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Arkansas Water Resources Center Annual Technical Report FY 2003

Introduction

Statewide Mission: The Arkansas Water Resources Center (AWRC) has a statewide mission to plan and conduct water resource research. AWRC cooperates closely with colleges, universities, and other organizations in Arkansas to address the state's water and land-related problems, promote the dissemination and application of research results, and provide for the training of scientists in water resources.

Support Provided: The Center acts as a liaison between funding groups and the scientists, and then coordinates and administers grants once they are funded. Accounting, reporting, and water analyses are major areas of support offered to principal investigators.

Technology Transfer: AWRC sponsors an annual water conference held in Fayetteville, Arkansas each spring, drawing in about 125 researchers, students, agency personnel, and interested citizens to hear about results of current research and hot topics in water resources throughout the state. AWRC also co-sponsors short courses and other water-related conferences in the state and region. In addition, AWRC maintains a technical library containing over 900 titles, many of which are on-line. this valuable resource is utilized by a variety of user groups including researchers, regulators, planners, lawyers, and citizens.

AWRC Water Quality Laboratory: The Center maintains a modern water quality laboratory that provides water analyses for researchers, and for farmers and others who submit samples through the Cooperative Extension Service and the Department of Housing and Urban Development.

Geographical Information System (GIS) Support: The Center for Advanced Spatial Technology (CAST) and the GIS Laboratory in the Department of Crop, Soil, and Environmental Sciences provide support in developing GIS data for the management and protection of water.

Projects Funded: Three of the six projects funded during FY2003 provided meager but invaluable summer support for three students (two Ph.D. candidates and one M.S. candidate) from three colleges (Arts and Sciences, Engineering, and Agriculture). The other three projects provided partial or full academic year support for graduate students in Biological and Agricultural Engineering, and Crops, Soils and Environmental Sciences. The projects focused primarily on topics of nonpoint source pollution related to nutrient loading from animal agriculture in northwest Arkansas. The projects providing summer stipend support were more diverse with topics ranging from alternate sources of public water supply, to quantifying impacts to infiltration and runoff related to watershed urbanization. Ultimately, all projects lead to publication in the form of conference proceedings, dissertations and journal articles although publication often occurs one to two years after the end date for the USGS 104 b projects. This lag in time to publication is reflected each year in the publication from prior years section of this annual report.

Research Program

AWRC has contributed substantially to Arkansas water resources via research and training of students. In a typical year, AWRC interfaces with about 25 researchers throughout the state with involvement in about 50 projects per year. In 2003, 52 project passed through AWRC and involved training of 52 students made up of 27 undergraduates, 20 masters, and 5 Ph.D. candidates.

Antibiotic resistance and the relationship between enzyme activity and P in runoff from poultry litter amended soil

Basic Information

Title:	Antibiotic resistance and the relationship between enzyme activity and P in runoff from poultry litter amended soil
Project Number:	2003AR47B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	Third
Research Category:	Water Quality
Focus Category:	Surface Water, Ecology, Non Point Pollution
Descriptors:	antibiotic resistance, phosphorus, runoff, microorganisms, enzymes, phosphatase, poultry litter
Principal Investigators:	Mary Cathleen Savin

Publication

1. Tomlinson, P.J., and M.C. Savin, 2004, Antibiotic Resistance in Runoff and Soil Receiving Poultry Litter, Annual Meetings Abstracts [CD-ROM], ASA, CSSA, and SSSA, Madison, WI, in press.
2. Tomlinson, P.J., and M.C. Savin, 2004, Poultry Litter, An Influence on Antibiotic Resistance in Soil, Annual Meeting Abstracts, Southern Branch of the American Society of Agronomy, Biloxi, MS, June 27-29, 2004 in press.
3. Tomlinson, P.J., K.R. Payne, K.R. Brye, and M.C. Savin, 2003, Microbial Dynamics in Long-Term Research Plots Receiving Alum-Treated and Untreated Poultry Litter, Annual Meetings Abstracts [CD-ROM], ASA, CSSA, and SSSA, Madison, WI.

PROBLEMS AND RESEARCH OBJECTIVES

While poultry litter amendments have provided a means to improve pastures, concern about runoff water quality is escalating. Phosphatase enzymes release P from organic sources and may be contributing to the subsequent P contamination of runoff from soils receiving long-term applications of poultry litter. Some previous studies have suggested that organic P in animal wastes is much more mobile than inorganic P. However, there is some question as to whether elevated phosphatase enzymes will be sustained after multiple years of poultry litter inputs. If phosphatase enzyme activity is high in soils receiving animal wastes, then this could provide valuable insight into soluble P concentrations found in runoff.

Previous research has also indicated that antibiotic resistant microbes are present in poultry litter and antibiotic resistance in general is increasing. However, it is not clear to what extent antibiotics in poultry litter-amended soil influence the development and transport of antibiotic resistant bacteria from soil into runoff waters.

Objectives

The primary objective of this research is to investigate the effect of poultry litter amendments on environmental microbial community functions and potential contributions to pollution of surface waters. Specific objectives include the following:

1. Determine contribution of poultry litter land applications to antibiotic resistance development in microbial communities transported in surface runoff.
2. Determine if there is a relationship between phosphatase enzyme activities in surface soil amended with poultry litter and dissolved P concentrations in runoff water.

METHODOLOGY

Runoff water and soil samples were collected in 2003 from 20 plots (4 replications per treatment) growing tall fescue and receiving annual inputs of poultry litter since 1995. Plots are located at the University of Arkansas Main Agricultural Experiment Station, Fayetteville, AR. Treatments included unfertilized, control plots (C), plots receiving alum-treated litter applied at 2.24 Mg/ha (A1), alum-treated litter applied at 8.98 Mg/ha (A4), untreated litter at 2.24 Mg/ha (L1), and untreated litter applied at 8.98 Mg/ha (L4). Litter was added to soil in May and soil samples were collected in May, June, July, and November. Soil microbial biomass was measured using chloroform-fumigation-extraction. Acid and alkaline phosphatase enzyme activities were measured colorimetrically after incubation of soil in buffered sodium p-nitrophenyl phosphate solutions.

Runoff was collected in July (3 time points), September, and November. Runoff collection troughs, covered with plexiglass to minimize inputs other than from runoff, were fitted at the bottom of each plot (5% slope). Runoff samples were collected after filtration in the field through fiberglass mesh and a 20-um filter into previously sterilized, plastic bottles placed in enclosed collection bins following rain events significant enough to generate runoff.

A small portion of the water sample was removed, filtered, acidified, and analyzed colorimetrically for soluble reactive P. Because of the filtration system used in the field to eliminate grazers, a subsample of runoff was extracted for total DNA. Another subsample was serially diluted and plated onto 0.1x tryptic soy agar (TSA) plates. Cultivated bacteria were then replica plated onto 0.1x TSA plates containing known concentrations of monensin, bacitracin, or tetracycline (November only). Antibiotic concentrations tested were as follows: 0, 10, 50, 250 µg/ml monensin, 0, 0.5, 2.5, 12.5 units/ml bacitracin, and 0, 10, 50 and 100 µg/ml tetracycline. Resistance was measured by the loss of bacterial growth at each antibiotic concentration as compared to replica plates containing no antibiotics. DNA from antibiotic resistant cultured bacteria was extracted and amplified by polymerase chain reaction (PCR) for 16S rRNA gene fragments. Amplified DNA was separated on polyacrylamide gels using denaturant gradient gel electrophoresis (DGGE) to generate profiles of bacterial community structure.

PRINCIPAL FINDINGS AND SIGNIFICANCE

Deeper insight into biological properties, such as antibiotic resistance, and processes, such as nutrient cycling, are necessary before we can consistently and effectively enhance the positive, and ameliorate the negative, environmental consequences of land management practices on surface runoff water quality. In this project we investigated the relationship between microbial activity in the soil and its impact on runoff water. The information collected in this research project will enhance the current state of knowledge concerning biological processes controlling the environmental impact of poultry litter amendments on soil and surface water quality.

Relatively few rain events were significant enough to generate runoff from our plots. It was not until autumn that natural runoff was collected from all 20 plots. Generally, rain had to be close to or exceed 1.5 cm to generate runoff. However, large rain amounts did not guarantee runoff. For example, at the end of August there were two rain events in less than one week where over 4 cm of rain fell each time, but no runoff was generated from our plots.

Objective 1.

We had hypothesized that antibiotic resistance would be higher in runoff from soil receiving high rates of poultry litter inputs. Our data, in fact, do not support that hypothesis. Runoff collected from four rain events (7/12-7/13, 7/22, 9/13, and 11/18) was screened for antibiotic resistance. We found very little difference in expression of antibiotic resistance from bacteria cultivated from runoff of the controls and four litter application treatments. Levels of antibiotic resistance were related to antibiotic tested, with use of monensin resulting in higher levels of antibiotic resistance as compared to bacitracin. Resistance to monensin was high at each sampling time, with greater than 80% resistance measured in all runoff treatments as well as in bacteria isolated from the litter itself. Bacitracin resistance was always greater than 50% in all treatments at all sampling dates with no consistent differences among treatments across sampling dates. These results contrast to resistance expressed by bacteria cultivated from the litter itself. Resistance to bacitracin among litter bacteria was 20% at a concentration of 2 units/ml.

Tetracycline was screened in November because a collaborator in Indiana found higher resistance to tetracycline-related antibiotics in soil receiving swine wastes than untreated soil. In our runoff communities, controls showed resistance in 30% of isolates whereas resistance in runoff from litter treated soils was less than 10% at the highest tetracycline concentration tested.

Preliminary results of DGGE profiles of soil bacterial communities growing on each of the antibiotics suggest that community structures of tetracycline resistant bacteria are not the same as communities growing on monensin and bacitracin. Additionally, community structures of bacteria isolated from control soils expressing resistance to tetracycline appear to be different from litter treated soils. We are continuing to analyze bacterial community structures by DGGE for soil and runoff bacterial isolates.

Objective 2.

It was hypothesized that phosphatase levels in surface soils can serve as positive indicators of potential soluble P concentrations in runoff waters. To assess this possibility we measured soluble reactive P (SRP) in runoff and alkaline and acid phosphatase activities in soil. Because visual inspection of samples indicated that differing amounts of dissolved organic carbon (DOC) were present in runoff samples, we measured DOC in each of the SRP runoff samples. Microbial biomass and soil DOC were also measured in June, July and November. Scatter plots of runoff SRP plotted as a function of runoff DOC suggested that SRP was linearly related to DOC concentration ($R^2 = 0.69$ for all points, $R^2 = 0.93$ with 3 outliers removed). When analyzing each treatment separately, runoff SRP was linearly related to runoff DOC in C ($R^2 = 0.99$), less so in runoff from alum-treated soil treatments A1 ($R^2 = 0.69$), and A4 ($R^2 = 0.73$). Preliminary analysis suggests that there was not a clear linear relationship in either L1 ($R^2 = 0.20$) or L4 ($R^2 = 0.37$).

November was the only sampling time that both runoff and phosphatase activity data were collected for all plots. Runoff SRP did not appear to be directly related to either soil acid or alkaline phosphatase activities at that sampling time.

