Water Resources Research Institute
Annual Technical Report
FY 2001

Introduction

The Alabama Water Resources Research Institute (AWRRI) serves to focus the talents of university faculty in our state on priority problems in water resources. This report, with the descriptions of each Section 104(b) research project supported in the Institute program, illustrates the range of problems and the variety of talent available in the states universities to work on solutions for these problems. Our goal is to produce useful results and to make the new technology, from each project, available to the specific people who can make use of it.

The activities supported through AWRRI not only provide valuable scientific information but also help to produce the future scientists and leaders so necessary to the development of this region.

Research Program

Studies to Evaluate the Effectiveness of Current BMPs in Controlling Stormwater Discharges from Small Construction Sites

Basic Information

Title:	Studies to Evaluate the Effectiveness of Current BMPs in Controlling Stormwater Discharges from Small Construction Sites
Project Number:	2001AL4121B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	VI
Research Category:	Not Applicable
Focus Category:	Water Quality, Sediments, Ecology
Descriptors:	Bioassessment, Invertebrate Communities, Fish Communities, Sediments, Construction, Erosion Control,Erosion
Principal Investigators:	Robert A. Angus, Melinda Lalor

Publication

1. 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.
2. Owens, J., Marion, K.R., Angus, R.A. 2001. Evaluation of sediment-sensitive biotic indices. Journal of the Alabama Academy of Science 72:96
3. 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.
4. 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.
5. 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.

6. 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.
7. 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.
8. 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.
9. 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.
10. 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
11. 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.
12. 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.
13. 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.

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

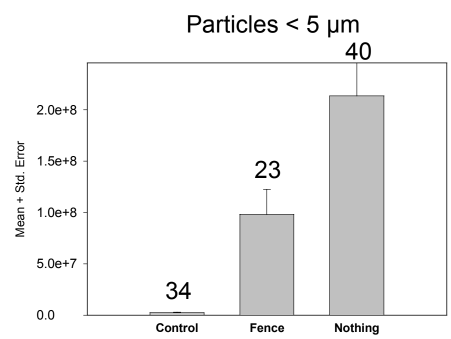

Figure 1. Counts of small particles in grab samples of runoff water taken in undisturbed vegetated areas (control), below silt fences and from areas with no runoff control.

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.

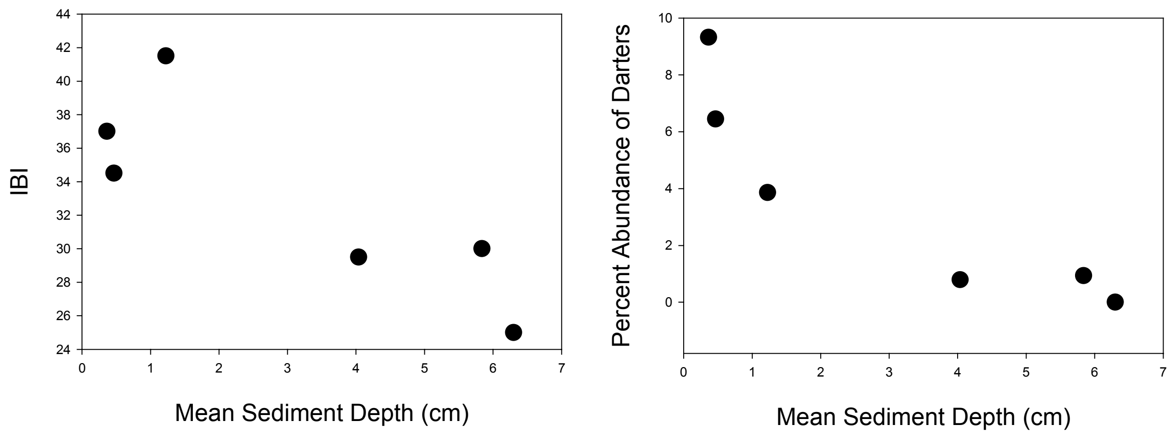

Figure 2. Association between two fish metrics and amount of sedimentation. The IBI (Index of Biotic Integrity) is based on numerous characteristics of the fish population. The percent relative abundance of darters is the percentage of all the fish collected at a site that are darters.

