# GEOMORPHOLOGY, GEOCHEMISTRY AND SOIL EROSION ALONG AN AGRICULTURAL STREAM

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## INTRODUCTION

The Prairie Creek basin (206 $km^2$) lies within the Cannon River watershed, a major tributary of the Mississippi River in southeastern Minnesota. Much of the area is agricultural land, which creates conflicting interests and competing uses. Farmers use tiling systems to more efficiently drain their land and boost production, but this practice often jeopardizes stream health and soil stability. Various measures, including grassed waterways, channelized waterways with buffers, and natural channels are utilized to protect streams from runoff from neighboring agricultural areas.

In this project, a half-kilometer reach of a small tributary of Prairie Creek was studied to determine how a wooded riparian buffer may be affecting water quality and soil erosion in an agricultural area. Our data support recommendations for future management of the study site, which is currently being evaluated for possible conversion to a prairie wetland.

## BACKGROUND

A number of studies have been conducted in recent years to evaluate the effects of woody vs. grassy vegetation on soil erosion and stream banks. Despite the growing body of research, there is currently no consensus on the topic. Where banks are shallow, grassy riparian vegetation generally has a well-developed root system that is effective in preventing erosion; furthermore, stream channels tend to be significantly narrower in areas with grassy vegetation (White and Brynildson, 1967; Zimmerman et al. 1967; Murgatroyd and Ternan, 1983; cited in Lyons et al,. 2000). The banks are generally narrower than those supporting woody vegetation, due to the grasses' ability to trap and support suspended sediment. Several studies have shown that during a successional transition from grassed to woody buffers, large quantities of sediment are released into the stream (Murgatroyd and Ternan, 1983; Smith 1992; Davies-Colley et al., 1997; Trimble, 1997; cited in Lyons, 2000).

Studies favoring woody riparian buffers note that in streams with banks needing stabilization, willows in particular are known to work well, as their root systems bind soil, reduce bank scouring and trap suspended sediment (Lyons and Courtney, 1990; Isenhardt et al., 1997; cited in Lyons et al., 2000). Woody debris creates dams that slow flood flow through the stream channel and trap sediment, reducing erosion associated with these events (Keller and Swanson, 1979; Gregory, 1992; Shields and Smith, 1992; cited in Lyons et al., 2000).

Aerial photos indicate that from at least 1938 until the 1970's the study area had been managed as a grassed waterway to protect the water quality of the stream and prevent erosion (Coffman, personal communication, 2001). Drainage tiles were installed in the surrounding fields and in the waterway at undetermined times. In the early- to mid-seventies, maintenance of the grassed waterway ceased and natural succession led to the proliferation of woody plants. Over the next several years cropland was lost as the buffer zone expanded. In 1986, the area was officially designated a wetland and fell under the protection of the Swampbuster Act. At present, if the landowner were to plow the area with crops, he would risk losing his federal farm benefits (EPA, 2001).

The Rice County Natural Resources Conservation Service, which is authorized to grant exemptions to the Swampbuster Act, has recently put forward a proposal to replace the trees from the study site with native grasses. Such a project would cost about $10,000.

# METHODS

A survey was conducted of the area using an automatic level and stadia rod to produce a map of the reach (Fig. 1). In addition to mapping the stream (approximate length = 625 m), the channel width and depth were determined at each of 98 survey points. Cross-sections were taken at seven sites according to geomorphic type and overall accessibility. Measurements were also taken in areas of severe gullying to quantify erosion.

Vegetation was characterized at each point. The abundance of large trees was rated on a 1-5 scale, 5 corresponding to the highest density. Species composition of large trees was determined and relative abundance visually estimated to the nearest 5% (a typical site might have 60% box elder, 20% willow, and 20% ash). Understory vegetation was classified as woody, grassy, or mixed and rated on a 1-5 scale for density. The amount of debris in the stream was also noted.