Analysis of data is continuing in 2004. However, preliminary results suggest that antibiotic resistance expressed in bacterial communities isolated from runoff depends on the particular antibiotic, and, for at least some antibiotics, the sampling time and/or soil treatments. Soluble reactive P appears to be related to the amount of dissolved organic C in runoff. Neither acid nor alkaline phosphatase activity six months after litter applications appeared to be related to runoff SRP. We are currently analyzing runoff collected in the spring 2004 before and after litter application to determine if soil phosphatase activity is related to runoff SRP in the spring.

Development of techniques for identifying and linking physical characteristics to surface runoff source areas

Basic Information

Title:	Development of techniques for identifying and linking physical characteristics to surface runoff source areas
Project Number:	2003AR48B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	Third
Research Category:	Ground-water Flow and Transport
Focus Category:	Hydrology, Non Point Pollution, None
Descriptors:	Hydrology, Soil Moisture Content, Runoff, Nonpoint Source Pollution
Principal Investigators:	Indrajeet Chaubey, Thomas A. Costello

Publication

PROBLEMS AND RESEARCH OBJECTIVES

Runoff contributing to the transport of nonpoint source pollution is highly nonlinear and spatially variable, involving surface and subsurface pathways (Hoover, 1990). Runoff originating from landscape is spatially and temporally variable and is a function of rainfall intensity and duration antecedent soil moisture conditions, soils, topography, and groundwater levels (Wolock, 1993; Wood et al., 1990). Freeze (1974) reported that spatially variable runoff originates from small but consistent portions of upstream areas that constitute less than 10% (usually 1-3%) of the watershed area, and even on these areas, only 10-30% of the rainfall causes overland flow. The areas that do contribute to the runoff and potentially nonpoint source pollution are called 'runoff contributing areas' or 'runoff-source areas.'

Although the runoff-source areas concept is not a new one, minimal research has been conducted towards integrating the idea into current nonpoint source pollution management techniques. In particular, this concept has not been integrating into watershed computer models that predict constituent inputs based on terrestrial management. This limits modeling accuracy and increases uncertainty in modeling results; which can be crucial when managing a specific constituent that is highly correlated with surface runoff. This project is a step in developing the knowledge needed to predict runoff-source areas as a function of soil, topographical, and hydrological characteristics.

The project objectives are to 1.) develop and test a field-scale methodology to measure the location of different runoff-source areas from pastureland and 2.) related the spatial variability of field runoff to soil, topographical, and hydrological characteristics.

METHODOLOGY

The objectives are accomplished through field data collection, GIS analysis, and statistical evaluations. Twenty subsurface saturation sensors, twenty surface runoff sensors, and a rain gage are installed on a 0.25 ha plot at Savoy Experimental Watershed located in Ozark Highlands. Sensors are connected to a series of multiplexors and CR-21X data loggers (Campbell Scientific, Inc.) for real time data collection. To obtain initial moisture content of the soil, a hand held soil moisture probe is used to measure initial moisture content at each subsurface sensor prior to rainfall events. These results are used to calibrate and interpret the data collected from the subsurface sensors. Soil moisture information, runoff sensors, and rain gage data will be used to interpret runoff source areas. We will link this hydrologic information to measured topographic (percent slope, shape, and direction) and soil characteristics data (hydraulic conductivity, bulk density, depth of soil, antecedent soil moisture) to develop relationships between the spatial variability of field runoff and topographic and soil characteristics. A GIS system will be used to derive the relationship among spatial physical data (e.g., topography, surface management, slope), antecedent soil moisture conditions, and runoff-contributing areas. Since pasture is the only land use type in the field, land use will not be treated as an independent variable in predicting runoff-source areas. Geostatistical techniques (Chiles and Delfiner, 1999) will be used to quantify spatial variability in topographic index and soil properties and to correlate it to spatial variability of runoff-source areas.

PRINCIPAL FINDINGS AND SIGNIFICANCE

We have collected preliminary runoff data. The data analyses is currently underway for this project. The results should be available by December, 2004.

Evaluating the Influence of Lake Francis on Phosphorus Concentrations and Transport at the Illinois River

Basic Information

Title:	Evaluating the Influence of Lake Francis on Phosphorus Concentrations and Transport at the Illinois River
Project Number:	2003AR50B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	Third
Research Category:	Water Quality
Focus Category:	Water Quality, Sediments, Surface Water
Descriptors:	Water Quality, Phosphorus, Sediment, Watershed Management
Principal Investigators:	Thomas S. Soerens, W. Fred Limp

Publication

1. Soerens, T., 2004, "Phosphorus Loads Upstream (Arkansas) and Downstream (Oklahoma) of Lake Frances: Are Differences Due to Monitoring Program Design, Natural Variation, or the Lake?," National Water Quality Monitoring Council, 2004 National Monitoring Conference, May 17-20, 2004, Chattanooga, TN.

PROBLEM AND RESEARCH OBJECTIVES

Lake Frances is a very small impoundment on the Illinois River that spans the border between Arkansas and Oklahoma. Results of water quality monitoring have shown apparent differences between nutrient concentrations upstream (Arkansas) and downstream (Oklahoma) of the lake. In Oklahoma, results have shown increasing trends in phosphorus loads. The sampling and load calculation are performed by different agencies on the different sides of the state line and monitoring strategies have changed over the years. The goal of this project was to identify the reasons for the differences between the states and to investigate the influence of Lake Frances on phosphorus concentrations and transport.

METHODOLOGY

The study used water sampling, sediment sampling, and historical data to evaluate changes in phosphorus concentrations and loads upstream and downstream of Lake Frances during base flow and surface runoff flow regimes. Water quality samples were taken on ten dates at four locations – upstream and downstream of Lake Frances and in two tributaries. Samples were analyzed at the USDA-ARS-PPPSRU laboratory. Sediment cores were taken at several locations and phosphorus flux was measured in the laboratory. Historical data was obtained from USGS and from published reports by state and federal agencies. Arkansas and Oklahoma newspaper archives were searched for stories related to Lake Frances and conversations were held with Siloam Springs water supply personnel.

PRINCIPAL FINDINGS AND SIGNIFICANCE

Initial results of water sampling show that Lake Frances is a phosphorus sink (higher concentrations upstream than downstream) and a phosphorus source during winter. Sediment sampling showed sediments very rich in phosphorus with high phosphorus exchange rates. Examination of historical discharge data shows no apparent discrepancies between upstream and downstream flows. It appears that differences between upstream and downstream loads are primarily due to the variation and imprecision in determining concentrations and loads and to differences in monitoring program design. These results underscore the need for monitoring programs on both sides of the state border to be consistent and comparable.

Impact of Urbanization on the Spatial and Temporal Distribution of Infiltration

Basic Information

Title:	Impact of Urbanization on the Spatial and Temporal Distribution of Infiltration
Project Number:	2003AR54B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	3
Research Category:	None
Focus Category:	Non Point Pollution, Surface Water, None
Descriptors:	None
Principal Investigators:	Ralph K. K Davis

Publication

1. Wilson, A.G., 2003, Impact of Urbanization on the Spatial and Temporal Distribution of Infiltration. M.S. Thesis, Department of Civil Engineering, University of Arkansas, Fayetteville, Arkansas, 132p.

Introduction

This project was funded in part through the USGS 104 b program at the level of summer stipend for the graduate assistant in the Department of Civil Engineering at the University of Arkansas. The project was carried out by a Master's candidate in the Department of Civil Engineering and focused on the impacts of urbanization on infiltration. Impervious surfaces reduce infiltration and increase runoff. The impact of urbanization on infiltration at the watershed scale is poorly understood but includes increased soil density due to increased traffic on the watershed surface. This in turn results in reduced infiltration and increased runoff. Most runoff estimations are made using models based on routing water through various hydrologic storage units. However, the differences in infiltration rates and runoff rates resulting from urbanization are significant and ultimately influence stormwater runoff predications using the U.S. EPA Stormwater Management Model (SWMM). This project focused on understanding differences in measured undeveloped and developed infiltration parameters. These parameters were then used as input to SWMM to assess the sensitivity of the model to the differences in infiltration changes from undeveloped and developed watersheds.

Objective

The objectives of this research were to 1) quantify through field experiments the urban impact on the spatial and temporal distribution of infiltration using double-ring infiltrometer tests, 2) develop modified infiltration algorithms for use in stormwater management models, and 3) to develop selection and implementation guidance for site design and stormwater infiltration practices in Northwest Arkansas. The objective for the field experiments was to conduct this to determine the difference in soil hydrological characteristics, specifically infiltration, for the same land parcel before development and after development.

Methods, Procedures, and Facilities

The field experiments were performed at the same site location during pre-development conditions and then developed conditions. The experiments were concentrated in an area roughly 1600 ft² (40' x 40'). Measurements were taken at the center of grid cells that are spaced approximately 10 feet apart. Measurements were made once per 3-4 weeks during the months of May, June, July, August, and September. The following suite of soil characteristics were measured:

- 1 . Soil classification (once per development scenario)
- 2 . Soil compaction (at every grid cell)
- 3 . Soil moisture (at every grid cell)
- 4 . Infiltration (at every grid cell)
- 5 . Soil temperature (average throughout the site)
- 6 . Ambient temperature (once per experiment set)

Significant Findings

1. The average initial and final infiltration rates measured within the undeveloped plot were greater than those measured within the developed plot at a commercial development.
2. The average soil water content within the undeveloped plot was higher than the soil water content within the developed plot, while the compaction at the undeveloped plot was lower.
3. Differences between the measured undeveloped and developed Horton infiltration parameters are significant enough to influence stormwater runoff prediction using SWMM.
4. Published infiltration parameters used in the SWMM model predicted a peak flow rate 20% lower than the peak flow rate predicted by the developed infiltration parameters.

These findings are relevant to city, county, and state planning personnel involved in design and implementation of stormwater management programs. Using the developed infiltration parameters will provide a more real-world prediction of anticipated runoff resulting from site development and will help alleviate problems associated with reductions in runoff lag-time and increased peak discharge resulting from urbanization of watersheds.

Viability of Obtaining Drinking Water From the Flooded Coal Mines in the Area of Greenwood, Arkansas

Basic Information

Title:	Viability of Obtaining Drinking Water From the Flooded Coal Mines in the Area of Greenwood, Arkansas
Project Number:	2003AR55B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	3
Research Category:	None
Focus Category:	Water Supply, Water Quality, Hydrogeochemistry
Descriptors:	None
Principal Investigators:	Ralph K. K Davis

Publication

1. Brahana, J.V., 2003, Hydrogeologic Research Along a Transect from the Ozarks to the Quachitas, Northwest to West?Central Arkansas: Field guide for University of Arkansas' 2003 Field Trip, 66 p.
2. Varnell, C. and J.V. Brahana, 2003, Factors Affecting Water Quality and Surface Water/Ground Water Interaction Associated with Flooded Coal Mines in Greenwood, Arkansas, Arkansas Water Resources Center Annual Water Conference,University of Arkansas, Fayetteville, Arkansas, April 2003.

