EPA’s Approach to Water Quality and Watershed Policy: New Directions and Programs
David Webster, EPA New England

In a December 2002 memo committing EPA’s Water Program to advancing the watershed approach, Assistant Administrator G. Tracy Mehan III stated: "We face many complex and challenging environmental problems related to the water environment. Unlike the problems of the past, today’s problems are often subtle, chronic, and inter-related. Addressing 21st century problems such as polluted runoff, suburban growth, drinking water security, ground water/surface water interactions, invasive species, microbes in drinking water, and atmospheric deposition demands a modern approach to environmental protection - an approach grounded in sound science, innovative solutions, and broad public involvement." EPA New England’s approach to watershed policy and protecting water quality in our region will be discussed with a particular focus on new directions and program emphases in these areas.

Developing Massachusetts Water Policy
Karl Honkonen, Massachusetts Executive Office of Environmental Affairs

The presentation will discuss how the following topics will be integrated: (1) Statewide Water Policy - how will EOEA and its agencies devise new policy in the current Administration; (2) Water Assets - this project focuses on water resources found within 131 Massachusetts towns around I-495; (3) Instream Flow - what is being done to determine flows needed to sustain stream flow, water quantity, and quality, Watershed Planning - using the watershed approach to determine environmental priorities.

Raising Watershed Awareness through Education and Recreation
Dave Small, Millers River Watershed Council

For the past decade and more, government agencies and NGOs around the country have been engaged in various versions of the "watershed approach". These efforts have produced innovative collaborations and creative strategies on a number of watershed issues, and have advanced the use of sound science in environmental decision making at all levels. However, progress towards the most fundamental goal of the watershed approach is less certain: are we strengthening the relationship between the individual and the watershed?

There are disturbing trends in the opposite direction - as personal schedules get busier and access to dwindling open spaces decreases, direct experiences in nature often decrease as well. When decisions must be made and efforts expended to preserve our watershed resources, do we, as individuals, and as a society, care deeply enough about the environment to make good use of our science and our collaborations? The presentation will discuss educational programs, web sites, and other strategies to instill watershed stewardship by engaging people in activities that encourage them to explore their watersheds in an entertaining and enlightening way.

Microbial Source Tracking - An Overview
Sharon Long, Dept. of Civil and Environmental Engineering, University of Massachusetts Amherst

With ever increasingly specific and sensitive diagnostic methods for infectious diseases, it has become recognized that different sources of microbial inputs/contamination to drinking waters are related to different potentials for the presence of pathogenic microorganisms. Coupled with the renewed emphasis on source water protection and watershed management under the Surface Water Treatment Rule and the Long Term 2 Enhanced Surface Water Treatment Rule, many drinking water utilities may be looking towards tools that allow them to discriminate among potential microbial contamination sources in their watersheds. The use of microbial source tracking (MST) tools can also provide a utility with information so that corrective actions can be applied in a more effective and cost-efficient manner.

Even though research into MST methods has spanned several decades, there is no consensus on the best or most reliable method to date. Application of MST tools within a source water protection plan depends on the goals and questions asked by the plan. Two general microbial indicator approaches to MST methods have been studied: the species-specific approach and the organism-specific approach. The species-specific approach looks to quantify microbial indicators associated with a specific "species" of
contamination such as human or non-human. The organism-specific approach looks at a single organism such as \textit{E. coli} and relates subtypes to the various hosts (human and different animal species). The organism-specific approach typically involves development of a geographically relevant library or database of isolates against which unknowns are compared. A third MST approach is to look for chemical markers indicative of sewage or human-related wastewater. This presentation will provide an overview of the methods currently being researched and applied. The information provided will include the state of development of each method, some of the strengths and limitations of each method, and the investment in training and equipment needed should a utility decide they want to implement such a method.

