Report as of FY2006 for 2006AR122B: "Sediment Characterization in Three Coves - Beaver Reservoir, Arkansas"

Publications

- Dissertations:
  - Patton, J.A., in progress, Comparative Sedimentation in Three Coves, Beaver Reservoir, Northwest Arkansas, Ph.D. Dissertation, Environmental Dynamics Program, Univesity of Arkansas, Fayetteville, AR, expected completion, May 2008.
- Other Publications:
  - Patton, J.A. and S.K. Boss, 2007, Selected Trace and Major Element Concentrations of Beaver Lake Sediment Cores: Arkansas Water Resources Center Annual Conference, 24-25 April 2007, Fayetteville, Arkansas (CD).
  - Boss, S.K. and J.A. Patton, 2006, Sedimentation in Beaver Lake: An Ozark Mystery?, Arkansas Water Resources Center Annual Conference, 18-19 April 2006, University of Arkansas, Fayetteville, Arkansas (CD).
  - Kurz, M.J., J.A. Patton and S.K. Boss, 2006, Comparative geomorphic analysis of three sub-watersheds of Beaver Reservoir, northwest Arkansas, Geological Society of America Annual Meeting Abstracts with Programs, v. 38, No. 7, p. 353.
  - Patton, J.A. and S.K. Boss, 2006, Fusion of disparate data sets in quantifying reservoir sedimentation, Geological Society of America Annual Meeting Abstracts with Programs, v. 38, No. 7, p. 137.
  - Patton, J.A. and S.K. Boss, 2005, Influence of land use change on reservoir sedimentation: A comparative study, Geological Society of America annual Meeting Abstracts with Programs, v. 37, No. 7, p. 354.

Report Follows

13. Title. Sediment Characterization in Three Coves - Beaver Reservoir, Arkansas

14. Statement of Regional or State Water Problem:

Need For Study:

Sediment has been identified by the USEPA as the primary non-point source of water quality impairment in United States lakes and streams and is currently responsible for the listing of 38% of all impaired freshwater streams in the United States (USEPA, 2000). Excessive sedimentation is considered a dangerous pollutant and can threaten the viability of aquatic biota. Sediment not only acts as a direct pollutant, but can act as both a sink and a source for other contaminants including heavy metals and nutrients.

Preliminary studies of sediment loading (Boss, 2004; ADEQ, 2004 and 2005) identified potential sedimentation 'hot spots' in upper Beaver Reservoir and the watershed of a major tributary (West Fork of the White River; ADEQ, 2004). Public complaints of excessive sedimentation in one arm of Beaver Reservoir (Monte Ne Cove) resulted in at least one citizens' lawsuit against the Beaver Water District (ongoing) and investigation by the Arkansas Department of Environmental Quality (ADEQ, 2005; Price, 2004). However, systematic studies to compare effects of watershed activities on sediment loading or to characterize the chemistry of sediment deposited within Beaver Reservoir since impoundment have not been conducted. Recently, the United States Environmental Protection Agency approved a three-year study to compare sediment loading in three coves of Beaver Reservoir (Fig. 1). The focus of this research is to relate sediment loading within each cove to specific changes that have occurred within each watershed during the last 40 years.

The following proposal is intended to supplement the EPA-supported research on sediment loading in three coves of Beaver Reservoir by providing funding to enable detailed characterization of sediment chemistry at the three study sites (Fig. 1).

Who Benefits from this Study?

Water quality issues in northwest Arkansas are at the forefront of environmental concerns. The northwest Arkansas Metropolitan Statistical Area (NWMSA) is among the most rapidly developing in the United States (Rogers-Lowell Chamber of Commerce, 2005). From 1990 to 2000, population within the NWMSA increased 47.5%, with Benton County growing 57.3% and Washington County growing 39.1%. Population during the next 5 years is projected to increase 18% within the NWMSA (21% in Benton County, 15% in Washington County) compared to 4% growth statewide. Approximately 440,000 people live within a 40-km radius of the NWMSA and 5-year growth within these outlying areas is projected to be nearly 40%.

