

**Connecticut Institute of Water Resources  
Annual Technical Report  
FY 2007**

# Introduction

The Connecticut Institute of Water Resources is located at the University of Connecticut (UCONN) and reports to the head of the Department of Natural Resources Management and Engineering, in the College of Agriculture and Natural Resources. The current Director is Dr. Glenn Warner, and the Associate Director is Dr. Patricia Bresnahan.

Although located at UCONN, the Institute serves the water resource community throughout the state. It works with all of Connecticut's water resource professionals, managers and academics to resolve state and regional water related problems and to provide a strong connection between water resource managers and the academic community.

The foundation for this connection is our Advisory Board, whose composition reflects the main water resource constituency groups in the state. IWR staff also participates on statewide water-related committees whenever possible, enabling our Institute to establish good working relationship with agencies, environmental groups, the water industry and academics. Our seminar series, a long-standing Connecticut IWR tradition, provides a unique opportunity for the water resource professionals and interested members of the public in our small state to gather, be informed, and become better acquainted with the issues and each other.

# Research Program Introduction

The USGS 104B program is the financial core of the CT IWR. The Institute does not receive discretionary funding from the state or the university, although it does seek out and facilitate projects funded through other sources.

The majority of our 104B funds are given out as grants initiated in response to our annual RFP, with the majority of those funds going to research projects. When selecting projects for funding, the Institute considers three main areas: 1. technical merit, 2. state needs and 3. CT IWR priorities (use of students, new faculty, seed money for innovative ideas).

In addition to its 104B program, the Institute is conducting a number of externally funded projects.

Warner, B.S. and P.A. Bresnahan. 2007. Water Basin Studies. Appropriation from the State of Connecticut, \$200,000. Three projects are underway: The Pomperaug Water Allocation Pilot Study, Status of Diversions and Discharges in the Quinnipiac, and Guidance for the Use of Modeling in Statewide Water Planning.

Bresnahan, P.A. 2007. Data Needs for Basin Planning Purposes. Grant from the Connecticut Water Planning Council. \$40,000.

Warner, G.S. and P.A. Bresnahan, 2007. Modeling the Effects of Reservoir Release Practices on Downstream Flows, Phase 2: Impact of Release Rules on Yield and Streamflow Metrics. Grant from CT DEP to support the work of the CT Instream Flow Scientific and Technical Workgroup. \$30,000.

Details from each currently active 104B research project follow.

# Development and evaluation of a multi-dimensional spatially and temporally dynamic mesohabitat classification model for stream management and water flow allocation planning in southern New England streams

## Basic Information

<b>Title:</b>	Development and evaluation of a multi-dimensional spatially and temporally dynamic mesohabitat classification model for stream management and water flow allocation planning in southern New England streams
<b>Project Number:</b>	2006CT123B
<b>Start Date:</b>	5/1/2006
<b>End Date:</b>	2/28/2008
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	2
<b>Research Category:</b>	Biological Sciences
<b>Focus Category:</b>	Ecology, Geomorphological Processes, Hydrology
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Jason Vokoun, Melinda Dawn Daniels

## Publication

**Title:** Development and evaluation of a multi-dimensional spatially and temporally dynamic mesohabitat classification model for stream management and water flow allocation planning in southern New England streams

**Statement of regional or state water problem:** Connecticut, through recent legislation, has entered a process to evaluate the allocation of stream waters between “human” and “environmental” uses. The State is seeking a better understanding of the biological and geomorphological significance of flow regimes to protect stream biota and ecosystem functions for all streams in the state. The question of how much water stream inhabitants really need has most often been answered using hydraulic models which cover a relatively short reach of stream. Such models make assumptions that modeled reaches are representative and inference from results are typically limited in space. To use this modeling approach for all streams in the state is essentially cost prohibitive. Connecticut has begun to evaluate the flow requirements of stream biota using a newer modeling approach based on mesohabitats (Parasiewicz 2001), which are also known as channel geomorphic units and hydraulic habitat units, among other names, but represent what are commonly known as pools, riffles, glides, etc. (Figure 1). The mesohabitat modeling approach covers a longer reach of river for the same cost and because of the larger spatial scale may be more transferable among similar streams. The question of transferability is under investigation at the University of Connecticut presently (R. Schimdt, personal communication).

Mesohabitats are known to be important to the stream biota and have been shown to support distinct biotic assemblages (Rabeni and Jacobson 1993a, Peterson and Rabeni

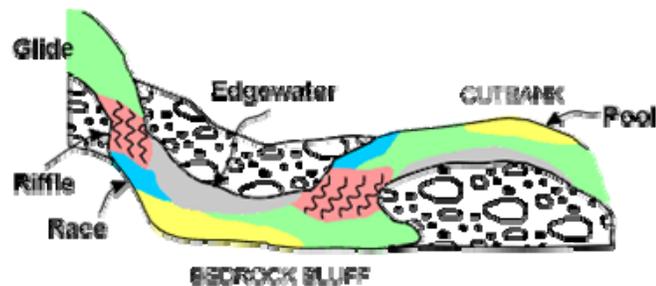


Figure 1. Sketch of a planview map of a stream reach with 5 mesohabitat types.

2001b, Rabeni et al. 2002). While pools, riffles, and runs seem easy enough to identify, mesohabitats are flow dependent (i.e. they get bigger and smaller with changes in stream stage) and are more numerous in type than one might initially suspect. Pools, riffles and runs are more correctly categories of mesohabitats, for example pools have been subdivided into obstruction, lateral, bluff, plunge, and beaver pools. Not all regions have streams with the same compliment of mesohabitats and regional variant classification schemes are numerous. Researchers in the Rocky Mountains use a scheme with different mesohabitats than those in the Ozark Plateaus region and again different than those in the southern Appalachian Mountains. **Connecticut needs a regionalized southern New England classification scheme for mesohabitats if it is to defensibly use mesohabitats to determine the effects of flow diversion on stream biota habitat quantity.** To address this need, a sound, scientific empirically-based investigation of geomorphic, hydraulic and biological mesohabitat distinctness in Connecticut should be prerequisite to the development and use of a classification system to inform management decisions. That

is to say, **definitions of physically distinct mesohabitats must be created and stream biota must show differences in assemblage structure and composition within these mesohabitats to be a meaningful basis for decision making.**

**Statements of results or benefits:** A physically distinct and biologically meaningful classification of mesohabitats for southern New England would result in the potential improvement of mesohabitat modeling efforts underway to quantify the effect of flow diversions on habitat quantity for stream biota. In addition, the classification scheme would serve to increase general understanding of stream ecosystems in the region. Future research and monitoring would benefit from the ability to stratify sampling among mesohabitats, increasing the quality of data and interpretations. Further, the evaluation of the classification scheme will also provide detailed information documenting the patterns of mesohabitat characteristics and size changes with varying discharge. This pattern of change is an extremely important underpinning of comparisons between high-water and low-water modeling scenarios. Furthermore, the significance of hydrogeomorphic classifications becomes more powerful when measurements are representative of the complete biologically significant variability within mesohabitats (e.g. three-dimensional vs. one dimensional velocity measurements).

Instream habitat classification has multiple management implications that require an ability to predict both the trajectory of the habitats themselves and the biota that live within the habitats. Classifications systems will have more utility if they have been verified biologically. It could be that a dozen or so physically distinct mesohabitats can be statistically defined in southern New England, but biologically only half of those may house distinct biotic assemblages. This information would inform managers that a collapsed set of mesohabitats may be important to conservation. Research has emphasized applications of minimum instream flow determination on regulated rivers (Newson and Newson 2000, Parasiewicz 2001), routine biological sampling (Poole et al. 1997, Rabeni 2002), and river rehabilitation and restoration (Sear 1994, Kemp et al. 1999). Our proposed empirical research would greatly improve the capability of mesohabitat models to contribute to these important management challenges.

Current mesohabitat delineation techniques in southern New England have to date been based on visual identification and limited (in both number and complexity) quantitative field measurements. Our proposed research will enable an unbiased, statistical delineation of mesohabitats based on objective hydrogeomorphological criteria. This refinement of mesohabitat classification will provide foundational background and definitions that will be helpful to the modeling efforts that are already in place.

**Nature, scope, and objectives of the project, including a timeline:** The proposed research is an integrated empirical field data collection and modeling study that will produce both a biologically meaningful classification of mesohabitats for southern New England streams and a model to predict spatio-temporal changes in these mesohabitats under variable streamflow conditions. The specific objectives of this research are to:

- 1) Collect hydraulic characterizations of mesohabitat channel units from three streams and use statistical classification to create a scheme of physically distinct mesohabitats based on channel morphology, flow depth and Froude number, and three-dimensional flow variability with stage

- 2) Develop a hydraulic model which demonstrates the spatio-temporal patterns of channel units as they vary with discharge
- 3) Collect macroinvertebrate and fishes (abundance, size classes, and species identity) from mesohabitats and statistically determine biological distinctness among channel units

The proposed research project began with intensive geomorphologic and hydraulic field data collection during summer 2006. Macroinvertebrate and fish sampling occurred during the summer and fall of 2006. Field work is complete. Data analysis of fish communities is complete. Data analysis of macroinvertebrates and hydraulic model development have taken longer than expected and will be completed by May 2008.

**Methods, procedures, and progress:** Three streams in southern New England were used for data collection, both physical and biological. Study reaches, one per stream, were 1-2 km in length and chosen to encompass heterogeneous habitat conditions. Streams sampled were the Willimantic River, the Still River (Farmington watershed) and Elldredge Brook.

