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Welcome

It is my pleasure to welcome you today to the *5th Annual Water Resources Research Center Conference* at the University of Massachusetts Amherst. The conference brings together a range of individuals from universities, government agencies, nonprofits, and the private sector to discuss critical water resources issues in our region, to share new ideas, and to forge future partnerships. This year's conference focuses on *Integrating Water Resources Management* and features four concurrent sessions with 36 presentations throughout the day and 30 posters addressing a range of water resources issues including best practices for managing water resources, stormwater challenges and solutions, ecological impacts, wastewater issues, and case studies in effective water resources education.

We are pleased to present Ira Leighton, EPA New England Deputy Regional Administrator, as this year's conference keynote speaker. As Deputy Regional Administrator, he oversees all of the Agency's regional operations, including the water, air and hazardous waste programs. Mr. Leighton is a national leader in spearheading innovative strategies to improve environmental protection and helping industry better achieve compliance with environmental requirements in a cost-effective manner, for example through Environmental Management Systems. His extensive knowledge with more than 30 years experience in the environmental field brings an invaluable perspective to understanding environmental issues confronting us today. We are proud to claim him as an alumnus of the University of Massachusetts Amherst where he received his B.S. degree.

We also are pleased to announce that today we are presenting the third John W. Olver Leadership Award to Mr. Ira Leighton, EPA New England, for his exceptional contributions and leadership in environmental research and in protecting our natural resources.

We warmly thank our conference co-sponsors and supporters: US Geological Survey, The Environmental Institute, UMass Amherst Extension, Massachusetts Department of Environmental Protection, Rinker Materials, New England Interstate Water Pollution Control Commission, Tighe & Bond, and FirstLight Power Resources. Thanks also to Fuss & O'Neill, the sponsor of this year's Student Poster Competition. On behalf of our Conference Steering Committee I also want to thank all our speakers, presenters, moderators and judges participating in today's event.

We hope you enjoy the conference. We welcome your feedback and suggestions for future tracks and platform sessions and hope you can encourage your colleagues to join us in participating in next year's water conference scheduled for Wednesday, April 8, 2009. For more information about the Water Center or to get involved in next year's conference please contact us at wrrc@tei.umass.edu or give us a call at 413-545-2842.

Paula Rees
Director, Massachusetts Water Resources Research Center

April 8, 2008

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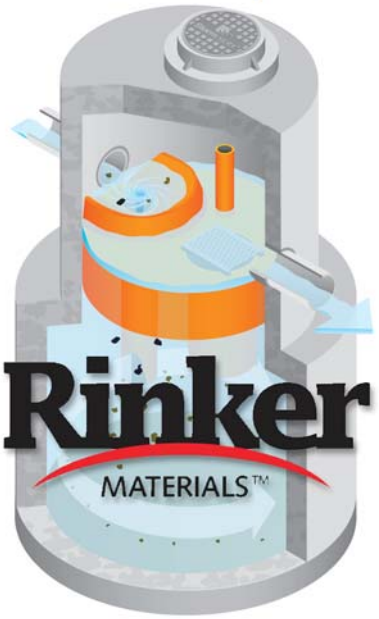

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Massachusetts Water Resources Research Center

The **Massachusetts Water Resources Research Center** supports research, education, and outreach on water resources issues of state, regional, and national importance as part of the national system of institutes authorized under the Water Resources Research Act of 1964. Established in 1965, the Center has been a unit of The Environmental Institute since 1984. The Center supports faculty research and training of graduate students and is a national leader in the use of volunteers for high quality water quality monitoring of surface waters. The Center's primary objectives are to conduct research responsive to state and regional needs; support the education and training of students; and disseminate information on water resources research and methods.

The Center encourages an interdisciplinary approach to address water resources problems and has involved the University and many other Massachusetts colleges and universities in Center research over the years. The Center operates a statewide competitive grants program open to all academic institutions in Massachusetts. Current research priorities include watershed and ecosystem management, non-point source pollution, drinking water supply, and water quality.

Funded Research in 2008

- *Environmental behaviors of engineered nanoparticles in water* by Dr. Baoshan Xing of the UMass Amherst Plant, Soil, & Insect Sciences Dept. will be funded for a second and final year.

Four graduate student projects were also awarded:

- *Quantifying sediment transport in Red Brook, Wareham, MA: Impacts of dam removal* by Steven Kichefski and Dr. Ellen Douglas, Dr. Allen Gontz, Dept. of Environmental, Earth & Ocean Sciences, UMass Boston;
- *Estimation of climatic and anthropogenic influences on freshwater availability* by Yushiou Tsai and Dr. Richard Vogel, Dept. of Civil & Environmental Engineering, Tufts University;
- *Toxicity of carbon nanotubes to the activated sludge process: Protective ability of extracellular polymeric substances* by Lauren Luongo and Dr. Xiaoqi Zhang, Dept. of Civil & Environmental Engineering, UMass Lowell;
- *Characterization of wastewater effluent from Western Massachusetts publicly owned treatment works using metaproteomic analysis* by Pamela Westgate and Dr. Chul Park, Dept. of Civil & Environmental Engineering, UMass Amherst.

WRRC Programs and Projects

The **Acid Rain Monitoring project** volunteers continue to survey pH and alkalinity for 150 sites. Of these, twenty-six long-term sites are analyzed further for major anions, cations, and color. This WRRC program updates information on acid deposition impacts on Massachusetts surface waters, and analyzes long-term trends in lakes and streams. A related project is the ARM database project, which has made the full ARM database of water chemistry (more than 40,000 records covering more than 20 years) available to search and download by all web users.

The **Massachusetts Water Watch Partnership**, provides technical assistance to citizen groups to monitor and remediate water quality problems.

The Center continues to work with UMass Extension on the **Stream Continuity Project** to examine the barrier effect created by road crossings on streams. The team is conducting pilot surveys of crossings in several watersheds, involving volunteers in developing an inventory of existing crossings. The project will result in a priority scheme for culvert replacement on a watershed basis.

A new Center project examines the concept of **Watershed Community**, employing a variety of approaches including the use of information technology to enhance individual and community relationships with local landscapes.

The **Massachusetts Stormwater Evaluation Project** created a stormwater clearinghouse that enables users to search the web for stormwater Best Management Practices and to find innovative technologies available to treat stormwater (www.mastep.net).

WRRC runs an inorganic chemistry laboratory on campus, the **Environmental Analysis Lab**, which provides chemical analysis of water, soils, tissue, and other environmental media for University researchers, public agencies, and other publicly-supported clients.

The WRRC Director leads the interdisciplinary **Water Working Group**, and staff also participate in other environmental working groups to facilitate interdisciplinary research and educational intiatives related to water.

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http://umass.edu/tei/wrrc

Cooperative State Research, Education, and Extension Service Water Quality Program

The Cooperative State Research, Education, and Extension Service (CSREES) Water Quality Program, was authorized under section 406 of the Agricultural Research, Extension, and Education Reform Act of 1998 for an Integrated Research, Education, and Extension Competitive Grants Program. This program provides the flexibility necessary for CSREES to bring the resources of researchers, instructors, and extension educators to national initiatives and programmatic partnerships that target evolving water quality needs.

The goal of the **New England Regional Water Program** is to improve water quality management through educational knowledge and extension programming that emerges from a research base. Extension programs have a unique role in the Region that complements our partners' efforts. We use state of the art approaches to tailor our programs to the unique attributes of a given watershed and the concerns of communities and producers. It focuses research, education, and Extension efforts in the following areas:

New England Private Well Initiative
The New England Private Well Initiative is a multi-state, inter-agency initiative that is a result of regional programming and coordination efforts. It helps to educate private well owners of potential man-made and naturally-occurring contaminant risks to their wells and how to protect against these risks.

New England Nonpoint Education for Municipal Officials (NEMO)
New England NEMO programs use a combination of geo-spatial technologies, educational programs, demonstrations, and hands-on training to allow local decision makers and citizens to obtain the most up-to-date information for informed decision-making and watershed management to improve and protect water quality throughout New England.

Nutrient and Pest Management on Organic Farms
Increases in organic production, particularly in the dairy industry, have created new opportunities for reducing the risks of pesticide contamination and new challenges for nutrient management. New England Cooperative Extension programs draw upon educational and applied research successes to address water quality issues related to organic farming systems.

Sustainable Landscaping
New England Extension programs are improving the ability of homeowners to manage sustainable landscapes, thereby reducing nutrient and pesticide pollution to ground and surface water. Extension programs in New England promote "smart" landscaping techniques to enhance and protect water quality by using methods to reduce surface runoff, minimize leaching of agrichemicals, and reduce nutrient contamination to water resources.

Reducing Phosphorus Impacts With Manure Management
Effective education and applied research programs are critical to assist farmers in achieving the goal of economically efficient livestock production and water quality protection. University Extension and its partners have assisted farmers making the transition to new management systems with information on nutrient management, nutrient testing programs, and applied research.

Volunteer Water Quality Monitoring
Extension programs seek to promote youth and adult volunteers' education of water quality and watershed issues and involvement in protecting and enhancing the quality of ground and surface water.

Programs are targeted and implemented in place-based priorities within our region. Each of Extension's focus areas has a proven track record of accomplishments and provides leadership in water quality education that serves a specific target audience. Our approach and coordinating structure are flexible to permit the New England Program to respond to emerging priorities within the region. Regional coordination in New England is by a steering committee of representatives from each state and each focus area. Monthly conference calls and face-to-face meetings facilitate regional coordination discussions.

http://www.usawaterquality.org/NewEngland/default.html

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Keynote Address

11:30 am – 12:30 pm - Auditorium

New Developments in Stormwater Policy and Remediation

Ira Leighton, Deputy Regional Administrator, USEPA New England

Ira Leighton is the Deputy Regional Administrator for EPA New England. In this capacity he oversees all of the Agency's regional operations, including the water, air, and hazardous waste programs. He is a leader at EPA on innovative strategies to improve environmental protection, and a personal champion of Environmental Management Systems (EMSs) and the various ways industry can better achieve compliance with environmental requirements.

Prior to being named Deputy Regional Administrator, Mr. Leighton was the Director of the Office of Environmental Stewardship. The Office of Environmental Stewardship is a one of a kind organization among EPA regions that is responsible for enforcement of all environmental laws and regulations *and* for providing compliance assistance and pollution prevention assistance to the regulated community. The Office is also prominent in national and regional efforts to experiment with innovative approaches that integrate compliance assistance, compliance incentives, and enforcement strategies to solve New England's environmental and compliance problems. Prior to directing the Office of Environmental Stewardship, Ira Leighton was a key management team member in the Office of Site Remediation and Restoration where the Superfund, Brownfields, and Resource Conservation and Recovery Act cleanup programs reside. He established a management review system that helps ensure consistency of cleanup decisions in the region and fosters redevelopment of contaminated sites, as well as providing emergency responders throughout the region.

Ira Leighton has worked in the environmental field for more than 30 years and over this time he has held a variety of other technical and management positions within EPA, and prior to that with the state of Massachusetts. These positions provided experience with a number of different regulatory and technical assistance programs. Mr. Leighton has a B.S. degree from the University of Massachusetts Amherst and an M.S. from Northeastern University in Environmental Engineering.

The keynote address will highlight the latest developments in stormwater policy and remediation and their importance to the environmental health of the region. The "*Stormwater Challenge*" is a call to action. It is an opportunity for key stakeholders and others to become drivers in program development, decision making tools, and the evaluation process. The challenge will be to assist municipalities, commercial and institutional facilities, and regulatory agencies in evaluating the quality and effectiveness of the scientific, technical, and policy decision making on stormwater.

The keynote will address stormwater challenges in light of the history of the water program. Leighton will discuss the MS4 universe and potential trend information. A variety of related programs and links to other environmental issues and entities will be discussed. In addition, the connections between a short term approach and longer term strategies for stormwater issues will be addressed.

Presentation Abstracts

Session 1: 9:00 am – 10:30 am

Track A: Water Quality Monitoring and Enforcement Room 163

Moderator: Eva Tor, Mass. Dept. of Environmental Protection

DEP's regional bacteria source tracking program – from search to solution

Christine Duerring, Matthew Poach, Daniel Kurpaska, Jennifer Sheppard, Tracie Beasley, Jenny Birnbaum, and Katherine Zink, Division of Watershed Management, Mass. Dept. of Environmental Protection

The MassDEP/DWM has begun regionally based water quality monitoring activities within the DEP Regional Offices. Since pathogens are by far the most common cause of water quality impairments listed in Massachusetts, finding and eliminating sources of bacteria contamination in surface water is a priority focus for the new regional monitoring coordinators.

Each regional office now has surface water sampling equipment as well as an in-house laboratory for bacteria analyses (IDEXX enzyme substrate system for E. coli (Coli-lert®) and Enterococci (Entero-lert®)). The DWM office located within the CERO of DEP in Worcester conducted bacteria source tracking studies during 2004 - 2006 that were used to develop sampling protocols and evaluate various bacteria source tracking strategies and methods. These projects included a pilot study in the Blackstone and Sudbury River watersheds, a beach bacteria source tracking study, and a collaborative, multi-agency bacteria source tracking study in the Shawsheen River watershed.

The strategies and protocols include intensive field reconnaissance and sampling for E. coli and Enterococci occasionally coupled with "high tech" methods such as analyses for human markers and personal care products (conducted at DEP's Wall Experiment Station) to locate hot spots and identify sources of bacteria contamination. An important component is the collaboration with local watershed groups and municipal officials to gather subwatershed information and collect the samples.

