

Water Resources Center Annual Technical Report FY 2001

Introduction

Delaware Water Resources Center Annual Technical Report FY 2001 (3/1/01 - 2/28/02) June 30, 2002

Introduction

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. Due to prevailing dry conditions for New Castle County during the final months of 2001, the water conditions index fell in the "potential shortage" range. Throughout the state, below-normal stream flows were reported in late 2001, in some cases with record low flows, and water levels in the water-table observation wells have been approaching record low levels. Water levels in non-artesian water-table observation wells in Kent and Sussex Country were 3 feet lower for the winter of 2001 than the preceding winter's levels. At the end of the reporting period for this annual report (March 2002), Delaware initiated a "drought warning" recommending water conservation.

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 10 research grant programs during March 2001 through February 2002 that address these state water resources priorities. Three are graduate fellowships in nutrient management; the others were internships in wetlands identification and assessment, estuary strata analysis, impact of local land use on water quality, groundwater laws analysis, nutrient management education, and fate and effect of enzymes in chicken litter on soil nutrient chemistry.

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.

Research Program

Graduate Fellowship in Water Quality: Baseflow and Storm Discharges of Nutrients to Delaware's Inland Bays

Basic Information

Title:	Graduate Fellowship in Water Quality: Baseflow and Storm Discharges of Nutrients to Delaware's Inland Bays
Project Number:	2001DE3681B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	At-Large
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Nutrients
Descriptors:	Eutrophication, Land Use, Nitrogen, Nutrients, Rainfall-Runoff Models, Rainfall-Runoff Processes, Water Quality, Water Quality Monitoring
Principal Investigators:	William J. Ullman, Jennifer Jennings, Joseph R. Scudlark

Publication

1. Jennings, Jennifer; William Ullman, and Joseph Scudlark, March 2002, Annual report to DWRC: "Land Use/Land Cover and Nutrient Discharges to Delaware's Inland Bays", Delaware Water Resources Center, University of Delaware, Newark, DE, 14 pages.

Basic Information: Fellow Project #3 (of 3)

Title:	The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays
Project Number:	G-03
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Non Point Pollution
Keywords:	Eutrophication, Land Use, Nitrogen, Nutrients, Rainfall-Runoff Models, Rainfall-Runoff Processes, Water Quality, Water Quality Monitoring
Lead Institute:	DE Water Resources Center
Principal Investigators:	Jennifer Jennings, William Ullman ullman@udel.edu , Joseph Scudlark scudlark@udel.edu

Publication

1. Jennings, J., W. Ullman, and J. Scudlark. Annual report to DWRC, March, 2002. Land Use/Land Cover and Nutrient Discharges to Delaware's Inland Bays. College of Marine Studies, University of Delaware, Newark, DE.

Names and degree level (highest level during the reporting period) of all students who worked on the research project: Jennifer A. Jennings, PhD candidate

Background/Justification

Many coastal plain estuaries within the mid-Atlantic region of the United States suffer from eutrophication. This nutrient over-enrichment is caused by elevated nutrient loadings from domestic, municipal, industrial, and agricultural practices in the surrounding watersheds. Surface and ground water discharges from uplands, atmospheric deposition, and in some cases inputs from the coastal ocean, are responsible for the delivery of nutrients to estuaries. In the estuary, nitrogen and phosphorus fertilize vegetation leading to high levels of plant production, changes in phytoplankton species, and potentially noxious and toxic algal blooms. Eutrophication can have several other adverse effects on the ecosystem including decreases in dissolved oxygen concentrations, reduced biodiversity, and fish and shellfish kills.

Although fairly extensive research has been done in the identification of nutrient sources, there is little definitive proof concerning the role of the watershed, if any, in the attenuation and delivery of nutrient loads from upland land uses to the estuary. In 1998, a study estimated nitrogen loading rates for various land use classes and atmospheric deposition, as well as loadings from point sources in the watershed, to compile total loading values to Delaware's coastal bays. These estimated loadings however, were not verified by comparison to actual measurements.

Objectives

1. Test the 1998 study results at one sub-watershed of Delaware's Inland Bays, Bundicks Branch

The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays

(Objectives, continued)

2. Assign realistic uncertainties to interpolated baseflow loadings through intensive sampling
3. Determine and include annual storm loads in the estimates of total nutrient loading and examine the seasonal and inter-annual variability
4. Determine the impact of indirect atmospheric deposition and within sub-watershed attenuation factors on total nutrient loads

Methods

Objective 1. Testing the 1998 study approach.

Geographic information systems (GISs) have been used to determine the areas of the various land use and land cover types within Bundicks Branch. These areas were then multiplied by corresponding loading factors, in the 1998 study estimates, to calculate the theoretical N-load due to the land use and land cover from the studied sub-watershed. The values computed will be compared to the loads derived from the sampled data from Bundicks Branch, which will be used to determine the tributary's annual total nutrient loads.

Objective 2. Assignment of uncertainties to baseflow loadings.

Daily baseflow loads of the particulate and dissolved constituents are desired for the entire sampling period at Bundicks Branch so that monthly, quarterly, and annual loadings can be estimated. The annual loads will later be used to test the 1998 approach. In order to compute these values, nutrient concentration data must be generated by linear interpolation between the bimonthly baseflow sampling dates. Loadings can then be computed by multiplying these concentrations by mean daily discharges. In doing this though, it is assumed that the mean daily discharge will accurately represent the discharge, and hence the loadings, over an entire day, and that a linear interpolation will correctly represent the fluxes in concentration and loading between samplings. These assumptions must be validated however and for their future use in management purposes, realistic uncertainties must be assigned to the calculated baseflow loadings. To achieve this, daily and monthly variations in nutrient concentrations will be investigated through more intensive sampling.

Objective 3. Determination and inclusion of annual storm loads.

