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Arkansas Water Resources Center Annual Technical Report FY 2009

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This publication serves as the annual report to the U.S. Geological Survey regarding the projects and activities of the Arkansas Water Resources Center for FY 2009. This document provides summary information for each of the 104B projects funded: 1) Denitrification, internal N cycling, and N retention in river impoundment reservoirs; 2) Land-use effects on resistance and resilience of stream metabolism to flood events in Ozark Highland headwater streams; and 3) Longitudinal evolution of nutrients in a mixed-use watershed under storm and non-storm flow regimes. This publication also summarizes the Arkansas Water Resources Center's information transfer program, student involvement, notable awards and achievements, and publications of previous 104B projects.

Keywords: Arkansas Water Resources Center, Funding, Information Transfer, Water Quality

Introduction

The Arkansas Water Resources Center located at the University of Arkansas, Fayetteville, Arkansas is part of the network of 54 water institutes established by the Water Resources Research Act of 1964. Since its formation, the Arkansas Water Resources Center (AWRC) program in cooperation with the US Geological Survey and the National Institute for Water Resources has focused on helping local, state and federal agencies understand, manage and protect water resources within Arkansas. AWRC has contributed substantially to the understanding and management of water resources through scientific research and training of students. Center projects have focused on topics concerned with water quality of surface water and ground water, especially non-point source pollution and sensitive ecosystems. AWRC helps organize research to insure good water quality for Arkansas today and in the future.

The AWRC focuses its research on providing local, state and federal agencies with scientific data and information necessary to understand, manage and protect water resources within Arkansas. AWRC cooperates closely with colleges, universities and other organizations in Arkansas to address the state's water and land−related issues, promote the dissemination and application of research results, and provide for the training of scientists in water resources. Each year, several research faculty participate in AWRC projects with the help of students who gain valuable experience doing environmentally related work across the state. AWRC research projects have studied irrigation and runoff, innovative domestic wastewater disposal systems, ground water modeling and landuse mapping, erosion and pollution, water quality and ecosystem functions.

The Center provides support to the State's water research by acting 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. The AWRC has historically archived reports of water resource studies funded by the 104B program or through the Center on its website.

In addition, the AWRC sponsors an annual water conference held in Fayetteville, Arkansas each spring, drawing over 100 researches, 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 online. This valuable resource is utilized by a variety of user groups including researchers, regulators, planners, lawyers and citizens.

The AWRC also maintains a modern water quality laboratory that provides water analyses for researchers, municipal facilities, and watershed stakeholders; farmers and other citizens submit samples through the cooperative extension service. This laboratory is certified through the Arkansas Department of Environmental Quality for the analysis of surface and ground water samples.

The AWRC has a technical advisory committee made up of professionals from educational institutions, environmental organization, water supply districts, and government agencies throughout Arkansas. This committee has the opportunity to evaluate proposals submitted annually to the USGS 104B program, to recommend session topics included in the annual research conference, and to provide general advice to the AWRC Director and staff.

Research Program Introduction

Each year, several researchers have participated in 104B projects funded through the Arkansas Water Resources Center (AWRC), and these projects were completed with the help of students in water and environmentally related fields. The research projects funded through the AWRC have studied a broad range of environmental and water issues facing Arkansas, including irrigation and rainfall–runoff, innovated domestic wastewater disposal, groundwater modeling and land use mapping, erosion and nonpoint source pollution, water quality and ecosystem function. The AWRC has given priority to solid scientific research proposals submitted by faculty to the 104B program; the intent has been to provide seed data to researchers such that larger proposals can be developed and submitted to extramural funding sources. The AWRC has funded several projects using 104B funding that have resulted in the award of extramural grants to continue the base research.

To formulate a research program relevant to state water issues, the Center works closely with state and federal agencies, and academic institutions. An advisory committee, composed of representatives from state and federal agencies, industry and academia, provides guidance for the Center. The technical advisory committee plays an important role in insuring that the water institute program (section 104) funds address current and regional issues. The priority research areas of the AWRC base program directly related to the program objectives of the Water Resources Research Act, including research that fosters improvements in water supply, explores new water quality issues, and expands the understanding of water resource and water related phenomena.

Denitrification, Internal N Cycling, and N Retentions in River Impoundment Reservoirs

Basic Information

Title:	Denitrification, internal N cycling, and N retention in river impoundment reservoirs
Project Number:	2009AR214B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	3rd Congressional District of Arkansas
Research Category:	Water Quality
Focus Category:	Geochemical Processes, Nutrients, Sediments
Descriptors:	
Principal Investigators:	Jefferson Thad Scott

Publications

1. Grantz, E.M., and J.T Scott. 2010. Nitrogen retention and denitrification efficiency in reservoirs. Arkansas Water Resource Center Annual Meeting, Fayetteville, Arkansas
2. Grantz, E.M. and J.T. Scott. 2010. Denitrification efficiency and water residence time in reservoirs. Annual Meeting of the American Society of Limnology and Oceanography, Santa Fe, New Mexico

Arkansas Water Resources Center 104B Program Project – March 2009 through February 2010

Project Title: DENITRIFICATION, INTERNAL N CYCLING, AND N RETENTION IN RESERVOIRS

Project Team: J. Thad Scott, Dept. of Crop, Soil, and Environmental Sciences, University of Arkansas

Interpretative Summary:
We are examining the role of reservoirs as landscape-scale reactive nitrogen (N) sinks that can attenuate excess human-derived N through natural processes such as denitrification. Measured denitrification rates in reservoirs ranged from 40 – 60 µmol N m^{-2} h^{-1}, which is similar to denitrification reported from eutrophic lakes (Seitzinger 1988). Furthermore, when denitrification rates were extrapolated to seasonal estimates and compared to reservoir N flux, we found that denitrification can account for as much as 100% of reservoir N retention. This estimate is similar to other recent estimates of denitrification efficiency in reservoirs (David et al. 2006) and suggests that reservoirs may be an effective tool to permanently remove reactive N from surface waters and protect downstream water quality.