Introduction

The City of Greenwood experienced a doubling of the population during the last decade. Growth projections for this community just south of Ft. Smith, Arkansas indicate that this city will continue to grow at a rapid rate. The city obtains its present water supply from Lake Greenwood, a 95-acre reservoir located just east of the city on Vache Grasse Creek. Currently, the city can supply 1.2 million gallons per day of treated water meet demand. This amount is currently exceeded on a number of days during the summer months. The city is constructing a larger treatment plant that can exceed 1.8 million gallons of water production per day. This would meet the cities projected needs for the next five years, but the production levels would exceed the storage capacity of the lake.

Construction of a new dam would entail costs exceeding 20 million dollars. The waters from the coal mine, if proven of sufficient quality and quantity, could provide the city a viable water source for the foreseeable future.

The water storage capacity of the underground mines exceeds 500 million gallons. If the water can be utilized, the city would be able to mix it with the current supply and meet the needs of the community for the next twenty-five years. The cost of the project is minimal when compared to the construction of a new dam, or an additional reservoir. The coal mines are a readily available source of water. If the water is deemed to be of sufficient quality, it would require minimal time to begin use of it along with the existing supply.

The overall purpose of this study was to assess the feasibility of using flooded coal mines as a safe, viable source of drinking water supplies for the city of Greenwood, Arkansas. Specific objectives include:

1. Facilitate the relationship between the various players involved in using the water from the coal mines, i.e. landowners, city officials, water experts and consultants, and various local, state, and federal regulating agencies.
2. Assist the city of Greenwood in complying with the various local, state, and national regulations during initial and testing phases. Serve as a liaison between the landowners, the general public, the city water council, and the various state agencies in order to ensure public confidence in the decision process.
3. Conduct research of historical data, compare surface and sub-surface maps, locate markers, and conduct personal interviews and field reconnaissance to determine the geographical and hydrological boundaries of the water impoundment within the coal mine.
4. Monitor water levels from potentially interconnected ground water and surface water sites in the study area during drawdown. These include Vache Grasse Creek, Greenwood #2, Fidelity Mine, nearby strip pits, Greenwood Reservoir, superjacent and subjacent aquifers, mapped fault zones for which data currently exists.
5. Determine potential changes in water quality stored in the mines as a result of extensive use of water from the mines, or from the introduction of highly oxygenated water into the mines from outside sources. Testing was conducted during periods of high and low precipitation.

The scope of this study included ground-water quality determination of major constituents, minor constituents, trace constituents, nutrients, and microbial components. The water analyses include the physical properties of temperature, specific conductance, and pH at the available wells, strip pits and other sites deemed necessary to the understanding of the hydrogeology of this system. Sampling was hydrologically based, meaning that low- flow, high flow, and anomalous hydrologic conditions such as major storms triggered sample collection. The scope encompassed flow to and from the system, and development of an integrated conceptual model.

Methodology:

The general physical boundaries of Fidelity and Greenwood #2 are known. It is also known that the mines began as slope mines, starting at or near the strip pits which are located on the east side of the city of Greenwood. The mineshafts follow a 7-degree dip to the east and the coal was confined in a layer varying from two to five feet in thickness. The base of the coal layer is found along the top of the Atoka Sandstone Formation. Void areas are generally five feet plus in height in the main tunnels and varying heights, usually less than 5 feet, in the side shafts. The coal was extracted by the room and pillar method, meaning that some areas of the mine have standing walls of coal left to support the overburden. The mines became flooded in 1929 and have not been used commercially since that time other than a surface venture to extract coal near the land surface in 1939. This endeavor proved uneconomical and was soon abandoned. These pits cut across the mine openings and have filled with water to become pits; in essence, small lakes interconnected to the waters of the coal mine.

Old mine maps and surface reconnaissance of such features as airshafts were used to determine drilling areas. Four wells were drilled into the void space from the surface; two of these are located in the Fidelity mine, two in Greenwood #2. One known well already existed on the property belonging to a local landowner and is located in the Fidelity mine. These subsurface sites as well as sites located on interconnected surface water sources are the primary sites for water sample extraction. These samples allow us to monitor the water quality for our watershed area.

Samples collected from the sites listed above were analyzed for major constituents, minor constituents, trace metals (beryllium, arsenic, aluminum, selenium, zinc), organic scans related to coals, microbial pathogens, nutrients, and other EPA drinking water requirements.

Surface reconnaissance and other geophysical methods were used to determine the recharge, inflow, outflow and the degree of interconnection between the strip pits, mines, Vache Grasse Creek, Jack Nolan Lake, Greenwood Reservoir, waste treatment discharge, sub-surface aquifers, and other water sources. Remote transducers were placed in well #4 and #7. These instruments continuously measure water temperature and pressure changes and were downloaded onto a laptop computer to provide water data over time. A weather station, including a tipping bucket rain gauge was installed at well #4 to determine precipitation events. Staff gauges were placed at the Alkali Pit, Holland's Pit, Patterson Pit, Vache Grasse, and Round Hole. These were continuously monitored in order to provide data concerning surface water flow rates. Water samples, stream flow, water temperature, pH, conductivity, turbidity rates, and coliform bacteria tests were conducted at each site.

Historical data compilation and consultation with scientists and individuals from other regions utilizing coal mines as a water source provided insight into the best methods to use to determine the viability of using water from the mines. They also provided useful insight into any possible health concerns that might arise.

A very important component in conducting the research was to coordinate the activities and data collection with the various involved parties. These include the property owners, the engineering firm, the city council, the city water treatment employees, the general public, and the various regulating agencies. These include the EPA, DEQ, Game and Fish Commission, State Health Board, Arkansas Geologic Survey, and others.

Significant Findings

Final determination about the viability of using the coal mines as a source of public water for the City of Greenwood has not yet been made. This project provided supplemental funding to support a Ph.D. graduate research assistant for the summer of 2003 to assist with this project. Significant findings based on research completed to date are listed below.

The quality of the water in the mines appears to change with the season. Changes from August 2001 to February 2002 include: decreased concentration in specific conductance, bicarbonate, chloride, sulfate, calcium and sodium.

These chemical changes appear to be caused by the following: decreased residence time that promotes dissolution; increased recharge rate to the mine causing mixing and dilution of chemical species; and location in mine with respect to main flow pathways that determines the extent of the mixing and dilution.

Specific concerns with using water from the mines that must be addressed are: 1) Presence of identified contaminants in the coal and the water in the surrounding containment basin, 2) changing mine chemistry (redox conditions), 3) debris from various sources that has been dumped into the mines over the years, 4) treated waste water that may enter the mine via surface water-ground water exchange, 5) storm water that may enter the mine via surface water-ground water exchange.

While utilization of these reservoirs offers many advantages, the presence and concentrations of undesirable constituents and the changing chemistry within the mine require the development of a monitoring system that will ensure a continuous and healthy water supply, if this is the option finally selected as the future water supply for the City of Greenwood.

Analysis of Water Conflicts in Pakistan and the Middle East A Comparative Study

Basic Information

Title:	Analysis of Water Conflicts in Pakistan and the Middle East A Comparative Study
Project Number:	2003AR57B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	3
Research Category:	None
Focus Category:	Law, Institutions, and Policy, Water Use, Water Supply
Descriptors:	None
Principal Investigators:	Ralph K. K Davis

Publication

Statement of Problem

Irrespective of race or nationality water is a spring of life for every living thing. Water is not however available to every one equally or even equitably. Extended drought during recent years and shrinking water resources in Pakistan and Middle Eastern countries (Jordan, Israel, Lebanon, Syria and Egypt) indicate that the countries are nearing conditions of chronic water stress. The gap between demand and supply of water across all the countries has increased to levels creating inter-provincial and transboundary conflicts. This is also true about the water situation in the USA, especially in Western region where Colorado fights with Kansas over water rights in the Arkansas River basin, and in the regions of the country experiencing significant groundwater depletion.

In the case of Pakistan, conflicts over water abound. Smaller provinces such as Sindh, NWFP and Blochistan complain that, Punjab the largest province is usurping their share of water. Additionally there is friction between Pakistan and India on water apportionment of the Indus River. This situation is further complicated by arch rivalry and cultural heterogeneity on both sides of the border.

Equitable water allocation is also a bone of contention among some Middle Eastern countries. The Jordan River system shared by Jordan, Israel, the Palestinians of the occupied territories, Syria, and Lebanon is a major focus of Middle Eastern politics. The Middle Eastern situation seems complex for many reasons. There are tribal systems that still prevail in many of the countries, and cultural and religious practices vary and sometimes conflict across nations. Most importantly attitudes towards water consumption vary across countries. For many Middle Eastern countries water is more valuable than oil for them to survive in 21st century. This situation highlights the importance of developing new resources and adopting water-conservation measures for extremely judicious use of the finite quantity of water including surface water, rainfall, and groundwater not only in Pakistan but in the Middle Eastern countries as well.

Objectives

The objectives of the proposed study are:

- 1) To examine socio-cultural, political, and water resources situations in Pakistan, India and the Middle East to search for sustainable approaches for managing and decreasing water resources in Pakistan and the Middle East, and
- 2) To evaluate alternative policy scenarios, within the design of the local and regional implementation schemes, for resolving inter-provincial and transboundary conflicts. The following sections discuss the background to the water conflicts between Pakistan and India and among the Middle Eastern countries, data sources and the expected results of the study.

Policy Issue Background

Water has a direct bearing on almost all sectors of economy not only in Pakistan, but other regions of the world including Middle East as well. In Pakistan it holds very high importance due to the agrarian nature of the economy. The share of agricultural sector in the Gross Domestic Product (GDP) of Pakistan is about 24 % (WAPDA, Pakistan 2000). Since agriculture¹ is the major user of water, therefore the sustainability of agriculture depends on the timely and adequate availability of water. The increasing pressures of population and industrialization have already placed greater demands on water, with an ever-increasing number and intensity of local and regional conflicts over its availability and use.

Once a water-surplus country with the huge water-resources of the Indus River System, Pakistan is now a water-deficit country. At present, the annual per capita water- availability in Pakistan is about 1100 cubic meter (m³); below 1,000 m³, countries begin experiencing chronic water stress (Population Action International, 1993). The worsening water situation in Pakistan often creates unrest among the four provinces and also contributes to inter-regional conflicts between India and Pakistan. India and Pakistan have waged war three times (1965, 1971 and recently battle of Kargil in 1999) most often it is described as a conflict over the area known as Kashmir (the disputed territory) issue, but water is always one of the underlying factors. Z. A, Bhutto (the then Prime Minister of Pakistan), while addressing the UN Security Council in 1965, clearly indicated that there cannot be peace between India and Pakistan unless problem of Kashmir is solved. The main hindrance in Kashmir's solution, he stressed is issue of water. Pakistan fears, if India takes over Kashmir, it can easily block the water to Pakistan, which will devastate Pakistan's economy.

There is a similar theme in the nature of conflicts among the Middle Eastern countries. In fact, water has become a key element in the balance of power among Syria, Israel, Lebanon, Iraq and Turkey (Wihbey & Berman, 2000). This is true for Israel and Lebanon where there has been an armed conflict over water, in particular, the Litani River. As noted by Dolatyar (1995), Israel invaded Lebanon in 1982 and occupied its South until the year 2000 to secure the waters of the Litani River. Then, on September 11, 2002, Israel considered pumping water from an affluent to the Jordan River by Lebanon – the Wazzani River – as a “casus belli” and declared war on Lebanon (L’Orient-Le-Jour, 2002). There is no war yet, but everybody became involved in the conflict from the UN to Mr. Colin Powell personally (Fisk, 2002).