Though mesohabitat spacing varies widely in nature, we attempted to sample 25 mesohabitat units within each study system. The geomorphology of each study reach was surveyed in detail using electronic total station surveying, sediment substrate characterization, and micro-habitat unit mapping. Hydraulic flow fields were characterized at low and moderate flows using a YSI FlowTracker acoustic doppler velocimeter (ADV). The combined geomorphic and hydraulic data will be used to generate a two-dimensional model of the study reaches using a well-established pre-packaged modeling program (River2D). This modeling software, when combined with our statistically-generated mesohabitat definitions (criteria) will enable



Figure 2. Sampling crew at the Still River electrofishing within a mesohabitat.

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quantification of mesohabitat aerial change with changing flow stage, as well as permit quantification of hydraulic variability in different mesohabitat units at multiple stages.

Macroinvertebrates and fish were collected from geo-referenced locations in the study reaches and will be later delineated to specific mesohabitats to generate species assemblage data for particular mesohabitats. Macroinvertebrates were sampled using a kick-net stream benthos sampler and fish with backpack and push-barge electrofishing gear. Fish species assemblages were compared among mesohabitat samples using principal component analysis and hierarchical cluster analysis (Peterson and Rabeni 2001b).

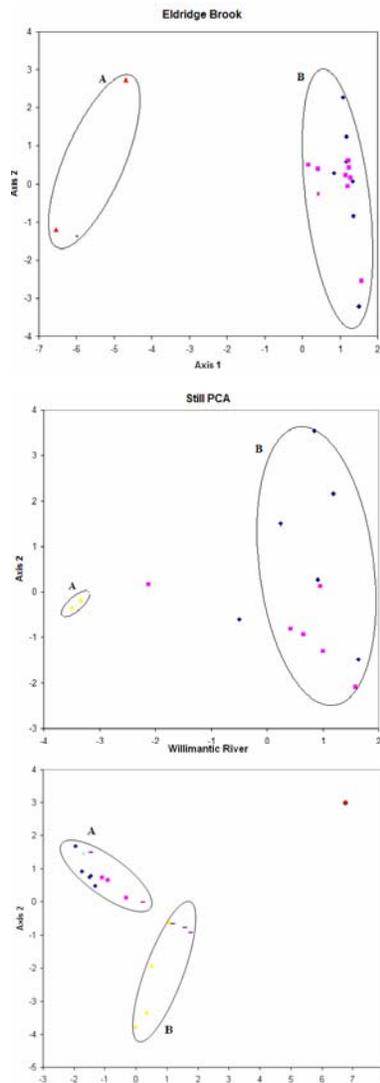


Figure 3. Principal components analyses of fish assemblage data collected in 2006

Results from the fish assemblage data analyses suggest that perhaps as few as two assemblages of fish occur in Connecticut streams. These two assemblages appear to relate to “fast-water” and “slow-water” habitats (Figure 3). While only part of the ecosystem, this may foretell that mesohabitat-level instream assessments using fish may be able to use a much simpler classification than those recently employed. Identification of invertebrates is a current priority. The hydrodynamic modeling portion was not completed and remains a work item.

**Personnel status:** Both senior personnel continue to work on the project. The research assistant that lead the biotic sampling during summer 2006 ended employment after six months as planned as in now enrolled in graduate school at Tennessee Technological University studying a crayfish species of conservation concern. A PhD student in Geography/fluvial geomorphology had taken up work on the hydrodynamic modeling but did not complete it. New personnel will be needed to complete this portion of the project. A crew member from the field crew of summer 2006 worked on the macroinvertebrate sorting and analyses as an independent study project during the fall 2007 and spring 2008 semester. In total to date, nine different students have participated in project-related data collection activities.

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# Development of a new generation of sensitive, fluorescence-based nitrate sensors for use in soil and water

## Basic Information

<b>Title:</b>	Development of a new generation of sensitive, fluorescence-based nitrate sensors for use in soil and water
<b>Project Number:</b>	2007CT130B
<b>Start Date:</b>	9/1/2007
<b>End Date:</b>	8/31/2009
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	CT District #2
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Methods, Nitrate Contamination, Nutrients
<b>Descriptors:</b>	None
<b>Principal Investigators:</b>	Shawn Christopher Burdette, Zoe G Cardon

## Publication

1. Daniel Kennedy, Randy Jackson, Hannah Mbatia, Yujiang Mei, Zoe G. Cardon\* and Shawn C. Burdette. Fluorescent sensors for iron and nitrate in the environment. Environmental Bioinorganic Chemistry Gordon Research Conference. June 15–19, Waterville Valley, NH.

**Title:** Development of a new generation of sensitive fluorescence-based nitrate sensors for use in soil and water

**Statement of regional or state water problem:**

Throughout the world, eutrophication of tributaries, rivers, estuaries, and coastal marine ecosystems by point and non-point sources (e.g. industry, sewage, development, atmospheric deposition and agriculture) is changing these ecosystems' biogeochemical function, ecology, and the human institutions dependent on them [1, 2]. Roughly one-third of the nitrogen (N) reaching Long Island Sound (LIS) is derived from non-point sources, and these non-point sources, and the sinks, transport and processing of N in pathways leading to LIS, are not well understood. Integrating data from 28 water monitoring stations (23 in CT) with land-use/land-cover information, population density, runoff volumes, and other landscape characters, Mullaney et al. (2002) developed a simple linear regression model capable of predicting N-loads and yields in streams as a function of watershed characteristics [3]. This model was used to estimate N-loading in unmonitored watersheds, but unexplained discrepancies were found that indicated unknown but important system drivers were affecting N-loading in both agricultural and forested landscapes [3]. In particular for the current effort, researchers noted that the type of forest cover (e.g. percent deciduous tree cover) significantly affects N-loading [3], suggesting either that the dominant tree types themselves [4], and/or perhaps edaphic factors correlated with those forest communities [5], strongly affect N-yield from forested areas. Recently published data suggest that dominant northeastern forest deciduous and evergreen species are associated with distinct rates of N-cycling and N-retention in the soils supporting them [4, 6]; these distinct N-cycling rates could lead to distinct N-load "signatures" in watersheds that correlate with forest cover.

Ultimately, we would like to explore how patterns of N-cycling, and dynamics of various dissolved N pools, correlate with the patterns and growth of diverse New England forests, but current monitoring methods are inadequate. Though current ecosystems ecological techniques for quantifying net and gross mineralization and nitrification, as well as microbial immobilization, of nitrogen have certainly led to greater understanding of patterns in and mechanisms underlying N-cycling in forested systems, those techniques invariably require destructive harvest of soil prior to assay [7]. Unfortunately, digging up the belowground system under study necessarily leads to severing plant roots that contribute carbon to soil, breaking hyphae of mycorrhizal and saprotrophic fungi, mixing up soil layers, and breaking up soil aggregates that otherwise can have cores hypoxic enough to support denitrification. Ecosystems ecology sorely needs a suite of miniature sensors capable of being deployed to continuously monitor dissolved nitrogen species in soils. Because soil processes are notoriously heterogeneous, ideal would be development of an inexpensive and sensitive enough design to support deployment of a suite of such sensors in multiple locations across a watershed so that networked, continuous pool data could be gathered across the landscape. Ecosystems ecologists have long used stream water concentrations of ions as an integrated measure of terrestrial system output (for example demonstrating that immobilization of otherwise mobile essential nutrients in new aggrading forest biomass after logging leads to dramatic and seasonal decreases in nitrate concentrations in streamwater [8]). But the N processing on the terrestrial landscape itself has been studied destructively, not continuously, and often not *in situ*.

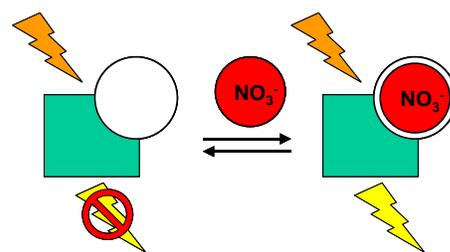
Ecosystems scientists are not alone in needing improved monitoring tools; land managers and environmental engineers also seek sensors that can be deployed in order to detect plumes of contaminants, including nitrate, moving through groundwater. Development of small nitrate sensors is already underway in that context, e.g. at UCLA (see the Center for Embedded Networked Sensing focus on contaminants and terrestrial ecosystems [9]). However, the concentrations of nitrate in a contaminated plume are much higher than background concentrations in forested systems. McDowell showed that nitrate concentrations in soil solution (extracted using zero tension lysimeters, and analyzed in the lab) were between 0 and 1 mg L<sup>-1</sup> over a time span of ten years in unmanipulated hardwood and pine stands at Harvard Forest [10]. In contrast, in plots experiencing chronic high N deposition (15 g N m<sup>-2</sup> yr<sup>-1</sup>) for those same ten years, nitrate concentrations in soil solution ranged between 10 and 28 mg L<sup>-1</sup> in pine and hardwood stands. In order to have any hope of monitoring, continuously, shifts in pools of nitrate (and potentially, ultimately, other dissolved N species) in soil solution under particular forest tree species, and in streams draining relatively pristine rather than highly polluted watersheds, very sensitive, miniature sensors are needed. Ideally, such a sensor would be inexpensive

and could be coupled into some of the already established protocols for networking sensors like those being developed at CENS. The first step, however, is how to improve sensitivity of sensors to nitrate in low (background or pristine) concentration in freshwaters and in soil solution, and how to package the sensors in a miniaturized form that is relatively inexpensive.