Introduction:
Although substantial quantities of N fertilizer are added to agricultural landscapes on an annual basis, only a fraction of this N is actually exported to coastal systems. The remainder is stored on the landscape or lost back to the atmosphere through balancing mechanisms such as denitrification. Wollheim et al. (2008) reported that more than 50% of the N input into streams, lakes, rivers, and reservoirs around the world is retained or removed by these systems. However, the global significance of denitrification in this retention is poorly understood.

Few studies have specifically quantified denitrification rates or the factors controlling denitrification in reservoir ecosystems. Equally important, few studies have quantified denitrification in terms of contribution to N retention. In a recent study, David et al. (2006) found that sediment denitrification accounted for 80% to 100% of N retention in an Illinois reservoir. Moreover, they found that reservoir denitrification efficiency was related to water residence time (Saunders and Kalff 2001, Seitzinger et al. 2002). But more work is needed to refine estimates of denitrification in reservoirs and to assess the effectiveness of reservoir denitrification in attenuating reactive N and protecting downstream water quality.

Methods:
Intact sediment cores (7.6 cm diameter; 10-20 cm depth) were collected from two northwest Arkansas reservoirs (eight cores per date) during fall and winter conditions. Cores were collected from reservoirs using a manual coring device equipped with a one-way rubber valve to maintain structural integrity of the core and overlying water. In addition to cores, 20 liters of site water were collected for use in incubations. Cores were fitted with an adjustable flow-through plunger with O-ring seal and Teflon inlet and outlet tubes to create a continuous flow chamber. Cores were incubated at in-situ temperature and site water was passed over the core surface at a flow rate of 1.0 ml min^{-1}. Cores were “pre-incubated”

for a period of approximately 18 hours to ensure steady state conditions. Following stabilization, changes in N_2/Ar ratio between core inflow and outflow were assessed once per day for two days using a membrane inlet mass spectrometer (MIMS) to estimate net denitrification.

Nitrogen retention in reservoirs was calculated as the difference between riverine N inputs and outputs. Nitrogen inputs to reservoirs were estimated using the rating curve method (Shivers and Moglen 2008). Briefly, a relationship between stream stage, streamflow, and total N concentrations were derived for inflowing streams to estimate N inputs from continuously monitored stream stage. Nitrogen outputs from reservoirs were estimated from water release rates and N concentrations, integrated using continuously monitored reservoir elevation data. Yields from gauged streams were applied to ungauged streams to estimate whole-system inputs. Whole-reservoir N retention was divided by lake surface area to estimate areal retention as a way to compare with denitrification estimates.

Results:

Preliminary data indicated that denitrification in reservoirs ranged from 40 – 60 µmol N m^{-2} h^{-1}, which is similar to denitrification reported from eutrophic lakes (Seitzinger 1988). Preliminary data also indicate that reservoir N mass balances should be accurate. The relationship between inflow and outflow stream depth and discharge was always strong and positive (Figure 1a). Unexpectedly, we found that DIN concentrations in inflow streams were always greatest during baseflow conditions and decreased during stormflow (Figure 2a). DIN concentrations were not strongly related to flow in outflow streams but were predictable based on seasonal variations (Figure 1c).

Overall, we found that the study reservoirs retained approximately 10 – 20 mg N L^{-1} day^{-1} during baseflow conditions but that some reservoirs became N sources during stormflow. By combining whole reservoir N flux estimates with denitrification estimates we found that as much as 100% of the N retained by the reservoirs may be ultimately denitrified, which is similar to studies from other reservoirs in human-developed landscapes.

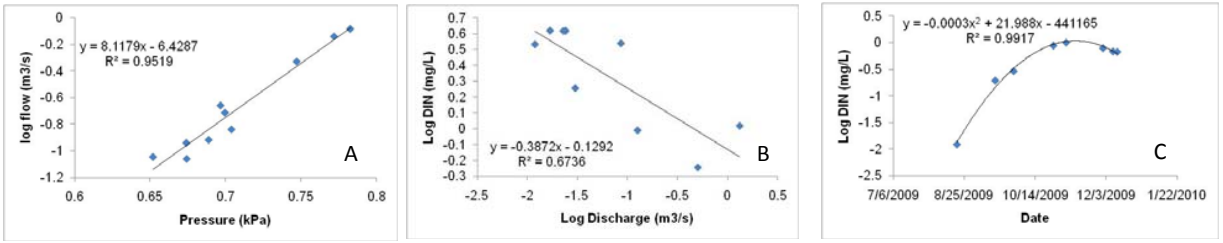

Figure 1. A) Example relationship between stream depth (measured as pressure) and flow, B) Example of the negative relationship between flow and DIN seen at all inflow sites, and C) Example of seasonal DIN trend oberserved at lake outflows.