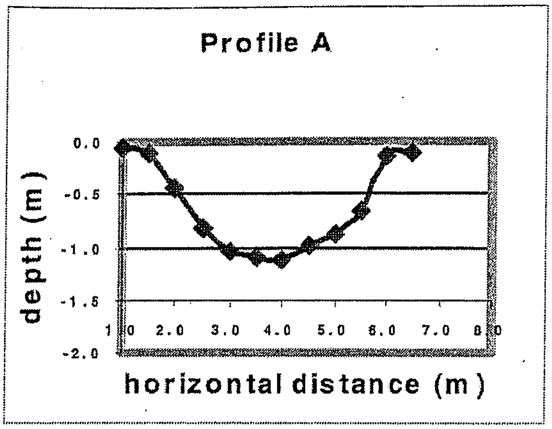
Water samples were taken at four sites on two separate days and analyzed in the field and the lab. In the field, water was tested for dissolved oxygen, pH, salinity, temperature, turbidity and conductivity. In the lab, samples were analyzed for anions using a HACH Colorimeter and an Ion Chromatograph.

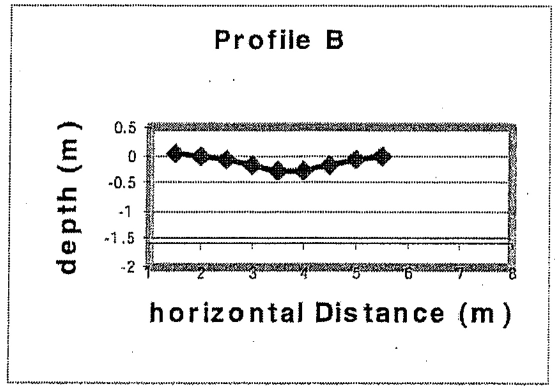
Soil cores were taken at two sites along each margin of the buffer. The samples were taken to the depth of the water table, which varied from 0.7 - 0.8 m, and identified using standard field soil description methods.

# RESULTS AND ANALYSIS

## Channel Geomorphology

Cross-sections reveal substantial differences in channel width and depth along the length of the reach (Fig. 2). Profile C is in one of the few grassy areas along the buffer. The profile is narrow, 3.5 m, and shallow, with relief of .2 m. Profile B, located in a denser, woodier area 25 m North, is wider than C (5.5 m), but maintains a similar depth. In contrast, cross-sections directly below man-made structures are noticeably wider and deeper than their natural counterparts. Profile A is located 475 m downstream from B and immediately downstream from a 3-foot diameter concrete pipe exposed in the channel. Here, the channel is 6 m wide, with nearly 1 m relief. Similarly, at Profile D, which is situated below a culvert crossing County Road 29, the stream has a width of 9.5 m and 1.5 m of depth.




Channel geomorphology appears to be directly related to the volume of water passing through the area. Cross-section D is both the widest and the deepest section of the stream. During storm flows, the large culvert upstream feeds a high volume of water into the stream in a short time. In contrast, cross-sections B and C are located in areas where there was little or no water during the study period, and the lack of water appears to have resulted in flat, shallow channel.

## Water Quality

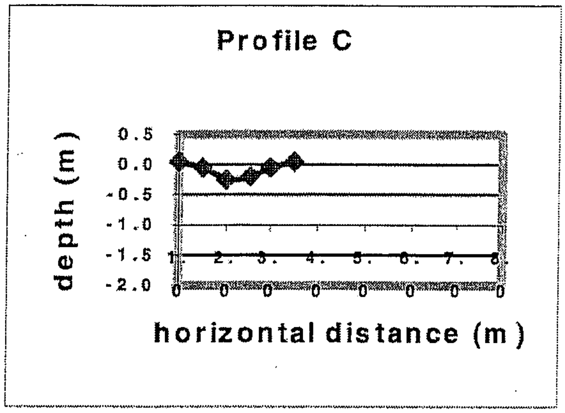
Despite changes in canopy cover, the temperature of the reach remained relatively constant at around 20 C° (Table 1).