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

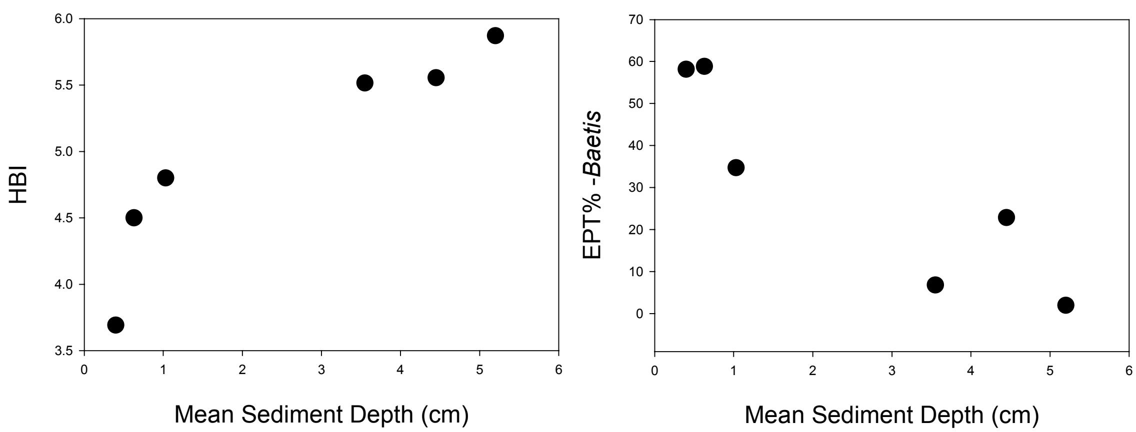

Figure 3. Association between two macroinvertebrate metrics and amount of sedimentation. The HBI index is a weighted mean tolerance value; high HBI values indicate sites dominated by disturbance-tolerant macroinvertebrate taxa. The EPT% index is the percent of the collection represented by organisms 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

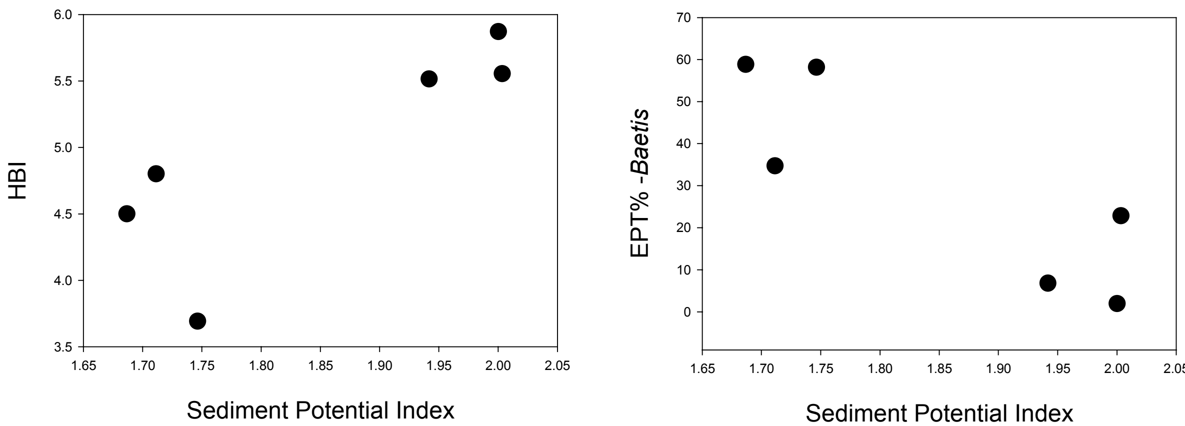

Figure 4. Association between two macroinvertebrate metrics and the sedimentation potential in the watershed as estimated by GIS technologies.

