GEOMORPHOLOGY AND WATER QUALITY OF PRAIRIE CREEK IN NERSTRAND BIG WOODS STATE PARK, MINNESOTA

ELEANOR BARTOLOMEO
Department of Geology, Smith College
Faculty Sponsor: Robert Newton

ADAM MYERS
Department of Geology, Pomona College
Faculty Sponsor: Sían Davies-Vollum

NICKLAUS WELTY
Department of Geology, College of Wooster
Faculty Sponsor: Greg Wiles

INTRODUCTION

Prairie Creek is a small stream located in Rice and Goodhue Counties in southeastern Minnesota, draining an area greater than 206 km^2. Prairie Creek flows through extensive agricultural areas and the Nerstrand Big Woods State Park before emptying into Lake Byllesby along the Cannon River. The Cannon River enters the Mississippi River near Red Wing, Minnesota. We focused on the portion of Prairie Creek running through Nerstrand Big Woods State Park, a 2,882-acre park located in the southern portion of the Prairie Creek watershed (Figure A). Prairie Creek enters the park at its southeastern tip and exits the park at its northeast border. The park contains some sections of restored prairie though it is mostly hardwood forest, with trees such as maple and oak dominating its landscape. Although not a virgin forest, much of the area was set aside as managed woodlots in about 1850 when the area was first settled, and it has never been clear-cut. It is probably the area within the greater Prairie Creek watershed that is closest to its natural, presettlement state.

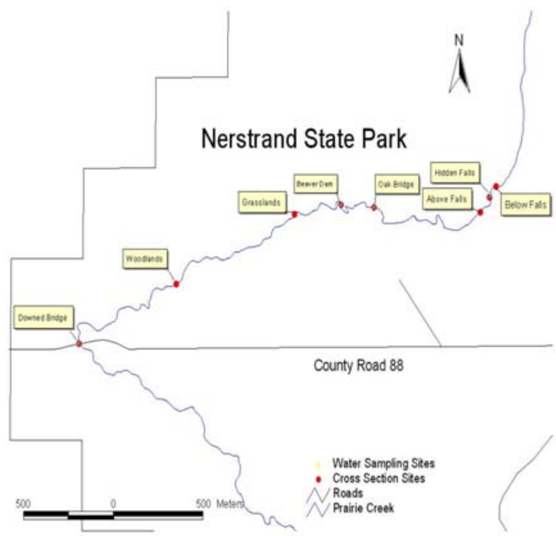


Figure A: Map of the study area

Our study area extends from where Prairie Creek is crossed by County Road 88 near the center of the Nerstrand Big Woods State Park and runs downstream to Hidden Falls, located at the north-central portion of the park. This reach of stream is approximately 2900 meters in length.

The focus of this study was to examine the decrease in fecal coliform bacterial concentrations that previous studies (Holshuh, 1999) had found in our study area. Our goals were twofold: one, to assess the geomorphologic and hydrologic variations in our section of Prairie Creek, and two, to correlate these variations with the changes in fecal coliform bacterial concentration.

METHODS

Geochemical Analysis

Two of our four sites, the Downed Bridge and Hidden Falls, were chosen because previous studies (Hulshuh, 1999) had used these sites and we wished to be able to correlate our results with theirs. Two sampling sites were chosen between Hidden Falls and the Bridge where some outside force was affecting the stream: man made trails at Oak Bridge and beavers at the Beaver Dam. Generally, we collected and analyzed water samples every third weekday.

Cross sections

We measured stream cross sections using a level and a stadia rod at eight sites: the four geochemical sampling sites, a site above and a site below Hidden Falls, and two sites that were reflective of a distinct geomorphology or vegetation.

E. coli

Our first run of *E. coli* samples was taken only at our four geochemical sampling sites. The results from testing these samples allowed us to narrow our range of inquiry to the area between Oak Bridge and the Grasslands cross section. Our second set of *E. coli* samples was taken at sites chosen for accessibility and to be equally spaced between these two points.

Transparency

We measured transparency using a transparency tube at all of our cross section sites. We took readings once before and every day after the rain events on July 22 and 23.