Annual storm loads will be estimated with the use of storm water samples collected between May 1999 and April 2000 and May 2001 and April 2002. Three methods of making this estimate are under evaluation. In the first approach, correlations between water discharge and nutrient concentration are examined. The second method involves the application of a ratio of the amount of precipitation that occurred during the monitored storms to the total amount of precipitation in the one-year sampling periods. Finally, the third method under evaluation is designed to take into account the seasonal influences on nutrient loads and is based on the simple relationship that the total load is the sum of the baseflow and runoff (storm) loads. All three methods will undergo further scrutiny to determine if one, or a combination of the three, produce the best estimate of annual storm loads. These data sets will also be examined for seasonal variations in storm loads and with the addition of the second storm data set the inter-annual variability of storm loads can be determined. Once this has been completed, the annual storm

The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays (Methods, continued)

loads at Bundicks Branch can be added to the annual baseflow loads and used to test the 1998 method at this particular site.

Objective 4. Determination of indirect atmospheric deposition and within sub-watershed attenuation factors.

The proposed comparison to test the 1998 method of determining nutrient loads to an estuary may find that this approach produces accurate estimates, but perhaps a more inclusive approach would include indirect atmospheric deposition and within sub-watershed attenuation factors as well. The final objective of the proposed research project is to develop estimates of the nutrient deposition and attenuation rates within the Inland Bays sub-watersheds. Monthly totals of dissolved inorganic nitrogen (NO_3^- and NH_4^+) in the rainfall collected at Cape Henlopen State Park have been made available and were used to estimate the indirect atmospheric deposition, which fell over Bundicks Branch during the study period. With the addition of the indirect atmospheric deposition component to the point source and land use loading factors from the previous method and the use of the compiled baseflow and storm data, a within sub-watershed attenuation factor can be back-calculated. More specifically, the input terms can be subtracted from the total stream loadings, which represent the total value exported from the watershed to the estuary, to determine the magnitude of the output term.

Results to date

- Using ArcView GIS and the 1998 study's land use classifications and corresponding loading factors, the theoretical N-load due to the land use and land cover from Bundicks Branch to Rehoboth Bay was determined. This method results in a load of 111 kgN/day. Similar calculations have been made for other sub-watersheds in the Inland Bays Basin.
- All samples from the every-hour-for-a-day and every-day-for-a-month sampling projects have been analyzed for the desired parameters and loads have been calculated. It appears from the hourly and daily sampling, that baseflow discharges can be sufficiently well characterized by biweekly water sampling and mean daily discharges.
- The storm water sampling was completed in April 2002 and these samples are currently in the process of being analyzed. The analysis of these data and the determination of an appropriate method for projecting annual storm loads is incomplete.
- The annually averaged indirect atmospheric deposition rate to Bundicks Branch has been determined as 43 kgN/day, which represents 40% of the total discharge estimated in 1998.

Program and Administration

Basic Information

Title:	Program and Administration
Project Number:	2001DE3701B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	
Congressional District:	At Large
Research Category:	
Focus Category:	Water Quality, Non Point Pollution, Geomorpological and Geochemical Processes
Descriptors:	Nutrient Management, water quality, environmental management and policy, Nutrient cycling and discharge to waters
Principal Investigators:	James Thomas Sims

Publication

Description of Delaware Water Resources Center
Program Management and Administration
March 1, 2001 through February 28, 2002 (FY01)

1. Institute Director
Dr. J. Thomas Sims
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2. Administrative Personnel:
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3. Budget Breakdown: see next page.

Delaware Water Resources FY01 Budget
 March 1, 2001 to February 28, 2002
 Revised June 1, 2001

	DOI	Matching	Total
	Funds	Funds	Funds
Professional Salaries:			
Director (Sims 5%)		5,000	5,000
Director (Nye 1%)		930	930
Research Assoc. Pautler (5%)		1,990	1,990
Research Assoc. Gartley (5%)		2,334	2,334
Research Assoc. Olsen (5%)		1,900	1,900
Other Wages			
Misc. Wage			
Coordinator Greene/Boyd	6,000		6,000
Total Salaries	6,000	12,154	18,154
Professional Fringe Benefits 27.5%		3,342	3,342
Other Wage Fringe Benefits 7.7%	462		462
Total Fringe Benefits	462	3,342	3,804
Total Salary & Fringe Benefits	6,462	15,496	21,958
Supplies	2,359		2,359
Travel	750		750
Water Resources Conference	2,000		2,000
Undergrad Internships	15,750	20,877	36,627
Other Costs – Competitive Projects			
Project Directors		25,107	25,107
Fringe Benefits		6,948	6,948
3 graduate students	36,000		36,000
Tuition		40,527	40,527
Travel	9,000		9,000
Supplies	3,000		3,000
Total Direct	75,321	108,955	184,276
Indirect Cost on Match @ 29% (Except Tuition)		19,844	19,844
Waived indirect on Federal Funds		21,843	21,843
Total Budget	75,321	150,642	255,963

4. 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 (continued)

Abstract of Program and Management Overview (continued)

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 FY2001DWRC research program will address these issues by supporting graduate fellowships in water quality (3), an undergraduate student internship program, and a statewide Water Resources Conference.

Three fellowships have been awarded for 2001-2002, based on a review of proposals submitted by potential graduate fellows and their advisors to the DWRC Advisory Panel:

a) On the Use of Nuclear Magnetic Resonance Spectroscopy to Determine Chemical Forms of Phosphorus in Soils: Implications for Phosphorus Mobility and Bioavailability

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.

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

Basic Information

Title:	Graduate Fellowship in Water Quality: Environmental Policies for a Sustainable Poultry Industry in Sussex County, Delaware
Project Number:	2001DE4301B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	At-large
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Non Point Pollution
Descriptors:	Land Use, Land-Water Interactions, Nutrients, Phosphorus, Water Quality
Principal Investigators:	William F. Ritter, John Byrne, Young-Doo Wang

Publication

1. Ward, Lynette; William Ritter, John Byrne, and Young-Doo Wang, March 2002, Annual report to DWRC: "Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware", Delaware Water Resources Center, University of Delaware, Newark, DE, 30 pages.