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.

Development of Geophysical Assessment Tools for a New In-Situ Groundwater Remediation Process

Basic Information

Title:	Development of Geophysical Assessment Tools for a New In-Situ Groundwater Remediation Process
Project Number:	2001AL4221B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	Third
Research Category:	Not Applicable
Focus Category:	Groundwater, Water Quality, Toxic Substances
Descriptors:	Anaerobic Treatment, Hydrogeology, Heavy Metals, Geophysics, Bacteria, Biological Treatment,Groundwater Quality
Principal Investigators:	Lorraine Wolf, Ming-Kuo Lee, James A Saunders

Publication

1. Saunders, J. A., M-K. Lee, L. W. Wolf, S. Park, C. Rutherford, 2001, In situ groundwater remediation using sulfate-reducing bacteria at Sanders lead site, Troy, Alabama, AL Water Resources annual meeting, 5-7 Sept 2001, Orange Beach, AL.
2. Saunders, J.A., Lee, M.-K.,Whitmer, J.M., and Thomas, R.C., 2001, In situ bioremediation of metals-contaminated groundwater using sulfate reducing bacteria: A case study, Proceedings 6th International Symposium on In-Situ and On-Site Bioremediation, Battelle Press, v. 9, p. 105-112.

a. Statement of Regional Water Problem and Research Objectives:

Groundwater is contaminated by a number of toxic heavy metals (e.g., Pb, Cd, Hg, Cr, Ag, Cu, Zn), and metalloids (As, Se) at thousands of sites in the U.S. These sites largely are associated with industries such as electroplating facilities, battery recycling plants, foundries, coal mines, and base and precious mines. Similar contamination problems occur at government (particularly DoD and DOE) sites. Bioremediation has largely been thought of as technique for treating *organic* contaminants; however, this technique appears to be well suited for both inorganic and organic contaminants, or mixtures of both. In 2000, researchers from Auburn University began a research endeavor using a new groundwater remediation process at a highly contaminated Alabama industrial site in southeastern Alabama. The company legally responsible for the site is Sanders Lead, Troy AL. The company contaminated groundwater at the site in their early days of operations, which involve the recycling of old car batteries to recover lead, sulfuric acid and plastic. Sanders Lead is the biggest employer in Pike County and produces ~15% of the U.S. lead supply. Groundwater at the site is acidic and contains high levels of lead, cadmium (primary contaminants of regulatory interest), zinc, copper, and sulfuric acid. Shallow contaminated groundwater discharges to a natural wetlands on the site and has caused extensive killing of natural vegetation. A large-scale conventional “pump-and-treat” remediation scheme has been ongoing for a decade at an estimated cost to date of $7 million. It has shown little success (with respect to EPA Maximum Contaminaents Levels) in improving water quality. In 1999, our research group approached Sanders Lead with the concept of a passive *in situ* bioremediation process at their site. The process involves the stimulation of naturally-occurring anaerobic bacteria to remediate, *in situ*, contaminated groundwater in an innovative way. Preliminary results indicate that the technique is very promising; however, the process of remediation is currently monitored only by direct measurements taken near the injection site. A realistic groundwater flow model that can be used to accurately predict the migration of the plume is lacking and cannot be tested without a better assessment of the actual flow and plume migration. The project supported through the Alabama Water Resources Research Institute (AWRRI) grant was aimed specifically at developing surface geophysical techniques (electromagnetic, electrical resistivity, and magnetic) to track the progress of bioremediation in the subsurface, in areas where monitoring wells are absent or are too far apart for proper assessment of remediation progress. The effort responded to AWRRI program focus 1A (Groundwater) in that the research was aimed at studying the fate and transport of contaminants and at developing improved methods for groundwater remediation using the bioremediation process. The real-time assessment techniques used in the project are based on well understood electrical, electromagnetic, and magnetic geophysical methods and the observation that the mineral phases produced in the zone of bioremediation are electrically conductive and potentially ferrimagnetic. The contaminated groundwater at the site is extremely conductive, containing >4000 ppm of divalent ions (sulfate, iron, calcium, magnesium, etc.). The project sought to determine whether the bioremediation process would decrease the electrical conductance of the groundwater by removing sulfate, iron, etc., or increase the electrical conductance of the aquifer minerals by precipitating metal-sulfide phases.

