

Environmental Resources Research Institute

Annual Technical Report

FY 2000

Introduction

Two base grant projects were completed in the budget year (3/1/00-2/28/01) State Water Resources Research Base Grants Program (PL. 98-242 Sect. 104). In addition, two projects were completed for the funded national competition program.

In the base grant project, Impact of Stream-Subsurface Exchange on Fine Sediment Dynamics in Streams funded through Drexel University, the objectives were to examine the complex interactions between high sediment loadings, downstream transport of suspended sediment, stream-subsurface exchange and siltation of stream beds. Results demonstrate that stream-subsurface exchange delivers suspended sediments to the stream bed, that this fine material accumulates in the stream bed under normal flow conditions, and that this accumulation plugs the bed surface and greatly reduces stream-subsurface exchange fluxes.

In an information transfer effort Development of Youth Water Conservation Education Materials for Pennsylvania 4-H Programs water conservation educational curriculum booklets have been reviewed and are in publication.

The Use of Oxygen-18 Variations in Modeling Shallow Groundwater Recharge, a competition funded project was completed. It was concluded that estimates of mean residence times of shallow groundwater in the Mid-Appalachian region is possible using temporal variations in oxygen-18 levels in precipitation.

In the completed project Occurrence of *Helicobacter pylori* in Surface, Ground, and Finished Water: Implications for Drinking Water Supplies a combined antibody-tetrazolium salt reduction (FA-CTC) assay which allows for the detection of *H. pylori* in water samples. Collaborative efforts have been initiated to continue work in Puerto Rico with InterAmericas University.

A newsletter describing Institute research and outreach was also maintained and circulated.

Research Program

Basic Information

Title:	Impact of stream-subsurface exchange on fine sediment dynamics in streams
Project Number:	B-01
Start Date:	3/1/1999
End Date:	2/28/2001
Research Category:	Water Quality
Focus Category:	Sediments, Geomorphological Processes, Water Quality
Descriptors:	sediment transport, fine suspended sediments, soil erosion, streams, geomorphology, contaminant transport
Lead Institute:	Environmental Resources Research Institute
Principle Investigators:	Aaron I. Packman, Michael Piasecki

Publication

1. MacKay, J. S. and A. I. Packman. Alteration of stream bed properties and stream-subsurface exchange due to deposition of kaolinite clay, *Journal of Hydraulic Engineering*, ASCE (in preparation). Packman, A. I., J. S. MacKay, J. D. Newbold, and D. Jerolmack. Hyporheic process dynamics: Interplay of stream-subsurface exchange, suspended sediment deposition, and stream bed evolution, *Water Resources Research* (in preparation).
2. MacKay, J. S. and A. I. Packman. Alteration of stream bed properties and stream-subsurface exchange due to deposition of kaolinite clay, *Journal of Hydraulic Engineering*, ASCE (in preparation).
3. Packman, A. I., J. S. MacKay, and J. D. Newbold. 2000. Variations in organic particle deposition rate and stream-subsurface exchange due to silt accumulation in a gravel bed, *ASCE Joint Conference on Water Resources Engineering and Water Resources Planning and Management*, Minneapolis, July 30 - August 2, 2000. Presentation and publication in the proceedings.
4. Packman, A. I. 2001. Re-examination of the wash load concept: Role of physicochemical processes, *ASCE/EWRI World Water Congress*, Orlando, May 20-24, 2001. Presentation and publication in the proceedings.
5. Jerolmack, D. with contributing researchers J. S. MacKay, A. I. Packman, and J. D. Newbold. 2001. Sedimentation and subsurface particle capture in a stream-side flume with a gravel bed, *Journal of Undergraduate Study and Independent Research*, Issue 1, Spring 2001, pp. 22-26.
6. MacKay, J. S., A. I. Packman, and J. D. Newbold. 1999. Interplay of stream-subsurface exchange, benthic delivery of particulate organic carbon, and stream bed siltation, presentation at *AGU Fall Meeting*, San Francisco, December 13-17, 1999. Abstract available in *EOS*, 80, 1999, p. F316
7. MacKay, J. S. and A. I. Packman. 2000. Clogging of stream beds due to extensive clay deposition, presentation at *AGU fall meeting*, San Francisco, December 15-19, 2000. Abstract available in *EOS*, 81, 2000, p. F493.

