Water Resources Center
Annual Technical Report
FY 2007

Introduction

Delaware Water Resources Center

June 30, 2008

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 2007.

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 ground water 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 1970s, 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 1970s and early 1980s 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 1970s 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 1930s and 1940s 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 April 1, 2008 combined 305(b) and 303(d) report, Delaware waters are generally considered to suffer from eutrophication and low dissolved oxygen related to nutrient enrichment.

Excessive macroalgae production in Delaware's 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 fishkills each in 2002 and 2003. Of the fishkills in 2003, four were from natural causes, four of unknown cause, and nine 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 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; 9651 have been properly abandoned and 2399 are still in use. Since the 1980s 314,040 releases to ground water have been confirmed and 2800 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 ground water samples analyzed by Delaware's Office of Drinking Water in 2002 exceeded the secondary contaminant level standard of 0.3 mg/L. Concerns exist 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 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 have 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 were completed in 2007 for 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. Now that TMDLs are in place, Pollution Control Strategies (PCSs) are being 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 found at: http://www.dnrec.state.de.us/water2000/Sections/Watershed/ws/ib_pcs.htm. Final PCSs for the Nanticoke, Murderkill, and Appoquinimink watersheds are expected to be finalized in 2008. 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. 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, 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 of 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 the 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 Association's (NOAA) Coastal NPS Management 6217 program along with the Delaware Nutrient Management Commission's (DNMC) 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 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. Visit: 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) provides 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, visit: http://www.wr.udel.edu/swaphome/index.html. Delaware SWAPP is a cooperative effort between DNREC, Delaware Division of Public Health, and the University of Delaware's Water Resources Agency. A citizen's 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 TATs 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, The Center for the Inland Bays, the 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 three−fold mission to meet the goals of the Water Resources Research Act:

(1) To support research that will provide solutions to Delaware's priority water problems;

(2) To promote the training and education of future water scientists, engineers, and policymakers; and

(3) To disseminate research results to water managers and the public.

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

(1) Graduate Fellowship Program: A competitive graduate fellowship program supports graduate fellows on a 3−year cycle. Of the two Ph.D. graduate fellows supported during the period of this report, one is in the UD College of Marine and Earth Studies and the other is in the UD College of Engineering. Their research focuses on hydrogeologic characterization of the Potomac Aquifer, Delaware, and modeling hydrologic and geochemical effects of land−based wastewater disposal.

(2) Undergraduate Internship Program: We initiated a highly successful undergraduate internship program in 2000. In the first seven years, 79 undergraduate internships were made possible via funding from DWRC/USGS, Delaware Geological Survey, DNREC, the Institute of Soil and Environmental Qualtiy, 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 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 water resources, a calendar of upcoming events, and a Kids 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, 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, email: 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 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 FY07 DWRC public water conservation/educational outreach program addressed 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 a statewide water resources conference.

2007−2008 DWRC Fellowship and Internship Research Program

Two fellowships were awarded for the first year in 2007−2008 based on a review of proposals submitted by potential graduate fellows and their advisors to the DWRC Advisory Panel:

a) Hydrogeologic Characterization of the Potomac Aquifer, Delaware

Graduate Fellow: Claudia Velez; Advisors: Susan McGeary, Department of Geological Sciences, College of Marine and Earth Studies, University of Delaware; and Peter McLaughlin, Delaware Geological Survey.

b) Modeling Hydrologic and Geochemical Effects of Land−based Wastewater Disposal

Graduate Fellow: Maryam Akhavan; Advisors: Paul Imhoff, Department of Civil and Environmental Engineering, College of Engineering, University of Delaware; and Scott Andres, Delaware Geological Survey.

Ten internships were awarded for 2007−2008 based on a review of proposals submitted by potential undergraduate interns and their advisors to the DWRC Advisory Panel:

a) Willingness to Pay for Sustainable Agricultural Practices in an Urbanizing Region

Undergraduate Intern: Sarah Chatterson; Advisor: Joshua Duke, Department of Food and Resource Economics, College of Agriculture and Natural Resources, University of Delaware.

b) Can a Parabolic Screen Filter Improve the Quality of Water in a Recirculating Aquaculture System?

Undergraduate Intern: Samantha−Jo Ebert; Advisor: Dennis McIntosh, Department of Agriculture and Natural Resources, Delaware State University.

c) Determining the Effect of Various Water Conditioners on Holding Success of Mummichog (Fundulus heteroclitus) in Simulated Commercial Holding Tanks

Undergraduate Intern: Adrienne George; Advisor: Dennis McIntosh, Department of Agriculture and Natural Resources, Delaware State University.

d) Evaluating the Use of Zerovalent Iron to Remove Viruses from Water: Effect of pH

Undergraduate Intern: Jennifer Handlin; Advisor: Yan Jin, Department of Plant and Soil Sciences, College of Agriculture and Natural Resources, University of Delaware.

e) Effects of Wastewater Disposal on Ground Water Flow in Southern New Castle County

Undergraduate Intern: Janine Howard; Advisor: A. Scott Andres, Delaware Geological Survey.

f) Comparison of the Impacts of Poultry Litter vs. Urea on Surface Runoff Water Quality

Undergraduate Intern: Nathan Kiracofe; Advisor: Shreeram Inamdar, Department of Bioresources Engineering, College of Agriculture and Natural Resources, University of Delaware.

g) Benefit−Cost Analysis of Pelletized Broiler Litter in Agronomic Crop Production and Turf Grass Management

Undergraduate Intern: Stephen Mayer; Advisor: Joshua Duke, Department of Food and Resource Economics, College of Agriculture and Natural Resources, University of Delaware.

h) Hydraulic Properties and Ground Water Flow Modeling of the Unconfined Aquifer in Southern New Castle County

Undergraduate Intern: Marie Rivers; Advisor: A. Scott Andres, Delaware Geological Survey.

i) Viability of a Freshwater Mussel (Elliptio complanata) as a Biomechanical Filter in Aquaculture Ponds

Undergraduate Intern: Oluchi Ukaegbu; Advisor: Gulnihal Ozbay, Department of Agriculture and Natural Resources, Delaware State University.

j) The University of Delaware Experimental Watershed: A Green Campus Initiative

Undergraduate Intern: Laura Yayac; Advisor: Gerald Kauffman, Delaware Water Resources Agency.

Research Program Introduction

None.

Modeling Hydrologic and Geochemical Effects of Land−based Wastewater Disposal

Basic Information

Title:	Modeling Hydrologic and Geochemical Effects of Land−based Wastewater Disposal
Project Number:	2007DE100B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	At Large
Research Category:	Water Quality
Focus Category:	Acid Deposition, Hydrogeochemistry, Groundwater
Descriptors:	
Principal Investigators:	Alan Scott Andres, Maryam Akhavan, Paul Imhoff

Publication

1. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 2 DWRC Spotlight on Graduate Research, http://ag.udel.edu/dwrc/newsletters/Winter07Spring08/WATERNEWSco−Spring2008.pdf , p. 7.

Modeling Hydrologic and Geochemical Effects of Land-based Wastewater Disposal

December 2006

Proposal To: Delaware Water Resources Center, 2007-2010 Graduate Fellowship in Water Resources

Co-Principal Investigator: Scott Andres, Delaware Geological Survey, email: asandres@udel.edu, phone:302-831-0599
Co-Principal Investigator: Paul T. Imhoff, Department of Civil and Environmental Engineering, email: imhoff@udel.edu, phone:302-831-0541

1. Project Justification and Objectives

a) Overview of Research Problem

Delaware faces significant water supply and waste water disposal problems that are common to larger states and the nation as a whole:

- Changes in land use and land cover driven by population growth and suburban sprawl are stressing water supplies. For example, population in one of the faster growing areas, southern New Castle County (SNCC, Figure 1), Delaware is projected to nearly double by 2030 (Delaware Population Consortium, 2005). **Because there are no viable sources of fresh surface water in SNCC, new ground water supplies must be improved to meet the growing demand** (Delaware Water Supply Coordinating Council, 2006).

- Decades of inadequate agricultural and wastewater disposal practices have led to serious eutrophication problems in surface water (DNREC, 2000; USEPA, 2002) and nitrate contamination in ground water (Denver et al., 2004). **Contamination of ground water is a serious problem in Delaware, as all areas south of the C&D Canal obtain drinking water from aquifers, and aquifers supply more than 70 percent of fresh water stream flow.** As a result, significant public resources are now expended to improve agricultural practices (direct subsidies for management plans and manure relocation, free training) and sewage treatment and disposal systems.

