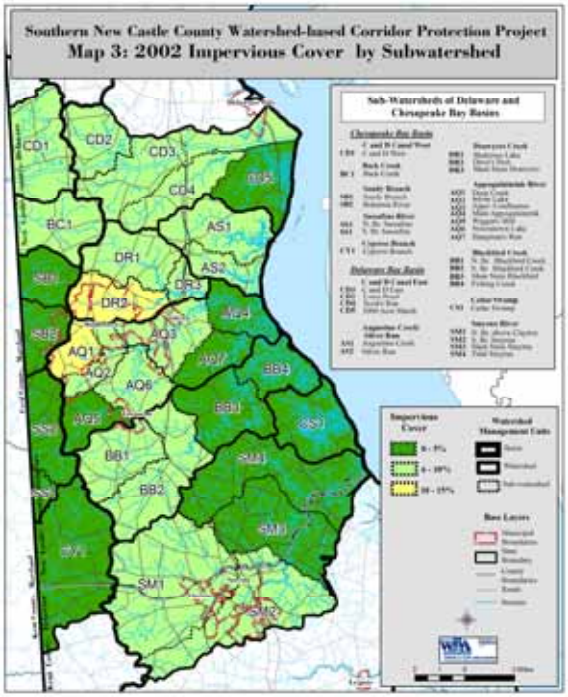
Southern New Castle County Priority Watershed Strategy

A Watershed-Based Approach to Protect Natural Resources in the MOT Planning District of Southern New Castle County, Delaware

Final Report July 4, 2006



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Foreword

This report provides a recommended priority watershed strategy for the streams in southern New Castle County, Delaware. This strategy is designed to be consistent with the (1) total maximum daily loads (TMDL) issued for the Appoquinimink River watershed by the USEPA and the Delaware Department of Natural Resources and Environmental Control (DNREC), (2) proposed revisions to the environmental protection articles of the New Castle County Unified Development Code (UDC), and (3) the 5-year New Castle County Comprehensive Plan Update currently underway. The priority watershed strategy concludes that the resource protection level (RPL) standards of the New Castle County UDC are adequate to protect water resources and natural resources in southern New Castle County at full build-out with current zoning in effect.

The contiguous chain of watersheds lining the Chesapeake and Delaware Canal, the Delaware Bay coast, and the Blackbird forest and wetland complex with low impervious cover and large amounts of forest, wetland and riparian buffers create an emerald ring around the rapidly growing towns of Middletown, Odessa, and Townsend (MOT) in southern New Castle County. These green watersheds should be protected from over-development by acquiring more open space and conservation easements, thus creating an unbroken ring of conservation open space-*a green belt*-around the periphery of the MOT village core.

1. The Watershed Approach

Approach

In 2002, the New Castle County Department of Land Use received a United States Environmental Protection Agency (USEPA) Wetland Program Development Grant to protect and enhance wetlands and riparian corridors in southern New Castle County, Delaware. The County retained the Water Resources Agency in the Institute for Public Administration at the University of Delaware to assist with a watershed-based approach to protect existing wetland and riparian corridors while being consistent with the following federal, state, and local programs:

- A watershed-based stormwater utility program recommended by the April 2005 Governor's Surface Water Task Force report and a December 2005 resolution forwarded by the County Executive for consideration by New Castle County Council.

- USEPA National Pollution Elimination Discharge System (NPDES) Stormwater Permit Part II by applicants New Castle County and the Delaware Department of Transportation.

- Appoquinimink River Total Maximum Daily Loads (TMDL) imposed by the Delaware DNREC in accordance with Section 305b of the federal Clean Water Act (DNREC, 2004).

- Appoquinimink Watershed Implementation Plan authored by the Center for Watershed Protection and being implemented by the Appoquinimink River Association (Center for Watershed Protection, 2004).

- New Castle County Comprehensive Plan 5-year update, currently underway, due by 2006.

- Amendments to the New Castle County Unified Development Code (UDC) environmental standards.

Objectives

The objectives of this project are to:

1. Provide a new subwatershed framework to assist New Castle County planners during development plan review to minimize environmental and water resources impacts in southern New Castle County.

2. Evaluate the adequacy of the New Castle County Unified Development Code (UDC) resource protection level standards in protecting water and environmental resources in southern New Castle County at the future full build -out condition under current zoning.

3. Recommend priority watersheds for protection under the New Castle County Unified Development Code and the 2006 New Castle County Comprehensive Plan Update using indicators such as impervious cover, forests, wetlands, protected open space, and riparian buffers.

Methods

The IPA-WRA developed a watershed-based approach in southern New Castle County in accordance with the following scope of work:

1. ***Review Unified Development Code*** - Research and recommend modifications to the New Castle County Unified Development Code and Comprehensive Plan Update to provide greater measures to protect the wetland, riparian, and watershed resources in southern New Castle County. Specific focus areas include

methods to minimize impervious cover and criteria to protect priority watersheds along the Route 9 coastal wetlands and the Blackbird forest/wetland complex south of Townsend.

2. ***Delineate Subwatershed Frameworks*** - Establish and delineate the watersheds in southern New Castle County as the basic hydrogeologic units for water resources planning utilizing the IPA-WRA Geographic Information System and in accordance with the following hierarchy:

Basins (> 1000 sq mi)
- Delaware River and Bay
- Chesapeake Bay

Subbasins (100 - 1000 sq mi)
- None

Watersheds (10 - 100 sq mi)
- Chesapeake and Delaware Canal
- Augustine Creek/Silver Run
- Drawyers Creek
- Appoquinimink River
- Blackbird Creek
- Cedar Swamp
- Smyrna River/Duck Creek
- Chester River
- Sassafras River/Cypress Branch
- Sandy Branch/Great Bohemia Creek
- Back Creek

Subwatersheds (1 - 10 sq mi)
- Delineate 20 to 30 subwatersheds as smaller hydrogeological planning units.

3. ***Estimate Impervious Cover by Subwatershed*** - Compute and map the existing percent impervious cover (roof and pavement area) for each of the watersheds and subwatersheds from land use data dating to 2002. Scientific literature indicates that percent impervious cover is a primary indicator of watershed and wetland health. Studies conducted in Delaware indicate the biological health of streams and associated riparian systems begins to decline significantly when the percent impervious of a watershed exceeds the threshold of 8 to 15 percent (Maxted and Shaver, 1996). Watershed health can then correlate to percent impervious cover in accordance with the following rating approach :

% Impervious	Watershed Health
0 – 7	Excellent
8 – 15	Good
16 – 20	Fair
21 – 30	Sub par
> 30	Poor

4. ***Compute Existing/Future Watershed Impervious*** - Prepare a database summarizing subwatershed impervious for existing and future land use conditions. With this knowledge county land planners can review land development applications and determine if the application meets the impervious cover threshold established for each watershed or subwatershed. This information would be used to determine whether or not additional development could be accommodated in a watershed and potentially be used as the means to delineate sending and receiving areas for transfer of development rights (TDR) programs. Watersheds with existing high percentages of impervious cover would serve as receiving areas forming the urban/suburban

core of southern New Castle County. Watersheds with low impervious cover would be sending areas in accordance with a strategy to reduce development in areas with large amounts of forest, wetland, riparian buffers, and open space. Watershed imperviousness was mapped based on the following three land use scenarios:

Scenario 1 - Existing condition with 2002 land use mapping provided by the State of Delaware.
Scenario 2 - Future full build-out base zoning in effect without the UDC resource protection levels.
Scenario 3 - Future full build-out base zoning with UDC resource protection levels in effect.

5. ***Natural Resource Overlay Map*** - Compile a resource protection levels map to measure how new development projects would be affected by the standards set forth in Table 40.10.010 in the Unified Development Code. Compute the area of each of the following natural resources and tabulate for each watershed and subwatershed:

   - Floodplains
   - Wetlands
   - Riparian buffer (50 and 100 feet wide)
   - Wellhead WRPA/recharge WRPA
   - Critical natural areas
   - Steep slopes (>25% and 15 to 25%)
   - Forests
   - Public/private open space

6. ***Priority Watersheds*** - Develop a methodology to designate priority watersheds as those sensitive watersheds that may receive a higher degree of protection from development under the provisions of the Unified Development Code. Priority watersheds would have superior watershed health with low amounts of impervious cover and high amounts of natural resources such as wetlands, forests, and riparian areas. Examples of a priority watershed may be the coastal wetlands in subwatersheds along Route 9. The designation of priority watersheds is based on the following criteria:

   - Impervious cover — Low amounts
   - Forests — High amounts
   - Wetlands — High amounts
   - Riparian buffers — High amounts
   - Public/private open space — High amounts

7. ***Public Policy/Public Input Meetings*** - Prepare for and attend public policy coordination and public input meetings to develop and disseminate the results of this watershed and wetland protection grant project. Visual tools for these sessions include PowerPoint and poster presentations. Post the watershed mapping and data on the Internet at *www.wr.udel.edu* to provide an interactive tool for planners and members of the public interested in the impact of new development in southern New Castle County on water resources and the environment.

8. ***Reports*** - Prepare a final report summarizing the project as presented in task items 1 though 7. The University of Delaware printing office published the document as a joint report of the New Castle County Department of Land Use and the University of Delaware IPA-WRA.

2. Southern New Castle County

Land Use

Southern New Castle County, Delaware is a rural yet rapidly suburbanizing 200-square-mile region south of the Chesapeake and Delaware Canal enveloping the towns of Middletown, Odessa, and Townsend. According to 2002 land use area calculations by IPA-WRA, 48 percent of the area is agriculture, 37 percent is forest, wetland or open space, and 15 percent is urban and suburban. The New Castle County Department of Planning estimates up to 20,000 dwelling units, with a mean gross density of one dwelling-unit per acre, may replace 20,000 acres (31 square miles) of agricultural land, thus doubling the area of urban and suburban land by 2030 (Table 2.1). The amounts of forest, wetlands, and public/private open space are expected to remain constant as these areas are protected by federal, state, New Castle County, and municipal regulations.

The projected growth of urban and suburban land with accompanying expansion of impervious cover has the potential to negatively impact watershed health. The New Castle County Unified Development Code Article 40, Chapter 10 is designed to mitigate the impact of new development on watershed health by protecting natural resources through resource protection level standards.

Table 2.1. Land use summary in southern New Castle County for 2002 and 2030.

Land Use	2002 Area (sq mi)	2002 Area (%)	2030 Area (sq mi)	2030 Area (%)
Urban/Suburban	30	15	61	31
Agriculture	96	48	65	32
Forest/Wetlands/Open	74	37	74	37
Total	200	100	200	100

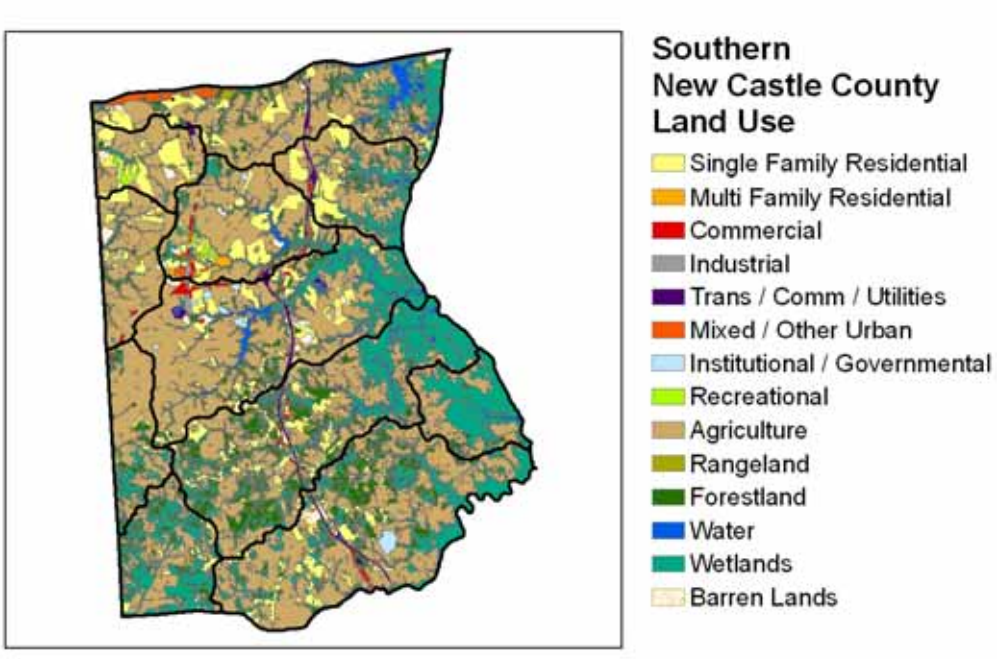

Figure 2.1. Land uses in southern New Castle County, Delaware in 2002.