Associated with explosive population growth are widespread landscape alteration and land use changes with dramatic potential impacts on available water resources. The NWMSA is served primarily by a single surface water reservoir (Beaver Reservoir) that is managed by the United States Army Corps of Engineers for multiple uses including public drinking water supplies, recreation, hydropower generation, and flood control. A recent conference concluded that Beaver Reservoir was the most critical regional asset developed during the 20th Century, and that creation of the reservoir in the 1960's was the

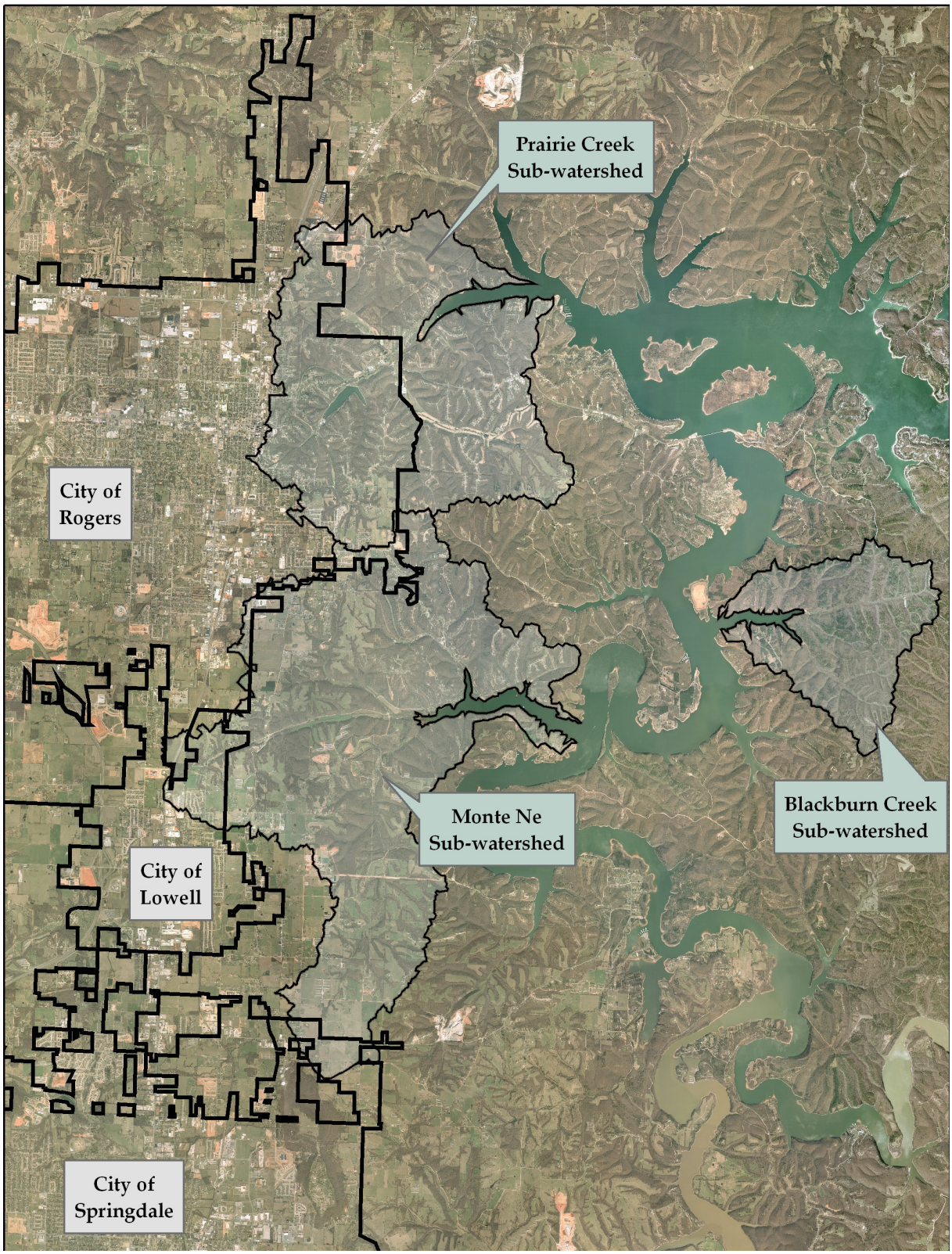

Fig. 1. Annotated aerial photograph of proposed study sites (Monte Ne, Prairie Creek, Blackburn Creek) showing extents of watersheds (highlighted), and incorporated limits of Rogers, Lowell, Springdale, Arkansas (bold black lines). Note relation of study sites to Beaver Reservoir.

principal component of the region's economic success (Arkansas Democrat-Gazette, 2004). As such, the importance of maintaining the environmental integrity of Beaver Reservoir and its watershed was underscored as critical to maintaining the region's economic viability.

Why Conduct This Study?