- As a result of a Clean Water Act lawsuit related to establishment of total maximum daily loads for water quality impaired water bodies, efforts are underway to reduce pollutant discharges to surface and ground water. Because of limited public funds to build or upgrade public sewage treatment facilities, though, wastewater disposal in DE and other states in the mid-Atlantic is now being directed to privately funded and operated land based wastewater disposal (LBWD) systems. Originally spray irrigation and large community septic systems were most common, but now with increasing land costs rapid infiltration basin systems (RIBS) have become the most popular permit application for new discharges in DE (John Barndt, DNREC, personal communication). **Unfortunately, the effects of significant increases in discharges from LBWD to ground water and surface water quality are unknown and comprise a large-scale "experiment" on regional water quality that may have deleterious consequences.**

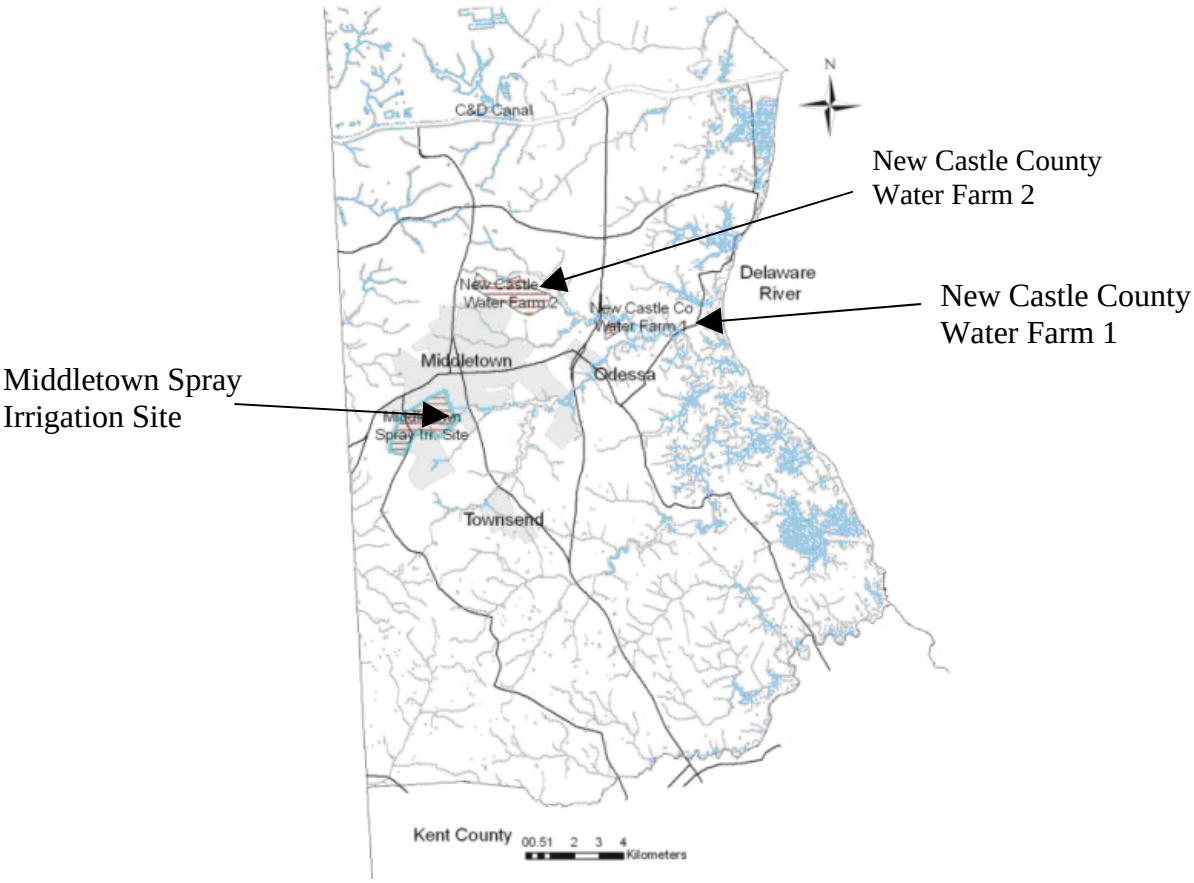

Figure 1. Map of Southern New Castle County, Delaware showing locations of towns and selected large land based wastewater disposal facilities.

One of the challenges that DE faces is the unknown impacts of RIBS on ground water and surface water quality. RIBS, also known as soil aquifer treatment systems, typically treat a much larger volume of wastewater per unit area of land than other LBWD's, which makes them desirable for the rapidly growing SNCC. In these systems primary or secondary wastewater is applied to shallow basins constructed in permeable deposits of porous soils or sands. As the wastewater moves through the soil, the water is filtered and adsorption, ion exchange, precipitation, and microbial degradation occurs removing or degrading many pollutants. Treatment is not complete, though, with total nitrogen removal ranging widely from 25-90% depending on the system (USEPA, 2003). The "treated" water is discharged to shallow ground water, where it either flows toward nearby surface water bodies or discharges to deeper drinking water aquifers. RIBS are operated in repetitive cycles of flooding, infiltration, and drying. The typical hydraulic pathway for RIBS is shown in Figure 2, while a photograph of a RIBS is given in Figure 3.

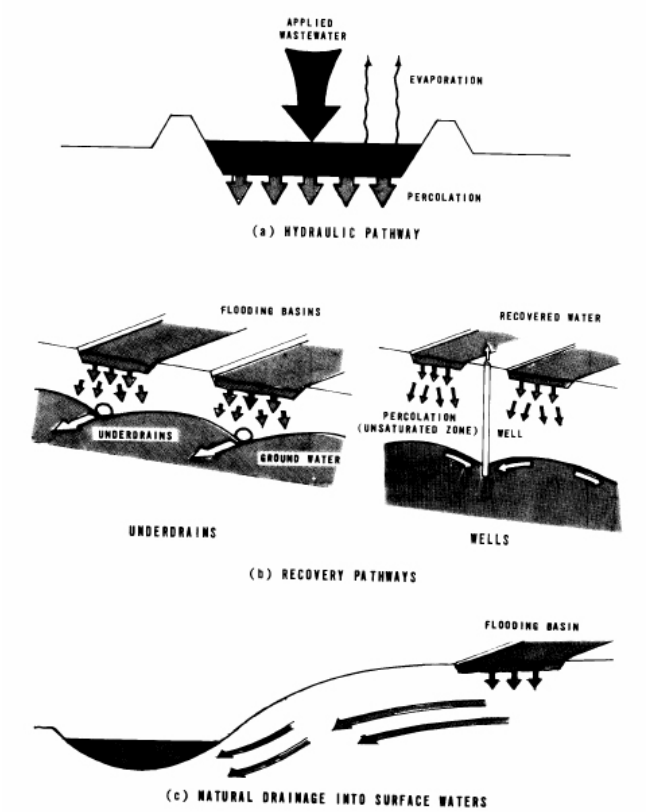

Figure 2. Simplified illustration of hydraulic flow paths in a RIBS (Crites, et al., 2000)

Figure 3. Photograph of a series of infiltration basins that are part of a RIBS (Minnesota Pollution Control Agency, 2005)

There are several potential benefits from increased use of LBWD and especially RIBS in SNCC (USEPA, 2003). When properly located and with adequate pre-treatment of wastewater, RIBS put good quality water back into upland areas of watersheds where it can be used for irrigation or to replenish aquifers and baseflow. In some arid and coastal areas, treated wastewater is used to create a barrier to saltwater intrusion. The direct impact to surface water can be partially mitigated by filtering the water through an aquifer.

On the risk side, although spray irrigation systems and RIBS are not new and generally thought to be relatively safe, the cumulative influence of one or more large RIBS on surface and groundwater in SNCC is unknown. RIBS are of particular concern because they use much larger hydraulic loading rates (30 meters/year) than the 2.5 to 3.5 meters/year applied by a typical spray irrigation system (Ronald Graeber, DNREC, personal communication) or the natural recharge rate of 0.3 meters/year (Johnston, 1976) . The high loading rate applied by RIBS is done over a limited area, usually a few 10's of square meters (Crites et al., 2000), a practice that will significantly alter natural ground water flow paths.

These issues are likely to have long-term consequences to areas such as SNCC, where the receiving aquifer for LBWD systems (Columbia aquifer) is very heterogeneous, ranging from very permeable to slowly permeable. In areas of high permeability, ground water typically is a more significant component of stream flow and flow velocities are greater than in other physiographic settings. As a result, in these locations shallow ground water contaminated by LBWDs will likely become contaminated surface water problems. The severity of problems will increase as LBWD discharges comprise an increasing portion of stream baseflow. In these cases, the water reuse benefits of LBWD might be lost if facilities are located too close to surface water. In areas of low permeability, failure of RIBS could lead to direct overland runoff of treated effluent to surface water.

In SNCC two major underlying aquifers (Mt. Laurel and Rancocas aquifers) are hydraulically connected to the Columbia and are major sources of water for domestic and public wells. RIBS will contribute biological oxygen demand, pathogenic organisms, metals, nitrogen, and phosphorus to these units. These aquifers also have physical and geochemical properties that will react with treated wastewater from the RIBS and potentially result in release of harmful metals, phosphorus, and radionucleides from the aquifer matrix to ground water (Rice et al., 1997; Barringer et al., 2005). Additionally, recent research indicates that a wide variety of organic wastewater contaminants of concern, such as pharmaceuticals, disinfectants, endocrine disrupting compounds, surfactant metabolites, and disinfection byproducts, are in both wastewater and in ground water beneath areas served by LBWD (Seiler et al., 1999; Moran et al., 2004; Zogorski et al., 2006).

Considering the above issues, careful use of existing field data with appropriate models will help identify and characterize impacts of LBWD on ground and surface waters in DE. At a minimum, models can be employed using existing data on pollutant transformation rates and sorption properties along with existing information on geological systems to estimate the risk to nearby surface water bodies and deeper drinking water aquifers. While one-dimensional models have been used to guide operations and design of RIBS, to the best of our knowledge only one multi-dimensional numerical model has appeared in the peer-reviewed literature for evaluation of RIBS (Kim et al., 2005). Although a significant advancement, this modeling study did not evaluate the influence of RIBS on surface water bodies and only examined nitrate and dissolved organic carbon transport. Thus, there is room for significant advancement in the application of numerical modeling methods for elucidating risks to surface and groundwater supplies from RIBS and other LBWD.

b) Project Objectives

The study we propose would touch on several of the focus areas stated in the request for proposals: sources, fate and transport of ground water pollutants and their impacts on surface water; nutrient management in non-agricultural settings; regional management of water supplies; protection of aquifer recharge areas; and re-use of treated wastewater. There are also significant regulatory and administrative benefits to conducting this research, since Delaware has a new program to guide permitting and monitoring of RIBS (DNREC, 2005). **Research of the type we propose is needed to evaluate existing guidance for siting RIBS (e.g., appropriate set back distances between RIBS and surface water bodies) and monitoring and modeling requirements for both design and on-going maintenance of these systems.**

With these issues in mind we propose the following research objectives:

1. Characterize the effects of RIBS and spray irrigation systems on hydrology and geochemistry at selected test sites (two to four) by application of linked ground and surface water flow and contaminant transport models.
2. Assess the probability of ground and surface water contamination by nitrogen and phosphorus at the selected test sites.
3. Based on the results from objectives 1 and 2 and additional analyses using "typical" hydrogeologic settings anticipated for future spray irrigation and RIBS systems, develop recommendations for flow and transport modeling that might guide future assessment of proposed RIBS and spray irrigation systems.
4. Develop recommendations for the design of RIBS and spray irrigation systems and monitoring of the vadose zone and ground water that will protect human health and the environment.

