Development of the University of Delaware

Experimental Watershed Project

March 31, 2001

Prepared to fulfill the requirements of:

Undergraduate Internships in Water Resources
Dr. Tom Sims, Director
Cynthia Greene
Delaware Water Resources Center
Department of Plant and Soil Sciences
University of Delaware
Newark, DE 19716-1303

Prepared by:

Jennifer Campagnini, Undergraduate Researcher
University of Delaware
College of Agriculture and Natural Resources
Newark, DE 19716

Project Advisor:

Gerald Kauffman PE, Water Coordinator
University of Delaware
Institute for Public Administration - Water Resources Agency
DGS Annex
Newark, DE 19716

Acknowledgements

This research report was prepared by Jennifer Campagnini to fulfill the requirements of the Undergraduate Internships in Water Resources program funded by the Delaware Water Resources Center (DWRC). Many thanks to Dr. Tom Sims and Cynthia Greene of the DWRC for their leadership in developing this program to provide opportunities for undergraduate research. Bernard Dworsky was successful in securing matching funding for the project. Gerald Kauffman created the concept of the Experimental Watershed for the University of Delaware and served as Project Advisor. Martha Corrozi and Justin Bowers, Graduate Research Assistants, provided many hours in the field and in the office collecting data and preparing GIS mapping for the Experimental Watershed Project. Many thanks to the Delaware Nature Society and the White Clay Watershed Association for their assistance providing research techniques and data. We hope this report provides the basis for establishing the University of Delaware Experimental Watershed as an on-campus education and research site in future semesters for faculty, staff, students and the public.

Table of Contents

List of Figures

List of Tables

List of Exhibits

Development of the University of Delaware Experimental Watershed Project
March 31, 2001

Chapter One: Background and Justification

Introduction

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 stream water quality (Schueler, 1995). Urban and suburban land uses, impervious cover, lack of riparian buffers, deforested land, and contaminant sources in a watershed can have a deleterious effect on stream water quality.

There is a critical mass of water resources interests at the University of Delaware (UD) that are interested in the use of an experimental watershed on university land for research and educational purposes. 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. 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 concept of a on campus experimental watershed is not new. The following colleges and universities throughout the United States have established the precedent for experimental watersheds for education and research purposes:

- Cornell University/Dartmouth College/Syracuse University consortium
- Michigan State University (Witter, Robach, Poston and Lang, 2000)
- Pennsylvania State University
- Shippensburg University (Woltemade and Blewett, 2000)
- University of Arizona - Walnut Gulch watershed
- University of California, San Diego
- Williams College, Massachusetts

Objectives

Project objectives were to develop a method to assess and characterize the health of the UD Experimental Watershed using a Geographical Information System (GIS) based on four key parameters: water quality, habitat availability, land use, and impervious cover. The effort is designed to create an outdoor living watershed laboratory to provide dynamic educational and research opportunities for university faculty, staff and students. The student researchers conducted the work in accordance with the following research approach:

1. **Delineate Experimental Watershed** - Conduct field reconnaissance and develop a GIS base map to delineate the experimental watersheds.
2. **Compile GIS Atlas -** Develop GIS overlays to assess the health of the experimental watershed including geology, topography, soils, land use and impervious cover.

3. **Conduct Field Research** -Conduct field research to collect data for stream water quality and stream habitat assessments.
4. **Develop Watershed Indicators** - Compile watershed indicators to assess the health of the streams.
5. **Compile Report Card** - Compile a report card based on a letter or numerical index that characterizes the health of the experimental watershed based on the environmental indicators.
6. **Prepare Research Report** - Prepare a poster and research report summarizing the findings of the University of Delaware Experimental Watershed Project.

Watershed Study Area

The University of Delaware dates to 1743 and is the land-grant, sea-grant, space-grant, and urban-grant institution of higher learning for the State of Delaware. The total University of Delaware enrollment is 18,000 students at the main campus in Newark, Delaware and at campuses in Wilmington, Dover, Georgetown, and Lewes (Figure 1). The UD Experimental Watershed is situated at the main campus in Newark. Figure 2 shows the location of the UD Experimental Watershed on a map of the United States divided by watershed boundaries.

Watersheds are often defined as all of the land areas contributing runoff or draining to a singular watercourse (Reimold, 1998). Watersheds are the logical hydrologic planning unit for water, land, and ecosystems management. Watersheds know no political boundaries. Therefore, the watershed can be used to include often disparate stakeholders and interests from different governments in water resources management. Watersheds are often classified according to the following hierarchy (Schueler, 1995):

- Basin (1000 - 100,000 sq. mi.)
  - Sub-basin (100 - 1000 sq. mi.)
    - Watershed (10 -100 sq. mi.)
      - Sub-watershed (1 - 10 sq. mi.)
        - Catchment (0.05 - 0.5 sq. mi.)

The University of Delaware Experimental Watershed, technically classified as a sub-watershed, is situated in the Delaware River Basin according to the following hierarchy of watersheds:

Table 1. The UD Experimental Watershed Nested in the Hierarchy of Watersheds.

Watershed	Area (sq. mi.)
Delaware River Basin (Figure 3)	13,000
Christina River Basin (Figure 4)	640
White Clay Creek Watershed (Figure 5)	108
University of Delaware Experimental Watershed (Figure 6)	2

The University of Delaware (UD) Experimental Watershed lies within the boundaries of the White Clay Creek watershed which drains 69,000 acres (108 sq. miles) in Pennsylvania and Delaware and is the home of 95,000 people. The White Clay Creek watershed 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 President and Congress designated the White Clay Creek 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 (U.S. National Park Service, 1999).

Student researchers selected two geographically separate candidate catchments for the University of Delaware Experimental Watershed based on the following criteria:

- **On-Campus** - All or part of the experimental watershed (s) should be on University of Delaware property.
- **Proximity to Classrooms** - At least one of the experimental watersheds should be within one mile of UD classrooms to facilitate use of the site for education and research purposes.
- **White Clay Creek** - The experimental watersheds should be situated in the White Clay Creek watershed, which has special significance as a recently designated Wild and Scenic River. This stream is the only Wild and Scenic River in Delaware and is the first to be designated nationally on a watershed basis instead of a river segment basis.
- **Physiographic Province** - The UD Newark campus is fortunately (from a hydrologic point of view) situated on the "fall line" which runs from Maine to Alabama and separates the hilly, rocky piedmont from the flat, sandy coastal plain province. The experimental watershed should be delineated in the piedmont and coastal plain provinces.
- **Land Use** - The experimental watersheds should include land uses characteristic to New Castle County, Delaware.

Because the University of Delaware has the unique feature of falling on the geographic fall line between the piedmont and coastal plain provinces, two sub-watersheds were delineated to differentiate between the provinces. The first sub-watershed includes three unnamed tributaries of White Clay Creek in the piedmont physiographic province. Called the "Piedmont Experimental Watershed," it drains 416 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" and it drains 896 acres of the coastal plain physiographic province into the headwaters of the Cool Run tributary to the White Clay Creek. The Coastal Plain Watershed includes the UD mall and agriculture farm facilities and downtown Newark, Delaware. Figure 6 depicts the Piedmont and Coastal Plain sub-watersheds of the experimental watershed superimposed on a University of Delaware (Newark) campus map.

Figure 1. *University of Delaware Campuses: Wilmington, Newark, Dover, Georgetown, and Lewes.*

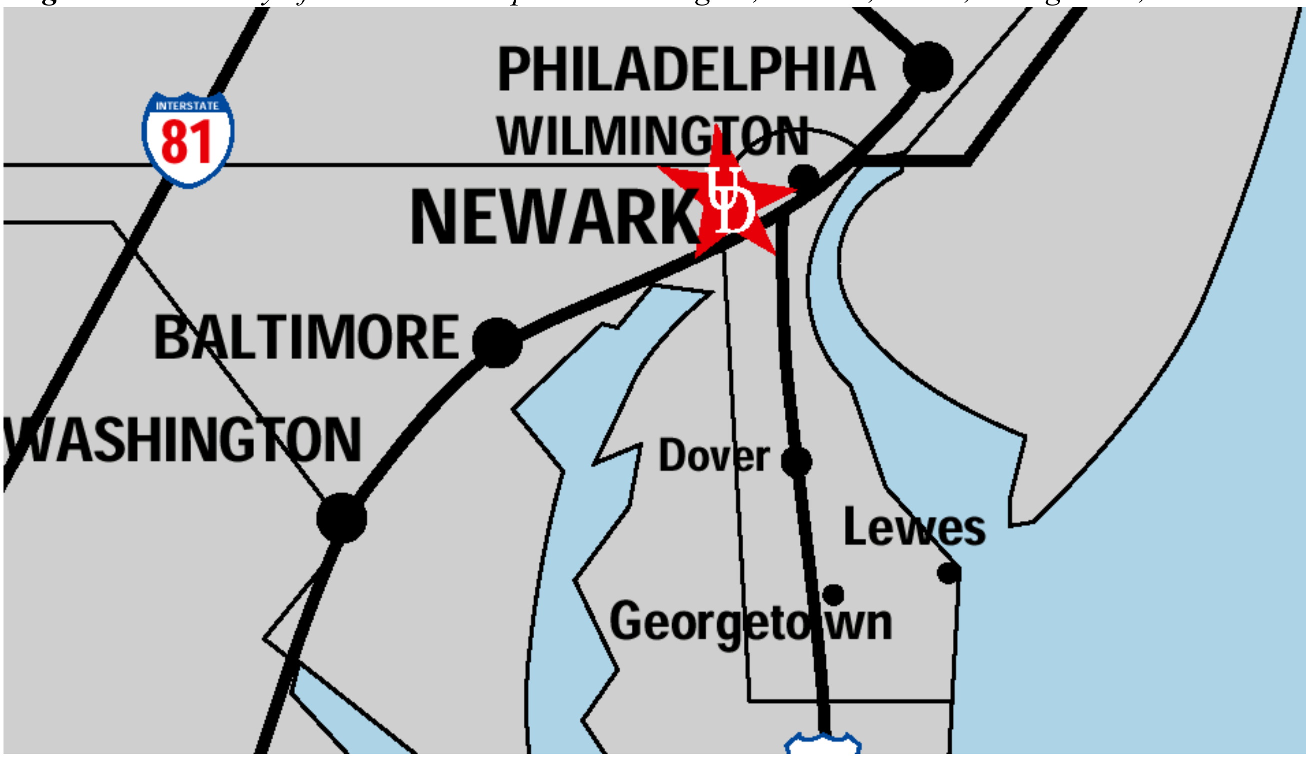


Figure 2. *University of Delaware shown on a US Map divided on a watershed basis.*

