DEVELOPMENT OF THE UNIVERSITY OF DELAWARE EXPERIMENTAL WATERSHED PROJECT

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ABSTRACT: In 2000, a team of University of Delaware undergraduate and graduate students developed the University of Delaware Experimental Watershed Project with a grant from the Delaware Water Resources Center. The University of Delaware (UD) is a land- and sea-grant institution in Newark, Delaware and is perched along the Atlantic seaboard's fall line. A critical mass of UD faculty and students in water resources and related disciplines are interested in the development of an experimental watershed on campus to provide (1) interdisciplinary undergraduate, graduate and faculty research opportunities, and (2) an outdoor education laboratory. Using GIS and field reconnaissance techniques, the three students delineated two small experimental watersheds respectively located in the Piedmont and Coastal Plain provinces of the White Clay Creek Wild and Scenic River Valley on the UD campus. The Piedmont watershed drains 427 acres of north Laird campus while the Coastal Plain watershed drains 896 acres including the UD Mall and southern sections of campus including the UD farm. The students then developed an ArcView GIS atlas integrating geology, soils, topography, land use, and impervious cover layers with a rating system for water quality and habitat characteristics to issue a "report-card" assessing each watershed's overall health. The White Clay Creek Wild and Scenic River Valley is an ideal campus location for an outdoor education and research laboratory because of its manageable scale, the diversity of its characteristic land uses and physical environment, and above all its accessibility for students, faculty, researchers, and the public.
KEY TERMS: watershed; GIS; White Clay Creek Wild and Scenic River; education; impervious cover; water quality.

Introduction

The Delaware Water Resources Center at the University of Delaware College of Agriculture and Natural Resources awarded a grant to develop and establish the University of Delaware's first Experimental Watershed. One of the fundamental indicators of a stream's water quality is the condition or health of the watershed. Numerous studies have documented that impacts from the land in a watershed will affect the water quality of streams. Urban and suburban land uses, impervious cover, lack of riparian buffers, deforested land, and contaminant sources in a watershed all can have a deleterious effect on stream water quality. Many colleges and universities throughout the U.S. have established on-campus experimental watershed programs, including Michigan State University (Witter, Kline-Robach, Poston, Lang, 2000) and Shippensburg University (Woltemade and Blewett, 2000). There is a critical mass of water resources interests at the University of Delaware that are interested in the use of an experimental watershed on University land for research and educational purposes. This paper describes the goals and objectives of the project, the methods used to designate and characterize the health of the watershed and the final results and implications of a watershed rating system based on the methods we have established. The overall intention of this report and the project is to establish the groundwork for a watershed-based education and research program at the University of Delaware. Further information and an update on the progress of this project can be obtained from the UD Water Resources Agency website at: www.wr.udel.edu.

Objectives

The objectives of this project are to develop a method to assess and characterize the health of the UD Experimental Watershed using a geographical information system (GIS) based on several key parameters: impervious cover, land-use, habitat availability, and water quality; and to create an outdoor living laboratory, providing dynamic educational and research opportunities for university faculty, staff and students.

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The Watershed Study Area

The White Clay Creek watershed drains 69,000 acres in Pennsylvania and Delaware and affects 95,000 people in its boundaries. It is one of only a few relatively intact, unspoiled and ecologically functioning river systems remaining in the highly congested and developed corridor between Pennsylvania and Delaware. In October 2000, the White Clay Creek was awarded the federal designation as a Wild and Scenic River, preserving the river system which is a key source of drinking water for northern Delaware, in a free-flowing condition and protecting the environment (White Clay Creek Wild and Scenic Rivers Study Task Force, 1999).

