

# Delaware Water Resources Center Annual Technical Report FY 2002

## Introduction

Delaware Water Resources Center Annual Technical Report Introduction and Program Management/Administration Description FY 2002 (3/1/02 - 2/28/03) June 30, 2003

Delaware has more than 2,509 miles of rivers and streams, and 2,954 acres of lakes and ponds that have been classified using the federal Clean Water Act's rating system of protected "designated uses" for purposes of drinking, swimming and recreation, fishing, and wildlife propagation. Delaware has promulgated surface water quality standards which are designed to protect the designated uses of each classified water body in the State. The Department of Natural Resources and Environmental Control (DNREC) has found, based on designated use support data for the period September 1997 through August 2001, that 99% of state rivers and streams do not fully support the swimming use, and 64% do not fully support fish and wildlife uses. Ponds and lakes, where pollutants washed from land and air accumulate, do not fully support swimming use in 87% of cases and 21% do not fully support the fish and wildlife uses. The major causes of non-attainment of designated uses of Delaware's water resources are high levels of pathogenic bacteria, nutrient over-enrichment, toxics, and degradation of physical stream habitat.

The majority of the water quality standard violations are due to nonpoint source pollution impacts. Bacteria concentrations above the level considered acceptable for primary contact recreation are found in 99% of Delaware's rivers and streams, most (~>80%) of ponds and lakes and 59% of estuarine waters (excluding the Delaware River and Bay). Safe shellfish harvesting and consumption is also adversely impacted by high bacteria levels in many of Delaware's estuarine and tidal waters. Although bacteria is the most widespread contaminant, nutrients and toxics pose the most serious threats to water quality, aquatic life, and human health. Nutrient over-enrichment of Delaware's water bodies is due to soil erosion, failing septic systems, and nutrient losses from the land application of manures and fertilizers. Lowered dissolved oxygen levels and nuisance plant growth result from excess nutrients in Delaware's waterbodies. Toxics, such as Polychlorinated Biphenyls (PCB's), dioxin, chlorinated benzenes and pesticides persist in the environment and accumulate in the flesh of fish. Several rivers and streams in Delaware, as well as the Delaware Bay, have fish consumption advisories due to toxics. Finally, physical habitat of most of Delaware's nontidal perennial streams is degraded due to several factors including increases in impervious surfaces as a result of urban land uses in the Piedmont, and stream channelization to improve drainage on agricultural lands in the Coastal Plain. Physically degraded stream habitats generally have decreased shade, less channel stability, and a reduction in runoff filtering vegetation. Results of degradation of physical stream habitat include reduced aquatic life diversity and violations of water quality standards for dissolved oxygen and temperature.

In general, surface water quality in Delaware has remained fairly stable despite stresses induced by increasing development and population growth. Factors contributing to this stability are: investments in wastewater treatment technologies, more widespread use of best management practices (BMPs) by private businesses, and improved storm water management & wetlands creation by the Delaware Department of Transportation that in turn mitigate the impact of new highway construction and maintenance.

Improvements in watershed assessment methodologies, in tandem with stricter water quality criteria, have increased both the number of water quality problems identified and the frequency of non-attainment of water quality standards. Targeted monitoring in areas of TMDLs, toxics in biota and sediments, and biological and general assessments, is being used to help identify improvements in basin-wide quality as a result of statewide efforts to improve surface water quality.

Delaware's ground water is relatively vulnerable to contamination due to the state's shallow water table and high soil permeability. Contaminant sources include domestic septic systems, landfills, underground storage tanks, agricultural activities, and chemical spills and leaks. High nitrate levels in underground sources of drinking water are a potential health concern, particularly in the agricultural areas of Kent and Sussex counties, as well as a source of nutrients to surface water. The seven highest priority sources of ground water pollution are animal feedlots (including poultry), federal/state superfund sites, application of fertilizers and animal manures to cropland, hazardous waste sites, salt water intrusion, septic systems, and underground storage tanks (primarily petroleum). Elevated dissolved iron concentrations in well water are also ground water concerns for the State. Radionuclides, particularly radon, are elevated in some areas.

In addition to water quality, water quantity is an area of serious concern in Delaware today. Indicators of streamflow and precipitation recognize Delaware's drought of 2002 as the drought of record for New Castle County, the northernmost of the state's three counties. Governor Minner imposed mandatory water use restrictions on August 2, 2002, when streamflows were reaching the lowest measured levels since recording these began in 1911. Precipitation measured at the county airport between Oct. 2001 and Sept. 2002 was the lowest recorded during this interval since 1894; hydrologic statistics indicate this was indeed the 100-year drought. Water purveyors in state governmental and utility agencies are cooperating across political and franchise boundaries to ensure safe and plentiful water for future drought years. Plans include use of an inflatable tidal capture and storage structure, new capacity in reservoirs and a water treatment plant, drilling new wells, pumping water into new aquifer storage and recovery wells, and the possible use of water scarcity pricing to encourage conservation. Legislation recommending water conservation rates was introduced for debate in the Delaware legislature during the spring of 2003. House Bill 118 would require utilities to impose conservation rates that raise costs for heavy water users or wasteful residential water consumption. These rates apply to utilities regulated by the Public Service Commission and water agencies operated by governments. The legislation also requires utilities to certify every three years that they have adequate dry-weather supplies.

The protection of the quality and quantity of the State's surface waters and aquifers remains a major concern to all agencies and individuals responsible for water resource management in Delaware. Groundwater protection (supply and quality) is particularly important given the fact that reliance on ground water for drinking water supplies has been increasing in Delaware. In general, the key priority areas for overall water quality and quantity research and implementation in Delaware today include (not in priority order): (1) enhanced management and control of stormwater runoff, erosion and sediment, (2) a better understanding of the sources, transport, fate and remediation of toxics, (3) comprehensive management of agricultural nutrients and sources of pathogenic bacteria, (4) increased understanding of the response of aquatic systems to specific pollutants, (5) identification and protection of key aquifer recharge areas, (6) better management of water supply and demand (including the financing of water supply infrastructures), (7) treatment and disposal of on-site sewage, protection and restoration of wetlands and (8) better understanding and prevention of saltwater intrusion to potable water supplies.

The Delaware Water Resources Center has funded 9 research grant programs during March 2002 through February 2003 that address these state water resources priorities. Three are graduate fellowships in nutrient management; the others were internships in modeling water quality, implementing streamside riparian buffers, building water monitoring equipment, understanding the spread mechanisms of invasive marsh reeds, regulating Delaware wetlands, and accelerating bioremediation of wastewater by using electrode reducing micro-organisms.

#### Delaware Water Resources Center Program Goals and Priorities

The primary goal of the Delaware Water Resources Center is to support research that will provide solutions to the State's priority water problems. A secondary goal is to promote the training and education of future water scientists and engineers. A third goal is to serve as a source of information to water researchers, decision makers, natural resource protection agency personnel and to the public through technology transfer projects.

Description of Delaware Water Resources Center Program Management and Administration March 1, 2002 through February 28, 2003 (FY02)

1. Institute Director Dr. J. Thomas Sims Professor of Soil and Environmental Chemistry Department of Plant and Soil Sciences University of Delaware Newark, DE 19717-1303 email: jtsims@udel.edu Phone: 302-831-1389 FAX: 302-831-0605

2. Administrative Personnel: Amy Boyd Program Coordinator e-mail: aboyd@udel.edu Phone: 302-831-1392, 302-738-6779 FAX: 302-831-0605

3. Abstract of Program and Management Overview: The Delaware Water Resources Center (DWRC) research, education and information transfer programs focus on issues of state and regional importance to both water quality and water quantity. Long-term priority areas of the DWRC have included nonpoint source pollution of ground and surface waters, development of ground water supplies, the impact of hydrologic extremes on water supply, and socio-economic factors affecting water supply and water quality. In 2000, the 16-member DWRC Advisory Panel identified five specific areas for near-term DWRC efforts: (1) Agricultural nutrient management and water quality; (2) Basic and applied research on sources, fate, and transport of water pollutants; (3) Quantifying response of aquatic ecosystems to pollutant inputs; (4) Water supply, demand, and conservation, as affected by changing land uses in Delaware and the mid-Atlantic states; and (5) Management and control of stormwater runoff. The FY2002 DWRC research program addressed these issues by supporting graduate fellowships in water quality (3), an undergraduate student internship program, and statewide presentations including an intern research poster session, water resources conference, and 2003 Governor's Conference.

2002-2003 DWRC fellowship and internship research program Three fellowships have been awarded for 2002-2003 based on a review of proposals submitted by potential graduate fellows and their advisors to the DWRC Advisory Panel:

a) Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation Graduate Fellow: Stefan Hunger; Advisor: D. L. Sparks, Department of Plant and Soil Sciences, College of Agriculture and Natural Resources, University of Delaware.

b) Land Use/Land Cover and Nutrient Discharges to Delaware's Inland Bays Graduate Fellow: Jennifer Jennings; Advisors: J. R. Scudlark, and W. J. Ullman, College of Marine Studies, University of Delaware.

c) Environmental Policies for a Sustainable Poultry Industry in Sussex County, Delaware Graduate Fellow: Lynette Ward; Advisors: William Ritter, Department of Bioresources Engineering and John Byrne, and Young-Doo Wang, Center for Energy & Environmental Policy, University of Delaware.

Six internships have been awarded for 2002-2003 to seven interns based on a review of proposals submitted by potential undergraduate interns and their advisors to the DWRC Advisory Panel:

a) Chemistry of Phosphorus in the Erodible Fraction of Delaware Soils Undergraduate Intern: Laura Boyer; Advisor: J. T. Sims, Department of Plant and Soil Sciences, College of Agriculture and Natural Resources, University of Delaware.

b) Implementation of Riparian Buffers in Southeastern Pennsylvania, Delaware, and Eastern Maryland Undergraduate Intern: Alexander DeWire; Advisor: J. B. Johnson, Department of Political Science, College of Arts and Sciences, University of Delaware.

c) Understanding the Mechanisms of the Spread of Phragmites: For Better or For Worse Undergraduate Intern: Michael League; Advisor: J. Gallagher, College of Marine Studies, University of Delaware.

d) Managing Wetlands in Delaware in a Changing Legal Environment Undergraduate Intern: Kristen Sentoff; Advisor: J. Duke, Department of Food and Resource Economics, College of Agriculture and Natural Sciences, University of Delaware.

e) Accelerated Bioremediation of Wastewater using Electrode-Reducing MicroOrganisms Undergraduate Interns: Aditya Sharma and Bret Strogon; Advisors: S. Dentel and P. Chiu, Department of Civil and Environmental Engineering, College of Engineering, University of Delaware.

f) An Autonomous Full-Water Column Environmental Monitoring System with Telemetry Undergraduate Intern: Kerrie Smith; Advisor: J. Glancey, Department of Mechanical Engineering and Department of Bioresource Engineering, University of Delaware.

## **Research Program**

# Graduate Fellowship in Water Quality: The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays

## Basic Information

<b>Title:</b>	Graduate Fellowship in Water Quality: The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays
<b>Project Number:</b>	2002DE1B
<b>Start Date:</b>	3/1/2000
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	At-large
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Water Quality, Non Point Pollution, Nutrients
<b>Descriptors:</b>	Eutrophication, Land Use, Nitrogen, Nutrients, Rainfall-Runoff Models, Rainfall-Runoff Processes, Water Quality, Water Quality Monitoring
<b>Principal Investigators:</b>	Jennifer Jennings, Joseph R. Scudlark, J. Thomas Sims, William J. Ullman

## Publication

1. Jennings, Jennifer, William Ullman, and Joseph Scudlark. March and June 2002. The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays. Annual reports to the Delaware Water Resources Center, University of Delaware, Newark, Delaware, 12 and 3 pages, respectively.
2. Jennings, Jennifer. 2003. The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays. M.S. Thesis, University of Delaware, Newark, Delaware. 163 pages.

## **Delaware Water Resources Center Research Program: Fellows**

The following three research projects are DWRC-funded graduate fellowships granted in December 1999 and spanning a three-year period. Related presentations are found in the Information Transfer section. A final report to the DWRC for each of the three fellowships is expected by August, 2003.