**Source Tracking Studies in the New York City Watersheds**

Kerri Ann Alderisio, New York City Dept. of Environmental Protection, Bureau of Water Supply, Division of Drinking Water Quality Control

In 1990, the New York City Department of Environmental Protection (DEP) began investigating a seasonal increase in the fecal coliform concentrations in Kensico Reservoir, Valhalla, New York. This location is significant since Kensico Reservoir is the last storage reservoir prior to chlorination for approximately 80-90% of the drinking water that is delivered to nine million New York City residents daily. This study, coupled with the new coliform regulations mandated by the Surface Water Treatment Rule (SWTR), required a new approach for the way DEP microbiologists would respond to all future investigations. The DEP formed a Research Microbiology Unit that would work with the routine microbiology staff to provide more in-depth investigations into unusual occurrences in the upstate watershed. The main function of this group has been to determine if fecal contamination, as suggested by microbial indicator analyses, is coming from human or non-human sources. This approach has helped to narrow down sources of fecal input in the watershed, and allowed preventative measures to be taken to greatly reduce or eliminate further contamination. In addition, the specificity of some of this work has also helped to assess the human infective potential of samples in some situations. This has been of great value when determining potential health risks to consumers.

The routine microbial indicators used by the Department have been total coliform, fecal coliform, \textit{Escherichia coli}, \textit{Giardia} spp. and \textit{Cryptosporidium} spp. Follow up analysis used to narrow down sources of fecal contamination have included: fecal streptococci, enterococci, FC:FS ratios, serotyping, electrophoretic typing, \textsc{f}-specific RNA coliphage typing, Ribotyping (RT), Small Sub-Unit (SSU) rRNA based Polymerase Chain Reaction (PCR), Restriction Fragment Length Polymorphism (RFLP) and gene sequencing. The level of confidence associated with each of these techniques is unique to each investigation and has also been dependent upon other water quality data and supplemental information provided. In studies where multiple techniques have been applied, and have been in agreement, the confidence in the conclusion has been greatly increased. Some of these techniques have not performed as well as others, and some have only appeared to be of benefit when used in combination with other techniques. Each investigation has been somewhat distinctive and has required a certain method, or combination of techniques, to reach a result. Conversely, there have been times when applied methods have not been helpful in making a source determination and no conclusions could be made. Consequently, the DEP continues to investigate and develop methods to become part of its “microbial toolbox”, and there are continued plans for future work in the science of source tracking.

**Microbial Source Tracking Panel Discussion**

Patricia Austin, Massachusetts Dept. of Conservation and Recreation - Source Water Protection; Oscar Pancorbo, Massachusetts Dept. of Environmental Protection; and Stephen Jones, University of New Hampshire

Each of the panel members has experience with implementing Microbial Source Tracking (MST) methods within their respective programs. The Panel members will discuss briefly the MST efforts that they are familiar with and elaborate on the practical issues of incorporating the specific method(s) they are familiar with into watershed protection plans and microbial contamination studies. The panel format was chosen to encourage audience members to ask questions of the expert panel members who can share their experiences on MST methods. It is hoped that the discussion can provide some insights into this complex topic.

**Session 3A: Impacts of Climate Change on Water Resources**

Chair: David Ahlfeld

A Perspective on Recent Climate Change

Raymond S. Bradley, Dept. of GeoSciences, University of Massachusetts Amherst
There are 6.3 billion people on earth today and world population is likely to reach 9 billion within the lifetime of today’s graduate students. With this rise in humankind, our impact on the planet has risen to the global scale and we have entered uncharted waters in terms of how climate and the environments that sustain life on earth will respond to the changes being imposed on them. Here, we consider the evidence for how climate has changed in the past, and various models of how it may vary in the future.

**Climate Change and New England Water Resources**

S. Lawrence Dingman, Dept. of Earth Sciences, University of New Hampshire

Hydrology is embedded in climate. The water potentially available for human use and management, \( Q \), is determined as the difference between long-term average precipitation, \( P \), and evapotranspiration, \( E \): 

\[
Q = P - E = 41 \text{ inches/yr (New England averages)}.
\]

\( P \) is obviously a central component of climate, and \( E \) is largely determined by climatic factors, especially temperature, humidity, wind, and the timing of precipitation inputs. The presentation will include a review of recent literature leading to an assessment of predicted and observed changes in aspects of New England hydroclimate as a result of projected global climate change.