Population

According to October 8, 2005 Delaware Population Consortium estimates, the population of southern New Castle County was 29,682 in 2000 and is projected to increase 223 percent to 95,996 by 2030 (Table 2.2). The population is expected to grow over 30 years at an average annual rate of 10 percent. This anticipated population growth is expected to increase the pressure on the health of streams, wetlands, and watersheds in southern New Castle County.

Table 2.2. Estimated population in southern New Castle County through 2030.
(Source: Delaware Population Consortium, October 2005)

Year	Population	% Increase
2000	29,682	--
2005	41,243	39
2010	53,060	29
2015	65,021	22
2020	79,501	22
2025	88,651	11
2030	95,996	8

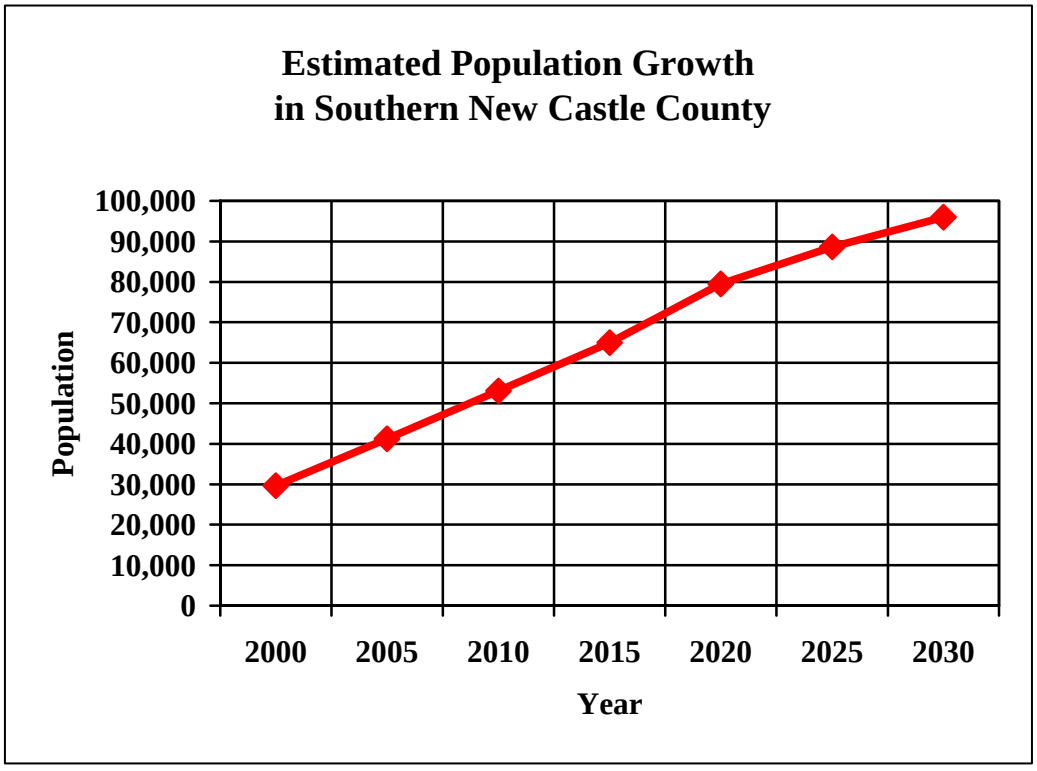

Figure 2.2. Projected population growth in southern New Castle County.
(Source: Delaware Population Consortium, October 2005)

Households

Table 2.3 summarizes October 2005 Delaware Population Consortium estimates that indicate that the number of households in southern New Castle County will increase 231 percent from 9546 in 2000 to 32,913 by 2030. Combining household and population data, the number of persons per household was 3.1 persons per dwelling unit (p/du) in 2000 and will be 2.9 p/du by 2030.

Table 2.3. Estimated number of households in southern New Castle County through 2030.
(Source: Delaware Population Consortium, October 2005)

Year	Household Units	% Increase
2000	9,949	--
2005	13,272	33
2010	17,280	30
2015	21,535	25
2020	26,733	24
2025	30,159	14
2030	32,913	9

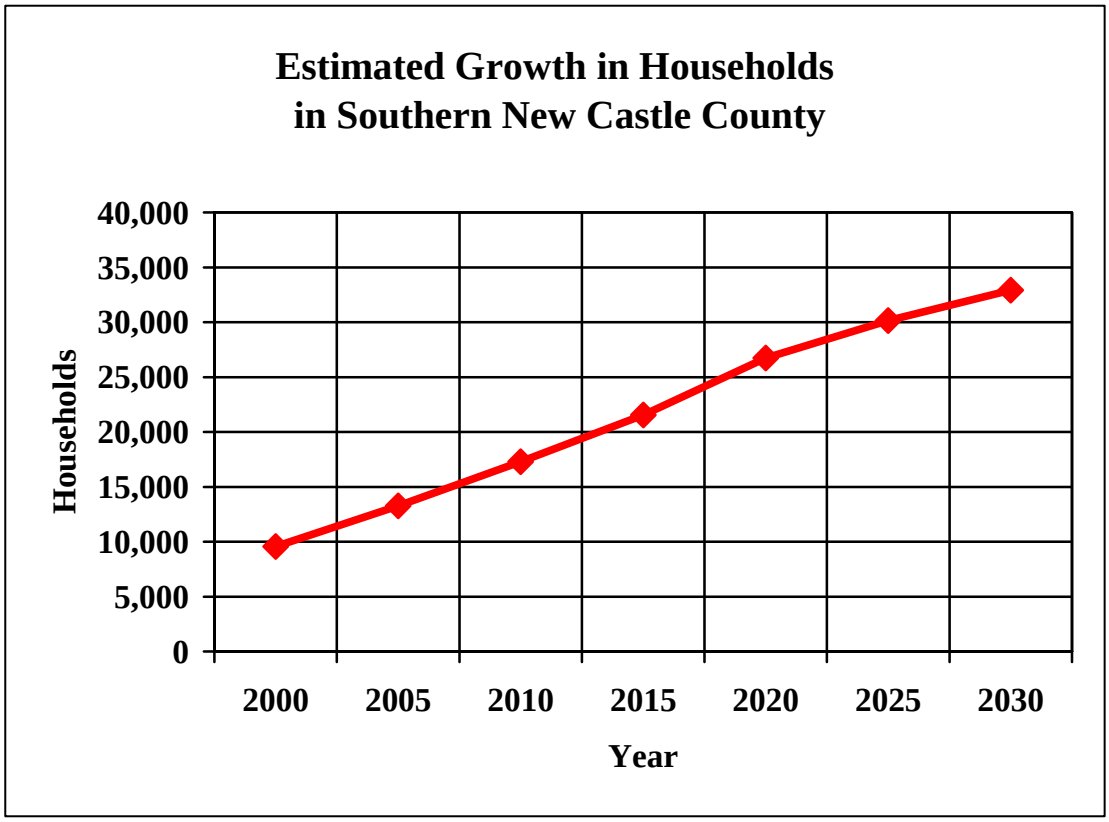

Figure 2.3. Estimated growth in households in southern New Castle County.
(Source: Delaware Population Consortium, October 2005)

3. Watershed Framework

Watersheds

The basic hydrogeologic units for water resources planning and management are watersheds. Table 3.1 lists the watersheds in southern New Castle County as delineated by IPA-WRA.

Table 3.1. Watersheds in southern New Castle County.

ID	Watershed	Area (sq mi)
CD	Chesapeake and Delaware Canal	31
AS	Augustine Creek/Silver Run	12
DR	Drawyers Creek	15
AQ	Appoquinimink River	32
BB	Blackbird Creek	32
CS	Cedar Swamp	8
SM	Smyrna River	34
CY	Cypress Branch/Chester River	11
SS	Sassafras River	8
SB	Sandy Branch/Great Bohemia Creek	9
BC	Back Creek	7
	Total	189

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Figure 3.1. Watersheds in southern New Castle County, Delaware.

Subwatersheds

Watersheds in southern New Castle County are delineated by the following hierarchy (Schueler, 1995): basins (over 1000 sq mi), subbasins (10-1000 sq mi), watersheds (10-100 sq mi), and subwatersheds (1-10 sq mi). Basin boundaries follow the sub-continental divide separating the Delaware Bay and Chesapeake Bay drainages. Watershed boundaries follow the hydrologic framework established by the Delaware DNREC in the State of Delaware Surface Water Quality Standards (DNREC, 2004). Table 3.2 and Figure 3.1 summarize the subwatersheds delineated according to the following criteria:

- Drainage area ranging from 1 - 10 sq mi.
- Sites of existing USGS stream gages or DNREC water quality monitoring stations.
- Hydrology demarcating the confluence of two major stream branches or at the head of tide.
- Land use as separating major changes in land use above and below towns or road crossings.

Table 3.2. Basin, watershed, and subwatershed framework in southern New Castle County.

Basin	Watershed	Subwatershed	Area (sq mi)
Chesapeake Bay	C&D Canal	CD1. C&D Canal West	9.6
	Back Creek	BC1. Back Creek	7.5
	Sandy Branch	SB1. Sandy Branch	4.1
		SB2. Bohemia River	4.6
	Sassafras River	SS1. North Branch Sassafras	1.4
		SS2. South Branch Sassafras	6.4
	Cypress Branch	CY1. Cypress Branch	15.5
Delaware River	C&D Canal	CD2. Lums Pond	9.6
		CD3. C & D Canal East	12.4
		CD4. Scotts Run	6.5
		CD5. 1000-Acre Marsh	7.5
	Augustine Creek/Silver Run	AS1. Augustine Creek	7.8
		AS2. Silver Run	3.7
	Drawyers Creek	DR1. Shallcross Lake	7.3
		DR2. Doves Nest	6.1
		DR3. Main Stem Drawyers	2.1
	Appoquinimink River	AQ1. Deep Creek	3.4
		AQ2. Silver Lake	3.1
		AQ3. Appoquinimink Confl.	6.7
		AQ4. Main Stem Appoquin.	4.7
		AQ5. Wiggins Mill	4.2
		AQ6. Noxontown Pond	5.5
		AQ7. Hangmans Run	4.2
	Blackbird Creek	BB1. North Branch Blackbird	7.4
		BB2. South Branch Blackbird	11.1
		BB3. Main Stem Blackbird	8.3
		BB4. Fishing Creek	5.4
	Cedar Swamp	CS1. Cedar Swamp	8.2
	Smyrna River	SM1. North Br. above Clayton	21.3
		SM2. South Br. Smyrna R.	14.9
		SM3. Main Stem Smyrna R.	11.8
		SM4. Tidal Smyrna River	15.6

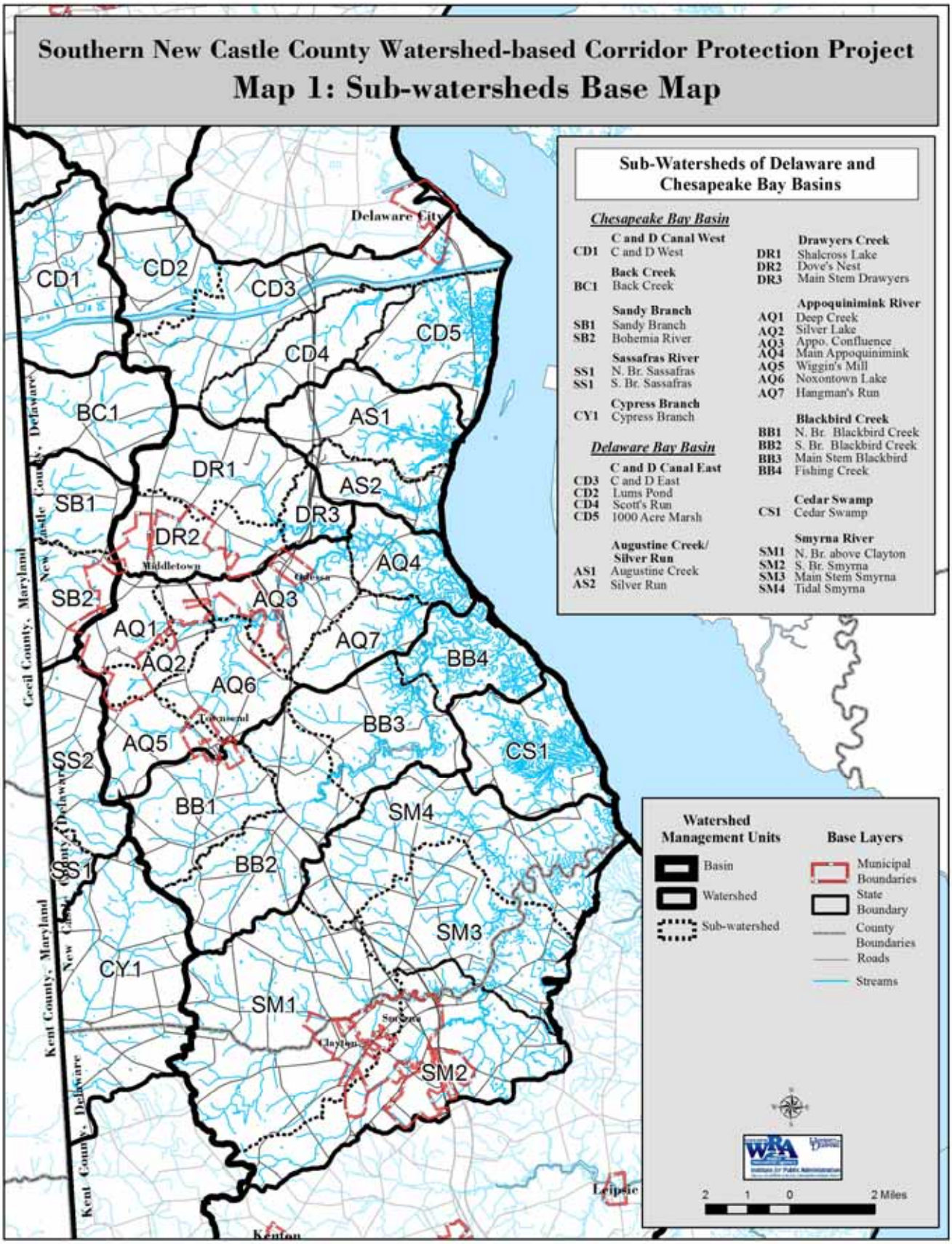

Figure 3.2. Subwatersheds in Southern New Castle County.

