

# Impact of Drought and Wet Season Conditions upon Nutrient Concentrations in an Agriculturally-Influenced Stream

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## Abstract

*Nutrient concentrations in stream water are inherently dynamic, varying at all temporal scales. The summers of 2002 and 2003 provided a unique opportunity to interpret the relationship between nutrient (phosphates and nitrates) concentrations and annual precipitation changes in an agriculturally-influenced stream, Spruce Creek—coincidentally, one of the premier trout streams in central Pennsylvania. The summer of 2002 was characterized by drought conditions, and the stream showed an overall progressive decrease in discharge. The summer of 2003 was an extremely wet summer, and the stream had high discharge with distinct surges on an almost weekly basis. The lowest stream discharge during the summer of 2003 was significantly greater than the highest discharge during the summer of 2002.*

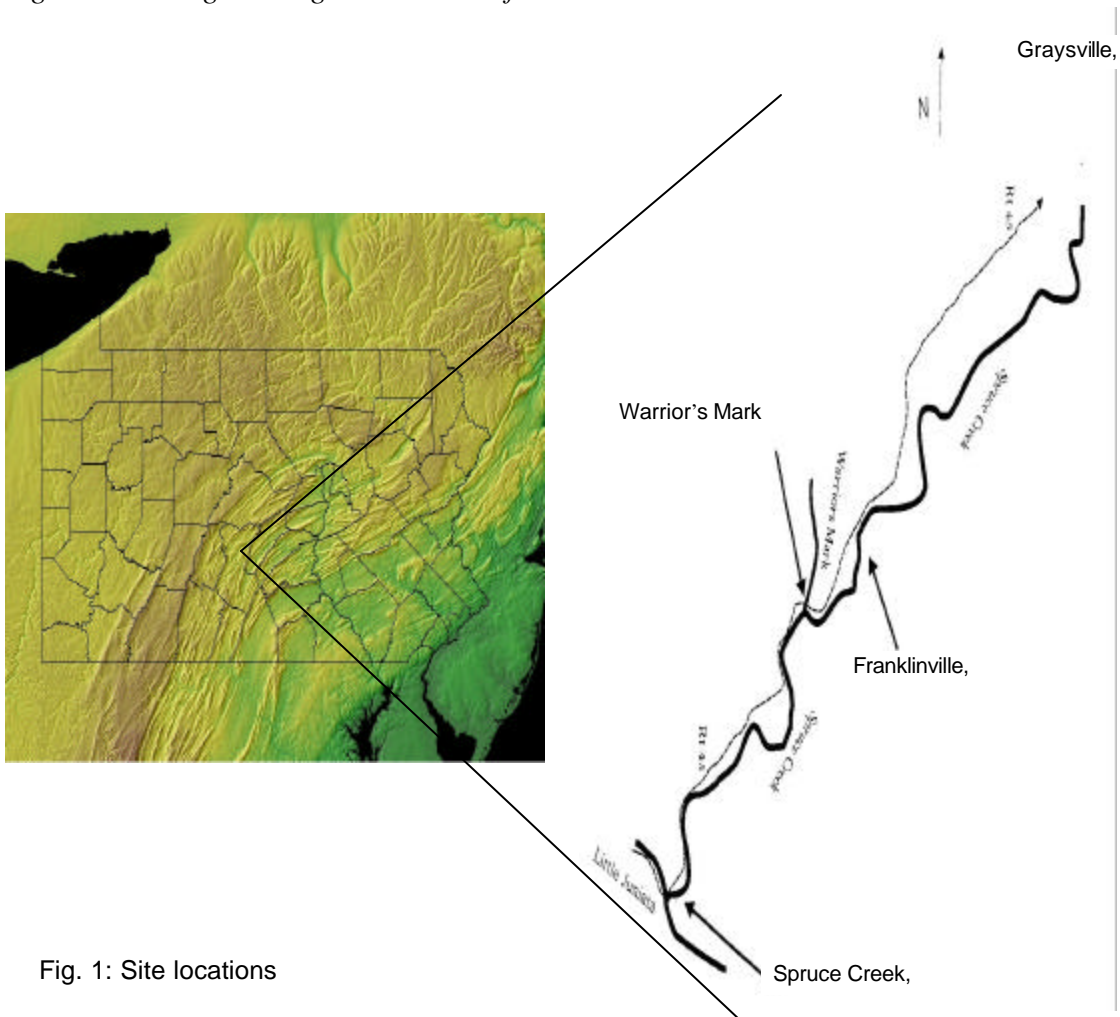
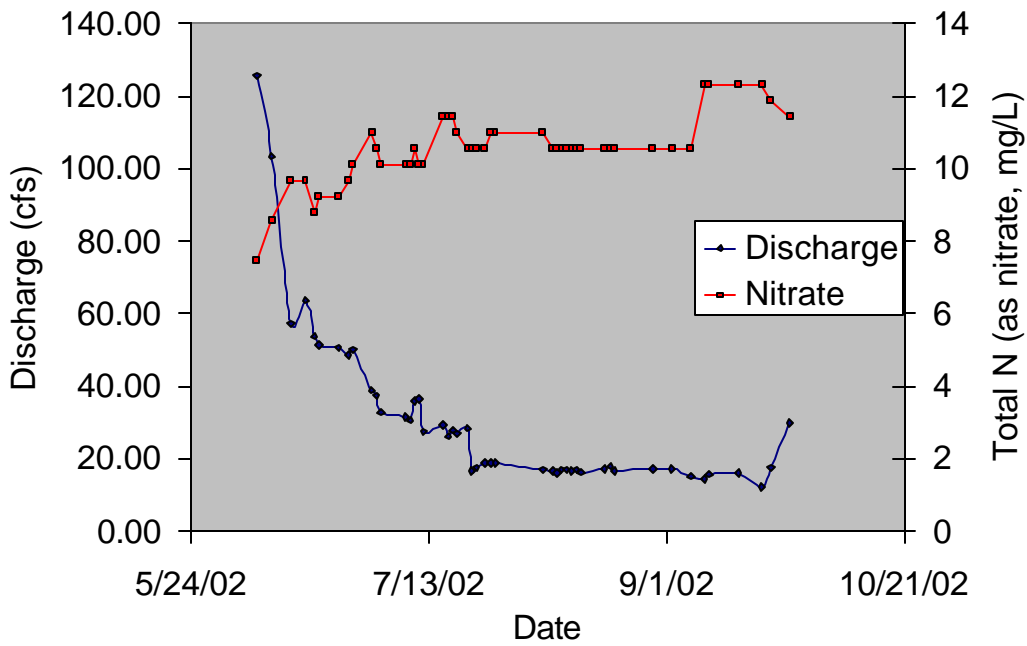