### **Basic Information: Fellow Project #1 (of 3)**

<b>Title:</b>	The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays
<b>NIWR Project Number:</b>	<b>2002DE1B</b>
<b>Start Date:</b>	3/1/2000
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Water Quality(WQL), Models (MOD), Nutrients (NU), Non Point Pollution (NPP)
<b>Descriptors:</b>	Eutrophication, Land Use, Nitrogen, Nutrients, Rainfall-Runoff Models, Rainfall-Runoff Processes, Water Quality, Water Quality Monitoring
<b>Principal Investigators:</b>	Jennifer Jennings, University of Delaware M.S. candidate
<b>Other Principal Investigators:</b>	William Ullman <a href="mailto:ullman@udel.edu">ullman@udel.edu</a> , and Joseph Scudlark <a href="mailto:scudlark@udel.edu">scudlark@udel.edu</a> , College of Marine Studies, University of Delaware, advisors.
<b>Project Class:</b>	Research

**Previous Project Numbers:** DWRC G-03 (FY00); NIWR 2000DE3G (FY00) and 2001DE3681B (FY01)

### **Publication**

1. Jennings, Jennifer, William Ullman, and Joseph Scudlark. March and June 2002. The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays. Annual reports to the Delaware Water Resources Center, University of Delaware, Newark, Delaware, 12 and 3 pages, respectively.
2. Jennings, Jennifer. 2003. The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays. M.S. Thesis, University of Delaware, Newark, Delaware. 163 pages.

Names and degree level (highest level during the reporting period) of all students who worked on the research project: Jennifer A. Jennings, M.S. recipient April, 2003.

A DWRC newsletter article on this project may be found at:  
<http://ag.udel.edu/dwrc/newsletters/JenningsSpr2002.pdf>

## **Abstract (of M.S. thesis based on this fellowship's research)**

In this research, the discharge of water and associated nutrients from one sub-watershed of Delaware's Inland Bays (Bundicks Branch) was studied in detail so that total nitrogen and phosphorus loads from this tributary, and potentially others with similar geological, hydrological, and land use characteristics could be determined. The calculated loads, based on measured data were compared to previous model estimates, which have been and continue to be used by managers, for the establishment of nutrient loading targets and land use management practices within the watershed.

In order to accurately determine storm loads at Bundicks Branch, an alternative baseflow minimization separation technique, which reduced and ultimately shut off groundwater inputs under the peaks of storm events, was developed. This model yields more reliable estimates of baseflow and storm loads at this tributary. Samples collected during both the hourly and daily sampling experiments revealed that dissolved nutrient concentrations fluctuated little (<12%) within a day and between sampling dates, while particulate constituents were more variable on both time scales and calculated loads can carry a greater degree of uncertainty (>40%).

Storm loads of 17 monitored events at Bundicks Branch were evaluated for seasonal trends and used to project annual storm loads. Normalization of storm loads by precipitation amount (P) and integrated storm discharge (Q) revealed that the loads per unit P or Q of sequential monitored events were fairly similar. The loads of unsampled storms between monitored events were therefore determined using the average "per unit" loads of the previous and following sampled storms.

These same, and similar, flow based calculations were applied to less studied sub-watersheds. As a result of the detailed study conducted at Bundicks Branch, annual nutrient loads in both the baseflow and stormflow discharge components could be estimated at two similar sites using the Bundicks Branch model calibrated with data from these sites. Using this approach, total, baseflow, and storm loads may be determined with substantially less discharge and water quality data.

The loads computed in previous chapters using flow-based calculations were used to evaluate loading estimates produced by land use-based nitrogen and phosphorus models. The estimated loads from the Ritter (1986a), Horsley & Witten (1998), and USDA (Cassell and Meals, 1999) models appear to represent an upper bound to the actual nutrient loadings. The Ritter (1986a) approach gave very good estimates of N when applied to Bundicks, while the Horsley & Witten (1998) approach produced a value approximately 30% greater than the measured loads. Both the Ritter (1986a) and USDA (Cassell and Meals, 1999) P models overestimated measured P loads at Bundicks Branch by 400%. These results indicate that existing non-point discharge targets should be revised in light of recent observations.

It was also determined, after analysis of atmospheric N and P deposition rates to the watershed, that the land uses of Bundicks Branch attenuated both N and P on a seasonal basis with peaks in attenuation occurring during the peak-growing season. Thus, the land uses and land covers of the studied sub-watersheds were found to take on both the role of net nutrient source and the role of net nutrient sink at different times of the year. Future management practices that take into account the seasonality of nutrient attenuation in the watershed, may better achieve management goals.

Finally, the nutrient loadings determined at Bundicks Branch during this study were extrapolated to represent the non-point source load from the entire Rehoboth Bay sub-basin and were compared to the loading contributions from direct atmospheric deposition and the Rehoboth Wastewater Treatment Plant. This analysis revealed that prior nitrogen budgets were sound, with the watershed contributing close to 80% of the annual N load to the bay, 17% from direct atmospheric deposition, and 4% from the WTP, but suggested that the actual phosphorus budget is substantially different than previously believed. On an annual average basis, this approach estimates that the watershed and Rehoboth WTP contribute relatively equal proportions of the P load to Rehoboth Bay at 41 and 45% respectively. In addition, it appears that the loading proportion from the WTP can be even greater during summer months, especially those that are dry, suggesting that focus should also be paid to the management of point sources in regard to nutrient pollution.



# Graduate Fellowship in Water Quality: Environmental Policies For a Sustainable Poultry Industry in Sussex County, Delaware

## Basic Information

<b>Title:</b>	Graduate Fellowship in Water Quality: Environmental Policies For a Sustainable Poultry Industry in Sussex County, Delaware
<b>Project Number:</b>	2002DE3B
<b>Start Date:</b>	3/1/2000
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	At-Large
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Economics, Water Quality, Nutrients
<b>Descriptors:</b>	Agriculture, Economics, Policy, Non Point Pollution, Nutrients, Water Quality
<b>Principal Investigators:</b>	Lynette Ward, John M. Byrne, William F. Ritter, Young-Doo Wang

## Publication

1. Ward, Lynette, William Ritter, John Byrne, and Young-Doo Wang. 2001 and 2002, Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware. Annual reports to the Delaware Water Resources Center, University of Delaware, Newark, Delaware, 30 and 5 pages, respectively.
2. Ward, Lynette. 2003. Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware. Ph.D. Dissertation, University of Delaware, Newark, DE. 348 pages.

## Basic Information: Fellow Project #2 (of 3)

<b>Title:</b>	Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware
<b>NIWR Project Number:</b>	2002DE3B
<b>Start Date:</b>	3/1/2000
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Agriculture (AG), Economics (ECON), Policy (LIP), Non Point Pollution (NPP), Nutrients (NU), Water Quality (WQL)
<b>Descriptors:</b>	Agriculture, Economics, Policy, Non Point Pollution, Nutrients, Water Quality
<b>Principal Investigators:</b>	Lynette Ward, University of Delaware PhD candidate
<b>Other Principal Investigators:</b>	William Ritter <a href="mailto:william.ritter@udel.edu">william.ritter@udel.edu</a> , Department of Bioresources Engineering; John Byrne <a href="mailto:jbyrne@udel.edu">jbyrne@udel.edu</a> and Young-Do Wang <a href="mailto:youngdoo@udel.edu">youngdoo@udel.edu</a> , Center for Energy and Environmental Policy, University of Delaware, advisors.
<b>Project Class:</b>	Research

**Previous Project Numbers:** DWRC G-02 (FY00); NIWR 2001DE4301B(FY01)

### Publication

1. Ward, Lynette, William Ritter, John Byrne, and Young-Doo Wang. 2001 and 2002, Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware. Annual reports to the Delaware Water Resources Center, University of Delaware, Newark, Delaware, 30 and 5 pages, respectively.
2. Ward, Lynette. 2003. Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware. Ph.D. Dissertation, University of Delaware, Newark, DE. 348 pages.

The names and degree level (highest level during the reporting period) of all students who worked on the research project is: Lynette Ward, PhD recipient May 6, 2003.

A DWRC newsletter article on this project may be found at:  
<http://ag.udel.edu/dwrc/newsletters/Spring2003p4.pdf>

### Abstract (of PhD dissertation based on this fellowship's research)

Sussex County, Delaware produces more broilers than any other county in the United States, producing 232 million broilers in 1998. While poultry production is the primary economic activity in the county, it is also the primary source of nutrient pollution. Poultry litter is commonly applied directly to cropland in Sussex County as a fertilizer and is the primary litter disposal method. The poultry industry is highly concentrated within the county and there is not

sufficient cropland in the county on which to apply poultry litter at agronomic application rates. As a result, phosphorus levels have built up in the soils and nutrients now enter the county's waterways causing water quality problems. Although agriculture is the largest single land use within the county, urban land use grew by 22 percent between 1992 and 1997 and is expected to continue to rise as cropland gives way to development, further intensifying the problem of land application. Consequently, land application can no longer be the sole disposal method for poultry litter in Sussex County.

The intent of this dissertation is to develop environmental policies that promote the creation of a sustainable poultry industry in Sussex County, Delaware. Sustainable poultry industry practices meet the triumvirate goals of being environmentally sound; economically viable in both the short-term and long-term; and socially responsible in the sense of promoting equity, and preserving rural communities and quality of life. This research will identify and evaluate the economic feasibility of methods to reduce the phosphorus content of poultry litter or to find beneficial uses other than direct land application. The following alternatives are to be evaluated in terms of their economic feasibility and effectiveness. The methods designed to reduce the phosphorus content of poultry manure to be studied are: 1.) the use of low phytase corn in poultry rations, and 2.) the addition of the enzyme phytase in poultry rations. The alternative uses of poultry litter to be studied are: 1.) biogas production, 2.) energy generation, 3.) composting, 4.) use as a cattle feed supplement, and 5.) pelletizing.

The economic analysis of alternative uses of poultry litter would be conducted using IMPLAN, a PC based economic analysis software system that uses both data files and software to create regional models. Data files are available that include information for 528 different industries and 21 different economic variables. These datasets are available at the county level. IMPLAN will be used to do an economic analysis of not only the alternative uses for poultry litter, but to measure the economic and social impacts of developing a sustainable poultry industry in Sussex County in terms of factors such as dollars of sales, local taxes received, environmental regulatory compliance costs, impact on tourism revenues, and jobs created.

This research is of particular interest to the Delaware agricultural community whose incomes are heavily reliant on livestock. In 1998, the value of crops in Delaware was \$164 million, while livestock and products were valued at \$609 million. During this period, Delaware experienced economic growth while the nation as a whole experienced a decline in net farm incomes. This robust farm economy may not be enough to insulate Delaware's agricultural revenues from short-term economic losses related to the costs of complying with nutrient management regulations, which restrict the land application of livestock manure. Over the long-term these compliance costs may be passed on to the consumer, however in the short-term they pose a serious financial risk to small farmers.

While the scope of the study area is limited to Sussex County, the recommendations of this dissertation have the potential to create substantial changes in the profitability and structure of the livestock industry on the Delmarva Peninsula. This research will identify policies that reduce agricultural water pollution in a manner that is economically viable and protects the existing rural community structure and values.

# Graduate Fellowship in Water Quality: Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation

## Basic Information

<b>Title:</b>	Graduate Fellowship in Water Quality: Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation
<b>Project Number:</b>	2002DE4B
<b>Start Date:</b>	3/1/2000
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	At-large
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Geochemical Processes, Nutrients, Water Quality
<b>Descriptors:</b>	Agriculture, Eutrophication, Nutrients, Phosphorus, Runoff, Soil Chemistry, Soil-Water Relationships, Water Quality
<b>Principal Investigators:</b>	Stefan Hunger, Donald Lewis Sparks

## Publication

1. Hunger, Stefan., and D. L. Sparks. 2001 and 2002. Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation. Annual reports to the Delaware Water Resources Center, University of Delaware, Newark, Delaware, 29 and 3 pages, respectively.
2. Hunger, Stefan, H. Cho, J. T. Sims, D.L. Sparks (2003). Direct speciation of phosphorus in alumamended poultry litter: A solidstate  $^{31}\text{P}$ NMR investigation, Environmental Science and Technology, in Review.
3. Hunger, Stefan. 2003. Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation. Ph.D. Dissertation, University of Delaware, Newark, DE. 131 pages.