Basic Information: Fellow Project #2 (of 3)

Title:	Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware
Project Number:	G-02
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Non Point Pollution
Keywords:	Land Use, Land-Water Interactions, Nutrients, Phosphorus, Water Quality
Lead Institute:	DE Water Resources Center
Principal Investigators:	Lynette Ward, William Ritter william.ritter@udel.edu , John Byrne jbyrne@udel.edu , Young-Do Wang youngdoo@udel.edu

Publication

1. Ward, L., W. Ritter, J. Byrne, and Y. Wang. Annual report to DWRC, March, 2002. Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware. Center for Energy and Environmental Policy, University of Delaware, Newark, DE.

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

Background / Justification

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.

Objectives

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

Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware (Objectives, continued)

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.

Methods

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.

Results to date

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 the EPA's proposed CAFO regulations and Delaware's Nutrient Management Law, 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

Title:	Graduate Fellowship in Water Quality: Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation
Project Number:	2001DE4302B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	At-Large
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Water Quality, Sediments
Descriptors:	Agriculture, Eutrophication, Nutrients, Phosphorus, Runoff, Soil Chemistry, Soil-Water Relationships, Water Quality
Principal Investigators:	Donald L. Sparks, Stefan Hunger

Publication

1. Hunger, Stefan, and Donald Sparks, March 2002, Annual report to DWRC: "Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation", Delaware Water Resources Center, University of Delaware, Newark, DE, 20 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. The summaries are for the projects' second year.

Basic Information: Fellow Project #1 (of 3)

Title:	Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation
Project Number:	G-01
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Water Quality, Sediments
Keywords:	Agriculture, Eutrophication, Nutrients, Phosphorus, Runoff, Soil Chemistry, Soil-Water Relationships, Water Quality
Lead Institute:	DE Water Resources Center
Principal Investigators:	Stefan Hunger, Donald L. Sparks dlsparks@udel.edu

Publication

1. Hunger, S., and D. Sparks. Annual report to DWRC, March, 2002. Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation. Department of Plant and Soil Sciences, University of Delaware, Newark, DE.

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

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

**Mechanisms of Phosphorus Stabilization in the Soil Environment:
A Molecular Scale Evaluation
(Background/Justification continued)**

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}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}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

**Mechanisms of Phosphorus Stabilization in the Soil Environment:
A Molecular Scale Evaluation
(Results to date, continued)**

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}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}P -NMR spectroscopy), however, are somewhat contradicting and a more thorough investigation is needed.

Undergraduate Internship: Fate of Microbial Phytase in the Gastrointestinal Tract of Chicks, and Effects on Phosphorus Solubility

Basic Information

Title:	Undergraduate Internship: Fate of Microbial Phytase in the Gastrointestinal Tract of Chicks, and Effects on Phosphorus Solubility
Project Number:	2001DE23B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	At-large
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Agriculture
Descriptors:	Agriculture, Animal Waste, Birds, Nutrients, Phosphorus
Principal Investigators:	William Saylor, Christina Eckstrand

Publication

Delaware Water Resources Center Research Program: Interns

The following seven research projects are DWRC-funded undergraduate internships which were granted for the period March 1st, 2001 - February 28th, 2002.

Basic Information: Intern Project #1 (of 7)

Title:	Fate of Microbial Phytase in the Gastrointestinal Tract of Chicks, and Effects on Phosphorus Solubility
Project Number:	G-13
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Agriculture
Keywords:	Agriculture, Animal Waste, Birds, Nutrients, Phosphorus
Lead Institute:	DE Water Resources Center
Principal Investigators:	Christina Eckstrand, Dr. William Saylor (bsaylor@udel.edu), Department of Animal and Food Sciences, University of Delaware

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

Background / Justification

The broiler industry is a vital component of the agricultural enterprise in Delaware, producing approximately 260 million chickens per year, and generating in excess of one billion dollars for the State. As a result of the intensive animal density, however, a number of environmental concerns have been created, particularly in the environmentally-sensitive watersheds of the inland bays. The most pressing issue for the industry is the high concentrations of phosphorus (P) in soils created by years of land application of P-rich broiler litter, and the potential movement of that P into surface and ground waters. The high P concentrations in broiler excreta and hence litter is caused by the inefficient utilization of phytic acid P in the grain-based diets fed to broilers (and other non-ruminant animals). However, the advent of new technologies, including the feeding of microbially-derived phytase enzymes and low-phytate grains, reductions in the total amount of P that must be fed to broilers to meet their nutritional requirements are being realized.

Objectives

The use of phytase in the diet shows significant promise for improving P utilization in chickens. One concern that has been raised, and requires study, is the fate of these phytase enzymes in the gastrointestinal (GI) tract of chickens and whether any meaningful quantities are excreted into the environment. The objectives of this study are:

1. To investigate how much active phytase is excreted by phytase-fed chickens
2. To investigate the impact of excreted active phytase on litter and soil P.

It has been suggested that phytase entering the environment might continue to hydrolyze organic P in the litter and soil, and by increasing the concentration of soluble P, promote the movement of

Fate of Microbial Phytase in the Gastrointestinal Tract of Chicks, and Effects on Phosphorus Solubility (Objectives, continued)

litter and soil P into surface and ground waters. The study investigates the fate of microbial phytase provided in the diet of broiler chicks through the length of the GI tract, and in the excreta.

Method

One-day-old broiler chicks were fed diets containing graded level of microbial phytase together with graded levels of non-phytate P (nPP) for periods of one, two, three, and four weeks. Excreta samples were collected from each pen on a weekly basis for phytase activity and total and soluble P. At the end of each period, chicks were euthanized and the gastrointestinal tract including the proventriculus, gizzard, duodenum, ileum, and cecum, were removed. The gut contents were collected from each gut section and immediately placed in liquid nitrogen to prevent loss of enzyme activity. All samples were analyzed for phytase activity, total, soluble, and phytate P. Phytase activity, and total, soluble and phytate P concentrations in all diets were determined as well.

If significant phytase activity is found to persist in the GI tract of chicks in this small-scale study, similar gut samples and samples of litter from broilers fed phytase in large-scale floor pen studies (planned as part of the USDA-IFAFS grant) will be examined.

