Water Resources Center
Annual Technical Report
FY 2006

Introduction

Delaware Water Resources Center

June 30, 2007

The Delaware Water Resources Center receives an annual Federal matching grant as authorized by section 104 of the Water Resources Research Act of 1984 (Public Law 98-242) as amended by Public Law 101-397, Public Law 104-147, and Public Law 106-374. The U.S. Geological Survey (USGS), Department of the Interior, administers the provisions of the Act. This annual evaluation report describes, in the format prescribed by the USGS, the research, training, and information transfer activities supported by the section 104 grants and required matching funds during fiscal year 2006.

Introduction

Understanding the nature of the water quality and water supply problems faced in Delaware, historically and today, requires knowledge of the physiographic nature of the state, its climate, and major land uses. Geologically, Delaware is comprised of the Piedmont and Atlantic Coastal Plain Provinces. Only the northernmost 6% of the state is within the Piedmont, a region created of very old igneous and metamorphic rock. Soils range from well-drained, highly productive silt loams in the Piedmont to well and excessively well-drained sandy loams and loamy sands in the Coastal Plain. Significant areas of poorly drained soils are also present, particularly in southeastern Delaware. Erosion and surface runoff are the main concerns in the Piedmont, while leaching of contaminants to shallow ground waters is the main water quality problem in the Coastal Plain. Average annual rainfall is plentiful (45 inches/year) and rather constant, averaging 3 to 4 inches/month in winter and spring and 4 to 5 inches/month in summer. Precipitation typically exceeds evapotranspiration by 12 to 18 inches/year, providing 10 to 12 inches/year of groundwater infiltration. Surface water is the main water supply source in the Piedmont, although the Cockeysville Formation is an important local aquifer of fractured marble and dolomite. This province is dominated by the Christina River Basin, fed by rivers that first flow extensively through Pennsylvania and Maryland. Water quality of the White Clay and Red Clay Creeks and Brandywine River is strongly affected by land use and point sources of pollution in neighboring states. Those rivers flow into the Christina River which, in turn, flows into the Delaware River. Ground water is the major water supply source for the Atlantic Coastal Plain, a province of southeastwardly thickening unconsolidated and semi-consolidated sediments over crystalline basement rock. A primary aquifer in this province for water supply, stream base flow, and confined aquifer recharge is the unconfined Columbia aquifer. In a southwardly expanding wedge, the western portion of this area flows to the Chesapeake Bay through headwaters of the rivers and creeks of the Delmarva Peninsula's eastern shore. The mideast section of the province flows to the Delaware Estuary, fed by the watersheds of 15 creek and river systems. The southwest portion of the state flows into the Inland Bays of Delaware and Maryland and the Atlantic Ocean. The major land use in Delaware is agriculture (526,070 acres; 41% of the 1.28 million acres in the state), which is dominated by a large, geographically concentrated poultry industry. Other main land uses are urban (19%), wetlands (19%), forests (15%), open water (4%), and barren land (1%). Delaware has 2509 miles of streams and rivers, 2954 acres of lakes/reservoirs/ponds, 841 square miles of estuarine waters, and 25 miles of ocean coastline. Approximately 2/3 of the state's wetlands are freshwater, and 1/3 is tidal. Protection of the quality and quantity of the state's surface waters and aquifers is a major concern to all agencies and individuals responsible for water resource management in Delaware. Ground water protection is particularly important given the increasing reliance on this resource for drinking water. In

general, the key priority water resource issues today are (not prioritized): (1) enhanced management and control of stormwater runoff, erosion and sediment; (2) improved understanding of sources, transport, fate, and remediation of toxic organics and trace elements; (3) comprehensive management of agricultural nutrients; (4) identifying sources of pathogenic organisms and preventing human health impacts; (5) increased understanding of the response of aquatic systems to pollutants; (6) identification and protection of wellheads and aquifer recharge areas; (7) better management of water supply and demand and development of a systematic means to deal with droughts and floods; (8) treatment and disposal of on-site sewage; (9) protection and restoration of wetlands; and (10) prevention of saltwater intrusion to potable water supplies.

The Water Resource Problems of Delaware

Surface Water Quality: Delaware has a number of serious, documented surface water quality problems. Many can be traced back to point source pollution problems in past decades; others reflect ongoing anthropogenic activities that degrade surface water quality. Water quality is a major state environmental priority and improvements have occurred, particularly since the 1970's, due to the use of state and federal regulatory and funding means to address "end-of-pipe" point sources of surface water pollution. Much of this improvement was due to aggressive use of federal funding, available in the late 1970's and early 1980's under the Clean Water Act and combined with local funding, to expand and improve municipal wastewater treatment systems.

The National Pollution Discharge and Elimination System (NPDES) Program in Delaware has reduced the number of "point sources" from over 200 in the 1970's to 59 as of 2000. Major reductions in oxygen demanding materials and toxics in surface waters were achieved. Today, however, large federal investments in the infrastructure needed to reduce point source pollution are more difficult to obtain. This raises the question of whether or not it is reasonable to expect additional major improvements in water quality due to increased control of point source pollution. Reductions in point source pollution of surface waters have drawn attention to the need to control nonpoint pollution. The consensus among state and federal agencies is that Delaware's main water quality challenge today is to manage diffuse sources of pollution from urban, suburban, and rural landscapes. The major surface water quality problems in Delaware include:

Urbanization: A rapidly expanding urban population is increasing pressures on Delaware's surface waters. Rivers and streams are being affected by elevated temperature and low dissolved oxygen levels that can result from degradation of streambanks and stream channels. In residential and urban areas, increases in impervious surface have resulted in greater and flashier stormwater runoff, leading, in turn, to erosion, sedimentation, shallower water levels and destabilization of stream channels. Biological and habitat quality are also being affected by removal of stream buffers and stream bank "hardening" through use of riprap and concrete.

Drainage: Extensive drainage systems have been installed throughout the state, especially in coastal plain areas. Most were constructed in the 1930's and 1940's by the Civilian Conservation Corps and the Works Progress Administration. At that time, building a drainage ditch system involved channelizing and straightening headwaters of existing natural streams, then constructing ditches out and back from the channelized stream. Upland wetlands were often drained to reduce mosquito populations. A state "tax ditch program" is re-constructing ditches and in doing so wetlands are protected or augmented and management practices are used to minimize impacts to habitat. The effects on the biological and habitat

quality of the waterway once it is stabilized are unknown. Another trend today, is the proliferation of public ditch projects instead of tax ditches. Public funding makes the choice by landowners to tax themselves for reconstruction and maintenance of ditches less compelling. Public ditch projects are typically smaller (a few hundred feet) in scope and take place in the upper reaches of streams (typical bottom width is 3 feet) to augment mostly residential and some agricultural drainage. These projects are often carried out by the Conservation Districts. Nothing is known about the impacts to water quality or ecology from such projects. This lack of information may be important since protection of small headwater streams is critical to watershed health. Few streams in Delaware are unaffected by current or historic drainage projects that modify watershed drainage, natural stream channel configuration, buffers, and nutrient transport.

Nutrients are a leading cause of water quality degradation in Delaware. Nutrient effects can be seen especially in lakes, ponds, bays, and estuaries that receive nutrients conveyed by rivers, streams, and ground water. According to the State of Delaware's Feb. 5, 2005 305(b) report, Delaware waters are generally considered to suffer from eutrophication and low dissolved oxygen related to nutrient enrichment. Excessive macroalgae production in Delawares Inland Bays (a national estuary) strongly affects dissolved oxygen levels. In localized areas, large mats of algae accumulate and rot creating "hypoxic and anoxic death zones". Aquatic life such as oyster beds that cannot move can be destroyed by these conditions. Beginning in 2000, plantings for a seagrass re-establishment project were not implemented due to extensive macroalgae growth in the Indian River system. Thirty-four fishkills were investigated in 2000 and 23 in 2001 by the state Division of Fish and Wildlife, some in dead-end lagoons and some in open waters. Many of the incidences are thought to be related to low dissolved oxygen. Though toxic organisms including Pfiesteria have been present in some cases those organisms cannot be directly linked as a cause of any kills. There were 17 fish kills each in 2002 and 2003. Of the fishkills in 2003, 4 were from natural causes, 4 of unknown cause, and 9 were from low dissolved oxygen. Two of those kills were compounded by large phytoplankton blooms.

Primary land-based sources of nutrients in Delaware are agricultural practices, septic systems, and urban runoff. About 41% of Delaware's land area is devoted to agricultural activities and 19% to urbanized uses. Delaware's agricultural industry has a strong broiler industry component that heavily influences the state's overall agricultural nutrient balance and has long created nutrient management problems because of the large amount of manure that must be land applied; commercial inorganic fertilizers used by farmers, other land managers and homeowners also contribute nutrients to ground and surface waters. About 70% of Delaware's cash farm income comes from broilers, with annual production ranging from 260 to 280 million broilers, primarily in Sussex County, the largest broiler producing county in the U.S.

Other problems: Toxics have affected Delaware waters resulting in fish consumption advisories for five lakes/ponds and portions of 12 rivers in 2002. The primary pollutant is polychlorinated biphenyl (PCB). Chlorinated pesticides, dioxins, and mercury have also been identified. Though PCB's have long been banned they are persistent in the environment and are transported from land to waters through runoff to settle in waterbody sediments where they enter the aquatic food chain.