## Basic Information: Fellow Project #3 (of 3)

<b>Title:</b>	Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation
<b>NIWR Project Number:</b>	2002DE4B
<b>Start Date:</b>	3/1/2000
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Agriculture (AG), GeoChemical Processes (GEOCHE), Non Point Pollution (NPP), Nutrients (NU), Sediments (SED), Water Quality (WQL)
<b>Descriptors:</b>	Agriculture, Eutrophication, Nutrients, Phosphorus, Runoff, Soil Chemistry, Soil-Water Relationships, Water Quality
<b>Principal Investigators:</b>	Stefan Hunger, University of Delaware PhD candidate
<b>Other Principal Investigators:</b>	Donald L. Sparks <a href="mailto:dvsparks@udel.edu">dlsparks@udel.edu</a> , Department of Plant and Soil Sciences, University of Delaware, advisor
<b>Project Class:</b>	Research

**Previous Project Numbers:** DWRC G-01 (FY00); NIWR 2001DE4302B(FY01)

## Publications

1. Hunger, Stefan., and D. L. Sparks. 2001 and 2002. Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation. Annual reports to the Delaware Water Resources Center, University of Delaware, Newark, Delaware, 29 and 3 pages, respectively.
2. Hunger, Stefan, H. Cho, J. T. Sims, D.L. Sparks (2003). Direct speciation of phosphorus in alumamended poultry litter: A solidstate <sup>31</sup>P NMR investigation, Environmental Science and Technology, in Review.
3. Hunger, Stefan. 2003. Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation. Ph.D. Dissertation, University of Delaware, Newark, DE. 131 pages.

The names and degree level (highest level during the reporting period) of all students who worked on the research project is: Stefan Hunger, PhD recipient, June 4, 2003.

A DWRC newsletter article on this project may be found at:  
<http://ag.udel.edu/dwrc/newsletters/Page4-Stefan.pdf>

## SUMMARY

### Background / Justification

In areas of intensive agriculture, eutrophication by nutrients run-off from the fields poses a severe threat to water quality. Phosphorus (P) has been recognized as the limiting nutrient for eutrophication to occur in fresh water and the reactions determining its mobility in soils deserve therefore special

attention. The most common form of P in soils is orthophosphate, either as the free or adsorbed anion, in inorganic mineral phases, or as organic phosphate esters. The most common sources of phosphate in agriculture are commercial, inorganic fertilizers and animal manures, containing mostly organic forms of phosphate. Unfortunately, only limited information exists about the mechanisms of phosphate sorption and desorption reactions in soils or in animal manures. To reduce the amount of water-soluble phosphate in poultry litter (PL), which is produced by confined animal operations on the Delmarva Peninsula and applied to fields locally, chemical amendments such as alum have been applied. Finally, phosphate interacts with a multitude of metals in soils and competes with anions for sorption sites on soil minerals. The sorption reactions of phosphate in soils and similar systems, such as PL, are thus complex. Some degree of knowledge about phosphate sorption reactions can be gained from macroscopic studies by measuring the phosphate uptake from solution by soil minerals and determining its dependence on environmental variables. Although this allows for some level of generalization, no information on the phosphate forms on a molecular level is available from these experiments. To extend the information gained from macroscopic data, one has to combine them with results from spectroscopic investigations. This will allow sound predictions of phosphate mobility and availability in soils or similar systems and help implement useful nutrient management plans.

Solid-state phosphorus nuclear magnetic resonance (NMR) spectroscopy and phosphorus X-ray absorption near edge structure (XANES) spectroscopy have emerged as important spectroscopic tools in the environmental and soils sciences, which allow the investigation of chemical forms of phosphate on a molecular scale. Both methods are suited for the study of phosphate species in soils and PL.

### **Objectives**

The objectives of the research in the past year were to:

1. Investigate phosphate speciation in alum-amended and unamended PL samples using solid-state  $^{31}\text{P}$ -NMR spectroscopy as a spectroscopic tool to identify major species and propose a mechanism for phosphate stabilization in alum-amended PL.
2. Investigate phosphate complexes at the gibbsite surface using solid-state  $^{31}\text{P}$ -NMR spectroscopy to elucidate the influence of reaction conditions such as time and pH on phosphate speciation. Gibbsite is used as a model aluminum mineral for clay-size aluminum hydroxides and hydroxide coatings on primary minerals in soils.
3. Investigate the cooperative sorption of phosphate and calcium to the gibbsite surface using a combined macroscopic-spectroscopic approach and identify possible reaction mechanisms responsible for the increased sorption of both ions according to the spectroscopic results.

### **Methods**

NMR experiments were conducted at the Environmental Molecular Sciences Laboratory in Richland, WA. XANES experiments were conducted at the National Synchrotron Light Source, which is part of Brookhaven National Laboratory in Upton, NY. Both techniques give information about the local environment of the observed atom and do not require the sample to be crystalline. Both are therefore ideally suited to investigate amorphous or heterogeneous samples such as poultry litter or sorption complexes on mineral surfaces.

The spectroscopic experiments were combined with macroscopic studies. Uptake of phosphate by gibbsite in suspension was investigated under different conditions and in the presence and absence of calcium. The amount of phosphate sorbed to the surface is defined as the amount disappearing from solution, which was measured as the difference between the initial concentration and the concentration after an equilibration time.

## Results to date

Calcium phosphate and organic phosphate diesters were identified as principal fractions in both unamended and alum-amended samples. A minor fraction in all samples was inorganic phosphate, probably bound by hydrogen bonds to functional groups in the organic matrix and to adsorbed water molecules. A major fraction of phosphate in the amended samples was adsorbed to amorphous aluminum hydroxide, which forms from alum by hydrolysis of Al after alum addition to the alkaline PL. Aluminum phosphate was detected in minor quantities in two of the alum-amended samples, indicating that it did not play a part in the process of fixing phosphate in alum-amended poultry litter or manure in general. It appears that the hydrolysis of aluminum is kinetically preferred over the formation of aluminum phosphate, although the latter is thermodynamically more stable at the pH values initially reached after the application of alum. This is to our knowledge the first comprehensive qualitative and quantitative investigation of phosphate species in alum-amended poultry litter.

- Results from a solid-state  $^{31}\text{P}$ -NMR investigation of phosphate complexes on the gibbsite surface indicate that with increasing reaction time the phosphate speciation changes to a higher coordination number of phosphate with aluminum and therefore to a higher stability. The same effect could be observed with lowering the reaction pH value at constant reaction times.

Results from the combined macroscopic – spectroscopic investigation of phosphate stabilization in the presence of calcium at the gibbsite surface indicate that the mechanism of increased phosphate uptake in the presence of calcium and increased uptake of calcium in the presence of phosphate is not due to the extensive formation of a calcium phosphate phase. Results from different spectroscopic approaches (P-XANES and solid-state  $^{31}\text{P}$ -NMR spectroscopy), however, are somewhat contradicting and a more thorough investigation is needed.

# Undergraduate Internship in Chemistry of Phosphorus in the Erodible Fraction of Delaware Soils

## Basic Information

<b>Title:</b>	Undergraduate Internship in Chemistry of Phosphorus in the Erodible Fraction of Delaware Soils
<b>Project Number:</b>	2002DE35B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Water Quality, Models, Nutrients
<b>Descriptors:</b>	Hydrogeochemistry, Models, Non Point Pollution, Nutrients, Sediments, Surface Water, Water Quality
<b>Principal Investigators:</b>	Laura Boyer, J. Thomas Sims

## Publication

1. Boyer, Laura, and J. Thomas Sims. 2003. Chemistry of Phosphorus in the Erodible Fraction of Delaware Soils. Report submitted to Delaware Water Resources Center, University of Delaware, Newark, Delaware, 28 pages.



## Delaware Water Resources Center Research Program: Interns

The following six research projects are DWRC-funded undergraduate internships which were granted for the period March 1<sup>st</sup>, 2002 - February 28<sup>th</sup>, 2003.

### Synopsis: Intern Project #1 (of 6)

<b>Title:</b>	Chemistry of Phosphorus in the Erodible Fraction of Delaware Soils
<b>NIWR Project Number:</b>	<b>2002DE35B</b>
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B and Other (Agway, \$1500)
<b>Research Category:</b>	Water Quality Modeling
<b>Focus Category:</b>	Hydrogeochemistry (HYDGEO), Models (MOD), Non Point Pollution (NPP), Nutrients (NU), Sediments (SED), Surface Water (SU), Water Quality (WQL)
<b>Descriptors:</b>	Hydrogeochemistry, Models, Non Point Pollution, Nutrients, Sediments, Surface Water, Water Quality
<b>Principal Investigators:</b>	Laura Boyer, University of Delaware undergraduate senior, Environmental Science
<b>Other Principal Investigators:</b>	Dr. J. Thomas Sims (jtsims@udel.edu), Department of Plant and Soil Sciences, University of Delaware, faculty advisor
<b>Project Class:</b>	Research

### Publication

1. Boyer, Laura, and J. Thomas Sims. 2003. Chemistry of Phosphorus in the Erodible Fraction of Delaware Soils. Report submitted to Delaware Water Resources Center, University of Delaware, Newark, Delaware, 28 pages.

Names and degree level (highest level during the reporting period) of all students who worked on the research project: Laura Boyer, undergraduate senior.

Laura Boyer worked on “Chemistry of Phosphorus in the Erodible Fraction of Delaware Soils”, with the goal of more accurate water quality modeling to prevent nonpoint source phosphorus pollution of Delaware’s surface waters. Laura’s advisor was Dr. Tom Sims of the University of Delaware (UD) Plant and Soil Sciences Department.

“The purpose of my project is to obtain information on the chemistry of phosphorus in the most erodible fraction of Delaware soils. The fine particles that are eroded from soils are often highly enriched in phosphorus, so a better understanding of this enrichment, relative to the sediments found in nearby streams, will help to improve water quality models that estimate nonpoint pollution of surface waters by phosphorus. I have been interested in solving water quality problems and hope to have a career in that area. Working with the DWRC is a good experience.”

– Laura Boyer

(continued)

Ms. Boyer will begin a M.S. degree program in the Department of Plant and Soil Science, University of Delaware College of Agriculture and Natural Resources, in June 2003. She completed a Degree with Distinction based on her DWRC research project with J. Thomas Sims, advisor, and graduated from UD with distinction in June 2003. Her M.S. advisor will be Dr. Greg Binford of the University of Delaware's Department of Plant and Soil Science.

### **Chemistry of Phosphorus in the Erodible Fraction of Delaware Soils**

#### **ABSTRACT**

The importance of phosphorus (P) originating from agricultural sources to the nonpoint source pollution of surface waters has been an environmental issue for decades because of the well-known role of P in eutrophication. The largest contribution to surface water problems is polluted runoff, which stems from soil erosion and the spreading of animal wastes and fertilizers rich in nitrogen (N) and phosphorus (P). The transport of P by soil erosion has not been viewed as a major problem in Delaware because of the generally flat topography of the state and the fact that most high P soils are found in southern Delaware and are coarse-textured and thus less susceptible to soil loss by erosion. However, two new concerns have arisen in Delaware today: (i) even if only a small amount of soil is lost from a field that has mainly coarse-textured soils, the fact that these soils are now highly enriched with P may be worse, in terms of P delivery to water bodies, than losing more soil from a field that is much lower in soil test P and P saturation, (ii) there is now an ongoing effort to re-locate manure generated in Sussex County to New Castle County, which could then enrich the fine-textured, more erodible soils in that county with P. The objectives of this study were to characterize the extent of P enrichment in the most erodible size fraction (fine sand, silt, clay) of a wide range of Delaware soils varying in physical and chemical properties and P content, and to determine which soil P measurements best predict the solubility of P in the size fractions of Delaware soils. The fine sand and silt and clay sized soil aggregates were the most enriched with P and are the most easily eroded soil aggregates, which implies that even if a small amount of "high P" soil is eroded into Delaware surface waters, large amounts of P could be lost. Also, the P saturation ratio had a significant relationship to water soluble P of the soil aggregates and can be used to predict water soluble P with varying soil test P concentrations.