Using these strategies and protocols, the regional monitoring coordinators have conducted bacteria source tracking surveys in over 50 subwatersheds throughout Massachusetts since 2006. Approximately 45 bacteria hot spots have been identified so far. Source tracking activities have found that over 60% of these are due to illicit sewage discharges. Solutions for remediation, directed by the DEP regional offices, range from the responsible parties collaborating with DEP to pinpoint the problem and fix it voluntarily, to DEP enforcement orders that result in a legally binding schedule for compliance and possibly fines.

Seagrass monitoring as a complement to water quality monitoring in coastal embayments of southern Massachusetts

Charles Costello, Division of Watershed Management, Mass. Dept. of Environmental Protection; W. Judson Kenworthy, Center for Coastal Fisheries & Habitat Research NCCOS, NOS, NOAA

Eelgrass (*Zostera marina* L.) meadows play an important role in coastal environments by stabilizing sediments, sheltering and nourishing fish, shellfish and wildlife, and preserving water quality while filtering sediments and recycling nutrients. Because they grow in nearshore environments, eelgrass beds are vulnerable to coastal development and since they are responsive to perturbations they can be used as an indicator of ecosystem health. In order to study the correlation between wastewater discharges of nitrogen, degrading water quality and eelgrass declines in southeastern MA, MADEP undertook a long-term statewide mapping program (commencing in 1994) to evaluate the status and trend of eelgrass abundance. Within MADEP the eelgrass mapping project is being closely coordinated with the Massachusetts Estuaries Project (MEP), a multi-year $12 million collaboration among coastal communities designed to address the impact of excess nutrient loading in Massachusetts coastal watersheds.

MADEP is using remote sensing techniques and ground truthing to develop a database of seagrass distribution and abundance and has 12 years of mapping data showing that eelgrass has declined in a majority of 30 estuaries inventoried over a period of 10-12 years. Rates of decline average 3%/y with some declines as fast as 5-8%/y. During the 12 year period eelgrass has completely disappeared from some embayments. These declines are accompanied by a loss of important positive naturally occurring feedback loops for maintaining good water quality which led to changes in the bio-physical state of these embayments. MADEP has also been in the forefront of water quality investigations by evaluating the utility of incorporating an optical water quality model into future eelgrass conservation and restoration programs. The optical water quality model is being developed to link eelgrass declines

with factors such as chlorophyll, suspended material and dissolved organic matter that influence water transparency and may be responsive to management actions.

Modeling hydrodynamics and water quality for Wachusett Reservoir

John Tobiason, David Ahlfeld, Mary Serdakowski and Christina Stauber, Civil & Environmental Engineering, University of Massachusetts Amherst

The purpose of this presentation is to present applications of long-term and multi-faceted approaches undertaken for the Division of Water Supply Protection of the Massachusetts Department of Conservation and Recreation (DCR) in modeling hydrodynamics and water quality in Wachusett Reservoir. The modeling work is part of a larger effort focused on the two reservoir (Quabbin and Wachusett) source of currently unfiltered drinking water for the Boston metropolitan area, with the long term research goal of providing a rational basis for watershed and reservoir management decisions through measurements of water quality and modeling of significant transport and transformation processes. Modeling of reservoir hydrodynamics and water quality has included extensive use of CEQUAL W2, a two dimensional (longitudinal segments, depth layers, lateral homogeneity) finite difference model available in the public domain. Assessment and calibration of annual water budgets have highlighted strengths and weaknesses of available data in properly characterizing water quantity. Wachusett, the terminal supply reservoir, can be significantly affected by transfers from the larger, more pristine, Quabbin reservoir; modeling has illuminated key impacts of this transfer. Another aspect of the project has been to assess inputs and transformations of natural organic matter (NOM) due to its influence on subsequent oxidant/disinfectant demands and by-product formation. The current modeling work is directed as assessing potential impacts of contaminant spills (sewage, hydrocarbons) into the reservoir on water quality in the overall reservoir and at the Cosgrove water supply intake. Impacts of spill date (season) and location as well as contaminant type are being investigated through use of both the two dimensional CE QUAL W2 model and a three dimensional computational fluid dynamics (CFD) model developed for the Thomas Basin. This paper will summarize and highlight key findings from the recent contaminant spill modeling work.

Track B: Fish: Water Resources Management Indicator — Room 165

Moderator: Scott Jackson, Natural Resources & Environmental Conservation, University of Massachusetts Amherst

Northeast regional mercury Total Maximum Daily Load

Susannah King and B. Card, New England Interstate Water Pollution Control Commission; T. Iott, P. Stacey, Conn. Dept. of Environmental Protection; A. Fisk, B. Mower, Maine Dept. of Environmental Protection; D. Dunn, R. Isaac, C.M. Smith, Mass. Dept. of Environmental Protection; G. Comstock, New Hampshire Dept. of Environmental Services; J. Bloomfield, R. Draper, R. Entringer, S. Quinn, New York State Dept. of Environmental Conservation; S. Ribas, E. Scott, Rhode Island Dept. of Environmental Management; T. Clear, N. C. Kamman, Vermont Dept. of Environmental Conservation

Elevated levels of mercury in freshwater fish have been a concern in the Northeast states (Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont) for many years. All of the states have fish consumption advisories that recommend their residents limit the amount of fish they consume from the states' waters. Over the past decade, these states have made tremendous progress in reducing mercury from in-region sources. Between 1998 and 2003, in-region mercury emissions decreased by approximately 70 percent. However, fish mercury levels remain high because a significant portion of mercury deposited in the region originates from sources outside of the region.

Due to the need for greater mercury reductions to eliminate fish consumption advisories, the Northeast states and the New England Interstate Water Pollution Control Commission embarked on the development of the first ever multi-state Total Maximum Daily Load (TMDL) for mercury-impaired waters. Modeled closely after the Minnesota Statewide Mercury TMDL, the Northeast Regional Mercury TMDL uses 1998 as a baseline year and states that fish tissue concentrations must be reduced by 74 to 91 percent from 1998 levels to meet fish tissue goals in each of the states. To meet this goal, anthropogenic atmospheric deposition of mercury must be reduced by 98 percent from all sources. The TMDL outlines the necessary reductions from in-region and out-of-region sources and recommends that more stringent federal controls are placed on coal-fired power plants and other mercury sources. A

three-phase implementation plan is proposed for both in-region and out-of-region sources.

The draft TMDL was released for public comment on April 11, 2007. Taking into consideration comments received, the TMDL was revised and the final version was submitted to EPA on October 23, 2007. On December 20, 2007, the final TMDL was approved by EPA Regions 1 and 2.

Characterizing and interpreting fish consumption rates for developing human health water quality criteria

Russell Keenan, Patrick Gwinn (presenter), Elizabeth Algeo, AMEC Earth & Environmental Inc. Portland, ME; Paul Anderson, AMEC Earth & Environmental Inc., Westford, MA

Derivation of water quality standards for substances that bioaccumulate in fish tissue is largely dependent on the selection of a fish consumption rate because the magnitude of the water quality standard is inversely proportional to the magnitude of that rate. While there is enormous variability in the amount of fish that people consume, an examination of fish consumption data demonstrates an important unifying trend. That is, as the fish consumption rate increases, the number of consumers decreases. As a result, the selection of a fish consumption rate for deriving water quality standards involves an implicit risk management decision. It is important that the variable levels of protection afforded by the selection of fish consumption rates are understood and quantified, so that the technical and economic implications of competing choices can be evaluated in an informed and transparent manner.

Wild brook trout (Salvelinus fontinalis) density as an indicator of stream flow condition and applicability towards streamflow classification in Connecticut

Chris Bellucci, Mike Beauchene, Mary Becker, Bureau of Water Protection & Land Reuse, Planning & Standards Division; Neal Hagstrom, Bureau of Natural Resources, Inland Fisheries Division; Conn. Dept. of Environmental Protection

The Connecticut Department of Environmental Protection (CTDEP) is in the process of revising minimum streamflow regulations pursuant to Public Act 05-142. One important aspect of streamflow regulations development in Connecticut pertains to the assigning a streamflow class to each perennial river and stream in the state. To accomplish this goal, CTDEP has proposed using the Hydrologic Stressor Index (HSI), an index comprised of four metrics - impervious cover, diversions, dams and return flow. These four metrics were chosen because of their potential to modify natural streamflow and because statewide data layers were available to calculate the metrics for these four parameters.

After calculating initial HSI scores, the streamflow class may be modified using a list of additional factors that indicate the existing or future streamflow condition. These additional factors will be outlined in the streamflow regulations and will be used to modify the HSI to develop a preliminary streamflow class map for public comment. One such "additional factor" being considered is density of a native fluvial specialist fish species, the brook trout (Salvelinus fontinalis). This presentation will explain how these "additional factors" can be used to modify initial HSI scores to develop streamflow class maps for public comment using brook trout as an example.

Track C: Low Impact Development
Room 101

Moderator: Jerry Schoen, Mass. Water Resources Research Center, University of Massachusetts Amherst

Silver Lake Low Impact Development demonstration project

Andrea Braga and Steven Roy, Geosyntec Consultants, Inc., Acton, MA

As part of a comprehensive restoration project for the Ipswich River Watershed, the Town of Wilmington hired Geosyntec Consultants to develop stormwater treatment designs for the Silver Lake town beach parking lot and three stormwater outfalls that discharge to the lake. The project is one of nine demonstration projects funded by the Massachusetts Department of Conservation and Recreation (MA-DCR) through a Targeted Watersheds grant from the US-EPA. Silver Lake is a 28.5-acre kettle-hole lake with a watershed area of 132 acres, which drains to Lubbers Brook, a tributary of the Ipswich River. The Silver Lake water quality and resource improvement project involved installation of several Low Impact Development (LID) practices to treat stormwater in the Silver Lake watershed. The project is located in a residential area and within the vicinity of the Silver Lake town beach parking lot.

The project involved the replacement of existing pavement along the street perimeter with “porous” pavers with underlying infiltration beds, the construction of several raingardens on residential properties, the restoration and enhancement of a stormwater outfall entering Silver Lake, replacing the

paved town beach parking lot with "porous" pavers and "pervious" asphalt systems and bioretention cells and the construction of two vegetated swales to daylight stormwater outfalls adjacent to the town beach.

This presentation will provide a summary of the LID components of the project including both the design and construction. The paper will present the LID elements that were implemented, provide summaries of the infiltration results collected on the porous surfaces, and summarize the findings along with recommendations for LID implementation.

Protecting our wetlands and water resources through innovative stormwater management "Cohasset Rain Garden Project"

Mark Bartlett, Norfolk Ram Group, LLC and John McNabb, Town of Cohasset

Cohasset is a South Shore community in which approximately 90 percent of the drinking water supply comes from the Lily Pond surface water treatment plant. Lily Pond is shallow and currently eutrophic. The reduction of nutrient loads and control of in-lake vegetation were identified as goals in the development of pond and water supply management strategy. Low Impact Development (LID) Techniques were instituted to treat roadway runoff within the water supply watershed prior to discharge to the pond. The stormwater Best Management Practices selected include bioretention cells (rain gardens) and vegetated bioretention swales. As a first step a demonstration rain garden was constructed at the Water Department parking lot to serve as an educational tool for the community. Twenty rain gardens and two vegetated bioretention swales have been constructed so far within roadway rights-of-way. Twenty-nine additional rain gardens will be constructed in Spring of 2008. The runoff filters through specially engineered soil reducing pollutant and nutrient levels, reducing elevated temperatures of stormwater during summer months, and attenuating peak flows. The treated stormwater is collected by under-drains and returned to the stormwater system or infiltrated back into the ground. The Cohasset Rain Garden Project is an example of applying LID techniques to retro-fit existing drainage systems in a developed watershed.

LID is an innovative approach to stormwater management involving site design that duplicates the hydrologic features of an undeveloped watershed. Instead of conveying, managing and treating stormwater in large, costly facilities located at the bottom of drainage areas, and often outside of the natural watershed, LID simulates natural hydrologic cycles by addressing stormwater through small, cost-effective landscape features located at the lot level. These landscape features include permeable paving, bio-retention cells / rain gardens, grass swales, filter strips, disconnected impervious areas, and cistern collection systems. Rain gardens represent a low-cost, low-maintenance technique to improve the quality of stormwater that enters the water supply.

Relationship between watershed impervious cover estimates and peak streamflow

Christiana Gerstner and Richard Vogel, Civil & Environmental Engineering, Tufts University

Estimates of watershed impervious cover are widely used in research, engineering, and policy studies that examine the hydrologic and environmental impacts of urbanization. Increasing availability of GIS tools and datasets has led to the development of many different methods of estimating the amount of impervious cover in an area. Four commonly used impervious estimation methods are compared for 25 watersheds in Eastern Massachusetts exhibiting a wide range of urban cover. Relationships between flood flows and percent imperviousness from each method are explored to document the impact of the choice of method on discharge estimates. In addition, a meta-analysis is presented comparing studies that show a correlation between watershed imperviousness and peak streamflow.

Track D: Surface / Ground Water Interactions — Room 162

Moderator: Qian Yu, Geosciences, University of Massachusetts Amherst

Implications of anthropogenically driven surface water fluctuations on ground water surface water exchange zones

David Boutt, Geosciences, University of Massachusetts Amherst

Ground water and surface water features in the humid northeast are intimately connected to one another. Rapid changes in surface water stage through flooding events or anthropogenic changes are transferred directly to the ground water reservoir. In the Deerfield River watershed of northwestern Massachusetts the mainstem of the Deerfield is highly impacted by a number of small hydroelectric dams that manage the river stage with scheduled

releases of water. River stage fluctuates on a daily basis with magnitudes up to 1.5 meters in large events. We have been studying the impacts of these releases on resulting ground water surface water interactions with an emphasis on quantifying the water exchange between the two systems. Through the instrumentation of multi-level piezometers to measure head and dedicated multi-level temperatures measurements we have inferred the distribution of the mixing zone of ground and surface waters. This zone appears to be a strong function of the river stage change and has implications for surface and ground water temperature distributions and nutrient transformations in the hyporheic zone.