Problem Statement and Research Objectives

High concentrations of fine sediments adversely impact stream ecosystems by decreasing light penetration through the water column and filling pore spaces in the stream bed. Further, the mobility of fine sediments controls the fate and transport of some aqueous contaminants, including metals, PCBs, and arsenic. In Southeastern Pennsylvania, reservoirs of contaminated sediments exist in many areas, and significant quantities of fine sediments may be mobilized by extensive ongoing construction and development. In spite of these issues, relatively little is known about how fine sediments progress through a watershed. Thus this project seeks to examine and describe the complex interactions between high sediment loadings, downstream transport of suspended sediment, stream-subsurface exchange, and siltation of stream beds. Four key questions are to be answered in this work:

1. What is the rate of uptake of suspended sediment by the stream bed?
2. How does the accumulation of fine sediment affect the hydraulic conductivity, porosity, and other physical characteristics of the bed?
3. How do these changes in the stream bed affect stream-subsurface exchange? That is, what feedback is there between the fine sediment accumulation in the bed and the rate of uptake?
4. What is the net effect on suspended sediment transport in the stream?

Results

In the first year of the project, we utilized stream-side flumes to examine the deposition of suspended sediments in a gravel bed. This work was conducted at Stroud Water Research Center in collaboration with Denis Newbold. The beds of these flumes were composed of river gravels representative of nearby streams, and the water and suspended sediments used in the experiments were taken directly from the adjacent stream. Thus, these flumes essentially reproduced actual stream conditions, but had controlled flow rates. We observed suspended sediment deposition in the stream-side flumes for over three months, and measured solute-exchange and particle deposition on a weekly basis.

Two flumes were utilized in this study, with different sizes of stream gravels. In their initial state, these gravels had been somewhat plugged by the natural suspended sediments. To assess exchange with the beds, a salt solution was injected as a pulse at the upstream end of the flumes and then the resulting output was measured. To assess particle deposition, suspended sediments which had been concentrated from the creek water were also injected as a pulse and their output measured over time at the flume outlets. Exchange and particle deposition were measured with the pre-existing bed condition, and then the flumes were cleaned to remove the accumulated silts from the gravel beds. Solute and particle releases were then repeated in order to assess the difference in exchange and deposition between the clean and clogged beds. Following cleaning, stream water was pumped through the flumes continuously for almost 3½ months, so that suspended sediments were continuously delivered to the flumes at the same concentration as in the nearby stream. Solute exchange and particle deposition rates were measured approximately weekly over the course of the experiment.

We observed that the stream bed readily silted up over time, and that this hindered subsequent deposition (Figure 1). In addition, we also observed that leaf input into the stream (from natural leaf fall in this wooded area) had a significant effect on suspended sediment transport through the flumes. Siltation of the stream bed greatly altered the porosity and permeability of the bed, as can be seen from our time-series of data on stream-subsurface exchange (Figure 2).

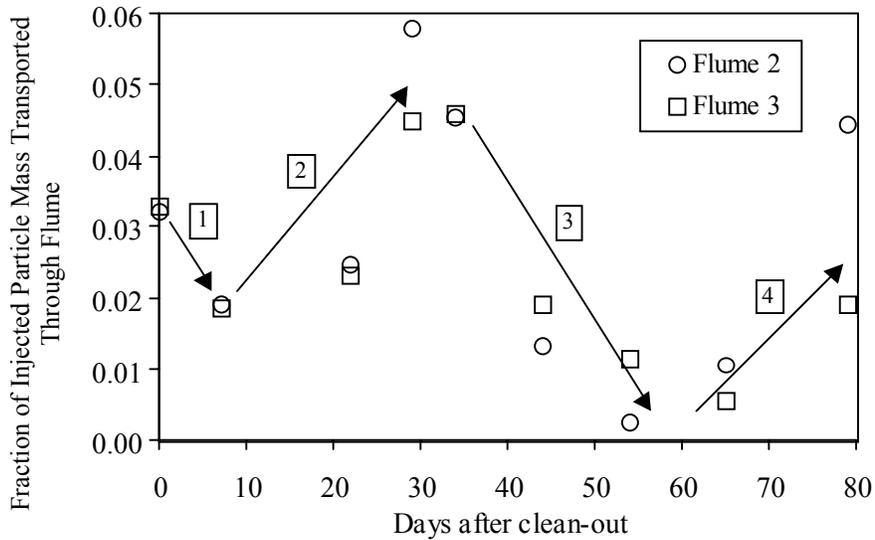


Figure 1: Change in suspended sediment transport over time observed in 1999. Four distinct trends can be seen as indicated on the graph by arrows with boxed numbers. (1) Deposition increased (and particle throughput decreased) initially after the beds were cleaned. (2) Additional particle throughput occurred as the bed became plugged with deposited silts. (3) Throughput decreased as leaves accumulated in the channels. (4) Throughput increased again following manual removal of the accumulated leaves.