Two geographically separate subwatersheds were selected for the University of Delaware Experimental Watershed, both lying within the White Clay Creek Wild and Scenic River Valley boundaries, in the city of Newark, Delaware. The University has the unique feature of falling on the geographic fall line between the Piedmont and Coastal Plain provinces. The first watershed includes three unnamed tributaries of White Clay Creek in the Piedmont physio-graphic province. Called the "Piedmont Experimental Watershed," it drains 427 acres of the northern boundaries of the UD campus, a residential development, and White Clay Creek State Park. The second area is known as the "Coastal Plain Experimental Watershed" because it drains 896 acres of the Coastal Plain physio-graphic province into the headwaters of the Cool Run tributary of the White Clay Creek, and includes the UD Mall and southern agriculture farm facilities and downtown Newark, Delaware. Figure A depicts the Piedmont and Coastal Plain portions of the UD Experimental Watershed.

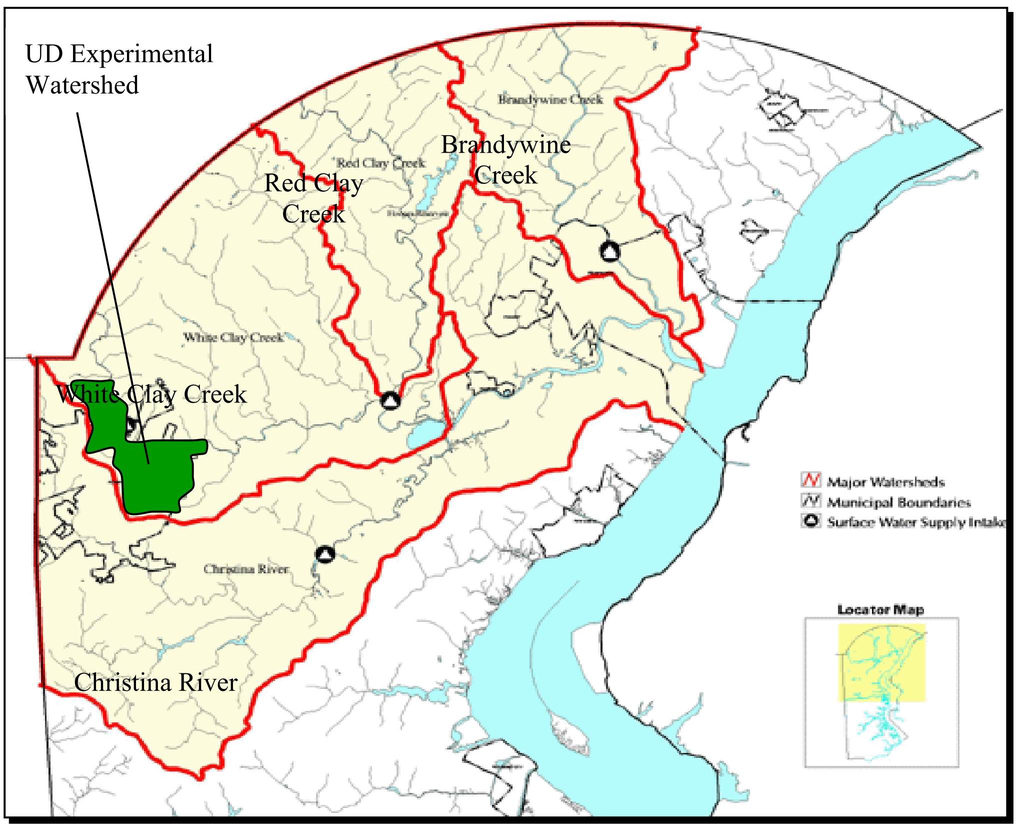

Figure 1. New Castle County, Delaware major watersheds.

Methodology

Field reconnaissance methods were used to develop a GIS base-map to delineate the University of Delaware Experimental Watershed. The selected areas contain land-uses representative of northern New Castle County, Delaware including urban and suburban uses, open space, forested land, and agriculture uses. The GIS watershed base-map includes hydrology, roadways, watershed boundaries, and digital ortho-photographs as a base. The watershed base map identifies 20 stations that will be used for water quality and habitat monitoring by researchers. Information on topography, soils, geology, land-use, and physical landmarks were also added to the project database for future use.

