Proceedings of

The Fourteenth Annual Tennessee Water Resources Symposium

March 31 - April 2, 2004

Proceedings from the

Fourteenth Tennessee Water Resources Symposium

Montgomery Bell State Park
Burns, Tennessee

March 31-April 2, 2004

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Tennessee Section of the American Water Resources Association

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PREFACE

Since the first symposium sponsored by the Tennessee Section of the American Water Resources Association (TN AWRA) was held in Nashville in 1988, the TN AWRA continues to provide a forum for water-resource managers, Federal, State, and local government agencies, and other officials, educators, researchers, and students involved in water resources to exchange ideas and to share innovations. This year's Fourteenth Tennessee Water Resources Symposium consisted of over 60 presentations and about 20 posters.

This Fourteenth Tennessee Water Resources Symposium would not have been possible without the efforts of the planning committee as well as the many sponsors, exhibitors, session moderators, speakers, poster presenters, and attendees who participated in and contributed to its success. As the Symposium Chair, I especially thank Tom Allen, Ernie Bazen, Lori Crabtree, David Duhl, George Garden, Randy Gentry, Jack Gordon, Rebecca Hallman, Kelie Hammond, Tommy Haskins, Susan Jacks, Rodney Knight, Larry Lewis, John Ricketts, Aaron Routhe, Brian Waldron, Sherry Wang, and Michael Woodside who, as members of the planning committee, developed the agenda, solicited and encouraged abstracts, and helped organize the symposium. I also thank Amy Knox who was chiefly responsible for compiling this year's symposium proceedings. On behalf of the TN AWRA officers, I also appreciate the support of the many other organizations that encouraged their members to participate in the symposium planning meetings and to attend this Fourteenth Tennessee Water Resources Symposium.

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1:30 – 3:00 p.m.
Wednesday, March 31

Keynote Address by **George William Sherk, D.Sc., J.D.,** author of *Dividing the Waters: The Resolution of Interstate Water Conflicts in the United States*

12:30 – 1:30 p.m.
Thursday, April 1

Luncheon presentation by Kim Trevathan, author of *Paddling the Tennessee River: A Voyage on Easy Water*

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AUGMENTING MONITORING STRATEGIES WITH VOLUNTEERS

SESSION 1B

WATER QUALITY ASSESSMENTS, #1

SESSION 1C

UNDERSTANDING WATER SUPPLY RESOURCES

SESSION 2A

ECOLOGICAL ASSESSMENT AND RISK

EXAMINING POLLUTANT EFFECTS

REMEDIATION TECHNIQUES FOR POLLUTED WATERS

EDUCATING WATER RESEARCHERS AND PROFESSIONALS

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MODELING WATER SYSTEMS

ASSESSING URBAN WATERSHEDS, #1

ASSESSING URBAN WATERSHEDS, #2

SESSION 2C

DECISION-MAKING TOOLS FOR WATER MANAGEMENT

STRATEGIES FOR ENHANCING WATER QUALITY

TECHNIQUES FOR FACILITATING MEANINGFUL CULTURAL CHANGE

SAMPLING AND DETECTING CONTAMINANTS

SESSION 3A

GROUNDWATER: CONTAMINATION AND RECHARGE ISSUES, #1

GROUNDWATER: CONTAMINATION AND RECHARGE ISSUES, #2

SESSION 3B

UNDERSTANDING SEDIMENT DYNAMICS

CONTAMINANTS IN WATER QUALITY

SESSION 3C

WATER POLICY: RECENT INITIATIVES AND IMPACTS

LAND USE IMPACTS

POSTERS

SESSION 1A

AUGMENTING MONITORING STRATEGIES WITH VOLUNTEERS
3:30 p.m. – 5:00 p.m.

A Comparative Analysis of Water Quality Monitoring Programs in the Southeast: Lessons for Tennessee
Ruth Anne Hanahan and Caitlin Cottrill

Clean Water Partnerships of Alabama
John Ricketts

Volunteer Visual Assessment of 303(D) Listed Streams: Implications for Resource Managers
John McFadden and Dorene Bolze

A COMPARATIVE ANALYSIS OF WATER QUALITY MONITORING PROGRAMS IN THE SOUTHEAST: LESSONS FOR TENNESSEE

Ruth Anne Hanahan* and Caitlin Cottrill[1]

The upsurge of state volunteer monitoring programs across the nation has been heralded as a way for citizens to turn knowledge into action including empowering them to make informed decisions and involving them in activities that directly protect state waterways. Tennessee does not currently have a statewide volunteer monitoring program, although there has been some preliminary discussion within the state's nonpoint source program to sponsor one. Building on this national movement and state interest, the TN Water Resources Research Center at the University of Tennessee has recently completed a study comparing three southeastern statewide volunteer monitoring programs, including Alabama Water Watch, Kentucky Water Watch and Georgia Adopt-A-Stream. The purpose of this comparative analysis was to examine how these programs have been implemented and learn from their experiences so that we could recommend to Tennessee policy decision makers and other stakeholders possible approaches to establishing such a program here in our state.

In order to provide a more substantive set of recommendations, we were also interested in acquiring information on the perceptions of the general benefits and limitations of volunteer monitoring. To that end, we surveyed volunteer monitors participating in the three state programs as well those in Tennessee who have an interest ("a stake") in expanding volunteer monitoring in the state. It is our hope that this study and its accompanying set of recommendations will advance a productive dialogue among Tennessee stakeholders on the viability of initiating a statewide volunteer monitoring program including actions necessary to make it happen.

[1] Ruth Anne Hanahan, Senior Research Associate and Caitlin Cottrill, Graduate Research Assistant, Tennessee Water Resources Research Center at the University of Tennessee. 311 Conference Center, Knoxville, Tennessee 37996, 865-974-9124, rhanahan@utk.edu.

CLEAN WATER PARTNERSHIPS OF ALABAMA

John Ricketts, P.E.*[1]

In Alabama in the late 1990's there were many programs and efforts aimed at improving water quality. The problem was that many of these programs and efforts were not aware of each other, some were duplicative, and others were in direct conflict with each other. Meanwhile water quality challenges were ever present.

A few brave souls began meeting with the Alabama Department of Environmental Management (ADEM) leaders about developing a program that coordinated not only the state programs, but that of local environmental groups, to really bring about water quality improvements. In addition, EPA was beginning to hold the state accountable for demonstrating water quality improvements for the Section 319 funded projects and the development of river basin management plans were looming on the horizon. Couple these demands with reduced funding, and the ADEM saw some significant limits to water quality efforts in the future.

To address water quality concerns, the coordination would need to be by river basin with direction provided by the local stakeholders. In addition, the river basins would need to be able to learn from each other. Thus, began the development of the Clean Water Partnerships of Alabama.

CLEAN WATER PARTNERSHIP STRUCTURE

The state is divided into eleven river basins or river basin groups (see Figure 1). ADEM provided seed money for a river basin facilitator to be hired to establish a Clean Water Partnership in each of the river basins. Eventually ten Clean Water Partnerships were formed. The Tombigbee and Alabama River Basins were combined to form one Clean Water Partnership.

The pioneering river basin was the Coosa, spearheaded by the Gadsden Water Works and Sewer Board. The preliminary framework for the river basin Clean Water Partnership structure and guiding principles was established by this river basin. The framework had to emphasize the importance of the Partnership being directed by the local stakeholders, while providing opportunity for coordination and collaboration up and down the river basin and between the river basins. The structure chart shown in Figure 2 is the basic format that the Coosa River Basin Clean Water Partnership developed and was used as a model for the other Clean Water Partnerships.

The structure chart was developed with the following thought:

- Realizing that the real work would be accomplished at the local level, each river basin would need to be divided into sections using dams or other logical dividers.

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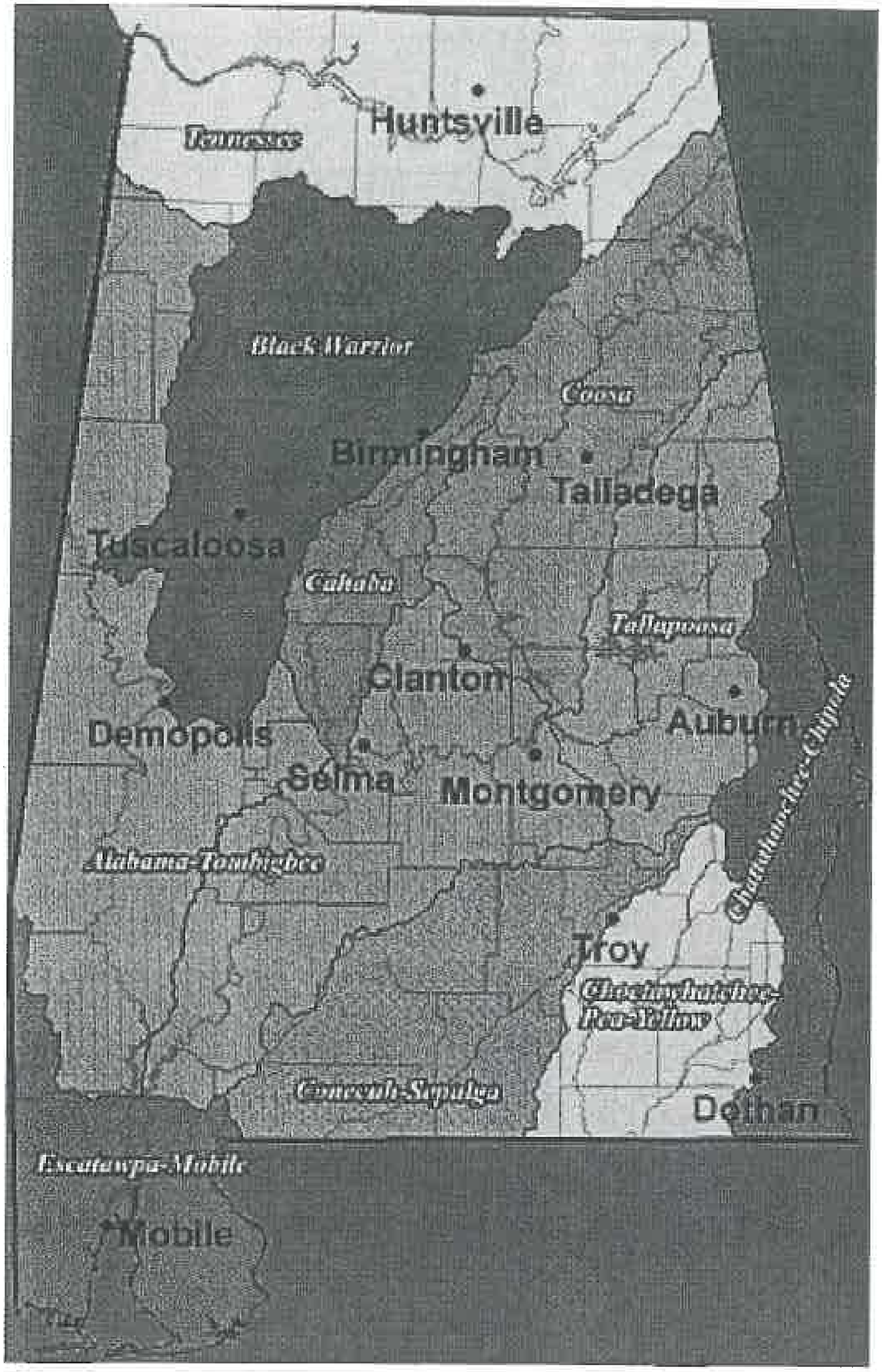
Figure 1
Alabama River Basins



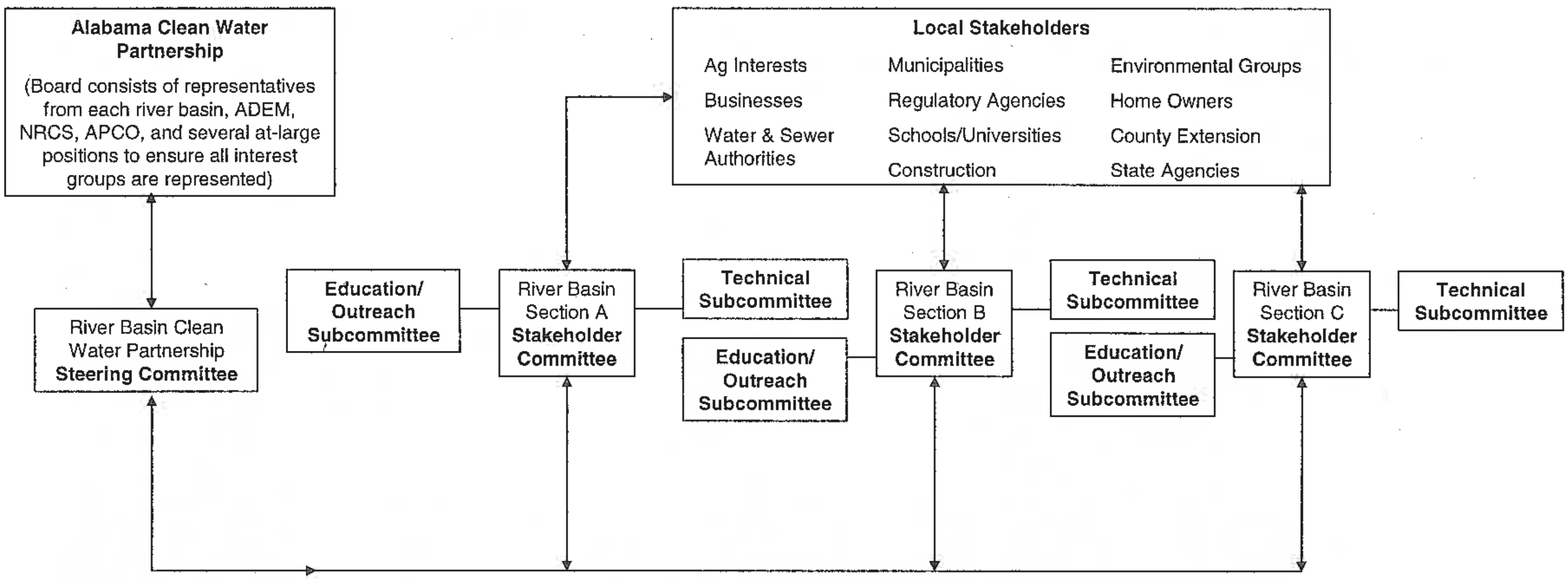


Figure 2 Clean Water Partnerships of Alabama Structure Chart

A Stakeholder Committee for each of these river sections would be established that would be the main action group. Additional groups at the watershed level would be developed as support existed.

- Extensive public education/outreach and sound scientific analysis are critical to the successful execution of any river basin efforts. Therefore, each river section Stakeholder Committee would also try to establish advisory subcommittees, especially an Education/Outreach Subcommittee and Technical Subcommittee.
- The river sections needed a coordinating entity that looked at the river basin as a whole. Therefore, each river section Stakeholder Committee would be shepherded by the River Basin Steering Committee. The Steering Committee would provide direction for the river basin and would consist of stakeholders that had a river basin interest and a representative from each of the river sections.
- With activities within each river basin having an entity to help coordinate and guide it, an entity was needed for the river basins as well. In addition, an entity was needed to receive funds that had been offered, but that were not designated to any specific river basin. The Board of Directors for this entity would be comprised of representatives from each of the river basins, a state regulator, NRCS, and several positions at large to be sure that stakeholder interests are represented.

ACCOMPLISHMENTS

In less than five years the Clean Water Partnership has moved from a concept to a success story. The Clean Water Partnerships are the only statewide organization of its kind in the country and has been promoted by EPA Region 4 as a model. Some of the accomplishments of the Clean Water Partnership are highlighted below:

- Each river basin has established a Clean Water Partnership
- An entity, the Alabama Clean Water Partnership, that could coordinate the river basins and receive funding was established. The Alabama Clean Water Partnership has obtained non-profit 501(c)3 status and has received funding that is distributed to the river basins on a demonstrated needs basis.
- Shortly after the Coosa River Basin was established, the Tallapoosa River Basin Clean Water Partnership was established and came on strong under the support and direction of The Water Works and Sanitary Sewer Board of the City of Montgomery (Board). The Board helped spearhead the following activities:
    - The development and hosting of a website for the Clean Water Partnerships of Alabama
    - The development of a Clean Water Partnerships of Alabama brochure
    - The development of a Clean Water Partnerships of Alabama video
    - The development of a clearinghouse for watershed related data in the Lower Tallapoosa River Basin. The data was summarized and placed on the website in a GIS interactive format to allow stakeholders to review local data across the internet. In addition, ADEM used the data to help develop their 305b Report.

ADEM noted that the data clearinghouse significantly reduced their data gathering efforts. This project was a model for the other rivers sections and river basins. Data templates and procedures were developed and made available to the other river sections and river basins.

Another major accomplishment is that stakeholders that typically did not communicate with each other, now work together under the Clean Water Partnerships' non-regulatory, stakeholder driven process. This alone has led to better understanding of river basin issues and better use of limited resources. Local watershed groups now have an avenue for obtaining much needed technical and financial help. And probably most of all, the Alabama water resources benefit because they are being protected and improved by a coordinated, more effective effort.

Could we benefit from a Clean Water Partnerships of Tennessee?

VOLUNTEER VISUAL ASSESSMENT OF 303(D) LISTED STREAMS: IMPLICATIONS FOR RESOURCE MANAGERS

John McFadden*[1] and Dorene Bolze[2]

The Tennessee Department of Agriculture's Non-Point Source Water Pollution program awarded the Harpeth River Watershed Association (HRWA) a 319 grant in 2001 to conduct a visual stream survey on 303(d) listed streams in the Harpeth River Watershed. Project staff modified existing visual protocols by the EPA, VA, and NRCS to allow for volunteer utilization. The survey identified land use, erosion, riparian zone area, bank stability, canopy cover, invertebrate habitat, sedimentation, water appearance, nutrient enrichment, and channel conditions.

Volunteers surveyed 217 stream sites of which 43 possessed gross conditions likely to be causing water quality degradation. Using a four-point scoring where "1 = poor" and "4 = excellent", over 50% of sites scored poor for riparian zone. The majority of bank stability scores were in the excellent range. Fifty-four sites scored excellent, 39 good, 52 fair, while 65 scored poor for canopy cover. Invertebrate habitat rated excellent at 50% + sites.

One hundred twenty five sites scored excellent, 36 good, 13 fair and 6 scored poor for riffle and pool sedimentation. One hundred thirty-three sites scored excellent for water appearance, while 43 scored good, 13 fair, and three poor. One site scored in the poor range for nutrient enrichment, while 15 scored fair, 50 good, and 118 excellent. Twelve sites were rated in the poor range for channel condition, 31 fair, 68 good, and 98 excellent.

The use of volunteers can make problem identification cost-effective and aid resource managers in meeting 303(d) listed stream restoration requirements. Lastly, volunteer programs can produce knowledgeable citizens around water quality issues.

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Denton, G., Vann, A., & Wang, S. (2000) The Status of Water Quality in Tennessee, 2000 305(b) Report. Tennessee Department of Environment and Conservation, Division of Water Pollution Control.

Harpeth River Watershed Association (2002). Volunteer Site-Specific Visual Stream Assessment of 303(d)/305(b) Listed Streams in the Harpeth River Watershed. Final Report for grant # GR-02-14290-00 from TN Department of Agriculture Nonpoint Source Program (EPA Assistance Agreement Number: C9994363-93-2.)

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2 Executive Director, Harpeth River Watershed Association (www.harpethriver.org), Box 1127 Franklin, TN 37065 dorie@doriebolze.com

SESSION 1B

WATER QUALITY ASSESSMENTS, #1
3:30 p.m. – 5:00 p.m.

Estimating Mean Annual Transport of Nutrients in Middle Tennessee Streams During 1992-2002 Using a Hybrid Statistical and Deterministic Model, SPARROW
Anne B. Hoos

Stream Buffers and Water Quality: Lessons Learned
Beth Chesson

Water Quality Characterization and Statistical Modeling of the MPLPR Great Smoky Mountain National Park
Chad Roby, Bruce Robinson, John Buchanan, Steve Moore, Tom Barnett, and John Shubzda

ESTIMATING MEAN ANNUAL TRANSPORT OF NUTRIENTS IN MIDDLE TENNESSEE STREAMS DURING 1992-2002 USING A HYBRID STATISTICAL AND DETERMINISTIC MODEL, SPARROW

Anne B. Hoos, U.S. Geological Survey[1]*

Water-resource managers increasingly are using water-quality models to estimate instream transport (load and mean concentration) of contaminants. Deterministic water-quality modeling is not feasible for many investigations because of intensive data and calibration requirements. Furthermore, model uncertainty and problems of parameter insensitivity and correlation cannot be rigorously addressed for deterministic models as calibration is typically done without formal parameter-estimation techniques. The SPARROW (SPAtially Referenced Regression On Watershed attributes) watershed model provides a hybrid statistical and deterministic approach: model parameters are estimated by correlating stream water-quality records with generally available GIS data on constituent sources and climatic and hydrogeologic properties that affect constituent transport. The fitted model can be used to estimate relative source contributions from agricultural nonpoint, point, natural, and atmospheric sources. This presentation provides an introduction to SPARROW, illustrates the application of the model to streams in Middle Tennessee to estimate relative source contributions and mean annual instream loads and concentrations for nitrogen and phosphorus for the period 1992-2002, and describes the uncertainty associated with these estimates.

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STREAM BUFFERS AND WATER QUALITY: LESSONS LEARNED

Beth Chesson*[1]

Stream buffers are a required element of Tennessee's NPDES Phase II program. While creating and maintaining stream buffers sounds simple, implementing buffer programs has proven to be complex and cumbersome. Fortunately, many governmental and non-governmental agencies have researched buffer effectiveness, and many municipalities have implemented buffer programs. These agencies include the Center for Watershed Protection, the North Carolina Dept of Environment and Natural Resources, Cary, NC, Nashville, TN, Lenexa, KS, and NRCS. Drawing on this existing database of information, NPDES Phase II municipalities in Tennessee can develop effective and relatively painless stream buffer programs. However, many issues must be considered before implementing buffer programs, including:

1. Determining how to define a stream.
2. Setting buffer widths.
3. Establishing approvable buffer activities.
4. Ensuring the perpetual maintenance requirements.
5. Public education on buffer requirements.

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WATER QUALITY CHARACTERIZATION AND STATISTICAL MODELING OF THE MPLPR GREAT SMOKY MOUNTAIN NATIONAL PARK

Chad Roby[1*], Bruce Robinson, John Buchanan, Steve Moore, Tom Barnett, and John Shubzda

INTRODUCTION

The Middle Prong Little Pigeon River (MPLPR) watershed within the Great Smoky Mountain National Park (GRSM) has an area of 48 square miles with 108 miles of streams. In preparation for scheduled road construction, pre-construction monitoring of the MPLPR is being conducted in order to compare water quality during construction and post-construction to a base line. Monitoring of this watershed offers unique opportunities to study relationships between acid deposition and stream water quality. The GRSM National Park is noted for having some of the highest acid deposition rates of any national park. Acid deposition comprised primarily of sulfuric and nitric acid is believed to play a role in altering aquatic ecosystems in this watershed and in others throughout the park. Acid deposition is believed to be a strong contributor in the degradation of stream water quality during storm events.

To monitor the MPLPR, three water quality-monitoring stations (upstream site, middle site, and downstream site) were installed on the lower three miles of the watershed's main channel. Each site has an YSI sonde that measures 15-minute pH, conductivity, temperature, turbidity, and stage. In order to collect water samples during storm events, each site has an Isco auto-sampler that is triggered based on rise in stage height with the intention of capturing the "first flush," rising limb, and falling limb of the hydrograph. Also, bi-weekly grab samples are collected at each site. In addition to this main focus area, there is multiple monitoring equipment throughout the watershed. A fourth sonde (Ramsey site) is located in a far reach of the watershed and measures 15-minute pH, conductivity, temperature, and stage. To ascertain the precipitation water quality in the watershed, two open site rain collection stations were installed. One contains a sequential precipitation collector and the other a bulk precipitation bucket. A tipping bucket rain gauge is also located at each open site. All samples collected will be analyzed for pH, conductivity, and acid neutralizing capacity using an auto-titrator, major anions and ammonium using an ion chromatograph, and several metals using an inductively coupled plasma spectrometer.

BACKGROUND

The University of Tennessee has been conducting watershed research and monitoring as part of the Long-Term Inventory and Monitoring Program in the GRSM. An intensive monitoring station was installed in the Noland Divide Watershed (NDW) located within the high elevation spruce-fir forest in 1991. The NDW consists of a deposition monitoring station where precipitation, through-fall, and soil solutions are collected, and a stream gauging station where two streamlets are sampled and monitored continuously for pH, conductivity, temperature, and flow. In 1993, an extensive Park-Wide Stream Water Quality Monitoring Program was initiated to include grab samples that would be representative of water quality throughout the entire Park. In 2001, the university received additional funding for water quality monitoring on the West Prong Little Pigeon during tunnel reconstruction activities. In addition to this construction sampling, the University has received funding for several small-scale construction projects and most recently

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received funding to monitor the MPLPR. These projects have helped to set the direction for the MPLPR project. They have shown that base line water quality is good but that there is significant water quality degradation during storm events. As a result, a major focus of this project will be storm event water quality.

EQUIPMENT INSTALLATION AND SET-UP

Installation of equipment on the MPLPR is challenging because it experiences very high velocities during storms that can easily move boulders and logs which can damage or destroy equipment. Every piece of equipment had to be sufficiently anchored to withstand such storm events.

YSI Sonde Installation. There are many methods for installing the YSI sondes (Figure 1) The chosen method should meet the following parameters:

1. Good flow to the sensors
2. Protected from debris
3. Anchored sufficiently to withstand high flow
4. Secure from theft or vandalism
5. Accessible to project personnel
6. Not pose a danger to park visitors

Figure 1. YSI 6920 Sonde (www.ysi.com)

To meet these parameters, the sondes were placed inside of a 4 inch diameter PVC pipe with multiple holes drilled in it to allow for adequate cross-flow while still protecting the sonde from debris. Each of the PVC shields were attached to a fence post driven into the streambed behind a large rock, which further protects the sonde from debris and protects boaters from colliding with the sonde. A chain was also attached to the sonde with a lock with the other end anchored to a large rock.

Isco Auto-Sampler Installation. Although there are multiple methods to trigger auto-samplers, using the stage measured by the sondes was the most practical and cost efficient. Using a SDI-12 (serial digital interface bus) connection, the sondes were connected to a Campbell Scientific CR-10 data-logger. The program used by the data-logger looks at stage height reported by the sonde every 15 minutes. If a preset stage height is exceeded the data-logger sends a pulse to the auto-sampler every 15 minutes for four samples and then every 60 minutes for 20 samples. This method provides an excellent record of water quality throughout the course of a storm event as Figure 2 illustrates. The time and stage height the storm samples were collected can be seen.

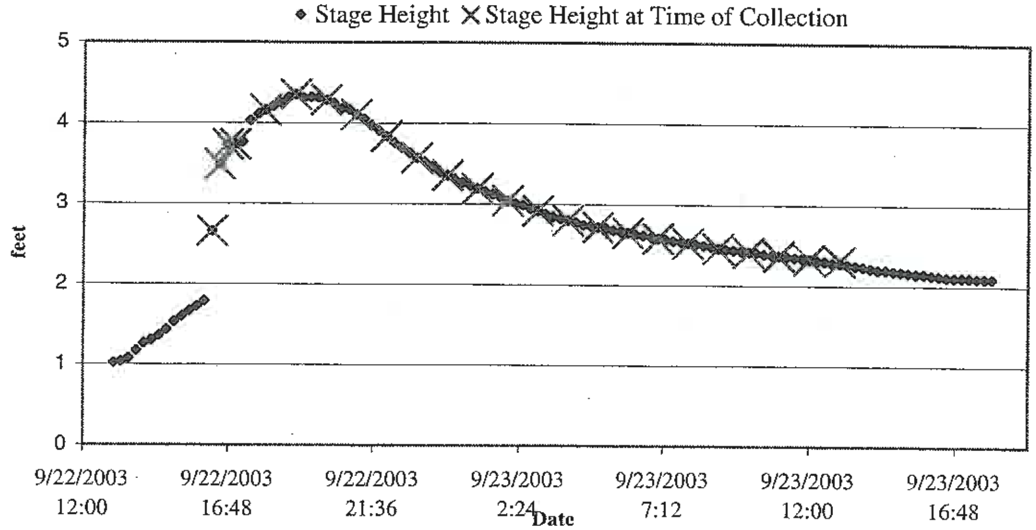

Figure 2. Graph showing auto-sampler samples captured at the middle site.

WATER QUALITY CHACTERIZATION AND STATISTICAL MODELING

Sonde data shows a mean stream pH of 6.46 at the upstream site with up to a 1.5-unit pH drop seen during a storm event (See Table 1 and Figure 3). The Ramsey site, as often seen at higher elevations, has a lower mean pH of 5.69 with pH as low as 3.96 recorded.

Table 1. pH statistics from 8/20/03 to 12/31/03. (*Lab pH).

Sonde or lab pH (Elevation, ft)	Ramsey (2800)	Upstream Site (1700)	Middle Site (1514)	Downstream Site (1370)	Ranger Station Open Site* (1540)	Porters Flat Open Site* (2240)
Mean	5.69	6.42	6.61	6.54	5.08	4.06
Median	5.71	6.46	6.64	6.53	5.06	4.06
Standard Deviation	0.3412	0.1745	0.1948	0.2459	0.3309	0.0901
Range	2.29	2.28	1.82	3.7	0.53	0.13
Minimum	3.96	5.04	5.34	5.07	4.78	3.99
Maximum	6.25	7.32	7.16	8.77	5.31	4.12
Count (n)	13149	8044	9749	10370	4	2

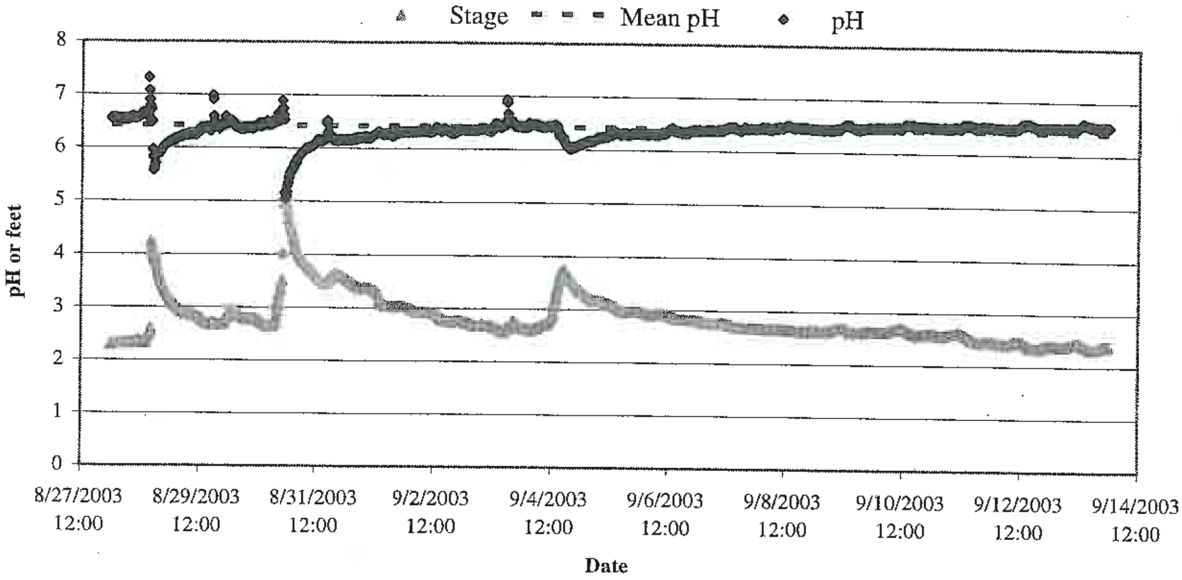

Figure 3. Depressed pH corresponding to increased stage height at upstream site.

Figure 3 shows a strong negative correlation between pH and stage height. The graph shows three stage peaks with corresponding depressed pH at each occurrence. The graph also shows a consistent spike increase in the pH at the beginning of storm events. The spike appears to be associated with the first flush but is not fully understood at present. A linear regression with pH as the dependent variable and stage as the independent variable gives an r-value of -0.881 and an r^2 of 0.776. Using this linear regression, actual pH and predicted pH were graphed together (Figure 4). The predicted pH illustrated the expected trends and followed closely with actual pH though the model has several limitations. It does not predict the extreme lows or unusual pH spikes seen during the first flush. During dry periods a distinct diel cycle is seen that the model fails to predict. Although this model does have its usefulness, it fails to predict several aspects. A more sophisticated model with multiple variables and larger data sets should be developed.

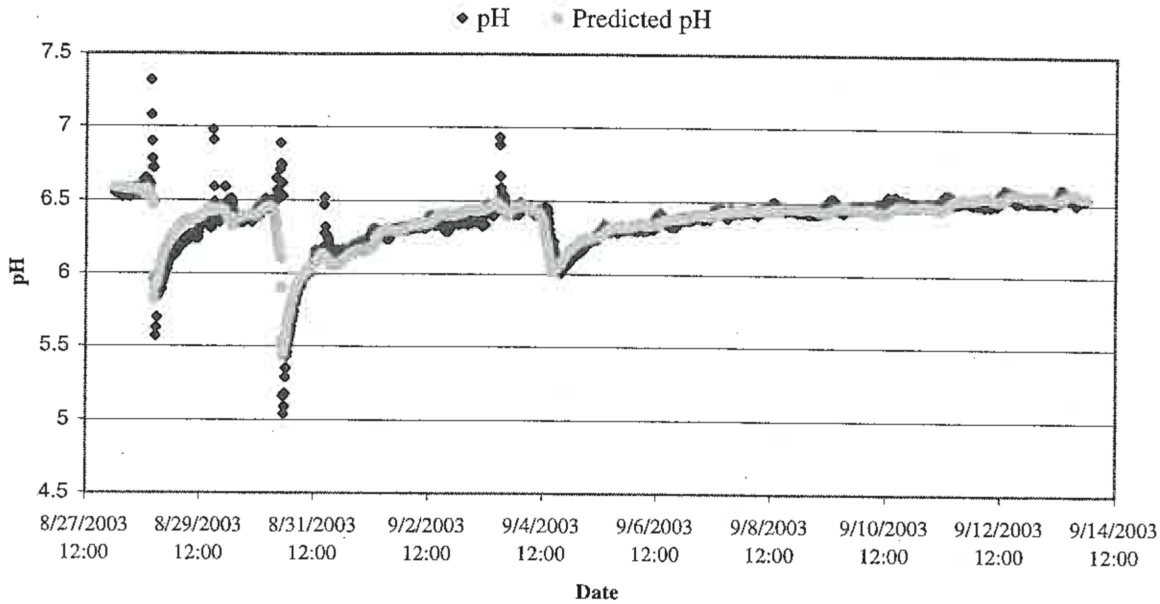

Figure 4. Actual sonde pH and predicted pH at upstream site.

Average overall rain pH in the watershed was 4.57 but varied spatially. The average pH was 5.08 at the ranger station open site and 4.06 at the Porters Flat open site (See Table 1.) The effect of acid deposition has an acute influence on park streams due to the low acid neutralizing capacity (ANC) commonly seen. The middle site had an average base flow ANC of 74.25 μeq/L (3.7 mg/L as $CaCO_3$) with ANC reaching nearly zero during storm events. Other ANC values are summarized in Table 2.

Table 2. ANC results from 8/20/03 to 12/18/03.

ANC, μeq/L (Elevation, ft)	Ramsey (2800)	Upstream Site (1700)	Middle Site (1514)	Downstream Site (1370)
Mean	16.71	39.33	68.55	63.06
Median	16.71	39.72	69.11	66.16
Standard Deviation	1.15	17.25	21.55	20.28
Range	1.63	50.72	63.92	61.04
Minimum	15.90	17.93	39.70	35.16
Maximum	17.52	68.65	103.62	96.20
Count	2	10	11	11

In addition to acid deposition, suspended solids can adversely affect aquatic ecosystems. Turbidity, a measure of clarity, is often used instead of suspended solids measurements. Persistent high turbidity situations can impair fisheries ecosystems by 1) acting directly on free swimming fish 2) preventing successful development of fish eggs 3) modifying the natural movements and migration of fish 4) reducing the abundance of food available to fish 5) altering habitat and 6) reducing catch per unit effort (Newcombe 2003). Turbidity statistics are summarized in Table 3. Although relational trends between turbidity and fish behavior are site specific it has been shown that increased turbidity for a day as seen in Figure 5 can lead to fish abandoning cover, avoidance behavior, and reduced feeding rates (Newcombe et al. 1996).

Table 3. Turbidity statistics from 8/20/03 to 12/31/03.

Sonde Turbidity (NTU) (Elevation, ft)	Upstream Site (1700)	Middle Site (1514)	Downstream Site (1370)
Mean	23.18	6.44	11.01
Median	7	2.4	6.8
Standard Deviation	108.69	51.64	44.13
Range	1217.6	1196.5	1173.9
Minimum	0.5	1	2
Maximum	1218.1	1197.5	1175.9
Count	10021	8059	10370

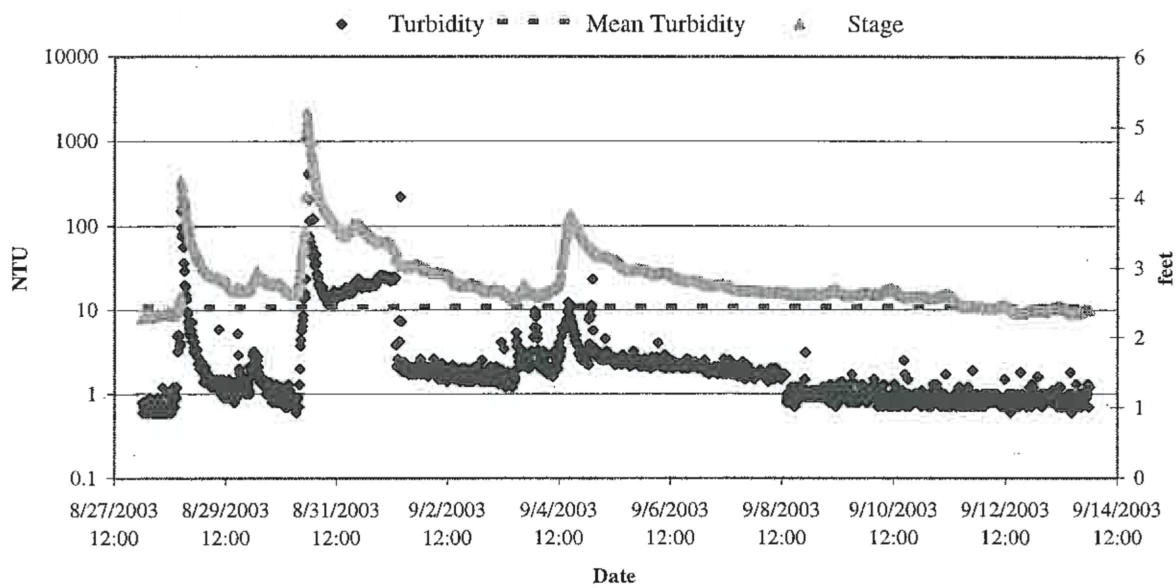

Figure 5. Storm event at upstream site showing increased turbidity corresponding to increased stage height.

As with pH, being able to predict turbidity is a valuable tool in assessing a stream. Also as with pH, turbidity seems to have a strong correlation with stage. However, it has a very poor linear r-value. Applying another simple regression, an exponential regression, provides a much better fit with an r-value of –0.891 and an r^2 of 0.794. Figure 6 shows how well the model fits for the given data set. Similar to the pH model, it has limitations in that it does not predict the peak turbidity values accurately and does not reflect the variability the sonde shows.

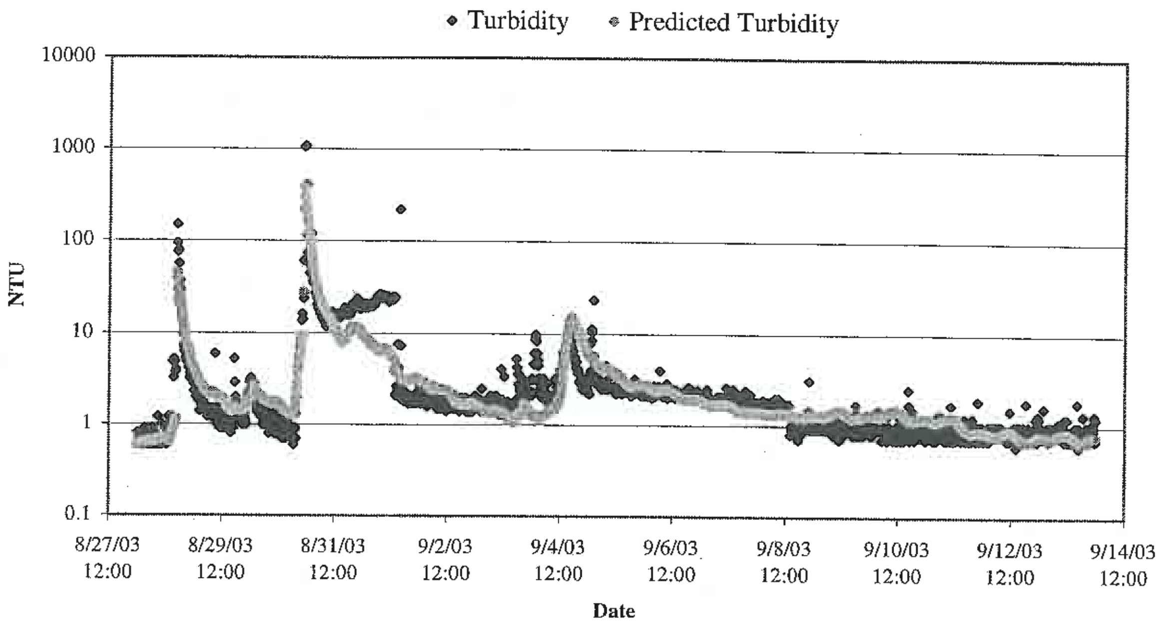

Figure 6. Actual turbidity with predicted turbidity at upstream site.

CONCLUSION

This project is currently in its infancy and data collection is still in an early stage. A great deal more data collection and data analysis will be done before the end of this project. This paper is the first step to reach the goals of the project, which are to:

1. Characterize water quality on the MPLPR in GRSM including the frequency, duration, and severity of pH and turbidity and the mobilization of several trace metals during storm events.
2. Determine the extent acid rain plays in stream water quality deterioration.
3. Create statistical models to accurately predict water quality.
4. Identify specific existing or emerging water quality problems caused from road construction.
5. Gather information to aide in design of specific pollution prevention procedures for road construction.
6. Determine effectiveness of Better Management Practices (BMP's) used in road construction.

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SESSION 1C

UNDERSTANDING WATER SUPPLY RESOURCES
3:30 p.m. – 5:00 p.m.

Preliminary Estimation of Livestock Water Usage in Tennessee at the State and County Levels
J. Bert Britton

Regional Water Supply Study: Giles County, Tennessee
Benjamin L. Rohrbach

Summary of Hydrologic Conditions, Tennessee, 2002
Paul Hampson

PRELIMINARY ESTIMATION OF LIVESTOCK WATER USAGE IN TENNESSEE AT THE STATE AND COUNTY LEVELS

J. Bert Britton*[1]

INTRODUCTION

Great competition for water resources is well documented in the southwestern United States. Less publicized are water shortages occurring in certain sectors in the southeastern region. Alabama, Florida, and Georgia have had legal battles with one another over water rights. These battles stem from competition for water in rivers that flow through these states. It is widely believed that Tennessee could enter the legal debate, as other states seek use of the water in the Tennessee River.

In the state of Tennessee, nearly all other sectors of the state's economy, including utility, mining, and manufacturing sectors, are required to report water usage. As of yet, however, the agriculture sector has been exempt from reporting water use under Tennessee's Water Information Act. The population of Tennessee grew from 16% between 1990 and 2000; the population of neighboring Georgia grew by 26% during the same time period (U.S. Census Bureau 2001). Given growing interstate competition for freshwater in the region and increasing demands on water within Tennessee, the state of Tennessee may soon need to document its agricultural water use in order to retain the right to continue to use that quantity of water. New legislation was introduced in 2003 to amend the Water Information Act. The legislation would have required a methodology for determining the annual amount of ground water and surface water withdrawn for agricultural purposes in Tennessee. The legislation was not enacted into law in the 2003 legislative session, but is expected to be re-introduced in 2004 or 2005 (Rose 2003).

My research has two objectives. First, I will develop a methodology to estimate agricultural water use in the state of Tennessee. Second, I will bring the study into a more local scale by studying water use in a county in both East and West Tennessee. In this paper, I present preliminary estimates of beef cattle water use, which are part of this ongoing project.

The study area reported here consists of two different scales. The first stage of my analysis is at the statewide scale. Tennessee's 95 counties are examined in depth, but used only to provide a broad estimate of annual statewide agricultural water usage. The state covers an area of 41,217 square miles, with 138 persons per square mile (U.S. Census Bureau 2001).

In the second stage I examine two counties at a larger scale than the state-level, and determine their agricultural water use. The two counties chosen reflect the typical agricultural practices found in that county's region. I selected Greene County to represent the eastern half of the state and Hardeman County as a typical county in western Tennessee.

Greene County covers 622 square miles and has a population density of 101.1 persons per square mile (TN Atlas 2001). The Census of Agriculture states that Greene County has 225,676 acres in farmland and 3,008 total farms. The number of farms in Greene County is large, due, in part, to the topography. The valleys and ridges in Greene County make cultivating row-crops difficult in terms of time and economic feasibility. Therefore, livestock operations are the most widespread

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agricultural use of the land. Greene County has obtainable groundwater and abundant surface water with which to maintain livestock operations.

Hardeman County, with 668 square miles, has a population density of 42.1 persons per square mile (TN Atlas 2001). Hardeman County had 559 farms with 166,241 acres in farmland, according to the U.S. Agriculture Census of 1997. Farms are much larger in Hardeman County than in Greene County, largely because of relatively flat topography. Therefore, row cropping is the primary agricultural operation in Hardeman County. Cotton and soybeans are the main crops. Groundwater is the main source of water for irrigating row crops, although surface water is available much of the year. Hardeman County does have minor livestock operations, with beef cattle being the primary animal raised.

DATA AVAILABILITY

Many governmental agencies release records containing various agricultural statistics. USGS and NASS are the primary agencies that provide the data. U.S. Geological Survey (USGS) releases to the public livestock and irrigation statistics on five-year intervals, with year 2000 data the latest released (Treece 2003). The data are compiled in part by Natural Resources Conservation Service (NRCS) county agents. County data are given to the USGS, which compiles and releases them as statewide data or individual county data (USGS 2002).

National Agricultural Statistics Service (NASS) conducts the Agriculture Census at five-year intervals. In the Agriculture Census, current farmers are asked to provide information on various attributes of their farms, i.e., acres irrigated, type of irrigation deployed, total cropland, and types and amounts of livestock. I use the latest Agricultural Census, from 1997, as the basis for livestock statistics. NASS provides estimates annually based from past Agriculture Census Data.

METHODS

I use datasets provided by NASS and USGS to estimate agricultural water usage for the state of Tennessee and for Greene and Hardeman Counties. Determining livestock water usage is an important factor in determining agricultural water use. Livestock water use can be estimated by assigning a livestock water use coefficient to each type of animal. Each coefficient is multiplied by the total population of the particular animal to estimate the total water used by the species. The method will be applied to each species of livestock raised in the state of Tennessee. Livestock statistics are taken from NASS's 1997 Agriculture Census Data.

The majority of livestock operations in Tennessee consist of beef cattle, dairy cattle, poultry, and swine. Beef cattle consist of different sizes and ages. A beef cow is a mature female cow that produces young on a regular basis, which is one calf per year. A beef heifer is an immature female cow that has not yet produced young because of its undeveloped body. A steer is a bull that has been castrated. A steer is usually kept on a yearly basis in which it is fed and either sold or slaughtered near the end of the year. A bull is the sire to beef cows. Due to the size of most bulls and the amount of food and other supplies to support them, farmers keep few bulls on the farm. Thus, bulls have the lowest population.

Each type of beef cow requires different amounts of nutrients and water. The table below shows the required amount of water per day by each type of cow, averaged over different seasons of the year.

Table 1. Beef cattle drinking water requirements	
Beef Cow ------	14.7 gallons/day/cow
Bull ------------	16.73 gallons/day/cow
Steer -------------	11.3 gallons/day/cow
Heifer ----------	- 8.8 gallons/day/cow
Calves ----------	5.8 gallons/day/cow

Source: Michigan State University (2003)

The Agricultural Census reports the number of beef cows and heifers separately. Drinking water requirements for heifers and beef cows are multiplied by the number of cows and heifers for the state and county. The result is the total amount of water drunk by cows and heifers per day. The number is multiplied by 365 days to give an annual total drinking water in gallons.

The Agricultural Census does not report steers, bulls, and calves. It states only a combined total at the state and county level. To solve the problem, I took the average of the drinking water requirement of the three types, which is 11.26 gallons/day/cow. I multiplied 11.26 gallons/day/cow by the combined number of bulls, steers, and calves. This gives a daily total, which is multiplied by 365 days to give an annual amount in gallons.

Beef processing is another factor that uses a huge amount of water. Water is used in nearly every aspect of processing beef, including hide removal and evisceration. Information on beef processing was only available at the state level. Therefore, calculations were only made on the state level. In 2001, 2,779,000 cows were slaughtered in Tennessee. The size of the beef processing plant causes the amount of water used to process beef to vary widely. Larger operations frequently use more water per cow than smaller operations. Water used in beef processing is averaged by many studies to be 300 gallons/cow (Sector Star 2001). The number of cows processed is multiplied by the water coefficient to determine total water used in processing beef.

RESULTS

Table 2 displays the results of total drinking water for Tennessee and Greene County and Hardeman County in gallons per year. Table 3 displays total water used in beef processing in 2001.

Table 2. Beef cattle total drinking water

Tennessee

Beef Cows in Tennessee = 1,069,595
Beef Cow water coefficient = 14.7 gal/cow/day
Annual drinking water = 5,738911,972 gal/yr

Heifers in Tennessee = 383209
Heifer Water Coefficient = 8.8 gal/cow/day
Annual drinking water = 1, 230,867,308

Bulls, steers, and calves in Tennessee = 399,526

Water Coefficient (Average) = 11.26 gal/cow/day
Annual Drinking Water = 1642,011,907 gal/yr

Total Drinking Water in Tennessee = 8,611,791187 gal/yr

Greene County

Beef Cows in Greene County = 33,434
Annual Drinking Water = 179,390,127 gal/yr

Heifers in Greene County = 16,948
Annual Drinking Water = 54,436,976 gal/yr

Bulls, Steers, and Calves in Greene County = 16,131
Annual Drinking Water = 66,296,796 gal/yr

Beef Cattle Total Drinking Water in Greene County = 393,151,449 gal/yr

Hardeman County

Beef Cows = 9184
Annual Drinking Water = 49,276,752 gal/yr

Heifers = 3207
Annual Drinking Water = 10,300,884 gal/yr

Bulls, Steers, Calves = 2842
Annual Drinking Water = 11,680,335 gal/yr

Table 3. Total water used in beef processing in 2001

Cattle Slaughtered in Tennessee = 2,779,000
Beef Processing Water Coefficient = 300 gal/cow
Total Water Used for Beef Processing in Tennessee = 833,700,000 gal/yr

CONCLUSIONS

Water use in beef cattle will fluctuate annually depending on total head of cattle and a drinking water coefficient. The water coefficient could change depending on temperature and cattle weight. Applying the methodology used in this study makes it possible to determine the amount of water used for drinking and beef processing annually on a county-by-county basis. This methodology, when applied to other livestock, will require multiple coefficients to accurately estimate total water use within that particular animal group. Total water used in dairy farming would have multiple water use coefficients—drinking water, cow washing, manure flushing, and washing equipment require water and have water coefficients (Van Horn et al. 1993). Poultry, sheep and goats, and hogs and pigs have different sets of water coefficients. By using the Agricultural Census, I can determine the total amount of water used by each animal. With these statistics, I expect to attain and map the total water used by livestock in Tennessee. Preliminary results presented in this paper for beef cattle support the feasibility of this method. The estimates should be helpful in determining total agricultural water consumption in the event of inter-state water conflict.

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REGIONAL WATER SUPPLY STUDY: GILES COUNTY, TENNESSEE

Benjamin L. Rohrbach*[1]

This Regional Water Supply Study serves the purpose of a reconnaissance or pre-feasibility investigation of the existing water supply conditions of Giles County and a preliminary investigation of water supply alternatives to supplement Giles County's existing capacity. The study was requested by Giles County, through the U.S. Army Corps of Engineers' Planning Assistance to States authority. It is the responsibility of the Giles County community and utility districts to refine and expand on this Preliminary Engineering Report (PER) through a detailed feasibility study if so desired.

An assessment of the county water supply needs was initiated with a preliminary Needs Analysis. This projection of water demand can be used to assess the adequacy of existing water supply sources and as a measuring stick when evaluating potential new water supply sources. For the purposes of this study, the historical growth trend of utilities in the county was selected for use in forecasting future water demand.

Alternatives investigated during the course of this study include raising the height of existing reservoirs, construction of new water supply reservoirs, groundwater supply (wells and springs), water harvesting, large scale pipeline, conservation efforts, and no action. Each alternative considered was sized to its maximum capacity for providing water supply. For those alternatives that required a target yield for design, such as a pipeline, the projected demand for the year 2050, 7.3 MGD, was used as the target yield. Preliminary benefit-cost and financial analyses and environmental screening of the various identified solutions were included in this study.

The Giles County community could elect to choose an alternative based on this Preliminary Engineering Report and proceed independently with the design and permit process. However, difficulties are likely to be encountered in pursuing this approach, without detailed feasibility planning, including meeting the provisions of the National Environmental Policy Act (NEPA). This Preliminary Engineering Report is intended to aid the community in planning for the long-term water supply needs of the Giles County region.

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SUMMARY OF HYDROLOGIC CONDITIONS, TENNESSEE, 2002

Paul Hampson*[1]

SURFACE WATER

The State of Tennessee derives many benefits from an abundance of water found in many streams, rivers, and lakes throughout the area. Excluding the Mississippi River, which flows south along Tennessee's western border, the largest rivers in the State are the Tennessee and Cumberland Rivers. Other large rivers in Tennessee include the Holston, French Broad, Little Tennessee, Ocoee, Elk, Duck, Buffalo, Obion, and Hatchie Rivers. Tennessee shares the benefits of these rivers with neighboring states. Adequate water supplies in the Tennessee's river systems are dependent upon rainfall and wise management by Federal, State, and local government agencies. Streamflow data is an integral part of the wise management of the water resources of the State.

Rainfall across Tennessee was significantly above average during the calendar year 2002. Memphis recorded about 20 inches above the long-term average rainfall of 53 inches, both Nashville and Knoxville were about 10 inches above the long-term normal of 48 inches. A comparison of annual mean discharges for the 2002 water year with means for the period-of-record for unregulated streams in Tennessee indicates that streamflow recovered during the 2002 water year and was higher than the 2001 water year across the State. Streamflows in the western parts of Tennessee were well above long-term averages and almost twice the long-term average in many streams. In the central portions of Tennessee, streams and rivers were flowing at average to slightly above average rates during water year 2002. Only the streams and rivers in eastern Tennessee, particularly those flowing out of Virginia and North Carolina, were still below the long-term average flow rates. Although, recovering significantly, the dry conditions that existed for several years in this area will require continued robust rainfall conditions to return to normal.

The western portion of Tennessee was affected by several significant flood-producing storms during the 2002 water year. A general rainstorm occurring during late November and early December 2001 produced flooding that was generally a 25-year event. However, several streams had flooding that approached the 50-year recurrence interval. The National Weather Service in Memphis recorded a single-day total of over 6 inches in late November and over 70 inches of rainfall for the calendar year 2002, the third wettest year in over 100 years of record.

The central portion of Tennessee was struck by unusually heavy flooding January 23-25, 2002. The storm that produced the heavy flooding was a general rainstorm with an extremely intense leading edge that passed through middle Tennessee in the early morning hours of January 23, 2002. The storm dropped over 7 inches of rainfall and produced heavy flash flooding and generalized flooding on many rivers and streams throughout the area. Recurrence intervals for this flood ranged from about 10 to 25 years, with a select few streams approaching the 50-year event.

A few areas of middle Tennessee and most of the upper eastern parts of the State experienced a significant flood during the period from March 17-19, 2002. The storm producing this flood was a general rainstorm with intense embedded cells that produced in excess of 6 inches of rain through many watersheds in the area. In middle Tennessee, Jones Creek in Dickson County

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recorded a 50- year flood. In east Tennessee, many streams in the Clinch River and Holston River basins were out of their banks and recorded 10- to 20-year flood events. The Clinch River recorded a flood in excess of the 30-year recurrence interval. Most of the runoff in the Clinch River came from Virginia which received heavier rainfall amounts than Tennessee during this storm.

GROUND WATER

Ground-water levels at key aquifers throughout Tennessee were affected by rainfall during the 2002 water year. Ground-water levels are recorded continuously at a series of observation wells across the State (fig. 1). Water levels at well Hm:O-15 (Hamilton County) are representative of conditions in Middle and East Tennessee. Water levels were near normal during the last 8 months of the year. Wells in Hamilton County (Hm:O-15), Lauderdale County (Ld:F-4), and Shelby County (Sh:P-99) show water levels recovering with increase rain during 2002.

Water levels recorded from wells throughout Middle and East Tennessee generally respond faster with larger fluctuations than wells drilled into the sand and gravel aquifers of West Tennessee. Observation wells in Shelby County show that ground water levels are strongly affected by ground-water withdrawals by the City of Memphis and surrounding communities. At well Sh:Q-1 (fig. 2), near downtown Memphis, water levels declined steadily since 1972, although a slower rate of decline began in 1988. The decline in ground-water levels in the Memphis area are not indicative of a reduction in the available ground-water supplies, but the response of the aquifer to additional withdrawals.

SESSION 2A

ECOLOGICAL ASSESSMENT AND RISK
8:30 a.m. - 10:00 a.m.

Ecological Risk and Liability Analyses of Ecosystem/Wetland Restoration of Agricultural and Reclamation Land
Mark Goodrich and Carl Crane

Climate Change Suppresses Tree Regeneration in a Tennessee Oak Swamp
William J. Wolfe

Distribution and Habitat Requirements of Athernia anthonyi in the Tennessee River
James R. Orr, Carl M. Crane, and Wendell Pennington

EXAMINING POLLUTANT EFFECTS
10:30 a.m. – 12:00 p.m.

Derivation of Site Specific Fluoride Aquatic Life Criteria
Liza Heise, Teri Horsley, Scott Hall, and Rick Lockwood

Identification and Control of Fish Pathogens in Industrial Effluents
Teri Horsley, Richard Lockwood, Liza Heise, and Scott Hall

Pharmaceutical and Personal Care Products in Tennessee Water
Ching-Ping Yu, Bo Yang, Fu-Min Menn, Gary Salyer, and Kung-Hui Chu

REMEDIATION TECHNIQUES FOR POLLUTED WATERS
1:30 p.m. – 3:00 p.m.

Biorestoration of a TCE-Contaminated Karst Aquifer by Stimulating Sulfate-Reducing Bacteria
Gregg Hileman, Koushik Chakraborti, and Tom D. Byl

Hydrologic Investigation for the Geotechnical Remediation of Sinkholes Beneath a Potable Water Supply Impoundment, Alcoa, Tennessee
Barry F. Beck, Arthur J. Pettit, Ramona C. Josefczyk, Jie Wang, and Wanfang Zhou

Use of Residence-Time Distribution Coupled with a Biodegradation Rate to Predict Toluene Removal in an Artificial Karst System
R. Painter, V. Watson, and T. Byl

EDUCATING WATER RESEARCHERS AND PROFESSIONALS
3:30 p.m. – 5:00 p.m.

Water Resource Education and Research at the University of Memphis and Ground Water Institute
Jerry L. Anderson

Water Resources Engineering Education and Research at Vanderbilt University
Eugene J. LeBoeuf

Water and Environment Research and Education at Tennessee Technological University
Dennis B. George and Vincent Neary

An Overview of Water Education Opportunities at the University of Tennessee-Knoxville
David L. Feldman

ECOLOGICAL RISK AND LIABILITY ANALYSES OF ECOSYSTEM/WETLAND RESTORATION OF AGRICULTURAL AND RECLAMATION LAND

Mark Goodrich* and Carl Crane[1]

Much of the ecosystem/wetland restoration focus has been, and will continue to be, on the conversion of agricultural landscapes and reclamation land into wetland systems of one kind or another. Restoring surface water volume and function will, in many places, require the reclamation of land back into flooded or periodically inundated systems. As these projects unfold, we are discovering the inadequacy of existing science to predict the consequences of converting soil-bound pesticides, mine leachate and other chemicals, accumulated over years of accepted agricultural and industrial practices, into muck-bound sediments in wetlands or other water bodies. This session will provide an example of risk based restoration and attempt to answer questions such as: What are safe standards for chemical levels traditionally measured for their effects on human beings, when those chemicals will now primarily become sediment pollutants before they actually become sediment pollutants? How do you evaluate environmental risks to the food chain posed by such chemicals? What liability is being faced by such a conversion? Who is liable, the public landowner who farmed with traditional practices, or the public agency that converts the soils to sediments? How can the risks be minimized? What is the relationship between public policy decision to restore wetlands and the legal liability inherent in that decision?

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CLIMATE CHANGE SUPPRESSES TREE REGENERATION IN A TENNESSEE OAK SWAMP

William J. Wolfe*[1]

Multiple lines of evidence point to climate change as the driving factor suppressing tree regeneration since 1970 in Sinking Pond, a 35-hectare seasonally flooded karst depression located on Arnold Air Force Base near Manchester, Tennessee. Annual censuses of 162 seedling plots from 1997 through 2001 demonstrate that the critical stage for tree survivorship is the transition from seedling to sapling and that this transition is limited to light gaps with shallow (less than 0.5 meters) ponding depths. Recruitment of saplings to the small adult class was also restricted to shallow areas. Analysis of the spatial and elevation distribution of tree-size classes in a representative 2.3-hectare area of Sinking Pond showed general absence of overcup oak saplings and young adults in deep (ponding depth greater than 1 m) and intermediate (ponding depth 0.5-1 m) areas, even though overcup oak seedlings and mature trees are concentrated in these areas.