RESULTS AND DISCUSSION

Cross Sections

We found two cross sections that characterize most of the length of Prairie Creek. Where the riparian buffer is grassed, the water depth is shallow. The channel is narrow and has high, steep banks and a clearly defined point bar and cut bank. In the wooded areas, the water is slightly deeper and the streambed is wider with a flat bottom and banks that rise gradually in steps. These steps represent previous stream banks (Figure 1). Although wooded areas are more prevalent along the length of the stream than grassy areas, there is no clear boundary between these two types of cross section. They blend back and forth into each other with many transition areas that incorporate some attributes of each type of cross section.

The sediment in the creek is sand for the entire length of our study area, except where tributaries carry gravel, cobbles, and boulders into the stream. None of the larger grains are found more than 10 meters downstream from their tributary sources. Most of the sediment in the stream banks seems to be pre-settlement alluvium and glacial outwash, but upstream of the Downed Bridge we found sites with the highly organic, thickly bedded sediment associated with post-settlement alluvium.

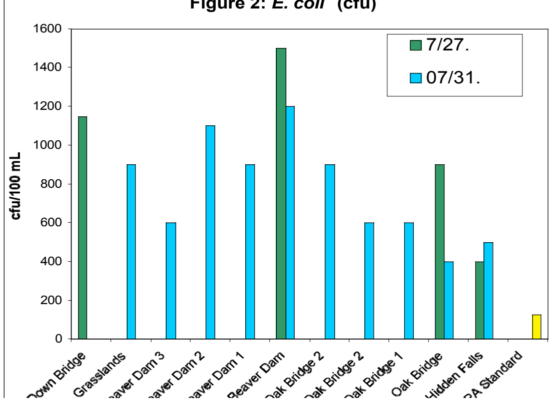
Escherichia coli

Escherichia coli, *E. coli* for short, is a form of fecal coliform bacteria found only in the intestines of warm-blooded animals. EPA criteria mandates a maximum concentration of 126 colony forming units (cfu) of *E. coli* bacteria per 100 mL of water for recreational use (Francy et al., 1993). None of our samples met this criterion (Figure 2).

The Downed Bridge had one of the highest readings, 1100 cfu/100 mL. After the Downed Bridge, the cfu count decreased, before rising again as the Beaver Dam approached. Levels peaked around the Beaver Dam with 1500 cfu/100 mL of water. Counts decreased downstream after the Beaver Dam. Samples at Hidden Falls' pool measured only 400 cfu/100 mL. One possible source for the high levels of *E. coli* found near the dam could be beaver fecal matter. However, it is unlikely that beavers are entirely responsible for the fecal contamination. High *E. coli* concentrations were also recorded in the grasslands region of our stream, upstream of the Beaver Dam, with water too shallow for beavers (15 cm). The high *E. coli* rates in these areas could be attributed to other kinds of wildlife, runoff from nearby feedlots, or the use of residential septic tanks.

There are several reasons why the *E. coli* concentrations in our section of Prairie Creek decrease downstream from the Beaver Dam. One reason is hyporheic flow. Hyporheic flow can be measured by observing changes in discharge over short distances along a channel (Wigington, 2000). After calculating discharge at all of our sites, we found a discrepancy in the measurements. The discharge at Oak Bridge (0.028 m^3/s) is noticeably greater than the discharge at the cross section site just above Hidden Falls (0.022 m^3/s). This change in discharge could be due to water flowing through the sediment on the bottom and sides of the channel instead of through the channel itself. Hyporheic flow filters the water and reduces amounts of nutrients such as nitrate, and may help filter *E. coli*. We observed

Figure 2: *E. coli* (cfu)



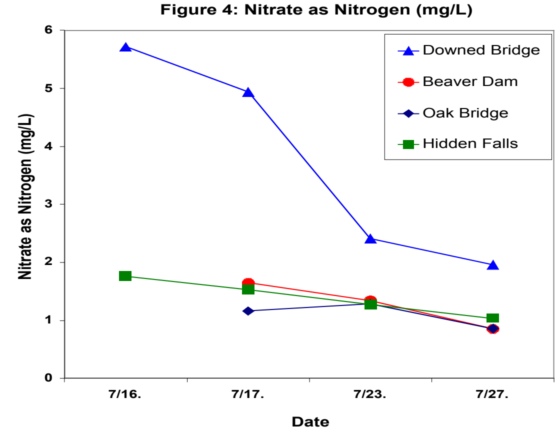
hyporheic flow in the sand of some of the shallower reaches of our stream and in several tributaries. Even in the reaches that appeared dry, the sand just below the surface was saturated. In certain areas, these conditions approached quicksand.