Conclusions:

This study indicates that reservoirs are indeed critical biogeochemical hotspots for N processing and that reservoir denitrification may effectively attenuate reactive N from surface waters and protect down-stream water quality.

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David, M.B., L.G. Wall, T.V. Royer, and J.L. Tank. 2006. Denitrification and the nitrogen budget of a reservoir in an agricultural landscape. Ecological Applications 16: 2177-2190.

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Research Publications Stemming from this Project:

Grantz, E.M., and J.T Scott. 2010. Nitrogen retention and denitrification efficiency in reservoirs. Arkansas Water Resource Center Annual Meeting, Fayetteville, AR.

Grantz, E.M. and J.T. Scott. 2010. Denitrification efficiency and water residence time in reservoirs. Annual Meeting of the American Society of Limnology and Oceanography, Santa Fe, NM.

Land-use Effects on Resistance and Resilience of Stream Metabolism to Flood Events in Ozark Highland Headwater Streams

Basic Information

Title:	Land-use effects on resistance and resilience of stream metabolism to flood events in Ozark Highland headwater streams
Project Number:	2009AR15B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	3rd Congressional District of Arkansas
Research Category:	Water Quality
Focus Category:	Ecology, Water Quality, Hydrology
Descriptors:	
Principal Investigators:	Michelle A. Evans-White

Publications

1. Allison, Autumn. 2010. Land-use effects on recovery of benthic macroinvertebrate to flood events in Ozark Highland Streams. Honors Thesis. Fulbright College of Arts and Sciences, University of Arkansas, Fayetteville, Arkansas
2. Case, Mckinley. 2010. Land-use effects on recovery of benthic algae to flood events in Ozark Highland Streams. Honors Thesis. Fulbright College of Arts and Sciences, University of Arkansas, Fayetteville, Arkansas
3. Bumpers, P. and M.A. Evans-White. 2010. Ecosystem metabolism responses to flood events in Ozark Highland forested, agricultural, and urban streams. ASLO/NABS Joint National Meeting, Sante Fe, New Mexico

Arkansas Water Resources Center 104B Program Project – March 2009 through February 2010

Project Title: LAND-USE EFFECTS ON RESISTANCE AND RESILIENCE OF STREAM METABOLISM TO FLOOD EVENTS IN OZARK HEADWATER STREAMS

Project Team: Michelle A. Evans-White, Dept. of Biological Sciences, University of Arkansas

Interpretative Summary:

Climate change models predict altered temperature and precipitation patterns across the globe. Altered precipitation frequency, amounts, and seasonality will likely alter nutrient, contaminant, sediment, and organic matter delivery to streams as well as in-stream processing of these materials. Watershed vegetation structure and land-use (e.g., urban, agriculture) can also mediate the delivery of water, nutrients, organic matter and sediments to streams. Therefore, studies examining the resistance or resilience of stream ecosystem processes to hydrologic disturbance within the major terrestrial biomes and major land-uses within those biomes are needed to predict the potential consequences of climate change for stream ecosystems. The Ozark Highlands region of Northwest Arkansas is a patchwork of predominantly forested watersheds to increasingly agricultural or urban watersheds, which lends well to natural experiments examining ecology within these different stream types. Water quality within this region affects water quality across state boundaries and in the Gulf of Mexico. The main objective of the proposed research is to determine whether resistance and resilience of stream metabolism, which includes gross primary production, ecosystem respiration, and net ecosystem production, to flood events differs among headwater streams draining watersheds dominated by forest, urban, or agricultural land-use in the Ozark Highlands. Stream metabolism will be measured in 12 streams (4 each from predominantly forested, urban, and agricultural watersheds) and related to measures of in-stream light levels, dissolved nutrients, turbidity, benthic organic matter standing stocks, periphyton biomass, grazer biomass, substrate size, and flood intensity. The proposed research would provide infrastructure in the form of multi-parameter sondes to help monitor water quality and to study the effects of regional climate and land-use change on stream ecosystems in northwest Arkansas. Infrastructure and funds would also be used to support spin-off projects for undergraduate and graduate students.

Introduction:

Climate change is expected to further alter precipitation frequencies and magnitude, which will cause altered hydrologic disturbance in lotic ecosystems due to flooding. Watershed vegetation structure and function and land-use (e.g.e, urban, agriculture) can mediate the delivery of water, nutrients, organic matter and sediments to streams (Jones et al., 2001; Paul and Meyer, 2001). Therefore, studies examining the resistance or resilience of stream ecosystem processes to hydrologic disturbance within the major terrestrial biomes and major land-uses within these biomes are needed to predict the potential consequences of climate change for stream ecosystems.

Stream metabolism including gross primary productivity, ecosystem respiration, and net ecosystem production is key stream ecosystem process that is linked to water quality and to nutrient uptake and

spiraling processes (Meyer et al., 2005). In addition, primary production is a major basal food resource affecting rates of secondary production and may indirectly alter benthic macroinvertebrate and fish community structure by controlling dissolved oxygen availability in stream ecosystems. Therefore, stream metabolism represents an excellent starting point to examine how resistance and resilience of stream ecosystems to flood events may depend upon land-use and to predict how climate change may affect stream water quality, communities and ecosystems processes in the Ozark Highlands region. Objectives include 1) determining if resistance and resilience of stream metabolism, including gross primary production, ecosystem respiration, and net ecosystem production to spring and autumn flood events differs among headwater streams draining watersheds dominated by forest, urban or agricultural land-use in the Ozark Highlands and 2) determining whether resistance and reliance of stream metabolism to flood events within forested, urban or agricultural streams is related to seasonally changing light levels or to patterns in benthic organic matter standing stocks, periphyton biomass and macroinvertebrate abundance.