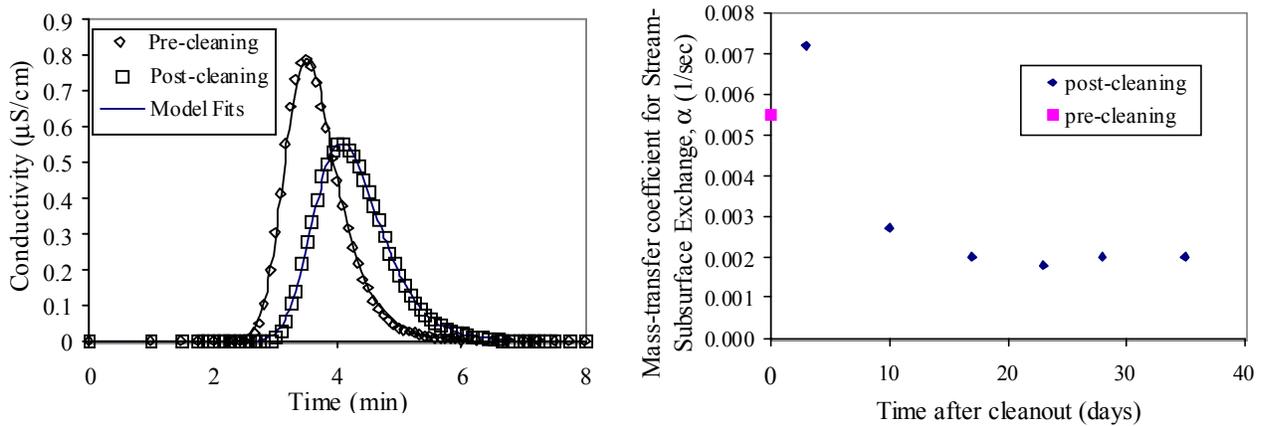


Figure 2. Left Panel: Curves of solute concentration vs. time measured at downstream end of flume following pulse inputs at the upstream end, before and after cleaning of the gravel bed. Additional tailing of the pulse shows that removal of silts from the bed increased stream-subsurface exchange. Right Panel: Following cleaning of the bed, exchange decreased considerably due to ongoing siltation.

In the second year of the project, we conducted an additional set of similar experiments to examine the initial phase of bed plugging and to try to determine the effect of microbial biofilm growth on particle capture. In our first set of experiments, siltation of the bed occurred much more rapidly than we expected. We theorized that this was related to rapid growth of benthic biofilms over the first few weeks of deposition into a clean bed. To test this theory, we conducted solute and particle injections as we did in the first set of field experiments, but increased the frequency of these injections in the early part of the experiment while simultaneously measuring biofilm mass, area, and chlorophyll content. We found that particle capture by the bed increased for approximately the first two weeks after the bed was cleaned, and then that particle capture decreased over the next three months. These results are consistent with

the results of the first year's experiments, but also show the initial phase of particle deposition. Our interpretation of these results is that particle retention increases initially due to alteration of the properties of the bed sediment surfaces, but this effect is eventually overwhelmed by the general decrease in stream-subsurface exchange due to bed clogging. As mentioned above, the mechanism of the initial increase in particle capture efficiency may be biological. We have some data that help clarify these processes, but we have not yet compiled all of the relevant data.