Undergraduate Internship: Connecting the Link between Land Use and Stream Health in the University of Delaware Experimental Watershed

Basic Information

Title:	Undergraduate Internship: Connecting the Link between Land Use and Stream Health in the University of Delaware Experimental Watershed
Project Number:	2001DE24B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	At-large
Research Category:	Water Quality
Focus Category:	Water Quality, Education, Management and Planning
Descriptors:	Geographic Information Systems, Land Use, Land-Water Interactions,
Principal Investigators:	Gerald Kauffman, Tara Harrell

Publication

1. Harrell, Tara, and Gerald Kauffman, March 2002, Report submitted to DWRC "Research Connecting the Link between Land Use and Stream Health in the University of Delaware Experimental Watershed", Delaware Water Resources Center, University of Delaware, Newark, DE, 76 pages.

Basic Information: Intern Project #2 (of 7)

Title:	Connecting the Link between Land Use and Stream Health in the University of Delaware Experimental Watershed
Project Number:	G-14; second year continuation of G-04
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Water Quality
Focus Category:	Water Quality, Education, Management and Planning
Keywords:	Geographic Information Systems, Land Use, Land-Water Interactions, Streams, Model Studies
Lead Institute:	DE Water Resources Center
Principal Investigators:	Tara Harrell, Mr. Gerald Kauffman (jerryk@udel.edu), Water Resources Agency, University of Delaware

Publication

1. Harrell, T., and G. Kauffman. Report submitted to DWRC, March, 2002. Connecting the Link between Land Use and Stream Health in the University of Delaware Experimental Watershed. Water Resources Agency, University of Delaware, Newark, DE.

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

Connecting the Link between Land Use and Stream Health in the University of Delaware Experimental Watershed

Background / Justification

Although people depend on water for their everyday lives, its source is generally taken for granted. The geographic area of land that drains into a waterway, regardless of size, is known as a watershed. Although the larger bodies of water may seem more significant, it is the compact watersheds where research can be focused. Student researchers of the University of Delaware Water Resources Agency (UDWRA) have delineated an experimental watershed through the University of Delaware campus which includes both the northern Piedmont Plateau and the southern Coastal Plain. The land use in these areas is rapidly changing, and the amount of impervious services, such as roads and driveways, is increasing. A negative relationship between land use and stream health was found in the Piedmont Plateau, and a report card for establishing a user-friendly way of tracking watershed health through the years was developed.

Objectives

The purpose of this project is to continue to research the link between stream health and land use and update the watershed report card for the Piedmont Plateau and the Coast Plain while exploring different methods and procedures.

Connecting the Link between Land Use and Stream Health in the University of Delaware Experimental Watershed (continued)

Method

In order to answer this pressing issue, stream sampling and chemical surveys were completed at each of the sampling stations through the watershed. The University of Delaware Water Resources Agency (UDWRA) was fortunate enough to have contacts in New Zealand. The National Institute of Water and Atmospheric Research (NZNIWA) has donated a Stream Health Monitoring and Assessment Kit to the WRA. A comparison between the two habitat assessment procedures will illustrate the differences and perhaps call for a modification of the current UDWRA assessment technique. Geographic Information Systems (GIS) software was used in order to determine the amount of land use and impervious surface in each sub-basin. The information gathered was analyzed by the application of the report card. Because the report card is such a standardized method, it is very easy to compare and contrast the streams and areas. The GIS software was analyzed using standard techniques and aerial maps in public circulation. GIS software is the most reliable and best method of land use and area research.

Results

The results were as expected. In the NZ-NIWA method, all of the measurements are extremely quantitative, whereas the USEPA methods were more subjective. The Overall Watershed Health Grade of the Piedmont Watershed was a C+, which has fallen from a B- in 2001. The stream in this watershed with the highest percentage of impervious cover had the lowest stream quality, in concurrence with the thesis of this report. The Coastal Plain in 2002 received an Overall Watershed Report Card Grade of C, which is another decrease in total watershed health. The Coastal Plain Watershed received a C+ in 2001. Tributary 3, which had the lowest percentage of impervious cover, had the highest water quality grade. The stream with the lowest overall grade had the highest amount of negatively impacting land uses and highest percentage of impervious cover. Future researchers will be able to update and modify the Experimental Watershed Report Card to monitor temporal changes in the surrounding land.

Undergraduate Internship: An Analysis of Delaware's Groundwater Allocation Laws: Proposing a Plan

Basic Information

Title:	Undergraduate Internship: An Analysis of Delaware's Groundwater Allocation Laws: Proposing a Plan
Project Number:	2001DE25B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	At-large
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, None, None
Descriptors:	Groundwater Management, Law, Policy Analysis, Water Law
Principal Investigators:	Joshua Duke, Katie Lemon

Publication

1. Lemon, Katie, and Joshua Duke, March 2002, Report submitted to DWRC " An Analysis of Delaware's Groundwater Allocation Laws: Proposing a Plan", Delaware Water Resources Center, University of Delaware, Newark, DE, 42 pages.

Basic Information: Intern Project #3 (of 7)

Title:	An Analysis of Delaware's Groundwater Allocation Laws: Proposing a Plan
Project Number:	G-15
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Policy Analysis
Focus Category:	Law, Institutions, & Policy
Keywords:	Groundwater Management, Law, Policy Analysis, Water Law
Lead Institute:	DE Water Resources Center
Principal Investigators:	Katie Lemon, Dr. Joshua Duke (duke@udel.edu), Department of Food and Resource Economics, University of Delaware

Publication

1. Lemon, K., and J. Duke. Report submitted to DWRC, March, 2002. An Analysis of Delaware's Groundwater Allocation Laws: Proposing a Plan. Department of Food and Resource Economics, University of Delaware, Newark, DE.

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

Background / Justification

Delaware has instituted legal rules and regulations to assist in the proper allocation of groundwater. The state's intervention has been necessary because of the physical nature of water resources. The means of storage and access, the regional coverage, and the number of users of an aquifer create challenges for the definition of clear property rights. Groundwater in Delaware is a common property resource, meaning no member of a group can be excluded from utilizing that resource. The consumption of the resource is considered rivalrous, meaning that one user's consumption will limit another user's consumption. Common property resources are often overexploited and used inappropriately because of the nature of the shared property (or, in this case, the right to use).