Relevance to Central Great Plains Water Situation, USA

The Central Great Plains Region includes Missouri River basin and the Arkansas River basin serving eastern Colorado, Montana, Nebraska, North Dakota, South Dakota, and Wyoming, as well as Kansas, Oklahoma, and the eastern Texas.

The biggest regional issue is the lack of surplus capacity in regional water supplies. For example, water from the Arkansas River serves multiple uses as it passes through the different states. The

¹ Irrigated agriculture in the Western state of the USA is the main end user as well. Though, there is transformation from agriculture to urban development, nevertheless agriculture continues to receive a major water share.

resulting conflicts over allocation of limited groundwater² and surface water supplies have led to a number of lawsuits in the region. Conflicts in Arkansas River basin are particularly contentious mainly due to falling groundwater table. Excessive pumping for irrigation and urban uses have increased demands for access to surface water or decreased supplies of surface water.

Irrigated agriculture being a main end user in the Central Great Plains claims about 76 percent of all withdrawals of surface water. This figure is much higher in many western states and river basins. For example, approximately 95 percent of the water diverted from the Rio Grande and the upper basin of the Colorado River is used for irrigating crops and livestock only. This situation calls upon policy makers to refine the water administration practices to avert water crisis in the future as increase in population and urbanization demand for water will increase the competition among the sectors.

Claims to water rights by Native Americans are another source of conflict in allocating water in the western states. Recently, many tribes have asserted their water rights, but most of them have not been able to succeed in claiming their due rights from long-established users. Many disputes remained unresolved, and most tribal water rights are not quantified³. Besides, challenges of living and farming in a river basin can be overwhelming to individual water users, when there is uncertainty over down stream water rights⁴, growing urban water demands, and increasing awareness of the need to protect aquatic ecosystems. This alarms that; the water distribution among competing sectors will pose a great challenge for water management in the western states.

Methods

In order to undertake a study of this magnitude requires the use of secondary data in most cases. However, the study was also substantiated with primary data. Primary data consisted of interviews with the key personnel in Pakistani water related institutions (for example, Water and Power Development Authority (WAPDA), On Farm Water Management (OFWM), Pakistan Irrigation and Drainage Authority (PIDA), Indus River Systems Authority (IRSA)). These personnel know the water situation very well and provide information about (1) the development and roles of water institutions in the historical context, (2) the coordination among institutions, (3) the inter-provincial water conflicts, and cultural and religious heterogeneity that complicates the water situation and (4) strategies to resolve the conflicts. This qualitative data collected through interviews were used to further understand secondary data sources. Secondary data for Pakistan came from published materials including departmental quarterly and annual reports, project documents, gazettes and bureau reports of WAPDA, OFWM, PIDA, IRSA and other relevant departments. Data on water use were supplemented by additional information

² Arkansas defines ground water as part of “the water of the state”. As such, it is subject to the full protection afforded by the Arkansas Water and Air Pollution Control Act.

³ Though to lesser extent, this situation is similar to one in the Middle Eastern countries as several tribes claim their rights to water.

⁴ Sindh province of Pakistan is the lower riparian province on Indus River, and is experiencing severe water shortages due to over withdrawal of water by the upper riparian. This situation has created a kind of mistrust among four federating units of Pakistan.

regarding GDP, international trade with emphasis on trade with India and the Middle Eastern countries, population, and annual freshwater withdrawals from the Indus river and other two small rivers, as well as facts pertaining to national governments, languages, and ethnicities, which are obtained from Pakistan Financial Statistics Yearbook, and the World Bank resources.

Data for India came mainly from secondary sources such as 1) Ministry of Irrigation, Ministry of Agriculture, Commission on Center-State Relations, Government of India, Indian National Water Development Agency, published materials from several economic and water resources journals, World Bank and World Commission on Dams reports.

Secondary data from Middle Eastern countries came from several country reports, published papers, water related research reports and most importantly database called the Transboundary Freshwater Dispute Database (TFDD) summarized by Hamner and Wolf. This database contains the general findings from comparative assessments of river basin treaties. The collection included water related treaties and also 39 U.S. inter-state compacts dating from 1870 to the present. The TFDD contains information regarding the basins involved in treaties, the principal focus of the management of the basins, the number of signatories to a given treaty, the non-water linkages (such as, money, land or other concessions) of a given treaty, the provisions for information sharing, monitoring, conflict resolution, and enforcement provided by a given treaty or agreement, the method and amount of water diversion acceptable under the terms of the treaty, and the date on which the agreement was signed.

Research will also made use of the water laws and water related legislations of the USA, especially Water Act 217 that was passed by the Arkansas Legislature in 1969 to make Arkansas soil and water conservation commission responsible for water planning at the state level and the development of the first Arkansas Water Plan⁵. Based upon the data, the dissertation identified scientific and socio-political approaches for simulating alternate policy scenarios, within the design of the local and regional implementation to resolve the future regional conflicts.

The emphasis was on the role of inter-provincial and regional geopolitics in the development and management of water resources in two regions. Research was undertaken in two parts. First, investigations was directed towards cooperative solutions to manage water both within the borders of Pakistan and between Pakistan and India. Second, water management strategies used in this region were compared to some used in the Middle East. Initial emphasis has been placed on the study of Jordan, Israel, Lebanon, Syria and Egypt.

Significant Findings

This project provided summer funding during the summer of 2003 in support of ongoing Ph.D. dissertation preparation by Mr. Itlaf Abro, Public Policy Ph.D. program, University of Arkansas. The dissertation is still in preparation with an anticipated completion date of May 2005.

⁵ The plan was completed and published in 1975. Due to the ever-changing nature and severity of water resources problems, the legislature enacted Act 1051 to the original plan in 1985 directing the Commission to make it relevant to the changed situation.

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Phosphorus Concentrations and Sediment Phosphorus Flux in Streams and Reservoirs:

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Introduction

Water quality is a central concern for meeting the needs of an ever-increasing population in Northwest Arkansas. Despite substantial improvement in water quality following the Clean Water Act (Sharpley et al., 1994), the quality of our nation's waters is still being degraded by point and nonpoint sources of pollution (U.S. EPA, 2000). Discrete or point source (PS) dischargers are readily identifiable and may be channels, pipes, or conduits that aid in transporting pollutants such as the outfall from municipal wastewater treatment plants (WWTPs). Nonpoint sources (NPS) or diffuse sources do not have a defined discharge point; nutrient loading in surface runoff from the urban landscape, pasturelands and other agricultural activities are examples of NPS pollution. Excessive nutrient inputs (especially phosphorus, hereafter referred as P) from PS and NPS pollution accelerate the natural process of eutrophication, thus potentially impairing designated beneficial uses of surface waters (Carpenter et al., 1998).

Almost 15% of rivers and streams in Arkansas have been identified as impaired for their designated uses (U.S. EPA, 2000). The total P (TP) criterion recommended by United States Environmental Protection Agency (U.S. EPA) is 0.1 mg L^{-1} for streams and rivers and 0.05 mg L^{-1} for lakes in Arkansas (U.S. EPA, 2003). Recently, the Arkansas Department of Environmental Quality (ADEQ) also indicated that about 15% of the state's assessed streams do not meet their designated uses because of elevated nutrient concentrations (ADEQ, 2002).

The Illinois River Basin is a trans-boundary watershed between Arkansas and Oklahoma (Figure 1.1) and has recently been the subject of political and environmental debate due to nutrient enrichment and accelerated eutrophication in some Scenic Rivers of Oklahoma. In 1992, a U.S. Supreme court ruling suggested that the U.S. EPA may require upstream states to adhere to downstream states' water quality standards. The Illinois River and Flint Creek, which flow from Northwest Arkansas into Northeast Oklahoma, have been listed as Scenic Rivers in Oklahoma and, therefore, are subject to TP criterion of 0.037 mg L^{-1} established by the Oklahoma Water Resources Board (OWRB, 2002). The average flow-weighted TP concentration at the Illinois River near the Arkansas-Oklahoma border was approximately 0.40 mg L^{-1} (Green and Haggard, 2001), over ten times greater than the TP criterion suggested by OWRB.



Figure 1.1. The Illinois River Basin, a trans-state watershed between Arkansas and Oklahoma with major cities and rivers. The Illinois River originates from Northwest Arkansas and flows into Northeast Oklahoma.

However, Vieux and Moreda (2003) did not include P loading from municipal WWTPs, which is a significant part (45%) of total P loadings at the Illinois River Basin (Haggard et al., 2003). Haggard et al. (2003) showed that municipal WWTPs were the major contributor to elevated P concentrations during base flow conditions, in Northwest Arkansas. These elevated P concentrations in the Illinois River near the Arkansas-Oklahoma border were traced to one municipal WWTP over 45 km upstream, demonstrating the pronounced impact of WWTPs in the basin (Haggard et al., 2003).

Several other researchers have demonstrated the impact of municipal WWTPs on the P concentrations in streams and sediments (e.g., Dorioz et al., 1998; House and Denison, 1997). Investigations have focused on whole-reach P retention, as well as specific mechanisms of P retention such as sediment-P buffering capacity and the amount of P in sediments (Haggard et al., 2001a; Dorioz et al., 1998; House and Denison, 1997; Reddy et al., 1996). P retention efficiency or adsorption capacity, of Ozark streams was reduced downstream from WWTPs, and the amount of P from WWTP inputs was significant in determining the degree of impact (Haggard et al., 2004). Stream sediments may play a major role in regulating P concentrations in the water column, especially when residence time of water is longer, i.e., under baseflow conditions (Svendsen et al., 1995; Fox et al., 1989). The affinity of dissolved inorganic P for sediments results in the important processes of adsorption and desorption, thus controlling P concentrations in freshwaters (Sharpley et al., 2002). The ability of sediments to retain P in streams receiving municipal WWTPs discharge has been found to be less than that in streams draining lands with extensive pastures and animal agriculture (Popova, 2000).

Both nutrient retention and sediment-P interactions influence P uptake, transport and transformation in stream systems. Thus, there is a need to investigate stream P retention and sediment-P interactions in streams of the Illinois River Basin receiving municipal WWTP effluent. This investigation could yield important information to watershed managers on elevated P concentrations and deteriorating water quality due to municipal WWTPs. These PS may further degrade water quality if left unaddressed, particularly in basins where P loads are elevated above eutrophic levels.

Based on the previous findings that WWTPs significantly affect the P concentrations in receiving streams, it was hypothesized that (i) P enrichment due to effluent from municipal WWTPs in headwater streams of the Illinois River has resulted in elevated water column soluble reactive P (SRP) and sediment-bound P in these stream ecosystems, (ii) dilution due to groundwater and lateral contributions, and not assimilation, is responsible for decreasing SRP concentration longitudinally downstream, and (iii) the relationship between water column SRP and sediment-bound P are the controlling mechanisms of P concentrations in stream systems.