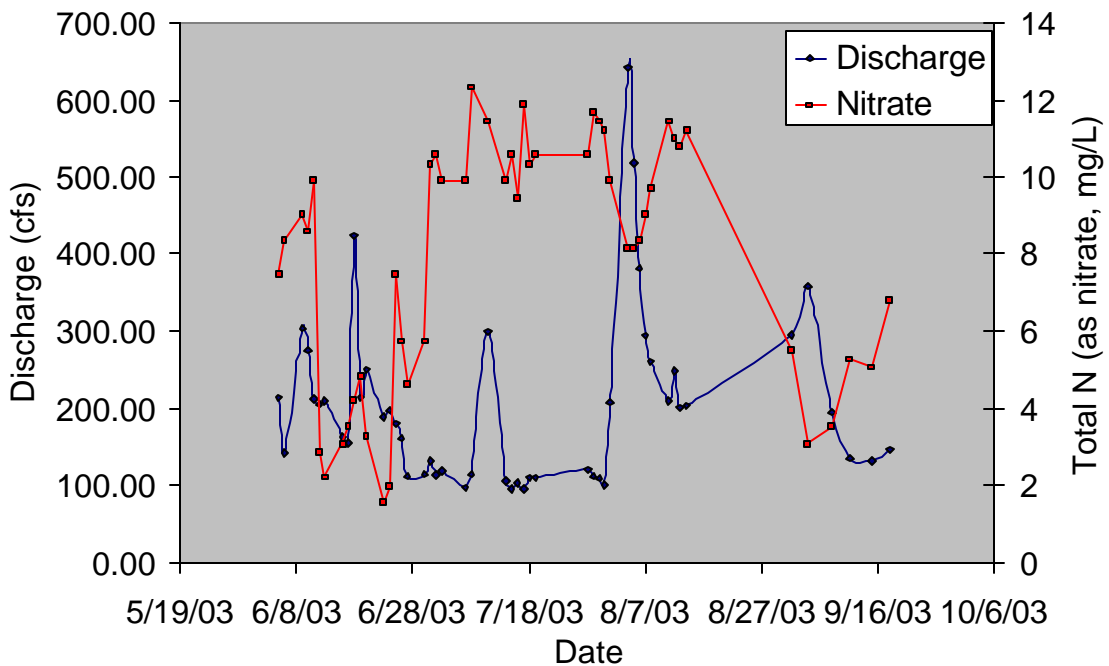
Fig. 1: Site locations

During the drought summer of 2002, phosphate was not effectively delivered to the stream. Peaks in discharge in late spring correlated with increases in phosphorus concentration, and as such, represent transport of phosphorus through surface runoff. During the summer however, peaks in discharge produced no visible change in phosphorus levels. Stream discharge did not reach requisite threshold values (minimum discharge at which phosphates reach measurable values) to effectively transport phosphate to the stream.

Nitrates and discharge 2002 (Graysville, PA)



Nitrates and discharge 2003 (Graysville, PA)



## **Fig. 2: Nitrate Concentrations at Graysville during dry (a) and wet (b) conditions**

*During the wet summer of 2003, discharge was always above threshold values for phosphate delivery. Initial increases in discharge following heavy rains coincide with increased phosphate concentrations. However, maximum discharge, in many cases, resulted in dilution of phosphate concentrations.*

*Nitrates are affected differently by drought and wet summers. During 2002, nitrate concentrations increased as discharge decreased throughout the summer. The relationship between nitrate concentration and discharge was more complex during the summer of 2003. There is a weak relationship between peaks in discharge and in nitrates; however, the magnitude of discharge events is disproportionately high compared to increases in nitrate concentrations. Additionally, the greatest increase in discharge coincides with a decrease in nitrate concentrations. These observations suggest that after sufficiently high discharges, nitrate concentrations are diluted by the large influx of water into the system.*