We aim to develop miniature, “turn-on”, fluorescence sensors for nitrate that, ultimately, can be deployed in sets in soil and in freshwaters to report nitrate concentrations continuously in background and low contamination ranges – e.g. 0-2 mg per liter. Nitrate sensors for deployment *in situ* are already on the market, for example designed for work in oceans (e.g. UV sensor, Satlantic’s ISUS V2) and streams and groundwater (e.g. Hydrolab nitrate ion selective electrodes [11]). Some are already very sensitive. Satlantic, for example, claims sensitivity of 0.007-28 mg nitrate per liter, +/- 0.028 or 10% of the measurement, whichever is larger. But, the sensor is 2 ft long, 4 inches in diameter, and weighs 11 lbs. New amperometry-based nitrate detectors for use in soil and groundwater are becoming more sensitive, but to date their major focal application has been on highly contaminated nitrate plumes in groundwater [9], though the focus is also shifting to detection in more undisturbed, terrestrial ecosystems. It is important to understand the background N-cycling processes occurring in more pristine environments in order to understand the magnitudes and multiple mechanisms of human impacts on that cycling, yet we lack the tools for *in situ* monitoring of pools within the heterogeneous N-cycling pool and flux network.

### Significance: Statement of results or benefits

Fluorescent sensors are an attractive target for developing a next generation of nitrate detection systems, because fluorescence methodologies are more sensitive, and easier to apply than current technologies. Assistant professor of chemistry Burdette specializes in the chemical synthesis and the principles of photochemistry relevant to sensor construction. Funding from CTIWR for 2 years that is earmarked to support work on developing a fluorescence-based nitrate sensor, and would provide the necessary seed money to initiate the molecular design of a sensing system. Cardon can guide the preliminary tests of sensitivity in real samples from the field, and analysis of comparable data from other detection methods (e.g. anion exchange membrane and buried resin bag-estimates, as well as KCl extraction-estimates of nitrate pools in soil [7]). With a proof-of-concept sensor in hand, more funding (e.g. from NSF’s Bioengineering and Environmental Systems program) will be sought to advance the technology beyond molecular design toward the miniaturization and field-readiness of continuous sensing systems. Because Cardon serves on the national SAMSI program steering committee for development of mathematical and statistical analysis of sensor network data [12], she already has the necessary contacts to help bring the established technology rapidly to an interested community nationwide. Cardon has already collaborated with John Mullaney at USGS and Paul Stacey at DEP in CT writing grant proposals (to NSF) to further explore nitrogen processing in Connecticut’s watersheds and Long Island Sound. The links from the sensor development proposed here to CT government agencies thus promises to be a natural progression.



**Figure 1.** Representation of a typical fluorescent sensor. Whether sensor refers to a small molecule, a polymer or a device, the signaling action involves fluorescence emission (yellow bolt) that occurs only in the presence of analyte binding ( $\text{NO}_3^-$ ) when the sensor is exposed to excitation light (orange bolt).

### Nature, scope, and objectives of the project

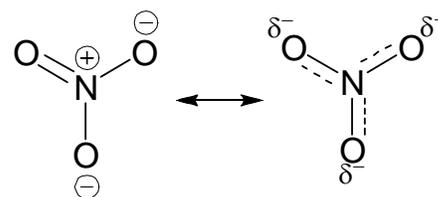
*Fluorescent Sensors (Fig. 1).* Fluorescent sensors have been vital in identifying the cellular functions of metal ions [13], as well as the impact of environmental contaminants like mercury [14] and polychlorinated biphenyls [15]. With appropriate molecular design, fluorescent sensors are capable of making sensitive measurements using signals that are easy to monitor [16]. Since these chemical tools are typically constructed using modular approaches, simple structural modifications can be made to adapt the sensor for a variety of different applications and circumstances. Analyte concentrations from sub-pM (equivalent of 0.1  $\mu\text{g/L}$  of nitrate) to saturated solutions can be accurately measured. In addition to these advantages, fluorescent sensors

are particularly amenable for monitoring environmental analytes because the imaging reagents and instrumental techniques are non-evasive and simple to employ. One distinct improvement over conventional techniques for measuring nitrate concentrations is that sensors are typically inexpensive and can be designed to be either disposable or reusable. As a result, an array of many individual sensors can be distributed easily over a large area and monitored by one research worker using an inexpensive, portable fluorescence spectrometer. While methodologies for constructing some types of fluorescent sensors are straightforward, designing useful sensors for anions presents a significant challenge. Although fluorescent anion sensors exist, very few systems have been reported for nitrate [17].

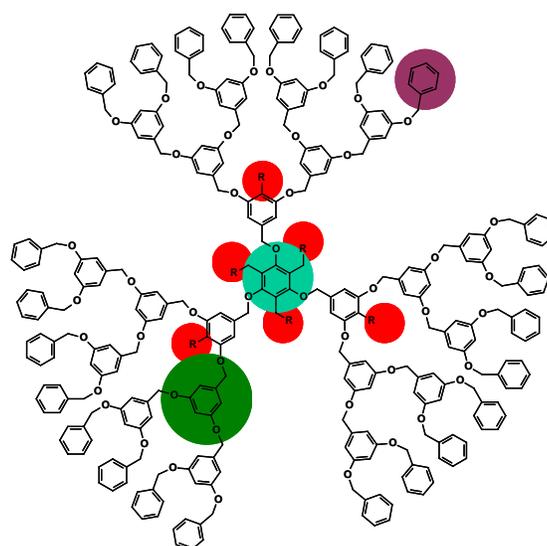
*Nitrate chemistry.* The most challenging obstacle to overcome when constructing a nitrate sensor is finding a receptor to bind what is essentially a non-coordinating anion (Fig. 2). Nitrate is a weak base that does not form covalent bonds with metal cations or protons readily, a behavior that is consistent with it being the conjugate base of a strong acid (nitric acid). In the majority of nitrate complexes characterized crystallographically to date, the nitrate group is located several angstroms away from other atoms, hence the nomenclature “non-coordinating” [18]. Unlike metal cations that can form strong covalent bonds with receptors containing electron-donating atoms like oxygen or nitrogen, anion receptors usually rely on noncovalent interactions like hydrogen bonding or electrostatic interactions for chelation [19]. Noncovalent interactions are weak forces, so it is counterintuitive that a receptor using these interactions can bind an analyte tightly; however, if a receptor takes advantage of several noncovalent interactions simultaneously, a reasonably high affinity interaction can be established.

Another challenge in anion receptor design is the ability to discriminate between other anions. In particular for nitrate found in the environment, anions like chloride ( $\text{Cl}^-$ ), sulfate ( $\text{SO}_4^{2-}$ ), and phosphate ( $\text{PO}_4^{3-}$ ) could interfere with measurements of nitrate concentration if the receptor lacks selectivity. In order to enhance selectivity for nitrate, the receptor can take advantage of the coordination number and charge density. Nitrate is a trigonal planar anion, as opposed to primary oxoanions competitors like  $\text{PO}_4^{3-}$  and  $\text{SO}_4^{2-}$  (tetrahedral), and anions like hydroxide ( $\text{HO}^-$ ) and halides ( $\text{F}^-$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{I}^-$ ) with simple geometrical shapes. Nitrate is monoanionic, with the charge distributed evenly over the 3 oxygen atoms, making them the primary targets for noncovalent interactions with receptors. The monoanionic, trigonal planar structure of nitrate is an uncommon structural motif for anions found in soil and water. Therefore, receptors that can only accommodate a trigonal anionic guest will provide the desired binding selectivity.

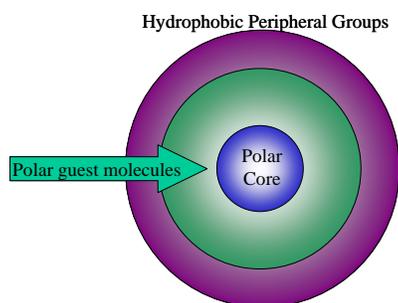
*Dendrimers.* Dendrimers are globular polymers frequently prepared using conventional organic synthetic methodologies (Fig. 3). When convergent synthetic methods are employed [20], dendrimers have uniform size, shape and molecular weight, a property reminiscent of enzyme structures [21, 22]. Because of their unique properties, dendrimers are attractive targets for a variety of applications in catalysis [23], medicine



**Figure 2.** The structure of the nitrate anion. The structure on the right shows the composite resonance structure the best describes the chemistry and structure. The molecule is trigonal planar ( $120^\circ$  O-N-O angles) and has a negative charge distributed evenly over the 3 oxygen atoms.



**Figure 3.** The basic structure of a dendrimer, shown is a 3<sup>rd</sup> generation poly(benzyl ether). The generation number refers to the number of repeating building blocks (green) between the core (blue) and the periphery (purple). The structure of the repeats and periphery groups determine the physical properties of the dendrimer, and can be changed to attain the desired features. Dendrimers of generation 1-5 are straightforward to prepare. In addition, functional groups such as nitrate receptors or fluorophores (red, “R” groups) can be incorporated at the core, or with in the branching units as needed. For use in water, the peripheral groups will be water soluble (polyethylene glycol) for soil-based systems, hydrophobic organic groups will be utilized.



**Figure 4.** Dendrimers as concentrators. In more hydrophobic environments like soil, a concentrator effect will help to transport nitrate inside the sensor.