In addressing these four objectives, many questions related to the design and monitoring of LBWD systems will be addressed. For example, what are appropriate set back distances between RIBS disposal basins and streams? What are appropriate monitoring designs to ensure protection of ground water and nearby surface water quality: how many wells, what spatial sampling density, what sampling frequency? Do RIBS add water to regional ground water flow systems, and is this hydrologic impact significant?

This work will also result in an assessment of appropriate modeling approaches for permitting RIBS and spray irrigation systems. Questions to answer include: are analytical models appropriate? Are two- or three-dimensional analyses of groundwater flow and contaminant transport necessary? Is the uncertainty of nitrification/denitrification rates and phosphorus sorption sufficiently large to warrant an extensive monitoring program, or are published biological and chemical reaction rates sufficiently accurate to use in permitting?

Completion of the four objectives will allow us to catalog and prioritize LBWD-related hydraulic and water quality issues for the mid-Atlantic Coastal Plain and by extension to other unconsolidated sediment aquifers. Because of existing field data at the test sites, the importance of nutrient addition to surface water and nitrate contamination in groundwater, and the state of scientific knowledge on nitrogen and phosphorus transformation and transport, these two contaminants will be used to assess water quality impacts from RIBS and spray irrigation systems. While this work will not address the impact of other pollutants (e.g., pharmaceuticals, endocrine disrupting compounds, etc.) that have been measured in LBWD discharges, the work will form the framework for future studies of these contaminants as field and laboratory data on transformation and transport become available.

2. Literature Review

There have been decades of research into geologic (Benson and Spoljaric, 1996; Ramsey, 2005), hydraulic (Johnston, 1973, 1976; Woodruff, 1986a, b, 1992; Baxter and Talley, 1996; Martin and Andres, 2006), and geochemical (Bachman and Ferrari, 1995; Baxter and Talley, 1997) characteristics of aquifers and confining units in SNCC. In the DGS files there also are many datasets and reports on physical hydrology and ground water quality prepared by consultants for contaminated sites; for design and monitoring of existing wastewater treatment plants, RIBS, and spray irrigation systems; and for support of water supply studies for privately owned utilities. A considerable volume of data, both published and unpublished is available through the DGS in-house GIS-enabled dataset of monitoring wells, ground water levels, stratigraphy, sedimentology, aquifer characteristics, and ground water quality. Pertinent to modeling impacts of LBWD facilities on local hydrology, the DGS in-house dataset contains more than 30 records of wells with slug tests and more than 15 records of aquifer pumping tests in SNCC. The slug tests were conducted in monitoring wells located at existing spray irrigation facilities and at the site of a proposed RIBS.

Additional data on physical and chemical characteristics of ground and surface waters are available from the US Geological Survey National Water Information System (http://waterdata.usgs.gov/de/nwis/). This includes four continuous record streamgaging stations and several low-flow monitoring stations in SNCC.

Appropriate hydrologic models are constructed by applying the correct numerical solution schemes and computer codes within a framework that represents real world conditions (Anderson and Woessner, 1992). Since the original version of the finite-difference ground water flow model MODFLOW (MacDonald and Harbaugh, 1988) was released many new capabilities have been added to improve computational efficiency; to simulate reactive contaminant transport, surface water - ground water interactions, and unsaturated and variably saturated flow; and to automate parameter estimation and telescopic mesh refinement (Barlow and Harbaugh, 2006). In addition there have been advances in incorporating geographic information system (GIS) technology (Hinaman and Tenbus, 2000; Andres et al., 2003) and aspects of solids modeling (EMS-I, 2006; Waterloo Hydrologic, 2006) into the groundwater modeling process . The few consultant studies that have used MODFLOW simulations for designing LBWD systems have not taken advantage of these newer capabilities and in many cases have used grossly simplified geologic models to represent complex hydrogeologic field conditions. **In the proposed research, the adequacy of these simplified approaches will be assessed.**

Risks from LBWD systems to ground water result from inappropriate design and location of treatment and disposal systems. Effluent from wastewater treatment systems can be characterized as complex mixture of carbon-rich breakdown byproducts of organic compounds, and depending on the treatment technology, significant biologic or chemical oxygen demands, suspended solids, nitrogen, phosphorus, and other substances. If done inappropriately, the introduction of these effluents to ground water can lead to long-term and large-scale degradation of ground water quality (USEPA, 1999; Repert et al., 2006). With RIBS specifically, there can be long-term accumulation of nitrogen and phosphorus in both the unsaturated and saturated zones in the subsurface (Sumner and Bradner, 1996), or release of metals and radionucleides from aquifer solids to ground water when wastewater is applied to them (Rice et al., 1997; Barringer et al., 2005).

Additional risks to the environment and to public health result from the introduction of man-made compounds to the subsurface. VOCs including disinfection byproducts (Squilace et al., 2002, 2004; Moran et al., 2004; Zogorski et al., 2006; Pellerito et al., 2006) and a host of non-regulated substances and compounds such as personal care and pharmaceuticals, hormones and other endocrine disrupting compounds (Seiler et al., 1999; Herberer, 2002; Snyder et al., 2003; Hinkle et al., 2005) are routinely

detected in ground water and in water supply wells. Flame-retardants, detected in surface waters (Meyer and Bester, 2004), can be a risk for ground water contamination under high hydraulic loading rates to LBWD systems. Eventually, many of these chemicals will discharge to surface water where they may have unintended impacts on aquatic organisms. Although these compounds are important, an understanding of the physical, chemical, and biological reactions controlling their fate and transport in ground water is not firmly established. For this reason and because of the limited field data on their occurrence at sites in SNCC, we will focus on the impact of nitrogen and phosphorus to ground and surface water in this work. We will develop a framework for future studies of these contaminants as field and laboratory data on transformation and transport become available.

3. Proposed Methodology

In this work a Ph.D candidate will model saturated and variably saturated ground water flow and contaminant transport associated with LBWD systems. This research will be conducted in conjunction with geologists, hydrogeologists, hydrologists, and GIS specialists at the DGS and Department of Civil and Environmental Engineering (CEE) with areas of specialization in stratigraphy, aquifer characterization and three-dimensional mapping, geospatial data applications, numerical methods, physical hydrology, chemical characterization of complex wastewaters, ground water flow and transport modeling and geochemistry, and watershed hydrology and geochemistry. This project will complement ongoing DGS research projects in modeling of ground water supply of SNCC, three-dimensional mapping, and Coastal Plain watershed processes, and CEE research programs in contaminant transport in porous media. The student will be encouraged to interact with others on campus in the areas of soil physics, geochemistry and soil chemistry, watershed sciences, water-supply planning, and wastewater disposal engineering.

To accomplish the four project objectives outlined above, the following tasks will be completed:

- Task 1: Selection of RIBS and spray irrigation test sites for analysis. The highest priority sites to investigate are New Castle County's Water Farm 1 and Middletown's Spray Irrigation System. (See Figure 1.)
- Task 2: Application of vadose zone – ground water – surface water flow models to test sites. Focus will be given to the affects of RIBS and spray irrigation systems on hydraulic impacts to systems, e.g., changes to groundwater flow and discharge patterns. Both analytical and numerical models will be evaluated, with an emphasis on numerical modeling.
- Task 3: Application of vadose zone – ground water – surface water solute transport models to test sites. Focus will be given to nitrogen and phosphorus transport to streams and drinking water aquifers. Both analytical and numerical models will be evaluated, with an emphasis on numerical models that account for nitrification, denitrification, and sorption/desorption processes.
- Task 4: Use of Monte Carlo analysis to quantify the uncertainty in nitrogen and phosphorus loadings to streams and drinking water aquifers at test sites. These analyses are expected to elucidate the most sensitive and uncertain model parameters, which should guide future field monitoring efforts at these and other RIBS and spray irrigation sites.
- Task 5: Develop guidelines for the use of analytical and numerical models for siting RIBS and spray irrigation systems that are protective of human health and the environment.
- Task 6: Develop guidelines for monitoring requirements of the vadose zone and ground water at RIBS and spray irrigation systems.

Test sites in SNCC that will be considered for the research are the Middletown Spray Irrigation Site, New Castle County Water Farm 1 (spray irrigation system and planned RIBS), and New Castle

County Water Farm 2 (planned RIBS). If RIBS in SNCC are not constructed soon enough for this project, we may study one or more existing RIBS in Kent and Sussex Counties. Test sites will be selected based upon available geologic, hydraulic and contaminant (nitrogen and phosphorus) data and how "representative" the site may be for future application of RIBS and spray irrigation systems.