Analysis of tree rings from 45 trees sampled in the 2.3-hectare spatial-analysis plot showed an even distribution of tree ages across ponding-depth classes from the 1800s through 1970, abruptly followed by complete suppression of recruitment in deep and intermediate areas after 1970. Trees younger than 30 years were spatially and vertically concentrated in a small area with shallow ponding depth, about 0.5 m below the spillway elevation. Results of hydrologic modeling, based on rainfall and temperature records covering the period January 1854 through September 2002, show ponding durations after 1970 considerably longer than their historical norms, across ponding-depth classes. This increase in ponding duration corresponds closely with similar increases documented in published analyses of streamflow and precipitation in the eastern United States and with the suppression of tree regeneration at ponding depths greater than 0.5 meters indicated by tree-ring analysis. Comparison of the modeled stage record for Sinking Pond with the ages and elevations of trees sampled for tree-ring analysis shows that prolonged inundation (200 or more days per water year) in more than 2 of the first 5 years after germination is inversely related to successful tree recruitment and survival and that such inundation was rare before 1970 and common afterwards.

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DISTRIBUTION AND HABITAT REQUIREMENTS OF *ATHERNIA ANTHONYI* IN THE TENNESSEE RIVER

James R. Orr*[1], Carl M. Crane[1], and Wendell Pennington[2]

INTRODUCTION

On April 15, 1994 the USFWS listed *A. anthonyi* was listed as an endangered species (USFWS 1994). Prior to 1994, only two populations of the species were known to still exist, one in the lower Sequatchie River, Marion County, Tennessee another in the lower reaches of Limestone Creek in Limestone County, Alabama. In 1994, Jenkinson located individuals of *A. anthonyi* near TRM 414.5 which indicated that the snail may have a greater distribution than earlier indicated. This study was conducted as part of an agreement between the U.S. Corps of Engineers and U.S. Fish and Wildlife Service to allow the construction of an unloading facility and channel dredging at TRM 416.5 to 414.5 near Bridgeport, Alabama. This study was conducted to identify the distribution of the species in the main stem of the Tennessee River and to characterize environmental and habitat requirements of the snail. Following completion of the unloading facility, A. anthonyi populations were monitored at a background location TRM 421 and downstream of the facility where tugs maneuvered barges for the unloading of raw material TRM 415.5.

METHODS

In order to quantify habitat requirements of *A. anthonyi* in the main stem of the Tennessee River, a number of physical and chemical variables were examined along river bottom transects where the snails were present and absent. Initially, TRM 402-423 was surveyed for the presence of *A. anthonyi*, while habitat analysis locations were between TRM 414 to 423. In several areas where *A. anthonyi* was located, habitat was evaluated in order to assess habitat preference. At each of four river locations, 0.1 m^2 areas were sampled in triplicate. A total of 30 samples per site were

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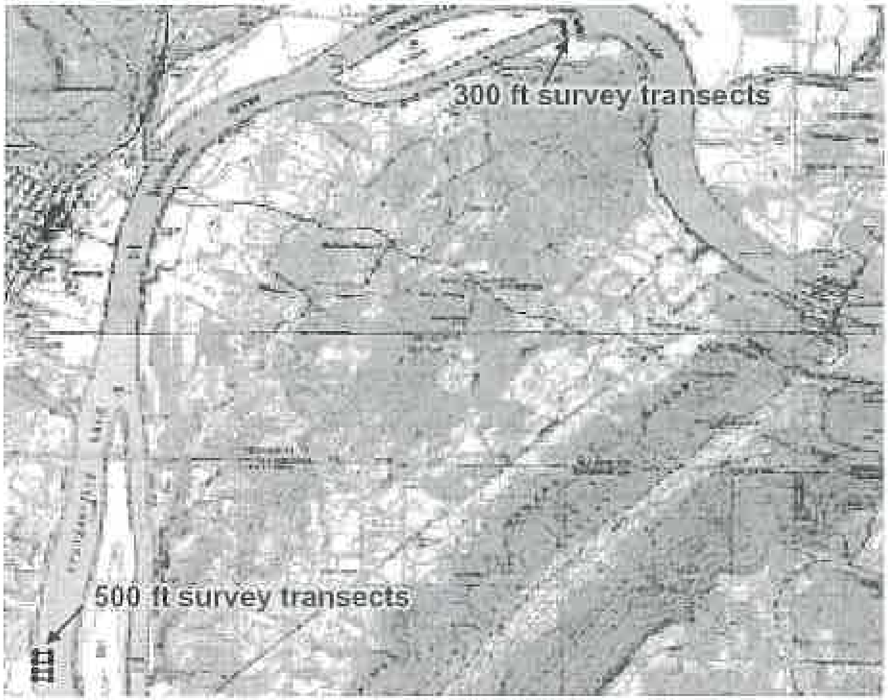
collected at 2 locations where *A. anthonyi* were present and 15 samples were collected at 2 locations where *A. anthonyi* were absent. The following information was recorded: type of substrate, size of substrate, depth of imbeddedness, flow velocity, number and species of snails, and position of *A. anthonyi* on substrate.

In addition to the physical information, light penetration, in-situ parameters: temperature, pH, dissolved oxygen, specific conductance at surface and bottom. Periphyton samples were also collected and analyzed for chlorophyl a and direct cell counts. During the 5-year post construction monitoring period, *A. anthonyi* counts were made along similar transect lines in one square meter areas at 20 foot intervals. Substrate type, and snail and mussels species present were also recorded.



RESULTS

Water temperature ranged from 29.2° C to 28.2° C with temperatures generally slightly lower near the surface. Specific conductance was generally higher on the bottom than surface indicating water with slightly higher density but warmer temperature along the bottom of the river. Dissolved oxygen (D.O.) levels in the main stem of the river were generally lower on the surface while the pH was generally slightly higher.

The mean number of snail species identified in each sample along the transects are given in Table 1. A total of 5 snail species were observed in the 4 sample locations. Five snail species were observed at TRM 421.7 (Burns Island) where *A. anthonyi* was present and 3 species

Table 1. Mean Densities of all Fresh Water Gastropods Sampled During this Investigation

Location	Species (#/m²)				
	AA	LV	LP	PC	PCa
TRM 421.7 Burns Island Side Channel	38.4	103.2	1.0	7.4	4.2
TRM 414.5 LB Long Island Side Channel	40.7	33.3	0	13.7	0
TRM 414.5 RB Long Island Side Channel	0	44.0	0	2.0	0
TRM 416.8 LB Head of Long Island	0	140.0	0	1.9	0.3

AA: Anthony's River Snail (*Athernia anthonyi*), LV: *Lithasia verrucosa*, LP: *Leptoxis praerosa*, PC: *Pleurocera corpulentum*, and PCa: *Pleurocera canaliculata*

observed at TRM 414.5 LB where *A. anthonyi* was present along the transects. The same 3 species were also observed at locations where *A. anthonyi* was absent. *A. anthonyi* was abundant at both TRM 421.7 and TRM 414.5 LB with average densities of 38.4 m^2 and 40.7 m^2, respectively. *A. anthonyi* was not detected at either the TRM 414.5 RB or the TRM 416.8 LB sites, with the exception of low numbers of *A. anthonyi* observed toward the channel end of the TRM 414.5 RB transect. The channel end of the TRM 414.5 RB transect was 3.1 m versus depths of 4.3 m and increased scour compared to the area near shore resulting in more exposed gravel and cobble. *Lithasia verrucosa* were very abundant and observed in every sample at every site in the river.

Lithasia verrucosa attained numbers as high as (103.3m^2) where *A. anthonyi* was present and were also relatively high (93.5/m^2) at locations where *A. anthonyi* were absent. *Pleurocera corpulentum* were observed at all locations at relatively low numbers ranging from 13.7/m^2 to 1.9/m^2. *Pleurocera canaliculata* were the least abundant snail species observed ranging from 4.2/m^2 at TRM 421.7 to 0.3/m^2 at TRM 416.8 LB and 0/m^2 at TRM 414.5 LB. *Leptoxis praerosa* were only detected at TRM 421.7 in low numbers (1.0/m^2).

The generally high number of species and density of snails at TRM 421.7 suggests that this area has high quality habitat for gastropods. This site is characterized as a shoal area at the head of the side channel where gravel and cobble are abundant and well exposed. Flow is consistent but reduced from the main channel and water depth is approximately 3.1 m at normal pool. Similar conditions exist at TRM 414.5 LB where water depth is generally 3.1 to 3.2 m at normal pool. At TRM 414.5 RB, water depth is slightly greater at 4.0 to 4.1 m and unstable substrate is common, consisting of shell fragments and sand. A general description of the substrate type at each of the sample areas is given in Table 2. At all locations the substrate consisted of gravel and cobble-size material imbedded partially in sand. Cobbles appeared to be the preferred substrate type of *A. anthonyi* and other gastropods and the location appeared to rely on the presence or absence of periphyton and water velocity. The location where substrate appeared unstable was the site where *A. anthonyi* were absent (TRM 414.5 RB and TRM 416.8 LB). At TRM 414.5 RB substrate included approximately 30% mussel shell fragments, while sand was abundant at TRM 416.8 LB. Both sand and shell fragments appear to be undesirable habitat features. Imbeddedness of cobble also appeared to affect *A. anthonyi* populations with the average of 40% where A. anthonyi was absent and about 25% where they were present. At location, TRM 416.8 LB, where *A. anthonoyi* was absent, imbeddedness was estimated at 7.5%. However at this site, cobble was sparse and sandy substrate was dominant. The imbeddedness data suggest that unstable substrate may be a limiting factor in *A. anthonyi* distribution. The substrate type, general size range of gravel and cobble, and percent imbeddedness are determined from bottom observations at the 90 sample locations.

Table 2. Substrate Description of the Tennessee River Anthony's River Snail Study July 1998

Location	Substrate type	Gravel Size (cm)	Size Range Cobble Size (cm)	% Cobble	% Imbeddedness
TRM 421.7	Gravel, Cobble, Sand	0.25-1	1-6	22	19
TRM 414.5 LB	Gravel, Cobble	0.25-2	2-4	23	23
TRM 414.5 RB	Gravel, Cobble, Shell Fragments (30%)	0.25-1	2-4	40	40
TRM 416.8	Gravel, Cobble, Sand (50%)	0.25-1	2-4	7.5	7.5

The total number of periphyton species (Table 3) was similar between locations ranging from an average of 6 to 7 species. The number of species within an individual sample ranged from 5 to 10. The chlorophyll-a (ug/m^3) and bio-volume mm^3/m^2 varied between locations and these parameters had a negative correlation with the density of *A. anthonyi* (per m$^{3)}$. Periphyton cell density was not as variable as the above parameters, but also did not correlate to the density of *A. anthonyi* with a correlation value of 0.2. Bio-volume was the most variable parameter between

Table 3. Periphyton Data Collected as Cells per mm^3, Biovolume (mm^3/m^2), and Chlorophyl ā Concentrations for this Study

Location	Average # of Taxa	Average Cells/mm^2	Average Biovolume (mm^3/m^2)	Chlorophyl ā (mg/m^2)	Dominant Species (biovolume)	# of Samples Where Species Occurred
TRM 421.7 (ARS present)	6.0	2.17	1,427.8	88.2	Cladophora sp Protoderma sp Conochilodes sp Lyngbya sp Tetraspora sp	6/6 G 4/6 G 5/6 R 5/6 B 3/6 G
TRM 414.5 LB (ARS Present)	7.2	0.45	102.6	47.1	Cladophora sp Diatoma sp Gyrosigma sp	6/6 G 6/6 D 4/6 D
TRM 416.7 (ARS Absent)	6.3	0.235	5.95	80.8	Cladophora sp Protoderma sp Lyngbya sp Spirulina sp	3/3 G 3/3 G 3/3 B 2/3 B
TRM 414 RB (ARS Absent)	7.0	2.24	2,512	159.1	Cladophora sp Centropyxis sp Protoderma sp Gyrosigma sp Navicula sp	3/3 G 3/3 P 2/3 G 2/3 D 2/3 D

G: Green algae, B: Blue green algae, R: Rotifera, P: Protozoan, D: Diatom

locations. This appears to be primarily influenced by the bio-volume of *Cladophora sp. Cladophora spp.* are generally more difficult to analyze due to their filamentous cell structure and variation in cell size thus resulting in the wide range of cell volume.

The survey of TRM 412 to 402 to determine the distribution of *A. anthonyi* indicated that in general, acceptable habitat exists from TRM 412 to approximately 408.0. This area includes water depths of 4.3 to 5.3 m during normal pool, with relatively consistent depths across the channel. The substrate is also very consistent including clean gravel and cobble that is not imbedded greater than 25%.

In the main stem of the Tennessee River, *A. anthonyi* populations ranged in density from $40/m^2$ to $1/40m^2$ from the head of Burns Island (TRM 421.7) to TRM 408.0. Populations of *A. anthonyi* and other snails are greatly reduced at TRM 408.0 where water depth abruptly increases by 0.6 m (elevation of approximately 580 msl).

The area below the shelf was thoroughly surveyed for snail species. Only two individual snails were collected in a 400 square foot area below the shelf; one *Lithasia verrucosa* and one *Pleurocera corpulentum* in the 5.6 m deep water. No *A. anthonyi* were observed at this or the two additional locations surveyed downstream. The habitat consisted of cobble and gravel; however, due to the increased depth, a relatively fine layer of silt was observed on the substrate. This silt layer appears to reduce periphyton growth and substrate suitability. A heavier silt layer was observed at the two additional downstream locations, TRM 403.5 and TRM 402, where depths were recorded at 6.1 m and 6.2 m, respectively. The increase in depth and subsequent siltation appears to result in the overall loss of snail and specifically *A. anthonyi* habitat.

The five-year monitoring survey has documented the populations of *A. anthonyi* and other mussels at the head of Burns Island TRM 421.7 and in the 600 x 500 foot area downstream of the unloading facility TRM 415.0. Populations appear to be stable and abundance increased from the time of the original survey conducted in 1996 to 2003. The populations of *A. anthonyi* at Burns Island have been compared to the population at the turn around zone for five years. Table 4 includes the results of the Students T-test for these pairs of data. The T-test reports the

Table 4. Snail Density by Year in Number per meter square

Location	1996	1999	2000	2001	2002	2003
Background 1	NA	16	13.4	7.4	1	7.25
Background 2	NA	12.6	42	13.9	1.25	12.4
average/meter		14.3	27.7	10.65	1.125	9.825
Turnaround Zone						
T-40	0.14	14.2	16.2	6.2	8.3	3.5
T-41	0.34	18.4	16	17.8	11.3	10.3
T-42	0.21	15.3	27.2	16.6	12.2	9
T-43	1.5	14.9	26.7	14.7	13.4	19.2
average/meter	0.55	15.7	21.5	13.8	11.3	10.5
T-test of probability by year		0.56	0.74	0.51	0.002	0.88
T-test all five years combined		0.64				

probability that the data sets are similar. It is generally accepted that the data are similar at p (probability) values greater than 0.05. The abundance of first year snails observed in the 2003 survey indicates that reproduction of this species is both successful and widespread in the turnaround zone. Populations vary greater at the Burns Island location and were found to be both higher and lower on the average than the turnaround zone. However, only during one year (2002) were populations statistically different at the 0.05 confidence level and during that year the population at the turnaround zone was higher than background. This study indicates that the population of A. *anthonyi* is not negatively impacted by the material unloading activity at the facility.

DISCUSSION

A total of 92, 0.1/m^2 samples from four separate sample transect locations were analyzed for *A. anthonyi* population densities as well as habitat utilization and presences of other molluscs (primarily snails) associated with *A. anthonyi*. A total of 31 samples were analyzed where *A. anthonyi* were absent while 61 samples were analyzed where *A. anthonyi* were present. No significant differences were noted between the in-situ water quality conditions at the locations where *A. anthonyi* were present versus where they were absent. Substrate conditions, however, appeared to be a limiting factor to the presence or absence of *A. anthonyi*. The substrate at TRM 414.5 RB was mostly fine shell fragments while the substrate at TRM 416.8 LB was primarily sand. It is speculated that discontinuous stable substrate (large gravel and cobble) impairs the movement of *A. anthonyi* such that they are unable to move between suitable substrates. Snails such as *Lithasia verrucosa* do not appear to be as limited in this movement. Other limiting factors appear to be velocity, light penetration, and potentially periphyton types, i.e., filamentous green algae.

Populations of *A. anthonyi* were found to increase from 1996 to 2003 in the area of the turn-around zone near TRM 415.0. This indicates that the barge movement has not had a negative affect on *A. anthonyi*.

DERIVATION OF SITE SPECIFIC FLUORIDE AQUATIC LIFE CRITERIA

Liza Heise[1], Teri Horsley, Scott Hall, and Rick Lockwood

Fluoride is present in many municipal wastewater discharges as a result of its addition to some potable waters. Fluoride is also present in some industrial wastewater discharges (e.g., coke facilities). Although there are no national water quality criteria for fluoride, some states have developed fluoride criteria based on small data sets. In developing site-specific fluoride criteria for an industrial effluent, acute and chronic toxicity data were developed for organisms occupying various trophic levels. Organisms tested were an aquatic snail (Physa sp.), midge larvae (*Chironomus tentans*), the fathead minnow (*Pimephales promelas*), and an aquatic worm (*Lumbriculus variegatus*).

Mean acute toxicity levels ranged from approximately 100 to 200 mg/L total fluoride for these organisms. Seven day and 28 day chronic toxicity levels to the fathead minnow ranged from 64 to 95 mg/L, indicating a low Acute to Chronic Ratio (ACR) for fluoride. Using the expanded database, the revised state water quality criteria for fluoride indicated that acute and chronic total fluoride criteria of less than 4 mg/L and less than 12 mg/L, respectively, should be protective of a wide range of aquatic life.

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IDENTIFICATION AND CONTROL OF FISH PATHOGENS IN INDUSTRIAL EFFLUENTS

Teri Horsley*, Richard Lockwood[1], Liza Heise, and Scott Hall

Data from studies with fathead minnows on two industrial effluents were compiled to characterize effluent pathogenicity and evaluate potential full-scale treatment options. As observed by other investigators, our testing confirmed in the test effluents that fish pathogens typically exhibit several characteristics including high intra-replicate variability and a lack of sublethal effects. Severe cases exhibited acute mortality and filamentous growths from fish gills. Techniques for confirming pathogenicity were examination of fish gills, selective culturing of potential pathogens on various media, and re-infection studies. The likely responsible pathogens were filamentous iron bacteria and opportunistic fungi. Treatments most consistently effective in controlling pathogens were 0.45 micron filtration, activated sludge, attached growth biological treatment and granular activated carbon. UV light, chlorination, coarse filtration, ozone, flocculation, and hydrogen peroxide were not consistently effective treatments. This is consistent with the problems associated with treating iron bacteria. Because the pathogens were typically associated with low COD/BOD wastewaters, attached-growth biological treatment was deemed the most feasible means of controlling effluent WET. However, in one state the pathogens were considered to be test interferences and laboratory sample filtration was allowed prior to assessing NPDES compliance for WET. Upcoming stream surveys will determine whether full-scale treatments must be implemented.

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PHARMACEUTICAL AND PERSONAL CARE PRODUCTS IN TENNESSEE WATER

Ching-Ping Yu[1], Bo Yang[1], Fu-Min Menn[2], Gary Salyer[2], and Kung-Hui Chu*[1, 2]

ABSTRACT

The presence of pharmaceuticals and personal care products (PPCPs) in our aquatic environment has recently gained public attention. A recent USGS survey of national reconnaissance of emerging contaminants in 138 US streams reported that 80% of surveyed streams (about 108 US streams) were contaminated with trace amount of PPCPs, including steroidal hormones, antimicrobial agent, stimulant, and many others compounds. However, among the streams surveyed, none of them is located in the State of Tennessee, raising the question about the occurrence of PPCPs in Tennessee water.

The objective of this study is to provide environmental occurrence of PPCPs in East Tennessee water. Since domestic wastewater is one of major source of PPCPs entering receiving water bodies, this study will examine the presence of PPCPs in untreated and treated wastewater. Particularly, the variation of PPCP removal among wastewater treatment plants (WWTPs) using different biological treatment process (such as oxidation ditch, completely mixed nitrified activated sludge, and plug flow activated sludge system) will be examined. River water receiving treated wastewater is also collected and analyzed for analyzed for four different types of PPCPs: steroidal hormones (estrogens), antimicrobial agent (triclosan), stimulant (caffeine) and antidepressants (Prozac). The results of this study will be beneficial to public, regulatory agencies, and water utilities.

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BIORESTORATION OF A TCE-CONTAMINATED KARST AQUIFER BY STIMULATING SULFATE – REDUCING BACTERIA

Gregg Hileman[1], Koushik Chakraborti[2], and Tom D. Byl[1,2]

A sanitary landfill situated on a karst terrain in northern Tennessee has leaked chlorinated solvents, primarily trichloroethylene (TCE), into a karst aquifer. TCE has been found in water samples collected from eight wells screened in the karst bedrock aquifer. In July 2002, a mixture of dye, methyl-lactate, sodium lactate, molasses, and soymilk was initially injected into six of the eight wells to determine if the mixture would enhance biological reductive dechlorination of TCE. The mixture was later injected into a 7th well. Water samples were collected and electronic monitoring devices were placed in selected wells following injection to monitor changes in bacteria, geochemistry, TCE and breakdown products, and dye. After 8 months, there was an 85- to 100-percent decrease in TCE concentrations in the injection wells, and a 65- to 100-percent decrease in cDCE concentrations in six of the eight wells. Two wells showed an increase in cDCE as TCE degraded to cDCE. Concurrent with decreases in TCE and cDCE, there were 10-fold increases in sulfur-reducing bacteria & sulfide. No dissolved oxygen was found in any of the wells 1 week after the mixture was injected. Also, the lactic acid was metabolized into acetic acid after 4 months.

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HYDROLOGIC INVESTIGATION FOR THE GEOTECHNICAL REMEDIATION OF SINKHOLES BENEATH A POTABLE WATER SUPPLY IMPOUNDMENT, ALCOA, TENNESSEE

Barry F. Beck[1], Arthur J. Pettit, Ramona C. Josefczyk*[1], Jie Wang[1], and Wanfang Zhou[1]

As part of its water treatment process the City of Alcoa, Tennessee, operates a potable water impoundment on a hill above the Little River. During construction in 1991, and again in recent years, the 55 million-gallon-impoundment was compromised by sinkholes. The collapse of sinkholes correlates with discharge from a number of small springs downslope from the impoundment. The flow of five out of seven springs ceases when the impoundment is emptied. Following construction-induced sinkholes, an impermeable liner was installed, and the more recent sinkholes were plugged with low-slump grout, but new sinkholes continued to collapse.

The impoundment is located on the nose of a plunging anticline, with its core composed of Pumpkin Valley Shale and its outside strata of Rutledge Limestone. The sinkholes form in the overburden above the limestone, not the shale. A complete karst inventory, including infrared thermography to detect submerged springs in the river, was conducted in the vicinity. A quantitative dye trace was then conducted by injecting Rhodamine WT into an open sinkhole in the impoundment. Water samples were collected at seven small springs and several locations along the Little River and analyzed in the field using a Turner Designs Model 10-AU Fluorometer to establish breakthrough curves.

The data collected indicate that frequent, small karstic drainage paths have developed in the steeply sloping limestone. These small flow paths merge into a network that discharges 1-2 meters above the present river level: dye went to all springs almost simultaneously. A remedial strategy to grout the karstic flow network using a quick-setting high-fluid grout has been suggested. The approach is to allow the grout to flow into the discharge network and plug all paths without having adverse effects on the river and groundwater flow from other areas.

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USE OF RESIDENCE-TIME DISTRIBUTION COUPLED WITH A BIODEGRADATION RATE TO PREDICT TOLUENE REMOVAL IN AN ARTIFICIAL KARST SYSTEM

R. Painter*[1], V. Watson[1], and T. Byl[1,2]

Approximately 40% of the United States east of the Mississippi River is underlain by karst aquifers (Quinlan, 1989). Karst ground-water systems are extremely vulnerable to contamination; however, the fate and transport of contaminants in karst areas are poorly understood because of the complex hydraulic characteristics of karst aquifers. Ground-water models developed using Darcy's Law coupled to rates of biodegradation are useful for predicting the fate of fuels in unconsolidated aquifers, but have little utility in karst conduits. Conceptual models developed for karst aquifers have a consistent theme of non-ideal flow, storage and active flow components. This research used a residence-time distribution (RTD) model approach that integrated residence times of contaminants isolated in storage areas with the residence time of contaminants moving through conduits coupled to a pseudo-first order rate of biodegradation. The microcosms consisted of 4 1-liter chambers connected with small glass tubing. A peristaltic pump provided a consistent flow of karst water from a 10-gallon reservoir. First, a quantitative dye study was done to establish the residence time distribution of the three systems. This was followed by a sterile toluene run to measure sorption of toluene to the microcosm systems. The third microcosm run incorporated karst bacteria and toluene. There was good agreement between the predicted toluene concentration by the RTD model and the experimental data. Eighty-seven micrograms of toluene was injected into each system. Recovery in the sterile systems ranged from 62.6 ug to 84.6 ug, indicating that sorption was minimal. Recovery of toluene in the biotic systems ranged from 36.5 to 41.6 ug indicating biodegradation occurred. The mean residence-time distributions for the 3 systems were ranged from 40 to 43 hours. The RTD model predicted 44, 48 and 52% toluene biodegradation for the 3 systems, respectively. The biodegradation calculated from the experiments was 44, 48 and 50% respectively. Thus, the RTD coupled to a pre-determined biodegradation rate appears to accurately predict the amount of toluene that the bacteria will degrade.

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WATER RESOURCE EDUCATION AND RESEARCH AT THE UNIVERSITY OF MEMPHIS AND GROUND WATER INSTITUTE

Jerry L. Anderson, Ph.D., PE [1]

The University of Memphis Department of Civil Engineering offers courses with emphases in surface water and ground water hydraulics and hydrology. The program was developed to meet the diverse needs of the water resources community with the ground water emphasis being the youngest part of the program. The undergraduate program is offers traditional fluid mechanics courses but, the program is augmented with courses in hydrology. The main portion of the water resources program is taught at the graduate level. These courses and the program were designed with a strong component of river hydraulics in close coordination with the Corps of Engineers. To date a strong partnership exists with Corps of Engineer personnel who seek to pursue professional development through graduate course work.

The ground water program is focused through the GWI which operates as a research arm of the Herff College of Engineering. Courses in ground water hydraulics, contaminant fate and transport and numerical modeling are offered for those who seek an emphasis in ground water hydraulics and hydrology. Many of the courses are cross listed with the Department of Geological Sciences and a strong inter-disciplinary research atmosphere exists at the GWI.

The GWI was initiated in 1992 in response to a need for regional ground water management and research needs in West Tennessee. The GWI is funded primarily from grant and contract funds from research agencies and regional municipalities with interests in ground water research. The Herff College of Engineering provides funds for facilities and some administrative costs associated with the GWI. The GWI maintains a computational laboratory, a training laboratory and field equipment for ground water research, see ***Figures 1***, ***2***, and ***3***, respectively. Through research collaborations researchers from GWI have partnered with researchers at The University of Tennessee, the US Geological Survey, Millsaps College and The University of Utah. In the recent past, collaborative efforts have been established with the University of Mississippi and Arkansas State University. Current research at GWI is focused on better understanding recharge to the Memphis aquifer and the use of environmental tracers to better understand aquifer vulnerability.

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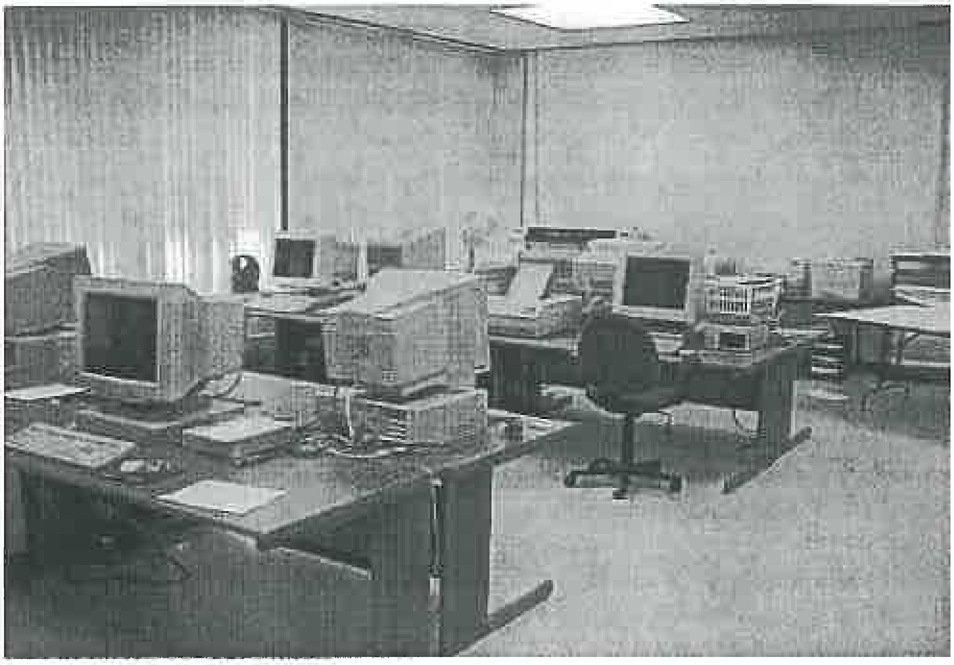

Figure 1. GWI computational Facilities.

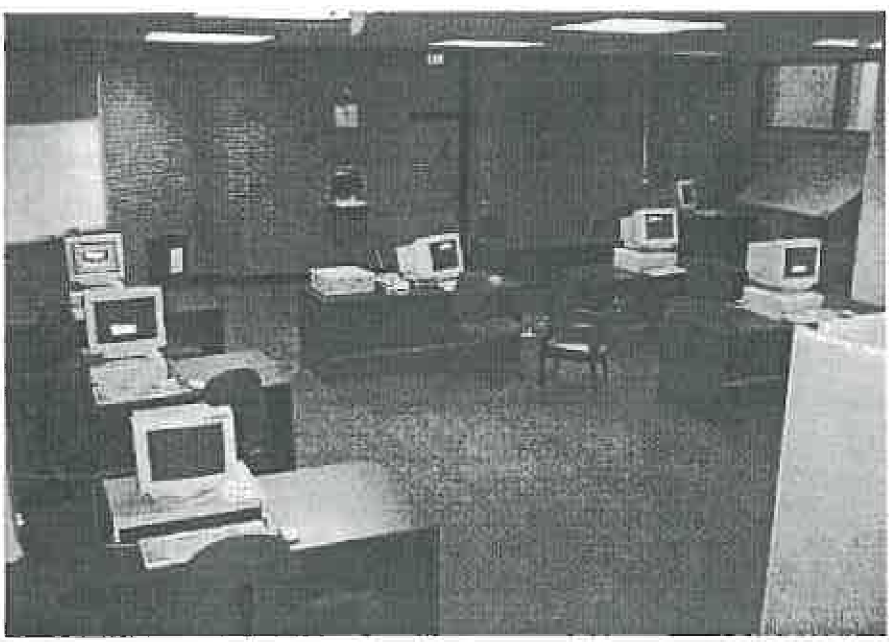

Figure 2. GWI training Facilities.

Figure 3. Robust GWI field equipment.

The GWI seeks to involve both undergraduate, to the greatest extent possible, and graduate students in active research projects. The involvement of undergraduate students allows the students to get a flavor for potential research and graduate school interests.

Close ties to regional collaborators and the water rich environment of west Tennessee offer and excellent opportunity for potential students to pursue water resources interests at The University of Memphis.

WATER RESOURCES ENGINEERING EDUCATION AND RESEARCH AT VANDERBILT UNIVERSITY

Eugene J. LeBoeuf, Ph.D., P.E.*[1]

Water resources engineers tackle complicated and challenging problems that have a major impact on individuals, communities, nations, and the world. The systems they design create and sustain the conditions that allow us to flourish and prosper. Whether the engineer is using smart materials in design of water resources structures, advanced information systems in water resources planning, or optimizing a water resources distribution system, the approach must ensure *reliability and risk management.*

MULTI-FACETED PROBLEMS - MULTIDISCIPLINARY TRAINING

Today's water resources engineers must draw on a wide range of disciplines to create the solutions needed for today's challenges. Whether they work within a private corporation, a public entity, or an academic setting, they will invariably work on multidisciplinary teams with other professionals from many different fields. Today's engineers must not only have a breadth and depth of expertise, but they must be able to communicate effectively, provide creative solutions with vision, and adapt to ever-changing demands.

BRIDGING DISCIPLINES - THE VANDERBILT EDGE

Building upon a foundation of engineering fundamentals, Vanderbilt is particularly strong in interdisciplinary training and research. Nowhere on campus is the commitment to an interdisciplinary approach stronger than in the School of Engineering. The Department of Civil and Environmental Engineering is home to the first National Science Foundation program in the world that integrates *reliability and risk management* education and research across many disciplines. The department also helps facilitate the Vanderbilt Center for Environmental Management Studies, which includes leadership of engineering and business faculty. These programs demonstrate the commitment to academic interdisciplinary research within the School of Engineering and throughout the University.

CUSTOM-BUILT CURRICULUM

In order to equip water resources engineers with the depth and breadth of expertise they will need in the future, the Department of Civil and Environmental Engineering helps students design an educational experience to fit their needs. All candidates receive a rigorous foundation in engineering science, advanced simulation approaches, statistical techniques, system analysis, data collection and interpretation, information management, and other areas critical to success today. They are also able to fine-tune their training, drawing on university-wide resources and partnerships with other institutions, national laboratories, research centers, government agencies, and industries. Our goal is to graduate engineers thoroughly grounded in engineering fundamentals, with the additional capability and flexibility to take on demanding leadership roles.

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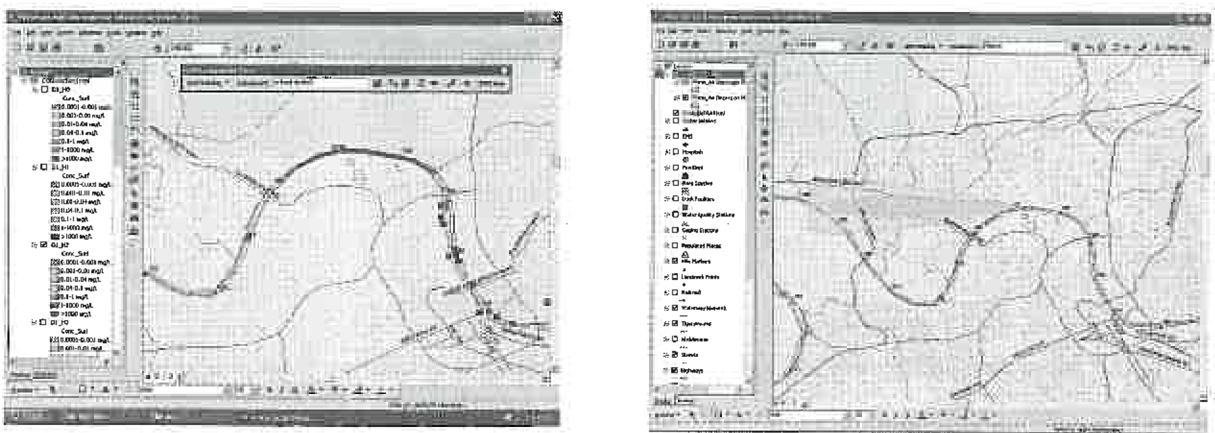
EXAMPLE RESEARCH ACTIVITIES

Numerous research opportunities provide students with a wide variety of research projects from which to participate or develop their own specific areas of interest. Following are two example research activities ongoing within our laboratories.

Development of a GIS-Based Spill Management Information System (SMIS). SMIS is a geographic information system (GIS)-based decision support system designed to effectively manage risks associated with accidental or intentional releases of a hazardous material into an inland waterway. Developed for the U.S. Army Corps of Engineers (USACE), SMIS provides critical planning and impact information to emergency responders in anticipation of or following such an incident.



(a) (b)

Figure 1. Example Contaminant Spill Migration on (a) Water; and (b) Air.

Tracking Sources of Indicator Bacteria in Davidson County Streams. Evaluation of the sources of bacteria exceeding State of Tennessee standards appearing in Davidson County streams necessitated the need to develop improved methods of multiple antibiotic resistance analysis (MARA) for bacteria source identification.

- MARA offers an inexpensive method for determining the source of bacteria in streams
- Databases based on *E. coli* and Fecal Streptococci correctly predict the source of isolates
- Additional data is needed to further refine classification of bacterial sources (to animal types).
- Method development is underway to streamline MARA assay

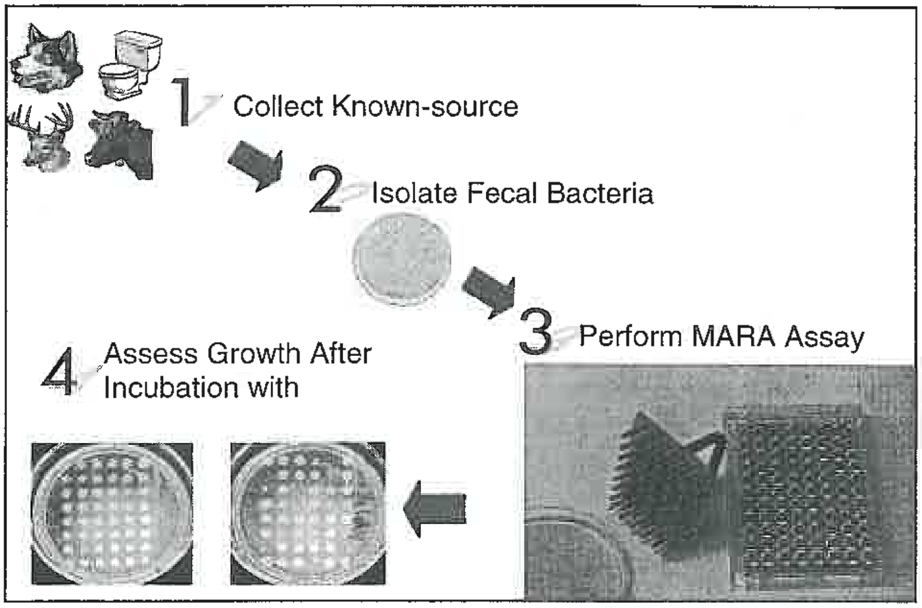


Figure 2. MARA Experimental Protocol.

DEGREE PROGRAMS

The department offers three degree programs, including two Masters-level programs and a Ph.D.-granting program.

- Master of Science: Two Options:
  - 30 Hours formal course work + Comprehensive Examination
  - 24 Hours formal course work + 6 hours of Thesis

- Master of Engineering: Oriented towards practicing professionals
  - 30 Hours formal course work + Project

- Ph.D.: Research terminal degree
  - 42 Hours of formal course work + Dissertation

WATER & ENVIRONMENT RESEARCH AND EDUCATION AT TENNESSEE TECHNOLOGICAL UNIVERSITY

Dennis B. George[1] and Vincent Neary [2]

INTRODUCTION

Education and research at Tennessee Technological University (TTU) have historically involved comprehensive management approaches or specific aspects of understanding the interrelationship between natural systems and anthropogenic activities. Educational and research opportunities at TTU provide students with the foundations needed for water resource management careers and for participation on interdisciplinary, comprehensive approaches to resource management.

Anthropogenic activities, particularly land-use changes, produce return flows that are altered physically, chemically, and biologically. Within watersheds and basins these altered flows often affect downstream uses and threaten biological diversity.

Comprehensive water resource management, which is most effective when conducted on a watershed- or basin-wide level, allows more accurate assessment of the impacts of land-use actions on downstream communities, natural resources, and ecological environments. Comprehensive resource management also requires interaction between water resource professionals and stakeholders, those who could be affected by proposed resource management changes.

To work effectively using comprehensive research management approaches, future water resource professionals earning their degrees at TTU and those involved in water-related research incorporate the following natural processes and systems.

- Hydrology (precipitation, surface runoff, infiltration, groundwater recharge, etc.)
- Hydraulics (surface and groundwater flow velocities, discharge, and hydraulic and energy grades)
- Morphology (sediment, erosion, transport, and deposition)
- Fate and transport of water quality components (organic matter, nitrogen species, phosphorus, pesticides, and herbicides, etc.)
- Eutrophication dynamics
- Aquatic ecological systems

EDUCATIONAL OPPORTUNITIES

Students gain valuable skills through their coursework, conduct research, participate on interdisciplinary teams, and present their work to their profession peers at conferences and in research journals. The multifaceted educational experiences they gain enhance their creative analytical capabilities, and as they assist their faculty mentors in advancing fundamental and applied engineering and scientific knowledge, they are transformed into professionals. This practical experience, coupled with formal instruction and personalized mentoring from nationally and internationally recognized faculty members, is in high demand on the job market.

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Coursework and opportunities to work on water management-related research projects prepare undergraduate and graduate civil engineering students for careers in resource management in a field that has shifted nationally a toward comprehensive management approach.

These courses and research opportunities provide students with the cognitive abilities and an appreciation for approaching comprehensive resource management issues in partnership with professionals from other disciplines. They give graduate students conducting research the skills to develop their research proposals, and to analyze and interpret results. Civil engineering students are provided with a strong foundation in hydraulic and hydrologic systems and processes. These and other available courses needed for approaching and integrating selected aspects of water resource management to be used in support of comprehensive management are listed below.

Hydraulic System and Processes Courses. *Hydraulics* deals with fundamental principles and design of water supply, storm water, and sanitary sewer systems and their components including pipes, pumps, storage facilities, detention basins, open channels, and culverts.

Open-channel Hydraulics deals with advanced topics in open-channel hydraulics, including design of hydraulic structures, gradually varied flow, unsteady flow, and flood routing techniques

Fluvial Hydraulics deals with fundamental principles, theories, and analytical methods applied in open-channel hydraulics, sediment transport mechanics, and fluvial morphology with applications in naturalized river design and restoration.

Hydrologic System and Processes Courses. *Engineering Hydrology* deals with fundamental processes in the hydrologic cycle including precipitation, infiltration, and runoff.

Quantitative Approaches in Engineering deals with estimating flows for a variety of design problems.

Water Resources Engineering deals with problems related to planning and designing systems for managing water resources for flood-damage reduction, hydropower, and river navigations.

Probabilistic Methods in Hydroscience deals with concepts of probabilistic approaches with an emphasis on hydroscience applications including the mathematical and statistical background for stochastic analysis.

Hydrogeology and Advanced Hydrogeology deal with the occurrence and movement of groundwater and well hydraulics.

Applied Geochemistry deals with applying the basic principles of geochemistry.

Biological and Chemical Fate and Transport Courses. *Environmental Microbiology* deals with the importance of microorganisms in the environment.

Limnology and Water Quality Aspects deals with the physiochemical and biological dynamics of inland waters.

Applied Environmental Chemistry deals with the theoretical concepts involved in the fate and transport of inorganic and organic compounds in the aquatic environment.

Natural System Engineering deals with the fate and transport of contaminants through wetlands, lagoons, and land application systems.

Numerous other courses that deal with biological and chemical fate and transport of natural resources are offered through the university's Ph.D. program in environmental sciences.

Data and Information Management Courses. *Environmental statistics* and *Advanced Environmental Statistics* deal with statistically analyzing highly dispersed, spatial and temporal data.

Vector-based Geographical Information Systems (GIS) and *Advanced Vector-based GIS* deal with managing and analyzing large, spatially distributed databases.

RESEARCH OPPORTUNITIES AND ACCOMPLISHMENTS

Research activities and classroom teaching are closely intertwined at TTU. As previously mentioned, researchers focus on pieces of a comprehensive management puzzle or explore management issues comprehensively. The following is a partial listing of current and historical water-related approaches TTU researcher have been involved in and are expanding into.

The following are among the project areas related to ***Assessment and Remediation of Anthropogenic Activities on Water Resources***.

Investigating parking lots, septic tanks, and landfills as potential point and nonpoint pollution sources causing low dissolved oxygen levels in 303D-listed waters

Evaluating the performance of storm water treatment technologies

Designing subsurface flow wetlands for removal of pesticides, nitrogen, and phosphorus from container nursery operations

Studying environmental markers adsorbed to soil as unique chemical signatures to specific land uses

Investigating treatment methods to reduce incidences of endocrine disrupting chemicals (ECDs) in water supplies. ECDs decrease immune functions, disrupt neurological development, disrupt sexual development and reproductive health, and cause cancer

Determining the toxicity of alum sludges wasted from drinking water treatment facilities on aquatic biological communities.

The following are among the project areas related to ***Ecological Assessment.***

Assessing functions of depressional wetlands based on hydrology, plant and animal ecology, and soil composition

Improving characterization efficiency of natural organic matter, particularly humic and fulvic acids, to determine how best to monitor these substances' interactions and to reduce disinfection by-product formation in water treatment

The following are among the project areas related to ***Hydrology and Hydraulics.***

Developing a hydrologic model, which uses spatial information such as elevation, land use and soil type, and radar precipitation data, to predict continuous rainfall events throughout a basin

Developing and evaluating continuous hydrologic models for real-time flood forecasting

Developing environmental hydraulics modeling to simulate the effects of vegetation on flows and transport processes

Developing a non-parametric statistical method that uses radar-rainfall data in several modeling applications to quantify the natural viability of rainfall in relation to radar gauge estimates

The following are among the project areas related to ***Aquatic Toxicology.***

Assessing recovery of benthic macroinvertebrate communities 10 years after mitigation of leachates that had resulted from highway construction in mountain rock formations

Testing freshwater fish survival and growth, and algal growth at various pH levels in waters receiving alum sludges from treatment plants

The following are among the project areas related to ***Holistic Watershed Management.***

Developing a user-friendly tool, which uses universally available data, for conceptual assessment of environmental and financial costs associated with changes in land and water resource management

Initiating a basin-wide, stakeholder-driven coalition that applies comprehensive water resource management approaches to achieve sustainable development and ongoing resource protection

CONCLUSION

Changing land use, population growth, and drought are causing mounting conflicts, especially in the southeastern United States, related to sustainable water quality and quantity, and economic growth that are similar to those already faced in the West. Educational and research opportunities at TTU produce graduates who are well prepared to address the challenging water resource issues facing our nation.

AN OVERVIEW OF WATER EDUCATION OPPORTUNITIES AT THE UNIVERSITY OF TENNESSEE-KNOXVILLE

David L. Feldman, Ph.D. *[1]

As the state's principal public research university and land grant institution, UT-Knoxville's opportunities for water-related education are both multiple and multi-disciplinary. This presentation provides an overview of those opportunities by considering three salient characteristics of water resources education at UT-Knoxville: 1) breadth – as well as depth – among a wide-range of scientific disciplines, including the physical, natural, engineering, biological, and social sciences; 2) unique opportunities for inter-disciplinary research and applied learning; and, 3) recent initiatives – often boosted by external funding – to collaborate with other institutions in the region and nation, particularly on policy-related problems.

Faculty and students in the basic physical, natural, engineering, and biological sciences have been involved in a range of water education issues related to surface and groundwater hydrology, water quality, environmental modeling, Geographic Information System development and use, land-water interface issues, and water resources management for decades. In addition to a broad range of courses in these areas, many of these efforts have been supplemented and enhanced by unique opportunities for inter-disciplinary learning afforded through – to cite a few organizations – the UT Institute of Agriculture; Agricultural Extension Service; Center for Environmental Biotechnology; Energy, Environment and Resources Center; Institute for Environmental Modeling; Tennessee Water Resources Research Center; and, Waste Management Research and Education Institute, among others. Opportunities for external funding, multi-disciplinary team building, and field research are among the strengths afforded undergraduate and graduate students through these institutes and inter-disciplinary initiatives.

Meanwhile, social science efforts in recent years have included opportunities to explore the behavioral basis for water use – and disagreements over that use; the sources of water resource conflicts; and the character of, and challenges facing, water law and policy. Recent initiatives, including the *Southeast Water Policy Initiative* and *Southeastern Water Resources Institute,* afford the potential for additional opportunities for water education through research, symposia, and conferences.

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SESSION 2B

WATER QUALITY ASSESSMENTS, #2
8:30 a.m. - 10:00 a.m.

Analysis of Water-Quality Data (1965-2002) for the Big South Fork National River and Recreational Area and Obed Wild and Scenic River
Gregory C. Johnson

A Hydrologic Investigation into the Occurrence and Causation of Pathogen Indicators in the Stock Creek Watershed, Knoxville, Tennessee
Randall W. Gentry, John McCarthy, Alice Layton, Larry McKay, and Shesh Koirala

A GIS Approach to Identifying Non-Point Source Pollution in an East Tennessee Watershed
Forbes Walker

MODELING WATER SYSTEMS
10:30 a.m. – 12:00 p.m.

Development of a 3-Dimensional Hydrodynamic Model for Boone Reservoir, TN
Brian J. Watson, J.M. Greenfield, and Christopher A. Goodrich

Duration and Frequency Analysis of Lowland Flooding in Western Murfreesboro, Rutherford County, Tennessee
George S. Law

Hydrologic Analysis Using GIS and HEC-1 Model
L. Yu Lin and Don Davenport

ASSESSING URBAN WATERSHEDS, #1
1:30 p.m. – 3:00 p.m.

Industries: Point Sources in a Non-Point World
Thomas B. Lawrence

Metro Nashville and Davidson County Aerial Infrared Sewer and Storm Water Line Inspection, 2003
Michael Hunt and William Bryant

Nonpoint Pollution Modeling in Small Urban Watershed
Peter Li

ASSESSING URBAN WATERSHEDS, #2
3:30 p.m. – 5:00 p.m.

Quantifying Organic Constituents of Urban Runoff in Murfreesboro, Tennessee: Potential Impact on Spring Water Chemistry
Rebecca R. James, Albert E. Ogden, and John P. DiVincenzo

The Effects of Carbonate Geology on Water Quality Land Use Linkages in Urban Watersheds-Knoxville, TN
Brooks A. Jolly

The Use of Aerial Infrared Thermography to Identify and Locate Discharges to Chattanooga Area Streams
J. Douglas Fritz

ANALYSIS OF WATER-QUALITY DATA (1965-2002) FOR THE BIG SOUTH FORK NATIONAL RIVER AND RECREATIONAL AREA AND OBED WILD AND SCENIC RIVER

Gregory C. Johnson*[1]

In 2002 and 2003, a retrospective analysis of historic water-quality data was conducted for the National Park Service for the Obed Wild and Scenic River in East Tennessee and for the Big South Fork National River and Recreational Area on the Tennessee-Kentucky border. Water-quality data from multiple agencies and databases were compiled for the period from 1965 to 2002. Water-quality data included concentrations of trace elements, major ions, nutrients, suspended sediment and bacteria, and physical properties such as pH and specific conductance. Although data from multiple agencies can be a challenge to interpret because of multiple detection limits, sampling designs, and periods of record, spatial patterns for selected water-quality constituents are evident for these watersheds. For instance, specific-conductance values and trace-element concentrations are two to three orders of magnitude greater and pH values are two to three ph units less in watersheds where minerals are extracted. In contrast, the spatial and temporal variation in suspended-sediment concentrations does not appear to reflect differences among either natural environmental setting or human activities in watersheds, but may reflect differences in sampling design among various monitoring programs. Temporal trends in concentration of selected constituents were evaluated for 25 sites in the Big South Fork and 12 sites in the Obed watershed where water-quality records were sufficient in length. Of these, four sites in the Big South Fork also had sufficient streamflow records to evaluate flow-weighted trends. From this analysis, the Big South Fork River near Stearns, Ky., showed significant decreasing flow-weighted trends in calcium, fluoride, and magnesium, and no trends in potassium, sodium, or silica concentrations.

This retrospective analysis will be used as a tool to design long-term water-quality monitoring programs for each park. Analysis of the spatial and temporal patterns will aid in determining sampling locations, as well as sample frequency, hydrologic regime, and constituents to be monitored. Improving coordination among various agencies and sampling programs will help to meet the needs data of numerous individual projects while providing a broader understanding of long-term environmental changes in the parks.

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A HYDROLOGIC INVESTIGATION INTO THE OCCURRENCE AND CAUSATION OF PATHOGEN INDICATORS IN THE STOCK CREEK WATERSHED, KNOXVILLE, TENNESSEE

Randall W. Gentry*[1], John McCarthy[2], Alice Layton[3], Larry McKay[4], and Shesh Koirala[5]

INTRODUCTION

An understanding of the transport mechanisms responsible for pathogens in a watershed is necessary before implementing TMDL or best management practices. The purpose of the research described herein is to evaluate land use practices in conjunction with the occurrence of *Escherichia coli* in a 303(d) designated stream (Stock Creek). This project in collaboration with other research efforts in Stock Creek has a focus on the use of specific qualitative and quantitative tools to assess *E. coli* and its presence with other specific fecal anaerobes that might be indicators of the source of the pathogens. In support of the *E. coli* source- and quantification tools, the research herein also identifies land use practices and possible travel times within a given watershed that could affect *E. coli* concentrations within the main channel. This research proposes an initial methodology for evaluating best management practices in a watershed. Correlations between hydrologic parameters, water quality and *E. coli* are being evaluated in order to examine the Stock Creek system and determines its behavioral response to watershed practices and hydrologic stresses.

METHODOLOGY AND RESULTS

The research team has collected samples for basic water chemistry, *E. coli* (using colilert and real-time PCR methods), and stream discharge during baseflow conditions. The watershed location and boundaries are shown in ***Figure 1***. The methodology for evaluation of pathogen occurrence and causation included a synoptic analysis. Identification of the specific sampling locations is shown in ***Figure 2***. The sampling locations were selected to provide analysis of potential correlations between hydrologic parameters, water quality and *E. coli*. The synoptic evaluation will aid in the examination of the Stock Creek system and determine its behavioral response to watershed practices and hydrologic stresses.

A summary of the *E. coli* data from April 2003 through November 2003 is provided in ***Table 1***. As an example, the spatial distribution of the *E. coli* for the August 13, 2003 sampling event is shown in ***Figure 3***. The data demonstrate a trend of increasing *E. coli* concentrations through the Fall of 2003. This likely due to observed changes in the cattle population and grazing activities associated with land management activities in the watershed.

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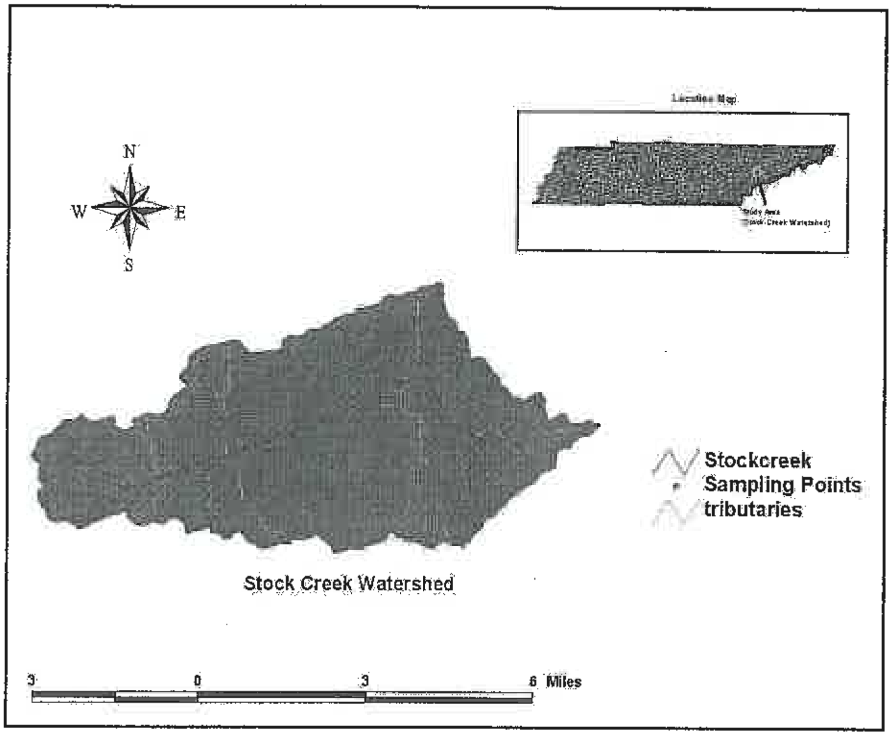

Figure 1. Site location map for the Stock Creek watershed.

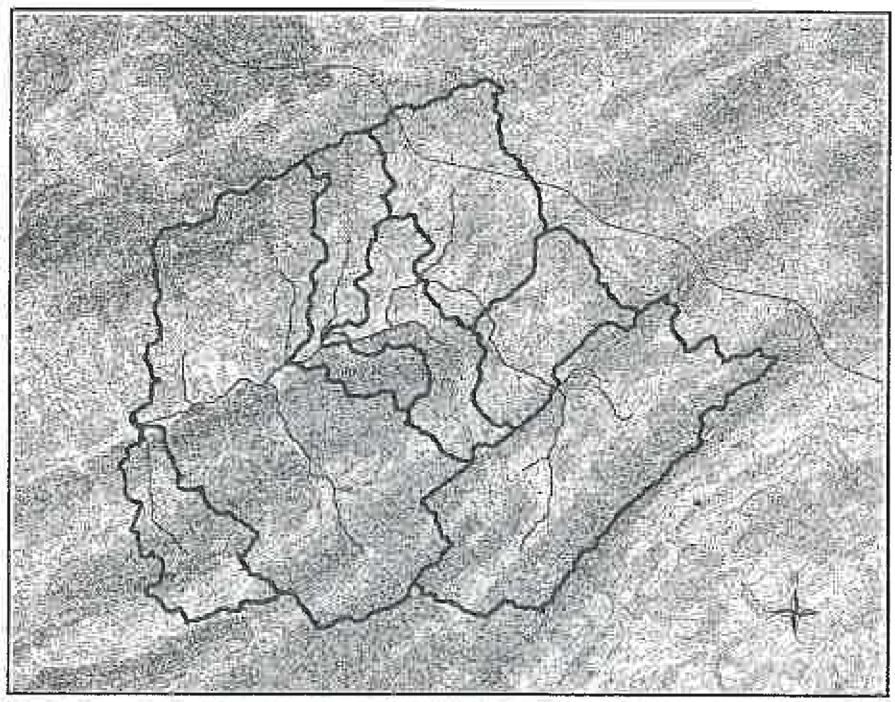

Figure 2. Sampling locations with associated drainage sub-basins in the Stock Creek watershed.

Table 1. *E. coli* concentrations summary for main channel sampling locations. (concentrations in CFU/100 ml)

Site	4/30/2003	6/4/2003	7/9/2003	8/13/2003	8/26/2003	9/16/2003	10/9/2003	10/30/2003	11/20/2003
SC-2	344	519	392	261	999	158	292	262	2350
SC-3	227	577	407	313	597	157	735	1190	1700
SC-4	162	665	304	281	163	171	1524	2500	1750
SC-5	403	1091	251	474	373	122	187	1540	1625
SC-6	197	284	527	116	323	317	225	798	1450
SC-7	76	69	136	120	202	103	122	18	810

Note: concentrations calculated from average of all analytical measurements.

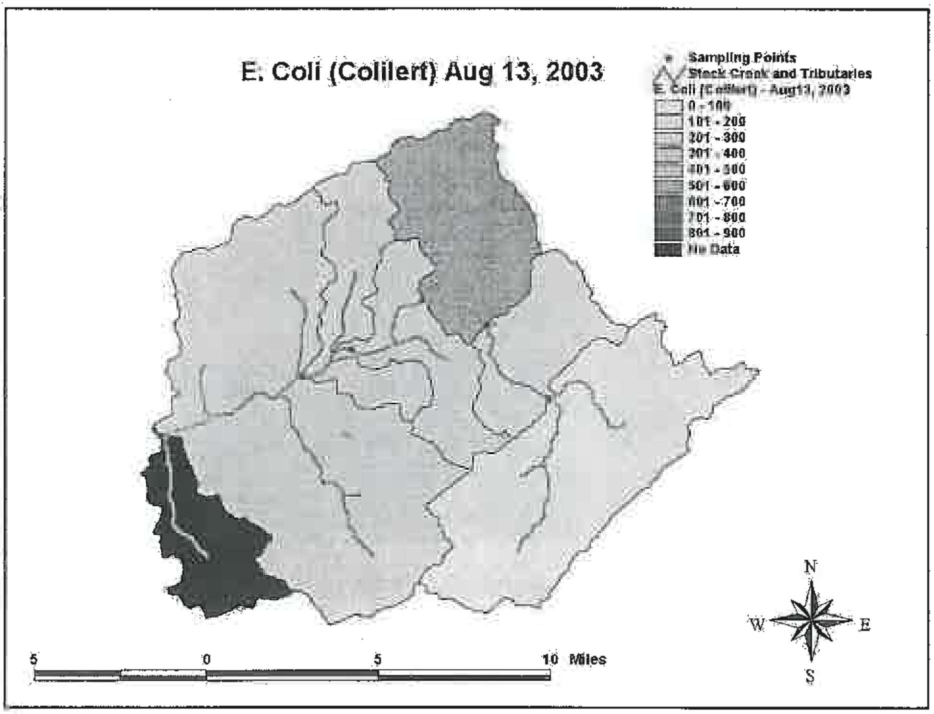

Figure 3. *E. coli* concentrations, as established by the Colilert method, associated with sub-basin drainage points.

Statistical analyses of the data are currently underway as a framework of describing *E. coli* occurrence at specific sampling locations and throughout the watershed. In addition, the correlation between certain hydrologic variables and *E. coli* concentrations are in progress.

DISCUSSION

The work being performed under the auspices of this project will provide a detailed analysis of pathogen behavior in the Stock Creek watershed. Currently work is being proposed to further the current synoptic evaluation to included detailed data related to frequency storm events. The outcomes of the project will allow technology transfer to the community that will result in a better understanding between stream response and land-use management.

ACKNOWLEDGEMENT

The researchers would like to express appreciation to Mr. Jonathan Burr with The Tennessee Department of Environment and Conservation. Mr. Burr helped with the selection of sampling sites and provided training on sampling techniques and equipment usage. In addition, the researchers would like to express appreciation to the Tennessee Department of Environment and Conservation's Knoxville Regional lab which provided sample analyses and sample bottles for the project.

A GIS APPROACH TO IDENTIFYING NON-POINT SOURCE POLLUTION IN AN EAST TENNESSEE WATERSHED

Forbes Walker*[1]

ABSTRACT

Non-point source pollution from agriculture is a major contributor to water quality impairments in Tennessee. Producers are encouraged to adopt best management practices (BMPs) that will reduce the impact of agricultural non-point sources on water quality. For beef and dairy producers recommended BMPs include improvements in manure handling, storage and application, the development of nutrient management plans, fencing to exclude or restrict cattle's access to surface water, the establishment of vegetative buffers and the provision of alternative watering systems. Many of these options are costly to install and maintain, and may have a limited impact or cost effectiveness on water quality.