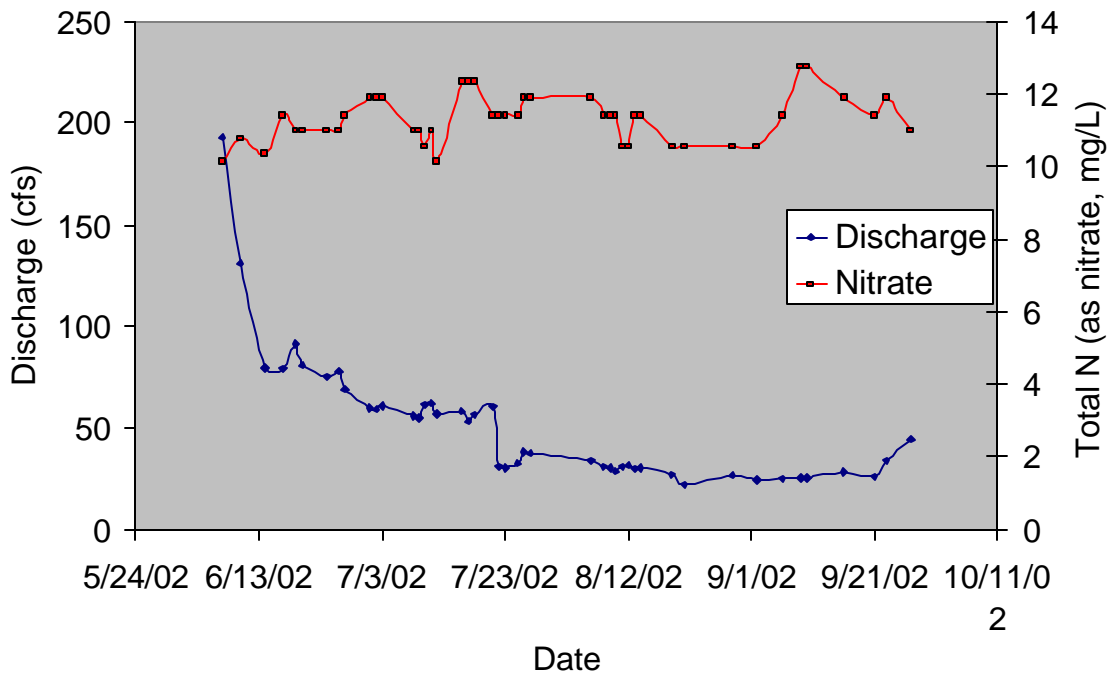
### **Introduction**

Spruce Creek is a small, agriculturally-influenced stream which drains an area of limestone bedrock in Huntingdon and Centre counties in central Pennsylvania. Studies conducted over the past two summers provide an interesting comparison of nutrient transport into the stream under greatly differing conditions. The summer of 2002 and summer of 2003 were dramatically different in rainfall amount and frequency, and in nutrient concentrations in the stream.

This study deals primarily with nitrate and total phosphate levels as indicators of nutrient transport. Students collected samples five days each week for ten weeks during the summer, and one to two times per week during the fall semester. Stream temperature and total dissolved solids were measured on the stream using a HACH sension5, while discharge measurements were taken using a flow probe. Water samples taken from the stream were tested in the laboratory for pH using a HACH sension1. Turbidity was measured directly using the HACH DR2000 Spectrophotometer. Nitrates were tested using a cadmium reduction method while phosphates underwent sulfuric acid digestion; both were measured using the HACH DR2000 Spectrophotometer.

The summer of 2002 brought near drought conditions to central Pennsylvania. Rainfall was very rare, and rain events tended to be very short occurrences. As a result, discharge levels on the stream show a sharp decline through the summer. Most of the water in the stream was a result of base flow, and the hydrographs for the three sites considered for comparison (Figs 2a, 3a, 4a) show a single, large base flow regression. These conditions represent 'dry' conditions on the Spruce Creek watershed.

Nitrates and discharge 2002 (Franklinville, PA)



Nitrates and discharge 2003 (Franklinville, PA)