The main focus of the work is the advancement of modeling approaches for assessing the effects of LBWD on ground water and surface water resources. We will build on our existing expertise with MODFLOW and take advantage of newer modules (SURFACT and MIKE 11) for variably saturated flow; ground water-surface water interaction; multi-parameter contaminant transport with diffusion, sorption, and decay; and parameter estimation with specific application to spray irrigation and RIBS methods. The utility of analytical models for flow and transport will also be evaluated. The study will take advantage of years of field data collected at spray irrigation facilities in SNCC to help calibrate and test the effectiveness of the hydraulics aspects of the models. We also will collaborate with on-going DGS research into the development of regional ground water supply models. Throughout the study, a continual literature review of wastewater characteristics, modeling techniques, and geochemistry issues will be performed.

4. Project Schedule and Outcomes

The project schedule is outlined in the table below.

PROJECT TASK	3/08 – 11/08				12/08 - 6/09				7/09 - 3/10			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1 – Selection of test sites.	x	x										
Task 2 – Flow modeling at test sites.			x	x	x	x						
Task 3: Contaminant transport modeling at test sites for N and P.					x	x	x	x	x			
Task 4: Uncertainty analysis for N and P loading predictions.								x	x	x	x	
Task 5: Guidelines on use of analytical and numerical models for siting RIBS and spray irrigation systems										x	x	x
Task 6: Guidelines for monitoring requirements at RIBS and spray irrigation systems										x	x	x

This research will result in an improved knowledge of appropriate modeling approaches for assessing ground water quantity and quality impacts from RIBS and spray irrigation systems. Recommendations will also result for appropriate modeling and monitoring requirements for permitting and operation of these LBWD systems for SNCC. Research results will be published in peer-reviewed journals, such as *Groundwater*, *Journal of Environmental Engineering*, and *Journal of Contaminant Hydrology*.

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Willingness to Pay for Sustainable Agricultural Practices in an Urbanizing Region

Basic Information

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Project Number:	2007DE103B
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Focus Category:	Law, Institutions, and Policy, Water Quality, Economics
Descriptors:	
Principal Investigators:	Joshua Duke, Sarah Chatterson

Publication

1. Chatterson, S. and J. Duke, 2008, Willingness to Pay for Sustainable Agricultural Practices in an Urbanizing Region, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 6 pages.
2. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 1 Introducing Our 2007−08 Interns, http://ag.udel.edu/dwrc/newsletters/Summer07Fall07/WATERNEWS−Fall2007.pdf , p. 2.
3. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 2 DWRC Annual Poster Session – May 2, 2008, http://ag.udel.edu/dwrc/newsletters/Winter07Spring08/WATERNEWSco−Spring2008.pdf , p. 3.

Undergraduate Internship Project #1 of 10 for FY07

Intern ***Sarah Chatterson's*** project, co-sponsored by the ***DWRC*** and the ***UD's College of Agriculture and Natural Resources***, was titled "Willingness to Pay for Sustainable Agricultural Practices in an Urbanizing Region." She was advised by Dr. Joshua Duke of the ***UD's*** Department of Food and Resource Economics.

"My DWRC internship was great exposure to the research process as well as to the survey method, which is very important in environmental economics. I now better understand how people value the environment and am able to think differently about potential solutions to environmental problems. Also, the research experience has made me feel much more comfortable and prepared in beginning my Senior Thesis." – Sarah Chatterson

Abstract

The objective of this study was to estimate the willingness to pay of residential neighbors to an agricultural operation for the improvement of the agricultural management practices with respect to sustainable practices. The region studied was the area surrounding St. Andrews School, a private school on 2,200 acres of land near Middletown, Delaware. Of the total acres, 1,500 acres are used for crop production and 600 acres are in forest cover. The population of residential neighbors of St. Andrews School was identified to be the three surrounding zip codes, overall 8,625 households. From this a sample of residents was drawn. This sample included two subsamples: (1) all residents living within 0.5 miles of St. Andrews School property; and (2) a random sample of remaining households in the zip codes. A mail survey was sent to 1,500 residents with a response rate of 45.8%. The survey instrument identified three survey attributes for a choice experiment: (1) acres of land preserved by management contract; (2) use of sustainability practices including pelletized broiler litter, riparian buffer zones, and no-till cropping; and (3) cost per household. The regression results show that the variables of acres preserved, cost per household, and the sustainable practice (other than no-till) were statistically significant (Table 1). Based on survey results, a household mean willingness to pay and a total population willingness to pay was calculated for the sustainability practices and acres preserved. The benefit to the population of utilizing all of the sustainability practices and preserving all acres is estimated to be $16,468,688 (Table 3). Duke and Johnston (2007) estimated the benefits to Delaware at $77,316,330. This gives total estimated benefits of $93,803,018. Costs were estimated to be $48,510,000 based on the Delaware PACE program for preservation and the use of management contracts. Of this, $42,000,000 is for preservation alone. Therefore, total net benefits of utilizing all of the sustainability practices and preserving all acres is estimated to be $45,293,018. Overall, public goods demand for preservation and management practices is significant. The results show that management contracts can increase benefits 2-4 times over preservation alone. In addition, the cost of sustainable management practices is lower than the cost of preservation and provides the same amount of benefits. Therefore, future policies should consider an increased focus on sustainable management rather than on preservation alone.

Benefit−Cost Analysis of Pelletized Broiler Litter in Agronomic Crop Production and Turf Grass Management

Basic Information

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Principal Investigators:	Joshua Duke, Stephen Mayer

Publication

1. Mayer, S. and J. Duke, 2008, Benefit−Cost Analysis of Pelletized Broiler Litter in Agronomic Crop Production and Turf Grass Management, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 14 pages.
2. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 1 Introducing Our 2007−08 Interns, http://ag.udel.edu/dwrc/newsletters/Summer07Fall07/WATERNEWS−Fall2007.pdf , p. 3.

Undergraduate Internship Project #2 of 10 for FY07

Intern *Stephen Mayer's* project, co-sponsored by the *DWRC* and the *UD's College of Agriculture and Natural Resources*, was titled "Benefit-cost Analysis of Pelletized Broiler Litter in Agronomic Crop Production and Turf Grass Management." He was advised by Dr. Joshua Duke of the *UD's* Department of Food and Resource Economics.

Abstract

Sussex County, Delaware, is a leading county in the production of broiler chickens nationwide. Broiler chicken production creates an abundance of broiler litter, which is laden with nutrients that partially run off into water bodies creating environmental hazards. This study seeks to enumerate and compare the private benefits and private costs of using pelletized broiler litter (PBL) in a nutrient deficit region. The approach followed Field and Field's four step benefit-cost analysis in *Environmental Economics: An Introduction, 4th*. The research uses facts from the first year of data collection at St. Andrews athletic and agricultural fields. These fields which were being treated with PBL in an experiment as part of the larger project led by Drs. Hansen, White-Hansen, Barton, and Sprinkle on management strategies to improve turf quality on the athletic fields at St. Andrews and by Drs. Sims, McGrath, and Collins for the improvement of agricultural production acres. This study shows that a significant subsidy would be needed to encourage farmers and turf grass managers to use PBL. PBL is not an economically feasible agricultural fertilizer for corn. Due to the large amount of nitrogen being applied, PBL is an expensive alternative to urea. However, turf fields have proven to be more economically feasible for PBL fertilizer use. Because of the low nitrogen rates typically applied to turf, PBL stands a much better chance as an alternative fertilizer when purchased in bulk.

Viability of a Freshwater Mussel (Elliptio complanata) as a Biomechanical Filter in Aquaculture Ponds

Basic Information

Title:	Viability of a Freshwater Mussel (Elliptio complanata) as a Biomechanical Filter in Aquaculture Ponds
Project Number:	2007DE108B
Start Date:	6/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	At Large
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Non Point Pollution
Descriptors:	
Principal Investigators:	Gulnihal Ozbay, Oluchi Ukaegbu

Publication

1. Ukaegbu, O. and G. Ozbay, 2008, Viability of a Freshwater Mussel (Elliptio complanata) as a Biomechanical Filter in Aquaculture Ponds, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 47 pages.
2. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 1 Introducing Our 2007−08 Interns, http://ag.udel.edu/dwrc/newsletters/Summer07Fall07/WATERNEWS−Fall2007.pdf , p. 3.
3. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 2 DWRC Annual Poster Session – May 2, 2008, http://ag.udel.edu/dwrc/newsletters/Winter07Spring08/WATERNEWSco−Spring2008.pdf , p. 3.

Undergraduate Internship Project #3 of 10 for FY07

Intern *Oluchi Ukaegbu's* project, sponsored by the **DWRC**, was titled "Viability of a Freshwater Mussel (*Elliptio complanata*) as a Biological Filter for Aquaculture Pond Water Quality." She was advised by Dr. Gulnihal Ozbay of *Delaware State University's* Department of Agriculture and Natural Resources.

