Report for 2001AL4121B: Studies to Evaluate the Effectiveness of Current BMPs in Controlling Stormwater Discharges from Small Construction Sites

- Conference Proceedings:
  - Owens, J., Angus, R., Lalor, M., McKinney, S., Meyer, E., and Marion, K. 2002. Utilization of GIS technologies in a sedimentation potential index. Pages 55 60 in Lesnik, J.R. (editor), Coastal water resources. AWRA 2002 Spring Specialty Conference Proceedings, American Water Resources Association, Middleburg, VA, TPS-02-1.
  - Owens, J., Angus, R., Lalor, M., McKinney, S., Meyer, E., Marion, K. Utilization of GIS technologies in a sedimentation potential index. Presented at the Alabama Water Resources Association 2002 Spring Specialty Conference, April, 2002.
  - Owens, J., Angus, R., Lalor, M., McKinney, S., Meyer, E., Marion, K. Characterizing a watershed sediment erosion potential using GIS technology. Presented at the annual meeting of the Alabama Academy of Science, University of West Alabama, Livingston, AL, March 29, 2002.
  - Honavar, J., Angus, R., Marion, K. Siltation effects on fish communities in the Cahaba watershed. Presented at the annual meeting of the Alabama Academy of Science, University of West Alabama, Livingston, AL, March 29, 2002.
  - Owens, J., Angus, R., Lalor, M., McKinney, S., Meyer, E., Marion, K. Association between sedimentation potential as estimated by GIS technology, habitat assessment scores, and macroinvertebrate community structure metrics in small southeastern streams. Presented at the annual meeting of the Association of Southeastern Biologists, March, 2002.
  - Angus, R., Marion, K., Owens, J., and Lalor, M. An Evaluation of the Effectiveness of Silt Fences in Controlling Stormwater Discharges from Small Construction Sites and the Effects of Siltation on Aquatic Communities. Presented at the Alabama Water Resources Research Institute Conference, Gulf Shores, AL, Sept 6, 2001.
  - Owens, J., Angus, R., Lalor, M., McKinney, S., Meyer, E., Marion, K. An evaluation of sediment sensitive biotic indices as biomonitoring tools in watershed management. Presented at the Alabama Water Resources Research Institute Conference, Gulf Shores, AL, Sept 6, 2001.
  - Marion, K., R. Angus and M. Lalor. The urbanizing of a river: the search for functional indicators of change. Seminar presented at Dauphin Island Sea Lab, May 2001.
  - Angus, R., K. Marion and M. Lalor. The effectiveness of silt fences in controlling stormwater discharges from small construction sites and the effects of siltation on stream communities. Presented at the Alabama Fisheries Association Meeting, Eufaula, AL, February, 2001.
  - Angus, R. and K. Marion. An evaluation of the effectiveness of current BMPs in controlling stormwater discharges from small construction sites and developing metrics to assess the effects of discharge on stream communities. Presented at the Annual Water Resources Conference Symposium, Gulf Shores, AL, September 2000.
- Other Publications:
  - Owens, J.S., R.A. Angus and K.R. Marion. A refinement of sediment-sensitive aquatic macroinvertebrate metrics. Poster presented at the Association of Southeastern Biologists meeting, New Orleans, LA, April 2001
  - Owens, J.S., R.A. Angus and K.R. Marion. Evaluation of sediment-sensitive biotic indices.

Poster presented at the Alabama Academy of Science meeting, Auburn, AL, March 2001.