New England has experienced severe droughts approximately once per decade since the late 1800s, the most severe and extensive of which was the drought of the 1960s. This drought and monthly and winter streamflows generally are correlated with the North Atlantic Oscillation (NAO), especially at decadal scales; but there is no correlation between NAO and precipitation. Winter streamflows are correlated with the Pacific North American pattern (PNA). There is no consistent correlation of New England hydroclimate and the El Nino-Southern Oscillation phenomenon.

Human population growth in New England has been accompanied by activities that have strong effects on the region’s hydrology, including land-cover changes (afforestation-deforestation, urbanization), inter-basin transfers of water (especially the Boston system), construction of dams, and withdrawals from surface and ground water. In general, these non-climatic factors are more profound and predictable than those that may accompany anthropogenically-induced climate change, at least in the short- to medium-term.

Support of government programs that monitor hydroclimate, especially those of NOAA and the U.S. Geological Survey, is essential for understanding and responding to non-climatic and climatic changes that affect the region’s water resources.

**Importance of State and Local Policy Efforts in Addressing Climate Change**

William R. Moomaw, The Fletcher School, Tufts University

Abstract not available by press time.

**Session 1B: GIS and Watershed Models**

Room 162 • 1:15-2:45 pm • Chair: Richard Taupier

**Landscape Ecology for Watersheds**

Jack Ahern and Andre B. Leitao, Dept. of Landscape Architecture and Regional Planning, University of Massachusetts Amherst and Inst. Superior Technico, Lisbon, Portugal

Landscape ecology is a transdisciplinary field that provides a useful theoretical and operational approach for watershed planning. Landscape ecology is primarily concerned with the interaction of landscape elements, in space and time, over broad geographical areas such as watersheds. The issues that landscape ecology is well suited to address include: land use change analysis, biodiversity assessment and planning, and water resource planning and management. This session will provide a brief overview of some key concepts and tools from landscape ecology, particularly landscape metrics. We will offer recommendations and review planning applications that address: (1) the challenge to integrate multiple land uses and functions in a given area (i.e., a watershed), (2) the identification of useful thresholds for monitoring and modeling landscape functions (e.g., biodiversity, water quality), (3) understanding the interactions between the visible and invisible (subsurface) components of landscapes, and (4) the basis for an adaptive approach to address uncertainty and change in landscape planning.

**MDCR Water Assets Study**

Sara Cohen, Massachusetts Dept. of Conservation and Recreation

The Water Assets Study currently underway at the Executive Office of Environmental Affairs will provide an assessment of current and potential water supply resources and current and potential water demands in 131 communities along the I-495 Beltway, the highest growth area of the Commonwealth. The objective is to promote proactive planning and protection of critical water resources.
supplies and essential ecosystem functions. The project will develop information on a community and watershed basis to highlight infrastructure and regulatory capacity of supplies, local service areas, conservation efforts, regional trends, priority assets, and unprotected land that may be significant to existing or potential supplies. The work will be aimed at helping communities understand the role of demand management, proactive land protection in meeting existing and future needs, and helping the State characterize local service areas and assess regional water supply infrastructure. The presentation will briefly review the background for the project, and provide a technical overview of the analysis and mapping.

Watershed-Scale Assessment of Environmental Impacts and Hazards of Dams
Karen Pelto, Riverways, Massachusetts Dept. of Fish and Game