4. Impervious Cover

This chapter outlines the use of impervious cover thresholds to protect environmental and water resources in southern New Castle County. The following sections summarize the science of imperviousness and the "Delaware Method" for calculating impervious cover from land use and land cover data.

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Literature Review

Research completed over the last 20 years shows an increasingly significant correlation between percent impervious surface coverage in a watershed and stream water quality. Streams with increasing imperviousness exhibit many of the following conditions: increased flood peaks, lower stream flow during dry weather periods, degradation in stream habitat structure, increased stream bank and channel erosion, fragmentation of riparian forest corridor, and a decline in fish habitat quality (Pelley, 1997). At 10 percent imperviousness, a large drop in stream water quality occurs, which suggests that impervious surface cover of less than 10 percent does not alter the natural hydrology. A strong negative relationship has been found between biotic integrity and increasing land use intensity, which begins at 10 percent imperviousness (Schueler, 1995). A study in Washington State found that channel stability and fish habitat quality deteriorate rapidly after 10 percent imperviousness (Booth, 1991 as cited in Schueler, 1995).

In particular, the correlation between initial degradation of water resources and impervious surface coverage is very strong (Arnold and Gibbons, 1996). Research done in Maryland found that macro invertebrate diversity declines above 10 percent imperviousness (Schueler and Gali, 1992 as cited in Schueler, 1995). A survey of 209 streams in Ontario found that there was a strong negative relationship between biotic integrity and increasing urban land use where degradation began at about 10 percent imperviousness (Steedman, 1988 as cited in Schueler, 1995).

Two studies in Delaware found a strong relationship between the ecological health of streams and impervious surface coverage (Shaver et al., 1994 as cited in Schueler, 1995). Shaver et. al. found that macroinvertebrate insect diversity at 19 stream sites in New Castle County, Delaware dropped sharply at 8 to 15 percent imperviousness. Shaver and others also found that the majority of 53 urban streams in New Castle County had poor habitat.

A growing body of literature also indicates that groundwater recharge and stream base flow decreases with increasing impervious cover. Studies throughout the United States indicate that recharge and base flow are noticeably reduced when impervious cover exceeds a threshold of 10 to 20 percent (Kauffman and Brant, 2000). The *Source Water Protection Guidance Manual for the Local Governments of Delaware* recommends the use of impervious cover thresholds to protect drinking water supplies such as wellhead and aquifer protection areas (Wozniak et. al., 2004).

Overlay zoning districts utilizing impervious cover thresholds are commonly used to protect environmental and water resources features in municipal or county zoning and land use codes (Maryland Department of the Environment, 2000). Arnold and Gibbons (1996) recommended incorporating impervious cover indices in zoning, subdivision, and land planning ordinances to protect water resources. Base zoning regulates the density and intensity of development according to the nature of land uses such as residential, commercial, manufacturing, or institutional uses.

New development entails construction of impervious area, which reduces the amount of groundwater recharge as compared to natural ground cover. Table 4.1 summarizes the results of a water budget model indicating that infiltration decreases with increases in impervious cover. Infiltration decreases from 50 percent of total precipitation for a natural ground cover condition at zero impervious cover to 35 percent infiltration for a ground cover with 35 to 50 percent impervious cover (USEPA, 1993).

Table 4.1. Water budget model results.
(Source: U.S. Environmental Protection Agency, 1993)

Ground Cover	Infiltration	Runoff	Evapotranspiration
Natural, 0% Impervious	50%	10%	40%
10-20% Impervious	42%	20%	38%
35-50% Impervious	35%	30%	35%
75-100% Impervious	15%	55%	30%

Klein (1979) reported that stream baseflow decreased as impervious cover increased in the Maryland Piedmont. Simmons and Reynolds (1982) reported that stream baseflow levels, which originate from groundwater, were 20 to 85 percent lower after development in urbanized watersheds on Long Island, New York. A study from the state of Washington indicated that increases in percent impervious cover directly result in decreases in percent infiltration (recharge) while runoff increases (City of Olympia, 1996). A hydrologic study in the Gwynns Falls watershed near Baltimore reaffirmed the existence of a threshold by concluding that the runoff ratio changes dramatically when the impervious cover exceeds the threshold of 20 percent (Brun and Band, 2000). Finkenbine, Atwater, and Mavinic (2000) found that summer baseflow was low in 11 Vancouver streams where impervious cover was 40 percent or greater. Jennings and Jarnagin (2002) conducted research in the Accotink Creek watershed in Virginia suggesting that a "statistically significant change ($p < 0.05$) in streamflow response occurred between the 13 percent (1963) and 21 percent (1971) impervious surface levels."

An article published by the Center for Watershed Protection divided urban land uses into three categories based on impervious coverage (Schueler, 1994). In watersheds with a low pollutant potential of less than 10 percent impervious coverage, the goal is to protect water quality with an emphasis on preservation and protection of open, natural space. In watersheds with a medium pollutant potential of 10 to 20 percent impervious cover, the goal is to limit degradation of water quality with zoning techniques and best management practices. And in areas of high pollutant potential exceeding 20 percent impervious, redevelopment should be encouraged.

Based on the weight of this research in Delaware and elsewhere, streams can be considered stressed in watersheds where the impervious coverage exceeds a threshold of 10 to 15 percent (Brant, 1999).

Impervious surface coverage can be an important and measurable indicator of stream water quality and watershed health. Therefore, it is important to understand the typical percentage impervious surface coverage associated with various urban and suburban land uses. Table 4.2 illustrates the typical impervious surface coverage for land uses common in Delaware and other states.

Table 4.2. Typical percent impervious coverage of land uses in Delaware.

Land Use	% Impervious Cover
Commercial and business district	85%
Industrial	72%
Residential district with 1/8 acre or less lot size	65%
1/4 acre lot size	38%
1/3 acre lot size	30%
1/2 acre lot size	25%
1 - acre lot size	20%
2 - acre lot size	12%

Sources: University of Delaware, Water Resources Agency, 1998 and USDA Soil Conservation Service, TR-55, 1983.

Most developed land uses exceed the threshold of 10 to 15 percent impervious cover that defines a healthy watershed or stream system. It may initially appear from Table 4.2 that dispersed development would be

desirable, perhaps lots on one or two acres with scattered commercial areas, as it results in the lowest percentage of impervious surface coverage. However, on a regional or watershed level, greater overall water quality protection is achieved through more concentrated development. Under the sprawl scenario, development is spread over a much broader area, and additional impervious area in the form of roads, would be needed to link the dispersed community together. Therefore, the best way to minimize impervious surface on a watershed level is to concentrate or cluster development in existing village centers or high density clusters (Schueler, 1994). A clustered approach will decrease the overall impervious cover, resulting in greater protection for the watershed, as a much larger percentage of the watershed will be left in its natural condition, preserving water quality.

Reducing impervious cover and utilizing these thresholds for watershed management can also save money. Roads and sidewalks and other infrastructure can account for over half the cost of a subdivision (CH2M-Hill 1993). If a 32-foot-wide roadway were narrowed to 30 feet, the savings would be up to $100 per linear feet or up to $528,000 per mile (Schueler, 1997). Reducing the imperviousness of new development not only benefits the health of streams and watersheds, but it also results in economic savings by the land development community.

New Castle County Water Resource Protection Area Ordinance

Since 1991, the water resource protection area (WRPA) ordinance has been a part of source water protection in New Castle County, Delaware. The New Castle County WRPA ordinance limits the amount of impervious cover (such as roof and pavement) to 20 percent by right for new development in mapped recharge and wellhead areas. The purpose of impervious cover thresholds in WRPAs is to minimize loss of recharge and protect the quality and quantity of ground and surface water as a source of drinking water supply.

According to the New Castle County Unified Development Code (UDC), new development in recharge and wellhead water resource protection areas may exceed the 20 percent impervious cover threshold, but not exceed 50 percent imperviousness, provided the applicant submits an environmental assessment recommending a climatic water budget and facilities to augment recharge. The environmental assessment must document that postdevelopment recharge will be no less than predevelopment recharge when computed on an annual basis. Commonly, the applicant offsets the loss of recharge due to increased impervious cover by constructing recharge basins that convey relatively pure rooftop runoff for infiltration to ground water.

The New Castle County UDC provides for the protection of natural resources in three ways. First, specific open space standards are proposed to protect each natural resource by ensuring that some portion of the area remains undisturbed. Secondly, site capacity calculations are provided to regulate development of sites consistent with the level of protection. Lastly, specific resource protection level standards are provided for each resource, including floodplains and floodways, riparian buffer areas, surface water bodies, steep slopes, water resources protection areas, the Cockeysville Formation, wellheads, and recharge areas.

The New Castle County Department of Land Use seeks to protect ground and surface waters in WRPAs through a source water protection hierarchy (ranked in descending order of preference):

1. Preserve WRPAs as open space and parks by acquisition or conservation easement.

2. Limit impervious cover of new development to 20 percent within WRPAs.

3. Allow impervious cover of new development to exceed 20 percent within WRPAs (but no more than 50 percent impervious) provided the applicant develops recharge facilities that directly infiltrate rooftop runoff.

4. Allow impervious cover of new development to exceed 20 percent within WRPAs (but no more than 50 percent impervious) provided the applicant develops recharge facilities that infiltrate stormwater runoff from forested and/or grassed surfaces with pretreatment.

Table 4.3. Water resource protection area criteria in New Castle County.