In 2003, the University of Tennessee Agricultural Extension Service in collaboration with the Tennessee Valley Authority (TVA), the Tennessee Department of Agriculture (TDA) and the Environmental Protection Agency (EPA) initiated the Pond Creek watershed improvement project. Pond Creek is a small agricultural watershed typical of dairy and beef pasture systems in the "ridge and valley" region of east Tennessee. A detailed assessment of land use in the watershed was conducted based on the interpretation of color infrared photography and the revised universal soil loss equation (RUSLE) using the Integrated Pollutant Source Identification (IPSI) system developed by TVA. Analysis of this data suggests that overgrazed, poor and fair pastures, as well as row crops with low residue cover are significant contributors to the sediment, nitrogen and phosphorus loads in Pond Creek. This analysis is being used to target the implementation of BMPs for water quality improvement in the watershed.

BACKGROUND

The Pond Creek watershed (TN06010202013) in the Upper Tennessee Basin of Eastern Tennessee is small predominantly agricultural watershed covering approximately 23,579 acres. Agriculture in the Pond Creek watershed is typical of beef cow-calf and dairy systems in the Southeastern United States. Pond Creek is listed as on the 303(d) list of impaired streams in Tennessee for pathogens and nutrients. Dairy and beef cattle operations are the main agricultural activities in the watershed and are suspected to be responsible for much of the pollution.

In April 2003, with support from the Tennessee Valley Authority (TVA), Tennessee Department of Agriculture and the Environmental Protection Agency the University of Tennessee Agricultural Extension Service initiated a long-term project to improve water quality in Pond Creek. A long-term objective of this project is to implement cost-effective best management practices (BMPs) on dairy and beef operations in the watershed that will improve water quality. The identification of probable sources of the non-point source pollution in the watershed was important to determining the most effective BMPs for the watershed.

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METHODS

In collaboration with the TVA an inventory of the Pond Creek watershed was developed between June and September 2003. Low altitude, color, infrared photographs were taken of the watershed in March 2002, and were analyzed by TVA photo interpreters in May 2003. Land-use across the watershed was assigned to one of several general land-use classes; urban, agriculture, forestland, barren land, disturbed areas and water. Agricultural land use was further delineated into cropland and pasture (Table 1).

Table 1. Delineation of Agricultural Land Use in Pond Creek Inventory

Crop Land	Pasture
Row crop: no residue, (0 to 10%)	Good pasture: well maintained
Row crop: with residue, (>30%)	Fair pasture: uneven growth and condition, minimal maintenance
Row crop: Medium residue (10 to 30%)	Heavily overgrazed pasture
	Poor pasture: sparse cover, shallow soils, steep slopes, often gullies

The identification of potential sources of non-point source pollutants was made possible by assigning different USLE (Universal Soil Loss Equation) factors to the different land-use classifications. The factors selected were similar to those used for an IPSI analysis conducted in Blount county located in the same ecoregion (67f) as Pond Creek. The computed LS factors (slope length and steepness) corresponded to a 100ft slope between 8 and 10%. The R factor (rainfall) was assumed to be constant through the watershed. The K factors (soil erodibility) were based on the dominant soil types in the land use area. The cover or C factors used are summarized in Table 2.

Table 2. C Factors Used in USLE Analysis

Land Use	C Factor Used
Row crop: no residue, (0 to 10%)	0.551
Row crop: with residue, (>30%)	0.149
Row crop: Medium residue (10 to 30%)	0.300
Fair pasture: uneven growth and condition, minimal maintenance	0.015
Heavily overgrazed pasture	0.200
Poor pasture: sparse cover, shallow soils, steep slopes, often gullies	0.045
Good pasture: well maintained	0.003

Estimates of soil and erosion loss potential from each land-use class and sub-watershed were made using the Integrated Pollutant Source Identification (IPSI) model developed by the TVA.

RESULTS

The development of the watershed land-use inventory and GIS database and the use of the IPSI model facilitated the identification of major land-use across the watershed. Estimated general land-use acreages and agricultural land-use acreages across the watershed are summarized in Tables 3a and 3b.

Table 3a. Major Land Use Classes in Pond Creek

Land Use Class	Acres	Percentage
Residential	938.5	4.0
Commercial / Industrial	921.9	3.9
Agriculture	14,540.6	61.7
Forest	6,986.3	29.6
Open Water	192.0	0.8
Total	**23,579.3**	**100.0**

Table 3b. Agricultural Land Use Classes in Pond Creek

Land Use Class	Acres	Percentage of Total Watershed
High Residue Crops	649.4	2.8
Medium Residue Crops	541.5	2.3
Low Residue Crops	366.7	1.6
Good pasture	3362.1	14.3
Fair pasture	5898.1	25.0
Heavily Overgrazed Pasture	3512.5	14.9
Poor pasture	107.2	0.5
Feedlot Loafing Area	82.8	0.4
Total	**14,520.3**	**61.8**

Using the data and the estimated USLE factors for different the land uses in the watershed, it was possible to identify and map potential sources of non-point source pollution in the watershed (Table 4).

Table 4. Summary of Estimated Contribution of Sediment, Nitrogen and Phosphorus Loading from Agricultural Sources

Land Use	% Sediment Loads	% Nitrogen Loads	% Phosphorus Loads**
High Residue Crops	5.0	2.8	2.3
Medium Residue Crops	7.0	4.0	3.3
Low Residue Crops	10.1	5.8	4.7
Good pasture	0.5	0.3	0.2
Fair pasture	4.1	2.3	1.9
Heavily Overgrazed Pasture	39.3	22.4	18.4
Poor pasture	2.6	1.5	1.2
Feedlot Loafing Area	2.5	7.2	1.2
Total	**71.1**	**46.3**	**33.2**

** Estimate based on phosphorus lost from soil erosion only.

SUMMARY

Unimproved pasture (heavily overgrazed, fair and poor pasture) and low and medium residue crops were identified as major land-uses in the Pond Creek as well as major potential sources of non-point source pollution in the watershed. Future efforts in the watershed will be directed at pasture improvements (fertility, weed and herd management). It is hypothesized that improvements in pasture management will not only reduce the amount of soil erosion coming from pastures but also increase the ability of the pastures to trap and retain sediments and manure solids. Unlike many other BMPs recommended for beef cattle on pastures (fencing, riparian buffers and alternative water systems) the economics of pasture improvement through increases in pasture quantity and quality should be more attractive to farmers.

Low and medium residue crops include those field where conventional tillage methods continue to be used, and on silage-corn fields on dairy operations.

The use of the IPSI and USLE models are promising tools for more effectively selecting BMPs for water quality improvement by identifying potential sources of non-point pollution and estimating pollutant loading on a watershed scale. The selection and implementation of BMPs at a field scale require more detailed field-level assessment and site visits.

ACKNOWLEDGEMENTS

The author recognizes the following individuals and organizations for their assistance with this project: Mr. Tom McDonough, Mr. Gary Springston and Mr. Don Malone (Tennessee Valley Authority), Mr. Alan Jolly, (Geography Department) and Dr. George Smith (Department of Agricultural Economics), University of Tennessee, Knoxville. Funding for this project was made possible with support from the Tennessee Department of Agriculture Non-Point Source Program.

DEVELOPMENT OF A 3-DIMENSIONAL HYDRODYNAMIC MODEL FOR BOONE RESERVOIR, TN

Brian J. Watson*[1], J.M. Greenfield[2], and Christopher A. Goodrich[1]

Boone Reservoir is located on the South Holston River (RM 18.6) in the northeastern part of Tennessee, just south of Bristol, Tennessee. The reservoir is formed by Boone Dam, which impounds two major tributaries, the South Fork Holston and Watauga Rivers, approximately 1.4 miles below their confluence. Boone Reservoir is operated by the Tennessee Valley Authority (TVA) and is used for hydroelectric power generation, flood control, navigation flow augmentation, maintenance of downstream water quality, irrigation, industrial and municipal water supply, recreation and it serves as a prime habitat for fish and wildlife.

In order to address the diverse conditions within the Boone watershed, a system of models will be developed that provides the simulation of the overland flow and instream hydrodynamics. The system design will be such that all flow conditions experienced within the Boone Reservoir watershed can be simulated using one set of tools.

The Loading Simulation Program C++ (LSPC) is the watershed model that will be constructed to calculate runoff based on historic precipitation records. LSPC is a comprehensive data management and modeling system that simulates hydrodynamic and pollutant loading from nonpoint sources. LSPC utilizes the hydrologic core program of the Hydrologic Simulation Program FORTRAN (HSPF), with a custom interface of the Mining Data Analysis System (MDAS), with modifications for non-mining applications such as nutrient and pathogen modeling. LSPC will be calibrated to nearby USGS flow gages. Once calibrated, the hydrologic output from the watershed model will then be used as an input to an instream hydrodynamic model.

The Environmental Fluid Dynamics Code (EFDC) will be used for the 3-dimensional hydrodynamic model. EFDC is a general purpose modeling package for simulating 1-D, 2-D, and 3-D flow and transport in surface water systems including rivers, lakes, estuaries, reservoirs, wetlands, and near shore to shelf-scale coastal regions. The EFDC model was originally developed at the Virginia Institute of Marine Science for estuarine and coastal applications, has been extensively tested and documented, and is considered public domain software (Hamrick, 1992). EFDC will be calibrated for water level, which is measured at the Boone Reservoir forebay, and temperature, which was measured at various instream stations.

The LSPC and EFDC models will be calibrated to data collected during the 1998 water year. One goal of the project is to create a system of models that adequately simulate the complex temperature dynamics that occur between the South Fork Holston and Watauga Rivers. Historical data shows that the South Fork Holston River is generally cooler than the Watauga River. This cooler water flows to the bottom of the Boone forebay and also moves up the bottom of the Watauga River. The warmer Watauga River flow inturn flows to the top of the Boone forebay and moves up the South Fork Holston River.

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DURATION AND FREQUENCY ANALYSIS OF LOWLAND FLOODING IN WESTERN MURFREESBORO, RUTHERFORD COUNTY, TENNESSEE

George S. Law[1]

INTRODUCTION

From October 1998 through September 2000, the U.S. Geological Survey in cooperation with the City of Murfreesboro Planning and Engineering Department, conducted a hydrologic study to define flood-prone areas in the vicinity of North Thompson Lane and Manson Pike in western Murfreesboro, Rutherford County, Tennessee. The area contains numerous lowlands, sinkholes, and caves, many of which are part of the West Fork Stones River flood plain. The purpose of this study is to develop water-level duration and frequency relations, independent of overflow from the West Fork Stones River, for selected off-river lowlands, sinkholes, and wells. The frequency of off-river lowland flooding is then compared to flooding along the West Fork Stones River. These relations are used with water levels measured at other lowlands, sinkholes, and wells to develop a flood map of this area that illustrates flooding that is independent of direct overflow from the river.

A rain-producing cold front occurring during this study on January 23-24, 1999, produced water levels on the West Fork Stones River and in lowlands, sinkholes, and wells in the study area that were the highest measured during this study (October 1, 1998 through September 30, 2000). Flooding on the West Fork Stones River had a recurrence interval of almost 10 years for this storm. Water levels in off-river lowlands, sinkholes, and wells had recurrence intervals ranging from 1 to 4 years for this storm. Conditions similar to these are illustrated on the study-area map (fig. 1).

APPROACH

A data-collection network was installed to measure rainfall and water levels to delineate flood-prone lowlands and sinkholes in the study area. Stations in this network (fig. 1) were selected to provide a uniform coverage of hydrologic information describing rainfall amount and stormwater-drainage rates and to detect area-wide differences in the drainage characteristics of lowlands and sinkholes in the study area. Wells were measured to monitor the depth of the water table in the area. A 50-year record of daily-mean discharge was estimated for the West Fork Stones River at the old milldam at Manson Pike using published discharge data from nearby streamgages on the same river. Also, a 50-year record of daily rainfall amounts for Murfreesboro published by the National Weather Service (1948-1998) was available for use in this study.

Hydrologic data measured during the study and streamflow for the West Fork Stones River at the old milldam at Manson Pike were used to calibrate a nonlinear equation that could be used to simulate water-level response to hydrologic conditions at lowlands, sinkholes, caves, and wells throughout the study area. The calibrated water-level simulation equation was used with the 50-year records of streamflow and rainfall to produce a 50-year record of daily water levels at selected sites in the study area. Water-level duration and frequency relations could be defined for these sites using the long-term record of simulated water levels from the calibrated equation.

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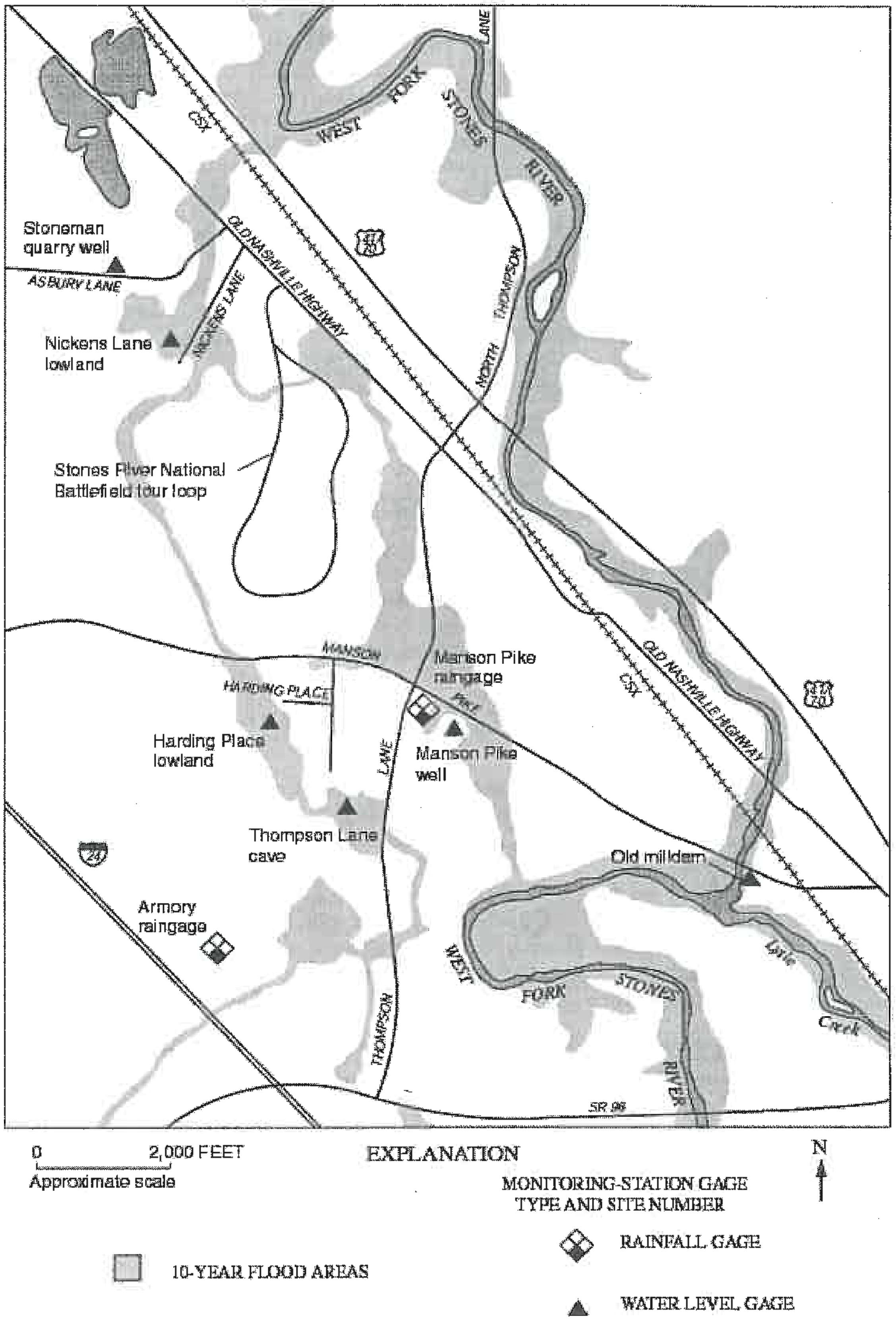

Figure 1. Gage sites and flood-prone areas, western Murfreesboro, Tennessee.

The basic form of the simulation equation can be expressed as:

$$\int H_t = 500 + \int h_t = 500 + \int [h_{t-1} - outflow_t + inflow_t], \qquad (1)$$

where

H_t	=	water level, in feet above the North American Vertical Datum of 1988 (NAVD 88), on day t,
500	=	a datum adjustment of incremental water levels to NAVD 88,
h_t	=	incremental water level, in feet, on day t,
h_{t-1}	=	incremental water level, in feet, on the previous day,
$outflow_t$	=	term to account for system abstractions and drainage, that is, interception and evapotranspiration, and ground-water outflow on day t; and
$inflow_t$	=	term to account for surface- and ground-water inflow on day t.

Eliminating the sea level adjustment and expanding the outflow and inflow terms in equation 1 to include independent variables and constants, the simulation equation can be expressed in numerical form as:

$$\sum_{t=1}^{n} h_t = \sum_{t=1}^{n} [h_{t-1} + \mathrm{D}(h_{t-1} - \mathrm{A}) + \mathrm{P}(rainfall_t) + \mathrm{Q}(discharge_t)], \qquad (2)$$

where

D	=	drainage constant,
A	=	abstraction constant,
P	=	rainfall response constant,
Q	=	river response constant,
$rainfall_t$	=	rainfall amount, in inches, on day t, and
$discharge_t$	=	daily mean river flow, in cubic feet per second (ft^3/s), for the West Fork Stones River at old milldam at Manson Pike on day t.

Equation 2 was used to simulate water-level response to hydrologic conditions in the study area. The dependent variable, water level on day t, was predicted using two independent variables: rainfall on day t and daily mean river flow on day t. The simulation equation was solved from day t=1 to day t=n, where n is the last day of water-level simulation at a site. The initial water level, h_0, was set to an initial elevation that is the starting elevation for the simulation equation. The initial water level was set to the minimum water level recorded at a continuously monitored site during the study. The period of continuous water-level monitoring at a site is the equation calibration period for that site.

DURATION AND FREQUENCY ANALYSIS OF LOWLAND FLOODING

A 50-year record of daily water levels was simulated for Manson Pike well, Thompson Lane cave, Harding Place lowland, Nickens Lane lowland, and Stoneman quarry well (fig. 1). These long-term records were developed using the calibrated simulation equation. Daily rainfall amounts for Murfreesboro published by the National Climatic Data Center (1948-1998) and estimated daily mean discharge for the West Fork Stones River at the old milldam at Manson Pike were the explanatory variables supplied to the simulation equation. A record of daily water levels was simulated for the period October 1, 1948 through September 30, 1998, from which water-level duration and frequency relations were developed for the modeled sites. The duration and frequency relations can be used with water-level data from periodically measured lowlands, sinkholes, and wells to describe flood-prone areas that are independent of widespread overflow from the West Fork Stones River.

Duration Analysis. Water-level duration curves illustrate the amount of time during a given year that the water level will be equaled or exceeded at a lowland, sinkhole, or well (fig. 2). The relations are defined by ranking the simulated water levels from smallest to largest and determining the percentage of time each water level was equaled or exceeded. Water-level duration data are used for studying drainage characteristics of lowlands, sinkholes, and wells and for comparing hydrologic characteristics of different parts of the study area. Water-level duration data do not represent probabilities and should not be used for prediction.

Duration curves for the monitored sites (fig. 2) and water levels measured at other sites in the study area indicate two areas have distinct stormwater drainage characteristics. Duration curves for the Manson Pike well, Thompson Lane cave, and Harding Place lowland have a linear shape, indicating slower, constant drainage rates. The curves for Nickens Lane lowland and Stoneman quarry well have exponential shapes, indicating faster, variable drainage rates in this part of the study area. Land east and south of the Stones River National Battlefield tour loop is slower draining than land west of the tour loop (fig. 1).

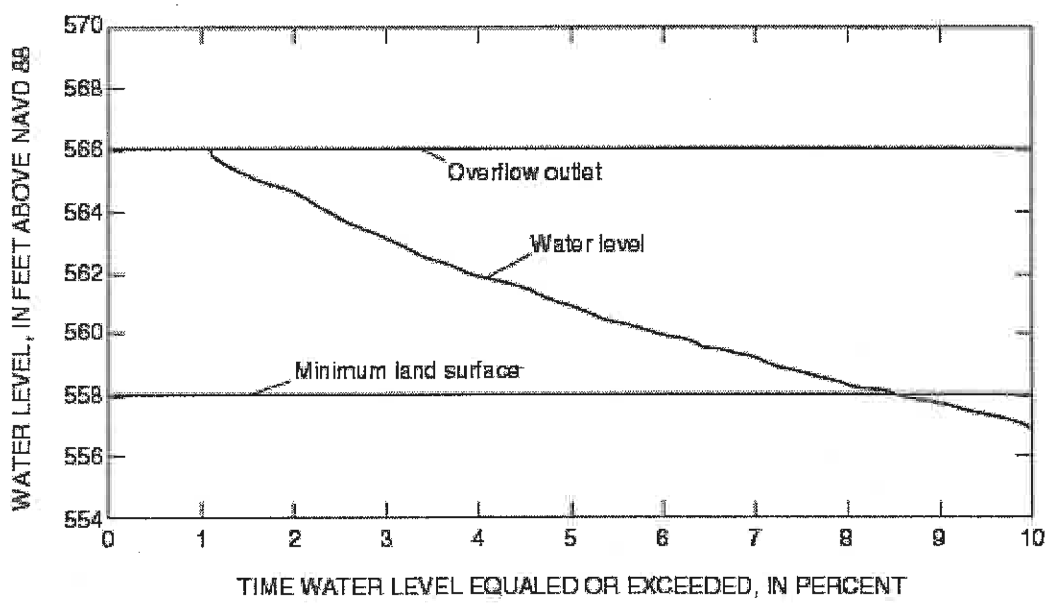

Figure 2. Water-level duration curve for Harding Place lowland, Murfreesboro, Tennessee.

Frequency Analysis. Water-level frequency at an off-river flood-prone area is described by a relation of water levels and corresponding recurrence intervals. Water-level frequency relations (fig. 3) for the continuously monitored sites were derived using the Weibull plotting position equation (Interagency Advisory Committee on Water Data, 1982). The frequency relations were developed from the 50-year record of simulated annual-peak water levels. Water-level recurrence intervals are determined by ranking the long-term annual-peak water levels from largest to smallest and using the Weibull plotting position equation to compute the recurrence interval for each observation:

$$\text{Recurrence interval (years)} = (n+1) / m. \qquad (3)$$

In equation 3, n is the number of annual peaks and *m* is the rank of a given peak when ordered from the largest to the smallest. For the highest peak water level, *m* is equal to 1. For the lowest peak water level, *m* is equal to n. In this study, n is equal to 50.

Water-level frequency curves for Manson Pike well, Thompson Lane cave, and Harding Place lowland show that the maximum water level, independent of overflow from the West Fork Stones River, will usually occur about once a year. The water-level frequency curve for Nickens Lane lowland indicates that the maximum water level which is independent of overflow from the West Fork Stones River will occur about once every 4 years. The Stoneman quarry well provides information about the fluctuation of the areawide ground-water table in the Asbury Lane and Old Nashville Highway area. The maximum water level observed in this well was measured on January 25, 1999. The recurrence interval of this water level is about 3.5 years.

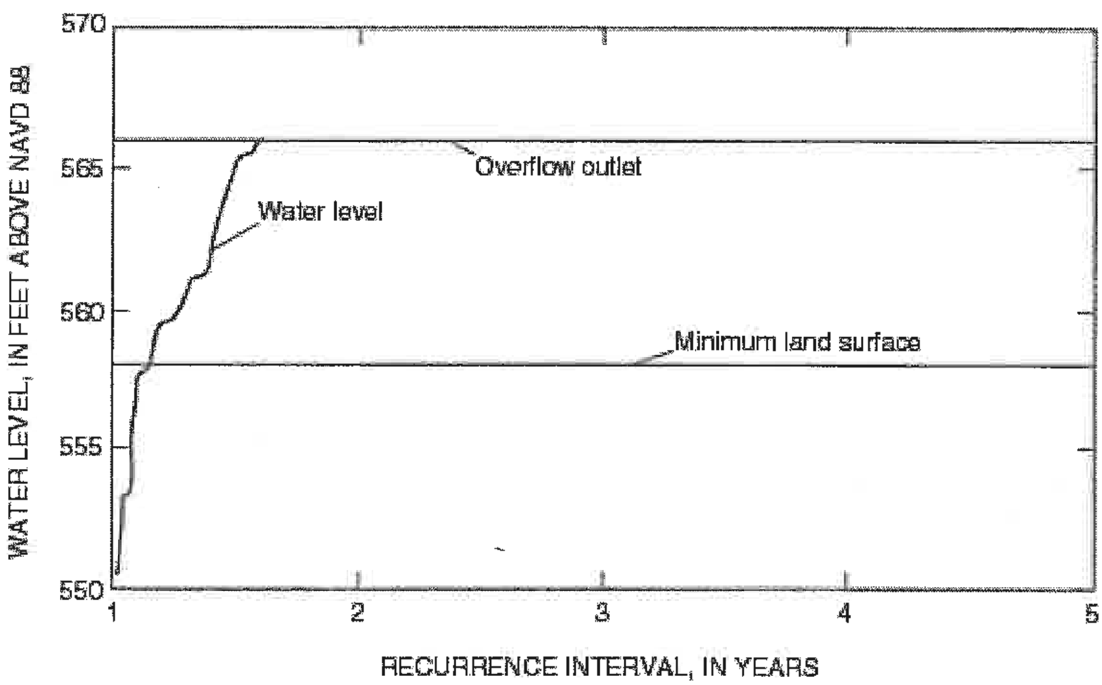

Figure 3. Water-level frequency curve for Harding Place lowland, Murfreesboro, Tennessee.

SUMMARY

The U.S. Geological Survey in cooperation with the City of Murfreesboro Planning and Engineering Department, conducted a hydrologic investigation of off-river flood-prone lowlands and sinkholes near the West Fork Stones River in western Murfreesboro, Tenn., from October 1998 to September 2000. Results of the study include a database of rainfall, water-level, and river discharge information for the study area. Water-level duration and frequency relations were developed for selected lowlands, sinkholes, and wells. An off-river flood-prone area map was developed by using 2-foot contour-interval maps of the study area. The map illustrates flooding that is independent of overflow from the West Fork Stones River.

Hydrologic data were used to develop and calibrate a water-level simulation equation at lowlands, sinkholes, and wells in the study area. The water-level simulation equation uses daily rainfall recorded at the study area and estimated daily-mean discharge for the West Fork Stones River at the old milldam at Manson Pike to estimate the water level at the continuously monitored sites Simulation equation constants were calibrated by using water levels observed at the continuously monitored sites during the period December 1998 through July 2000. The water-level simulation equation was used to simulate a 50-year record of water levels at these sites.

Water levels for the period October 1, 1948, through September 30, 1998, were calculated by using National Climatic Data Center rainfall records for Murfreesboro and estimated daily-mean discharge for the West Fork Stones River at the old milldam at Manson Pike. Water-level duration and frequency relations for the monitored sites were developed from these data. Maximum water levels in lowlands, sinkholes, and wells in the study area, independent of river flooding, can be expected every 1 to 4 years. A storm occurring during this study on January 23-24, 1999, produced off-river flooding having a recurrence interval of 1 to 4 years. Flooding on the West Fork Stones River had a recurrence interval of almost 10 years for this storm. Conditions similar to these are illustrated on the study-area map.

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HYDROLOGIC ANALYSIS USING GIS AND HEC-1 MODEL

L. Yu Lin*[1] and Don Davenport[2]

ABSTRACT

A hydrologic analysis was conducted in one of the fastest growing watersheds in the Memphis Metro area, the Horn Lake Creek Basins using Geographic Information Systems and HEC-1 model. According to urban land use criteria, the size of newly developed urban areas between 1997 and 2002 were identified and computed using ArcGIS (8.x). The percentages of urban area were then applied to calculate the lag time for Snyder's unit hydrology. In this study, a flood hydrograph computer program (HEC-1), developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, was designed to simulate the surface runoff responding to the increase in urban land use. The model consists of 108 sub-drainage basins and 25 routing reaches. The results indicate that the urban area in the Horn Lake Creek Basins increased significantly between 1997 and 2002 with an approximately 50% increase in the past five years. The increase of urban areas attributed to a significant amount of runoff in the basins. From the HEC-1 analysis, the runoff volume at the most critical areas has increased 14%, which may result in more floods and a rising flowline in Horn Lake Creek.

INTRODUCTION

The Horn Lake Creek Basins are located in northwestern DeSoto County, Mississippi, and adjoins the City of Memphis and Shelby County, Tennessee, along its northern boundaries. The total drainage area of the Horn Lake Creek Basins is approximately fifty-four square miles with the average slopes between 1.8 ft/mile to 5.9 ft/mile. The runoff in the basins mainly attributes to Horn Lake Creek, which eventually drains into the Mississippi River (in Figure 1).

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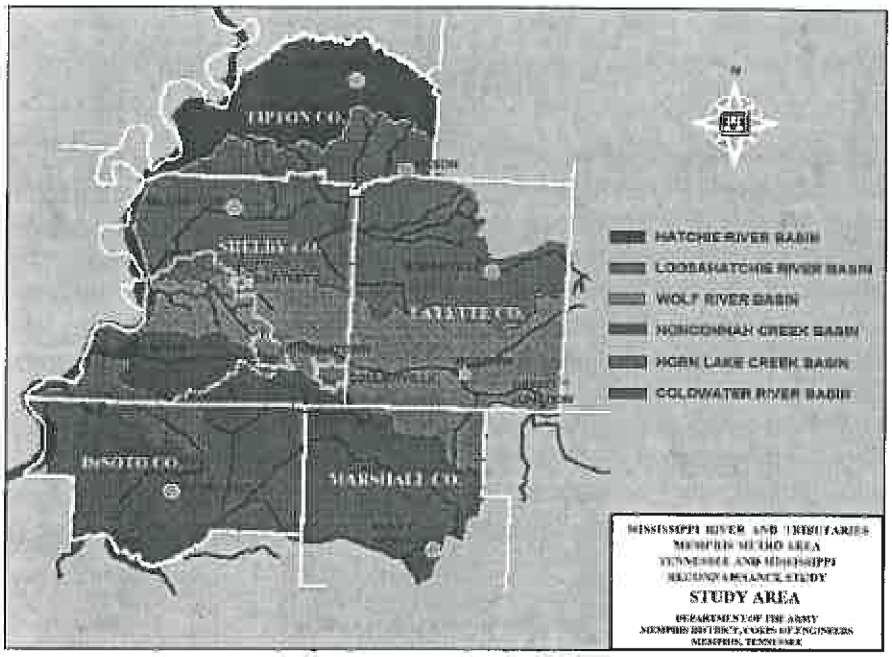

Figure 1: Horn Lake Creek Basin and Memphis Metro Study Area

Due to more urban development in the basins, the numbers of flood events have been reported in some areas. The U.S. Army Corps of Engineers conducted a comprehensive study in 1997, revealing that the existing stormwater facilities in the Horn Lake Creek Basins are inadequate to control stormwater runoff. It may result in widespread erosion and damage to current municipal stormwater facilities.

Since 1997, the Horn Lake Basins are still the fastest growing watersheds in the Memphis Metro area. More floods and stormwater management problems have been stated. Local business and residents urged the State and Federal Governments that remediation actions should be quickly taken in order to prevent more property losses. This study is to re-evaluate rainfall excess and to identify additional runoff produced during 1997 and 2002 because of urban development.

MATERIAL AND METHODS

Geographic Information System (GIS) is the computer tool to collect, store, retrieve, analyze and display geographical information. GIS has been used in supporting surface water modeling and flood analysis. Particularly, GIS provides functions for data storage, calculation of required input parameters, data manipulation, and output process (Greene and Cruise, 1995; and Boyle et al, 1998). This application has been used in various studies and shows very promising results. In this study, GIS was applied to determine hydrological parameters for Snyder's unit hydrograph. Methods to identify urban developed areas were conducted in ArcGIS (8.x). First of all, aerial photos were obtained from the Geospatial Branch at the U.S. Army Corps of Engineers, Memphis District. The photos were registered in the Mississippi State Plane. Because these photos and the basin map were registered in different coordinate systems, the ArcCatalog was then used to convert (or project) all aerial photos to the same coordinate systems as the basic map.

After the projection, the aerial photos were overlapped to the basin map, so that the newly developed urban areas were identified and obtained. Using Edit Tools in ArcMap, the urban areas in each subwatershed area were digitized. To update the new drawing urban areas, the following VBA statement was used to compute the polygon area:

```
Dim dblArea as double

Dim pArea as IArea

Set pArea = [shape]

dblArea = pArea.area
```

A hydrologic analysis was conducted using the Snyder unit hydrograph method. This method has been widely accepted at the U.S. Army Corps of Engineers to compute the discharge in the eastern region of the United States. The determination of lag time and the initial loss rate of the Snyder unit hydrograph (Chow, et al., 1988) are listed below:

$$T_p = C_t (L * L_{ca})^{0.3} \quad (1)$$

$$T_{pu} = Tp *(1/(1 + \% \text{ Urban Area}/100)) \quad (2)$$

$$L_i = \text{Initial Loss Rate} - 0.5 * \% \text{ Urban Area}/100 \quad (3)$$

$$L_u = \text{Uniform Loss Rate} - 0.05 * \% \text{Urban Area}/100 \quad (4)$$

Where Tpu is the lag time, hr

Ct is the coefficient constant ranging between 1.8 to 2.2

L is the centroid of watershed to the outlet, mile

Lca is the longest travel distance of the main channel to the outlet, mile

There are one hundred and eight sub-watersheds in the Horn Lake Creek Basins (in Figure 2). The rainfall excess generated from these sub-watersheds is directly or indirectly discharged into Horn Lake Creek. The HEC-1 hydrological model (USACE, 1990) based on the discharge relationship was prepared. The input data include basin runoff data, designed rainfall data, lag times, the initial loss rates, and channel routing data. For the flood simulation, the 1.01-year, 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, and 500-year design rainfalls were used. The data were obtained from the U.S. Department of Commerce TP-40 (USDOC, 1961).

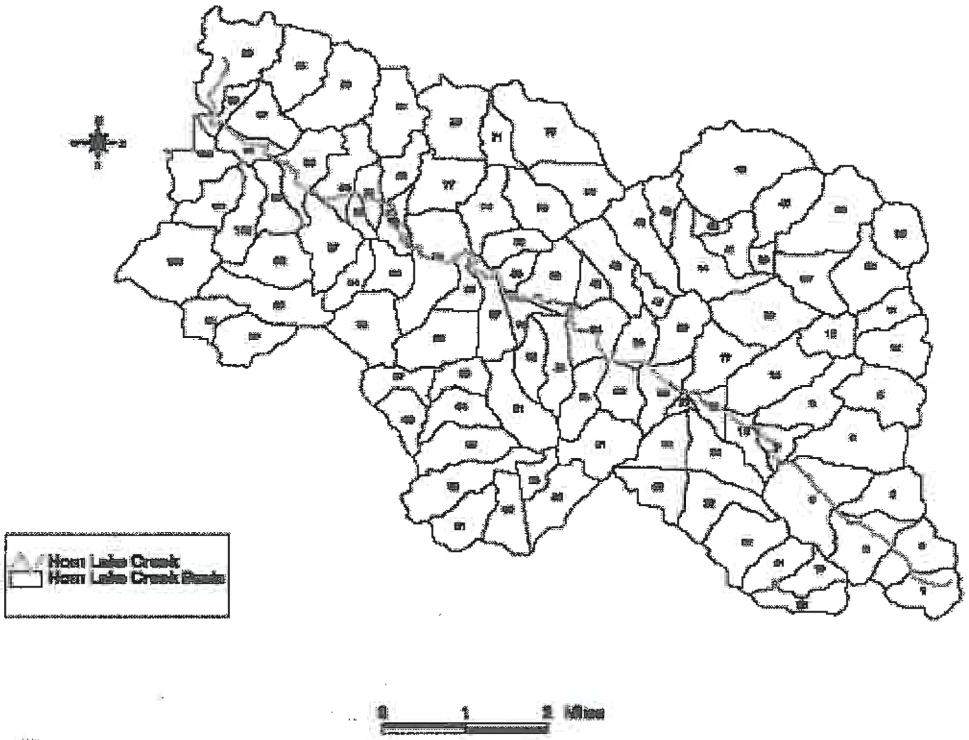

Figure 2: Subwatershed layout in Horn Lake Creek Basins

To perform channel routing, channel storage and discharge were required. There are twenty-five routing reaches in the floodplain of the study area. The channel data were obtained from field surveys and the HEC-2 model calibrations.

RESULTS AND CONCLUSIONS

ArcMap and Geodatabases in ArcGIS (8.x) (ESRI, 2003) were easily used to manipulate urban areas in the study watershed. After the basin map and aerial photos were overlapped, the urban areas were digitized and accurately computed in the tabular table. The results showed that urban areas in the Horn Lake Creek Basins increased between 1997 and 2002 from 11.22 sq miles (or 24%) to 16.31 sq miles (or 35%). Figure 3 indicates that the most concentrated urban development is at the center region and the northeast parts of the Horn Lake Creek Basins. There is also a trend that the urban development is moving to the southwest part of the watershed due to Casino business being extended in that area.

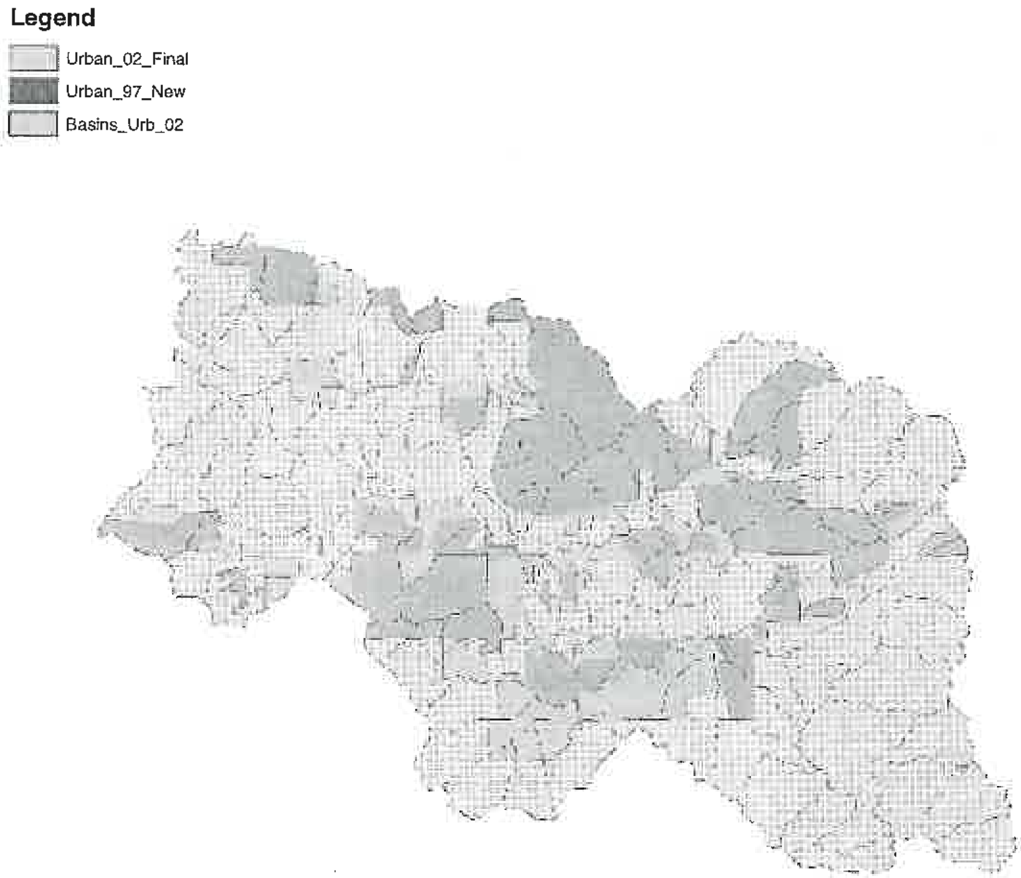

Figure 3: Comparison of Urban Area of 1997 and 2002 in Horn Lake Creek Basins

From the mapping and geodatabases, the geographic information system provides more accurate and promising results for this study.

Because urban areas in the Horn Lake Creek Basins have increased approximately 50% in the past five years, an increase in rainfall excesses and floods are expected. The most critical area was found in the downstream side of highly developed areas, such as subwatershed 67, 73 and 86. Table 1 shows the most critical subwatershed in the Horn Lake Creek Basins. It indicated that the peak discharges of the rainfall excess increased from 13% to 35% downstream of subwatershed 67 between 1997 and 2002. The most significant increase was found in the 1-year design rainfall.

In 1997, this area already experienced high water flowlines, approximate 2 feet in 100-year design flow. The higher the percentage of urban area is developed, the larger amount of discharge is expected in the Creek. As the urban areas continue increasing, more serious floods will occur. According to the Memphis Metro Study, the Horn Lake Creek Basins will be fully developed in 2020. At that time, over 99% of the watershed area will be used in business, commercial, institutional, or residential land, which may cause more flood damage. Although only 35% of the areas were developed in 2002, the developing rate will rapidly increase in the next eighteen years. In order to prevent hazardous floods or property damage in the study area, stormwater management or stormwater practice should be well prepared.

Table 1: Change of the Peak Discharge Flow at Sub Watershed 67

Project Design Flow (yr)	Discharge in 1997 (cfs)	Discharge in 2002 (cfs)	Difference
1	824	1116	35.44%
2	1805	2129	17.95%
5	2511	2845	13.30%
10	3005	3440	14.48%
25	3492	3985	14.12%
50	3924	4477	14.09%
100	4341	4945	13.91%
500	5313	6021	13.33%

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INDUSTRIES: POINT SOURCES IN A NON-POINT WORLD

Thomas B. Lawrence, P.E. *[1]

In the 30 years since the passage of the Clean Water Act, great strides have been made in addressing water pollution issues. However, testing of waterways in the 1980's revealed that water pollution still existed in many locations; it had been there all along, it was just masked by the previously large pollutant discharges from what became regulated point sources. At that time, the term 'non-point source' came into common usage to describe these pollutants, which were the result of activities over a relatively large area. In urban areas, 'non-point source' came to describe pollutants that were discharged by everyday activities from unregulated sources, such as homeowners and small businesses.

It is generally accepted that most water pollution in the US is now from non-point sources, not the traditional point sources. Public perception still has not changed. Although non-point source pollution prevention program regulations were implemented over 10 years ago, the public and the media still focus on industries and industrial type facilities as the sources, when asked to identify causes of water pollution.

It is important to educate the public about the true causes of water pollution, so that people will take actions eliminate activities that they may be involved in that cause pollution.

As part of its compliance with its storm water permit, the City of Memphis developed and implemented an industrial site sampling, inspection and education program to address discharges from industrial facilities. During the inspections and sampling, few issues outside of those commonly considered 'non-point source' were observed. The City of Memphis Industrial Inspection procedures and forms (see next pages) ensure that a thorough inspection of the industrial facilities is conducted, so that if any problems are present they are identified.

If there is a spill or an illicit discharge from an industrial source, it usually has the potential to be a big problem, though, due to the quantity and type of materials stored at the facility and the fact that an industrial spill usually results in media coverage, while a neighbor pouring their oil in the storm drain does not.

The result of the growing awareness by those in the environmental field of the relatively larger role that non-point sources have in causing water pollution is reflected in the storm water requirements in that industrial issues are a much smaller part of the requirements for Phase II than they were for Phase I. As part of their outreach efforts, storm water professionals often emphasize that individual actions can result in improving water quality. The City of Memphis industrial inspection program has shown that focusing efforts on the reduction of traditional non-point source pollutants should result in water quality improvements.

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[1] City of Memphis Public Works, 901-576-7122

FACILITY INSPECTIONS

1. Choose locations to visit.
2. Look in Storm Water Program industry files to see what inspections have occurred in the past and what correspondence has been sent and received. Other information about the company or type of business may be obtained from the Internet, TN Manufacturer's Directory or the Thomas Register.
3. Make Appointment. If the facility operator will not grant an appointment or refuses to let you see part of the facility, see "Appointment Denied" below.
4. Go to facility. Bring the following items:
   - Identification
   - Copy of Ordinance to leave at Facility
   - List of Opening Meeting Questions
   - Inspection Report for Facility
   - Safety Equipment
5. Meet with whoever handles environmental matters. Don't just meet with facilities manager if this is not the person who can implement changes. State reason for inspection and go over the questions and their Storm Water Pollution Prevention Plan (SWPPP) with them. This is Part IV of their Multi-Sector Permit.
6. Get map of the facility from the facility personnel showing, at a minimum, the following:
   - Structures
   - Paved areas
   - Chemical Storage/Processing Areas
   - Storm Water Flow
   - Facility outflow locations
   - Nearest storm drain inlet locations

   If map is not available, then draw one while touring facility.
7. Tour Facility with plant personnel.
8. Point out situations where operational or structural improvements could be made to improve storm water quality. Examples include:
   - Storing chemicals inside.
   - Installing a cover over outside storage areas.
     - Making sure that drains in loading and unloading areas do not drain directly to the storm drain. A preferred design would be a valve that remains closed during normal operations, but that could be opened to drain rainwater if needed.
   - Training employees about spill response and cleanup.
   - Making sure that all drains are connected to the proper system (sanitary sewer or storm drain) depending on what will flow into them.
   - Reducing the quantity or toxicity of chemicals that are needed for their process.
9. Write down comments during the inspection and discuss the comments with the facility operator. Discuss and try to agree on a timetable for getting necessary repairs or changes completed. Write down agreements and include with the inspection letter.
10. Offer to give them a copy of the Storm Water Ordinance.
11. Within 10 days of the inspection, follow up the inspection with a letter containing the deficiencies noted and the suggestions discussed.

City of Memphis
Division of Public Works
Storm Water Program
Industrial Facility Opening Meeting

ATTENDEE NAME	COMPANY/TITLE	PHONE

1. Verify name, title and phone number of primary contact.
2. What does the facility do or produce?
3. What are the basic raw materials?
4. What are the major manufacturing processes?
5. How many shifts do they operate?
6. How do they handle environmental issues on the 2nd and 3rd shifts?
7. How many storm water outfalls do they have?
8. Where are they located?
9. How often are they inspected and/or sampled?
10. Are there any roof drains?
11. How often do they inspect the roof?
12. How often do they clean the roof?
13. How many dumpsters do they have?
14. Are they covered? Plugged? Any materials on the ground around the dumpsters?
15. Do they have a SWPPP?
16. Do they have any tanks outside?
17. Do they have any external storage?
18. Do they have any detention ponds?

19. Do they conduct any monitoring?

20. Where are the fleet management areas (oil changes, truck washing)?

21. Where are the floor drains inside the facility? Are there plans showing if and where they connect to the sanitary sewer?

20. Are there any safety issues that you need to be aware of before you tour their facility?

21. You may have a need to take pictures. How can this be accomplished?

Records Review

Sampling results from Permit sampling (SWAT should have copies of results. If not, remind them that we are to be CC'd)

Spills within last 10 years. Fill out information below and show location on facility map.

WHEN	TYPE OF MATERIAL	QUANTITY	DID ANY LEAVE SITE?	HOW WAS IT CLEANED? WHO CERTIFIED IT CLEAN?

Any other areas of concern:

City of Memphis
Division of Public Works
Storm Water Program
Industrial Facility Inspection Report

Industry Name:	
Address:	
Contact Person:	Phone Number:
Storm Water Permit Number:	
SIC Number(s):	
City Basin Number(s) and Name(s):	
Date of Inspection:	

Reason For Visit:

Items to Investigate During Facility Tour

Areas Where Product or Materials Are Stored Outside
Areas Where Machinery Is Outside
Discoloration
Drains - Floor (Are interior floor drains connected to the sanitary sewer?)
Drains - Outside (What can enter them?, To which outfall do they connect?)
Dumpsters (Can liquids leak from dumpsters?, where does water drain?)
Erosion Potential
Illicit Discharges

Foam
Loading/Unloading Areas (In particular, check for how spills will be kept from entering the storm drain system)
Oil Sheens
Outfalls
Roof Drains
Signs of Chronic Discharges
Smells
Storm Water Detention Ponds (Number and Maintenance Condition)
Vegetation
Anything Else That Could Affect Storm Water Quality

Is Reinspection Necessary?	If So, When Is It Scheduled?

METRO NASHVILLE & DAVIDSON COUNTY AERIAL INFRARED SEWER AND STORM WATER LINE INSPECTION, 2003

Michael Hunt* and William Bryant[1]

INTRODUCTION

Metro has and continues to utilize various methods that aim to identify and eliminate sources of water pollution that adversely affect the quality of Davidson County streams and rivers. As part of this ongoing effort, Metro applied for and received a grant from the Tennessee Division of Water Pollution Control to utilize infrared "thermography" as part of several simultaneous pilot projects conducted across the State of Tennessee. Thermography (as used in this project) is a photographic procedure that involves taking aerial photos of stream segments using digital infrared cameras that can effectively and efficiently assist in the identification of leaking sanitary sewers and various other illicit discharges. To minimize light and foliage sight interferences and emphasize water temperature differences, these photos are usually acquired at night in the winter by an aircraft flying at 1,200 to 1,500 feet altitude. Illicit wastewater plumes discharging to land, conveyances, or directly into the stream segments are expected to have a somewhat elevated temperature compared to ambient flows that have been directly exposed to the environment for extended periods. These fugitive flows (although invisible to the naked eye) appear white on the infrared film and are identified and classified as "anomalies." Metro staff and their representatives investigated these anomalies, conducting sampling and source tracking in order to identify and eliminate any discovered illicit discharges.

APPROACH

During the evening and early morning hours of Feb. 8 and 9, 2003, four Nashville streams were the subject of an aerial infrared (IR) survey. Liquid from a leaking underground sewage or storm water line typically appears warm compared to the surface water in a creek, stream or river--particularly during cooler times of the year, due to the relative warmth of the ground a short distance below the surface. Leaks from nearby lines often come to the surface through lateral transfer to the creek bed or from slopes leading down to the water surface. These leak areas and the warm plume of liquid that join and flow downstream with the body of water are visible in the thermal infrared spectrum due to the temperature difference between the two flows. Late fall, winter and early spring are well suited to this type of inspection because of the heightened water temperature differential (ground and surface waters) and because sight interference by foliage is minimized. Ground water seeps and outfalls of many types are also easily distinguishable for similar reasons.

An aircraft with a thermal imager was flown following subject creeks in a manner that allowed each creek bed to be imaged and recorded on digital video tape. The video was annotated with GPS-derived information including date, time, altitude (MSL), groundspeed and ground track. In the cockpit, a moving map with the creeks highlighted permitted the crew to monitor their location with respect to the creek drainage to ensure complete coverage.

Once the flyover was complete, the infrared imagery was reviewed and images and locations of the thermal anomalies were captured from the GPS-encoded video tape. A map was then

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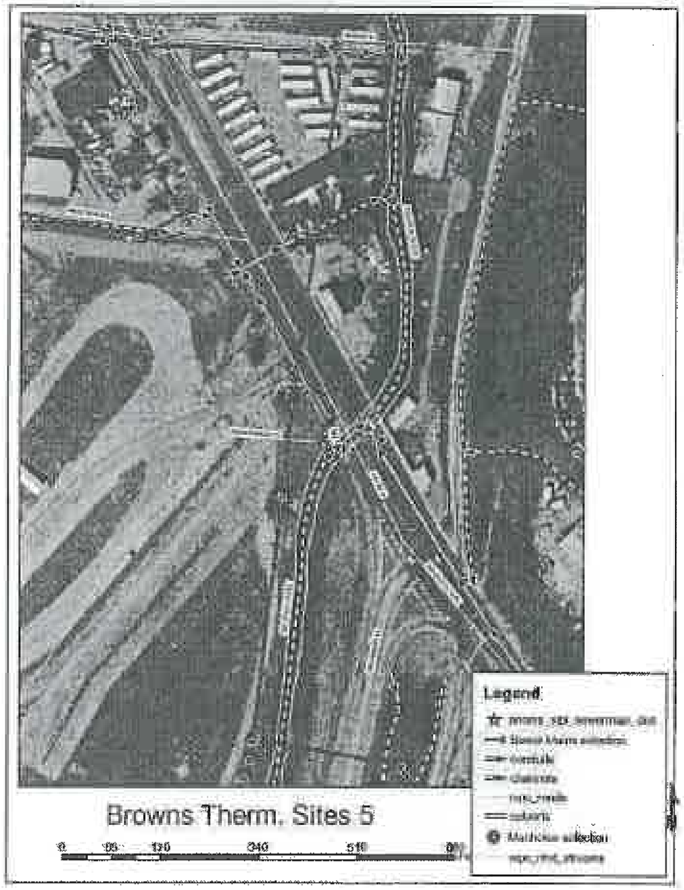
prepared by the interests performing the flyover, which showed the locations (see example, Figure 1) of the anomalies (as well as a textual list of the leak coordinates). The imagery and maps exhibited 162 anomalies for the approximately 41.83 stream miles of Davidson County creeks flown.

Richland Creek	(56 anomalies)
Brown's Creek	(13 anomalies)
Mill Creek	(69 anomalies)
Mansker's Creek	(24 anomalies)

Figure 1

Using GIS maps generated from the flyover (see example, Figure 2), Metro staff initiated the "ground truthing" phase of the process. This involved identifying a team of investigators, making the necessary sampling/analytical testing arrangements, and formulating an investigation process. Investigation teams were chosen based on their knowledge of the respective areas of Davidson County. These teams then did field investigations and sampling, where determined necessary. Observations and data gathered at the site was then considered per the problem resolution flow chart that had been formulated. This flow chart documented the standard process by which sites would be investigated, documentation of investigations, problem sites determined, who would be responsible for problem resolution based on inspection data, and the ultimate resolution status of each anomaly (or other issues evidenced during field investigations). The main anomaly categories were natural ground water seeps/spring flows, leaks/discharges, and anomalies found to be no longer flowing at the time of the field investigation. It should be noted that during field investigations, some additional questionable flows were found, which were added to the anomaly list. This resulted in a total of 212 (verses the 162 Thermograph anomalies) sites being investigated.

Figure 2



RESULTS AND DISCUSSION

In considering the possible outcomes of this project, the basic goals were to:

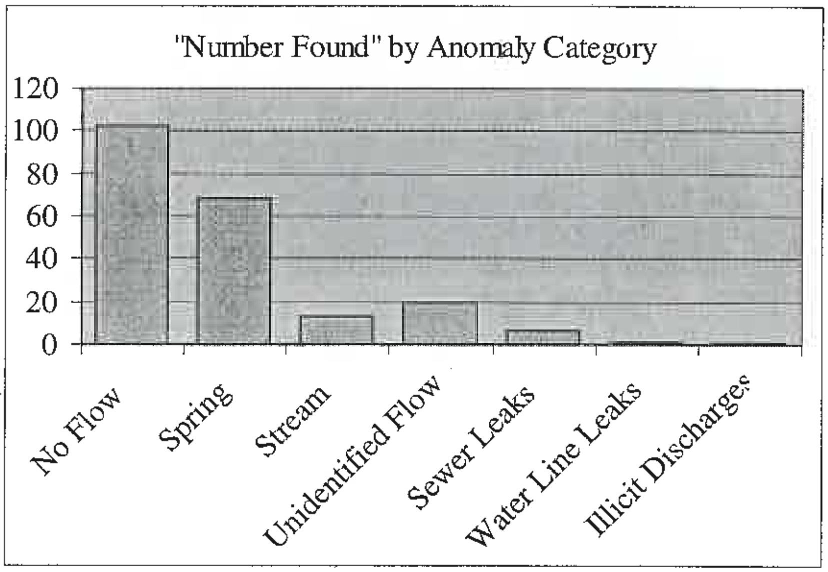
- gain overall experience using Infrared technology;
- gain some degree of proficiency in collecting and intrepeting Thermographic data;
- develop proficiency in generating GIS maps needed during the flyover and subsequent field investigations;
- identify and eliminate any illicit discharges discovered during the project;
- document the Project, to include "anomaly investigations";
- determine if this technology/method can provide long-term environmental and cost-effective benefits for Metro and, if so, formulate a strategy by which future Thermographic studies can be increasingly effective and efficient.

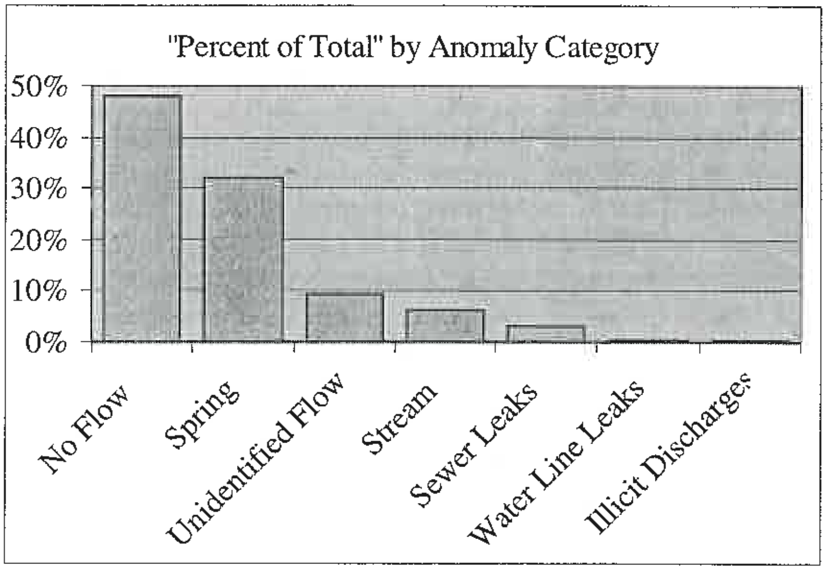
In considering the results of our field investigations of identified anomalies, it was somewhat disappointing from a staff resource expenditure perspective to find relatively few anomalies that were eventually identified as illicit discharges. Conversely from an environmental and remedial perspective, it was extemely encouraging to have identified so few illicit discharges. Data (Table 1) and charts (Charts 1 and 2) relating our categorical findings are shown below.

Table 1

Anomaly Category	Number Found	% of Total
No Flow	102	48.1%
Spring	68	32.1%
Unidentified Flow	20	9.4%
Stream	13	6.1%
Sewer Leaks	7	3.3%
Water Line Leaks	1	0.5%
Illicit Discharges	1	0.5%
Total=	212	13.7%

Charts 1 and 2





CONCLUSION

In considering the various project data and findings, Metro is optimistic that the Thermography technology holds promise in making periodic, widescale leak/discharge detection investigations in urban settings possible, while at the same time cost-effective. As Metro moves forward with additional Thermography projects in the future, the lessons learned by this initial flyover will be invaluable as we will be better able to consider such flight variables as time of flight (day, dusk, night, etc.), day of the week (weekday verses weekend), air temperature at the time of the flight, ambient water temperatures at the time of the flight, recent weather conditions, and visibility issues. All of these initial project experiences will serve to make Metro's ongoing oversight of its utility systems (sanitary sewer, storm sewer, and potable water lines) and NPDES-related water pollution control obligations within the community more effective.

NONPOINT POLLUTION MODELING IN SMALL URBAN WATERSHED

Peter Li, Ph.D.[1]

Pollution in surface water comes from rain water carrying agricultural pesticides, herbicides, fertilizers, toxic chemicals, animal wasters, industrial, construction, and transportation wastes into the streams. The urban development in a small watershed has influential impact on local watershed. This study concentrates on estimating pollution loading in a small watershed. The PLOAD program in BASINS was used for calculation. Impervious area of watershed was computed using aerial photos, land use data from local government, and TR-55. Impervious cover percentage ranges from 2% of agricultural area to 85% in commercial areas within the boundary of Cookeville. EMC (Event Mean Concentration) table for the local Results were calibrated using field measurements. The PLOAD calculated TP,DP, NOx, NH3, BOD, COD, TDS The study also presents maximum and minimum loadings of BMP and other alternative schemes were compared to show the difference in loading. Temporal variations are also presented. The findings from this study can serve as a reference for the health of local waterbodies. Maximum and minimum concentrations and loadings of each pollutant are computed and presented. The study identified the major sub-basins contributing pollutant loading into local streams. A GIS-rasterization process was implemented to show the transitional between sub-basins and the overall land use pattern correlating to the pollution loadings. The study provides a tool for management of small urban watershed and the prediction of pollution loading based on proposed BMP.

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QUANTIFYING ORGANIC CONSTITUENTS OF URBAN RUNOFF IN MURFREESBORO, TENNESSEE: POTENTIAL IMPACT ON SPRING WATER CHEMISTRY

Rebecca R. James[1], Albert E. Ogden, Ph.D.[2], and John P. DiVincenzo, Ph.D.[3]*

INTRODUCTION

Due to rapid urban growth, the Stones River Watershed is identified by the Tennessee Department of Environment and Conservation (TDEC) as an impacted watershed. The four springs in this study, Murfree, Oakland Mansion, Black Fox, and James, are located within the Upper Stones River Watershed. An earlier phase of the project delineated the recharge areas for the springs and assessed their water quality (Ogden et. al., 2003). This phase of the project involved sampling of stormwater runoff entering sinkholes that lead to the springs. Samples were taken during rainfall events and analyzed for both chemical oxygen demand (COD) and biochemical oxygen demand (BOD). In addition, oil and grease (O&G) and total petroleum hydrocarbons (TPH) were analyzed using EPA Method 1664.

STUDY AREA

Figure 1 shows the location of the two most urban springs, Murfree and Oakland Mansion. These two springs are within the Murfreesboro city limits. All four springs are located within Rutherford County. Dye tracing results are also shown on Figure 1. All stormwater runoff sampling occurred within the recharge areas of Murfree and Oakland Mansion springs.

MATERIALS AND METHODS

Conductivity was measured with a YSI Model 33 S-C-T Meter. The grab sampling technique (Standard Methods 1995) was employed, and the samples were preserved at 4 ± 1°C until taken to the laboratory for analysis. Standard Methods (1995) were used in measuring BOD_5, DO, and COD. DO levels were determined using a Winkler titration. The COD of the samples was determined by the Closed Reflux, Colorimetric Method. EPA Method 1664 (1999) was used to measure oil and grease (n-hexane extractable material). A solid phase extraction (SPE) approach was used as an alternative to the traditional liquid-liquid extraction. Water samples were passed through a hydrophobic adsorbent filter (47 mm, 3M Empore®, St. Paul, MN). The oil and grease components adhered to the filter and are then eluted using n-hexane (GC resolved grade, Fisher Scientific, Fair Lawn, NJ). Samples were subsequently dried and weighed for gravimetric determination. Each sample is then redissolved and treated with silica gel (100 – 200 mesh, Fisher Scientific, Fair Lawn, NJ). The more polar components of the mixture adhere to the silica gel, and the remainder is dried and weighed. This component is commonly referred to as total petroleum hydrocarbons (TPH).