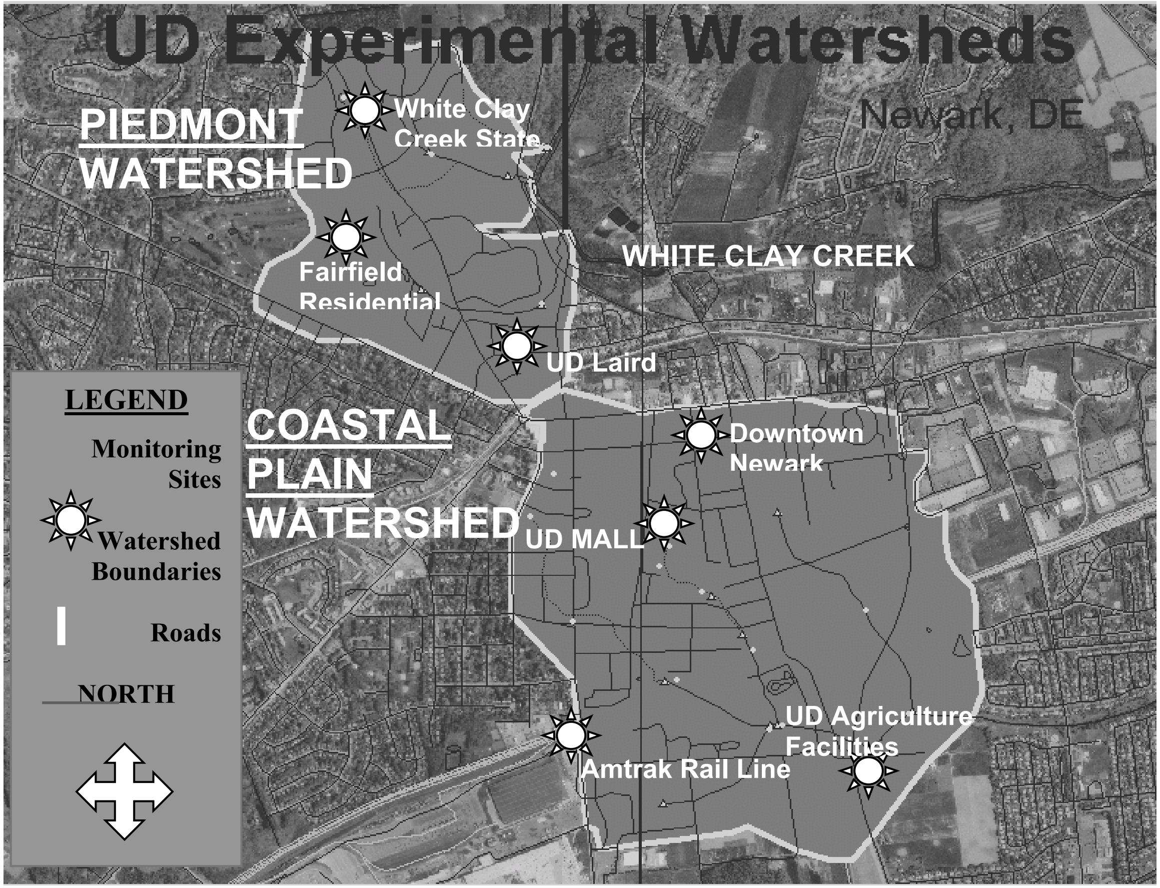

Figure 2. ArcView GIS map of the subwatersheds of the University of Delaware Experimental Watershed.

Following the compilation of the GIS Atlas, field inventories were conducted to collect water quality and habitat data. Water quality tests were completed at each monitoring site identified on the GIS base-map, and used to assess the links between land-use and water quality and to establish baseline data. Water samples were tested for the following concerns: alkalinity, ammonia, chlorides, chlorine, chromium, copper, dissolved oxygen, biochemical demand, hardness, iron, nitrates, phosphates, pH, and hydrocarbons. A 1 to 4 rating scale was developed for each chemical parameter, based on state and federal recommended contaminant limits, and a recommended (normal) range for each test. A site receiving a rating of one indicated the stream was in excess of the recommended limit. A rating of four indicated the contaminant level tested at the lowest end of the recommended (normal) range.