Methods:

We chose 11 study streams that drain each of 3 predominant land-use types (forest, urban, and agricultural pasture land) in the Ozark Highland ecoregion of Northwest Arkansas. Four streams drained watersheds that were primarily forested [mean + 1 SE %forest (85.3 + 3.2), %pasture (8.7 + 1.3), and %urban (2.5 + 1.1)]. Three streams drained primarily pasture agricultural lands [mean + 1 SE % forest (38.3 + 6.7), %pasture (48.6 + 7.1), and %urban (6.2 + 0.7)]. Four streams drained watersheds with higher urban land cover [mean + 1 SE % forest (33.3 + 8.8), %pasture (24.3 + 9.0), %urban (36.3 + 7.7)]. Base flow discharge and flood events were monitored using USGS gaging stations or pressure transducers at each site.

We began collecting data for stream metabolism at each study site in the late summer and early autumn of 2009. Dissolved oxygen (DO; %saturation and mg/L), temperature, turbidity (NTU), and conductivity (µS/cm) was recorded at 15-minute intervals using Hydrolab multi-parameter sondes that were acquired in June 2009. Sonde measurements over time were corrected for drift in measurements based on DO measured using the Winkler method (APHA 2005) and a digital burette during launch and approximately every other week after launch. At least five Winkler samples were taken during each calibration. Gross primary production and ecosystem respiration were determined using an opensystem, single-station diel approach (Odum 1956; Bott 2006). Photosynthetically-active radiation (PAR) was measured at 15 minute intervals at representative sites using Odyssey light loggers that have been calibrated with a LICOR.

We began collecting data to assess periphyton within 2 streams draining each predominant land use type (n=6) in the Spring of 2009 and began sampling the full suite of 11 streams in late summer and early autumn of 2009. Cobble periphyton samples were collected approximately every 2 to 3 weeks before and after flooding from 3 riffles and 3 pools within each 200-m stream reach at least 20-m apart. Cobbles were then be transported back to the lab in a cooler, submerged in ethanol (78oC, 5 min;

Sartory et al. 1984), allowed to extract in a refrigerator (4oC, 24 h), and analyzed for chlorophyll a (chl a) on a Gensys spectrophotometer (APHA 2005). Cobble areas were determined by wrapping them in aluminum foil and comparing the foil mass to the mass of a 1cm2 piece of identical aluminum foil. We also collected benthic organic matter (BOM) and macroinvertebrate samples when periphyton samples were collected at each site. A pipe corer (0.018m2) was placed into the substrate and benthic macroinvertebrates and BOM were collected from the benthos in 3 riffle and 3 pool locations within a 200-m study reach. Within each core, the substrate was disturbed and macroinvertebrates and other organic matter > 250 µm were netted from the corer and placed in a sample bag to be frozen once returning to the laboratory. The remaining fine benthic matter slurry (< 250 µm; FBOM) in the core was sub-sampled and returned to the lab for processing. Core volume for each sample was calculated from the average water depth in each core. In the laboratory, macroinvertebrates were separated from coarse benthic organic matter (>1 mm; CBOM) and fine benthic organic matter (250-999µm; FBOM) placed in 90% ethanol for later identification to family or genus. CBOM and FBOM were dried (50oC, 48-72 h), weighed, ashed in a muffle furnace (550oC, 4 h), and re-weighed to obtain AFDM. A sub-sample of the remaining fine particulate slurry was filtered through a glass fiber filter (1µm pore size) and processed as described above for the other BOM fractions (VFBOM; 1-250 µm).

Flood intensity will be estimated using hydrological, chl a, and BOM data. The ratio of peak discharge to mean discharge prior to the disturbance and flood duration will be quantified to estimate flood intensity. In addition, flood intensity will be gaged by taking the difference of mean chl a or BOM mass prior to and after the flood event divided by the mean chl a or BOM mass prior to the flood event. Resistance and resilience of metabolism will be defined as the proportional change in metabolism response variables following a flood event and the return interval (Uehlinger 2000).

Results:

Motabolism data, as well as nutrients, periphyton, BOM, and benthic macroinvertebrates were collected in Autumn 2009. The results of these samples are currently being processed and analyzed. Preliminary data will soon be available.

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Bott, T.L. 2006. Primary productivity and community respiration. Pages 663-690 in Hauer, F.R. and G.A Lamberti (eds) Methods in Stream Ecology. Second ed. Academic Press, Burlington, MA.

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Odum, H.T. 1956. Primary production in flowing waters. Limnology and Oceanography 2:102-117.

Paul, M.J. and J.L. Meyer. 2001. Streams in the urban landscape. Annual review of ecology and systematic 32: 333-365.

Uehlinger, U. 2000. Resistance and resilience of ecosystem metablis in a flood-prone river system. Freshwater Biology 45;319-332.

Research Publications Stemming from this Project:

Allison, Autumn. 2010. Land-use effects on recovery of benthic macroinvertebrate to flood events in Ozark Highland Streams. Honors Thesis. Fulbright College of Arts and Sciences, University of Arkansas, Fayetteville, AR.