The Department is developing a watershed-scale, GIS-based analytical framework and rating system to (1) assess the environmental impact of dams on wetland and aquatic resources, and (2) characterize the environmental hazard to wetland and aquatic resources from the uncontrolled breach or failure of dams. This system will help focus scarce public dollars on necessary environmental restoration projects through appropriate dam repair or removal. Currently, dam safety hazard ratings focus on damages to people and property. However, there is considerable potential for environmental damages if a dam failure were to release or mobilize contaminants from the sediments or from sources in the inundation zone. In addition, the many impacts that dams have on wetland and aquatic systems have prompted resource agencies to consider removal or breaching of dams in order to restore these impacted systems. Assessment techniques underway consider fragmentation and habitat alteration caused by dams through metrics such as: the length and type of stream habitat above a dam; the area of wetland and length of stream inundated by the impoundment; an estimate of the change in hydrologic residence time or the ratio of the size of the impoundment to stream discharge; and consideration of flow alterations based on the operation of the dam (e.g. flood control, hydropower). These metrics have been applied in multiple watersheds to begin to account for the environmental impacts and hazards of the more than 3,000 dams in Massachusetts.

Session 2B: Pollutant Loading and Source Tracking – Section II
the constituents to be measured. In particular, correlations of the resulting data with meteorological and hydrologic conditions will be explored to determine if an optimum time for sample collection can be identified.

**Use of Artificial Neural Networks for Modeling Indicator Organisms in a Watershed**

Diane Mas and David Ahlfeld, Dept. of Civil and Environmental Engineering, University of Massachusetts Amherst

Forecasting stream water quality is important for numerous aspects of resource protection and management. Fecal coliform is one of the primary indicator organisms used to assess potential pathogen contamination in drinking water supplies. Consequently, modeling the occurrence and concentration of fecal coliform is an important tool in watershed management. While many process-based, statistical, and empirical models exist for water quality prediction, artificial neural network (ANN) models are increasingly being used for forecasting of water resources variables because ANNs are often capable of modeling complex systems for which behavioral rules are either unknown or difficult to simulate.

This research presents the preliminary results of an ANN model developed to predict fecal coliform concentrations in a tributary to the Wachusett Reservoir, which supplies drinking water to the metro Boston area. The model was developed using water quality parameters easily and rapidly measured in the field and standard meteorological data. In addition to assessing model performance, the effect of input data selection and preparation and ANN model architecture on model performance is assessed.

**Use of Remotely Sensed Data in Monitoring Water Quality in Lake George, New York**


Lake George is one of the few remaining places where inhabitants regularly consume unfiltered lake water. Institute researchers monitor Lake George and other regional lakes to determine short-term and long-term effects of human activity, biological and chemical contamination, acid deposition, and other disturbances. For example, researchers monitor the effects of development and the extent of human activities on Lake George, mainly through funds provided by the Fund for Lake George, a private foundation. Lake monitoring research has included studies of phosphorus dynamics, general chemical limnology, contamination by coliform bacteria, and invasion by exotic aquatic vegetation.

A recent study was performed to assess water quality in the lake using subpixel photobathymetry and water quality mapping software referred to as QSC2 (Quantitative Shoreline Characterization, Version 2.0). The study investigated the performance of QSC2 with processing results from two Landsat Thematic Mapper images (TM 4/5, August 1993 and TM 7, August 2002). The processing results demonstrate that QSC2 software was able to effectively extract depth, suspended chlorophyll, suspended minerals, colored dissolved organic carbon, and water clarity information from the satellite imagery. TSI was also calculated based on processed results. Results indicate that the lake is moving from oligotrophic to mesotrophic and correspond well to TSI measurements collected using traditional monitoring methods. The processing was fully automatic, requiring no ground truth or other ancillary information about the scene. A prime benefit of the output is the wide-area three-dimensional synoptic view of the parameters it provides.

**Session 3B: Natural and Anthropogenic Influences on Water Chemistry — Section I**

**Room 174 • 1:15-2:45 pm • Chair: Richard Yuretich**

**Field-Flow Fractionation-Inductively Coupled Plasma-Mass Spectrometry: A Versatile Approach for Size-Based Speciation and Identification of Trace Metals Complexed to Aqueous Natural Organic Matter and Humic Substances**

Dula Amarasiriwardena, School of Natural Science, Hampshire College, Atitaya Siripinyanond, and Ramon Barnes, Dept. of Chemistry, University of Massachusetts Amherst