Surveys for stream habitat and riparian buffer were conducted using a hybrid version of a Delaware Nature Society habitat survey, the USEPA Habitat Assessment and the USEPA Rapid Stream Bio-assessment procedures in order to test the stream and characterize the health. A similar 1 to 4 rating system was applied here as well. A rating of one represented conditions were very poor, while a rating of four indicated a very healthy habitat. Land-use and impervious cover ratings were determined using a slightly different system, rather then determining a land-use and impervious cover score for each monitoring site, a single score was determined for the stream, then averaged together to arrive at the final sub-watershed rating. Each land-use identified in the Experimental Watershed was given a rating using the equations in Table 1.

Table 1. Land use equations to determine grade for rating.

Land Use	Rating	Equation
Institutional	3	3 x (# institutional acres/total # acres in sub-watershed)
Commercial	2	2 x (# commercial acres/total # acres in sub-watershed)
Agricultural	2	2 x (# agricultural acres/total # acres in sub-watershed)
Wooded	4	4 x (# Wooded acres/total # acres in sub-watershed)
Public/Private Open Space	4	4 x (# open space acres/total # acres in sub-watershed)
Single Family Residential	3	3 x (# Single family acres/total # acres in sub-watershed)
Multi-family Residential	2	2 x (# multi-family acres/total # acres in sub-watershed)

Each specific land-use was issued a rating, then multiplied by the percentage to determine the grade. The land-use grades were then summed to establish the overall land-use grade for each stream. The impervious cover grade was derived in a similar fashion. The percentage of imperviousness was determined for each stream by multiplying the number of acres for each land-use by an impervious factor, then applying a 1 to 4 rating system based on the percentages in Table 2 that were taken from a study conducted by Anne Kitchell of the Water Resources Agency and most recently from the Center for Watershed Protection.

Table 2. Impervious cover rating scale.

Rating	Watershed Imperviousness	Impact to Stream
4	0%	No Impact
3	0-10%	Sensitive
2	10-25%	Impacted
1	> 25%	Non-Supporting of Aquatic life

From the data collected in the water and habitat quality inventories, a set of indicators were compiled based on the total sub-watershed area, land-use, and impervious cover and developed into GIS layers to indicate stream health on the base-map. The indicators were also used to design the overall rating system, also on a scale of 1 to 4, with streams receiving a score of one having the lowest health or quality, and those with a four being of the highest quality. The individual rating systems developed for the four parameters, water quality, habitat quality, land-use, and impervious cover were collected from each monitoring site or segment and averaged to obtain a stream grade. The stream grade was then averaged with all the streams in the sub-watershed to establish an overall watershed grade for each parameter. The scores for each parameter were then averaged together to determine the final watershed rating. Each rating corresponded with a letter "grade, " similar to the grading system for academic institutions in order to issue a "report card" assessment of the UD Experimental Watershed. Table 3 is an example of the report card for the University of Delaware "Piedmont" Experimental Watershed. The University of Delaware community will be able to use the data collected annually as a research and education tool to monitor temporal trends.

Table 3. Piedmont UD Experimental subwatershed final report card.

PIEDMONT WATERSHED REPORT CARD					
STREAM	WATER QUALITY	LANDUSE	IMPERVIOUS COVER	HABITAT ANALYSIS	FINAL GRADE
PENCADER CREEK					C
P1PC	2.5	3.1	1.0	1.1	1.9
P2PC	2.6			2.9	2.4
P3PC	2.5			2.4	2.2
FINAL GRADE	2.5	3.1	1.0	2.1	2.2
FAIRFIELD RUN					C+
P5FR	2.8	3.3	1.0	3.1	2.5
P6FR	2.6			2.5	2.3
P7FR	2.6			2.7	2.4
FINAL GRADE	2.7	3.3	1.0	2.8	2.4
LOST STREAM					B
P9LS	2.9	3.8	3.0	3.0	3.2
FINAL GRADE	2.9	3.8	3.0	3.0	3.2
WATERSHED FINAL GRADE	2.7	3.4	1.7	2.6	2.6
WATERSHED FINAL LETTER GRADE*	B-	B+	C-	B-	B-