Case, Mckinley. 2010. Land-use effects on recovery of benthic algae to flood events in Ozark Highland Streams. Honors Thesis. Fulbright College of Arts and Sciences, University of Arkansas, Fayetteville, AR.

Bumpers, P. and M.A. Evans-White. 2010. Ecosystem metabolism responses to flood events in Ozark Highland forested, agricultural, and urban streams. ASLO/NABS Joint National Meeting, Sante Fe, NM. (poster)

Longitudinal Evolution of Nutrients in a Mixed-use Watershed under Storm and Non-storm Flow Regimes

Basic Information

Title:	Longitudinal evolution of nutrients in a mixed-use watershed under storm and non-storm flow regimes
Project Number:	2009AR217B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	3rd Congressional District of Arkansas
Research Category:	Water Quality
Focus Category:	Hydrology, Non Point Pollution, Nutrients
Descriptors:	
Principal Investigators:	J. Joshua Romeis, Kristofor R. Brye, Andrew Sharpley, Jerral Vaughn Skinner

Publications

None to date.

Arkansas Water Resources Center 104B Program Project – March 2009 through February 2010

Project Title: LONGITIDUNAL EVOLUTION OF NUTRIENTS IN A MIXED-USE WATERSHED UNDER STORM AND NON-STORM FLOW REGIMES

Project Team: Andrew Sharpley, Dept. Crop, Soil and Environmental Sciences, University of Arkansas

Interpretative Summary:
Non-point source nutrient management in watersheds to mitigate eutrophication emphasizes phosphorus (P)-based source and transport best management practices (BMPs). Protocols for P load reductions in agricultural areas include the use different source (e.g., manure management) and transport (e.g., riparian buffers, constructed wetlands) BMPs. However, there is limited information on BMP efficacy due, in part, to the complexity of P fate and transport processes in local watersheds. This research investigates the longitudinal evolution of in-stream nutrient concentrations and loading as a function of near-stream hydrogeology, flow regime (i.e. storm vs. non-storm), land use, and soil and sediment characteristics in an agricultural watershed at the Watershed Sustainability Research Center (WSRC). Those patterns may change substantially during stormflow conditions when the larger watershed and its spatial distribution of nutrient CSAs are hydrologically-connected to the stream.

Introduction:
While P management approaches, are deservedly the focus of much environmental research, the most effective approaches are those that integrate P and N because focusing solely on one nutrient (i.e. P) can have limited returns by negatively impacting the other nutrient (i.e. N) and ultimately, both nutrients are critical for algal productivity. Integration of P and N into nutrient management approaches must take into account the concept that P and N in watersheds typically have different spatial distribution of source areas and hydrologic pathways, and sinks. Further, P and N are subject to different biogeochemical processes in upland, near-stream (riparian), and aquatic environments.

Given differing source area, pathway and sink processes, P and N should hypothetically exhibit unique ratios, concentration-flow relationships, and loading patterns in streams draining a watershed. These should vary temporally due to seasonal or short-term variations in flow regime, as well as longitudinally as the spatial distribution of geologic features, soils, hydrologic connectivity, land use and other factors evolve as a function of increasing or decreasing watershed drainage area. How those patterns evolve longitudinally will vary as a function of the relative importance of in-stream nutrient processing respective to P and N and the spatial and temporal distribution of N and P loading. Studies to test the above hypotheses are common, but they typically are performed in large watersheds. Of the studies that focused on small watersheds, they were performed in neighboring or entirely-unconnected watersheds within one larger unifying watershed, or they focused on one nutrient. Further, few of these studies have directly analyzed both in-stream and near-stream nutrient processes to account for observed temporal and longitudinal changes in stream water quality.

Research Branch (Figure 1) is a first-order stream (184 hectares) in the upper Illinois River basin of Northwest Arkansas. The stream drains WSRC that is managed through the Arkansas Agricultural Research and Extension Center (AAREC) (http://aaes.uark.edu/fayrec.html). The watershed is on the urban – agriculture interface, with source water for the North Branch mainly agricultural and for the South Branch urban runoff. Research Branch Watershed is an ideal site to test the above hypotheses in a small watershed and then use the results in future BMP-efficacy studies. Parent material includes both sandstone and limestone. A notable soil series in the watershed is Leaf silt loam which coincides spatially with the NRCS-delineated wetland area shown in Figure 1. While these areas remain wet (hydric) during a large part of the year, their vegetation is not typical of wetlands on Wetland Branch (Figure 1). Predominant land use types of the watershed are identified in Figure 1. A network of ditches drains overland flow from different land areas in the watershed.