Natural organic matter (NOM) and aquatic humic substances are polydisperse mixtures of highly complexed polyelectrolytic organic macromolecules. They perform an important role in mobilization of aquatic trace elements of environmental and biological significance (McCalady and Ranville, 1998). The acidic functional groups like carboxylic groups facilitate the acid-base buffering while ubiquitous ligands in NOM readily complex with trace metal cations. Size based information on trace metal bound to aqueous NOM and humic substances are vital to understanding of the mobility of these molecules in aqueous and soil environments. Flow field-flow fractionation (flow-FFF) is a relatively mild size fractionation approach based on diffusion properties of the colloidal macromolecules like humic substances (Becket et. al, 1987). The coupling of a sensitive elemental detector like inductively...
coupled plasma-mass spectrometer to flow FFF effluent can facilitate the identification of trace metals complexed to these separated size fractions (Amarasiriwardena et. al., 2001). Application of flow-FFF-ICP-MS for the investigation of trace metal complexed to different stages of municipal wastewater treatment process, river sediments and soil humic substances will be presented. In addition to the size-based chemical information obtained from flow FFF-ICP-MS, the physical properties like hydrodynamic particle diameters, molar masses, and diffusion parameters that are important for the investigation of environmental behavior of these aquatic colloids will be discussed.

Efficacy of Wood Fibers for Removal of Pollutants from Roadways
Tom Boving, Dept. of GeoSciences, University of Rhode Island

Roadway runoff derived polynuclear aromatic hydrocarbons (PAHs) impact the quality of surface and ground water. Inexpensive aspen wood fibers have been investigated as a means to remove dissolved PAH under laboratory conditions. Our isotherm experiments demonstrated that the uptake of naphthalene, fluorene, anthracene, and pyrene required up to 12.5 days to reach equilibrium. Aspen wood-water sorption coefficients, $K_{\text{sol}}$, were linearly correlated to octanol-water partition coefficients and the molecular weight of the studied PAH compounds. Column experiments were carried out to study the sorption and desorption of fluorene, anthracene, and pyrene under dynamic conditions. The results indicate linear sorption, but non-linear desorption behavior. The degree of desorption was inversely correlated to a compound’s hydrophobicity. Flow interruption experiments showed that sorption and desorption was rate limited. A mass balance of the sorption and desorption tests indicated that sorptive uptake exceeded desorptive release over a given number of pore volumes. Further, absolute mass-removal efficiency increased with the molecular weight and hydrophobicity of the PAH compound. Batch and column studies demonstrated that aspen wood has the potential to become an effective remedial agent for PAH in stormwater runoff or other PAH contaminated waters.

Potential Movement of Pesticides Related to Dissolved Organic Matter from Fertilizer Application on Turf
Kun Li and Baoshan Xing, Dept. of Plant and Soil Sciences, University of Massachusetts Amherst

Turf grass systems - including golf courses, turf farms, parks and lawns - are the most intensively managed lands in the United States. Establishment and maintenance of high quality turf grass usually imply substantial inputs of water, nutrients, and pesticides. The impacts of these inputs to groundwater and surface water are a major concern of public and government agencies with over 17,816 golf courses in the U.S. and more than one new golf course opening every day (National Golf Foundation, 2002). Recent results from various facets of agricultural research have indicated very significant effects of dissolved organic matter (DOM) on increased mobility of pesticides through soils to groundwater. These findings may have important ramifications to the golf turf industry in that the frequent use of certain organic fertilizers and amendments may actually enhance rather than inhibit movement of certain pesticides through highly managed greens and tee areas having a high level of sand incorporated into profiles. This is not only a regional, but also a national problem. The Northeast is more susceptible due to the coarse texture of soils in general.

There is a significant amount of research devoted to the efficacy of organic fertilizers currently on the market such as NatureSafe, Milorganite, Sustain and Ringers, some containing as much as 3.5 % DOM (water extraction). Organic fertilizers are considered slow release materials with low burn potential and are often applied at higher rates compared with soluble inorganic fertilizers. Higher application rates could easily result in higher loading of DOM into soil profiles. In addition, high density and much more root turnover in turf grass ecosystems could directly contribute to the pool of natural DOM, which could affect the behavior of pesticides in soil and water.