# Undergraduate Internship in Implementation of Riparian Buffers in Southeastern Pennsylvania, Delaware, and Eastern Maryland

## Basic Information

<b>Title:</b>	Undergraduate Internship in Implementation of Riparian Buffers in Southeastern Pennsylvania, Delaware, and Eastern Maryland
<b>Project Number:</b>	2002DE36B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Water Quality
<b>Focus Category:</b>	Water Quality, Methods, Conservation
<b>Descriptors:</b>	Conservation, Education , Management and Planning , Methods, Non Point Pollution, Surface Water, Water Quality
<b>Principal Investigators:</b>	Alexander DeWire, Janet B. Johnson

## Publication

1. DeWire, Alexander, and Janet B. Johnson. 2003, "Implementation of Riparian Buffers in Southeastern Pennsylvania, Delaware, and Eastern Maryland", Report submitted to Delaware Water Resources Center, University of Delaware, Newark, Delaware, 36 pages.

## Synopsis: Intern Project #2 (of 6)

<b>Title:</b>	Implementation of Riparian Buffers in Southeastern Pennsylvania, Delaware, and Eastern Maryland
<b>NIWR Project Number:</b>	2002DE36B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Research Category:</b>	Water Pollution Reduction through Reforestation
<b>Focus Category:</b>	Conservation (CP), Education (EDU), Management and Planning (M&P), Methods (MET), Non Point Pollution (NPP), Surface Water (SU), Water Quality (WQL)
<b>Descriptors:</b>	Conservation, Education , Management and Planning , Methods, Non Point Pollution, Surface Water, Water Quality
<b>Principal Investigators:</b>	Alexander M. DeWire, University of Delaware undergraduate senior, Natural Resource Management
<b>Other Principal Investigators:</b>	Dr. Janet B. Johnson ( <a href="mailto:jbj@udel.edu">jbj@udel.edu</a> ), Department of Political Science, University of Delaware, faculty advisor
<b>Project Class:</b>	Research

## Publication

1. DeWire, Alexander, and Janet B. Johnson. 2003, "Implementation of Riparian Buffers in Southeastern Pennsylvania, Delaware, and Eastern Maryland", Report submitted to Delaware Water Resources Center, University of Delaware, Newark, Delaware, 36 pages.

Names and degree level (highest level during the reporting period) of all students who worked on the research project: Alexander DeWire, undergraduate senior.

Alexander M. DeWire's internship project is studying the "Implementation of Riparian Buffers in Southeastern Pennsylvania, Delaware, and Eastern Maryland" under advisement of Dr. Janet B. Johnson of the UD Department of Political Science. He hopes to measure the extent of streamside reforestation by property owners to reduce nonpoint pollution, notably in the Chesapeake Bay watershed, and to develop a means tracking these efforts by coordinating organizations.

"I want to gain insight about the difficulties, advantages, and methods of researching political and environmental issue; riparian buffering research is timely and interesting as well. A final product will be a comprehensive brochure to give to landowners explaining the advantages of riparian buffering, who to contact, and how to get funding." – Alex DeWire

Alexander DeWire is continuing his employment with the Delaware Department of Natural Resources and Environmental Control surveying the impact on DNREC protection programs on female terrapin populations.

(continued)

## **Implementation of Riparian Buffers in Southeastern Pennsylvania, Delaware, and Eastern Maryland**

### **Abstract**

As land becomes scarcer the challenge of conserving the land and its resources becomes increasingly difficult. Over the past 15 years, programs have been developed on the national, state, local, and private levels devoted to projects that fund conservation practices like riparian buffering. Programs have developed at such a fast pace that little effort has been given to evaluating the programs and tracking progress. Many organizations on the private level remain unaware of the benefits available to them by the federal and state governments and vice versa. While some very successful partnerships have developed, many more are possible. One objective of this research was to create a comprehensive database that lists programs available in the Mid-Atlantic region to engage in conservation practices like riparian buffering. This database could be used to partner organizations as well as a resource for landowners to consult on what is available to them. A second objective of this research was to evaluate the effectiveness of the programs in the database and to compare each program's characteristics to one another. Programs were placed into four categories: cost-share, set aside, planning, and grant. These categories were used to determine what kinds of programs were being funded the most and having the greatest effect. The research found that cost-share programs are receiving increasing amounts of funding. Also a template for policy development called community-based social marketing was applied. This template helped show why the programs that facilitate riparian buffering are effective.

# Undergraduate Internship in Understanding the Mechanisms of the Spread of Phragmites: For Better or For Worse

## Basic Information

<b>Title:</b>	Undergraduate Internship in Understanding the Mechanisms of the Spread of Phragmites: For Better or For Worse
<b>Project Number:</b>	2002DE37B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Biological Sciences
<b>Focus Category:</b>	Wetlands, Water Quality, Waste Water
<b>Descriptors:</b>	Ecology, Models, Wastewater, Water Quality, Wetlands
<b>Principal Investigators:</b>	Michael League, John Gallagher

## Publication

1. League, Michael, and John Gallagher. 2003. Understanding the Mechanisms of the Spread of Phragmites: For Better or For Worse. Report submitted to Delaware Water Resources Center, University of Delaware, Newark, Delaware, 20 pages.

### Synopsis: Intern Project #3 (of 6)

<b>Title:</b>	Understanding the Mechanisms of the Spread of Phragmites: For Better or For Worse
<b>NIWR Project Number:</b>	<b>2002DE37B</b>
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Research Category:</b>	Wetlands Protection and Restoration
<b>Focus Category:</b>	Ecology (ECL), Models (MOD), Wastewater (WW), Water Quality (WQL), Wetlands (WL)
<b>Descriptors:</b>	Ecology, Models, Wastewater, Water Quality, Wetlands
<b>Principal Investigators:</b>	Michael League, University of Delaware undergraduate senior, Biological Sciences Education
<b>Other Principal Investigators:</b>	Dr. John L. Gallagher ( <a href="mailto:jackg@udel.edu">jackg@udel.edu</a> ) of the University of Delaware College of Marine Studies Halophyte Biotechnology Center, faculty advisor
<b>Project Class:</b>	Research

A DWRC newsletter article on this project may be found at:

<http://ag.udel.edu/dwrc/newsletters/MichaelLeague02.pdf>

“Understanding the Mechanisms of the Spread of Phragmites: For Better or For Worse” is the project Michael T. League hopes will provide valuable research experience supporting improved wastewater treatment methodologies as well as wetlands protection and restoration. His internship advisor is Dr. John L. Gallagher of the UD College of Marine Studies.

“During the heat and drought conditions of 2002, I began initial chemical analysis to illuminate the cellular mechanisms that this plant has adapted to allow for survival under these extreme stresses. Understanding the growth and survival mechanisms behind this invasive problem, which plagues Mid-Atlantic wetlands especially in the state of Delaware, will allow better control strategies and treatments to preserve the wetlands’ critical role in water quality.” – Michael League

While an undergraduate, Michael was involved in graduate level research at the University of Delaware College of Marine Studies in Lewes, Delaware through research grants from the National Science Foundation and the Delaware Water Resources Center, taking graduate level courses through a unique program. He received a bachelor’s degree in Biological Sciences Education in May 2003 and is beginning an M.S. program in Marine Biology/Biochemistry at the UD College of Marine Studies in Lewes in June 2003, funded through a grant from NOAA and SeaGrant. However, unlike most new graduate students, he will enter having begun his thesis research and completed more than one-third of his graduate coursework. He plans to graduate with an M.S. in Marine Biology/Biochemistry in less than the typical two-year period and then pursue a doctorate in marine biology, ultimately teaching and conducting research at the college level.

**Publication (see next page)**

## Publication

1. League, Michael, and John Gallagher. 2003. Understanding the Mechanisms of the Spread of Phragmites: For Better or For Worse. Report submitted to Delaware Water Resources Center, University of Delaware, Newark, Delaware, 20 pages.

Names and degree level (highest level during the reporting period) of all students who worked on the research project: Michael League, undergraduate senior

### Understanding the Mechanisms of the Spread of Phragmites: For Better or For Worse

#### ABSTRACT

In the last century, *Phragmites australis* (common reed) has expanded from a minor component of the Mid-Atlantic wetlands to a dominant species. Invasion by *Phragmites* is characterized by decreased plant diversity and alterations to the tidal characteristics of the marsh, potentially resulting in decreased value as a nursery for animal species. As a result of the perceived loss in wetland value, management efforts have targeted *Phragmites* as a nuisance weed, and attempted to eradicate it through a variety of treatment regimes. Many of these treatments are effective on the aboveground culms, but the effects of treatments on rhizomes are unknown. Recent studies suggest that the best mechanism for expansion lies in vegetative growth through rhizome spread and clonal integration; thereby, making rhizomes the primary focus of management efforts. These efforts are greatly hindered by the inability to quantify effects of treatments on rhizomes in advance of the growing season. We tested a greenhouse bioassay, which accurately predicted the relative shoot densities of three sites in the Alloway Creek Watershed, NJ well in advance of the growing season. Effects of past treatments were quantified through a study of growth potential from rhizomes and photosynthetic contributions from shoots.

Rhizomes from 6 locations in Alloway Creek watershed, NJ were excavated in early spring. Rhizomes were classified by depth (0-25 cm and 25-75 cm) and appearance (white or brown), and grown in sand under greenhouse conditions void of nutrient supplements for 70 days. At the 70-day mark, shoots from rhizomes exhibiting growth were harvested to remove apical dominance and the rhizomes replanted for 30 days. Less than 0.5% of brown rhizomes produced growth upon initial planting and none produced growth upon replanting. Shoot production efficiency, i.e. shoots per node, was similar in the shallow and deeper rhizomes, however at 3 of the 5 sites exhibiting growth, the deeper rhizomes produced the most shoots. Predicted shoot density and shoot biomass were compared to actual results in the field measured in July 2001. Field sites could be accurately ranked compared to one another on the basis of average shoot density per square meter and average shoot biomass per square meter quantified in the greenhouse bioassay.

Work conducted this summer also shed light on the cellular-based ability of *Phragmites* to withstand increased concentrations of salt. Preliminary data has shown that tissue cultures continued to gain weight after 6 weeks of salt treatments. The cause of the increased weight is unknown, but further research is currently underway to determine whether succulence or the build up of osmotic factors, such as amino acids, causes the increased weight.



# Undergraduate Internship in Regulating Wetlands in Delaware in a Changing Legal Environment

## Basic Information

<b>Title:</b>	Undergraduate Internship in Regulating Wetlands in Delaware in a Changing Legal Environment
<b>Project Number:</b>	2002DE38B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Social Sciences
<b>Focus Category:</b>	Law, Institutions, and Policy, Wetlands, None
<b>Descriptors:</b>	Environmental Law, Wetlands
<b>Principal Investigators:</b>	Kristen Sentoff, Joshua Duke

## Publication

1. Sentoff, Kristen, and Joshua Duke. 2003. Regulating Wetlands in Delaware in a Changing Legal Environment. Report submitted to Delaware Water Resources Center, University of Delaware, Newark, Delaware, 21 pages.
2. Duke, Joshua M. and Kristen A. Sentoff. 2003. Managing isolated wetlands after Solid Waste and Tahoe: The case of Delaware. Journal of Land Use and Environmental Law 18(2):\_\_\_

## Synopsis: Intern Project #4 (of 6)

<b>Title:</b>	Regulating Wetlands in Delaware in a Changing Legal Environment
<b>NIWR Project Number:</b>	2002DE38B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Research Category:</b>	Wetlands Regulation
<b>Focus Category:</b>	Law, Institutions, and Policy (LIP), Wetlands (WL)
<b>Descriptors:</b>	Environmental Law, Wetlands
<b>Principal Investigators:</b>	Kristen Sentoff, University of Delaware (UD) undergraduate junior, Natural Resource Management
<b>Other Principal Investigators:</b>	Dr. Joshua Duke ( <a href="mailto:duke@udel.edu">duke@udel.edu</a> ), University of Delaware Department of Food and Resource Economics, faculty advisor
<b>Project Class:</b>	Research

Kristen A. Sentoff has researched aspects of "Regulating Wetlands in Delaware in a Changing Legal Environment" for her internship. Her project advisor is Dr. Joshua Duke of the University of Delaware (UD) Department of Food and Resource Economics.

"I'm interested in land use and wetlands issues policy and want to investigate a career in environmental law. The project aims to determine the significance of and responses to recent Supreme Court cases affecting wetlands, the current status of wetlands regulation in Delaware, and the actions necessary to protect Delaware wetlands in the future." – Kristen Sentoff

Ms. Sentoff, a rising senior Natural Resource Management major in June 2003, is also the winner of a *DWRC* 2003-2004 water resources undergraduate internship and will be researching aspects of "*Fairfield Run: An Evaluation of Stream Habitat Restoration at the UD Experimental Watershed*". Her project advisor is Mr. Gerald Kauffman of the UD Water Resources Agency. She plans to identify candidate areas for habitat restoration and recommend stream restoration techniques along Fairfield Run, one of three streams classified by *DWRC* 2001 intern Jennifer Campagnini and 2002 intern Tara Harrell as impaired by bank erosion due to watershed urbanization.

### Publications

1. Sentoff, Kristen, and Joshua Duke. 2003. Regulating Wetlands in Delaware in a Changing Legal Environment. Report submitted to Delaware Water Resources Center, University of Delaware, Newark, Delaware, 21 pages.
2. Duke, Joshua M. and Kristen A. Sentoff. 2003. Managing isolated wetlands after Solid Waste and Tahoe: The case of Delaware. *Journal of Land Use and Environmental Law* 18(2): \_\_\_\_

Names and degree level (highest level during the reporting period) of all students who worked on the research project: Kristin Sentoff, undergraduate junior

**Regulating Wetlands in Delaware in a Changing Legal Environment**  
**ABSTRACT**

**Abstract**

Perhaps as few as fifteen states have adequate protection of isolated wetlands, which were left vulnerable by the U.S. Supreme Court's *Solid Waste* decision. Delaware is among those that lack specific State-level protections for freshwater wetlands and relied on the federal government to protect these areas. Consequently, Delaware's isolated wetlands, which have been found to be valuable and abundant, currently have no protection from detrimental uses. This report also examines regulatory takings doctrine, which has complicated efforts to craft new legislation to fill in this gap. The recent *Tahoe* decision constrains regulatory takings doctrine, reducing the likelihood that the state will face takings challenges to new wetlands regulation. However, it also suggests that State lawmakers ought to act quickly. The interim between *Solid Waste* in 2001 and any forthcoming legislation is the most challenging time, for this is when landowners can manifest their investment-backed expectations for recently proscribed land uses. The interim also produces uncertainty, which may lead to suboptimal landowner decisions. If State law is put in place soon, the government will minimize the possibility of costly compensation for regulatory takings and minimize the degradation of isolated wetlands. One possible solution to the difficulties in crafting swift legislation is the use of moratoria.

# Undergraduate Internship in An Autonomous Full Water Column Environmental Monitoring System with Telemetry

## Basic Information

<b>Title:</b>	Undergraduate Internship in An Autonomous Full Water Column Environmental Monitoring System with Telemetry
<b>Project Number:</b>	2002DE39B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	3/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Engineering
<b>Focus Category:</b>	Models, Water Quality, None
<b>Descriptors:</b>	Models, Water Quality
<b>Principal Investigators:</b>	Kerrie Smith, James Glancey

## Publication

1. Smith, Kerrie, and James Glancey. 2003. An Autonomous Full Water Column Environmental Monitoring System with Telemetry. Report submitted to Delaware Water Resources Center, University of Delaware, Newark, Delaware, 18 pages.

## Synopsis: Intern Project #5 (of 6)

<b>Title:</b>	An Autonomous Full Water Column Environmental Monitoring System with Telemetry
<b>NIWR Project Number:</b>	<b>2002DE39B</b>
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B and Other (Delaware Department of Natural Resources and Environmental Control, and University of Delaware Undergraduate Research Program)
<b>Research Category:</b>	Water Quality Testing
<b>Focus Category:</b>	Models (MOD), Water Quality (WQL)
<b>Descriptors:</b>	Models, Water Quality
<b>Principal Investigators:</b>	Kerrie Smith, University of Delaware undergraduate senior, Mechanical Engineering
<b>Other Principal Investigators:</b>	Dr. James Glancey ( <a href="mailto:jglancey@udel.edu">jglancey@udel.edu</a> ), University of Delaware Departments of Mechanical Engineering and Bioresource Engineering, faculty advisor
<b>Project Class:</b>	Research

Kerrie Smith teamed with advisor Dr. James Glancey of the UD Departments of Mechanical Engineering and Bioresource Engineering to study “An Autonomous Full Water Column Environmental Monitoring System with Telemetry.” Her goal was to design, build, and test a prototype automated water quality testing system, including variable depth profiling and an automated telemetry system, and to later present this improved engineering design to Delaware’s Department of Natural Resources and Environmental Control.

“Through this internship I’ve learned how to use a solid modeling program used by many engineering firms and gained experience with water quality data transmission via cellular telemetry and microprocessor control systems.” – Kerrie Smith

Smith will begin a M.S. degree program at the University of Maryland in fall 2003, funded by a National Aeronautics and Space Administration (*NASA*) grant. She recently was awarded a Mechanical Engineering undergraduate degree from the University of Delaware’s (*UD’s*) College of Engineering.

### Publication

1. Smith, Kerrie, and James Glancey. 2003. An Autonomous Full Water Column Environmental Monitoring System with Telemetry. Report submitted to Delaware Water Resources Center, University of Delaware, Newark, Delaware, 18 pages.

Names and degree level (highest level during the reporting period) of all students who worked on the research project: Kerrie Smith, undergraduate senior

(continued)

# **AN AUTONOMOUS FULL WATER COLUMN ENVIRONMENTAL MONITORING SYSTEM WITH TELEMETRY**

## **ABSTRACT**

A remote water monitoring system has been developed for use in Delaware's waterways. This low-cost system includes a winch-powered vertical profiling system, weather-sensing equipment, and cellular telemetry. Remote functions of the platform, including data logging, are performed by an internal microcontroller. From the host site, a LabView program automatically polls the monitoring system for data, and displays to a dedicated website. This system will not only increase the amount of data available about a given site, but also provide this data in an easily-accessible format in near real-time.

# Undergraduate Internship in Accelerated Bioremediation of Wastewater using Electrode-Reducing MicroOrganisms

## Basic Information

<b>Title:</b>	Undergraduate Internship in Accelerated Bioremediation of Wastewater using Electrode-Reducing MicroOrganisms
<b>Project Number:</b>	2002DE40B
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Engineering
<b>Focus Category:</b>	Waste Water, Treatment, Sediments
<b>Descriptors:</b>	Economics, HydroGeoChemistry, Models, Sediments, Surface Water, Treatment, Wastewater, Water Quality
<b>Principal Investigators:</b>	Bret Strogon, Pei Chiu, Steven K Dentel, Aditya Sharma

## Publication

1. Strogon, Bret, Steven Dentel and Pei Chiu. 2003. Accelerated Bioremediation of Wastewater using Electrode-Reducing MicroOrganisms. Report submitted to the Delaware Water Resources Center, University of Delaware, Newark, Delaware, 20 pages.

## Synopsis: Intern Project #6 (of 6)

<b>Title:</b>	Accelerated Bioremediation of Wastewater using Electrode-Reducing MicroOrganisms
<b>NIWR Project Number:</b>	<b>2002DE40B</b>
<b>Start Date:</b>	3/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Research Category:</b>	Wastewater Remediation
<b>Focus Category:</b>	Economics (ECON), HydroGeoChemistry (HYDGEO), Models (MOD), Sediments (SED), Surface Water (SW), Treatment (TRT), Wastewater (WW), Water Quality (WQL)
<b>Descriptors:</b>	Economics, HydroGeoChemistry, Models, Sediments, Surface Water, Treatment, Wastewater, Water Quality
<b>Principal Investigators:</b>	Project begun by: Aditya Sharma, University of Delaware undergraduate senior, Winter graduate in Biochemistry and Biology/Psychology Completed by: Bret Strogon, University of Delaware undergraduate senior, Spring graduate in Environmental Engineering
<b>Other Principal Investigators:</b>	Dr. Steven Dentel ( <a href="mailto:dentel@udel.edu">dentel@udel.edu</a> ) and Dr. Pei Chiu ( <a href="mailto:pei@ce.udel.edu">pei@ce.udel.edu</a> ), University of Delaware Department of Civil and Environmental Engineering, faculty advisors
<b>Project Class:</b>	Research

“Accelerated Bioremediation of Wastewater using Electrode-Reducing MicroOrganisms” is the title of this research project on design and use of bioremediation systems begun by Aditya Sharma and continued after Aditya’s winter graduation by Bret Strogon. Their advisors are Dr. Steven Dentel and Dr. Pei Chiu of the UD Civil and Environmental Engineering Department.

“I want to develop a simple pollution removal system to improve sanitation in subsistence-level countries. My research has determined how best to measure the current I am using to accomplish bioremediation in my reactor.” – Aditya Sharma

“Recent research shows electricity can be created by electrically connecting marine sediment to the overlying surface water. My reactor obtains a current by connecting anaerobic wastewater sludge to an aerated water zone. This research may shed light on new ways to accelerate pollution removal or even to provide small amounts of useful electricity.” – Bret Strogon

Bret Strogon will pursue a master’s degree at University of California (Berkeley) starting in Fall 2003 on a fellowship and plans to stay for a PhD in Environmental Engineering.

### Publication

1. Strogon, Bret, Steven Dentel and Pei Chiu. 2003. Accelerated Bioremediation of Wastewater using Electrode-Reducing MicroOrganisms. Report submitted to the Delaware Water Resources Center, University of Delaware, Newark, Delaware, 20 pages.



Names and degree level (highest level during the reporting period) of all students who worked on the research project: Aditya Sharma and Bret Stroger, undergraduate seniors

**Accelerated Bioremediation of Wastewater using Electrode-Reducing MicroOrganisms**  
**ABSTRACT**

Although methane capture from anaerobic wastewater treatment processes has been a successful method for recovering energy from wastewater for years, a new method of harnessing electricity from sludge presents new possibilities for streamlining the processing of wastewaters. Anaerobic bacteria use iron and sulfur as electron acceptors (instead of oxygen), producing a much more reduced environment in sediments than would be found in a well-aerated water body (typically a 700mV difference). Scientists have recently shown that an electrical current will be produced by connecting anaerobic marine sediment to its overlying (aerated) water zone.

The aim of this research project has been to apply this principle to wastewater systems, which contain a much richer supply of organic material than marine sediments. The installation of a graphite electrode system is anticipated to have value in wastewater facilities through a) producing a useful current, b) providing a useful tool for monitoring organic matter digestion rates as they relate to current production, and/or c) accelerating the rate at which microbes degrade organic matter in the anaerobic digesters of wastewater treatment plants.

A very simple setup was used in these experiments. Approximately 3 inches of sludge was poured into a 2-L hexagonal fish tank, and the rest of the tank was filled with water. One graphite electrode was placed beneath the sediment layer in the tank and another electrode placed in the overlying clear zone (which contained an airstone to keep it aerated). Acetate was added in varying amounts to the tanks, and current measurements were taken nearly every day. After the current stabilized for several weeks, a few experiments were performed to pinpoint limiting factors on current production.

The surface area of the sediment electrode was clearly the most significant limiting factor in the tank systems, although there is a finite limit to the rate a given amount of sludge can produce electrons. In addition to biological and surface reaction rates, other factors that were found or suspected to strongly impact the system's electrical activity include diffusion (alleviated by mixing), temperature, pH, dissolved oxygen concentration, concentration of "food", and the concentration of (reducible) electron-shuttling compounds such as iron, sulfide, metabolic intermediates, etc. *Geobacter*, an iron-reducing bacterium mentioned in journal articles about electricity production in sediment systems, was identified in the sludge samples through the use of 16S rRNA analysis.

The current density, voltage, and DNA analysis of the sludge systems provide results very similar to those published by researchers dealing with marine sediments. As one researcher already showed that 82% of acetate digestion can be detected through the monitoring of current production, the possibility of monitoring sludge digestion (aka BOD removal) rates is very promising. Assuming BOD removal is similarly converted into a useful current, this system shows much promise for powering low-voltage (~500mV) devices at wastewater treatment plants.