[24] and sensing [25]. Several properties of dendrimers make them attractive scaffolds for environmental nitrate sensors. Dendrimers can be prepared with robust chemical linkages that will resist degradation by microorganisms and variations in acidity/basicity in soil and water. Dendrimers also provide encapsulation, and hence protection, for the nitrate receptors and fluorophores that are susceptible to decomposition reactions under the conditions the sensors will be deployed. Most importantly, however, dendrimers can act as “molecule concentrators” (Fig. 4) [26]. When mobility of an analyte like nitrate is lower (like in soil before reaching water), the ability of the dendrimer to concentrate a substrate will amplify the resulting fluorescent signal. The ability of a dendrimer to act as a concentrator, as well as many other physical properties, is dictated by its chemical structure. Dendrimers have three important structural components, the core, the branching groups (polymer repeat units) and the peripheral

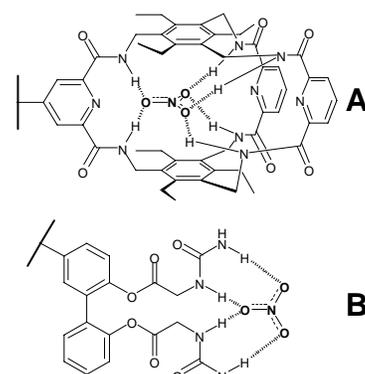
groups, that can be varied to tune the properties of the resulting macromolecule. As shown in Figure 4, a dendrimer with a hydrophobic periphery and a polar interior will be predisposed to concentrate a charged molecule like nitrate from nonaqueous sources.

### Specific Aims

1. Construct nitrate receptors for incorporation into dendritic fluorescent sensors
2. Verify the ability of dendrimers to concentrate nitrate anions
3. Investigate the strategy of using accumulation of anionic charge inside a dendrimer to modulate the emission intensity of polarity sensitive fluorophores
4. Investigate the viability of displacing a negatively charge fluorescence quencher at the core of a fluorescent dendrimer as a detection strategy
5. Investigate the strategy of using charge-induced swelling and contracting of dendrimers to induce fluorescence resonance energy transfer
6. Demonstrate proof-of-concept nitrate sensing with dendrimers in prepared solutions and environmental water samples
7. Devise methodology to attach/adsorb dendritic sensors onto glass surfaces for nitrate sensing in soil samples

### Methodology

*General sensor design strategy: dendrimer structure and nitrate receptors.* The majority of the existing sensors for anions (e.g.  $F^-$ ,  $Cl^-$ ,  $Br^-$ ,  $PO_4^{3-}$ ,  $CO_3^{2-}$ ) rely on either photoinduced electron-transfer (PET), which requires the formation of covalent bonds with the receptor, or electronic energy transfer (EET), a “turn-off” mechanism which requires an analyte with an electronic structure that triggers fluorescence quenching, as the signaling mechanism [17]. Neither of these common strategies is applicable to the disparate requirements of sensing nitrate. An alternative approach to anion sensing is to couple an accumulation of negative charge with a change in the fluorescence intensity. In aqueous solution, nitrate can freely flow into the dendrimer, and be trapped by the receptors; however, in soil nitrate may be less mobile with respect to entering the dendrimer. In order to concentrate anions, dendritic molecules will be utilized as concentrators. As a consequence of dendrimers possessing hydrophobic peripheries and polar cores, a concentration gradient is established between the interior of the macromolecule and the exterior that provides the driving force to amass nitrate. All three sensor strategies described below will take advantage of

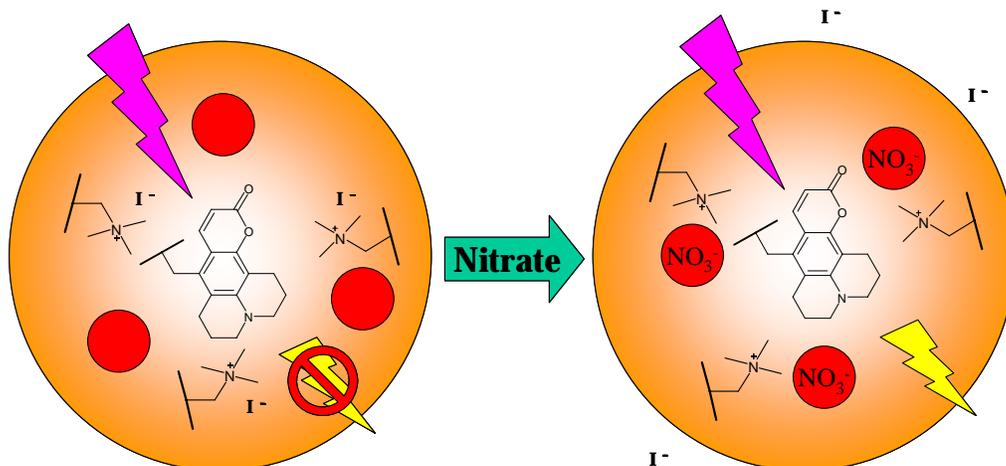


**Figure 5.** Examples of nitrate receptors. Both cryptate (A) and “tweezer” type ligands selectively bind nitrate (illustrated) in the presence of other anions. The dendrimer attachment site is shown as the squiggly line on the left of each receptor.

the concentrator effect to sequester nitrate in soil. For sensing in water, the hydrophobic peripheral groups will be substituted for with water-soluble groups like short polyethylene glycol (PEG). In addition to concentrator effects, the interior of the dendrimer will be functionalized with molecules capable of binding nitrate to provide anion selectivity and trapping. Several receptors have successfully been applied to nitrate binding (Fig. 5). Both cryptate [27] and “tweezer” type ligands [28] possess nitrate selectivity, because of the common feature that the binding cavity orients hydrogen-bonding interactions in a trigonal planar coordination sphere.

These molecules will be the primary candidates for incorporation into the sensors in this initial phase of the research project. Design of new and improved nitrate receptors will not be a major component of CTIWR funded research; however, future proposals and projects will address any limitations of these systems.

*Displacement of a quenching anion by nitrate as a sensing strategy.* Although nitrate typically is incapable of quenching fluorescence, large anions (e.g.  $\text{Br}^-$ ,  $\text{I}^-$ ) quench fluorescence through enhancement of spin orbit coupling (SOC) [29] and electron deficient anions (e.g. 4-nitrobenzene-sulfonate) through SOC [30] or EET [17]. A simple proof-of-principle sensor for this strategy can be constructed with a dendrimer functionalized with ammonium iodide groups and fluorophores. Diffusion of nitrate into the interior will displace the quenching anions restoring fluorescence (Fig 6).

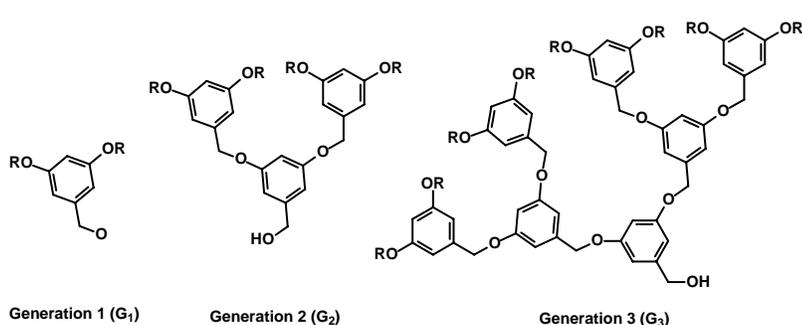


**Figure 6.** Mechanism of signaling action with quenching anions. The presence of iodide anions quenches the emission of the coumarin fluorophore (center), when nitrate binds to the receptors, the iodide will be expelled from the dendrimer restoring the emission.

## Principle Findings: Progress Report

**General progress.** Work did not begin on the development of new nitrate sensors until October 2007, as we were awaiting the arrival of new personnel in the Burdette laboratory to conduct the research. In accordance with our initial proposal, our work has focused on proof-of-concept research that is focused on three main areas: 1) synthesis of dendrimers; 2) synthesis and characterization of fluorescent nitrate receptors; and 3) testing of mechanisms capable of detecting nitrate by fluorescence enhancement.

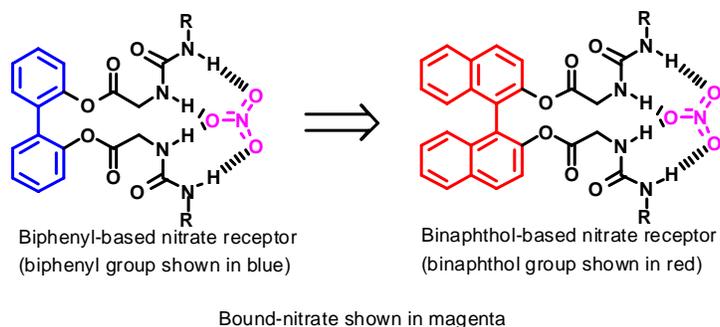
**Dendrimer synthesis.** Several other projects in the Burdette lab involve dendrimers. We have had ongoing



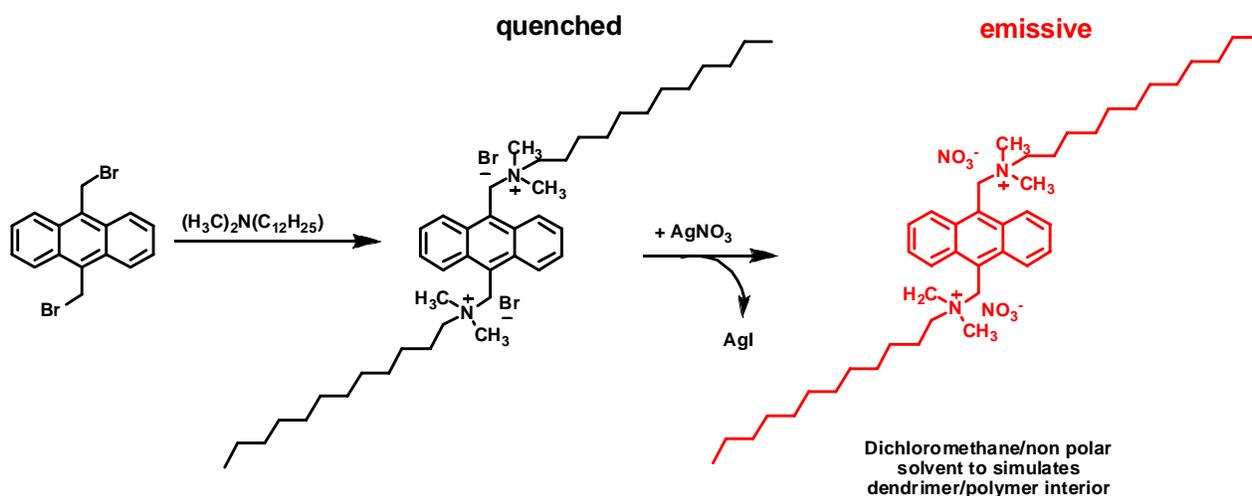
**Figure 7.** Dendrimers prepared to date

efforts to synthesize poly(benzyl ether) dendrimers, and to date we have prepared  $G_1$ - $G_3$  dendrimers with benzyl groups as well as alkyl chains on the periphery (Fig. 7). These components of the eventual nitrate sensor are available when other elements of the project described below are sufficiently advanced to warrant assembly of the dendritic nitrate sensors proposed originally. We can either assemble a “spherical” sensor by assembling 3 or more of the dendrons shown in Fig. 1 onto a central core, or a “flat” sensor by linking to linear polymers or onto surfaces.