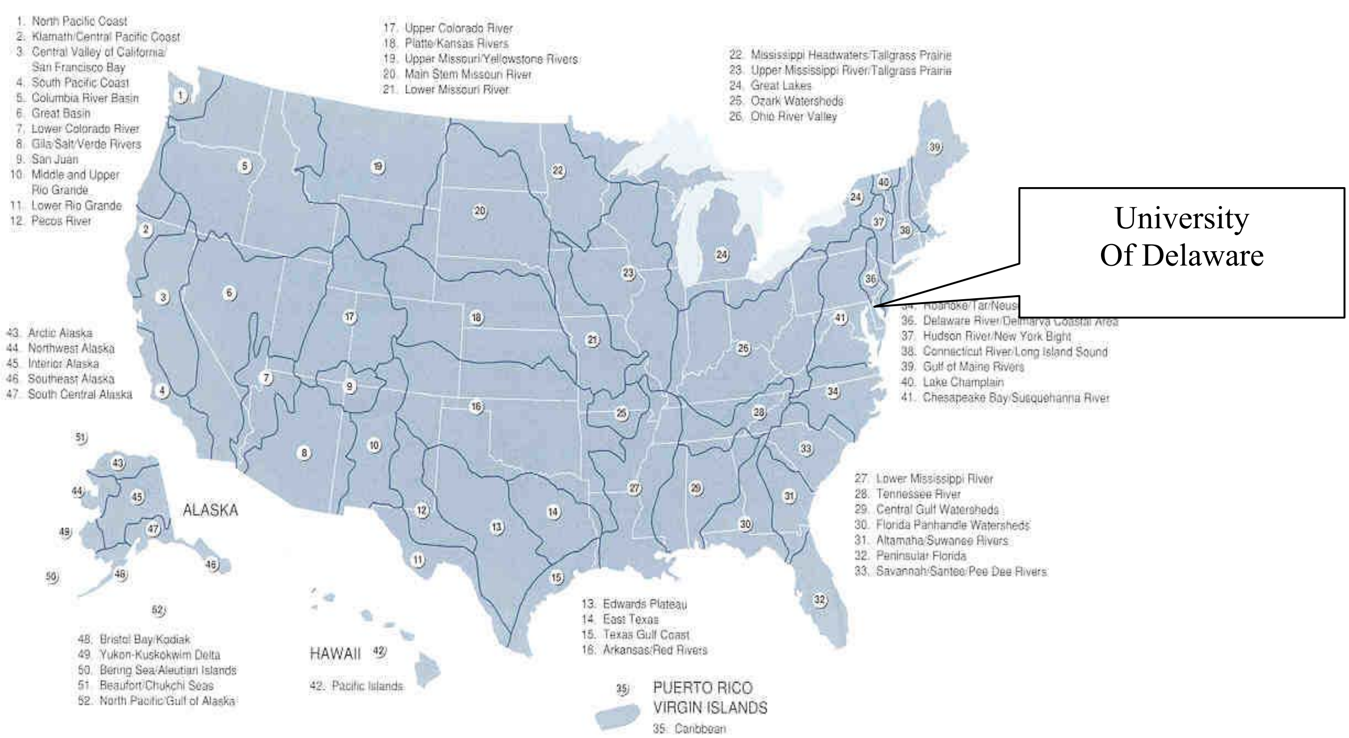


Figure 3. *Delaware River Basin Map.*

Figure 4. *Christina River Basin Map.*

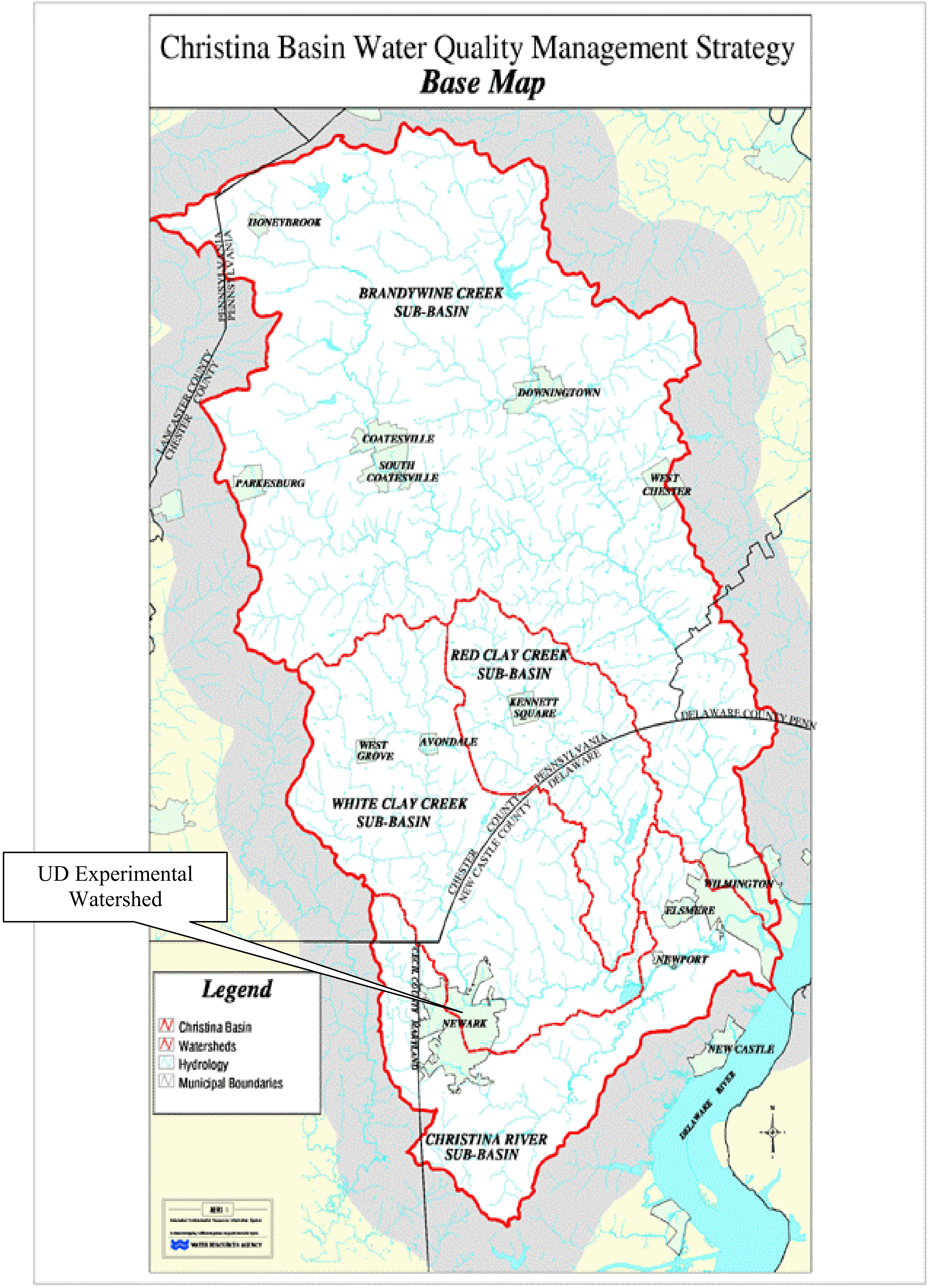


Figure 5. *White Clay Creek Wild and Scenic River Watershed.*

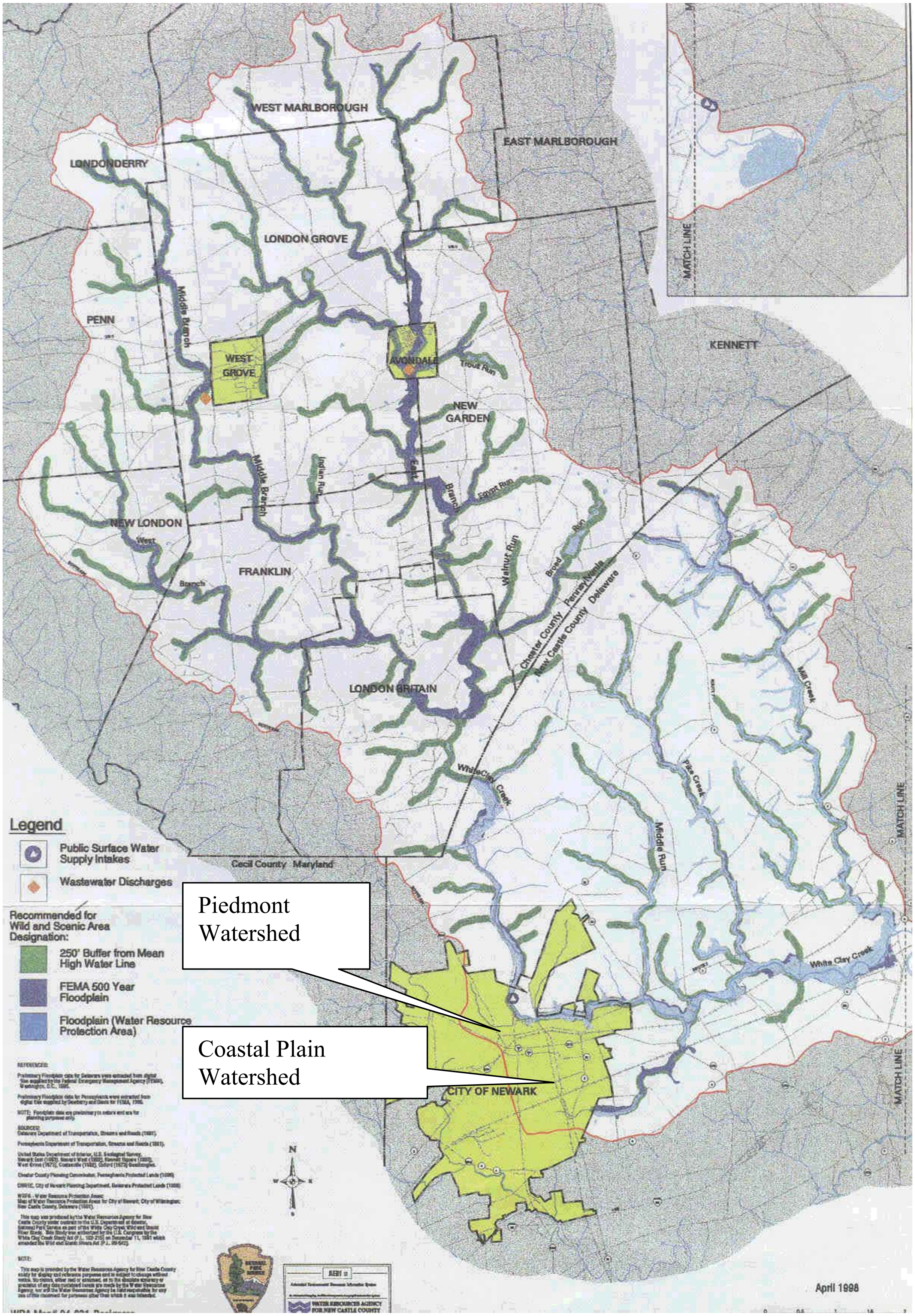
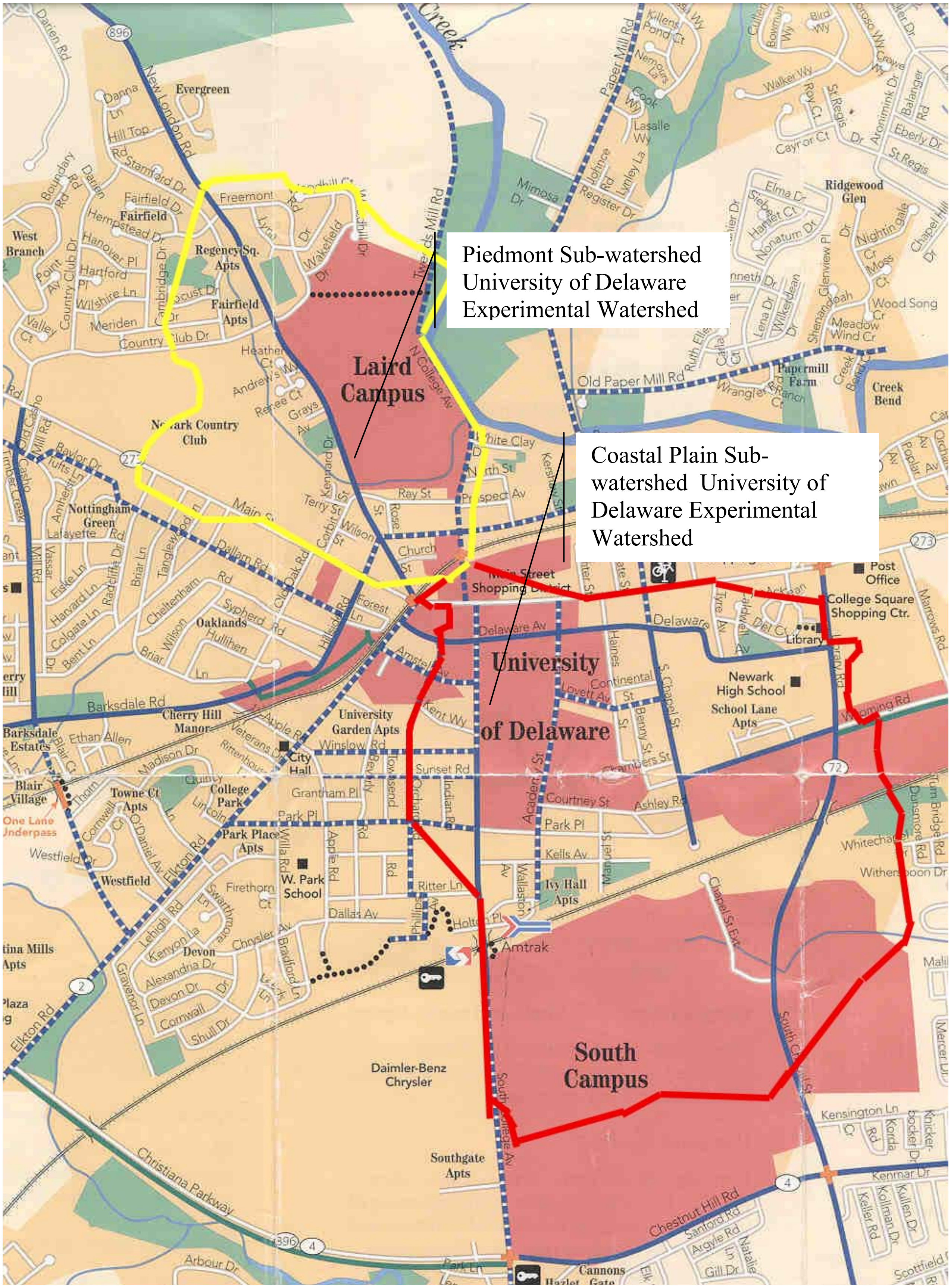


Figure 6. *The Delineation of the Experimental Watershed Superimposed on the University of Delaware Campus Map..*