Objectives

Due to sources of conflict in the physical characteristics of the underground water supply, the economic failures of this common property resource, and legal complications, a statewide comprehensive plan for the management of this resource is essential. This research will identify the possible sources of conflict that would prevent an equitable, efficient, and sustainable allocation of groundwater.

Method (see next page)

An Analysis of Delaware's Groundwater Allocation Laws: Proposing a Plan (continued)

Method

Equity is the standard by which all resource users' interests are weighed impartially. Hindrances include:

- Exemptions for various users
- The uncertainty of which user should bear external costs of depletion
- Different governmental oversight for different users

Efficiency maximizes the total net benefits of resource use over time. Hindrances include:

- Guarantees of water to users who are first in time
- Requirements that a user utilize all allocated water to receive same allocation for following year
- Guarantees to irrigators

Sustainability can be described as the ability of future generations to maintain an equal or greater standard of living. Hindrances include:

- Allocation based solely on consumer demand, not including supply
- Hidden true scarcity of water resources

To determine the legal analysis of Delaware's management, law review articles, statutes, regulations, and court documents were consulted.

Results

The results conclude that although the institutions have established a management scheme for the resource that has proven useful, many sources of conflict still persist.

There is currently no statewide groundwater allocation plan for Delaware. Management strategies for water allocation have been made at the local level and interstate level. Statewide plans for the protection of groundwater resources have been made, yet a comprehensive plan for allocation is still needed. Through a statewide plan all interests can be considered and the long-term as well as short-term consequences of potential uses can be evaluated before decisions for allocation are made. The plan can produce proper and effective incentives for individuals to conserve and use groundwater for maximum social benefit. A comprehensive statewide plan enacted through the legal statutes would have the authority to obtain the goals of equity, efficiency, and sustainability in Delaware's groundwater allocation.

Undergraduate Internship: Functional Assessment of Wetlands for Mitigation Purposes

Basic Information

Title:	Undergraduate Internship: Functional Assessment of Wetlands for Mitigation Purposes
Project Number:	2001DE26B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	At-large
Research Category:	Ground-water Flow and Transport
Focus Category:	Wetlands, Hydrology, Models
Descriptors:	Aquatic Plants, Geomorphology, Groundwater Hydrology, Hydrologic Models, Plant-Water Relationships, Wetlands
Principal Investigators:	Bruce L. Vasilas, Kirsten Lloyd

Publication

1. Lloyd, Kirsten, and Bruce L. Vasilas, March 2002, Report submitted to the DWRC: "Functional Assessment of Wetlands for Mitigation Purposes", Delaware Water Resources Center, University of Delaware, Newark, DE, 7 pages.

Basic Information: Intern Project #4 (of 7)

Title:	Functional Assessment of Wetlands for Mitigation Purposes
Project Number:	G-16; second year continuation of G-09
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Ground Water Flow and Transport
Focus Category:	Wetlands, Hydrology, Models
Keywords:	Aquatic Plants, Geomorphology, Groundwater Hydrology, Hydrologic Models, Plant-Water Relationships, Wetlands
Lead Institute:	DE Water Resources Center
Principal Investigators:	Kirsten Lloyd, Dr. Bruce Vasilas (bvasilas@udel.edu), Department of Plant and Soil Sciences, University of Delaware

Publication

1. Lloyd, K., and B. Vasilas. Report submitted to DWRC, March, 2002. Functional Assessment of Wetlands for Mitigation Purposes. Department of Plant and Soil Sciences, University of Delaware, Newark, DE.

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

Background / Justification

Since the mid-1800s, over one-half of the area of wetlands in the United States has been lost. Although wetland conservation practices began in the mid-1970s, the diversity of wetland ecosystems continues to decrease. Compensatory mitigation has been used in an attempt to replace lost natural wetlands; however, there are many problems with this approach.

Objectives

The objective of this study was to collect plant community data at two wetland sites as part of a long-term monitoring project of fifty reference wetlands selected to represent the class of Mid-Atlantic Piedmont slope discharge wetlands.

Method

The Hydrogeomorphic (HGM) approach to wetland functional analysis has been designed to increase the successes of compensatory mitigation. It relies on rapid assessment techniques to collect data that can be used in a model that establishes how that wetland functions in comparison to reference standards, using data collected from wetlands in the same HGM class. The HGM class is based on geomorphic setting, hydrology, and hydrodynamics.

Results

When data collection has been completed for the long-term project, it will be used to develop a model that establishes how well other wetlands of the same class function in comparison to reference standards derived from the study.

Undergraduate Internship: A Nutrient Management Program for Delaware Youth

Basic Information

Title:	Undergraduate Internship: A Nutrient Management Program for Delaware Youth
Project Number:	2001DE27B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	At-large
Research Category:	Water Quality
Focus Category:	Education, Nutrients, None
Descriptors:	Conservation, Information Dissemination, Nutrients, Phosphorus, Pollutants, Soil-Water Relationships, Water Quality, Water Law
Principal Investigators:	Susan Truehart Garey, John Place

Publication

1. Place, John, and Susan Truehart Garey, March 2002, Report submitted to the DWRC "A Nutrient Management Program for Delaware Youth", Delaware Water Resources Center, University of Delaware, Newark, DE, 5 pages.

Basic Information: Intern Project #5 (of 7)

Title:	A Nutrient Management Program for Delaware Youth
Project Number:	G-17
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Education
Focus Category:	Education, Nutrients
Keywords:	Conservation, Information Dissemination, Nutrients, Phosphorus, Pollutants, Soil-Water Relationships, Water Quality, Water Law
Lead Institute:	DE Water Resources Center
Principal Investigators:	John Place, Susan Truehart Garey (truehart@udel.edu), University of Delaware Cooperative Extension Office

Publication

1. Place, J., and S. Truehart Garey. Report submitted to DWRC, March, 2002. A Nutrient Management Program for Delaware Youth. University of Delaware Cooperative Extension Office, University of Delaware, Newark, DE.