Conclusions

Student researchers have conducted research to delineate and develop baseline data for a University of Delaware Experimental Watershed as an on-campus education and research tool for faculty, staff, students and the public. The researchers have designed a user-friendly "report card" which can be used to assess and compare the temporal changes in health of the Experimental Watershed as analysis is conducted by students during future semesters. Several conclusions and implications can be drawn from the research:

1. **Basis for the Experimental Watershed** - This research forms the basis for establishing the University of Delaware Experimental Watershed as an on-campus education and research tool for faculty, staff, students and the public.

2. **Precedence Among Other Universities -** The UD Experimental Watershed joins a host of other universities and college through the U.S. that have established watersheds for on-campus education and research opportunities.

3. **Applicability to UD Curriculum** - Faculty and staff from several disciplines in the various colleges and departments at the University of Delaware have expressed interest in conducting education and research at the Experimental Watershed. The class of UAPP 667 Regional Watershed Management offered by the School of Urban Affairs and Public Policy conducted a fall 2000 class in stream geomorphology at the experimental watershed. A cohort of middle school teachers toured the Experimental Watershed as part of a watershed training module for 7^{th} graders sponsored by the UD Math and Science Education Resource Center.

4. **Transferability of the Watershed Mapping Process** - The 4-step ARCVIEW watershed mapping process developed during this research can be used to delineate experimental watersheds at colleges, high schools, and elementary schools and other campuses. For instance, the researchers trained staff from the St. Andrews School in Middletown, Delaware in the techniques to map an experimental watershed on their campus.

5. **Relationship of Watershed Land Use to Stream Health** - Through the analysis of land use, impervious cover, water quality, and stream habitat; the student researchers learned about the relationship between watershed land use and stream health. For instance, the Lost Stream Watershed with the largest areas of forest and open space and lowest imperviousness had a grade of "B" which is higher than the Pencader Creek and Fairfield Run watersheds, which had grades of "C" with larger areas of urban/suburban use and higher imperviousness.

6. **Transferability of Watershed Report Card** - The student researchers developed a user-friendly report card to track the health of the Experimental Watershed now and in future semesters. The report card uses an A, B, C, D, F grading system (familiar to teachers, students, and the public) that can be used not only for the UD Experimental Watersheds but in other watersheds throughout Delaware and the mid-Atlantic region.

7. **Recommendations for the Future:**

   Grant Proposal - Prepare and submit a grant proposal to secure more permanent funding from a public agency, corporation, and or foundation to sustain the University of Delaware Experimental Watershed. The grant would be intended to fund scholarship and research at the experimental watershed during future semesters.

   Oversight Committee - Form a committee of interested faculty, staff, and UD facilities management to oversee the UD Experimental Watershed. The committee would also work with the UD facilities management department to recommend that maintenance, landscaping, and improvements on campus include best management practices to protect the streams.

   Official Stream Names – File an application to assign official USGS names to the three unnamed tributaries of the White Clay Creek in the Piedmont Watershed and to the branches of the Cool Run Tributary that make up the Coastal Plain Watershed to provide a method of recognition for the Experimental Watershed.

   Public Outreach - Work with the UD Facilities Management Department to erect a series of signs delineating the experimental watershed for faculty, staff, students and visitors to the campus. The signs would be discrete and aesthetic.

   Field Station Indicators - Begin keeping a log to establish a long term period of record for the following indicators to track possible climate changes:

   - Temperature/Precipitation - State Climatologist's Office at Pearson Hall.

- Stream Flow -USGS Gage at White Clay Creek at Newark.
- Date of Leaf Off/Leaf on - Sugar Maple Tree on UD Main Mall.
- Date of First Flower Crocus, Forsythia, Cherry Tree on UD Main Mall.
- Date of Ice On/Ice off White Clay Creek.