- Articles in Refereed Scientific Journals:
    - Owens, J., Marion, K.R., Angus, R.A. 2001. Evaluation of sediment-sensitive biotic indices. Journal of the Alabama Academy of Science 72:96

Report Follows:

Research Problem

Stormwater runoff from construction sites has become an increasingly major contributor of fine inorganic sediment input into our streams and rivers. The negative impacts of excess fine sediment loads extend to all segments of the aquatic ecosystems from microbes to fish. While large construction projects represent single major potential pollution sources and are usually more visible, smaller construction sites (usually future home sites <5 acres) are both more numerous and are less likely to employ adequate erosion control best management practices (BMPs). The most common BMPs employed at such sites are plastic silt fences and hay bales. Few scientific studies have been performed to evaluate the effectiveness (or lack of it) in the field of such BMPs, especially as affected by physical site and rainfall characteristics. This is especially true for the more upland and hilly terrain regions of Alabama and the Southeast. Information on the effectiveness of such BMPs in hilly terrain situations and the factors influencing the effectiveness is needed to assist in the selection of appropriate BMPs and the design of future erosion controls. Such information would be directly useful to federal, state and local regulatory agencies charged with the protection of aquatic environments. Data we have obtained from recent studies indicate clearly that silt fences alone are not very effective at controlling erosion from small construction sites. Additional cost-effective control methods are needed.

Research Objectives

We evaluated the effectiveness of a low-cost erosion control method (vegetated buffer strips) in this project. Additionally, we studied the effects of silt on the biological communities in receiving streams. Since total control of fine sediment runoff is unlikely to be achievable with reasonable efforts, it is important to know how much sediment input can be tolerated by a stream or river without causing serious detriment to the aquatic ecosystem. Although EPA-approved rapid bioassessment procedures are currently available to assess the "health" of stream ecosystems, the metrics that are currently available were not derived specifically to measure the impacts of siltation of the communities. Nor, have the sensitivities of the metrics to siltation-caused stress been evaluated. One of our objectives was to develop or refine metrics that are more sensitive biocriteria for comparing the level of impairment between sites. Such improved metrics will be extremely useful for evaluating the utility of alternative erosion control procedures.

Methods

Reducing Silt in Runoff from Construction Sites - This study was done in the upper Cahaba River watershed in north central Alabama. This is an ideal location to evaluate factors influencing the outcomes and impacts of silt fences and/or vegetated buffer strips for several reasons: 1) the topography and soil types are representative of the upland physiographic regions in the Southeast (i.e., southern Appalachian and foothill areas). Thus, findings from this study should be relevant to a large portion of the Southeast. 2) rainfall amounts and intensities in this region are representative of many areas of the Southeast, and 3) the expanding suburbs of the metropolitan Birmingham area are rapidly encroaching upon the upper Cahaba River and its tributaries.

The effectiveness of in–place erosion control devices (silt fences) was evaluated at small construction sites. Stormwater runoff samples were collected to investigate the relationship between the quality and quantity of the runoff and physical site characteristics. Stormwater runoff samples escaping from the silt fences were collected during "intense" (≥1 inch/hr) rain events. The runoff samples were analyzed for turbidity (using a nephelometer), particle size distribution (using a Coulter counter), and total solids (dissolved solids and suspended solids, using methods 2540B and 2540C in Standard Methods for Examination of Water and Wastewater; NSTM, 1998).

The effectiveness of silt fences used in conjunction with vegetated buffer strips was also investigated. Sampling was carried out on sites with properly installed and well maintained silt fences, located immediately upgrade from areas with good vegetative cover. Stormwater runoff samples were collected from sheet flows above silt fences, and from points below the fence within the vegetated buffer. Analyses were carried out as described above.

Six tributary or upper mainstream sites were studied to investigate the effects of sedimentation input from upstream construction sites on both habitat quality and the biological "health" of the aquatic ecosystem (using benthic macroinvertebrates and fish). Two of the sites have a heavy sediment load, two have been moderately impacted, and two (reference sites) have had little or no sediment input. Each site was assessed in the spring, after the period of winter rains (to evaluate immediate effects), and again the following late summer or early fall (to evaluate delayed effects).

An evaluation of habitat quality is an important component of the assessment of the ecological integrity of a site. We used EPA–recommended procedures for high gradient streams, as outlined in the "Revision to Rapid Bioassessment Protocols for Use in Streams and Rivers", to assess the habitat quality at our study sites. This procedure quantifies the degree of impaction at each site and permits the making of comparisons between sites.