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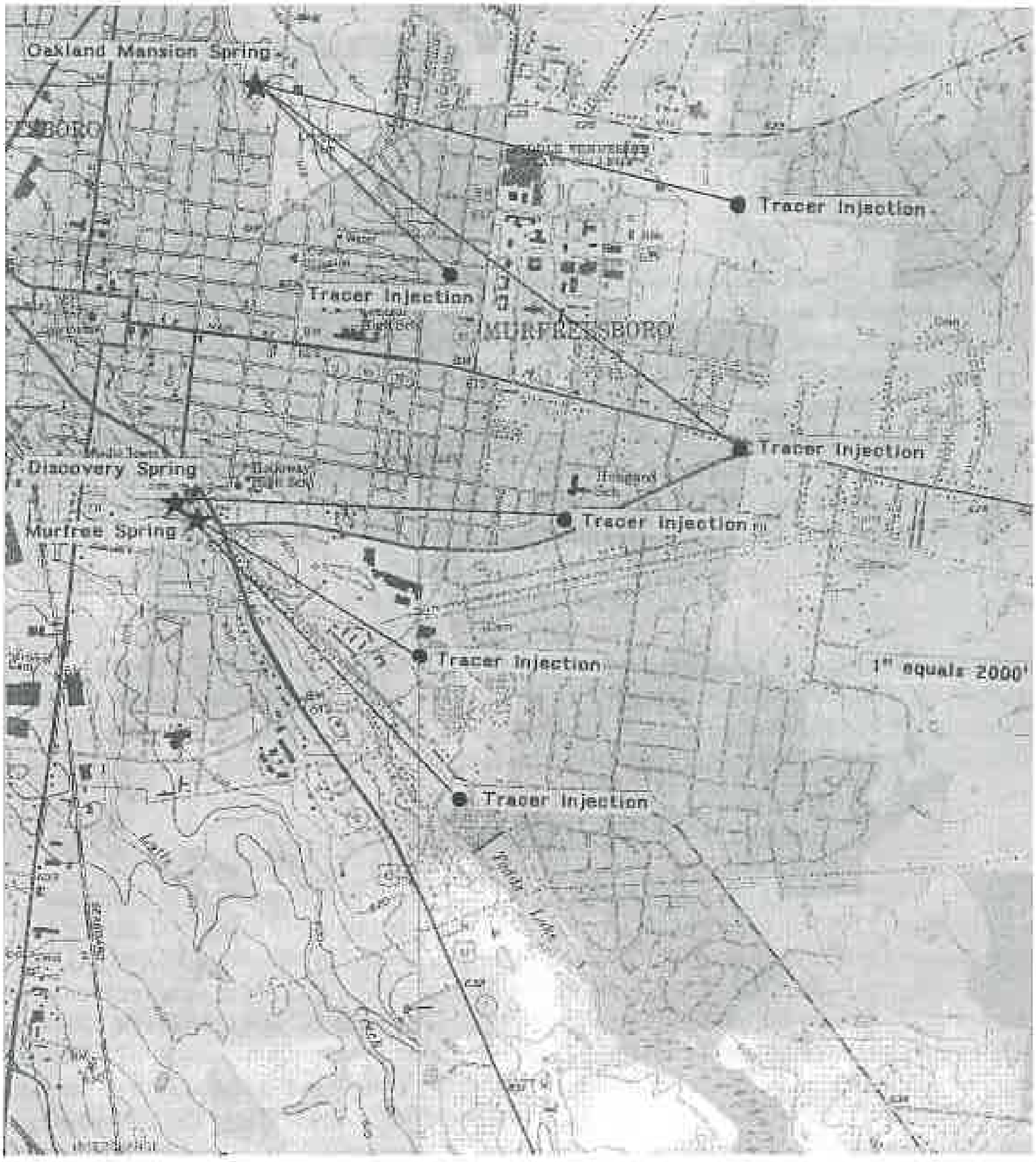

Figure 1. Dye injection points and tracing results for Murfree Spring and Oakland Mansion Spring.

RESULTS AND DISCUSSION

Coefficients of variation (CV) were calculated for both temperature and conductivity values on all four springs. Shuster and White (1971) were the first to use the CV of spring water quality parameters to distinguish open conduit flow from diffuse flow (no solution-enlarged fractures or cavities). Springs with high CV's, particularly of temperature, indicate open conduit flow from recharge points and thus greater potential to be polluted. Ogden and Rauch (1975) then found that springs with shallow open conduit flow and small drainage basins had greater CV's than large spring basins with deeper flow paths. Coefficients of variation for temperature range from 1 – 18 (Table 1).

Table 1. Coefficients of variation for temperature

Spring	$\bar{x}$	s	C. V.
Black Fox	15.4 °C	± 0.2	1.1
Guy James	14.3 °C	± 1.2	8.6
Murfree	15.5 °C	± 2.8	17.8
Oakland Mansion	16.4 °C	± 0.5	2.8

Murfree Spring, the most urban spring, shows the greatest variation in temperature with a C.V. of 17.8. The coefficients of variation for conductivity range from 7.9 – 17.1 (Table 2). Murfree Spring again has the highest coefficient of variation. These results suggest that Murfree spring is recharged by runoff flowing into sinkholes in close proximity to the spring.

Table 2. Coefficients of variation for conductivity

Spring	$\bar{x}$	s	C. V.
Black Fox	346 µS	± 46	13.4
Guy James	394 µS	± 45	11.3
Murfree	363 µS	± 62	17.1
Oakland Mansion	447 µS	± 35	7.9

Runoff samples collected within the Murfree Spring and Oakland Mansion Spring drainage basins had consistently high COD levels. These levels were substantially higher than for the spring samples, suggesting potential impact on the most urban studied springs which discharge into the Upper Stones River Watershed. All BOD levels were much lower than the corresponding COD values suggesting nonbiodegradable organics. Oil & grease extracted from the runoff samples ranged between 6 – 840 mg/L. Total petroleum hydrocarbons extracted from the runoff samples ranged between 5 – 277 mg/L. The largest concentration of TPH recovered (119 mg/L) from a runoff sample was collected within the Murfree Spring drainage basin. The largest concentration of TPH recovered from a runoff sample collected within the Oakland Mansion Spring drainage basin was 277 mg/L. Because the dye traces proved that the water collected within these drainage basins would reach the springs, a potential for the degradation of the springs' water quality exists. A summary of results appears in Table 3.

Table 3. Oil and grease, total petroleum hydrocarbons, and COD from Runoff

Runoff Sample Name	Chemical Oxygen Demand (mgO_2/L)	Oil and Grease Concentration (mg/L)	Total Petroleum Hydrocarbon Concentration (mg/L)
Impervious Surfaces			
MTSU Library	197	405	49
MTSU Library	46.8	53.6	22.3
Bell Street Lot	427	538	277
Super Sub	298	12.7	11.8
Blue Raider	643	840	26.5
Kroger Gas	147	309	119
Scarlett Commons	205	27.2	22.4
Super Sub	89.0	19.6	17.3
Kroger Drain	143	44.8	18.1
Clement Hall	133	27.0	17.4
Bell Street Lot	367	93.4	50.2
Super Sub	86.5	37.5	10.8
Drainage Ditches			
Roses	143	5.8	5.0
Fred's	205	60.7	NA
Bell Street Ditch	180	30.6	NA
Bell Street V	89.3	69.5	31.2
Fred's	39.3	56.4	30.3
Cemetery	137	18.1	17.4
Bell Street V	120	12.8	NA

CONCLUSIONS

A major source of pollution for the most urban springs, Murfree Spring and Oakland Mansion Spring, is runoff containing oil and grease from impervious surfaces such as parking lots and roads. This runoff often contains very high levels of petroleum contaminants and is a potential source of water quality degradation. These results can aid the Murfreesboro Stormwater Advisory Committee which is acting on a federal mandate to set guidelines for keeping contaminants out of stormwater. They can also be used to involve and educate the public.

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THE EFFECTS OF CARBONATE GEOLOGY ON WATER QUALITY LAND USE LINKAGES IN URBAN WATERSHEDS - KNOXVILLE, TN

Brooks A. Jolly[1]

Impervious surfaces accumulate pollutants derived from many sources, which are delivered into receiving streams through surface flow during storm events. Many watershed models use imperviousness as a key predictor of pollutant loads and imperviousness has been suggested as a tool for the quick assessment of water quality. Research in urbanized watersheds in Knoxville, TN suggests that geology may mitigate the impact of impervious surfaces. These studies indicate that urban pollutant loads are greatly reduced in catchments underlain by soluble carbonate geologic formations. A substantial amount of predicted runoff and the associated pollutant load from impervious surfaces not directly connected to the receiving stream was lost to subsurface flow, potentially reducing the impact of urbanization on surface water quality. Alkalinity, hardness, and specific conductance are indicators of water quality that are closely linked to geology. In natural waters alkalinity and hardness are functions of the geology and the amount of chemical weathering that takes place, and they generally vary in unison. Correlations between these three parameters can provide a non-specific indication of water quality by assessing the strength of their relationship. Ten stream sites in two Knoxville urban watersheds were sampled for alkalinity, hardness, and specific conductivity on at least 20 separate occasions. Expected relative water quality degradation for the sample sites was determined using pollutant loads, modeled using PLOAD, and total impervious area, estimated from land use. Geologic factors were then explored as a possible explanation for deviations in the predicted water quality and the observed water quality at sample sites.

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THE USE OF AERIAL INFRARED THERMOGRAPHY TO IDENTIFY AND LOCATE DISCHARGES TO CHATTANOOGA AREA STREAMS

J. Douglas Fritz*[1]

ABSTRACT

Infrared thermography, or thermal imaging, is utilized in detecting thermal differences in currents. This process is successful as temperature differences in the thermal plumes are easily visible when viewed in the infrared spectrum. The Chattanooga Public Work's Waste Resources Division and Stormwater Management conducted a collaborative pilot project to determine the effectiveness of utilizing aerial infrared thermography to identify and locate "anomalies" with a temperature variance to the receiving stream. An aircraft equipped with a thermal imager, digital video recorder and GPS equipment was flown parallel to sixty-seven miles of stream in Chattanooga. A total of 125 anomalies were identified on nine different streams. Field crews located the anomalies utilizing previously produced orthographic maps, topographic maps and hand-held GPS-units. Fifteen percent of the anomalies were found to be dry during the follow-up inspections while 10% could not be located. True location of anomalies varied from aircraft derived GPS locations by up to approximately 500-feet with several actually located outside the City limits. Anomalies with flow were sampled for potential contamination. The majority of the anomalies were determined to be "normal" discharges such as springs and seeps. Crews followed up on six sites with fecal coliform plate counts greater than 1,000cfus. Seven anomalies tested positive for the presence of chlorine. Six anomalies tested positive for detergents. Aerial infrared thermography proved to be an effective, time saving tool in detecting discharges to streams. However, the technology must be used in conjunction with other available technologies to be effective in locating and eliminating polluted discharges.

INTRODUCTION

This project is funded under an agreement with the Tennessee Department of Environment and Conservation, the Tennessee Department of Agriculture and the Environmental Protection Agency.

Infrared thermography, or thermal imaging, is utilized in detecting thermal differences in currents, as temperature differences in the plumes are easily visible when viewed through the infrared spectrum. This process also works in liquid, as plumes of warmer liquid are easily distinguishable from cooler bodies. This property could provide an opportunity for water resource professionals to locate sanitary seeps, failed septic tanks, illegal discharges, groundwater seeps and broken potable water sources to both improve surface water quality, as well as, direct limited operational and capital resources.

In the fall of 2002, Jordan, Jones and & Goulding, Inc. (JJG) approached the Chattanooga Waste Resources Division with an innovative approach to detect defects and leaks in an interceptor sanitary sewer that ran parallel to South Chickamauga Creek for approximately twenty-miles. An aircraft equipped with a thermal imager would fly along the creek in a manner that allows the creek bed to be imaged and recorded on digital videotape. The videotape is annotated with GPS-derived information including date, time and latitude and longitude coordinates of the plane. JJG

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would then groundtruth the located "anomalies" where temperature differences where detected to determine if the difference was due to sewer line leaks.

Chattanooga's multi-sector separate stormwater sewer system (MS4) NPDES permit requires that Chattanooga conduct inspections on "waters of the state" to eliminate illicit discharges. With over 520-miles of stream in Chattanooga and with limited resources, Stormwater Management proposed a coordinating pilot project to evaluate the effectiveness of aerial infrared thermography in detecting illicit discharges entering an additional forty-seven miles of "waters of the state." Stormwater crews would then locate individual anomalies, determine their source and work to eliminate any illicit discharges located as a result of the groundtruthing. In order to assist in this pilot project, Stormwater Management applied for and received a grant from the Tennessee Department of Environment and Conservation.

METHODS AND MATERIALS

Davis Aviation, Kent, OH, conducted an aerial infrared survey on approximately sixty-seven miles of Chattanooga streams on during the late evening and early morning hours of February 13 and 14, 2003 (Table I). The survey was conducted at night in the winter in order to maximize the temperature differences between the plumes and reduce interference from overhanging vegetation. The aircraft flew over the streams at altitudes ranging between 1,000 and 1, 500 feet above the existing terrain. During the survey, images and locations of the thermal anomalies were captured from a GPS-encoded videotape. Davis Aviation supplied the City of Chattanooga digital image files of the infrared images and printed maps indicating the approximately location of each anomaly.

Table I: Chattanooga Streams Surveyed by Aerial Infrared Thermography (Feb. 13-14, 2003)

Chattanooga Creek	Mackey Branch
Citico Creek	Mountain Creek
Dobb's Branch	North Chickamauga Creek
Friar Branch	South Chickamauga Creek
Lookout Creek	

The digital image file of each anomaly was compared to existing orthographic photographs to narrow the location search by pinpointing obvious land markers. Each anomaly was physically located in the field and GPS-located. When flow was present, Chattanooga Stormwater Management field crews conducted tests for detergents, chlorine, ph, dissolved oxygen, temperature and conductivity. Observations were made for sheen, color, odor and presence of oil. A sample was taken and sent to the Moccasin Bend Wastewater Treatment Plant laboratory for fecal coliform analysis. This process was repeated for each anomaly found along Chattanooga Creek, Citico Creek, Dobb's Branch, Lookout Creek, Mountain Creek and North Chickamauga Creek. JJG staff located anomalies along South Chickamauga Creek, Friar's Branch and Mackey Branch. When flow was present, JJG staff collected only a sample for fecal coliform analysis.

Stormwater crews conducted upstream source investigation and took follow-up fecal coliform samples on anomalies where the initial fecal coliform count exceeded 1,000 cfus including those found by JJG staff. Anomalies where the fecal count ranged between 500 and 1,000 cfus were placed on a watch list for future monitoring. All collected data was entered into a GIS-compatible database and mapped on the GIS system.

RESULTS AND DISCUSSION

Infrared imaging located a total of 125 anomalies on the roughly sixty-seven miles of flown stream (Figure 1). Crews spent an average of 3.9 man-hours locating each anomaly, which is much less time than would be needed to locate each anomaly without the infrared thermography. It is also probable that all anomalies would not have been found if the infrared technology had not been used. Crews relied heavily on pre-existing orthographic photographs to find landmarks to "close in" on anomalies shown by the infrared photographs. Anomalies were found to be as much as 500-feet away from where they were shown on the map provided by Davis Aviation. The latitude and longitude provided with each anomaly was that of the location of the plane when the picture was taken, not the location of the anomaly. Field crews had to interpret the infrared photograph for direction of the plan and work off the orthographic photograph to locate the anomaly. Without the existing orthographic photographs, considerable more time would be needed to locate the anomalies.

The greatest number of anomalies was found on South Chickamauga Creek followed by North Chickamauga Creek and Citico Creek (Figure 2). Dobb's Branch and Friar's Branch had the least number of total anomalies. The number of anomalies per stream was directly correlated with the total number of miles flown per stream (r=0.9).

When the total number anomalies per stream were compared to the number of flown miles per stream, Dobb's Branch and Citico Creek were found to have the most anomalies per mile while Friar's Branch and Mackey Branch were found to have the least number of anomalies per mile (Figure 3). There was little correlation (r=-0.2) between the total number of anomalies per individual stream and the number of anomalies per mile. This indicates that the proximity of the anomalies to one another is not based on the total number of anomalies on each stream or the number of miles flown per stream.

Stormwater Management personnel conducted groundtruthing on all streams except South Chickamauga Creek and Friar and Mackey Branches. JJG personnel conducted groundtruthing on those three creeks. Of the 125 anomalies, eight were found to be outside of the city limits, twelve could not be found and nineteen were dry. Six of the anomalies had fecal counts greater than 1,000 cfus; while four had counts between 500 and 1,000 cfus. Crews found positive chlorine readings on seven anomalies and six anomalies tested positive for detergents. Stormwater personnel conducted follow-up inspections and sampling on all sites where fecal coliform analysis exceeded 1,000 cfus.

Continued follow-up has found that one anomaly with high fecal counts has been eliminated and the fecal counts reduced an average of 85%. Fecal counts have dropped dramatically at one additional anomaly. One potable water line has been found and repaired based on the positive chlorine readings. There is some concern regarding the actual presence of detergents at the seven sites testing positive. It is possible that cross-contamination has provided false positive readings.

CONCLUSION

Aerial infrared thermography is an effective technology to locate discharges to streams. Its effectiveness is enhanced by the utilization of orthographic photographs that provide landmarks that reduce search times for field crews. The total number of anomalies per stream is directly related to the number of stream miles flown. However, there is little relation between the number of individual anomalies per mile and the total number of anomalies found on a stream.

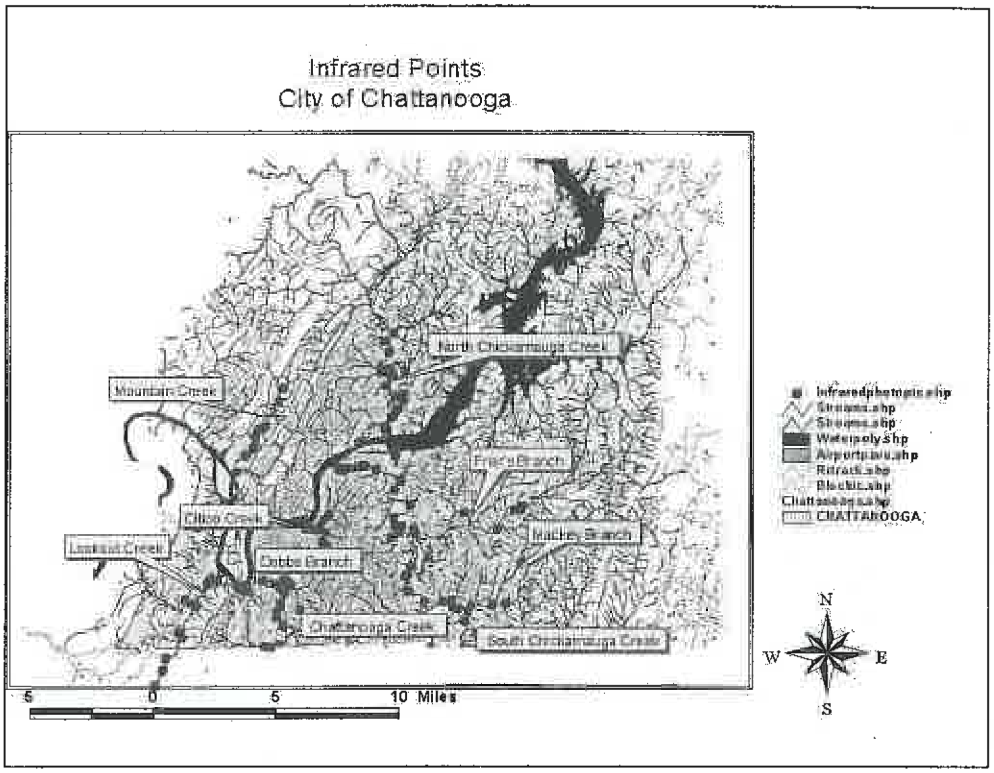

Figure 1: Location of Chattanooga streams located by aerial infrared photography on February 13-14, 2003.

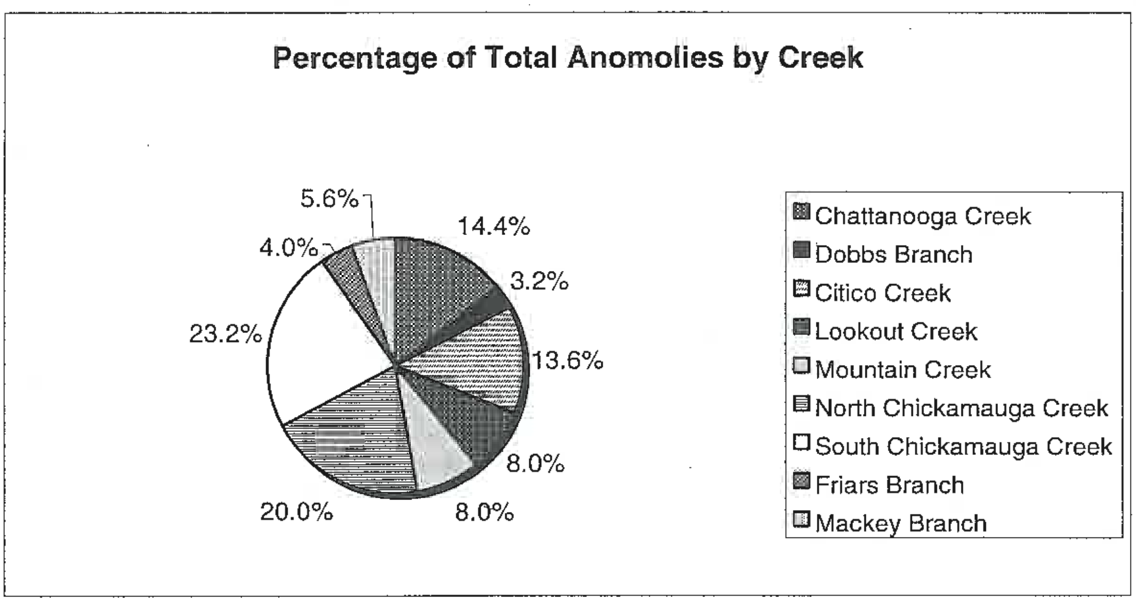

Figure 2: Percentage of total anomalies found on each Chattanooga stream.

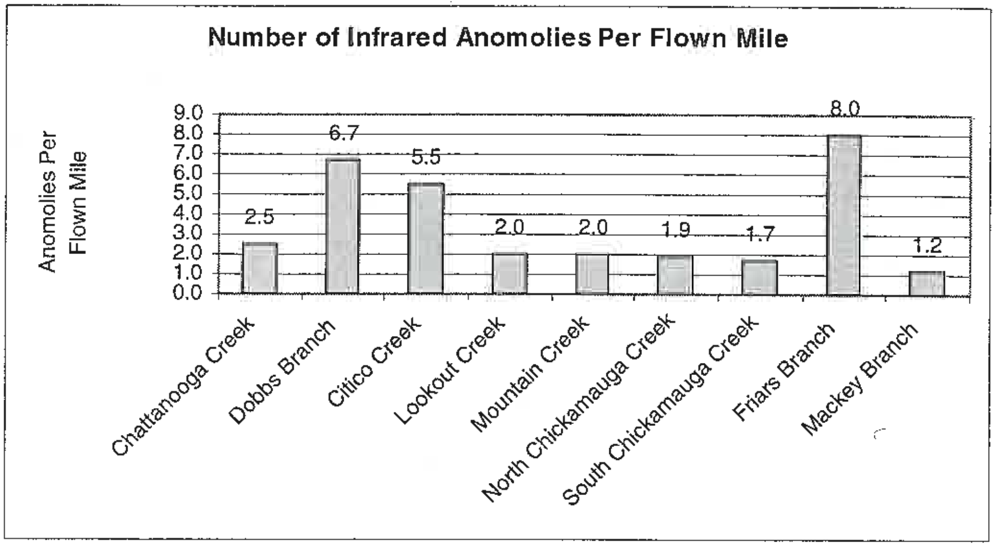

Figure 3: Average number of anomalies per flown mile located on Chattanooga streams

SESSION 2C

DECISION-MAKING TOOLS FOR WATER MANAGEMENT
8:30 a.m. - 10:00 a.m.

Consumptive Use of Water in the Tennessee River Watershed (paper was also presented as a poster)
Susan S. Hutson, Sidney E. Gibson, and M. Carolyn Koroa

Implementation of the Corps Water Management System (CWMS) in U.S. Army Corps of Engineers, Nashville District
William R. Barron, Jr.

Spill Management Information System for Inland Waterways
Edsel B. Daniel, Paul H. Martin, James E. Dobbins, Eugene J. LeBoeuf, and Mark D. Abkowitz

STRATEGIES FOR ENHANCING WATER QUALITY
10:30 a.m. - 12:00 p.m.

Advancements in Discrete Analysis for Environmental Testing
Karin Bogren

Initial Use of Probabilistic Monitoring Techniques in Tennessee
Gregory M. Denton

Water Quality Trading: A Cost-Effective Way to Improve Water Quality in Tennessee?
Christopher D. Clark, William M. Park, and Ernest F. Bazen

TECHNIQUES FOR FACILITATING MEANINGFUL CULTURAL CHANGE
1:30 p.m. - 3:00 p.m.

Catfish in the Mainstream: Social Marketing and Change
Karen Hargrove

Two Simple Physical Models for Classroom Instruction of Hydrologic Concepts
Robert L. Hunt

Using Internet Mapping for Management and Outreach in Crooked Fork Watershed
Joanne Logan

SAMPLING AND DETECTING CONTAMINANTS
3:30 p.m. - 5:00 p.m.

Development of Real-Time PCR Assays for the Detection of Bacteriodes Sp. as a Method to Quantify Fecal Contamination
Alice C. Layton, Dan Williams, Victoria Garrett, and Larry D. McKay

Quantification of Enterovirus and Hepatitis A Virus in East Tennessee Ground Waters Using Real-Time RT-PCR
Trisha Baldwin, Alice Layton, Victoria Garrett, Dan Williams, Sid Jones, Greg Johnson, and Larry D. McKay

Influence of Different Sampling Strategies on Estimating Volatile Organic Compound Loads and Maximum Concentrations at Three Karst Springs in Tennessee
Shannon D. Williams, William J. Wolfe, and James J. Farmer

CONSUMPTIVE USE OF WATER IN THE TENNESSEE RIVER WATERSHED

Susan S. Hutson*[1], Sidney E. Gibson[2], and M. Carolyn Koroa[2]

ABSTRACT

Consumptive use of water in the Tennessee River watershed was 649 million gallons per day (Mgal/d) in 2000, or 5 percent of the total water withdrawals or of 12,211 million gallons per day. Consumptive use was projected to increase about 51 percent to 980 Mgal/d by 2030 and to account for 7 percent of the total projected water withdrawals of 13,990 Mgal/d. Water withdrawals were projected to increase by category, as follows: thermoelectric power, 11 percent or 1,152 Mgal/d, to 11,428 Mgal/d; industry, 31 percent or 368 Mgal/d, to 1,573 Mgal/d; public supply, 35 percent or 233 Mgal/d, to 895 Mgal/d; and irrigation, 37 percent or 25.2 Mgal/d, to 94.1 Mgal/d. The reuse potential of the Tennessee River is high because most of the water that is withdrawn for offstream use is returned to the river system. In 2000, 11,562 Mgal/d were returned to the river. In 2030, the reuse potential is expected to remain high with 93 percent, or 13,010 Mgal/d, projected to be return to the river system. Water transfers from the Tennessee River to the Tennessee-Tombigbee waterway for navigation lockages were estimated as 200 Mgal/d for 2000 and 800 Mgal/d for 2030. Water transfers for hydropower commitments through Barkley Canal averaged 3,361 Mgal/d for 2000, and were estimated to be an average of 4,524 Mgal/d in 2030.

INTRODUCTION

Consumptive use is that part of the water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock or otherwise removed from the immediate water environment. For this study, consumptive use, also referred to as net water demand, was calculated by subtracting return flow from water withdrawals. Understanding how water use, of which consumptive use is a component, varies categorically, spatially, and temporally is important to the overall analysis of water supply in the Tennessee River watershed. The U.S Geological Survey, in cooperation with the Tennessee Valley Authority (TVA) conducted an investigation in 2002 to collect and analyze water-use information to determine consumptive use for 2000 and 2030 for the Tennessee River watershed. The results of the investigation were used as part of the water-supply analysis of the reservoir operations study conducted by TVA.

Study Area. The Tennessee River system is the Nation's fifth largest river system encompassing an area of about 40,910 square miles within Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee and Virginia (fig. 1). A series of 49 dams and reservoirs regulate flow on the Tennessee River. Reservoirs developed by the TVA and the U.S. Army Corps of Engineers add more than 643,749 surface acres to the water resources of the watershed and contribute significantly to public supplies, navigation, flood damage reduction, power production, water quality, and fisheries and wildlife management. About 4.5 million people resided in the watershed in 2000, an increase of 15 percent since 1990.

The reuse potential of the Tennessee River system is high because most of the water that is withdrawn is returned to the river system. Besides water quality factors, reuse potential reflects the quantity of water available for subsequent uses and is gauged by consumptive use. Within the

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conterminous United States, the Tennessee River watershed, as measured by intensity of freshwater withdrawals in gallons per day per square mile (gal/d/mi^2), was the most intensively used watershed in 1995 among the Water Resource Regions (WRR) with an average withdrawal of 244,439 gal/d/mi^2. However, as a percent of the total water withdrawals, consumptive use in the Tennessee WRR was the smallest of the WRRs within the conterminous United States.

The study area was subdivided into reservoir catchment areas (RCA) (fig. 2) and water use tabulation areas (WUTA). The RCA is a natural drainage area truncated by a dam. Within this topographically distinct area, precipitation, runoff, evapotranspiration, and shallow and deep infiltration to and discharge from the soil and surface storage contribute to the water impounded in the reservoir by the dam. Consumptive use is calculated at the RCA level. The WUTA accounts for the complete site-specific water-use transactions between adjoining RCAs and, therefore, accounts for consumptive use at a large scale. The boundaries of a WUTA were determined by the natural drainage area to account for water availability and the water-use transactions that occurred within that drainage area.

Purpose and Scope. This paper presents estimates of consumptive use for 2000 and 2030 for the Tennessee River watershed. The data from this report aggregated to the RCA were input to the TVA reservoir management models for evaluating alternative water-supply scenarios in the process of determining future multi-purpose reservoir management practices. Water withdrawal data were collected for the categories of thermoelectric power, industry (industry, commerce, and mining), public supply and irrigation. Data were not collected for rural use (withdrawals from rural wells for residential use or livestock watering).

Methods. Site-specific water withdrawal and return flow data for 2000 collected by State and Federal agencies were compiled by RCA and used to calculate cumulative consumptive use at key junctures of the WUTAs of the river system and the watershed. Demographic and economic data were used to project water withdrawals to 2030. Return flow for 2030 was estimated as a proportion of water withdrawals based on the return flow to water withdrawal ratio in 2000. The base year for the water-use projections was 2000. In addition to daily consumptive use, daily water transfers from the Tennessee watershed to the Tombigbee Waterway and the Cumberland River were accounted for in 2000 and projected to 2030 based on estimates provided by TVA.

ESTIMATED WATER USE IN 2000

Total freshwater withdrawals during 2000 were estimated as 12,211 Mgal/d for thermoelectric power, industrial use, public supply, and irrigation. Estimates indicated that during 2000, total surface-water withdrawals were 98 percent of the total withdrawals, or 11,996 Mgal/d. Total ground-water withdrawals were 215 Mgal/d. Return flows to streams in the watershed from thermoelectric power, industrial, and municipal wastewater facilities were estimated as 95 percent of the withdrawals, or 11,562 Mgal/d. The remaining 5 percent, or 649 Mgal/d, was consumptively used.

Estimates of water use by category for 2000 are summarized in table 1. Thermoelectric- power water withdrawals are more than 8 times larger than industrial water withdrawals. Industrial withdrawals are nearly twice that of public supply; and public supply withdrawals are nearly a magnitude larger than irrigation. Consumptive use accounts for 5 percent of the total water withdrawals. Consumptive use for irrigation is more than twice that of thermoelectric power. Consumptive use for industry and public supply is about the same for both categories and together the categories account for 84 percent of the total consumptive use. The combined consumptive use for industry and public supply is nearly 17 times greater than that of thermoelectric power.

Table 1. Surface- and ground-water withdrawals, return flow, and consumptive use by category for the Tennessee River watershed in 2000

[Figures may not add to totals because of independent rounding. Water-use values are in million gallons per day.]

Category	Withdrawals			Return flow	Consumptive use
	Surface water	Ground water	Total		
Thermoelectric	10,276	00.0	10,276	10,244	32.2
Industrial	1,134	71.1	1,205	942	263
Public supply	526	136	662	377	285
Irrigation	61.3	7.62	68.9	00.0	68.9
Total	**11,996**	**215**	**12,211**	**11,562**	**649**

A comparison of total water withdrawals by WUTA indicated that Watts Bar-Chickamauga (3,187 Mgal/d) and Wheeler-Wilson (2,552 Mgal/d) accounted for nearly one-half of the water withdrawn in the watershed. Cumulative consumptive use at key WUTA junctures of the river were as follows: Fort Loudoun, 176 Mgal/d; Watts Bar-Chickamauga, 288 Mgal/d; Nickajack, 300 Mgal/d; Guntersville, 317 Mgal/d; Wheeler-Wilson, 533 Mgal/d; Pickwick, 563 Mgal/d; and Kentucky 649 Mgal/d (fig. 3). Water transfers to the Tennessee-Tombigbee waterway for navigation lockages were estimated as 200 Mgal/d for 2000 and 800 Mgal/d for 2030. Water transfers for hydropower commitments through Barkley Canal averaged 3,361 Mgal/d for 2000, and were estimated to be an average of 4,524 Mgal/d in 2030.

PROJECTED WATER USE IN 2030

From 2000 to 2030, total water withdrawals in the Tennessee River watershed were projected to increase about 15 percent, or 1,779 Mgal/d, from 12,211 to 13,990 Mgal/d. By category, water withdrawals were projected to increase as follows: thermoelectric power, 11 percent or 1,152 Mgal/d, to 11,428 Mgal/d; industry, 31 percent or 368 Mgal/d, to 1,573 Mgal/d; public supply, 35 percent or 233 Mgal/d, to 895 Mgal/d; and, irrigation, 37 percent or 25.2 Mgal/d, to 94.1 Mgal/d. Of the water withdrawn, ninety-three percent, or 13,010 Mgal/d, was returned to the Tennessee River. Total consumptive use was projected to increase about 51 percent or 331 Mgal/d, to 980 Mgal/d.

The cumulative consumptive use at key WUTAs junctions projected for 2030 was as follows. The consumptive use for Cherokee (114 Mgal/d), Douglas (94 Mgal/d), and Fort Loudoun (34 Mgal/d) WUTAs was accumulated at the Fort Loudoun WUTA juncture and is 241 Mgal/d (fig. 3). Projected cumulative consumptive use to the Watts Bar-Chickamauga WUTA was 413 Mgal/d; Nickajack, 440 Mgal/d; Guntersville, 468 Mgal/d; Wheeler-Wilson, 804 Mgal/d; and to Pickwick, 861 Mgal/d (fig. 3). As calculated at the terminus of the Kentucky WUTA at the Kentucky dam, the projected consumptive use was 980 Mgal/d.

TRENDS

Estimates of water use show that after continual increases in the Tennessee River watershed from 1965 to 1980, withdrawals declined from 1980 to 1985 and remained relatively steady from 1985 through 1995 (Murray, 1968; Murray and Reeves, 1972; Murray and Reeves, 1977; Solley and others, 1983; Solley and others, 1988; Solley and others, 1993; Solley and others, 1998). The 2000 estimate of water withdrawals was the second highest estimate of use on record, less than one-half of one percent less than the 1980 estimate. All categories showed an increase in water withdrawals since 1995 (table 2). Total water withdrawals for 2000 were estimated as 12,211 Mgal/d, an increase of 22 percent from 1995 and an increase of 2 percent from the previous high of record, 1980. Consistent return flow and consumptive use data were unavailable and, therefore, changes over time for these categories cannot be described.

Table 2. Trends of estimated water use in the Tennessee River watershed, 1965 to 2030
[Population, in thousands; per capita use, in gallons per person per day; withdrawals by category and source of water, in million gallons per day; *, data not collected in 2000]

	1965	1970	1975	1980	1985	1990	1995	2000	2030	Percent change 2000 to 2030
Population										
Population	3,107	3,234	3,319	3,677	3,848	3,911	4,198	4,506	5,903	31
Population served by public supply	1,730	2,080	2,370	2,680	2,940	3,030	3,250	3,470	4,546	31
Per capita use	1,800	2,400	3,200	3,200	2,390	2,350	2,382	2,710	2,370	-12
Offstream use										
Total withdrawals	7,400	7,900	11,000	12,260	9,190	9,200	10,000	12,211	13,990	15
Thermoelectric	5,900	6,100	8,700	9,300	6,810	7,070	8,010	10,276	11,428	11
Industrial	1,050	1,400	1,600	2,000	1,779	1,338	1,103	1,205	1,573	31
Public supply	250	330	330	410	469	511	574	662	895	35
Irrigation	8.8	8.1	8.1	6.8	10	27	48	68.9	94.1	37
Rural	100	83	79	102	121	257	269	*		
Source of water										
Surface	7,200	7,700	10,447	12,000	8,960	8,900	9,750	11,996		
Ground	200	170	270	260	233	305	258	215		

Per capita use is a common measure useful for comparing relative rates of change in population to relative rates of change in water use over time. Per capita use of water was 2,710 gallons per person per day (gpd) in 2000 and was projected to decrease to 2,351 gpd by 2030. Per capita use was projected to decrease although total water withdrawals increase, because of how the growth in water use is categorically distributed. In 2030, thermoelectric power water withdrawals were estimated to account for 82 percent of the total water withdrawals compared to 83 percent in 1995 and 84 percent in 2000 (table 3). This small decrease in percent translates into a large enough volume of water to reduce the per capita use by 13 percent.

Table 3. Percent of total water withdrawals by water use category
[<, less than]

Category of use	**1995**	**2000**	**2030**
Thermoelectric power	80	84	82
Industry	10	10	11
Public supply	6	5	6
Irrigation	<1	<1	<1

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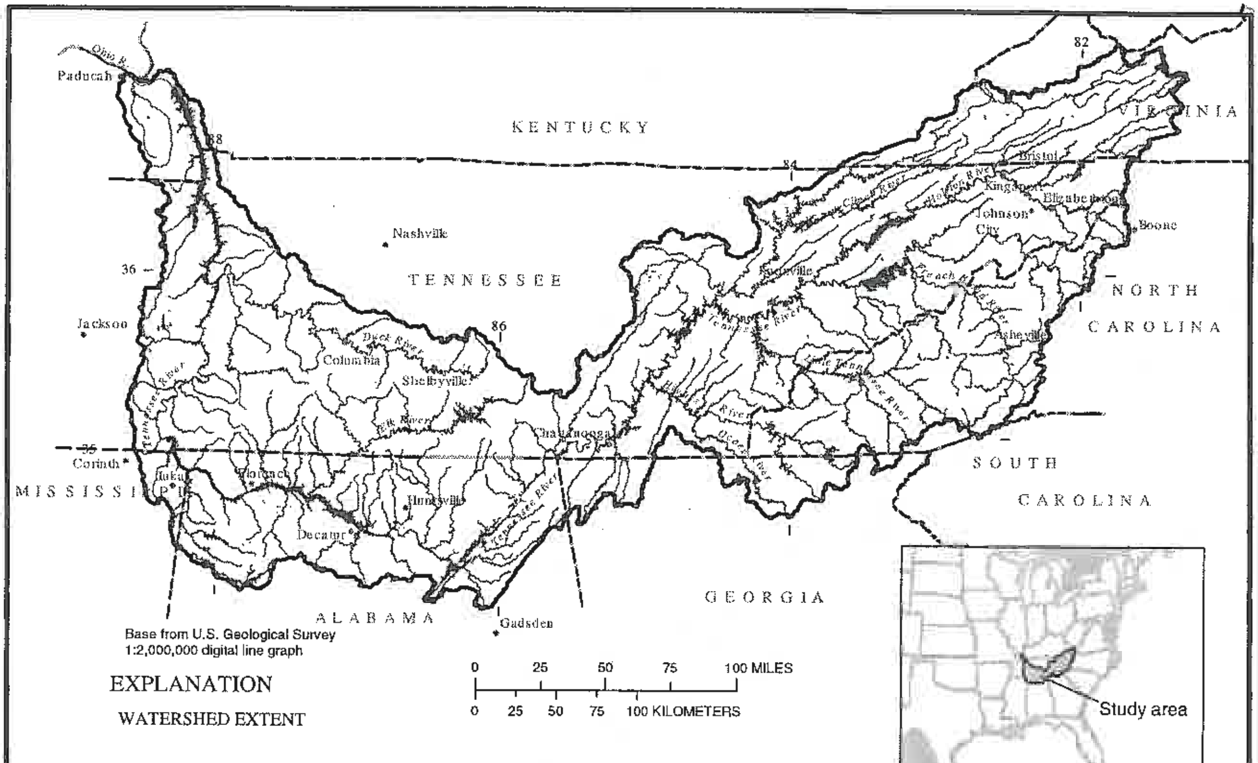

Figure 1. The Tennessee River watershed and major tributaries.

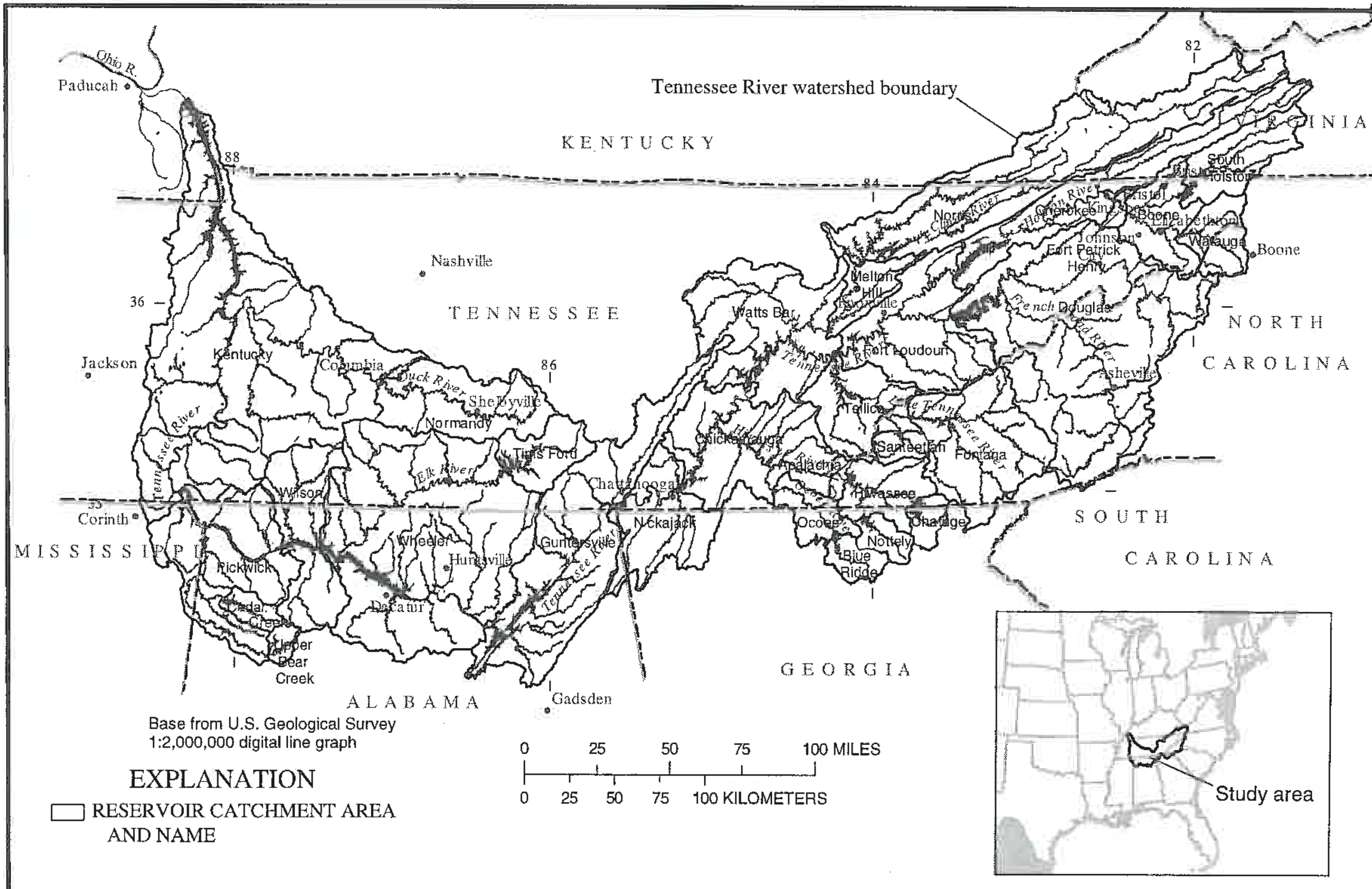

Figure 2. Reservoir catchment areas in the Tennessee River watershed.

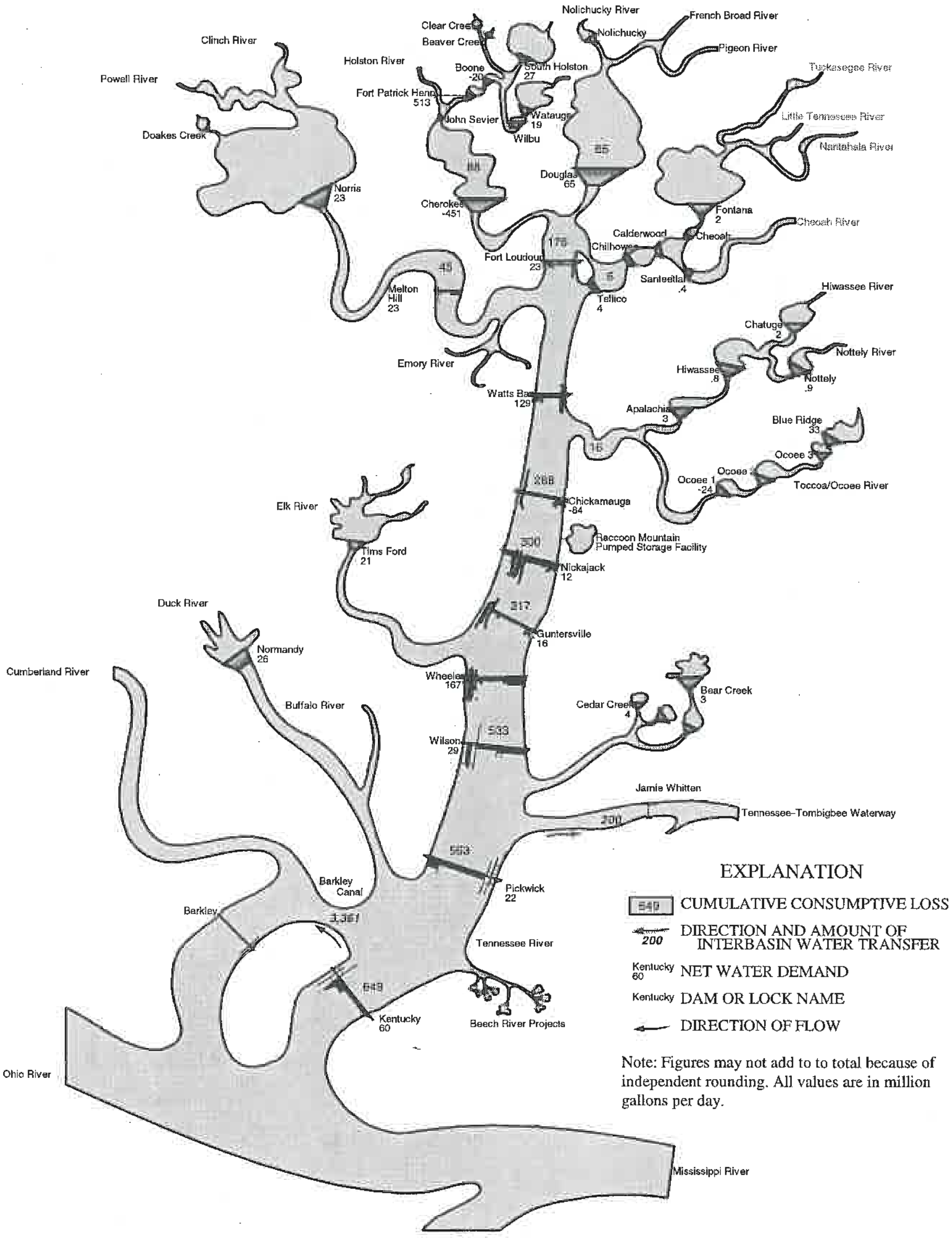

Figure 3. Schematic showing cumulative consumptive use at major water-use tabulation area junctures in the Tennessee River watershed in 2000.

IMPLEMENTATION OF THE CORPS WATER MANAGEMENT SYSTEM (CWMS) IN U.S. ARMY CORPS OF ENGINEERS, NASHVILLE DISTRICT

William R. Barron, Jr.*[1]

ABSTRACT

Nashville District is in the process of implementing the Corps Water Management System (CWMS). The Corps Water Management System is the data acquisition, management, modeling, and decision support system that assists the Corps in its water management mission of regulating more than 500 dam and reservoir projects. CWMS is a nationwide integrated system of hardware, software, and other resources that acquires, analyzes, and stores data; develops decision support information; and allows user access to any data and information on the system.

This paper will describe the progress that Nashville District has made in implementation of CWMS. Major emphasis will be placed upon the modeling portion of the implementation, but some emphasis will be placed upon the data acquisition and management part of the software.

Data acquisition is real-time. Data dissemination uses web based technology. The database consists of Oracle and Data Storage System (DSS) files. Forecasting is based upon National Weather Service, Nexrad, Stage3 rainfall radar. The meteorological model and the hydrological model (HEC-HMS) are grid based models that are tied to geographic information system (GIS) data. Operation of the dams is done within a model called the Reservoir Simulation System (ResSim). Flow is routed using the River Analysis System (HEC-RAS), unsteady flow model. Inundation mapping is created based upon the HEC-RAS water surface elevations. Flood damage impacts are determined from first floor elevations of structures in the floodplain.

CWMS is an integrated, active suite of software. It is designed to provide the user with a multitude of graphical options for making operational decisions.

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SPILL MANAGEMENT INFORMATION SYSTEM FOR INLAND WATERWAYS

Edsel B. Daniel[1], Paul H. Martin[1], James E. Dobbins[1], Eugene J. LeBoeuf*[1], and Mark D. Abkowitz[1]

ABSTRACT

A geographic information system (GIS)-based decision support system designed to effectively manage risks associated with accidental or intentional releases of a hazardous material into an inland waterway is presented. Developed for the U.S. Army Corps of Engineers (USACE), Spill Management Information System (SMIS) provides critical planning and impact information to emergency responders in anticipation of or following such an incident. This new information management tool will be useful for responders to accidental and intentional chemical spill incidents, including USACE Districts, U.S. Coast Guard Marine Safety Offices, U.S. Environmental Protection Agency on scene coordinators, and state and local agencies. SMIS couples GIS and database management systems (DBMS) with state-of-the-art surface water and air contaminant transport models to predict the impacts of a waterway injection of a hazardous material. Live 'real-time' data links are established within the software to utilize current meteorological information and flowrates within the waterway. Capabilities include rapid modification of modeling conditions to allow for immediate scenario analysis and evaluation of "what-if" situations. Additionally, SMIS is designed to overcome many of the communication and coordination challenges encountered during a spill event by providing responders with access to uniform information comprised of real-time incident data and maps, contaminant transport model outputs, and chemical response data. The presentation will cover SMIS design and implementation, as well as suggestions for future enhancements.

INTRODUCTION

The U.S. Army Corps of Engineers (USACE) maintains over 11,000 miles of navigable waterways, which include a number of infrastructure elements related to flood control, beach erosion control and shoreline protection, hydroelectric power, recreation, water supply, and environmental restoration and protection. Marine transportation on these navigable waterways has long been considered one of the nation's most efficient, safe, and economical modes of freight transportation (*1*). Commodities routinely transported include coal, sand, gravel, steel, bulk chemicals, grain, and petroleum products. Hazardous materials, comprising a large portion of the commodities transported by barge, however, place communities along navigable waterways at risk of being exposed to toxic chemicals in the event of a collision, grounding, or terrorist attack. For example, on April 20th, 1995, the tanker "Maersk Shetland" collided with tank barge DC-304, being pushed by the towboat "Big Bay" (*2*). The barge was loaded with cumene and the collision caused the entire load to be released into the Corpus Christi channel. The initial assessment made by responders was that the cumene would remain on the surface and evaporate into the air after 18 hours. Winds were blowing out into the bay and evacuation of nearby residents was not considered necessary. However, within 30 minutes the wind direction shifted 180 degrees and 5,000 people were subsequently evacuated from the surrounding community. A similar scenario can easily be envisioned for intentional chemical spill incidents prompted by terrorist attacks.

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Coordinating a navigable water body chemical spill response will involve coordination and communication among a number of federal, state, and local entities. For example, observation of a spill response exercise conducted in April 2002 by the Tennessee Valley Authority (TVA) at the Colbert Fossil Fuel Plant, Colbert, Alabama, as part of the TVA's participation in the National Preparedness for Response Exercise Program, revealed the large number of agencies involved in spill management (*3*). Participants in the exercise included: (i) U.S. EPA Region IV; (ii) USCG; (iii) Alabama Department of Environmental Management; (iv) Colbert County Emergency Management Agency; (v) spill containment private contractor; and (vi) several elements of TVA, including environmental response teams, river systems operation and environment teams including water quality modeling personnel, community and government relations teams, information services teams, and TVA police. *Overall responsibility for spill response management initially resided with TVA emergency management personnel until a FSOC from the U.S. EPA or USCG arrived on site.*

Communicating and coordinating activities among a diverse group of agencies responding to a chemical spill incident such as that noted above will likely pose considerable challenges in a number of areas as noted below (*4*).

- **Chemical Data.** Currently, there are several sources of data describing chemicals routinely transported by water. Once a chemical is positively identified, the lack of a common chemical nomenclature among the different response agencies compounds the difficulty in determining exactly what hazards are presented by the released chemical.
- **Jurisdiction**. Most navigable waterways form state borders and U.S. EPA region boundaries and it may be unclear as to which emergency management units should take the lead in the accident response. Furthermore, coordination with the USCG is necessary. On-scene communications are carried out mainly by means of VHF radio. Responders on shore may be unable to communicate with the USCG or vessel crew via marine frequencies. Dynamically broadcasting information to several proximate response units immediately following an incident is difficult if done without a computer system.
- **Access**. Reaching the accident scene by water can be time-consuming and the delay can adversely affect the quality of response. There are areas on inland waterways where response by the USCG may take hours, depending on the status of response vessels at the time of the spill. Land-based responders must first transport their vessels to the water at a boat launch.
- **Community Notification**. Since many navigable waterways also form area code borders, notifying the population becomes problematic as residents on both banks must be alerted. Timely notification can protect the community against exposure to toxic vapors.

Further, in the TVA chemical spill response exercise, *response agencies looked to TVA to provide continuous updates of contaminant spill migration through employment of contaminant transport models coupled with reservoir release information, as well as locations and extent of deployed spill containment systems* (*3*). Dissemination of this information to the various responders was hampered by (i) the use of numerous maps with various states of currency, (ii) employment of one-dimension contaminant transport models that may not reflect well the hydrodynamics of the system being modeled, and (iii) the lack of reliance on technology that is mature and readily available, such as geographic information systems (GIS). Expectations for similar information may likely arise for respective USACE Districts. It is in this light that a decision support system to assist USACE Districts in aiding responders in identifying, responding to, and mitigating the effects of chemical release incidents was established.

SPILL MANAGEMENT INFORMATION SYSTEM OVERVIEW

To more effectively manage the risk associated with accidental or intentional chemical releases into the environment, a decision support system was developed to aid responders in identifying, responding to, and mitigating the effects of chemical release incidents. The overarching goal of this project was to develop an information system based on global positioning systems (GPS) and GIS technology that can provide real-time information to emergency responders following an incident involving hazardous substances. (For the purposes of this research, hazardous substances are defined as any commodity, including petroleum products, which, if released, would pose considerable danger to human health and the environment.) More specifically, this project resulted in the development of a spill management information system (SMIS) for USACE, utilizing the Cheatham Reach of the Cumberland River located in Nashville, Tennessee, as a "case study" template from which additional spill management information systems for other USACE water bodies may be developed. The spill management information system couples database management systems and geographic information systems with surface water and air contaminant transport models. This system effectively eliminates many of the aforementioned communication and coordination challenges by providing responders to spill events access to uniform information comprised of real-time incident information and maps, contaminant transport model outputs, and chemical response data as noted below. Descriptions of the significance of the proposed activity to the advancement of knowledge, project scope, system design, and project accomplishments follow in subsequent sections.

Specific challenges that SMIS addresses include:

- **Preparedness.** The Readiness Branches of USACE Districts are responsible for preparing and responding to meet the needs of future emergencies. Establishment of a SMIS within a District can greatly assist District Emergency Operations Centers (EOCs) by improving their ability to coordinate with other agencies to ensure an appropriate and adequate response to a chemical spill emergency. In addition, SMIS can provide invaluable training opportunities through execution of spill response exercises, as well as enhanced decision support through implementation of "what if" scenarios both during exercises and actual spill incidents.
- **Response Time.** Response times of U.S. EPA or USCG FSOC personnel traveling from base locations may take several hours. Similar to the aforementioned TVA spill response exercise, local and state responders will likely look to USACE for spill management guidance during this initial, but critical time period, and likely after the arrival of the FSOC. Keeping the SMIS "hot" by dynamically linking the model to real-time streamflow and meteorologic information greatly minimizes the time required to provide predictive model capability.
- **Use of Proper Contaminant Transport Models.** Many USACE water bodies, like the Cheatham Reach, are highly regulated flow systems for navigation and flood control. USCG and U.S. EPA do not maintain constant access to USACE and U.S. Geological Survey (USGS) stream flow information. As such, responding agencies may look to USACE to provide flow and bathymetry information while they attempt to initialize and run their spill models, which can consume valuable time. Additionally, it is not possible for the one-dimensional contaminant transport models commonly employed by U.S. EPA or USCG for spill management to adequately

model the complex hydrodynamics of regulated reservoir systems. (Although the National Oceanic and Atmospheric Administration's (NOAA's) General NOAA Oil Modeling Environment provides predictive capabilities on how wind, currents and other processes may move oil spills, it is applicable to open water harbors, bays, and coasts, and not riverine segments.) Further, such models do not possess the ability to route spill events through dam spillways or locks, or link separate reservoir segments to track a spill through sequential reservoir systems. Employment of a SMIS with proper water and air contaminant transport models greatly enhances the ability of spill responders to trace contaminant movement.

SYSTEM DESIGN

Two types of information systems comprise SMIS: a GIS and a database management system (DBMS). GIS is an information technology that is used to maintain and analyze geographic data. The GIS organizes data into layers, and relates data sets by geography. Certain relationships and operational trends are more easily conveyed in a geographic context than in a traditional tabular format. GIS functionality can also be delivered through a standard Internet browser, a recent advancement. DBMS refers to software that collects, manipulates, queries and retrieves tabular data. Programming is required to make GIS and DBMS function as a single risk management system. Figure 1 displays the conceptual data flow design. GIS enables users to view information describing all spill incidents on their waterway. Employment of risk analysis routines provide opportunities to estimate the number of people residing within a spill isolation zone, predict concentrations and times of arrival/passage of pollutants at downstream drinking water intakes, and locate responders within a user-specified distance from the incident. All of this data could be served to responders via the Internet GIS in a secure manner. This site will provide responders with a wide range of potentially useful information (real-time incident information and maps, contaminant transport model outputs, and chemical response data). Specific GIS data layers employed in this project include: (i) waterway network and water area;

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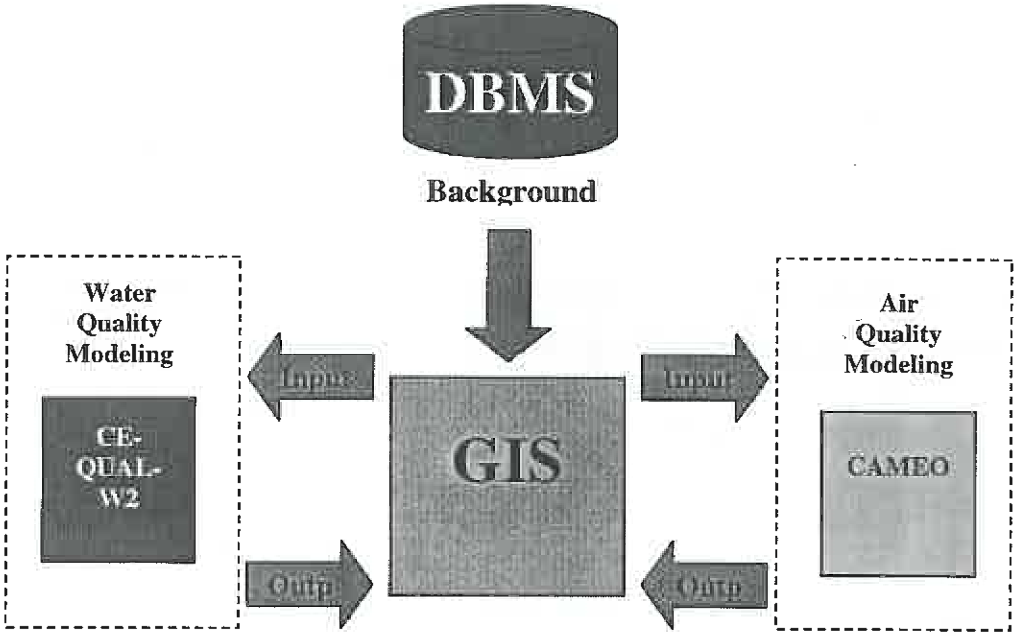


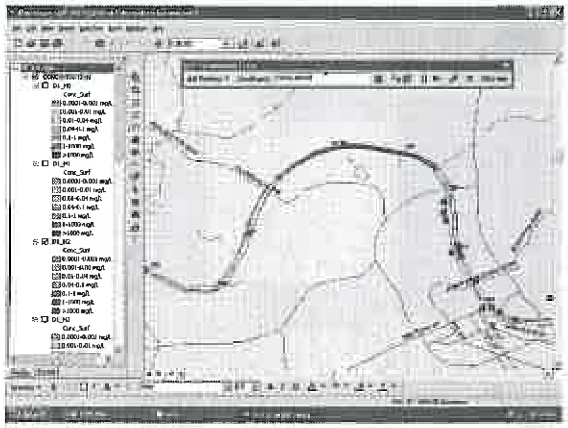
Figure 1. Spill Management Information System Data Flow.