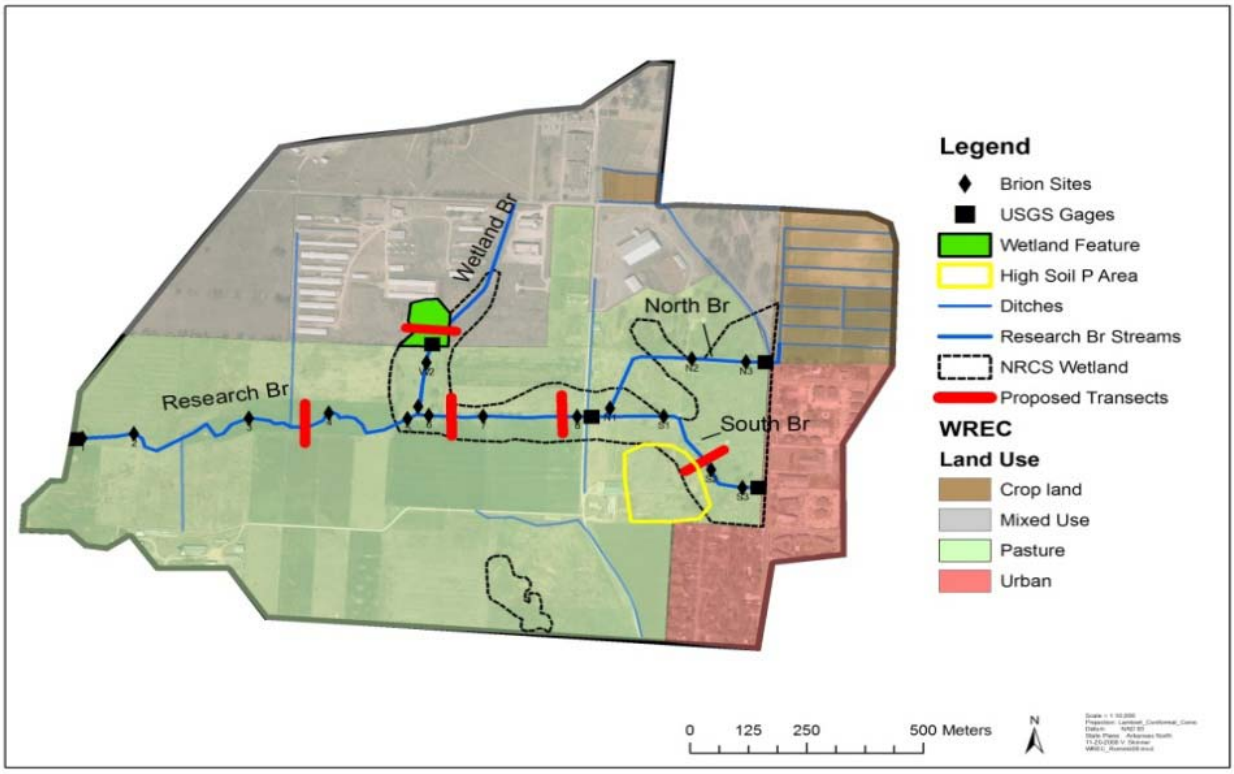

Figure 1. Research Branch watershed within the Watershed Sustainability Research Center

Methods:

The proposed research is comprised of two studies characterizing longitudinal nutrient variability on a reach-by-reach basis. Streamflow will be measured continuously by the U.S. Geological Survey (USGS) at five locations total on Research Branch and its North, South, and Wetland Branch tributaries. Streamflow data will be made available to the public via the Internet. Rainfall will be measured by USGS at two (Research Branch outlet and Wetland Branch) of the gages. Shallow groundwater wells will be installed along four transects (Figure 1). Four wells are planned per transect—two on each side of the

stream with one located near the riparian zone and the other approximately 30-40 meters upland. The wells will be drilled to refusal using hollow-stem auger methods. A shallow piezometer down to the surface of the Bt horizon will accompany each near-stream well. Samples from all wet cuttings (0-5 cm and then at 0.25 m intervals) will be saved for nutrient analyses. Depth to groundwater (DTW) in the wells and piezometers will be measured using a combination of manual and automated (pressure transducers or capacitance probes) methods.

Results:

We collected soil profile samples along the stream channel, at transects 10, 20 and 50 m from the main channel. These soil samples were collected to a depth of approximately 1 m. Phosphorus and nitrogen forms in the soil are being determined to elucidate dominant forms and pathways of nutrient movement horizontally thought the soil profile from recharge areas to the stream channel. At the same time samples from the North, South and Main Branch of the stream flowing through the watershed are being collected during stormflow events and at regular interval during baseflow conditions.

Conclusions:

The soils, geology, and mixture of land use practices in the study watershed are representative of the Illinois basin and the Ozark Highlands region as a whole. Anticipated results include 1) a differentiation between in-stream vs. near-stream (i.e. riparian groundwater) nutrient inputs (or losses) during nonstorm conditions and 2) a relative comparison of non-storm and storm event nutrient loading on the expectation that reaches exhibiting the highest non-storm loads may not exhibit the highest storm loads. Findings will provide a foundation for future hydrologic and nutrient transfer studies in this and other regional watersheds, including studies aimed at quantifying effects of best management practices for mitigating diffuse nutrient losses to streams. Due to the educational nature of WSRC, visiting students and others will be exposed to the types of experimental methods used to investigate factors that can influence in-stream water quality.

Research Publications Stemming from this Project:

None to date.

Information Transfer Program Introduction

Dissemination of information is one of the main objectives of the Arkansas Water Resources Center. To achieve this objective, AWRC sponsors an annual water conference held in Fayetteville, Arkansas, which draws approximately 100 researchers, students, agency personnel, and interested citizens to learn about current research and hot topics in water resources throughout the State. AWRC also co-sponsors workshops and other water-related conferences in the state and region.

The AWRC maintains a technical library containing over 900 titles, many of which are available online. This valuable resource is utilized by a variety of user groups including researchers, students, regulators, planners, lawyers and citizens. Many of AWRC library holdings have been converted to electronic PDF format which can be accessed via the AWRC website at www.uark.edu/depts/awrc/publications.htm. AWRC is continuing to add archived documents from the library to this electronic data set, and all new titles are added when received.