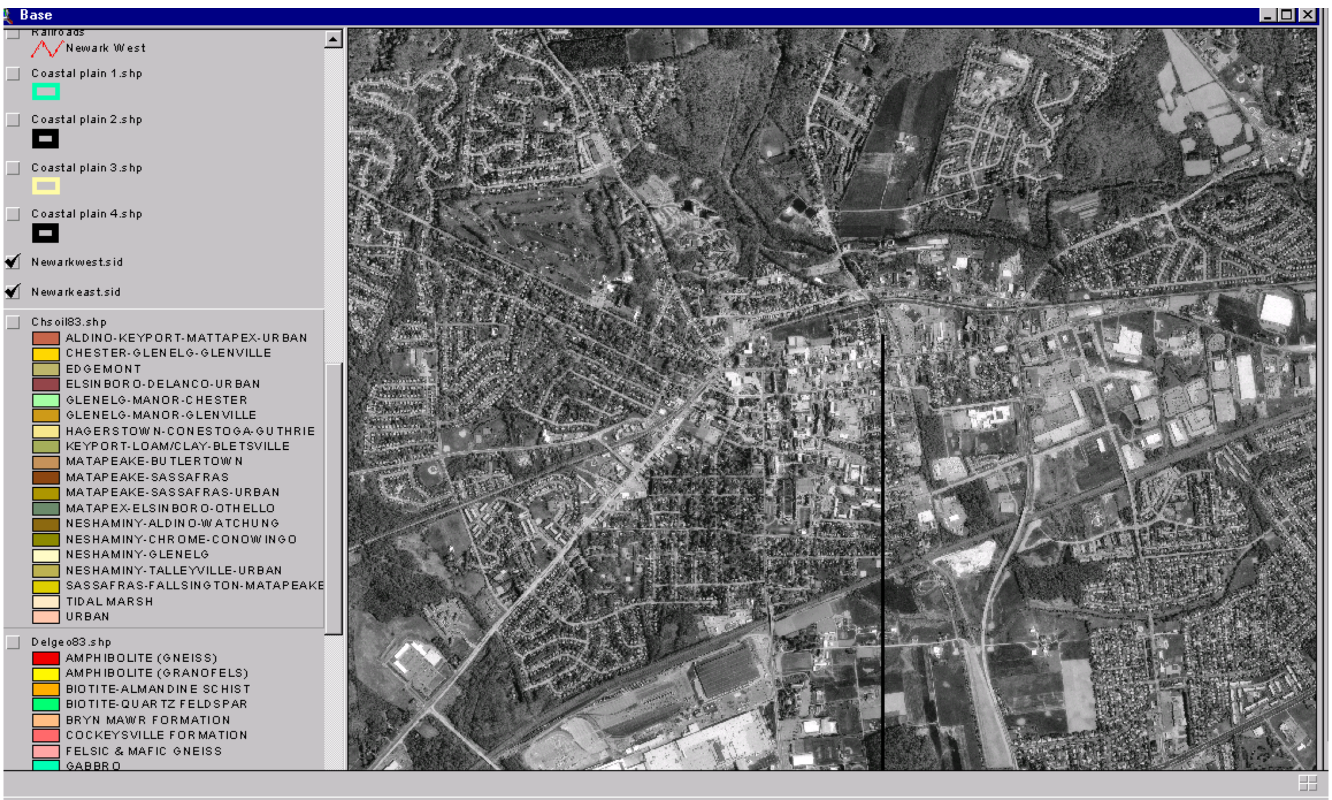
Chapter Two: Methodology

GIS Mapping

Field reconnaissance methods and ArcView mapping techniques were used to develop a GIS base-map for the University of Delaware Experimental Watershed. The GIS watershed base-map includes hydrology, roadways, watershed boundaries, and digital ortho-photographs. The team of student researchers delineated and built the base map for the University of Delaware Experimental Watershed in ArcView 3.2 using a four-step process:

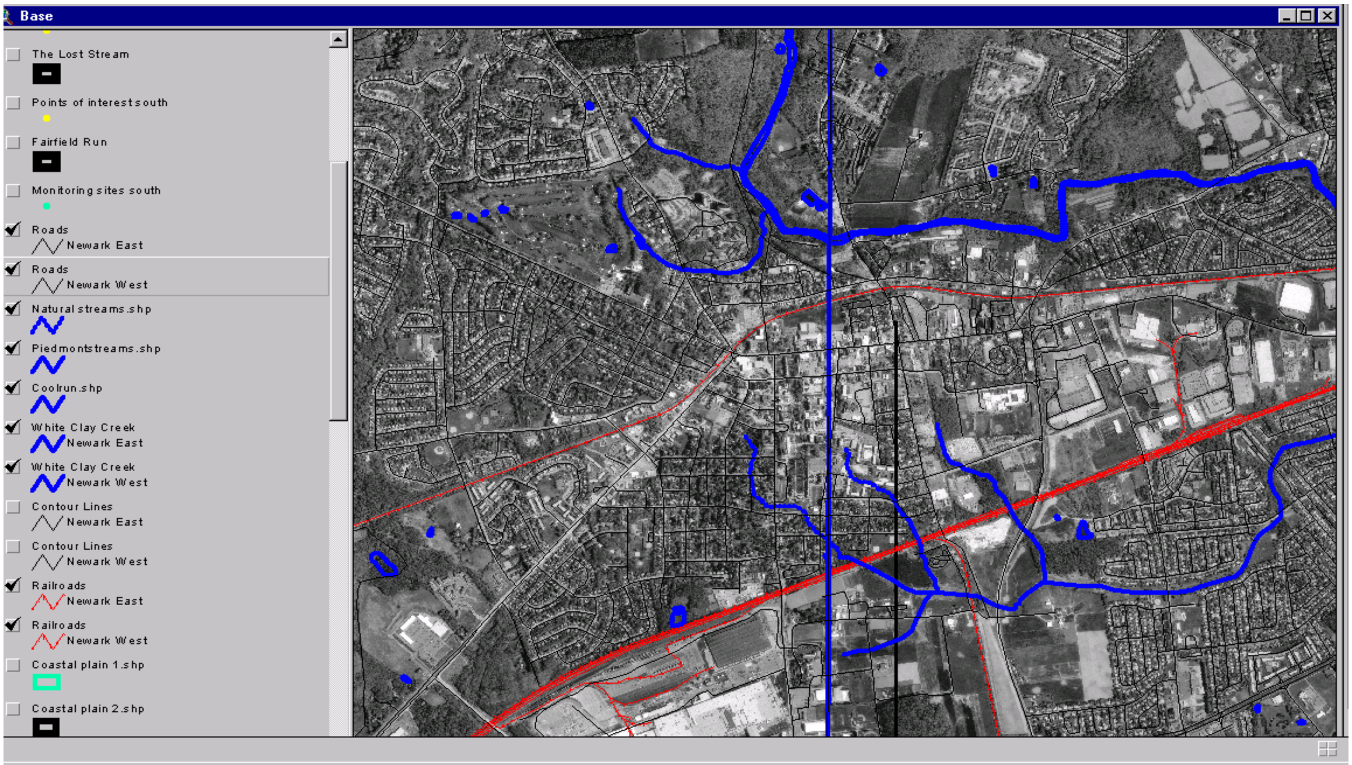
Step 1. Load Aerial Photographs (DOQQs) - The Newark East and Newark West digital orthophoto quarter quadrangle files were loaded into ArcView 3.2 using the "add theme" capability. The Delaware Office of Information Services developed the aerial photographs in 1997. The primary horizontal datum is NAD83.

Step 1: This digital ortho-photo shows downtown Newark, DE and the University of Delaware and the immediate surrounding areas.



Step 2. Add Themes, Streams, Roads, Streams - Next basic hydrologic features including streams, ponds and man-made features such as roads and railroads were added to the ArcView base map. These features were obtained from a 1999 Delaware Department of Transportation GIS file.

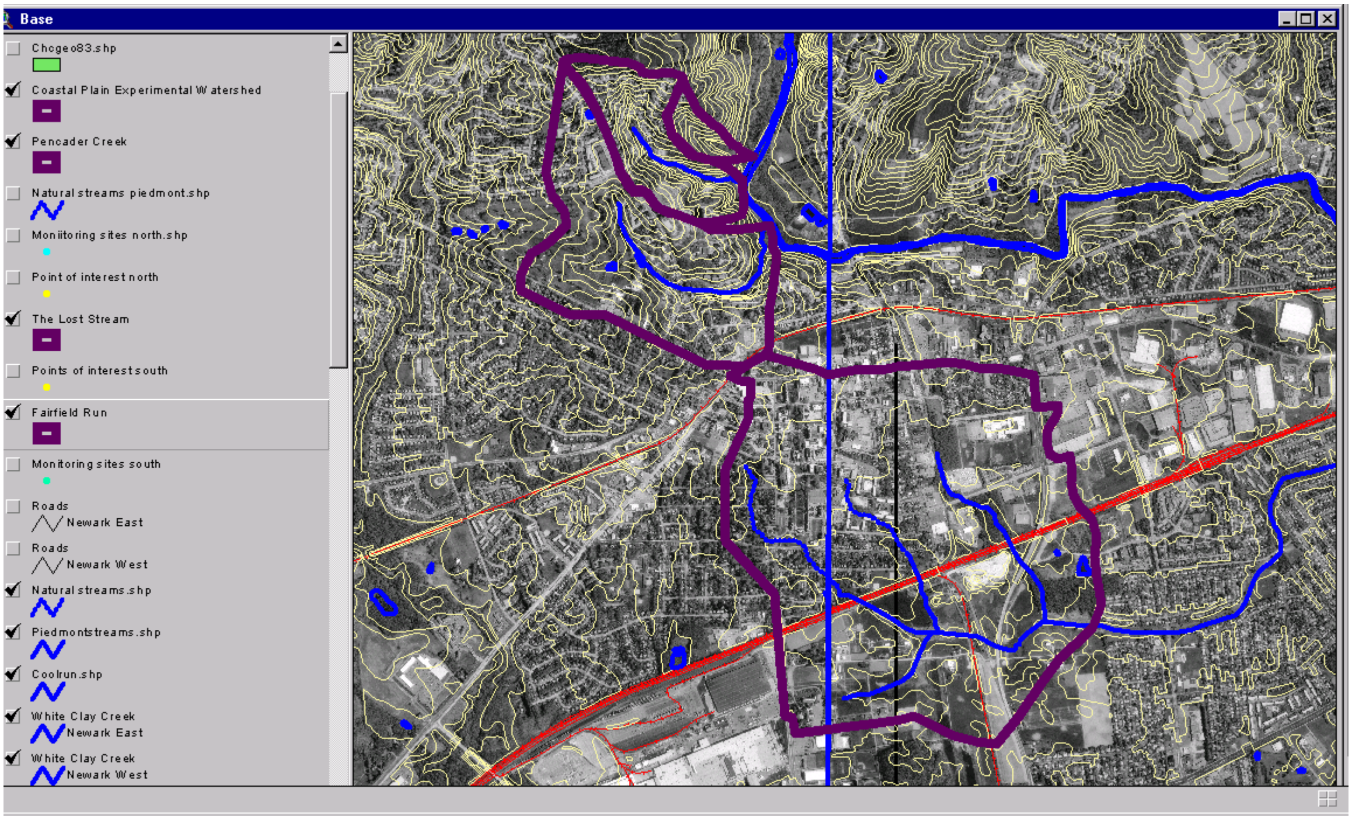
Step 2: The blue lines shown here are the natural streams being used in the project. The northern streams are direct tributaries of the White Clay Creek, while the southern streams are the headwaters of the Cool Run tributary which bisects the White Clay Creek downstream (east) of the area shown.