Objectives:

The overall goal of this study was to evaluate whole-stream P retention in four Ozark streams receiving effluent from municipal WWTPs with varying degrees of P enrichment. In order to accomplish this goal, the following objectives were identified:

- (1) Compare the SRP concentrations in the water column and stream sediments between reference sites (upstream) and sites downstream from the WWTP inputs;

- (2) Examine longitudinal variation in SRP and CI concentrations (if any) downstream of WWTP inputs to determine if assimilation rather than dilution is responsible for net P retention;
- (3) Conduct smaller-scale investigations to evaluate the ability of sediments to adsorb or release P by measuring easily exchangeable P (EXP), P sorption index (PSI), and equilibrium P concentration (EPC_0) in benthic sediments.

Methods

The focus of my study was on the Illinois River Basin and, specifically, four of its headwater streams in Northwest Arkansas that receive effluent from municipal wastewater treatment plants (WWTPs). The Illinois River and its tributaries are a model representation of the streams for the central United States (Brown and Matthews, 1995). The southwestern Ozark streams fall in the mid-continent region (region-4) of conterminous United States based on variations of longitudinal patterns of channel form succession. The headwater streams of this region are unique because of their uniformly spaced alluvial gravel, riffle-pool geomorphology (Brussock et al., 1985). The Illinois River Basin is dominated by karst, cherty-limestone topography with associated sandstones and shale. White et al. (2002) estimated the land use of Illinois River Basin in Arkansas as 58% pasture, 36% forest, and 6% urban.

I selected reaches at Mud Creek, Osage Creek, and Spring Creek, which are headwater streams of the Illinois River Basin, and receive WWTP effluent from the cities of Fayetteville, Rogers, and Springdale in Northwest Arkansas, respectively (Figure 3.1). The fourth stream reach was at Sager/Flint Creeks which receive WWTP effluent from Siloam Springs, Arkansas (Figure 3.1). Sager Creek directly receives effluent discharge from Siloam Springs and is a tributary to Flint Creek. Flint Creek and the Illinois River are potentially subject to the Scenic River TP criterion at the Arkansas and Oklahoma state line. All these selected streams have some similar physical characteristics such as a

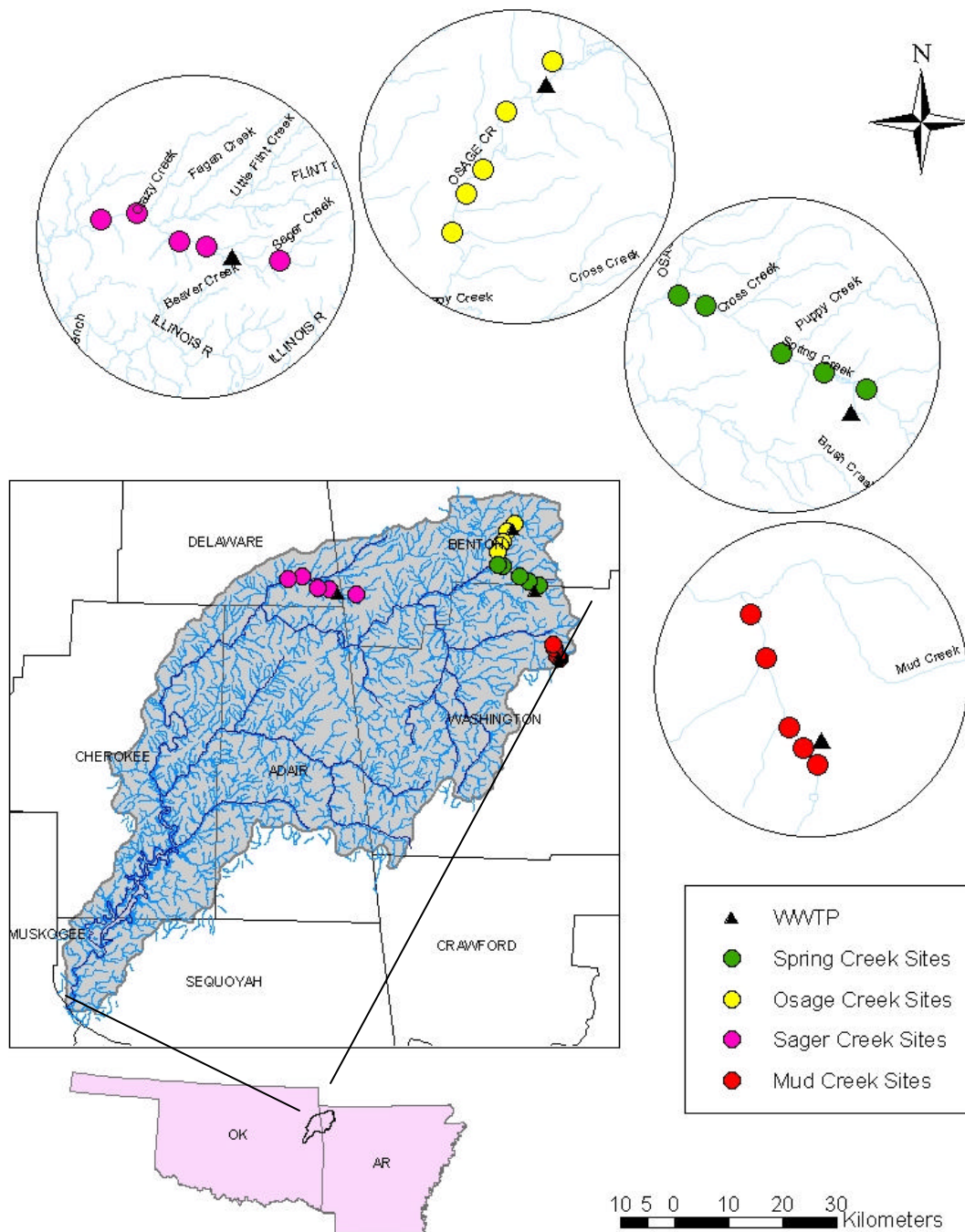


Figure 3.1. Water quality and sediment sampling sites upstream and downstream of municipal wastewater treatment plants at headwaters at Mud Creek, Spring Creek, Osage Creek, and Sager/Flint Creeks within the Illinois River Basin.

typical riffle-pool geomorphology with bedrock outcroppings and larger cobbles common at few sites.

At Mud Creek, I selected a site about 0.5 km upstream and downstream sites from 0.4, to 3.1 km from the WWTP input. This WWTP is at a distance of about 53 km upstream from the Arkansas-Oklahoma state border, as estimated by ArcGIS8 software (ESRI, 2003). The generic land use along the stream reach is mostly urban and almost all sampling sites are located in small urban neighborhoods within the city of Fayetteville. Fayetteville's WWTP is a tertiary level treatment plant and has current treatment capacity of about 67,000 human equivalents on a 378.5-L (100 gallons) per person per day basis. The current population of the City of Fayetteville is about 58,000. The facility has a regulatory P (1.0 mg L^{-1}) and N (NH_4 : summer= 2.0 mg L^{-1} and winter= 5.0 mg L^{-1}) management plan (Personal Communication with Thom Vinson, September 10, 2003). He also indicated that the annual average P concentration (July 2002 to June 2003) in effluent from this facility was about 0.25 mg L^{-1} .

At Spring Creek, the upstream site was about 1.1 km from WWTP input and the four downstream sites were approximately 2.0 to 7.5 km from the WWTP input. The Springdale municipal WWTP input is almost 45 km upstream from the Arkansas-Oklahoma state border, as estimated by ArcGIS8 software (ESRI, 2003). The generic land use along the selected stream reach at Spring Creek is mostly pastureland with some suburban neighborhoods surrounding the upstream and the site immediately downstream of WWTP input. The Springdale WWTP facility is an advanced secondary system with treatment capacity for about 120,881 (total suspended solids, TSS) and 167,830 people (biochemical oxygen demand, BOD). The current population of the city is approximately 45,000. The facility has limits on ammonium (NH_4) of 1.5 mg L^{-1} monthly average in summer and 4.0 mg L^{-1} monthly average in winter in the effluent, but does not have a regulatory limit on P (Personal Communication with Jennifer Enos, Lab Director, Springdale WWTP, July 8 and September 11, 2003). However, the WWTP has been making voluntary efforts to keep effluent TP concentrations $< 1.0 \text{ mg L}^{-1}$. The lab director also provided data for P concentration in effluent, which indicated that the annual average P concentration (July 2002 to June 2003) in effluent from this facility was about 4.4 mg L^{-1} .

The selected sampling reach at Osage Creek was about 5.7 km long with an upstream site about 0.2 km from the WWTP input and the downstream sites were approximately 1.5 to 5.5 km from WWTP input. The WWTP input from City of Rogers municipal WWTP is almost 43 km upstream from the Arkansas-Oklahoma state borders. The generic land use along this stream reach is mostly pastureland and the site immediately downstream of WWTP input is within the premises of the facility. The City of Rogers facility is an advanced secondary WWTP with treatment capacity for about 35,428 human equivalents and current city population is approximately 39,000. The WWTP has a voluntary limit for P (1.0 mg L^{-1}) and regulatory limits for N ($\text{NO}_3 = 3 \text{ mg L}^{-1}$, $\text{NH}_4 = 1.5 \text{ mg L}^{-1}$ in summer and 2.3 mg L^{-1} in winter) in the effluent (personal communication with Robert Moore, City of Rogers municipal WWTP, September 10, 2003). The annual average P concentration (July 2002 to June 2003) in effluent from this facility was about 0.35 mg L^{-1} (Courtesy: Mike Lawrence, City of Rogers Municipal WWTP, July 18, 2003).

Siloam Springs WWTP is a tertiary level facility and discharges effluent into Sager Creek, a Flint Creek tributary. The selection of sites at Sager/Flint Creeks was based on easy access and interest in sampling Flint Creek. The site upstream of the WWTP input was about 3.3 km and sites downstream from the WWTP input were from 2.0 to 10.0 km. The WWTP input

from Siloam Springs is very near to the Arkansas-Oklahoma state line (0.5 km) as compared to the other three municipal WWTPs. The generic land use along upstream part of this stream reach is urban and sites downstream are mostly pastureland. The current treatment capacity of this facility is about 17,000 people and city population is approximately 10,000. The facility has N management plan but no limits on P in the effluent (Personal Communication with Tom Myers, Siloam Springs WWTP, July 8, 2003). The annual average P concentration in effluent from this facility was unavailable.

The distance of water quality sampling stations downstream of the WWTP input was estimated at each stream reach (Table 3.1). The approximate distance (river km) between the sampling stations and WWTP was estimated by plotting the latitude and longitudes (GPS-V, Garmin) in ArcGIS 8 software (ESRI, 2003) and using the distance-measuring tool.

Table 3.1. Distance of sampling sites upstream and downstream from the municipal wastewater treatment plant (WWTP) input as estimated by ArcGIS 8 software.

Sampling Site	Distance from the Wastewater treatment Plant Input (km)			
	Mud Creek	Spring Creek	Osage Creek	Sager/Flint Creek
Upstream	-0.5	-1.1	-0.2	-3.3
WWTP Input	0.0	0.0	0.0	0.0
1 st downstream	0.4	2.0	1.5	2.0
2 nd downstream	0.9	3.9	3.4	3.9
3 rd downstream	2.2	4.6	4.2	7.5
4 th downstream	3.1	7.5	5.5	10.0
Total length	3.6	8.6	5.7	13.3

Negative distances denote the site upstream from the municipal WWTP.