Land Use	Recharge WRPA	Wellhead WRPA
Residential/Single Family	Maximum 20% Impervious	Maximum 20% Impervious
Residential/Multi Family/Townhouse	Maximum 20% Impervious	Maximum 20% Impervious
Nonresidential, Commercial, Office, Industrial, Institutional	Maximum 20% Impervious	Maximum 20% Impervious

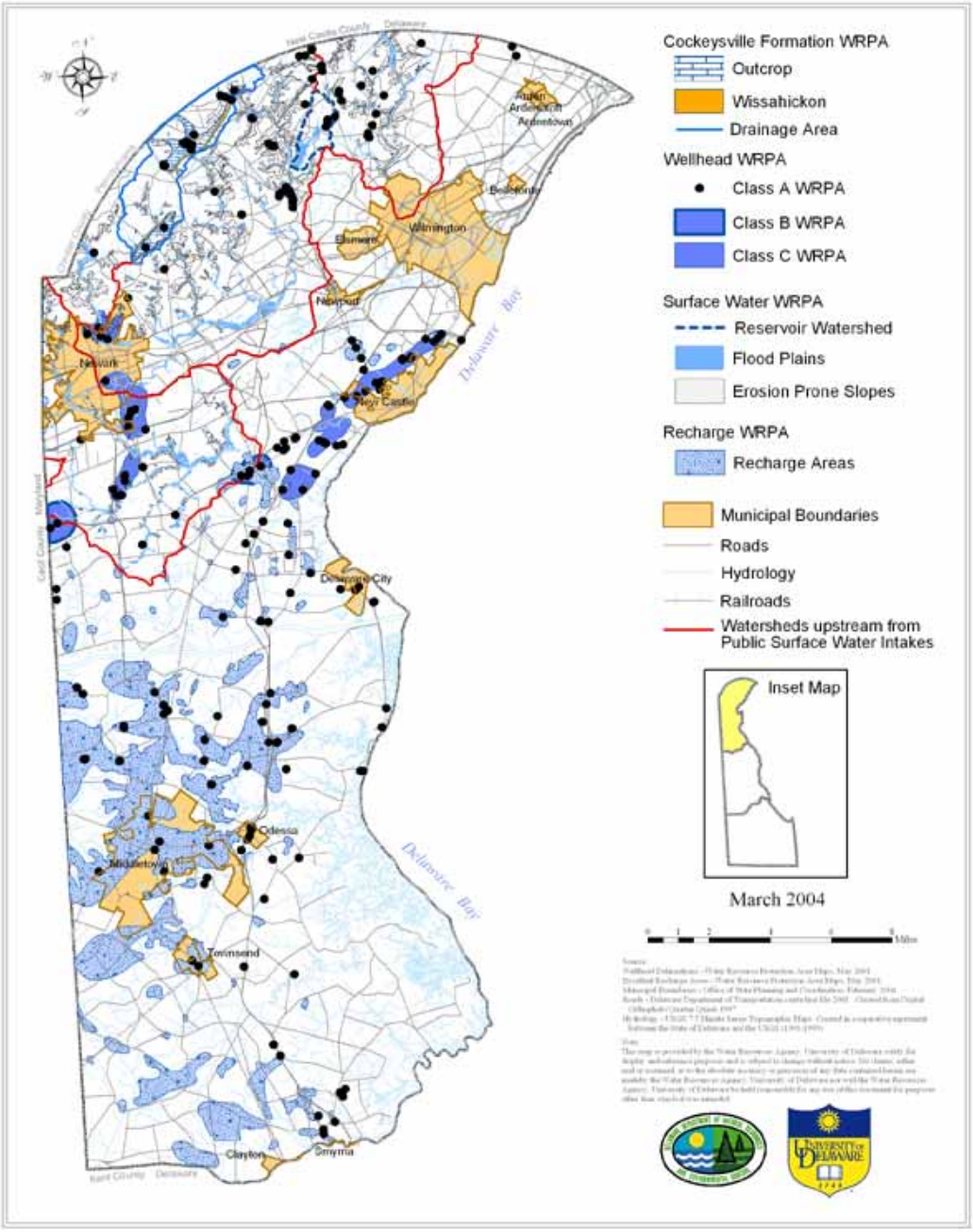

Figure 4.1. Water Resource Protection Areas in New Castle County.

Impervious Cover Calculations

IPA-WRA utilized the Arc View® geographic information system (GIS) to calculate impervious cover values according to the following methods:

1. ***Map watershed and subwatershed boundaries*** - Delineate the watershed and subwatershed boundaries using existing GIS topographic data.

2. ***Compute land use in watersheds*** - Utilizing 2002 land use data supplied by the Delaware State Planning Office, use GIS to compute the area (acres and square miles) of each of the following land uses within each subwatershed (Figure 4.2):

- Single Family Residential, 1/4 - to 2- acre lots
- Multi-Family Residential, less than 1/4 - acre lots
- Office/Commercial
- Industrial
- Transportation/Utility
- Institutional
- Public Open Space
- Wooded
- Agriculture
- Water/Wetlands
- Vacant

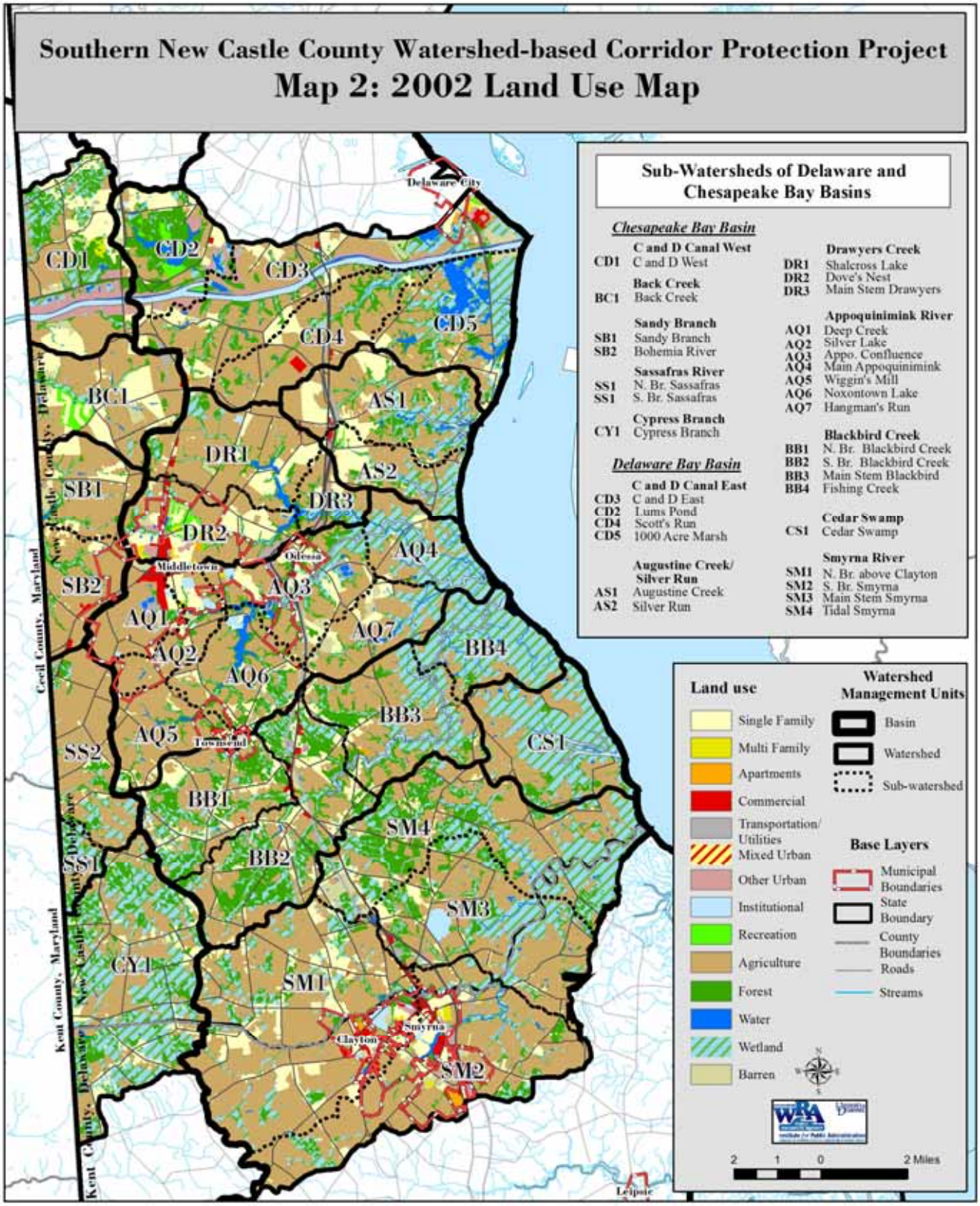

Figure 4.2. Land use in subwatersheds in southern New Castle County in 2002.

2. ***Compute Impervious Cover*** - Compute the composite impervious cover of each watershed utilizing three methods developed specifically for southern New Castle County.

Method 1 determines impervious cover values through hand digitization of impervious surfaces from 2002 aerial photography. Since aerial photography is an actual snapshot of the landscape, this is deemed the most accurate method. Five study subwatersheds are selected to delineate impervious cover based on their degrees of urbanization. Based on 2002 land use, Doves Nest and Back Creek subwatersheds are considered high urban, C&D Canal West and Main Stem Drawyers Creek are low urban, and 1000-acre Acre Marsh is considered rural.

Classifying the study subwatersheds allows for sampling of varying zoning densities for southern New Castle County. Hand digitization was done for five subwatersheds at a consistent map scale. Once impervious cover was hand digitized, a percent impervious cover per subwatershed was determined by dividing the total area of impervious cover by the total area of the subwatershed. To determine the impervious cover value for each land use class, the data was extracted from the hand digitized impervious surface data to obtain an average impervious cover value. These values are then compared to the values from Table 4.2 and adjusted. Appendix D summarizes the individual land use impervious cover values obtained from hand digitization.

Method 2, known as the "Delaware Method", compared digitized impervious cover values with the New Castle County Land Use Department for expert review. The Planning Department adjusted the values based on estimates from actual site plans. Once impervious cover values were finalized as shown in Table 4.4, they were used to calculate a composite impervious cover for each of the five subwatersheds.

Table 4.4. Impervious cover values for each land use in southern New Castle County.

Land Use	% Impervious
Single family residential	20
Multi-family residential	45
Office/Commercial	70
Industrial	72
Transportation/Utility	50
Institutional	30
Recreation/Forest/Open Space	0
Water/Wetlands/Vacant	0

Method 3 further refined the impervious cover values utilizing Feature Analyst software, which automatically extracts specified features from aerial photography. Once the computer has been "trained" by the user to select objects of a specified color, the software is able to extract from the aerial photo any surface that is rooftop or pavement. Values obtained from this method are within less than 5 percent of hand digitized values. Table 4.5 compares composite impervious cover values for the five study subwatersheds using the three methods: hand digitization, "Delaware Method", and Feature Analyst software.

Table 4.5. Comparison of composite impervious cover values using three methods.

Subwatershed	% Impervious from Hand Digitization	% Impervious from "Delaware Method"	% Impervious from Feature Analyst
Back Creek	6	7	8
C & D Canal West	6	6	8
Doves Nest	10	13	14
Main Stem Drawyers	6	7	9
1000-Acre Marsh	6	6	8

The impervious cover values of each land use class were entered into the following formula to calculate impervious cover values for each of the 31 subwatersheds:

% Imp = [(SFR Area)(SFR Imp) + (MFR Area)(MFR Imp) + (OC Area)(OC Imp) + (IND Area)(IND Imp) + (TU Area)(TU Imp) + (INS Area)(INS Imp) + (POS Area)(POS Imp) + (WOD Area)(WOD Imp) + (AGR Area)(AGR Imp) + (WW Area)(WW Imp) + (VAC Area)(VAC Imp)] / Area

Where:

% Imp	=	Composite impervious cover of a watershed.
SFR Area	=	Area of single family residential land use within watershed.
MFR Area	=	Area of multi-family residential land use within watershed.
OC Area	=	Area of office/commercial land use within watershed.
IND Area	=	Area of industrial land use within watershed.
TU Area	=	Area of transportation/utility land use within watershed.
INS Area	=	Area of institutional land use within watershed.
POS Area	=	Area of public open space land use within watershed.
WOD Area	=	Area of wooded land use within watershed.
AGR Area	=	Area of agriculture land use within watershed.
WW Area	=	Area of water and wetlands land use within watershed.
VAC Area	=	Area of vacant land use within watershed.
SFR Imp	=	Impervious cover of single family land use in Delaware = 20%.
MFR Imp	=	Impervious cover of multi-family residential land use in northern Delaware = 45%.
OC Imp	=	Impervious cover of office/commercial land use in northern Delaware = 70%.
IND Imp	=	Impervious cover of industrial land use in northern Delaware = 72%.
TU Imp	=	Impervious cover of transportation/utility land use in northern Delaware = 50%.
INS Imp	=	Impervious cover of institutional land use in northern Delaware = 30%.
POS Imp	=	Impervious cover of public open space land use in northern Delaware = 0%.
WOD Imp	=	Impervious cover of wooded land use in northern Delaware = 0%.
AGR Imp	=	Impervious cover of agriculture land use in northern Delaware = 3%.
WW Imp	=	Impervious cover of water and wetlands land use in northern Delaware = 0%.
VAC Imp	=	Impervious cover of vacant land use in northern Delaware = 0%.
Area	=	Total area within a watershed.

For example, compute the impervious cover of a 10 – square – mile watershed, with 2 sq mi of single family residential, 1 sq mi of multi-family residential, 1 sq mi of office/commercial, 3 sq mi of wooded, and 4 sq mi of agriculture land uses.

Percent impervious watershed = [(2 sq mi) (20%) + (1 sq mi) (45%) + (1 sq mi) (70%) + (3 sq mi) (0%) + (3 sq mi) (3%)]/10 = [40 + 45 + 70 + 0 + 9]/10 sq mi = 16.4%

Estimates of watershed imperviousness can vary depending on the assumed intensity and density of land use. As a sensitivity analysis, assume the representative impervious cover for single family residential in the example is 30 percent instead of 20 percent, and office/commercial is 80 percent instead of 70. The estimate of watershed impervious cover is then:

Percent impervious watershed = [(2 sq mi) (30%) + (1 sq mi) (45%) + (1 sq mi) (80%) + (3 sq mi) (0%) + (3 sq mi) (3%)]/10 = [60 + 45 + 80 + 0 + 9]/10 = 19.4% or within 3 percent of the previous example.