In recent years, impacts to the quality of water from Beaver Reservoir resulting from rapid area development have been recognized. Degradation of water quality due to nutrient loading (agricultural, septic, and suburban sources) and sediment loading (non-point sources), contamination from urban and storm-water runoff (point and non-point sources), and pollution due to lakeshore residential development (point-source) and recreational boating (non-point source) are of paramount concern. Ongoing watershed-scale research efforts are addressing urban and storm-water runoff (REFS?), lakeshore residential development (Beaver Water District, 2005), and nutrient loading (Chaubey et al., 2005; Dennis et al., 2002).

Rapid population growth and ongoing urbanization of NWMSA during the last 40 years undoubtedly increased sedimentation pressure on Beaver Reservoir. Well-known impacts of urbanization include increased impervious area runoff, increased peak storm flow, and high sediment flux from construction sites. Less understood impacts include hydrologic modification of stream channels, rural unpaved road runoff, and sediment discharges from expanded drinking water treatment activities.

For example, sediment accumulation in Monte Ne Cove (Fig. 1) has been the focus of intense public scrutiny due to possible impacts of the periodic back flushing of the water filtration system of the Beaver Water District (the primary local water authority). Local residents claimed that up to 3 m of sediment in the cove resulted from BWD discharges and that the sediment threatened submerged cultural resources of the cove (remains of the utopian settlement of Monte Ne; Nichols, 1958), ecosystem health of the cove (ADEQ, 2005; Price, 2004), aesthetic quality of the cove, and value of private property along the lake shore. However, a portion of the sub-watershed surrounding Monte Ne Cove is located within the urban boundaries of Lowell, Arkansas and the entire sub-watershed has experienced rapid development. A preliminary watershed model (GeoWEPP; Renschler, 2003) indicated sediment yield from the urbanized portion of the watershed was 10- to 16-times greater than that from the sub-watershed receiving discharge from the drinking water treatment facility (Patton and Boss, 2005). The proposed study will attempt to better determine sediment sources to Monte Ne Cove through chemical fingerprinting of sediment throughout the watershed.

Elliot et al. (1990) documented a variety of heavy metals in drinking water treatment sludge that originated from impurities found in the flocculating agent. These metals included Al, Cd, Cu, Cr, Ni, Pb, and Zn. According to the ADEQ NPDES searchable database, there are more than 60 drinking water treatment plants in Arkansas using treatment processes and flocculating agents similar to those of BWD. All also discharge resulting sludge to local water bodies. Little is known about the ultimate fate of these constituents.

The Arkansas Department of Environmental Quality (ADEQ) completed two studies related to the deposition of sediment in Monte Ne Cove. Price (2004) reported results of analyses of two water samples, six sediment samples, and multiple benthic samples across three transects in Monte Ne Cove during March 2004. ADEQ (2005) reported concentrations of 24 trace elements in thirty sediment samples. In these two studies, elevated levels of Al, As, Cd, Cr, Cu, Mn, and Ni were found when compared to levels in other Beaver Lake coves. Many of these

trace elements were above background levels for Arkansas soils and in one sample, As exceeded the EPA Consensus Based Probable Effect Concentration (USEPA, 2002b), while multiple samples of Cd, Cr, and Ni exceeded the EPA Consensus Based Threshold Effect Concentration (USEPA, 2002b). The first study also indicated possible sediment toxicity to benthic fauna in Monte Ne Cove.

Ongoing development pressure along the shores of Beaver Lake is intense. At the Prairie Creek area (Fig. 1), new controversy has arisen regarding plans to construct a number of high-rise, high occupant condominiums (Askins, 2005a and b). Proposed coring and chemical characterization of sediment in Prairie Creek Cove will provide baseline data against which sedimentation and sediment chemical changes resulting from these developments might be compared, or which might be used to inform long-term management plans.

Sedimentation in Monte Ne and Prairie Creek coves will be compared to natural background sedimentation as determined from analyses of cores to be collected from Blackburn Creek Cove. Blackburn Creek Cove lies at the mouth of a nearly pristine, forested watershed protected by the Hobbs Wildlife Management Area during the last 40 years. As such, it is hypothesized that sediment accumulating in this cove will reflect watershed processes in a relatively undisturbed setting.

Detailed, systematic characterization of sediment chemistry from various locations of Beaver Reservoir will determine whether or not specific watershed-scale activities yield distinctive chemical signatures that are preserved in lacustrine sediments (Van Meter et al., 2001; Ging et al., 1999; Van Metre, 1999; Van Metre and Mahler, 1997; Van Metre et al., 1996), help provide an assessment of impacts of sediment chemistry on water quality (Dennis et al., 2002; Van Metre and Mahler, 1999), and help describe impacts of sediment contaminants on aquatic biota (Price, 2004; Van Meter et al., 2003; Van Metre and Mahler, 1999). In addition, detailed chemical characterization of cores will aid in development of contaminant mass balances and contaminant flux models. Results of these models, combined with ongoing efforts to develop watershed-scale process models (e.g. Chaubey et al, 2005; Haggard and Green, 2002), will provide regional planning authorities and decision makers with insights and a scientific basis to develop long-term, sustainable management plans for the Beaver Reservoir watershed.