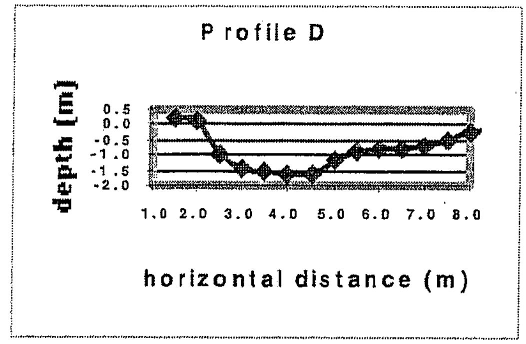
Dissolved oxygen decreased steadily downstream until a confluence with a larger stream. The dissolved oxygen was highest at site 4, at 7.16 mg/L; the lowest value was found where a drainage tile empties directly into the stream at site 3, where the concentration was 2.17 mg/L. Transparency increases downstream, to a high at site 2 of 74.6 cm. Once the stream intersects the larger tributary, transparency decreases to 47.1 cm. Phosphate levels at sites 1, 3 and 4 range between 0.36 and 0.88 mg/L, while the level at site 2 is 1.78 mg/L. Nitrate levels ($NO_3^-$) decline below the roadside culvert, reaching a low of 21 mg/L. At the entrance of the tile at site 3, the nitrate level rises to 24 mg/L. Again, below the influx of water from the larger stream, the nitrate level dropped to 12 mg/L. Nitrate values are reported as Nitrogen.

The water chemistry of the area is strongly impacted by the tiling system meeting the stream at site 3. The nitrate levels at this site were much higher than the rest of the stream, presumably from the runoff flowing through the tile. Extremely shallow water and muddy ground are likely responsible for the phosphate peak at site 2. The phosphate readings, which were relatively high throughout the study area, reflect high levels of sediment in the water.

## Soil and Erosion

According to the Rice County Soil Survey, the length of the study stream lies in Epsom 761 soil series. The parent material in this area is loess over till. This soil is poorly drained; permeability is moderate in the upper alluvium and loess, and moderately low in the underlying till. The native vegetation of the soil is water-tolerant prairie species (USDA, 2001).



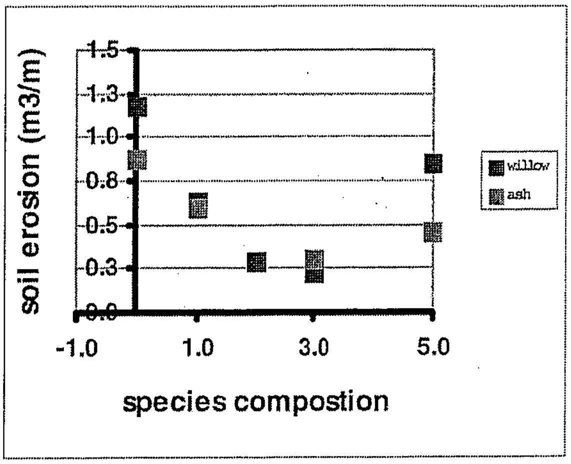

Soil cores on the eastern and western sides of the stream revealed a water table depth of 70 cm and 80 cm, respectively. At 36 cm on the east side, the soil grades from a dark, organic-rich silt loam material to a light tan sandy loam. The western side, includes three distinct horizons: a dark, organic-rich silt loam to 33 cm below the surface, followed by a light tan, silty clay, and light tan sandy loam immediately above the water table. Field observations are consistent with the Epsom 761 soil series.

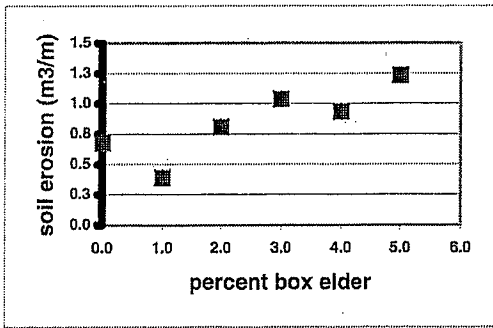
Soil erosion rates were determined using the surveying data for the stream channel and particularly large gullies. Rates represent only the soil that has been directly displaced by the establishment of the stream channel. Soil loss was estimated by multiplying the stream width and depth for each survey point and is expressed as $m^3/m$, or cubic meters of soil eroded for each meter of stream length. These rates, as well the channel width, were then analyzed in relation to several variables, including overall abundance of large trees, independent of species; species composition of large trees; amount and type of understory vegetation; and location relative to drainage tile. This data can be found at the Keck Consortium website.