Step 3. Add Topography and Delineate the Watersheds in the Laboratory - Next the digital hypsography (topographic data) were loaded into ArcView. The digital topographic files were obtained from 1995 files provided by the Delaware Geological Survey. The hypsography is at a 10-feet contour interval. The student researchers delineated the boundaries of the experimental watershed using the "heads up" digitizing capability of ArcView by:

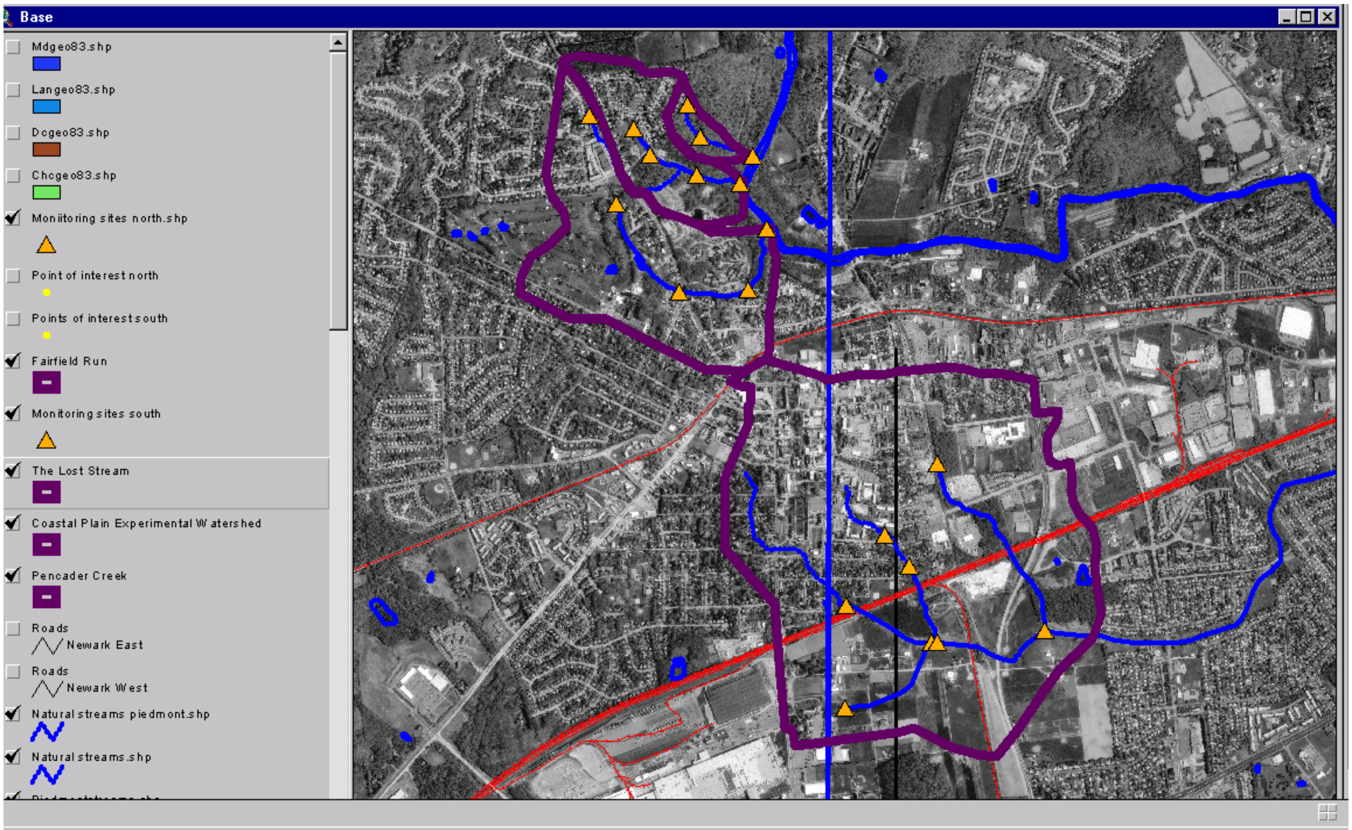
a. Highlighting the stream or tributary of the White Clay Creek in question.
b. Identifying the downstream point of interest where the tributary intersects the main stem of the White Clay Creek (for the northern piedmont watersheds) or the property line of the UD campus (for the southern coastal plain watersheds).
c. Starting at the point of interest and working upstream and clockwise to delineate the boundary of the watershed noting that the boundary should be perpendicular to the contour line and that the "closed" circles usually represent hill or ridge tops.
d. Continue delineating the watershed boundary until the loop is closed meeting back at the point of interest.

Step 3: The purple closed loops show the delineation of the experimental watershed boundaries. Each stream in the northern sub-watershed has been delineated to show its own smaller watershed, which together forms the experimental sub-watershed for the UD Experimental Watershed Project. The thin yellow lines designate the hypsography (topographic contour lines) and the red lines designate railroads.



Step 4. Conduct Field Reconnaissance to Verify the Watersheds and Locate Sampling Stations - The students researchers then verified the boundaries of the watersheds in the field by noting drainage patterns, storm pipes, and ridgelines, preferably when it was raining. The students also identified the locations of 20 sampling stations and approximately 15 points of interest based on criteria of accessibility, landmarks such as roads, and location in relation to upstream land uses.

Step 4: The orange triangles designate the stream monitoring stations that have been identified in each experimental sub-watershed.



Figures 7 and 8 show the final delineation of the Piedmont and Coastal Plain Experimental Watershed boundaries. The finalization of these boundaries marked the completion of the first "layer" of the base map which allows researchers to identify monitoring stations, topography, soils, geology, land-use, and physical landmarks in subsequent "layers" in a GIS atlas. The layers are used for water quality and habitat data collection. The layers allow information to be added to the atlas database that can be manipulated to assess links between data.

Geology

The geology map (Figure 9) summarizes the subsurface characteristics that can affect the quality and quantity of ground and surface waters. Geology layers were obtained from the Delaware Geological Survey. The fall line, the boundary between the hilly piedmont and the flat coastal plain, bisects the experimental watershed. The geology has been identified and included in the GIS atlas for future research purposes.

Soil Classifications

Soils provide indicators of permeability, depth to groundwater, and drainage class that are necessary to predict the relationship between precipitation and runoff to streams. Generally, silts and clays are less permeable resulting in greater storm water runoff and less recharge. In contrast, sands and gravel are more permeable resulting in less runoff and more recharge. Soil associations were obtained from the U.S. Department of Agriculture Soil Conservation Service Soil Survey for New Castle County, Delaware published in 1970. The soils in the Experimental Watershed have been identified in Figure 10 and have been included in the GIS atlas to be used for future studies.

Land Use

Land use is a fundamental indicator of storm water loads and impacts on the quality of receiving waters. Generally, watersheds with low intensity land uses such as forests and protected open space experience relatively good water quality. Watersheds with large areas of urban/suburban or agricultural use experience poor water quality. The nature and intensity of land use directly influences water quality in a watershed. The GIS land use files were obtained from the Phase I/II Christina Basin Water Quality Management Strategy report (Bowers, Greig and Kauffman, 1995). The land uses in the experimental watersheds are representative of New Castle County, Delaware.

Figure 11 shows the land uses designated in the UD Experimental Watershed. Institutional land includes university or educational buildings or government facilities. Commercial land uses are shopping centers or commercial lots. Agriculture uses are designated farm land. Wooded areas are forested parcels. Open space is considered parks and recreation, meadows and natural areas. Single family residential uses are detached dwellings. Multi-family residential are apartments or townhouses. Each land use identified in the experimental watershed was given a rating using the equations in Table 2.

Table 2. Land Use Equations to Determine Grade for Watershed Health 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)

Impervious Cover

Impervious cover is the amount of pavement and roof area in a particular watershed. Each land use is assigned an impervious cover percentage factor. Then the number of acres for that land use are multiplied by the impervious factor. All the values for land use acres multiplied by the impervious factor are summed, then the figure is divided by the total number of acres in the watershed to arrive at the percentage of imperviousness.

Table 3. Impervious Cover Factor of Representative Land Uses.

Land Use	Impervious Factor (%)
Institutional	55
Commercial	85
Wooded	0
Public/Private Open Space	0
Single Family Residential	30
Multi-Family Residential	65
Agriculture	0

A masters thesis conducted by Anne Kitchell of the University of Delaware College of Marine Studies and the Water Resources Agency cited the impacts of imperviousness on a watershed (Kitchell, 2001). Watersheds with less than 10% impervious cover are usually the most sensitive streams with relatively good water quality. Table 4 assigns a numerical rating to each stream depending on the imperviousness of a particular watershed

Table 4. 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

Water Quality

Following the compilation of the GIS atlas layers, the researchers conducted field inventories to collect water quality and habitat data to add to the database and design a reporting mechanism for watershed health. A standard set of water quality tests were completed on site for: alkalinity, ammonia, chlorides, chlorine, chromium, copper, dissolved oxygen, biochemical demand, hardness, iron, nitrates, phosphates, pH, and hydrocarbons. The samples were collected at each monitoring station site identified on the GIS base map. Then the data were used to assess the links between land-use and water quality and to establish baseline data.

Water quality results were recorded on a data form designed for this project (Exhibit 1) and based on guidelines distributed with the test kits that outlined the recommended (normal) range of limits. These guidelines (Exhibit 2) were then used to determine an individual 1 to 4 rating for each chemical parameter that was tested (Table 5). 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.

Habitat Assessment

An evaluation of habitat quality is critical to an assessment of ecological integrity because "habitat" incorporates all aspects of physical and chemical constituents along with the biotic interactions in an area (USEPA, 1999). "Habitat" for this project has been narrowed to the quality of the in-stream and riparian buffer habitat that influences the structure and function of the aquatic community in a stream. 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 and collect an array of data to be used in future studies. Exhibit 3 shows the specific data that was collected at each stream. Researchers focused on performing a visual assessment of the in-stream and riparian quality. The assessments also provided a monitoring site description and a general characterization of land and water uses in the vicinity of the monitoring site. The data was again assigned a 1 to 4 rating to incorporate findings into the report card.

Table 5. *Water Quality Rating Guidelines for the University of Delaware Experimental Watershed.*

Parameter	Recommended Maximum Limit	Excellent (4)	Good (3)	Fair (2)	Poor (1)
Alkalinity	200 PPM	<20-50 PPM	50-100PPM	100-150PPM	>150 PPM
Ammonia	10 PPM	<1 PPM	2-2.9 PPM	3-4 PPM	>5 PPM
Chlorides	250 PPM	< 40 PPM	40-60 PPM	60-150 PPM	>150 PPM
Chlorine	0.5 PPM	< 0.1 PPM	0.1-0.2 PPM	0.2-0.4 PPM	> 0.5 PPM
Chromium	0.05 PPM	< 0.003 PPM	0.003-0.01 PPM	0.01-0.03 PPM	> 0.04 PPM
Copper	< 1PPM	< 0.03 PPM	0.03-0.3 PPM	0.3-0.6 PPM	> 0.6PPM
Dissolved Oxygen (DO)	5-6 PPM (optimal)	5-6 PPM	4 PPM	3 PPM	<2 PPM
Biochemical Oxygen Demand (BOD)	5-6 PPM (optimal)	5-6 PPM	4 PPM	3 PPM	<2 PPM
Hardness	180 PPM	< 60 PPM	60-120 PPM	120-180 PPM	> 180 PPM
Iron	0.3 PPM	< 0.1 PPM	0.1-0.15 PPM	0.5-0.2 PPM	> 0.2 PPM
Nitrate	40 PPM (Delaware MCL 10 PPM)	< 4 PPM	4-6 PPM	6-8 PPM	> 8 PPM
pH	5.0-8.5 (6.5-8.5 Delaware MCL)	7.0	6.5-6.9 or 7.1-7.5	6.0-6.5 or 7.5-8.0	< 6.0 or > 8.0
Phosphate	0.03 PPM	< 0.01 PPM	0.01-0.02 PPM	0.02-0.03 PPM	> 0.03 PPM
Turbidity		clear	slightly turbid	turbid	opaque
Odor		no			yes
Sheen		no	trace	some	thick
Hydrocarbon		no			yes
Conductivity		> 50	50-100	100-150	> 200

Report Card

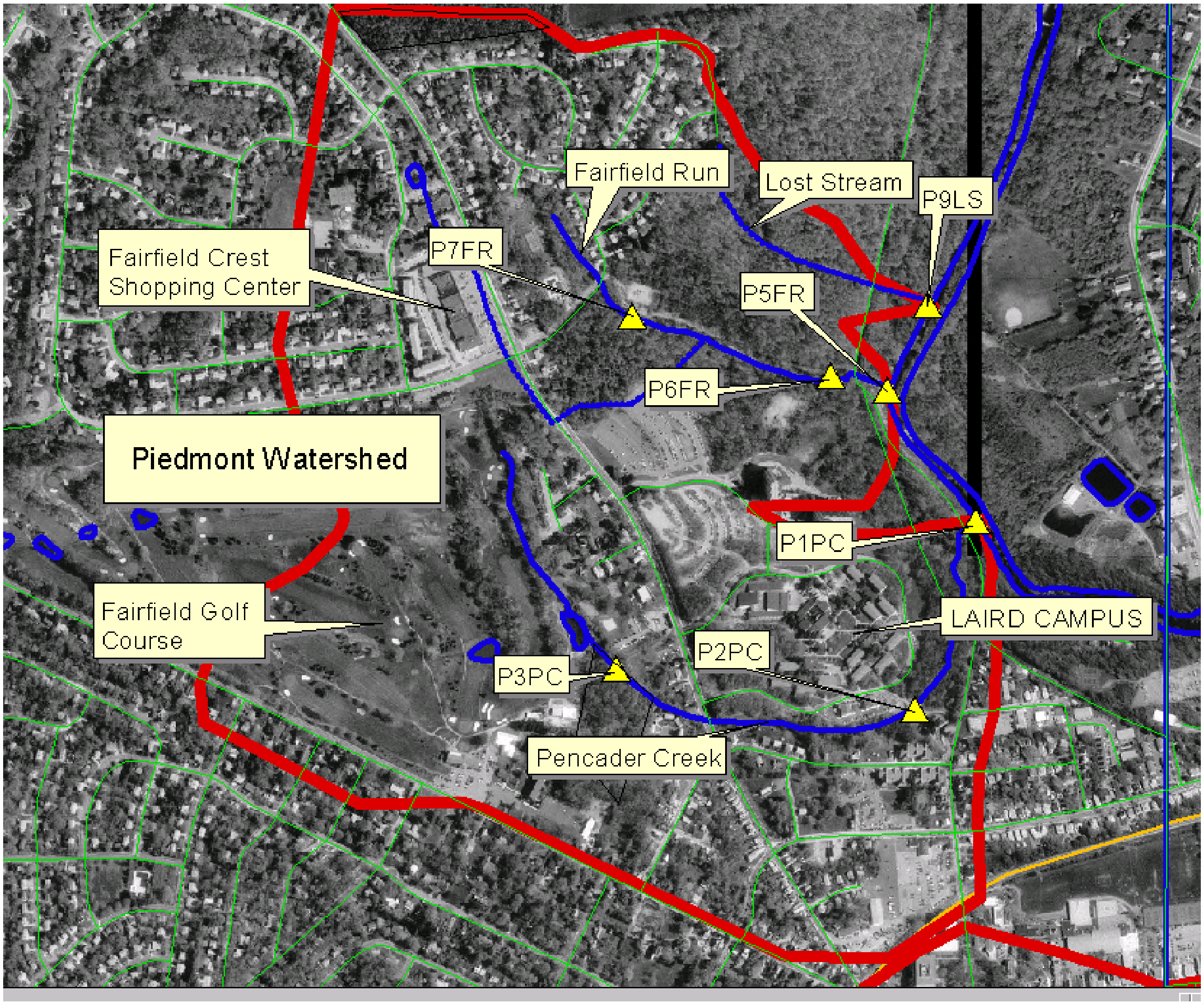
The purpose of developing a watershed report card was to have a method of tracking watershed health now and in future semesters. By applying the watershed rating scale to an A through F academic grading scale, the system becomes user friendly. It allows researchers and the public the opportunity to understand the state of their watershed using a bottom line approach. The report card for this project was designed using Microsoft Excel spreadsheets. The parameters that were graded included water quality and habitat assessments, which were tested and results recorded by stream segment (by monitoring sites); and land use and impervious cover which were graded by stream for the Piedmont Experimental Watershed. Table 5 shows the template for the Coastal Plain Experimental Watershed report card. The data for this sub-watershed will be compiled during a future semester.