15. Statement of Results or Benefits:

The proposed research directly benefits an ongoing sedimentation study funded by the U.S. Environmental Protection Agency focused on understanding the correspondence of land use changes to sediment yield through comparative analysis of sedimentation in three coves of Beaver Reservoir. Blackburn Creek Cove is a nearly pristine sub-watershed draining the Hobbs Wildlife Management Area within the Ozark National Forest and serves as a control site to estimate background sedimentation to Beaver Reservoir from sub-watersheds.

As previously mentioned, Monte Ne Cove has been the site of local controversy over sedimentation effects due to discharge of effluent from drinking water treatment. Controversy over effluent from drinking water treatment facilities is of national interest (Hudson, 2002a and b; Radanovich, 2002). Characterization of sediment chemistry from cores at Monte Ne Cove will aid is assessing toxicity of water treatment effluents during the last 40 years, and may help discriminate sediment sources within the watershed.

At Prairie Creek Cove, interest in sedimentation and other potential pollution sources recently peaked when real estate developers announced plans to construct high-rise, high-occupancy condominiums near the lake shore (Askins, 2005a and b; Beaver Water District, 2005a). Sediment chemical data acquired for this study will provide needed baseline information on sediment contaminants and the basis for development of long-term environmental monitoring and watershed protection programs (Beaver Water District, 2005b; Arkansas Democrat-Gazette, 2005; Askins, 2005c).

A direct benefit of the project will be a better understanding of the fate of chemical constituents found in drinking water sludge and other sediment deposited in Beaver Lake. A better understanding of the fate of these potentially toxic elements and their processing in natural aquatic systems can lead to better regulatory guidance.

16. Nature, Scope, and Objectives of the Project, Including a Timeline of Activities.

Nature

The nature of this project is a geochemical characterization of sediment cores in Beaver Reservoir to estimate 1) the mass of major and trace elements contained in the sediments from three coves, 2) mass accumulation rates for major and trace elements, 3) estimates of mass balances of chemical constituents, 4) chemical tracer studies to aid in determining sediment flux related to various watershed activities.

Scope

Three coves will be studied (Fig. 1). Each of these coves is of similar dimensions and is at the mouth of similarly-sized watersheds. Underlying geology of these watersheds is identical (Dowell et al., in press; Dowell, 2004; Sullivan and Boss, 2002), being dominated by limestone mantled with discontinuous regolith and some outcrops of shale (Chattanooga Shale) along the lake shores. Sediment cores up to 2 m in length will be acquired using simple gravity coring methods. Cores will be deployed from R/V *Ozark Traveler*, an 8-m pontoon boat used for limnological research. Three cores will be obtained from each cove. Each core will be sliced in half at the University of Arkansas, and one half will be logged and described visually. The other half will be sampled at 0.2 m intervals or where distinctive sedimentological discontinuities are observed. These sediment samples will be processed as described below for chemical analyses.

Objectives

The objectives of the proposed study are:

1. Characterize major and trace element chemistry of sediment deposited in three coves of Beaver Reservoir, northwest Arkansas. Two coves are at the terminus of watersheds where different land use changes have occurred since impoundment of Beaver Reservoir 40 years ago. One cove is at the terminus of a relatively pristine watershed protected by the Hobbs Wildlife Management Area and serves as a control site documenting natural background sedimentation in Beaver Reservoir;
2. From chemical analyses of sediments, estimate the masses of major and trace elements in each core and attempt to determine major or trace element signatures related to urbanization, industrialization, or sub-urbanization within each watershed;
3. From estimated masses of major and trace elements, estimate mass fluxes within the watershed based on known lake age, watershed area, and sediment volume within each cove;

4. Use patterns of chemical constituents in cores to elucidate watershed-scale chemical signatures that may be related to specific land use changes over time.