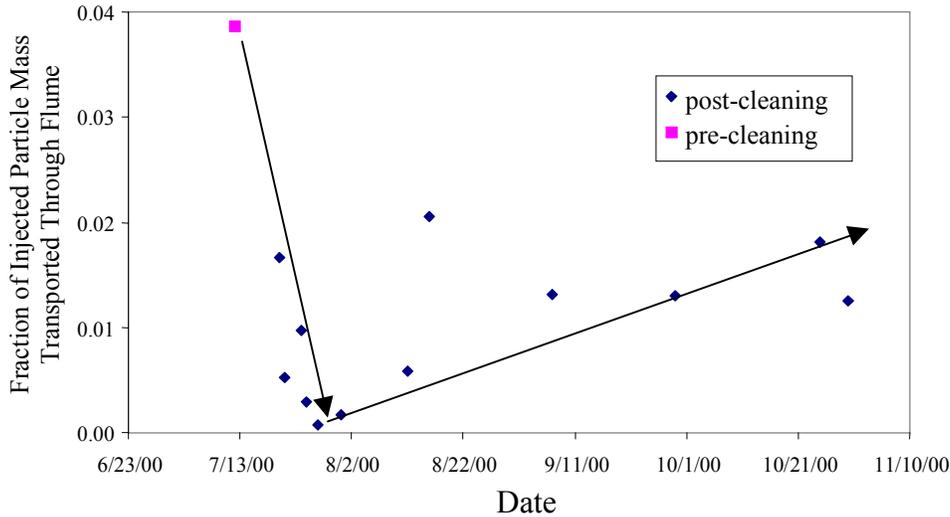


Figure 3: Change in suspended sediment transport over time observed in 2000. Arrows indicate two major trends. Deposition increased (and particle throughput decreased) initially after the beds were cleaned. Deposition continued to increase for two weeks after cleanout. Later, additional particle throughput occurred as the bed became plugged with deposited silts.

Complimentary experiments were performed in a recirculating flume at Drexel University to examine the plugging of a sand bed by kaolinite clay under much more controlled conditions. The recirculating flume is very convenient for these types of experiments, as the closed system allows observation of net stream-subsurface exchange for an extended period of time. All relevant physical and chemical parameters were well-defined in these experiments. This includes major factors such as the sediment size distributions, stream depth and discharge, water composition, and chemical state of all sediments. In addition, the roughness of the stream bed was allowed to adjust naturally under the stream flow in order to produce realistic bedforms under steady, uniform flow. Four separate experiments were performed to investigate various modes of clay loading. A typical result is shown in Figure 4. The results showed that stream-subsurface exchange and particle deposition were initially unaffected by clay accumulation, but the accumulation eventually began to plug the bed and to decrease the rate of subsequent exchange and deposition. These effects occurred despite the fact that we increased the clay fraction in the bed to, at most, around 0.25% of the bed sediment mass.

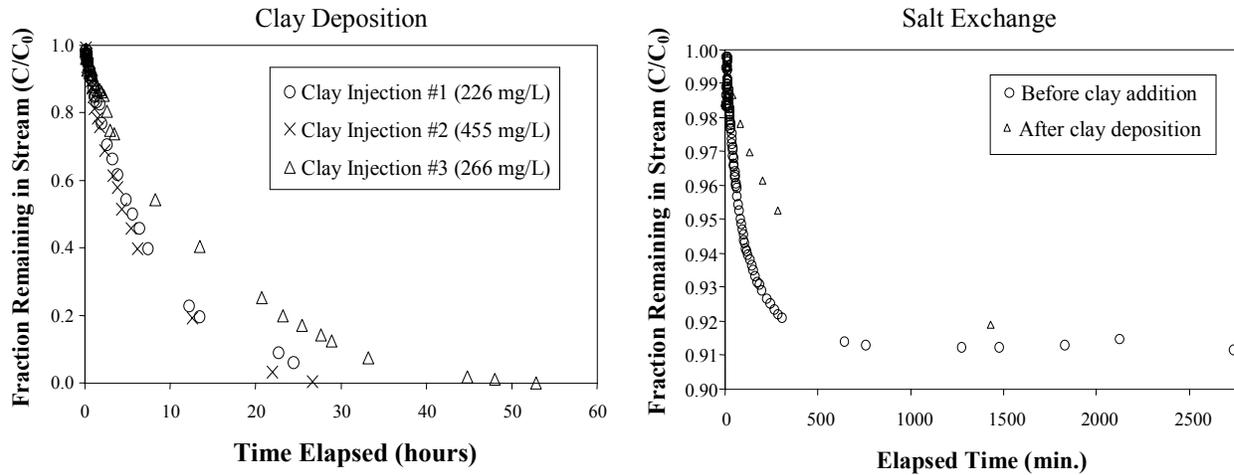


Figure 4: Clay deposition and solute exchange measured in a laboratory flume with a sand bed. Accumulation of clay reduced the rate of stream-subsurface exchange and hindered subsequent clay deposition. Note *extreme* difference in scale between the two figures.