Preliminary Results

Effectiveness of Silt Fences - We have made comparisons between runoff collected immediately below silt fences and water collected nearby but not below a silt fence (Fig. 1, Table 1). Silt fences are better than no control measures at all, but not a lot better. The mean count of small particles below silt fences was 54.1% less than that from areas with no erosion control measures; however, even though the fences appeared to be properly installed and in good order, the variability between samples was sufficiently great that the difference between these means was not statistically significant (Table 1). The silt fences did not reduce particle counts to levels comparable to nearby undisturbed sites. The mean count for small particles below silt fences was more than an order of magnitude greater than the mean for undisturbed control sites (Table 1). For every

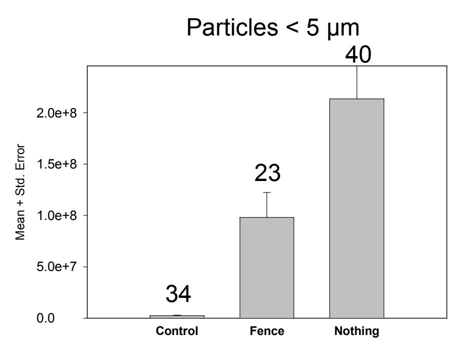

Figure 1. Counts of small particles in grab samples of runoff water taken in undisturbed vegetated areas (control), below silt fences and from areas with no runoff control.

variable measured, the mean values of samples taken below silt fences were significantly higher ($p < 0.001$) than samples collected from undisturbed vegetated control sites.

These data indicate that silt fences are only marginally effective at reducing soil particulates in runoff water. Surprisingly, the amount of silt in runoff (as measured with the variables mentioned above) was not significantly correlated with slope of the site, amount or intensity of rainfall. This may reflect the fact that we only sampled "intense" (>1 inch/hour) rainfall events.

	No Barrier (n=40)	Fence (n=23)	Control (n=34)
Total Particles	$2.18\times10^{8} \pm 3.28\times10^{7}$	$1.01\times10^{8} \pm 2.48\times10^{7}$	$2.45\times10^{6} \pm 3.54\times10^{5}$
Small Particles	$2.13\times10^{8} \pm 3.21\times10^{7}$	$9.82\times10^{7} \pm 2.43\times10^{7}$	$2.36\times10^{6} \pm 3.44\times10^{5}$
Large Particles	$4.37\times10^{6} \pm 9.20\times10^{5}$	$2.91\times10^{6} \pm 7.28\times10^{5}$	$8.56\times10^{4} \pm 1.31\times10^{4}$

Table 1. Mean values (± std. error) of particle counts in grab samples taken during >1"/hr rain events in unvegetated control sites, below silt fences, and in disturbed areas with no barrier. In each row, the mean for the Control is significantly lower than for the other cells in the same row (ANOVA on log transformed data, $p \ll 0.001$). Means for the No Barrier and Fence treatments are not significantly different for any of the particle size groups ($p > 0.05$).

Effectiveness of Silt Fences with Vegetated Buffers

Stormwater runoff samples were collected immediately below silt fences, and below silt fences after flow over 5, 10, and 15 feet of dense vegetation. Only sites with fences which appeared to be properly installed and maintained were sampled. Mean total solids in samples collected below silt fences and a 15 foot wide vegetated buffer zone were 21% lower, on average, than those samples collected immediately below the silt fence.

Preliminary analysis of the data indicate that the installation of silt fences, above a vegetated buffer zone with good vegetative cover, removes sediment from stormwater runoff more effectively than the use of silt fences alone. High variation in effectiveness was observed, perhaps due to variation in site microenvironments. Wider buffer zones (15 feet) generally resulted in greater removal of sediment than narrower buffer zones (5 feet). An increase in the percent removal of sediment by vegetated buffer zones appears to correlate weakly with a decrease in the site slope.