Abstract

Many freshwater aquaculture facilities utilize earthen ponds for the growth of their commercial products. The production and livelihood of these facilities depends on the increased growth of the species being harvested, which is usually done through manufactured foods or increased feeding. In fish, only 30% of nitrogen and phosphorus are retained from feeding that remaining nutrients in waters may lead eutrophication. Eutrophication can cause algal blooms which lead to the sudden die off of vegetation causing oxygen depletion in the system. Bivalves have been proven to be an inexpensive method for removing suspended solids, dissolved nutrients, and controlling algal growth through suspension feeding. *Elliptio complanata* is the most abundant species in Delaware and it is additionally favorable because of its hardiness against environmental stress and good filtration efficiency. This study examines the possibility that biomechanical filters such as *E. complanata* can replace expensive chemical and mechanical filtration regiments in aquaculture pond management. We asked two major questions in our study: 1) Will the ponds with the highest mussel treatments have a substantial improvement in water quality and 2) Will mussel treated ponds have higher growth and survivorship of mussel and fish? The twelve earthen aquaculture ponds located at the Delaware State University were stocked with 1000 and 500 catfish (*Ictalurus punctatus*), respectively. Four different concentrations (0, 75, 150, and 300) of *E. complanata* were placed in three trays suspended six inches below the surface of an aquaculture pond stocked with catfish. These mussels were suspended in the water column for a period of nine months. Water samples were taken weekly during the course of the study and tested for nitrate, nitrite, ammonia, total nitrogen, total phosphorous, soluble reactive phosphorous, alkalinity, total suspended solids, and chlorophyll-*a*. Fish and mussel growths were measured biweekly starting in May. The ponds with the highest mussel treatments did not have a substantial improvement in water quality ($P > 0.05$). Mussel treated ponds did not have significantly higher growth and survivorship ($P > 0.05$) of mussel and fish in this study. However, higher survivorship, 95%, was monitored for the mussels in the highest mussel treated ponds while the lowest mussel treatment resulted in higher growth of mussels, a trend favoring lower concentration treatments. Although not significant, fish growth was much higher in 150 mussels treated ponds. Even though there was not any significant effect on water quality or fish growth their use in aquaculture ponds may still be very beneficial. These ponds could be used for mussel conservation and/or using freshwater mussels in ponds may be beneficial for restoration efforts by serving as a habitat for propagated mussels. This project demonstrates to pond managers and others associated with high nutrient-laden water systems that use of a native biological organism may be beneficial in controlling water quality. However, further mesocosm study in the mussel's natural habitat should be conducted to verify their effects on water quality and fish growth.

Basic Information

Title:	
Project Number:	2007DE109B
Start Date:	6/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	

Publication

The project “Impacts of Urbanization on Kent County Water Quality” was withdrawn by the PIs, and hence not funded as Project 2007DE109B.

Comparison of the Impacts of Poultry Litter vs. Urea on Surface Runoff Water Quality

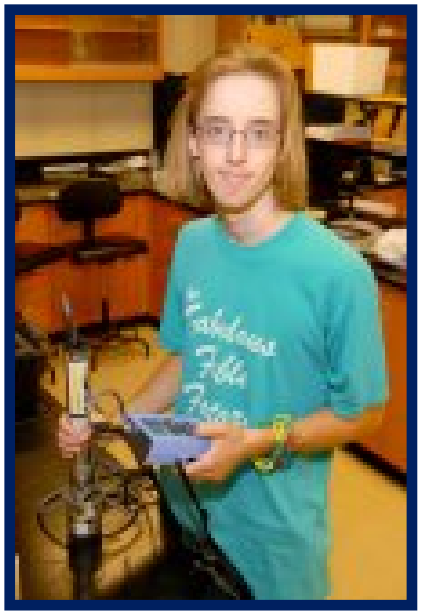
Basic Information

Title:	Comparison of the Impacts of Poultry Litter vs. Urea on Surface Runoff Water Quality
Project Number:	2007DE110B
Start Date:	6/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Nutrients, Toxic Substances
Descriptors:	
Principal Investigators:	Shreeram P. Inamdar, Nathan Kiracofe

Publication

1. Kiracofe, N. and S. Inamdar, 2008, Comparison of the Impacts of Poultry Litter vs. Urea on Surface Runoff Water Quality, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 10 pages.
2. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 1 Introducing Our 2007−08 Interns, http://ag.udel.edu/dwrc/newsletters/Summer07Fall07/WATERNEWS−Fall2007.pdf , p. 3.
3. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 2 DWRC Annual Poster Session – May 2, 2008, http://ag.udel.edu/dwrc/newsletters/Winter07Spring08/WATERNEWSco−Spring2008.pdf , p. 2.

Undergraduate Internship Project #4 of 10 for FY07



Intern *Nathan Kiracofe's* project, co-sponsored by the *DWRC* and the *UD's College of Engineering*, was titled "Assessment of Baseline Water Quality and Influent Pollutant Source Identification in the Noxontown Pond Watershed, Middletown, DE." He was advised by Dr. Shreeram Inamdar of the *UD's* Department of Bioresources Engineering.

Abstract

A study on six plots of corn was conducted on the St. Andrews School farm near Townsend, DE to compare the runoff water quality characteristics between pelletized broiler litter (PBL) and conventional fertilizers, in this case urea. The objective of this comparison was to see whether or not PBL is a suitable replacement for conventional fertilizer. Within the six corn plots, three of the plots were conventionally tilled (CT) and three were under no-till treatment (NT). In each of the tilling methods one of the plots was fertilized with PBL, one with urea, and one was left unfertilized (control plot). Five-gallon plastic buckets were placed at the lower end of each of the plots in order to collect rainwater runoff. Sampling was performed following natural rainfall events which were monitored using the Delaware Environmental Observation System rain gauge in Townsend, DE. These samples were tested for both nutrients, including nitrate-N (NO_3-N), ammonium-N (NH_4-N), and total-P (TP), as well as trace metals aluminum (Al), arsenic (As), calcium (Ca), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn). Although no statistical difference was found in the average concentrations of both the nutrients and trace metals, comparison of total mass for these materials indicates that overall in the CT plots PBL tends to give off more total mass while in the NT plots urea tends to give off more total mass. These results suggest that PBL applications may have a greater potential for releasing nutrients and trace metals in surface runoff.

Evaluating the Use of Zerovalent Iron to Remove Viruses from Water: Effect of pH

Basic Information

Title:	Evaluating the Use of Zerovalent Iron to Remove Viruses from Water: Effect of pH
Project Number:	2007DE111B
Start Date:	6/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Water Quality, Treatment, Toxic Substances
Descriptors:	
Principal Investigators:	Yan Jin, Jennifer Handlin

Publication

1. Handlin, J. and Y. Jin, 2008, Evaluating the Use of Zerovalent Iron to Remove Viruses from Water: Effect of pH, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 5 pages.
2. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 1 Introducing Our 2007−08 Interns, http://ag.udel.edu/dwrc/newsletters/Summer07Fall07/WATERNEWS−Fall2007.pdf , p. 3.
3. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 2 DWRC Annual Poster Session – May 2, 2008, http://ag.udel.edu/dwrc/newsletters/Winter07Spring08/WATERNEWSco−Spring2008.pdf , p. 2.

Undergraduate Internship Project #5 of 10 for FY07

Intern ***Jennifer Handlin's*** project, co-sponsored by the ***DWRC*** and the ***UD's Department of Plant and Soil Sciences***, was titled "Evaluating the Use of Zero-valent Iron to Remove Pathogens from Water." She was advised by Dr. Yan Jin of the ***UD's*** Department of Plant and Soil Sciences.

"This experience has taught me how important it is that we continue researching new technologies in order to have safe drinking water for future generations." – Jennifer Handlin

Abstract

The removal of pathogens, especially viruses, has been one of the biggest challenges facing water treatment facilities today. The use of chlorine to disinfect has been shown to be less effective against viruses than bacteria due to viruses' small size and resistance to disinfection and filtration. The pathogens come from a variety of point and non-point sources such has runoff and infiltration from animal waste-amended fields, leaking septic tanks, wastewater discharge, and land disposal of biosolids. The use of zerovalent technology has already been shown to remove viruses from water at neutral pH (You et al., 2005). This research has been focused on evaluating the removal efficiency of viruses by zero-valent iron at three different pHs, 5, 7.5 and 9. The research showed that zero-valent iron was effective over the wide range of pH tested. At all three pHs, a 6-log (99.9999%) removal was achieved. This technology would prove to be very beneficial in reducing dependence on chlorine for disinfection, thus reducing the harmful disinfection byproducts (DBP') resulting from its use.

The University of Delaware Experimental Watershed: A Green Campus Initiative

Basic Information

Title:	The University of Delaware Experimental Watershed: A Green Campus Initiative
Project Number:	2007DE113B
Start Date:	6/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Sediments, Acid Deposition
Descriptors:	
Principal Investigators:	Gerald Kauffman, Laura Yayac

Publication

1. Yayac, L. and G. Kauffman, 2008, The University of Delaware Experimental Watershed: A Green Campus Initiative, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 22 pages.
2. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 1 Introducing Our 2007−08 Interns, http://ag.udel.edu/dwrc/newsletters/Summer07Fall07/WATERNEWS−Fall2007.pdf , p. 3.
3. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 2 DWRC Annual Poster Session – May 2, 2008, http://ag.udel.edu/dwrc/newsletters/Winter07Spring08/WATERNEWSco−Spring2008.pdf , p. 3.

Undergraduate Internship Project #6 of 10 for FY07

Intern *Laura Yayac's* project, co-sponsored by the *DWRC* and the *UD's Water Resources Agency*, was titled "The University of Delaware Experimental Watershed: A Green Campus Initiative." She was advised by Mr. Gerald Kauffman of the *UD's* Water Resources Agency.

Abstract

The Experimental Watershed at the University of Delaware (UDEW) was created in 2001 by student researchers of the UD Water Resources Agency and Delaware Water Resource Center. It was delineated based on a number of factors, including the physiographic provinces, location on campus, proximity to classrooms, characteristic land use, and position within the larger White Clay Creek watershed. It encompasses 1,312 acres, or two square miles. Specifically, it is comprised of two subwatersheds so that it is better able to represent the two different geographic areas in which the University is located – the Piedmont and the Coastal Plain. The purpose behind the creation of the experimental watershed is to provide research and education opportunities at UD (Campagnini).