Table 6. Coastal Plain Experimental Watershed Report Card Template (to be completed at a later date).

COASTAL PLAIN WATERSHED					
STREAM	WATER QUALITY	HABITAT ANALYSIS	LAND USE	IMPERVIOUS COVER	FINAL GRADE
TRIBUTARY 1					
CP1	0.00	0.00	0.00	0.00	0.00
CP2	0.00	0.00			0.00
CP3	0.00	0.00			0.00
FINAL GRADE	0.00	0.00	0.00	0.00	0.00
TRIBUTARY 2					
CP4	0.00	0.00	0.00	0.00	0.00
CP5	0.00	0.00			0.00
CP6	0.00	0.00			0.00
FINAL GRADE	0.00	0.00	0.00	0.00	0.00
TRIBUTARY 3					
CP7	0.00	0.00	0.00	0.00	0.00
CP8	0.00	0.00			0.00
CP9	0.00	0.00			0.00
FINAL GRADE	0.00	0.00	0.00	0.00	0.00
TRIBUTARY 4					
CP10	0.00	0.00	0.00	0.00	0.00
CP11	0.00	0.00			0.00
CP12	0.00	0.00			0.00
FINAL GRADE	0.00	0.00	0.00	0.00	0.00
TRIBUTARY 5					
CP13	0.00	0.00	0.00	0.00	0.00
CP14	0.00	0.00			0.00
CP15	0.00	0.00			0.00
FINAL GRADE	0.00	0.00	0.00	0.00	0.00
WATERSHED FINAL GRADE	0.00	0.00	0.00	0.00	0.00
WATERSHED FINAL LETTER GRADE*					

*Final Watershed Letter Grade is Based on the Following Scale:				
A+ 4	B+ 3.4	C+ 2.5	D+ 1.5	F <0.7
A 3.9-3.7	B 3.4-3.0	C 2.4-2.0	D 1.4-1.0	
A- 3.7-3.5	B_ 3.0-2.6	C- 2.0-1.6	D- 1.0-0.7	

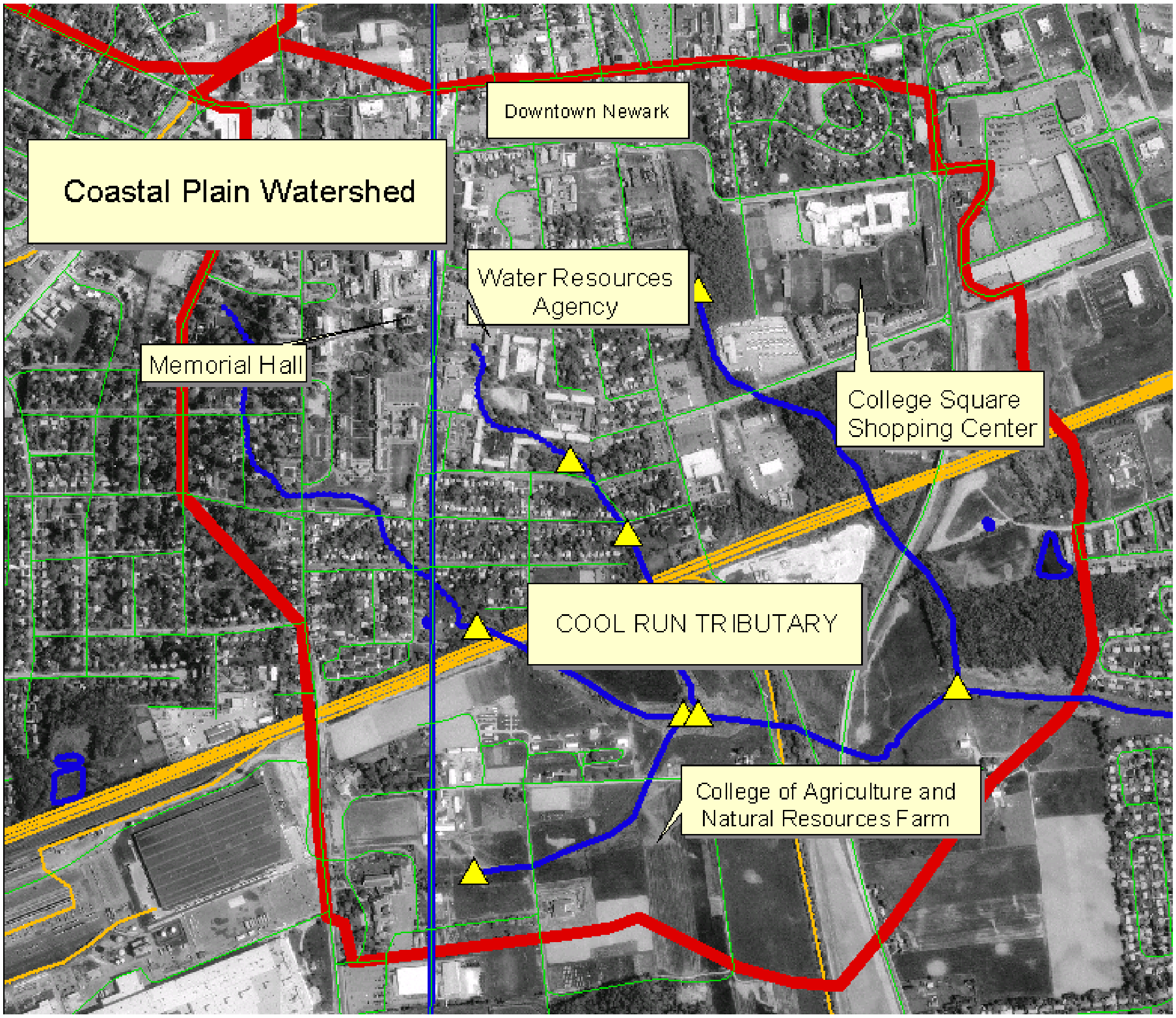
Figure 7. The University of Delaware Piedmont Experimental-Watershed



Map Legend

Watershed Boundaries	(red)
Streams	(blue)
Roads	(green)
Railroads	(orange)
Monitoring Sites	(yellow triangles)

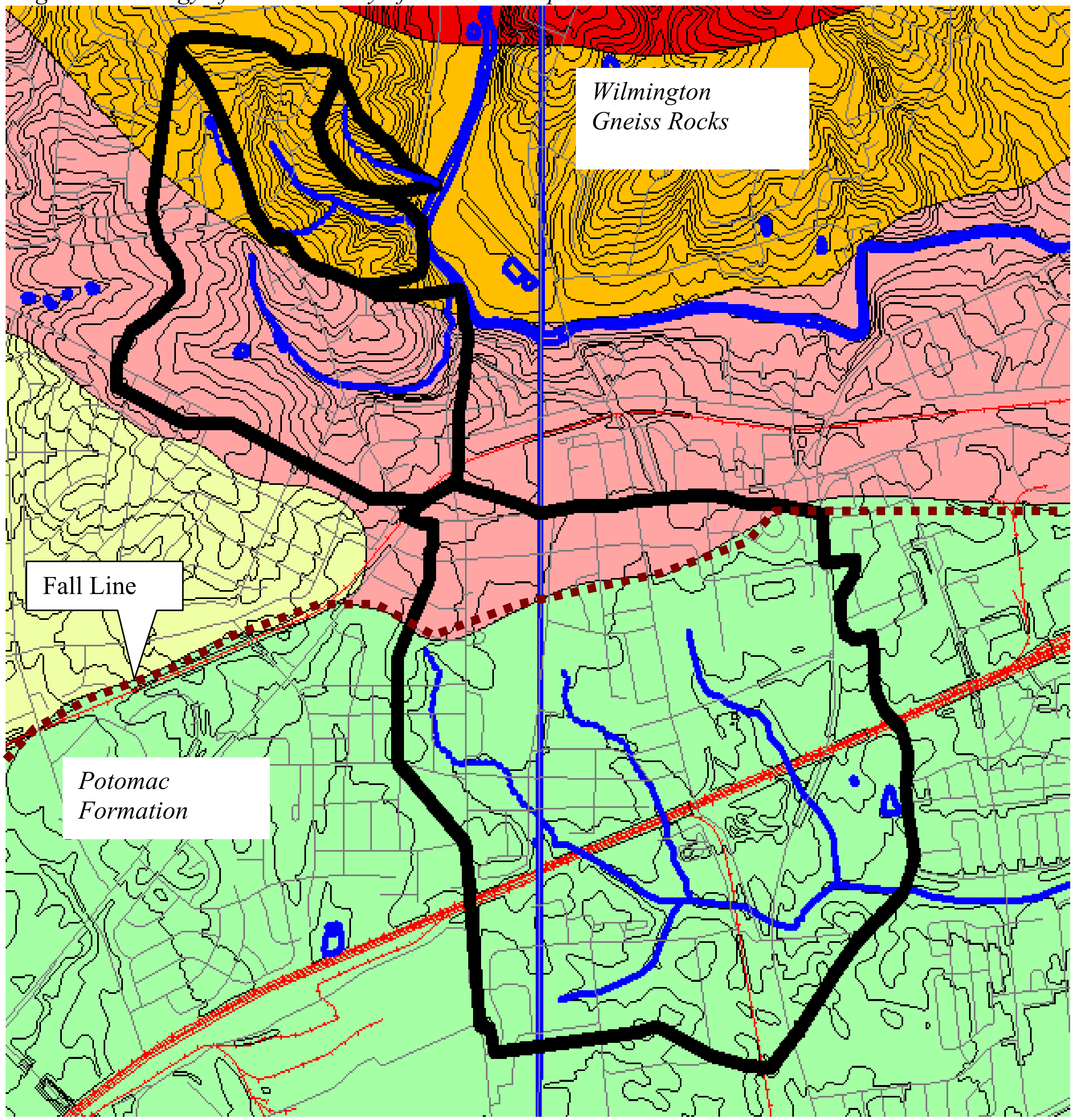
Figure 8. The University of Delaware Coastal Plain Experimental Watershed



Map Legend

Watershed Boundaries	(red)
Streams	(blue)
Roads	(green)
Railroads	(orange)
Monitoring Sites	(yellow triangles)