# **Information Transfer Program**

# Delaware Water Resources Center "WATER NEWS" Vol. 3 No.s 1 and 2

## Basic Information

<b>Title:</b>	Delaware Water Resources Center "WATER NEWS" Vol. 3 No.s 1 and 2
<b>Project Number:</b>	2002DE41B
<b>Start Date:</b>	5/1/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	Education, None, None
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	J. Thomas Sims, Amy Boyd

## Publication

# **Information Transfer Program**

## **Basic Information: Center Print Publication**

<b>Title:</b>	“WATER NEWS“
<b>Issues during FY02:</b>	5/2002 and 11/2002 Vol. 3 No. 1 and 2
<b>Description:</b>	Newsletter published biannually by the University of Delaware Water Resources Center
<b>Lead Institute:</b>	DE Water Resources Center
<b>Principal Investigators:</b>	Dr. J. Thomas Sims, Director, Amy Boyd, Editor

WATER NEWS is received by nearly 500 recipients in Delaware water-related academia, government, public and private agencies, agriculture and industry. It may be accessed via the Delaware Water Resources Center web site at: <http://ag.udel.edu/dwrc/news.html>.

Spring 2002 topics included:

- For Delaware Drought Information
- A Historic Drought for Delaware
- Storing Water Reserves
- WSCC Water Conservation Tips
- Jobs in Water Resources
- DNS-NWF Backyard Habitat Program
- Scarcity Pricing for Water Conservation
- Menhaden Murder Mystery Solved
- **DWRC** Fellow Jennifer Jennings Studies Excess Nutrients in the Inland Bays
- New 2002 – 2003 **DWRC** Undergraduate Interns
- UD Marine Policy Fellowship Winners
- **DWRC** Annual Meeting & Intern Poster Session
- DE Nutrient Management Commission Update
- **DWRC** History, Goals and 2002 Advisory Pane
- Water News and **DWRC** Contact Information

Fall 2002 topics included:

- **DNREC's** Kevin Donnelly on Water Quality Goals and Achievements
- Wilmington's Combined Sewer Overflow (**CSO**) System
- **DWRC** Fellow Applying Molecular Scale Research to Water Quality Problems
- **DWRC** Intern Studies Two Faces of Phragmites Reeds
- "Drought.02" 10/9/02 University of Delaware (**UD**) Water Forum
- New Clean Water Protection Legislation
- **UD's** new membership in the Consortium of Universities for the Advancement of Hydrologic Science (**CUASHI**)
- Water Quality, Private Wells, and Septic Systems
- New **USGS** Water Quality Publications, **NEMI** water monitoring database, and national real-time "WaterWatch" website
- Links for: **UD** Water Resources Researchers/Courses list, Grants/Fellowships, Water Resources Conferences, Nutrient Management Training, and Publications and Water Resources Web Sites

## **Delaware Water Resources Center Web site**

**<http://ag.udel.edu/dwrc>**

### **Basic Information**

<b>Title:</b>	Delaware Water Resources Center Web site <a href="http://ag.udel.edu/dwrc">http://ag.udel.edu/dwrc</a>
<b>Project Number:</b>	2002DE42B
<b>Start Date:</b>	12/1/2001
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	J. Thomas Sims, Amy Boyd

### **Publication**

## Basic Information: Center Website

<b>Title:</b>	Web site <a href="http://ag.udel.edu/dwrc">http://ag.udel.edu/dwrc</a>
<b>Start Date:</b>	Since 12/2001
<b>End Date:</b>	Ongoing
<b>Description:</b>	Comprehensive site serving Delaware water resources community
<b>Lead Institute:</b>	DE Water Resources Center
<b>Principal Investigators:</b>	Dr. J. Thomas Sims, director, Amy Boyd, administrator

Site contains:

- **Delaware Water Resources Center (DWRC) and Director's News:** Latest updates on DWRC activities and information on the DWRC's mission, history, and role in the National Institute of Water Resources (NIWR).
- **Delaware Water Concerns:** Summary of the major areas of concern related to Delaware's ground and surface waters, with links to key organizations and agencies responsible for water quality and quantity.
- **Projects and Publications:** Descriptions of DWRC's undergraduate internship and graduate fellows programs, annual conference proceedings, and project publications dating back to 1993.
- **Advisory Panel:** Purpose, contact information and e-mail links for the DWRC's Advisory Panel.
- **Request for Proposals and Application Forms:** For undergraduate interns, graduate fellowships and other funding opportunities available through the DWRC.
- **Internships and Job Opportunities:** Information on undergraduate and graduate internships from a wide variety of local, regional, and national sources along with current job opportunities in water resource areas.
- **University of Delaware (UD) Water Courses and Faculty:** Current listing of UD water resource courses and researchers with an interest in water resources research; also, science and natural resource curricula links.
- **Water Resources Contacts:** Links to local, regional, and national water resource agencies and organizations categorized as government, academia, non-profit, and US Water Resource Centers.
- **Calendar:** Upcoming local, regional, and national water resources events sponsored by the DWRC and other agencies, such as conferences, seminars, meetings, and training opportunities.
- **Newsletters:** Access to DWRC newsletters dating to 1993.
- **Annual and 5-year Reports:** DWRC annual and 5-year reports, dating to 1993.
- **KIDS' Zone:** Water Resources Activities and Information for Kids and Teachers

**Delaware Water Resources Center / Water Resources Agency listserv, built upon the online listing of University of Delaware water teachers and researchers found on the DWRC site:  
<http://ag.udel.edu/dwrc/faculty.html>**

**Basic Information**

<b>Title:</b>	Delaware Water Resources Center / Water Resources Agency listserv, built upon the online listing of University of Delaware water teachers and researchers found on the DWRC site: <a href="http://ag.udel.edu/dwrc/faculty.html">http://ag.udel.edu/dwrc/faculty.html</a>
<b>Project Number:</b>	2002DE43B
<b>Start Date:</b>	12/1/2001
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	J. Thomas Sims, Amy Boyd, Gerald Kauffman

**Publication**

## Basic Information: Center Electronic Database

<b>Title:</b>	Delaware Water Resources Center / Water Resources Agency listserv, built upon the online listing of University of Delaware water teachers and researchers found on the DWRC site: <a href="http://ag.udel.edu/dwrc/faculty.html">http://ag.udel.edu/dwrc/faculty.html</a>
<b>Start Date:</b>	Since 12/2001
<b>End Date:</b>	
<b>Description:</b>	Listserv serving Delaware water resources community
<b>Lead Institute:</b>	DE Water Resources Center
<b>Principal Investigators:</b>	Dr. J. Thomas Sims, director, Amy Boyd, administrator

The online listing of approximately 70 **University of Delaware (UD) Water Faculty Researchers and Interests** found on the Delaware Water Resources Center web site forms the foundation for a broader listserv reaching additional academic, public, private, and government water community contacts, who are notified via a monthly email newsletter of events and job postings of interest in water resources. The online listing page permits visitors to add or correct entries, volunteer to advise student researchers, propose an internship / fellowship project, discuss arrangements for off-campus undergraduate internships, and identify current or past student research advisors and proposed projects for the past year. The total list numbers 108 ,as of June 2003.



# Delaware Water Resources Center "WATER E-NEWS" Vol. 1 Issues 1-5 and Vol. 2 Issue 1

## Basic Information

<b>Title:</b>	Delaware Water Resources Center "WATER E-NEWS" Vol. 1 Issues 1-5 and Vol. 2 Issue 1
<b>Project Number:</b>	2002DE44B
<b>Start Date:</b>	7/5/2002
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	J. Thomas Sims, Amy Boyd

## Publication

## Basic Information: New Center Electronic Newsletter

<b>Title:</b>	“WATER E-NEWS”
<b>Issues during FY02:</b>	<b>Vol. 1 Issues 1-5: 7/5/02, 8/25/02, 8/28/02, 10/10/02, 12/12/02, and Vol. 2 Issue 1: 1/28/03</b>
<b>Description:</b>	Online newsletter published periodically and emailed to center’s water resources electronic listserv by the University of Delaware Water Resources Center
<b>Lead Institute:</b>	DE Water Resources Center
<b>Principal Investigators:</b>	Dr. J. Thomas Sims, Director, Amy Boyd, Editor

WATER E-NEWS is now received by over 100 recipients in Delaware water-related academia, government, public and private agencies, agriculture and industry. The current issue and back issues dating to its July 2002 inception may be accessed via the Delaware Water Resources Center web site at: <http://ag.udel.edu/dwrc/news.html>.

Featured in each issue of Water E-News are:

- I. Undergraduate Internships and Jobs in Water Resources from DWRC and more;
- II. Graduate Fellowships, plus post-doc and professional opportunities;
- III. Project funding and awards programs;
- IV. Upcoming seminars and conferences; and
- V. New information and training sources in water resources.

# Undergraduate Intern Presentation "Connecting the Link between Land Use and Stream Health in the University of Delaware Experimental Watershed"

## Basic Information

<b>Title:</b>	Undergraduate Intern Presentation "Connecting the Link between Land Use and Stream Health in the University of Delaware Experimental Watershed"
<b>Project Number:</b>	2002DE45B
<b>Start Date:</b>	4/26/2002
<b>End Date:</b>	4/26/2002
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	Presentation at annual proceedings of the National Conference on Undergraduate Research, University of Wisconsin-Whitewater.
<b>Principal Investigators:</b>	Tara Harrell, Gerald Kauffman

## Publication

### Basic Information: Intern Presentation

<b>Title:</b>	“Connecting the Link between Land Use and Stream Health in the University of Delaware Experimental Watershed”
<b>Start Date:</b>	4/26/2002
<b>End Date:</b>	4/26/2002
<b>Description:</b>	Presentation at annual proceedings of the National Conference on Undergraduate Research, University of Wisconsin-Whitewater.
<b>Lead Institute:</b>	DE Water Resources Center
<b>Principal Investigators:</b>	Tara Harrell, Gerald Kaufmann ( <a href="mailto:jerryk@udel.edu">jerryk@udel.edu</a> ), Institute for Public Administration Water Resources Agency, University of Delaware

# Six Undergraduate Interns Posters Presentations: University of Delaware 2002 Undergraduate Research Scholars Poster Session

## Basic Information

<b>Title:</b>	Six Undergraduate Interns Posters Presentations: University of Delaware 2002 Undergraduate Research Scholars Poster Session
<b>Project Number:</b>	2002DE47B
<b>Start Date:</b>	4/19/2002
<b>End Date:</b>	4/19/2002
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	Undergraduate Interns presented their 2001-2002 DWRC-funded projects.
<b>Principal Investigators:</b>	Joan Bennett, J. Thomas Sims

## Publication

# DWRC information table display at Delaware Water Resources Center co-sponsored Oct. 9, 2002 "Drought.02" Water Forum, University of Delaware, Newark, DE

## Basic Information

<b>Title:</b>	DWRC information table display at Delaware Water Resources Center co-sponsored Oct. 9, 2002 "Drought.02" Water Forum, University of Delaware, Newark, DE
<b>Project Number:</b>	2002DE48B
<b>Start Date:</b>	10/9/2002
<b>End Date:</b>	10/9/2002
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	Presentation of DWRC recent accomplishments and program goals.
<b>Principal Investigators:</b>	J. Thomas Sims, Amy Boyd, Gerald Kauffman

## Publication

## Basic Information: “Drought.02” Water Forum Co-Sponsor & Participant

<b>Title:</b>	DWRC information table display at DWRC co-sponsored Oct. 9, 2002 “Drought.02” Water Forum, University of Delaware, Newark, DE
<b>Start Date:</b>	Oct. 9, 2002
<b>End Date:</b>	Oct. 9, 2002
<b>Description:</b>	Presentation of DWRC recent accomplishments and program goals. Forum proceedings may be found on the web at: <a href="http://www.wr.udel.edu/publicservice/proceedings2002waterpolicyforum.pdf">http://www.wr.udel.edu/publicservice/proceedings2002waterpolicyforum.pdf</a>
<b>Lead Institute:</b>	Co-sponsored by University of Delaware Institute for Public Administration Delaware Water Resources Agency, Delaware Department of Natural Resources and Environmental Control, DE Water Resources Center
<b>Principal Investigators:</b>	Gerald Kauffman, State Water Coordinator, University of Delaware Institute for Public Administration Delaware Water Resources Agency ( <a href="mailto:jerryk@udel.edu">jerryk@udel.edu</a> ); Kevin Donnelly, Director, Division of Water Resources, Delaware Department of Natural Resources and Environmental Control ( <a href="mailto:kevin.donnelly@state.de.us">kevin.donnelly@state.de.us</a> ); and J. Thomas Sims, Director, Delaware Water Resources Center ( <a href="mailto:jtsims@udel.edu">jtsims@udel.edu</a> )

The Delaware Policy Forum titled *Drought.02: A Debate and Panel Discussion Concerning Water Supply Policy in Delaware* was held on Wednesday October 9, 2002 at Clayton Hall on the University of Delaware campus in Newark, Delaware. The University of Delaware, Institute for Public Administration cosponsored this event with the Delaware Department of Natural Resources and Environmental Control and the University of Delaware Water Resources Center. In the midst of the record drought of 2002, invited panelists from government, private sector, and academia were asked to debate the pros and cons of issues concerning drinking water policy in Delaware. The panelists were asked to address the following question: *In the wake of multi-year droughts in Delaware, what should be done to ensure the delivery of clean and plentiful drinking water to Delaware residents and businesses?* Several speakers advocated a supply-side approach such as expanding existing reservoir capacity or building desalination plants. On the demand side, several speakers recommended water conservation practices through pricing controls.