Another possibility for the improvement in water quality downstream is the presence of a large pool of water trapped upstream of the Beaver Dam. The water's retention time in the pool may exceed the average *E. coli* life span, decreasing the number of cfu downstream. Moreover, the dam itself may act as a filter, straining the water of its *E. coli* concentration.

TRANSPARENCY

Our transparency measurements varied both

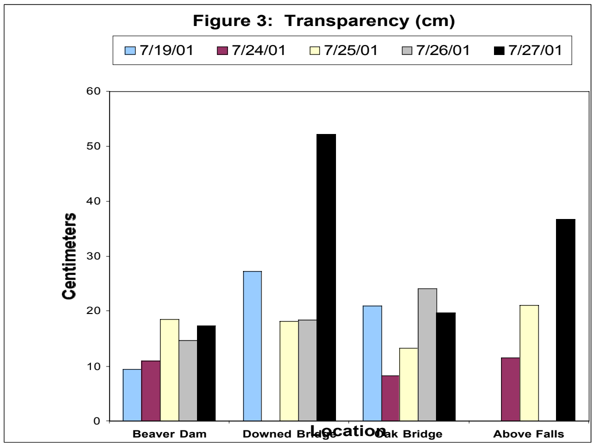
Figure 4: Nitrate as Nitrogen (mg/L)



spatially and temporally. The most turbid water was collected from near the Oak Bridge and the Beaver Dam. The clearest water was sampled near the Hidden Falls and the Downed Bridge (Figure 3).

The water upstream of the Beaver Dam is stagnant and supports a heavy crop of algae. This leads to decreased water clarity. The Oak Bridge site just downstream of the Beaver Dam also has algae-laden waters, in addition to sediment runoff from the trails that cross the stream.

Unlike the Beaver Dam and the Oak Bridge, Hidden Falls' water is quite transparent. It is far enough downstream, roughly half a kilometer, to avoid the algae. Furthermore, its nutrient concentrations are generally low, as will be discussed later in the abstract, and thus there is little of the biochemical material needed to promote algal growth. Our sampling site for Hidden Falls was in a large pool,



giving any suspended sediment a chance to settle. Surprisingly, the Downed Bridge is also clear. It was a construction site with fast-flowing water, loose sediment on the step banks on either side of the stream, and often a backhoe parked in the middle of it. Despite these factors, all of its transparency measurements were high.

The transparency of our sampling sites nearly halved after the rain on July 22 and 23, which carried fine sediment into the stream from fields, hill slopes, and stream banks. Transparency then increased gradually at most sites over the following days to better than its pre-rain condition. Our study area lies on the border of Aggregate Ecoregions VI and VII, each of which has a very different standard. Unfortunately, the EPA standard is measured in NTU (Nephelometric Turbidity Units) while our measurements are in cm (EPA, 2000). We know of no reliable way to convert between these two units.