Timeline

Project Task	J	F	M	A	M	J	J	A	S	O	N	D
Prepare for field coring operations			■	■								
Field coring operations					■	■						
Core descriptions, sample preparation						■	■	■	■	■		
Sample analyses						■	■	■	■	■		
Data synthesis	■	■									■	■
Report results of research		■										

17. Methods, Procedures, and Facilities.

Methods

Sediment coring will use a 0.05 m diameter aluminum piston corer with an internal polycarbonate sleeve. The corer will be driven by gravity into the sediments until refusal. Three cores will be taken from each cove for a total of nine cores. Upon removal of the piston core from the sediments, the inner polycarbonate sleeve containing the intact sediment cores will be removed. Upon return to the lab, each core will be processed and sampled at 0.2 m intervals. Assuming cores up to 2 m long, there will be a total of approximately 90 sediment samples to be analyzed. These samples will be processed and digested in the lab using nitric acid and the resulting samples will be cataloged and sent to the AWRC Water Quality Laboratory for metals analysis.

Each sample will be processed in a five stage sequential extraction technique developed by Tessier (1979) and later modified by Chao and Jhou (1983) with an alternative total extraction (Anderson et al., 1991). The sequential extraction has five steps:

1. Exchangeable fraction (TF1) – agitate 1 g of sediment at room temperature for 1 hour with 8 ml of 1M NaOAc (sodium acetate) at pH = 8.2
2. 2) Carbonate fraction (TF2) – solid residue from TF1 agitated for 4 hours with 8 ml of 1M NaOAc to pH 5.
3. 3) Amorphous Fe + Mn oxides fraction (using Chao reagent) (TF3) – solid residue from TF2 is added to 20ml of M NH2-OH-HCl (hydroxylamine hydrochloride) in 0.25M HCl. Heat to 50°C for 30 minutes.
4. 4) Organic fraction (TF4) – solid residue from TF3 is added to 3 ml of 0.02M HNO3 and 5 ml of 30%H2O2 to pH 2 and heated to 85°C for 2 hours. Then another 3 ml of 30% H2O2 is added and then heated to 85°C for 3 hours.
5. 5) Total extraction – solid residue from TF4 is added to 7.5 ml of 7M HNO3 for 2.5 hours on a water bath at 70°C for 30 minutes, then heated to 100°C for 2 hours.

After each extraction step, the suspensions are centrifuged at 4000 rpm for 30 minutes. The supernatant is decanted into 50 ml collecting centrifuge tube and 8 ml of DI water is added to the extraction tubes. The extraction tube is centrifuged at 4000 rpm for 30 more minutes and the resulting supernatant decanted into the previous collecting centrifuge tube. It is then filtered using a 0.45 µm syringe filter into a 50 ml centrifuge tube and diluted up to the 50 ml mark on

the centrifuge tube using DI water. The centrifuge tube is preserved by freezing for trace element analysis and the next extraction step will start with the same extraction tube.

Facilities

Facilities available for this project include the Arkansas Water Resources Center (AWRC) Water Quality Laboratory (an EPA-certified analytical laboratory at the University of Arkansas) and a sedimentological laboratory at the University of Arkansas Biomass Center (Dale Bumpers College of Agriculture). Some raw sediment samples and processed samples may be sent to other facilities (e.g. environmental chemistry laboratory at New Mexico State University) for specialized chemical assays. The AWRC Water Quality Laboratory is the only lab in Arkansas that is accredited under the new EPA NELAC standards.

18. Related research.

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Dowell, J.C., Hutchinson, C., and Boss, S.K., in press, Revised bedrock geologic map of Rogers quadrangle, Benton County, Arkansas: Journal of the Arkansas Academy of Sciences, v.59.
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Haggard, B.E. and Green, W.R., 2002, Simulation of hydrodynamics, temperature, and dissolved oxygen in Beaver Lake, Arkansas, 1994-1995: United States Geological Survey Water-Resources Investigations Report 02-4116, 28p.
Hudson, A., 2002a, Sludge dumping proceeds despite review: The Washington Times, 23 March 2002, http://www.radanovich.house.gov/press/2002/Mar02/032302sludgedumping.htm, accessed 11/10/2005.
Hudson, A., 2002b, EPA says toxic sludge is good for fish: The Washington Times, 19 June 2002, http://www.radanovich.house.gov/press/2002/newsclips/june02/061902SludgeisgoodWT.htm, accessed 11/10/2005.
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Van Metre, P., 1999, Chemical quality of sediment cores from the Laguna Madre, Laguna Atascosa and Arroyo Colorado, Texas: Texas Natural Resource Conservation Commission and United States Geological Survey, 4p.
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Van Metre, P. and Mahler, B.J., 1999, Town Lake bottom sediments : a chronicle of water quality changes in Austin, Texas, 1960-98: United States Geological Survey, Fact Sheet FS-99-183, 8p.
Van Metre, P. and Mahler, B.J., 1997, Water-quality trends in the Rio Grande/Río Bravo Basin using sediment cores from reservoirs: United States Geological Survey, Fact Sheet FS-96-221, 8p.