The initial period where the properties of the stream bed remain essentially unchanged is termed the “clean bed condition” in the colloid filtration literature. The PI had previously developed a fundamentally-based model for stream-subsurface exchange and suspended sediment deposition for this clean-bed conditions. This model was applied to the experimental results in order to analyze the alteration of the stream bed properties due to clay deposition. The model predicted initial solute exchange and clay deposition well, as shown in Figure 5. However, plugging of the bed caused the exchange rate to decrease, and the resulting net exchange was therefore less than that predicted by the model. The extent of modification of the stream bed could then be analyzed by fitting the model to the later results by selecting appropriate values for bed state parameters. Clay deposition had a considerable effect on the hydraulic conductivity of the sediments. Based on the above analysis, we found that clay plugging reduced the hydraulic conductivity of the bed from an initial value of 10.8 cm/min to a final value between 2.6 and 3.0 cm/min: a reduction by roughly a factor of four. These results show that fine sediment accumulation can have a significant effect on transport in the stream bed at concentrations much lower than what is normally assumed.

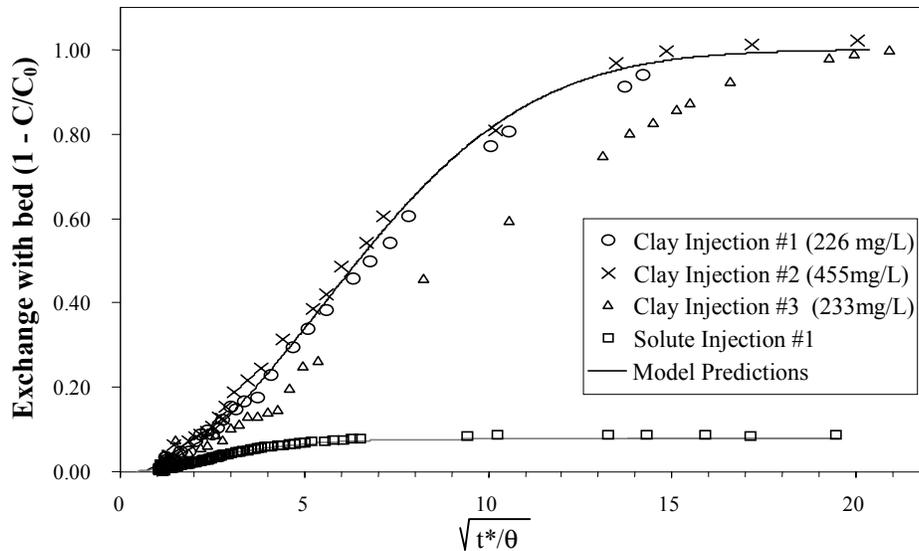


Figure 5: Modeling of results from Figure 4. Fundamental models for stream-subsurface exchange of solutes and colloids successfully predicted the observed exchanges until clay deposition became sufficient to violate the assumption of a clean bed. t^* is a dimensionless time based on a bedform length scale and characteristic pore water velocity; θ is the porosity of the bed sediment.

Significance

The results of this project clearly demonstrate that stream-subsurface exchange delivers suspended sediments to the stream bed, that this fine material accumulates in the stream bed under normal flow conditions, and that this accumulation plugs the bed surface and greatly reduces stream-subsurface exchange fluxes. The implication is that high sediment loads can readily degrade benthic habitats and thereby adversely affect stream biota. The exact impact of these processes on the stream ecosystem has not been addressed in this study, but stream-subsurface exchange is known to be an important aspect of good-quality benthic habitat.

We have further demonstrated that clean gravel beds may become plugged rather rapidly, so that stream-subsurface exchange can vary significantly over a period of a few weeks. This clearly indicates that stream-subsurface exchange rates can have a high degree of temporal variability, and that exchange rates measured from isolated solute injections are not necessarily characteristic of the watershed, or even of the stream reach. In addition, laboratory experiments demonstrated that sand beds are readily plugged by clay even at low mass loadings. This further supports the argument that the rates of hyporheic and benthic processes will be highly variable in nature due to natural variability in the stream bed composition (for example, due to normal variation in stream flows and suspended sediment loadings). Additional variability may occur due to biological alteration of stream bed properties, but these processes require further study.

More work will be required to understand both the long-term dynamics of fine sediment transport through watersheds and how these processes affect stream habitat. We are utilizing the results from this study in an investigation of the effects of urbanization on the Valley Creek watershed outside of Philadelphia (funded by the NSF/EPA Water and Watersheds program). This area has experienced rapid suburban development, which has greatly altered the hydrology and erosion/sedimentation characteristics of the watershed. The methods and process-level understanding developed in the USGS project will assist our evaluation of stream-subsurface exchange, stream bed evolution, nutrient transport, and ecological impacts in Valley Creek.

