

Spatial and Temporal Trends of Nutrient Loading in the Spruce Creek Watershed

Caitlan Zlatos, Elizabeth Diesel, Evan Teeters, David Lehmann, and Ryan Mathur
Dept. of Geology, Juniata College

Background

Spruce Creek is seven miles long and flows through an area of karst topography in Huntingdon County, Pennsylvania. It is a nationally renowned trout fishing stream where many people, including former President Jimmy Carter, go each year to vacation and fish. In recent years, it has experienced declines in its rainbow and brown trout populations.

This environmental problem has many negative effects:

- Tourism and recreation businesses that bring money to the local economy suffer losses
- The fact that Spruce Creek is a tributary of the Little Juniata River, which flows into the Juniata River, consequently affects the water quality of the entire Juniata River watershed
- Human health concerns arise because the Juniata River drainage basin provides water for residential and industrial use to a multi-county area less than 20 miles downstream of Spruce Creek, including the Alexandria, Huntingdon, and Petersburg municipalities.

The main factor thought to contribute to low water quality in the Spruce Creek watershed is agricultural runoff. This is because Spruce Creek flows through a heavily agricultural area (including both traditional livestock farms and Pennsylvania's largest Concentrated Animal Feeding Operation). High amounts of nutrients (nitrate and phosphate) can enter surface water through agricultural runoff. Thus the primary focus of our study is nitrate and phosphate concentrations.

Problem

The decline in fish populations of Spruce Creek necessitated an explanation of the causes of the stream's poor water quality. This problem led to the question of how land use (and thus agricultural runoff) is related to water quality.

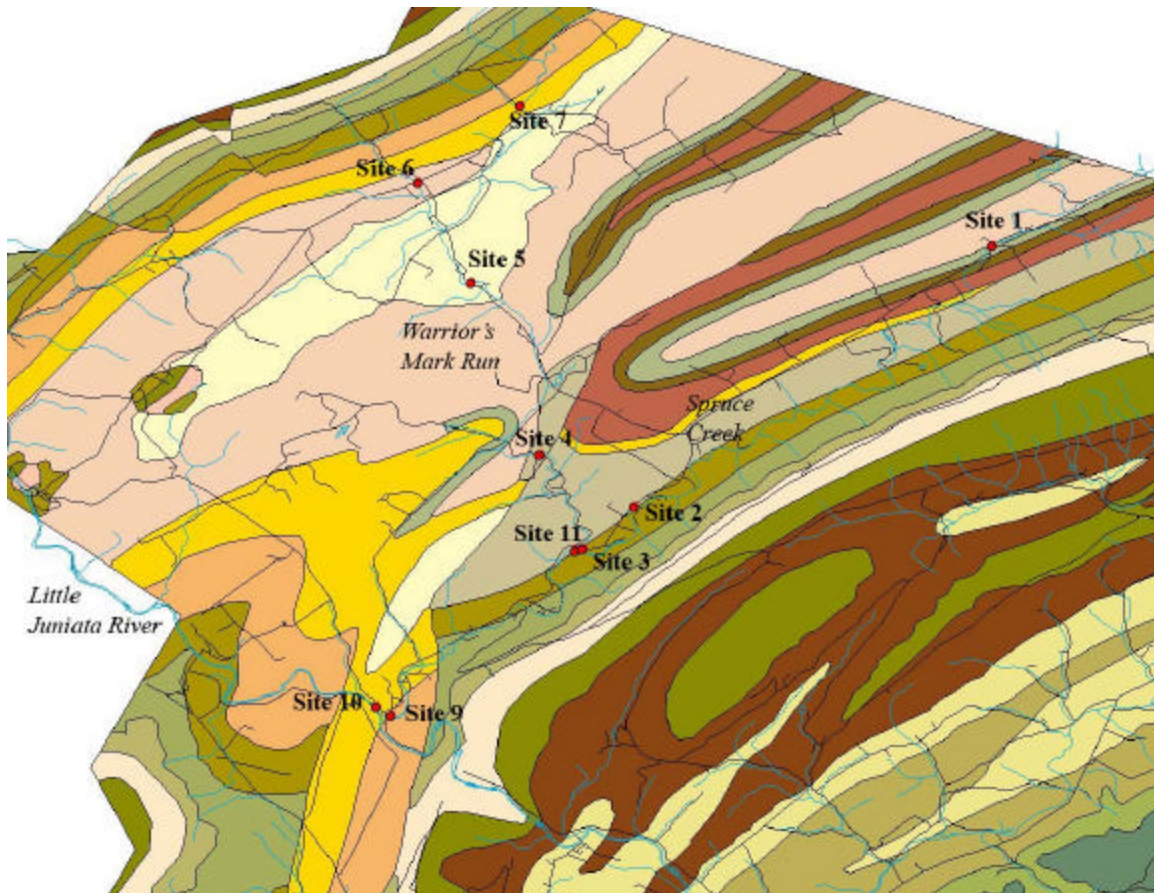


Figure 1: Map of Sites Along Spruce Creek, Warrior's Mark Run, and the Little Juniata River.

Hypothesis

Our study based itself on the hypothesis that water quality correlates with surrounding land use. More specifically, agricultural runoff leads to nutrient loading, which in turn causes poor water quality and fish deaths.

Methods

Sampling

Samples were taken from ten sites along both Spruce Creek and one of its major tributaries, Warrior's Mark Run, as shown in Figure 1. Sites were chosen both upstream and downstream of agricultural areas in order to observe variations in nutrient concentrations. Samples were taken 5 days per week during the summers of 2002 and 2003, and twice a week during the other seasons. We sampled this frequently because the source of nutrients in the stream could be controlled by discharge and/or agricultural land use.

Laboratory Procedure

Nitrate concentrations were obtained using a cadmium reduction method. Phosphate concentrations were obtained from a reaction with potassium persulfate followed by a sulfuric acid digestion. Procedures for these analyses appear in the HACH DR2000/Spectrophotometer Laboratory Procedures Manual.

Results

Spatial

Over the two-year span of data, the highest nitrate concentrations most consistently occurred at Site 2, the site immediately downstream from the CAFO. For example, during the summer of 2003, Site 2 had the highest nitrate concentrations on Spruce Creek for 21 out of 48 sampling days. Site 1, the site immediately upstream from the CAFO, consistently had lower nitrate concentrations than Site 2. During the summer of 2003, average nitrate concentrations along Spruce Creek ranged from 10.4 to 11.4 mg/L, as shown in Table 1. Site 2 had an average concentration of 11.3 mg/L while Site 1 had an average of 10.4 mg/L. During the same season, concentrations for Warrior's Mark Run (which flows through traditionally farmed land) ranged from 9.0 to 13.9 mg/L (Table 1).

In the fall and winter, average phosphate concentrations in Spruce Creek were higher below the confluence with Warrior's Mark Run than above it. For instance, during the fall and winter of 2003, Site 4 had an average concentration of 0.450 mg/L, and Site 2 had an average concentration of 0.406 mg/L (Table 2). Additionally, phosphate concentrations increased downstream of the CAFO.

Site Number	Average Nitrate Concentration (mg/L)	Discharge (cfs)
1 (SC)	10.4	200
2 (SC)	11.3	222
3 (WMR)	9.7	80
4 (SC)	11.4	490
5 (WMR)	9.0	71
6 (WMR)	13.8	45
7 (WMR)	13.9	9
8 (WMR)	13.8	21

Site Number	Average Phosphate Concentration (mg/L)	Discharge (cfs)
1 (SC)	0.349	141
2 (SC)	0.406	--
3 (WMR)	0.443	66
4 (SC)	0.450	>200

Table 1: (A) Comparison of Average Nitrate Concentration and Discharge on Spruce Creek (SC) and Warrior's Mark Run (WMR) for the summer of 2003. (B) Comparison of Average Phosphate Concentration and Discharge on Spruce Creek and Warrior's Mark Run Above and Below the Confluence.

Temporal

The summer of 2002 was characterized by drought conditions, while the summer of 2003 was extremely rainy. As a result, discharge was relatively low during the summer of 2002, but relatively high for the summer of 2003. During the wet summer, nitrate concentrations tended to decrease with large increases in discharge, though in several instances this was not the case (Figures 2a). In contrast during the dry summer, nitrate concentrations remained relatively constant and were independent of discharge (Figure 2b).

Phosphate concentrations were minimal during the dry summer (Figure 3). In the wet summer, phosphate concentrations were higher, and did not display a direct correlation with discharge (Figure 4).

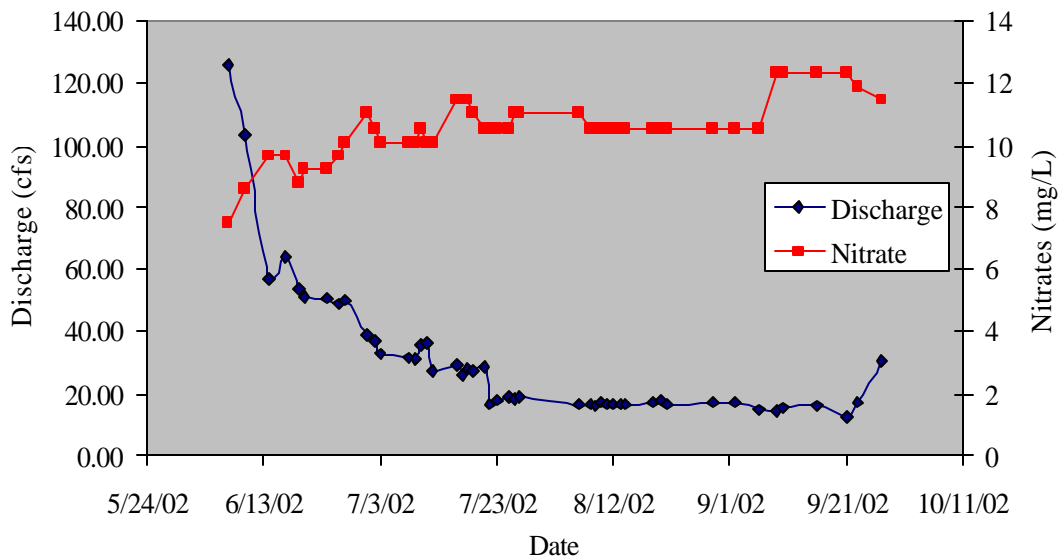
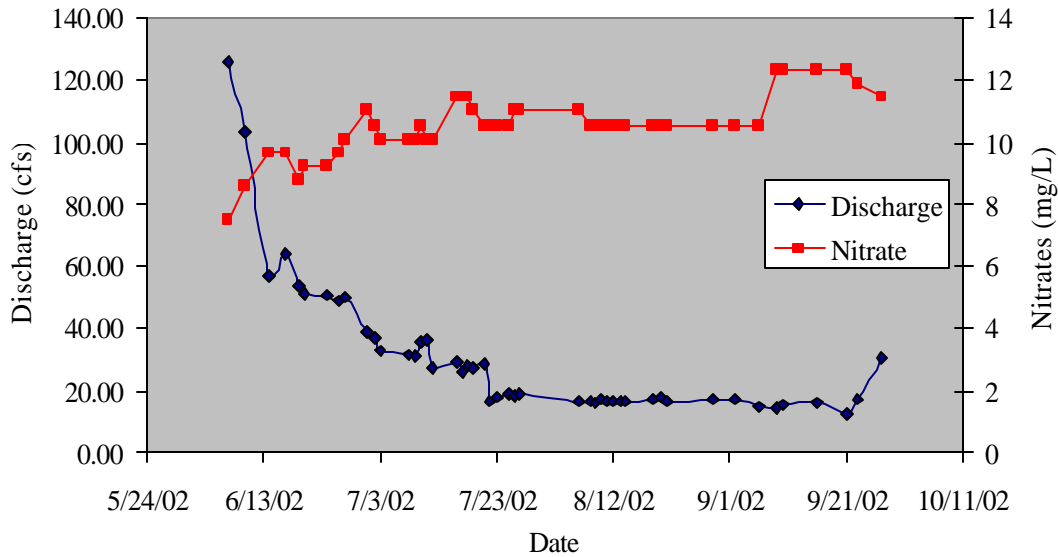


Figure 2: (A) Discharge and Nitrate Concentrations for a Dry Summer (2002) at Site 8. (B) Discharge and Nitrate Concentrations for a Wet Summer (2003) at Site 1.

Discussion

Nitrate and phosphate concentration data show spatial and temporal relationships. Concentrations vary between sites along the streams, suggesting a correlation between land use and nutrient levels. The fact that the highest nitrate concentrations were consistently at the site immediately downstream of the CAFO indicates a greater amount

of nutrient loading due to agricultural runoff. This is supported by the fact that nitrate concentrations were consistently lower upstream from the CAFO than downstream. Nitrate concentrations for Warrior's Mark Run are higher than those of Spruce Creek, but the fact that the discharge of Warrior's Mark is several orders of magnitude less than that of Spruce Creek suggests that dilution plays a role in lowering concentration values on Spruce Creek (Table 1). Nutrient data exhibit a strong relationship with seasonal precipitation. The summers of 2002 and 2003 differed radically in this respect. The fact that nitrate concentrations decreased with increasing discharge in the wet summer indicates a dilution effect (Figure 2a). The independence of nitrates from discharge in the dry summer indicates that under dry conditions nitrates behave differently (Figure 2b). The low phosphate concentrations indicate that discharge must meet a requisite threshold value in order for phosphates to enter the stream (Figure 3).

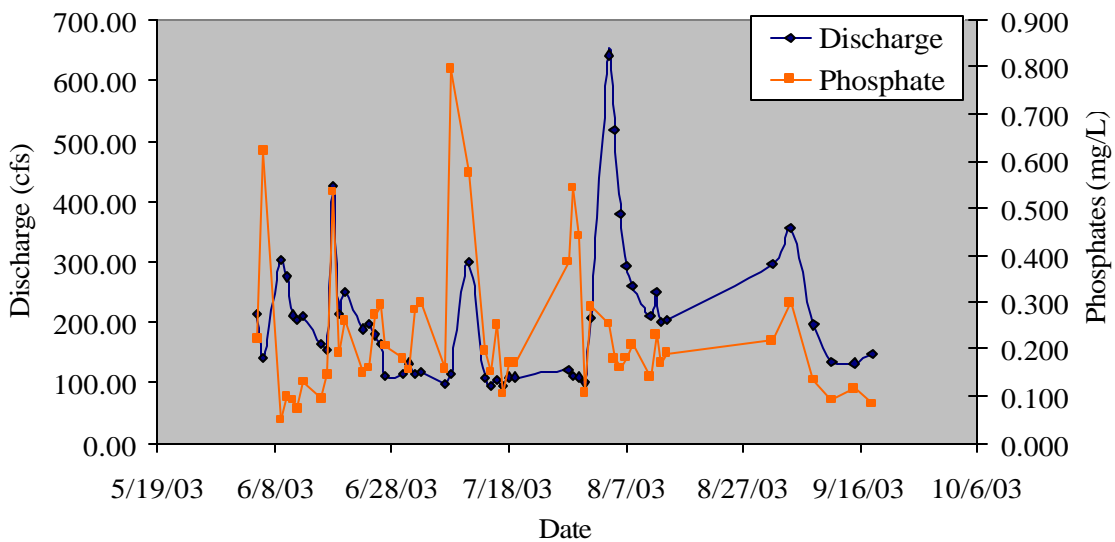
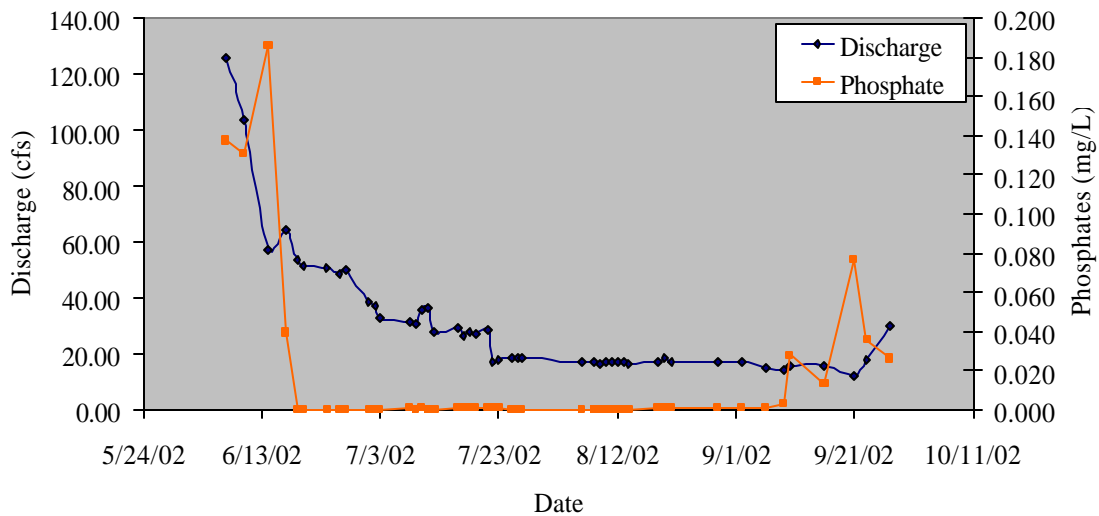


Figure 3: (A) Discharge and Phosphate Concentrations for a Dry Summer (2002) at Site 1. (B) Discharge and Phosphate Concentrations for a Wet Summer (2003) at Site 1.

Research plans to further explore these trends include

- Continuation of a recently begun Geographical Information Systems project— Mapping land use patterns will allow us to gain further knowledge of the relationship between land use and nutrient levels
- Measurement of dissolved oxygen levels—Low levels of dissolved oxygen occur as a result of excess nutrients, so collecting such data could help to identify where major sources of excess nutrient loading occur along Spruce Creek and Warrior's Mark Run.

Conclusion

- Nutrient concentrations vary as a result of land use. Total nitrates were higher downstream from the CAFO on Spruce Creek than downstream of the traditional farms along Warrior's Mark Run. This is not immediately apparent because Spruce Creek's high discharge dilutes nutrient concentrations.
- Nutrient concentrations vary with seasonal precipitation.