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

Background / Justification

In 1999, Delaware passed legislation to establish a Nutrient Management Commission to “develop, review, approve, and enforce regulations governing the certification of individuals engaged in the business of land application of nutrients and the development of nutrient management plans” and to oversee citizen education. The legislation was spurred by significant water quality issues. Many of Delaware’s water bodies are considered “impaired” by the Delaware Department of Natural Resources and Environmental Control (DNREC) due to the introduction of excess nutrients from a variety of sources including but not limited to: agriculture, lawn and golf course upkeep, sewage treatment, septic system leakage and industrial discharge and other urban sources. Enrichment of the nutrients nitrogen and phosphorus in soil and water can lead to groundwater contamination, acid rain, soil acidification, and surface water eutrophication leading to accelerated algae and/or nuisance plant growth in water bodies. The increased growth rate depletes dissolved oxygen in the water, resulting in fish kills, and sediments from dying plants increase foul odors and turbidity.

Unfortunately, home owners often place blame on farmers, when in fact they contribute to pollution themselves through over-application of lawn fertilizers which run off into ground and surface waters. A need exists for youth education in nutrient management to influence citizen behavior and beliefs in the coming generation to support new legislative nutrient management mandates.

(Background / Justification, continued next page)

A Nutrient Management Program for Delaware Youth (Background / Justification, continued)

University of Delaware Cooperative Extension Agents Susan Truehart Garey (Animal Science) and Becky Marasco (Renewable Resources), with guidance from Extension Nutrient Management Specialist David J. Hansen, University of Delaware Associate Professor in Soil and Water Quality, and Joy Sparks, Delaware State 4-H Program Coordinator, have developed and published the youth curriculum “Soil, Water, and Nutrient Management (SWANM) Youth Curriculum Guide” (2001). This environmental education program was funded in part by a grant from the Environmental Protection Agency (EPA)

Objectives

- The objective of the internship is to instruct youths on
1. Making a personal difference at home and in the neighborhood to improve water quality and
 2. Encouraging the greater community to protect soil and water resources.

The curriculum’s concepts, designed to give youth a broad understanding of complicated nutrient management issues, are:

1. Why the fate of our soil and water matters; importance of soil and water
2. The nature of soil composition and supply; nature of water supply; interrelationships with the human population.
3. Polluting effects of human activity on soil and water
4. Testing for nutrient management in your own backyard

Method

The curriculum was taught to youth ages eight to twelve years old in six week-long summer camps as a series of daily one-hour hands-on small group workshops. The interactive activities follow the experiential learning model also found in 4H curriculums. Additionally, participants had the opportunity to participate in community awareness activities such as developing a local garden, educating others about soil testing, and performing soil tests for neighbors or relatives. The six camp locations were: Dover Air Force Base Science and Math Camp, Dover; State 4H camp, Camp Barnes, South Bethany Beach (2 camps); Newark 4H Day Camp; Harrington 4H Day Camp; and Strengthening Families Day Camp at the Kent County Extension Office, Dover.

Leaders were also trained on two occasions: at the Kent County Extension Office, Dover, and the state 4H leader forum in Newark. Eleven adult leaders and five older teen leaders were taught how to present the curriculum by the intern.

Results

The intern gained experience in education, youth development, nutrient management and water science issues, responsibility, and self-motivation.

A total of 150 children from primarily urban or suburban backgrounds learned the concepts for the first time. The average increase in basic soil and water knowledge as reflected in a pre- and post-test was over 30%. The greatest gains were seen in group containing students

**A Nutrient Management Program for Delaware Youth
(Results, continued)**

who had chosen to participate in the program, whose parents brought them each day, whose group was supervised by a teen leader, and who were not challenged by attention deficit disorders (ADD). Students also benefited when group sizes were smaller, permitting more instructor interaction and supervision on hands-on activities.

The sixteen individuals trained to present the curriculum in the future expressed confidence in their training and in the curriculum to effectively impart nutrient management information to youth.

The curriculum is an effective method to promote sound conservation practices by teaching youths to care for soil and water resources and to relay their concern to their peers.

Undergraduate Internship: Stratigraphic Analysis of the St. Jones River Estuary

Basic Information

Title:	Undergraduate Internship: Stratigraphic Analysis of the St. Jones River Estuary
Project Number:	2001DE28B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	At-large
Research Category:	Climate and Hydrologic Processes
Focus Category:	Geomorphological Processes, Sediments, Climatological Processes
Descriptors:	Estuarine Modeling, Geomorphology, River Beds, Sedimentation
Principal Investigators:	Ronald E. Martin, Lindsay Scanlon

Publication

1. Scanlon, Lindsay, and Ronald Martin, March 2002, Report submitted to the DWRC, "Stratigraphic Analysis of the St. Jones River Estuary", Delaware Water Resources Center, University of Delaware, Newark, DE, 5 pages.

Basic Information: Intern Project #6 (of 7)

Title:	Stratigraphic Analysis of the St. Jones River Estuary
Project Number:	G-18
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	River Geomorphology
Focus Category:	Geomorphological Processes, Sediments, Climatological Processes
Keywords:	Estuarine Modeling, Geomorphology, River Beds, Sedimentation
Lead Institute:	DE Water Resources Center
Principal Investigators:	Lindsay Scanlon, Dr. Ronald Martin (daddy@udel.edu), Department of Geology, University of Delaware

Publication

1. Scanlon, L., and R. Martin. Report submitted to DWRC, March, 2002. Stratigraphic Analysis of the St. Jones River Estuary. Department of Geology, University of Delaware, Newark, DE.

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

Background / Justification

Estuaries are affected by natural and anthropogenic changes in their associated environmental settings. To fully understand the extent to which current depositional processes result from either factor, the historical stratigraphic record must first be explored. Importantly, the long-term record documents historical trends in depositional environments.

Objectives

This project entails a study of the stratigraphic record for the St. Jones Estuary within the Delaware National Estuarine Research Reserve (DNERR), with the hopes of providing information for future studies concerning sea-level rise or other stresses that have a potentially averse effect on the estuary.

Method

Methods involving the use of three inch, dutch-auger core devices within the St. Jones marsh accomplish the field aspect of this study, and the first step towards arriving at a detailed stratigraphic record for the area. Careful, field documentation of the meter-long sections of these cores provides the basis for subsequent construction of vertical core columns. These columns are constructed according each layer's respective lithologies and inferred depositional environment. A GPS locating system records the location of each core recovered out in the field, allowing for the possible correlation of the cores later on in the lab.