Appendices

I. Dissertations and Students Supported

Graduate student: Jeffrey MacKay. M.S. Thesis: Alteration of stream-subsurface exchange and sedimentation processes due to the accumulation of fine sediments in stream beds. Drexel University. Expected graduation: June, 2001.

Undergraduate student: Douglas Jerolmack (summer, 2000).

Basic Information

Title:	The Use of Seasonal Oxygen-18 Variations in Modeling Shallow Groundwater Recharge
Project Number:	C-03
Start Date:	9/1/1998
End Date:	8/31/2000
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Geomorphological Processes, Hydrology
Descriptors:	groundwater hydrology, isotopes, model studies
Lead Institute:	Environmental Resources Research Institute
Principle Investigators:	David Russell DeWalle

Publication

1. McGuire, K. J., D. R. DeWalle, and W. J. Gburek. 2000. Evaluation of mean residence times in subsurface waters using oxygen-18 fluctuations during drought conditions in the Mid-Appalachians. Revised and re-submitted to J. Hydrol.
2. DeWalle, D. R., K. J. McGuire, M. A. ODriscoll and B. Gburek. 2000. Seasonal oxygen-18 variations in shallow ground water in central Pennsylvania. Amer. Geophy. Union, Fall Annual Meeting, San Francisco, CA. Abstract, H21G-03.
3. McGuire, K. J. 1999. Determining mean residence times of groundwater using oxygen-18 fluctuations in the Mid-Appalachian. M.S. Thesis Forest Resources, Graduate School, Penn State Univ., Univ. Park. 73 p.
4. DeWalle, D. R., K. J. McGuire, W. Gburek, and W. E. Sharpe. 2001. Groundwater recharge processes and mean residence times estimated using oxygen-18 variations in central Pennsylvania. In preparation.

Problem and Research Objectives

The main objective of this research is to investigate ways in which the seasonal variations in oxygen-18 in soil water, stream baseflow and shallow wells can be used to determine the mean residence time of groundwater. Timing of response of water quantity and quality to environmental change will be determined in large measure by the average time for water to move from the surface through the available subsurface flow pathways to the outlet in a stream or well. The well known seasonal variation in oxygen-18 in precipitation in the Mid-Appalachian regions can be modified by recharge patterns and propagated through the subsurface to create a unique signature in outlet waters over time. A comparison of input and output oxygen-18 signatures or variations permits one to compute the mean residence time of percolating waters using various theoretical models describing the nature of subsurface mixing and movement.

The question remains what type of theoretical model best describes the mixing process dominant in a basin. In this study we attempt to show the most appropriate theoretical model for soil water and shallow groundwater movement in the Mid-Appalachian region. Many theoretical models exist, but we have chosen to test the 1) no-mixing or piston flow model, 2) the perfect mixing or exponential model, 3) the partial mixing or dispersion model and 4) the exponential-piston flow model.

Models best fit to soil water and stream baseflow data will likely vary with geologic setting. Data will be collected and models derived for three geological settings typical of the region: an Appalachian Plateau sandstone terrain typical of forested regions, Ridge and Valley sandstone ridge to karst valley terrain which is intensively farmed, and Ridge and Valley upland sandstone to valley shale/sandstone terrain which is also highly developed for agriculture. Thus we can see if models and mean residence times of soil and baseflow water vary with geologic settings typical in this area.

Previous research in the area suggested that mean residence time of stream baseflow water increased with basin area, with virtually no apparent seasonal signal or residence times greater than 5 yr for a watershed area of about 1,000 ha. In order to determine effects of basin size, we are also sampling streams in a nested watershed design within each geologic setting to look for increasing residence times with increasing basin area.

Methodology

Precipitation/throughfall, soil water and stream baseflow were sampled at three locations in central PA (sandstone, karst and shale) beginning in April 1999. Soil water was sampled biweekly with zero-tension pan and ceramic suction lysimeters at 15, 30 and 90 cm depths in a representative soil pit at each site. Baseflow was grab-sampled biweekly at five nested basin stream sites in each geologic setting. Precipitation/throughfall samples were collected biweekly at each soil pit site using funnels and collection bottles. A software package developed by Maloszweski and Zuber (FLOWPC) was used to model these data and will be used to select the best model fit to experimental data. A partial preliminary data set from two sites with sandstone/shale dominating water

movement was available for the prior drought year and formed the basis for Kevin McGuire's M.S. thesis provides preliminary results. The data gathering phase of the larger data set was just concluded in May 2000 due to delays in the start of sampling due to the drought and freeze/thaw damage to soil pits due to lack of snow.