**Nitrate receptor synthesis.** As we suggested in our original proposal, our 1<sup>st</sup> generation of nitrate sensors will utilize known nitrate receptors that we will modify to act as fluorescence switches or to contain synthetic handles for attachment to macromolecules. Based on literature precedence, we have modified the structure of a biphenyl-based nitrate receptor to contain a binaphthol scaffold (Fig. 8). Unlike biphenyl, binaphthol is inherently fluorescent, and we are in the process of determining if and how the emission of our ligand changes when it binds nitrate. We accessed the binaphthol ligand through a multi-step synthesis that is amenable to making a variety of related derivatives or making additional structural modifications.

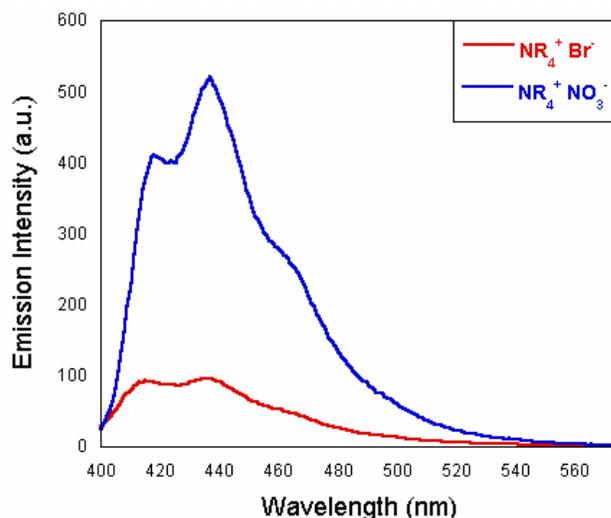


**Figure 8.** We have substituted a fluorescent binaphthol group (red) for biphenyl one (blue) in a nitrate (magenta) receptor. Additional structural changes are possible using our synthesis, and fluorescence studies are being initiated on the new receptor.



**Figure 9.** Proof-of-concept nitrate sensing with alkyl ammonium anthracene compounds. Displacement of iodide anions with nitrate anions removes a potent fluorescence quencher away from the sensor.

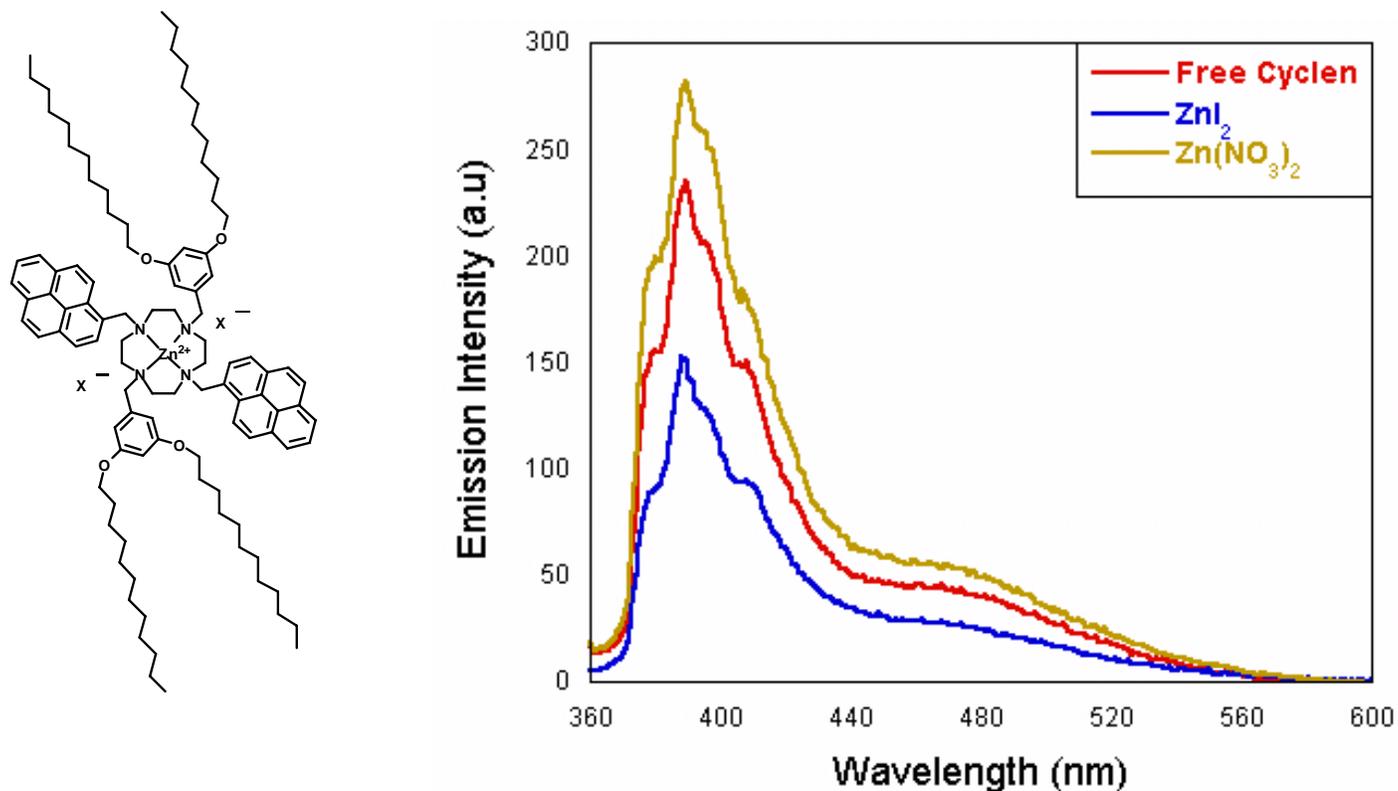
**Investigation of sensing mechanisms.** One of the key preliminary studies we have undertaken is an attempt to determine a mechanism that will allow changes in nitrate concentration to increase sensor emission. As described in the proposal, nitrate is a weakly coordinating anion, and therefore many common sensing mechanisms are not appropriate for our purposes. We have tested the hypothesis that nitrate can displace a quenching group that is in proximity to a fluorophore by preparing an anthracene derivatives containing two tetra-alkyl ammonium iodides (Fig. 9). We chose a lipophilic alkyl groups to give the resulting sensor solubility in nonpolar solvents like hexanes or dichloromethane. In these nonpolar solvents, the bromide anions form a close ion pair with the ammonium cation, and the close proximity of the bromide quenches the emission of the anthracene by creating spin-orbit coupling quenching pathways. Subsequent replacement of the quenching bromides by relatively electron deficient nitrate should restore the anthracene fluorescence (Fig. 10).



**Figure 10.** Emission intensity of sensor shown in Fig 9. 410  $\mu\text{M}$  sensor in  $\text{CH}_2\text{Cl}_2$ ,  $\lambda_{\text{ex}} = 384 \text{ nm}$ .

Additional structural changes are possible using our synthesis, and fluorescence studies are being initiated on the new receptor.

In addition to ammonium species, we have also investigated using metal-based halide interactions to quench fluorescence. Figure 11 shows the structure and the fluorescence response of a zinc-based proof of concept sensor system.



**Figure 11.** Structure of zinc-based system for generating emission increases with nitrate. 10  $\mu$ M sensor in Et<sub>2</sub>O,  $\lambda_{ex}$  = 350 nm

We are currently integrating our proof of concept sensing strategy into a dendritic system with a nitrate receptor.

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# The Geochemical Record of Cultural Eutrophication in Sediments of Beseck Lake and Lake Waramaug, Connecticut: Implications for Nutrient Cycling and Remediation Efforts

## Basic Information

<b>Title:</b>	The Geochemical Record of Cultural Eutrophication in Sediments of Beseck Lake and Lake Waramaug, Connecticut: Implications for Nutrient Cycling and Remediation Efforts
<b>Project Number:</b>	2007CT134B
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<b>Funding Source:</b>	104B
<b>Congressional District:</b>	3
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Geochemical Processes, Sediments, Nutrients
<b>Descriptors:</b>	None
<b>Principal Investigators:</b>	Timothy Ku

## Publication

## **The Geochemical Record of Cultural Eutrophication in Sediments of Beseck Lake and Lake Waramaug, Connecticut: Implications for Nutrient Cycling and Remediation Efforts**

**Proposal IDs:** Ku2007\_104B\_R, Ku20082009\_104B\_R

**Principle Investigator:** Timothy Ku, Wesleyan University

### **Problem and Research Objectives**

Anthropogenic activities have dramatically altered the biogeochemical cycles of carbon, sulfur, nitrogen, and phosphorous in nearly every major aquatic ecosystem on Earth (Smith, 2003). Cultural eutrophication is the process whereby human activity increases the amount of nutrients, primarily nitrogen and phosphorous, entering an aquatic ecosystem causing excessive biological growth. The accelerated production of autochthonous organic matter results in anoxic conditions within the water column, thereby changing the community structure of aquatic ecosystems and degrading the recreational and retail value of the surrounding land.