For purposes of regional watershed planning, these impervious cover estimates are considered accurate to within a range of 5 percent, which is suitable because:

- The scientific literature relating impervious cover to watershed health specifies thresholds as a range instead of a precise value. For instance, in Delaware the literature indicates that the biological health of

streams based on macroinvertebrate insect data declines markedly when watershed impervious cover exceeds 8 to 15 percent, a range of 7 percent.

- There is a slight inherent error when using land use data because it is representative of the actual landscape. The "Delaware Method", the most streamlined and less labor intensive of the impervious cover methods was within 3 percent of the most precise method, which is hand digitization.

Table 4.6. Existing impervious cover in southern New Castle County according to 2002 land uses.

Basin	Watershed	Subwatershed	Area (sq mi)	Scenario 1 % Impervious 2002 Land use
Chesapeake Bay	C & D Canal	CD1. C & D Canal West	9.6	6
	Back Creek	BC1. Back Creek	7.5	8
	Sandy Branch	SB1. Sandy Branch	4.1	5
		SB2. Bohemia River	4.6	4
	Sassafras River	SS1. North Br. Sassafras	1.4	5
		SS2. South Br. Sassafras	6.4	9
	Cypress Branch	CY1. Cypress Branch	15.5	3
Delaware River	C & D Canal	CD2. Lums Pond	9.6	6
		CD3. C & D Canal East	12.4	6
		CD4. Scotts Run	6.5	7
		CD5. 1000-Acre Marsh	7.5	2
	Augustine Creek/Silver Run	AS1. Augustine Creek	7.8	7
		AS2. Silver Run	3.7	8
	Drawyers Creek	DR1. Shallcross Lake	7.3	6
		DR2. Doves Nest	6.1	13
		DR3. Main Stem Drawyers	2.1	7
	Appoquinimink River	AQ1. Deep Creek	3.4	14
		AQ2. Silver Lake	3.1	8
		AQ3. Appoquinimink Confl.	6.7	10
		AQ4. Main Stem Appoquin.	4.7	2
		AQ5. Wiggins Mill	4.2	5
		AQ6. Noxontown Pond	5.5	6
		AQ7. Hangmans Run	4.2	4
	Blackbird Creek	BB1. North Br. Blackbird Cr.	7.4	6
		BB2. South Br. Blackbird Cr.	11.1	8
		BB3. Main Stem Blackbird	8.3	3
		BB4. Fishing Creek	5.4	0
	Cedar Swamp	CS1. Cedar Swamp	8.2	1
	Smyrna River	SM1 North Br. above Clayton	21.3	7
		SM2. South Br. Smyrna R.	14.9	8
		SM3. Main Stem Smyrna R.	11.8	4
		SM4. Tidal Smyrna River	15.6	2

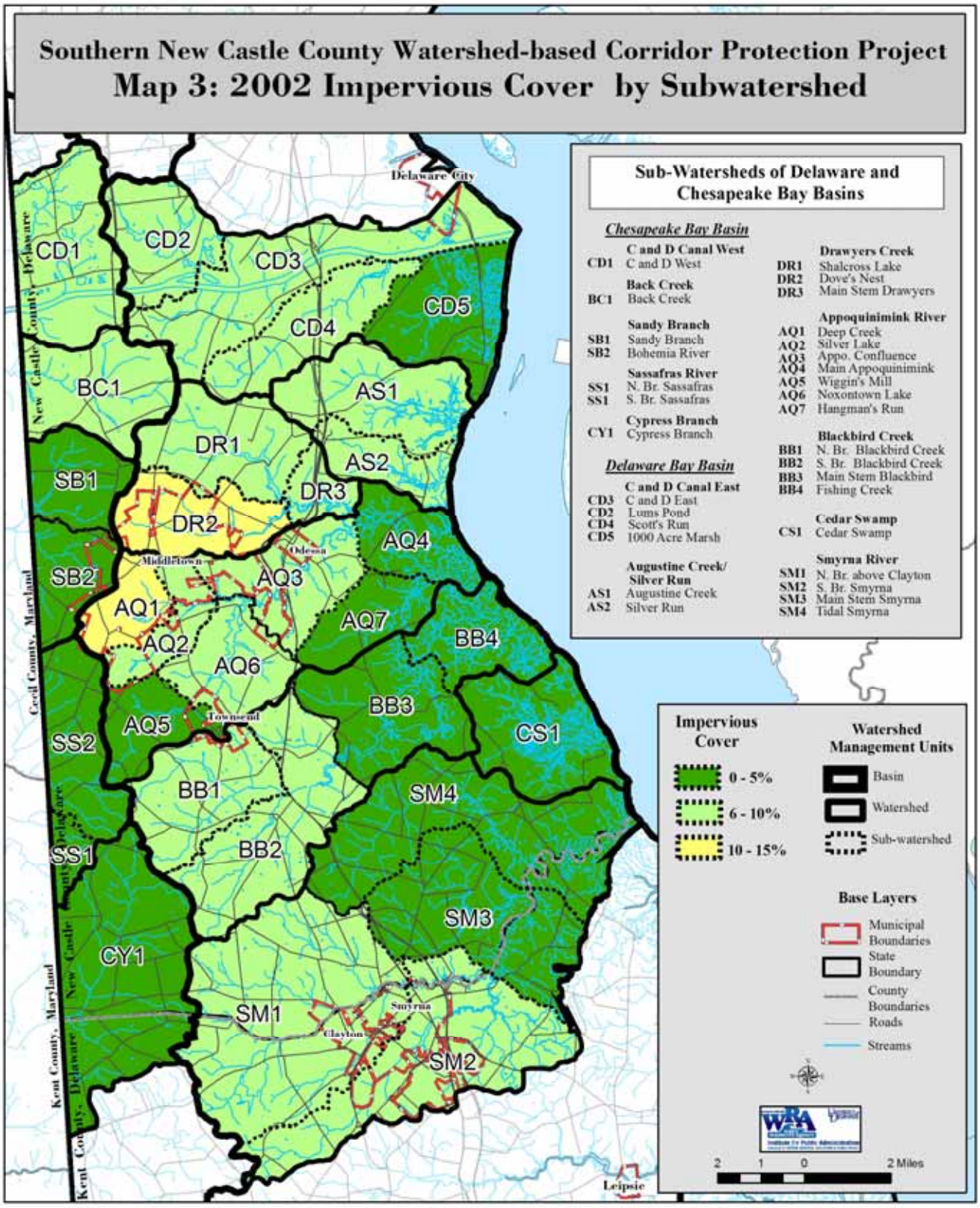

Figure 4.3. Existing impervious cover in southern New Castle County.

5. Future Watershed Imperviousness

Future Land Use

Subwatershed impervious cover ratios were estimated for the following land use scenarios to assess the effectiveness of the New Castle County Unified Development Code (UDC) in protecting water and environmental resources in southern New Castle County:

Scenario 1. Existing land use conditions based on 2002 mapping. Estimates of existing land uses by area are compiled by subwatershed and estimates of existing impervious cover are calculated with GIS using the "Delaware method" as described in the preceding chapter.

Scenario 2. Future land use condition at full build-out in accordance with current base zoning without the UDC resource protection levels of Article 40, Chapter 10 of the UDC in effect. Estimates of future land use areas are calculated using the base zoning districts in New Castle County and the zoning for the municipalities of Middletown, Odessa, and Townsend. Natural resources that would otherwise be protected under existing federal and local ordinances are excluded from the calculations (wetlands, forests, permanently protected lands). Once the area of each future land use class is calculated, the future impervious cover of each subwatershed is estimated using the "Delaware method." For this scenario, the UDC resource protection level restrictions are not considered. Therefore, impervious cover values reflect conditions if current zoning is followed without the additional resource protection level restriction applied through the UDC.

Scenario 3. Future land use condition at full build-out in accordance with current base zoning with the UDC resource protection levels of Article 40, Chapter 10 in effect. Future land use areas at full build-out are estimated from the base zoning as in Scenario 2 and future impervious cover is estimated using the "Delaware Method." Then future development restrictions are projected for areas within each subwatershed in accordance with the resource protection levels (RPL) for natural resources set by the New Castle County UDC. Table 5.1 summarizes the resource protection level standards from Article 40, Chapter 10 of the New Castle County UDC. Two calculation layers are created in the GIS. One layer contains the future impervious cover percent per zoning category and the other layer contains the percent restriction that is placed on the future impervious cover through the UDC resource protection level standards (Figures 5.1 and 5.2). These two layers are multiplied to obtain the amount of impervious cover that is allowed per zoning class throughout the subwatershed. Table 5.2 summarizes the results of this modeling.

Table 5.1. Resource protection levels from the New Castle County Unified Development Code.

Natural Resource	Resource Protection Level (RPL)
Floodplain	1.0
Wetland	1.0
Riparian Buffer	1.0
Cockeysville Formation WRPA	0.5
Cockeysville Formation Drainage Area WRPA	0.5
Wellhead Class A WRPA	1.0
Wellhead Class B and Class C WRPA	0.5
Recharge Area WRPA	0.5
Steep Slope > 25%	1.0
Steep Slope 15–25%	0.25– 0.5
Forests, Mature	0.5–0.7
Forests, Young	0.2–0.5

For example, under the UDC if a watershed is covered by a recharge WRPA with a resource protection level of 0.5, then 50 percent of the land would be protected from development at full build-out. Therefore, if the area underlain by recharge was zoned single family, and single family contains 30 percent impervious cover, than that particular area will be restricted to 0.50 multiplied by 30 or 15 percent impervious cover. If an area of the watershed is covered by wetlands with an RPL of 1.0, then 100 percent of this land would be protected from development. Most of the watersheds in southern New Castle County are composed of one or more natural resourcestherefore, the estimate of future land use and corresponding impervious cover at full build-out considers the natural resource with the highest protection level. Thus, if an area is composed of both a riparian area with an RPL of 1.0 and recharge with an RPL of 0.5, then the protection of 100 percent from the riparian area will be used in the calculations.

This analysis indicates the Unified Development Code is effective in protecting water and environmental resources in southern New Castle County because at full build out with resource protection level standards in effect, the future watershed imperviousness is 15 percent or less. This threshold of 15 percent is selected from the wealth of literature from Delaware and other states that correlate impervious cover with watershed and stream health.

Unified Development Code Effectiveness

Table 5.2 illustrates the effectiveness of the UDC in protecting natural resources in southern New Castle County according to this future land use/impervious cover analysis. Figure 5.3 displays the results of Scenario 3. Except for a few subwatersheds in and near Middletown that in 2002 already have had high existing impervious cover ratios such as Doves Nest in the Drawyers Creek watershed (13 percent) and Deep Creek in the Appoquinimink watershed (14 percent), the resource protection levels in the UDC are effective in maintaining future impervious cover levels at full build-out below the 15 percent threshold that correlates with an environmentally healthy watershed.

Consider the Back Creek watershed. In Scenario 2, without the UDC resource protection levels in effect and at full build-out, the Back Creek impervious cover would ultimately reach 25 percent, well above the 15 percent healthy watershed threshold. But with the resource protection levels of the UDC in effect, the impervious cover at build out in the Back Creek watershed is projected to be 15 percent, which correlates to a healthier watershed threshold.

In the 1000-Acre Marsh subwatershed within the C&D Canal watershed, the future impervious cover would climb to 17 percent without the UDC resource protection levels in effect. With the UDC RPLs in effect, the future impervious cover at full build out is reduced to a much more environmentally favorable estimate of 5 percent.

Many of the watersheds in southern New Castle County such as Cypress Branch, Cedar Swamp, and the tidal Blackbird Creek are naturally inoculated against the effects of potential development because they have high amounts of wetlands and forest. With the resource protection level standards of the UDC in effect, these emerald watersheds will have low amounts of future impervious cover (less than 5 percent). These environmental features naturally protect the health of these watersheds even at full build-out.

Table 5.2. Watershed imperviousness for existing and future land use in southern New Castle County.