(continued next page)

(Stratigraphic Analysis of the St. Jones River Estuary, continued)

Results

The field and lab portions of this study result in stratigraphic columns that summarize the depositional history for various locations within the St. Jones estuary. This information provides useful information for future studies addressing the present condition of the estuary system since it provides a context for those current depositional environments.

Undergraduate Internship: Ectomycorrhizae as a Hydrologic Indicator in Wetland Identification

Basic Information

Title:	Undergraduate Internship: Ectomycorrhizae as a Hydrologic Indicator in Wetland Identification
Project Number:	2001DE29B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	At-large
Research Category:	Climate and Hydrologic Processes
Focus Category:	Wetlands, Hydrology, Groundwater
Descriptors:	Groundwater, Hydrologic Models, Soil-Water Relationships, Wetlands
Principal Investigators:	Bruce L. Vasilas, Kristin Staats

Publication

1. Staats, Kristin, and Bruce Vasilas, March 2002, Report submitted to the DWRC, "Ectomycorrhizae as a Hydrologic Indicator in Wetland Identification", Delaware Water Resources Center, University of Delaware, Newark, DE, 7 pages.

Basic Information: Intern Project #7 (of 7)

Title:	Ectomycorrhizae as a Hydrologic Indicator in Wetland Identification
Project Number:	G-19; second year continuation of G-11
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Climate and Hydrologic Processes
Focus Category:	Wetlands, Hydrology, Groundwater
Keywords:	Groundwater, Hydrologic Models, Soil-Water Relationships, Wetlands
Lead Institute:	DE Water Resources Center
Principal Investigators:	Kristin Staats, Dr. Bruce Vasilas (bvasilas@udel.edu), Department of Plant and Soil Sciences, University of Delaware

Publication

1. Staats, K., and B. Vasilas. Report submitted to DWRC, March, 2002. Ectomycorrhizae as a Hydrologic Indicator in Wetland Identification. Department of Plant and Soil Sciences, University of Delaware, Newark, DE.

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

Background / Justification

Wetlands are an important ecosystem, of which acreage of had decreased over the past decades. Because of seasonal saturation of some true hydric soils, delineation of these environments is challenging given current technology and methods. Ectomycorrhizal fungi, ubiquitous soil microorganisms, may be an indicator of hydroperiod and/or hydrology of an area in question.

Objectives

The overall objective of this study is to develop a relationship between the presence of ectomycorrhizal fungal and hydrology/hydroperiod of soils.

Method

The collection of fungal mantles in three field locations, monitoring of depth to water table, and description of the soils at the sites has been in progress since 1998.

Results

It appears that ectomycorrhizae do not colonize the roots of plants below a depth which saturation occurs for any length of time. This positively supports the hypothesis. Given further analysis of root samples collected, this information will hopefully become part of the documentation used to identify hydric soils.

Information Transfer Program

WATER NEWS Newsletter

Basic Information

Title:	WATER NEWS Newsletter
Project Number:	2001DE21B
Start Date:	12/1/2001
End Date:	12/1/2001
Funding Source:	104B
Congressional District:	At-large
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	Newsletter published biannually by DE Water Resources Center
Principal Investigators:	

Publication

Information Transfer Program

Basic Information: Center Print Publication

Title:	“WATER NEWS“
Issue during FY01:	12/2001 Vol. 2 No. 1
Description:	Newsletter published biannually by the University of Delaware Water Resources Center
Lead Institute:	DE Water Resources Center
Principal Investigators:	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>.

Fall 2001 topics included:

- Launch of new DWRC web site <http://ag.udel.edu/dwrc>
- DWRC 2001 Student Research Conference Highlights
- Drinking Water Policy Forum 10/11/01
- New DWRC Research and Education Initiatives for 2002-2003
- Meet the 2001-2002 DWRC Undergraduate Interns
- Nutrient Management News

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
- 2000 – 2003 **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

New DWRC Web site <http://ag.udel.edu/dwrc>

Basic Information

Title:	New DWRC Web site http://ag.udel.edu/dwrc
Project Number:	2001DE22B
Start Date:	12/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	At-large
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	Comprehensive new site serving Delaware water resources community
Principal Investigators:	

Publication

Basic Information: Center Website

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

New web 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

**Center listserv of UD water resources faculty and researchers, at
<http://ag.udel.edu/dwrc/courses.html>**

Basic Information

Title:	Center listserv of UD water resources faculty and researchers, at http://ag.udel.edu/dwrc/courses.html
Project Number:	2001DE30B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	At-large
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	New listserv serving Delaware water resources community
Principal Investigators:	J. Thomas Sims, Amy Boyd

Publication

Basic Information: Center Electronic Database

Title:	New 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/courses.html
Start Date:	12/2001
End Date:	
Description:	New listserv serving Delaware water resources community
Lead Institute:	DE Water Resources Center
Principal Investigators:	Dr. J. Thomas Sims, director, Amy Boyd, administrator

The online listing of approximately 60 **University of Delaware (UD) Water Courses and Faculty** 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.

Fellow Project Presentation "On the Use of 31-P NMR Spectroscopy to Determine Chemical Forms of Phosphorus in Soils"

Basic Information

Title:	Fellow Project Presentation "On the Use of 31-P NMR Spectroscopy to Determine Chemical Forms of Phosphorus in Soils"
Project Number:	2001DE31B
Start Date:	10/21/2001
End Date:	10/25/2001
Funding Source:	104B
Congressional District:	At-large
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	Presentation to ASA Oct. 21-25, 2001 conference, Charlotte NC.
Principal Investigators:	Stefan Hunger, Donald L. Sparks

Publication

Basic Information: Fellow Project Presentation

Title:	“On the Use of 31-P NMR Spectroscopy to Determine Chemical Forms of Phosphorus in Soils“
Start Date:	10/21/2001
End Date:	10/25/2001
Description:	Presentation to ASA Oct. 21-25, 2001 conference, Charlotte NC.
Lead Institute:	DE Water Resources Center
Principal Investigators:	Stefan Hunger, Donald L. Sparks (dlsparks@udel.edu), Department of Plant and Soil Sciences, University of Delaware

Presentation 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 31P-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.