19. Training Potential.

The proposed research will augment doctoral dissertation research of one doctoral student in the Environmental Dynamics Program at the University of Arkansas who is currently supported (stipend + tuition) by a U.S. EPA Greater Research Opportunities Doctoral Fellowship. Requested funding will be the primary source of funds for sediment chemical analyses.

20. Investigator's Qualifications. Stephen K. Boss, Ph.D., P.G.

Present Position:

Director, Environmental Dynamics Program, U. of Arkansas, Fayetteville, AR 72701
Associate Professor, Dept. of Geosciences, University of Arkansas, Fayetteville, AR 72701.

Education:

University of North Carolina, Chapel Hill, NC, Ph. D., Marine Sciences	1994
Utah State University, Logan, UT, M.S., Geology	1985
Bemidji State University, Bemidji, MN, B.S., *Magna Cum Laude*, Geology	1981

Relevant Grants in Support of Research:

2005: United States Geological Survey: "Sediment Characterization in Three Coves - Beaver Reservoir, Arkansas" (Principal Investigator) $18,366 (pending – this proposal)

2005: Fulbright College of Arts & Sciences, U. of Arkansas: "An Historic and Bathymetric Study of Lake Sequoyah, Washington County, Arkansas" (Principal Investigator) $10,662

2005: Environmental Protection Agency Greater Research Opportunities Program: "Influences of Water Treatment and Development on Reservoir Sedimentation, Northwest Arkansas:" (Principal Investigator with Mr. Jason Patton, ENDY program) $111,000

2004: Lake Fayetteville Watershed Partnership: "Bathymetry, Sedimentation History, Sediment & Water Chemistry of Lake Fayetteville, Fayetteville, Arkansas" (Principal Investigator with Dr. M.A. Nelson, Arkansas Water Resources Center) $8,421

2003: Beaver Water District: "Upper Beaver Reservoir Bathymetry and Sedimentation Survey" (Principal Investigator) $75,994

2000: Fort Smith Utilities Department, Fort Smith, Arkansas: "Comparative Limnology of Lake Shepherd Springs and Lee Creek Reservoir, Northwest Arkansas" (Principal Investigator) $72,361

1999: City of Alma, Arkansas: "Bathymetry and Sediment Thickness of Alma Reservoir" (Principal Investigator, cooperative research with McClelland Engineering, Inc., Fayetteville, AR) $4,074

1999: Fort Smith Utilities Department, Fort Smith Arkansas: "Bathymetry and Sediment Thickness of Lake Fort Smith, Arkansas" (Principal Investigator) $5,564

Research Related Experience:

Chief Scientist or co-Chief Scientist on 41 oceanographic or limnologic expeditions since 1990; supervised doctoral dissertations and master's thesis projects of 19 students since joining faculty of UA in 1996.

Pertinent Publications:

1. Boss, 2005, Side-scan sonar mapping of upper Beaver Reservoir: Phase II Final Report: Final report of Phase II to Beaver Water District, October 2005, 99p.
2. Boss, S.K., 2004, Bathymetry and sediment thickness of Beaver Lake, northwest Arkansas: Final Report of Phase I to Beaver Water District, May 2004, 33p.
3. Brown, B.J., and Boss, S.K., in press, Bathymetry and sedimentation patterns of Lake Fort Smith, Crawford County, Arkansas: submitted to *The Compass of Sigma Gamma Epsilon*.
4. Hansen, J.T. and Boss, S.K., in press, Empirical modeling of lacustrine sedimentation in the Prairie Creek sub-basin of Beaver Reservoir, northwest Arkansas: submitted to *The Compass of Sigma Gamma Epsilon*.

5. Odhiambo, B.K., and Boss, S.K., in review, Watershed physiography, land use, and sediment yield: A case study from northwest Arkansas, USA: submitted to *Geological Society of America Bulletin*.
6. Odhiambo, B.K., and Boss, S.K., 2004, Integrated echo sounder, GIS and GPS for sedimentation studies in reservoirs: Examples from two Arkansas lakes: submitted to *Journal of the American Water Resources Association*, v.40, p.971-997
7. Polly, A.M. and Boss, S.K., 2003, Acoustic mapping of sediment and aquatic vegetation in lakes: An example from northwest Arkansas: *Journal of Arkansas Academy of Sciences*, v.57, p.221-225.
8. Boss, S.K., and Odhiambo, B.K., 2000, Bathymetric survey data for Lee Creek Reservoir, Arkansas: Written report and CD-ROM prepared for City of Fort Smith Utilities Department, August 2000, 22p.
9. Boss, S.K., and Odhiambo, B.K., 2000, Bathymetric survey data for Lake Shepherd Springs, Arkansas: Written report and CD-ROM prepared for City of Fort Smith Utilities Department, August 2000, 30p.
10. Boss, S.K., Polly, A.M., 2000, Bathymetric survey data for Lake Wedington, Arkansas: Written report and CD-ROM prepared for U.S. Forest Service, Ozark National Forest, August 2000, 75p.
11. Boss, S.K. and Brown, B.J., 1999, Bathymetric survey data for Lake Fort Smith, Arkansas: Written report and CD-ROM prepared for City of Fort Smith Utilities Department, August 1999, 68p.
12. Boss, S.K. and Brown, B.J., 1999, Bathymetric survey data for Lake Alma, Crawford County, Arkansas: Technical report prepared for McClelland Engineering, Inc. and City of Alma Water Department, July 1999, 10p.