Eutrophication is a widespread environmental problem as it accounts for ~50% of impaired lake area and 60% of impaired river reaches in the U.S. (U.S. EPA, 1996). In Connecticut, prior to the mid-1800s the land was mostly forested, but increases in agriculture, urban, and residential land areas contributed to the eutrophication of several Connecticut lakes by the 1930s (Deevey, 1940; Bell, 1985). Progressive eutrophication associated with land-use changes continued in many Connecticut lakes as average Secchi disk depths decreased by 1.2m and total phosphorous concentrations doubled from the late 1930s to the early 1990s (Siver et al., 1996). During approximately the same time, mean estimated total phosphorous (eTP) and mean estimated total nitrogen (eTN) concentrations increased from 15 and 374  $\mu\text{g/L}$  to 25 and 450  $\mu\text{g/L}$ , respectively (Field et al., 1996). These results, together with biological-based paleolimnology studies, clearly demonstrate that anthropogenic activities have accelerated the eutrophication process in many Connecticut lakes (Siver et al., 1999).

To reverse or decelerate cultural eutrophication, many regulatory agencies have implemented stringent laws intended to lower the delivery rate of nutrients into impacted water bodies such as the Chesapeake Bay, Lake Erie, and Lake Baldeggersee (Switzerland) (Lotter, 1998; Boesch, 2002). In Connecticut, the Long Island Sound study aims to reduce nutrient inputs delivered to Long Island Sound, but restoration or preservation of inland lakes is usually the responsibility of local governing agencies working in conjunction with the Connecticut Department of Environmental Protection (NYSDEC and CTDEP, 2000). This study focuses on two eutrophic Connecticut lakes that have been the focus of major remediation efforts, Lake Waramaug and Beseck Lake. Lake Waramaug experienced significant eutrophication from the 1950s through the 1980s and two hypolimnetic withdrawal systems were installed in 1983 to contain the phosphorous in the bottom waters of the lake. Since 1983, additional remediation efforts have included the installation of two in-lake layer aeration systems, the passing of new zoning regulations to limit soil and water runoff, and the stocking and seeding of fish and zooplankton to improve water quality (<http://www.lakewaramaug.org>). The Lake Waramaug Task Force (LWTF) is a non-profit organization of volunteers and scientists and together with Ecosystem Consulting Services, Inc. has continuously monitored the lake since 1977. During this time, the lake water clarity has improved and epilimnion phosphorous concentrations have declined (ECS data, pers. comm.). Beseck Lake is a manmade impoundment created by a dam in

the mid 1800s and has experienced episodic eutrophic conditions from the 1970s to the 1990s, in part due to the addition of nutrients from failing septic systems (Canavan and Siver, 1995; Cinotti, 1997; Jacobs and O'Donnell, 2002). To decrease the flux of nutrients entering the lake, surrounding residences were converted from septic systems to a city sewer system. This transition was completed in 2002 and the Lake Beseck Association now helps maintain and monitor the lake water quality (R. Boyton, pers. comm.).

While these efforts to decelerate the eutrophication process have yielded positive results, future remediation policies must set realistic goals of water quality (chemical composition and biologic activity). By using historical data, time series data, or reference region data, regulatory agencies can determine pristine water quality conditions that are absent of the effects of human activity (Smith, 2003). Sediment cores collected from Beseck Lake and Lake Waramaug record the pre-anthropogenic lake conditions and the onset and remediation of cultural eutrophication. This project examines the history of these two lakes, which will help guide future remediation efforts in Beseck Lake and Lake Waramaug as well as in other worldwide lakes experiencing similar eutrophication problems.

### **Methodology**

The three main objectives of this study are 1) determine the sedimentation rates of organic C, organic N, and detrital minerals, 2) determine the source of organic matter and detrital minerals, and 3) determine the paleoredox history of these lakes. Sediment push cores and freeze cores were collected using a pontoon boat. Linear sedimentation rates (LSR, cm/yr) and mass accumulation rates (MAR, g/cm<sup>2</sup>/yr) were determined by <sup>210</sup>Pb, <sup>137</sup>Cs, and Hg and Pb methods (Appleby and Oldfield, 1992; Siver and Wozniak, 2001; Callender, 2004; Fitzgerald and Lambourg, 2004; Varekamp et al., 2005). Organic C and N concentrations were analyzed with an elemental analyzer. Major, minor, and trace element compositions were determined by digesting sediments in a HCl/ HNO<sub>3</sub>/ HF/ HClO<sub>4</sub> solution followed by ICP and ICP-MS analyses. δ<sup>13</sup>C and δ<sup>15</sup>N organic matter measurements were performed at the Stable Isotope facility at Indiana University. Paleoredox indicators (DOP, C/S, or δ<sup>34</sup>S<sub>pyrite</sub>) are currently being analyzed using standard Fe-S methods in combination with pyrite framboid size distributions (Canfield et al., 1986; Raiswell et al., 1994; Wilkin et al., 1996; 1997).

### **Principal Findings and Significance**

While we are still waiting for a few key <sup>210</sup>Pb measurements, two Lake Waramaug sediment cores have been dated and contain a 200- to approximately 400-year record of lake history. The lake sediments in the early 1800s are well documented and represent conditions prior to major human occupation of the watershed. At about 1900 A.D., there was a period of higher C/N ratios that indicates a greater proportion of allochthonous organic matter being delivered from the surrounding watershed. This could be related to increased forest clearing, a major storm event, or a period of increased rainfall. The organic C, C/N, and δ<sup>15</sup>N values all indicate increasing cultural eutrophication throughout the 1900s and the highest organic matter δ<sup>15</sup>N value occurs in the 1970s-1980s. The δ<sup>15</sup>N values decrease from this peak time until today and this is likely related to the remediation efforts of the Lake Waramaug Task Force, which significantly decreased the external nutrient inputs and implemented in-lake restoration solutions since the 1970s-1980s. This finding needs to be verified by δ<sup>15</sup>N measurements of water nitrate and particulate matter nitrogen, but is significant because this likely represents one of the few

cases where remediation results are documented by lake sediments. In addition, the combination of  $^{210}\text{Pb}$ , Hg, and Pb sediment chemistries in Lake Waramaug will provide future studies a reference site so that relative sediment dating may be accomplished by simply measuring Hg or Pb concentrations, which are cheaper and require less time than  $^{210}\text{Pb}$  analyses.

In Beseck Lake, the sediments document the time from prior to the mid-1800s, when the lake water was raised by damming the outflow, to the last few years. Higher C/N ratios mark the older swamp sediments and increased cultural eutrophication results in greater concentrations of organic C, lower C/N ratios, and higher  $\delta^{15}\text{N}$  values. Unlike Lake Waramaug, a decrease in  $\delta^{15}\text{N}$  values is not observed, however, that signal may be lost due to moderate bioturbation of the bottom sediments.

Ongoing studies are examining the paleoredox record by measuring Fe-S sediment geochemistries as well as measuring sediment phosphorous phases to reconstruct the cultural eutrophication record of these lakes. Our findings will help the Lake Waramaug Task Force and Beseck Lake Association with future remediation decisions and provide the scientific community with a rare opportunity to compare recent sediment geochemistry with long-term, remediation efforts. We expect that future researchers will use the techniques and results from this study to examine other eutrophic water bodies, thereby making Beseck Lake and Lake Waramaug the model examples for this type of work.

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# Information Transfer Program Introduction

The Connecticut Institute supports information transfer supports information transfer projects through its competitive RFP process as well as through ongoing internal information transfer project "Water Resources Technology Transfer Initiative," described below.

We have two 104B supported projects in this review period, one that is concluding a 2–year effort on providing a GIS decision support system for assessing the allocation status of Connecticut basins, and the other is the Institutes information transfer program.

# Development of a Digital Geospatial Database to Support the Connecticut Water Allocation Policy Planning Model

## Basic Information

<b>Title:</b>	Development of a Digital Geospatial Database to Support the Connecticut Water Allocation Policy Planning Model
<b>Project Number:</b>	2006CT112B
<b>Start Date:</b>	3/1/2006
<b>End Date:</b>	2/28/2008
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	second
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	Water Quantity, Water Quality, Management and Planning
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Sandy Prisloe, Chester Arnold, Daniel Civco

## Publication

# **Development of a Digital Geospatial Database to Support the Connecticut Water Allocation Policy Planning Model**

Status Report for the period

April 2007 – July 2008

**Project Problem and Research Objectives:** During the summer of 2005, a special workgroup of the Water Planning Council Advisory Group was organized and charged with investigating how better to address water allocations issues in Connecticut. The workgroup issued a September 16, 2005 final report titled “Water Allocation Policy Planning Model Implementation Workgroup – Basin Screening,” and recommended that a comprehensive digital geospatial database be assembled to aid and support water allocation planning and basin screening in the state. Creation of this baseline database was identified as the first step necessary for proactive water allocation planning. The lack of such a database makes it difficult, if not impossible, to effectively and accurately assess the degree to which waters currently are allocated, where current and future demands exceed water availability, and how water allocation in one watershed compares to and impacts water allocation in other watersheds. Without this comprehensive and integrated database, water allocation decisions will continue to be made on a case by case basis and the cumulative impacts of decisions will continue to be difficult to assess.