## DISCUSSION

The site is dominated by forested vegetation, with box elder, willows, ash, and elm present. Channel width was noticeably greater in areas with a higher abundance of large trees. As the abundance of trees increases, channel shape changes, but the total volume of eroded material is not affected. Presumably this is because different tree species in the study site have divergent effects on channel morphology, so that erosion rates differ depending on which species is locally dominant. Soil erosion was consistently lower in areas dominated by ash and willow trees (Fig. 3).
Box elder trees have an opposite correlation: as the relative abundance of box elder trees increased, soil loss rises proportionally (Fig. 4).

A correlation exists between increased density of understory vegetation and reduced channel width for both woody and grassy or mixed areas. Points with grassy or mixed vegetation exhibit slightly lower channel widths than areas with woody vegetation of comparable density. However, there are few sites in grassy or mixed regions and hence very little data




available on these vegetation types. Soil erosion is dramatically higher in areas of relatively dense woody understory vegetation than in areas of light coverage.

Areas of dense grassy or mixed understory vegetation are associated with low rates of soil erosion compared to similar woody areas and areas of lighter grassy or mixed cover. Again, due to the small number of survey points in the study characterized by grassy or mixed vegetation, this cannot be considered conclusive. Still, these results indicate that dense grassy vegetation may be more effective than wooded areas at controlling erosion.

Though broken tile was observed at several sites within the study area, only one fully functional drainage tile was noted, just downstream from County Road 29. The average rate of erosion downstream from the tile is much higher than the upstream rate (1.506 $m^3/m$ vs. 0.423 $m^3/m$), suggesting that tiling contributes significantly to soil erosion. Exposed pieces of broken tile were also found in a large gully extending some 28 m back from the stream, indicating that intense headward erosion occurred where this tile originally entered the stream.

# RECOMMENDATIONS

While the primary factor shaping our recommendations was how to best control soil erosion, other important issues included cost-effectiveness, disturbing the least amount of land possible, and producing a solution that is acceptable to the public at large. Although the NRCS is authorized to remove trees from the protected area, they must first convince the landowner of the appropriateness of their action.

After analyzing the data, it is clear that the intact drainage tile should be plugged or removed. This would halt the constant flow of nutrient-rich water into the stream and reduce peak flow during storm events, substantially decreasing the erosion rate downstream.

The other recommendation is to remove the box elder trees from the buffer zone. Although the trees are numerous in the area, they do not effectively prevent bank erosion. There are several possible ways to change the current vegetation pattern. One option is to leave the buffer as it is and wait for ecological succession to run its course. Box elder is a first order succession plant that establishes itself quickly in disturbed areas, but is soon replaced by more shade-tolerant species such as ash, elm, and willow. A second option is to speed the succession process along by selectively removing box elders. Saplings of other species could be planted to further encourage the transformation. The final option follows the proposal from the NRCS to remove the wooded buffer entirely and replace it with native grasses. The soils in the area are prairie soils, so grass should be quite successful in the area. The data suggest that replacing the woody vegetation with prairie grass may effectively decrease the erosion of the banks, assuming the vegetation reaches a relatively high density. However, it is important to note that we have little data on the effects of grassy vegetation on our study site. Therefore, a strong recommendation cannot be made to proceed with the NRCS proposal without further study.

# SUGGESTIONS FOR FUTURE RESEARCH

- Further study the effects of removing trees from a wooded riparian buffer on channel morphology and channel switching.
- Compare this stream to similar streams with predominantly grassy vegetation, as well as streams with areas of both woody and grassy vegetation. This will provide a more complete picture of the effects of vegetation on both erosion and channel morphology.
- If the transition from a woody buffer to grass does occur, the long- and short-term effects of the transformation on erosion and water quality should be monitored.

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