Basin	Watershed	Subwatershed	Area (sq mi)	Scenario 1 % Impervious 2002 Land Use	Scenario 2 % Impervious Future Zoning No UDC RPL	Scenario 3 % Impervious Future Zoning w/ UDC RPL
Chesapeake Bay	C & D Canal	CD1. C & D Canal West	9.6	6	16	13
	Back Creek	BC1. Back Creek	7.5	8	25	14
	Sandy Branch	SB1. Sandy Branch	4.1	5	24	13
		SB2. Bohemia River	4.6	4	26	10
	Sassafras River	SS1. North Br. Sassafras	1.4	5	8	7
		SS2. South Br. Sassafras	6.4	9	10	9
	Cypress Branch	CY1. Cypress Branch	15.5	3	4	3
Delaware River	C & D Canal	CD2. Lums Pond	9.6	6	8	7
		CD3. C & D Canal East	12.4	6	18	17
		CD4. Scotts Run	6.5	7	40	23
		CD5. 1000-Acre Marsh	7.5	2	17	5
	Augustine Cr./Silver Run	AS1. Augustine Creek	7.8	7	21	8
		AS2. Silver Run	3.7	8	16	12
	Drawyers Creek	DR1. Shallcross Lake	7.3	6	22	10
		DR2. Doves Nest	6.1	13	21	16
		DR3. Main Stem Drawyers	2.1	7	26	15
	Appoquinimink River	AQ1. Deep Creek	3.4	14	38	29
		AQ2. Silver Lake	3.1	8	19	14
		AQ3. Appoquinimink Confl.	6.7	10	21	16
		AQ4. Main Stem Appoquin.	4.7	2	9	4
		AQ5. Wiggins Mill	4.2	5	8	5
		AQ6. Noxontown Pond	5.5	6	9	7
		AQ7. Hangmans Run	4.2	4	13	9
	Blackbird Creek	BB1. North Br. Blackbird Cr.	7.4	6	7	7
		BB2. South Br. Blackbird Cr.	11.1	8	8	7
		BB3. Main Stem Blackbird	8.3	3	6	5
		BB4. Fishing Creek	5.4	0	1	1
	Cedar Swamp	CS1. Cedar Swamp	8.2	1	1	1
	Smyrna River	SM1 North Br. above Clayton	21.3	7	10	8
		SM2. South Br. Smyrna R.	14.9	8	13	11
		SM3. Main Stem Smyrna R.	11.8	4	7	7
		SM4. Tidal Smyrna River	15.6	2	4	5

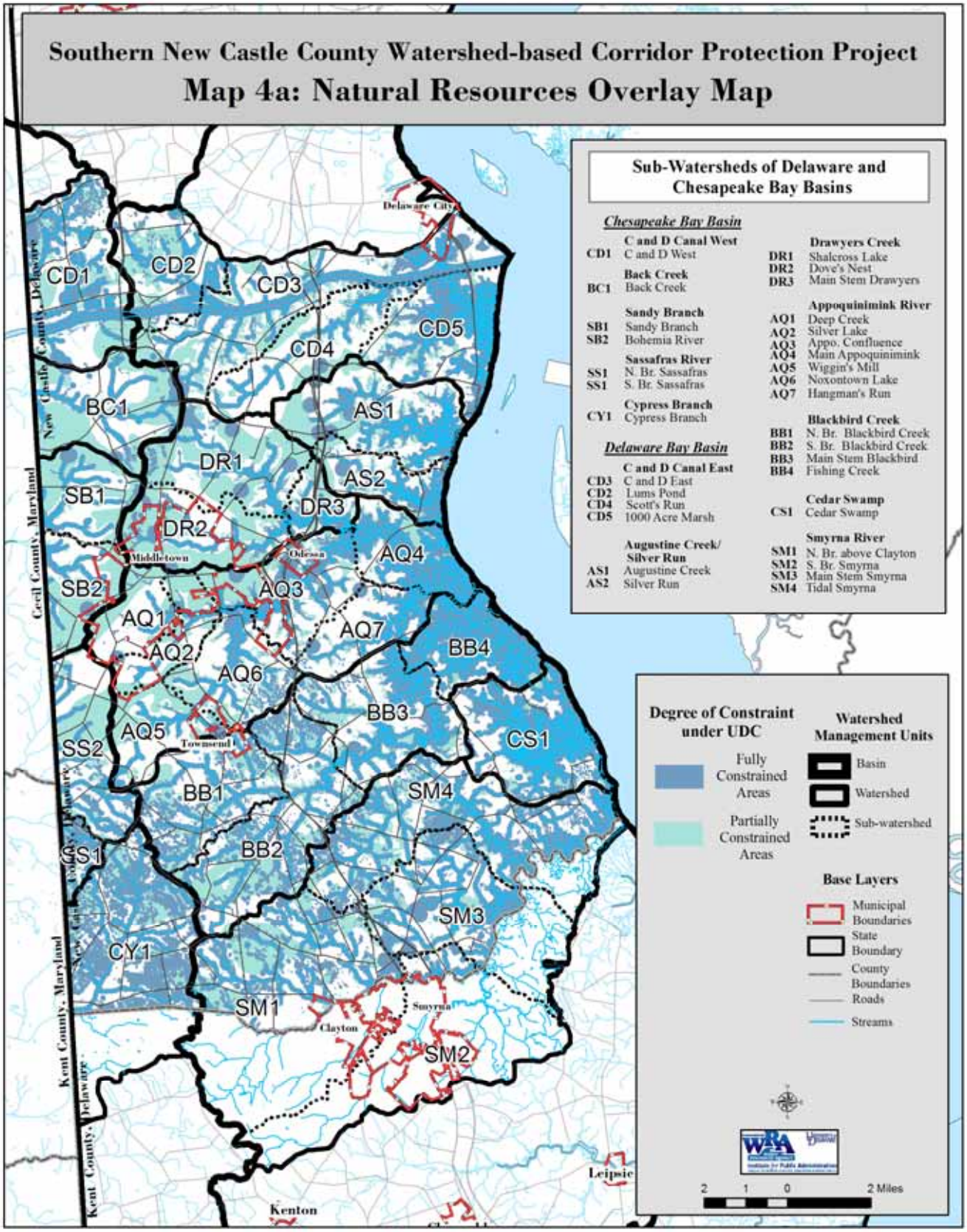

Figure 5.1. Consolidated natural resources overlay map in southern New Castle County.

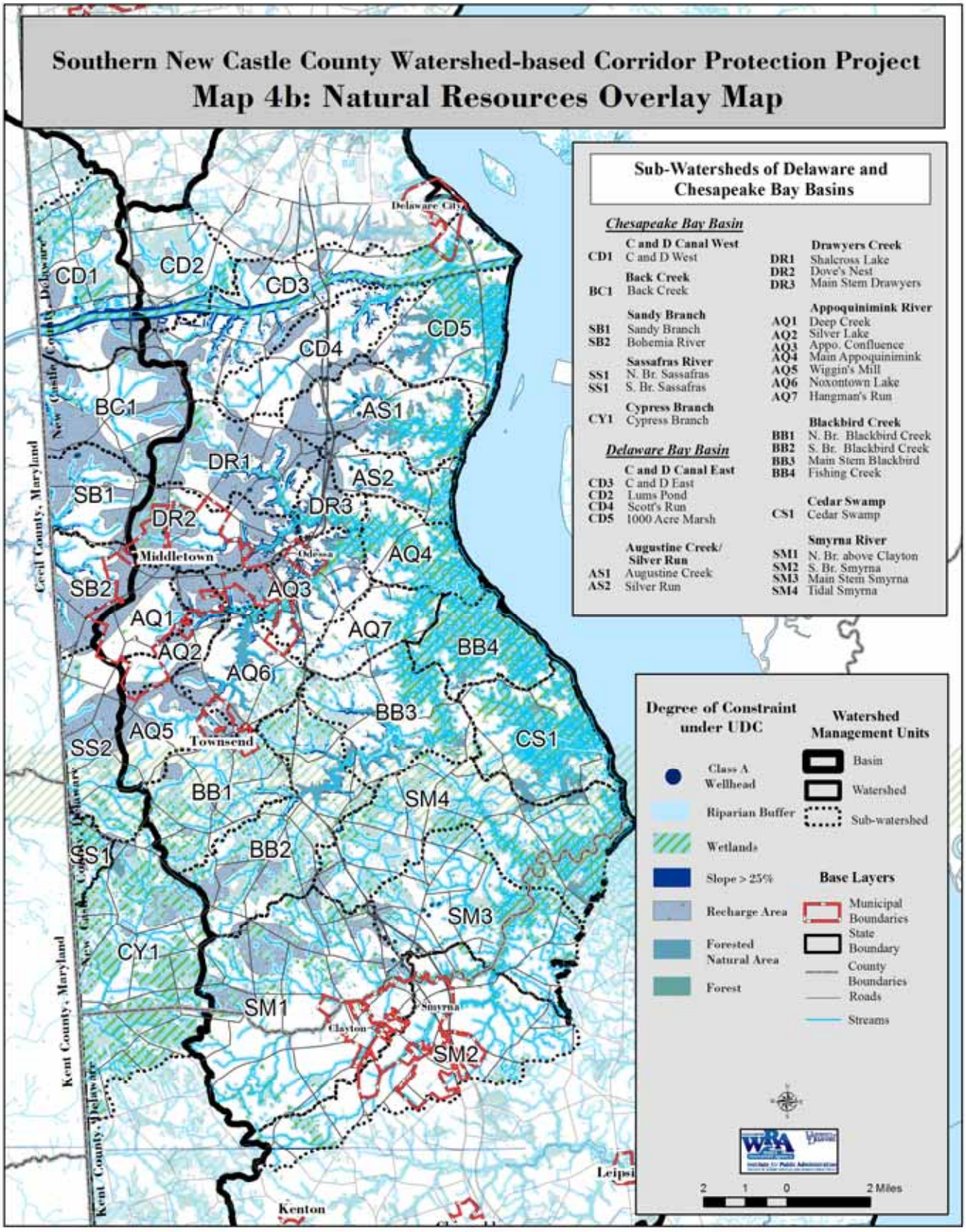

Figure 5.2. Natural resources overlay map in southern New Castle County.

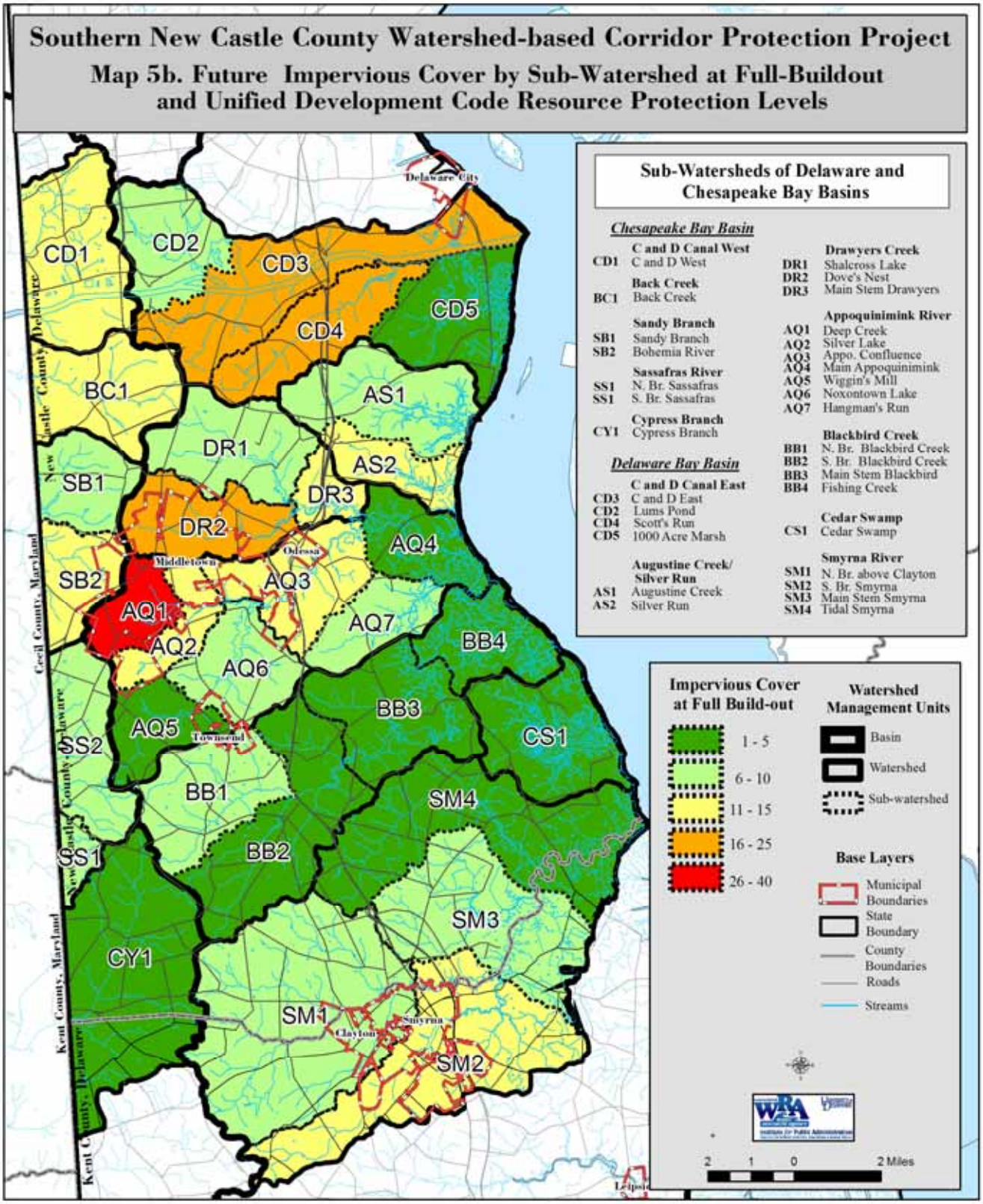

Figure 5.3. Impervious cover by subwatershed at full build out with UDC Resource Protection Levels.

Recharge WRPAs

IPA – WRA estimated existing and future impervious cover ratios within the recharge water resource protection areas in southern New Castle County (Figure 5.4). The analysis indicates the existing (2002) impervious cover of the 34 recharge WRPAs in southern New Castle County ranges from 0 to 20 percent. The future impervious cover of the recharge WRPAs at full build out with the UDC resource protection levels in effect will range from 0 to 20 percent. This indicates natural resources such as forests and floodplains and wetlands can protect the recharge WRPAs and keep the overall impervious cover at or below 20 percent which is the threshold mandated by the UDC to protect the quantity and quality of ground and surface water sources in New Castle County.

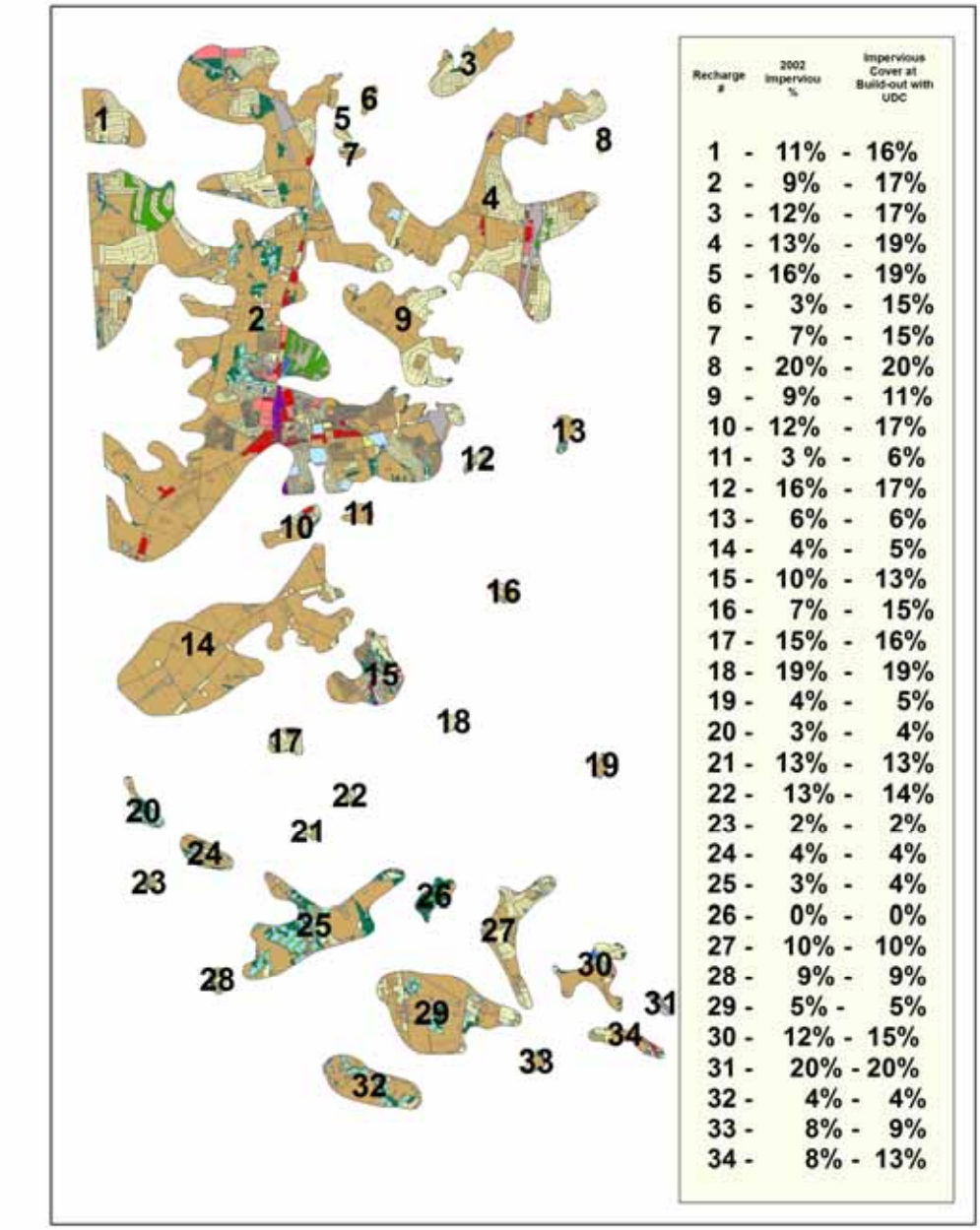

Figure 5.4. Percent impervious of recharge water resource protection areas southern New Castle County.

6. Priority Watershed Strategy

Strategy

To further mitigate the effect of new development on the health of water resources, the IPA-WRA developed a methodology to designate priority watersheds in southern New Castle County. Watersheds with low amounts of impervious cover and high amounts of wetlands, forest, and riparian buffers are designated as preservation watersheds where best management practices such as open space acquisition and conservation easements would be used to preserve the "blue and green" nature of these sensitive watersheds. Watersheds that have high amounts of impervious cover and low amounts of wetlands, forest, and riparian buffers are designated as restoration watersheds where best management practices such as stream restoration, reforestation, and stormwater retrofitting would be employed to offset the effects of suburbanization on the water resources.

The 200-square-mile southern New Castle County is a large region and includes 12 major watersheds and 32 subwatersheds. The benefits of prioritizing watersheds are to focus new development in watersheds that are less environmentally sensitive, focus watershed protection funding from federal and state resources, and implement best management practices more effectively depending on whether the goal is to protect or restore a particular watershed. The subwatersheds were prioritized for two types of protection or restoration strategies:

Preservation watersheds are designed to protect streams with existing good water quality and the following characteristics:

- High percentages of forests, wetlands, stream buffers, and protected open space.
- Low percentages of urban/suburban land uses with low amounts of impervious cover.
- Good stream water quality that supports recreation and habitat uses.

Restoration watersheds are designed to improve stream water quality and have the following characteristics:

- Low percentages of forests, wetlands, and riparian buffers.
- High percentages of urban suburban land and impervious cover.
- Relatively poor water quality that is impaired for recreation and habitat uses.

Methodology

Priority watersheds are rated according to a scale of 0 to 10. A low score close to zero indicates a watershed in the poor health category with little or no wetlands, forests, and riparian buffers and high amounts of impervious cover. A high score close to 10 indicates a watershed in the good health category nearly completely covered with wetlands, forests, riparian buffer, and protected open space and little or no impervious cover.

Priority watersheds were rated according to the following methods:

1. Calculate the percentage of wetlands, forests, and public and private open space in each subwatershed.

2. Calculate the percentage of a 100-foot-wide riparian buffer on either side of a stream or wetland that includes forest or wetlands within each subwatershed.

3. Calculate the percentage of impervious cover within each subwatershed.

4. Calculate the watershed priority score of each subwatershed according to the criteria in Table 6.1.

5. Summarize the watershed priority calculations for subwatersheds as shown in Table 6.2.

6. Recommend strategy for protecting natural and water resources in subwatersheds as shown in Table 6.3.

Table 6.1. Watershed priority rating criteria for southern New Castle County.

Watershed Priority Strategy	Score	Wetlands	Forest	Buffer w/ Forest and Wetlands	Open Space	Impervious Cover	Watershed Score
Preservation	2	26-100%	26-100%	76-100%	-	0-7%	6-10
	1	11-25 %	11–25%	51-75%	16-30 %	8-15%	4 - 5
Restoration	0	0-10 %	0-10%	0-50%	0-1 %	16-100 %	0-3

Table 6.2. Watershed priority score calculations for subwatersheds in southern New Castle County.

Basin	Watershed	Subwatershed	Area (sq mi)	% Wetland	% Forest	% Riparian Forest/ Wetland	% Open Space	% Impervious Cover (2002)	Watershed Priority Score
Chesapeake Bay	C & D Canal	CD1. C & D Canal W.	9.6	18 (1)	20 (1)	65 (1)	33(2)	6 (2)	**7**
	Back Creek	BC1. Back Creek	7.5	6 (0)	4 (0)	37 (0)	10(0)	8 (1)	**1**
	Sandy Branch	SB1. Sandy Branch	4.1	7 (0)	7 (0)	44 (0)	1(0)	5 (2)	**2**
		SB2. Bohemia River	4.6	4 (0)	7 (0)	49 (0)	0(0)	4 (2)	**2**
	Sassafras River	SS1. N. Br. Sassafras	1.4	45(2)	16(1)	43(0)	3(0)	5(2)	**5**
		SS2. S. Br. Sassafras	6.4	11(1)	8(0)	16(0)	2(0)	9(1)	**2**
	Cypress Br.	CY1. Cypress Branch	15.5	46 (2)	17 (1)	78 (2)	32(2)	3 (2)	**9**
Delaware River	C & D Canal	CD2. Lums Pond	9.6	13 (1)	30 (2)	59 (1)	72(2)	6 (2)	**8**
		CD3. C & D Canal East	12.4	19 (1)	11 (1)	60 (1)	39(2)	6 (2)	**7**
		CD4. Scotts Run	6.5	8 (0)	11 (1)	61 (1)	5(0)	7 (2)	**4**
		CD5. 1000 Acre Marsh	7.5	49 (2)	9 (0)	84 (2)	26(1)	2 (2)	**7**
	Augustine Cr./Silver Run	AS1. Augustine Creek	7.8	23 (1)	9 (0)	74 (1)	25(1)	7 (2)	**5**
		AS2. Silver Run	3.7	30 (2)	5 (0)	73 (1)	42(2)	8 (1)	**6**
	Drawyers Cr.	DR1. Shallcross Lake	7.3	10 (1)	9 (0)	65 (1)	15(0)	6 (1)	**3**
		DR2. Doves Nest	6.1	10 (1)	6 (0)	59 (1)	13(0)	13 (1)	**3**
		DR3. Drawyers	2.1	19 (1)	13 (1)	66 (1)	15(0)	7 (2)	**5**
	Appoquinimink	AQ1. Deep Creek	3.4	5 (0)	3 (0)	48 (0)	2(0)	14 (1)	**1**
		AQ2. Silver Lake	3.1	5 (0)	6 (0)	49 (0)	7(0)	8 (1)	**1**
		AQ3. Appoquinimink	6.7	18 (1)	11 (1)	68 (1)	23(1)	10 (1)	**5**
		AQ4. Appoquinimink	4.7	58 (2)	1 (0)	77 (2)	50(2)	2 (2)	**8**
		AQ5. Wiggin's Mill	4.2	5 (0)	9 (1)	50 (1)	14(0)	5 (2)	**4**
		AQ6. Noxontown Pond	5.5	15 (1)	18 (1)	68 (1)	<1(0)	6 (2)	**5**
		AQ7. Hangmans Run	4.2	24 (1)	4 (0)	63 (1)	18(1)	4 (2)	**5**
	Blackbird Cr.	BB1. N. Br. Blackbird	7.4	21 (1)	15 (1)	69 (1)	20(1)	6 (2)	**6**
		BB2. S. Br. Blackbird	11.1	20 (1)	28 (2)	70 (1)	26(1)	8 (2)	**7**
		BB3. Blackbird	8.3	26 (2)	14 (1)	26 (0)	48(2)	3 (2)	**7**
		BB4. Fishing Creek	5.4	75 (2)	2 (0)	85 (2)	89(2)	0 (2)	**8**
	Cedar Swamp	CS1. Cedar Swamp	8.2	56 (2)	5 (0)	81 (2)	93(2)	1 (2)	**8**
	Smyrna River	SM1. N. Br. Clayton	21.3	11 (1)	5 (0)	46 (0)	12(0)	7 (2)	**3**
		SM2. South Br. Smyrna	14.9	29(2)	19(1)	45(0)	15(0)	8 (1)	**4**
		SM3. Smyrna	11.8	26(2)	12(1)	32(0)	26(1)	4(2)	**6**
		SM4. Tidal Smyrna	15.6	38(2)	19(1)	45(0)	37(2)	2(2)	**7**

Table 6.3. Recommended preservation/restoration strategy for southern New Castle County watersheds.