Academic recognition (most recent 5 years):

2005: Selected by Vice-Provost for Research and Dean of Graduate School to attend NSF-sponsored workshop on Research Ethics at Indiana University, 12-14 May 2005.

2004: Named “Integrated Scholar” by Provost Robert Smith, University of Arkansas, Fayetteville, AR.

2004: NASA Opportunities for Visionary Academics Program designates Earth System Science Course “Exemplary”.

2003: Appointed to Technical Review Panel, Lindbergh Foundation, Anoka, MN

2003: Museum of Science, Boston, MA featured research on Red River of the North in an exhibit describing innovative applications of the Global Positioning System (GPS).

2002: Appointed Director, Environmental Dynamics Program (interdisciplinary doctoral program), University of Arkansas, Fayetteville, Arkansas.

2002: Promoted to Associate Professor, Department of Geosciences, University of Arkansas, Fayetteville.

2001: Appointed Associate Editor, Journal of Geoscience Education, official journal of the National Association of Geoscience Teachers (3-year appointment).

2001: Appointed to Committee on Environmental Information for Naval Use, Ocean Studies Board, National Research Council, National Academies of Science, Washington, DC. Committee task is to develop comprehensive report assessing needs of U.S. Navy for environmental data collection and dissemination through 2010.

2000: Preliminary nomination for the Webby Award (“The Oscars of the Internet”) for Best Education Web Site from the International Academy of Digital Arts & Sciences.

BRIAN E. HAGGARD, Ph.D.

203 Engineering Hall
University of Arkansas
Fayetteville, AR 72701
E-Mail: haggard@uark.edu

Office: 479.575.2879
Fax: 479.575.2846
Cell: 479.790.7097

Educational Background:

Degree	Date	University	Major
B.S.	1994	University of Missouri - Rolla	Life Sciences
M.S.	1997	University of Arkansas	Environmental Soil and Water Science
Ph.D.	2000	Oklahoma State University	Biosystems Engineering

Professional Experience:

2000–2000 Hydrologist, GS-9, U.S. Geological Survey, Tulsa, Oklahoma
2000–2001 Hydrologist, GS-11, U.S. Geological Survey, Tulsa, Oklahoma
2001–2004 Research Hydrologist, GS-12, USDA–ARS Poultry Production and Product Safety Research Unit, Fayetteville, Arkansas
2005–Present Research Hydrologist, GS-13, USDA–ARS Poultry Production and Product Safety Research Unit, Fayetteville, Arkansas

2001–Present Adjunct Assistant Professor, Biological and Agricultural Engineering Department, University of Arkansas, Fayetteville, Arkansas
2003–2005 Associate Editor, Soil and Water Division, Applied Engineering in Agriculture & Transactions of the American Society of Agricultural and Biological Engineers

Honors and Awards:

Gentry Land and Water Resources Scholarship, University of Arkansas 1995
USDA National Needs Water Sciences Fellowship, Oklahoma State University 1997–1999
Williams Outstanding Thesis Award, College of Agriculture, Oklahoma State University 2000
USDA–ARS Outstanding Performance 2001, 2002, 2003, & 2004
American Society of Agricultural and Biological Engineers, Outstanding Reviewer 2003
American Society of Agricultural and Biological Engineers, Honorable Mention Paper Award 2005
USDA–ARS Southern Plains Area, Early Career Research Scientist 2005

Past Research Accomplishments and On-Going Projects:

- Evaluated the influence of external nutrient sources, transient storage, and hydrology on stream nutrient transport and retention in the highly publicized Eucha–Spavinaw Basin and other catchments in Northwest Arkansas and Northeast Oklahoma.