Projects within the UDEW have included assessments of Blue Hen Creek and Fairfield Run, two of the main streams within the watershed. Preliminary plans for the restoration of Blue Hen Creek have been prepared. In addition, a rain garden was created as a master's thesis that demonstrates the integration of research, learning, and education for the community. Initiatives to restore wetlands and buffers on the UD Farm are in progress, and there have been recent improvements in manure management. There are many opportunities to conduct research, carry out projects, study processes, and educate others in the UDEW.

The UDEW aims to create a greener campus and protect the resources of the community. Through education, research, and related projects, the UDEW allows for consideration of the anthropogenic impacts on our water and provides opportunities for students to expand their knowledge and apply their findings to improving the quality of campus and the surrounding areas. As the University considers enhancements and expansion plus the impacts of increased impervious cover, reduced native vegetation, fertilizer and pesticide application, and construction disturbances must be mitigated to protect the health of the watershed. Particularly since the UDEW drains to the White Clay Creek, the quality of drinking water, wildlife habitat, and aesthetic value will benefit greatly from careful consideration and planning of future campus growth.

Can a Parabolic Screen Filter Improve the Quality of Water in a Recirculating Aquaculture System?

Basic Information

Title:	Can a Parabolic Screen Filter Improve the Quality of Water in a Recirculating Aquaculture System?
Project Number:	2007DE143B
Start Date:	10/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	At Large
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Non Point Pollution
Descriptors:	
Principal Investigators:	Dennis McIntosh, Samantha Jo Ebert

Publication

1. Ebert, S. and D. McIntosh, 2008, Can a Parabolic Screen Filter Improve the Quality of Water in a Recirculating Aquaculture System?, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 6 pages.
2. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 1 Introducing Our 2007−08 Interns, http://ag.udel.edu/dwrc/newsletters/Summer07Fall07/WATERNEWS−Fall2007.pdf , p. 2.
3. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 2 DWRC Annual Poster Session – May 2, 2008, http://ag.udel.edu/dwrc/newsletters/Winter07Spring08/WATERNEWSco−Spring2008.pdf , p. 3.

Undergraduate Internship Project #7 of 10 for FY07

Intern ***Samantha-Jo Ebert's*** project, sponsored by the ***DWRC***, was titled "Can a Parabolic Screen Filter Improve the Quality of Water in a Recirculating Aquaculture System?" She was advised by Dr. Dennis McIntosh of ***Delaware State University's*** Department of Agriculture and Natural Resources.

"My internship was a lot of work and at the same time very fun. I used to take the quality of water for granted when it came to aquarium [recirculating aquaculture system] fish. Now I know so much more needs to be done to maintain a good living environment for the animals in the system… An important aspect that I will appreciate for grad school is how scientific research is done and how scientific papers need to be written." – Samantha-Jo Ebert

Abstract

With continued press coverage of the benefits of eating seafood, diminishing fisheries stocks, an annual seafood trade deficit of $9.5 billion and an ever increasing consumption rate (i.e., the average person consumes 16.5 lbs of seafood per year), aquaculture will continue to increase in importance as a producer of seafood. Currently, aquaculture contributes a little over 33% of the world's fisheries products (FAO, 2007).

There are three primary aquaculture production systems: ponds, race-ways and recirculating systems. Recirculating systems typically take up less space, use less water, provide a controlled culture environment and are generally thought to have less of an environmental impact than other systems. In general, water quality in a recirculating system is maintained through a combination of filtration and treatment equipment. The type of filtration and treatment equipment chosen depends upon several factors including setup and maintenance costs and overall filter efficiency.

Although in use for many years in the municipal wastewater treatment industry, the Parabolic Screen Filter (PSF) was recently introduced to aquaculture for use in ponds and recirculating systems. This filter is relatively inexpensive and advertised for reducing solids, enhancing water quality and requiring little to no maintenance. The filter works by water cascading over a wedge wire screen so that particles are stopped and the water keeps moving through. As particles build up on the screen, they eventually fall into a drain and are carried to a holding basin. The addition of a PSF placed prior to a primary nitrification filter in the system should reduce the amount of solids in the recirculating aquaculture system and therefore enable the primary nitrification filter to function more efficiently.

Determining the Effect of Various Water Conditioners on Holding Success of Mummichog (Fundulus heteroclitus) in Simulated Commercial Holding Tanks

Basic Information

Title:	Determining the Effect of Various Water Conditioners on Holding Success of Mummichog (Fundulus heteroclitus) in Simulated Commercial Holding Tanks
Project Number:	2007DE144B
Start Date:	10/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	At Large
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Non Point Pollution
Descriptors:	
Principal Investigators:	Dennis McIntosh, Adrienne George

Publication

1. George, A. and D. McIntosh, 2008, Determining the Effect of Various Water Conditioners on Holding Success of Mummichog (Fundulus heteroclitus) in Simulated Commercial Holding Tanks, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 4 pages.
2. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 1 Introducing Our 2007−08 Interns, http://ag.udel.edu/dwrc/newsletters/Summer07Fall07/WATERNEWS−Fall2007.pdf , p. 2.
3. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 2 DWRC Annual Poster Session – May 2, 2008, http://ag.udel.edu/dwrc/newsletters/Winter07Spring08/WATERNEWSco−Spring2008.pdf , p. 2.

Undergraduate Internship Project #8 of 10 for FY07

Intern ***Adrienne George's*** project, sponsored by the ***DWRC***, was titled "Determining the Effect of Various Water Conditioners on Holding Success of Mummichog (*Fundulus heteroclitus*) in Simulated Commercial Holding Tanks." She was advised by Dr. Dennis McIntosh of ***Delaware State University's*** Department of Agriculture and Natural Resources.

"As a DWRC intern, I have learned shills that are priceless. I was able to develop communication skills, presentation skills, and research techniques. I know that this program has provided me with a great background that will benefit me in grad school." – Adrienne George

Abstract

Mummichog (*Fundulus heteroclitus*), also known as mud minnows, are local species that reside in shallow estuarine and freshwater areas (Stierhoff et. Al, 2002). They are popular as live bait for flounder, speckled trout, and red drum (Bradley, 2000). Whether they are in a retail holding tank or out in the estuary, water quality is crucial to their survival. During this study mummichog were placed into simulated retail holding tanks under either control conditions, or exposed to one of three water conditioner treatments: sodium chloride, calcium chloride, or Better Bait™ (Sure-Life Laboratories Corporation, Seguin, Texas). Basic environmental conditions (temperature, pH, salinity and dissolved oxygen) and mortalities were counted twice a day, while ammonia was checked three times per week. This study determined that using either salt as a water conditioner (NaCl or CaCl) was a better choice than either the control or the commercial baitfish holding tank water conditioner, Better Bait™.

Effects of Wastewater Disposal on Ground Water Flow in Southern New Castle County

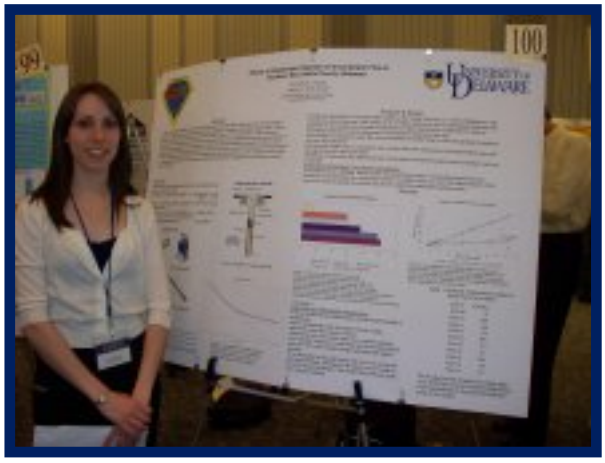
Basic Information

Title:	Effects of Wastewater Disposal on Ground Water Flow in Southern New Castle County
Project Number:	2007DE145B
Start Date:	10/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	At Large
Research Category:	Ground−water Flow and Transport
Focus Category:	Groundwater, Waste Water, Hydrology
Descriptors:	
Principal Investigators:	Alan Scott Andres, Janine Howard

Publication

1. Howard, J. and A.S. Andres, 2008, Effects of Wastewater Disposal on Ground Water Flow in Southern New Castle County, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 19 pages.
2. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 1 Introducing Our 2007−08 Interns, http://ag.udel.edu/dwrc/newsletters/Summer07Fall07/WATERNEWS−Fall2007.pdf , p. 3.
3. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 2 DWRC Annual Poster Session – May 2, 2008, http://ag.udel.edu/dwrc/newsletters/Winter07Spring08/WATERNEWSco−Spring2008.pdf , p. 3.

Undergraduate Internship Project #9 of 10 for FY07



Intern ***Janine Howard's*** project, co-sponsored by the ***DWRC*** and the Delaware Geological Survey, was titled "Effects of Wastewater Disposal on Ground Water Flow in Southern New Castle County." She was advised by Mr. A. Scott Andres of the Delaware Geological Survey.

"My internship at the DGS [Delaware Geological Survey] was a wonderful introduction into real-life field work. I learned how to conduct slug tests on monitoring wells and was also introduced to drill rigs and was able to see one in operation. It was especially beneficial for me to get to participate in the whole process of data acquisition, analysis and interpretation." – Janine Howard

Abstract

The Columbia Aquifer is the main water-bearing Formation that caters to much of New Castle County's water needs, including domestic water supplies, irrigation and public supply wells. The Columbia aquifer is the source of all base flow in the streams of New Castle County. The composition of the Columbia Formation is dominated by sand and gravel and generally unconsolidated featuring high amounts of quartz and moderate amounts of glauconitic sand. Its high permeability, characteristic of unconsolidated sediment, allows it to function as an excellent aquifer. Single well aquifer tests, or slug tests, yield a value of the hydraulic conductivity of the aquifer near a particular well. Thorough testing of wells spread out over a certain region can be used to assemble a ground water flow model of the area which is useful in understanding the transport and fate of contaminants as well as determining the ground water recharge potential of a particular area and, subsequently, sustainable pumping rates. Grasping the behavior of an aquifer is essential to effective management of the water resource which it yields.