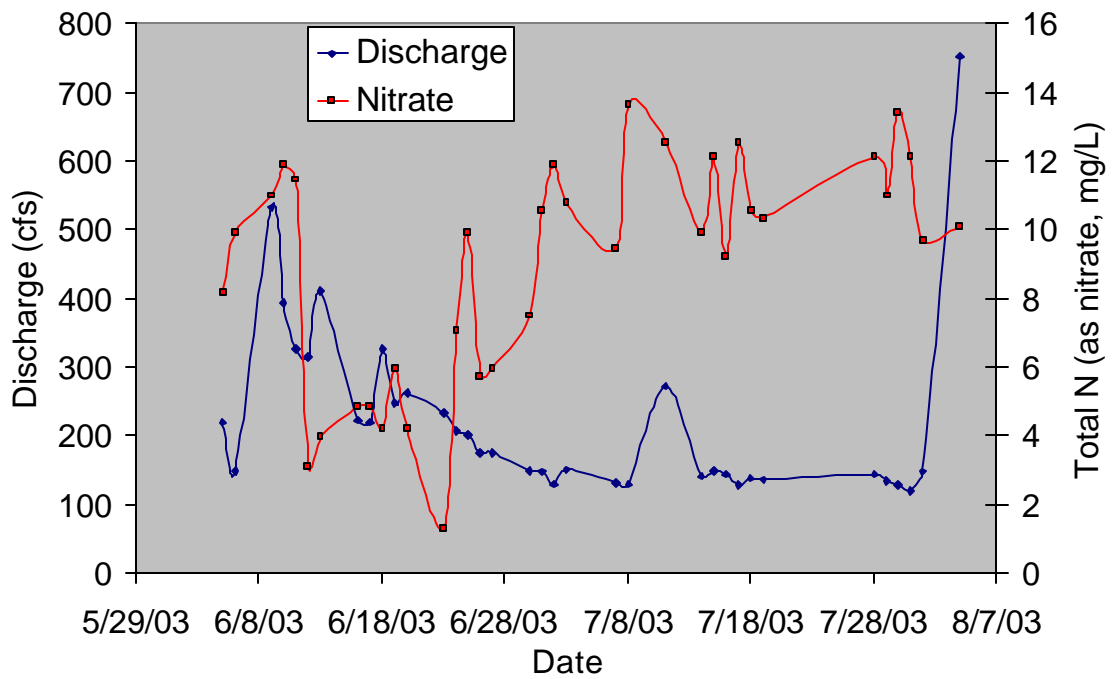
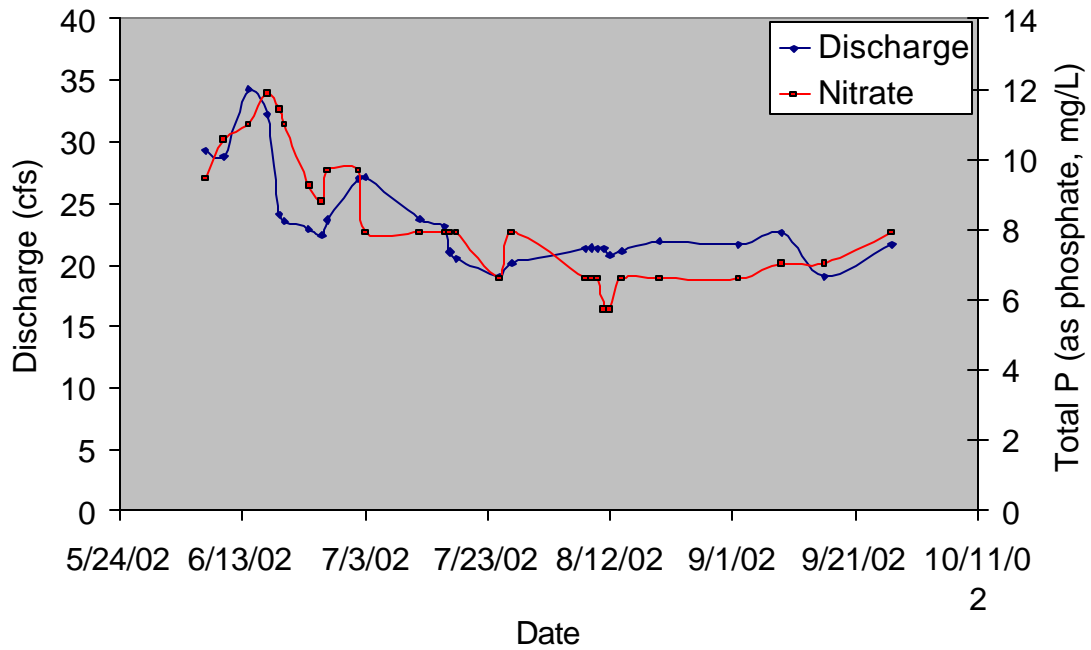
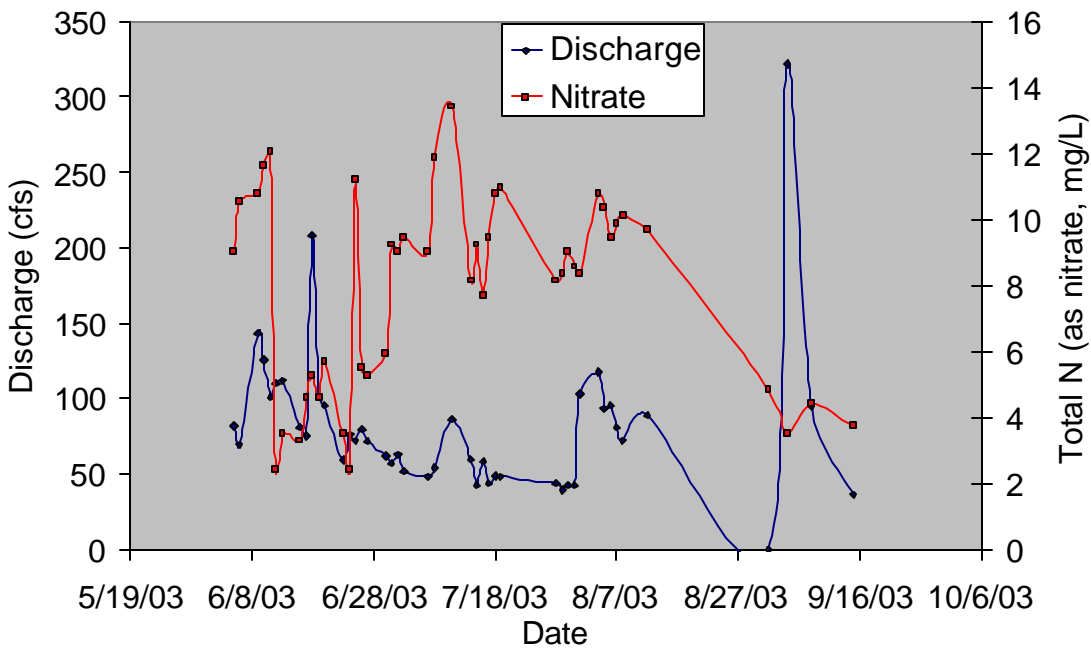


Fig. 3: Nitrate Concentrations at Franklinville during dry (a) and wet (b) conditions

Nitrates and discharge 2002 (Warrior's Mark Run, PA)



Nitrates and discharge 2003 (Warrior's Mark Run, PA)



**Fig. 4: Nitrate Concentrations at Warrior's Mark Run during dry (a) and wet (b) conditions**

The summer of 2003, however, was dramatically different in the area. Rain events were a nearly weekly occurrence and tended to be of longer duration. These frequent events show up as a series of peaks in discharge in Figs 2b, 3b, and 4b. There is an overall increase in stream discharge over the summer, and the minimum discharge for the summer is comparable to the maximum discharge for the previous summer. These circumstances represent 'wet' conditions on the Spruce Creek watershed.

## **Results/Discussion**

### *Nitrate patterns during dry and wet conditions*

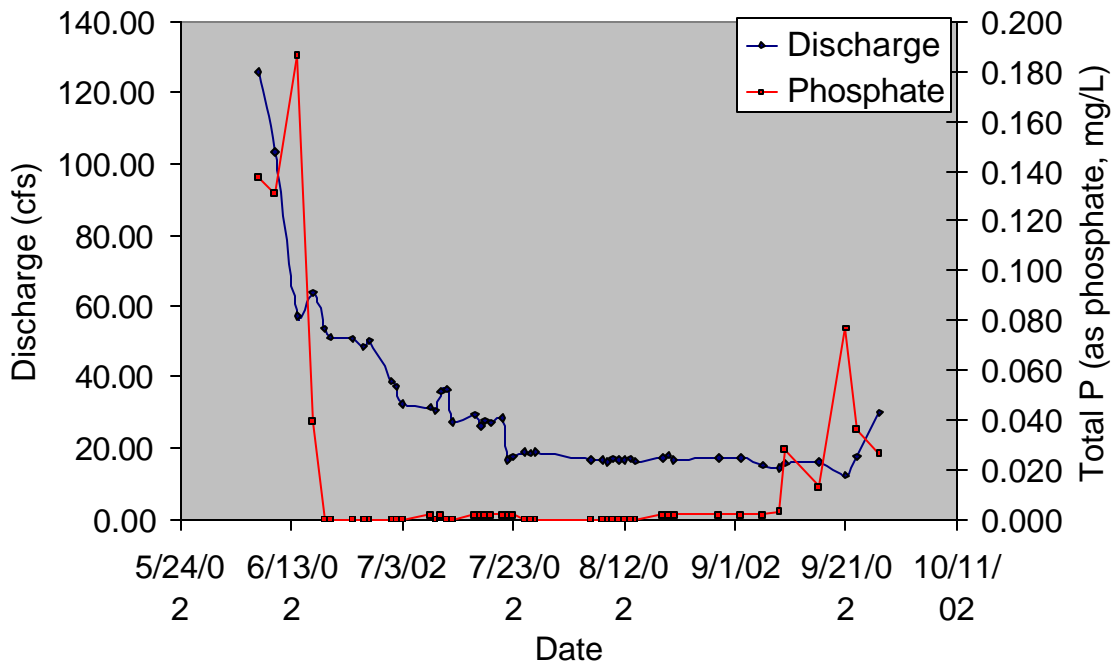
During dry conditions, nitrate transport into Spruce Creek seems to operate independently of discharge (Fig 2a). As noted above, discharge decreases throughout the summer. Nitrate concentrations, however, remain relatively constant over the same time period and show a weak linear increase. The few peaks in discharge do not produce noticeable increases in discharge. This behavior suggests that neither base flow nor runoff sufficiently explains nitrate transport into the stream under dry conditions. Nitrate is continually supplied to the stream throughout the summer, and levels concentrate slightly as flow decreases.

Under wet conditions, however, the relationship between nitrate concentration and discharge is more complex (Fig 2b). In the beginning of the summer, peaks in nitrate correspond temporally fairly well with increases in discharge. In late June-early July, nitrate peaks appear with no apparent increase in discharge. From this point on, there is an inverse relationship between discharge and nitrate concentration – large influxes of water into the stream produce decreased nitrate concentrations.

The influence of overland flow explains most of the nitrate behavior effectively under wet conditions. Smaller rain events (which produce smaller peaks in discharge) wash nitrate from the fields via overland flow, while larger rain events (producing larger peaks in discharge) provide a sufficient volume of water to dilute nitrate concentrations in the stream. Nitrate transport must also occur through some other means to account for nitrate peaks that do not correlate with discharge.

At Franklinville, nitrate concentrations show a similar pattern of weak linear increase over the summer of 2002, even as flows drop dramatically during dry conditions (Fig 3a). This trend is very similar to that demonstrated at Graysville (Fig 2a). During wet conditions, similarities between the two sites persist (Figs 3b and 2b). These similarities argue for related processes of nitrate transport on Spruce Creek proper.

Phosphates and Discharge 2002 (Graysville, PA)



Phosphates and Discharge 2003 (Graysville, PA)

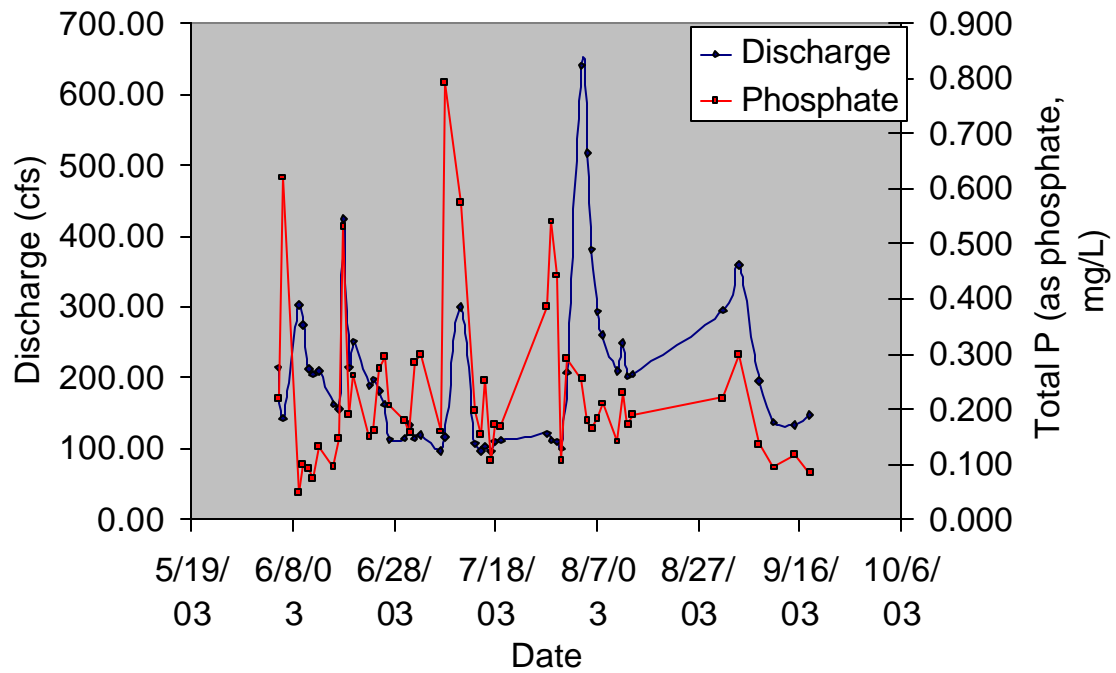


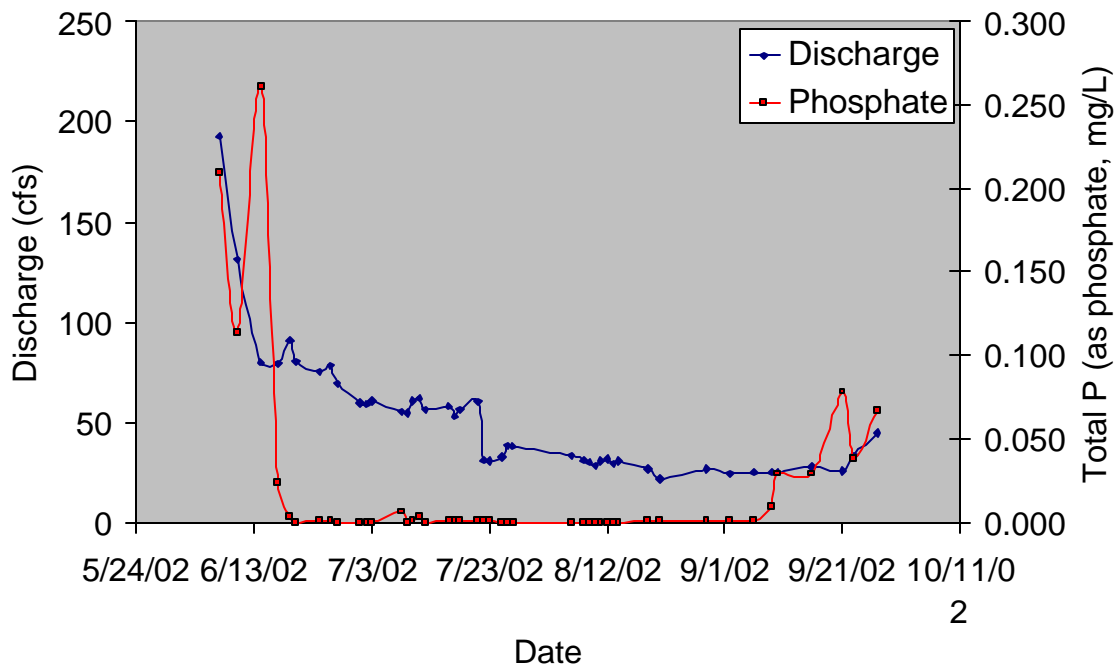
Fig. 5: Phosphate Concentrations at Graysville during dry (a) and wet (b) conditions

Warrior's Mark Run, a smaller tributary of Spruce Creek, shows a different pattern of nitrate transport. During dry conditions, nitrate levels correspond with discharge levels, and transport can be directly attributed to runoff/base flow (Fig 4a). During wet conditions, there is a better correlation between peaks in nitrate and peaks in discharge (Fig 4b) than on Spruce Creek proper. The dilution effects observed earlier in the summer on Spruce Creek appear only with the very high discharge event in September. Overland flow seems to explain nitrate transport during both dry and wet conditions on the smaller stream, with two non-storm related events accounting for the two anomalous peaks.

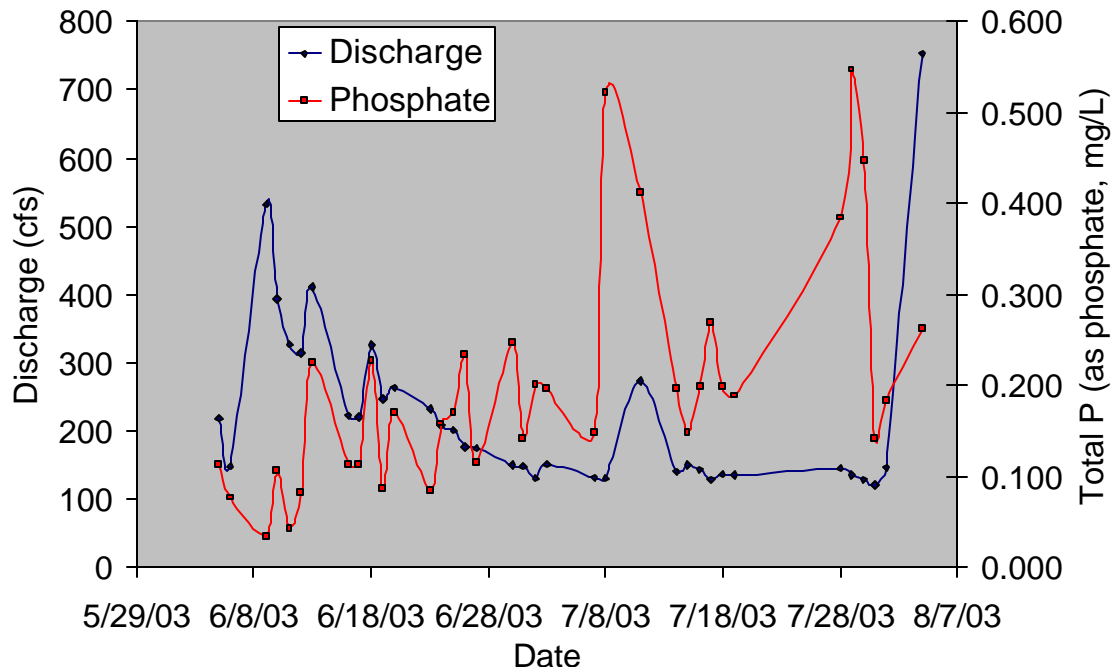
*Phosphate patterns during dry and wet conditions*

During dry conditions, phosphate does not appear in the stream. More likely, the minor amount of phosphate that does reach the stream is quickly used up as the limiting reagent in photosynthetic processes. As Fig 2b illustrates, phosphate levels drop quickly and remain near zero for the duration of the summer as discharge levels steadily decline. This pattern changes only with the arrival of rain in September. These storm events are conspicuously absent from the graph of discharge because of the severity and speed with which they moved through the area. With no overland flow for transport, phosphate levels remain near zero, and increase dramatically only with the onset of rain.

Phosphates and discharge 2002 (Franklinville, PA)