Session 1C: Sustainability of the Connecticut River Watershed
Room 162 • 3:00-4:30 pm • Chair: Marie-Françoise Walk

Water Quality Trends in the Connecticut River Watershed in Connecticut
John Mullaney, U.S. Geological Survey

Degradation of water quality in the Connecticut has been documented since the late 1800’s. Throughout the late 19th century and much of the 20th century, water-quality continued to be degraded. By 1930, the wastewater discharge to the basin from towns and cities in Massachusetts and Connecticut had reached 266,000 m³/d, with only about 20 percent of the effluent having some form of minimal treatment. By 1962, 95 municipalities in four states were discharging wastewater to the Connecticut River basin; of these only 41 provided primary
treatment and 26 provided secondary treatment. Industrial discharges of untreated wastes from paper, chemical, metal plating, textile dyeing, and other industries also contributed to a serious health and environmental problem. A number of initiatives, including the Connecticut Clean Water Act of 1967, the Federal Water Pollution Control Act of 1972, and the Clean Air Act of 1970 (including the 1990 amendments) have led to improvements in the water quality of the Connecticut River basin during the past 30 years.

Trend analysis of selected U.S. Geological Survey water-quality monitoring data collected in Connecticut from 1968-98 was conducted using the nonparametric seasonal Kendall test. Selected sites were further analyzed as part of a later investigation using a time-series model with a periodic autoregressive moving average (PARMA) filter. Downward trends that were detected included total phosphorus, total nitrogen, indicator bacteria, and sulfate concentrations; upward trends that were detected included pH, dissolved oxygen, and chloride concentrations. However, despite improvements in water quality in the Connecticut River, significant challenges remain. These include, but are not limited to, the need for: reduction in non-point source pollutants due to increasing urbanization, further reductions in nitrogen loads to improve dissolved oxygen concentrations in Long Island Sound, further reductions in bacteria concentrations to attain Connecticut Class B water-quality criteria, and separation of combined sewers to prevent overflow of untreated sewage.

Influence of Land Use on Water Quality of a Diverse Northeast Watershed - the Mill River
Amy Rhodes, Dept. of Geology, Smith College

The Mill River Watershed (MRW), a 125 km² catchment of the Connecticut River, possesses heterogeneous human settlement patterns suitable to distinguish natural sources of chemical loading to rivers from anthropogenic sources. The MRW is divided into catchments by drainage patterns of dominant tributaries, which are further classified into land-use zones defined by intensity of human activity. Water chemistry in Zone I areas, where human activity is minimal to absent, serves as a baseline for assessing human impacts on water quality from within the watershed. Zone II areas are affected by water removal from drinking water reservoirs on two tributaries (~9500 m² per day, combined). Zone III regions receive runoff from agricultural, residential, and transportation areas. Since 1997, water samples collected from 13 sites in MRW have been analyzed for specific conductance, temperature, pH, ANC, base cations (Ca, Mg, Na, K, NH₄), anions (Cl, SO₄, NO₃, PO₄), and dissolved silica. GIS software was used to calculate percent area of different land uses that drain to each sample site.

Average concentrations of both NO₃ and SO₄ show a positive correlation with percent catchment area altered by human land uses ($R^2 > 0.68$), and concentrations of Cl increase with road density ($R^2 = 0.82$). However, water removal from municipal reservoirs increases the downstream concentration of NO₃ and SO₄ over that predicted by land use, showing that removal of high quality upstream water concentrates pollutants downstream. Streams impacted by road salt show a strong correlation between Na and Cl ($R^2 = 0.86$ to 0.95); yet Cl exceeds Na by 10-15% due to cation exchange reactions that bind Na to soil. The net effect of nonpoint source pollution is to elevate ANC in the most developed areas, which impacts the natural acidity of a large swamp. ANC of the stream draining the swamp shows high variability, ranging from −90 to 600 μeq/L. The sum of base cations ($C_B$) exceeds ANC for all tributaries, due to addition of salts that add $C_B$, addition of acids that remove ANC, or both. Plotting $C_B$ against ANC and subtracting Cl quantifies the impact of road salt from the impact of strong acids. For all zone III sites, salt impacts are greater than local sources of acid. An ANC loss of 100 μeq/L by local acids is observed downstream of a municipal reservoir, accounting for 32% of excess $C_B$.