Intern's Project "A Nutrient Management Program for Delaware Youth" six seminars & training

Basic Information

Title:	Intern's Project "A Nutrient Management Program for Delaware Youth" six seminars & training
Project Number:	2001DE32B
Start Date:	6/1/2001
End Date:	7/31/2001
Funding Source:	104B
Congressional District:	At-large
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	Presentation of nutrient management curriculum as part of undergraduate internship project
Principal Investigators:	John Place, Susan Truehart Garey

Publication

Basic Information: Intern Project's Six Seminars

Title:	"A Nutrient Management Program for Delaware Youth" seminars & training
Start Date:	June 2001
End Date:	July 2001
Description:	Presentation of nutrient management curriculum as part of undergraduate internship project G-17.
Lead Institute:	DE Water Resources Center
Principal Investigators:	John Place, Susan Truehart Garey (truehart@udel.edu), University of Delaware Cooperative Extension Office

A total of 150 children from primarily urban or suburban backgrounds ages eight to twelve years old were taught a new interactive nutrient management curriculum. Six week-long summer camps were conducted as a series of daily one-hour hands-on small group workshops. For many it was the first introduction to concepts of taking personal responsibility for water quality and the protection of soil and water resources. Topics, designed to give youth a broad understanding of complicated nutrient management issues, are:

1. Why the fate of our soil and water matters; importance of soil and water
2. The nature of soil composition and supply; nature of water supply; interrelationships with the human population.
 1. Polluting effects of human activity on soil and water
 2. Testing for nutrient management in your own backyard

The average increase in basic soil and water knowledge as reflected in a pre- and post-test was over 30%. The six camp locations were: Dover Air Force Base Science and Math Camp, Dover; State 4H camp, Camp Barnes, South Bethany Beach (2 camps); Newark 4H Day Camp; Harrington 4H Day Camp; and Strengthening Families Day Camp at the Kent County Extension Office, Dover.

Sixteen leaders were also trained on two occasions: at the Kent County Extension Office, Dover, and the state 4H leader forum in Newark. These eleven adult leaders and five older teen leaders were taught how to present the curriculum by the intern.

Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 RCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	0	70	0	0	7
Masters	0	0	0	0	0
Ph.D.	0	30	0	0	3
Post-Doc.	0	0	0	0	0
Total	0	10	0	0	10

Notable Awards and Achievements

Dr. Tom Sims, Director of the DWRC, received the Environmental Quality Research Award from the American Society of Agronomy in 2001. This award is intended to recognize contributions enhancing the basic understanding of environmental sciences in relation to agriculture or demonstrating sound and effective management practices for maintaining or improving the quality of soil, water, and air resources. Principal criteria to be used in the selection process are creativity and originality of the research and significance of the research and its contribution to the field of environmental quality.

Jennifer Campagnini, recipient of a DWRC undergraduate research internship during 2000-2001, was successful in publishing and presenting her research work at two national conferences. The AWRA/UCWRI published her paper "Development of the University of Delaware Experimental Watershed Project" in peer-reviewed proceedings. The conferences were the May 31, 2001 Spring Conference of the American Geophysical Union (AGU) in Boston, Massachusetts, and the June 27, 2001 American Water Resources Association (AWRA) / University Council of Water Resources Institutes (UCWRI) Summer Specialty Conference in Park City, Utah.

Twenty-five copies of the 2001 University of Delaware Department of Food and Resource Economics Research Report RR 01-04 "A spatial analysis of the distributional effects of water quantity management", authored by Robert Ehemann, recipient of a DWRC 2000-2001 undergraduate research internship, with Joshua Duke and John Mackenzie, were disseminated to stakeholders and policy makers in Delaware. As a result, contacts at the University of Delaware Water Resources Agency invited Mr. Ehemann and Dr. Duke to present their results at a statewide conference for State administration officials and others on October 11, 2001. Within the field of natural resource economics, this project generated scholarly contributions. Indeed, to our best knowledge, this is the first economic study to integrate water-quantity pricing and GIS. The results are proving to be policy relevant. The research report is generating interest among water policy specialists in Delaware.

Publications from Prior Projects

1. Campagnini, Jennifer, and Martha Corrozi, Justin Bower, and Gerald Kauffman, June 27 2001, Proceedings of Decision Support Systems for Water Resources Management, American Water Resources Association/ University Council of Water Resources Institutes Summer Specialty Conference, Park City, Utah, Pages 81 - 86.
2. Campagnini, Jennifer, and Martha Corrozi, Justin Bower, and Gerald Kauffman, May 31 2001, Proceedings of the American Geophysical Union (AGU), Spring Conference, Boston, MA. Project report is also posted on University of Delaware Water Resources Agency site at <http://www.udel.edu/ipa>
3. Ehemann, Robert, and Dr. Joshua Duke, Jan. 2002, Publication ER02-01 of College of Agriculture and Natural Resources, University of Delaware Department of Food and Resource Economics, Newark, DE
4. Ehemann, R. 2001. A spatial analysis of the distributional effects of water quantity management. Undergraduate Degree with Distinction Thesis, University of Delaware, Newark, DE.
5. Ehemann, Robert, and Joshua Duke and John Mackenzie, 2001, "A spatial analysis of the distributional effects of water quantity management", FREC Research Report RR 01-04, Department of Food and Resource Economics, University of Delaware, Newark, DE
6. Duke, Joshua, and Robert Ehemann and John Mackenzie, October 11 2001, "An efficient pricing mechanism to manage water quantity in New Castle County, Delaware", Proceedings of A Delaware Public Policy Forum: Drinking Water 2001: The Issues Concerning Delaware's Most Precious Natural Resource, Univ. of Delaware Water Resources Agency, Newark, DE.
7. Duke, Joshua, and Robert Ehemann and John Mackenzie, October 2001, "Pricing water for quantity management in New Castle County," Quarterly meeting of Delaware Water Supply Coordinating Council, Artesian Water Company, Newark, DE.
8. Duke, Joshua, and 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