Principal Findings and Significance

Seasonal variations in precipitation isotope levels are quite similar among the three regions of Pennsylvania monitored, but small offsets exist due to differences in elevation among sites. Oxygen-18 levels in precipitation became more negative with increasing elevation, varying from -0.06 to -0.15 parts per thousand per 100 m of elevation among the three sites. Elevation differences among the three sites in Pennsylvania were less than 600 m. Differences in mean oxygen-18 levels in stream baseflow and soil water among sites due to elevation were also apparent. Variations due to elevation, even in regions with relatively small elevation differences, may preclude extrapolation of precipitation isotope data from one elevation to another.

Watershed geology/physiography, soil depth and basin area appeared to have a minor effect on average levels of oxygen-18 in stream baseflow. After allowance for elevation effects, mean stream baseflow oxygen-18 was lower at the sandstone-Appalachian Plateau site than the other two sites. This difference implied recharge events prior to the two-year period of this study with much lower oxygen-18 levels also had an influence on the groundwater at this site.

Mean residence time of soil water and shallow groundwater was modeled using patterns of seasonal isotope variation in precipitation over a two-year period. A simple model using precipitation isotope signatures weighted by time since the event and more theoretical approaches based upon assumed distributions of residence times related to piston-flow plus dispersion flow assumptions were employed. For either modeling approach, a large adjustment for the fraction of precipitation that became recharged in each season was needed to achieve realistic results.

The weighted precipitation modeling approach indicated mean residence times of stream baseflow of about 13 months for all sites. Application of this method was limited by the two-year period of prior precipitation isotope data in this study. Results implied that groundwater with greater mean residence times and lower oxygen-18 levels was also influencing stream baseflow at all sites.

Using the theoretical modeling approach, an exponential-piston flow model gave the best results for baseflow and soil water oxygen-18 data. Unique sine-wave functions were derived to represent the differential recharge of precipitation to groundwater between seasons of the year. Mean residence time functions in these models peaked at a residence time of about 40-150 days showing the influence of relative rapid piston flow, with gradually declining exponential flow thereafter. For the exponential-piston flow model, this translated into about 12-25% of water received as direct piston flow. Mean residence times for the observed baseflow was estimated at about 8.5-10.5 months using this

approach. Again, the contribution of groundwater with longer mean residence times may not have been completely accounted for. Analysis of soil water oxygen-18 showed mean residence times at the 100 cm depth at this site of about 2.3-4.5 months.

Estimation of mean residence times of shallow groundwater in this region is possible using temporal variations in oxygen-18 levels in precipitation. In future modeling efforts, greater emphasis should be given to monitoring of year-to-year, as well as seasonal isotope levels in precipitation, for up to five years prior to stream measurements to insure adequate evaluation of the effects of groundwater with long mean residence times. Although the effects of rapid piston-like recharge on stream baseflow was apparent in this study, mean residence times for stream baseflow may have been underestimated using the available two-year data set.

Basic Information

Title:	Occurrence of <i>Helicobacter pylori</i> in Surface, Ground, and Finished Water Implications for Drinking Water Supplies
Project Number:	C-05
Start Date:	9/1/1998
End Date:	8/31/2000
Research Category:	Water Quality
Focus Category:	Water Quality, Water Quality, Water Use
Descriptors:	drinking water, pathogens, <i>Helicobacter pylori</i> , disinfection, ulcers
Lead Institute:	Environmental Resources Research Institute
Principle Investigators:	Katherine H. Baker, Diane S. Herson

Publication

1. Baker, K. H. and J. P. Hegarty, 2001, Presence of *Helicobacter pylori* in drinking water is associated with clinical infection, *Scan. J. Infect. Dis.* (in press).
2. Hegarty, J. P., M. T. Dowd, and K. H. Baker, 1999, Occurrence of *Helicobacter pylori* in surface water in the United States. *J. Appl. Microbiol.* 87(5), 697-701.
3. Baker, K. H., J. P. Hegarty, Y.-L. Ma, B. R. Redmond, and D. S. Herson. 1999. *Helicobacter pylori* and drinking water: Occurrence, persistence and clinical infection. 10th International CHRO Workshop. Baltimore, MD. September 13-14, 1999.
4. Herson, D. S. and K. H. Baker, 1999, Current research on waterborne pathogens. 3rd CECIA-Interamericas University of Puerto Rico Symposium & Workshop, San Juan. February 2, 1999. Occurrence of *Helicobacter pylori* in surface water: Implications for transmission.
5. Hegarty, J. P., H.-L. Ma, C. M. Lebo, T. L. Konopka and K. H. Baker, 1999, Water borne transmission of *Helicobacter pylori*: Convergence of environmental and clinical observations. 99th General Meeting American Society for Microbiology.
6. Ma, Y.-L., J. P. Hegarty and K. H. Baker, 1999, Persistence of *Helicobacter pylori*, *Campylobacter jejuni* and *Escherichia coli* in culturable form in groundwater. 99th General Meeting American Society for Microbiology.
7. Hegarty, J. P., D. S. Herson, B. W. Redmond, N. A. Reed and K. H. Baker, 1999, Effect of oxidizing disinfectants on *Helicobacter pylori* and *E. coli* A comparative study. 99th General Meeting American Society for Microbiology.