This project was conducted to further understand the hydraulics of a region which is due to become a location where up to 13 million gallons per day of wastewater treatment and disposal will need to be carried out in the future (Duffield, 1). Because of water quality problems in the local bodies of surface water and State of Delaware requirements, much of this treated wastewater will be disposed of on the ground (Delaware Code). With the potential for such high quantities of wastewater being applied to the ground at Water Farm No. 2 it is essential to understand the hydraulic properties of the Columbia aquifer at this site in order to accurately predict just how much wastewater it is possible to dispose of per day at the site. Slug tests were used to test the recharge at wells throughout Water Farm No. 2. The results were analyzed to determine the hydraulic conductivity at each well, which ranged from approximately 10 ft/day up to 500 ft/day using the Bouwer (1989) method of calculating hydraulic conductivity.

Hydraulic Properties and Groundwater Flow Modeling of the Unconfined Aquifer in Southern New Castle County

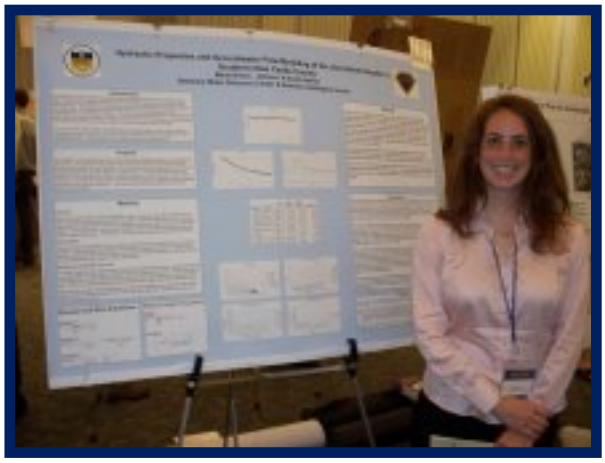
Basic Information

Title:	Hydraulic Properties and Groundwater Flow Modeling of the Unconfined Aquifer in Southern New Castle County
Project Number:	2007DE146B
Start Date:	10/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	At Large
Research Category:	Ground−water Flow and Transport
Focus Category:	Groundwater, Hydrology, Models
Descriptors:	
Principal Investigators:	Alan Scott Andres, Marie Rivers

Publication

1. Rivers, M. and A.S. Andres, 2008, Hydraulic Properties and Ground Water Flow Modeling of the Unconfined Aquifer in Southern New Castle County, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 14 pages.
2. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 1 Introducing Our 2007−08 Interns, http://ag.udel.edu/dwrc/newsletters/Summer07Fall07/WATERNEWS−Fall2007.pdf , p. 3.
3. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 8 Issue 2 DWRC Annual Poster Session – May 2, 2008, http://ag.udel.edu/dwrc/newsletters/Winter07Spring08/WATERNEWSco−Spring2008.pdf , p. 3.

Undergraduate Internship Project #10 of 10 for FY07



Intern *Marie River's* project, co-sponsored by the *DWRC* and the Delaware Geological Survey, was titled "Hydraulic Properties and Ground Water Flow Modeling of the Unconfined Aquifer in Southern New Castle County." She was advised by Mr. A. Scott Andres of the Delaware Geological Survey.

Abstract

Ground water is a valuable resource with properties that cannot be directly observed. Through monitoring wells, the quantity and movement of groundwater can be studied and modeled. In particular, slug tests can be used to determine hydraulic conductivity (K) and the rate that ground water moves in an aquifer. In the field this is achieved by instantaneously adding or removing a volume of water from a monitoring well. For this study, the unconfined aquifer in southern New Castle County, Delaware was chosen. Data were analyzed with the Bouwer and Rice equations by using an Excel spreadsheet and the AquiferTest Pro program by Waterloo Hydrogeologic, Inc.

Hydraulic conductivity is a key factor in determining the amount of water that can flow through or infiltrate into an aquifer. Having site specific K values is important when designing a land-based wastewater disposal system. The study area includes the site of a future Rapid Infiltration Basin (RIBS) that will be designed to serve a new residential development. Slug test-determined K values were used in the Khan and Hantush equations to model mound height and flow rates associated with disposal of wastewater.

Hydrogeologic Characterization of the Potomac Aquifer, Delaware

Basic Information

Title:	Hydrogeologic Characterization of the Potomac Aquifer, Delaware
Project Number:	2007DE97B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	At Large
Research Category:	Ground−water Flow and Transport
Focus Category:	Water Supply, Water Quality, Toxic Substances
Descriptors:	
Principal Investigators:	Susan McGeary, Peter McLaughlin, Claudia Velez

Publication

1. Velez, C., S. McGeary, and P. McLaughlin, 2008, Hydrogeologic Characterization of the Potomac Aquifer Progress Report, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 4 pages.
2. Pautler, M., ed., 2008, Delaware Water Resources Center WATER NEWS Vol. 7 Issue 2 DWRC Announces Two New Graduate Fellowships, http://ag.udel.edu/dwrc/newsletters/Fall06Spring07/WATERNEWS−Spring2007.pdf , p. 6.

Progress Report
Delaware Water Resources Center Graduate Fellowship Project: "Hydrogeologic Characterization of the Potomac Aquifer, Delaware"

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May 1, 2008

Introduction

The Potomac Formation of northern Delaware encompasses the second most used aquifer in Delaware and the most important confined aquifer, providing nearly 20% of the groundwater used each year in the state (Wheeler, 2003). The purpose of this study is to conduct a multidisciplinary analysis of the geologic framework of the Potomac aquifers in the area of the Chesapeake and Delaware Canal. This study will delineate the distribution and extent of aquifer sands, and thereby help to better understand aquifer connectivity and fluid flow pathways. The methodology will employ a novel combination of tools, combining seismic reflection imaging of subsurface geology with analysis of wireline geophysical data from boreholes, collection of core data from the subsurface geologic units, and application of the concepts of sequence stratigraphy. The resulting geologic framework will be tested against hydrological data and observations from the Potomac aquifer. The resulting understanding of aquifer architecture will have significant application to issues in *water supply*, notably a framework of aquifer volume and connectivity for water-use allocations, and in *water quality*, particularly the identification of potential ground-water contaminant pathways below industrial sites in the Delaware City area.

The multidisciplinary analysis was started in 2007 – 2008 with the collection of seismic tests and seismic reflection lines, and establishing an agreement with the Illinois State Geological Survey to collaborate on collection of a seismic reflection dataset with their innovative land streamer system in May 2008.

Objectives

Overall project objectives are:

1) Collect approximately 30 km of intersecting seismic profiles in a 12 km by 12 km area across the buried Potomac Formation down to a depth of about 150 to 300 m (modified slightly from original proposal);
2) Collect 3.5 km of conventional seismic data in farm fields in the study area (newly added objective);
3) Process the seismic reflection data to image subsurface stratigraphy in each profile;
4) Drill two new coreholes and collect geophysical logs at new coreholes and wells,
5) Correlate prominent reflections with the existing and new core, well-log, and geohydrologic database;
6) Interpret the seismic profiles and borehole data to create a 3-dimensional model of the subsurface fluvial architecture within a sequence-stratigraphic framework.

Specific goals for the year 2007 – 2008 are:

1. Collect seismic test profiles in field area using conventional seismic methods
2. Collect seismic reflection data using conventional and land-streamer systems
3. Process seismic data and correlate with borehole data on file at the DGS

Methodology

The methodology that will be used to characterize the hydrogeology of the Potomac aquifer includes:

- Seismic data collection with conventional seismic equipment and a land streamer system.
- Seismic facies analysis using amplitude, frequency, and continuity of the reflections.
- Stratigraphic correlation of well logs using pattern matching and marker beds.
- Coring to obtain sediment cores near the collected seismic lines to characterize the Potomac Formation facies.
- Synthetic seismogram construction to correlate well logs with seismic sections
- Facies mapping to show the distribution of the sand bodies of the Potomac Formation.
- Porosity and permeability measurement of core samples.

Summary of accomplishments for this reporting year (through 1 May, 2008)

- *Successful initial seismic tests completed.* During the spring and summer of 2007, six seismic tests were performed in areas adjacent to the roads where the land-streamer seismic lines for this project will be collected. The seismic equipment owned by the Department of Geological Sciences was used for these tests. Four of the seismic tests were successful, indicating that it is possible to use the seismic reflection method to image the stratigraphy of the study area down to 350 ms (315 m depth). Two unsuccessful tests were performed in areas of the C&D Canal where there appears to be landfill (dredge spoils, etc), suggesting these areas should be avoided for seismic data collection.

- *Conventional, high-resolution seismic profiles acquired.* An opportunity to collect seismic data using conventional seismic methods in the vicinity of the Delaware City Refinery became available to us. Access to the field site, a farm field owned by the Valero refinery (Figure 1), was granted in November of 2007. The data are expected to serve as a control for facies interpretation due to the fact that the field site has been drilled extensively. Access to well data and geophysical logs has been granted and numerous core samples have been donated to the DGS. Four seismic lines comprising 3.5 km of seismic reflection data were collected this past winter using the conventional seismic equipment owned by the Department of Geological Sciences at this field site.