Connecticut River Watershed Initiative
Stephen Rideout, U.S. Geological Survey and Craig Nicolson, Dept. of Natural Resources Conservation, University of Massachusetts Amherst

The Connecticut River Watershed (CRW) is a significant regional eco-zone within New England, spanning four states and covering a wide range of economic activities, land-use practices and ecological habitat. From its headwaters near the Canadian border down its length to the Long Island Sound, the watershed encompasses areas of high population density, suburban sprawl, farmland, and forest, and supplies water not only to the metro areas of Boston, Worcester, Springfield and Hartford, but also to numerous small towns and, through groundwater, to hundreds of thousands of rural residents. These water supplies are critical to the long-term economic and ecological health of the region. Changes in land use and economic conditions within the CRW have important effects on a host of biophysical resources such as water quality, biodiversity protection, and invasive species. These impacts on the natural capital
of the region in turn affect human well being in areas such as health, economic opportunity (tourism, agriculture, energy) and social capital. Significant expertise exists within the region for addressing the pressing issues of sustainable resource use and economic sustainability, but there has to date been very little coordination between the scientific experts in their isolated disciplines, and between agency managers and academic researchers.

The initiative described in this talk aims to develop, simulate and help visualize a Desired Future Condition for the CRW. It is being done in collaboration with USGS, UMass and USFWS. In early 2004 two focus groups will be held, and following a conference in March 2004 a coordinated science-based perspective on the key sustainability issues facing the watershed will be published. One anticipated longer term product of the project is a suite of visual tools that will give managers and planners the ability to ‘see’ in a dynamic way the present and future conditions of the watershed.

**Session 2C: Water Resources Modeling: Groundwater-Surface Water Interaction**

**Room 168 • 3:00-4:30 pm • Chair: David Ahlfeld**

**Use of Distributed Hydrologic Models in New England**  
Fred Ogden, Dept. of Civil and Engineering, University of Connecticut

The New England landscape is dominated by glacial geomorphic features. The role of groundwater in runoff production is undeniable. This talk focuses on the role of uncertainty in subsurface conditions on the applicability of distributed hydrologic models, with implications for hydrologic predictability in New England.

**Nitrogen Dynamics in a Suburban Coastal Watershed - Effects of Population Density, Land Use, and Soil Characteristics**  
Michelle Daley, Dept. of Natural Resources, University of New Hampshire

A suburban coastal watershed in New Hampshire, the Lamprey River, will be used to develop models that link groundwater quality to landscape characteristics (land use, population density and soil characteristics) and to document biogeochemical transformations along flow paths (i.e. denitrification, adsorption of dissolved organic nitrogen (DON) and microbial uptake). Previous research in the Lamprey basin has shown that population density controls stream water nitrate export and wetlands drive DON export. These relationships will be used as the starting point for construction of groundwater models. Additionally, stream water quality will be compared to groundwater quality.

**Ipswich River: Surface Water - Groundwater Interactions**  
Sara Cohen and Vicki Gartland, Massachusetts Department of Conservation and Recreation

In April 2003, the Ipswich River was designated as the nation’s third most threatened river by a national organization, American Rivers, due to critically low flows and extended periods of no flow. Under the direction of the Ipswich River Council, a public/private working group, a surface run-off model was adapted and used by the U.S. Geological Survey to simulate the impacts of ground water and surface water withdrawals as well as land use on the river (Zarriello and Ries, 2000). A habitat study (Armstrong et. al., 2001) in combination with the model results provided the scientific basis and quantification for restoration. However, further modeling scenarios (Zarriello, 2001) indicate that due to the high degree of connectivity between the groundwater and surface water systems and the limited extent of the aquifers, restoration can only be achieved through a combination of methods including reduced water use, wastewater discharge and stormwater recharge.

**Session 3C: Natural and Anthropogenic Influences on Water Chemistry – Section II**  
**Room 174 • 3:00-4:30 pm • Chair: Richard Yuretich**

**Biogeochemistry and Natural Attenuation of Acid-Mine Drainage at Davis Pyrite Mine, Rowe, MA**  
Richard F. Yuretich, Dept. of Geosciences, David Ahlfeld, Sarina Ergas, Dept. of Civil and Environmental Engineering, Allan Feldman, School of Education, Klaus R.L. Nüsslein, Dept. of Microbiology, University of Massachusetts Amherst

Davis Pyrite Mine collapsed in 1910 after 28 years of operation. Since that time, acidic drainage has been transporting iron and other trace elements into a local stream and groundwater. Initial observations indicate that the environment has remained stable for decades. New data show a restricted lens of impacted groundwater that moves rapidly through the mine tailings and shallow bedrock fractures, but is contained by ambient
groundwater from uncontaminated recharge areas. In these peripheral areas, there is evidence of an active microbial community that reduces the dissolved sulfate, and possibly Fe (III), to remediate the acidic drainage. Present research involves detailed mapping and modeling of the impacted area, and experiments are underway to document the identity and cultivate the sulfate- and iron-reducing bacteria.

**Land-Use Zoning and Water Quality in Jamestown, RI: A Fractured Aquifer Case Study**
Ann Veeger, Dept. of Geosciences, University of Rhode Island

The impact of land-use and housing density on ground-water quality has been extensively studied in areas dominated by permeable surficial materials. In New England, however, many residential areas derive their water supply from fractured bedrock aquifers. The relationship between land use, in particular housing density, and water quality in these areas has received little attention and the degree to which existing zoning laws protect the fractured-bedrock ground-water resource is unclear.

This study examines a detailed water quality investigation on Conanicut Island, a small fractured bedrock island in Narragansett Bay, Rhode Island. Ground-water samples were collected from 174 domestic wells in areas with housing lot sizes ranging from 1/8 to > 2 acres. Background ground-water chemistry was assessed and wells with evidence of anthropogenic impact were classified where possible according to the source of impact: saltwater intrusion, septic systems, or road salt. Nitrate concentrations ranged from non-detectable to 16 mg/L as N. 81 samples yielded background NO\textsubscript{3} concentrations (below 1 mg/L) and 25 samples yielded significantly elevated NO\textsubscript{3} concentrations (above 5 mg/L). The highest occurrence of elevated nitrate concentrations was found in the Jamestown Shores area where 1/8 to 1/4 acre lots are common and all homes are served by individual septic systems and wells.

A statistical analysis of housing lot size and groundwater chemistry was completed to determine whether this association was statistically significant. One acre was identified as a threshold lot size below which degradation of water quality was significant. This lot size criterion suggests that the existing RI Department of Environmental Management 100-foot septic system/well separation distance may be inadequate in this fractured bedrock setting.

**Arsenic Contamination Caused by Groundwater Remediation**
Carl Renshaw, Dept. of Earth Sciences, Dartmouth College

The increasingly common practice of remediating groundwater supplies contaminated with organics by monitored natural attenuation may cause or exacerbate arsenic (As) contamination, even in the absence of anthropogenic inputs of As. X-ray spectroscopy and batch experiments confirm that naturally occurring As is present and strongly retained on ferrihydrite in a glaciomarine clay layer underlying a mixed waste Superfund site. Over the five year study period, decreases in dissolved benzene concentrations in the groundwater are correlated with increases in As concentrations, consistent with the microbial decomposition of both benzene and iron oxides and the subsequent release of As. Almost 20% of U.S. groundwater supplies have both detectable levels of As and volatile organic compounds (VOCs). The correlation of elevated As levels to VOC contamination in groundwater systems throughout the U.S. indicates that the enhancement of As contamination by natural attenuation may be a widespread phenomenon.