Problem and Research Objectives

Chronic gastritis is one of the most common diseases in the world. The recognition of *Helicobacter pylori* as the major causative agent of chronic gastritis, gastric ulcer disease, and stomach cancer has spawned intensive research on the pathophysiology and epidemiology of this organism. In spite of the widespread occurrence of *Helicobacter pylori* infections, estimated to be as high as 50% of the world's population, little is known about the mode of the transmission and natural history of this organism. Current opinion regarding the mode of transmission of *Helicobacter pylori* is divided with some epidemiological evidence supporting the hypothesis of direct transmission and other studies implicating a water-borne transmission route.

This research examined the possible water-borne transmission of *Helicobacter pylori* via two primary research objectives:

1. Monitoring of aquatic environments for *Helicobacter pylori*.
2. Evaluating the effect of common disinfection treatments on the survival of *Helicobacter pylori*.

Methodology

Water samples were aseptically collected in sterile Whirl-Pak bags and shipped to our laboratory on ice. Samples were analyzed for the presence of *Helicobacter pylori* using fluorescent-antibody-CTC (FACTC) staining. Total coliforms and *E. coli* were enumerated on m-Coli Blue broth. In addition, for several of the samples, the presence of *Helicobacter pylori* was confirmed using a semi-nested PCR amplification of a 203 bp segment of the urease gene.

Disinfection studies specifically examined the effects of free chlorine, chloramines and ozone on *E. coli*, *Campylobacter jejuni* and *Helicobacter pylori*. Disinfectant efficiency was determined using viable count reduction in a culture after disinfection.

Principal Findings and Significance

1. Developed a combined antibody-tetrazolium salt reduction (FA-CTC) assay which allows for the detection of *H. pylori* in water samples.
2. Developed a semi-nested polymerase chain reaction (PCR) primer set and protocol for the detection of *H. pylori* in water samples. Note: This assay was developed at the conclusion of the research project and we are still in the process of optimizing the final assay.

3. Using primarily the FACTC assay, evaluated 37 water samples for the presence of *H. pylori* as well as assaying for the presence of traditional indicators – fecal coliforms and *E. coli*. This work is continuing at present with collaborative projects involving USGS (Baker/Penn State), CDC (Baker, Penn State and Herson, U. Del.), and New Jersey DEP (Herson, U. Del.). Preliminary research has been conducted in Puerto Rico involving collaboration with InterAmericas University. This collaboration will be expanded over the next year.

Information Transfer Program

Basic Information

Title:	Development of Youth Water Conservation Education Materials for Pennsylvania 4-H Programs
Start Date:	3/1/1999
End Date:	2/28/2001
Descriptors:	youth, water conservation education
Lead Institute:	Environmental Resources Research Institute
Principle Investigators:	William E. Sharpe

Publication

1. A 4-H Leaders Guide and Member Workbook are in publication.

Problem and Research Objectives

Adapt existing water conservation educational materials for use in Pennsylvania with 4-H Club members.

Methodology

4-H curriculum booklets for leaders and members

Principal Findings and Significance

Drafts of the member and leader curriculum booklets have been reviewed by Penn State's 4-H Natural Resources Curriculum Committee. The booklets were extensively revised in response to the committee's comments. The final publications are in publication.

USGS Summer Intern Program

Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 RCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	1	N/A	N/A	N/A	1
Masters	1	N/A	N/A	N/A	1
Ph.D.	N/A	N/A	N/A	N/A	0
Post-Doc.	N/A	N/A	N/A	N/A	0
Total	2	N/A	N/A	N/A	2

Notable Awards and Achievements

None

Publications from Prior Projects

1. Review in progress