New designated uses and surface water quality standards as amended on July 11, 2004 indicate that pathogenic organisms in surface waters have negatively affected shellfish harvesting and caused 94% of Delaware's rivers and streams to not fully support the swimming use; 65% do not fully support the fish and wildlife use. Most waters do not meet standards because of nonpoint source pollution impacts.

Ground Water Quality: The domestic needs of approximately two-thirds of the state's population are met with ground water provided by both public and private wells. Most of the water used for agriculture, Delaware's largest industry, and self-supplied industrial use, is also derived from ground water sources. A shallow water table and high permeability soils make Delaware's ground water vulnerable to pollution. Shallow unconfined aquifers are especially vulnerable, though deeper confined aquifers are susceptible as well because they subcrop beneath and are recharged by unconfined aquifers.

Major ground water quality problems in Delaware today are:

Nutrients: Nitrates from agriculture and septic systems are, by far, the major contaminant in Delaware's ground water. There are also some concerns about dissolved phosphorus transport to surface waters by shallow ground water flow in parts of the state where shallow water tables are interconnected with surface waters by ditches and/or tiles.

Organics: Hydrocarbons have also been found as have pesticides, though not at levels which cause alarm. A major source of hydrocarbons, such as MBTE, is leaking underground storage tanks (USTs) while agricultural activities are the source of pesticides. There are 12,050 regulated underground storage tanks in the state; 9,651 have been properly abandoned and 2,399 are still in use. Since the 1980s 314,040 releases to ground water have been confirmed and 2,800 of those (USTs) have been closed. Over the period 2002-2003, 142 sites had confirmed releases with 30 confirmed ground water releases.

Salt Water Intrusion: Problems with private wells occur sporadically from seasonal salt water intrusion along the Delaware River and the Inland Bays/Atlantic Ocean coastal areas. No major problems have occurred and only one public well in Lewes required abandonment.

Trace Elements: Though not considered a health threat, iron concentrations are a widespread problem in Delaware for cosmetic reasons. Many public water supplies have treatment systems to remove iron. Thirty-four percent of 561 raw groundwater samples analyzed by Delaware's Office of Drinking Water in 2002 exceeded the secondary contaminant level standard of 0.3 mg/L. Concerns are emerging about arsenic in ground waters because of the long-term application of this element in poultry manure to soils overlying shallow drinking water aquifers, the presence of brownfield soils in urban areas that had been used as tanneries or other industries, and the lowered drinking water standard for arsenic.

Wetlands Quality: A watershed study of nontidal wetlands is currently under way that will provide information regarding overall condition of wetlands and identify major stressors affecting wetland function. For now, the primary evaluation of wetlands lies in determining trends, primarily rate of loss. About 2000 acres of vegetated wetlands were lost statewide between 1981/2 and 1992, predominantly palustrine vegetated wetlands (1890 acres). Of the palustrine vegetated wetlands, the greatest loss was of palustrine forested wetlands (1505 acres). Agricultural activities are considered the primary cause of loss (954 acres) and residential activities had the second greatest impact (436 acres). Estuarine wetlands were destroyed to a much smaller extent (106 acres), mainly due to saltwater impoundments and filling.

Water Supply: Half of Delaware's population is located in the Piedmont (6% of land area) and uses surface water for drinking water. The other 50% of the population relies on ground water and is spread throughout the remaining 94% of the state. With regard to the amount of water used, ground and surface water are of equal importance; with regard to area served, ground water is overwhelmingly dominant. Capacity concerns are important north of the Christina River due to population concentration and the reliance on surface water. For the rest of the state, the reliance on abundant ground water and a diffuse

pattern of development suggest that the supply of potable water is not currently a problem. Recent drought emergencies have brought water supply demand in northern Delaware into conflict with the need to maintain minimum pass-through flows in streams for protection of aquatic resources. Benthic organisms, the foundation of the aquatic food chain, cannot move to avoid dry stream bed conditions. This suggests that not maintaining pass-through flows at all times would be detrimental to stream aquatic life. Required pass-through flows can be high; the need to ensure those flows can result in practices or structures such as reservoirs that are economically inhibitory or may cause as much or greater environmental degradation as occasional dry stream bed periods.

Recent Initiatives Promoting Delaware Water Quality

Water quality standards for Delaware surface waters in Delaware, revised and adopted effective July 11, 2004 by the Delaware Department of Natural Resources and Environmental Control (DNREC), include amendments to protect swimmers by making bacteria standards consistent with U.S. Environmental Protection Agency guidance and 2000 federal Beaches Environmental Assessment and Coastal Health (BEACH) Act requirements.

To ensure that Delaware waters meet state, regional and national water quality requirements and goals, the state has one of the most extensive water quality monitoring networks in the nation. Our water resources in this state are regularly tested for biological and chemical parameters. The results are reported in even years in the state's 305(b) report. Waters that do not meet water quality standards are listed in the state's 303(d) list. Both of these reports are available on the DNREC website at: http://www.dnrec.state.de.us/water2000/Sections/Watershed/TMDL/305and303.htm. The extensive water quality data has allowed tracking of long term progress made towards improving Delaware's water resources.

Delaware's non-attainment of Clean Water Act standards as described in the 303(d) list is addressed by a federal court order requiring the development of total maximum daily load (TMDL) regulations for nearly the entire state, according to a schedule that stretches into 2010. TMDLs establish the maximum amount of pollutants a water body can receive daily without violating water quality standards, allowing the use of these waters for swimming, fishing, and drinking water supplies. TMDLS are being established for PCBs, toxics, nutrients, dissolved oxygen and bacteria. TMDLs were finalized in December 2003 for PCBs in the Delaware Estuary in cooperation with the Delaware River Basin Commission. Information on this effort including monitoring, plan implementation, etc. is found at: http://www.state.nj.us/drbc/toxics_info.htm.

TMDLs for nutrients, dissolved oxygen, and bacteria will be completed in all affected watersheds. Completed TMDLs are found on DNREC's website: http://www.dnrec.state.de.us/water2000/Sections/Watershed/TMDL/tmdlinfo.htm.

Additional programs are in place to ensure continued compliance with the court order and to achieve water quality standards. Once TMDLs are in place, Pollution Control Strategies (PCSs) are developed to address how, where, and when pollutant loads will be reduced to achieve TMDL levels. The first PCS in the state, developed to address the TMDLs in the Inland Bays has been drafted and is anticipated to be final in 2007. Final PCSs for the Nanticoke, Murderkill, and Appoquinimink watersheds are also expected to be finalized in 2007. The PCSs generally offer voluntary and regulatory strategies for urban, suburban and agricultural land uses and are developed through a public process where recommendations are made by Tributary Action Teams (TATs), groups of stakeholders formed with the purpose of addressing water quality concerns.

In the Inland Bays, Nanticoke, Murderkill, and Appoquinimink watersheds, the TAT process and the development of a draft PCS has taken up to seven years. However an expedited process has been developed to shorten the PCS development process to 15-18 months in new watersheds where TATs are formed. Since 2005, new TATs have been formed in the Christina, St. Jones, Broadkill, Chester and Choptank watersheds to work on PCSs to address TMDLs in those watersheds. DNREC anticipates having recommendations from those teams by the end of 2007. Teams are expected to be formed in other impacted watersheds over the next several years. To follow progress of the Tributary Action Teams or get more information about them, please visit:
http://www.dnrec.state.de.us/water2000/Sections/Watershed/ws/.

Other DNREC Water Quality Initiatives Include:

Sediment and Stormwater: Amended Sediment and Stormwater Regulations became effective in April 2005. The revised regulations require the use of green technology stormwater treatment practices to better address water quality concerns associated with site development. These practices may also include the use of conservation design principles in stormwater management plans. More information on sediment and stormwater program is available at:
http://www.dnrec.state.de.us/DNREC2000/Divisions/Soil/Stormwater/StormWater.htm.

Non-point Source (NPS) Pollution: DNREC continues to reduce non-point source pollution through enhanced coordination of the Division of Soil and Water Conservation Cost Share Programs through the USEPA's NPS Management 319 Program and the National Oceanic and Atmospheric Associations (NOAA's) Coastal NPS Management 6217 program along with the Delaware Nutrient Management Commission's (DNMC's) program through the Delaware Department of Agriculture (DDA) and other programs. The effort allows the Department to direct millions of dollars every year toward a comprehensive NPS program to reduce pollutant loads, restore streams and buffers, and install best management practices (BMPs) such as cover crops, nutrient management plans, manure storage structures, manure relocation, and now urban best management practices within impaired watersheds. More information on the NPS 319 program is available at:
http://www.dnrec.state.de.us/dnrec2000/Divisions/Soil/NPS/index.htm; and information on Delaware's Coastal Management Program is available at:
http://www.dnrec.state.de.us/dnrec2000/Divisions/Soil/dcmp/index.htm.

Stream and Wetland Restoration: Rehabilitating stream corridors and wetlands, stabilizing stream banks, decreasing erosion, improving biological water quality and providing buffers along the stream for riparian habitat are examples of the types of projects DNREC has implemented to improve water quality in our watersheds. Several projects completed in the last several years including those at Perkins Run in northern New Castle County, the Three Little Bakers Theater in Pike Creek, and a restoration project at Christ the Teacher Catholic School.