Over 150 attendees at the *Drought.02* policy forum were able to react to the proceeding policy debate, ask a series of interactive questions, and participate in a survey concerning the future of water policy in Delaware. Participants had an opportunity to visit the DWRC’s information table, which featured:

1. DWRC Poster display featuring current research projects of 3 fellows and 6 interns.
2. Brochures describing the DWRC Internship program for 2002-2003.
3. Copies of Spring 2002 print newsletters “Water News,” with subscription sign-up for this and the DWRC’s electronic newsletter.

## Delaware Water Resources Center presentation at 2003 Governor's Conference on Agriculture, Dover, DE

### Basic Information

<b>Title:</b>	Delaware Water Resources Center presentation at 2003 Governor's Conference on Agriculture, Dover, DE
<b>Project Number:</b>	2002DE49B
<b>Start Date:</b>	2/21/2003
<b>End Date:</b>	2/21/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	Presentation of DWRC recent accomplishments and program goals
<b>Principal Investigators:</b>	J. Thomas Sims

### Publication



**Basic Information: Delaware Water Resources Center presentation at 2003 Governor's Conference on Agriculture, Dover, DE**

<b>Title:</b>	DWRC presentation at 2003 Governor's Conference on Agriculture, Dover, DE
<b>Start Date:</b>	Feb. 21, 2003
<b>End Date:</b>	Feb. 21, 2003
<b>Description:</b>	Presentation of DWRC recent accomplishments and program goals
<b>Lead Institute:</b>	DE Water Resources Center
<b>Principal Investigators:</b>	J. Thomas Sims, Director, Delaware Water Resources Center ( <a href="mailto:jtsims@udel.edu">jtsims@udel.edu</a> ), presenter

An audience of nearly 150 at the state of Delaware Governor's Conference on Agriculture heard a presentation on Delaware Water Resources Center goals and accomplishments by Center Director Dr. J. Thomas Sims. Participants had an opportunity to visit the Center's information table, which featured:

1. DWRC Poster display featuring current research projects of 3 fellows and 6 interns
2. Brochures describing the DWRC Internship program for 2003-2004
3. Copies of 2002 print newsletters "Water News"
4. Printed copies of Jan. 2003 "Water E-News" Vol. 2 Issue 1, new electronic periodical emailed currently to listserv of over 100 recipients.

## Five Presentations of fellowship research and 2003 dissertation results based on 2000-2003 DWRC Fellowship Project by Stefan Hunger entitled "Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation"

### Basic Information

<b>Title:</b>	Five Presentations of fellowship research and 2003 dissertation results based on 2000-2003 DWRC Fellowship Project by Stefan Hunger entitled "Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation"
<b>Project Number:</b>	2002DE50B
<b>Start Date:</b>	3/1/2001
<b>End Date:</b>	2/28/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	Five Presentations of fellowship research and 2003 dissertation results based on 2000-2003 DWRC Fellowship Project by Stefan Hunger entitled "Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation", College of Agriculture and Natural Resources, University of Delaware, D. L. Sparks, advisor.
<b>Principal Investigators:</b>	Stefan Hunger, Donald Lewis Sparks

### Publication

**Five Presentations of fellowship research and 2003 dissertation results based on 2000-2003 DWRC Fellowship Project by Stefan Hunger entitled “Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation”, College of Agriculture and Natural Resources, University of Delaware, D. L. Sparks, advisor.**

1. Hunger, Stefan, and D. L. Sparks, 2001. "On the Use of  $^{31}\text{P}$  NMR Spectroscopy to Determine Chemical Forms of Phosphorus in Soils", Annual Meetings of the Soil Science Society of America, Agronomy Abstracts, Charlotte, NC.
2. Hunger, Stefan, J. D. Peak, and D. L. Sparks, 2002. "Spectroscopic Investigation of  $\text{CaPO}_4$  Stabilization at the Gibbsite/Water Interface", 223rd Meeting of the American Chemical Society, Orlando, FL.
3. Hunger, Stefan, and D.L. Sparks, 2002. "NMR spectroscopic investigations of chemical forms of phosphorus in alum amended poultry litter", Annual Meeting of the Soil Science Society of America, Agronomy Abstracts, Indianapolis, IN.
4. Hunger, Stefan, and D.L. Sparks, 2002. "Solidstate speciation of phosphorus in natural and chemically amended poultry litter", 3rd European Meeting on Environmental Chemistry, Geneva, Switzerland.
5. Hunger, Stefan, and D.L. Sparks, 2003. "Phosphate speciation on calcite and gibbsite surfaces: A combined Xray absorption spectroscopy and solidstate NMR investigation", 225th Meeting of the American Chemical Society, New Orleans.

**Presentations Abstract**

In agricultural areas, non-point source contamination of surface and ground water by phosphorus (P) and nitrogen (N) poses a severe threat to water quality. The most common form of phosphorus in soils is inorganic phosphate, the mobility and bioavailability of which are mostly determined by surface reactions with iron and aluminum (hydr)oxides. Despite extensive past research, basic reactions are still not totally understood on a molecular level. In this study, the sorption reactions of phosphate to the common aluminum mineral gibbsite are investigated. The structure and bonding environment of phosphate sorbed under different reaction conditions are examined using CP-MAS  $^{31}\text{P}$ -NMR as a molecular spectroscopic technique. An attempt is made to identify the species responsible for the increasing stability of phosphate at the surface. These results could have significant implications concerning the mobility and stability of P in the soil environment.

## Three Presentations of fellowship research and 2003 PhD dissertation results based on 2000-2003 DWRC Fellowship Project by Lynette Ward entitled "Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware"

### Basic Information

<b>Title:</b>	Three Presentations of fellowship research and 2003 PhD dissertation results based on 2000-2003 DWRC Fellowship Project by Lynette Ward entitled "Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware"
<b>Project Number:</b>	2002DE51B
<b>Start Date:</b>	6/24/2002
<b>End Date:</b>	6/26/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	Three Presentations of fellowship research and 2003 PhD dissertation results based on 2000-2003 DWRC Fellowship Project by Lynette Ward entitled "Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware", College of Agriculture and Natural Resources, University of Delaware. W. Ritter, J. Byrne, and Y. Wang, advisors.
<b>Principal Investigators:</b>	Lynette Ward, Young-Doo Wang

### Publication

**Three Presentations of fellowship research and 2003 PhD dissertation results based on 2000-2003 DWRC Fellowship Project by Lynette Ward entitled “Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware”, College of Agriculture and Natural Resources, University of Delaware. W. Ritter, J. Byrne, and Y. Wang, advisors.**

1. Ward, Lynette. June 24, 2002. Poster presentation: Market and Technical Barriers to Alternative Uses for Poultry Litter. Air and Waste Management Association Conference, Baltimore, MD.
2. Ward, Lynette. March 25, 2003. Paper: Overcoming Market and Technical Barriers to Poultry Litter Compost. International Solid Waste Management and Technology Conference, Philadelphia, PA.
3. Ward, Lynette. June 26, 2003. Paper: Phosphorus Management Options for the Delmarva Poultry Industry. World Water and Environmental Resources Congress, Philadelphia, PA.

Presentation abstract: (Taken from the DE Water Resources Center fellowship and University of Delaware PhD dissertation upon which these presentations were based.)

Sussex County, Delaware produces more broilers than any other county in the United States, producing 232 million broilers in 1998. While poultry production is the primary economic activity in the county, it is also the primary source of nutrient pollution. Poultry litter is commonly applied directly to cropland in Sussex County as a fertilizer and is the primary litter disposal method. The poultry industry is highly concentrated within the county and there is not sufficient cropland in the county on which to apply poultry litter at agronomic application rates. As a result, phosphorus levels have built up in the soils and nutrients now enter the county's waterways causing water quality problems. Although agriculture is the largest single land use within the county, urban land use grew by 22 percent between 1992 and 1997 and is expected to continue to rise as cropland gives way to development, further intensifying the problem of land application. Consequently, land application can no longer be the sole disposal method for poultry litter in Sussex County.

The intent of this dissertation is to develop environmental policies that promote the creation of a sustainable poultry industry in Sussex County, Delaware. Sustainable poultry industry practices meet the triumvirate goals of being environmentally sound; economically viable in both the short-term and long-term; and socially responsible in the sense of promoting equity, and preserving rural communities and quality of life. This research will identify and evaluate the economic feasibility of methods to reduce the phosphorus content of poultry litter or to find beneficial uses other than direct land application. The following alternatives are to be evaluated in terms of their economic feasibility and effectiveness. The methods designed to reduce the phosphorus content of poultry manure to be studied are: 1.) the use of low phytase corn in poultry rations, and 2.) the addition of the enzyme phytase in poultry rations. The alternative uses of poultry litter to be studied are: 1.) biogas production, 2.) energy generation, 3.) composting, 4.) use as a cattle feed supplement, and 5.) pelletizing.

The economic analysis of alternative uses of poultry litter would be conducted using IMPLAN, a PC based economic analysis software system that uses both data files and software to create regional models. Data files are available that include information for 528 different industries and 21 different economic variables. These datasets are available at the county level. IMPLAN will be used to do an economic analysis of not only the alternative uses for poultry litter, but to

measure the economic and social impacts of developing a sustainable poultry industry in Sussex County in terms of factors such as dollars of sales, local taxes received, environmental regulatory compliance costs, impact on tourism revenues, and jobs created.

This research is of particular interest to the Delaware agricultural community whose incomes are heavily reliant on livestock. In 1998, the value of crops in Delaware was \$164 million, while livestock and products were valued at \$609 million. During this period, Delaware experienced economic growth while the nation as a whole experienced a decline in net farm incomes. This robust farm economy may not be enough to insulate Delaware's agricultural revenues from short-term economic losses related to the costs of complying with nutrient management regulations, which restrict the land application of livestock manure. Over the long-term these compliance costs may be passed on to the consumer, however in the short-term they pose a serious financial risk to small farmers.

While the scope of the study area is limited to Sussex County, the recommendations of this dissertation have the potential to create substantial changes in the profitability and structure of the livestock industry on the Delmarva Peninsula. This research will identify policies that reduce agricultural water pollution in a manner that is economically viable and protects the existing rural community structure and values.

**Three Presentations of 2003 M.S. Thesis results based on 2000-2003 DWRC Fellowship Project by Jennifer Jennings entitled "The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays"**

**Basic Information**

<b>Title:</b>	Three Presentations of 2003 M.S. Thesis results based on 2000-2003 DWRC Fellowship Project by Jennifer Jennings entitled "The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays"
<b>Project Number:</b>	2002DE52B
<b>Start Date:</b>	5/20/2003
<b>End Date:</b>	6/20/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	Three Presentations of 2003 M.S. Thesis results based on 2000-2003 DWRC Fellowship Project by Jennifer Jennings entitled "The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays", College of Marine Studies, University of Delaware, W.J. Ullman, advisor.
<b>Principal Investigators:</b>	Jennifer Jennings, Joseph R. Scudlark, William J. Ullman

**Publication**

**Three Presentations of 2003 M.S. Thesis results based on 2000-2003 DWRC Fellowship Project by Jennifer Jennings entitled “The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware’s Inland Bays”, College of Marine Studies, University of Delaware, W.J. Ullman, advisor.**

1. Jennings, Jennifer. "The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware’s Inland Bays", Delaware Nutrient Management Commission (DNMC) meetings of the “Technology” and “Program and Education” committees, Dover, DE. May 20, 2003.

