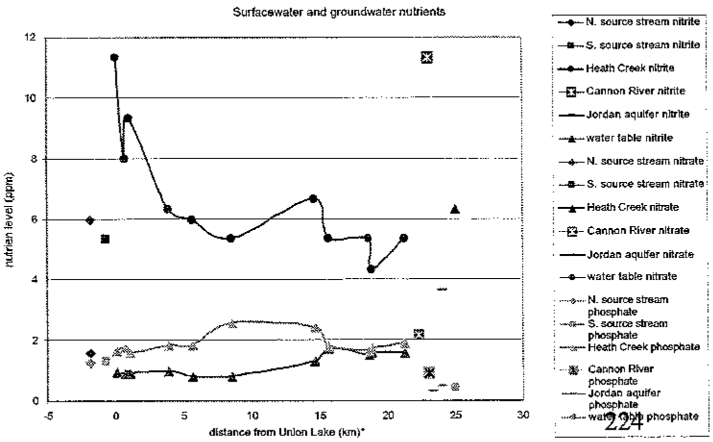

Figure 3. NO_2^-, NO_3^-, and PO_4^{3-} concentrations. *distances for Cannon River, Jordan aquifer, and water table samples are not representative of distance from Union Lake

4, and 9. It would be expected that nitrate levels would fall and nitrite levels would rise in anoxic wetland environments, but the data shows that the opposite is the case. However, the general trend from the headwaters of Heath Creek at Union Lake to the mouth at Sechler Park, is a decrease in nitrite concentration and increase in nitrate levels. The hydrologic data suggest that these general trends could be a result of increased oxygenation through higher streamflow velocity, turbulence due to riffles.

Phosphate levels in most natural surface waters range from 0.005 to 0.020 mg l^{-1} (2). Heath Creek shows a consistently high range of phosphate levels (Figure 3). Phosphate levels are lowest at the northern and southern source streams, 1.28 mg/L and 1.29mg/L respectively. Thereafter, phosphate concentrations increase steadily downstream, with peaks of 2.57mg/L at Baldwin Ave., and 2.43mg/L at Decker Ave.

Phosphate levels are highest in areas of agricultural land use, and drop off slightly in the residential areas. These high values suggest significant human and animal interaction with the creek. It appears that fertilizer and animal waste runoff from agricultural fields in the Heath Creek Basin are the largest contributing phosphate sources. Accordingly, runoff from farmland directly above the banks of Heath Creek results in local spikes in phosphate levels. Interesting to note is phosphate peak at the Baldwin Ave location. This location is an agricultural area with no riparian buffer to intercept runoff. Improperly maintained septic systems and runoff from phosphate-containing domestic detergents may be sources of phosphate in residential areas. An increase of phosphate levels between the source streams into Union and the head of Heath Creek indicate that there is a phosphate input from the lake to the stream.

Cations. Potassium concentrations fluctuate slightly along Heath Creek, from 3.2 mg/L at Baldwin Ave to 3.8 mg/L at Sechler Park. Concentrations in the southern source stream are lower, at 2.1 mg/L. Well water from the Jordan aquifer has a K concentration of 1.4 mg/L. Sodium concentrations along Heath Creek were a constant 9.0 mg/L except at Lonsdale Blvd. and Sechler Park, where concentrations increased to 10 mg/L. The well sample, with a Na concentration of 2.0 mg/L, was significantly lower. Calcium levels increased slightly along Heath Creek, rising steadily from 9.0 mg/L at the Union Lake confluence to 10.4 mg/L at Sechler Park. The source streams reported significantly higher concentrations -- 15.8mg/L at the north stream and 13.2mg/L at the south stream -- as did the Cannon River and the water table at the gravel pit. The well water, at 6.4 mg/L, contained the lowest calcium concentrations.

Temperature, pH, and Conductivity. Temperature decreases steadily downstream, from 23.5°C at the Union Lake confluence to 21°C at Sechler Park. Changes in temperature may be an indication of additional sources of water flowing into the creek.

pH at Union Lake is higher than at the source streams. From Union Lake, pH falls to a low mid-reach of the study site, and then rises until the confluence at Sechler Park. Conductivity, measured as TDS, was relatively constant along Heath Creek. TDS was higher at the source streams and at the Cannon River. The highest TDS measurement was taken at the well, and the lowest measurement at the gravel pit water table.

Coliform. Coliform levels in Heath Creek are very high throughout, decreasing towards the downstream reaches. Union Lake measures 10,400 cfu/mL, decreasing to 3,500 cfu/mL at mid-reach, to 3,200 cfu/mL at Sechler Park. Initial observations suggest that these high levels are due to the lack of fences between feedlots and the creek. The decrease may be attributable to the increased discharge downstream, which in addition to being a less conducive environment for bacterial growth, also serves as a diluting agent. Acting in conjunction with increased discharge is the change in landuse, from agricultural fields and feedlots upstream, to residential developments downstream.

Macroinvertabrates. Organisms found in Heath Creek are indicative of the increasing DO levels downstream. Pouch snails and leeches, indicators of low DO, were found upstream, while caddis fly nymphs, indicators of higher DO, were found downstream.

CONCLUSIONS

Installation of tile drains, culvert networks, and removal of natural riparian buffers have increased the rate of runoff into the channel immediately following precipitation events. As a result, the downstream reaches of Heath Creek are experiencing bank instability. Restoration of natural riparian buffers along the stream would help to reduce land loss due to erosion during high runoff events.

The visual water quality of Heath Creek improves with distance from Union Lake, despite increased concentrations of NO_3^-, and PO_4^{2-} downstream. Increased stream velocity is possibly responsible for this visual change since there are no significant inputs of water between Union Lake and the Cannon River.

EXPERIMENTAL ERROR AND SUGGESTIONS FOR FUTURE STUDY

The principal source of discharge for Heath Creek is Union Lake. Due to a lack of precipitation events during the study period, springs, tile drains, and ephemeral tributaries were dry. Their effects on the water chemistry of Heath Creek were therefore unable to be studied. This month-long study began three days after a severe precipitation event. Increased runoff into the creek may have flushed the sediments of the drainage basin, resulting in unusually elevated nutrient concentrations in the creek.

Suggestions for future study include: (1) Study during a period with precipitation, in order to provide a different perspective of stream dynamics, (2) Long-term monitoring of stream banks for relative stability and/or bank loss to erosion, (3) Chemical analysis of water quality at high discharge, (4) Comparison of nutrient levels before planting and after seasonal harvests, (5) Location of tile drains and springs and geochemical analysis of their discharge, (6) Study of the filtration efficacy of wetlands, and (7) a thorough long-term study of entire drainage basin.

ACKNOWLEDGEMENTS

Many thanks and leech-free living to: Prof. Mary Savina, Prof. Bereket Haileab and Prof. Tom Gardner, project directors; Sara Bertelsen, project TA; Prof. Gary Wagenbach, Martina Muehlegger and Jon Kenning, Carleton Biology; Tim Cowdery, USGS; Matt Drewitz and Trent McCorkell, Rice County Water Planning; Lisa Lukis, CRWP; Molly Woehrlin, and Chris Robbins. Thanks to home college advisors and special thanks to the residents of Rice County.

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