AWRC Information Transfer Program

Basic Information

Title:	Arkansas Water Resources Center Information Transfer Program
Project Number:	2009AR207B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	3rd Congressional District of Arkansas
Research Category:	Not Applicable
Focus Category:	Surface Water, Groundwater, Water Use
Descriptors:	
Principal Investigators:	Brian E. Haggard

Publications

1. Longing, S.D. 2009. Frequency distributions of median nutrient and chlorophyll concentrations across the Red River Basin, 1996-2006. Arkansas Water Resources Center, Fayetteville, Arkansas. MSC 350: 32 pp.
2. Longing, S.D. 2009. Heterostenuta sulphuria (Coloptera: Dytiscidae) Occurrence in the Sulphur Springs Headwater System and in Buffalo National River Tributaries (Arkansas, USA): Current Distribution, Habitat Conditions, and Biomonitoring Framework. Arkansas Water Resources Center, Fayetteville, Arkansas. MSC 351: 18 pp.
3. Massey, L.B. 2009. Water quality sampling, analysis and annual load determinations for the Illinois River at Arkansas Highway 59 Bridge, 2008. Arkansas Water Resources Center, Fayetteville, Arkansas. MSC 352: 10 pp.
4. Massey, L.B. 2009. Water quality sampling, analysis and annual load determinations for nutrients and solids on the Ballard Creek, 2008. Arkansas Water Resources Center, Fayetteville, Arkansas. MSC 353: 9 pp.
5. Massey, L.B. 2009. Illinois River Volunteer Monitoring. Arkansas Water Resources Center, Fayetteville, Arkansas. MSC 354. 19 pp.
6. Arkansas Water Resources Center. 2010. Annual Conference Program. Fayetteville, Arkansas, April 13-14, 2010. http://www.uark.edu/depts/awrc/pdf_files/Program[032910].pdf

Student Support

Category	Section 104B Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	7	0	0	3	10
Masters	4	0	0	3	7
Ph.D.	0	0	0	0	0
Post-Doctoral	1	0	0	1	2
Total	12	0	0	7	19

Notable Awards and Achievements

Establishing Effective Partnerships

The Arkansas Water Resources Center (AWRC) continued to develop the Watershed Management Plan (WMP) for the Upper Illinois River Watershed in northwest Arkansas under the guidance and direction of the Illinois River Watershed Partnership (IRWP). The finalized draft of the WMP highlighted priority areas where specific, voluntary best management practices should be implemented within the watershed to reduce concentrations of nitrogen, phosphorus and sediments in regional streams. The funding for this project was provided by the Walton Family Foundation and the USEPA through the Arkansas Natural Resources Commission (ANRC).

The AWRC also teamed up with other organizations and non-profits to monitor water quality throughout northwest Arkansas. The AWRC partnered with Beaver Water District to monitor seven sites in the White River Watershed, with IRWP to monitor eight sites in the Upper Illinois River Watershed and with Kings River Watershed Partnership to monitor a site on the Kings River near Berryville, Arkansas. These projects were all funded through the ANRC with matching funds provided by AWRC and or the respective organization.

Collaborative Multidisciplinary Research Education Programs

The AWRC was funded by USEPA Region 6 and Headquarters to provide technical assistance to develop nutrient criteria within the multi-jurisdictional Red River Basin through two phases: Phase I organized the database compiling water quality data from the USGS, Arkansas Department of Environmental Quality, Louisiana Department of Environmental Quality, Oklahoma Conservation Commission and Oklahoma Water Resources Board, and the Texas Commission on Environmental Quality; Phase II provided summaries of the statistical distribution of median nutrient concentrations across the Red River separated into aggregate watersheds and eco-regions, as well as statistical relations between nutrient concentrations and algal biomass (i.e., chlorophyll a concentrations); and Phase III provided specific training to each state's agency responsible for the development of water quality standards via a statistical tools workshop. These reports will be used in a weight-of-evidence approach to assist the states in the development of numerical nutrient criteria applicable to the Red River Basin.

The AWRC along with faculty from other disciplines (including Animal Sciences, Geosciences, Soils, Environmental Sciences, Ecological Engineering and Biology) have used the USGS 104B funding as a source to initiate research projects at the University of Arkansas Savoy Experimental Watershed (SEW) and to stimulate the inflow of funding from other federal sources to further support this research. The research projects at SEW have addressed a variety of important water issues, and these project were broad across multiple disciplines. Examples of these projects include: 1)Identification of mechanisms (infiltration excess or saturation excess) that produce surface runoff from pasture hill slopes (Ecological Engineering); 2)Water quality of springs and groundwater downslope from ponds holding swine manure (Geosciences & Animal Sciences); and 3)Nitrogen transport and utilization along a shallow groundwater flow path (Biology &Geosciences). The focus of research at SEW often revolves around understanding the transport and fate of nutrients in a strongly linked surface-subsurface karst agricultural watershed, which is critical to developing best management practices that will improve water quality and protect human health.

The Watershed Research and Education Center (WREC) was established by the UA Division of Agriculture in 2006, and it encompasses 235 acres of pasture, wetlands and streams within an area subject to both urban storm water and agricultural runoff. WREC evaluates best management practices for urban and rural environments, as well as to educate students, the public, and city and county planners in science-based methods for managing stormwater runoff. AWRC has coordinated with UA Division of Agriculture Cooperative Extension Service to restore riparian buffers along the main channel of the stream running through the watershed; these buffers include urban forest buffers, typical three-zone riparian forest buffers, wildlife management areas, and switchgrass buffers for uses as bioenergy. AWRC has worked with the USGS to establish a network of stream discharge monitoring stations to measure the inputs and outputs of storm water, nutrients and sediments from agricultural and urban land uses within this experimental watershed.