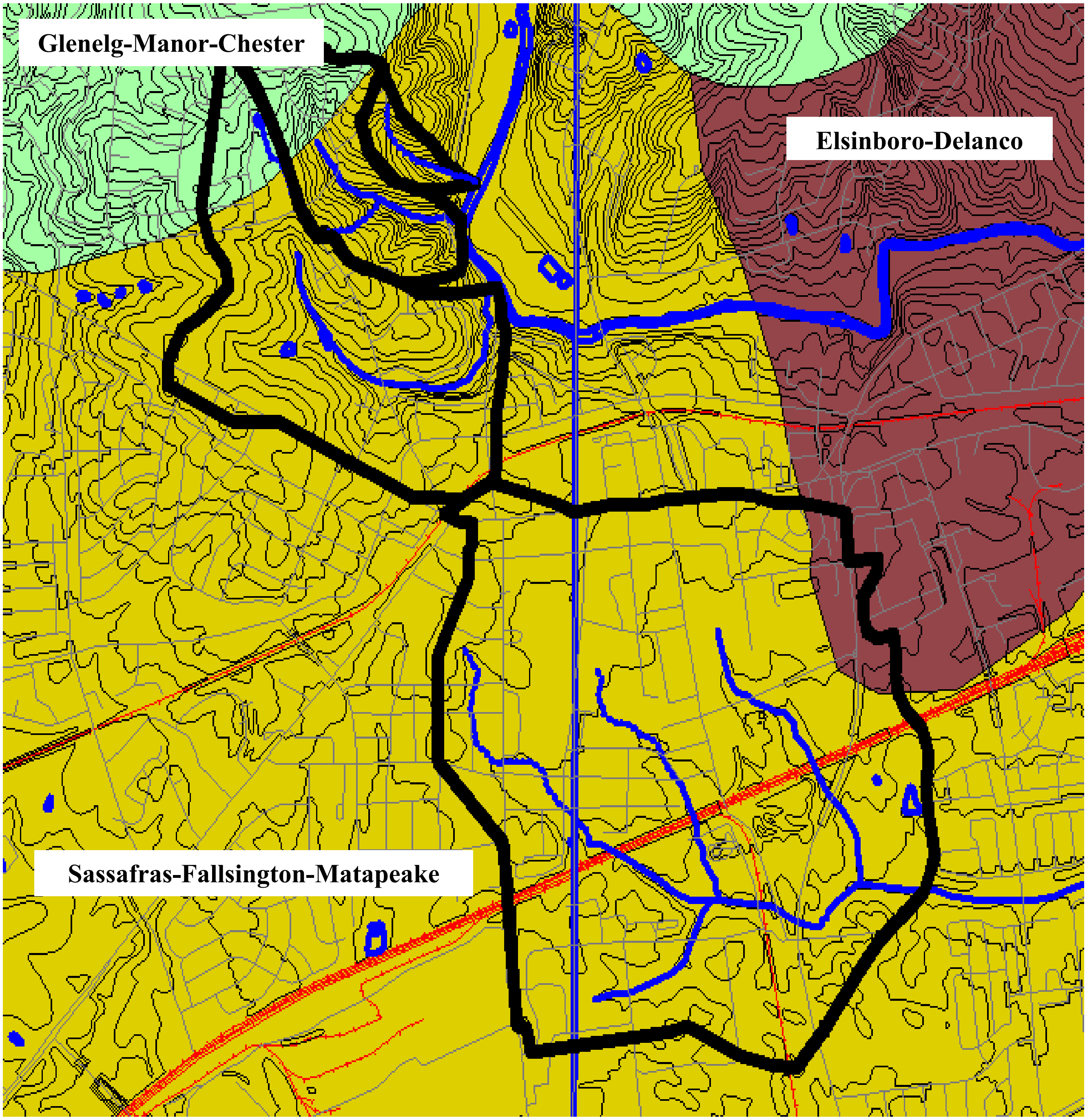
Figure 9. Geology of the University of Delaware Experimental Watershed.



Geology Color Legend

Wilmington Gneiss Rocks	(pink, orange, red)
Potomac Formation Sands and Sediments	(green)

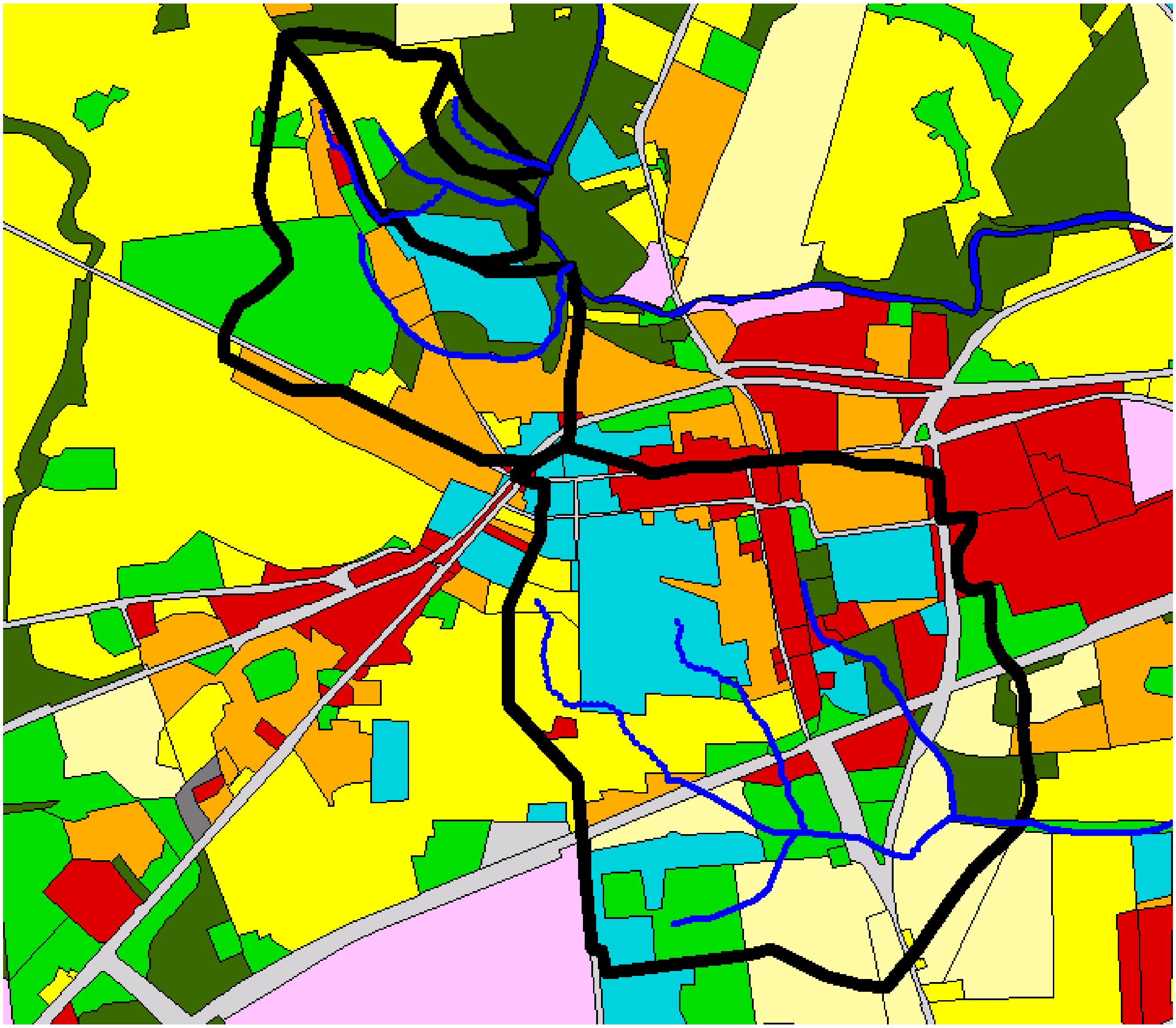
Figure 10. Soil Classifications in the University of Delaware Experimental Watershed.



Soils Color Legend

Glenelg-Manor-Chester	(green)
Elsinboro-Delanco	(brown)
Sassafras-Fallsington-Matapeake	(yellow)

Figure 11. *Land Uses in the University of Delaware Experimental Watershed*



Land Use Color Legend

Single Family Residential	(yellow)
High Density Residential, Townhouses, Apartments	(orange)
Commercial	(red)
Industrial	(purple)
Institutional, university	(light blue)
Transportation, roads, railroads	(gray)
Agriculture	(light tan yellow)
Open Space/Parks	(light green)
Forest	(dark green)
Streams and creeks	(dark blue)

Chapter Three: Results and Discussion

GIS Mapping

Table 7 provides a comparison of the characteristics of the selected sub-watersheds in 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. Figures 7 and 8 show the final delineation of the UD Experimental Watershed base maps with the monitoring sites and points of interest identified by symbols.

Table 7: University of Delaware Experimental Watershed Characteristics.

Characteristic	Northern Watershed	Southern Watershed
Watershed	White Clay Creek Wild and Scenic River	White Clay Creek Wild and Scenic River
Geology	Piedmont Rock	Coastal Plain Sands/Sediments
Topography	Hilly, Steep Slopes Incised Stream Valleys	Flat, Mild Slopes Shallow Stream Channels
Streams/Tributaries	1. Lost Stream 2. Fairfield Run 3. Pencader Creek	1. Cool Run Tributary A 2. Cool Run Tributary B 3. Cool Run Tributary C 4. Cool Run Tributary C
Drainage Area	416 acres (0.65 sq. mi.)	896 acres (1.4 sq. mi.)
Land Use	Institutional/Commercial (15.6%) Forested/Open Space (40.3%) Residential (44.1%) Agricultural (0%)	Urban/Suburban (--%) Forested/Open Space (--%) Agriculture (--%)
Landmarks	UD Laird Campus Old Pomoroy Rail Line Fairfield Subdivision Newark CC Golf Course	Newark Main Street UD Main Campus/ Mall AMTRAK Rail Line UD Agriculture Farm

One of the appeals of the Experimental Watershed project is students have the opportunity to select names for previously unnamed streams. An application will be filed with the U.S. Geological Survey at a later date to formally designate names for the streams in the Experimental Watershed.

The Piedmont Watershed includes three streams named by the UD Experimental Watershed research team. The first stream is named the Lost Stream and is almost entirely forested. The second stream, known as Fairfield Run, is approximately half residential and commercial in the headwaters and the lower half forested. The third stream is called Pencader Run and has a golf course in the headwaters and the university Laird Campus downstream.

The Cool Run tributary of the White Clay Creek in the Coastal Plain Experimental Watershed includes the downtown Newark commercial district, Newark residential neighborhoods, the UD main campus and mall, and the UD Agricultural Farm. Student researchers will determine watershed health ratings for the Coastal Plain Experimental Watershed in future phases of this project.

Soil Classifications

The UD Experimental Watershed includes the following soil associations that can be seen in Figure 10:

- **Glenelg-Manor-Chester**: Nearly level to steep, well-drained, medium textured soils formed over micaceous crystalline rocks, on piedmont uplands.
- **Elsinboro-Delanco**: Level to gently sloping, well drained, medium textured soils, relatively undisturbed to disturbed, formed in old alluvium on stream terraces.
- **Sassafras-Fallsington-Matapeake**: Level too gently rolling, well-drained moderately coarse textured and medium textured on uplands.

Soil classifications were recorded in the GIS atlas and can be used for future studies by faculty and student researchers.

Land Use

Table 8 shows the area and percentages of major land uses by acres in the UD Piedmont Experimental Watershed. Land-use ratings were established by determining a score for each stream as a whole rather than a stream segment, then averaging the stream grades to arrive at the final sub-watershed rating. Figure 11 shows the land use map for the Experimental Watershed. Each specific land-use was issued a rating, then multiplied by the percentage of the total sub-watershed acreage to determine the grade. The land-use grades were then summed to establish the overall land-use grade for each stream.

Table 9 shows the results of the land use survey for the Piedmont Experimental Watershed. The Piedmont Watershed received an overall watershed health rating of 3.16, a grade of B. Each stream grade is also available in Table 9. The highest rated stream for land use was the Lost Stream, receiving a grade of 3.75. The higher watershed health rating for land use may be because the catchment area for the Lost Stream is 75% forested with the remaining area single family residential. Pencader Creek had the lowest rating with a score of 3.06. The catchment area in the Pencader watershed is almost one-third multifamily residential and almost one-third open space with less forested land.

Table 8. Land Uses in the University of Delaware Experimental Watershed.

Watershed	Commercial/ Institutional (ac.)	Forested/ Open (ac.)	Residential (ac.)	Agriculture (ac.)	Total (ac.)
Piedmont	67.2 (15.7%)	172.8 (40.5%)	187.2 (43.8%)	0 (0%)	427.2
Lost Stream	0 (0%)	19.2 (75%)	6.4 (25%)	0 (0%)	25.6
Fairfield Run	25.6 (21.33%)	44.8 (37.33%)	49.6 (41.33%)	0 (0%)	120.0
Pencader Creek	41.6 (14.8%)	108.8 (38.6%)	131.2 (46.6%)	0 (0%)	281.6

Table 9. *Piedmont Experimental Watershed Land Use Results.*

PIEDMONT LANDUSE SURVEY												
LANDUSE	PENCADER CREEK			FAIRFIELD RUN			LOST STREAM			TOTAL		
	Acres	Percentage	Grade	Acres	Percentage	Grade	Acres	Percentage	Grade	Acres	Percentage	Grade
Institutional (Score = 3)	40	14.20%	0.43	19.2	16.00%	0.48	0	0.00%	0	59.2	13.86%	0.42
Commercial (Score = 2)	1.6	0.57%	0.01	6.4	5.33%	0.11	0	0.00%	0	8	1.87%	0.04
Wooded (Score = 4)	25.6	9.09%	0.36	38.4	32.00%	1.28	19.2	75.00%	3	83.2	19.48%	0.78
Open Space (Public/private) (Score = 4)	83.2	29.55%	1.18	6.4	5.33%	0.21	0	0.00%	0	89.6	20.97%	0.84
Single family residential (Score = 3)	41.6	14.77%	0.44	44.8	37.33%	1.12	6.4	25.00%	0.75	92.8	21.72%	0.65
Multifamily residential (Score = 2)	89.6	31.82%	0.64	4.8	4.00%	0.08	0	0.00%	0	94.4	22.10%	0.44
TOTAL	281.60	1.00	3.06	120.00	1.00	3.28	25.60	1.00	3.75	427.20	1.00	3.16
GRADE	3.06			3.28			3.75			3.16		

Impervious Cover

Impervious cover was determined using the results of the land use survey. Table 10 shows the results of the survey. The Lost Stream had the highest rating due to its high percentage of open space and low amounts of pavement and roofs. The Lost Stream is considered a sensitive area because it has a low watershed imperviousness of 7.50%. The Fairfield Run and Pencader Creek watersheds, at 29.93 % and 33.42 % impervious respectively, are thought to be non-supportive of aquatic life due tot he high amounts of development.