Water Quality Sampling

Field Techniques and Laboratory Analysis

Water samples were collected from the four headwater streams from July 2002 through June 2003 at least once a month under baseflow conditions. One reference (or background) site upstream from the WWTP and four sites downstream from the WWTP effluent were selected at each stream. Water samples were collected in two 20-ml scintillation vials (filtered with 0.45- μ m nylon membranes) from the middle of the stream channel. The bottles and syringes were pre-rinsed with ambient stream water prior to collecting water samples at each site. Each of the 20-ml vials was acidified to pH < 2 with concentrated HCl at each site. All of the water quality samples collected were stored on ice and kept in dark until return to the laboratory.

Physico-chemical parameters were measured at a single point (mid-stream) at each sampling site. These measurements included specific conductivity, temperature (Orion conductivity Meter 115A plus, Beverly, MA), dissolved oxygen (YSI-Model 85, Yellow Springs, OH) and pH (pH Testr 2 double junction pH meter, Oakton Instruments, West Caldwell, NJ). Discharge was estimated at all sampling sites at a transect perpendicular to stream flow (Gore, 1996). Typically, the transect was divided in equally spaced intervals and water velocity was measured with an electromagnetic flow meter (Flo-Mate 2000; Marsh-McBirney Inc., Frederick, MD). The depth at mid-points of these width intervals was measured to obtain the cross-sectional area of stream. The discharge was estimated as a product of water velocity and cross-sectional area.

In some streams, dissolved inorganic P concentration has been shown to be approximately 75% to 95% of the amount of TP in the water column (Reddy et al., 1996; Jarvie et al., 2002) and was useful as a surrogate for evaluating changes in stream P under high P loading conditions (Dodds, 2003) such as from the WWTPs. Therefore, the filtered and acidified water samples were analyzed for soluble reactive P (SRP) colorimetrically by the ascorbic acid reduction method (APHA, 1992). The filtered and unacidified samples were analyzed with mercuric thiocyanate reaction for CI (Skalar Methods, the Netherlands).

Net- uptake lengths (S_{net})

When evaluating changes in P concentrations and P retention, selection of a conservative solute is critical especially in stream systems where downstream dilution may occur because of

groundwater contributions and other factors (Bencala et al., 1987). Chloride (Cl), a conservative solute, is widely used as a hydrologic tracer for dilution correction, especially in stream systems to observe the gradual downstream declines in P concentrations (e.g., see Marti and Sabater, 1996; Marti et al., 2003). Marti et al. (2003) used longitudinal variation of nutrient concentrations relative to Cl concentrations downstream from several WWTP input to measure stream P retention (see also Haggard et al., 2004).

As P travels downstream, several abiotic and biotic factors may retain or transform P from the dissolved form to the particulate form. Phosphorus uptake length (S_w) is the distance a P molecule travels downstream in the dissolved inorganic form before uptake by biotic or abiotic processes (Newbold et al., 1981; Stream Solute Workshop 1990). In the present study, a different parameter S_{net} (whole reach net uptake length, Haggard et al., 2001a) was estimated whenever a gradual decline in SRP concentrations was observed longitudinally downstream of WWTP input. The SRP concentrations at sites downstream from the WWTP input were background corrected using upstream SRP concentrations.

Dilution correction using Cl concentrations with respect to the first site downstream from the WWTP input was also done to estimate the proportion of SRP remaining in the water column. It can mathematically be represented as:

$$C_x = C_o e^{-kx} \quad (3.1)$$

$$\ln(C_x/C_o) = -kx \quad (3.2)$$

where C_x is the background and dilution-corrected SRP concentration (mg L^{-1}) at distance x (km) downstream from the WWTP effluent, C_o is the corrected SRP concentration (mg L^{-1}) at first downstream site from WWTP effluent, and k is the SRP change coefficient (km^{-1}). S_{net} is the inverse of the slope of the regression line relating natural logarithm of proportion of dilution-corrected SRP concentrations in the water column and downstream distance from the WWTP input (equation 3.2).

$$S_{net} = 1/\text{slope} = -1/k \quad (3.3)$$

Dilution-corrections were not used where Cl concentrations did not change appreciably downstream of the WWTP input and only background (up stream) corrected SRP concentrations were used to estimate S_{net} . S_{net} is used as a measure of net retention efficiency with shorter S_{net} suggesting higher P retention efficiency. The distance of water quality sampling stations downstream of the WWTP input was determined to estimate S_{net} at each stream reach (Table 3.1).

Sediment Sampling

Field Techniques

A single sediment sample was collected seasonally beginning summer 2002 through summer 2003 (July 2002, October 2002, January 2003, April 2003, June 2003) at the reference site upstream and three downstream sites of the WWTPs at all four study reaches. For sediment samplings, I left out the site before last downstream sampling site where water quality samples were collected, at each stream. Composite benthic sediments were collected with a trowel at various points along a transect perpendicular to streamflow from top 2 to 5 cm of streambed. The sediment samples were placed in plastic bags and stored in the dark until transported to the

laboratory. About 1-L of stream water was collected in HDPE bottles, and stored in ice in the dark until return to the laboratory.

Laboratory Techniques and Analysis

After returning to the laboratory, sediments were sieved through a 4.5-mm sieve and particles < 4.5 mm in diameter were used in extraction procedures. Fresh, wet sediments were used to determine loosely exchangeable phosphorus (EXP), phosphorus sorption index (PSI), and equilibrium phosphorus concentration (EPC_0). The stream water was filtered through nylon membranes (0.45- μm pore size) to be used in extractions.

Exchangeable P (EXP) (Ruttenberg, 1992) was determined from a single extraction with 1M MgCl_2 and represented easily and readily exchangeable P in the benthic sediments. One hundred milliliters of 1M MgCl_2 was added to 20 to 30 g of fresh sediments in 250-ml Erlenmeyer flasks. The flasks were shaken in a reciprocating shaker for 1 h to mix the contents, which were also stirred vigorously for about 5 s at 15-min intervals. After 1 h, sediments in flasks were allowed to settle for about 30-min, and 15 to 20 ml of the solution was filtered through 0.45- μm nylon membranes to pre-labeled 20-ml scintillation vials. The aliquots were acidified to $\text{pH} < 2$ and stored in a refrigerator until analyzed for SRP. The remaining sediments were transferred to aluminum pans and dried for 48 h at 80°C to determine sediment dry mass. Exchangeable P content was determined as the amount of P extracted per unit dry weight of sediment ($\mu\text{g-P g}^{-1}$ dry sediment).

The P sorption index (PSI) (Klotz, 1988; Bache and Williams, 1971) is a simple single-point method for estimating sediments ability to adsorb $\text{PO}_4\text{-P}$ molecules from aqueous solutions. One hundred milliliters of filtered stream water was spiked with an additional 2 mg L^{-1} $\text{PO}_4\text{-P}$ and added to about 20 to 30 g of fresh sediments in 250-ml Erlenmeyer flasks. The flasks were shaken in a reciprocating shaker for 1 h to mix the contents, which were stirred vigorously for about 5 s at 15-min intervals. After 1 h, sediments in flasks were allowed to settle for about 30-min, and 15 to 20 ml of the solution was filtered through 0.45- μm nylon membranes to pre-labeled 20-ml scintillation vials. The aliquots were acidified to $\text{pH} < 2$ and stored in a refrigerator until analyzed as previously described. The remaining sediment slurry was transferred to aluminum pans and dried for 48 h at 80°C to determine sediment dry mass. The sorption index (PSI) was calculated as:

$$PSI = \frac{X}{\log C} \quad (3.4)$$

where X is the P adsorbed by the sediments from aqueous solution (mg-P g^{-1} dry sediment)

and C is the final SRP concentration (mg-P L^{-1}) in aqueous solution after 1 h.

Equilibrium P concentration (EPC_0) (Froelich, 1988; Klotz, 1985) is the concentration when sediments and water column are in equilibrium and there is no net adsorption or release of $\text{PO}_4\text{-P}$ from sediments to the water column (Taylor and Kunishi, 1971). Fresh, wet sediments were used for measuring EPC_0 since dried sediments may yield significantly higher concentrations (Klotz, 1988). Extractions for EPC_0 used a series of filtered stream water

solutions spiked with additional P from 0.0 to 4.0 mg-P L⁻¹ (0.0, 0.10, 0.25, 0.50, and 2.0 mg-P L⁻¹ for Mud and Osage Creeks; 0.0, 0.50, 1.0, 2.0, and 4.0 mg-P L⁻¹ for Spring and Sager and Flint Creeks, respectively). For example, if the filtered stream water in Mud Creek had an ambient SRP concentration of 0.10 mg-P L⁻¹, then the series of spikes in filtered stream water initially contained becomes 0.10, 0.20, 0.35, 0.60, and 2.10 mg-P L⁻¹. About 20 to 30 g of fresh, wet sediments and 100-ml of filtered stream water spiked with additional PO₄ was added in 250-ml Erlenmeyer flasks. The flasks were sealed with a rubber stopper and kept in a reciprocating shaker for about 1 h with vigorous manual stirring for about 5 s at 15-min intervals. After 1 h, sediments in flasks were allowed to settle for about 30-min, and 15 to 20 ml of the solution was filtered through 0.45- μ m nylon membranes to pre-labeled 20-ml scintillation vials. The aliquots were acidified to pH < 2 and stored in refrigerator until analyzed. The remaining sediments were transferred to aluminum pans and dried for 48 h at 80°C to determine sediment dry mass. Simple linear regression of P sorbed (μ g g⁻¹ dry sediment) against initial SRP concentration in the solution was used to determine the EPC₀, which is the x-intercept (Figure 3.2).

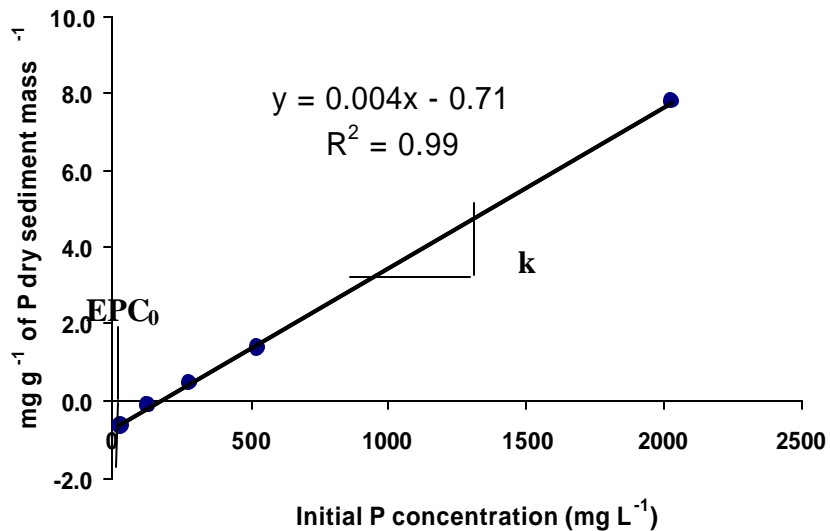


Figure 3.2. Simple linear regression of P sorbed (μ g g⁻¹ dry sediment) against initial SRP concentration (mg L⁻¹) in the solution to calculate the sediment equilibrium P concentration (EPC₀).