Development of Biological Metrics Sensitive to Sedimentation Effects

Fish - Analysis of the fish biota indicates that various metrics used to evaluate the biological integrity of the fish community are altered in highly sedimented streams. In these streams the overall composition of the population, as quantified by the Index of Biotic Integrity is lower (Fig. 2), the proportion and biomass of darters, a disturbance-sensitive group, is lower (Fig. 2), the proportion and biomass of sunfish is higher, the Shannon-Weiner diversity index is lower, and the number of disturbance-tolerant species higher.

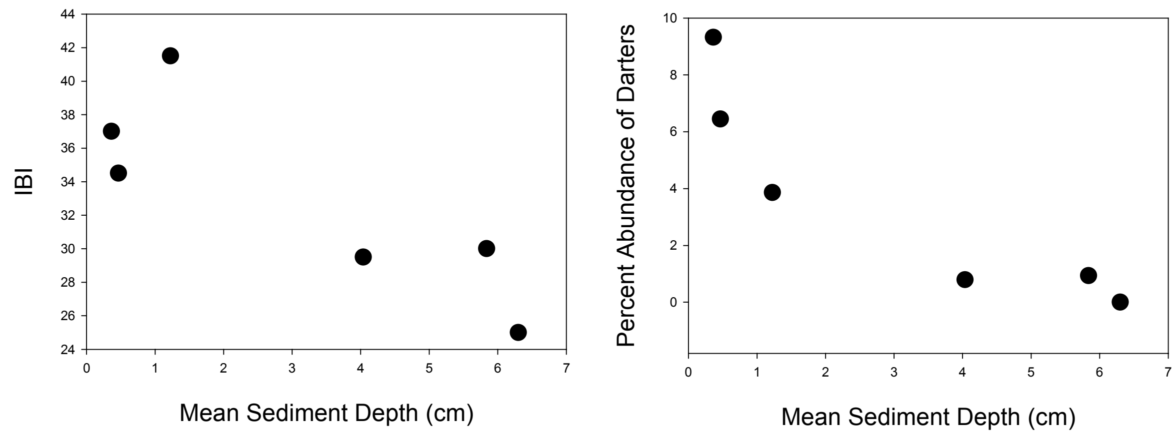

Figure 2. Association between two fish metrics and amount of sedimentation. The IBI (Index of Biotic Integrity) is based on numerous characteristics of the fish population. The percent relative abundance of darters is the percentage of all the fish collected at a site that are darters.

Benthic Macroinvertebrates – We have identified a number of characteristics of stream benthic macroinvertebrate communities that are sensitive to sedimentation. Metrics based on these characteristics differ greatly between sediment-impacted and control sites (Fig. 3). Some of the metrics that appear to reflect sediment-associated stresses include the