Onsite Wastewater Treatment Systems (Septics): Regulations for the onsite wastewater treatment systems were revised in 2002 and again in April of 2005. Legislation was also passed creating a Class H Licensed Septic Inspector Program. Grant funds have been used during the last few years to implement a septic system pumpout and inspection program and a holding tank inspection and pumpout program in Sussex County. Both programs have been very successful in identifying failing systems and allowing DNREC to provide assistance to system owners in making repairs or replacements as needed. The Department has also been working with the wastewater community to develop new performance standards for onsite

wastewater systems. See:
http://www.dnrec.state.de.us/water2000/Sections/GroundWat/DWRGrndWat.htm.

Source Water Assessment and Protection: The DNREC Source Water Assessment and Protection Program (SWAPP) provide for the assessment and protection of sources of public drinking water, both surface and ground water. The assessment consists of three critical steps, first-delineation of source water areas; second-identification of existing and potential sources of contamination; and finally assessment of the susceptibility of the source water area to contamination. The Site Index Database identifies the location and status of both existing and potential sources of contamination within the State. Most potential point sources have been mapped and rated.

In 2004, the Source Water Protection Program developed a guidance manual for local governments. This document was updated in 2005. For more information on source water protection, please visit the following website: http://www.wr.udel.edu/swaphome/index.html. Delaware SWAPP is a cooperative effort between DNREC, the Delaware Division of Public Health, and the University of Delaware's Water Resources Agency. A citizens advisory group (CTAC) was formed to assist DNREC in the development and implementation of the program and to ensure public involvement. SWAPP is a multi-phase program that is expected to be completed in the next few years.

Cooperative Efforts: Cooperation among DNREC, residents, other agencies-state and federal, universities, county and municipal governments, conservation districts, and non-governmental organizations (NGOs) helps bring Delaware water goals to fruition. Pollution Control Strategy development and implementation of TMDL regulations is driven by Tributary Action Teams (TATs). The Center for the Inland Bays, University of Delaware Cooperative Extension, the Sea Grant Program at the University of Delaware College of Marine and Earth Studies, University of Delaware Water Resources Agency, Delaware State Cooperative Extension, the Camden-Wyoming Rotary Club, the State of Delaware's Nutrient Management Commission, New Castle, Kent and Sussex County governments, Sierra Club, the county conservation districts, USDA, other DNREC divisions and many others have been vital contributors in the development of PCSs and TATs.

All of the projects implemented in TMDL watersheds to address water quality concerns require a cooperative effort and partnerships to be formed, not just in government interactions, but between members of Tributary Action Teams as well. Finding a solution for cleaner water will require more innovative solutions, greater regulatory control, additional financial resources, and a willingness to make a change by everyone affecting Delaware's watersheds, as we are all part of the problem and we must work together to find a reasonable solution for everyone.

Delaware Water Resources Center: An Overview

The Delaware Water Resources Center (DWRC) has been a part of the University of Delaware since 1965. From 1965 until 1993 the DWRC was located in the University of Delaware's Research Office. In 1993, the DWRC was formally moved to the College of Agriculture and Natural Resources (CANR) where, since 1997, Dr. Tom Sims, Associate Dean for Academic Programs and Research, has served as DWRC Director. The DWRC works with all organizations and agencies in Delaware with an interest or responsibility in water resources. We have a 15-member Advisory Panel representing a wide variety of water resource backgrounds. We regularly cooperate with the Delaware Water Resources Agency, Delaware Geological Survey, Delaware Department of Natural Resources and Environmental Control, Center for the Inland Bays, Delaware Nutrient Management Commission, Delaware State University,

USDA Natural Resources Conservation Service, Delaware Nature Society, and The Nature Conservancy, to name but a few. The DWRC has always supported a wide range of water resource related research, education, and information transfer programs. We cooperate with many academic departments and units that conduct water-related research at Delaware State University's Department of Agriculture and Natural Resources and the University of Delaware (UD), including the UD Water Resources Agency in the Institute for Public Administration, the Institute for Soil and Environmental Quality at UD, the UD Departments of Biology; Bioresources Engineering; Chemistry; Civil and Environmental Engineering; Geography; Geology; and Plant and Soil Sciences; as well as the UD Colleges of Agriculture and Natural Resources; Arts and Sciences; Engineering; Human Services, Education and Public Policy; and Marine and Earth Studies. Close communication is maintained between the DWRC and state natural resource agency representatives and water officials to address priority water quality and water quantity concerns in the state. Through efforts such as these, the DWRC has provided key stakeholders a forum for discussion and an opportunity for education regarding water resources.

Section 104 Objectives

The DWRC has defined a two-fold mission to meet the goals of the Water Resources Research Act:

(1) To support research, education, and public outreach programs on water supply, water quality, and water management, issues of major importance to Delaware citizens; and

(2) To support training and education programs for future water scientists, engineers, managers, and policymakers who will lead water resources research, planning, and management efforts in the future.

To meet these goals we have focused our efforts during 2006 into three major areas:

(1) Graduate Fellowship Program: A competitive graduate fellowship program supports graduate fellows on a 3-year cycle. The two Ph.D. graduate fellows supported during the period of this report are both in the University of Delaware College of Agriculture & Natural Resources. They are researching water quality topics of virus deactivation/removal and arsenic transport/fate;

(2) Undergraduate Internship Program: We initiated a highly successful undergraduate internship program in 2000. In the first six years, 69 undergraduate internships were made possible via funding from DWRC/USGS, four Colleges within the University of Delaware, and the Department of Agriculture and Natural Resources at Delaware State University. DWRC interns work with faculty to conduct research, prepare a written project report, and present their findings at an annual poster conference;

(3) Information Transfer: The DWRC website and newsletters (print and electronic) are sources of up-to-date information on DWRC activities and water-related issues of importance to Delaware and the region. Our website provides information on water resources problems, links to water-related organizations, internship and job opportunities in the water resources, a calendar of upcoming events, and a Kid's Zone for teachers and parents. We also co-sponsor state-wide conferences on water resource topics of current interest.

Delaware Water Resources Center Program Goals and Priorities

1. Institute Director: Dr. J. Thomas Sims T.A. Baker Professor of Soil and Environmental Chemistry Associate Dean for Academic Programs and Research Director, Institute of Soil and Environmental Quality and Delaware Water Resources Center College of Agriculture and Natural Resources 113 Townsend Hall University of Delaware Newark, DE 19716-2103 Phone: 302-831-2698 FAX: 302-831-6758 email: jtsims@udel.edu

2. Administrative Personnel: Maria Pautler Program Coordinator Phone: 302-831-0847 FAX: 302-831-0605 e-mail: mpautler@udel.edu

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 research 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 FY06 DWRC public water conservation educational youth program addressed all these issues. DWRC's research program during the same period addressed these concerns by supporting graduate fellowships in water quality, an undergraduate student internship program, and public information forums including an intern research poster session and two statewide water resources conferences.

2006-2007 DWRC Fellowship and Internship Research Program

Two fellowships have been awarded for a final year in 2006-2007 based on a review of proposals submitted by potential graduate fellows and their advisors to the DWRC Advisory Panel:

a) Removal and Inactivation of Water-borne Viruses Using Permeable Iron Barriers

Graduate Fellow: Liping Zhang; Advisors: Yan Jin, Department of Plant and Soil Sciences, College of Agriculture and Natural Resources, University of Delaware; and Pei Chiu, Department of Civil and Environmental Engineering, College of Engineering, University of Delaware.

b) Fate and Transport of Arsenic in Poultry Litter Amended Delaware Soils: Impacts on Water Quality

Graduate Fellow: Jennifer Seiter; Advisor: Donald Sparks, Department of Plant and Soil Sciences, College of Agriculture and Natural Resources, University of Delaware.

Nine internships have been awarded for 2006-2007 based on a review of proposals submitted by potential undergraduate interns and their advisors to the DWRC Advisory Panel:

a) The Effect of Proposed Climatic Warming on the Hydrological Cycle

Undergraduate Intern: Jennifer Boutin; Advisor: David Legates, Department of Geography, College of Arts and Sciences, University of Delaware.

b) Enhanced Pollutant Biodegradation by Electrode Use

Undergraduate Intern: Belinda Gao Advisor: Steven Dentel, Department of Civil and Environmental Engineering, College of Engineering, University of Delaware.

c) Predators of Galerucella Beetles, Biocontrol Agents of Purple Loosestrife

Undergraduate Intern: Jason Graham; Advisor: Judith Hough-Goldstein, Department of Entomology and Wildlife Ecology, College of Agriculture and Natural Resources, University of Delaware

d) Measuring Groundwater Discharge to the Inland Bays

Undergraduate Intern: Garrett Peters; Advisor: William Ullman, College of Marine and Earth Studies, University of Delaware.

e) Detection of Salmonella in Biosolids using PCR

Undergraduate Intern: Samantha Smith; Advisor: Diane Herson, Department of Biological Sciences, College of Arts and Sciences, University of Delaware.

f) Assessment of Macro-infauna Associated with Oyster (Crassostrea Virginica) Aquaculture in the Indian River Bay

Undergraduate Intern: Le'Sasha Stewart; Advisor: Gulnihal Ozbay, Department of Agriculture and Natural Resources, Delaware State University

g) Sustainable Mosquito Control for Stormwater Ponds

Undergraduate Intern: Sarah Sturtz; Advisor: Jack Gingrich, Department of Entomology and Wildlife Ecology, College of Agriculture and Natural Resources, University of Delaware.

h) The Effects of Dietary Level and Source of Copper on Broiler Copper Excretion and Movement of Copper through Broiler Excreta-Amended Soils

Undergraduate Intern: Jarvon Tobias; Advisor: Bill Saylor, Department of Animal and Food Sciences, College of Agriculture and Natural Resources, University of Delaware.

i) Hydraulic Properties of the Unconfined Aquifer in Southern New Castle County

Undergraduate Intern: Elizabeth Wolff; Advisor: Scott Andres, Delaware Geological Survey.