The slope (k) of the relation between P sorbed and initial PO₄-P concentration represents the quantity of PO₄ sorbed on sediments at equilibrium. This mass may be available for release from sediments to PO₄ deficient solutions. This slope was used as another measure of sediment-P buffering capacity.

Statistical Analysis

Logarithmic transformations of the water quality data were used to achieve normality requirements (Sawyer et al., 2003). Simple linear regression was used to estimate the correlation between various parameters such as SRP and EPC₀, EXP and EPC₀ along the reach length at

individual streams and combined at all streams. One-tailed paired t-test was used to determine differences between the sites upstream and immediately downstream of the WWTP input different parameters (EXP, PSI, SRP, CI), as well as for comparisons at each site (e.g., SRP and EPC_0). A significance level of 0.10 was used for all comparisons and confidence interval of 90% for all regression analyses.

Significant Findings

The Illinois River that flows from Northwest Arkansas into northeast Oklahoma has aesthetic and recreational value and is listed as a Scenic River in Oklahoma. Point sources, especially municipal wastewater treatment plants (WWTPs) are still a significant source of P loading in headwater streams of the Illinois River, Northwest Arkansas (Haggard et al., 2003). Therefore, the overall goal of this study was to evaluate whole-stream P retention in four Ozark streams (Mud Creek, Spring Creek, Osage Creek, and Sager/Flint Creeks) receiving effluent from municipal WWTPs with varying degrees of P enrichment. The specific objectives were:

- (1) To compare the SRP concentrations in the water column and stream sediments between reference sites (upstream) and sites downstream from the WWTP inputs;
- (2) To examine longitudinal variation in SRP and CI concentrations (if any) downstream of WWTP inputs to determine if assimilation rather than dilution is responsible for net P retention;
- (3) To conduct smaller-scale investigations to evaluate the ability of sediments to adsorb or release P by measuring easily exchangeable P (EXP), P sorption index (PSI), and equilibrium P concentration (EPC_0) in benthic sediments.

These objectives were based on the hypothesis that (1) P enrichment due to effluent from municipal WWTPs in headwater streams of the Illinois River has caused elevated water column soluble reactive P (SRP) and sediment-bound P in these stream ecosystems; (2) dilution due to groundwater and lateral contributions, and not assimilation is responsible for decreasing SRP concentration longitudinally downstream; and (3) the relationship between water column SRP and sediment-bound P are the controlling mechanisms of P concentrations in stream systems.

Elevated SRP concentrations at sites downstream from the WWTP input support the hypothesis that effluent discharge from the municipal WWTPs in Northwest Arkansas have enriched the receiving stream systems with P. In addition, an increase in sediment-bound P (EXP and EPC_0) and reduced ability of sediments to remove P from the water column is another line of evidence supporting the hypothesis of P enrichment from WWTPs. Elevated sediment-bound P and water column SRP demonstrate the profound impact of WWTPs on services provided by these stream ecosystems, such as nutrient assimilation (Costanza et al., 1998).

Results indicated that at Spring and Sager/Flint Creeks dilution due to groundwater and lateral contributions was responsible for decline in SRP concentrations longitudinally, downstream from the WWTP input. Long net uptake lengths (S_{net}) estimated up to 43 km suggest low net P retention efficiency of these stream ecosystems. The significant negative S_{net} that was common in this study indicated a P release from the sediments into the water column. It is noteworthy that the negative S_{net} at Spring Creek occurred on sampling dates after November 2002 when P concentrations in the effluent were probably less than sediment EPC_0 and

sediments became a potential P source. However, this is not surprising, since this WWTP has been making voluntary efforts to reduce P in its effluent.

The EPC_0 was strongly correlated with water column SRP across all streams suggesting that any changes in P from source i.e., WWTPs could alter this relationship, and either initiate a release or adsorption of P by stream sediments. However, at different sites the sediments were either in equilibrium with water column SRP, acting as a conduit to transport P, or behaved as a source or sink of P. Thus, sediments most likely played an important role in regulating the SRP concentrations in water column in these Ozark streams. These sediments can thus act as a potential P source, maintaining elevated water column SRP even if the municipal WWTPs will reduce the P concentration in the effluent.

The water column SRP and sediment-bound P in WWTP impacted streams may reduce temporally, however, it is difficult to predict a definite time-period. It may be a few years that self-purifying capacity of streams will reduce P concentrations below eutrophic levels. The recovery rate of these aquatic ecosystems will depend on loading from municipal WWTPs, amount of sediment transported or retained, and distance between other P inputs. The most important factor will be of in-stream uptake capacity by both abiotic and biotic components.

Municipal WWTPs are still a significant source of phosphorus (P) loading in the headwater streams of Northwest Arkansas and have significantly altered the P transport and retention in these streams. This study demonstrated the complexity of managing and maintaining the critical in-stream ecological service of nutrient cycling.

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Chemical Variation of Water From The Alluvial Aquifer

Basic Information

Title:	Chemical Variation of Water From The Alluvial Aquifer
Project Number:	2003AR21B
Start Date:	3/1/2002
End Date:	12/31/2003
Funding Source:	104B
Congressional District:	03
Research Category:	Water Quality
Focus Category:	Hydrogeochemistry, Water Quality, None
Descriptors:	Variation of ground water chemistry, mixing of ground waters, geochemical
Principal Investigators:	Kenneth F. Steele

Publication

1. Steele, K.F., T.M. Kresse, R.K. Davis, Small-scale variation of water quality within the Mississippi River Valley Alluvial Aquifer, Arkansas, USA, Two Rivers 4th Joint International Association of Hydrologists-Canadian National Chapter/Canadian Geotechnical Society Conference (ed. for IAH papers, Bob Betcher), Noval Digital Images, Winnepeg, Canada, 8 pages on CD volume.
2. Steele, K.F., R.K. Davis, and T.M. Kresse, 2003 Spatial and Temporal Nitrate Concentration Variability within the Mississippi River Valley Alluvial Aquifer on a Small Scale at Selected Arkansas, USA Sites, "in" Proceedings of the 7th International Water Association International Conference on Diffuse Pollution and Basin Management, (ed., Michael Bruen), Excel Print, Boyne House, Co., Meath, Ireland, p. 7-33 to 7-38.

Problem and Research Objectives

Many studies of the alluvial aquifer have noted spatial variability of ground-water chemistry on regional or county scale. These data have often been represented on contour maps of specific conductance, chloride and other ions. Until this project, there had been no studies of small-scale spatial and temporal variability of the alluvial aquifer water chemistry in Arkansas. In order to compare water quality among aquifers, it is critical to determine the density of the wells necessary to represent the aquifers and to establish meaningful contour intervals for parameter values. The impact of season also must be determined so that appropriate sample collection dates and frequency may be selected. Furthermore, there have been comparisons of water quality between shallow and deep wells, but this has rarely been done on small-scale. The objective of this project was to ascertain the spatial and temporal variability of groundwater chemistry from the alluvial aquifer, Arkansas on a small-scale.

Methodology

Wells at three sites in three counties in eastern Arkansas were used in this project. The distribution of the wells used in this study are as follows: (1) three monitoring wells and three irrigation wells at a site in Monroe County, (2) three monitoring wells, a domestic well and three irrigation wells at a Pulaski County site, and (3) four monitoring wells and a domestic well at the Woodruff County site. Samples were collected for the shallow wells at Monroe and Pulaski Counties on June 25 and 26, 2002 and the shallow wells and the nearby deep irrigation wells were sampled on August 11 and 12, 2002. There were existing data for the Woodruff county site from a June 18, 1996 collection date. There were also an additional 8-10 additional historical analyses for nitrate concentrations at the Monroe and Pulaski County sites. The samples collected in 2002 and the historical nitrate collection dates were classed as either recharge (e.g., June samples) or non-recharge (e.g., August samples) conditions in order to determine the impact of recharge conditions (season) on the water chemistry. The ground-water samples were collected and analyzed under standard methodology and quality assurance procedures. The AWRC Water Quality Laboratory performed all of the analyses except for the samples from Woodruff County, which were analyzed by the Arkansas Department of Environmental Quality.

Principal Findings and Significance

Because there are differences in the chemical processes affecting the major ions and nitrate, nitrate will be discussed separately. Shallow wells exhibited significant spatial variation for Ca, Mg, Na, HCO₃, Cl, and SO₄. These ions have maximum concentrations 1.4 to 6.8 times the minimum concentration for shallow wells. Some temporal variation occurs for shallow wells at one site, the maximum to minimum concentration ratios range from 1.3 to 4.7. Deep wells have ion concentrations similar to shallow wells, but generally, the ions have smaller concentration ranges. Heterogeneous mineral and organic carbon abundances, and variable residence times, which affect amount of mineral dissolution and cation exchange, have a major impact on the water chemistry. These factors are the result of discontinuous sedimentary units with variable

thickness and extent that affect ground-water movement. Other factors affecting the water chemistry are recharge conditions and fluctuating water table depths that change ground water flow directions, and that allow de-watering of saturated fine-grained sedimentary units when the water table is declining. There is significant spatial and temporal variability of nitrate. Spatial variability is as great as 0.04 to 14.45 mg/L NO₃-N, and temporal (45 days) variability in a well is as great as 0.11 to 14.45 mg/L NO₃-N. Deeper wells generally have low nitrate concentrations. The variation of nitrate concentrations can be explained by transport of nitrate from fertilizer to the ground-water system and subsequent denitrification within the alluvial aquifer.

Information Transfer Program

AWRC sponsors an annual water conference held in Fayetteville each spring, drawing in about 125 researchers, students, agency personnel, and interested citizens to hear about results of current research and hot topics in water resources throughout the state. AWRC also co-sponsors short courses and other water related conferences in the state and region. The 2003 conference was entitled "Quality Water Resources To Meet Our Competing Needs" and featured Eighteen oral presentations and fifteen posters during the one and one half day conference.

In addition, AWRC maintains a technical library containing over 900 titles, many of which are on-line. This valuable resource is utilized by a variety of user groups including researchers, regulators, planners, lawyers, and citizens. We have recently started converting many of our library holdings to electronic pdf format which can be accessed via our WEB site at <http://www.uark.edu/depts/awrc>. Just follow the link to electronic publications. We are slowly adding archived documents from our library to this electronic data set, and all new titles are added as we receive them.