Nitrogen

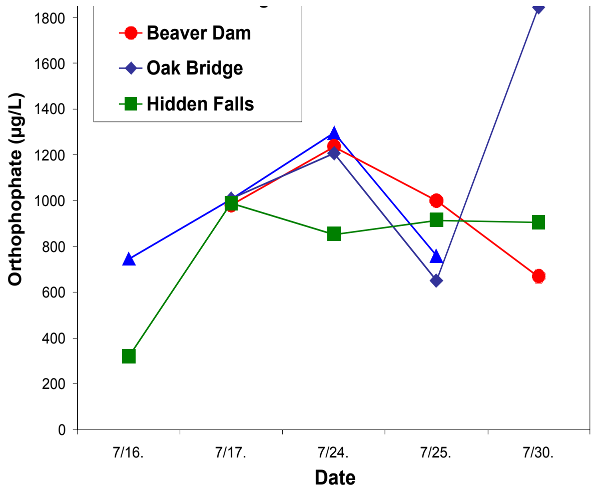
Nitrogen in the form of nitrate and nitrite may occur naturally in streams but is also correlated to human activities such as "fertilizer application, nitrogen fixation by legume crops, human and animal waste disposal, and fossil fuel combustion" (Peterson et al., 2001, pg. 86). Since the section of Prairie Creek that we studied was mostly within a state park, agricultural runoff was limited to flow from the tributaries which carried water only after rain events. Because of this, the nutrient levels were lower than is usual for this area of the country. The differences in nitrogen levels among our sampling sites still warrant attention. The levels of nitrate measured as nitrogen found near the Downed Bridge were consistently higher than the levels at any other sampling site (Figure 4).

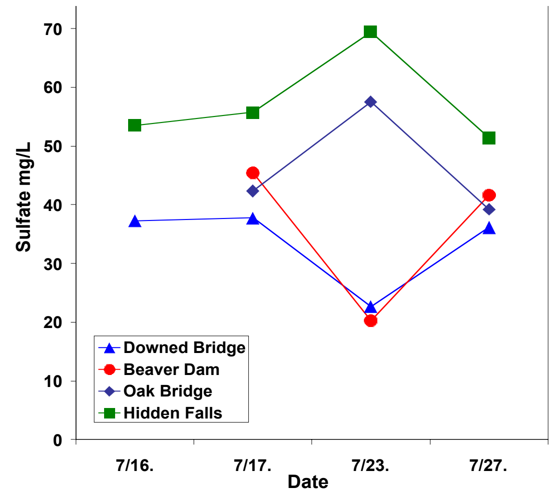
The Downed Bridge was a construction site at the time of our study, with a lot of loose dirt on its banks that would wash into the stream when it rained. It is also the site nearest to agricultural land. The concentration of nitrogen recorded in our study area fell after the rain event on July 23, probably because the nitrogen was diluted by the larger amount of water. Determining if our nitrogen levels are reasonable by EPA standards is difficult. By Aggregate Ecoregions VII's nitrogen standards, a range of 0.46 to 1.88 mg/L, all the readings taken at the Downed Bridge are distressingly high. Even by Ecoregion VI's more generous nitrogen range of 1.16 to 3.26 mg/L (EPA, 2000) there are still two days on which are nitrogen readings at Downed Bridge were too high.

Orthophosphate

Phosphorus is a nutrient that, like nitrogen, can be related to human activity. The amount of phosphorus within a stream correlates with the amount of sediment runoff more strongly than nitrogen does. We measured phosphorus as orthophosphate. Our results demonstrate this. The sampling sites whose transparency measurements indicate the highest sediment content (the Downed Bridge, the Beaver Dam, and Oak Bridge) consistently contain much more orthophosphate than the Hidden Falls pool (Figure 5).

This is especially evident on July twenty-fourth, the day after the heavy rainfall. Samples for the Downed Bridge, the Beaver Dam, and the Oak Bridge taken on this day all show an orthophosphate concentration of over 1200 µg/L. In contrast, the phosphorus concentration for the Hidden Falls pool was 854 µg/L. Sediment input from tributaries clearly influenced the phosphorus concentrations of the three upstream sites. Interestingly, the water near Oak Bridge





shows heavy fluctuations in orthophosphate content, ranging from 650 µg/L on July 25 to 1840 µg/L on July 30. The Oak Bridge site is located near both a trail and a tributary stream, and these fluctuations in orthophosphate concentration are most likely due to fluctuations in sediment runoff from one or both of these features. Unfortunately, the EPA criteria for phosphorous recommends a concentration range of 62.5 to 118.3 µg/L in Ecoregion VI and only 20.63 to 80 µg/L in Ecoregion VII (EPA, 2000). Our lowest reading is close to ten times that.