The DNMC is currently developing a statewide plan to implement best management practices to reduce nutrient loading to surface and groundwaters. Jennings' research provides a quantitative estimate of relative nutrient loading to Delaware's Inland Bays by base flow and storm flow and thus is vital to the DNMC efforts to identify the most effective BMPs for water quality protection.

2. Jennings, Jennifer. "The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware’s Inland Bays", Meeting of the Delaware Department of Natural Resources and Environmental Control (DNREC), Watershed Assessment Branch, Dover, DE. June 4, 2003.

3. Jennings, Jennifer. "The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware’s Inland Bays", Meeting of the Center for the Inland Bays (CIB) “Scientific and Technical Advisory” committees, Lewes, DE. June 20, 2003.

**Presentation Abstract**

Annual total nitrogen and phosphorus loads have been determined at one sub-watershed of Delaware’s Inland Bays (Bundicks Branch) using an extensive water quality data set and flow-based loading calculations, where load is determined as the product of concentration and discharge. The total discharge, which was measured, was separated into the baseflow and stormflow components using a baseflow minimization separation technique that reduces the baseflow component of discharge during storm periods in proportion to storm-related stage height increases. High frequency sampling experiments were conducted to determine the uncertainty associated with estimated baseflow loads. Dissolved constituent concentrations appear to be less variable than the particulate counterparts and as such, the dissolved baseflow loads have less uncertainty (<12% compared to >40% for particulate loads). Storm loads can be estimated for unsampled rain events by normalizing loads to storm discharge, which produces annual storm loads with uncertainties less than 10% during monitored periods of time. Based on an analysis of water budgets, a considerable amount of water and nutrients appear to bypass the Bundicks Branch gauging station and discharge further downstream or directly into Rehoboth Bay. This underflow component can be estimated using a water budget at Millsboro Pond to calculate average monthly evapotranspiration. The loading rates utilized in several land use loading models were applied to Bundicks Branch. The annual nitrogen loads determined at Bundicks Branch during this study (28,000-34,000kg/yr) are within 30% of the annual average load estimated by the Horsley & Witten (1998) N-model (40,000kg/yr). The annual phosphorus loads determined during this study (170-290kg/yr), however, are substantially less than the annual average load estimated by the USDA P-model (1,365kg/yr) (Cassell and Meals, 1999). This implies that the non-point source P load from the entire Rehoboth Bay sub-basin is also likely less than previously believed. As a result, P contributions to Rehoboth Bay from the Rehoboth Wastewater Treatment Plant (RBWTP) and direct atmospheric deposition are both relatively greater than anticipated. Atmospheric deposition of P, which has been assumed to be negligible, actually contributes 14% of the annual P load, while the RBWTP may contribute anywhere from 50-75% of the P load, depending on the season.



**Two Presentations based on Prior DWRC Internship Projects: by 2000 intern Jennifer Campagnini entitled "The University of Delaware Experimental Watershed Project" (NIWR project number 2000DE4G) and 2001 intern Tara Harrell entitled "Connecting the Link between Land Use and Stream Health in the University of Delaware Experimental Watershed"(NIWR project number 2001DE24B), Institute for Public Administration Water Resources Agency, University of Delaware, G. Kauffman, advisor.**

**Basic Information**

<b>Title:</b>	Two Presentations based on Prior DWRC Internship Projects: by 2000 intern Jennifer Campagnini entitled "The University of Delaware Experimental Watershed Project" (NIWR project number 2000DE4G) and 2001 intern Tara Harrell entitled "Connecting the Link between Land Use and Stream Health in the University of Delaware Experimental Watershed"(NIWR project number 2001DE24B), Institute for Public Administration Water Resources Agency, University of Delaware, G. Kauffman, advisor.
<b>Project Number:</b>	2002DE56B
<b>Start Date:</b>	11/5/2002
<b>End Date:</b>	5/29/2003
<b>Funding Source:</b>	104B
<b>Congressional District:</b>	Delaware
<b>Research Category:</b>	Not Applicable
<b>Focus Category:</b>	None, None, None
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Gerald Kauffman

## **Publication**

**Two Presentations based on Prior DWRC Internship Projects: by 2000 intern Jennifer Campagnini entitled “The University of Delaware Experimental Watershed Project” (NIWR project number 2000DE4G) and 2001 intern Tara Harrell entitled “Connecting the Link between Land Use and Stream Health in the University of Delaware Experimental Watershed”(NIWR project number 2001DE24B), Institute for Public Administration Water Resources Agency, University of Delaware, G. Kauffman, advisor.**

1. Kauffman, Gerald, November 5, 2002. “The Public Land Grant University as the Basis for a National Network of Experimental Watersheds: The Delaware Model,” Annual Conference of the American Water Resources Association, Philadelphia, PA.

2. Kauffman, Gerald, May 29, 2003. “The University of Delaware Experimental Watershed. Watershed Management and the University: A Working Conference for Higher Education, Institutions, Watershed Managers and Other Watershed Stakeholders”, Event sponsored by the New Jersey Water Resources Research Institute, Rutgers University. New Brunswick, NJ.

## Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 RCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	6	0	0	0	6
Masters	1	0	0	0	1
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
<b>Total</b>	9	0	0	0	9

## Notable Awards and Achievements

### Notable Awards and Achievements

Research Program: The Delaware Water Resources Center (DWRC) has funded nine research grant projects during March 2002 through February 2003 that address state water resources priorities identified by the DWRC's 17-member Advisory Panel. Three of these projects are graduate fellowships in nutrient management; the other six are internships in modeling water quality, implementing streamside riparian buffers, building water monitoring equipment, understanding the spread mechanisms of invasive marsh reeds, regulating Delaware wetlands, and accelerating bioremediation of wastewater by using electrode reducing micro-organisms.

FY00-FY02 Fellowship Program Concludes: The Delaware Water Resources Center (DWRC) has funded three graduate fellowships since 2000 in support of the efforts of the Delaware Nutrient Management Commission to develop a state nutrient management program that protects and improves Delaware's water resources. DWRC fellows Stefan Hunger, Lynette Ward, and Jennifer Jennings have now completed research on topics in environmental soil chemistry, water resource policy, and water quality modeling, respectively. During spring of 2003, Hunger and Ward successfully defended their PhD dissertations, and Jennings completed her M.S. thesis; all were based on their DWRC research efforts.

Stefan Hunger's DWRC-funded research fellowship focused on improving our understanding of the basic chemistry of P in alum-amended manures and soils. His research is unique in that it applied modern chemical methods, such as nuclear magnetic resonance (NMR) and x-ray absorption near edge (XANES) spectroscopy to determine the exact forms of phosphorus present in manures and soils. Hunger believes this research can contribute to the effort towards a more sustainable agriculture. He will continue working with spectroscopic techniques in the field of environmental chemistry, studying how contaminants are retained and degraded in natural media and how their mobility and bioavailability is influenced by environmental factors.

DWRC fellow Lynette Ward's research on the development of "Environmental Policies for a Sustainable Poultry Industry in Sussex County, Delaware" has evaluated several approaches to improving efficiency of manure management in terms of their economic feasibility and practical effectiveness. Techniques studied include the use of low phytate corn and phytase enzymes in poultry rations, bioenergy production using manure as a renewable fuel source, composting or pelletizing manures for transport to other areas for use as a fertilizer for agronomic, vegetable, and horticultural crops, and use as a cattle feed supplement. Her research revealed some of the more promising options, including composting, pelletizing, and improving nutrient use efficiency by modifying animal diets to reduce phosphorus excretion.

In choosing her DWRC fellowship research proposal topic, Jennifer Jennings was interested in the idea of exploring how, or if, changes in the land use brought about by human encroachment in the coastal area of Delaware's Inland Bays were affecting the nutrient levels there, and if this rising trend could be reversed by improved land management practices. In May 2003, Jennings presented her findings to the Delaware Nutrient Management Commission (DNMC), which is currently developing a statewide plan to implement best management practices to reduce nutrient loading to surface and groundwaters. Jennings' research provides a quantitative estimate of relative nutrient loading to Delaware's Inland Bays by base flow and storm flow and thus is vital to the DNMC efforts to identify the most effective Best Management Practices for water quality protection.

Delaware institute presents at Feb. 2003 Delaware Governors Conference on Agriculture: Dr. J. Thomas Sims, Director of the Delaware Water Resources Center (DWRC) presented the center's recent accomplishments and goals at a statewide conference on agriculture held February 21, 2003 in Dover. Nearly 150 professionals and citizens interested in water resources from a variety of governmental, academic, private and civic organizations attended and had the opportunity to visit the Center's information display throughout the conference.

Delaware undergraduate intern wins graduate research fellowships: A Delaware Water Resources Center undergraduate intern has won a graduate research fellowship as a result of his research work for the DWRC. Michael League, who graduated with an undergraduate degree in Biological Sciences Education from the University of Delaware (UD) in June 2003, found his DWRC experience researching mechanisms of the spread of common marsh reeds to be valuable toward supporting improved wastewater treatment methodologies as well as wetlands protection and restoration. "During the heat and drought conditions of 2002," League explains, "I began initial chemical analysis to illuminate the cellular mechanisms that this plant has adapted to allow for survival under these extreme stresses. Understanding the growth and survival mechanisms behind this invasive problem, which plagues Mid-Atlantic wetlands especially in the state of Delaware, will allow better control strategies and treatments to preserve the wetlands' critical role in water quality." League will begin an M.S. program in Marine Biology/Biochemistry at the UD College of Marine Studies in Lewes, Delaware in June 2003, funded through grants from the National Oceanic and Atmospheric Administration (NOAA) and SeaGrant. Unlike most new graduate students, he will enter having begun his thesis research and completed more than one-third of his graduate coursework. He plans to graduate in less than the typical two-year period and then pursue a doctorate in marine biology, ultimately teaching and conducting research at the college level.

Four 2002 Delaware undergraduate interns will pursue graduate education in the fall of 2003. Delaware Water Resources Center (DWRC) intern Laura Boyer will begin a M.S. degree program in the Department of Plant and Soil Science, University of Delaware (UD) College of Agriculture and Natural Resources, in

June 2003. She recently completed an Environmental Science undergraduate Degree with Distinction based on her DWRC water quality modeling research project, advised by DWRC director J. Thomas Sims, and graduated from UD with distinction in June 2003. Her M.S. advisor will be Dr. Greg Binford of the UD Department of Plant and Soil Science.

Michael League, who graduated with an undergraduate degree in Biological Sciences Education from the University of Delaware (UD) in June 2003, researched mechanisms of the spread of common marsh reeds in his Delaware Water Resources Center (DWRC) internship project. League has begun an M.S. program in Marine Biology/Biochemistry at the UD College of Marine Studies in Lewes, Delaware, funded by grants from the National Oceanic and Atmospheric Administration (NOAA) and SeaGrant.

Delaware Water Resources Center (DWRC) intern Kerrie Smith will begin a M.S. degree program at the University of Maryland in fall 2003, funded by a National Aeronautics and Space Administration (NASA) grant. She recently was awarded a Mechanical Engineering undergraduate degree from the University of Delaware's (UD's) College of Engineering. Smith's DWRC internship project, advised by James Glancey of UD's Departments of Mechanical Engineering and Bioresource Engineering, successfully created a water monitoring telemetry system.

Bret Stroger, a June 2003 recipient of a University of Delaware Environmental Engineering bachelor's degree, has completed his Delaware Water Resources Center (DWRC) internship on the design and use of water bioremediation systems and will pursue a master's degree at the University of California at Berkeley (UC-B) on fellowship. He plans to stay at UC-B for a PhD in Environmental Engineering.

## **Publications from Prior Projects**

1. 2000DE6G ("A Spatial Analysis of the Distributional Effects of Water Quantity Management") - Articles in Refereed Scientific Journals - Duke, Joshua, Robert Ehemann, and John Mackenzie. 2002. The distributional effects of water quantity management strategies: A spatial analysis. *The Review of Regional Studies* 32(1):19-35.