CONTAMINANT TRANSPORT MODELS

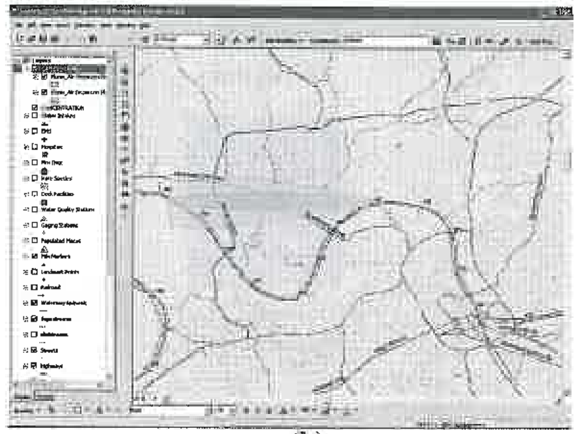
The impact of a waterway injection of a hazardous material will be modeled through two pathways: surface water and air. Although spill effects propagate through other pathways, the most acute and immediately dangerous effects travel through these means. GIS aids decision makers by overlaying incident impact areas on the population, environment and infrastructure.

Modeling Contaminant Transport in Surface Water. Numerous contaminant transport models are available for evaluating contaminant transport in surface water bodies (*5*). The selection of the appropriate model is normally based on the hydrodynamics of the water body being modeled (i.e., river, estuary, lake, or reservoir), the need for accuracy (e.g., a 1-D model may suffice in many instances, greatly reducing the data input requirements compared to a 2-D or 3-D model), and the required level of detail for contaminant behavior, including biotic and abiotic decay rates, and interaction with sediments and other water body constituents. In the case of many USACE water bodies (including the Cheatham Reach), desirable qualities include the ability to: (i) transform the contaminant plume through regulating devices such as dam spillways; (ii) track plume migration through multiple, interconnected reservoir and/or river sections; and (iii) include the influence of wind on contaminant transport. These desirable qualities effectively negate the employment of most other water quality and contaminant transport models other than USACE's CE-QUAL-W2.

CE-QUAL-W2 (Version 3.0) is a two-dimensional, longitudinal/vertical, hydrodynamic and water quality model. Because the model assumes lateral homogeneity, it is best suited for relatively long and narrow waterbodies exhibiting longitudinal and vertical water quality gradients (*6*). The model has been applied to rivers, lakes, reservoirs, and estuaries (*13*). Advantages of the use of this model include its relatively robust ability to model well the hydrodynamics of many of USACE's water systems, USACE and contractor personnel familiarity with CE-QUAL-W2, and the ability to incorporate updates of the model as newer versions are released. This last point is particularly noteworthy in that planned model updates provide for the inclusion of toxics and any number of other user-defined constituents (*6*). Typical inputs to the model include: (i) geometric data; (ii) initial and boundary conditions; (iii) hydraulic and kinetic parameters; and (iv) calibration data. Outputs include spatial information on constituent locations and concentrations, flow velocities, and water temperatures. An example display of model output for a contaminant plume is provided in Figure 2a.



(a)



(b)

Figure 2. Example Contaminant Spill Migration on (a) Water; and (b) Air.

The primary limitation of this model for this application arises from the fact that the model performs lateral-averaging over the width of the river or reservoir. The model thus overpredicts lateral plume migration should the contamination originate on one of the lateral banks. Future phases of this work can overcome this limitation by employing a quasi-3-dimensinal model that provides an ability to effectively track lateral migration of the plume (*7*).

Modeling Contaminant Transport in Air. Contaminant transport modeling for air is accomplished through use of the U.S. EPA's Computer Aided Management of Emergency Operations (CAMEO) database and information management program (*8*). Although there exist numerous transport models for air similar to the number of transport models for surface water, CAMEO was specifically developed by the U.S. EPA's Chemical Emergency Preparedness and Prevention Office (CEPPO) and the National Oceanic and Atmospheric Administration Office of Response and Restoration (NOAA) to plan for and respond to chemical emergencies.

The CAMEO system actually integrates three separate program modules (chemical data base, air dispersion model, and mapping capability) into one single information management system (*7*). The chemical database comprises chemical-specific information on fire and explosive hazards, health hazards, firefighting techniques, cleanup procedures, and protective clothing for over 6,000 hazardous chemicals. Areal Locations of Hazardous Atmospheres (ALOHA) provides the contaminant transport information for CAMEO. ALOHA allows the user to estimate the downwind dispersion of a chemical cloud based on the toxicological/ physical characteristics of the released chemical, atmospheric conditions, and specific circumstances of the release. Input parameters for CAMEO include spill location, chemical type, volume and rate of spill, and weather conditions (temperature, air stability, wind speed/direction). Spatial outputs include a "cloud footprint" that can be imported to the GIS-based information management system. An example model output is provided in Figure 2b.

FUTURE PHASES OF WORK

SMIS Version 1.0 constitutes "Phase I" of what may be considered a multi-phase project. Additional phases of the project can take advantage of the modular structure of the overall information management system to employ additional attributes such as: (i) using different air or water quality and contaminant transport models; (ii) modifying existing air or water quality models to more accurately reflect conditions of specific water bodies; (iii) linking to multiple, contiguous sections of the Cumberland River reach and tributaries; and (iv) extending the model to other water bodies.

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ADVANCEMENTS IN DISCRETE ANALYSIS FOR ENVIRONMENTAL TESTING

Karin Bogren*[1]

BACKGROUND

In the last four years discrete analysis has begun to emerge as a viable option for environmental analysis. Discrete analyzers come from the medical industry where they have been used for routine testing of blood, plasma and other fluids since the late 1970's. Like medical laboratories, environmental laboratories are attracted to the simple setup, low reagent consumption and waste, low maintenance, minimal training, high throughput with flexible use, and less sample batching required. Discrete systems are an ideal solution for laboratories that need flexibility to run a variety of tests per sample. Several systems are already being sold and used for environmental testing. Although the discrete systems sold in the market today are operating successfully, several inherent limitations are present that reduce their total productivity.

SEPARATE PIPETTES FOR REAGENTS AND SAMPLES

Over ten years ago, the medical industry migrated from single pipette systems to dual pipette systems for dispensing reagents and samples. They found switching to a dual pipette approach gave them advantages with speed, flexibility, and reduced carryover from reagent to sample.

A dual pipette system can operate both sample and reagent dispensing arms simultaneously resulting in throughputs of 300+ tests per hour versus 150-200 tests per hour. Since throughput slows with each additional reagent, higher throughputs of 300+ tests per hour can be needed to approach the same productivity of a continuous flow system.

Dual pipette systems also offer the user the ability to run the instrument in batch mode where the analytes are batched or by sample mode where all of the tests are done on one sample before running the next sample. Having two pipettes allows the user to run the by sample mode without trading off throughput.

A two -pipette version minimizes the potential of carryover between analytical tests. For example, the pipette used to dispense phosphate buffer for the cyanide assay will not be in contact with samples that will be measured for phosphate. Carryover performance data will be shown where the reagent component in the first test will be the analyte in the second test.

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NITRATE BY CADMIUM REDUCTION

A new approach for reducing nitrate to nitrite has been developed that offers good precision, accuracy, and sensitivity without sacrificing throughput. The sample is dispensed into a cadmium coated reduction cup. Because the cup is coated with a very thin layer of cadmium, the waste generation is equivalent or less than that generated by a continuous flow system. The sample is mixed and allowed to incubate until the reduction is complete. The reduced sample is then aspirated into the incubator cuvette and sulfamilamide is added and the sample is measured. The cups can be used as a one- time use or can be recopperized by the user for multi-use. No activation or pretreatment is required of the surface prior to first use. Accuracy, precision, and spike recovery performance data in real-world samples will be shown.

INCREASED STANDARD AND REAGENT POSITIONS

In a typical laboratory, samples need to be run that are digested, distilled, or preserved in several different matrices. To handle these varying matrices, analysts need to calibrate with separate calibrations. For example, cyanide needs to be calibrated separately from ammonia. The new Lachat system offers 16 standard positions. The analyst can load up to three separate five- point calibrations into the system, program the system and walk away. With fewer calibration positions, the analyst would need to return to the system to remove the first calibration vials and replace them with the second set.

Some laboratories may need to run up to 4-6 different tests on a single sample. The analyst may quickly run out of locations on their system for storage of the necessary reagents to do these tests. The user will need to run the system in a batch mode, stopping the system to reload the next set of reagents. The Lachat QD 300 will offer 30 user-programmable reagent positions so the user should never be short of reagent positions.

PREPROGRAMMED METHODS

Discrete methods can be tricky to program due to complicated timing between the reagents, read times etc. Lachat will be offering preloaded methods for the top 300 series EPA methods. Lachat will also do customized method development as they have done for years with their FIA instrument.

CONCLUSION

Discrete Analysis will continue to grow as a testing solution in the environmental market place. Improved speed, flexibility, reduced carryover, increased standard and reagent capacity, and preprogrammed methods are all improvements that are necessary to make discrete analysis one of the most productive tools in your laboratory.

INITIAL USE OF PROBABILISTIC MONITORING TECHNIQUES IN TENNESSEE

Gregory M. Denton*[1]

In January 2000, the Division of Water Pollution Control initiated a probabilistic monitoring study to assess water quality in subecoregion 71i (Inner Nashville Basin), one of five ecological subregions within the Interior Plateau in Tennessee. Chemical, biological, and bacteriological samples as well as flow measurements and habitat assessments were completed at each of 50 randomly selected sites beginning in January 2000 and ending in June 2001 (the winter 2001 quarter was not sampled).

The project was designed to meet the following objectives:

1. Characterize water quality at each of the probabilistic monitoring stations. Document violations of water quality standards and determine the degree of support of designated uses. Identify likely sources of pollutants in impacted segments.
2. Extrapolate probabilistic data to the entire subecoregion, providing information for the development of the statewide assessment report.
3. Compare water quality assessment information extrapolated from probabilistic sampling to historical assessments within 71i to provide a sense of the accuracy of targeted monitoring efforts.
4. Determine if random sampling would identify additional reference quality streams in the subecoregion.

As a follow-up to this project, probabilistic techniques are again being employed in a study of streams below small impoundments. At fifty randomly selected sites directly downstream of small to medium sized dams, streams will be sampled to determine the frequency in which the impoundment of small streams leads to violation of water quality standards. At those locations in which standards are not violated, the conditions or impoundment management techniques that translate into maintenance of water quality values will be identified.

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WATER QUALITY TRADING: A COST-EFFECTIVE WAY TO IMPROVE WATER QUALITY IN TENNESSEE?

Christopher D. Clark*, William M. Park, and Ernest F. Bazen[1]

The passage of the Clean Water Act (CWA) in 1972 ushered in a new era in water pollution control in this country. In addition to consolidating much of the authority for water pollution control at the federal level, the CWA - despite its explicitly ambient goal of "restor[ing] and maintain[ing] the chemical, physical, and biological integrity of the nation's waters"[2] - imposed technologically-based discharge limits on "point sources," i.e., pollution from pipes or discrete conveyances from industrial plants and municipal sewage treatment facilities. However, while in the thirty years since its passage, the CWA has substantially reduced pollution from point sources,[3] it has largely failed to achieve its ambient water quality goals. At last count approximately 39% of the nation's (and slightly more than 30% of Tennessee's) assessed river and stream miles were impaired for one or more uses. (USEPA, 2002 and TDEC, 2002). This failure is primarily due to the unchecked level of pollution flowing from "non-point sources," i.e., runoff from agricultural and urban lands. While regulatory efforts to curb runoff from urban areas are increasing, the CWA's explicit exemption of "agricultural stormwater discharges and return flows from irrigated agriculture" from the limits on discharges has, to date, effectively blocked such approaches with respect to agricultural sources.[4]

In the absence of regulatory approaches, water quality and agricultural officials have attempted to control agricultural non-point source pollution through a variety of "voluntary arrangements." These voluntary arrangements, while highly effective in some limited instances, have failed to have the aggregate impact that mandated discharge limits have had on point sources. As a result, agriculture is now the largest single source of pollutants to impaired rivers and streams across the country (USEPA, 2002), and in Tennessee, where it contributes to approximately 37% of the impaired river and stream miles.[5] (TDEC, 2002). Agriculture's contribution to impaired rivers and streams occurs primarily through sedimentation from land disturbances and the runoff or leaching of excess nutrients from both mineral fertilizers and livestock manure. In Tennessee, siltation and nutrients contribute to 36% of the impaired river and stream miles (TDEC, 2002). Thus, it is clear that achieving the CWA's goals, both in Tennessee and across the nation, will require reductions in loadings from agricultural non-point sources. Further, given the current state of the law and the historical reluctance to regulate agricultural non-point sources,[6] it is equally clear that the nation cannot depend upon mandatory discharge limitations as the means by which these reductions can be achieved.

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[2] Section 101(a), 33 U.S.C. § 1251(a).

[3] See, for example, Adler, *et al.*, 1993, and USEPA, 1989.

[4] Section 14, 33 U.S.C. § 1362.

[5] One might argue that these numbers should not be too surprising, given that agricultural lands cover a little more than 42% of Tennessee's land mass.

[6] Our historical preference for regulating point sources over non-point sources is not without its logic. For non-point sources, research has shed less light on the relationship between inputs (e.g., fertilizer applied to agricultural lands) and pollution than with point sources, measuring and monitoring emissions present a much greater challenge than with point sources, and discharges depend largely on random events such as rainfall (Crutchfield, *et al.*, 1994).

This may not be such a bad thing. For one thing, point sources have, in complying with mandatory discharge limits, largely exhausted the inexpensive ways of abating pollution. Thus, further reductions by point sources, as well as additional abatement associated with increases in capacity, will prove expensive relative to earlier levels of abatement. On the other hand, abating pollution from non-point sources appears to be much cheaper than abating it from point sources,[7] at least partly due to the fact that non-point sources still face a full range of abatement options. In addition, economists have long suggested that traditional approaches to environmental regulation, such as discharge limits, be replaced by market-based incentives and cost-driven approaches, in order to minimize the costs of meeting a given ambient environmental standard. An example of a market-based incentive program is provided by "marketable permit" systems, where permits to discharge a given quantity of pollution are sold or issued to individual sources and sources are allowed to buy and sell these permits. Marketable permit systems reduce the costs of meeting ambient environmental goals by allowing those sources with high abatement costs to purchase "permits to pollute" from those sources with low abatement costs. In this way, the market in permits effectively allocates pollution abatement to those who can do it at least cost.

These suggestions have recently begun to influence the structure of environmental policies. Thus, marketable permit systems currently dominate the federal government's approach to regulating air emissions and are now increasingly viewed as a way to cost-effectively address the nation's lingering water quality problems. In 1996, USEPA issued draft guidelines for effluent or water quality trading programs (USEPA, 1996) and has more recently formalized its commitment to these programs. (USEPA, 2003b). States and local governments have taken note, and, at last count, there were 16 active water quality trading programs in the US and at least 9 others under development (Woodward and Kaiser, 2002). However, this enthusiasm is tempered by the knowledge that trading programs are not the answer for all pollutants in all watersheds, and USEPA's formal support for water quality trading programs is currently limited to programs trading in sediment and nutrients. (USEPA, 2003b).

In an effort to provide guidance to states and local governments on developing and implementing water quality trading programs USEPA's Region 10 has published a water quality trading assessment handbook that outlines a set of criteria for judging the suitability of a particular watershed for a water quality trading program. (USEPA, 2003a). This paper represents a first attempt to apply the criteria described in this handbook to Tennessee. This evaluation will be of a preliminary nature in that it will focus on a single watershed and in that it will abstract from many of the details associated with designing such a program, focusing solely on the presence of both significant stream miles impaired due to siltation or nutrients and a number of potential traders sufficient to support a functioning market. In doing so, the research will be similar in approach to an assessment of the potential for water quality trading in watersheds in the nation's coastal zones (Crutchfield, *et al.*, 1994, and Letson, *et al.*, 1993).

The greatest contributor to the number of stream miles impaired by siltation or sedimentation and nutrients in Tennessee is agriculture. Agricultural producers would make more effective market participants not only because they are the leading source of these discharges but also because their large landholdings will allow greater non-point source control with fewer transactions and lower transactions costs. As a result, this analysis will focus on agricultural point sources as the likely seller of effluent reduction and point sources as the likely buyer. Livestock production is likely the primary source of excess nutrients from agricultural lands. Thus, one test of a trading program's

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[7] Current estimates suggest that this difference is likely an order of magnitude or greater. (Faeth, 2000).

potential for addressing the water quality problems in an individual watershed is the extent to which point and agricultural non-point sources contribute to these water quality problems. A second is whether there are a sufficient (but likely not too large of a) number of point and agricultural non-point sources (particularly livestock operations) for a functioning market to exist. (Cites).

As an example watershed, we have chosen the Upper Duck River. This watershed encompasses 1,553 square miles and 1,606.9 stream miles spread over parts of eight southern Middle Tennessee counties. Approximately 63% of the stream miles have been assessed, and of those miles, approximately 36.5% are impaired. Siltation is a cause of impairment for 51.2% of the impaired stream miles and nutrients for 17.2%.[8] Figure 1 provides an overview of the watershed, with the darker lines representing impaired streams and the lighter lines representing streams that fully support water quality standards or have not been assessed.[9] Thus, this watershed suffers from a significant amount of impairment due to siltation and nutrients.

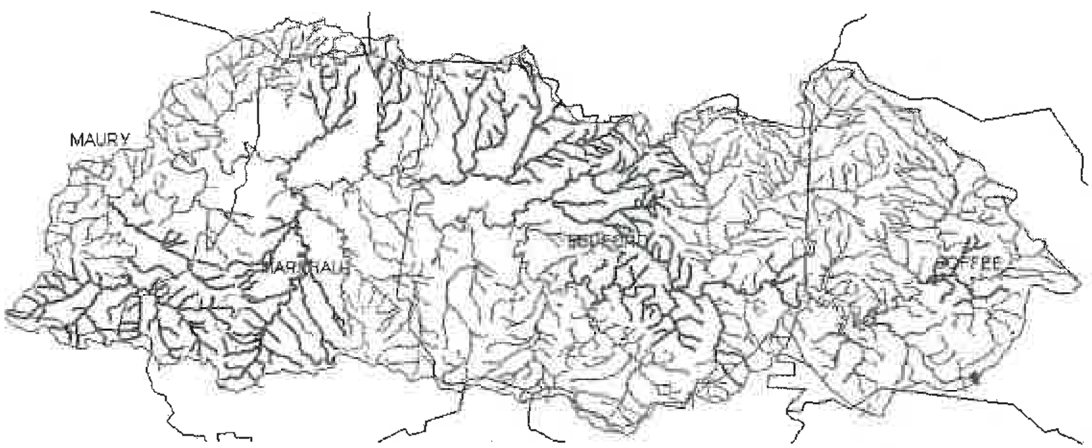

Figure 1

For a trading program to be viable, it must also have a sufficient number and quantity of both point and non-point sources of these discharges. Table 1 lists those permitted point sources within the watershed that are discharging total suspended solids (TSS) and/or nitrogen (N), with annual loading information. Although there were 25 permitted point sources in the watershed, only those listed in the table were discharging significant quantities of TSS or N.[10] Thus, there would appear to be a relatively limited number of potential buyers of effluent reductions. Due to an absence of data, we have made no attempt to determine the ratios of point and non-point source discharges to the reduction in loading that would be necessary to meet applicable water quality standards. (Cite).

Table 1. Upper Duck Watershed Permitted Point Sources of TSS and N (1999)[11]

NPDES Permit No.	Standard Industrial Classification	Total Suspended Solids (lbs/yr)	Nitrogen (lbs/yr)

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[8] Other leading causes of impairment include habitat alterations, which contribute to 53% of the impaired stream miles, and pathogens at 38.8%. TDEC, 2000.

[9] Source: USEPA's Watershed Assessment, Tracking and Environmental Results data downloaded from http://www.epa.gov/waters/data/downloads.html on January 10, 2004.

[10] No data was available for phosphorous discharges.

[11] Source: USEPA Permit Compliance System (PCS3) data downloaded from http://www.epa.gov/waterscience/basins/b3webdwn.htm on January 10, 2004.

TN0002135	Poultry Slaughtering & Processing	34684.50	44767.42
TN0002143	Leather Tanning and Finishing	5860.25	8199.96
TN0002445	Refrigeration & Heating Equip.	14237.35	
TN0002470	Distillation of Rectified & Blended Liquids	792.03	
TN0020443	Sewerage Systems	4665.57	
TN0020591	Sewerage Systems	1758.38	0.00
TN0022802	Water Supply	4743.88	
TN0023888	Sewerage Systems	69413.90	5973.81
TN0024180	Sewerage Systems	106245.43	
TN0025038	Sewerage Systems	12282.27	2433.31
TN0064670	Sewerage Systems	17568.69	
Totals		272252.25	61374.50

The spatial distribution of these point sources within the watershed is shown in Figure 2, along with the impaired streams.

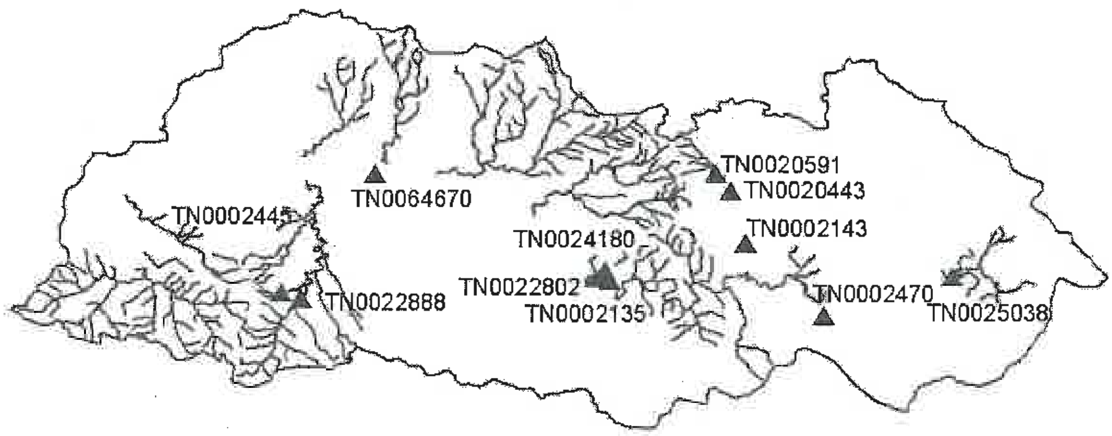

Figure 2

What about agricultural non-point sources of these pollutants? Farms cover approximately 752,464 acres in the four counties that primarily contain the watershed (Bedford, Coffee, Marshall, and Maury), accounting for about 62% of the land mass. In these counties, there are approximately 5,000 farms, 3,624 of which produce livestock, overwhelmingly cattle and poultry.[12] This livestock produces an estimated 258,718 tons of dry manure per year, which translates into approximately 22,650,442 pounds of nitrogen and 6,796,925 pounds of phosphorous. Of these nutrient only about 75% of the nitrogen and 60% of the phosphorous can be spread at agronomic rates on the farms on which it is produced. (Kellogg, *et al.*, 2000). The distribution of poultry grower houses within the watershed, gleaned from aerial photographs taken in 1993, is shown in Figure 3.

[12] These four counties account for approximately 8.5% of Tennessee's beef cattle production, 12.2% of its dairy herd, and 22.8% of its broiler (meat poultry) production. USDA, 1999.

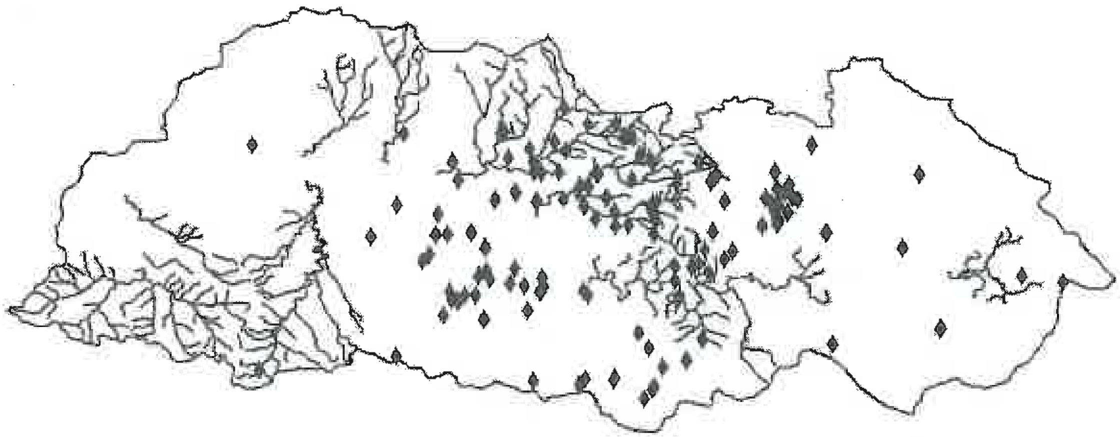

Figure 3

Thus, there would appear to be a limited number of point sources, but a significant contribution from, and number of, agricultural non-point sources. The relatively small number of point sources is not necessarily fatal as long as their discharges are great enough to support the reductions necessary to bring water quality into line with standards and as long as there are sufficient regulatory and financial incentives to convince those point sources to participate in a trading program.

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CATFISH IN THE MAINSTREAM: SOCIAL MARKETING AND CHANGE

Karen Hargrove*[1]

INTRODUCTION

Social marketing=advertising? The average person may equate the two terms, but according to an expert in this field, Les Robinson (A 7-Step Social Marketing Approach), advertising is "not about changing behavior. It's about changing *brands.*" In thinking about solutions to environmental issues and problems, the focus is usually on a change in *behavior*, one brought about either through a revision of attitudes or a forced compliance to a rule or law. Robinson's focus is not on building awareness but on removing barriers to behavior change.[2] An excellent source about the theory and application of social marketing techniques is Fostering Sustainable Behavior by Douglas McKenzie-Mohr, who advises those interested in social marketing techniques to study benefits of, and barriers to, the desired behavior.[3]

WaterWorks!, a new education initiative funded by the TN Department of Agriculture Nonpoint Source Program and implemented through the Center for Environmental Education at Middle Tennessee State University, was launched to improve water quality in Tennessee, and has a multi-faceted approach with components added and strengthened over the project period. The WaterWorks! education campaign is designed to change behavior by first promoting awareness, then adding knowledge and skill-building with subsequent messages, so that citizens are brought to an awareness that individual decisions affect water quality, their actions make a difference, and that together, responsible attitudes and actions can change water quality for the better.

THE PROJECT

The first phase of the project was to develop a series of video and audio messages promoting clean water through responsible action, a statewide survey to create a baseline about what Tennessee citizens know and *do* about water quality, a recognition program for youth, and stakeholder meetings with others involved in water quality statewide. A website to showcase the messages and provide an information base for the program was begun, with links to other helpful watershed organizations and state agency sites. Additionally, currently on the website is a watershed map in its basic form, with plans to add information about whom to contact locally for information on particular municipalities within a county or a watershed.

PROJECT COMPONENTS

Video and Audio Messages. Three video messages and four radio messages were created and were aired for the first time September 16, 2003; they are aired as non-commercial sustaining messages through the Tennessee Association of Broadcasters (TAB) and were sent to 321 radio stations and 33 commercial television stations across the state. The television spots featured Chuck the Catfish, a gruffly lovable character who in one message, a la Dr. Seuss, exhorts citizens to "abstain from putting bad stuff in the drain" in order "to maintain my wet domain"; in

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[2] Robinson, Les, "A 7-Step Social Marketing Approach" in a presentation to Waste Educate 98 Conference, Social Change Media, http://media.socialchange.net.au/strategy/

[3] McKenzie-Mohr, Douglas, "Fostering Sustainable Behavior", published June 29, 1999 by New Society Publishers.

another message, Chuck admonishes adult citizens who exhibit irresponsible behavior that hurts water quality; in the third message, he is teaching clean water tips to a classroom of children who are already very aware of the right behavior.

Two of the radio messages are the voice of Chuck the Catfish; the other two are an original song, "I Am the River" by Nashville singer/songwriter Dan Tyler ("Bobbie Sue," "Hearts on Fire," "Twenty Years Ago," "The Light in Your Eyes") who graciously donated the use of his song for this campaign.

Statewide Survey. In 2003, the Social Science Research Institute at the University of Tennessee, Knoxville, conducted a telephone survey of adult residents of Tennessee regarding perceptions of water quality across the state and household habits pertaining to the disposal methods of potential pollutants. Additionally, respondents were asked about their knowledge of nonpoint source pollution and preferences for the financing of water quality improvement. The survey was conducted using the Random Digit Dialing method. A total of 871 randomly-selected adult residents of Tennessee were interviewed with a resulting +/- 3.3% margin of error. The cooperation rate for the survey was 35.9%.

Trained personnel, using a Computer-Assisted Telephone Interviewing (CATI) System, conducted all interviews. The survey was designed and analyzed by Dr. Michael M. Gant, Director, Social Science Research Institute and Linda M. Daugherty, Program Director, Social Science Research Institute for the WaterWorks Program at the Center for Environmental Education, Middle Tennessee State University.

Youth Recognition Program. In Fall 2003, WaterWorks! began its 'Stream Savers' program. Youth groups, both formal and informal (classrooms, clubs, Scouts, 4-H, Boys and Girls Clubs, etc.) in Tennessee could win $300 for their water quality project; monthly winners are eligible for further recognition by competing for an annual award of an additional $500.

Eligible projects could include, but are not limited to:

- River or stream cleanup
- Water testing
- Stream bank repair/restoration
- Education or awareness project

Applications must be email dated/postmarked by the 10th of the month in which they are to be considered and will be announced at the end of that month. Youth in grade levels 5-12 are eligible.

Stakeholder Meetings. WaterWorks! is connected with a variety of water-related organizations and groups, and has had representation at state, regional, national and international levels. Sample groups include: TN Environmental Education Association, Environmental Education Association of Alabama, TN Council of Social Studies, TN Educators of Aquatic and Marine Sciences, TN Section of the American Water Resources Association, National Conference Nonpoint Source Pollution Information & Education Programs, North American Association of Environmental Education.

Website. WaterWorks! website is unique in that its homepage showcases beautiful water features of Tennessee, with the permission of the photographer, Mack Prichard. Opportunities for others to share their TN water pictures are available; credit is always given to the photographer.

Website features include:

- About WaterWorks!
- Public Service Announcements
- Youth Recognition
- Brochures (under 'construction')
- Survey
- 10 Water Tips
- Watershed Map
- Watershed Groups
- Links

Watershed Groups. Watershed groups, 'friends' groups, and other water-related organizations are listed on our website; updates are made as groups asked to be listed or linked. Additional links are/will be made to state (and other agencies) and organizations on another page.

Watershed Map. One of the most interesting features of the website is a state map with watersheds overlaid on the counties. Plans for developing this page include adding contact information about watershed groups in each watershed, city/county officials in charge of stormwater permits, whom to contact for suspected pollution, etc.

WATERWORKS! IN THE 'MAINSTREAM'

Opportunities for the Tennessee Phase I and Phase II MS4's (municipal separate stormwater sewer systems) to fulfill their public education and outreach through the use of WaterWorks! video and audio messages, brochures and other print media are easily available.
Contact information:

Website: www.tennesseewaterworks.com (Contact Us)

Email: khargrov@mtsu.edu

Phone: 615-898-2660

FAX: 615-217-7865

Mail: Karen Hargrove
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TWO SIMPLE PHYSICAL MODELS FOR CLASSROOM INSTRUCTION OF HYDROLOGIC CONCEPTS

Robert L. Hunt*

INTRODUCTION

This paper describes two of the physical demonstrations (demo's) used in the Corps of Engineers "Hydraulic & Hydrologic Considerations in Planning" course for planners. The two demo's have been presented to adults, and one has been presented to junior high school students. The two demo's illustrate runoff hydrograph generation and model calibration/verification.

During the past two years, the Corps of Engineers has been conducting seven nationwide training courses for its planning personnel. These seven "CORE" courses, so called, were developed in recognition of the need to maintain water resources planning skills throughout the Corps. One of the seven training courses is entitled "Hydraulic & Hydrologic Considerations in Planning," and the author is one of seven instructors for that course.

The "Hydrologic Considerations" course is aimed at planners who are not engineers. Many of the Corps non-engineer planners have biology or social science backgrounds. At the time of the writing of this article, the "Hydrologic Considerations" course has been conducted three times. The non-engineer students in the "Hydrologic Considerations" course have proven eager to learn fundamental engineering concepts in hydrology and hydraulics.

It is the author's observation that two of the difficulties that non-engineers face in learning hydraulics and hydrology is a comparative lack of practice in visualizing mechanical events distributed through time and space, and a lack of practice in the mathematical description of such events. Such skills cannot be attained during a one-week course. Therefore, in order to better connect with non-engineer students, the "Hydrologic Considerations" instructors sought a way to de-emphasize mechanical and mathematical rigor.

Part of the solution adopted by the "Hydrologic Considerations" instructors was the inclusion of a few physical demonstrations in the classroom. The demonstrations included random generation of log-normally distributed annual maximum floods, stream channel routing, hydrostatic pressure, runoff hydrograph generation, orifice flow, weir flow, and model calibration/verification. Experience suggests that many, perhaps most, of the non-engineer planners benefited from and enjoyed the physical demo's.

The two models described in this paper are easy and inexpensive to build, dry, portable, do not make a mess in the classroom, provide immediate results, and are operable by the students themselves. Moreover, the models are built from materials that are familiar to the student and readily available at low cost to the instructor.

The use of materials familiar to the student is probably more important that it might seem. Not only may the use of familiar materials in an unfamiliar setting offer comic relief, but it also prevents students from wondering what the components are and how they work--helping them to focus on the subject of the demo.

The philosophy behind these models includes student participation, mechanical action, and an aversion to electronics. Moreover, hydrologic exercises involving the passing of materials from student to student are intended to connect with anthropomorphically-oriented students, helping them to personify, or identify with, physical elements of the watershed.

No claim of originality is made in this paper; the physical demos described are so obvious it would not be surprising if they have been used by others at various times and places.

RUNOFF HYDROGRAPH GENERATION

Design. As shown in Figure 1, a bar-graph made of 1/4 inch diameter wooden dowels and segments of 1/2 inch diameter PVC pipe is used to demonstrate the generation of a runoff hydrograph. The wooden dowels are inserted into holes drilled into the top of a piece of wood (brick mould works well) about 18 inches long. The pipe segments serve as counters that form bar graph columns when stacked on a dowel. All but a few pipe segments are unpainted (white). A few pipe segments are painted red; the use of the red segments is explained below.

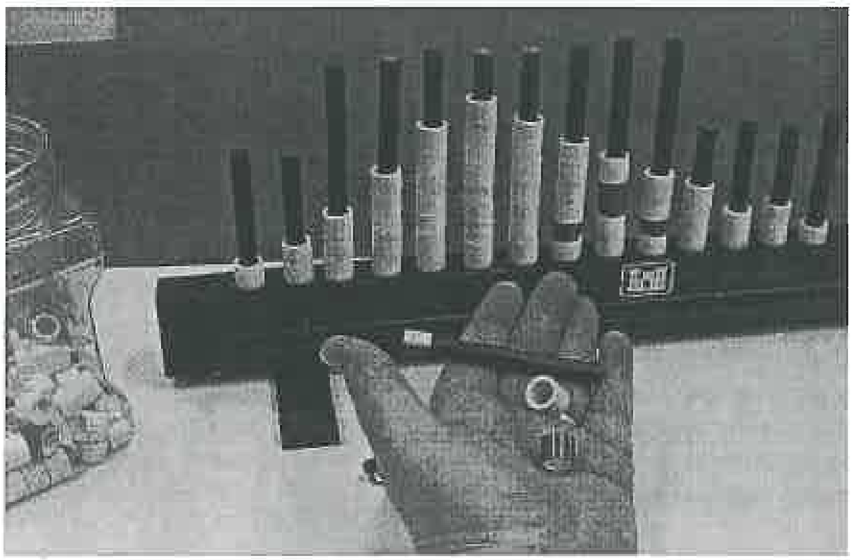

Figure 1. Bar-Graph of Hydrograph

Procedure. As shown in Figure 2, a "watershed" is delineated by "roping in" a set of seated students with survey ribbon or string. Each student represents a unit area of the landscape. A main stream is delineated by passing another ribbon alongside a central column of students. The students outside the watershed boundary are spectators in this demo. The student on the front row who is also on the main stream (i.e. central column) represents the outlet of the watershed.

Each student in the watershed, including those seated on the main stream, is given four counters (pipe segments). The student(s) at the end of the longest path(s) to the outlet is given red counters instead of white. A hydrograph is generated by an orderly passing of counters to the outlet in discrete time steps. A student who was not seated within the watershed is assigned the task of standing at the front of the class and receiving counters from the "outlet" student and stacking the counters on the wooden dowels. Counters are placed on the left-most dowel first (from the watershed-students' point of view). Subsequent counters are placed on the next dowel to the right until the process is over. Each dowel represents one time step; all counters collected in one time step must be placed on the same dowel.

The passing *pathway* rule is that counters are passed inward along a row from left and right sides of the class until collected by the student on the central column who represents the main stream. This inward passing represents flow of runoff along small tributaries to the main stream. Students on the main stream pass their counters to the student in front of them who is also a "main stream" student.

The passing *timing* rule is that each student, whether representing an ordinary watershed point, or a main stream point, passes a *portion* of what he has in hand to the person downstream of himself *before accepting counters* from people upstream of himself.

The *storage/outflow* rule is that each person passes down approximately half of the counters he has in hand during a given timestep. Watershed students seated along the boundary of the watershed, but not at the upstream end of the main stream, will find themselves passing downstream two counters during the first time step, one counter on the second time step, and the remaining counter on the third time step.

The result of these rules is the occurrence of an upstream-moving wave of the passing of counters downstream during a given timestep. Students will probably tend to pass counters downstream so as to produce a continuous flow toward the outlet, unless prevented by the instructor. Time steps must be clearly announced and ruthlessly enforced. All passing of counters must cease before a subsequent time step commences.

More often than not, the general shape of the hydrograph will be a bell-curve with a steep rise on the left (early) side, one clearly defined peak, and a longer falling tail on the right (later) side. Such a shape is called a gamma-hydrograph. As students select half of the counters in hand for passing forward, the red counters must be selected and passed forward at the earliest possible opportunity by everyone along the path to the outlet. If this is done scrupulously, the dowel on which the first red counter appears will represent the time step coinciding with the *time of concentration* of the watershed. At the time of concentration, all points within the watershed have delivered some runoff to the outlet.

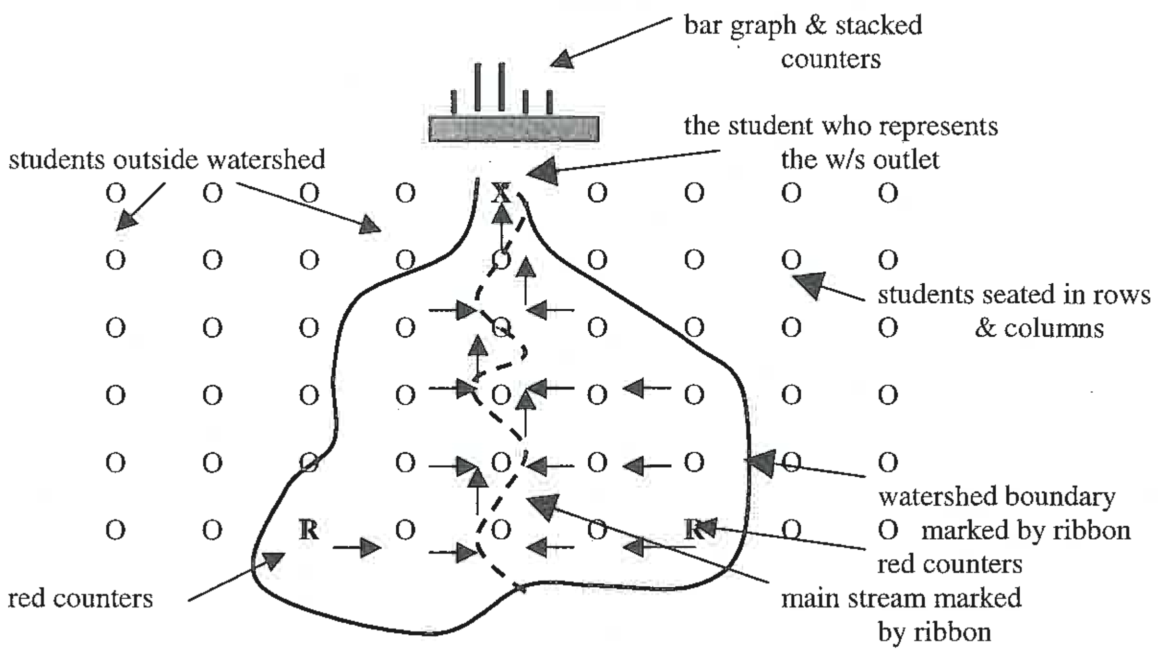

Figure 2. Layout of the Student-Watershed

Questions. Students may ask why passing is divided into time steps. There are two reasons. The first reason is that the bar chart is discrete, rather than continuous. The second reason is that hydrologic computer programs work in time steps, and this is an opportunity to expose the student to a very important principle of numerical modeling. Students may ask why they must pass downstream only a portion of what is in hand. Passing a portion of what is in hand imitates a principle of hydrologic routing, such that outflow is a function of the amount of water present in length of stream. The decision to pass half was arbitrary and made for convenience.

MODEL CALIBRATION & VERIFICATION

Design. A rubber-band catapult is used to demonstrate model calibration and verification. Shown in side view in Figure 3, the catapult is made of scrap wood and aluminum. The "gun" can be fired horizontally, or tipped up. The catapult is single-shot and is triggered by a clothes-pin that is fastened to the gun. The overall length of the catapult is 16 inches (marking pen in photo for scale). A plastic coffee-can lid makes the firing angle scale; the angle variable is *continuous*--set by a wing-nut. A piece of flat aluminum strap metal has been notched in seven places, allowing a rubber band to be stretched in *discrete*, one-inch steps.

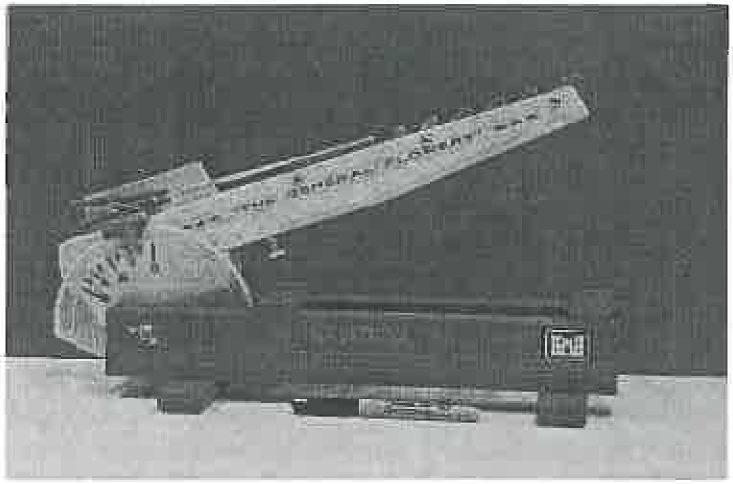

Figure 3. Side View of Rubber-Band Catapult

Figure 4 provides a top view of the catapult. The rubber band is shown attached to notch number 2. Uniform ammunition is critical. One should obtain a bag of rubber bands all of the same size and strength from a reputable merchant.

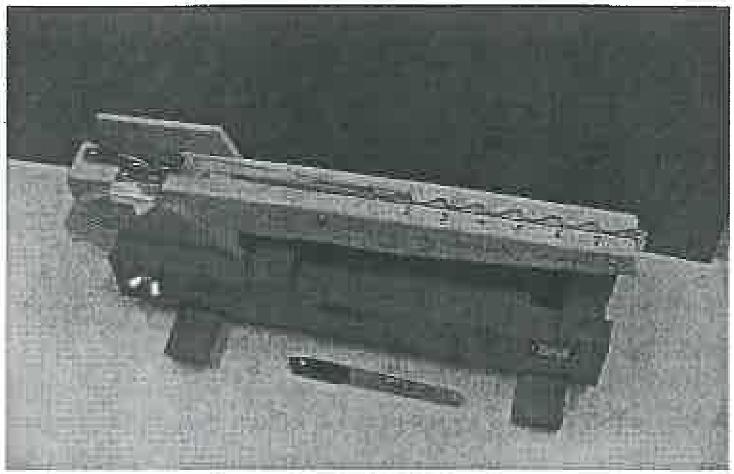

Figure 4. Top View of Rubber-Band Catapult

Procedure. The procedure described is for the simplest case were there is only one dependent variable and one independent variable. The horizontal distance that a rubber band travels when shot from the catapult is the *dependent variable*, measured in feet by tape measure. The tilt of the gun is set at a handy angle and not changed, leaving the amount of stretch in the rubber band as the sole *independent variable*.

Data is collected for model calibration by firing rubber bands from various notches on the gun. Multiple shots may be made from one notch in order to check *repeatability* of the results. However, at least one notch should not be used, being reserved for later verification. Data is recorded as (x,y) pairs (i.e., notch number, distance traveled).

The (x,y) pairs are plotted by hand on a blackboard as a graph (Figure 5). The students are asked to visualize a curve that would represent the relationship between rubber band stretch and distance. Should the curve be a straight line? Concave upward? Convex upward? Should the curve pass exactly through each data point? Need the curve pass through any of the data points? Does the repeatability of the data influence our notion of a well-fitting curve? Students should do the plotting and the testing and adjusting of the model curve. The plot should be big enough for the whole class to see.

Ultimately, the *model* of catapult performance is the fundamental shape of the curve drawn through the data, i.e. straight line, simple curve convex up, simple curve concave up, etc. *Calibration* is the fine adjustment of the fundamental curve to well-represent the data. The principle of Occam's razor is introduced--the calibrated curve is not to be over-refined by implausible twists and turns.

Verification is performed after stretching the rubber band to a notch setting that was never used during the first spell of data collection and firing. Does the latest data point lie on, or near, the calibrated curve? Did the latest data appear to reveal new information about the behavior of the catapult? Is the calibrated curve suitable for use without adjustment?

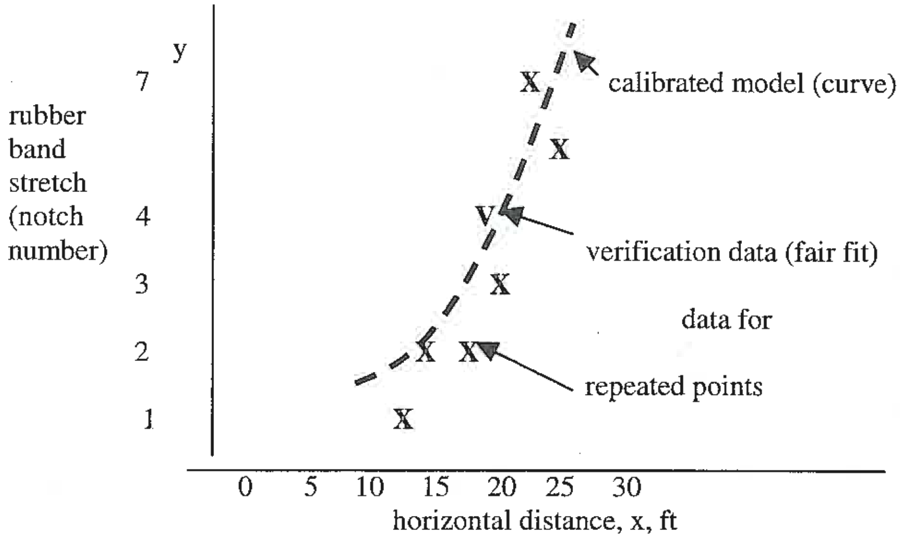

Figure 5. Catapult Data, Calibration, and Verification

Questions. The student may ask what the purpose of the model is. In this case, provided the distance to a target is known, the model helps the student know in advance what notch to set the rubber band on in order to hit the target on the first try. Time can be of the essence in all-out rubber-band conflicts. In hydrology, on the other hand, models may predict the magnitude of floods. The student may ask what purpose is served by verification. Verification is to modeling what the test-drive is for car-buying.

USING INTERNET MAPPING FOR MANAGEMENT AND OUTREACH IN CROOKED FORK WATERSHED

Joanne Logan*[1]

ABSTRACT

Crooked Fork, located within the Emory River Watershed (HUC 06010208), is approximately 12,960 ha with mixed land use. Many sections of Crooked Fork stream and its tributaries are on the 303(d) list (Tennessee Department of Environment and Conservation, 2003) as only partially supporting for nutrients, sediments, and habitat alteration. Much of the development in this area is concentrated along the stream that runs along the valley of the mountainous area. Rapid development has created water quality problems as people have built homes, businesses, and roads along the floodplains in this region. Main sources of impairments include past channelization, a wastewater treatment plant, two prisons, three towns, sewage leaks, livestock, construction, junk yards, logging/ATV roads and abandoned mines. A collaborative effort between the Emory River Watershed Association, Tennessee Valley Authority, and the University of Tennessee was initiated as the result of a one year water quality study of this watershed. An ArcIMS Internet Map Server was used to create an Internet-based map that can be used to educate the stakeholders in the watershed, to coordinate watershed assessment efforts, and to help continuing studies to identify sources of pollution. Map information includes hydrology, topography, imperviousness, pollutant model results, status of surveys, water quality data, and photographs.

INTRODUCTION

The goal of watershed management is to plan and work toward an environmentally and economically healthy watershed that benefits all that have a stake in it. A watershed plan is the roadmap to this goal. Watershed plans try to encourage local citizens to become more involved with and concerned about water quality issues in their watershed. One approach is to involve citizens in data collection and water monitoring. Citizen science encourages people to reclaim responsibility for themselves and their sense of place. It allows citizens to use their own senses and expertise to perform serious scientific research. Citizens bring varied areas of interest and expertise to the table, and can take what they learn from participating in citizen science projects back to their community (Citizen Collaborative for Watershed Sustainability, 2003). It is critical for watershed planners and citizen scientists to be able to communicate and exchange information and coordinate efforts such as stream assessments and windshield surveys. A GIS tool to assist in watershed planning would be beneficial to everyone. ArcIMS (ESRI, Redlands, CA) provides the foundation for distributing high-end geographic information systems (GIS) and mapping services via the Internet. ArcIMS software enables users to integrate local data sources with Internet data sources for display, query, and analysis in an easy-to-use Web browser (ESRI, 2003).

METHODS

An ArcIMS server was installed in the Department of Biosystems Engineering and Environmental Science. Also installed was base GIS data for the State of Tennessee, including digital ortho quarterquads (DOQQ), digital raster graphics (DRG), National Hydrological Data

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(NHD), 10-meter and 30-meter Digital Elevation Models (DEM), road centerlines, and Hydrologic Units (HUD). A map service for the Crooked Fork watershed was created with the base GIS data, and other relevant GIS data such as:

- Location of sampling points
- Location and tracking of assessments
- Future landuse
- Stormwater retrofits
- Floodplains
- Stormwater hotspots (abandoned mines, logging roads)
- Land ownership
- Drinking water supplies
- Septic fields
- Hazardous waste sites
- WWTP
- Historical sites
- Soils and geology
- Stream adoptions

RESULTS AND DISCUSSION

The Crooked Fork watershed was divided into 17 subwatersheds based on topography and land use. As part of the educational outreach component of the map server, general information, including photos, about the main sources of point and non-point pollution determined from surveys and models is available for each subwatershed, as well as sources of assistance for remediation. Water quality data collected by TDEC, the University of Tennessee, TVA, and various school groups is included, if available, for each subwatershed. To help with planning, the status of surveys and assessments are tracked within the ArcIMS system. Thus, at any time, a planner can know, for example, how many reaches of his assigned stream segment have been assessed, and the results of those assessments. One concern is public awareness and access to the Crooked Fork Internet Map Server. ArcIMS works best with broadband Internet and is slow over a modem. Therefore, we plan to provide brochures at public Internet sites with fast connections located within the watershed, such as public libraries and the local schools, and computer-based kiosks at chambers of commerce, court houses, and the Obed Wild and Scenic River office in Wartburg.

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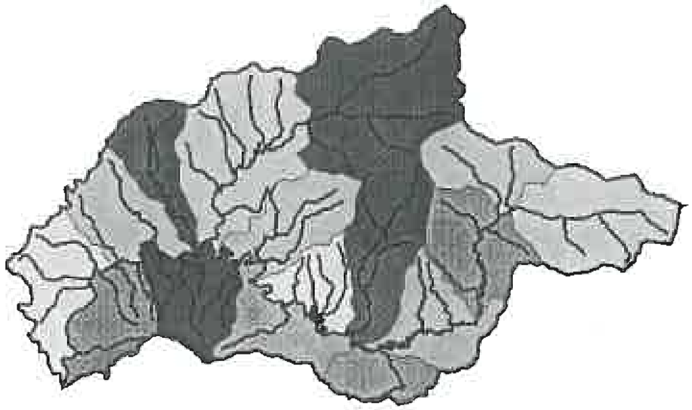

Figure 1: Subdividing the Crooked Fork watershed into 17 subwatersheds was the first step in Internet map development.

Figure 2: Map showing the status of stream assessments in the subwatershed.

Thanks to Tennessee Valley Authority and the Emory River Watershed Association for their help with this project.

DEVELOPMENT OF REAL-TIME PCR ASSAYS FOR THE DETECTION OF *BACTERIODES* SP. AS A METHOD TO QUANTIFY FECAL CONTAMINATION

Alice C. Layton*[1], Dan Williams[2], Victoria Garrett[2], and Larry D. McKay[3]

Whereas it is generally assumed that higher amounts of traditional fecal indicator bacteria, such a fecal coliforms and *E. coli,* represent higher levels of contamination, they are not used to determine the amount of fecal contamination in water samples. Bacteria belonging to the genus *Bacteroides* have been proposed as alternative bacterial indicators of fecal contamination because they are anaerobic, exist in high concentrations (10^{11} cells per gram of feces) and are host-specific thus providing a means for differentiating fecal source contamination. The main drawback to their use is that they are difficult to culture. Real-time PCR is an enumeration method, based on amplification of nucleic acid sequences and does not require bacterial cultivation. We designed a real-time PCR assay to detect *Bacteriodes* 16S rRNA genes based on DNA sequences obtained from human, cattle, horse, dog, fish and chicken feces. The *Bacteroides* rRNA gene assay and a previously designed assay for *E. coli* rRNA genes were used to determine the concentrations of *Bacteriodes* and *E. coli* in DNA extracted from 16 fecal samples from different animals. The mean *Bacteroides* rRNA gene copies were 2×10^{11} per gram of feces. *E. coli* rRNA gene copies were more than 200 fold lower (mean of 9×10^{8} gene copies per gram of feces). The *Bacteroides* rRNA gene assay could quantify 0.5 ppm (0.5 mg feces/L water) in water samples spiked with feces and is currently being used to determine the amount of fecal contamination in creek water samples.

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QUANTIFICATION OF ENTEROVIRUS AND HEPATITIS A VIRUS IN EAST TENNESSEE GROUND WATERS USING REAL-TIME RT-PCR

Trisha Baldwin*[1], Alice Layton[2], Victoria Garrett[2], Dan Williams[2], Sid Jones[1], Greg Johnson[3], and Larry McKay[1]

ABSTRACT

The purpose of this paper is to provide an introduction to research being conducted by the University of Tennessee's Center for Environmental Biotechnology and the USGS regarding occurrence of enteric viral pathogens in east Tennessee groundwater. The paper will describe the progress of the research to date and outline plans for future work.

INTRODUCTION

Enteric viruses are the most common waterborne pathogens associated with disease outbreaks in groundwater (Rose and Yates 1998), and can cause an array of illnesses and even death. There is limited information about their survival and transport in groundwater or their spatial and temporal occurrence in wells and springs used for drinking water. Groundwater in east Tennessee is expected to be particularly susceptible to enteric viral contamination because this region is underlain in many areas by karst aquifers. These aquifers are productive drinking water sources and, in east Tennessee, wells and springs are used for water supply by small towns, rural schools, churches, farms, and private homes. Numerous studies (Kacaroglu 1999, Boyer 1999, Mahler et al. 2000, USEPA 2000) have confirmed that karst aquifers are especially vulnerable to contamination by microbial pathogens. Possible sources of enteric viruses to these groundwater supplies may include septic tanks and fields, leaking sewer lines, land application of wastes, animal feed lots, dairy farms, and other animal-husbandry operations, injection wells, landfill leachates, unintentional wastewater plant overflows, and treated wastewater effluent (Gantzer et al. 1998, Azadpour-Keeley et al. 2003, Environment Agency 2000). Additionally, fractured and fine-grained subsoils derived from the weathering of carbonate-rich rocks, commonly referred to as saprolite or residuum, sometimes blanket the karst aquifers of east Tennessee. Ongoing field studies in these materials (McKay et al. 2002) indicate that microorganisms can travel rapidly through fractured saprolite, thereby increasing the potential for contamination of the underlying karst aquifers.

Even though the potential for enteric viral contamination of groundwater in east Tennessee seems cause for public health concern, enteric viral occurrence in this region has not been examined due to a lack of viral monitoring. Most often, viruses are detected in groundwater using cell-culture methods or traditional reverse transcriptase-polymerase chain reaction (RT-PCR). Cell culture methods are expensive, labor-intensive, and quantify only viruses that successfully replicate in cultured cells. Traditional RT-PCR is faster and can detect both culturable and nonculturable viruses, but is qualitative and gives only a presence or absence result.

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Real-time RT-PCR is a rapid, highly sensitive method for amplifying and quantifying nucleic acid sequences. It is already widely used in clinical settings (Harms et al. 2003) but has seen limited use in environmental testing applications. Real-time monitoring of fluorescent signals during PCR amplification eliminates the need for post-PCR sample processes such as electrophoresis (Harms et al. 2003). Thus, real-time RT-PCR has all the capabilities of RT-PCR but is quantitative and much faster. Analysis times can be reduced from 6 hours to < 1 hour. Studies of real-time RT-PCR assays for detection and quantification of enteric viruses in groundwater have not yet been published.

RESEARCH GOALS

The overall goals of this research are to (1) develop and validate a fast, efficient method of quantitatively measuring concentration of two common enteric viruses, enteroviruses and hepatitis A viruses (HAV), in groundwater samples using real-time RT-PCR assays, (2) use the real-time RT-PCR assays to conduct the first field scale snap-shot survey of enterovirus and HAV occurrence in karst aquifers of east Tennessee, and (3) investigate the relationship, if any, between concentrations of enterovirus and HAV and commonly used indicators of human fecal contamination such as *E. coli*, turbidity, and chemical indicators. The field study will involve sampling of both "high risk" and "low risk" wells and springs (for a total of at least 10 sites) in east Tennessee during varying flow conditions. Samples will be tested for enteroviruses, HAV, *E. coli*, *Bacteroides*, water quality field parameters, and major ions and nutrients. Sites will be designated as at "high risk" or at "low risk" for human fecal contamination based on historical *E. coli* data at each site in addition to other preliminary data collected by the research team.

HYPOTHESES

The first hypothesis for this study is that real-time RT-PCR will be a fast and efficient method for the detection and quantification of enteroviruses and HAV in groundwater. This hypothesis is the easiest yet most important to test. If this hypothesis is not true, additional hypotheses will be difficult to test. A second hypothesis is that the highest concentrations of enterovirus and HAV will be found in the wells and springs designated as at "high risk" for fecal contamination. "High risk" wells and springs will also be expected to have higher concentrations of indicators of fecal contamination other than *E. coli*, such as *Bacteroides*, than "low risk" wells and springs. The null hypothesis, that commonly used indicators of fecal contamination will not be predictors of viral occurrence, if proven, has many possible causes. These could include differences in contaminant sources, survivability characteristics, and transport behavior between bacteria and viruses in these hydrogeologically complex systems. A subhypothesis is that an individual well or spring sample will not be positive for both enterovirus and HAV, as has been the case in other studies (Metcalf et al. 1995). The suggested reason for this is that concentrations of viruses in the watershed vary according to outbreaks of enteric illness (i.e. viruses are only shed into the environment when people are infected).

CURRENT PROGRESS

The first step in accomplishing the above research goals has been completed. Researchers at the University of Tennessee's Center for Environmental Biotechnology have developed real-time RT-PCR assays for quantification of enteroviruses and hepatitis A viruses by adapting already available RT-PCR assays to a real-time RT-PCR format. The assays were validated using known concentrations of viral RNA standards as the amplification template. The viral RNA standards used were Armored RNA®-Enterovirus and Armored RNA®-Hepatitis A Virus (Ambion, Inc., Austin, TX). Armored RNA® is completely characterized viral RNA packaged in bacteriophage coat proteins that both protect the RNA from ribonucleases and stabilize the RNA for long-term storage. Both the annealing temperature and the primer and probe concentrations for the assays were determined from numerous optimization experiments. The linear detection range for the enterovirus assay was determined to be 4 orders of magnitude, from 52.5 to 5.25×10^5 copies per PCR (see Figure 1), with a detection limit of <10 copies per PCR. The linear detection range for the hepatitis A virus assay was determined to be 2 orders of magnitude from 2.2×10^2 to 1.4×10^5 copies per PCR (Figure 2), and a detection limit of about 200 copies per PCR. One important advantage of using real-time RT-PCR for this work is that once processed, groundwater samples can be frozen and then reanalyzed by the real-time RT-PCR assays in the future, as the assays continue to improve with further optimizations.

Figure 1. Standard curve of serial dilutions (in triplicate) of Armored RNA®-Enterovirus.