Fate and transport of road salt during snowmelt through a calcareous fen: Kampoosa Bog, Stockbridge, MA

Amy Rhodes, Geology, Andrew Guswa and Ann Pufall, Picker Engineering Program, Smith College

Kampoosa Bog is the largest and most ecologically diverse calcareous lake-basin fen in Massachusetts. Situated within a 4.7 km² drainage basin, the open fen consists of a floating sedge mat that overlies peat and lake clay deposits. Mineral weathering of marble bedrock supplies highly alkaline ground and surface waters to the fen basin. The natural chemistry has been greatly altered by road salt runoff from the Massachusetts Turnpike. The purpose of this study is to characterize the hydrologic and chemical response of the wetland during snowmelt events to understand the fate and movement of road salt (NaCl). Concentrations of Na and Cl in the fen groundwater are greatest close to the Turnpike. Concentrations decrease with distance downstream but are still greatly elevated. During snowmelt events, the fen's outlet shows a sharp rise in Na and Cl concentrations at the onset of melting that is soon diluted by the added meltwater. The Na and Cl flux, however, is greatest at peak discharge, suggesting that high-flow events are significant periods of export of dissolved salts from the fen. Pure dissolution of rock salt produces an equal molar ratio between Na and Cl, and sodium and chloride imbalances in stream and ground waters suggest that approximately 20% of the Na is stored on cation exchange sites within the peat. The largest imbalances between Na and Cl occur deeper within the peat, where the peat is more compact and groundwater has a longer residence time. CEC measurements show that Ca>Mg>Na>K on exchange sites and suggest that Na in groundwater preferentially displaces Mg. Management questions to be addressed include what percentage of applied salt is flushed through the fen during snowmelt each year? How much salt is retained in the fen? For how long would salt concentrations remain elevated if salt application were to cease?

The effect of precipitation variability on root depth and the partitioning of hydrologic fluxes

Andrew Guswa, Picker Engineering Program, Smith College

The depth of the root zone affects and is affected by the dynamics of water in the shallow subsurface. Using a stochastic model of soil-moisture dynamics along with a carbon cost-benefit analysis, a water-optimal root depth is determined as a function of climate, soil, and vegetation characteristics. Changes to precipitation intensity, frequency, and amount affect this depth and the partitioning of soil moisture among evaporation, transpiration, and recharge fluxes. For a given climate – fixed average precipitation and potential evapotranspiration – the optimal root depth and recharge flux both decrease with increasing precipitation frequency (and decreasing intensity). Evaporation increases as the frequency of precipitation increases, and the transpiration flux often displays a maximum for intermediate values of precipitation frequency.

Session 2: 1:30 – 3:00 pm

Track A: Effective Water Management Regulations — Room 163

Moderator: Ralph Abele, USEPA New England

Sustainable water resources management in Massachusetts

Martin Pillsbury, Metropolitan Area Planning Council, Boston, MA

Based on research by the Metropolitan Area Planning Council (MAPC) in collaboration with the 495/MetroWest Partnership, the challenges of sustainable management of water resources in one of the state's fastest growing regions, the 495/MetroWest corridor, are explored. Innovative water management techniques that address water supply, wastewater, and stormwater issues are evaluated. Case studies in three areas are included: Low Impact Development, water reuse, and seasonal

peak water demand, focusing on examples of successful implementation as well as challenges and obstacles.

Like many growing regions, the 495/MetroWest corridor faces challenges in three key aspects of water resources management: increasing water demand to serve growing residential and commercial/industrial customers, stormwater management in urbanizing watersheds, and wastewater management in communities with constraints on both infrastructure capacity and permitted discharges. To help communities meet these challenges, MAPC and the 495/ MetroWest Partnership recently completed the 495/MetroWest Water Resources Strategy project, funded by a grant from the U.S. Environmental Protection Agency. The project's research into innovative water management techniques informed the creation of a WaterSmart Tool Kit, which presents the findings in a series of accessible manuals and guides geared towards practical implementation at the local level. Components of the project include the Guide to Water Reuse in Massachusetts, the Guide to Peak Summer Water Demand Management, and the Massachusetts Low Impact Development Tool Kit, which was awarded Best Project by the Massachusetts chapter of the American Planning Association. The project also includes the WaterSmart Indicators, a regional database that tracks trends in water supply, wastewater, and stormwater in the 32 communities in the 495/MetroWest Corridor. Finally, the project features collaborative research by the U.S. Geological Survey, which conducted hydrological modeling of the projected impacts of year 2030 population growth on the water resources of the Charles and Assabet River watersheds, using MODFLOW groundwater models.

Using water budgets to assess impacts on streamflow

Nigel Pickering, Charles River Watershed Association, Weston, MA; Greg Rowe, ESS Group, Providence, RI; Christian Jacqz, MassGIS; John Clarkeson, Mass. Executive Office of Energy & the Environment

The statewide water budgets project is designed to assess the human impact on streamflow in Massachusetts communities. The assessments are intended to provide a framework for long-term water resources planning and protection of essential aquatic ecosystems.

The water budgets analyses will be performed on approximately 2,200 small subbasins in Massachusetts that average about 5 square miles in area. Water use impacts cover the public, private and commercial sectors and include water withdrawals, wastewater discharges, septic tank return flows, import/export of water via pipe networks, evaporative losses from irrigation, and lost recharge from impervious surfaces. The approach focuses on the impacts to baseflow and presents the results for both the wet and dry periods of the year.

The approach identifies basins that are hydrologically out of balance and provides an estimate of the impact relative to natural streamflow. Reports on the subbasin water budgets are summarized by community (for local use) and major watershed (for state use). Results from completed studies of major watersheds will be presented.

Use of streamflow and habitat studies in Massachusetts Water Management Act permitting policy

Duane LeVangie, Mass. Dept. of Environmental Protection

The Massachusetts Water Management Act (WMA), administered by the Massachusetts Department of Environmental Protection (MassDEP), was enacted in 1985 and requires regulation of water withdrawals above a threshold volume of 100,000 gallons per day. After an initial registration period between 1981 and 1985 for water users withdrawing over the threshold volume, permits were required for existing users that had increased water use or added new sources, and new users above the threshold volume. In its review and issuance of permits, MassDEP must consider the environmental impact of proposed withdrawals, including the impact on the safe yield of the water basin. WMA Regulations 310 CMR 36.00 previously included a specific methodology for calculating basin safe yield that was later found to inadequately balance the competing water needs of humans and the environment.

MassDEP, recognizing the problems in the original basin safe yield calculations and with increasing concern over low streamflows in the Ipswich River Basin, contracted with the U.S. Geological Survey (USGS) to conduct a number of hydrologic assessment reports between 2000 and 2004 in the Ipswich River Basin. These studies confirmed that water withdrawals were having a significant impact on streamflow in the basin. One of these reports, which focused on habitat and streamflow requirements for the basin, indicated that the decreased flow regime observed in the basin caused a shift in the fish community structure from cold-water fluvial fish to warm water generalist species. In response to these studies, MassDEP modified the permits issued in the Ipswich River Basin to include a number of conservation measures,

including the condition that nonessential outside water uses, in particular, lawn irrigation, cease when streamflows reach specific levels identified in the USGS reports.

Recently the Department of Conservation and Recreation has developed index streamflows for Massachusetts based on a USGS report that identified the least impacted streamflow gaging stations within southern New England. The index streamflows provide information specific to Massachusetts watersheds that can be used to assess near natural flow conditions. This data supplements the U.S. Fish and Wildlife Service's Aquatic Base Flow values that are representative of the greater New England area. Use of the index flows in WMA permitting policy will allow MassDEP to further the goal of balancing competing water needs and uses by requiring outside water use restrictions triggered by index streamflow values that are more pertinent to Massachusetts streams.

Track B: Water Research and Climate Change — Room 165

Moderator: Pat Bresnahan, Connecticut Institute of Water Resources, University of Connecticut

Proteins as important reactive compounds in drinking water treatment

David Reckhow, Civil & Environmental Engineering, University of Massachusetts Amherst; Junsung Kim, City of Tampa Water Dept., Tampa, FL

Climate change is likely to result in substantial changes in autochthonous production of organic carbon. One important feature of this material is its relatively high abundance of proteins, polypeptides and amino acids. This could affect the quality of treated drinking water in significant ways. The common amino acids comprise 22 compounds, all of which may form disinfection by-products (DBPs) and TOX during disinfection with chlorine. This research focused on regulated DBP formation from the chlorination or chloramination of amino acids and related compounds. For chlorination, model compound solutions (2 mg·C/L) were adjusted to the desired pH and then dosed with chlorine at 20 mg Cl_2/L. Samples were then incubated head space-free for 2 days at 20°C. After collecting the samples for DBP analysis, quench reagents were added to the bottles and the samples were stored at 4°C. Trihalomethanes (THMs) and haloacetic acids (HAAs) were analyzed using standard gas chromatographic methodology. Total organic halide (TOX) was determined and from this we calculated the unknown TOX. Asparagine, aspartic acid, proline, tryptophan and tyrosine were found to produce high TOX yields by chlorination. Some amino acids were major producers of haloacetonitriles. Tests with polypeptides and purified proteins revealed the role of peptide bonds on reactivity and byproduct formation. These data will be discussed and interpreted within the context of changing autochthonous carbon levels, drinking water quality and human health.

Distribution and transport of dissolved organic carbon in watersheds and adjacent coastal waters using the SWAT model

Yong Tian, Robert Chen, Wei Huang, and Bernie Gardner, Environmental, Earth & Ocean Science, University of Massachusetts Boston; Qian Yu, Geosciences, University of Massachusetts Amherst

We introduce a GIS-based integrative modeling approach to examine the sources and transport mechanisms of dissolved organic carbon (DOC) from terrestrial ecosystems to coastal oceans. The modeling is based on a set of in situ measurements collected monthly over the last two years. A soil and water assessment tool (SWAT) model was adopted as a framework for studying DOC transport processes and linking them with terrestrial biophysical properties. First, we discuss a statistical analysis of in situ measurements of freshwater DOC endmember samples and examines their spatial variability with precipitation, season, hydrological processes, and soil physical characteristics. Then we present a predictive model describing the seasonal and spatial patterns of terrestrial DOC sources as well as daily fluxes to coastal water. Our study shows that terrestrial sources of DOC to estuaries can be associated with biophysical and climate conditions that are obtainable using GIS and remote sensing. The model has been tested in the Neponset and Hudson watersheds in the northeast US.

Rethinking water resources design under climate change

Paul Kirshen, Civil & Environmental Engineering, Tufts University

Climate change over the next century and beyond can be slowed, but not reversed. The major impact to the hydrologic cycle will be increased and nonstationary variability of precipitation and streamflow. The challenges to water managers are planning for climate change when most expected changes are unknown. Approaches must include:

- The Principles of Integrated Water Resources Management
- Adaptive Management
- Life Cycle Analysis
- Use of Co-Benefits
- Watershed Approach
- Robust Solutions
- Risk-Based Analysis

Track C: Stormwater Best Management Practices — Room 101

Moderator: Jerry Schoen, Mass. Water Resources Research Center, University of Massachusetts Amherst

Future goals for stormwater management: Getting beyond 80%

James Houle, Stormwater Center, University of New Hampshire

Stormwater treatment device selection is largely governed by regulatory compliance. Often stormwater management strategies are selected to comply with a regulatory performance requirement rather than being designed based upon actual performance characteristics of the systems. While technical performance evaluation of stormwater treatment devices is an evolving science, regulatory guidelines struggle to keep in step with regional demands for information. A discussion of the origin of a TSS performance standard and its potential limitations is presented against a comprehensive statistical analysis of pollutant relationship patterns of influent and effluent water quality across a range of stormwater management practices. Complex pollutant relationships, or lack-there-of, suggest that in the future we will need to integrate our stormwater designs into the building blocks of regional watershed improvement strategies with careful attention to altered hydrology. One effective means for addressing this is by implementing innovative BMPs employing some form of filtration or infiltration mechanisms. Selection criteria that possess a foundation in regional watershed protection objectives need to be advanced using standards of performance that examine the fundamental causes of watershed impairment, namely altered hydrology.

Analysis of long term rainfall to develop stormwater quality flow rate design criteria

Daniel Nason, Imbrium Systems Corp., Worcester, MA

The intent of stormwater quality best management practices (BMPs) is to preserve and/or improve the existing quality of water resources by achieving a water quality outcome. The water quality outcome is often expressed as a desired level of annual total suspended solids (TSS) removal and by a minimum volume of runoff that must be stored called the water quality volume (WQV).

Traditional structural BMPs such as wet ponds and wetlands are designed based on the WQV which is defined by a depth of rainfall that represents treating the 80th to 90th percentile volume of the annual runoff. However, the design basis for the WQV is often applied generically to all types of stormwater management BMPs without considering unit process limitations to manufactured BMPs.

Manufactured BMPs are intended for water quality improvement and are designed for space constrained sites. The design criteria for manufactured BMPs are flow based, and performance is dependent on a prescribed particle size gradation. Therefore, applying the WQV design methodology to manufactured BMPs would be contrary to a flow based design principle and problematic when land for large detention facilities is not available. Flow based sizing, however does not mean treatment of design storms (i.e., 2 to 100 year storms which are typically applied for quantity control design) but rather treating the flows that contribute to the majority of the average annual runoff volume.

This presentation will propose a sizing methodology for manufactured BMPs called the water quality flow (WQF). An overview of the "first principles" used to determine a WQV is discussed and a similar approach to determine a WQF is proposed. Like the WQV, the WQF is selected based on treating the 80th to 90th cumulative percentile volume of the annual runoff.

The nuts and bolts of manufactured treatment systems: An in-depth look at critical design variables

Derek Berg, CONTECH Stormwater Solutions, Scarborough, ME

The use of manufactured stormwater treatment systems to mitigate the adverse impacts of urban runoff has become commonplace. Not surprisingly, as the demand for manufactured treatment systems has grown the number of available options has followed suit. The typical stormwater professional

could make deciphering the various performance claims, sizing methodologies and other supposed benefits marketed with each device a full time job, but most have little time for such endeavors. The majority of state and local agencies have not established sizing criteria for manufactured treatment systems, so agencies often rely on the manufacturers' sizing recommendations. However, manufacturers' sizing methods tend to be unique to each device, making it virtually impossible to directly compare competing technologies to one another. Unfortunately, limited knowledge of critical sizing assumptions on the part of engineers and reviewers as well as fierce competition among vendors is resulting in the installation of undersized and poorly sited systems. Establishing uniform sizing criteria creates a level playing field from which to compare manufactured systems to one another and to other types of treatment systems, and ensures that devices are sized to meet applicable standards.

This presentation explores the fundamental unit processes that govern the performance of manufactured devices and the sizing variables often manipulated by vendors to make their units seem superior or more financially attractive to the end user. Examples of common sizing methodologies and associated assumptions are presented in a manner that allows the reader to make informed decisions regarding device selection and sizing. Standardized sizing methodologies that are already in use by a number of state and local agencies are also discussed.

Track D: Contaminants in Water

Room 162

Moderator: Scott Stoodley, AMEC Earth & Environmental Inc., Westford, MA

The measurement and fate of trace organic compounds in municipal wastewater treatment plant effluents

Kimberly Groff , P. Anderson, M. Hoyt, B. Pugh, J. Samuelian, AMEC Earth & Environmental Inc., Westford, MA

Approximately 785 million gallons of treated sewage is discharged into the surface waters in Massachusetts each day by 126 state and federally permitted facilities. Many communities that rely on groundwater or surface water for their public water supplies are finding that current demand is approaching the limit of their available resources. Thus, water is a limited resource around the world as well as right here in Massachusetts. As a result, the protection of our water resources is one of the most essential environmental issues facing the Commonwealth.

Nation-wide concerns have been raised over the adverse impacts on human and ecological health effects resulting from numerous chemicals used by society. Some of the most frequently detected compounds included DEET (insect repellent), caffeine (stimulant), triclosan (antimicrobial disinfectant), and tri(2-chloroethyl)phosphate (fire retardant). Prescription pharmaceuticals and antibiotics also have been detected in surface waters. Household chemicals, pharmaceutical and personal care products as well as hormones produced by our bodies are released directly to the environment after passing through wastewater treatment plants or domestic septic systems which were not specifically designed to remove these chemicals.

This presentation explores the ways that researchers in the U.S. and abroad are looking at the myriad of trace organic chemicals in common use today and their presence in municipal wastewater and surface water. Methods used to quantify the measurement of anthropogenic trace organics in wastewater and surface will be reviewed along with their occurrence and fate in municipal wastewater treatment facilities.

A first pass at evaluating potential human health risks from estrogens in surface water

Paul Anderson, AMEC Earth & Environmental Inc., Westford, MA, and Daniel Caldwell, Johnson & Johnson, New Brunswick, NJ

Estrogens fall into three general classes: endogenous (e.g., estrone (E1), estradiol (E2)); synthetic (e.g., ethinylestradiol (EE2)); and phytoestrogens (e.g., genistein). Detection of low levels of estrogens has raised concerns because of their potential to affect both aquatic and human health. A recent study found that estrogens derived from therapeutic use are predicted to be present in drinking water at less than 0.0001% of total estrogen exposure for all age groups studied. Phytoestrogens (present in surface water at 322 ng/L) dominate drinking water exposure, followed by naturally produced E1, E2 and E3 (present at a total of 6.4 ng/L), endogenous estrogens used in HRT (present at 0.3 ng/L), and the synthetic EE2 (0.02 ng/L). Estrogens from HRT in drinking water are predicted to account for <0.002%, while EE2 accounts for <0.0001% of total estrogen exposure in drinking water. However, the biological activities of these different estrogenic compounds on a mass basis are not equivalent and, as recent research demonstrates, are not determined solely by receptor binding

affinity. The ability of a compound to elicit a response varies greatly from one organ, tissue, and endpoint to another. Evaluating the combination of these different biological responses requires an integrated measure of potential effects. One way to assess the overall impact of estrogens in surface water on human health is to compare measured or predicted concentrations to safe exposure levels that have been developed to protect workers occupationally exposed and evaluate the margin of safety (MOS). Preliminary calculations for prescribed E2 and EE2 indicate MOS of 640 and 3300, respectively. These values can be put into perspective by comparing them to the phytoestrogen, genistein, with a MOS >5000, and total drinking water exposure (all sources combined) of naturally occurring hormones (E1, E2, and E3) with a MOS of no less than 30.

Defining abiotic and biotic contributions to metal sequestration within acidic mine drainage in Appalachia

Colleen Hansel, Cara Santelli, School of Engineering & Applied Sciences, Harvard University; Bill Burgos, Civil & Environmental Engineering, Pennsylvania State University

Acidic mine drainage (AMD) is a significant environmental problem worldwide. In Appalachia, for instance, more than 700 mine sites are undergoing treatment to remove extreme concentrations of heavy metals, including Mn, Zn, and Cu. Passive treatment of AMD via in situ oxidation of Mn(II) within limestone treatment beds presents a promising means of water purification and environmental remediation. In these systems, stimulated oxidation of water containing elevated (>150 mg/L) concentrations of Mn(II) results in the precipitation of highly reactive Mn(III/IV) oxide phases, which serve as powerful sorbents and repositories of accompanying metals. While the oxidation of Mn(II) by molecular oxygen is thermodynamically favorable at circumneutral pH, the reaction is kinetically limited in the absence of mineral surface or enzyme catalysts. In particular, the oxidation of Mn(II) is catalyzed by the activity of microorganisms and has primarily been attributed to a phylogenetically diverse group of bacteria. In an attempt to improve the Mn(II) oxidation capacity of limestone treatment beds, we have investigated the abiotic and biotic Mn(II)-oxidizing components of eight systems in Appalachia. Here we reveal that the role of fungi in metal oxidation has been grossly underestimated within these systems. In fact, not only is the Mn(II)-oxidizing bacterial community sparse in regions undergoing active Mn(II) oxidation, the total bacterial community appears to be stunted in comparison to the diverse fungal community. We further highlight that surface associated autocatalysis is significant in these systems. Together, we find that in passive AMD treatment systems in Appalachia the traditional assumption that bacterially-mediated processes control Mn(II) oxidation is disobeyed but rather fungal and mineral catalysis dominate the sequestration of metals in these systems.

Session 3: 3:15 - 4:45 pm

Track A: Water Resources Planning
Room 163

Moderator: Marianna Vulli, New England Interstate Water Pollution Control

Defining ecological sustainable yields for water supply reservoirs

Mark Smith, The Nature Conservancy; Brian Joyce, Stockholm Environment Institute; Richard Vogel, Civil & Environmental Engineering, Tufts University; Stacey Archfield, USGS; Yongxuan Gao, Civil & Environmental Engineering, Tufts University; Colin Apse, The Nature Conservancy; Jack Sieber, Stockholm Environment Institute

Our project focuses on defining what can be considered a 'sustainable yield' for water supply reservoirs. We define 'sustainable yield' as "the amount of water that can be reliably supplied to meet human needs while meeting key downstream ecological flow requirements." We use an existing water allocation decision support model to quantify the trade-offs of various reservoir release policies on the water yield for human uses. We describe the different types of downstream flow alterations caused by different size reservoirs and therefore require different release policies to be 'sustainable.' We also demonstrate how a comprehensive approach that includes clearly defining flow requirements and strategically using water conservation and drought management is able to meet the ecological and human water needs. As a case study we demonstrate how our decision support system, and similar efforts by others, is helping the state of Connecticut DEP to develop state flow protection policies. By examining a spectrum of typical release and demand management policies we are able to demonstrate that a 'sustainable yield' for a water supply reservoir can

be quantified and that this yield is often 55-80% of the yield predicted by more traditional definitions of 'safe yield' that include no ecological flow requirements. We also show how drought management can restore most of these decreased yields.

Integrating ecosystems costs and benefits into water resources planning

Brian Joyce, Stockholm Environment Institute; Paul Kirshen (presenter), Civil & Environmental Engineering, Tufts University; David Mitchell, M. Cubed, Inc.; Jack Sieber, Stockholm Environment Institute

While financial costs are an important component in water resource planning and management, it is rare for water resource planning to thoroughly identify and calculate all costs and benefits, including both environmental costs and the true costs of water, wastewater and stormwater infrastructure and systems. Added to this shortfall of knowledge is the reality that environmental impacts have not traditionally been a significant factor in assessments and are challenging to isolate and quantify. Long term operation, maintenance, upgrades and replacement costs of water, wastewater, and stormwater systems are key variables in a thorough assessment though they are too often overlooked or under-represented. This study considered an integrated approach to water resource planning – one incorporating wastewater, potable water and stormwater – that accounted for the costs and benefits of water management across all sectors. Of particular interest was the incorporation of short and long term economic and ecological costs and benefits of viable water resource management options. The study team collaborated with water managers in the town of Sharon, Massachusetts to conduct a thorough and comprehensive environmental and economic cost benefit analysis of their water resources system. The Water Evaluation And Planning (WEAP) system was used as the analytical platform to evaluate the physical and financial implications of management alternatives. The town of Sharon was selected as a test case for applying a more broadly applicable water planning methodology because it has a mix of water resources issues that are representative of the challenges that other municipalities face. This case study provides a transferable example of methods to help a community or region with their water resource planning and decision making process.

Development of a dynamic reservoir flow model: Sensitivity of policy impacts to changing hydrologic conditions

Patricia Bresnahan, Glenn Warner, Kynoch Reale-Munroe, Connecticut Institute of Water Resources, University of Connecticut

In a stream with a managed impoundment the frequency, magnitude and duration of flows may be altered. Reservoir release policies attempt to preserve the essential quality of the aquatic environment while simultaneously satisfying the needs of a growing human population. The Connecticut Institute of Water Resources (CTIWR) has developed a simulation model to help resource managers quantify the impacts of release policies on both downstream flows and water supply reliability.

The model, developed using STELLA, contains a single artificial reservoir with configurable rating curves. Input flows are simulated using either actual streamflow data, or by a synthetic flow with the hydrologic attributes expected to exist in some future climate change scenario. Water leaves the reservoir in one of four ways: direct evaporation, withdrawal for human use, spillage, or through an actively managed release.

The current version of the model contains three main types of release rules and each rule has several configurable settings that control the amount and timing of release flows. A "Fractional Release" rule sets the managed release to some percent of the natural inflow, with the percent perhaps varying by season. A "Fixed Release" rule sets the release to some constant rate, regardless of the amount of flow into the reservoir, but that rate may vary by season. A "Pulse Release" rule requires the manager to punctuate periods of very low release with a few days of higher flows.

The model may be used to estimate safe yield for each configured system, for either current conditions or some future hydrologic regime. Other model outputs such as the downstream hydrographs and storage timeseries may be post-processed to quantify the frequency of drought conditions and the degree of alteration in flows and storage resulting from each policy.

Model outputs for selected release scenarios and Connecticut basins will be presented.

Track B: Case Studies in Effective Water Resources Education Room 165

Moderator: Craig Nicolson, Natural Resources Conservation, University of Massachusetts Amherst

A dozen undergraduate research projects on the Westfield River: A meta-analysis of student findings about human impacts on the Westfield River ecosystem

Michael Vorwerk, Environmental Science Program, Westfield State College

At Westfield State College, Westfield, MA, a capstone environmental research project is required for Environmental Science majors. While the subject of the research is open and determined by each student, many chose to study impacts of human activities on the Westfield River in Western Massachusetts. Some of this work has been presented at previous WRRC conferences including work to: determine the impact of parking lot runoff on the Westfield River; model the impact of dams on river temperature; and use flow records to calculate watershed primary productivity. Other student work has been presented at various undergraduate research conferences in the Northeast and includes research on: the effects of a small dam on aquatic macro-invertebrates; effects of an adjacent highway on river temperatures; whether pH or temperature are limiting factors in Atlantic Salmon habitat; and the existence of Atlantic Salmon micro-habitats during periods of adverse conditions on the Westfield River.

This presentation will include a meta-analysis of the students' findings and identify commonalities in their results. For instance, several studies supported the hypothesis that even small impoundments (~1-2 km, dams < 10m) cause significant impacts on water quality. Other studies refuted the students' hypotheses that human development (roads, parking lots) caused detectable changes in water temperatures. Two studies found that the river appears to be marginal habitat for salmonoids, while a third found that suitable refuges exist in the river throughout the year. The presentation will conclude with a discussion of common benefits and pitfalls of undergraduate student research projects.

Integrating hydrogeology field training with real world applications

Jennifer Rivers, Earth & Environmental Sciences, Northeastern University

Northeastern is an urban university with strong practice-oriented education mission. In the Earth and Environmental programs, access to field sites for course laboratories is a goal, but a challenge. Installing a network of monitoring wells for teaching was not an option. However, there exists a number of groundwater monitoring wells installed as part of the engineering studies for construction and rehabilitation of campus buildings. These wells have been used for water level and water quality monitoring, and are typically capped at the completion of the project. The Department of Earth and Environmental Sciences (DEES) arranged ongoing permission to access these wells, and to obtain long-term data from the wells through both the University Physical Plant office and the geotechnical engineering firm who installed the wells. Students in hydrogeology thus have the opportunity to learn in an applied sense about water quality issues, construction and excavation issues, historical water table issues in the Back Bay, Boston area, and the geological history of the campus and of the Boston region, through the hydrologic data. Monitoring wells are used as labs in the upper-undergraduate Hydrogeology course and for demonstration in introductory environmental geology courses. Since the logistics of getting into the field is resolved, a number of independent student projects have been completed which investigate surface water and groundwater interactions including: investigating a possible tidal influence on the wells, discovering a water main leak under campus, and documenting structural imperfections in campus buildings and relating them to declining groundwater levels and resultant settling. As the monitoring continues through class laboratories, the long-term database of the hydrogeology of campus is growing, and students recognize that their class laboratory exercises involve contributing real data that will have increasing value in the future.

The undergraduate component of the Arsenic Project

Julian Tyson, Chemistry, University of Massachusetts Amherst

In response to calls from agencies, such as the NSF and NAS, for the introduction of authentic research experiences early in the undergraduate science curriculum, and for the provision of opportunities for students to "acquire literacy in [STEM] subjects by direct experience with the methods and processes of inquiry", PI Tyson has created an undergraduate component of The Arsenic Project. The Arsenic Project has grown out of interests in the environmental chemistry of arsenic, and the first offshoot was a program for middle

school students in STEM Connections, funded by the NSF's Graduate Student in K-12 Education program. The undergraduate component of The Arsenic Project consists of a one-credit, independent study Honors Colloquium involving several small groups, each of which consists of one graduate student mentor, one student taking a junior-level analytical chemistry course, and several students taking freshman chemistry. The program, which started in fall of 2004 and so far has involved about 220 freshmen and 55 juniors, is designed to have many of the characteristics of an authentic research project. It takes place over a significant time period, allowing students the opportunity (a) to become familiar with the relevant big picture, detailed background, and previous work, (b) to conduct a series of experiments, in which the designs of the later ones can be based on the outcomes of earlier ones, (c) to draw conclusions, summarize the findings, make suggestions for further work, and (d) write a report containing the findings of interest to the broader community. Each group (a) researches background topics by the PI, and writes about their findings, (b) works on a project selected by PI Tyson in conjunction with the graduate student mentor, (c) writes a proposal and final report, and (d) makes 2 or 3 oral presentations to the other groups. Most of the projects involve taking environmental samples and measuring the arsenic content, which can be done either with a simple test kit or in the research laboratory. Feedback indicates that participants acquired relevant content knowledge and skills, and that they were motivated to look for further research experiences.

Track C: Stormwater Monitoring and Management — Room 101

Moderator: Jerry Schoen, Mass. Water Resources Research Center, University of Massachusetts Amherst

Fifteen reasons you should think twice before using percent removal to assess BMP performance

Marcus Quigley, Geosyntec Consultants, Acton, MA

This presentation summarizes some key shortcomings of percent removal as a tool to assess stormwater Best Management Practices performance. While percent removal is an easy-to-understand concept that is attractive to many entities and that numerous references provide, significant shortcomings that require alternative measures of BMP performance be used will be reviewed. A recommended alternative will be described, based on runoff volume reduction, treated vs bypassed volume of water, statistical significance, effluent quality, and peak runoff reduction.

TMDL and future stormwater management challenges, issues, and opportunities: Case example – The lower Charles River nutrient TMDL

Mark Voorhees, USEPA New England

Stormwater runoff from developed watershed areas causes and/or contributes to excursions of State Water Quality Standards in waterbodies throughout New England (New England States Clean Water Act Section 303(d) Lists). Stormwater runoff from development causes water quality impacts due to increased watershed pollutant loadings and alters hydrologic regimes which decrease habitat suitability because of more frequently occurring excessive storm flows and depleted stream base flows. In accordance with Section 303(d) of the Clean Water Act, the New England States are establishing Total Maximum Daily Loads (TMDLs) for waterbodies to address water quality impairments caused by storm water runoff. A TMDL defines the amount of pollution that a waterbody can receive and still attain Water Quality Standards and support the designated uses (e.g., aquatic life and recreation) of the water resource.

Since 1995, EPA has promoted the "Clean Charles" initiative, working closely with other government agencies and private organizations, with the common goal of making the lower Charles River from the Watertown Dam to Boston Harbor fishable and swimmable by Earth Day 2005. EPA, as part of the initiative, and Massachusetts Dept. of Environmental Protection cooperatively developed a TMDL for phosphorus for the Lower Charles River located in the metropolitan Boston area in eastern Massachusetts. The Lower Charles River is a 9-mile, mostly impounded, segment that drains a 308 square mile watershed covering area in 35 communities before flowing into Boston Harbor at the New Charles River Dam. Severe algal blooms have been documented to occur in the Lower Charles during each growing season (1998-2007) since EPA began a core water quality monitoring program in 1998. Also, severe toxic cyanobacteria (blue green) blooms have occurred in 2004, 2006, and 2007. The blooms are caused by excessive nutrient loading from the watershed in combination with long hydraulic residence times in the impounded lower segment. The major sources of phosphorus to the Charles River are stormwater drainage systems serving urban and suburban areas, wastewater treatment facilities

located in the upper watershed, and combined sewer overflows that occasionally discharge to the Lower Charles.

In many ways, the water quality problems of the Lower Charles River are typical of many river segments in New England that are impounded because of dams and that drain developed watershed areas. In fact, nutrient-related water quality problems are not limited to the Lower Charles but exist throughout the upper Charles River watershed and are presently the subject of a second TMDL study that is nearing completion. The Lower Charles phosphorus TMDL will be presented as an example for waters where stormwater impacts represent a substantial contributing factor to existing water quality problems.

The technical approach used to develop this TMDL will be briefly summarized and details of the approaches used to generate phosphorus loading estimates, including a GIS-based land cover phosphorus loading analysis for the Charles River watershed, will be described. The talk will present estimates of needed phosphorus load reductions from existing developed areas by both subwatershed area and by land use categories. The recommended implementation plan as it pertains to stormwater discharges will be presented including the relationship between the TMDL pollutant load allocations and NPDES stormwater permits. Finally, ongoing work to refine stormwater management approaches including further analyses of watershed characteristics (e.g., impervious cover) and a project to estimate long-term cumulative performance of selected storm water best management practices will be addressed.

Stormwater challenges: Panel discussion

Dan Nason, Imbrium Systems Corporation, Worcester, MA; Derek Berg, CONTECH Stormwater Solutions, Scarborough, ME; Marcus Quigley, Geosyntec Consultants, Acton, MA; Eric Winkler, Pine Street Consulting, Florence, MA; Tom Maguire, Mass. Dept. of Environmental Protection

Track C will conclude with a panel discussion comprised of speakers and other experts presenting various perspectives critical to stormwater challenges and their proposed solutions. The panel will also take questions from the audience.

Track D: Wastewater Issues

Room 162

Moderator: David Reckhow, Civil & Environmental Engineering, University of Massachusetts Amherst

Use of bioretention systems to control non-point sources of nitrogen

Sarina Ergas and Ryan Siegel, Civil & Environmental Engineering, University of Massachusetts Amherst; Sukalyan Sengupta, Yifu Yao and Arka Pandit, Civil & Environmental Engineering, University of Massachusetts Dartmouth

Control of non-point sources of nitrogen to prevent surface water eutrophication and groundwater contamination is a major challenge faced by water quality managers. Critical non-point sources of nitrogen include animal wastes, on-site wastewater treatment systems, atmospheric deposition, combined sewer overflows and urban and agricultural runoff. A number of best management practices (BMPs) have been used for control of non-point pollutants, including grassed swales, infiltration and detention basins, media filters, and wetland systems. Little information is available, however, on the design, performance and optimization of stormwater BMPs for total nitrogen removal. This research investigated a denitrifying bioretention system for total nitrogen removal. In the denitrifying bioretention system, runoff is conveyed to a ponding area and gradually infiltrates through a nitrifying sand filter. The nitrified stormwater travels through a submerged denitrification zone, which is supplied with an electron donor, where nitrate is reduced to nitrogen gas by anoxic heterotrophic or autotrophic bacteria. Two pilot scale reactors were tested, which utilized either wood chips or elemental sulfur as electron donors for denitrification. Influent and effluent BOD5, COD, pH, alkalinity, total N, ammonium, nitrate, nitrite, sulfate, phosphate and solids concentrations were measured over time during selected storm events. Tests performed under controlled laboratory conditions with simulated runoff resulted in 90% total N removal after system acclimation. Results of field tests under varying operating conditions with runoff from a dairy farm in Putnam, Connecticut will be presented.

Regional planning for the Great Bay Estuary watershed: Evaluation of wastewater management alternatives for the New Hampshire seacoast region

Aaron Weieneth and Betsy Shreve-Gibb, Metcalf & Eddy, Inc., Wakefield, MA

The Great Bay Estuary, known as the "jewel of the New Hampshire seacoast," is located in one of the fastest-growing regions in New England. Increasing population growth resulting in substantial land development is contributing to increased wastewater generation and some increased nutrient loadings to the Great Bay Estuary. Seventeen wastewater treatment facilities (WWTF) discharge to the Great Bay watershed. Some of the WWTF discharges do not meet current limits and others are not able to meet future limits, which are expected to include nitrogen and phosphorus. Important concerns that guided development of the wastewater management alternatives for this study included water quality protection, habitat protection, and sustainable growth management within the 44-community study area. The study resulted in the selection of four alternatives for the New Hampshire Seacoast Region: a regional centralized collection system with local treatment and subsequent offshore discharge to the Gulf of Maine; upgrading existing WWTFs and discharging treated effluent to existing surface water discharge locations; requiring decentralized wastewater treatment and local discharge for a significant portion of all new growth; and treating wastewater locally and discharging to local land application sites. The study does not recommend a particular alternative to implement. Rather, the intent of the study is to present a number of issues and impacts associated with the implementation of the four alternatives and allow stakeholders to subsequently decide on the next steps for wastewater management for this region.

Impact of wastewater metals on bioflocculation of activated sludge and their effect on wastewater effluent quality

Chul Park, Civil & Environmental Engineering, University of Massachusetts Amherst

It is believed that more than 35 billion gallons of wastewater are treated daily in public treatment facilities in the United States and discharged to receiving waters including streams, lakes, and oceans. The consistent and efficient wastewater treatment is therefore tremendously important for conserving our precious water resources. In this study, wastewater samples including influent wastewater, activated sludge, and process effluent were collected from nine different activated sludge plants (the most common type of wastewater treatment facility) and the relationships between metals, bioflocculation, and effluent quality were investigated. None of the facilities performed external metal addition to the plant reactors so that all the metals detected from the samples originated from the raw sewage. The study showed that the effluent quality, designated with effluent chemical oxygen demand and effluent biopolymers (sum of proteins and polysaccharides), was well correlated with the level of metal ions in influent wastewater. Among the metals investigated, higher concentrations of iron and aluminum corresponded to effective flocculation of activated sludge and good effluent quality, which indicated that they are critical components in bioflocculation of activated sludge and are responsible for the quality of facility effluent. The further characterization of wastewater effluent also revealed that protein is more abundant than any other organic matter tested. Consequently, better understanding of the role and fate of protein in the activated sludge process and its relation to metals and effectiveness in bioflocculation would be an important future area for investigation. The current effort on metaproteomic characterization of wastewater effluent (separating and identifying proteins) will also be discussed.

Poster Abstracts

Auditorium - 10:30 – 11:30 am

1. Delineation, validation and application of EPA's level III and IV ecoregions in New England

Greg Hellyer, K. Kipp and D. Switzer, Ecosystem Assessment Unit, USEPA New England Regional Lab

EPA's ecoregions are defined as areas of similarity based on patterns and composition of aquatic and terrestrial ecosystem components of the abiotic (non-living), biotic (living), and cultural (human) environment, including geology, physiography, vegetation, climate, soils, hydrology, land use, and wildlife, with humans being considered as part of the biota. EPA's ecoregional geographers have mapped over 85% of the conterminous US at Level IV, the finest scale of ecoregional delineation, most useful for environmental decision-making. This project has included extensive federal, state and NGO stakeholder involvement. At least 47 of the lower 48 states have used ecoregions programmatically. Some federal, state and NGO uses have included:

• Monitoring aquatic biota (e.g. fish, benthic macroinvertebrates, zooplankton, periphyton, and algae);
• Identifying reference conditions and developing indices of ecological health and integrity;
• Developing narrative and numeric biological criteria, water quality criteria and standards, and nutrient criteria;
• Development and monitoring of TMDLs;
• 305(b)/303(d) and Integrated Reporting;
• Basin assessment, facilities permitting and waste management;
• Statistical and spatial/geographic assessment and modeling (e.g. REMAP/EMAP data);
• Large-scale monitoring of aquatic communities; Ecosystem assessment of watersheds;
• Identifying Target Fish Communities (TFC) and fisheries restoration goals;
• Assessment and classification of streams, rivers, and lakes;
• Point source and non-point source impact assessment;
• Development of state Comprehensive Wildlife Conservation Strategies;
• Identifying critical habitat to preserve biodiversity; Park land acquisition and planning;
• Conservation and recreational planning;
• Wetland protection: planning, permitting, mitigation and determining reference conditions;
• Land cover status and trends; Assessing urbanization; Highway and road planning;

All final peer-reviewed reports, maps and digital datasets, including metadata, from this research will be available online. The final project step will be to assist project partners, including EPA New England, to incorporate ecoregional information and perspectives into their natural resource program assessments and decision-making.