- *Seismic line surveys completed.* Evaluation of the raw seismic data indicated that changes in topography in the area may have an effect on the arrival times of the signal. Therefore, the four lines were surveyed this spring to obtain elevation data for processing purposes.

- *Seismic data processing underway.* The four seismic lines are currently being processed. Initial processing confirmed that reflections were observed in the seismic tests down to 350 ms, which for a velocity of 1800 m/s indicates a depth of 315 m. According to DGS stratigraphic picks, this depth is within the range of basement in the area. Further processing will be conducted.

- *Land-streamer seismic acquisition arranged and scheduled.* After extensive discussions, planning, and contract negotiations between our group and the Illinois State Geological Survey, seismic acquisition is now tentatively scheduled to begin on May 12, 2008. This work is beginning later than anticipated originally due to logistics of the collaborative work arrangement. An additional positive development is that the ISGS will contribute their technician to the project as an operator for the entire period we are using their equipment (original plan was for rental with brief initial orientation).

- *Land-streamer seismic logistics mostly arranged.* In order to collect the seismic data along paved roads, DelDOT requires traffic control personnel during the work. Therefore, three graduate students and four DGS staff members took the flagger course certified by ATSSA in March and April of 2008. These UD personnel, plus possible additional DelDOT and/or contractor personnel, will manage traffic during the field work

Figure 1. Map showing the location of the four conventional, high-resolution seismic profiles (red lines).

Information Transfer Program Introduction

None.

Delaware Water Resources Center FY07 Information Transfer Activities

Basic Information

Title:	Delaware Water Resources Center FY07 Information Transfer Activities
Project Number:	2007DE142B
Start Date:	3/1/2007
End Date:	2/29/2008
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 FY07, consolidating reporting into a single project **#2007DE142B**. All activities from the DWRC's FY06 Information Transfer project **(#2006DE114B)** continued into this year. A new addition to the program for FY07 was conversion of WATER NEWS to an electronic-only format.

The FY07 DWRC Information Transfer Activities include:

- Delaware Water Resources Center Electronic Publication WATER NEWS (2000 – 2006 = print; 2007 – present = electronic)
- 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 Conference Co-sponsor and Participant (2001 – present)
- Delaware Water Resources Center Co-sponsored 2007 Lecture Series

Basic Information:
Delaware Water Resources Center Electronic Publication WATER NEWS

Title:	"WATER NEWS"
Issues during FY07:	Volume 7 Issue 2 (Fall 2006 – Spring 2007) Volume 8 Issue 1 (Summer – Fall 2007)
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; Maria Pouter, Editor

WATER NEWS is received electronically by over 250 recipients in water-related academic, government, public and private agency, agriculture and industry positions in Delaware and the surrounding area as well as 100 nationwide contacts for water resource issues. It may be accessed via the Delaware Water Resources Center website at: http://ag.udel.edu/dwrc/news.html.

FY07 topics included:

- Delaware River Was the Focus of the 6th Statewide Water Forum
- Delaware AWRA Hosted the 2007 Mid-Atlantic Sections' Conference
- DWRC Announced Two New Graduate Fellowships
- DGS Completed Report on Domestic Well Water Quality
- Ten New DWRC 2007-2008 Interns Selected
- Mid-Atlantic Regional Water Quality Program
- DWRC History, Goals, Advisory Panel, Contacts

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

Title:	"WATER E-NEWS"
Issues during FY07:	Vol. 7 Issue 1 Feb. '08
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; Maria Pouter, Editor

WATER E-NEWS is received electronically by over 250 recipients in water-related academic, government, public and private agency, agriculture and industry positions in Delaware and the surrounding area. 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. News items about the DWRC, including undergraduate internships and graduate fellowships
II. Jobs in Water Resources
III. Upcoming Water Conferences / Events
IV. Water Resources Information / Training

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; Maria Pouter, 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; Maria Pouter, 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 website 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 an e-mail 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 February 2008.

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

Title:	University of Delaware 2008 Undergraduate Research Scholars Poster Session with DWRC Advisory Panel Meeting
Date:	May 2, 2008
Description:	Undergraduate interns presented their 2007-2008 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 May 2, 2008, nine of the ten undergraduate student interns who had been funded in 2007-2008 by the DWRC, accompanied by their advisors, presented the results of their research 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 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 2008-2009 with regard to research funding and public education outreach efforts such as statewide water forums.

Poster Presentations by 2007-2008 DWRC Undergraduate Interns – May 2, 2008

1) Chatter son, Sarah. Presentation May 2, 2008. Willingness to Pay for Sustainable Agricultural Practices in an Urbanizing Region. 2008 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

2) Ebert, Samantha-Jo. Poster Presentation May 2, 2008. Can a Parabolic Screen Filter Improve the Quality of Water in a Recirculating Aquaculture System? 2008 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

3) George, Adrienne. Poster Presentation May 2, 2008. Determining the effect of various water conditioners on holding success of mummichog (*Fundulus heteroclitus*) in simulated commercial holding tanks. 2008 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

4) Handlin, Jennifer. Poster Presentation May 2, 2008. Evaluating the Use of Zerovalent Iron to Remove Viruses from Water: Effect of pH. 2008 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

5) Howard, Janine. Poster Presentation May 2, 2008. Effects of Wastewater Disposal on Ground Water Flow in Southern New Castle County. 2008 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

6) Kiracofe, Nathan. Poster Presentation May 2, 2008. Comparison of the Impacts of Poultry Litter vs. Urea on Surface Runoff Water Quality. 2008 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

7) Rivers, Marie. Poster Presentation May 2, 2008. Hydraulic Properties and Ground Water Flow Modeling of the Unconfined Aquifer in Southern New Castle County. 2008 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

8) Ukaegbu, Oluchi. Poster Presentation May 2, 2008. Freshwater Mussels (*Elliptio complanata*) as a Biomechanical Filter in Aquaculture Ponds. 2008 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

9) Yayac, Laura. Poster Presentation May 2, 2008. The University of Delaware Experimental Watershed: A Green Campus Initiative. 2008 University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

Basic Information:
Delaware Statewide Conference (served as the annual Delaware Water Policy Forum) Co-Sponsor and Participant

Title:	2007 American Water Resources Association Mid-Atlantic Conference: "Green Opportunities for a Blue Resource: An Economic Perspective"
Date:	September 19-21, 2007
Description:	Presentation of DWRC recent accomplishments and program goals; DWRC information booth; Complete article is found in DWRC Summer – Fall 2007 WATER NEWS at http://ag.udel.edu/dwrc/newsletters/Summer07Fall07/WATERNEWS-Fall2007.pdf , pages 3-4
Lead Institute:	Co-sponsored by the Delaware Water Resources Center, University of Delaware Institute for Public Administration-Water Resources Agency, Delaware Department of Natural Resources and Environmental Control, Delaware Department of Transportation, Terre Hill Stormwater Systems, University of Maryland Department of Environmental Science and Technology-Natural Resources Management Program.
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)

The 2007 American Water Resources Association Mid-Atlantic Conference (taking the place of the seventh annual Delaware Water Policy Forum this year), titled "Green Opportunities for a Blue Resource: An Economic Perspective" was held for about 100 visitors from Delaware government, water agencies, academia, and the public, from September 19-21, 2007 at Clayton Hall on the University of Delaware campus in Newark, Delaware. Expert speakers, in panel and concurrent sessions, discussed economic impacts and solutions, watershed planning, restoration/retrofits, drinking water, and urban case studies. Four local field trips were offered as well.

Basic Information:
Delaware Water Resources Center Co-sponsored 2007 Lecture Series

Title:	DWRC co-sponsored 2007 lecture series
Dates:	November 5, 2007: "Christina River: Linking Land, Water, and People"
Description:	Series of free public presentations on Delaware's Watersheds
Lead Institute:	**Coordinated by:** Delaware Nature Society **Sponsored by:** United Water Christina Conservancy City of Wilmington Dept. of Public Works **Delaware Water Resources Center** **Supported by:** Partnership for the Delaware Estuary Delaware Dept. of Natural Resources and Environmental Control

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR−USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	10	0	0	0	10
Masters	0	0	0	0	0
Ph.D.	2	0	0	0	2
Post−Doc.	0	0	0	0	0
Total	12	0	0	0	12

Notable Awards and Achievements

Research Program: The Delaware Water Resources Center (DWRC) has funded twelve research grant projects during March 2007 through February 2008 that address state water resources priorities identified by the DWRC's Advisory Panel. Two of these projects are graduate fellowships with research focuses on 1) hydrogeologic characterization of the Potomac Aquifer, Delaware and 2) modeling hydrologic and geochemical effects of land−based wastewater disposal. The remaining ten projects were undergraduate internships researching 1) willingness to pay for sustainable agricultural practices; 2) parabolic screen filters for improved aquaculture water quality; 3) stress levels to mummichogs; 4) zerovalent iron to remove pathogens from water; 5) effects of wastewater disposal on ground water flow in southern New Castle County, DE; 6) the impacts of poultry litter vs. urea on surface runoff water; 7) the benefit−cost analysis of pelletized broiler litter in crop production and turf grass management; 8) ground water flow modeling of the unconfined aquifer in southern New Castle County, DE; 9) freshwater mussels as filters for aquaculture pond water quality; and 10) the University of Delaware experimental watershed.

Publications from Prior Years

1. 2002DE4B ("Graduate Fellowship in Water Quality: Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation") − Articles in Refereed Scientific Journals − Hunger, S., J.T. Sims, and D.L. Sparks, 2008, Evidence for Struvite in Poultry Litter: Effect of Storage and Drying, Journal of Environmental Quality, 37, 1617−1625.