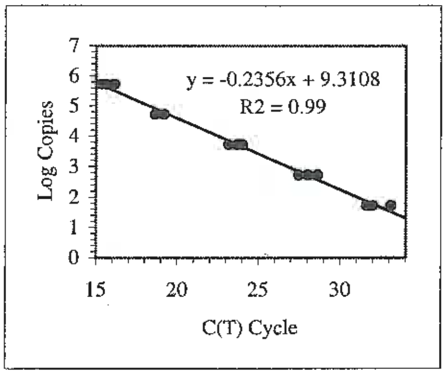
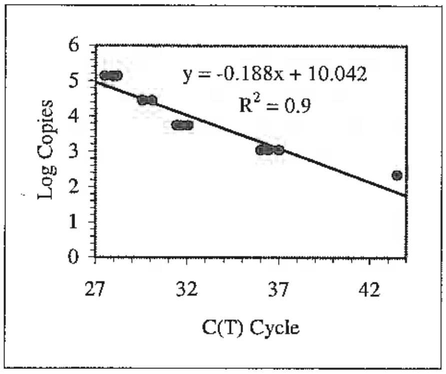


Figure 2. Standard curve of serial dilutions (in triplicate) of Armored RNA®-Hepatitis A Virus.



FUTURE WORK AND BENEFITS

The next phase of this research is to test the real-time RT-PCR assays on actual groundwater samples through spiked recovery experiments using the Armored RNA®. If the assays perform well on groundwater samples, they will then be used to conduct the field scale snapshot sampling for enteroviruses and HAV in east Tennessee wells and springs. EPA will also analyze the groundwater samples for viruses using the traditional viral detection methods, cell culture and RT-PCR, for a comparison to the real-time RT-PCR assays.

There are many benefits to the successful completion of this study. A fast and efficient method of analyzing groundwater samples for enteric viruses should help to increase viral monitoring and lead to more intensive field studies of the spatial and temporal occurrence and concentration of enteric viruses in the source waters of east Tennessee. These studies are needed to evaluate current drinking water treatment strategies, properly conduct microbial risk analyses, assess current regulations for developing Wellhead Protection Plans, and further our understanding of fate and transport of viruses in karst aquifers. In addition, future research will help to determine whether there is any relationship between enteric virus occurrence and other measures of fecal contamination in karst aquifers.

ACKNOWLEDGEMENTS

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INFLUENCE OF DIFFERENT SAMPLING STRATEGIES ON ESTIMATING VOLATILE ORGANIC COMPOUND LOADS AND MAXIMUM CONCENTRATIONS AT THREE KARST SPRINGS IN TENNESSEE

Shannon D. Williams*[1], William J. Wolfe[1], and James J. Farmer[1]

ABSTRACT

The influence of different sampling strategies on estimating volatile organic compound (VOC) loads and characterizing VOC concentrations was evaluated at three karst springs in Tennessee. During a six-month period, VOC samples were collected weekly at all three springs and as frequently as every 20 minutes during storms at the two springs with variable water-quality conditions. Total 6-month loads were calculated using the VOC data and the data were systematically subsampled data to simulate several potential sampling strategies. Results from the study indicate that sampling strategies for karst springs need to be developed on a site-specific basis. The use of fixed sampling intervals (as infrequently as quarterly or semiannually) produced accurate concentration and load estimates at one of the springs; however, additional sampling was needed to detect storm related changes at a second spring located in a similar hydrogeologic setting. High frequency or flow-controlled sampling was needed at the third spring, which had the most variable water-quality conditions. The use of fixed sampling intervals at the third spring significantly affected the accuracy of load calculations and the detection of pulses of high contaminant concentrations that might exceed toxicity levels for aquatic organisms.

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SESSION 3A

GROUNDWATER: CONTAMINATION AND RECHARGE ISSUES, #1
8:30 a.m. - 10:00 a.m.

Comparison of Aquifer Characterization Parameters and Metals Between Background and Affected Monitoring Points for Solid Waste Landfills Located in the Great Valley of East Tennessee
Randy M. Curtis

Recharge to the Aquifer System in Western Tennessee
John K. Carmichael

Signature of Regional Groundwater Discharge to Surface Water at the Unconfined/Confined Aquifer Transition: Example from the Loosahatchie River in West Tennessee
Lensyl Urbano and Brian Waldron

GROUNDWATER: CONTAMINATION AND RECHARGE ISSUES, #2
10:30 a.m. - 12:00 p.m.

The Effect of Ground-Water Production for Peak Power Plants on Water Levels in Haywood County, Tennessee
Michael Bradley

Stream-Flow Loss Along North Chickamauga Creek: An Important Source of Ground-Water Recharge for Cave Springs, Hixson, TN
Connor H. Haugh

Drops of Water in Oceans of Sand: Ground Water Resources of West Tennessee
Thomas Moss

COMPARISON OF AQUIFER CHARACTERIZATION PARAMETERS AND METALS BETWEEN BACKGROUND AND AFFECTED MONITORING POINTS FOR SOLID WASTE LANDFILLS LOCATED IN THE GREAT VALLEY OF EAST TENNESSEE

Randy M. Curtis, R.P.G.*[1]

INTRODUCTION

Detection monitoring programs for landfills typically require the analysis of groundwater samples for volatile organic compounds (VOC's) and metals with a strong emphasis on metals with established maximum contaminant levels (MCL's). Groundwater monitoring parameter lists may also include certain "indicator" parameters, which are also commonly evaluated during regional aquifer chemistry studies. Solid waste disposal sites are monitored to ensure that any effects from disposal operations are not adversely impacting human health or the environment. The presence of the solid waste disposal facility can affect local groundwater by (1) direct mixing of leachate that seeps into the groundwater from the waste, (2) the physical aspects of site construction and operation, during which native soils are excavated and the remaining air space is filled with waste materials over tens or hundreds of acres, thus affecting groundwater recharge and discharge, or (3) movement of landfill gas generated via waste decomposition from the landfill into surrounding and/or underlying soils. Landfill gas, in displacing soil atmosphere with large amounts of methane, carbon dioxide, and entrained volatile organic compound vapors, can significantly affect infiltration water chemistry. The objective of the investigation was to compare the levels of metals from points obviously affected by the landfill with the natural amounts of metals found in groundwater and to contrast those levels with the differences in the more traditional indicator parameters. Population distributions of all of the aforementioned parameters were also evaluated to determine how closely they approach the normal distribution upon which many statistical tests depend.

METHOD

Groundwater monitoring data were examined for five landfill sites where VOC's and aquifer characterization parameters were monitored concurrently or historically. The five sites were all unlined sites that had received predominantly municipal solid waste, along with some industrial and special wastes. The data were first lumped into a common database, by parameter, so that the distribution of each parameter, regardless of sample time or location, could be determined. Next, a subset of monitoring data was selected to represent two groups: samples from wells with persistent and consistent VOC detections and those without evidence of VOC contamination. The statistics for these two broad categories were compared to evaluate the differences in the amount of barium, calcium, magnesium, sodium, potassium, chloride, sulfate, and nitrate in the groundwater due to the effects of landfill leachate and landfill gases on the surrounding Cambro-Ordivician age calcareous bedrock and associated soil/regolith materials. The data from the more commonly analyzed metals from the State's detection monitoring list were also examined to determine the percent detection rate, the degree of difference between affected and the presumed unaffected subsets and the distribution patterns of the metals' group characteristics. Table 1 summarizes the findings from the group and subset data evaluation. All concentrations in the table are parts per

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million.

Table 1—Average Concentrations and Detection Rates of Groundwater Monitoring Parameters Around Solid Waste Landfills

Parameter	Avg. Concentration in Background Wells	Avg. Concentration in Affected Wells	Detection Rate in Background Wells	Detection Rate in Affected Wells
Calcium	107.57	131.10	100%	100%
Chloride	8.87	8.5	89%	94%
Iron	1.793	33.572	97%	92%
Magnesium	21.759	31.257	100%	100%
Manganese	0.1725	1.1872	63%	99%
Nitrate	1.988	2.36	100%	67%
Potassium	3.183	2.602	100%	97%
Sodium	11.541	5.24	95%	95%
Sulfate	21.029	24.579	97%	91%
Fluoride	0.3718	0.3534	96%	98%
Antimony	0.0227	0.703	14%	42%
Arsenic	0.0097	.01546	15%	31%
Barium	0.366	1.744	100%	78%
Beryllium	0	0	0%	0%
Cadmium	.0118	.0115	11%	6%
Chromium	0.0221	0.018	59%	49%
Cobalt	.003	.027	2%	9%
Copper	0.007	0.049	12%	63%
Lead	0.125	0.137	12%	29%
Mercury	0	.0009	0%	6%
Nickel	.0245	.0473	16%	57%
Selenium	0.006	0.022	37%	3%
Silver	0.0110	0.204	4%	30%
Thallium	0.0538	0.0418	8%	11%
Vanadium	0	0.275	0%	4%
Zinc	0.0613	0.1842	60%	76%

Almost all of the metals listed in Table 1 are found in some concentration in the native soil, so it is not surprising that some of the metals are detected in both affected and unaffected groundwaters. The aquifer characterization parameters are not indicators of potential environmental or health risk, but they are extremely useful in distinguishing trends over time and demonstrating whether an impact from disposal operations is occurring. The primary advantage is that they typically will be detected and, thus, can provide valuable information for evaluation. The frequency of non-detection of the more commonly monitored Appendix I metals is a concern, in that potential groundwater impacts may not be evident until the problem has progressed to a considerable degree. Some metals are so infrequently detected that they are of little assistance in detecting contamination or establishing background aquifer conditions for comparison purposes.

CONCLUSIONS

The purpose of a groundwater monitoring program is to detect whether any impact is occurring from solid waste disposal operations before that impact affects public health or the environment. The Tennessee Division of Solid Waste Management (DSWM) solid waste processing and disposal regulations include a monitoring list with VOC's and specific inorganic constituents. The VOC's have obvious utility in that any persistent, consistent detection indicates a problem, since VOC's do not exist naturally in any significant quantity. The DSWM's inorganic list does not appear to be as useful as the VOC's for monitoring purposes because of the low frequency of detection and the problem in distinguishing natural background quality fluctuations from actual leakage from the landfill acting on native soils. The problem is exacerbated because the leachate in the older sites is derived from solid waste mixed with native soils as cover material during daily operations. Any metals from industrial or municipal wastes that is mobilized by leachate from the waste are probably also going to be mixed with metals derived from cation or anion exchange in the native soil, either as daily cover in the waste or in the subgrade beneath the site. The distributions of inorganics from all points monitoring groundwater around landfills appear to represent a continuum of concentrations from native materials to affects from contaminant loads. The distributions are not normally distributed and only approximate normality after being logarithmically transformed. This should be considered in evaluating the effectiveness of the monitoring systems for landfills in Tennessee and a return to some of the past dependence on indicator constituents is advocated by the author.

RECHARGE TO THE AQUIFER SYSTEM IN WESTERN TENNESSEE

John K. Carmichael*[1]

Ground water is the sole source of public water supply for nearly 1.5 million people in western Tennessee, including about 0.9 million people in Memphis and Shelby County. Although the region contains ample surface-water resources, use of ground water for public supply in the area began in the late 19th century following several surface-water-born disease epidemics earlier in the century. As a result of the importance of this resource, much has been learned about the hydrogeology of western Tennessee over the past 100 years; however, the mechanisms and rates of recharge to the aquifer system remain poorly understood. With demand for ground water in western Tennessee continuing to increase and as development continues in the subcrop and outcrop areas of the Memphis aquifer, the understanding of recharge processes becomes more important as the management and sustainability of this resource is predicated on a balance between rates of withdrawal and recharge.

Recharge in western Tennessee presumably is derived from two sources: direct infiltration of precipitation and, locally, surface-water (primarily streamflow) losses. These two modes represent possible end members of a continuum, with the relative contributions from each dependent on factors such as land slope, vegetation, surficial geology, degree of aquifer confinement, and location relative to major pumping centers (depth to water). The locations of losing or gaining stream reaches and the amount of streamflow lost to or gained from the ground-water system can be obtained by measuring stream discharge at sites of interest in a study area. Because of cost and complexity, however, few studies in western Tennessee have included direct evaluation of water-budget variables such as evapotranspiration and runoff, which exert control on the amount of recharge from infiltration of precipitation to the ground-water system. Furthermore, a poor understanding exists of the mechanisms and rates of water infiltration and percolation through the loess, the principal surficial geologic unit in much of western Tennessee. The effects of long-term and large-volume withdrawals from the Tertiary aquifers and associated water-level declines in these units on drainage of water from shallower zones also is poorly understood, as is whether these withdrawals have resulted in inducing additional recharge from streamflow.

A broad range of techniques for calculating or measuring recharge rates are available, ranging from relatively simple to complex, and generally may be categorized into methods based on water budgets, naturally occurring and applied tracers, streamflow hydrograph analysis, water-table fluctuations, and other techniques. Because of scarcity of water, much of the focus on developing methods for determining recharge rates has been in arid regions; however, many of these techniques also are applicable to regions like western Tennessee with more humid climates. Rates derived from all of these methods generally are regarded as estimates only because of error introduced from spatial and temporal non-uniformity of variables that control recharge.

Generally, recent recharge estimates for western Tennessee have been made for, or as a result of, ground-water-flow modeling studies. However, because few of the studies have included detailed local assessments of variables that control recharge, the estimated recharge rates span a wide range, varying from less than 1 to as many as 10 inches per year. Methods used to obtain these estimates also vary from model to model, but generally are based on streamflow hydrograph analysis, or are estimated during model calibration based on assumed or known aquifer hydraulic

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properties and head matching, sometimes with limited or no information on ground-water fluxes into or out of the system, thus resulting in non-unique calibrated model results. Over the last 25 years, the vertical leakage of water downward from the surficial aquifer system to the deeper Memphis aquifer through "windows" in the confining unit separating the two zones has been identified at several locations in the Memphis area. This downward leakage of ground water rather than discharge to surface streams has further complicated flow-model application by removing one side of the flux term that could be used as a verification of recharge estimates in modeling studies conducted in areas containing these features. A better understanding of sources and processes that control rates of recharge in western Tennessee will enhance knowledge of the hydrology of the area and provide for more effective management of the resource by enabling improved simulation of ground-water flow in the aquifer system.

SIGNATURE OF REGIONAL GROUNDWATER DISCHARGE TO SURFACE WATER AT THE UNCONFINED/CONFINED AQUIFER TRANSITION: EXAMPLE FROM THE LOOSAHATCHIE RIVER IN WEST TENNESSEE.

Lensyl Urbano*[1] and Brian Waldron[2]

ABSTRACT

While there have been many studies of local ground-water/surface-water interactions there have been much fewer investigating the impact of regional hydrogeology on the pattern of ground-water discharge to streams. Here we investigate the pattern of ground-water discharge to streams such as the Loosahatchie River of Western Tennessee whose passage over an aquifer transition zone is representative of many river systems within the Mississippi Embayment and Coastal Plain aquifer systems. The Loosahatchie River emerges in the unconfined reaches Memphis aquifer, flowing across the aquifer's unconfined/confined transition before ultimately discharging into the Mississippi River. Using a conceptual ground-water flow model, we find that without the presence of the confining unit, ground-water discharge into the Loosahatchie should remain relatively constant – the Loosahatchie River acting as a gaining system throughout its length. With the inclusion of the subcropping confining unit, the model indicates a rapid increase in ground-water discharge near the unconfined/confined aquifer transition with a subsequent abrupt drop in ground-water discharge as the stream flows over the edge of the confining unit. Streamflow measurements in the Loosahatchie confirm a rapid increase in ground-water discharge to the river approximately 1.5 km downstream from the suspected aquifer transition point, following the general pattern described above.

INTRODUCTION

Understanding groundwater-surface water (gw/sw) interactions is crucial in determining the physical, chemical and biological characteristic of rivers and streams (Sophocleous, 2002). Under baseflow conditions these interactions are dominated by the hydrodynamics of local and regional variations in groundwater flow. At the stream reach scale Vaux (1968) and Woessner (2000) have shown that stream-bed geometry, such as the pattern of pools and riffles, is a large determinant of ground and surface water exchange within the hyporheic zone. On a larger scale Toth (1963) and Winter (1999) have described the patterns of groundwater flow and the relationship of the regional water table to gw/sw interactions, while Skalash and Farvolden (1973) and Brunke and Gonser (1997) have analyzed the effects of bank storage and interflow on stream discharge in response to precipitation events. Yet while it has long been recognized that the regional groundwater flow pattern is affected by the regional hydrogeological patterns (Toth, 1963; Larkin and Sharp, 1992; Sophocleous, 2002) there is a dearth of research on the effects of regional hydrogeology on gw/sw interactions.

In this paper we present an idealized numerical model of gw/sw interactions in the case where a stream flows across the edge of shallow, gently dipping sedimentary deposits as might be found along the flanks of shallow sedimentary basins or continental shelf deposits. In these regions there is a dramatic change in the hydrogeologic regime as streams that are in direct hydraulic contact with shallow sandy aquifers find that contact cut off by the intercession of fine grained confining units. The model is used to show that the change in hydrogeology results in changes in

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groundwater discharge to the stream. These results are confirmed by stream discharge measurements from the Loosahatchie River in western Tennessee.

METHODS

In West Tennessee, the Memphis aquifer (Lower Claiborne unit) has a southeast to northwest trend toward the Reelfoot Rift axis – the Rift axis plunges south to the Gulf of Mexico paralleling the present course of the Mississippi River. Similar to the Wolf River to the south and the Hatchie River to the north, the Loosahatchie River flows from east to west, ultimately discharging into the Mississippi River along the Tennessee-Arkansas border (Figure 1 – inset). The Loosahatchie's headwaters begin approxiamtely 20 km east of the Mississippi River. As the river flows west, it crosses over the Memphis aquifer transition from unconfined to confined where the Upper Claiborne subcrops. This transition point is indicated by the hatched area in Figure 1 depicting the outcropping of the Memphis aquifer (Parks, 1990). In Shelby County, a shallow water table aquifer exists above the Upper Claiborne composed of alluvial and fluvial deposits.

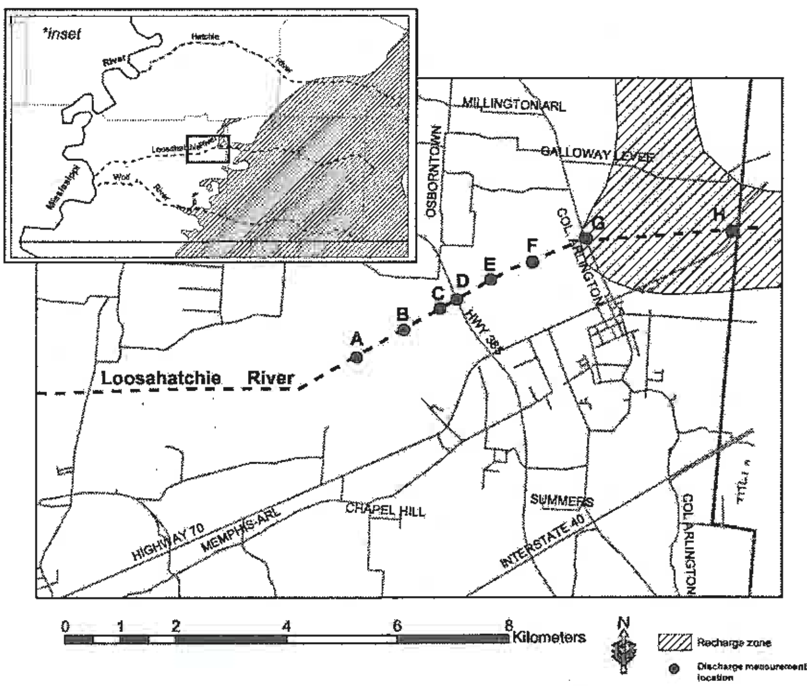

Figure 1. Map showing the Loosahatchie River and location of stream flow measurements.

A generalization of this sedimentary sequence was incorporated into a numerical model as shown in Figure 2. Both the confined and unconfined aquifers were given the same hydraulic conductivity (10^{-4} m/s), while the confining unit was assigned a hydraulic conductivity 5 orders of magnitude lower (10^{-9} m/s). The western boundary, representing the Mississippi River, was defined at a constant head while the remaining boundaries were treated as impermeable to flow. Diffuse recharge of $2.0\text{x}10^{-8}$ m/s was imposed on the model from the top. The numerical model used, SECOFL_3D (Knupp 1996), is an integrated finite difference model that implements a moving top boundary and a deforming numerical mesh to accurately simulate the elevation of the water table. We used 20 cells in the vertical dimension, along with 60x40 cells in the horizontal, to capture the three dimensional flow patterns. The cell dimensions (meters) in the x-, y-, and z-directions were 200, 100, and 3, respectively. The stream channels were represented as constant head boundaries along the top of the model, and the groundwater discharge rate to surface water was determined by the model and is reported.

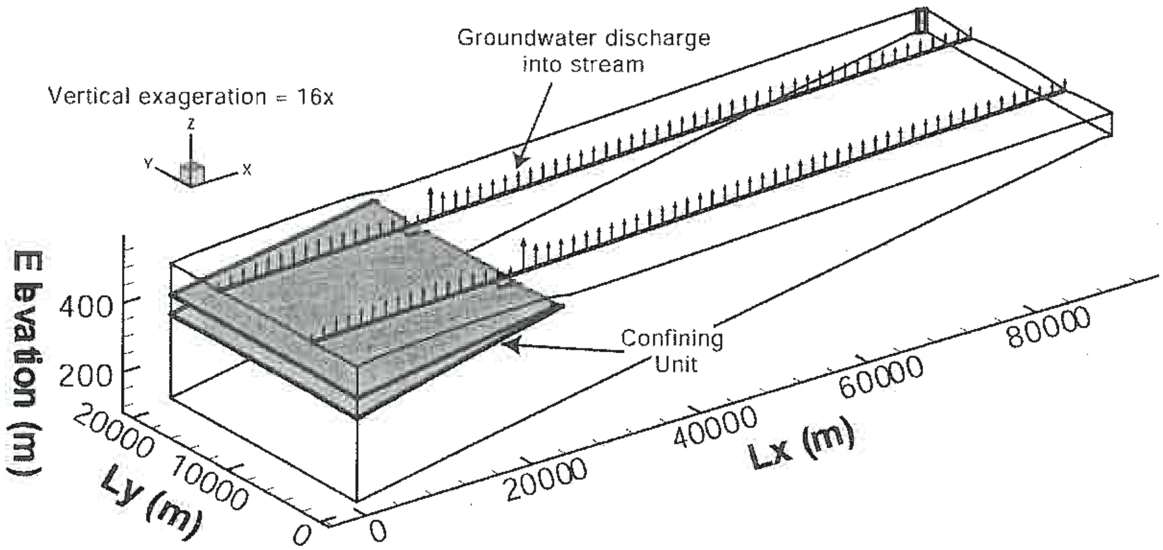

Figure 2. Idealized model of gw/sw interactions with a confined-unconfined aquifer, a partially covering confining unit (grey), and a shallow surface unconfined aquifer above the confining unit.

A physical comparison of measured discharge measurements within the Loosahatchie River bracketing the point of transition as delineated by Parks (1990) was conducted during low-flow conditions in the Fall of 2003. Discharge was measured using AA current meters integrated with Aquacalc™ data recorders. This work was conducted in cooperation with personnel from the USGS.

RESULTS

The conceptual model predicts a significant spike in groundwater discharge into the stream just before the river reaches the transition zone, followed by a significant dip in groundwater discharge as the river flows above the subcropping confining unit (Figure 3). The spike is a result of the diversion of groundwater flow upwards and away from the confined portion of the aquifer. Over the edge of the confining unit the deep upward flow is cut off, so the groundwater discharge rate drops significantly, falling even below the level of the upper reaches of the stream. This is indicative of the fact that most of the water captured by the confined aquifer comes from the area close to the edge of the confining unit, thus the confined aquifer intercepts water that would be discharged to the stream.

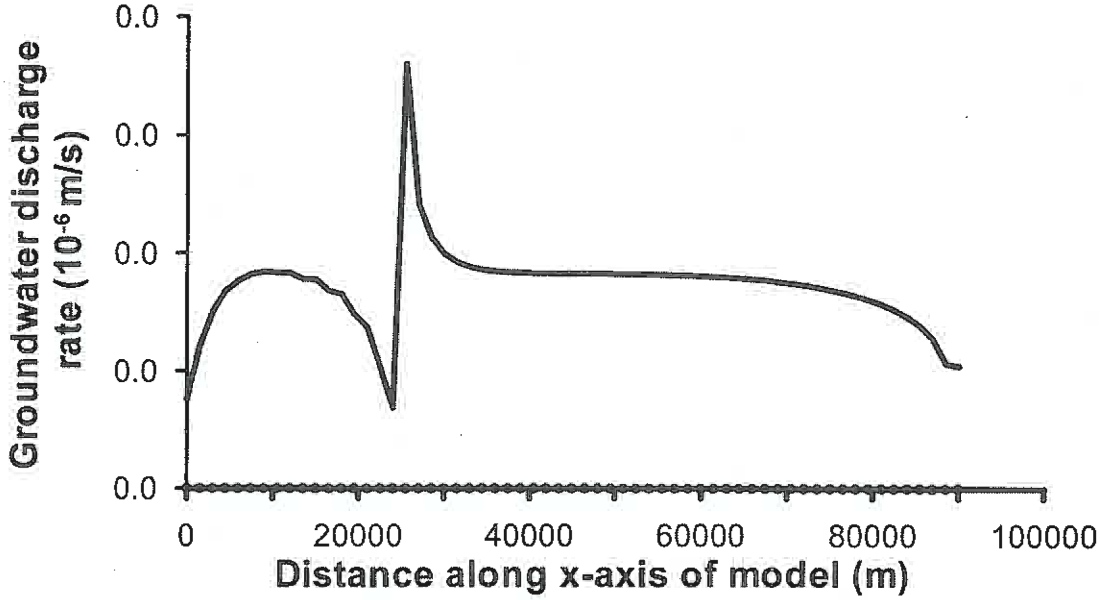

Figure 3. Modeled groundwater discharge into stream.

The model does not directly calculate flow in the stream, but since it assumes that water discharged into the streams rapidly exit the system, the stream flow should be equivalent to the cumulative ground water discharge along the course of the stream (Figure 3). Measurements of stream discharge in the Loosahatchie confirm that there is a rapid increase with a subsequent decrease in stream discharge indicative of crossing the transition zone (Figure 4); however, reversion back to a gaining stream (as indicated by the model) was not observed. This discrepancy may be due to temporary bank storage, a rapid thickening of the unconfined aquifer owing to possible faulting in the area, or a change in stream geomorphology. What is interesting is that the spike in discharge occurred approximately 1.5 km downstream of Parks' interpreted transition point (Figure 1 – Point E).

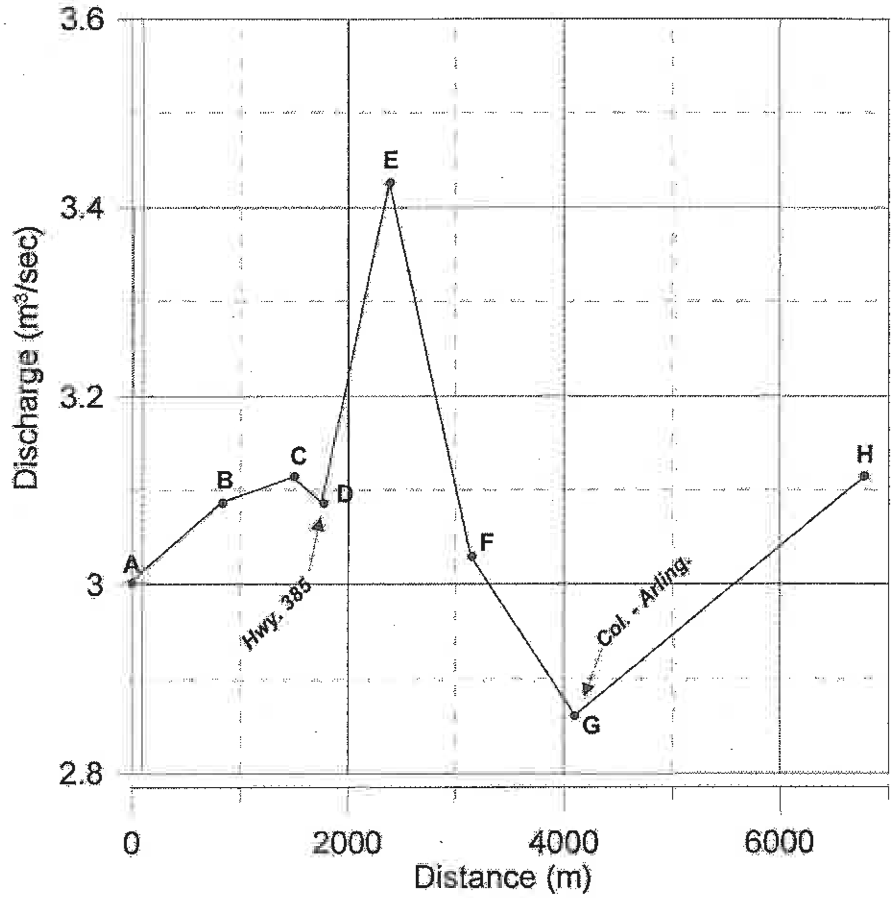

Figure 4. Measured stream discharge along the Loosahatchie River.

CONCLUSION

The effects of regional scale hydrogeology on gw/sw interactions was considered using a numerical model based on the flow of a stream across the unconfined-confined transition zone of a generalized representation of aquifer systems within the Mississippi Embayment. The model shows that there are substantial changes in groundwater discharge at the edge of the confining unit, which is confirmed by measurements of stream flow in the Loosahatchie River. These fluctuations are generated as the flow regime changes from one dominated by the more local unconfined flow system to the more regional flow system of the confined aquifer. Larkin and Sharp (1992), who investigated the interactions between streams and their alluvial aquifers describe this as a change from baseflow dominated to underflow dominated groundwater flow regime. Further investigation into this pheñomenon will increase our understanding of groundwater/surface-water interactions and possibly allow identification of aquifer transition zones beneath river systems via conducting detailed discharge measurements.

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THE EFFECT OF GROUND-WATER PRODUCTION FOR PEAK POWER PLANTS ON WATER LEVELS IN HAYWOOD COUNTY, TENNESSEE

Michael Bradley*[1]

Peak power plants are used to produce electricity during peak demand periods. Plants located in West Tennessee use ground water for cooling and emission control during generation. Current plants near Brownsville in Haywood County, Tennessee use relatively small amounts of water, primarily for emission control. Larger plants that would require ground-water production of 10 million gallons per day or more have been proposed. The impact of the current and proposed plants on ground-water levels in West Tennessee has not been evaluated. The U.S. Geological Survey, in cooperation with the Tennessee Division of Water Supply, conducted a cooperative investigation to evaluate the effect of ground-water production at peak power plants on ground-water levels.

A reconnaissance near two active plants and two plants under construction was conducted to identify available wells for water-level measurements and to evaluate the aquifers being used for production. An observation well at the southern plant was identified and instrumented with a water-level recorder. The monitor well at this site was completed to the same depth as two production wells; about 300 feet below land surface. A series of wells completed at several depths ranging from about 200 to more than 1,100 feet below land surface were identified near the northern plant. Monthly water-level measurements have been collected at the observation wells near the northern plant. The production wells at each plant are capable of pumping 1,000 to 1,500 gallons per minute from the Tertiary sand aquifers. The water-level data show the local effect of short-term pumping from the production wells.

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STREAM-FLOW LOSS ALONG NORTH CHICKAMAUGA CREEK: AN IMPORTANT SOURCE OF GROUND-WATER RECHARGE FOR CAVE SPRINGS, HIXSON, TN

Connor J. Haugh*[1]

Loss of stream flow to the subsurface is a significant source of recharge to the aquifer that supplies Cave Springs and the Cave Springs well field, one of two well fields owned and operated by the Hixson Utility District, located in northern Hamilton County, Tennessee. Average annual stream-flow loss along a two-mile reach of North Chickamauga Creek near the base of the Cumberland Plateau escarpment is about 18 cubic feet per second (cfs) or 12 million gallons per day. The extent of the losing reach of North Chickamauga Creek was defined with a series of stream-flow measurements made during low-base-flow conditions on October 12, 2000 and during high-base-flow conditions on April 26, 2001. Stream-flow losses indicated by these measurements were 2 and 40 cfs, respectively. The losing reach begins near the mouth of the North Chickamauga Creek Gulch where the North Chickamauga Creek flows eastward off of the sandstone rocks of the Cumberland Plateau and onto the Newman Limestone. The downstream end of the losing reach is located where North Chickamauga Creek turns to the southwest and flows parallel to Cave Spring Ridge. Two continuous stream-flow gages were established near the upstream and downstream ends of the losing reach. Continuous stream-flow data collected from November 2000 through October 2003 show that when flow at the upstream gage is about 15 cfs or less, all stream flow sinks into the subsurface before reaching the downstream gage. The downstream gage had no flow for a period of about 5 months during 2001, but only a few weeks had no flow during 2003. Average annual stream-flow loss calculated by subtracting the daily mean stream discharge from the two gages for the period November 2000 through October 2003 is about 18 cfs. Flow-path results from a ground-water model and a water budget analysis indicate this stream-flow loss is a significant source of recharge to Cave Springs and the Cave Springs well field, accounting for about 70 percent of the total water discharged at Cave Springs and withdrawn at the Cave Springs well field.

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DROPS OF WATER IN OCEANS OF SAND: GROUND WATER RESOURCES OF WEST TENNESSEE

Thomas Moss[*1]

The sand aquifers of West Tennessee are valuable, high quality resources that are vulnerable to contamination. It is critical that the general public be made aware of the unique concerns of sand aquifers and the delicate balance that must be maintained if these areas are to be protected from pollution.

The Tennessee Department of Environment and Conservation's Division of Water Supply contracted with University of Memphis's Ground Water Institute for an educational video on environmental concerns for sand aquifers. The Ground Water Management Section in the Division of Water Supply contracted for the video with EPA ground water grant funding. The resultant video is titled "Drops of Water in Oceans of Sand: Ground Water Resources of West Tennessee." The video is being distributed to schools and other non-profit organizations on a limited basis across the state as funding allows. This video is the second of the series of ground water videos that have been contracted. The first was with Middle Tennessee State University and is titled "Hollow Ground: Land of Caverns, Sinkholes and Springs." A DVD version has been created with both videos as well as a Spanish version of "Drops of Water in Oceans of Sand: Ground Water Resources of West Tennessee."

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SESSION 3B

UNDERSTANDING SEDIMENT DYNAMICS
8:30 a.m. - 10:00 a.m.

Including Sediment Dynamics in Studies of Geomorphic Adjustment: Preliminary Results from a Tributary of the Hatchie River, West Tennessee
M.A. Lisa Boulton and Carol P. Harden

Not My Sediment! Using GIS, Satellite Imagery, and Aerial Photography to Identify Sediment Sources in the Blue Ridge Mountains
T. Pat Curley and John K. Ricketts

Techniques and Results of Geomorphic and Numerical Tools for Developing Water-Quality Targets for Sediment in the Southeastern United States (abstract not available)
A. Simon

CONTAMINANTS IN WATER QUALITY
10:30 a.m. - 12:00 p.m.

Modeling of Fate of Herbicides Used in Pine Plantations on the Cumberland Plateau Using GLEAMS Model
Rong Jiang and John Harwood

The Effect of Nutrients on Macroinvertebrate Populations of Streams in the Inner Nashville Basin
Deborah H. Arnwine

To Be Announced

INCLUDING SEDIMENT DYNAMICS IN STUDIES OF GEOMORPHIC ADJUSTMENT: PRELIMINARY RESULTS FROM A TRIBUTARY OF THE HATCHIE RIVER, WEST TENNESSEE

M. A. Lisa Boulton*[1] and Carol P. Harden[2]

INTRODUCTION

The Hatchie River is a low gradient, alluvial river that begins in northern Mississippi and flows northward into western Tennessee, where it travels approximately 322 km before joining the Mississippi River 32 km north of Memphis (USGS, 1976). In west Tennessee, the Lower Hatchie drains approximately 3,822 km^2 (NRCS, 2001). Its headwaters, near Corinth, Mississippi, are channelized; but, shortly after flowing into Tennessee, the river is unchannelized and exhibits a relatively natural state.

The perception of the Lower Hatchie River as undisturbed is only valid on the main stem and only to the extent that the river has not been subjected to direct modification by engineering works. In recent times, the channel has become shallower and flooding has increased (USDA, 1986). Changes in the bed elevation suggest increased sediment contribution from tributary streams to the main channel. Diehl (2000) identified sediment shoals forming in the main channel at confluences with some tributary streams. The location of shoals at tributary main stem confluences implies that sources of the shoal-forming sediment are tributary streams.

Tributary streams of the Hatchie River, in both Mississippi and Tennessee, are heavily disturbed from historical land use activities (USDA, 1986), which resulted in the development of an extensive network of gullies in the headwater areas. The gully network vastly increased sediment inputs to the tributary streams, although specific quantities are unknown. As a result, the streams began to aggrade. Aggradation in tributary streams is so severe that some channels are completely filled with sediment, so that any additional sedimentation at the location spreads across the floodplain, forming a blockage, which eventually diverts flow and creates a new channel (Diehl, 2000). Accelerated aggradation also causes a reduction in channel capacity of tributary channels, resulting in a decreased ability to conduct larger flows, and consequently, increased flood frequency. Some of the tributary streams were channelized at some time in the 1970s to reduce flood frequency (Diehl, 2000). Although channelization succeeded to some extent in alleviating flooding, it also increased flow velocity in tributary streams by decreasing hydraulic resistance and increasing channel gradient. Therefore, channelization enhanced the ability of tributary streams to transfer large quantities of sediment to the main channel and led to shoal formation in the Lower Hatchie main channel (Diehl, 2000). In one case, a valley plug formed in a channelized tributary and migrated into the Hatchie main stem, creating a blockage 6.44 km wide across the channel and the floodplain (Diehl, 2000). Tributary streams contribute an estimated 580,480 metric tonnes of sediment to the Lower Hatchie each year (USDA, 1986). The U.S. Fish and Wildlife Service estimates that more than 40.5 ha/year of hardwood bottomland forest is lost in the Lower Hatchie from flooding related to accelerated sedimentation.

It is clear from the presence of valley plugs and gully networks in some tributary streams of the Lower Hatchie that these streams are responding to disturbance probably related to land-use

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changes and channelization. The spatial or temporal degree to which geomorphic adjustment has occurred is unknown at present and is the main focus of a much larger, ongoing research project in three sub-watersheds of the Hatchie River. In this paper, preliminary findings of channel morphology surveys, geomorphic mapping, and radionuclide analysis of sediment conducted in one sub-watershed, Richland Creek, are presented and discussed.

RESEARCH OBJECTIVES AND RATIONALE

There are two primary research objectives for the research presented in this paper. The first is to qualitatively compare channel morphologic characteristics observed in Richland Creek to those stated in an existing conceptual model of geomorphic adjustment to channelization. The second objective is to test the applicability of radioisotopes in determining sediment source areas.

Rates and types of fluvial adjustment processes to disturbance are greatly under-researched (James, 1999). However, the research available emphasizes the role of sediment in fluvial adjustment, specifically aggradation and degradation processes. Sediment dynamics, including erosion, transport, and storage, are considered the primary control of fluvial adjustment processes because they greatly regulate the amount of available energy for geomorphic work by altering channel gradient through aggradation or by using stream power in sediment transport processes (degradation) (James, 1999).

Current knowledge of fluvial adjustment and recovery only incorporates those aspects of sediment dynamics that relate to channel morphology (Simon, 1989; 1992; 1995). However, it is important to recognize that changes in channel morphology are indirectly related to the disturbance instigating change and are, in fact, a product of changes in sediment dynamics (amount and type) and/or discharge (Lane, *et al.*, 1996). Failure to incorporate all aspects of sediment dynamics, specifically those that operate on longer timescales, such as sediment storage and the re-working of temporarily stored sediment, may lead to gross underestimates of adjustment and recovery rates, and a gap in the knowledge of the geomorphic processes integral to recovery (James, 1999).

In order to better understand the role of sediment dynamics in geomorphic adjustment processes, it is first necessary to establish rates of aggradation and degradation, sediment source areas, and transportation pathways. The application of radionuclide analyses to develop rates of erosion and deposition, with respect to ^{137}Cs, is widely known and generally accepted (Ritchie and McHenry, 1990; Walling and Quine, 1992, 1995; Walling, 1998; International Atomic Energy Agency, 1998). ^{137}Cs, a product of nuclear fission, is found in the natural environment because of fallout from nuclear testing or releases from nuclear reactors (Ritchie and McHenry, 1990). In undisturbed soil profiles, quantities of ^{137}Cs decrease with depth and peaks occur in layers that correspond to years of active, aboveground nuclear testing: 1952, 1958, 1963, 1971, and 1974. Lows in concentrations correspond to years with moratoriums on testing: 1958-1961. It has a half-life of ~ 40 years. The use of ^{7}Be to estimate rates of erosion and deposition in sediment studies is a relatively novel but effective technique. Like ^{137}Cs, ^{7}Be is a fallout radionuclide, but it has a half-life of only 53 days, and because it is natural in origin, its fallout is continuous. It occurs in the natural physical environment as fallout from spallation of cosmogenic rays in the Earth's outer atmosphere. Both ^{137}Cs and ^{7}Be quickly adsorb to soil and sediment particles (Walling *et al.*, 1999).

By using both ^{137}Cs and ^{7}Be, it is possible to study sediment behavior in streams on long (decades) and short (days and months) timescales. In addition to helping ascertain sediment movement on a range of timescales, ^{137}Cs and ^{7}Be can be used to differentiate sediment contribution for different source areas. Sediment that originates from surfaces with vertical faces, such as exposed banks and gullies, should contain much less ^{137}Cs and ^{7}Be than sediment originating on horizontal surfaces, including channel sediment and sediment entrained in runoff from fields, which receive maximum atmospheric exposure to fallout (Walling and Woodward, 1992; Zhang *et al.*, 1997).

METHODS

In total, eight reaches were surveyed using standard channel morphology survey techniques. Selection of stream reaches was based primarily on stream junction patterns to enable better understanding of system connectivity (Harvey, 2002). Stream segments chosen for analysis were located 100 m to 50 m upstream and downstream (or some distance determined in the field that removes any characteristics specific to a stream confluence) of each stream junction point. Channel cross-sections were surveyed in three places along a reach judged typical to a particular segment of the tributary. The length of the reach surveyed was equal to at least five times the channel width of the primary cross-section but at minimum was 50 m in total length. At each study reach, three cross-sections were surveyed and the following variables measured: channel depth, channel width, bank heights, cross-sectional area, bankfull width, and longitudinal profile. At one of the cross-sections (considered the "primary cross-section"), banks were characterized in great detail in the field with measurements of shape, angle, presence and type of mass failures, texture of bank material. In addition, the thickness of channel sediment was measured across the primary cross-section. Samples of channel and bank sediment were taken for particle size analysis in the lab but results are not reported here.

Results of the channel morphology surveys, bank descriptions, and channel sediment depths were qualitatively compared to a conceptual model of fluvial geomorphic adjustment in a channelized stream developed by Simon (1989; 1994; 1995). Simon (1992) surmised that most low-energy alluvial systems respond to disturbance mainly by making vertical adjustments, including incision, channel aggradation, and vertical accretion. Simon (1989; 1994; 1995) identified six stages of channel evolution post-channelization (Table 1). The stages of channel evolution are based on the spatial and temporal distribution of geomorphic processes, specifically aggradation and degradation, as inferred from channel morphology (cross-sectional area, thalweg location, and bank stability or instability) that dominate individual reaches or geomorphic zones.

Table 1: Summary of fluvial geomorphic stages of adjustment from Simon (1994).

Stage	Major Characteristics
I. Premodified	uppermost reaches; transport of sediment or mild aggradation; absence of widening
II. Constructed	where applicable; dredging; constructed widening
III. Degradation	upstream of AMD*; migrating degradation; absence of widening
IV. Threshold	immediately upstream of AMD; migrating degradation; active widening
V. Aggradation	secondary aggradation; upstream of AMD; active widening
VI. Restabilization	downstream-imposed aggradation; downstream of AMD; absence of widening

*AMD = area of maximum disturbance; in this case, a channelized reach.

In order to examine the potential for using radioisotopes to establish sediment source areas and pathways, five samples were collected from several different geomorphic environments: one from a gully face; one from a vertical bank face; one from the lower portion of a convex bank face; and two main channel deposit samples. It was hypothesized that the gully face and vertical bank faces should not yield any isotope content because they do not have enough horizontal surface area to trap isotopes in atmospheric fallout. The samples were weighed and isotope content analyzed at a radioisotope counter laboratory in the Department of Ecology and Evolutionary Biology at the University of Tennessee, following standard procedures.

RESULTS AND DISCUSSION

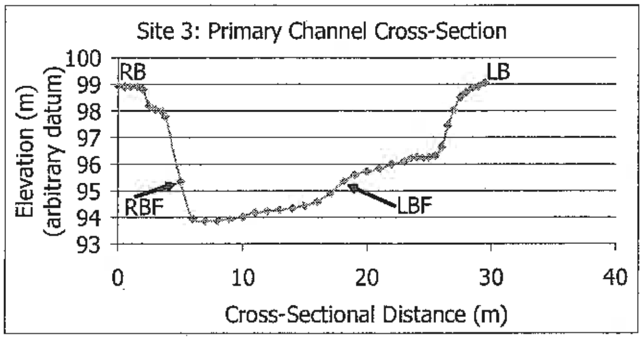
Results of the channel morphology surveys conducted on a reach basis in Richland Creek, summarized in Table 2, suggest that Richland Creek has reached a kind of quasi-equilibrium state in some reaches because an identifiable bankfull stage is present. However, adjustment processes continue in other reaches, as indicated by: ongoing incision in the upper reaches (site 1), channel widening by bank failure (sites 2 through 4), and aggradation in the lower reaches (sites 5 through 8). The geomorphologic survey also indicates considerable spatial variation of adjustment processes.

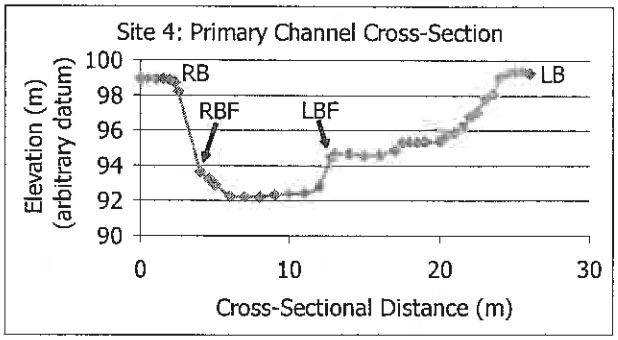
Table 2: Summary of channel morphology survey results.

Site	Top of Bank Width (m)	Bankfull Width (m)	Avg. Bank Height (m)	Avg. Bank Angles (degrees)	Geomorphic Characterization	Adjustment Stage (Simon Model)
1	5.7	5.00	2.62	63	incising	Stage III or Stage I
2	21.5	12.50	3.68	53	widening and aggrading	Stage IV or Stage V
3	23.7	13.15	4.04	73	widening and aggrading; dominated by bank failures	Stage IV or Stage V
4	21.7	8.15	3.14	90	widening and aggrading; dominated by bank failures	Stage IV or Stage V
5	21.2	16.50	4.8	51	aggrading	Stage V
6	16	9.20	2.61	51	aggrading	Stage V
7	15.2	10.80	2.45	55	aggrading	Stage V
8	10.8	9.10	2.00	52	aggrading; geometry artificially maintained?	Stage II(?), Stage V

Qualitative application of the six stages of geomorphic adjustment conceptual model developed by Simon (1989; 1994; 1995) resulted in mixed results, Table 2. Although the model does explain the general spatial pattern of adjustment processes (aggradation in lower reaches and channel widening in middle reaches), defining the stage of adjustment was difficult. Field observations indicated that Site 1 is an incising reach with knickpoint formation. It matched the description of Stage I and Stage III. Sites 2 also exhibited characteristics of two separate stages – Stages IV and V. Sites 3 – 8 all exhibited evidence in the field of being dominated by aggradation processes. However, without knowing specifically which channels were or were not channelized there is no way to differentiate between primary or secondary aggradation. Also, the model, for the most part, does not allow for temporarily stored alluvium in the channel to be a major source of downstream aggradation and instead focuses on contributions from bank failures. Field observations in Richland Creek suggest re-mobilization of material stored in the channel is a source of downstream sediment in addition to failed bank material. Furthermore, the presence of temporarily stored alluvium in the form of berms or bar deposits may be involved in the onset of channel widening by directing flow towards the opposing bank and thusly, initiating bank failure. This process explains how several of the reaches surveyed could be classified as both aggrading and widening, Stages IV and V, respectively (see Figures 1 and 2 for examples).

Figure 1 and Figure 2: Examples of channel morphology surveys that qualified for both Stages IV and Stage V. Note channel widening on right banks and berm formation on left banks.





Results of the radioisotope analysis revealed good potential for the use of ^{7}Be and ^{137}Cs to be used to differentiate bank and gully wall material from re-worked channel fill. Of the five samples taken (one gully, two lower banks, and two main channel deposits) only three had detectable concentrations of isotopes. No isotopes were detected in the gully sample or the vertical bank samples. Locations that did test positive for isotope content included the following: convex bank – ^{7}Be = 1.94 mBq/g; ^{137}Cs = 0; main channel – ^{7}Be = 1.76 mBq/g; ^{137}Cs = 0; and main channel – ^{7}Be = 2.88 mBq/g; ^{137}Cs = 0. It was hypothesized that the vertical gully wall and banks would not yield any isotopes because they lack the horizontal surface area to trap atmospheric fallout isotopes. This was true in the case of the gully and the one vertical bank face tested. However, the convex bank face tested positive, meaning the lower portion of the convex slope is horizontal enough to trap some fallout isotopes. It was expected that both of the main channel deposits would test positive for isotope content. The lack of ^{137}Cs and relatively high ^{7}Be content in these deposits suggests their deposition was recent and their origin was re-worked channel deposits.

CONCLUSIONS

Difficulty in applying Simon's conceptual model to Richland Creek can be explained by several factors: (1) in Richland Creek, it is currently unknown which reaches were channelized and which were not (the stages in Simon's model are spatially dependent on the location of channelization), (2) the model was developed in a main stem river and not a tributary, and (3) the model does not address localized effects on geomorphic processes caused by sediment storage, which can lead to lateral migration.

The simple and basic pilot study undertaken to establish the potential for using radioisotopes as tracers to identify sediment source areas suggests there is potential for the technique to succeed provided care is taken during sample collection to differentiate truly vertical geomorphic surfaces. The relatively high isotope content detected in the convex bank highlights the potential for error when surfaces have some horizontal surface available.

ACKNOWLEDGEMENTS

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NOT MY SEDIMENT! USING GIS, SATELLITE IMAGERY, AND AERIAL PHOTOGRAPHY TO IDENTIFY SEDIMENT SOURCES IN THE BLUE RIDGE MOUNTAINS

T. Pat Curley*[1] and John K. Ricketts, P.E.[2]

INTRODUCTION

Residential growth in the North Georgia Mountains, and throughout the remainder of the Blue Ridge Mountains region of the Southeast during the past decade has brought with it an increase in awareness of environmental issues for the long-time residents. In some areas, the impact of development has caused these folks to develop various preservation efforts to reduce the sediment loading to their local streams. The challenge in taking action to reduce impacts on the streams is to properly identify the sediment sources and accurately assess their contributions to sedimentation so that necessary preventative measures can be implemented.

The use of Geographic Information Systems (GIS) is a valuable tool for delineating these problematic sediment sources in watersheds to either support the residents' claims or defend the parties being held responsible. In this specific case study, GIS techniques in conjunction with satellite imagery and aerial photography were used to assist a local county government in North Georgia determine their sediment contributions in a small mountain watershed. Some local residents filed suit against the county claiming that they were the primary source of excessive sedimentation of the stream flowing behind their property, and demanded that the county fix the problem to restore near natural conditions to the stream.

The study area in question is a small, narrow watershed located in the North Georgia Blue Ridge Mountains (Figure 1.). This area has traditionally been sparsely populated with the residents practicing some small scale agriculture and insignificant amounts of forestry. Prior to 2000, all of the roads in the watershed were gravel, including the county road (CR 42) that runs through the watershed. The County began widening and paving CR 42 in the summer of 1999, at the same time other land disturbance activities began to occur. During this time residents began to notice problems with sediment buildup in the study stream and in particular one privately owned impoundment. The residents filed suit against the County, claiming that it was the CR 42 road work that created the excessive sediment loading to the stream after the summer of 2000.

DERIVATION OF MODEL INPUTS

To assist the county government in identifying all of the source areas of sediment in the study watershed in order to prove to the residents that they were not the major contributor of excessive sedimentation, GIS was used in conjunction with a widely used soil erosion model, the Revised Universal Soil Loss Equation (RUSLE). The RUSLE was chosen for this study because of its general acceptance in the hydrologic scientific world, and its ease of use. The RUSLE estimates soil erosion by assigning values to six different factors which influence soil erosion in the environment. The Equation can be calculated as follows:

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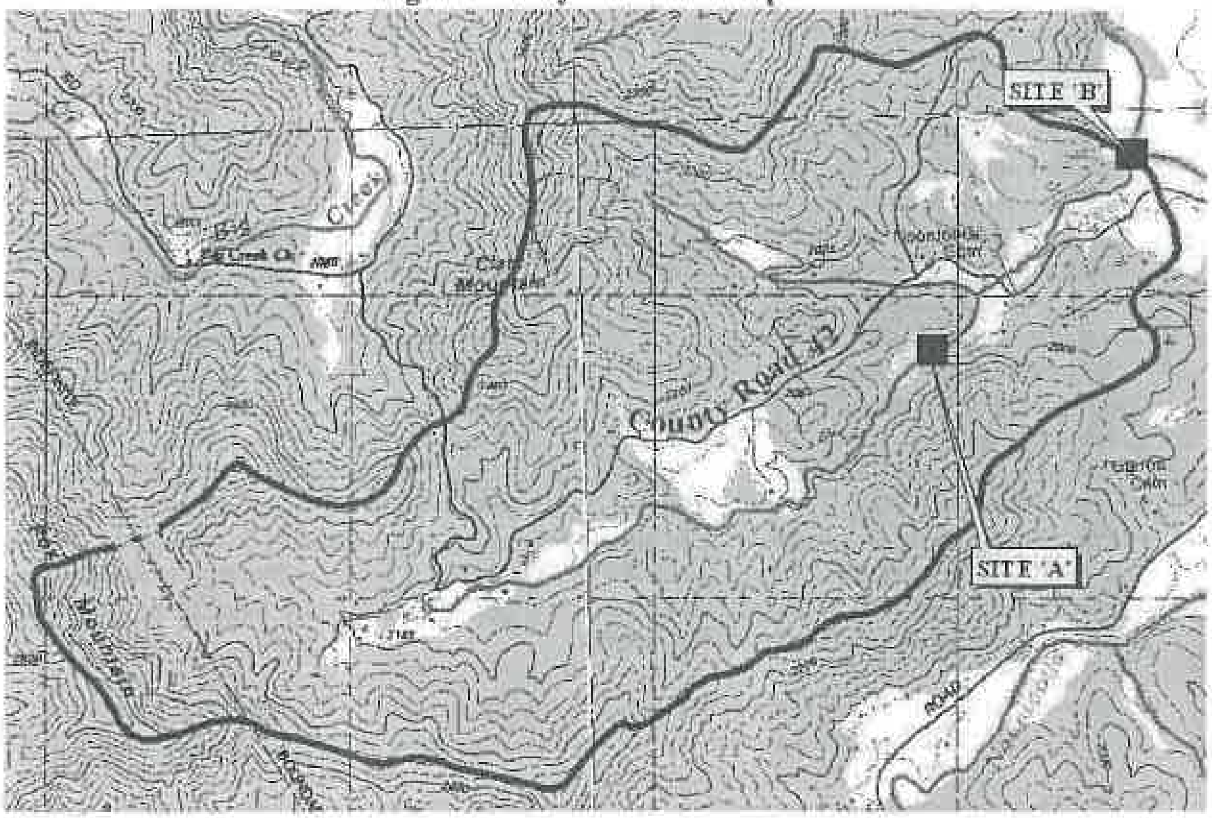
Figure 1. Study Watershed Map



A = RKLSCP where:
A is the estimated tons of soil loss expressed in tons/acre/year
R is the Rainfall Erosivity Factor
K is the Soil Erodibility Factor
L is the Slope Length Factor
S is the Slope Steepness Factor
C is the Cover-Management Factor
P is the Support Practice Factor
(Renard et al., 1997)

The K and R Factors are dimensional and expressed in terms of tons/acre/year. The L,S,C, and P factors are dimensionless. The output of the model, the A, can be mapped using GIS. Different conditions in the same study area can easily be modeled using GIS by altering the input factors to reflect existing conditions.

The input factors for the RUSLE model for the study watershed were represented in GIS using layers referred to as Grids. Grids are spatial representations of some geographic data in a raster or continuous format, made up of numerous grid cells of an equal dimension. In this study, the original Digital Elevation Models (DEMs) was represented by a continuous surface of 30 meter grid cells, resized to 10 meter grid cells to better represent the areas of interest in the study watershed. All of the factor layers were represented in 10 meter grids, and all model runs were calculated using these input grids.

In order to save time and effort calculating the R factor using the RUSLE's complicated equation, the R factor was interpolated from a map supplied by the U.S. Department of Agriculture

(USDA) RUSLE guidelines document (Renard et al. 1997). The interpolated R factor value was determined to be 260 tons/acre/year. This value was applied uniformly across a GIS grid of 10 meter grid cells.

The soil erodibility factor (K) was derived from the Natural Resources Conservation Service (NRCS) soil survey for this study area. Within the Soil Survey, the K Factor is provided for each soil type based upon depth of the soil. For the purposes of this study, the K factor value for topmost layer of each soil type was used. The soil map of the study watershed was digitized, and corresponding K factor values were assigned and then converted to a 10 meter grid cell layer.

The slope length (L) and slope steepness (S) factors represent the effect of topography on erosion. Usually when used in the RUSLE the L and S factors are combined for ease in calculation. This combined factor is termed the LS, or Slope length/gradient factor. The LS factor was represented in this study using the outputs from a series of GIS scripts authored by Hickey et al.(1994) and modified by Van Remortel and Hamilton (2002). This methodology calculates slope lengths from high points towards low points using individual grid cells as slope length units, based on a LS-calculation algorithm in accordance with numerous RUSLE improvements documented in chapter 4 of the RUSLE Handbook (Renard et al., 1997). This series of scripts, when run, calculates the LS factors based upon the source elevation grid, and applies the LS factor value to an output 10 meter grid cell grid for use in the RUSLE model.

The cover-management (C) factor is the factor which is most readily changed to represent the different areas of land cover disturbances in the study watershed. A total of nine different dates of satellite imagery and aerial photography were acquired in order to derive the C Factor layer for each different model run corresponding to a different date. The information on the imagery used in this study can be seen in Table 1. The land cover in the study watershed was determined using GIS methods from each image corresponding to each date. A C factor value corresponding to specific land use/land cover types was then assigned to each land use type for each date and then the layers were converted into a series of nine grids, each corresponding to a specific date. This methodology allows the RUSLE model to output different numbers from different dates, and any disturbances in the watershed can be seen to affect the output of the GIS RUSLE model.

Table 1. Digital Imagery Information Table, Study Watershed

Image Date	Image Type	Image Band	Image Source	Image Resolution
January, 1994	Aerial Photograph	Visible	Georgia GIS Clearinghouse	1 meter
November 26, 1998	Satellite Image	Panchromatic	SPOT Image Corp.	10 meter
September 10, 1999	Satellite Image	MultiSpectral	LANDSAT (NASA)	15 meter
April 7, 2000	Satellite Image	Panchromatic	SPOT Image Corp.	10 meter
July 10, 2000	Satellite Image	MultiSpectral	LANDSAT (NASA)	15 meter
March 27, 2001	Satellite Image	Panchromatic	SPOT Image Corp.	10 meter
August 14, 2001	Satellite Image	MultiSpectral	LANDSAT (NASA)	15 meter
March 10, 2002	Satellite Image	MultiSpectral	LANDSAT (NASA)	15 meter
August 1, 2002	Satellite Image	MultiSpectral	LANDSAT (NASA)	15 meter
April 14, 2003	Satellite Image	MultiSpectral	LANDSAT (NASA)	15 meter

The study watershed was identified as having six major land use types: forest, pasture, residential, clear cut, road, and water. Each category was then assigned a C Value factor derived from various source tables in different documents related to the RUSLE. Forest C factor values were assigned the value assigned to the closed canopy forest designation in a table found in the T. Del M. Lopez et al. (1998) document. Pasture C values were derived from the same table, using the value assigned to the pasture classification. Residential C values were derived from the T. Del M. Lopez (1998) table classification of Less Dense Urban. Clear cut areas were assigned C values from the Toy and Foster (1998) Table 5-3 value for the 'Cut – Scalped surface (some roots remain from weeds)' classification.

The C value designation for the roads in the study watershed required a higher level of detail in representing the land cover types within the 10 meter area defined as the roadway. Within this 10 meters of roadway, it was assumed that 75% of the area would be actual road surface, and the remaining 25% would consist of a grassy shoulder (for paved and gravel road designations) and a bare soil ditch bottom running parallel to the roadway on either side. For the gravel road land cover type, the road surface was assigned a value for 90% gravel cover (Table 5-2, Toy and Foster (1998)), with the grassy shoulder assigned a C value for pasture as defined in Table 3 from T. Del M. Lopez (1998), and the ditch bottoms assigned a value for bare dirt from Table 3, T. Del M. Lopez et al. (1998). Furthermore, the C Values of the road were assigned three different values dependent upon the state of the roads at various times during the examined time period: one for gravel or unpaved, one for road under construction, and another value for paved road. After the calculation of all the C values for the existing land covers in each of the nine different dates, they were then converted into 10 meter grid cell layers for use in the GIS model.

The P factor was used in the model to represent management practices employed in the study area during the study time frame. Specifically two different instances of sediment control practices were implemented in the study watershed. The first was two sediment ponds installed by the County located on CR 42 near a tributary to the study creek, and the second was a sediment pond installed on one private property intended to catch sediment from the land disturbances occurring at the site. The P factor in this model is represented as a ratio expressing the effectiveness of the management practice installed. In this case, a series of sediment ponds were installed and rated at 80% sediment removal efficiency.