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2. Groundwater contamination from embalming fluid in Massachusetts

Shweta Bansal, Civil &Environmental Engineering, University of Massachusetts Lowell

This research studies the implications of subsurface contamination from embalming fluid, particularly in Massachusetts. Embalming fluid contains carcinogenic chemicals such as formaldehyde, which can be a major source of groundwater pollution. Each year in the United States, hundreds of thousands of bodies are embalmed, with each body requiring about 5 gallons of 4% formaldehyde. According to the Massachusetts Toxics Use Reduction Institute, over 180,000 lbs of formaldehyde are used every year in Massachusetts. As a body decomposes, formaldehyde is released into the subsurface potentially contaminating groundwater. Furthermore, it has been documented that human exposure to embalming fluid has negative health effects. These effects include: bronchitis, body tissue destruction, brain damage, lung damage, impaired coordination, and inflammation and sores in the throat, nose, and esophagus.

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3. Quabbin Reservation: Culvert mapping project

Scott Campbell, Philip Lamothe, and Don Wakoluk, Mass. Dept. of Conservation and Recreation

The Department of Conservation and Recreation, Division of Water Supply Protection (DCR-DWSP) is responsible for the management of a system of watersheds and reservoirs serving the metropolitan Boston area. Integral to the protection of water supply land is timber harvesting and the access provided to the forest by a network of 200 miles of woodland roads. Improper road drainage can increase the rate of sediment transport to nearby streams and result in unsafe travel conditions. Neglecting to

maintain these systems can result in plugged systems, greatly increasing the risk of major failures and road washouts. Wildlife such as beaver can also wreak havoc on a drainage system and impact local hydrology.

DCR staff recognized that a comprehensive inventory of the drainage infrastructure was needed to assist and improve upon on-going maintenance efforts. In 2007 staff set out to locate, map, and assess all culvert pipes servicing its road network. No previous inventory and no authoritative assessment on the condition of the existing infrastructure existed prior to this project.

The breadth of this mapping project was designed to serve multiple purposes:
- Mapping the location of system components was needed to assist staff charged with infrastructure maintenance;
- An accurate inventory was needed to adequately plan for and budget infrastructure maintenance and replacement; and
- Spatial and integrity assessment provides a useful tool for Quabbin managers to efficiently plan and prioritize maintenance activities.

At project completion more than 500 culverts were mapped and data was compiled into a computerized management database. The knowledge gained and the baseline historical reference created will be an invaluable tool for future program evaluation and improvements, resource allocation and planning.

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4. Enhancing Massachusetts clean water infrastructure through a targeted energy management pilot for municipal wastewater and drinking water facilities

Michael DiBara, Tom Bienkiewicz, John Felix (presenter), Mass. Department of Environmental Protection

Each year, Massachusetts public drinking water and wastewater operations treat 662 billion gallons of water for the Commonwealth. Municipal treatment facility managers operate aging collection and distribution systems and are faced with competing customer and regulatory demands to provide clean water at stable utility rates. In Massachusetts, approximately 30% of a municipality's total energy use (and as much as 35 – 40% of the treatment plant's operating budget) involves treating drinking water and wastewater. Since the cost to produce new electricity in Massachusetts is nearly three times the cost to conserve electricity through energy efficiency (9.1 cents per kilowatt-hour versus 3.2 cents per kilowatt-hour), finding efficiencies for treatment facilities has tremendous potential for cost and energy savings. Recognizing these competing demands and challenges, the Patrick Administration launched the first phase of an innovative pilot program, targeting 14 wastewater and drinking water treatment plants across the state, which will reduce the amount of energy that municipal facilities currently use to treat wastewater and drinking water, reduce greenhouse gas emissions, and save communities money. The Energy Management Pilot for Wastewater and Drinking Water Plants brings together state and federal agencies and electric and gas utilities to conduct facility energy audits, assess each plant for its renewable and clean energy possibilities, and offer support for the implementation of these energy-related projects. MassDEP is taking the lead on the pilot program, and is being joined by the following project partners: Massachusetts Division of Energy Resources (DOER); U.S. Environmental Protection Agency Region I; NSTAR; National Grid/KeySpan; Bay State Gas; Cape Light Compact; Western Massachusetts Electric; Unitil; Berkshire Gas; the Massachusetts Technology Collaborative; the University of Massachusetts-Amherst's Center for Energy Efficiency and Renewable Energy; and the Consortium for Energy Efficiency. The cost of implementing the first phase of this pilot is estimated at $326,000.

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5. Exploring the depth and nature of flow systems in fractured igneous and metamorphic bedrock aquifers

John Diggins and David Boutt, Geosciences, University of Massachusetts Amherst

In rocks possessing highly discontinuous and heterogeneous flow paths, such as fractured igneous and metamorphic rocks, regional scale flow concepts are not as easily applied due to the lack of continuity in flow paths. It is traditionally assumed that flow in these bedrock systems decreases with depth due to a stress-induced decrease in permeability. However, recent hydrogeologic studies have suggested that deeper crustal materials are likely more porous then previously assumed and that critically stressed fractures are the most permeable. In the Northeast U.S. most bedrock consists of these rocks and is more frequently being relied upon as a source of drinking water for both private and public water supplies. It is of essential importance to understand the nature and depth of flow systems in these settings for determining the sustainability and vulnerability of water supplies.

Previous workers have completed an extensive fracture mapping study of the Nashoba Terrane, a bedrock terrain located in the densely populated

suburbs of Boston, MA, in an attempt to link the surface expression of fractures with the hydrogeologic properties of the subsurface. They suggest a series of hydrostructural domains, based on fracture orientation and density, which govern direction and quantity of flow. We present geophysical and hydrologic data collected in fifteen deep (> 100 meters) boreholes in this domain, in conjunction with a series of discrete fracture network (DFN) models that incorporate the field data, to test the structural domain hypothesis, and to quantify the depth and nature of flow in the terrain. DFN models are used to explore the relationship between flow and fracture orientation, employing a simple relationship between fracture aperture and depth.

The field data suggests that most flow occurs in the upper 40 meters of shallow crust, but some flow is found deeper. Field data and DFN models suggest that these fractures are preferably oriented with respect to the assumed local stress field and support the hypothesis that even at shallow depths, permeable fractures are controlled by the local stress state.

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6. Back from the dead? Evaluating in situ microbial treatment to rehabilitate nitrate and chlorinated solvent contaminated bedrock aquifers

Stephen Druschel, Nobis Engineering, Inc./University of New Hampshire

Bedrock aquifers are an important resource for community and individual water supply, generally providing high volume flows that are relatively free of organic and microbial contaminants. However, bedrock aquifers can be severely affected by contamination from nitrates and chlorinated solvents, compounds that have significant human health impacts but that act conservatively in the water column by traveling with little sorption or mineral-derived degradation. While reverse osmosis or ion exchange can remove nitrate from water, and air stripping or activated carbon adsorption can remove chlorinated solvents from water, such treatments are costly, inconvenient and require frequent maintenance; all of which can be substantial burdens to most homeowners or community plant operators.

Fortunately, microbially-mediated treatment (biodegradation) of nitrate and chlorinated solvents in groundwater can occur, under certain conditions, to reduce concentrations and protect human health. A method was developed to discern slow rates of in situ nitrate and chlorinated solvent biodegradation and estimate what is the longest half-life (i.e., the smallest biodegradation rate) that can be predicted for a reasonable incubation period, an acceptable statistical confidence and the fewest replicates when evaluating bedrock aquifer rehabilitation. A factorial experiment method using microcosms was also developed to evaluate potential biostimulants (i.e., organic carbon source, nutrients or vitamins) for optimum biostimulated rehabilitation of bedrock aquifers. The procedures and methods developed in this study substantially enhance the ability to evaluate biotic fate of nitrate and chlorinated solvents in fractured rock aquifers, providing an effective approach for rehabilitation at low to moderate cost.

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7. High spatial resolution mapping of water quality and bathymetry

Rob Ellison, YSI Integrated Systems, Marion, MA

To address the need for higher resolution environmental data within a reasonable cost, YSI, Inc has developed the first autonomous underwater vehicle specifically designed for water quality mapping. The EcoMapper AUV is a person-deployable autonomous vehicle featuring intuitive mission planning software, 12 hour run times with remote RF communication, and the complete on-board water quality sensor suite that samples at a frequency of 1Hz. The result is detailed maps of water quality parameters and bathymetry at a highly resolved spatial scale that does not require a boat and only one technician's time from shore. Water quality parameters include salinity, temperature, depth, pH, dissolved oxygen, turbidity, chlorophyll, blue-green algae and bathymetry. Well suited for difficult to reach or shallow areas, expanding monitoring frequency and spatial resolution, and to 'fill in the gaps' of fixed point monitoring programs. Data will be presented from field trials in freshwater and coastal areas around Massachusetts.

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8. Is precipitation in northern New England becoming more extreme?

Chelsea Fairbank, Environmental, Earth, & Ocean Sciences, University of Massachusetts Boston

In recent years, northern New England has experienced unusually extreme rainfall events, such as the Mother's Day storm of 2006, where some communities received up to 14 inches of rain within 72 hours, and the Patriot's Day storm of 2007. These extreme events produce great material losses, collapse of lifeline infrastructure, and the breakdown of public health services among other things. State and local administrators have an interest in determining the probability and frequency of extreme storm events in order to plan accordingly. One

commonly used publication on extreme rainfall events is Technical Paper 40 (TP-40) published by the National Weather Service. Based on the frequency of recent storms in northern New England, it is increasingly apparent that the estimates of TP-40 are out of date. In order to address this deficiency, we evaluated the statistical characteristics of annual maximum rainfall time series of 58 northern New England stations provided by the National Climatic Data Center.

The data were first reviewed and missing data was filled to the extent possible. To evaluate the presence of trends in the annual maximum time series, linear regression analyses were performed on the entire time series and on the time series from 1970 to present. We found that trends from 1970 to present were in general more statistically significant ($P<0.05$) than that of the entire time series of each station. We also determined that the extreme precipitation events are more likely to occur during August and September (the hurricane season) than between October thru July. In Massachusetts, average extreme rainfall depth from October to July is 2.77 inches, whereas the average from August and September is 3.34 inches. This is consistent with the findings of Zheng et. al (2000). We also performed a factor analysis in order to evaluate the characteristics shared by stations that showed statistically significant trends.

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9. Modeling of the Wachusett Reservoir watersheds, central Massachusetts, for improved watershed management

Erich Fiedler, Paula Rees, and David Reckhow, Civil & Environmental Engineering, University of Massachusetts Amherst

Nutrient, pathogen, and sediment inputs to drinking water reservoirs from point and nonpoint sources are a major concern for watershed managers working to protect public drinking water supplies. Knowledge of the input loads and transport pathways can lead to better watershed management. Accurate quantification of the effects of hydrologic variability and land use change on watershed, river, and reservoir water quantity and quality is of particular importance for long-term management, source water protection, microbial risk assessment, and for the prediction of the effects of climate change on water quality. Watershed modeling, in combination with focused data collection efforts, has the potential to extend our understanding of these dynamics.

During the past five years, UMass has worked on the development of empirical and physically based watershed models of the Wachusett Reservoir watersheds, central Massachusetts. These models are designed for load and hydrologic estimation, and are thus useful for management purposes. The current models simulate daily runoff and load for nine basins and four constituents (nitrate, total phosphorus, total organic carbon, and fecal coliform) based on a daily rainfall trace. Land use effects are accounted for in terms of a curve number, for hydrologic routing, and in terms of calibrated export coefficients, for water quality. Development of basin average rainfall time series based on radar data is planned to further improve subbasin hydrologic estimation capabilities by better accounting for spatial variability.

Results will be presented describing usefulness of the models for setting watershed monitoring schemes. The development and evaluation of monitoring schemes focuses on combining modeling and monitoring to address the following priority questions:

- What is the most appropriate hydrologic data to collect for adequate water quantity characterization?
- Is characterization of water quality in additional hydrologic components (e.g., in ground and soil water in addition to stream water) important for making sound watershed management decisions?
- What range of hydrologic conditions should be sampled for water quality to ensure accurate characterization of seasonal and monthly loads?
- What is the most critical part of a storm event to monitor and what is the most efficient means of capturing this information?

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10. Substituting hazardous DNAPL chemicals for contamination teaching and research: Phase partitioning of ternary mixtures comprising of an alcohol, a substitute DNAPL fluid, and water

Piyush Jain, Chemical Engineering; Kenneth Lee, Civil & Environmental Engineering, University of Massachusetts Lowell

Methoxy-nonafluorobutane (HFE-7100) and Ethoxy-nonafluorobutane (HFE-7200) are dense nonaqueous phase liquids (DNAPLs) engineered by the 3M© corporation for a wide variety of industrial and commercial applications. These chemicals are relatively less hazardous as compared against common DNAPL contaminants such as tetrachloroethylene (PCE) or trichloroethylene (TCE). Therefore, these compounds are ideal substitute DNAPLs for subsurface contamination teaching and research purposes. Depending on the type and composition of the mixture, a ternary system comprising of an alcohol, a DNAPL fluid and water may form a single-phase solution or a two-phase liquid-liquid system. In this study, the equilibrium phase partitioning behavior of each of these two

engineered fluids in an alcohol and water system is experimentally determined. The alcohols used in this study are ethanol, isopropanol, and methanol. The results are presented in ternary phase diagrams and compared against published ternary phase diagrams where PCE or TCE is the DNAPL fluid.