**Methods:** The project was funded for the first year for \$25,050. In April, Cary Chadwick was hired as a Research Assistant to work on the project and to begin the data acquisition process. Approximately 50% of her time is dedicated to the project.

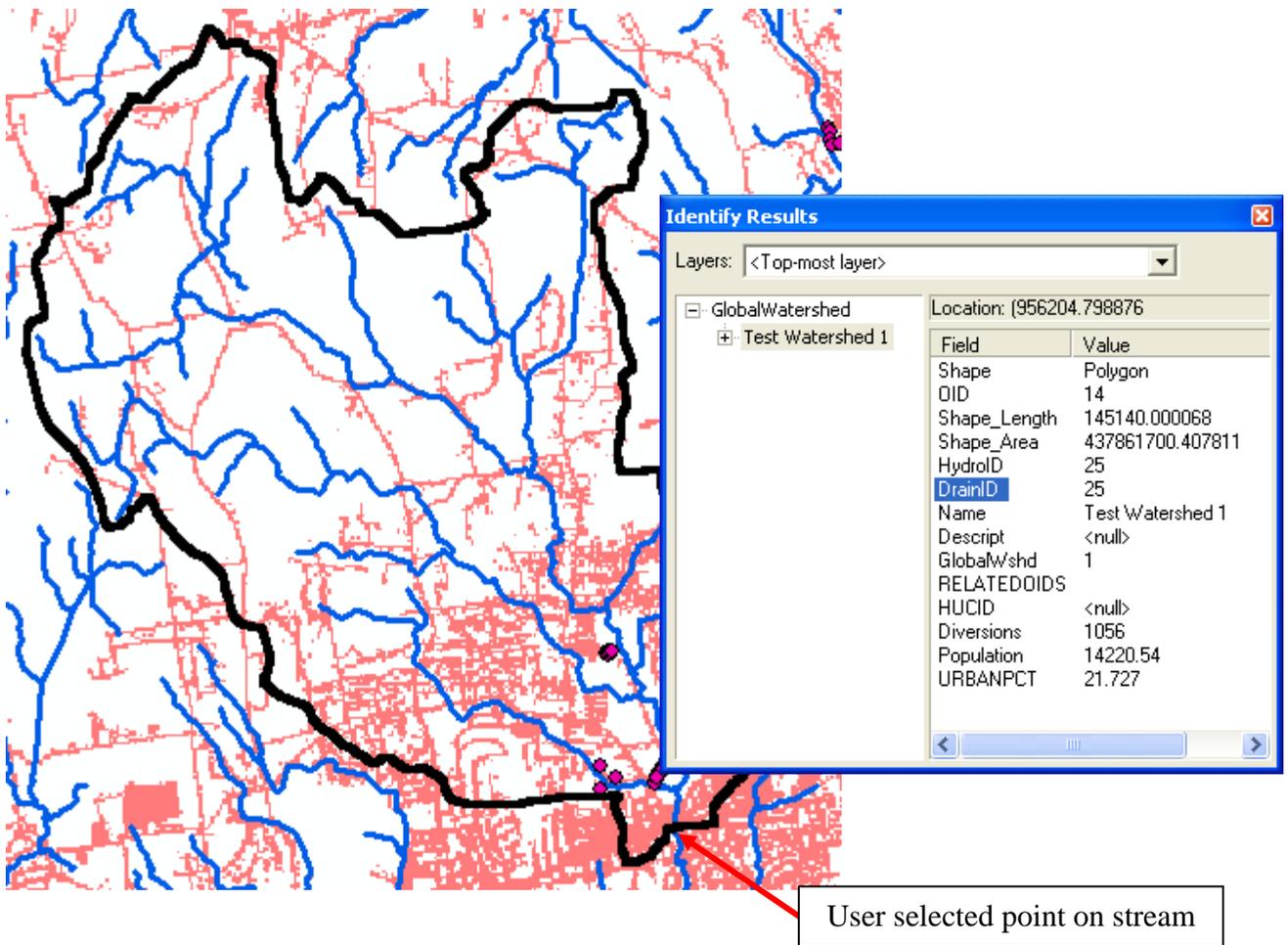
Initial work focused on researching the availability of GIS datasets that were identified in the proposal and acquiring those datasets that were deemed appropriate. This required looking into data availability not just in Connecticut but also for those portions of New York, Massachusetts and Rhode Island that drain into the state. The upper Connecticut River Watershed in Massachusetts, Vermont and New Hampshire was not included in this work and is outside the geographic scope of our work.

Several dataset issues were identified early on in the project. These include data standards and content for datasets that cross state lines. GIS datasets produced by state agencies are typically inconsistent from one state to another. For example, land cover mapping in all four states has been done but using different protocols, source data, and classification systems. Part of our work has been to acquire available datasets and to evaluate what will be necessary to combine them into “regional” datasets that extend into the surrounding states. Datasets produced by federal agencies tend to be created based on national standards and thus avoid these state boundary problems. Part of the data assessment included a determination of what data can be used from federal sources, which must come from state sources and what level of effort will be necessary to merge state datasets together. Tables 1 – 3, included at the end of this report, summarize the GIS datasets that have been acquired and/or reviewed to date.

An issue that arose early on is what watershed units to use for basin characterization and screening. There are two choices: the CT DEP subregional watersheds, which include 374 watershed units to cover the state, and the NRCS HUC 12 Watershed Boundary Dataset (WBD), which includes 194 units to cover the state. The WBDs were delineated to national standards and where possible their boundaries are coincidental with CT DEP watershed units. At this point, we are planning to process the state datasets and to assemble them into regional datasets that cover CT and the adjoining areas and to develop watershed metrics based on WBD HUC 12 cataloging units. However, it should be noted that future development of metrics for CT subregional watersheds, should such be needed, will be a relatively simple task since the region-wide GIS datasets will be in place.

Project personnel also have investigated the use of ArcHydro as an assessment tool to characterize conditions within user defined watersheds. The ArcHydro extension to ArcGIS, is being modified by a team of researchers from the USGS, ESRI, the University of Texas and others to support the USGS's web-based StreamStats program. Pete Steeves, USGS MA, provided us with the most current ArcHydro extension and preprocessed elevation, HUC and NHD data for Connecticut watersheds.

The advantage of the ArcHydro extension is that it lets a user create and analyze non-standard watershed units and it includes the entire upstream drainage area which is not the case when individual WBD HUC12s are used for assessment. ArcHydro delineates the upstream watershed to a user selected point along any stream and then generates a set of metrics, also selected by the user, from a list of all possible metrics for the watershed. The GIS data that's to be evaluated must be in a grid format and each grid must represent a single factor. The Connecticut 2002 land cover data, which includes 11 separate land cover classes, were converted into 11 single-factor land cover grids. Also converted to a grid format was 2000 Census Block population data, water service areas, sewer service areas and a synthetic dataset of water diversions. The ArcHydro extension was modified to calculate metrics for these grid datasets. The screen capture below illustrates the output from the ArcHydro tool.



In the above example, a point along the stream was identified and the watershed to this point was calculated. The watershed is outline in the heavy black line. Within the watershed are areas in light pink that represent developed land and small circles that represent water withdrawals. Not shown but also part of the analyzed data is a grid of 2000 population. The ArcHydro tool first delineates the watershed and then calculates metrics within this area. In this example, metrics were calculated for diversion amounts, population counts and percent area in urban land use.

At this point we have acquired many of the geospatial datasets that were identified in the original work plan and are now focusing on those datasets included in TABLE 2 - DATASETS TO BE USED AS WATERSHED SCREENING FACTORS. These data were identified as being of particular importance by Drs. Warner and Bresnahan, UConn. The water diversion data have been acquired from the CT DEP as a set of GIS point locations along with hundreds of Excel spreadsheets that contain data on registered and actual withdrawals. Unfortunately, these data are inconsistent and it has been determined that additional assistance from the DEP will be required if they are effectively to be used. The registered diversion data are especially problematic. When Connecticut's water diversion legislation was enacted, existing water users were grandfathered and allowed to

register their existing use. Many registered quantities far exceeding actual use to ensure future access to water.

**Work plan revisions for year 2:** The original work plan stated that in Phase 2 of the project we would investigate the use of ESRI's Model Builder as an assessment framework. Given the successful results of our testing of the ArcHydro tool, we propose to instead explore its use for Phase 2. The tool provides significant flexibility in that it does not require working with a set of predefined static watersheds. Rather, watersheds to any point along streams can be created "on-the-fly". This will provide a great deal of flexibility and will let a user focus on specific areas of interest.

Additional resources also have been made available to the project. The Institute for the Application of Geospatial Technology (IAGT) is providing \$20,000 of funding support that will be used to extend Cary Chadwick's work. IAGT also is providing in-kind technical support. With IAGT we will be investigating methods, utilizing geospatial technologies, to quantify and describe the spatial distribution of land cover within watersheds. If successful, this will allow us to generate more meaningful metrics that summarize not just the percent of each land cover within a watershed but also the relationship between its location in the watershed and the location of receiving streams and waterbodies. We intend also to characterize these relationships for first order, second order, third order and other streams.

A website also has been established to provide some basic information about the project. It is located at <http://clear.uconn.edu/geospatial/iwr.htm>.

This project will conclude in the Summer of 2008 with a presentation to the state's Water Allocation Policy Planning Model Committee, where the impetus for this project originated.