2004 Annual Arkansas Water Resources Conference: Quality Water Resources To Meet Our Competing Needs

Basic Information

Title:	2004 Annual Arkansas Water Resources Conference: Quality Water Resources To Meet Our Competing Needs
Project Number:	2003AR22O
Start Date:	4/22/2003
End Date:	4/23/2003
Funding Source:	Other
Congressional District:	03
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Ralph K. K Davis

Publication

1. Davis, R.K., In Review, Quality Water Resources to Meet Our Competing Needs. Proceedings of the Arkansas Water Resources Center Annual Conference. University of Arkansas, Center for Continuing Education, Fayetteville, Arkansas, April 22 and 23, 2003

**Quality Water Resources To Meet
Our Competing Needs**

**2003 Arkansas Water Resources
Center Conference**

TUESDAY, April 22

8:00am to 4:30pm

**Registration and Continental
Breakfast.....8:00 am**

Welcome and Introductions by Ralph K. Davis,
Director, Arkansas Water Resources
Center.....8:40 am

PRESENTATIONS

*** Denotes Speaker**

Session Moderator: Marty Matlock, Assistant
Professor, Biological and Agricultural
Engineering, University of Arkansas, Fayetteville

**Occurrence and Transport of Arsenic in the
Alluvial Aquifer of Eastern Arkansas.**
Tim Kresse*, J. Fazio, R. Davis, K. Steele and P.
Hays 8:45 am

**Chemical Weathering and the Biotic Ligand
Model – Black Shales and Toxicity.**
Robyn Hannigan*, J. Farris and N.A. Bickford
.....9:15 am

**How Uniform is the Ground Water Chemistry
of the Alluvial Aquifer?**
Kenneth. Steele*, T. Kresse, R. Davis and S.
Boss9:45 am

Break10:15 am

**Tracking Environmental Conditions in the
West Fork of the White River – Changes in
Fish Assemblages.**
Andrea Radwell*, A. Brown and R. Reese
.....10:45 am

**Allochthonous Carbon in Alluvial Sediments
as an Indicator of Climate Change.**
Phillip Hays* and M.
Guccione.....11:15 am

**Lunch Buffet
Provided.....11:45 am**

**Use of On-Farm Reservoirs in Rice
Production: Results from the MARORA
Model.** Jennie. Popp* and E. Wailes.....1:30 pm

Session Moderator: Janie Hipp, J.D., LL.M.
Agricultural Law Agricultural and Natural
Resources Public Policy Specialist, Division of
Agriculture, University of Arkansas, Fayetteville

**Introduction to Session: Managing Conflict
Concerning the Competing Needs for Quality
Water.**
Janie Hipp.....2:00 pm

**Rules of Engagement for Conflict Resolution
in Watershed Management.**
Marty Matlock.....2:15 pm

Break2:45pm

**An Open Discussion on Regionalization of
Water.** Weldon Schiffer.....3:15pm

**Who Gets a Seat at the Table? Lessons
Learned and What's to Come in the
Management of Multi-Party, Multi-Issue
Conflicts over Natural Resources.**
Molly Sizer-Stephenson3:45 pm

It's Harder to Blame Friends than Strangers.
Floyd Gilzow.....4:15pm

**RECEPTION AND POSTER
SESSION*.....4:45-7:00 pm**

***See back page for information**

WEDNESDAY, April 23

8:00am to 12:30pm

**Registration and Continental
Breakfast.....8:00 am**

Session Moderator: Phil Hays, Research
Hydrologist, U.S. Geological Survey and
Adjunct Professor Department of Geosciences,
University of Arkansas, Fayetteville

**Factors Affecting Water Quality and Surface
Water/Ground Water Interaction Associated
with Flooded Coal Mines, Greenwood,
Arkansas.**
Curtis Varnell* and J. Van Brahana ...8:30 am

**Release of Phosphorus from Stream and
Reservoir Sediments: Effect of Chemical
Amendments.**
Brian Haggard*, P. Moore, M. Matlock and
S. Ekka.....9:00 am

**Upper Beaver Lake Annual Taste and Odor
Events.** James Hoelscher, Jr9:30 am

Break.....10:00 am

**Demonstration of SWAT Model Using Beaver
Lake Watershed.**
Kati White* and I.
Chaubey.....10:30 am

**Assessment of Nutrient Dynamics in an
Agriculturally Dominated Stream.**
Indrajeet Chaubey*, B. Haggard, K. White and
M. Matlock11:00 am

**Pasture Management Strategies for Reducing
Nutrient Runoff.**
Philip Moore Jr.*, S. Formica, M. Van Eps, T.
Morris, J. Beck, A. Cotter, L. Self-Davis, B.
Haggard, B. Bellows and P.
DeLaune.....11:30am

Wrap Up.....12:00pm

POSTER SESSION

The Missouri Watershed Initiative - An Objective Approach to Watershed Planning by William B. Kurtz and Robert R. Broz, University of Missouri, Columbia, Missouri..

Effects Of Solar Radiation on the Use Of Dissolved Organic Matter in Ozark Streams by Sherri Brisco and Sue Ziegler, Biological Sciences, University of Arkansas, Fayetteville, Arkansas.

Arkansas Delta Wetland Planning Region Wetland Prioritization Methods by Jessica Brooks, Chris Landgraf, Angie Smith, Molly Reif, Malcolm Williamson and W.F. Limp, Center for Advanced Spatial Technology, University of Arkansas, Fayetteville, Arkansas.

Water Quality Matters...in the Morning News by Scott Davis, Morning News, Fayetteville, Arkansas.

Monitoring Potable Reservoir Water Quality Through Algal Enumeration and Identification by D. Clover and Paul R. Easley, City of Fort Smith, Fort Smith, Arkansas.

Acoustic Imaging of Submerged Topography and Mass Wasting Features In Beaver Lake, Northwest Arkansas by Stephen K. Boss, Department of Geosciences, University of Arkansas, Fayetteville, Arkansas, Dorothy G. Neely, Environmental Dynamics Program, University of Arkansas, Fayetteville, Arkansas and James E. Hoelscher, Beaver Lake Water District, Lowell, Arkansas.

Willingness To Pay To Preserve Water Quality In The Illinois River by Felix Rondon and Jennie Popp, Department of Agricultural Economics and Agribusiness, University of Arkansas, Fayetteville, Arkansas.

A Report on the Beaver Lake, White River, Arkansas Watershed Washington County Water Quality Improvement Project by Sarah Franklin, Water Quality Technician, Washington County Soil and Water Conservation District.

Developing A Framework for Sustainable Water Resources – Integrating Hydrologic, Ecological, Socioeconomic, and Legal Considerations, Donald Catanzaro, Kent Thornton, FTN Associates, Fayetteville, Arkansas, Ann Fisher, Jim Shortle, Agricultural Economics and Rural Sociology, Pennsylvania State University, University Park, Pennsylvania, Kristyn Stevens, TPMC Environmental Services, Scituate, Massachusetts.

Producer Education Program on Reduction of Erosion and Sedimentation in Eastern Arkansas Delta, Project 96-550, CWA Section 319(h), Phil Tacker, University of Arkansas Cooperative Extension Service, Little Rock, Arkansas.

Hydrogeology and Physical Characteristics of Water Samples at the Red River Aluminum Site, Stamps, Arkansas, John B. Czarniecki, Gregory P. Stanton and David A. Freiwald, U.S. Geological Survey, Little Rock, Arkansas.

An Approach to Designing Septic System Filter Fields, E. Moye Rutledge, Mark A. Gross, Robert L. Goff, Phillip R. Owens, C. Roland Mote and D.T. Mitchel.

Water Quality During Base Flow and Surface Runoff Conditions at the Buffalo Nationa River Near St. Joe, Arkansas from 1991-2001 by Kati White, Brian Haggard and I. Chaubey, Biological and Agricultural Engineering, University of Arkansas, Fayetteville, Arkansas.

WELCOME TO THE



ARKANSAS WATER RESOURCES
CENTER
ANNUAL CONFERENCE

Focus Topic:

**QUALITY WATER
RESOURCES TO MEET OUR
COMPETING NEEDS**

April 22 & 23, 2003
at the

**Center for Continuing Education
and the
Fayetteville Radisson**
70 North East Avenue
Fayetteville, Arkansas



Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 RCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	1	0	0	0	1
Masters	3	0	0	0	3
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	5	0	0	0	5

Notable Awards and Achievements

Antibiotic Resistance and the Relationship between Enzyme Activity and P in runoff from Poultry Litter Amended Soil, M.C. Savin, Information from this research was presented on April 21, 2004 at the Arkansas Water Resources Center Conference in Fayetteville, Arkansas as referenced below:

Antibiotic Resistance of Bacteria Isolated from Run-Off and Soils Receiving Poultry Litter, M.C. Savin and P.J. Tomlinson, Arkansas Water Resources Center Conference, Fayetteville, Arkansas, April 20-21, 2004.

Tomlinson, P.J., 2004, Microbial Dynamics in Long-Term Research Plots Receiving Alum-Treated and Untreated Poultry Litter. Third Place Award for M.S. Posters, 2004 Student Research Presentation Competition, Gamma Sigma Delta.

Publications from Prior Projects

1. 2001AR15B ("Linkages Between Watershed Dynamics and Habitat Contraction of an Endemic Species in Little Red River Headwaters (LRRH)") - Articles in Refereed Scientific Journals - Bickford, N.A., and R.E. Hannigan, 2004, Trace Element Chemistry of Fish Tissues: Uptake Routes in Genus Moxostoma. Environmental Geoscience 11(2): 226-236.
2. 2001AR15B ("Linkages Between Watershed Dynamics and Habitat Contraction of an Endemic Species in Little Red River Headwaters (LRRH)") - Articles in Refereed Scientific Journals - Hannigan, R.E. and N.A. Bickford, 2003 Hydrochemical Variations in a Spring-Fed River, Spring River, Arkansas, Environmental Geoscience, v. 10(4): 167-188.
3. 2001AR15B ("Linkages Between Watershed Dynamics and Habitat Contraction of an Endemic Species in Little Red River Headwaters (LRRH)") - Conference Proceedings - Hannigan, R.E., N. Bickford, and O. Bogdevich, 2003, Otolith Microchemistry of Freshwater Fish: Stock Discrimination of Brown Trout and Walleye "in" Proceedings of the Sixth International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe and the Commonwealth of Independent States, Prague, Czech Republic, in press.

4. 2001AR15B ("Linkages Between Watershed Dynamics and Habitat Contraction of an Endemic Species in Little Red River Headwaters (LRRH)") - Other Publications - Hannigan, R.E. and N.A. Bickford, 2003, End-Member Mixing Analysis: Application to the Spring River, AR, Proceedings of the Arkansas Water Resources Center Annual Conference, April 2003, 54-61.
5. 2001AR3641B ("Critical Evaluation of TMDL Data Requirements for Agricultural Watersheds") - Articles in Refereed Scientific Journals - Cotter, A.S., I. Chaubey, T.A. Costello, T.S. Soerens, and M.A. Nelson, 2003, Water Quality Output Uncertainty as Affected by Spatial Resolution of Input Data. Journal of American Water Resources Association, 39(4): 977-986.
6. 2001AR3641B ("Critical Evaluation of TMDL Data Requirements for Agricultural Watersheds") - Conference Proceedings - Chaubey, I., T.A. Costello, K.L. White, and A.S. Cotter, 2003, Stochastic Validation of SWAT Model Proc. Total Maximum Daily Load: Environmental Regulations II, ASAE, St. Joseph, MI, pp. 168-176.
7. 2001AR3641B ("Critical Evaluation of TMDL Data Requirements for Agricultural Watersheds") - Other Publications - Cotter, A.S., I. Chaubey, T.A. Costello, M.A. Nelson, and T.S. Soerens, 2002, Effect of Spatial Data Resolution on SWAT Output Uncertainty, ASAE Paper No. 02-2012, ASAE, St. Joseph, MI.