AWRC is currently working the City of Fayetteville to establish an educational walking trail through the watershed that will be open to the general public, and this trail (if approved by the UA Division of Agriculture) will connect existing city trails through WREC. Information Transfer through Invited Presentations. The AWRC Director and several faculty associated with the Center were invited to give presentations, including:

- Haggard, B. Illinois River Watershed Management Plan - Update to the Joint Performance Review Committee, Arkansas State Legislature, Rogers, Arkansas - October 2009 (INVITED)
- Haggard, B., and T. Scott. Nutrient Criteria Development Mini-Workshop, includes 4 oral presentations and 3 group exercises with the States, USEPA Region IV, Dallas, Texas - February 2010
- Haggard, B. Arkansas - Oklahoma Nutrient Issues: What's Happened on the Arkansas Side? USDA National Land and Sea Grant Water Conference, Hilton Head, South Carolina - February 2010 (INVITED)
- Scott, J.T. The significance of nitrogen retention and denitrification in reservoirs of the White River Basin in Arkansas and Missouri. NSF-Research Coordination Network on Denitrification, the University of Rhode Island Coastal Institute - May 2009 (INVITED)
- Scott, J.T. Timescales and mechanisms of fixed nitrogen retention freshwater benthic and planktonic communities. American Society of Limnology and Oceanography, 2010 Ocean Sciences meeting, Portland, Oregon - February 2010 (INVITED)
- Sharpley, A., J. Romeis, T. Scott, and B. Haggard. Nutrient loading in steams and eutrophication of reservoirs. Soil and Water Conservation Society Annual Meeting, Kansas City, Missouri - September 2009 (INVITED)

Notable Research

The AWRC is involved with a multi-disciplinary and -institutional research project evaluating the effect of natural gas development on streams within the Fayetteville shale of the Gulf Mountain Wildlife Management Area; the project team includes the University of Arkansas, University of Central Arkansas, US Geological Survey, and Arkansas Game and Fish Commission. The University of Central Arkansas is the lead on the project assessing biological and chemical effects of natural gas drilling on headwater streams in the region. And, the AWRC is the lead on the project evaluation biological and chemical effects on the larger South Fork of the Little Red River, which runs through the Wildlife Management Area where drilling is on-going. These projects are funded through the State Wildlife Grant Program.

Publications from Prior Years

1. 2007AR162B ("Long-term runoff water quality in response to natural rainfall as affected by poultry litter application rate") - Articles in Refereed Scientific Journals - Pirani, A.L. K.R. Brye, B.E. Haggard, T.C. Daniel, and J.D. Mattice, 2007, Broiler litter rate effects on nutrient leaching from soil under pasture vegetation in the Ozark Highlands. Soil Sci. 172:1001-1018.

2. 2007AR171B ("Continuous Water-Quality Monitoring and Potential Phosphorus Source Identification with Oxygen Isotopes") - Conference Proceedings - Breaker, B., E. Pollock, P. Hays, and B. Haggard. 2008. Use of phosphate-oxygen isotope ratios as a tracer for sources and cycling of phosphorus in the Illinois River in AR and OK at American Geophysical Union, San Francisco, California.

3. 2007AR171B ("Continuous Water-Quality Monitoring and Potential Phosphorus Source Identification with Oxygen Isotopes") - Articles in Refereed Scientific Journals - Toor, G.S., R.D. Harmel, B.E. Haggard, and G. Schmidt. 2008. Regression methodology with low-frequency water quality sampling to estimate constituent loads for ephemeral watersheds. Journal of Environmental Quality 37:1847-1854.

4. 2007AR173B ("Metal Mobilization, Especially Arsenic, in the Alluvial Aquifer in Response to Water Level Fluctuations Measured by Field and Laboratory Column Data ") - Articles in Refereed Scientific Journals - Sharif, M.U., R. K. Davis, K. F. Steele, B. Kim, T. M. Kresse, P.D. Hays and J.A. Fazio,2008, Distribution and Variability of Redox Zones as Control of Spatial Variability of Arsenic in the Mississippi River Valley Alluvial Aquifer, Southeastern Arkansas, USA. Journal of Contaminant Hydrology, 99:49-67.

5. 2007AR173B ("Metal Mobilization, Especially Arsenic, in the Alluvial Aquifer in Response to Water Level Fluctuations Measured by Field and Laboratory Column Data ") - Articles in Refereed Scientific Journals - Sharif, M.U., R. K. Davis, K. F. Steele, B. Kim, P. Hays, T. M. Kresse, and J.A. Fazio, 2008, Inverse geochemical modeling of groundwater evolution with emphasis on arsenic in the Mississippi River Valley alluvial aquifer, Arkansas (USA). Journal of Hydrology, 350:41-55.

6. 2008AR193B (" Biogeochemical controls and interactions of carbon and nutrient cycling in karst hydrologic systems.") - Dissertations - Knierim, Katherine J. 2009. Seasonal variation of carbon and nutrient transfer in a northwestern Arkansas cave. M.S. Thesis, Department of Geosciences, University of Arkansas.