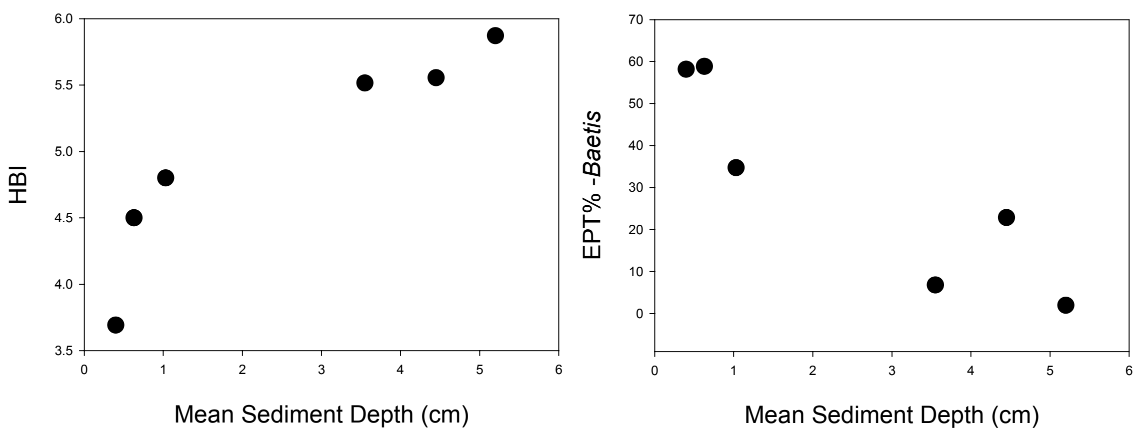

Figure 3. Association between two macroinvertebrate metrics and amount of sedimentation. The HBI index is a weighted mean tolerance value; high HBI values indicate sites dominated by disturbance-tolerant macroinvertebrate taxa. The EPT% index is the percent of the collection represented by organisms in the generally disturbance-sensitive orders Ephemeroptera, Plecoptera, and Trichoptera. Specimens of the genus *Baetis* were not included in the index as they are relatively disturbance tolerant.

Hilsenhoff Biotic Index, a variation of the EPT index (%EPT minus *Baetis*), and the Sorensen Index of Similarity to a reference site. The HBI and the EPT index also show positive correlations to several other measures of disturbance, such as percent of the watershed altered by development. In collaboration with Steve McKinney (Stormwater Management, Inc.), we have developed a method for predicting the soil erosion potential of a site. This is done using Geographic Information Systems (GIS) and remote sensing technologies. The cartographic model consistes of selected data layers for the study area, including NRCS soils, multispectral satellite imagery, parcel level land use, and a digital elevation model. The derived layers are then combined to yield measurable areas for the determined characteristics. These are used to produce a Sedimentation Potential Index (SPI). This is a measure of the "erodibility" of the soils at a site and an indication of the potential to produce excessive silt runoff if the site is disturbed by such activities as construction. We

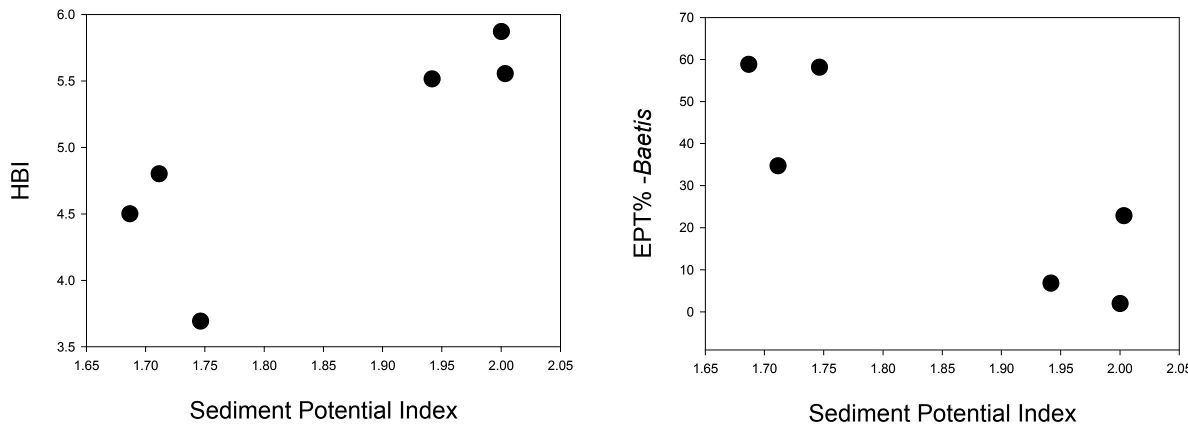

Figure 4. Association between two macroinvertebrate metrics and the sedimentation potential in the watershed as estimated by GIS technologies.

have compared the SPI values of various sub-watersheds with biological characteristics of study sites in the same sub-watersheds (Fig. 4). The SPI scores correlated strongly with a number of metrics that respond to sedimentation impacts. The integration of biomonitoring and GIS characterization for pollutant potential will be extremely useful as an aid in management for specific watershed stressors.