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11. Recent innovations and applications of the Target Fish Community approach: 2000 – 2008

Jeffrey Legros, Natural Resources Conservation, University of Massachusetts Amherst and P. Parasiewicz, Northeast Instream Habitat Program, Mount Holyoke College

Since Bain and Meixler's (2000) inception of the Target Fish Community Approach as a concept, and their initial application of the method as part of an ecohydrology study of the Quinebaug River (Connecticut & Massachusetts), their conception has evolved into an effective and efficient ecological assessment tool which has been applied on multiple rivers throughout Southern New England by various agencies and organizations. The purpose of this presentation is to recognize the importance of this method and describe some of the recent innovations that have served to increase the efficiency, utility and effectiveness of the approach. In outlining the evolution of the approach, from its conceptual inception through its past applications and recent methodological developments, I will illustrate the ability of the approach to be applied to an array of stream macrohabitat types on a regional zoogeographic scale. I will also infer potential implications of such applications as they pertain to fisheries conservation in general, and in particular, to the objectives of the National Fish Habitat Initiative.

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12. Toxicity of carbon nanotubes to the activated sludge process: Protective ability of extracellular polymeric substances

Lauren Luongo and Xiaoqi Zhang, Civil & Environmental Engineering, University of Massachusetts Lowell

Carbon nanotubes (CNTs) are considered a novel material with growing commercial application due to their unique properties. Massachusetts is a leader in nanotechnology growth and production; in 2003 alone, nanotechnology companies in Massachusetts received over 100 million in venture capital investment. With the growing demand of CNT production, concerns regarding the toxicity of CNTs to biological systems arise. The transport of CNTs as a result of manufacturing will lead to their inevitable presence in surface waters and ultimately to a wastewater treatment facility. An understanding to how these materials will impact the microbial community present within these facilities needs to be understood further.

The proposed study will, for the first time, examine the possible toxicity single-walled carbon nanotubes (SWCNTs) incur on the microbial communities present in activated sludge. A comparative study using sheared activated sludge and unsheared activated sludge will be performed to better understand the extent of extracellular polymeric substances (EPS) in protecting the microorganisms from the toxicity of CNTs (if there is any). A significant increase in respiration inhibition and release of EPS with sheared activated sludge will be expected owing to the fact that EPS has been shown to protect bacteria.

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13. Watershed scale modeling of pollution reduction scenarios in the Blackstone River watershed using HSPF

James Mangarillo, Jr. and Paula Rees, Civil & Environmental Engineering, University of Massachusetts Amherst

The reduction of nutrient loads into our streams and rivers has typically been focused on reductions in point source effluent loadings. Little to no concern for the associated costs of continued point source reductions has been shown in recent years.

The purpose of this study is to evaluate, in a cost effective manner, the effects of ongoing and expected point source reductions on the water quality of the Blackstone River in Massachusetts and Rhode Island. Current upgrades taking place at the Upper Blackstone Water Pollution Abatement District are aimed at reducing the total phosphorus effluent concentrations to 0.75 mg/L and the total nitrogen effluent concentrations to 10 mg/L, both on a seasonal basis. Current upgrades are expected to be completed in 2009 at an approximate cost of $130 million. A newly proposed NPDES permit calls for year round effluent reductions to the current upgrade levels while further reducing the TP and TN effluent concentrations to 0.1 and 5 mg/L respectively, on a seasonal basis. The newly proposed estimates are expected to cost an additional $300 million.

Our purpose is to evaluate the improvement in water quality that is expected to be achieved through the current upgrade scenario and compare it to the additional water quality improvement expected under the newly proposed NPDES permit levels. Furthermore, the impacts on water quality of expected changes in land use on nonpoint source loadings into the watershed will be investigated.

Expected changes in the loading of nutrients delivered from the Blackstone into Narragansett Bay under all aforementioned scenarios will also be investigated.

The study utilizes an HSPF hydrologic model developed for the Blackstone River by the USGS. UMass and CDM then added water quality simulation capabilities to the model. Results from the upgrade scenarios on overall loading patterns and in stream concentrations will be presented.

14. Emerging methods to generate hydropower in Massachusetts

Isabelle Montesi, Civil & Environmental Engineering, University of Massachusetts, Lowell

Rainwater captured from the precipitation and accumulation on top of buildings and hydrokinetic energy from Massachusetts oceans was studied as source for renewable electricity. Potential energy from captured stormwater on rooftops of big box-stores and several high-rise structures was evaluated for the generation of electricity. Perpetual motion of the ocean is also studied for the generation of electricity using both tidal flows and waves as identified sources of energy. Both of these sources are untapped and renewable, allowing for future growth thus alleviating current electrical demand.

15. Bayesian network predictions of Enterococcus exceedences at four Boston Harbor beaches

Ann Michelle Morrison, Exponent, Inc., Maynard, MA

Recreational beaches require daily public notification of water quality during the swimming season, but previously collected water samples often provide inaccurate information on current water conditions. Many efforts have been made to model fecal indicator bacteria concentrations using physical, environmental, and meteorological data. We have used a probabilistic approach to modeling Enterococcus concentrations at four Boston Harbor beaches using Bayesian networks. Bayesian networks naturally accommodate missing, irregularly collected, and collinear data that are common problems for fecal indicator regression models. The networks we designed use easily obtained data from the National Weather Service in conjunction with simple parameters measured at, or modeled for, the beaches to predict Enterococcus exceedences. We compare the performances of the Bayesian networks for each beach to alternative management models that use antecedent rainfall or previously sampled Enterococcus concentrations. Beyond the ability of the networks to predict an Enterococcus exceedence with all data known, the networks are able to make predictions about Enterococcus concentrations with minimal known data, which is an advantage for daily predictions that may not have all data parameters available. Bayesian networks are a visual tool that inform decision makers and the public about the inter-connections between variables and how these variables impact Enterococcus exceedences.

16. Where is all that rubber?

Shawn Moynihan, Civil & Environmental Engineering, University of Massachusetts Lowell

Highway runoff is one of the major contributors to the pollution of receiving waters such as rivers, lakes and oceans. This study uses the existing literature and data to estimate the quantity, distribution, and environmental impact of tire debris in the Merrimack River Watershed which is located in central New Hampshire and Northeastern Massachusetts. The Merrimack River has a large population density and highway infrastructure within very close proximity to the river. Many of the communities in this region depend on the Merrimack River for their drinking water. The interactions of a tire-pavement interface are numerous and complex, with many variables such as chemical makeup, speed, tire pressure, friction, driving habits, and road conditions all significantly influencing the wear rates and particulate size generated. Particulate distribution typically occurs via wind transport and surface runoff. The particulate and its chemical components can pose a health threat in quantity.

17. Atlantic salmon microhabitat dynamics in the Westfield River

Thomas Naughton, Jenna Flynn, and Michael Vorwerk, Environmental Science, Westfield State College

The Westfield River includes the southern-most reaches of Atlantic salmon (Salmo salar) habitat. Palpini (2004) showed that main tributaries and branches are too warm for salmon during summer months, especially during warm weather and low flow conditions. However, fisheries experts speculate that salmon are still able to survive these adverse conditions through sanctuary in microhabitats within the river. Russell et. al. (2006) found that there are many natural pools which could function as microhabitats in the river (~20% of linear river habitat). Our preliminary literature review suggests that salmon need temperatures of 15-19°C for

optimal growth. In addition, salmon prefer a pH of approximately 6.7 and dissolved oxygen concentrations of greater than 7.5 mg/l. In our research, we studied the bathymetry and temperature dynamics of one aquatic microhabitat, a 100-meter long pool in the Westfield River. This specific microhabitat provided a large volume of cold (≤17°C) water, creating a suitable habitat for the salmon when main stem river temperatures were detrimental (24°C). We found two explanations for this cold water: stratification of the study pool during low flow (~10cfs) conditions, and a significantly colder (~10°C) groundwater inflow source. Levels of pH and dissolved oxygen concentrations were within optimal ranges for Atlantic salmon. Our findings support the hypothesis that microhabitats provide the physical conditions needed for the survival of Atlantic salmon during adverse summer conditions.

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18. Modeling the effect of leachate transport on regional groundwater chemistry

Nicholas Newcomb, Natural Science, Hampshire College, and Robert Newton, Geology, Smith College

Three municipal landfills exist over the primary recharge area of the Barnes Aquifer which provides several towns in Hampshire and Hampden counties, Massachusetts with drinking water. Existing water chemistry data from wells in the vicinity of the Northampton landfill provide preliminary evidence suggesting that landfill leachate may produce reducing conditions capable of mobilizing iron, manganese, and arsenic constituents from aquifer sediments. The purpose of this study is to construct a groundwater flow model using MODFLOW in order to quantify the extent and concentration of dissolved organic carbon (DOC) present in leachate plumes generated from three landfills and assess the potential effects on municipal water sources. Leachate production was estimated using the EPA Hydrologic Evaluation of Landfill Performance (HELP) model. Contaminant transport was modeled coupling RT3D and MT3DMS. The model was able to accurately predict groundwater head under steady state conditions. Contaminant transport results indicate that a contaminant plume containing high biological oxygen demand (BOD) may produce a geochemical environment capable of mobilizing arsenic, iron and manganese. Model sensitivity analysis demonstrates that the BOD plume is significantly affected by the quantity of leachate and concentration of DOC. In conservative estimates, the contaminant transport model illustrates that mobilized arsenic, manganese, and iron reach a high yield municipal well.

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19. Impacts of coal liquefaction on water resources

Ryan Niles, Environmental Studies, University of Massachusetts Lowell

Due to the increased cost and scarcity of petroleum, the United States is searching for other dependable alternative energy sources to supply its energy demand. One such abundant energy source is coal. Based on extensive estimated coal reserves, an unending demand for liquid fuel, and concerns over foreign energy sources, coal liquefaction promises to become of greater importance to satisfy American fuel demand. Coal liquefaction is an intense thermo-chemical process that converts solid coal to liquid fuel. This coal-derived liquid fuel can be used to alleviate US demand for gasoline; however, environmental and water impacts from the process are relatively unknown. This research studies the potential environmental and water impacts of the coal liquefaction process, which generates hazardous byproducts such as mercury and sulfur.

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20. Simple hydraulic structures to alleviate flooding in a Peruvian village

Kelly Oslin, Civil & Environmental Engineering, University of Massachusetts Lowell

Simple hydraulic structures were investigated for the purpose of flood control in the Ancash region of Peru to reduce the vulnerability of an agrarian population from displacement. The benefits of man-made flood control are that they help to keep the river or waterway contained within a specified area so as to ensure the safety and functionality of homes and livelihoods located nearby. Reforestation and the construction of simple levees, dams, reservoirs, diversions and floodways were investigated as viable methods for flood control. The possibility for multipurpose use of harvested flood and rainwater for supplemental irrigation was also considered.

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21. Substituting hazardous DNAPL chemicals for contamination teaching and research: Viscosity of mixtures comprising of an alcohol and a substitute DNAPL fluid

Neil Pietrantonio, Chemical Engineering, and Kenneth Lee, Civil & Environmental Engineering, University of Massachusetts Lowell

In this study, viscosity variations of binary mixtures comprising of an alcohol and a 3M© Novec™ engineered fluid are experimentally determined. The engineered fluids used are the HFE-7100 and HFE-7200 fluids. These two engineered

fluids are considered dense nonaqueous phase liquids (DNAPLs), because they are immiscible with water and have a specific gravity greater than one. These two engineered fluids are relatively less hazardous and environmentally-friendlier than common DNAPL contaminants such as tetrachloroethylene (PCE) or trichloroethylene (TCE). Thus these engineered fluids are ideal substitute DNAPLs for laboratory subsurface contamination teaching and research applications. Alcohols can be used as a cosolvent in remediation of DNAPL contaminants. Therefore, understanding the viscosity variations of an alcohol-DNAPL mixture is important in predicting the movement of the mixture in the subsurface. The alcohols considered in this study are ethanol, isopropanol, and methanol.

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22. A novel approach to empirically describe the binodal curve on a cosolvent-NAPL-water ternary phase diagram

Shruthi Rajegowda and Kenneth Lee, Civil & Environmental Engineering, University of Massachusetts Lowell

A novel approach to empirically describe the binodal curve on a three component, cosolvent-NAPL-water ternary phase diagram is presented. The approach utilizes a regression curve based on a Weibull distribution model to mimic the binodal curve. The approach involves transforming the experimental phase partitioning data points of each ternary mixture from the ternary phase diagram to equivalent Cartesian coordinates. The regression curve is then generated, and the regression curve becomes the Weibull-derived binodal curve by superimposing the regression curve onto the original ternary phase diagram. Based on availability of experimental data, several regression curves are generated and presented. The approach presented in this research allows researchers to empirically describe a binodal curve, which is useful in analyzing and predicting the various phase partitioning scenarios of a cosolvent-NAPL-water system.