- Evaluated catchment–scale sources of phosphorus and mechanisms of phosphorus transport within the highly publicized Illinois River Drainage Area in Northwest Arkansas, tracing the elevated phosphorus concentrations at the Illinois River to one municipal wastewater treatment plant effluent discharge almost 47 km upstream.

- Evaluated the influence of a small impoundment on phosphorus concentrations and transport at the Illinois River; demonstrated that bottom sediments in the impoundment are phosphorus laden and could release substantial amounts back into the water column.

- Systematically quantified sediment phosphorus sorption and sediment–aqueous phase phosphorus equilibrium in streams draining catchments across multiple ecoregions;

demonstrated the effect of aluminum sulfate and calcium carbonate treatment on reducing dissolved phosphorus concentrations when in equilibrium with the solid phase.

- Quantified sediment phosphorus release rates in Lake Eucha, Oklahoma and Beaver Lake, Arkansas, showing the importance of internal phosphorus sources relative to external catchment sources; demonstrated the effect of aluminum sulfate on reducing phosphorus release from reservoir bottom sediments under aerobic and anaerobic conditions.

- Maintained productive collaborations with hydrologists from the US Geological Survey and has used extensive regional databases of the US Geological Survey National Water Information Systems (NWIS) to evaluate water–quality trends and estimate nutrient load in select streams across Northwest Arkansas.

Short List of Publications:

Haggard, B.E., Stanley, E.H., and Hyler, R. 1999. Sediment-phosphorus relationships in three north central Oklahoma streams. Transactions of American Society of Agricultural Engineers 42(6): 1709-1714.

Green, W.R. and Haggard, B.E. 2001. Phosphorus and nitrogen concentrations and loads at Illinois River South of Siloam Springs, Arkansas, 1997-1999: U.S. Geological Survey Water-Resources Investigations Report 01-4217. 12 pp.

Haggard, B.E., Storm, D.E., Tejral, R.D., Popova, Y.A., Keyworth, V.G., and Stanley, E.H. 2001. Stream nutrient retention in three northeastern Oklahoma agricultural catchments. Transactions of the American Society of Agricultural Engineers 44(3):597-605.

Haggard, B.E., Storm, D.E., and Stanley, E.H. 2001. Effect of a point source input on stream nutrient retention. Journal of American Water Resources Association 37:1291-1299.

Haggard, B.E. and Green, W.R. 2002. Simulation of hydrodynamics, temperature and dissolved oxygen in Beaver Lake, Arkansas, 1994-1995: U.S. Geological Survey Water-Resources Investigations Report 02-4116. 21 pp.

Haggard, B.E., Moore, Jr. P.A., Chaubey, I., and Stanley, E.H. 2003. Nitrogen and phosphorus concentrations and export in an Ozark Plateaus catchment in the United States. Biosystems Engineering 86(1):75-85.

Haggard, B.E., Soerens, T.S., Green, W.R., and Richards, R.P. 2003. Using regression methods to estimating stream phosphorus loads at the Illinois River, Arkansas. Applied Engineering in Agriculture 19(2):187-194.

Haggard, B.E., Ekka, S.A., Matlock, M.D., and Chaubey, I. 2004. Phosphate equilibrium between stream sediments and water: potential effects of chemical amendments. Transactions of the American Society of Agricultural Engineers 47(4):1113-1118.

White, K.L., Haggard, B.E., and Chaubey, I. 2004. Water quality at the Buffalo National River, 1991-2001. Transactions of the American Society of Agricultural Engineers 47(2):407-417.

Haggard, B.E., Moore, P.A. Jr., and P.B. DeLaune. 2005. Phosphorus flux from reservoir bottom sediments in Lake Eucha, Oklahoma. Journal of Environmental Quality 34:724-728.

Haggard, B.E., and Soerens, T.S. 2005. Potential influence of a small impoundment on phosphorus concentrations and transport at the Illinois River, Arkansas and Oklahoma, USA. Ecological Engineering *In Review*.

Haggard, B.E., Stanley, E.H., and Storm, D.E. 2005.Nutrient retention in a point source enriched stream. Journal of the North American Benthological Society 24:29-47.

Sen, S., Haggard, B.E., Chaubey I., Brye, K.R., Costello, T.A., and Matlock, M.D. 2005. Sediment phosphorus release at Beaver Reservoir, Northwest Arkansas, 2002-3. Transactions of the American Society of Agricultural and Biological Engineers *In Review*.

Vadas, P.A., Haggard, B.E., and Gburek, W.J.. 2005. Predicting dissolved phosphorus in runoff from manured field–plots. Journal of Environmental Quality 34:1347-1353.