By looking at the results from the land use survey in Table 9, one can deduce the results of the impervious study. At a watershed impervious of 23.61%, overall the Piedmont sub-watershed is considered impacted. The watershed is almost one-fourth multi-family residential which has the third highest impervious factor. The high rate of single family residential areas also has a significant impact on the area as it is the second highest land use in the watershed even though it has a much lower impervious factor.

Table 10. Impervious Cover Ratings of the Piedmont Experimental Watershed.

Experimental Watershed	**Area (acres)**	**% Imp.**	**Impact To Stream Habitat**	**Watershed Health Rating**
Piedmont Sub-Watershed	416	23.61%	Impacted	1.67
Lost Stream	25.6	7.50%	Sensitive	3
Fairfield Run	108.8	29.93%	Non-supportive	1
Pencader Creek	281.6	33.41%	Non-supportive	1

Water Quality

To assess the health of the experimental watersheds, the student researchers sampled the water quality of the streams using LaMotte Company Water Testing kits. Table 11 summarizes the water quality analyses for the Piedmont Watershed. The same format will be used in future semesters to complete the water quality study in the Coastal Plain sub-watershed. Based on the results, overall, the water quality of the Piedmont sub-watershed received a rating of 2.71 (B-). Low ratings for several parameters are a contributing factor to this result. Low results from biochemical demand (BOD) and a positive response to the presence of hydrocarbons, and a high concentration of phosphates were main contributors. Lower pH, hardness, and iron, alkalinity, chlorides, dissolved oxygen (DO), and conductivity results also were significant.

Individually, the Lost Stream had the highest water quality rating with a 2.93 (B-) of the three streams in the Piedmont sub-watershed. Significant concerns were caused by low ratings for BOD, the presence of hydrocarbon, high concentration of phosphates, and a poor hardness rating. Fairfield Run also received a B- grade with a rating of 2.67 overall. Significant issues here were similar to those of the Lost Stream however, conductivity received the lowest rating for 2 of the 3 monitoring sites along the stream. Pencader Creek, again had the lowest results of the three streams. There were concerns with the same parameters as the overall concern, however two monitoring sites had a very poor iron rating, as well as lower alkalinity results and hardness results.

Table 11. Water Quality Results for the Piedmont Experimental Watershed.

PIEDMONT WATERSHED CHEMICAL ANALYSIS															
PARAMETER	SITE														PARAMETER GRADE
	Pencader Creek						Fairfield Run						Lost Stream		
	P1PC		P2PC		P3PC		P5FR		P6FR		P7FR		P9LS		
	Raw Data	Rating	Raw Data	Rating	Raw Data	Rating	Raw Data	Rating	Raw Data	Rating	Raw Data	Rating	Raw Data	Rating	
Alkalinity (PPM)	120	2	120	2	160	1	80	3	120	2	80	3	80	3	2.29
Ammonia (PPM)	<1	4	0	4	0	4	0.5	4	0	4	0	4	0	4	4.00
Chloride (PPM)	>60	2	>60	1	40	3	60	3	>60	1	>60	2	20	4	2.29
Chlorine (PPM)	<0.5	2	0	4	0	4	0.5	1	0	4	0	4	0	4	3.29
Chromium (PPM)	0	0	0	4	0	4	0	4	0	4	0	4	0	4	3.43
Copper (PPM)	0	4	0	4	0	4	0.5	2	0	4	0	4	0.5	3	3.57
Dissolved Oxygen (PPM)	4	2	6	4	4	2	4	2	3	1	4	2	5	3	2.29
Biochemical Oxygen Demand (BOD) (PPM)	-3	1	-3	1	-3	1	2	1	0.5	1	-4	1	0.2	1	1.00
Hardness (PPM)	200	1	120	2	120	2	160	2	120	2	120	3	120	2	2.00
Iron (PPM)	<0.5	2	1	1	1	1	0	4	0	4	0.3	1	0	4	2.43
Nitrate (PPM)	<0.5	3	2.5	4	1	4	<2.5	4	5	3	5	3	2	4	3.57
pH	8.22	1	7.92	2	7.88	3	7.95	2	7.4	3	8.7	1	7.5	3	2.14
Phosphate (PPM)	0.5	4	3	1	1.5	1	1.5	1	2	1	2	1	3	1	1.43
Turbidity (Clear or Not)	Clear	4	Clear	4	Slightly yellow	3	0	4	0	4	0	4	0	4	3.86
Odor (Yes/No)	0	4	0	4	0	4	0	4	0	4	0	4	0	4	4.00
Surface Sheen (Yes/No)	0	4	Bubbles	3	Yes	1	0	4	Foam	3	0	4	0	4	3.29
Conductivity (??)	0	4	309.2	1	228.7	2	15	4	311	1	405	1	39	4	2.43
Hydrocarbon (Yes/No)	Yes	1	Yes	1	Yes	1	Yes	1	Yes	1	Yes	1	Yes	1	1.00
SITE GRADE	2.50		2.61		2.50		2.78		2.61		2.61		2.93		2.71
STREAM GRADE	2.54						2.67						2.93		

GRADING SCALE:			
EXCELLENT	FAIR	POOR	VERY POOR
4	3	2	1

Habitat Assessment

Table 12 shows the results of the Piedmont Watershed Habitat Survey. The study looked for litter along stream banks and in the stream itself, point source and non-point source (NPS) pollution, erosion, manmade structures, epi-faunal substrate and available cover, pool substrate characterization, pool variability, sediment deposition, channel flow status, channel alteration, channel sinuosity (the number of bends in the stream), bank stability, vegetative protection, and the width of the vegetative zone width. The study also looked at the types of recreation along the streams, and the types of vegetation in the buffer zone.

Overall the Piedmont sub-watershed received a 2.81 habitat rating (B-). This was attributed to low ratings received for erosion, sinuosity, bank stability. NPS pollution and pool substrate characterizations also received fairly low scores. Overall the sub-watershed received the best scores for channel alteration, point source pollution, vegetative protection, and recreation. Exhibit 3A shows the Habitat Assessment Field Data sheet from the USEPA Rapid Bioassessment Protocols, an explanation of each parameter for this study is explained.

Individually, the Lost Stream scored the highest of the three streams, receiving a 3.0 habitat rating (B). This stream tended to score either a 4 (best) or a 1 (worst), with few in between ratings for the parameters in this study. The stream had a high amount of erosion, less than 10% stable habitat, little variability in the pools, there was very little water in the channel, most of the water was present as standing pools, and the banks tended to be very unstable on both sides. However the stream had little litter and no NPS or point source pollution, nor any manmade structures. More than 90% of the stream banks were protected by vegetation and there was so mowing evident, the stream itself seemed undisturbed and the riparian vegetative buffer zone was greater than 18 meters, human activity has little to no impact on the stream.

Fairfield Run received the second highest rating with a score of 2.77 (B-). This stream received fewer high scores and low scores, the ratings here were much more variable. Again the same concerns were present at monitoring locations along this stream as along Lost Stream. Erosion and bank stability were the main concerns, however sediment deposition was also an problem here. In some locations, more than 80% of the stream bottom was changing frequently due to sediment bar development in pools and in or around obstructions and bends in the stream. Fairfield Run had few manmade structures, a majority of deep pools 70-90% of the banks were protected by vegetation, and positive recreational activities (little impact).

Pencader Creek also received a grade of B- with a rating of 2.67. Concerns arose along this stream due to non-point source pollution attributed to a golf course in the headwaters of the stream. Along the rest of the stream, however recreation had little impact on the health. Other concerns were characterization of pool substrate, sinuosity and there was little to no root map or evidence of submerged vegetation. The stream channel had few bends to increase the length of the stream. Again, vegetative protection was a high score for the study along Pencader Creek. 70-90% of the bank had vegetation cover. Other parameters received average ratings. A key feature along the stream was a bio-swale landscaped to filter storm water runoff from the parking lots before entering the stream.

Table 12. Habitat Assessments Analysis results for the Piedmont Experimental Watershed.

PIEDMONT HABITAT ASSESSMENT SURVEY								
PARAMETER	SEGMENT							PARAMETER GRADE
	PENCADER CREEK			FAIRFIELD RUN			LOST STREAM	
	P1PC	P2PC	P3PC	P5FR	P6FR	P7FR	P9LS	
LITTER	3	1	2	4	2	3	4	2.71
NPS POLLUTION	1	1	2	3	2	1	4	2.00
POINT SOURCE POLLUTION	4	4	4	4	3	1	4	3.43
EROSION	2	3	2	2	1	2	1	1.86
MANMADE STRUCTURES	2	3	2	3	4	4	4	3.14
EPIFAUNAL SUBSTRATE/AVAILABLE COVER	2	3	2	2	3	3	1	2.29
CHARACTERIZATION	2	1	2	2	3	3	2	2.14
POOL VARIABILITY	2	2	2	4	4	1	1	2.29
SEDIMONT DEPOSITION	2	3	3	2	1	2	4	2.43
CHANNEL FLOW STATUS	3	4	1	3	1	3	1	2.29
CHANNEL ALTERATION	4	4	4	3	2	4	4	3.57
SINUOSITY	2	1	2	2	2	2	2	1.86
BANK STABILITY	3	3	1	1.5	1	1.5	1	1.71
VEGETATIVE PROTECTION	2	4	4	4	3	3	4	3.43
RIPARIAN VEGETATIVE ZONE WIDTH	2	2.5	2.5	3.5	1.5	3.5	4	2.79
RECREATION	4	4	1	4	4	3	4	3.43
SITE GRADE	**2.67**	**2.90**	**2.43**	**3.13**	**2.50**	**2.67**	**3.00**	**2.81**
STREAM GRADE	2.67			2.77			3.00	

Report Card

From the data collected in the water quality 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:

	Watershed Health Rating
• Piedmont Experimental Watershed	B-
• Pencader Creek	C
• Fairfield Run	C+
• Lost Stream	B

Each rating corresponded with a letter grade similar to the grading system for academic institutions to issue a report card assessment of the UD Experimental Watershed. Table 13 is 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 and changes in Experimental Watershed and stream health. Looking at the land uses as well as some of the key points of interest that were identified, one can deduce the potential causes of water quality and habitat concerns in the watershed.

Table 13. Piedmont Experimental Watershed 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	2.7	2.3
P2PC	2.6			2.9	2.4
P3PC	2.5			2.4	2.2
FINAL GRADE	2.5	3.1	1.0	2.7	2.3
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	2.8	2.6
WATERSHED FINAL LETTER GRADE*	B-	B+	C-	B-	B-

Chapter Four: Conclusions and Implications

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 7th 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:**
    a. **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.
    b. **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.

c. **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.

d. **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 and erected at the following locations;

Piedmont Watershed

One sign at Creek Road along the White Clay Creek.
One sign near Clayton Hall along Route 896.
One sign identifying the innovative wetland BMP on Laird Campus.

Coastal Plain Watershed

One sign near the UD main campus mall.
One sign near Main St/College Avenue intersection.
One sign on UD Agriculture Farm Campus.
One sign identifying the stream BMP at the parking garage on Main St.
One sign identifying the stormwater pond near the Perkins Student Center.

e. **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, Forsynthia, Cherry Tree on UD Main Mall.
Date of Ice On/Ice off White Clay Creek.

Chapter Five: References

Barbour, M.T., Gerritsen, J., Snuder, B.D., and Stribling, J.B., 1999. Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers, 2nd Edition. USEPA 841-B-99-002, Pp. (2-1) - (6-22).

Campbell, G. and Wildberger, S., 1992. The Monitor's Handbook. LaMotte Company, Pp. 28-53.

Department of Natural Resources and Environmental Control, Division of Water Resources, Water Supply Section, 1999. Source Water Assessment Plan. State of Delaware, Pp. (4-1)-(4-4).

Kitchell, A.C., 2000. Managing Impervious Surfaces in Coastal Watersheds. University of Delaware. Pp. 26-46.

Mayio, A., 1997. Volunteer Stream Monitoring: A Methods Manuel. USEPA 841-B-97-003, Pp. 23-185.