Research Program

REMOVAL AND INACTIVATION OF WATER-BORNE VIRUSES USING PERMEABLE IRON BARRIERS

Basic Information

Title:	REMOVAL AND INACTIVATION OF WATER-BORNE VIRUSES USING PERMEABLE IRON BARRIERS
Project Number:	2003DE30B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Water Quality, Toxic Substances, Geochemical Processes
Descriptors:	None
Principal Investigators:	Yan Jin, Liping Zhang

Publication

INTRODUCTION AND OBJECTIVES

Microbial pathogens (bacteria, protozoa, and viruses) in drinking waters represent a serious public health problem. Sources of enteric pathogens in source water include septic tanks, landfills, sewage sludge application on land, and wastewater discharge and reuse (Yates, et al., 1985), as well as runoff and infiltration from animal waste-amended fields (McMurry et al., 1998). Among the different microbial pathogens, viruses are particularly problematic because they are highly mobile in soil and groundwater and difficult to remove by filtration due to their small size. Viruses were reported to be responsible for approximately 80% of disease outbreaks for which infectious agents were identifiable (Ryan et al., 2002). The U.S. EPA has promulgated Long Term 1 Enhanced Surface Water Treatment Rule (SWTR) and put forward Long Term 2 Enhanced SWTR (U.S. EPA, 2003) to set treatment requirements to reduce microbial contamination.

Chlorination is the most common process for water and wastewater disinfection. However, chlorine was shown to be less effective against viruses than bacteria (Payment and Armon, 1989, Bull et al., 1990). A recent study (You et al., 2005) demonstrated that in a flow-through column containing Fe(0), two bacteriophages, MS2 and φX174, were removed from artificial groundwater with an efficiency of 4-log (99.99%) in an initial pulse test, and more than 5-log (>99.999%) in the second pulse test after passage of 320 pore volumes of artificial groundwater. These authors suggested that the viruses might be removed by iron corrosion products, and that the improved efficiency over time might be due to continued formation of surface iron oxides through corrosion.

In a previous (FY2004) annual progress report to DWRC, we showed results of MS2 and φX174 removal by elemental iron after different treatments (as-received, acid-treated, and after anaerobic corrosion). The main findings were that iron as-received effectively removed MS2 and φX174 under the experimental conditions, and the removal was mostly due to inactivation rather than adsorption. φX174 was inactivated by both acid-treated iron and its corrosion products whereas MS2 was inactivated primarily by iron corrosion products.

X-ray diffraction (XRD) characterization of corroded iron demonstrated that magnetite (Fe_3O_4) was the major oxidation product of anaerobic iron corrosion. We also measured aqueous Fe(II) in batch experiments with 1 g of acid-treated iron and observed increasing Fe(II) concentration over time. We decided to examine the effects of the two corrosion products individually on the removal of the two viruses.

The main objective of our study in 2005 was to evaluate the roles of Fe(0) itself and its anaerobic corrosion products, aqueous Fe(II) and magnetite (Fe3O4), on the removal of φX174 and MS2 from water.

In the year of 2006, we investigated the effect of natural organic matter (NOM) on virus removal by elemental iron. NOM was shown to adsorb to iron oxides. NOM present in drinking water may react with chemical disinfectants to produce toxic disinfection by-products. We wanted to assay whether NOM at environment-relevant concentrations would affect virus removal by iron and also wanted to investigate the capability of elemental iron to remove viruses and NOM simultaneously.

RESULTS TO DATE (FY04-FY06)

In summary, our experiments show that Fe(0) itself had little effect on either of the MS2 or φX174 bacteriophage. Aqueous Fe(II) inactivated φX174 to a large extent but had little influence on MS2. Fe_3O_4 adsorbed and inactivated both viruses, although φX174 appeared to be more susceptible to inactivation by Fe_3O_4 than MS2. The results suggest that it was the corrosion products, rather than Fe(0) itself, that were responsible for the observed virus removal and inactivation in Fe(0) systems. NOM at high concentrations may reduce virus removal through competitive adsorption on surfaces of iron corrosion products. Meanwhile, removal of NOM was observed.

Table 1 summarizes the main results on removal of viruses by several iron species.

Table 1

Iron Sample	MS2		φX174	
	Removal	BEX recovery	Removal	BEX recovery
1g Fe(0) as-received	93.2% in 4 hr	16.8%	99.5% in 4 hr	0.5%
1g Fe(0) treated with 0.5 M HCl	53.0% in 3 hr	80%	98.7% in 3 hr	1.9%
1g Fe(0) treated with 1 M HCl	No removal	N/A	90.8% in 3 hr	1.0%
1g Acid treated Fe(0) + 3mM citrate	N/A	N/A	No removal	N/A
0.5 mM Fe(II)	No removal	N/A	95.7 % in 12 min	N/A
Fe(II) at four conc.: 0.01, 0.03, 0.1, 0.3mM. Reaction time: 10 min	N/A	N/A	52.4% at 0.01mM 83.6% at 0.03mM 85.8% at 0.1 mM 91.7% at 0.3 mM	N/A
1g Corroded iron	99.4% in 3 hr	53.9%	99.9% in 3 hr	2.5%
1 g Fe_3O_4	99.6% in 3 hr	84.8%	99.9% in 3 hr	22.9%

An oral talk and a poster presentation by L. Zhang, P.C. Chiu, and Y. Jin were given in the spring of 2007 at the Pennsylvania Water Environment Association (PWEA) 79th Annual Technical Conference & Exhibition in State College, PA. The title of each was "Removal and Inactivation of Waterborne Viruses Using Elemental Iron."

Fate and Transport of Arsenic in Poultry Litter Amended Delaware Soils: Impacts on Water Quality

Basic Information

Title:	Fate and Transport of Arsenic in Poultry Litter Amended Delaware Soils: Impacts on Water Quality
Project Number:	2003DE32B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Water Quality, Geochemical Processes, Toxic Substances
Descriptors:	None
Principal Investigators:	Donald L. Sparks, Jen Seiter

Publication

INTRODUCTION AND OBJECTIVES

The fate, cycling, and transport of arsenic (As) in Delaware's agricultural and urban/suburban soils are areas of intense interest and environmental concern today. Past, and ongoing, anthropogenic activities have added As to Delaware soils, creating questions about the potential for As to contaminate ground and surface waters. There are also concerns about As bioavailability and carcinogenicity when humans come into contact with or ingest soils that are contaminated with As. The overall goal of this study was to improve our ability to assess the risk of As to human and ecological health by increasing our understanding of the amounts, forms, solubility, and bioavailability of As in Delaware soils. Our research primarily focused on agricultural cropland, especially situations where broiler litter, well-known to be a long-term source of As to Delaware soils, had been used as a fertilizer for crop production.

RESULTS TO DATE (FY05-FY06)

Detailed laboratory studies of As sorption and desorption showed that Delaware's agricultural soils have good capacities to retain dissolved As that is released from litters, manures, fertilizers and other soil amendments. Subsoils had greater capacities to retain As than topsoils, primarily due to higher concentrations of aluminum and iron oxides, soil constituents known to sorb and tightly retain As. Arsenic sorption was greatest at the soil pH values recommended for crop production (pH 5.5 to 7.0). Kinetic studies showed that As sorption by soils occurred very rapidly (<< 60 minutes), followed by a slower, long-term phase that continued to remove As from solution for hours.

Phosphate, present at high concentrations in many Delaware soils from long-term applications of manures and fertilizers, was preferentially sorbed by soils, relative to As, and thus has the potential to inhibit As sorption through competition for similar sorption sites on soil constituents. Desorption studies showed that solutions with high phosphate concentrations could displace previously sorbed As from soils, particularly subsoils.

X-ray absorption near edge structure (XANES) and x-ray fluorescence (XRF) spectroscopy were used to provide direct *in-situ* speciation of As and its distribution and association with other elements, respectively, in broiler litters. These analyses showed that the organo-arsenical Roxarsone found in litters is rapidly converted to arsenate (As (V)) during litter storage. A significant portion (~50%) of the total As in litters was found to be water-soluble. Our results suggest that if litters are thoroughly incorporated with soils, soluble litter As will be sorbed quickly and will not be susceptible to significant losses by leaching or surface runoff. However, if bypass flow pathways (cracks, old root channels, macropores) predominate in soils with shallow water tables, soluble As in litters has the potential to leach through soil profiles to the water table. Similarly, if litters are applied to the soil surface, runoff may dissolve and transport As to nearby surface waters.

Hydraulic Properties of the Unconfined Aquifer in Southern New Castle County

Basic Information

Title:	Hydraulic Properties of the Unconfined Aquifer in Southern New Castle County
Project Number:	2006DE70B
Start Date:	6/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	At large
Research Category:	Climate and Hydrologic Processes
Focus Category:	Groundwater, Geomorphological Processes, None
Descriptors:	None
Principal Investigators:	Alan Scott Andres

Publication

1. Wolff, E., and A.S. Andres, 2007, Hydraulic Properties of the Unconfined Aquifer in Southern New Castle County, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 17 pages.
2. Boyd, A., ed., 2006, Delaware Water Resources Center WATER NEWS Vol. 6 Issue 2 Nine DWRC Internship Winners for 2006 2007, http://ag.udel.edu/dwrc/newsletters/Summer06.pdf, p. 6-7.

Undergraduate Internship Project #1 of 9 for FY06

Southern New Castle County is a water source for domestic, irrigation, and public well use, the source of all base flow in local streams, and a conduit to all ground water in deeper confined aquifers. Measuring the saturated hydraulic conductivity of this important aquifer was the goal of ***Elizabeth Wolff's*** project *"Hydraulic Properties of the Unconfined Aquifer in Southern New Castle County."* Her research will allow future quantitative analysis of water availability, sustainable pumping rates, and contaminant transport. Elizabeth was advised by Mr. Scott Andres of the ***Delaware Geological Survey (DGS)*** for her ***DWRC / DGS*** co-sponsored internship.

"My experience this past summer was quite enriching. I learned a great deal about the process of data collection, interpretation, and analysis. This project was enjoyable, and I would recommend it to future undergraduate researchers." - Elizabeth Wolff

Abstract

In many hydrologic studies, hydraulic testing is required to determine rates of recharge, groundwater flow, and contaminant transport. These rates are related to the hydraulic conductivity (K) and porosity (n) of earth materials. In this study, K is ascertained through lithological records and compared to single-well aquifer tests. Using procedures outlined by previous studies, over 50 single-well aquifer, or slug, tests were administered in monitoring wells located at three spray irrigation facilities in the southern portion of New Castle County. The methods described by Bouwer (1989) were used to analyze the data. Statistical procedures (f test) of results found no significant differences in variance between the sites indicating that all K came from the same population. The values found for K ranged from a minimum of 0.14 ft/s to a maximum of 580 ft/s with an overall average of 182 ft/s. Lithological descriptions were inadequate for interpreting the findings.

Enhanced Pollutant Biodegradation by Electrode Use

Basic Information

Title:	Enhanced Pollutant Biodegradation by Electrode Use
Project Number:	2006DE71B
Start Date:	6/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	At-Large
Research Category:	Water Quality
Focus Category:	Geochemical Processes, Sediments, None
Descriptors:	None
Principal Investigators:	Steven K Dentel

Publication

1. Gao, B., and S. Dentel, 2007, Enhanced Pollutant Biodegradation by Electrode Use, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 8 pages.
2. Boyd, A., ed., 2006, Delaware Water Resources Center WATER NEWS Vol. 6 Issue 2 Nine DWRC Internship Winners for 2006 2007, http://ag.udel.edu/dwrc/newsletters/Summer2006.pdf, p. 6-7.

Undergraduate Internship Project #2 of 9 for FY06

For her *DWRC / University of Delaware (UD) College of Engineering* co-sponsored project, ***Belinda Gao*** studied the practicality of using electrodes for water pollution treatment in situations where a lack of oxygen would otherwise inhibit microbial oxidation of organic material. The project, titled "*Enhanced Pollutant Biodegradation by Electrode Use," wa*s advised by Dr. Steven Dentel of ***UD's*** Department of Civil and Environmental Engineering.

Abstract

For this experiment, the electricity generation of an electrode fuel cell was monitored by the installation of graphite electrodes in biodegradable environments; the two settings examined involved sediment underlying natural ground waters and anaerobic sludge obtained from a wastewater treatment plant. An aerobic and anaerobic zone was set up in the top and bottom, respectively, of hexagonal fish tanks. The purpose of this experiment was to see if improvements could be made on previous experiments by varying certain factors, such as temperature, to increase the rate of biodegradation (as measured by the electrical current produced between aerobic and anaerobic zones). While it was apparent that the electrodes did indeed affect the biodegradation rate since a notable current could be measured from the tanks, no discernible pattern could be observed from the data collected.

Sustainable Mosquito Control for Stormwater Ponds

Basic Information

Title:	Sustainable Mosquito Control for Stormwater Ponds
Project Number:	2006DE72B
Start Date:	6/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	At large
Research Category:	Biological Sciences
Focus Category:	Surface Water, Wetlands, Ecology
Descriptors:	None
Principal Investigators:	John Gingrich

Publication

1. Sturtz, S., and J. Gingrich, 2007, Sustainable Mosquito Control for Stormwater Ponds, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 6 pages.
2. Boyd, A., ed., 2006, Delaware Water Resources Center WATER NEWS Vol. 6 Issue 2 Nine DWRC Internship Winners for 2006 2007, http://ag.udel.edu/dwrc/newsletters/Summer2006.pdf, p. 6-7.

Undergraduate Internship Project #3 of 9 for FY06

"Sustainable Mosquito Control for Stormwater Ponds" was the title of ***Sarah Sturtz's*** internship, cosponsored by the ***DWRC / College of Agriculture and Natural Resources*** under the advisement of Dr. John Gingrich of the ***University of Delaware*** Department of Entomology and Wildlife Ecology. Sarah built on previous research by two previous ***DWRC*** interns studying conditions promoting the breeding of West Nile virus vector mosquitoes in retention ponds. She investigated the success and cost-effectiveness of applications to retention ponds of aluminum sulfate with the goal of reducing mosquito-feeding nutrients with minimum effects on non-target organisms.

Abstract

Nuisance species and West Nile vectors (WNV) thrive and prosper in retention ponds. This study investigated the effectiveness of aluminum sulfate (alum) treatments on 26 retention ponds throughout Delaware from June to August 2006. We analyzed mosquito abundance, bacteria levels, water quality, types of vegetation, degree of vegetation coverage, and predator levels in each pond. After analysis, we found that *Anopheles punctipennis, Anopheles quadrimaculatus, Anopheles walkeri,* and *Culex erraticus* increased in the ponds treated with alum. *Culex pipiens, Culex restuans, Culex territans,* and *Uranotaenia sapphirina* had noticeably less larvae in alum ponds than in the control ponds. The ponds treated with alum also contained lower phosphorus and bacteria levels than the control ponds. The species of mosquitoes that increased in the treatment ponds are surfaces feeders, and the species of mosquitoes that decreased due to treatment are column feeders. Among the column feeders are *Culex pipiens* and *Culex restuans,* two of the most important species of WNV. The alum likely influenced the effects on these mosquitoes by limiting the food sources of these column feeders. The alum accomplished this by reducing the mean phosphorus and bacteria levels in the retention ponds.

Detection of Salmonella in Biosolids using PCR

Basic Information

Title:	Detection of Salmonella in Biosolids using PCR
Project Number:	2006DE73B
Start Date:	6/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	At Large
Research Category:	Biological Sciences
Focus Category:	Wastewater, Treatment, None
Descriptors:	None
Principal Investigators:	Diane Herson

Publication

1. Smith, S., and D. Herson, 2007, Detection of Salmonella in Biosolids Using PCR, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 12 pages.
2. Boyd, A., ed., 2006, Delaware Water Resources Center WATER NEWS Vol. 6 Issue 2 Nine DWRC Internship Winners for 2006 2007, http://ag.udel.edu/dwrc/newsletters/Summer2006.pdf, p. 6-7.

Undergraduate Internship Project #4 of 9 for FY06

Samantha Smith built on her *DWRC* internship research of last year, in which she compared the effectiveness of a combination of techniques versus a new method proposed by the EPA to detect and count *Salmonella* in treated biosolids. Her FY06 internship project, titled *"Detection of Salmonella in Biosolids Using PCR"*, was advised by Diane Herson, *University of Delaware (UD)* Department of Biological Sciences, and was co-sponsored by the *DWRC* and *UD Institute of Soil and Environmental Quality (ISEQ).* Samantha worked to develop a short-term, effective procedure using PCR (polymerase chain reactions) that decreased the length of time and cost of detection of these pathogens.

Abstract

Biosolids are produced as byproducts of waste water treatment. *Salmonella* spp. are major pathogens of concern in this material. Recently, the EPA proposed a new procedure for the detection of *Salmonella* in biosolids. In the newly proposed Method 1682, after an initial enrichment in a Trypticase Soy Broth (TSB) 15 tube Most Probable Number (MPN) assay, selection of *Salmonella* spp. occurs on modified semi-solid Rappaport Vassiliadis (MSRV). This medium contains an antibiotic (novobiocin) and a dye (malachite green) to inhibit non-*Salmonella* species. Method 1682 requires several days due to the multiple cultural steps involved. The standard polymerase chain reaction (PCR) assay is a molecular assay that can be used for the detection of *Salmonella* spp. This method takes less time, but DNA from dead as well as live organisms is amplified, and false positive results may be obtained. Other concerns are that DNA amplification may be inhibited by the presence of coliforms or by inhibitors present in biosolids. Our studies first tested biosolids samples using the cultural EPA method 1682 and compared them to the PCR assays run on the same samples. The results indicated that we could not use the TSB MPN samples in PCR assays because of inhibitory substances present in biosolids. Inhibition was again observed when cells isolated from MSRV plates were used as a source of DNA in the PCR assay. We determined that this inhibition was due to the MSRV media components. We then tested several different ways of separating cells or DNA from the inhibitors present in MSRV. It was found that heating the sample taken from MSRV in a hot water bath for 1-2 minutes to melt the agar, followed by centrifugation and removal of the supernatant prior to the addition of Instagene, gave results in the PCR assay consistent with those obtained from the cultural method.

Predators of Galerucella Beetles, Biocontrol Agents of Purple Loosestrife

Basic Information

Title:	Predators of Galerucella Beetles, Biocontrol Agents of Purple Loosestrife
Project Number:	2006DE74B
Start Date:	6/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	At Large
Research Category:	Biological Sciences
Focus Category:	Invasive Species, Ecology, None
Descriptors:	None
Principal Investigators:	Judith Hough-Goldstein

Publication

1. Graham, J., and J. Hough-Goldstein, 2007, Predators of the Galerucella Beetle: Biocontrol Agent of Purple Loosestrife, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 37 pages.
2. Boyd, A., ed., 2006, Delaware Water Resources Center WATER NEWS Vol. 6 Issue 2 Nine DWRC Internship Winners for 2006 2007, http://ag.udel.edu/dwrc/newsletters/Summer2006.pdf, p. 6-7.

Undergraduate Internship Project #5 of 9 for FY06

A *DWRC / University of Delaware (UD) College of Agriculture and Natural Resources* co-sponsored internship advised by Dr. Judith Hough-Goldstein of the *UD* Department of Entomology and Wildlife Ecology dealt with purple loosestrife, an invasive plant clogging Delaware freshwater ponds. Intern *Jason Graham* studied the effectiveness of beetles released to control targeted loosestrife stands at Ashland Nature Center and Flat Pond near the C & D canal. He investigated to what extent potential predators such as praying mantids, ladybird beetles, arachnids, and assassin bugs are feeding on the biocontrol beetles as a possible explanation for their failure to establish a colony in the Ashland location. His project was titled "*Predators of* Galerucella *Beetles, Biocontrol Agents of Purple Loosestrife."*

Abstract

During the summer of 2004, two species of *Galerucella* beetle were released in two distinct ecosystems to control stands of the invasive plant, purple loosestrife. The two species *G. pusilla* and *G. calmariensis* are indistinguishable by the unaided eye and were reared and shipped together from the Phillip Alampi Beneficial Insect Laboratory, New Jersey Department of Agriculture. The ecosystems were different in that Flat Pond, bordering the C&D canal, is a near monoculture of purple loosestrife while the stand of loosestrife at Burrow's Run, Ashland Nature Center is mixed in with a diverse selection of plants.

The *Galerucella* beetles were successful in establishing at Flat Pond within the first year. While successful at establishing in undetectable numbers at Burrow's Run, during the first two years they were thought to have failed. A small population of *Galerucella* was discovered in the third year after release at Burrow's Run.

My hypothesis is that the *Galerucella* beetles establishment at Burrow's Run was subject to interference by arthropod predators. This hypothesis was explored by: conducting arthropod sample sweeps at both sites on a weekly basis throughout the summer, conducting predation experiments in the laboratory and monitoring both sites in 2006.

The results of the arthropod sample sweeps gave an overview of the predator biodiversity within the two habitats. The predators found in higher numbers at Burrow's Run include Heteroptera, Coleoptera and Mantodea. In predation experiments the lady beetle (Coleoptera, Coccinellidae, *Harmonia axyridis* Pallas) was found to prey upon *Galerucella* eggs. In another predation experiment the wheel bug (Hemiptera; Reduviidae; *Arilus cristatus* L.) nymph was found to prey upon *Galerucella* in adult, egg and larval stages. The results of the monitoring sessions of 2006 show that *Galerucella* adults, eggs and larvae were found at Burrow's Run. There were fewer larvae and eggs in comparison to Flat Pond, but higher numbers of adults.

These results support the hypothesis that biotic interference from predators may have interrupted the establishment of *Galerucella* at Burrow's Run in comparison to Flat Pond. This report provides a better understanding of the use of *Galerucella* as biocontrol agents and the predators which they have overcome in two habitats of Delaware.

The Effects of Dietary Level and Source of Copper on Broiler Copper Excretion and Movement of Copper Through Broiler Excreta-Amended Soils

Basic Information

Title:	The Effects of Dietary Level and Source of Copper on Broiler Copper Excretion and Movement of Copper Through Broiler Excreta-Amended Soils
Project Number:	2006DE75B
Start Date:	6/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	At Large
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Toxic Substances, Groundwater
Descriptors:	None
Principal Investigators:	William Saylor

Publication

1. Tobias, J., and W. Saylor, 2007, The Effects of Dietary Level and Source of Copper on Chemically-defined Fractions of Copper in Broiler Excreta, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 6 pages.
2. Boyd, A., ed., 2006, Delaware Water Resources Center WATER NEWS Vol. 6 Issue 2 Nine DWRC Internship Winners for 2006 2007, http://ag.udel.edu/dwrc/newsletters/Summer2006.pdf, p. 6-7.

Undergraduate Internship Project #6 of 9 for FY06

Jarvon Tobias researched *"The Effects of Dietary Level and Source of Copper on Broiler Copper Excretion and Movement of Copper through Broiler Excreta-Amended Soils"* for her *DWRC / Institute of Soil and Environmental Quality (ISEQ)* co-sponsored project. The advisor for this internship, which is a continuation of work done by another *DWRC* intern last year, was Dr. William Saylor of *University of Delaware's (UD)* Department of Animal and Food Sciences. From her research on the effects of copper in poultry feed on the fate of copper in manures applied to cropland, Jarvon improved our understanding of how diets can be formulated to optimize poultry health while protecting water quality.

Abstract

An experiment was conducted to determine the effect of dietary Cu level and source on broiler Cu excretion in 192 day-old straight run male broiler chickens from 1-21d. Diet treatments were 1) Control- basal diet without any additional supplemental Cu; 2) Inorganic Cu at 25 mg/kg Diet- composed of basal diet plus 25 mg/kg Cu from Cu_2SO_4; 3) Organic Cu at 25 mg/kg Diet— composed of basal diet plus 25 mg/kg Cu from Cu-proteinate[1]; 4) Inorganic Cu at 100 mg/kg Diet— composed of basal diet plus 100 mg/kg Cu from Cu_2SO_4; 5) Organic Cu at 100 mg/kg Diet—composed of basal diet plus 100 mg/kg Cu from Cu-proteinate[a]; 6) Inorganic Cu at 250 mg/kg Diet- composed of basal diet plus 250 mg/kg Cu from Cu_2SO_4; 7) Organic Cu at 250 mg/kg Diet—composed of basal diet plus 250 mg/kg Cu from Cu-proteinate[a]. Diets one, two and three were randomly assigned to 8 replicate pens and four through seven to 6 replicate pens. The broiler chicks were randomly assigned to one of the 48 pens in Petersmine Battery Brooders (4 birds per pen.) On day 7, the pens were equalized to 4 birds per pen and reared on a 23-hour light: 1-hour dark lighting cycle. The excreta collected from a random sample of diets 2, 4, 6, and 7, were subjected to a fractionation procedure in order to determine the passage of different types and concentrations of Cu to the excreta. It was determined that as the Cu concentration in the excreta increased, the amount recovered in the excreta increased as well. Organic form of Cu was found to be more prevalent in the samples of the same Cu concentration. Most Cu lost in the fractionation procedure was at the Oxide and Sulfur Bound fractionation.

1 Bioplex™ Minerals; Alltech, Inc., Nicholasville, KY 40356

The Effect of Proposed Climatic Warming on the Hydrological Cycle

Basic Information

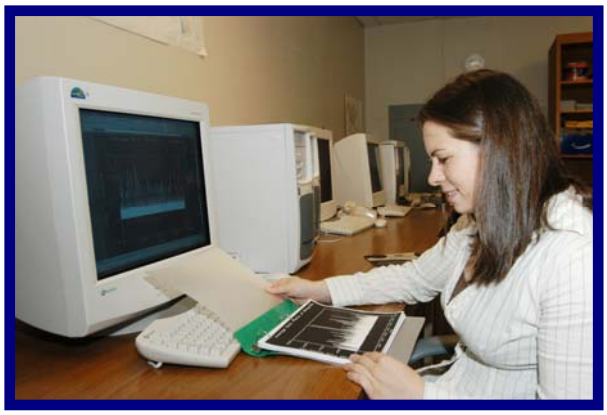
Title:	The Effect of Proposed Climatic Warming on the Hydrological Cycle
Project Number:	2006DE76B
Start Date:	6/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	At Large
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Hydrology, None
Descriptors:	None
Principal Investigators:	David Legates

Publication

1. Boutin, J., and D. Legates, 2007, The Effect of Proposed Climatic Warming on the Hydrological Cycle, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 13 pages.
2. Boyd, A., ed., 2006, Delaware Water Resources Center WATER NEWS Vol. 6 Issue 2 Nine DWRC Internship Winners for 2006 2007, http://ag.udel.edu/dwrc/newsletters/Summer2006.pdf, p. 6-7.

Undergraduate Internship Project #7 of 9 for FY06

Jennifer Boutin investigated *"The Effect of Proposed Climatic Warming on the Hydrological Cycle"* in a project co-sponsored by the *DWRC* and the *University of Delaware (UD) College of Arts and Science.* Her advisor was Dr. David Legates of the *UD* Department of Geography. Jennifer learned about contradictory studies of rate of change of the hydrological cycle. She compared regional flood, drought, and storm frequency and intensity data from the Delaware State Climate Office and Delaware Geological Survey to related global data.



Abstract

Air temperature and precipitation are climatic controls that strongly influence the type of ecosystem a region can support. Changes in air temperature have the potential to increase atmospheric moisture content, which could ultimately produce an enhanced hydrologic cycle with more storms and more droughts. These changes, if they occur, would have drastic implications for regional ecosystems, forcing them to adapt the new conditions or be replaced to other ecosystems more suited for survival. This study offers an assessment of climate change throughout the state of Delaware derived from climatic records taken from as early as 1893 through 2006 at thirteen locations. Short-term changes in air temperature, precipitation, snowfall, and snow depth were discovered at some locations but no change is outside the range of natural climate variability. Differences in the timing and length of such short-term changes lead to the conclusion that there is no evidence of long-term climate change within the State. Lastly no correlation is apparent between air temperature fluctuations and the various components of the hydrologic cycle.

Measuring Groundwater Discharge to the Inland Bays

Basic Information

Title:	Measuring Groundwater Discharge to the Inland Bays
Project Number:	2006DE77B
Start Date:	6/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	At Large
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Hydrology, Non Point Pollution
Descriptors:	None
Principal Investigators:	William J. Ullman

Publication

1. Peters, G., and W. Ullman, 2007, Measuring Groundwater Discharge to the Inland Bays, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 15 pages.
2. Boyd, A., ed., 2006, Delaware Water Resources Center WATER NEWS Vol. 6 Issue 2 Nine DWRC Internship Winners for 2006 2007, http://ag.udel.edu/dwrc/newsletters/Summer2006.pdf, p. 6-7.

Undergraduate Internship Project #8 of 9 for FY06

Intern ***Garrett Peters*** worked with advisors Dr. William Ullman and Dr. Douglas Miller of the ***University of Delaware (UD) College of Marine and Earth Studies (CMES)*** on his ***DWRC / CMES*** co-sponsored internship project, *"Measuring Groundwater Discharge to the Inland Bays."* Garrett investigated the patterns and rates of groundwater seepage and any related ecological and environmental impacts to the coastal zone. He used new methods, such as water temperature, as an indicator of the rate of groundwater flow as well as more traditional methods that use salinity as an indicator of flow. The region of study included the northern edge of the Indian River, locations in the Inland Bays, and marshy areas.

"*I found the internship extremely valuable because I was able to see first hand how research is conducted and it allowed me to develop skills necessary for my future - both as a student and an engineer****." - Garrett Peters***

Abstract

The focus of this research was to study the patterns of flow in an intertidal groundwater seepage zone, where discharges may impact the rates of nutrient loading. A range of complementary methods were compared and used together to interpret flow patterns, tidal control of discharge rates, and to determine directly discharge rates. The methods used were horizontal hydraulic head and gradient measurements which are proportional in any setting to horizontal flow, seepage meters that collect discharging waters over a set area of collection, and subsurface temperature logging, which monitors flow directions based on the temperature difference between fresh groundwater and surface seawater. Our results showed that the hydraulic head and temperature logging methods were consistent with each other, both showing maximum horizontal flow at low tide, while the seepage meters showed a maximum vertical flow at high tide. These observations suggest that saline tidal waters act to focus groundwater discharge to a narrowing intertidal zone during rising tide, although the total discharge over the whole intertidal zone may in fact decrease during this period. The results of this work suggest that multiple survey techniques are needed to properly quantify groundwater discharge to intertidal zones and to properly identify the processes controlling discharge at such sites.

Assessment of Macro-infauna Associated with Oyster (Crassostrea Virginica) Aquaculture in the Indian River Bay

Basic Information

Title:	Assessment of Macro-infauna Associated with Oyster (Crassostrea Virginica) Aquaculture in the Indian River Bay
Project Number:	2006DE78B
Start Date:	6/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	At Large
Research Category:	Biological Sciences
Focus Category:	Ecology, Water Quality, None
Descriptors:	None
Principal Investigators:	Gulnihal Ozbay

Publication

1. Stewart, L., and G. Ozbay, 2007, An Assessment of Macro-infauna Associated with Oyster (Crassostrea Virginica) Aquaculture Indian River Bay, Delaware, Delaware Water Resources Center, University of Delaware, Newark, Delaware, poster.
2. Boyd, A., ed., 2006, Delaware Water Resources Center WATER NEWS Vol. 6 Issue 2 Nine DWRC Internship Winners for 2006 2007, http://ag.udel.edu/dwrc/newsletters/Summer2006.pdf, p. 6-7.

Undergraduate Internship Project #9 of 9 for FY06

Container aquaculture of oysters addresses oyster decline caused by over-fishing, reef destruction, sedimentation, and disease. The industry may provide many of the same ecological services attributed to natural or restored reefs. Examining the benefits or detriments of oyster farms on macro-infauna, or animals living in aquatic sediments large enough to be seen with the naked eye, was the goal of **Le'Sasha Stewart's** project *"Assessment of Macro-infauna Associated with Oyster (*Crassostrea Virginica*) Aquaculture in the Indian River Bay."* She hopes her *DWRC*-sponsored research will help shape the future fate and structure of shellfish aquaculture. Le'Sasha's advisor was Dr. Gulnihal Ozbay of the *Delaware State University* Department of Agriculture and Natural Resources.

Abstract

This past century has witnessed dramatic declines in oysters throughout the Mid-Atlantic due to overfishing, reef destruction, sedimentation, and diseases. The culture of Eastern oysters (Crassostrea virginica) in containment gear has become a viable industry in many states on the East Coast of the United States, and some have proposed that operations of this type can provide many of the same ecological services attributed to natural or restored reefs. This project was designed to examine the impacts of oyster aquaculture gears on sediment infaunal community structure. The primary objective of this research is to compare the diversity, evenness, abundance, and biomass of macro-infaunal communities inhabiting a subtidal oyster cultivation area with adjacent open sand flat along with water quality data. The sediment composition and macro-infaunal communities below the oyster cages with a nearby control transect of open sand/mud bottom was examined over four months (June, August, September, and October of 2006).

Average water quality parameters at the research site respectively were: temperatures ranged from 12.3-24.5ºC, salinities ranged from 27.0-31ppt, and dissolved oxygen ranged from 7.6-12.6g/ml. The sediments below the oyster cages showed a slight reduction in the silt and clay fraction. Of the seven most abundant infaunal taxa, Streblospio benedicti Webster 1879 (Polychatea: Spionidae) was the only species significantly different ($P<0.05$) in abundance between treatments. This species may have been flushed away along with sediment silt and clay during disturbance from oyster culture activities. Despite these minor impacts to sediments and infauna, we feel that this style of oyster culture is largely sustainable, supporting a number of other species of economic and ecological importance, and is playing an important role in restoring the oyster resource and associated industry in the Mid-Atlantic United States. There is a limited body of knowledge concerning the ecological impacts of oyster aquaculture gears especially in the Mid-Atlantic United States. More information about possible benefits and detriments to estuarine ecosystems will help to shape the future fate and structure of shellfish aquaculture in the state of Delaware and other Mid-Atlantic states. Along with social and

economic considerations this information will aid decision-makers, interest groups, and the general public in formulating opinions and policies on this emerging industry.

Information Transfer Program

Delaware Water Resources Center FY06 Information Transfer Activities

Basic Information

Title:	Delaware Water Resources Center FY06 Information Transfer Activities
Project Number:	2006DE114B
Start Date:	3/1/2006
End Date:	2/28/2007
Funding Source:	104B
Congressional District:	At Large
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	J. Thomas Sims

Publication

Information Transfer Program

The following section describes all Delaware Water Resources Center information transfer activities during FY06, consolidating reporting into a single project **#2006DE114B**. All activities from the DWRC's FY05 Information Transfer project (**#2005DE94B)** continued into this year. New additions to the program for FY06 include a new lecture series and also researcher poster and/or platform presentations.

The FY06 DWRC Information Transfer Activities include:

- Delaware Water Resources Center Print Publication WATER NEWS (2000 – present)
- Delaware Water Resources Center Electronic Newsletter WATER E-NEWS (2002 – present)
- Delaware Water Resources Center Website (updated 2001 – present)
- Delaware Water Resources Center E-group / Courses Link (2002 – present)
- Delaware Water Resources Center Intern Project Poster Session / Advisory Panel Annual Meeting (2001 – present)
- Delaware Statewide Water Forum Co-Sponsor and Participant (2001 – present)
- Delaware Water Resources Center Co-sponsored Lecture Series (Fall 2006)

Basic Information:
Delaware Water Resources Center Print Publication WATER NEWS

Title:	"WATER NEWS"
Issues during FY06:	Volume 7 Issue 1 (Summer 2006)
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 over 900 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.

Summer 2006 topics included:

- Delaware Dept. of Natural Resources and Environmental Control (DNREC) Water Quality Initiatives Update
- USGS Delaware Water Quality Programs
- Update of Delaware's Nutrient Management Program
- New "Green" Home for the Center for the Inland Bays
- Nine New DWRC 2006-2007 Interns Selected
- DWRC Advisory Panel Member Changes
- DWRC History, Goals, Advisory Panel, Contacts

Basic Information:
Delaware Water Resources Center Electronic Newsletter WATER E-NEWS

Title:	"WATER E-NEWS"
Issues during FY05:	Vol. 5 Issues 2, 3, 4, 5; Vol. 6 Issues 1, 2 Mar. '06, Apr. '06, May '06, Oct. '06, Feb. '07, Mar. '07
Description:	Online newsletter published periodically and emailed to Center's water resources e-group by the University of Delaware Water Resources Center
Lead Institute:	DE Water Resources Center
Principal Investigators:	J. Thomas Sims, Director; Amy Boyd, Editor

WATER E-NEWS is now received by nearly 250 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 DWRC website 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

Basic Information: Delaware Water Resources Center Website

Title:	Website: http://ag.udel.edu/dwrc
Start Date:	Second edition; since December 2001
End Date:	Ongoing
Description:	Comprehensive site serving Delaware water resources community
Lead Institute:	DE Water Resources Center
Principal Investigators:	Dr. J. Thomas Sims, Director; Amy Boyd, Administrator

The website 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.
- **Water Courses and Faculty:** Link to search engine for current list of University of Delaware water resource courses. List of researchers at Delaware universities 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 back 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.

Basic Information: Delaware Water Resources Center E-group / Courses Link

Title:	Delaware Water Resources Center / Water Resources Agency E-group, originating from the online listing of Delaware water teachers and researchers found on the DWRC website: http://ag.udel.edu/dwrc/faculty.html
Start Date:	Since December 2001
End Date:	Ongoing
Description:	E-group and link to university water resources courses taught, serving Delaware water resources community
Lead Institute:	DE Water Resources Center
Principal Investigators:	J. Thomas Sims, Director; Amy Boyd, Administrator

The online listing of approximately 70 researchers at the University of Delaware, Delaware State University, and Wesley College found on the Delaware Water Resources Center web site at http://ag.udel.edu/dwrc/faculty.html forms the foundation for a broader e-group list maintained by the DWRC 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 website also links to a search engine and site for water-related courses currently offered by the researchers.

The total list of e-group members numbered approximately 250 as of June 2006.

Basic Information:
Delaware Water Resources Center Intern Project Poster Session / Annual Advisory Panel Meeting

Title:	University of Delaware 2007 Undergraduate Research Scholars Poster Session with DWRC Advisory Panel Meeting
Date:	April 20, 2007
Description:	Undergraduate interns presented their 2006-2007 DWRC-funded projects following the annual meeting of the DWRC Advisory Panel
Lead Institute:	University of Delaware Undergraduate Research Program Co−Sponsors: Delaware Water Resources Center, Northeast Chemical Association, Howard Hughes Medical Institute, Howard Hughes Medical Institute, National Science Foundation, Delaware Biotechnology Institute, Beckman Foundation, University of Delaware Research Foundation, Charles Peter White Fellowship, HHMI/Arts and Sciences Dean's Special Scholar Award, Center for Composite Materials, UNIDEL Foundation – David Roselle Scholarship
Principal Investigators:	Joan Bennett, Director, UD Undergraduate Research Program (jbennett@udel.edu), J. Thomas Sims, Director, DWRC (jtsims@udel.edu)

On April 20, 2007, eight of the nine undergraduate student interns who had been funded in 2006-2007 by the DWRC presented the results of their research accompanied by their advisors at an informal poster session sponsored by the University of Delaware Undergraduate Research Program. Over one hundred UD Science and Engineering Scholars joined the DWRC interns to present to a crowd of over 500 visitors. The 15-member DWRC Advisory Panel also convened for lunch with the interns and their advisors and then held their annual meeting prior to the poster session. DWRC Director Tom Sims described the Center's plans for 2007-2008 with regard to research funding and public education outreach efforts such as statewide water forums.

Poster Presentations by 2006-2007 DWRC Undergraduate Interns – April 20, 2007

1) Boutin, Jennifer. Presentation April 20, 2007. The Effect of Proposed Climatic Warming on the Hydrological Cycle. 2007 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

2) Gao, Belinda. Poster Presentation April 20, 2007. Enhanced Pollutant Biodegradation by Electrode Use. 2007 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

3) Graham, Jason. Poster Presentation April 20, 2007. Predators of Galerucella Beetles, Biocontrol Agents of Purple Loosestrife. 2007 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

4) Peters, Garrett. Poster Presentation April 20, 2007. Measuring Groundwater Discharge to the Inland Bays. 2007 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

5) Smith, Samantha. Poster Presentation April 20, 2007. Detection of *Salmonella* in Biosolids Using PCR. 2007 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

6) Stewart, Le'Sasha. Poster Presentation April 20, 2007. An Assessment of Macro-infauna Associated with Oyster (*Crassostrea virginica*) Aquaculture, Indian River Bay, Delaware. 2007 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

7) Sturtz, Sarah. Poster Presentation April 20, 2007. Sustainable Mosquito Control for Storm-water Ponds. 2007 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

8) Tobias, Jarvon. Poster Presentation April 20, 2007. The Effects of Dietary Level and Source of Copper on Broiler Copper Excretion and Movement of Copper through Broiler Excreta-Amended Soils. 2007 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

9) Wolff, Elizabeth. Poster Presentation April 20, 2007. Hydraulic Properties of the Unconfined Aquifer in Southern New Castle County. 2007 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

Basic Information:
Delaware Statewide Water Forum Co-Sponsor and Participant

Title:	Sixth Annual Delaware Statewide Water Policy Forum: "The Delaware: Challenges and Opportunities Affecting a Working and Environmental River"
Date:	October 16, 2006
Description:	Presentation of DWRC recent accomplishments and program goals; DWRC information booth; Complete article is found in DWRC Fall 2006 – Spring 2007 WATER NEWS at http://ag.udel.edu/dwrc/newsletters/Fall06Spring07/WATERNEWS-Spring07.pdf , pages 3-4
Lead Institute:	Co-sponsored by the Delaware Water Resources Center, University of Delaware Institute for Public Administration, Water Resources Agency, Longwood Graduate Program in Public Horticulture, and Delaware Department of Natural Resources and Environmental Control.
Principal Investigators:	J. Thomas Sims, Director, Delaware Water Resources Center (jtsims@udel.edu); Jerome Lewis, Director, University of Delaware Institute for Public Administration (jlewis@udel.edu); Gerald Kauffman, Director of Watershed Policy, University of Delaware Institute for Public Administration Water Resources Agency (jerryk@udel.edu); Robert Lyons, Coordinator, Longwood Graduate Program in Public Horticulture (rlyons@udel.edu); Kevin Donnelly, Director, Division of Water Resources, Delaware Department of Natural Resources and Environmental Control (kevin.donnelly@state.de.us)

The sixth annual Delaware Water Policy Forum titled "The Delaware: Challenges and Opportunities Affecting a Working and Environmental River" was held for about 125 visitors from Delaware government, water agencies, academia, and the public, on October 16, 2006 at Clayton Hall on the University of Delaware campus in Newark, Delaware. Expert speakers discussed how private citizens, city and state planners, subdivision and campus engineers, and groups of private and government agencies can work together toward better water quality and supply in Delaware using wetlands, subdivision design, rain gardens, and more. The Forum's presentations, materials, and poster session were free of charge, courtesy of co-sponsors: Delaware Water Resources Center, University of Delaware Institute for Public Administration, Water Resources Agency, Longwood Graduate Program in Public Horticulture at the University of Delaware, and Delaware Department of Natural Resources and Environmental Control.

Basic Information:
Delaware Water Resources Center Co-sponsored 2006 Lecture Series

Title:	DWRC co-sponsored 2006 lecture series
Dates:	October 10, 2006: "Red Clay Creek: Flood or Drought – Where's the Balance?" and November 8, 2006: "Red Clay Creek: On the Road to Recovery"
Description:	Series of free public presentations on the Red Clay Watershed
Lead Institute:	**Coordinated by:** Delaware Nature Society Red Clay Valley Association **Sponsored by:** Duffield Associates United Water **Supported by:** Stroud Water Research Center **Delaware Water Resources Center** Partnership for the Delaware Estuary Delaware Dept. of Natural Resources and Environmental Control University of Delaware Water Resources Agency

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	9	0	0	0	9
Masters	0	0	0	0	0
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	11	0	0	0	11

Notable Awards and Achievements

Research Program: The Delaware Water Resources Center (DWRC) has funded eleven research grant projects during March 2006 through February 2007 that address state water resources priorities identified by the DWRC's 15-member Advisory Panel. Two of these projects are graduate fellowships investigating the impact of soil arsenic on water quality and the removal of water-borne viruses. The remaining nine projects are undergraduate internships researching 1) climatic warming on the hydrological cycle; 2) pollutant biodegradation using electrodes; 3) predators of biocontrol agents for freshwater invasive plants; 4) groundwater discharge to Delaware's Inland Bays; 5) detection of Salmonella in biosolids; 6) oyster aquaculture farm impacts; 7) sustainable mosquito control for stormwater ponds; 8) copper transport in broiler excreta-amended soils; and 9) hydraulic properties of the unconfined aquifer in southern New Castle County, Delaware.

Six additional undergraduate internships have been awarded by the DWRC for the period March 2007 through February 2008. Topics under investigation include 1) willingness to pay for sustainable agricultural practices; 2) using zerovalent iron to remove pathogens from water; 3) influent pollutant source identification in the Noxontown Pond Watershed, Middletown, Delaware; 4) benefit-cost analysis of pelletized broiler litter in crop production and turf grass management; 5) freshwater mussels as filters for pond water quality; and 6) restoration of a Piedmont headwater stream.

Publications from Prior Projects

1. 2002DE1B ("Graduate Fellowship in Water Quality: Baseflow and Storm Discharges of Nutrients to Delaware's Inland Bays") - Articles in Refereed Scientific Journals - Volk, J.A., K.B. Savidge, J.R. Scudlark, A.S. Andres, and W.J. Ullman, 2006, Nitrogen Loads through Baseflow, Stormflow, and Underflow to Rehoboth Bay, Delaware, Journal of Environmental Quality, 35, 1742-1755.