MODEL CALCULATIONS

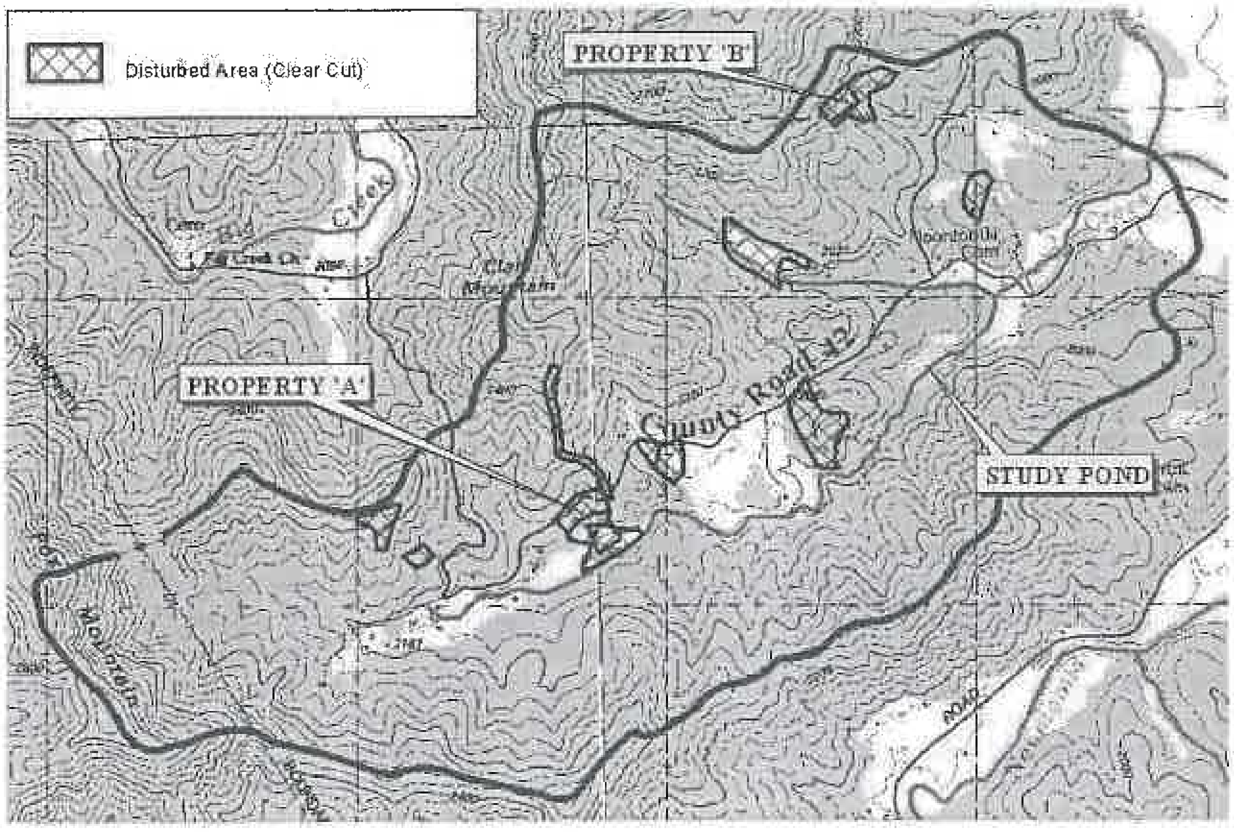
Using the grid layers representing each of the factors of the RUSLE model, the potential erosion was then calculated using ArcView 3.3 software Spatial Analyst techniques. The input layers were spatially multiplied together to result in a final output grid containing potential erosion estimates per 10 meter grid cell in the study watershed. After the output grids were created for each of the nine dates used in this study, a hydrologic modeling tool was then used in ArcView 3.3 to determine erosion accumulation patterns based on the topography of the watershed. Using the outputs from this tool, accumulated potential soil erosion estimates could be determined upstream from any point in the watershed. For purposes of this study, the potential erosion upstream from two specific locations was used: at the outfall of the pond downstream from one private property A (Figure 1, Site A), and at the mouth of the study creek (Figure 1, Site B).

The nine different dates were represented in nine different model runs to estimate the effect of various land disturbance practices and road construction activities in the Study Watershed from 1998-2003. Specifically, CR 42 was considered to be gravel prior to June 1999, being widened between June and August 1999, gravel between August 1999 and September 2000, and paved from September 2000 to the present. The road was assigned appropriate C values during the changes. All other land cover characteristics for each date were derived and represented as existing conditions using satellite imagery (Table 1). The model outputs enabled estimates of soil erosion accumulation at any point in the watershed, as well as being able to estimate erosion production potential from specific areas.

MODEL RESULTS

After completing the nine different model runs representing nine different dates during the study watershed's history, the resulting erosion accumulation estimates values were analyzed to delineate specific sediment source locations. There were numerous activities which occurred in the watershed during this 5-year period of time, including clear cutting, residential construction and agricultural activity changes, along with the County's paving of CR 42. The model results show that the impact of other activities in the watershed contributed much more sediment to the study stream than all County activities combined. Various areas in the watershed that were impacted during the study time period, as well as private properties (Properties A and B) of concern can be seen in Figure 2.

Figure 2. Impacted areas of study area



Erosion estimate values from the RUSLE model output were measured and spatially analyzed to get values in tons per year for specific areas in the watershed. Properties 'A' and 'B' were known to have extensive land cover modification. The estimated sediment production rate from their activities was measured versus the County's sediment production rate from their modifications in the watershed. For the purposes of this comparison, the potential erosion upstream from 'Site A' and 'Site B' were examined.

The study found that a vast majority of the potential sediment contribution in the Study Watershed is from the surrounding forest and pasture lands, not land disturbance activities. In examining the potential contributions of CR 42 to the sediment loading of the watershed, it was shown that CR 42 does not contribute more than 5 percent of the potential sediment contribution rate to Study Pond, except for one date when it was 8 percent. Furthermore, CR 42 does not contribute more than 4 percent of the potential sediment contribution rate to the entire Study Watershed, except for one date when it was 6.3 percent.

Some private properties in the Study Watershed (Properties 'A' and 'B') were shown to have contributed extensive sedimentation to the stream during the study time period due to land cover changing activities, specifically road and vacation home construction. The model results show that the Property 'A' land disturbance areas contributed more than 12 percent of the potential sediment contribution rate to the Study Pond, and even exceeded 15 percent for one date. The model results also show that the Property 'A' land disturbance areas contributed more than 8 percent of the potential sediment contribution rate to the entire Study Watershed for three of the nine dates, and even reached 10 percent for one date. The model results show that the Property 'B' land disturbance area contributed almost 11 percent of the potential sediment contribution rate to the entire Study Watershed for one of the dates.

In terms of the total potential sediment estimated to be delivered to the Study Pond during the study time period for land disturbance activities, Property 'A' was calculated to have contributed almost 85 percent and CR 42 only contributed 10 percent. CR 42 contributed less than 7 percent of total sediment to the mouth of the watershed, while Property 'A' contributed 60 percent and Property 'B' 23 percent with the remainder coming from other land disturbances in the watershed.

In conclusion, the RUSLE model integrated into a GIS proved to be invaluable to the County in winning the legal defense of the lawsuit filed against them. The model results, based upon real-world data and scientifically accepted modeling techniques, allowed the County to show the plaintiffs that they were clearly responsible for a minority of the sediment contribution to the study stream. In fact, because the County paved CR 42, it in effect *reduced* sediment contribution from the road after the year 2000. As a result, the plaintiffs in this situation dropped their suit against the County, and decided to pursue the responsible parties within their watershed.

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MODELING OF FATE OF HERBICIDES USED IN PINE PLANTATIONS ON THE CUMBERLAND PLATEAU USING GLEAMS MODEL

Rong Jiang* and John Harwood[1]

Herbicides may have an adverse impact on aquatic ecosystems and water quality by leaving treated sites and entering surface or ground water. The potential for adverse environmental impacts exists whenever herbicides used. Some sites are more susceptible to potential adverse impacts than others because of their special soil properties, climates, locations, and other site-specific factors. The soils of the Cumberland Plateau in Tennessee are thin, have high permeability to water and are generally low in organic matter, characteristics which lead to increased likelihood of migration of organic contaminants into surface and ground waters. Herbicides used in forestry are more polar and water soluble than other organic soil contaminants, again characteristics which increase the likelihood of contaminant migration. In this study, the fate of herbicides applied in pine plantation preparation and "pine release" operations is modeled using the USDA GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) model.

Realistic modeling of chemical migration in soils must account for varying soil characteristics, hydrology, including the effects of evapotranspiration, adsorption of chemicals by soils and plants, and degradation of chemicals. GLEAMS is a refined model which accounts for these factors in predicting herbicide fate. Herbicide losses are partitioned into those occurring through surface runoff, sediment transport, by percolation through soil, and by degradation. GLEAMS simulates the movement of herbicides in surface run-off and movement into, through, and below the effective rooting depth of the soil. GLEAMS allows the user set variable soil properties which occur in different layers of a soil column.

With the GLEAMS model the effect of the management system (application method and timing, rainfall frequency and intensity, etc.) on the fate of herbicides can be evaluated. A detailed soil profile, the plant profile, and characteristics of the herbicides are included in formulating the model scenario. The fraction of herbicides reaching the soil (not intercepted by canopy) is estimated by the user, allowing the initial concentration in the soil to be computed.

In our modeling a twenty year cycle is simulated, a standard rotation period for pine plantations. A 40-acre segment of land in Grundy County, Tennessee is selected as our study area. Site-specific soil characteristics are taken from the NRCS soil survey for the county. The soils are well-drained, have a loamy surface layer and a subsoil formed in residuum derived from the underlying capstone of acid sandstone. The organic content of the loam ranges from 0.5 to 2 percent. Water permeability ranges from 0.6 to 6 inches per hour. We used long-term climatic records for the Coalmont, Tennessee weather station. While we model degradation of the herbicides using estimates of soil half-life, we have not considered the fate of degradation products.

Our modeling results indicate that the rainfall mainly produces percolation of water (around 82%) as opposed to runoff (less than 1%) with our modeled soil and conditions. Most herbicide losses are found to occur through percolation. The organic content of soil is predicted to

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influence leaching of the herbicides. There is more percolation loss in low organic content soil. Also, application immediately preceding a rainfall event significantly increases loss of herbicide in runoff. All herbicide losses are limited the first several years. The levels of herbicides in surface waters predicted to result from pine plantation preparation and conifer release operations are predicted to be in the low and sub-mg/L concentration range, and to occur in pulses of approximate one month duration.

Results obtained using the GLEAMS model will be compared with those obtained using two other pesticide fate models: PESTAN and LEACHP. PESTAN is a simpler model for estimating vertical transport of dissolved contaminants through the vadose. The model assumes a one layer profile and homogeneous soil properties. PESTAN is used for preliminary assessment of the transport of chemicals through soil to groundwater. LEACHP is transport model for pesticides developed by John Hutson and R. J. Wagenet which is used in Australia and other countries. Like GLEAMS, it is a full-featured model which can account for variation in soil composition with depth, plant adsorption of pesticides and variations in water movement resulting from evapotranspiration, and herbicide degradation.

THE EFFECT OF NUTRIENTS ON MACROINVERTEBRATE POPULATIONS OF STREAMS IN THE INNER NASHVILLE BASIN

Deborah H. Arnwine*[1]

In December 2003, the Division of Water Pollution Control completed a probabilistic monitoring study on 50 streams in the Inner Nashville Basin. One of the objectives of this study was to study the relationship between the biological community and nutrient levels.

The macroinvertebrate community was measured using the Tennessee Macroinvertebrate Index (TMI), seven biometrics that make up the index and a nutrient tolerance metric developed by the state of Kentucky. Nutrients were measured as nitrate+nitrite and total phosphorus.

There were no significant direct correlations between nutrients and any of the biological metrics in the spring. A negative correlation was observed between total phosphorus levels and the number of EPT taxa in the fall. Three components of the fall macroinvertebrate community had a measurable relationship with nitrate+nitrite. These were the percent nutrient tolerant taxa, the abundance of oligochaetes and chironomids and the abundance of EPT.

Nutrients are generally considered a secondary stressor rather than a direct toxicant. Elevated nutrients, under certain conditions promote the growth of algae. Excessive algae growth can be harmful to macroinvertebrate populations because of its influence on diurnal dissolved oxygen patterns and its potential to make rock habitat unsuitable for colonization.

Since nutrients are associated with algae growth, sunlight a key factor for algae to survive, was added as a variable. The amount of sunlight penetration was estimated using a spherical densiometer to measure percent canopy. Relationships were significantly stronger when canopy was included as a variable in the comparisons between nutrients and macroinvertebrates. With the inclusion of canopy, the percent contribution of chironomids and oligochaetes showed the strongest relationship to nitrate+nitrite. The Tennessee Macroinvertebrate Index, North Carolina Biotic Index and percent clingers were responsive to total phosphorus.

In addition to the amount of sunlight penetration, which helps regulate algae growth, canopy can also affect water temperature, leaf litter (a food source) and habitat availability. Additional analyses were conducted to determine if nutrient levels were the most significant factor in the observed relationship between canopy cover and macroinvertebrate populations. Bank vegetation type, riparian width and water temperature were all tested. The macroinvertebrate population showed little response to any of these variables with or without nutrients.

Since the strongest correlations were observed in the fall when dissolved oxygen and flow are lowest these variables were also tested. Only biometrics that did not demonstrate a relationship with canopy showed a correlation with DO. Two biometrics showed a response to flow. None of these was as strong as the relationship observed between canopy, nutrient levels and the macroinvertebrate community.

Although promising, these relationships were based on a single fall and two spring sampling events at each site. Additional data are needed to help confirm these preliminary findings.

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Results are only applicable to the Inner Nashville Basin ecoregion. The Division intends to evaluate macroinvertebrate, nutrient and canopy data from other ecoregions as it is available to determine if similar relationships exist in other parts of the state.

Relationship (adjusted R^2) between nutrient levels, percent canopy and nine biometrics at 50 test sites and two reference sites in the Inner Nashville Basin, fall 2000. Values in bold p < 0.05.

Biometric	NO2-3	TP	NO2-3 TP	Canopy	Canopy NO2-3	Canopy TP	Canopy NO2-3 TP
Count	26	26	26	16	16	16	16
TMI	-.001	-.086	.010	**+.243**	.161	**.566**	**.549**
TR	+.049	-.014	..057	+.080	.082	.084	.017
EPT	+.071	**-.302**	**.283**	+.053	.058	**.280**	.237
%EPT	**-.149**	-.016	.110	+.039	.143	.078	.103
%OC	**+.190**	+.004	.137	+.027	**.567**	.131	**.615**
NCBI	-.042	+.117	.067	-.180	.054	**.417**	**.373**
%DOM	-.005	+.002	.006	-.030	.033	.125	.126
%CLING	+.009	-.133	.060	+.221	.133	**.641**	**.626**
%NUTOL	**+.221**	+.009	**.186**	+.001	.018	.082	.062

SESSION 3C

WATER POLICY: RECENT INITIATIVES AND IMPACTS
8:30 a.m. - 10:00 a.m.

Protecting Tennessee's Water with Farm Bill Provisions and Agricultural Conservation Practices
Jenny E. Adkins

Tennessee's New Permitting Rules
Saya Qualls

Opportunities and Realities in Water Quality Restoration: An Analysis of Tennessee's 303(D) List
Dodd Galbreath

LAND USE IMPACTS
10:30 a.m. - 12:00 p.m.

Economic Evaluation of Conservation Practices: Buffer Strip Versus Improved Pasture (paper was also presented as a poster)
Ernest Bazen and Michael Barrowclough

Persistent Effects of Land Use Change on a Stream Channel: Upper North Potato Creek in the Copper Basin, Tennessee
Carol Harden and Donald Kemp, Jr.

The Relationship Between Watershed Characteristics and Stream Channel Morphology
Martin D. Lafrenz

PROTECTING TENNESSEE'S WATER WITH FARM BILL PROVISIONS & AGRICULTURAL CONSERVATION PRACTICES

Jenny E. Adkins*[1]

One component of the Farm Security and Rural Investment Act of 2002 (Farm Bill) is to provide conservation funding and meet environmental challenges on private lands. This is accomplished through a variety of conservation programs administered through the Natural Resources Conservation Service Agency (NRCS). Approximately $1.5 billion has been budgeted in funding for conservation programs for 2004. Many of the NRCS programs are designed to improve water quality and quantity and, overall, health of aquatic ecosystems in addition to protecting valuable wetland ecosystems and wildlife habitat on private lands, while maintaining and protecting farmland.

The Environmental Quality Incentive Program (EQIP) receives the largest amount of funding, $661 million. The Wetlands Reserve Program is second, budgeted at $259 million. Tennessee will receive $13 million to support these conservation programs, $9 million will be budgeted for EQIP

Accomplishments have been made on the ground under these Farm Bill programs protecting and improving water quality in Tennessee. In 2003 under the Wetlands Restoration Program 4,019 acres have been created, restored and enhanced in Tennessee. Approximately 2,546 acres of riparian forest buffers, 1,749 acres of grass filter, 104,215 feet of streambank fencing were accomplished under conservation programs in Tennessee in 2003.

In 2004 EQIP will be targeting conservation plans which consist of these practices: riparian forest buffers, filter strips, water/sediment control basins, stream and shoreline protection (bioengineering), fencing, manure and wastewater handling and storage systems.

All conservation practices and technical assistance provided to landowners must meet NRCS standards and specifications. The development of effective conservation standards and designs are constantly being considered and evaluated by NRCS specialists at the state and national level. In addition to providing conservation designs and specifications, assessment tools and references are being developed to help field personnel better assess conditions and provide guidance in developing land management plans. A few of the tools developed and supported by the NRCS National Water and Climate Center are Stream Visual Assessment Protocol, and the Windows Pesticide Screening Tool (WIN-PST). Information on these technical resources can be found at the Water and Climate Center, http://www.wcc.nrcs.usda.gov/wcc.html.
Information on conservation programs is available at
http://www.nrcs.usda.gov/programs/farmbill/2002/products.html.

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TENNESSEE'S NEW PERMITTING RULES

Saya Qualls*[1]

The Division of Water Pollution Control received authorization from EPA to administer the NPDES permit program in December 1977. The division receives its authority to do so under the Tennessee Water Quality Control Act (TWQCA). The division implements the NPDES permit program as well as the state operating permit program for wastewater disposal that does not involve discharge to waters of the state through Chapters 1200-4-1 and 1200-4-5 of the department's rules. The changes to 1200-4-1 and 1200-4-5 represent the first major revision to those rules since their promulgation in 1977. In order to maintain program delegation from EPA, the state rules must be kept consistent with federal rules. Over the past twenty-plus years, EPA has made many changes to the federal rules. Tennessee revised its rules in order to maintain consistency with EPA's rules.

The rule revision included changes to the construction of both chapters to remove unnecessary, outdated and/or duplicative provisions. As a result of the action, Chapter 1200-4-1 contains the duties and authorities of the board and commissioner and Chapter 1200-4-5 contains the permitting rules.

The most substantial change to Tennessee's rules is the inclusion of specific provisions related to concentrated animal feeding operations or CAFOs. In 1999, TDEC, responding to statewide concerns about CAFOs, formed a multi-agency, multi-interest advisory group that developed a strategy for permitting CAFOs. That strategy has worked well for Tennessee. In April 2003, EPA promulgated new CAFO rules that addressed many aspects of CAFO operation including nutrient management, waste storage and land application. EPA's rules also require states to modify their permitting programs to accommodate the new federal requirements. In order to do so, the division again formed a multi-agency, multi-interest advisory group that provided input on the CAFO provisions that are included in this rule revision. The new rules are consistent with federal CAFO rules, but also contain elements of Tennessee's 1999 CAFO Permitting Strategy. The division's basis for including state-specific requirements is rooted in circumstances particular to Tennessee.

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OPPORTUNITIES AND REALITIES IN WATER QUALITY RESTORATION: AN ANALYSIS OF TENNESSEE'S 303(D) LIST

Dodd Galbreath*[1]

Tennessee's 2002 303(d) list represents the latest summary of individual stream reaches that either partially or completely fails to provide water uses protected by law. The list highlights water pollution in these reaches that exceeds official water quality standards.

A broad assessment of the Tennessee 303(d) list verifies recent assumptions that modern water pollution no longer predominantly originates from discrete pipes and independent discharge points. Modern pollution now largely results from a variety of diffuse sources and runoff arising from multiple and cumulative impacts.

Runoff containing principally sediment, bacteria and nutrients migrates into our waterways. Other pollution originates within streams themselves, where riparian vegetation and natural stream channels have been altered or impounded, thereby removing habitat, natural defenses and internal cleansing mechanisms. Still other pollution cited within the list has been static in the environment for many years. Overall, today's pollution represents reversible and potentially irreversible impacts to the environment. These impacts reflect current lifestyles, uses of our land and water resources for growth and production of food and fiber for a rapidly growing population.

Detailed analysis of the 303(d) list provides some insight for pollution solutions. When this data is summarized and viewed in the context of potential remedies, available information and experience, then certain trends and proposals emerge.

The presentation will:

- Illustrate trends and conclusions concerning modern day pollution and its sources based on an analysis of the most recent 303(d) list
- Asses future water quality restoration from the perspective of three categories:
  - "most attainable" water quality restoration stream candidates
  - "least attainable or unattainable" water quality restoration stream candidates
  - "attainable" water quality restoration stream candidates
- Discuss the issue of targeting, the landowner equation and TMDL implementation
- Propose to focus solutions on the highest density of the "most resolvable" impacts in streams with the highest likelihood of restoration
- Suggest avoiding certain investments in "least" or "unattainable" stream reaches
- Briefly review the wide array of funding sources, programmatic solutions and Best Management Practices currently available and potentially available in the State of Tennessee and those deemed most appropriate in-field experiences and research
- Briefly address the current status of interagency cooperation, public private partnerships and incorporating broader benefits into targeting (e.g., aquatic species)
- Briefly touch on the importance of high quality stream preservation

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ECONOMIC EVALUATION OF CONSERVATION PRACTICES: BUFFER STRIP VERSUS IMPROVED PASTURE

Ernest Bazen* and Michael Barrowclough[1]

ABSTRACT

Agriculture's contribution to water quality problems is receiving increased attention from policy-makers and other interest groups. In Tennessee agriculture, forestry and urban land use are cited as the predominant nonpoint sources contributing to decreasing water quality. Nonpoint pollution in agriculture may be controlled through the adoption of best management practices (BMPs). Despite the success of water quality programs that encourage and assist farmers with implementing BMPs, the ambient water quality goals of the Clean Water Act remain largely unmet, due, in part, to the absence of similar reductions in non-point source pollution. Some governmental programs offer cost share initiatives to entice livestock producers to adopt BMPs while others encourage voluntary program participation. Choosing the right BMP or combination of BMPs to achieve a specific goal can be overwhelming for both producer and researcher. While producers are concerned about profit maximization, researchers are focused upon policy impacts.

Evaluating economic tradeoffs between BMPs could shed new light on the benefits that each practice offers in relation to reaching water quality goals. Learning how to better manage pasture land and manure nutrient application has become important to both researchers and public alike. The increasing environmental problems and policy debates surrounding beef and dairy pasture operations have centered on the implementation of buffer strips, fencing cattle out of rivers/streams, cattle crossings, and alternative watering systems to name a few. This paper provides an economic overview of buffer strip versus improved pasture conservation practices as a means to reduce water pollution.

INTRODUCTION

The impact of agricultural practices on water quality continues to be a major public concern. Sediments, nutrients, and pesticides can run off farm fields to rivers, streams, and public water supplies. Good manure management practices are needed more than ever before. Livestock practices which can cause impacts to water quality include both intensive and non-intensive operations. These operations can be successful environmentally when managed correctly, but animal waste can cause degradation of water resources if it is not properly managed. Quality water is essential to maintaining not only a healthy environment, but also a healthy economy. Typically, major contaminants arise from residential, industrial, or agricultural sources. To maintain high quality fresh water it is necessary to minimize contamination of surface and ground water sources.

Nutrients entering the water supply come from existing sources (native or non-improved pastures) or from imported nutrients (feed, minerals, chemicals, fertilizer). Existing nutrients come and go as organic material is recycled through the environment. Imported nutrients include fertilizers, livestock feeds and supplements, and chemicals used by humans or in agricultural practices. Nutrient mismanagement can have devastating impacts on stream ecosystems. Ackerman and Taylor (1995) identified intensive livestock operations as point sources of pollution to streams.

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For example, a swine operation in Illinois was linked to ongoing fish kills in an adjacent stream. The open-front facility lacked any waste collection structure to collect nutrient-rich runoff. Manure drained directly from the feedlot into the adjacent stream. Dissolved oxygen, phosphorus and ammonia concentrations exceeded Illinois water quality standards. Applied research is required to identify technologies that will enable Tennessee producers (especially livestock producers) to remain competitive while complying with current and emerging federal and state water and environmental regulations.

The application of plant nutrients (nitrogen and phosphorus) in excess of pasture or crop demand can result in the contamination of surface and ground water. For example, Andres (1995) found nitrate contamination in ground water under cropland that received excessive applications of manure. Factors contributing to the nitrate contamination include: agricultural land use; flat topography; well drained, highly permeable soils and aquifer characteristics. However, Andres (1995) found that nitrate contamination was more severe in areas with intensive animal production than elsewhere. Approximately one-third of the wells had nitrate concentrations in excess of the drinking water standards. Although cow-calf operations have lower livestock densities than feedlots, grazing and cow-calf operations can potentially contaminate surface water. Robbins (1979) found that runoff is proportionately higher from a heavily grazed watershed than moderately or lightly grazed watersheds. High runoff is due to the compaction of the soil from cattle's hooves and grazing practices. Water contamination from grazing operations includes increased sediment and bacterial counts in runoff (Walker, 2003).

Grazing land managers can minimize water quality problems by practicing good grazing management. The key is having a good understanding of livestock behavior. Careful application of common grazing management principles to manipulate behavior can help managers remain profitable while minimizing adverse impacts on water quality. How grazing management strategies are applied will depend on the topography, productivity, and vegetative type of the grazing resources; and management resources such as livestock, fences, water, time, and management ability.

Best management practices (BMPs) are designed for the specific purpose of controlling non-point source pollution. BMPs must be effective and practical. With the exception of very large feedlots, animal waste disposal is largely a non-point source problem. No one system is "best." Every scenario has advantages and disadvantages. It is up to the land user to determine which compromises will be most effective. These trade-offs will include labor needs, cost of setup and maintenance, regulations, convenience, and technical competency of the individual available to oversee operations. While these BMPs appear costly to install, in some circumstances they may provide economic benefits to offset the lost profits from alternative uses. Before beginning construction, however, landowners and users should understand the economic tradeoffs. Benefits of vegetative buffer strips and improved pasture need to be compared with installation and maintenance costs. This paper provides an overview of several studies that have conducted economic analysis of buffer strip and improved pasture establishment.

ECONOMICS

Previous research by Waikato Regional Council (2004), Ohio State University (Nakao, et al., 1999), Campbell and Vere (1983) and Greg Cuomo (2001) have started the difficult task of evaluating the benefits (measurable and non-measurable) and costs of BMPs such as buffer (filter) strips and improved pasture. Table 1 presents the results of a four study by the Waikato Regional Council that measured both on-site and off-site benefits to the region and assessed both the measurable (in environmental outcomes or dollar terms) and non-measurable benefits. In this study measurable benefits of soil conservation were mostly on-site, such as: (1) reducing property damage; (2) reducing agricultural production loss by stabilizing land mass movement and surface erosion; and (3) reducing farm infrastructure damage to farm roads, fences, water supplies and buildings. Non-measurable benefits of soil conservation were mostly off-site benefits, such as: (1) aesthetics; (2) improved water quality for swimming and boating; (3) improved water quality for stock and humans; (4) improved habitat for aquatic animals and plants; (5) increased biodiversity from land returned to native vegetation; and (6) market access – probable market pressure to demonstrate sustainable farming.

Likewise, the study conducted by Ohio State University (1999) estimated the social and private benefits of filter strips. The social benefits under this study were environmental, where the public downstream obtains benefits through reduced sediment flows, improved stream water quality, additional fish and wildlife habitat, and better scenery along streams. Using estimates from Forster, Bardos, and Southgate (1987) of $0.32 per ton for treatment of sediment in water supplies (a 10% reduction in annual gross soil erosion could lower annual water treatment costs by 4%), this study estimated that a 25% reduction in the amount of sediment entering surface water supplies could save $3.2 million per year in water treatment costs. In addition, there are potential economic benefits due to reduction in ditch maintenance and cleaning costs. The estimated cost of ditch maintenance in western Ohio counties averages $450 per mile per year. Based on an estimate by Forster and Abrahim (1985), each 10% reduction in soil erosion could reduce these costs by 11%.

The private benefits calculated under this study dealt with harvesting and marketing the vegetation grown on buffer (filter) strips. Two examples of revenue producing filter strips estimated were hay and timber. For hay, the average price for alfalfa in Ohio in 1996 was $134.58 per ton, and for other hay it was $75.42 per ton (Ohio Department of Agriculture Annual Report 1996). Using a conservative price of $75 per ton, annual returns were calculated at $225 for years 1 and 2, $375 in years 3 and 4, and $338 in year 5. Harvesting costs of $35 per ton must also be taken into account. Note, however, that some logistical problems caused by baling small areas, or safety problems associate with baling a long, narrow filter strip along a stream or ditch bank, may cause relatively high costs for baling.

Although timber production brings revenue, tree planting requires the landowner to have a longer time horizon that the other options because the benefits occur 60 to 80 years in the future. Further, total revenue will vary depending on site quality, and on the effort placed on timber management. Under a low managed timber option planted with oaks, the stands estimated worth is approximately $6,080 after 80 years of growth. Under the high managed timber option planted in walnut, the stands estimated worth is approximately $20,323 after 80 years of growth and management.

The costs of installing and maintaining filter strips on pasture and cropland include: (1) land rental costs, (2) seed and fertilizer costs, and (3) equipment and labor costs. Some costs, such as seed and fertilizer, will occur only when the filter strip is installed, while others, such as land rental, equipment, and labor, may occur throughout the life of the filter strip to maintain it. These costs will vary from place to place, depending on soil fertility, planting and management systems, and the intended use of the vegetative material in the filter strip.

The previous studies have looked solely at the economic benefits related to buffer strip establishment while Campbell and Vere (1983) investigated the economics of improved pasture establishment. Improved pasture establishment has long been recognized as being the most economic means of permanently improving livestock production and farm incomes. Over 40 years ago, Gruen (1959) concluded that the long run return to on farm investment in pasture improvement was considerably greater than that of any method of raising farm income – including the purchase of additional land. Because these conclusions remain valid, it is worth restating the two components of Gruen's underlying economic question: (i) how profitable is such investment likely to be?; and (ii) what is the best pasture establishment program that can be adapted to the producer's own resources and circumstances?

The profitability of pasture improvement is the difference between the long run costs and returns from the investment. The costs are those of establishment and maintenance (including seed, fertilizer, herbicide, fuels, machinery, and extra stock), capital costs (including fences, water and buildings) and interest on borrowed funds. The returns are the increased value of livestock production and the capitalized value of the land and improvements. Although it usually takes several years before new pastures mature to full stocking potential, existing pastures will reap benefits much sooner to the producer and public alike. A study many years ago rings all too true today, Pearse (1963) noted that producers requiring a quick return to alleviate cost-price pressures find no comfort the fact that pasture establishment could take three to eight years before returns from pasture establishment exceed the costs. Thus the decision to invest in pasture improvement/establishment must give due consideration to the associated risks and the producer's attitudes towards them.

Campbell and Vere (1983) demonstrated that pasture improvement/establishment programs are costly but become self-financing in relatively short periods. Their study showed that the program pays for itself in five years with the present day value of the projected net returns (discounted at 18%) estimated to be $25,116 or approximately $25 per hectare. A study by Cuomo (2001) estimated that a modest increase of $50 per acre in net returns from currently under-managed pastureland could be attainable. This project focused on extending current 150-day grazing season to 210 days, ensuring a season-long forage supply, and developing pasture and grazing management strategies that will maintain desirable forage species.

CONCLUSIONS

Water quality is a critical issue facing all livestock producers. When proposing best management practices, it is important to evaluate the entire operation. There is no one system that will be 'best' for all producers. Every situation is different and has its own circumstances. Regardless of the BMP(s) adopted, understanding of livestock behavior could help in developing a conservation program that reduces manure impacts on water quality while helping farm operations to remain profitable. Because technical and economic recommendations for buffer strips and improved pasture are based on a number of assumptions and qualifications, they may not be appropriate in each individual situation. Previous studies have shown that given careful planning and management on-farm investment in buffer strips and improved pasture to be most profitable.

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Table 1. Results of the Waikato Regional Council Benefits of Project Watershed Project (Waikato Regional Council 2004).

Soil conservation work	Benefits	Measurement
Fenced riparian strips (no planting)	Reduced faecal coliforms	By up to 50 percent
	Reduced sediment to waterways	More than 40 percent
	Reduced dissolved phosphorus	More than 25 percent
	Reduced particulate nitrogen	More than 30 percent
Riparian tree planting	Reduced bank erosion	From 24 - 39 percent to 5 - 8 percent in big storms
Pole planting on slopes	Reduced hill country type erosion	From 10 to 2 - 5 percent in big storms, from 1 to 0.2 - 0.5 percent in small storms
	Reduced farm infrastructure damage	$7 - $48/ha.
Block tree planting	Reduced hill country type erosion	From 1 percent to 0.1 percent in small storms and from 10 percent to 1-2 percent in big storms
	Reduced sediment to waterways	By 50 to 90 percent when the whole catchment is planted. Planting only the headwaters can reduce sediment by 30 to 50 percent
	Reduced production loss in big storms	2 percent loss in plantation forest compared with 10 percent for pasture in erosion prone headwaters
Land retirement on slopes	Reduced hill country type erosion	From 1 to 0.1 percent in small storms From 10 to 1-2 percent in big storms
	Reduced sediment in waterways	By more than 90 percent when the whole catchment is retired
Engineering measures	Land stabilised after 10 to 20 years	Pasture levels returned to 100 percent Stock carrying capacity increased from 1 - 2 to 5 - 7 stock units per hectare

PERSISTENT EFFECTS OF LAND USE CHANGE ON A STREAM CHANNEL: UPPER NORTH POTATO CREEK IN THE COPPER BASIN, TENNESSEE

Carol Harden[1]* and Donald Kemp, Jr.[2]

INTRODUCTION

Over time, natural stream channels adjust to the inputs of water and sediment they receive. Thus, it is possible to calculate a stream's discharge at various stages from characteristics of the resultant channel. Because changes in land use affect a watershed's response to rainfall, effects of land use change should be evident in stream cross-sectional area, sizes of bed particles, and other morphometric characteristics. One area in Tennessee where land use change has been especially dramatic is the Copper Basin, in the southeastern corner of the state. In this paper, we report on a study of upper North Potato Creek, in the Copper Basin, in which we sought to identify evidence of the effects of land use change on the stream channel.

Our upper North Potato Creek project had the following objectives:

(1) To determine how land use in upper North Potato Creek has changed over the last 50 years,
(2) To compare the present size and mobility of sediment in upper North Potato Creek to that in a reference stream in the same ecoregion,
(3) To develop data with which to evaluate whether changes in land use have produced differences in channel shape and sediment deposition, and
(4) To consider implications of these findings for restoration.

The Copper Basin is a 130 km^2 erosional depression in the Unaka Mountains in Southeastern Tennessee, which was repeatedly cleared for mining, smelting, and grazing, and underwent over 100 years of exposure to direct rainfall, leading to widespread erosion and massive gully formation. Persistent reforestation efforts have succeeded in establishing tree cover, primarily loblolly pine (*Pinus taeda* L.) and Virginia pine (*Pinus virginiana* Mill.), in most of the basin (Mathews and Harden, 2000). Upper North Potato Creek, which drains about 15 km^2 in the eastern portion of the basin, drops approximately 200 m from its headwaters to its confluence with Burra Burra Creek, over a distance of about 10 km. Above this confluence, the stream has been only indirectly affected by mining activities in the watershed and has relatively good water quality today. The lower section of North Potato Creek, below the Burra Burra confluence, however, is on the Tennessee 303(d) list for high sediment load, habitat alteration, heavy metal contamination, and low pH (Denton et al. 2000).

Sediment yields of North Potato Creek were extremely high for over a century. In 1941 the Tennessee Valley Authority (TVA) joined an ongoing reclamation effort in the basin, hoping to reforest the entire basin and slow the rapid sedimentation of its three downstream reservoirs on the Ocoee River (Cochran, 2000). TVA rerouted North Potato Creek into an abandoned mine in 1987 (Mathews and Harden, 1999), but air photos show that the stream has since resumed its previous course.

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The map drawn by Hursh (1948) shows the watershed of upper North Potato Creek in 1948 descending from a forested zone at the periphery of the Copper Basin, to a gullied grassland zone below the forest, and a bare zone on the floor of the basin. Today, previously bare areas of the upper North Potato Creek watershed are covered with pine trees, farms, pastures, roads, and homes. Dense riparian corridors in most of the upper North Potato Creek watershed contain native hardwood trees and shrubs. The upper slopes of the watershed now support hardwood forests typical for the region, and appear to have escaped the extremes of soil erosion and SO_2 fogging to which lower slopes were exposed. Major changes in land use, from the partially denuded state recorded by Hursh to the present replanted vegetation cover, have been visually dramatic. Changes of this magnitude could be expected to have left a record in the stream channel.

Changes in land use can affect the amount of water that enters a stream during storm events, the rate at which water enters the stream channel, and the solid and dissolved load the water carries. Tree clearing typically increases runoff and erosion, thus causing a channel to have a larger cross-sectional area and an increased fine sediment load. Conversely, we expected that reforested land would behave more like forest, and reverse the changes of deforestation. Schumm et al. (1977) proposed that the channel width to depth ratio should decrease as depth increases following reforestation.

RESEARCH DESIGN AND METHODS

For this study, we selected three sites on upper North Potato Creek, and two in the nearby Tellico River watershed. The three North Potato Creek sites were chosen to represent conditions in the upper, mid, and lower reaches of the creek above the Burra Burra confluence. In the 100-m-long upper reach site, water cascades over tilted bedrock shelves. Unconsolidated sediment is scarce, but some small boulders are present. In the 200-m middle reach site, bedrock is visible throughout the reach, and fine to coarse sand, cobbles, and small boulders are present. At the middle reach site, the creek has incised about 1.5 m into what is now a heavily vegetated terrace. At the lowest site, a 200-m reach, the stream flows tranquilly over a bed covered with sand, gravel, and occasional boulders. One kilometer downstream from this site, the stream flows over a filled sediment dam. Cooperative landowners allowed access to the three study sites and provided sources of anecdotal information about present and past conditions. The two sites on the upper Tellico River near the Tennessee–North Carolina border are in areas forested for at least 60 years. They have not directly been affected by land use changes occurring in the Copper Basin, but are located in a geologically, topographically, and climatologically similar landscape.

Recent land use changes were identified and quantified by analyzing air photos of the area taken in 1952, 1964, and 1994. Photos were scanned and geo-referenced using ESRI ArcGIS software to create digital raster images; then, each image was rectified using known points. Images were reprojected to a common map projection (UTM 1928) and scale (ca. 1:50,000), so that the three images could be compared. Land use within the watershed was digitized and classified as forested, bare, or sparsely vegetated. Once the areas occupied by different land uses had been classified, the percentage of land in each land cover category was readily determined by the software. One of us (Kemp) interviewed seven local residents about the past nature and history of land use in the basin.

We measured channel geometry at six cross-sections along every study reach on North Potato Creek and two on the upper Tellico River (Harrelson et al.,1994). At each cross-section, we made detailed measurements of width, depth, gradient, roughness, and flow. Stream sinuosity was determined from topographic maps from 1927, 1957, and 1978; reach sinuosity was measured on the 1952, 1964, and 1994 air photos.

Along each cross-section, the b-axes (intermediate axes) of the five largest cobbles or boulders were measured. Fine particles were sampled from pools of bedrock reaches (upper and middle) and along each cross-section in the sand bed reach. In the lower (sandy) reach, we also probed with a rebar rod to estimate the volume of unconsolidated sediment. Fine sediment samples were air-dried, sieved, and weighed in the laboratory. Dry particles (sand, gravel, and a few cobbles) were spray painted and returned to the stream bed at low flow to serve as reference markers for identifying particle movement.

RESULTS

The distribution of vegetation in the watershed has changed dramatically since 1952. Forested land has slowly extended down through the watershed, and large areas of bare land have disappeared (Table 1, Figure 1). The position of the creek at the upper and middle sites appears the same in the series of photos, but its position in the lower reach is different. In the 1952 photo, the lower portion of upper North Potato Creek was a braided stream in a floodplain more than 50 m wide. By 1964 the stream had become entrenched as a single-thread channel through the alluvium, and by 1994, the same reach had changed its meander pattern, but was still a single channel in what had become a wooded riparian zone.

Table 1. Changes in land use in upper North Potato Creek watershed 1952–1994.

	1952	%	**1964**	%	**1994**	%	**Change (%)**
Watershed area (ha)	2,510	100	2,510	100	2,510	100	0
Forested land (ha)	520	21	790	31	1,350	54	+33
Bare land (ha)	1,270	51	990	39	300	12	-39
Sparsely vegetated land (ha)	720	29	720	29	860	34	+5

Interviews with local residents informed us that the floodplain adjacent to the upper North Potato Creek site flooded only once in the past 30 years and that the channel at the lower site moved about 20 m west, probably due to an avulsion during a single large storm event.

Morphometric analyses (Table 2) show that cross-sectional area, sinuosity, and entrenchment ratio increase downstream on upper North Potato Creek. W/D ratios are expected to decrease following reforestation (Schumm et al. 1977), but results from this work do not show an evident difference between W/D ratios of upper Tellico(long forested) and upper North Potato Creek (recently replanted).

Bed materials are generally much larger in the upper Tellico River than upper North Potato Creek. Bed materials at the lower study site on North Potato Creek site are notably smaller and far more homogeneous in size than those in higher reaches (Figure 2). When re-introduced into the channel at low-flow conditions, painted particles were actively transported at all sites. Probing documented 117 m^3 of unconsolidated alluvial sediment stored in the 100 m reach of our lowest North Potato Creek site (0.24m average depth). During our six months of observation, riffles migrated, new sand bars and gravel riffles formed, and banks eroded at the lower site.

Figure 1. Land use change in the watershed of upper North Potato Creek, 1952, 1964, and 1994.

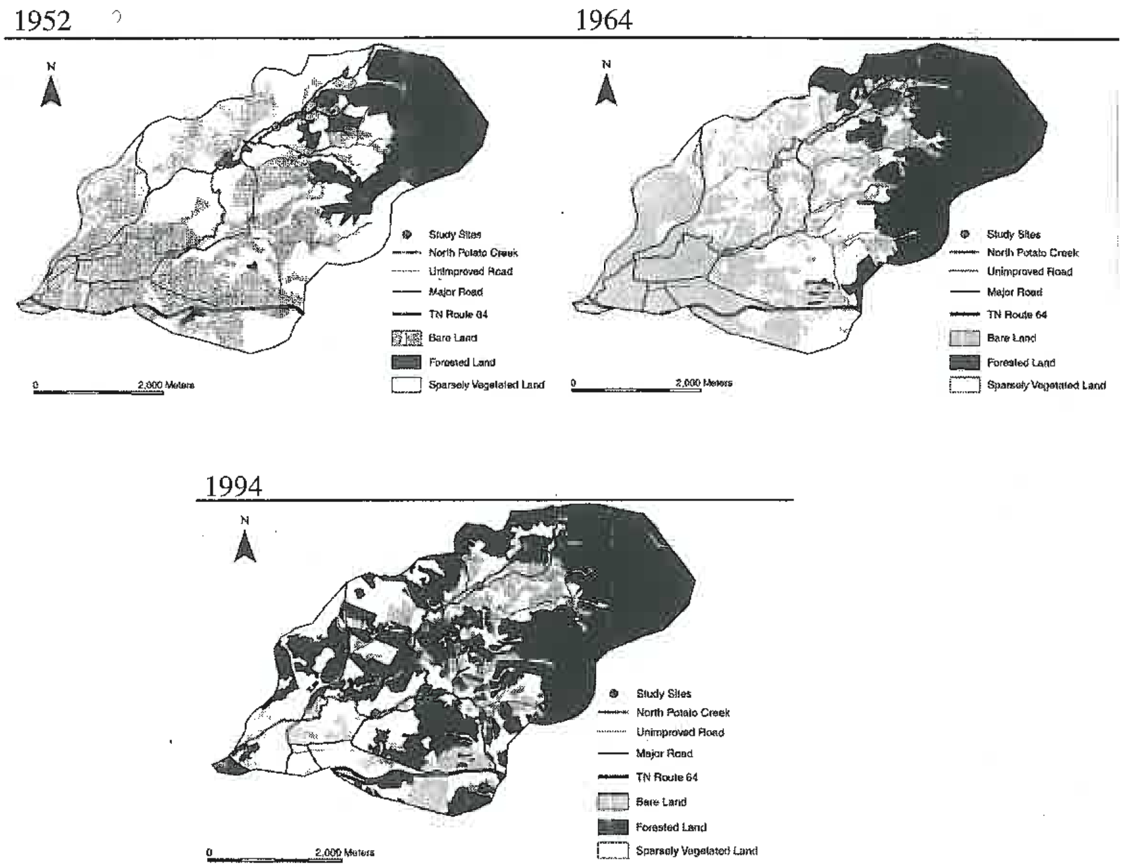

Figure 2. B-axis measurements of largest particles at study sites. Each box shows the median, with upper and lower quartiles; extremes are shows as whiskers. On upper North Potato Creek, the Prince site is the upper site, Bethlehem is the middle site, and Monastery is the lower site.

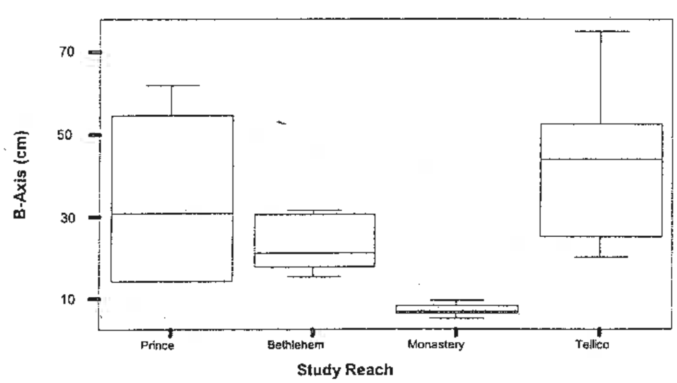

Table 2. Characteristics of Study Sites

	N. Potato--upper site	N. Potato--middle site	N. Potato--lower site	Upper Tellico
Valley gradient	0.0172	0.0172	0.0172	n.d.
Channel gradient	0.042	0.00093	0.00093	0.0013
Channel material	Bedrock channel with one alluvial bank	Bedrock channel, cobbles and small boulders	Alluvial, sand and gravel	Bedrock channel, cobbles and boulders
Bankfull area (m^2)	1.7	4.1	4.9	10.5
Width/Depth Ratio (average value) (range of values)	 9.9 7.3-11.6	 8.2 8.3–12.7	 9.6 6.7–11.3	 10.1 9.9–10.3
Sinuosity	1.2	1.3	1.8	
Entrenchment ratio(1)	2.2	2.3	>>2.2	
Rosgen stream type	A	C	C	B
Rosgen, level 2	A_1	B_1	C_4	B_2 or B_3

[1] Entrenchment ratio calculated as stream or valley width at two times bankfull depth divided by bankfull width.

DISCUSSION AND CONCLUSIONS

We expect that exposed soil and increased erosion in the late 19th and early 20th centuries caused an episode of sedimentation and floodplain formation across the valley floor. Later, decreased sediment loads led to incision and formation of terraces at the middle site, and channel migration at the lower site. Fines in the channel move even at low flow, resulting in a boulder to cobble channel where sediment export exceeds influx. The channel at our lower site is affected by a sediment dam, built prior to 1952 at a site 1 km downstream. At some time between 1952 and 1964, North Potato Creek filled and topped the dam, raising the local base level and allowing the creek to flow over previously deposited materials. In late 1970s and early 1980s, reforestation would have reduced sediment loads (Harden and Mathews, 2000), causing a new period of channel scour—evident as bank erosion at our upper North Potato Creek site and as terraces at the middle site. With much less sediment input now, sediment moving downstream exposes more bedrock in upper reaches. Only the lower site remains alluvial. It differs from the streams of the surrounding ecoregion.

Bedrock channels at our upper and middle North Potato Creek sites, with relatively high gradients and wooded banks, have remained stable over the past 40 years. We interpret short-term changes at our lower site to be part of a complex and ongoing response to historic changes, as well to contemporary inputs of runoff and sediment. The lower site (located at a Catholic monastery) thus serves as an important example of a stream reach still responding to historic as well as contemporary influences, and responding to influences originating down- as well as up-stream. Sediment now in this reach may have originally eroded from the watershed in its denuded state (late 1800s through 1980s) or reflect current sources of sediment, well-connected to the stream by the dense gully network developed in the denuded period. The expected signal of reforestation at this site may be overwhelmed by the downstream movement of residual material. The bedrock channel of North Potato Creek below the Burra Burra confluence attests to the role of the sediment dam below our lower site in capturing and storing sediment. The dam causes this reach to remain unstable, and also disconnects this and higher reaches from the regional aquatic ecosystem. Removal of this dam would trigger adjustment, largely expressed as channel incision and removal of finer particles to reveal the underlying bedrock channel.

Understanding channel response to land use change is important for better understanding the fluvial geomorphology of streams and for making decisions about stream restoration. Fluvial systems may be used as proxy for general health of watershed (Denton et al. 2000); but, as seen in upper North Potato Creek, present-day fluvial systems may contain persistent effects of past land use. Ultimately, it is important to study these areas so that land use managers can make well-informed decisions and be able to control or predict morphological change in the fluvial system based on changing land use.

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THE RELATIONSHIP BETWEEN WATERSHED CHARACTERISTICS AND STREAM CHANNEL MORPHOLOGY

Martin D. Lafrenz*[1]

INTRODUCTION

Human impacts to stream channels and to the watersheds that contribute sediment, which alters stream channel morphology, have been extensively documented in nearly every region of North America. Stream restoration of these disturbed environments has recently focused on using "natural channel design," and in fact, several government and non-profit agencies have published guidelines for stream restoration (see www.saw.usace.army.mil/wetlands/Mitigation/stream_mitigation.html for an example of stream mitigation techniques for the southeastern U.S.). Many techniques in natural channel design rely on stream classification schemes, such as the Rosgen classification of natural rivers (1994), and the use of regional curves in order to prescribe the bankfull dimensions and the gradient of the restored stream. Unfortunately, differing geology and precipitation patterns between and within regions create large variability in the channel dimension expressed in most regional curves. Further, the dimensionless values commonly used in stream classifications make it difficult to predict the best actual width, depth, and cross-sectional area values for a particular stream. Hence, "fitting" the correct stream channel dimension for a restoration project can be complicated by watershed characteristics other than area. Since regional curves are based only on the area or discharge regime of a drainage basin, it may be possible to decrease variability in channel dimension prediction by including other watershed characteristics when considering stream restoration.

BACKGROUND

Classic studies in stream channel hydraulic geometry by Leopold and Maddock (1953) introduced the dependent relationship between the stream channel dimensions of width, depth, and cross-sectional area and the area of a drainage basin. This relationship was documented by several other workers and summarized by Leopold and Dunne (1978) in a series of regional curves for different physiographic regions in North America. These regional curves display the log-linear relationship between drainage basin area and stream channel geometry; the term regional is used because the location of the best-fit line varies depending on physiography and climate. For instance, streams draining similar sized basins tend to be wider in the southeastern U.S. than in the semi-arid intermontane areas of Idaho and Wyoming (Leopold and Dunne 1978). However, even within a particular region there can be significant scatter around the mean regarding the actual size of a stream channel.

Efforts to restore degraded streams have taken advantage of the dependent relationship between basin area and channel morphology. This relationship allows workers to calculate the bankfull dimension that should be expected for a particular stream in a particular region. Additionally, restoration workers have recently been incorporating natural channel design, where the gradient, shape, meander wavelength, and entrenchment of a stream are "fitted" to a reference reach based on a stream classification. The most frequently applied stream classification is the Rosgen classification of natural rivers (1994). The Rosgen scheme classifies streams according to one of eight types based on stream planform; these eight types are further delineated based on slope and

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channel materials. The Rosgen scheme uses a dimensionless ratio for stream channel morphology, however the typical range of stream widths has been reported (Rosgen 1994). These widths are not exclusive to stream type; hence they are used in conjunction with regional curves when conducting stream channel restoration.

Much like regional curves, the range of values reported for stream widths in the Rosgen system is large. This makes choosing a stream width for a re-designed stream difficult. If the channel is designed too narrow, the banks will be undercut and eroded. If the channel is designed too wide, the stream may meander and also lead to bank instability. In both cases, the natural adjustment processes in fluvial systems may hinder design success. Several studies of regional curves have noted the large range of values for stream width compared to basin area. In North Carolina, regional curves have been plotted for the mountain, piedmont, and coastal plain physiographic provinces (Harman, et al. 1999). Even with division by province, stream widths showed as much as a 50% difference in width with similar basin drainage area. Variability was highest in the mountain physiographic province because of the complex geology and precipitation, patterns according to the authors. Hence, choosing the correct stream width for restoration purposes can be problematic, and it is particularly difficult in areas of high relief.

If drainage basin area alone cannot predict channel geometry with enough precision to ensure the success of costly restoration efforts, then perhaps the inclusion of additional watershed characteristics can narrow the range of values expected. In this study, I present results on stream width variability from 51 different stream surveys conducted in Great Smoky Mountains National Park (GSMNP). I surveyed exclusively in headwater contributing areas, since land surfaces and stream channels are often most closely connected in low order streams (Meyer and Wallace 2001). Hence, the influence of watershed characteristics other than area should be most pronounced in small headwater basins. I calculate that headwater contributing areas comprise over 76% of the land area of GSMNP. Thus, knowledge of the relationship between catchment characteristics and channel geometry for these areas allows for prediction of stream dimensions and the possible improvement of stream restoration designs for a large portion of this region.

METHODS

The methods of this project involve combining information from digital elevation models (DEMs) and other digital datasets in a geographic information system (GIS) and using statistical techniques to stratify watersheds by significant characteristics. I used GIS software to delineate contributing areas based on a DEM with 10-meter resolution and a minimum size watershed of 0.5 km^2. Preliminary fieldwork showed this minimum size to be the smallest catchment likely to have perennial streamflow. I retained all headwater catchments with the exception of those watersheds having a significant portion of drainage area outside of the park boundary as well as an area in the southern portion of the park for which there is no existing information on basin geology. I then used GIS to intersect the catchments with the layers of geology and disturbance history (i.e., heavily logged, selectively cut, farmed, developed, burned, insect outbreak, and undisturbed) calculating percent coverage of each by contributing area. I then calculated basin area, perimeter, and shape for each contributing area. Rather than calculate a simple slope and aspect for each catchment, I determined these two parameters for each pixel in the study area and grouped pixels by slope and aspect class. Additionally, I created elevation classes rather than simply calculating mean elevation for each catchment. I then intersected these layers with the delineated catchments and determined the percent coverage of the various slope, aspect, and elevation classes for each watershed.

In order to collect information of channel geometry, I selected 51 streams to be surveyed. Since a standard random sample procedure did not create a sample set that was representative of geology across the study region, I used a stratified random sampling procedure based on a k-means cluster analysis. Some of the sample locations were changed after consultation with park scientists in order to accommodate other research projects being conducted in the park. In the field, I chose a representative reach approximately 100 meters upstream from the mouth of the contributing area and recorded several bankfull widths, depths, and reach slope according to standard USGS protocol.

I used correlation analysis to determine the auto-correlation among watershed characteristics and to assess the relationship between stream width and watershed characteristics of the 51 sampled streams. I used the rank-based Kendall's tau as the correlation coefficient since many of the parameters used were not normally distributed. This process allowed me to choose several of the watershed characteristics that showed a significant relationship to stream width as well as to determine several variables that should be combined (e.g. types of geology) because of auto-correlation. I then stratified the data using the significant variables identified in the correlation analysis and plotted the linear relationship of log stream width and log catchment area for each stratified set of catchments. If the stratified grouping led to a significant log-linear relationship that showed a smaller variation in the range of values for stream width than using the entire data set, I considered that watershed characteristic to be a good candidate for better predicting the true width of streams in this region.

RESULTS AND DISCUSSION

Prior to stratifying the sample data set by any watershed characteristics, I plotted the linear relationship between the log stream width and log drainage basin area as is typically done when constructing a regional curve (Figure 1). The significant r-squared value for this relationship of 0.27 ($p < 0.01$) is low but does indicate good predictive power for stream width based on drainage basin area. However, the range in width values is 5.1 m with a mean 3.2 m (min, mean, max is 0.90, 3.2, 6.0 respectively). It should be noted that these catchments only range over one order of magnitude in size; therefore, these results indicate a large degree of scatter. It would problematic at best to determine the correct stream width for stream restoration based only on this relationship.

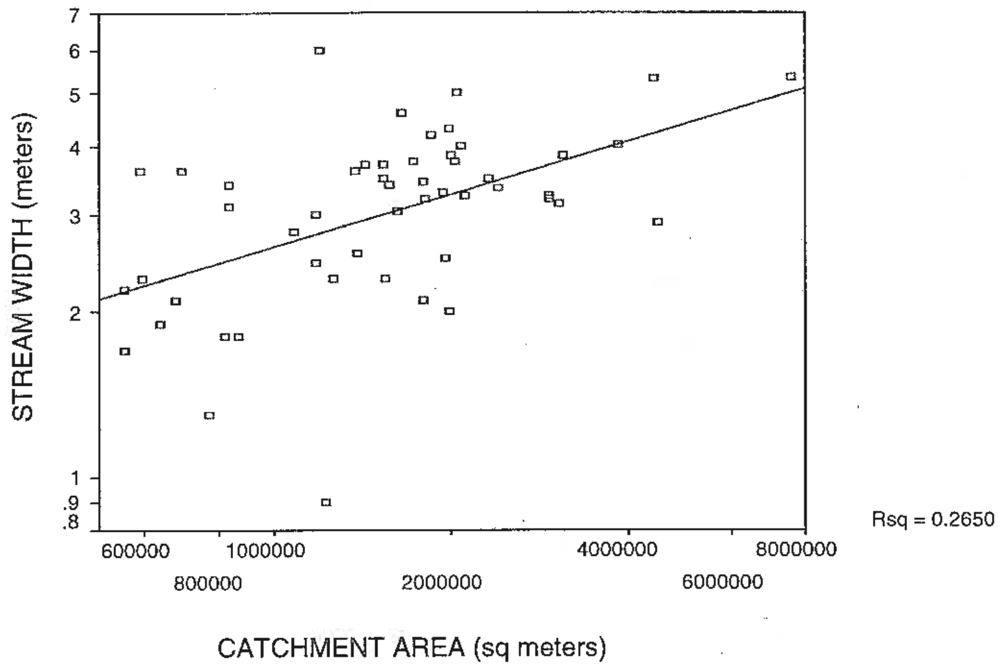

Figure 1. Scatter plot for the values log of stream width and log of catchment area.

The correlation analysis, however, provides information that improves our predictive ability for this region. Table 1 lists the 9 significant relationships between individual watershed characteristics and log stream width, which are northern aspect, southern aspect, western aspect, heavily cut forest (negative correlation), undisturbed forest, Longarm Quartzite geology (negative correlation), 25-40% slope, 40-60% slope, and 60+% slope. The significance of the aspect characteristics north, south, and west is not clear. However, in this region winter storms approach from the west, which may lead to higher precipitation rates, greater surface flow, and wider streams for western aspect watersheds. Heavily cut watersheds are negatively correlated with stream width, which seems to run contrary to most theories of fluvial adjustment where logging causes increased sediment loading, stream aggradation, and widening (Schumm 1977). However, it has been over 70 years since these watersheds were logged, and it is likely that the streams are currently incising back into the aggraded material. Catchments with large areas of undisturbed forest are positively correlated with stream width, which is expected by regional curve theory. It is interesting that of all 18 types of geology in this data set, only Longarm Quartzite shows a significant correlation with stream width. However, this quartzite and several other geology types rarely occur over large areas in these watersheds; thus, they have little influence over channel morphology by themselves. Finally, watersheds dominated by high relief, which is common in this mountainous study area, are strongly correlated with stream width. This is the only significant variable in this model that may be related to a Rosgen stream classification.

Table 1. Correlation coefficients between log stream width and watershed characteristics.

Watershed Characteristic	tau	Sig.
North Aspect	.24	.01
South Aspect	.23	.05
West Aspect	.28	.01
Heavy Cut	-.24	.05
Undisturbed	.30	.01
Longarm Quartzite	.-28	.01
Slope 25-10%	.26	.01
Slope 40-60%	.38	.01
Slope 60+%	.22	.05

Using the information from the correlation analysis, I was able to stratify the watersheds based on each of the watershed characteristics that showed a significant correlation with stream width. For each set of stratified watersheds I calculated an r-square value for the relationship between log stream width and log catchment area; in addition, I calculated the range of stream widths and average width for comparison to the entire data set (Table 2).

As stated previously, the range of stream widths for the entire data set is 5.1 m. Most stratification techniques resulted in a smaller range, which will provide better information for stream restoration. Watersheds dominated by heavily logged areas (min, mean, max of 1.8, 2.6, 3.6 m) have a small range of stream width value, but there is no significant regression line between stream width and catchment area. Thus, it is not possible to use this stratification to predict possible stream widths for restoration purposes. Even though it has been over 70 years since these areas were cut, it appears the streams have not re-established a stable channel morphology. This is similar to findings in the Copper Basin, southeastern Tennessee, where forest hydrology has not recovered following the long-term re-establishment of forest (Harden and Mathews 2000). However, watersheds with large areas of undisturbed forest in this study region have a small variation around the mean of stream width (min, mean, max of 3.2, 3.7, 4.3 m) and display a significant regression relationship between stream width and catchment area (.34, $p < .05$). In addition, there is a significant difference in average stream widths between heavily cut and undisturbed watersheds, while there is no average difference between their catchment areas. Thus, watersheds with large areas of undisturbed forest should make for good reference reaches; however, 70 years is not a sufficient amount of time to allow inclusion of formerly logged areas into a regional curve.

Table 2. Range and mean of stream widths by stratified by watershed characteristics and r-square value for log stream width and log catchment area by each stratification. Parentheses in Elkmont/Cades Sandstone refer to values after discarding watershed sampled over limestone substrate.

Stratified By	Min (m)	Mean (m)	Max (m)	Range (m)	r^2	Sig.
All Watersheds	.90	3.2	6.0	5.1	.27	.01
Heavy Cut	1.8	2.6	3.6	1.8	.01	not sig.
Undisturbed	3.2	3.7	4.3	1.1	.34	.05
Slope > 40%	1.8	3.2	6.0	4.2	.22	.01
Slope < 40%	0.9	2.9	5.3	4.4	.37	.05
NE Aspect	0.9	3.0	4.6	3.7	.14	not sig.
SW Aspect	1.3	3.2	6.0	4.7	.32	.01
Elmont/Cades Sandstone	0.9 (1.3)	3.1 (3.7)	5.3	4.4 (4.0)	.39	.05
Other Sandstones	1.8	3.0	5.0	3.2	.60	.01

Watersheds with steep slopes showed mixed results in regression analysis. Low to moderate slope classes were highly auto-correlated, as were steep slope classes. Hence, a regression analysis with all slope classes was not significant. However, by creating two slope classes, one less than 40% and one greater than 40%, I was able to stratify the watersheds and achieve significant results. Watersheds dominated by low to moderate slope areas less than 40% had relatively high variation around the mean for stream width (min, mean, max of 1.8, 3.2, 6.0 m); however, the variation was smaller than for the entire data set and the r-square value for the stream width/catchment area was significant (.22, $p < .01$). For watersheds with steep slopes greater than 40%, there was also relatively high variation around the mean for stream width (min, mean, max of 0.9, 2.9, 5.3 m), and the r-square value was significant (.37, $p < .05$). There was no significant difference between the average stream widths for these two classes, yet the relationship between stream width and catchment area is stronger with the stratification. Since this value is included in most stream classification, it seems prudent to maintain at least these two slope classes for predicting possible stream widths.

When stratified by each of the three significant aspect criteria, there was no significant regression between stream width and catchment area. Since there was auto-correlation among these characteristics, I combined the aspect classes into the more statistically exclusive categories of northeast and southwest aspect. With this stratification the southwest aspect showed high variation (min, mean, max of 1.3, 3.2, 6.0 m) but a significant r-square (.32, $p < .01$). The northeast aspect showed no significant relationship. This, again, may be a function of storm tracks in this region. Southwest slopes will receive more precipitation and will have higher discharge; this should lead to more steadily increasing stream width with larger catchment areas. As such, this parameter could be effectively used to limit possible stream width criteria if the restored stream drains a watershed with predominately southwest facing slopes.

Lithology is usually thought to play a dominant role in channel morphology. Although there is only one type of geology with a significant relationship in the correlation analysis, I determined to group similar types of geology in order to assess a possible relationship that may have been muted by the complex geology of this study area. I combined several of the different sandstones including Thunderhead, Roaring Fork, and Rich Butt Sandstone into one group and the Cades and Elkmont Sandstones into another based on their similar chemical and physical properties (King, et al. 1968). I did not combine any of the remaining geologic types that occurred in significant quantity within the sampled watersheds, including the Wilhite Coarse and Anakeesta formations, Metcalf Phylite, and Longarm Quartzite, because each was so markedly different than the other.

None of the four former groups showed significant relationships between stream width and catchment area in watersheds where they were dominant; this is likely because there were too few samples to properly conduct regression analysis. However, both sandstone groupings showed good relationships. The Elkmont/Cades Sandstone group had a relatively high variation (min, mean, max of 0.9, 3.1, 5.3 m); however, smaller variation is possible with the exclusion of one watershed, the 0.9 value, which was sampled near the mouth where the underlying geology was actually limestone. The r-square for both groups was significant at .39 ($p < .05$) for Elkmont/Cades and .60 ($p < .01$) for the other sandstone grouping. The Thunderhead/Roaring Fork/Rich Butt Sandstone group had a lower variation for stream width (min, mean, max of 1.8, 3.0, 5.0 m), which is encouraging since this geology is the most common type for this study region.

CONCLUSIONS

As natural channel design becomes more common in stream restoration, it is increasingly important that we be able to accurately fit the proper channel dimension to a particular respective watershed. The use of regional curves, whereby the log of stream width is graphed against the log of watershed area, along with stream classifications can help us to narrow the range of channel dimensions that are pertinent for a particular restoration project. However, with the inclusion of additional watershed characteristics such as geology, land cover, slope, and aspect, we can further delimit the range of channel dimension values that will be appropriate in natural channel design. In this study, I showed that the amount of undisturbed area, southwest aspect and the dominant lithology play key roles in channel maintenance. Ignoring the natural variability than exists in southern Appalachian watersheds may lead to channel designs that are ill suited to the respective watershed. In addition, I showed that areas logged over 70 years ago had yet to regain geomorphic stability. Hence, workers must always be cognizant of the landuse history of the watershed for both the stream being restored and any reference stream that is being used as a guideline. Natural stream design is a vast improvement in stream restoration, and the inclusion of additional watershed characteristics beyond drainage basin area can only improve the efficacy and success of the stream restoration for both the geomorphic system and the entire stream ecosystem.

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POSTERS

Presenters will be available to answer questions from 5:30 to 6:00 p.m. on Thursday, April 1, 2004.

Assessing National Land Cover Data (NLCD) for Spatial Prioritization of Nutrient Risk Areas in the Little River Watershed, Tennessee
Chris A. Moniodes, Carol P. Harden, and Roger Tankersley, Jr.

Cometabolism of Perchloroethylene by Ammonia-Oxidizing Bacteria Collected from a PCE-Contaminated Karst Aquifer
LyTreese Hampton and Thomas Byl

Comparison of Bioluminescent Bacteria and Oxygen Consumption as Indicators of Water Quality
Dominic Anako, Janique Suber, Paul Frymier, and Tom D. Byl

Consumptive Use of Water in the Tennessee River Watershed
Susan S. Hutson, Sidney E. Gibson, and M. Carolyn Koroa (see text beginning on page 2C-1)

Distribution and Transport of Coal Tar Contaminants in the Chattanooga Creek Floodplain
Dalphanià Syreeta Dickerson, Vijay Vulava, Larry D. McKay, and Fu Min Menn

Drainage Density, Stream Networks, and GIS
Carl Alexander, Ben Palko, and Peter Li

Economic Evaluation of Conservation Practices: Buffer Strip Versus Improved Pasture
Ernest Bazen and Michael Barrowclough (see text beginning on page 3C-4)

Effects of Best Management Practices on Water Quality in the Bullrun Watershed
Candice Jones

Effect of Sediments and Nutrients on Benthic Macroinvertebrates in Nails and Ellejoy Creeks
Susanna Sutherland

Evaluating Oxygen-Releasing Compounds to Enhance Toluene Biodegradation by Free-Living Bacteria
Lashun King, Khalid Woods, LyTreese Hampton, and Tom D. Byl

Ex-Situ Dechlorination of Chlorinated Solvents in a Combined Biological and Zero-Valent Iron Reactor
Jason Carney, Russell Carter, and Roger Painter

GIS Survey of Bedford County Poultry Facilities in Conjunction with GIS Thematic Representation of Bedford County Soils, Watersheds, and Streams
Destry Greenway

Impacts of Fresh and Decomposed Cattle Manure on Dissolved Oxygen Patterns of Pond Creek
Tyaisha Blount, Joanne Logan, Forbes Walker, and John Buchanan

Potential Sources of Non-Point Sediment Pollution in the Little River, Blount County, Tennessee (Preliminary Findings from Total Suspended Solid and Turbidity Data for Ongoing Study)
Heather Hart, Paul D. Ayers, Joanne Logan, and Galina Melnichenko

Seasonal Assessment of Constructed Wetland for Wastewater Remediation
S.D. Johnson, M.L. Self-Davis, and Paul G. Fader

Supplements to Enhance Groundwater-Microbial Growth and Biodegradation Processes
LeMiracle Hendking, Patricia Burton, and Tom D. Byl

Survival of Fecal Bacteria in Sediments and Development of a Numerical Model to Predict Storage and Transport in a River
J. Finke, R. Graham, J. Carpenter, T. Rashid, L. Sharpe, J. Farmer, and T. Byl

ASSESSING NATIONAL LAND COVER DATA (NLCD) FOR SPATIAL PRIORITIZATION OF NUTRIENT RISK AREAS IN THE LITTLE RIVER WATERSHED, TENNESSEE

Chris A. Moniodes*[1, 2], Carol P. Harden[1], and Roger Tankersley, Jr.[2]

ABSTRACT

Land cover is a primary data source needed for quantifying the amount of total nitrogen (TN) and total phosphorus (TP) delivered to surface waters. The National Land Cover Dataset (NLCD) is available free of charge for the continental United States. Using export coefficient modeling (ECM) and raster-based GIS in the Little River watershed, Tennessee, we compared model results produced from NLCD (at 30 m resolution) to results from fine scale land cover (at 10 m resolution). The ECM was altered to incorporate topographic and buffer indices, which identify runoff likelihood and nutrient trapping potential. Results indicate that NLCD captures 73% to 97% of the loading modeled by fine-scale, fine resolution land cover data, suggesting that 30 m NLCD is appropriate for prioritizing areas within watersheds similar to the Little River.

INTRODUCTION

Land cover composition is a primary component for managing nutrient delivery to surface water, such as total nitrogen (TN) and total phosphorus (TP). Well-developed empirical studies have shown a strong relationship between land cover and TN and TP exports from watersheds (Hill 1978; Reckhow *et al.* 1980). Federal regulations on water quality, such as the Environmental Protection Agency's (EPA) Clean Water Act, require states to assess nutrient loadings annually. Ideally, this is done through direct in-stream monitoring programs; however, the time and money required for monitoring make comprehensive sampling prohibitively expensive for most states (McFarland and Hauck 2001).

Alternatively, the *Export Coefficient Model* (ECM) allows researchers to target stream remediation areas quickly and inexpensively. The ECM assumes that for similar climatic regimes a known amount of nutrient load will export from a given land cover. Using readily available land cover data and export coefficient values (ECV), which are annual estimations of pollutant loading per land cover area unit, it is possible to quantify a watershed's annual nutrient export (Winter and Duthie 2000). The ECM, built within a GIS framework, allows the researcher to evaluate broad scale areas for management *a priori*, visualizing risk areas and prioritizing them accordingly (Johnes *et al.* 1996; Endreny and Wood 2003). Unlike complex, hourly-time step hydrologic models with large data requirements that are cumbersome and complicated to implement at broad scales, the ECM provides a method for modeling nutrient loading broadly, using general rules of watershed response from commonly available data to estimate real world watershed processes (Endreny and Wood 2003).

Since the introduction of ECModeling in the 1970s, several land cover datasets have been developed for general landscape modeling. Today, the mostly widely used is the National Land Cover Dataset (NLCD). Derived from Landsat-5 Thematic Mapper (TM) satellite imagery, NLCD characterizes the landscape with 21 classes of land use (*See* USGS 2004) at 30 m

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resolution (Loveland and Shaw 1996). NLCD is freely distributed by the Multi-Resolution Land Characterization (MRLC) consortium and United States Geologic Survey (USGS) (*http://seamless.usgs.gov*), and is available for the continental United States. Although accurate ECVs are critical components to ECModeling, their use relies on the scale and resolution of land cover data. However, fine scale land cover development is costly and usually not practical for large areas, which raises a question for the watershed manager or researcher—Can NLCD capture enough detail to produce comparable water quality modeling results? ECVs measure pollutant loading as a function of land cover per unit area, and different model results may be obtained from coarse resolution versus fine resolution land cover data due to differences in measurements of each land cover type.

The purpose of this paper is to test how well ECM results produced from freely available NLCD compare to more costly, fine resolution land cover model results in the Little River watershed, Tennessee. Fine-scale land cover data are represented by a 55 class land cover/land use dataset derived from low-level aerial photography and developed by the Tennessee Valley Authority (TVA) circa 2000 (TVA 2002). We developed a raster based ECM within the Arc/Info© GIS that alters the traditional ECM methods to include runoff and nutrient trapping likelihood such that ECVs are adjusted for topography, rather than distributed homogenously across the landscape (Endreny and Wood 2003).

METHODS

Our study area is the Little River watershed (LRW), Tennessee (Figure 1). LRW (979 km^2) spans portions of Blount, Sevier, and Knox counties and is situated in the Ridge and Valley and Blue Ridge Mountain physiographic provinces. Topography varies from gently rolling valleys to extremely steep slopes with elevation ranging from roughly 228 m in the valleys to 1,500 m in the mountains, creating a hydrologic environment where streams flow through narrow valley floors or cut across steep ridges (Smith 2000).
In the lower reaches, land use is dominated by agricultural, consisting of mostly livestock operations (60%) (USDA 1997). In upland reaches, forest is the dominant land cover, including roughly 27,435 ha of Great Smoky Mountains National Park. Several LRW tributary streams are on the EPA 303(d) list of impaired waters for excessive nutrient loads (TVA 2003).

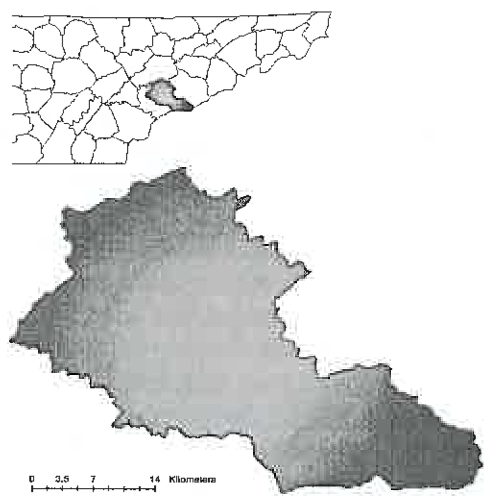

Figure 1: Little River watershed.

The fine-scale, fine resolution TVA land cover data (TVA-LC) used in this study are produced on a client-by-client basis and only available to TVA personnel. Land cover data are generated from low-level, sub-meter resolution aerial photography as a vector GIS layer with a minimum mapping unit of roughly 1 ha. The modeling procedure in this paper requires raster data; therefore, TVA-LC was converted to a 10 m resolution raster layer. The two land covers incorporate different classification schemes, and were reclassified to a common six-class scheme (Table 1). To compare nutrient modeling results between the two land cover datasets, we took a three-step approach: (1) calibrate the LRW-ECM using in-stream nutrient measurements; (2) devise a ECV weighting scheme using digital elevation models (DEM) and pollutant trapping ability; (3) compare total TP and TN loading results produced from NLCD and TVA-LC.

The ECM was calibrated with in-stream measurements of TP and TN taken from Ellejoy and Nails Creek (sub-watersheds of LRW), and ECVs derived from existing literature. We calculated annual nutrient loads (kg/yr) from in-stream concentrations collected during the summer and fall of 2003. We used only these sub-watersheds because a comprehensive water quality dataset was not available for the entire LRW. The calibration analysis assumes that the TVA-LC represents land cover more accurately than NLCD. Because ECVs reported in the literature vary widely, we compiled only those reported for similar climatic conditions as LRW and aggregated their distributions into percentiles (Table 1). A suite of model simulations was performed using each ECV percentile within Ellejoy and Nails watersheds to test the sensitivity and reduce the uncertainty of ECVs. Results from the sensitivity analysis indicate that both median TP and TN percentiles produced simulated nutrient loads that were within ±5% of observed loads in Ellejoy and Nails Creek and thus were selected for the overall ECM.

Table 1: Percentile aggregation of literature reported TP and TN ECVs by land cover.

	TP (kg/ha/yr)					*TN (kg/ha/yr)*				
Land Cover	**Min.**	**25%**	**50%**	**75%**	**Max.**	**Min.**	**25%**	**50%**	**75%**	**Max.**
Urban*	0.43	1.90	2.25	4.34	5.35	1.56	7.19	10.88	13.32	28.00
Forest*	0.01	0.20	0.39	1.23	2.00	0.03	0.13	0.24	2.19	3.12
Pasture*	0.14	0.16	0.56	1.35	3.80	3.46	6.28	9.23	10.99	13.00
Cropland*	0.40	1.14	2.41	3.70	17.64	3.04	4.05	14.98	19.30	46.50
Barren Land*	0.05	0.15	0.25	0.39	0.52	0.50	1.25	2.00	4.00	6.00

*Obtained from Reckhow *et al.* (1980)

The ECV weighting scheme was devised from the work of Beven (1995) and Endreny and Wood (2003). Using commonly available DEMs available from USGS, we used raster algorithms available in Arc/Info© to generate a topographic index (TI) and buffer index (BI). The TI uses an index of wetness based on topography to illustrate the variability in hydrologic response from different areas within the watershed by determining the relationship between a pixel's upslope contributing area, per contour length, and slope. Areas that have a high potential for saturation have a high potential for runoff (Horton 1933; Dunne and Leopold 1978). The BI identifies a watershed pixel's potential nutrient filtration by calculating pixel dispersal areas and relative pollutant trapping ability. The BI identifies overland flow dispersal areas and estimates relative values for each pixel's buffering likelihood using a DEM and land cover analysis that determines if each pixel's runoff actually enters a vegetative buffer (Endreny and Wood 2003). Nutrient trapping ability was obtained from empirical field studies conducted by Lee *et al.* (2003). The raster-based ECM was implemented within the GIS as:

$$L_N = \sum_{i=1}^{N\sim} \left[(E_i * TI_i * BI_I) * A_i \right]$$

where L is the summarized load for watershed N, E is the ECV for watershed pixel i, TI and BI are the topographic and buffer index values for watershed pixel i, and A is the area of watershed pixel i. The area of each watershed pixel remained consistent (100 m^2 or 900 m^2) in each land cover dataset.

Traditional ECMs (*see* Reckhow *et al.* 1980) calculate a total annual nutrient load (kg/yr) per watershed, allowing the researcher to examine spatial variability between, for example, 8-digit

HUCs across the Mid-Atlantic region. However, traditional methods assume ECVs to be homogonously distributed across the landscape and do not take into account interactions between watershed pixels, such as the relationship between a watershed pixel's upslope contributing area and downslope dispersal area (Endreny and Wood 2003). When modeling smaller areas, such as LRW, an ECM weighting scheme allows the researcher to capture these relationships and examine spatial variability within the watershed, identifying the degree of loading from one raster pixel relative to the next.

RESULTS AND DISCUSSION

The LWR-ECM results indicate that freely available NLCD captures 80% of the TP and 73% of the TN modeled by TVA-LC (Table 2). The weighted scheme produced by TI and BI values allows for a more precise examination of variability within the watershed. Therefore, we extracted nutrient loads from areas within 100 m of all LRW streams and found the proportion of nutrients captured by NLCD compared to TVA-LC increased to 98% (TP) and 76% (TN). In both cases, TP simulations were the most successful, capturing 80% and 98% of the TP modeled with TVA-LC. Endreny and Wood (2003) note that although modeling TN using this approach is possible, there is greater uncertainty associated with the fate and transport of TN through a watershed system. The calibration procedure attempts to minimize the amount of uncertainty associated with ECM results; overall uncertainty would have been lower if we had calibrated the model at more locations across LRW. It is important to note that ECModeling is intended for scoping risk areas and prioritizing them accordingly (Reckhow *et al.* 1980; Wickham and Wade 2002). Thus, the researcher should focus on identifying and prioritizing risk areas, not on reporting absolute loading amounts. Once critical risk areas have been identified and prioritized a more detailed modeling campaign may be implemented.

Table 2: ECM TP and TN predictions and NLCD comparison for the Little River watershed.

	TP (kg/yr)		*TN (kg/yr)*	
Land Cover	Entire Area	Riparian Only	Entire Area	Riparian Only
NLCD	67,587	16,866	326,627	75,541
TVA-LC	84,712	17,280	446,408	99,070
% Captured	80	98	73	76

Although comparing nutrient loadings produced by the weighted LRW-ECM yields good results, assessing risk areas within smaller sections of LRW using NLCD is less precise. For example, Figure 2 illustrates the variation in TP loading between NLCD and TVA-LC model results from a 1 km^2 section of LRW. The finer resolution of the TVA-LC allows one to more precisely depict risk areas. As one moves from fine to broad scales detailed processes and patterns are sacrificed for increasing spatial extent (Meentemeyer 1989). When considering nutrient loading from all of LRW, discrepancies between the two sets of model results become less apparent, and NLCD reveals the same general pattern of nutrient loadings as the TVA-LC (Figure 3). Thus, the TVA-LC data are more appropriate for prioritizing remediation areas within a small area, such as a square kilometer area or a 50 m riparian buffer zone. NLCD is more appropriate for watershed-sized assessments of nutrient loading, such as prioritizing remediation areas within and/or between entire urban sections, or examining nutrient variability between larger watersheds across multiple counties.

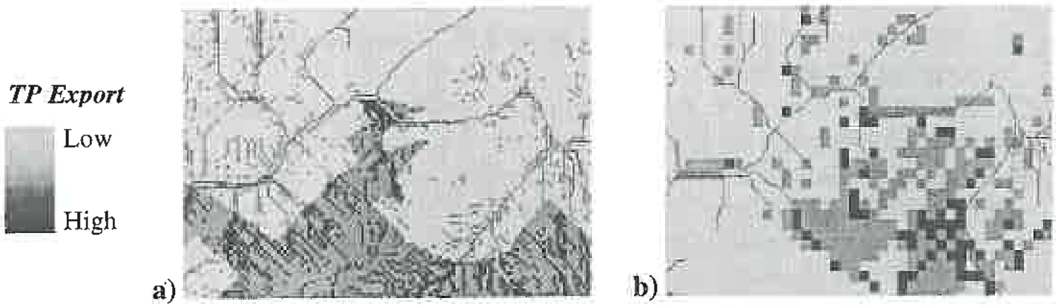

Figure 2: A $1 km^2$ section of LRW illustrating variability of TP export from (a) NLCD (30 m resolution) and (b) TVA-LC (10 m resolution) to streams. Darker areas represent areas of higher loading, while light areas are lower loadings.

The NLCD used in this analysis was developed in 1992, whereas the TVA-LC was produced in 2000. During the intervening years, LRW experienced urban growth, which may affect comparison of the land covers. MRLC and USGS have indicated that NLCD 2001 will be available within the next year. For future research, it would be interesting to examine the differences between ECM results produced from fine scale land cover, such as the TVA-LC, and the 2001 NLCD.

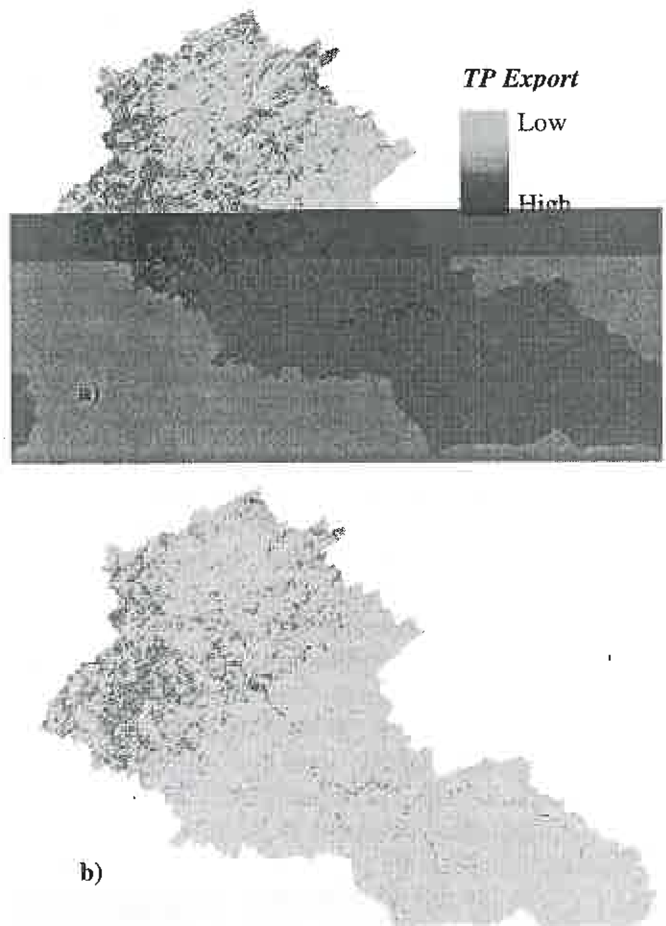

Figure 2: Spatial variability of TP risk areas across the entire LRW area. Loadings were calculated from (a) TVA-LC and (b) NLCD.

CONCLUSIONS

This paper illustrates the use of NLCD within a GIS-based ECM. The ECM is a simple, broad-scale model that can be implemented quickly and inexpensively with commonly available data. The ECM used in this paper was raster-based, built within Arc/Info© GIS, and was altered with a weighting scheme that used topographic and buffer indices. TP and TN ECM simulations using NLCD indicate that 30 m NLCD captures 73% to 98% of the loading produced by 10 m TVA-LC simulations. The analysis results suggest NLCD can be used by researchers to successfully model watershed-sized areas similar to LRW. Model results may then be used to prioritize different stream remediation areas and implement management decisions accordingly.

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COMETABOLISM OF PERCHLOROETHYLENE BY AMMONIA-OXIDIZING BACTERIA COLLECTED FROM A PCE-CONTAMINATED KARST AQUIFER

LyTreese Hampton*[1] and Thomas Byl[1,2]

Water containing bacteria was collected from a PCE-contaminated karst aquifer in northern-central Tennessee to establish liquid, 1-liter microcosms. The microcosms were spiked with known concentrations of perchloroethylene (PCE) and 11 different formulations of lactic acid. The ammonia-lactate formulation caused a rapid removal of PCE and oxygen (O_2). Similar results achieved using a second set of microcosms established with ammonia-lactate to re-test the removal rate of PCE and O_2 indicated a possible co-metabolic PCE-removal process. Although only one report of PCE-cometabolism was found in the literature, we hypothesized that ammonia-oxidizing bacteria indigenous to the karst aquifer were capable of cometabolizing PCE with the ammonia mono-oxygenase (AMO) pathway. To test this hypothesis, microcosms were established using different forms of ammonia (ammonia-lactate, ammonia-chloride, ammonium plus sodium lactate), reference controls (sterile, live-no food, sodium lactate, sterile + ammonia lactate), and ammonia mono-oxygenase inhibitor (2-chloro-6-(trichloromethyl) pyridine). Microcosms treated with ammonia-lactate had the most rapid reduction of PCE and O_2, followed by the ammonium + Na-lactate treatment. The other live microcosms treated with ammonia also experienced significant drops in PCE and O_2 after 24 hours. The control (sterile and live-no food) microcosms did not experience a significant drop in PCE in the same time period. After 24 hours, the rapid PCE removal in all the ammonia-treated microcosms slacked off, due to the consumption of the oxygen. Tests with the AMO inhibitor did not prevent the PCE removal or O_2 consumption, indicating the inhibitor did not work on this particular AMO enzyme or bacteria. It is possible that the lactate stimulates AMO or protects the enzyme from inhibition. Additional tests need to be conducted to characterize the optimum pH, stoichiometric balance, and different AMO inhibitors. None-the-less, these preliminary results provide strong evidence that karst bacteria indigenous to this aquifer can cometabolize PCE.

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COMPARISON OF BIOLUMINESCENT BACTERIA AND OXYGEN CONSUMPTION AS INDICATORS OF WATER QUALITY

Dominic Anako*[1], Janique Suber[1], Paul Frymier[2], and Tom D. Byl[1,3]

Toxic compounds in influent wastewater can have a negative effect on the quality and performance of activated sludge systems. Monitoring the influent wastewater by chemical analysis and periodic bioassays is often too slow in response to avoid problems. Biolumincent in certain bacteria with a luciferase enzyme can provide quick and early toxicity information. Two bioluminescent bacteria, Shk1 and PM6, were exposed to increasing concentrations of selected chemicals and their bioluminescense monitored to develop dose-response toxicity curves. Likewise, activated sludge bacteria were exposed to increasing concentrations of the same chemicals and their oxygen consumption measured. The bioluminescense and oxygen consumption responses are both indicators of bacteria activity and health. These responses were compared to determine if the bioluminescent responses were comparable to the oxygen consumption response of activated sludge. A control test done with sodium chloride salt did not cause a noticeable change in bioluminescense or oxygen consumption at any of the test concentrations (10 – 100,000 μ g/l). Chemicals that elicited a toxic response were zinc (Zn^{2+}), nickel (Ni^{2+}), silver (Ag^{2+}), quaternary ammonia compounds, toluene and sodium hypochlorite. The responses of the two bioluminescent bacteria and the oxygen uptake were found to be similar in most cases with PM6 being the most sensitive and Shk1 being the least. These results indicate that water quality can be monitored using the bioluminescent response in a way that is protective of the activated sludge chamber of the wastewater treatment plant.

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DISTRIBUTION AND TRANSPORT OF COAL TAR CONTAMINANTS IN THE CHATTANOOGA CREEK FLOODPLAIN

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In Chattanooga, Tennessee, 10's of thousands of tons of coal tar were dumped into the Chattanooga Creek during operations of the Chattanooga Coke Plant (1918-1987). As a result of the dumping, Chattanooga Creek has been placed on the National Priority List for Superfund Sites. According to the U.S. EPA, the coal tar contaminants exist in the creek bottom sediments and portions of the floodplain along a 4 km stretch of the Chattanooga Creek.

The focus of the research described in this poster is to assess the influence of flooding on redistribution of polynuclear aromatic hydrocarbons (PAHs), heterocyclic aromatic compounds, phenolic compounds, and monaromatic hydrocarbons, which are present in creek-bottom sediments of Chattanooga Creek. Specifically, we hypothesize that PAHs and related compounds will most commonly be found in sediments deposited from 1918-1987, when the coke plant was in operation. Seven split-core hand auger samples were extracted from depths of up to 1.5 m at two sites within the floodplain: Hamill Rd. site (which is near the coke plant) and Crabtree farms (which is approximately 1 km downstream and on the opposite side of the creek). Chemical, mineralogical and geological analyses are being carried out using XRF, GC-MS, and thin-sections for microscopic analysis. The investigations are relevant to clean-up strategies and to development of a proposed greenway along the floodplain.

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DRAINAGE DENSITY, STREAM NETWORKS AND GIS

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Using digital elevation models, GIS can provide stream networks delineated from flow direction and flow accumulation layers with selected cell sizes. This study investigates and compares the results generated from Hydrology Models extension in ArcGIS, a GIS software by ESRI. Stream networks generated from the GIS program are compared to the USGS's stream network to identify the cell size which reflects the true stream networks. Drainage density are computed and compared in different karsification region in Tennessee. Ratio of karsification to drainage density in watersheds show the influence of karstification in Tennessee.

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EFFECTS OF BEST MANAGEMENT PRACTICES ON WATER QUALITY IN THE BULLRUN WATERSHED

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INTRODUCTION

The Bullrun Creek Watershed is a long, narrow, 104 square mile tract that flows NE to SW, parallel to the ridge and valley undulations of East Tennessee. The creek headwaters form in Grainger County and flow through Union, Knox and Anderson Counties before merging into Melton Hill Lake. The creek is currently classified by the Tennessee Department of Environment and Conservation (TDEC) as partially supporting (per CWA 313(d)), and has initiated a Total Maximum Daily Load (TMDL) program. Further concerns over the deteriorating water quality have invoked the formation of the Bullrun Creek Restoration Initiative (BCRI). The BCRI is a professional conglomerate with an interest in the restoration of water quality of Bullrun Creek, and its removal from the TDEC 303d list. The BCRI proposes the introduction of Best Management Practices (BMPs) to restore quality to the creek waters, which have been degraded primarily by channelization and runoff from pasture grazing (TDEC 2002). TDEC also states the major problems associated with the creek as the presence of pathogens, siltation and habitat alteration (2002). The methods used by the BCRI are based on physical, biological and chemical data of the Bullrun watershed, and will be analyzed for spatial and temporal trends, as well as relationships to storm events. Geographic data will be presented using the Integrated Pollutant Source Identification (IPSI) database of the Tennessee Valley Authority (TVA), and will assist in the location and prioritization of target sites (TVA 2003). Such data will represent sites within the watershed both prior to and following the implementation of BMPs by landowners. The goal of the BCRI is to utilize the illustrative data to develop appropriate BMPs for each target site, while maintaining economic feasibility. Effective watershed management regimes mandate cost-effective, goal-oriented and environmentally appropriate constructs to ensure the realization of increased water quality. Therefore, the study imposed by the BCRI will assess the function of suggested BMPs, and analyze their water quality benefits against their true cost. From this analysis, the most effective BMP scenario can be supported to achieve the total pollution reduction goal.

OBJECTIVES

The objectives of the Bullrun watershed project are three-fold:

1) Best Management Practices on all agricultural sites in the Bullrun watershed will be located, cited and classified by type.
2) Water quality data from seven target sites in the watershed will be collected quarterly and following storm events in order to assess spatial and temporal trends for the entire watershed.
3) Pollution load models with varying BMP scenarios will be employed in order to determine thresholds of realized increases in water quality.

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METHODS

Analyses of the Bullrun watershed include compiled biological, chemical and physical data, and pollution load models. Bullrun Creek was initially analyzed by aerial photography, interpreted into GIS data, and loaded into the Integrated Pollutant Source Identification (IPSI) database by TVA. The watershed was divided into sixteen sub-watersheds based on drainage and practicality (See Figure 1). Land use percentage by type was determined for the entire watershed and for each sub-watershed. Bullrun watershed was then assessed for soil loss, using the Universal Soil Loss Equation, and total suspended solids (TSS), total nitrogen (TN) and total phosphorous (TP) loading by both land type and by each watershed. Results from the loading model were calibrated using data from land use and water quality samples taken from the creek (TVA 2003). A list of implemented BMPs is obtained by consultation with the Natural Resources Conservation Service (NRCS) and mapped onto Bullrun Creek using Geographic Information Systems (GIS).

Water quality samples were gathered by TDEC and the Hallsdale-Powell Utility District (HPUD) at seven sites along Bullrun Creek and evaluated for fifteen biological, chemical and physical parameters (See Table 1). Water quality testing for the same parameters is conducted by TDEC and the University of Tennessee at the same seven sites for evaluation of temporal trends and relation to storm events. Water quality samples are also taken at specific sites within both the northern Bullrun Creek sub-watershed and North Fork. Water quality data from north Bullrun Creek will be evaluated for changes in quality following BMP implementation, and compared to the effluent of the residential and commercial North Fork watersheds.

Pollution load models are simulated using IPSI inventory data based on varying BMP scenarios. Each scenario is run in the model and presented. Scenarios will be assessed for their feasibility and impact on water quality. A standard measure of water quality acts as a threshold point, and the scenarios that are effective at realizing the water quality goals will be selected. Costs of implementing selected scenarios can be estimated by NRCS worksheets, and can predict the cost-effectiveness of each scenario.

IPSI FINDINGS (TVA 2003)

Using GIS interpreted data, the span of Bullrun watershed is divided into sixteen sub-watersheds, delineated by both drainage and practicality. The watershed 518 acres of open water, which constitutes 0.8% of total land use acres. Forests and green space account for 61% of the total land use, followed by pasture with 22.6% and residential at 12.3%. Remaining land is comprised of 2.6% commercial and industrial use, 0.4% as mines, quarries and disturbed (construction) areas, and 1% each active row crops and wetlands. IPSI modeling identified degraded (fair and heavily overgrazed) pasture as the primary source of soil loss, comprising nearly 50,000 tons lost per year. More than 8,000 tons are lost per year each by the north Bullrun Creek, Raccoon Creek, and Hill Road to Raccoon Creek watersheds. Pasture, unpaved roadways and residential areas account for the largest sources of TSS. Pasture alone accounts for more that 6 million tons per year, while unpaved roads and residential areas average 5 million tons each per year. Raccoon creek is the largest exporter of TSS, at 2.5 million pounds, yet Williams Branch delivers the greatest loss per area, at over 800 pounds per acre per year. Total nitrogen loss (TN) is primarily sourced by residential areas and runoff from pasture, each delivering more that 25,000 pounds per year. Again, Raccoon Creek is the largest source for TN at 14,000 pounds per year, and Williams Creek delivers approximately 2.7 pounds per acre per year. Finally, total phosphorous (TP) highest sources include residential areas and mine/quarry areas, delivering approximately 19,000 and 8,000 pounds per year, respectively. As before, Raccoon Creek is a large load source, delivering nearly 7,000 pounds per year. However, Williams Branch is the primary load source by year, 8,500 pounds per year, and by area, delivering over two pounds per acre per year.

CONCLUSIONS

Water quality in Bullrun Creek can be increased and optimized by the use of best management practices. Likewise, BMP scenarios can be optimized by the use of IPSI database and GIS technology. Reports from this project will aid the adoption of favorable and cost-effective and management practices in Bullrun Creek and in other agricultural watersheds.

REFERENCES CITED

Natural Resources Conservation Service, 2003

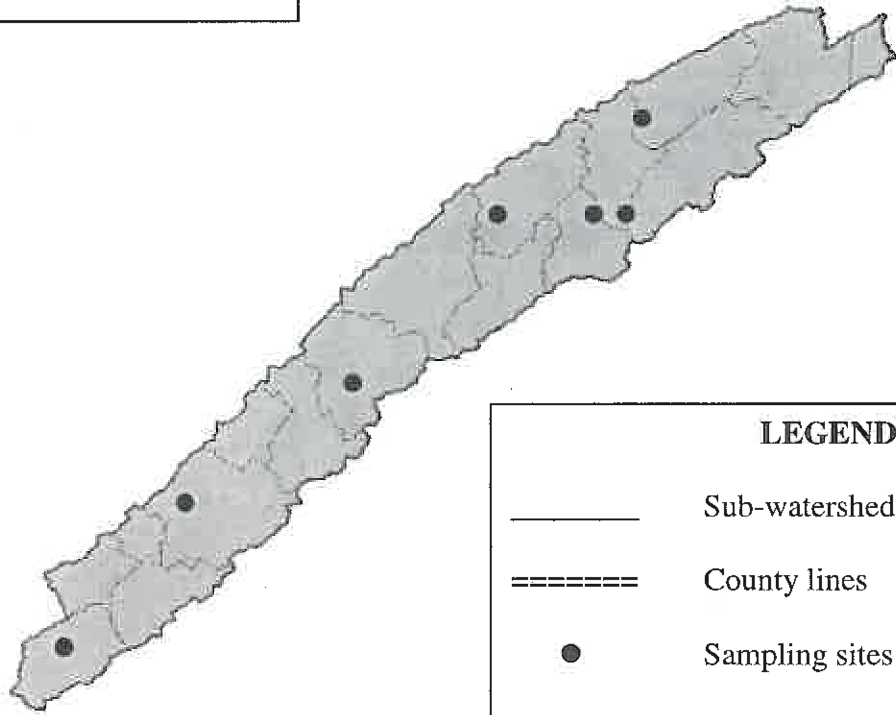
Tennessee Department of Environment and Conservation, 2002

Tennessee Valley Authority, 2003

Table 1. Water Quality Parameters and Sampling Sites

Testing Parameters Sites		Sites
Ammonia		Bullrun Creek at Highway 25
Dissolved Oxygen		Bullrun Creek at Highway 441
Escheria Coli		Bullrun Creek at Malone Rd.
Fecal Streptococcus		Raccoon Creek
Fecal Coliform		Bullrun Creek at Highway 144
Instream Flow		North Fork at mouth
Nitrate and Nitrite		North Fork at Johnson Rd.
Total Kjeldahal Nitrogen		
Total Phosphate		
Orthophosphate		
PH		
Specific Conductivity		
Suspended Solids		
Temperature		
Turbidity		

Figure 1.
Sub-watershed delineations and Sampling Sites



LEGEND

________	Sub-watershed boundaries
=======	County lines
●	Sampling sites

EFFECT OF SEDIMENTS AND NUTRIENTS ON BENTHIC MACROINVERTEBRATES IN NAILS AND ELLEJOY CREEKS

Susanna Sutherland*[1]

ABSTRACT

Ellejoy and Nails Creeks are subwatersheds of the Little River watershed, which flows into the Fort Loudon Lake watershed. Located in Blount County, they are side by side and include roughly 56 miles of land. Small dairy and beef operations are the primary use of this land, with residential areas scattered throughout. Water sampling from 12 sites began in spring of 2003 and will continue through spring of 2004. Benthic sampling occurred during August of 2003, with results to be returned in February 2004. A full water quality analysis is being conducted on the samples, including analyses for sediment, nutrient and oxygen parameters. Benthic samples are being classified to the species level. Use of the EPA's model Aquatox will give an idea of what kind of life to expect from a stream with the input data from these streams. Use of GIS will show the kinds of land use upstream of each site and the estimated sediment loads they contribute. Data will be analyzed using the SAS program, with the expectation that these streams will be classified as poor habitat for aquatic life. Past data from these streams has shown generally poor water quality and poor benthic diversity, and both streams were 303-D listed in 2000 by the EPA. Data collected for this study is expected to show a continuing poor water quality, and reveal a correlation between poor water quality and low benthic species diversity.

INTRODUCTION

The focus of this study is to address the problem of poor environmental health and water quality due to nonpoint source pollution and agricultural influences in small tributaries. The goal is identification of the influences of nonpoint source pollution on aquatic life and habitat in order to knowledgeably construct Total Maximum Daily Loads (TMDL) and ideally improve the overall environmental quality for this area of Tennessee. The specific objectives of this quantitative study is to effectively assess the impact of sedimentation and nutrients on aquatic organisms in the Nails and Ellejoy Creeks, which are a part of the Upper Tennessee River Basin and located in Blount County, Tennessee. The study has two components: a field and lab component sampling and analyzing water quality and benthic macroinvertebrates in order to establish a correlation between the two, and a modeling component using the simulation model AQUATOX, which will be incorporated to aid in predicting and understanding possible outcomes of a given ecological scenario between organic pollution inputs and aquatic life. I hypothesize that high sediment and nutrient inputs in agricultural environments have a negative effect on species diversity and the health of aquatic organisms, and anticipate that this study will further the development of realistic TMDL's for the Fort Loudoun Lake Watershed.

Low species diversity in poor aquatic environments such as these may not at first glance appear problematic, but upon closer inspection it is evident that the health of an entire ecosystem and watershed can be critically damaged by small problem areas (NRCS, 1998). The significance of high sediment and nutrient levels impairing aquatic health rests in the fact that species diversity serves as an indicator of overall aquatic health, which in turn serves as an indicator of environmental quality in the watershed as a whole (Barbour et al., 1999). The U.S. Geological Survey has identified 54 watersheds in Tennessee that drain into a river or reservoir, around

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which the Division of Water Pollution Control bases its assessments. According to the new 303(d) list proposed for Tennessee in September of 2002, hundreds of the streams assessed are listed as impaired, many of which are new entries since 1998. This indicates a growing problem of poor environmental and water quality in Tennessee, which is being addressed by government organizations, but is getting little attention from local landowners contributing to the problem.

Subwatersheds of the Little River and the Fort Loudoun Lake watershed, the Nails and Ellejoy Creeks wind through pasture and farmlands. Along many of the sample sites cattle have full access to these creeks, allowing feces to filter or be deposited directly into the flowing water, making nitrates a strong contributor to high nutrient loads in the watershed (TDEC, 2002). It is visually evident in this area that sedimentation is high due to runoff from the pasture grazing and cattle traffic in and out of these streams.

According to Tennessee's Department of Environment and Conservation's proposed September 2002 303(d) list, both the Nails and the Ellejoy creeks are considered to be only partially supporting, meaning that they are somewhat impacted by pollution, they exceed water quality criteria on some frequency, and their overall water quality is considered moderately impacted. This is an issue deserving of time and study in order to more knowledgeably remedy the existing water and environmental quality issues that this area faces.

In 1998, Tennessee Valley Authority (TVA) and Tennessee's Department of Environment and Conservation (TDEC) conducted benthic and fish studies on both streams. These studies revealed that both creeks support fish and aquatic life, but only as depressed diversities, and with many of the more pollutant intolerant species missing (Burr, 2002). According to the agreement between Tennessee and the U.S. Environmental Protection Agency, the absence of these species is one of the methods used to justify the impairment of these waterbodies, as in Tennessee it is not necessary to have a virtually dead stream before placing it on the 303(d) list (TDEC, 1998).

No further study of either of these creeks has been documented since 1998, though there was benthic testing in 2000, and the problem of nonpoint-source pollution in these areas has not yet been addressed in a manner that gives it weight. Studies that deal with organic pollutants and their environmental effects will be valuable in drawing recognition to this problem. Ideally, positive pressure will be placed on the local landowners to implement better land management practices (BMP's), and provide information which will be valuable in developing TMDL's for non-point source pollutants in this area of the Fort Loudoun Lake Watershed.

MATERIALS AND METHODS

Twelve sample sites were selected, eight along Ellejoy and four along Nails, along tributaries, after each major confluence and at the mouth of each stream. Grab samples were taken and placed on ice, with biological oxygen demand, total oxygen content, ammonia, phosphate, and nitrates being analyzed immediately upon return to the lab. Temperature, pH, conductivity, and dissolved oxygen were taken at site with a multi-parameter probe. Flow was measured with a Swoffer portable meter. Turbidity, total Kjedahl nitrogen, total phosphate, total suspended solids and total dissolved solids were analyzed in the following days. Other tests performed on these samples but not included in this paper included fecal coliform, *E.coli*, and fecal *Enterococcus*.

Benthic samples were collected in August 2003, at four sites on Ellejoy and three sites on Nails. Samples were placed in a 98% ethanol solution and sent to a Tennessee State taxonomy lab for review and classification. Old benthic data was obtained from TDEC for review and comparison.

RESULTS AND DISCUSSION

Data for this study has to date suggested a continuation of poor water quality. Benthic collections in the past have been a mix of fair and poor habitat for both streams and results from August of 2003 are anticipated to have similar findings. Landuse from the contributing areas is mainly pastoral and residential, with little or no riparian zone or cattle access restriction at many of the 12 sites, indicating that runoff and non point source pollution is still a problem along these creeks that has yet to be corrected.

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ACKNOWLEDGEMENT

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EVALUATING OXYGEN-RELEASING COMPOUNDS TO ENHANCE TOLUENE BIODEGRADATION BY FREE-LIVING BACTERIA

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Microcosm studies done in our lab found that anaerobic biodegradation of toluene was generally 25 to 50 times slower than aerobic biodegradation. Considering the potential for rapid transport of dissolved contaminants in karst conduits, it follows that aerobic conditions are desired for enhancing bioremediation. The objective of this study was to evaluate the ability of three oxygen-release compounds (ORCs) to enhance fuel biodegradation by free-living bacteria found in karst aquifers. The ORCs that were evaluated were hydrogen peroxide (H_2O_2), calcium peroxide (CaO_2) and magnesium peroxide (MgO_2). The H_2O_2 molecules will break down into oxygen (O_2) and water (H_2O). The CaO_2 and MgO_2 will break down in the presence of water into O_2 and either CaOH or MgOH, respectively. In this study, 2.25-liter liquid-karst microcosms (i.e., flasks containing water and free-living karst bacteria) were spiked to 100 ug/L toluene and different ORC concentrations were added. Sterile controls were also established with toluene and ORCs to verify toluene removal was due to biological processes. Additional controls with live bacteria, but no ORC supplements were also established for comparison. Microcosms enriched with 3 mg/L H_2O_2, CaO_2, or MgO_2 all showed >95% toluene removal in 7 days, as compared to, 45% removal in live microcosms with no ORCs. When the microcosms were enriched with 300 mg/L H_2O_2, CaO_2, or MgO_2, only the H_2O_2 treatment elicited a >99% reduction in toluene in 7 days. The other peroxide treatments had slightly enhanced toluene removal compared to the live control, but were generally not effective at this higher concentration. The decline in MgO_2 and CaO_2 performance was possibly due to the simultaneous release of hydroxide, which was found to inhibit biodegradation processes. Other parameters that will be discussed in the poster are dissolved oxygen concentration, bacteria concentration, and pH. Based on these results H_2O_2 appears to be the best ORC candidate for enhancing biodegradation in karst aquifers.

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EX-SITU DECHLORINATION OF CHLORINATED SOLVENTS IN A COMBINED BIOLOGICAL AND ZERO-VALENT IRON REACTOR

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An Ex-situ pump-and-treat remedy for groundwater contaminated with chlorinated solvents usually involves stripping these volatiles from the groundwater and discharging them to the atmosphere. It is desirable to develop an ex-situ treatment method that destroys the solvents by reducing them to less harmful products before discharging them to the atmosphere. Combustion of these materials by flaring is not viable because the combustion products are themselves often toxic. Carbon adsorption directly from the gas phase is viable except this in turn creates another toxic stream as the carbon must then be disposed of or recycled. Biological degradation of chlorinated solvents is possible under anaerobic conditions but the rate of these reactions is often limited by the availability of electron donors for the microbes. It may be possible to augment the biodegradation of chlorinated solvents in an ex-situ reactor by incorporation of zero-valent iron dechlorination of the solvents in the same reaction volume. In the case of dechlorination of solvents with zero valent iron, molecular hydrogen is produced. Hydrogen is also produced as a result of the parallel reaction of iron in the hydrolysis of water. Theoretically the hydrogen produced by the iron reactions may serve as an electron donor and directly benefit an anaerobic microbial community. The viability of this approach will be studied in several experimental phases. In the first phase of research underway at Tennessee State University, iron is oxidized in a well stirred anaerobic reactor by the hydrolysis of water. The resulting concentration of hydrogen in the dissolved phase is being interpreted as a function of the hydrogen concentration in the head-space of the reactor and equilibrium considerations. In the second stage of the experiment, dechlorination of tetrachloroethylene by zero-valent iron will be investigated. Finally, at a later stage of the study, anaerobic degradation will be studied in the reactor with similar head space hydrogen concentrations. This experimental approach will investigate the rates of the individual biological and chemical dechlorination mechanisms and the synergy of the combined processes.

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GIS SURVEY OF BEDFORD COUNTY POULTRY FACILITIES IN CONJUNCTION WITH GIS THEMATIC REPRESENTATION OF BEDFORD COUNTY SOILS, WATERSHEDS, AND STREAMS

Destry Greenway*[1]

ABSTRACT

This project is the result of an independent student project at Pellissippi State Technical Community College. The project involved the "feature extraction" of poultry production facilities from Digital OtrhoPhoto Quarter Quads (DOQQs) for Bedford County, along with the thematic representation of data on soils, watersheds and streams. The project report describes the techniques or methods used to: (i) combine the DOQQs into a county-wide image and visually scan this image for selected features; (ii) compile and process the soils data used in the thematic map; and (iii) symbolize the various features for the thematic map. The report also contains example images and figures as well as an explanation of the data including data origin, organization of data, and method of processing data into meaningful groupings for symbolization. The report is designed to provide the reader with an elaboration and example of how the feature extraction methodology described above can be applied to any of various environmental topics where data is readily attainable in either compiled or raw form.

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IMPACTS OF FRESH AND DECOMPOSED CATTLE MANURE ON DISSOLVED OXYGEN PATTERNS OF POND CREEK

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ABSTRACT

Pond Creek is located within the Watts Barr/Fort Loudon watershed (HUC 06010201). It covers approximately 8,090 ha of land. Dairy operations are the primary land use. Dissolved oxygen (DO) levels were monitored with a CS302/304 Stevens/Greenspan Combination Sensor at three sites along Pond Creek. Continuous DO data was collected from three sites from October 2003 to January 2004. Biochemical oxygen demand (BOD) samples were also collected. Monitoring is part one of a study designed to determine whether fresh or decomposed manure has a greater impact on dissolved oxygen. Vegetated buffers, storm gutters, and creek fencing are BMPs present at the research site. Study results will be used to develop best management practices (BMPs). Results and analysis will be presented at the Symposium.

INTRODUCTION

Dissolved oxygen levels below 5 mg/L are an indication of poor water quality. Aquatic animals may be sensitive to DO levels lower than 5 mg/L.

Acceptable DO levels are vital to the ecological health of an aquatic system. DO criteria may vary, depending on natural conditions. Nutrient loading from agricultural wastes introduce organic materials to runoff which may greatly impact DO of streams. Decomposition of organic materials requires oxygen. The amount of oxygen consumed during decomposition, BOD, may also have an impact on streams.

The Tennessee Department of Environmental Conservation (TDEC) has classified Pond Creek as non-supporting in the Final Version 2002 303 (d) List. Pathogens and nutrients contribute to its impairment. Pond Creek is also of medium priority, and is not in a watershed being studied within the next two years. Possible impacts on DO levels should be evaluated. The objectives of this research are:

1. Measure DO at 3 sites in Pond Creek.
2. Measure BOD consumption at 3 sites in Pond Creek.
3. Determine whether fresh or decomposed manure has a greater impact on DO levels.
4. Identify BMPs that have the greatest positive impact on water quality.

METHODS

Dissolved oxygen levels were monitored at three sites in Pond Creek. Sites were monitored from October 2003 to January 2004. Stevens/Greenspan meters were deployed at each site. The meters measured DO, pH, temperature, and conductivity. Site selection was based land use and vegetation. The mean values of DO at each site will be compared. SAS will provide correlation statistics and a prediction equation for the data. Temperature, pH, and conductivity will be analyzed to determine its correlation to DO.

A prediction equation, representing the parameter with the highest correlation to DO will be determined. The prediction equation will be tested at a reference stream for validity. Fresh manure samples will be collected and placed on turf grass to be monitored as it decomposes. The test variable, age, is a continuous distribution and will be analyzed using regression statistics. A rainfall simulator will be used to simulate a natural environment where runoff samples will be collected and tested for DO, pH, temperature, conductivity, and BOD_5. This experiment will be run from February to May 2004.

RESULTS

Present DO data indicates no difference in DO levels between the 3 sites. Levels are above the critical threshold of 5 mg/L, indicating that the BMPs are having a positive effect on stream quality. Studies have also shown that the amount of original organic nitrogen decreases as manure ages. Age of manure may not significantly impact original organic nitrogen.

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POTENTIAL SOURCES OF NON-POINT SEDIMENT POLLUTION IN THE LITTLE RIVER, BLOUNT COUNTY, TENNESSEE (PRELIMINARY FINDINGS FROM TOTAL SUSPENDED SOLID AND TURBIDITY DATA FOR ONGOING STUDY)

Heather Hart*[1] and Paul D. Ayers, Joanne Logan, and Galina Melnichenko

The Little River originates in the Great Smoky Mountains National Park, providing drinking water to thousands of residents in Blount County as it makes its way to the Tennessee River. In 2000, the Tennessee Department of Environment and Conservation classified the lower parts of the Little River as threatened. There has been a documented decline in biological diversity, although the reasons are unknown. According to a 2003 TVA study, the estimated soil loss for the Little River Basin is 265,368 tons per year, mostly due to agriculture. As development increases in this basin, so will imperviousness, initially resulting in greater sediment levels in the river. The objectives of this study are to measure the total suspended solids (TSS) and turbidity at 18 locations along the Little River and its tributaries, to relate TSS with current land uses, and to forecast effects on TSS from increasing development along the Little River. Water, if present, from sediment samplers was collected and analyzed after significant storm events from June 2003 to October 2003. Additionally, sediment loadings will be calculated from flow estimates using hydrological models. Land use based on aerial photography will be used to relate TSS with current land use, and to develop what-if scenarios for the basin.

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SEASONAL ASSESSMENT OF CONSTRUCTED WETLAND FOR WASTEWATER REMEDIATION

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Certain soils due to their hydrological characteristics prevent adequate infiltration of wastewater from septic field lines. One proposed method to reduce water volume and improve water quality leaving the septic system is to first cycle the wastewater through constructed wetlands. It has long been established that wetlands, due to their high rate of biological activity, function as excellent pollution filters. Therefore, a wetland was constructed in July 2001 in Ramer, Tennessee to treat and reduce wastewater from the local Ramer Elementary School septic system. In order to determine the efficiency of this system, several water quality parameters will be monitored weekly over the course of one year. Analysis will include the following parameters, pH, redox potential, nitrate, ammonia, phosphate concentrations, total suspended solids and biological oxygen demand (BOD_5). As wetlands are living ecosystems, seasonal variability in the performance of these systems is of special importance. Therefore, characterization of bacterial groups and plant density counts will also be performed periodically throughout the study.

Preliminary data for the first summer quarter indicate that nitrate, ammonia, BOD, and total suspended solids effluent concentrations are all within standard levels for wastewater discharged to the environment.

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SUPPLEMENTS TO ENHANCE GROUNDWATER-MICROBIAL GROWTH AND BIODEGRADATION PROCESSES

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Recent research found that there is a large diverse bacteria population in karst aquifers. These bacteria have been shown to biodegrade fuels and chlorinated solvents in liquid microcosms. In one chlorinated solvent experiment, bacteria ceased biodegrading PCE. Biodegradation resumed only after vitamin B12 was added. Thus it appears that the karst conduit water is oligotrophic and requires additional vitamins to sustain a vigorous bioremediation. To test this hypothesis, microcosms were established using karst bacteria and toluene. The growth of bacteria was monitored over time. Then different vitamin supplements were provided and continued bacteria growth was evaluated. Bacteria supplied with a mixture of complete vitamin B (B1, B2, Niacin, B6, Folate, B12, Biotin, Pantothenic acid) grew 50% faster and 5-times more than control with no supplement. Vitamin B12 alone did not have a significant influence on growth or number. Bacteria supplied a complete vitamin supplement (Vitamins A, all the B's, C, D, E, and various minerals) also grew faster than controls, but did not remain viable as long as the complete–B supplement. The optimum pH for biodegradation of toluene by karst bacteria was also found to be 6 – 8. Based on these results, future studies will evaluate different buffers to maintain optimum pH in conjunction with different concentrations of the B-vitamins.

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SURVIVAL OF FECAL BACTERIA IN SEDIMENTS AND DEVELOPMENT OF A NUMERICAL MODEL TO PREDICT STORAGE AND TRANSPORT IN A RIVER

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Fecal pollution in surface waters is a serious water-quality problem. As a result, scientists have developed a number of models in an attempt to predict the fate and transport of fecal pollution in riverine systems. Various models, such as CE-QUAL-W2, predict the rate of bacteria removal from the water column based on density, settling rates and water velocity. Such models, however, do not consider survival and reproduction of bacteria in sediments, or re-suspension. Flume experiments are being conducted to measure the survival, reproduction and resuspension of fecal bacteria in sediments. These results will be used to improve numerical models by incorporating survival of bacteria in bed sediments and re-suspension into the water column, in addition to other parameters such as water velocity, initial bacteria concentration, and settling rate. The flume is 10 feet long and 6 inches wide with 2 inches of pre-sterilized sediment (gravel, sand and organic matter) spread on the bottom and 12 inches of water over the sediments. Water was circulated at a velocity of 0.1 meters per second using 2 small pond pumps. Two strains of *Escherichia coli* (*E. coli*) and two strains of *Klebsiella* were introduced into the circulating water at known concentrations and monitored as they settled or remained suspended. Bacteria concentrations were measured in the water column and the sediment along the flume to determine bacterial fate and transport. The model accurately predicted bacteria settling from the water column. Once the bacteria settled onto the sediments, the population declined at an exponential rate over several weeks. The bacteria decomposition in the sediments was described by the equation

$$B_t = B_i \, e^{-\mu t}$$

where B_t equals bacteria concentration in the sediment at time t, B_i equals initial bacteria concentration in sediments, and $-\mu$ equals the exponential decomposition rate (experimental value = -0.2735), and t equals the residence time in days. This decomposition rate will be coupled to the numerical model after additional tests are done on bacteria re-suspension associated with different velocities to improve the bacterial storage and transport model.

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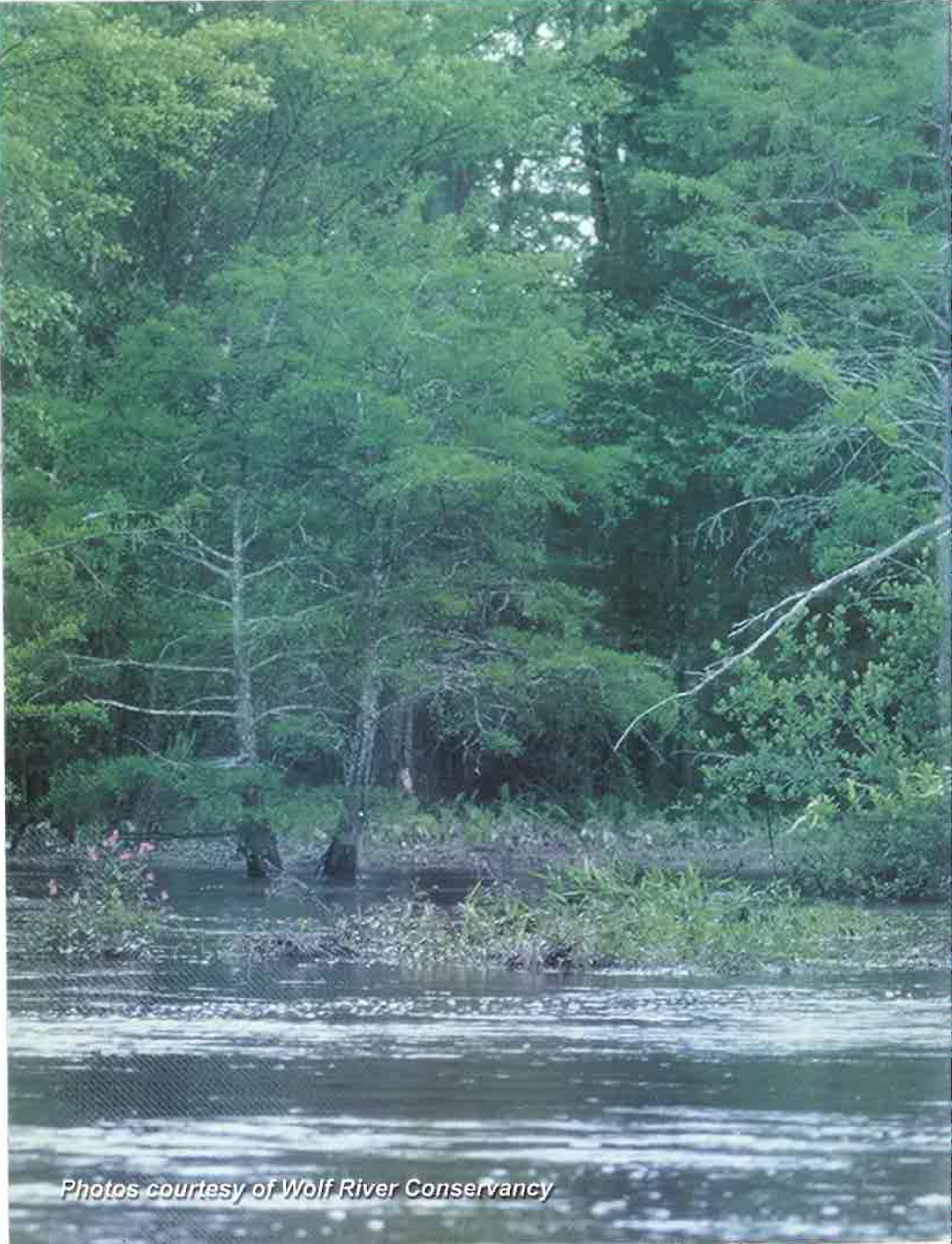
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