Reimold, R.J., 1998. Watershed Management: Practice, Policies, and Coordination. Pp. 1-9.

Schueler, T., 1995. Site Planning for Urban Stream Protection, Metropolitan Washington Council of Governments, Washington.

Bowers, J., Greig, D., Kauffman, G., 1998. Phase I and II Christina River Basin Water Quality Management Strategy, Water Resources Agency for New Castle County.

White Clay Creek Wild and Scenic River Study Task Force. White Clay Creek and Its Tributaries, White Clay Creek Wild and Scenic Rivers Study Watershed Management Plan, 1999.

Wilson, M.P., 1983. Erosion of Banks Along Piedmont Urban Streams. Water Resources Research Institute of the University of North Carolina.

Witter, S.G., Kline-Robach, R., Poston, F., and Lang, M.J., 2000. MSU-WATER. Michigan State University. Water Resources Impact 2(6): 19-22.

Woltemade, C.J. and Blewett, W.L., 2000. Development of an Interdisciplinary Watershed Research Laboratory for Undergraduate Education, Shippensburg University. American Water Resources Associations Annual Water Resources Conference Proceedings: "Water Quantity and Quality Issues in Coastal Urban Areas, pp. 229-232.

Exhibits

Exhibit 1. *Water Quality Chemical Testing Data Sheet*

Chemical Data Sheet

DATE:_______________________

Recorder: ____________________________________Time________________

SITE NUMBER:________________ STREAM______________________________
WATER TEMPERATURE___________C STREAM FLOW____________________
TURBIDITY____

PARAMETER	**TEST 1 Results**	**Comments**
Alkalinity		
Ammonia		
Chloride		
Chlorine		
Chromium		
Copper		
Dissolved Oxygen		
BOD		
Hardness		
Hydrocarbon		
Iron		
Nitrate		
Phosphate		
Specific Conductance		
GPS COORDINATES	LAT/LON	

Exhibit 2. *Water Quality Guidelines*

PARAMETER	RECOMMENDED RANGE	INDICATES:	RECOMMENDED MAXIMUM RESULT	UNIT OF MEASURE
Alkalinity	100-200PPMto stabilizes pH in a body of water 20-200 PPM are typical freshwater levels	Critical to maintaining pH levels, neutralizes acids in process called buffering, prevents drastic pH fluctuations	200PPM	PPM of CaCO3
Ammonia	Less than 1PPM = non-polluted, well oxygenated 5-10PPM = low dissolved oxygen, large amounts of decaying organic materials	Source of Nitrogen. 2 forms exist in water: NH3 (un-ionized) is toxic to fish and NH4 (ionized) Is nontoxic except at extremely high levels	10PPM	PPM
Chloride	0 ppt (freshwater) 35 ppt (seawater)	Presence may be due to natural process of water passing through natural process of salt formations or may b evidence of sea water intrusion. Salinity is the total of all salts dissolved in water	250PPM (EPA Drinking water standard) and Delaware MCL	Ppt (parts per thousand)
Chlorine	Less than 0.5PPM 1-3PPM = swimming pools	Not present in natural waters, high levels of chlorine are harmful or fatal to plants and fish	0.5PPM = EPA drinking water standard	PPM
Chromium	0.003-0.040 PPM	Found naturally in trace amounts, maybe found in bottom mud of polluted water, considered toxic chemical. Certain shellfish may concentrate this element, endangering health of consumer organisms	0.05 or greater + evidence of pollution from untreated or incompletely treated waste Delaware MCL=0.05PPM (mg/l)	PPM
Copper	0.03-0.6PPM normal range Levels greater than 1PPM	Found in small amounts in natural waters, elevated amounts may be due to industrial	Less than 1PPM 1PPM Delaware MCL	PPM

	may cause water to have a bitter taste and may cause staining or discoloration	effluents or corrosion of pipes or fittings. Copper is added to swimming pools and aquariums to control algae and bacteria.		
<u>Dissolved Oxygen</u>	1-2 PPM or below will not support fish below 3PPM are stressful to most aquatic organisms 5-6 PPM are usually required for growth and activity of organisms	O2 is required for respiration. O2 dissolved readily from atmosphere until water is saturated. O2 diffuses very slowly once dissolved and distribution depends on movement of aerated water. O2 is also produced as a byproduct of photosynthesis	5-6 is optimal	PPM
<u>Biochemical Demand (BOD)</u>	See DO above	Measure of quantity of dissolved o2 used by bacteria as break down organic wastes. IN slow moving and polluted waters, much of available o2 is consumed by bacteria, taking do from other organisms that require it	5-6PPM	PPM
<u>Hardness</u> *<u>Hardness (con't)</u>*	*Total hardness* 0-60 PPM : soft 60-120 PPM: med. Hard 120-180 PPM: hard 180+ is very hard *Calcium* 10 PPM or less can support only sparse plant and animal life 25PPM + excessive levels of plant nutrients and may contribute to algae growth. *Magnesium:*	Amount of calcium and mg ions in water, enter by leaching from rocks and soil. Hard water can cause problems in home and industrial water systems, including scaly deposits in plumbing and appliances and decreased cleaning action of soaps and detergents		PPM of $CaCO_3$ Multiply by 0.4 fir calcium or by 0.24 for Mg

	Freshwater ranges from 5-50PPM			
Iron	0.1PPM -several PPM	Present in most natural waters, important nutrient for many organisms. Most common source is soil and rocks. Industrial waste can contribute to elevated levels. High amounts may cause orange stains on fixtures and laundry, or may affect taste of beverages	0.02 PPM for domestic use for some industrial applications may not tolerate even trace amounts 0.3PPM (mg/l) Delaware MCL	PPM
Nitrate *Nitrate (cont')*	Unpolluted waters = less than 4PPM 4-40PPM	Nutrient that acts a fertilizer for aquatic plants. High nitrogen levels cause excessive plant and algae growth and creates water quality problems. Enters water form human and animal waster, decomposing organic matter and lawn and crop fertilizer runoff.	40 + PPM are unsafe for drinking water 10PPM Delaware MCL	PPM
pH	6.5-8.2 optimal for aquatic organisms 5.5 -6.0 is acidic freshly fallen rain. Alkaline soils and minerals can raise pH to 8.0-8.5	Measurement of activity of hydrogen ions. Can range from 0-14, anything below 7 is acidic and above 7 is basic. 7 is neutral. Rapid growing algae and vegetation remove CO2 from water during photosynthesis, can result in significant increase in pH.	5.0-8.5 naturally occurring 6.5-8.5 Delaware MCL	
Phosphate	Less than 0.03PPM	A nutrient that acts as a fertilizer High nutrient levels cause excessive plant and algae growth creating water quality problems. Occurs in natural waters in form of (PO4)	0.03 PPM or greater contribute to increased plant growth	PPM

***Exhibit 3A**: Habitat Assessment Data Collection Form from the USEPA Rapid Bioassessment Protocols for Low Gradient Streams.*

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (FRONT)

STREAM NAME	LOCATION	
STATION #________ RIVERMILE________	STREAM CLASS	
LAT ____________ LONG ____________	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS		
FORM COMPLETED BY	DATE ________ TIME ________ AM PM	REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Total Score ________

Exhibit 3B: *Non-tidal Stream Data sheet from the Delaware Stream Watch Program.*

14 Monthly/Quarterly Survey **NON-TIDAL STREAM DATA SHEET**

BASIC DATA

Surveyor(s)____

Name of Stream/River______________________ County/City______________________

Tributary of______________________ Watershed #______ Date______________ Time______________

Sampling Site Location (Use county road #'s or street names when possible and ATTACH a copy of the site location map.)

____

Stream type: ____Piedmont ____Coastal Plain

Today's weather____

Recent Weather____

VISUAL DATA (Survey approximately a 100 yard long stream section.)

STREAM VELOCITY non-detectable____ greater or equal to walking speed____

WIDTH & DEPTH range of stream width (ft.)____________ range of stream depth (ft.)____________

BOTTOM TYPE - Circle the predominant type: mud/silt sand pebble/cobble boulder

WATER CONDITION

Water Odor:*	Water Color:*	Surface Coating:*	Streambed Coating:*
rotten egg____	muddy____	scum____	orange to red____
chlorine____	green/blue-green____	foam____	green____
fishy____	tea____	oily____	black____
sewage____	milky____	none____	brown____
musky____	clear____		greyish-white____
none____			none____

*Specify below if condition not listed:

________________ ________________ ________________ ________________

AQUATIC VEGETATION

Algae Abundance:	Algae Location:	Algae Colors:	Abundance of Other Aquatic Plants:
in most places____	on streambed____	light green____	in most places____
in spots____	surface____	dark green____	in spots____
none____		brown____	none____

LITTER Approximate number of litter items:

	0	1-10	11-50	50+
small items: paper, cans, bottles, etc.	____	____	____	____
large items: tires, carts, etc.	____	____	____	____

BIOLOGICAL DATA (optional)

Animals - List kinds and numbers of fish, amphibians, reptiles, birds, or mammals observed. (If a macroinvertebrate survey is conducted, record tally in that section; otherwise, include invertebrates here.)

____

____

Vegetation - List major types of trees, shrubs, and smaller plants growing in or along the stream.

____

PLEASE FILL OUT REVERSE SIDE ALSO

***Exibit 3B**: Page 2 of the Non-tidal Stream Data sheet from the Delaware Stream Watch Program.*

NON-TIDAL STREAM DATA SHEET (continued)

CHEMICAL/PHYSICAL DATA (record results of any tests performed) Complete Chemical Parameter[15] Survey

Air ~~Temp. (F)~~____ pH____ ~~Nitrate Nitrogen (mg/l)~~____

~~Water Temp. (F)~~____ ~~Dissolved Oxygen (mg/l)~~____ ~~Turbidity (J.T.U.)~~____ ~~Secchi Depth (m.)~~____

MACROINVERTEBRATE TALLY (If surveyed, please record approximate numbers) Rate 0-4 (see below)
Complete Benthic Macro Field Data Sheet

Stonefly________

Mayfly________

Caddisfly________

True Fly________

Dragonfly________

Damselfly________

True Bug________

Beetle________

Isopod________

Scud________

Snail________

Worm________

Leech________

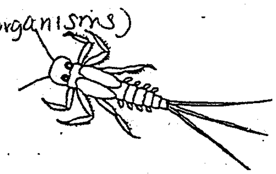
Unknown________

Other________

Total # of organisms________

Total # of kinds of organisms________

= absent/not observed 1 = Rare (1-3 organisms) 2 = Common (3-9 organisms)
3= Abundant (>10 organisms) 4= Dominant (>50 organisms)



ASSESSMENT How would you rate the quality of the stream?

(circle one) POOR FAIR GOOD EXCELLENT

If you rated the stream poor or fair, did you verify chemical and/or macroinvertebrate results with a second sample?

YES NO

What do you think caused the degradation? If you attempted to trace this degradation upstream, describe what you found.

____

____

____

MISCELLANEOUS OBSERVATIONS/COMMENTS - Please list any other observations that have not been recorded above that you think might affect stream quality.

____

____

____

____

____

***Exhibit 3C**: Water/Land Use Data Sheet adapted from the Delaware Stream Watch Program.*

10

Annual Survey

WATER/LAND USE DATA SHEET

BASIC DATA

Surveyor(s)____

Name of Stream/River_______________________ County/City_______________

Tributary of_______________________ Watershed #_____ Date_______________

Sampling Site Location (Use county road #'s or street names when possible.)_______________

PLEASE ENCLOSE: 1) a hand-drawn map of survey area, approx. 1/4 mile length of stream corridor (about four football fields); see the sample in the *Stream Watch Guide*; 2) a copy of the site location map.

LAND USE - estimate %

homes_____ businesses_____ factories_____ construction sites_____ marsh_____ pastures____

cropland_____ woods_____ swamp_____ other____

WATER USE

Recreation:
swimming_____
fishing_____
boating_____
other____

Water Withdrawal (if known):
drinking water____
industrial water____
agricultural water____

MANMADE STRUCTURES - Record approx. #

dams_____ bank stabilizers_____ bridges____

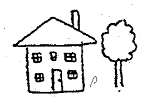
piers_____ boat ramps_____ other (describe)________________________

POINT SOURCES (pipes and drainage channels)

Map Reference No.	Location: right or left bank as looking downstream	X = pipe flowing when surveyed	NPDES permitted discharge? (Yes,No)	Description of pipe (diameter and material) and comments about purpose of pipe
e.g. P4	right	X	no	4-inch plastic pipe from private home; Steady flow of raw sewage; grey-green color, bad odor

***Exhibit 3C**: Page 2 of the Water/Land Use Data Sheet adapted from the Delaware Stream Watch Program.*

WATER/LAND USE DATA SHEET (continued)



NONPOINT SOURCES (unconfined runoff)

Type of Land Use	Location	Influence on Stream
e.g. residential construction site	approx. 300 yds. downstream of Rd. 384 bridge	water extremely muddy

MISCELLANEOUS OBSERVATIONS/COMMENTS - Please list any other observations that have not been recorded above that you think might affect stream quality: