Grabow, 1999

Grabow

INTRODUCTION

This analysis focused on detecting a change in water quality due to changes in land treatment in both treatment (Willow and Marshall) and control (Haines) watersheds. Land use was the indicator of BMP implementation used in the analyses. The water quality variables analyzed were total suspend sediment (TSS) and total phosphorus (TP).

Percent of land in no-till and percent of land in continuous cover were used as indicators of BMP implementation. From the graphs in Figures 1 and 2, it is evident that Haines drain is not a classical control watershed, but changes as much or more than the treatment watersheds. It is also clear that the BMP implementation is a gradual change over time versus a discrete, one-time implementation. As such, the initial statistical analysis focused on detecting a trend, rather than a discrete change. Since the monitoring design was effectively a before/after design, explanatory variables were included in the analysis rather than simply the water quality variables as would be done in a paired watershed analysis.

The analysis also sought to determine if there was a correlation between the extent of BMP implementation and water quality.

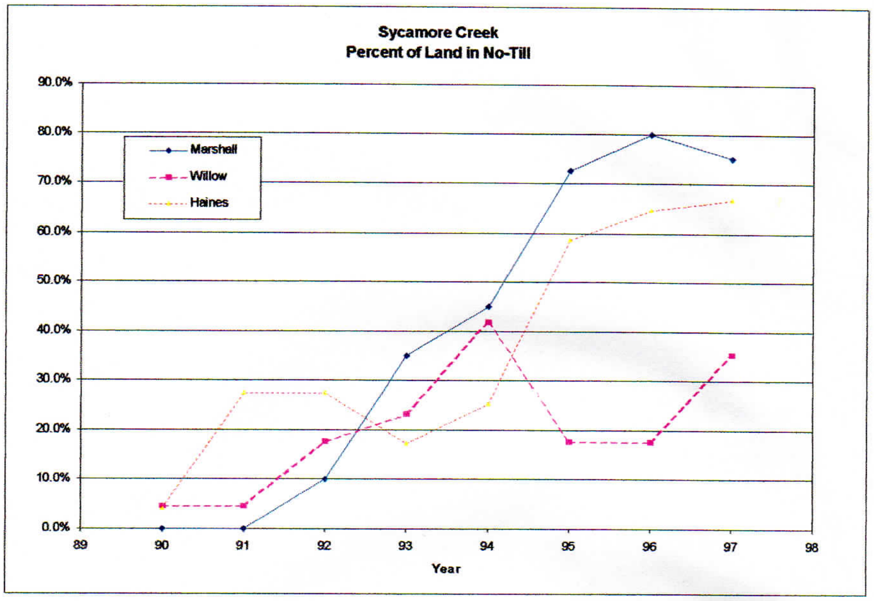

Figure 1. Percent of Land in no-till

METHODS

All three watersheds were analyzed separately. The explanatory variables considered were storm discharge and peak flow. Since discharge, peak flow and sediment data were not normally distributed, but skewed, the data were log transformed for the analysis.

The first step was to perform a regression analysis on sediment yield (TSS in kilograms versus storm

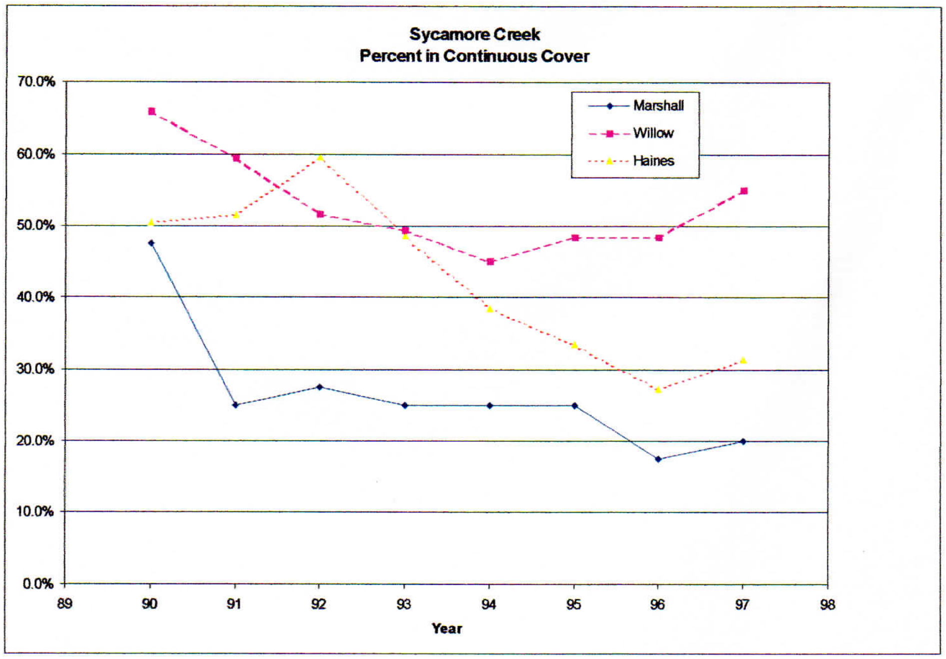

Figure 2. Percent of Land in Continuous Cover

discharge (mm) and/or peak flow (lps). Haines TSS was found to be correlated with storm discharge, Willow Creek was correlated with both storm discharge and peak flow, and Marshall TSS was found to be correlated with peak discharge. These factors were statistically significant. In the case of Willow creek, storm discharge and peak flow were checked for collinearity. The existence of collinearity means that two or more independent variables are highly related and explain the same variability. In this case both peak flow and storm discharge were significant and not collinear. This initial regression process served to remove hydrologic variability, and reduce the analysis to water quality change over time independent of hydrologic variability.

GRADUAL CHANGE IN WATER QUALITY

The first analysis was meant to answer the question, "Is there a trend in water quality over time?". In this analysis, the land use data were not used, but rather the water quality data (sediment yield) and explanatory variables alone.

Two methods were used to answer the above question. The first method incorporates elapsed time in the regression equation with the explanatory variables, while the second method takes the residuals from the regression on the water quality variable and explanatory variable(s) and regresses them versus elapsed time to look for a change. The first method is more "elegant" as it requires only one step.

The question posed by the first method is "Has there been a water quality change over time while **simultaneously** accounting for hydrologic variability", while the second method might be phrased "Has there been a water quality change over time ***after*** adjusting for hydrologic variability"?

The regression equation for method one is:

$$WQ = \beta_0 + \beta_1 Q + \beta_2 Q_p + \beta_3 t \qquad (1)$$

where WQ is the water quality variable of interest, log TSS lbs or log TP lbs, Q is total storm discharge, log mm, Qp is peak storm discharge log lps, t is elapsed time in days, and $\beta_{i,\ I=0,1,2,3}$ are regression parameter estimates. If β3 is statistically significant and negative, there has been a reduction in load over time. By inserting average log values of total storm discharge and peak discharge, and setting the beginning and ending days (1 and 2,629) into Equation (1), the average change in loadings from the inception of data collection to the last available data can be estimated.

The regression equation for method two is:

$$WQres = \beta_0 + \beta_1 t \qquad (2)$$

where t is elapsed time. A trend in the residuals (statistically significant β1) would indicate a change in the relationship between sediment load and the explanatory variable(s) indicating an impact due to land use change. In this case β1*2,629 gives the estimate of the change in loading (in log units) over the data collection period. To find the average reduction, the change in loading is applied to the WQ variable predicted using the equation that generated the residuals, using average values of explanatory variables.

CORRELATION OF LAND USE CHANGE TO WATER QUALITY CHANGE

The next analysis used percent of land in no-till and percent of land in continuous cover percentage as factors. This term was brought into a multiple linear regression analysis along with the terms previously identified (storm discharge and /or peak discharge). If the regression parameter estimate was significant, the implication is that extent of land use in BMPs is correlated to independent variable (water quality). The estimated magnitude of the impact can be determined from the regression coefficient.

RESULTS

GRADUAL CHANGE IN WATER QUALITY

Results of both tests indicated that there is a statistically significant trend in TSS and TP in the Willow watershed, but in neither of the others. The trend in TSS is significant at a 95% confidence level while the trend in TP is significant at a 90% confidence level. ~~The TP data was autocorrelated, however, and the appropriate steps to remove the autocorrelation reduced the confidence (statistical significance) in the results to only about an 80% confidence level.~~

Using method 1, the reduction over the length of the data set for TP is ~~43%~~ 57% and for TSS is ~~57%~~ 60%. Using method 2, the reduction for TP is ~~46%~~ 54%and for TSS is ~~58%~~ 59%. As mentioned above, only the TSS reduction is significant at the normally accepted confidence level of 95%.

CORRELATION OF LAND USE CHANGE TO WATER QUALITY CHANGE

Percent of land in no-till was statistically significant for Willow TP data and Willow TSS data. The negative parameter on notill indicates a reduction in load with a increase in no-till. Both no-till land and continuous cover were significant for Haines drain, but the positive value on the regression parameter indicates that these factors do not show a positive impact on water quality (with an increase in no-till or continuous cover the TP load increases). Neither term was statistically significant for Marshall.

This suggests that elapsed time and percent no-till are correlated, which seems logical since percent no-till generally increases with elapsed time. The parameter (or coefficient) value on the factor of % no-till for Willow Creek was ~~-0.0106~~ -0.01969 which means that for every percent increase in no-till, TSS load expressed in log kg is reduced by .01969 log units. Using the regression estimates based on average storm discharge and peak flow and using 1990 and 1997 values of no-till (4% and 32% no-till respectively) the percent reduction in TSS load is ~~49%~~ 52%. For TP, the average reduction was 47%

Given the uncertainty in the coefficient on no-till, a 95% confidence interval on the coefficient results in a 95% confidence interval in average percent reduction in TSS load of ~~10%-72%~~ 18-72%. Note that these first two analysis give very similar results for Willow Creek.

CONCLUSIONS

The general conclusion from this initial analysis, is that water quality in terms of sediment load and TP is improving (decreased load) for Willow Creek, but it not statistically detectable in the other two watersheds. In Willow Creek, the water quality improvement can be tied to percent land in no-till.

The two watersheds (Haines and Marshall) that didn't show a change in this analysis appear to have had a greater increase in no-till than Willow Creek, and therefore would have been expected to also show a water quality improvement. Other factors may be at play here such a localized problem areas. Knowledge of what is physically happening on the ground is invaluable.

Table 1. Summary Table – TSS or TP reduction by Predictor

Site	Nutrient	Statistical Method and predictor	Average Reduction	95% CI range in Reduction
Willow	TSS	1 step (elapsed time)	~~57%~~ 60%[1]	~~12% to 79%~~ 25-79%
Willow	TSS	2 step (elapsed time)	~~58%~~ 59%[1]	~~8% to 81%~~ 27-77%
Willow	TP	1 step (elapsed time)	~~43%*~~ 57%[2]	~~NA~~ 15-76%
Willow	TP	2 step (elapsed time)	~~46*~~ 54%[2]	~~NA~~ 16-78%
Marshall	TSS	1 step (elapsed time)	-	
Marshall	TP	1 step (elapsed time)	-	
Haines	TP	1 step (elapsed time)	-	
Haines	TSS	1 step (elapsed time)	-	
Willow	TSS	1 step (no-till percent)	~~49%~~ 52%	~~10% - 72%~~ 18-72%
Willow	TP	1 step (no-till percent)	47	14-67

~~*significant only at an 80% confidence level~~
~~[1] 90% C.I. not significant at α=0.05 (95% C.I.)~~
[1] Significant at 95% Confidence level / 95% Confidence Interval
[2] Significant at 90% Confidence level / 90% Confidence Interval