# IWR Project Dataset Inventory

TABLE 1 - DATA AVAILABLE IN GIS FORMAT

<b>Data</b>	<b>Sources</b>	<b>CT</b>	<b>MA</b>	<b>NY</b>	<b>RI</b>	<b>Compatible?</b>
Aquifer protection areas Well head protection areas	CTDEP	Y	Y	?	Y	Y**
Committed open space	Various*	Y	Y	N	Y	Y**
Dams and impoundments	Various*, NHD	Y	Y	N	Y	Y
Diversion withdrawals	CTDEP	Y	?	?	?	--
Endangered species	Various*	Y	Y	?	Y	Y
Groundwater quality classifications	Various*	Y	?	?	Y	Y
Gaging stations	USGS	Y	Y	N	N	Y
Hydrography	USGS NHD	Y	Y	Y	Y	Y
Land cover	Various*. Also NLCD available	CCL 2002 (30m Landsat)	1999 (1:25,000 aerial)	N	1995 (1:12,000)	N
Leachate Wastewater Discharge Points, Lines	Various*	Y	Y	Y	Y	Y
Political boundaries	Various*	Y	Y	Y	Y	Y
Population; Population Density	2000 Census Data	Y	Y	Y	Y	Y
Precipitation	Annual Estimates (PRISM) 1961-1990; 1971-2000	Y	Y	Y	Y	Y
Roads	Various*	Y	Y	N	Y	Y
Sewer Service Areas	Various*	Y	Towns	N	Y	Y**
SSURGO Soils	USDA NRCS	Y	Partial	N	Y	Y
Surficial materials	Various*	S. materials	S. Geology	S. Geology	Glacial Geology	N
Surface water quality classifications	CTDEP	Y	N	?	Y	Y
Topography	30m DEM (NED)	Y	Y	Y	Y	Y
Water Utility Areas	Various*	Y	Towns	N	Water Districts	Y**
Watershed Boundaries	WBD (HUC12's)	Y	Y	Y	Y	Y

\*Primary data sources include CT Department of Environmental Protection (CTDEP), Massachusetts Geographic Information System (MassGIS), Rhode Island Geographic Information System (RIGIS), and the NY State Geographic Information Systems Clearinghouse. We are in the process of establishing a formal data sharing partnership with NY in order to access NY State data. \*\* Datasets produced using different protocols and standards and may be difficult to merge.

TABLE 2 - DATASETS TO BE USED AS WATERSHED SCREENING FACTORS

<b>Data</b>	<b>Source</b>
Percent Stratified Drift	DEP surficial materials(possible data source) Contact Liz Ahern
% Urbanization	CCL 2002 Land Cover
Location of Sewage Treatment Outfall Points	DEP Leachate Wastewater Discharge Points
Reservoirs and Large Impoundments	NHD, DEP Hydrography layers
Stream Metrics (stream length, drainage density)	NHD, DEP Hydrography layers
Basin Metrics (L:W, slope)	WBD, DEM
Diversions (registered and permitted)	CT DEP
Stream crossings	Hydrography layers; culverts, bridges, infrastructure

TABLE 3 - GRID DATASETS THAT HAVE BEEN PREPARED FOR USE WITH ARCHYDRO

<b>Data</b>	<b>Grid Size</b>	<b>Extent</b>
CCL 1985, 1990, 1995, 2002 Land Cover Data	30 meter	CT, slightly beyond
2000 Population (based on census blocks)	30 meter	CT, MA, NY, MA
Water Service Areas	30 meter	CT
Sewer Service Areas	30 meter	CT
Precipitation (Yearly Average-based on PRISM model 1961-1990)	30 meter	CT, MA, NY, RI
Precipitation (Yearly Average-based on PRISM model 1971-2000)	800 meter	CT, MA, NY,RI
Synthetic Water Diversion Point Data	10 meter	CT



# Water Resources Technology Transfer Program

## Basic Information

<b>Title:</b>	Water Resources Technology Transfer Program
<b>Project Number:</b>	2006CT128B
<b>Start Date:</b>	3/1/2006
<b>End Date:</b>	2/28/2008
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	2nd
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Glenn Warner, Patricia Bresnahan

## Publication

1. Bresnahan, P., G.S. Warner, R.A. Jacobson and J.M. Stella. 2007. Modeling the effects of reservoir release practices on downstream flows. Connecticut Conference on Natural Resources. March 9, 2007. Storrs, CT
2. Warner, G.S., P. Bresnahan, R.A. Jacobson, J.M. Stella. 2007. Modeling the Effect of Reservoir Release Practices on Available Water Supply Using STELLA. Massachusetts Water Resources Conference. April 9, 2007. Amherst, MA.
3. Warner, G.S., P. Bresnahan, and R.A. Jacobson, 2007. Modeling Flows Downstream of Water Supply Reservoirs. Paper # 072092. Annual International Conference, ASABE. Minneapolis, MN; June 17-20, 2007.
4. Warner, G.S. and P.A. Bresnahan. 2007. Final Report for Project entitled: "Modeling Flows Downstream of Reservoirs" submitted to Connecticut Department of Environmental Protection, April 6, 2006.

The Connecticut Institute of Water Resources information transfer program has several components:

1. CT IWR web site
2. Publications
3. Seminar Series
4. Conferences and Workshops
5. Liaison Work

**Web Site:** Our office maintains the CT IWR web site, which is updated on a quarterly basis (or as needed). It includes information about the WRI program, our institute and its board, a listing of the current year's seminars, a list of sponsored projects and publications, and access to electronic copies of our "Special Reports" series. We also use the web to announce special events and our RFP. We continue to cooperate with the University of Connecticut's digital archives department, which maintains our electronic reports as a part of its "Digital Commons @ University of Connecticut" project.

**Publications:** No new publications were generated.

**Seminar Series:**

The CTIWR has begun co-sponsoring the seminar series offered by the Department of Natural Resources Management and engineering, the administrative home for our Institute, instead of holding its own, separate series. Pat Bresnahan serves on the steering committee and actively seeks out speakers with a water interest. Each semester the CTIWR provides financial support to bring in one outside speaker as the "Kennard Water Resources Lecturer." Dr. William Kennard was the first Director of our Institute, and we honoring his contribution to our program in this way. The water seminars in this year's series included:

**CTIWR / NRME Seminar Series**

- |           |   |
|-----------|---|
| 18-Apr-08 | Modeling the Effects of Predicted Changes in New England Precipitation on Water Supply and Downstream Flows<br>Kynoch Reale-Munroe, University of Connecticut<br>Seminar MS Student, CTIWR Reservoir Project Storrs, CT |
| 28-Mar-08 | Land use and developmental deformities in New England amphibians<br>David Skelly, Yale University<br>Seminar Former 104B PI Storrs, CT  |
| 15-Feb-08 | The Massachusetts Sustainable-Yield Estimator: A probabilistic decision support system to assess surface-water resources in Massachusetts<br>Stacey Archfield, USGS<br>Seminar Storrs, CT                               |

**CTIWR Kennard Lecture / NRME Seminar Series**

- |           |  |
|-----------|--|
| 21-Mar-08 | Biogeochemistry of a suburban basin - putting people into the landscape<br>William McDowell, University of New Hampshire<br>Seminar Storrs, CT |
| 05-Oct-07 | The Penobscott River Restoration Project<br>Gordon Russell, US FWS<br>Seminar Storrs, CT   |

**Conferences:** The Institute co-sponsored or served on the steering committee for a number of conferences:

10-Mar-08 Connecticut Conference on Natural Resources 2008

CTIWR, Various cosponsors  
CTIWR Contributed \$500. Steering Committee: Warner, co-chair, Bresnahan, Member.

11-Jan-08 Hydropower in Connecticut and the Northeast  
CTIWR, Various cosponsors  
CTIWR Contributed \$500 towards cost of publishing proceedings.

08-Apr-08 Massachusetts Water Conference  
Pat Bresnahan (CTIWR) served on the Steering Committee

23-Jun-08 Seventh International Chrysophyte Symposium  
CTIWR contributed \$976 to cover travel expenses for a speaker

05-Mar-08 Water Wise: Mansfield Water Forum  
CTIWR, Mansfield LWV  
CTIWR was asked by the Mansfield LWV to help develop this forum.  
Pat Bresnahan Co-chaired the Steering Committee. Glenn Warner served on the panel.

**Liaison Work:** At the invitation of the DEP Commissioner's office, Glenn Warner has been participating in the Scientific and Technical Standards Workgroup of the Stream Flow Advisory Group. The purpose of the group is to provide guidance for the development of flow regulations for streams and rivers in Connecticut. In support of this work, our Institute received a \$30,000 grant to do simulation modeling to assess the impact of reservoir release rules on downstream flows and reservoir safe yield. In addition, Pat Bresnahan was asked to serve on a modeling expert panel:

23-Jan-08 Ecologically Sustainable Water Management of the Saugatuck River Watershed  
The Nature Conservancy, Aquarion Water Company

# Student Support

<b>Student Support</b>					
<b>Category</b>	<b>Section 104 Base Grant</b>	<b>Section 104 NCGP Award</b>	<b>NIWR-USGS Internship</b>	<b>Supplemental Awards</b>	<b>Total</b>
<b>Undergraduate</b>	3	0	0	0	3
<b>Masters</b>	0	0	0	0	0
<b>Ph.D.</b>	2	0	0	0	2
<b>Post-Doc.</b>	1	0	0	0	1
<b>Total</b>	6	0	0	0	6

## **Notable Awards and Achievements**

Within the State of Connecticut there is a growing recognition that water policy and management need to be supported by sound science. Questions related to water allocation and basin water budgets are emerging as critical needs. The CTIWR has actively addressed these needs in recent years through its research and information transfer programs, and in the process developed a network of cooperators and supporters. Last year this network came together to ask the state legislature to provide financial support to our Institute. As a result, our Institute received a \$200K state appropriation for water basin planning. There is an additional \$500K for our Institute for basin studies in the bond package that was approved by the legislature, but this has not been approved by the Governor.

# Publications from Prior Years