Sulfate

Unlike nitrate and phosphate, the presence of sulfate is not generally associated with human activity. Sulfate appears either where streams come into contact with bedrock or alluvium that contains sulfur or where groundwater that has been in contact with such materials enters the stream (NSW, 1995). The Platteville Limestone, which our section Prairie Creek overlies, is known to contain pyrite, a sulfur-containing mineral. This explains why at Hidden Falls, where the stream is flowing directly over bedrock, we recorded the highest sulfate concentration (Figure 6).

Hidden Falls' Pool shows sulfur levels ranging from 17.1 to 23.2 mg/L. Our other three sampling sites only range from 6.7 to 19.2 mg/L with the high values coming from the Oak Bridge where limestone chunks have been piled in the stream as bridge supports. Most sulfate values dropped after the rain, suggesting a dilution effect.

CONCLUSIONS

The geomorphology of our stream and its banks affects its nutrient content in significant ways. The influence of unusual features, such as Hidden Falls and the Beaver Dam on the stream, combined with the stream's variation in geomorphology, make our section of Prairie Creek difficult to assess.

Our section of Prairie Creek is clearly being affected by the part of the creek further upstream that flows through agricultural areas. This is shown by the high levels of nitrogen and orthophosphate found in our most upstream sampling site, the Downed Bridge. The state park does not buffer the nutrient content of the stream. For instance, the levels of orthosphosphate that we recorded in the central parts of our study area (the Beaver Dam and the Oak Bridge) are higher than those of the Downed Bridge. This indicates that other nutrient sources are entering the stream even while within park limits. Steps must be taken to improve the buffering capabilities of the state park.

The high rates of *E. coli* contamination are a major cause for concern, because water at Hidden Falls' Pool is often used for recreational purposes. Our study found the major point of change in *E. coli* levels to be at the Beaver Dam. It should be kept in mind that the Beaver Dam is not a permanent geological feature. There is no telling when it may break or decompose, perhaps causing the entire stretch of Prairie Creek within the state park to become heavily contaminated with *E. coli.* Management measures must now be taken to isolate the exact causes of the high *E. coli* rates, and to deal with them appropriately so that the rates decrease.

Prairie Creek has been on the EPA list of impaired streams since 1998 (State of Minnesota, 2000). It is unfortunate that the stream is impaired, and more research is required to improve it. A more thorough examination of this area is needed to fully understand the complex interaction between geomorphology and water quality.

SUGGESTIONS FOR FUTURE STUDY

Future researchers in this area should look into the impact of beavers on our *E. coli* concentrations, and the possibility of *E. coli* filtering through hyporheic flow. Can hyporheic flow significantly change nutrient concentrations? A more general study of how beaver dams change a stream's geomorphology and geochemistry might give insight into our results.

AKNOWLEGEMENTS

Thanks to Professors Mary Savina and Bereket Haileab for all of their knowledge and experience. Their help in setting up our project and helping us to understand what we were looking at was invaluable. Thanks to the Minnesota Department of Natural Resources for their willingness to assist us and for allowing us to conduct research inside of the park. Thanks to Christina Kaba for her help and patience and to Professor Gary Wagenbach for helping us with the *E. Coli* testing. Thanks also to the Keck Consortium and Carleton College.

REFERENCES CITED

EPA, 2000, http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/sumtable.pdf, 8/5/01

Francy, D., Myers, D., Metzker, K., 1993, *Escherichia Coli* and Fecal-Coliform Bacteria as Indicators of Recreational Water Quality: U.S. Geological Survey, Water Resources Investigations Report.

Holshuh, I., Unpublished Data, 1999

NSW Environment Protection Agency, 1995, http://www.epa.nsw.gov.au/soe/95/12_2.htm#Acid_Sulfate_Soils, 8/6/01

Peterson, B.J., et al., 2001, Control of nitrogen export from watersheds by headwater streams: Science, v. 292, p. 86-90

State Of Minnesota, 2000 http://www.pca.state.mn.us/water/pubs/305b-lowermiss.pdf, 8/7/01

Wigington, P.J., 2000, http://www.epa.gov/wed/pages/news/may00/wigin.htm, 8/4/01