Acknowledgements

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FRIDAY
JUNE 29, 2001

DAY-AT-A-GLANCE

7:30 AM-12:00 NOON
BOOK/JOURNAL EXHIBIT OPEN

7:30 AM-3:30 PM
REGISTRATION DESK OPEN

8:30 AM-10:30 AM
CONCURRENT SESSIONS
24, 25, 26, 27

10:00 AM-10:30 AM
NETWORKING BREAK

10:30 AM-12:00 NOON
CONCURRENT SESSIONS
28, 29, 30, 31

12:00 NOON-1:15 PM
LUNCH BREAK (ON YOUR OWN)

1:30 PM-3:00 PM
CONCURRENT SESSIONS
32, 33, 34, 35

3:00 PM-3:30 PM
NETWORKING BREAK

3:30 PM-5:00 PM
CONFERENCE SUMMATION

SATURDAY
JUNE 30, 2001

DAY-AT-A-GLANCE

8:00 AM-5:00 PM
TECHNICAL FIELD TRIP #3 – THE 2002 WINTER OLYMPIC VENUES & CENTRAL UTAH PROJECT'S JORDANELLE DAM & SCADA PROJECT (SEE PG. 13)

Book/Journal Exhibit

During the conference there will be a display of publications from a variety of publishers on numerous aspects of water resources, education, conservation, and technology. It is a unique opportunity for you to review new literature in the field. Books will be on display Wednesday and Thursday, and until 12:00 noon on Friday, June 29.

FRIDAY / JUNE 29 / 8:30 AM-10:00 AM
CONCURRENT SESSIONS 24, 25, 26, 27

SESSION 24
TMDL ISSUES AND CHALLENGES

Issues Related to the Success of the TMDL Program - Bethany T. Neilson, Utah State University, Logan, UT

Designing a Risk Based TMDL Process - Upmanu Lall, Columbia University, New York, NY

TMDL Analysis in the Teton Watershed Using Bayesian Decision Networks - Daniel P. Ames, Utah State University, Logan, UT

The Pollutant Loading Model - Chuck Gillette, Psomas and Associates, Salt Lake City, UT

Evaluation of Biological Assessment Data and Protocols for TMDL Reports - Tamim Younos, Virginia Tech, Blacksburg, VA (co-author: Jane L. Walker)

SESSION 25
INNOVATIVE APPROACHES TO WATERSHED MANAGEMENT

Development of the University of Delaware Experimental Watershed Project - Jennifer Campagnini, University of Delaware, Newark, DE (co-authors: Gerald Kauffman, Martha Corrozi, Justin Bower)

Incorporating Land Use and Land Cover into Watershed Decision Support - Daniel G. Brown, University of Michigan, Ann Arbor, MI (co-authors: J. David Allan, Gloria Helfand, Joan Nassauer, Jiunn-Der Duh)

Integrating an Inventory of Watershed Resources Using GIS Dynamic Segmentation - Jane F. Ruthford, City of Seattle, North Bend, WA

Application of the Fuzzy Logic Approach for Watershed Assessment - D. Phillip Guertin, The University of Arizona, Tucson, AZ (co-author: Scott N. Miller)

SESSION 26
USE OF DECISION SUPPORT IN WATER SUPPLY SYSTEMS

Dynamic Model of Mexico City's Water Supply System - Ricardo Martinez-Lagunes, Comision Nacional del Agua, Mexico, D.F. (co-authors: Jorge Hidalgo, Juan Huerta, Juan C. Valencia)

A Decision Support Model for Operating the Reservoirs and Aqueducts of the Eastern Massachusetts Water Supply System - Kirk Westphal, Tufts University, Southborough, MA (co-authors: Richard Vogel, Paul Kirshen)

Sarasota County, Florida Water Supply Decision Support System - A Case Study - Wendy Nero, CH2M Hill, Tampa, FL (co-author: Edward Goscicki)

Standley Lake Emergency Response Plan - Dan Strietelmeier, City of Westminster, Westminster, CO