## Phosphates and discharge 2003 (Franklinville, PA)

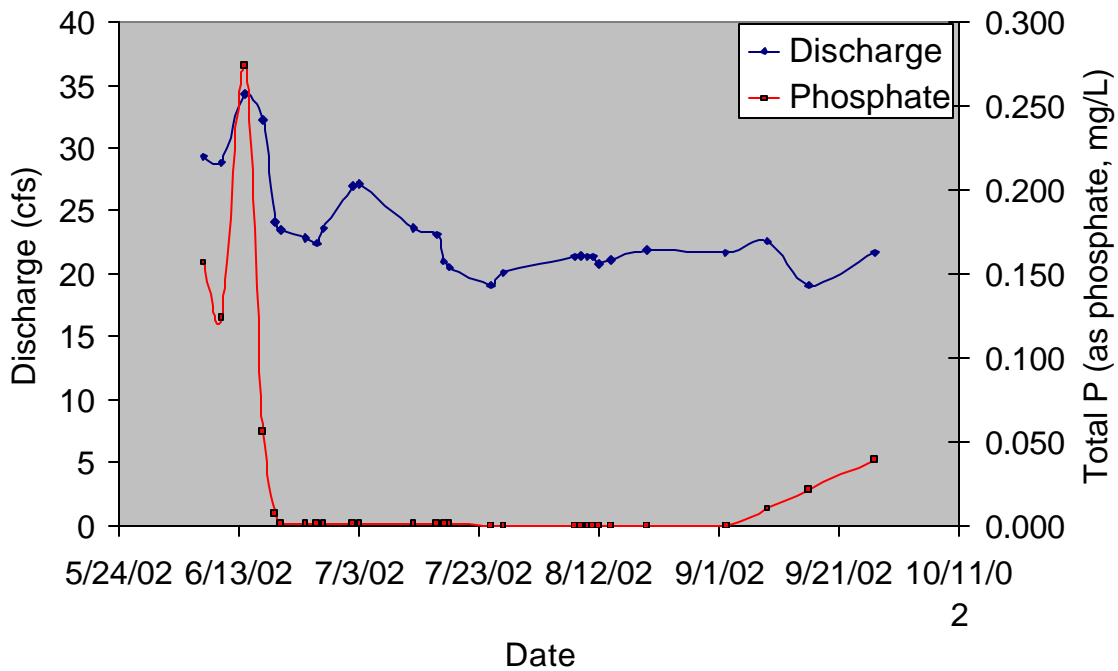


**Fig. 6: Phosphate Concentrations at Franklinville during dry (a) and wet (b) conditions**

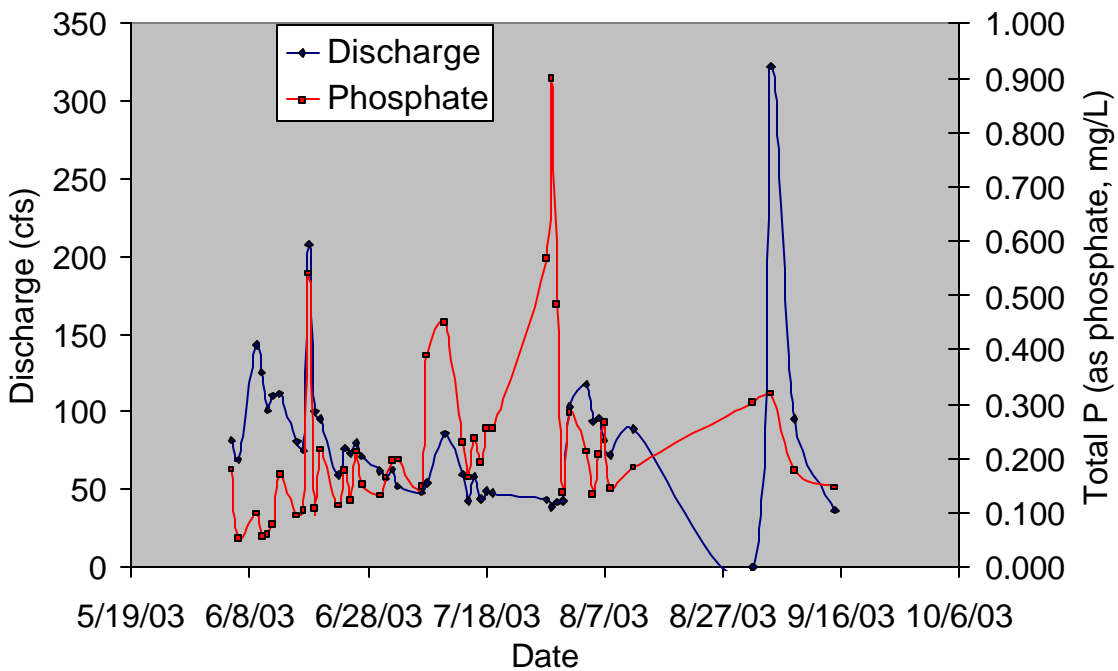
During wet conditions, phosphate transport is much more complex. Through June, peaks in phosphate correspond fairly well with increased flows (Fig 5b). After June ‘ghost peaks’ appear that do not seem to correlate with any particular discharge events, and peaks in phosphate also begin to appear before discharge events. There is no apparent relationship between the height of discharge and the height of phosphate peaks, and dilution of phosphate levels only occurs with very high flows.

Explaining these behaviors is problematic. Overland flow does not entirely account for phosphate transport during wet conditions. If it did, all peaks in phosphate would correspond with peaks in discharge and there would be no ‘ghost peaks.’ However, base flow is also insufficient to explain these ‘ghost peaks.’ The lag time between possible discharge events and ‘ghost peaks’ is too great for base flow to act as the means of phosphate transport into the stream. Hydrologic equations relating distance of source and lag times in discharge peaks reveal source distances that lie well outside of the Spruce Creek watershed. Phosphate transport through the system is very complex, and farming practices must be considered to explain the presence of these ‘ghost peaks’ in phosphate concentration.

Phosphates and discharge 2002 (Warrior's Mark Run, PA)



Phosphates and discharge 2003 (Warrior's Mark Run, PA)



**Fig. 7: Phosphate Concentrations at Warrior's Mark Run during dry (a) and wet (b) conditions**

Again it is interesting to note how these behaviors change at different locales in the watershed. During both summers, the pattern of phosphate concentration at Franklinville (Fig 6) is similar to that at Graysville (Fig 5). These similarities argue that phosphate transport is relatively similar on Spruce Creek proper and that local variations do not explain the complex processes involved.

Although phosphate patterns are similar between Spruce Creek and Warrior's Mark Run during dry conditions, wet conditions lead to somewhat different patterns on the two streams (Fig 7). Peaks in phosphate correspond fairly well with increased discharge, and 'ghost peaks' in phosphate are much less common than on Spruce Creek proper. Overland flow seems to account for much of the phosphate transport, with other means again responsible for anomalous peaks.

### **Conclusions**

In order to understand nutrient transport processes on Spruce Creek, it is important to consider a wide range of conditions. The past two summers have provided an opportunity for observation on the stream during periods of both extremely dry and extremely wet weather. Not surprisingly, the behaviors of both nitrate and phosphate are very different under these conditions. Nitrate continues to appear during dry conditions, while phosphate transport tends to be severely restricted during long dry spells. Transport of both nutrients, however, becomes more complex during extended periods of rainfall.

Interestingly, the two sets of weather conditions represent opposite ends of the spectrum, with minimum water levels during wet weather being well above average flows during dry weather. In order to more fully understand the system, the long range of intermediate conditions must also be considered.

As neither overland nor base flow satisfactorily explain nutrient transport in the Spruce Creek watershed, a careful study of localized agricultural practices is necessary to fully understand the system (for a discussion, see Diesel, et al. *The Effects of Traditional and CAFO Agriculture on Summer Nitrate Levels in Stream Water*, this conference).