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23. Suburbanization and residential water demand: Case study of Ipswich, MA

Nagraj Rao, Economics, Clark University

Despite a relatively high average annual rainfall, many suburban communities in northeastern Massachusetts disconnected from Boston's water supply system continue to experience water shortages in the summer. One hypothesis for explaining these water shortages is the sprawl-like development pattern, typical of suburban Massachusetts. In these areas, residences are built on large lots with a significant portion devoted to well-manicured lawns, resulting in excessive lawn irrigation and increased water consumption. The purpose of this study is to analyze the factors affecting summer residential water consumption for Ipswich, Massachusetts using a spatial econometric model. The novelty of this project lies in the inclusion of spatial variables, such as lawn area, that are acquired from a sub-1 meter land cover classification map.

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24. Geochemical linkages between increasing rural development and elevated manganese levels in domestic wells in fractured crystalline bedrock

Gary Robbins, Kynoch Reale-Munroe, Natural Resources Management & Engineering, University of Connecticut; Jonathan Goldman, Conn. Department of Environmental Protection

High density developments of single family homes are being constructed in rural parts of Connecticut having individual bedrock wells for their water supply. The Connecticut Department of Environmental Protection (DEP) has identified developments in 34 towns in metamorphic highland areas where concentrations of dissolved manganese in bedrock wells exceed the State of Connecticut Department of Public Health's drinking water action level of 0.5 mg/l. In these cases, the DEP can provide water filtration systems but only at a substantial cost. In some cases, pre-existing homes, which had not experienced anomalous manganese levels, began to exhibit high levels following nearby development. Manganese is a neurotoxin and nuisance for clothes and fixtures. This on-going study is directed at evaluating the underlying geochemical linkages, if any, between the high levels of manganese and increasing rural development. To evaluate background levels, a GIS based study was conducted using water quality data from over 1,200 wells sampled during National Uranium Resource Evaluation project of the late 70s. The mean manganese level was about 0.1 mg/l, with the highest level being less than 1 mg/l. This mean value is similar to that observed in bedrock groundwater studies conducted in other New England states and clearly reinforces the anomalous nature of the high manganese levels found at new developments. Based on manganese geochemistry and its abundance in rocks and soils in the State, the high concentrations observed might be attributed to changes in subsurface geochemical conditions (lowering of pH or Eh), which are conducive to the dissolution of manganese oxide from soils and rock surfaces. These conditions

can potentially result from bedrock exposure, burial of rock or vegetation in the soil during site development, septic and lawn start-up or blasting. They may also be related to construction on pyrite bearing formations.

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25. Alternate models for representing the hydrodynamics of Thomas Basin in Wachusett Reservoir

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Generalized Environmental Modeling System for Surfacewaters (GEMSS) commercial software was used to model the hydrodynamics of the Thomas Basin in Wachusett Reservoir. Wachusett Reservoir, located in Worcester, MA, serves as a major contributor to the drinking water supply of eastern Massachusetts, including the City of Boston.

GEMSS is distributed by ERM, Inc, as a modeling package which includes water quality and particle transport modules. The hydrodynamic code solves equations in three dimensions, developed from horizontal momentum balance, continuity, constituent transport, and the equation of state. The hydrodynamic relationships are integrated numerically and implicitly forward in time. Density is dependent of salinity and constituent concentrations. Turbulence is incorporated through the 0-equation, which was chosen for computational efficiency.

Four curvilinear grids of increasing resolution were generated from bathymetric data gathered by the U.S. Geological Survey (USGS) in 1907 before the reservoir was inundated. The grid sizes varied from 4,000 to 300,000 cells. Each of these grids was analyzed under isotropic and no wind conditions. Velocity fields and flow balances were compared between the grids in order to determine which grid resolution would best fit for future modeling studies, such as particle transport within the Basin.

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26. Enhancing the bacterial source-tracking toolkit: A collaborative approach

Jason Sorenson and Marcus Waldron, MA-RI Water Science Center, U.S. Geological Survey; Rueyjing Tang, Ronnie Stoner, and Oscar Pancorbo, Wall Experiment Station, Massachusetts Dept. of Environmental Protection; William Dunn, Christine Duerring, Michael DiBara, Richard Chase, and Joanne Beskenis, Division of Watershed Management, Mass. Dept. of Environmental Protection

A collaborative study evaluated and compared relatively simple and inexpensive field and laboratory techniques with more traditionally accepted and cost-prohibitive methods to determine if representative sampling and analysis could be performed more cost-effectively. Dry- and wet-weather samples were collected in the Shawsheen River Basin in eastern Massachusetts as part of a larger bacterial source tracking effort designed to improve the detection and identify sources of sewage contamination. Analyses of microbiological and chemical constituents in surface-water samples collected using passive "first-flush" surface-water samplers compared favorably with traditional and automated grab sampling, showing that relatively inexpensive passive samplers could be used to collect representative samples. Traditional and cost-effective analyses of some microbiological and chemical constituents were also compared and evaluated as tools for identifying human/sewage sources of bacterial contamination. Bacterial counts obtained by traditionally accepted membrane filtration and the newer EPA-approved most probable number (MPN; IDEXX Quanti-Tray) techniques were shown to be in fair agreement for E. coli (Kendall-Tau correlation = 0.726; $p < 0.01$; $n = 92$), but inconsistent for Enterococcus spp. (Kendall-Tau correlation = 0.809; $p < 0.01$; $n = 93$). Relatively inexpensive lab and field fluorometry and more complex and expensive solid-phase extraction (SPE) high-performance liquid chromatography methods were used to detect fluorescent whitening agents and optical brighteners. Surface water and blind challenge samples were also analyzed for two Polymerase Chain Reaction genetic marker assays, and analysis for caffeine using optimized SPE capillary gas chromatography-mass spectrometry. Detections of the putative human genetic markers in Bacteroidetes spp. and Enterococcus faecium in blind challenge samples were respectively 80 and 100 percent effective at distinguishing human from non-human sources of bacterial contamination. Analytical results and subsequent evaluations were used to support the development of a preliminary decision-making protocol to determine human/sewage sources at bacterially contaminated sites.

27. Linking advection, temperature, and wind in a spill study for the Wachusett Reservoir

Christina Stauber, John Tobiason, Mary Serdakowski, and David Ahlfeld, Civil & Environmental Engineering, University of Massachusetts Amherst

The 62 billion gallon Wachusett Reservoir, in Central Massachusetts, supplies drinking water to the Boston Massachusetts Metropolitan area. DCR and MWRA, responsible for reservoir operations and management, are concerned with possible contaminant spills from nearby roadways and rail line, and the impact a spill would have on water quality and operations management decisions.

CE QUAL W2 is a two dimensional laterally averaged hydrodynamic and water quality model. Version 3.5 of the model is used in this research to simulate contaminant spills into Wachusett Reservoir. The complex response of the reservoir to a pollutant spill was investigated by modeling contaminant concentrations as a function of time at the reservoir outflow (Cosgrove intake), along with velocity and concentration profiles throughout the reservoir.

Model results show that time of year (mixed versus stratified conditions), and the depth of the spill in the reservoir (surface spill or below surface) are factors that have the most significant effect on contaminant concentration at the outflow. Spills travel through the reservoir most quickly in the spring, when the reservoir is fully mixed and water surface velocities are high. During the fall season, the spill resembles a spring spill, but arrives more slowly due to lower reservoir velocities and different wind directions. A spill modeled in the summer, when the reservoir is stratified and the Quabbin transfer is flowing, has a delayed arrival time and a variable concentration at the outflow. A spill that is dense enough to sink to the elevation of the Quabbin transfer (10 meters below surface) can be delayed from reaching the outflow by decreasing the flow of the transfer. A surface spill is primarily affected by wind and surface velocity.

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28. Surface and groundwater contamination from the release of brake dust in automobiles

Hoilai Tseung and Katie Weaver, Civil & Environmental Engineering, University of Massachusetts Lowell

Surface water and groundwater contamination from brake dust is of increasing concern in today's car-dependent society. Brake dust contains hazardous materials, such as heavy metals, that can be transported into surface water and/or groundwater, affecting water quality. The objective of this presentation is to provide an overview of this emerging problem from an environmental engineering perspective, and to determine the implications as well as possible solutions to this problem. Various brake pad materials were evaluated for their hazardous properties. Possible routes of surface and groundwater contamination were identified and a summary of the human health effects of various brake dust compounds in the water supply are presented. Finally, we have evaluated possible remediation techniques that can be used to remove brake dust in both surface water and groundwater systems.

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29. Pharmaceutical compounds in aquatic environments: Fate and potential adverse effects in the Merrimack River watershed

Andrew Wadden, Lauren Luongo, and Kenneth Lee, Civil & Environmental Engineering, University of Massachusetts Lowell

Traces of pharmaceutical compounds in waterways have led to increased concern in the last decade. Potential harm to aquatic environments has provided researchers with the motivation to research pharmaceuticals' fate in waterways and wastewater. Disposal of expired or unwanted pharmaceuticals from domestic households and manufacturing of pharmaceuticals for distribution are the primary pathways into waterways. Recent research has revealed possible adverse effects to aquatic organisms as a result of wasted, un-metabolized drugs that are not removed in wastewater treatment facilities and ultimately pass into rivers and other waterways. Residuals of pharmaceuticals and un-metabolized to partially metabolized pharmaceuticals in soils and sediments have also received attention in recent years. The main concern of researchers today regarding pharmaceuticals' presence in waterways is not their initial input, which is known to be low; but their potential accumulation over years into much larger concentrations. The focus of our study is to use statistical data to determine pharmaceutical input from industrial and household sources in a portion of the Merrimack River Watershed in order to determine the fate, transport and adverse ecological effects in this area of southern New Hampshire and northeastern Massachusetts. Disposal and handling regulations from each of these pharmaceutical companies is also investigated.

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30. Effect of stand characteristics on precipitation throughfall in a New England forest

Alex Webster, Biology; Andrew Guswa, Picker Engineering Program; and Virginia Hayssen, Biology; Smith College

The interception of rainfall by the forest canopy has a major effect on forest ecosystems, accounting for the loss of significant percentages of precipitation and affecting throughfall distribution on the forest floor. Spatial and temporal variability of throughfall is an important control on many aspects of forest ecology, including the distribution of soil moisture, nutrients, microbial activity, and root growth, and processes of erosion and pedogenesis. Many studies have found vegetation properties to influence throughfall patterns, suggesting that the effects of throughfall will differ among distinct forests and distinct stands within a forest. The complexities of these interactions have proven such that on-site pilot studies remain the best way to understand throughfall patterns in any given forest.

This study examined the effect of forest stand characteristics on spatial and temporal variability of throughfall within a New England forest in Whately, MA. Three stands were characterized by overstory tree species, stand development, and vertical and horizontal structures. Throughfall was collected in fixed grids of 25 collectors for 8 multi-event periods in October and November 2007. Data were compared within and among stands, seasons, and storm magnitudes. Gross precipitation, stand type, and the canopy cover associated with each collection point, were strong predictors of throughfall depth ($p<0.001$, R-sq=91.3%). Distance from stem, contribution of extremely wet and dry points, and meterological variables were also important. Throughfall distribution patterns were highly variable through space and time, but exhibited some consistencies within stand types and rainfall magnitudes, and a strong correlation with canopy cover ($p<0.001$, R^2=58.4%). In addition to providing insight into the complexities of throughfall distribution, this is an important early investigation into the hydrology of Smith's property in Whately for use in further scientific research.

Thank you and join us for the Sixth Annual Water Resources Research Conference next year, Wednesday April 8, 2009 here at UMass Amherst!

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Geosciences Dept. 2008 Birdsall-Dreiss Distinguished Lecturer

Room 163 - 5 – 6 pm

Cracks in the clay: The role of fractures and macropores in critical zone hydrology

Larry McKay, Jones Professor of Hydrogeology in the Department of Earth and Planetary Sciences at the University of Tennessee

Fine-grained geologic deposits often contain extensive networks of fractures, root holes and other macropores which can strongly influence groundwater flow and contaminant transport. The extent and depth of these features vary greatly according to the origin and geologic/pedologic history of the material. Rootholes typically persist to depths of only a few meters, although in some clays they can be found at much greater depths. Desiccation fractures, which are common in glaciolacustrine deposits, also tend to rapidly decrease with depth, but fractures caused by sub-glacial stresses may be pervasive throughout thick till sequences. Recent research in weathered clay-rich residuum developed on sedimentary rocks in east Tennessee shows evidence of fractures and fracture-induced flow to depths of up to 40 m. Fractures and macropores can also act as pathways for transport of natural and anthropogenic constituents to underlying aquifers. Solutes are transported by advection along the fractures/macropores but can also be strongly attenuated by diffusion into the fine pore structure. In contrast, mineral colloids and microorganisms are largely size-excluded from the fine-pore structure and hence can travel at much faster rates than solutes. Field tracer experiments in fractured clays in Canada, Denmark and Tennessee showed colloid transport rates of a few m/day to >100 m/day at sites where solute tracers were transported at rates that were 100s of times slower. Immiscible phase liquids, such as industrial solvents or coal tar, can enter some fractures or macropores, even in relatively low hydraulic conductivity materials and can lead to extensive contamination. These immiscible liquids dissolve and diffuse into the fine pore structure, where they can act as long term sources of contamination to adjoining streams or underlying aquifers. Although there has been substantial progress over the past 25 years in developing a better understanding of the role of fractures in controlling flow and transport in clay-rich deposits, considerable work remains to be done. This includes better education of geo-environmental researchers and professionals, as well as development of better conceptual and numerical models of fracture origin, vadose and saturated zone flow, and contaminant transport.

The lecture tour is sponsored by the Geological Society of America Hydrogeology Division with travel funding provided by the GSA Foundation and The University of Tennessee

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Posters, Exhibits and Refreshments
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Numbers refer to poster numbers (see abstracts on pages 23-33)