b. Methodology Used

To test the effectiveness of geophysical techniques to be used at the bioremediation site, we conducted several baseline geophysical surveys prior to the new injection test proposed under this contract. The surveys conducted were electromagnetic (EM-31 ground conductivity meter), magnetic (proton precession magnetometer), electrical resistivity (direct current). These baseline surveys were used to establish the natural background characteristics of sediments in the monitoring area, and later, post-injection surveys were used to track changes related to the plume movement and progress of bioremediation. Geochemical data from the injection well was collected prior to and during these baseline geophysical surveys. After groundwater geochemical data from the well indicated that the contaminant levels in the well had returned to the pre-injection amounts, a second injection was conducted at the site using the same injection well. Groundwater geochemistry was tracked at regular intervals following the injection. Once contaminant levels of Pb and Cd were significantly altered (indicating that the bacteria population was thriving and responding), we repeated the geophysical surveys, using identical methodology and measurement points. The surveys were conducted over a period of several months, and the geochemical sampling strategy was continued throughout this period. The repeated surveys were designed to (1) track the precipitation of magnetic minerals that form in conjunction with or as precursors to iron sulfide byproducts of the SRB activity, which, in turn, can be used to establish the rates of the various stages in the remediation process, and (2) characterize at small scales (~ 1 to 2 m) sediment properties of the aquifer and zones in which the SRB are active. .In addition to electrical resistivity, electromagnetic (EM-31), and magnetic surveys, we also collected additional electromagnetic data (using an EM-34 conductivity meter) and self-potential data. Finally, a detailed site map that included topography was constructed using both high-precision GPS unit and total station surveying instruments. Detailed topography is required for constructing future flow models at the site, and is also used for making static corrections to the geophysical data, if needed.

c. Principal findings and significance

According to Archie's Law, ground conductivity for partially saturated materials, σ_a,, is a function of the soil water conductivity, σ_w, the soil porosity, ϕ, and particle factor, m, which varies with particle shape and type:

$$\sigma_a = \sigma_w \phi^m$$

Using the strategy discussed above, we assume that ϕ^m remains constant during the course of the experiment because measurements are taken with each technique at the same location. Furthermore, we make the assumption that if the groundwater level at the site changes due to periods of heavy rain or drought, that the change in bulk ground conductivity would be uniformly affected over the entire site. From these assumptions, we conclude that any change in the relative conductivity of points within the site would be due to changes in the soil water conductivity related to the remediation process.

Figure X shows an example of the relative change in conductivity at specific measurement points through the experiment period. Our preliminary conclusions based on the repeated surveys at the sites are (1) the bioremediation process appears to lower electrical conductance, (2) rates of plume migration at the site are probably on the order of 10 meters per year, (3) flow paths at the site are effectively determined from the surface geophysical surveys. An intriguing result from the self-potential surveys suggests that the sulfate-reducing bacteria may be involved in creating streaming potentials. This possibility will be explored in future work by the PIs and their students.

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Basic Information

Title:	Please remove this test
Project Number:	
Start Date:	1/1/2001
End Date:	1/1/2001
Funding Source:	Supplemental
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	

Publication

Information Transfer Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	3	0	0	0	3
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	7	0	0	0	7

Notable Awards and Achievements

Publications from Prior Projects