Basin	Watershed	Subwatershed	Area (sq mi)	Priority Score	BMP Strategy
Chesapeake Bay	C & D Canal	CD1. C & D Canal West	9.6	7	P - Open Space Protection
	Back Creek	BC1. Back Creek	7.5	1	R - Restoration
	Sandy Branch	SB1. Sandy Branch	4.1	2	R - Restoration
		SB2. Bohemia River	4.6	2	R - Restoration
	Sassafras River	SS1. North Br. Sassafras	1.4	5	R - Restoration
		SS2. South Br. Sassafras	6.4	2	R - Restoration
	Cypress Branch	CY1. Cypress Branch	15.5	9	P - Open Space Protection
Delaware River	C & D Canal	CD2. Lums Pond	9.6	8	P - Open Space Protection
		CD3. C & D Canal East	12.4	7	P - Open Space Protection
		CD4. Scotts Run	6.5	4	R - Restoration
		CD5. 1000 Acre Marsh	7.5	7	P - Open Space Protection
	Augustine Cr./Silver Run	AS1. Augustine Creek	7.8	5	R - Restoration
		AS2. Silver Run	3.7	6	P - Open Space Protection
	Drawyers Creek	DR1. Shallcross Lake	7.3	3	R - Restoration
		DR2. Doves Nest	6.1	3	R - Restoration
		DR3. Main Drawyers	2.1	5	R - Restoration
	Appoquinimink River	AQ1. Deep Creek	3.4	1	R - Restoration
		AQ2. Silver Lake	3.1	1	R - Restoration
		AQ3. Appo. Confl.	6.7	5	R - Restoration
		AQ4. Main Stem Appo.	4.7	8	P - Open Space Protection
		AQ5. Wiggin's Mill	4.2	4	R - Restoration
		AQ6. Noxontown Pond	5.5	5	R - Restoration
		AQ7. Hangman's Run	4.2	5	R - Restoration
	Blackbird Creek	BB1. N. Br. Blackbird	7.4	6	P - Open Space Protection
		BB2. S. Br. Blackbird	11.1	7	P - Open Space Protection
		BB3. Main Blackbird	8.3	7	P - Open Space Protection
		BB4. Fishing Creek	5.4	8	P - Open Space Protection
	Cedar Swamp	CS1. Cedar Swamp	8.2	8	P - Open Space Protection
	Smyrna River	SM1. N. Br. Abv. Clayton	21.3	3	R - Restoration
		SM2. S. Br. Smyrna	14.9	4	R - Restoration
		SM3. Main Stem Smyrna	11.8	6	P - Open Space Protection
		SM4. Tidal Smyrna	15.6	7	P - Open Space Protection

Figure 6.1 depicts the results of the watershed priority score calculations. The watersheds with the highest scores (6 to 10) are shaded in green and appear as an “emerald necklace” around the perimeter of southern New Castle County. A contiguous chain of preservation watersheds lines the C & D Canal, the Delaware Bay coast, and the Blackbird forest and wetland complex. Large amounts of forest, wetland, riparian buffers, and protected open space protect these environmentally sensitive watersheds, creating a green belt around the growing towns of Middletown, Odessa, and Townsend in southern New Castle County. These green watersheds are recommended for protection by acquiring more open space and conservation easements thus creating an unbroken ring of conservation open space around the periphery of the MOT village core.

The watersheds with the lowest scores shaded in yellow (1 to 3) and brown (4 to 5) have lower amounts of natural resources and higher amounts of impervious cover. These watersheds will receive more development pressure and could potentially be used to delineate sending and receiving areas for transfer of development rights (TDR) programs. Watersheds with existing high percentages of impervious cover would serve as receiving areas forming the urban/suburban core of southern New Castle County in and around the MOT towns. Watersheds with low impervious cover would be sending areas in accordance with a strategy to reduce development in areas with large amounts of forest, wetland, riparian buffers, and open space.

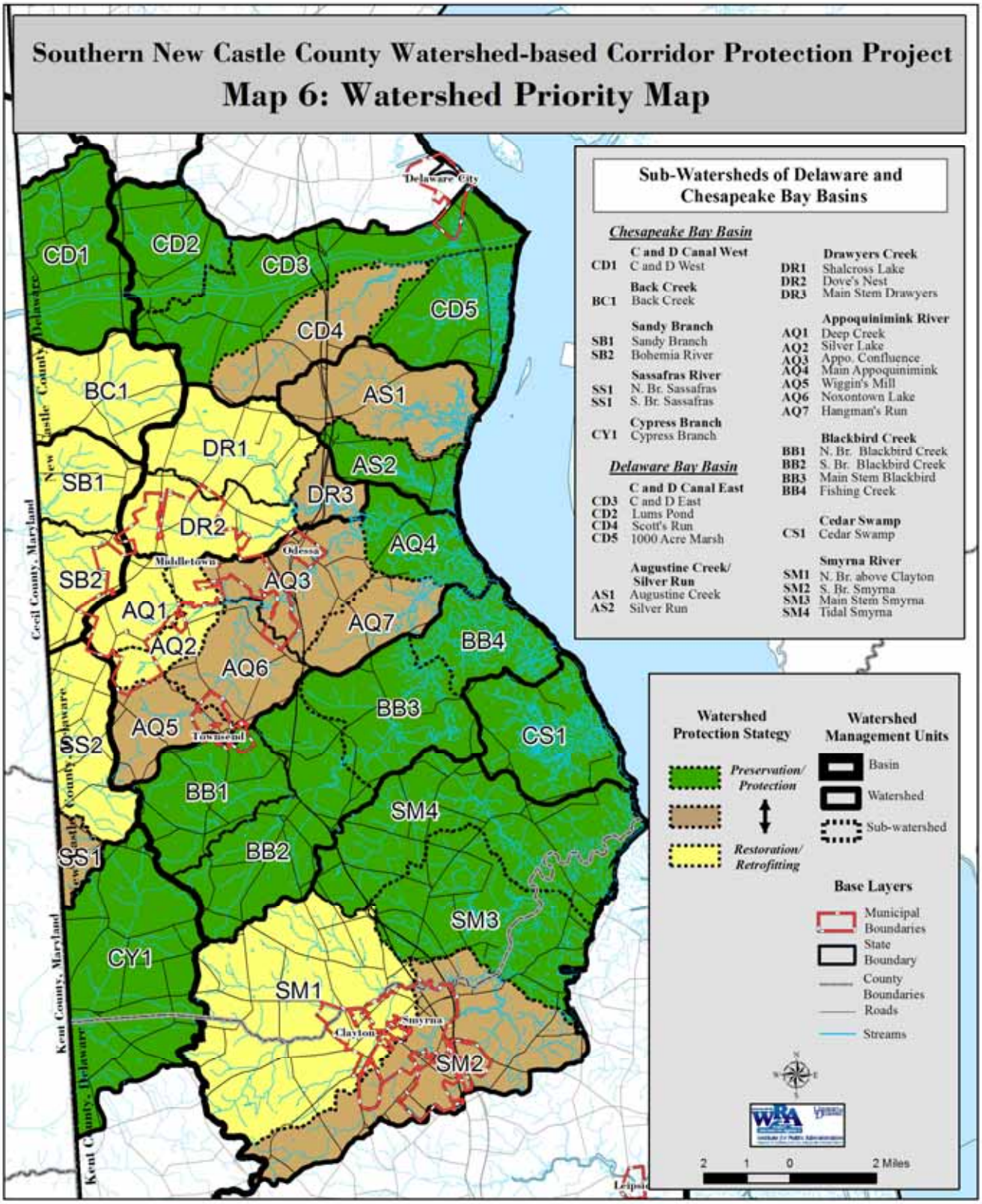

Figure 6.1. Watershed priority strategy map for southern New Castle County.

7. Conclusions and Recommendations

The following watershed-based strategy is recommended to protect and restore the waters and the watersheds of southern New Castle County as the population is projected to double from 41,000 in 2005 and reach 96,000 people there by 2030. The Appoquinimink River Association should be funded as the lead coordinator to implement this watershed strategy for southern New Castle County with the assistance of the lead organizations as identified below.

Preservation Watersheds

These undeveloped (green) watersheds generally have healthy water quality due to low amounts of impervious surfaces and high overall amounts of forests, wetlands, and open spaces. The strategy is to keep these "green" watersheds "green" and maintain existing good water quality through the following preservation techniques:

P-1. Acquire and Conserve Open Space. Prioritize funding to acquire more public open space, particularly forested and wetland tracts, specifically in the following subwatersheds:

CD1	C & D Canal West
CD2	Lums Pond
CD3	C & D Canal East
CD5	1000-Acre Marsh
AS2	Silver Run
AQ4	Main Stem Appoquinimink Creek
CS1	Cedar Swamp
CY1	Cypress Branch
BB1	North Branch Blackbird Creek
BB2	South Branch Blackbird Creek
BB3	Main Stem Blackbird Creek
BB4	Fishing Creek
SM3	North Branch Smyrna River above Clayton
SM4	South Branch Smyrna River

Representatives from Delaware DNREC Division of Parks and Recreation and Division of Fish and Wildlife, and the New Castle County Department of Special Services would be appointed as leads for this initiative.

P-2. Retain Conservation Easements. Continue to seek opportunities to acquire conservation easements for the preservation of open space in the watersheds listed above. The Delaware Coastal Management Program, Delaware Nature Society, and the Natural Lands Trust would be appointed as leads for this initiative.

P-3. Minimize Impervious Cover. Recommend in the New Castle County 5-year Comprehensive Plan Update and amend the existing New Castle County Unified Development Code to designate the preservation watersheds listed in P1 above as water resource protection areas (WRPAs) which would set a 20 percent impervious cover threshold on any new development in these sensitive watersheds. The Water Resources Agency at the University of Delaware and New Castle County Department of Land Use are appointed as the leads for this task.

P-4. Transfer of Development Rights. Recommend in the New Castle County 5-year Comprehensive Plan Update utilizing the subwatersheds as the means to delineate sending and receiving areas for transfer of development rights (TDR) programs. Watersheds with low impervious cover would be sending areas in accordance with a strategy to reduce development in areas with large amounts of forest, wetland, riparian buffers, and open space. Watersheds with existing high percentages of impervious cover would serve as receiving areas, forming the urban/suburban core of southern New Castle County in and around the towns of Middletown, Odessa, and Townsend.

Restoration Watersheds

These more developed watersheds have more impaired water quality with higher amounts of impervious surfaces and lower amounts of forests, wetlands, and open space. The strategy is to restore these watersheds and improve existing water quality by implementing the following restoration and retrofitting techniques.

R-1. Restore Stream, Wetlands, and Riparian Corridors. Restore stream and riparian corridors using techniques such as bioengineering and wetland restoration, paying close attention to first-order streams that may not appear on topographic maps, but are crucial to watershed health. The Delaware DNREC Division of Soil and Water Conservation will be requested to act as lead for stream restoration.

R-2. Reforest Watersheds and Headwaters. Reforest watersheds particularly in watersheds where agricultural land is taken out of production. The Delaware Department of Agriculture's Forest Service Section and the New Castle Conservation District will be requested to act as the leads for the reforestation initiative.

R-3. Retrofit Stormwater Quality Basins. Find opportunities to retrofit existing stormwater basins and convert them into rain gardens and bioretention areas incorporating native landscaping. The New Castle County Department of Special Services and Appoquinimink River Association will be requested to serve as the leads.

R-4. Reduce Remaining NPDES Wastewater Discharge. Reduce the wastewater discharge at New Castle County Water Farm No. 1 into the Appoquinimink River in accordance with the TMDL set by the Delaware DNREC. The Delaware DNREC Division of Water Resources is identified as the lead.

R-5. Implement Agricultural Conservation BMPs. Prioritize existing U.S. Department of Agriculture, Conservation Reserve Enhancement Program funds for nutrient management, grassed waterways, filter strips, manure storage, and stream fencing in the agricultural watersheds of southern New Castle County. The Delaware Nutrient Management Commission requires development of a nutrient management plan for any business operation that applies nutrients to greater than 10 acres of land or manages 8,000 pounds of animals. The USDA Natural Resources Conservation Service, New Castle Conservation District, and the Delaware Nutrient Management Commission are identified as the leads. The following southern New Castle County subwatersheds have agricultural lands that exceed 50 percent of the watershed area:

Subwatershed		Percent Agricultural
CD3	C & D Canal East	42
CD4	Scott's Run	70
BC1	Back Creek	55
AS1	Augustine Creek	48
SB2	Sandy Branch	66
SB1	Bohemia River	66
SB2	Sandy Branch	65
DR3	Main Stem Drawyers Creek	40
DR1	Shallcross Lake	65
SS2	S. Br. Upper Sassafras River	75
AQ1	Deep Creek	66
AQ2	Silver Lake	63
AQ3	Appoquinimink Confluence	41
AQ5	Wiggins Mill	76
AQ6	Noxontown Lake	53
AQ7	Hangmans Run	55
BB3	Main Stem Blackbird Creek	48
SM1	N. Br. Smyrna River above Clayton	63
SM2	S. Br. Smyrna River	44

R-6. SMARTYARD Lawn Care Program. Provide incentives to homeowners to remove grass turf and plant water-friendly native landscaping to conserve water and reduce fertilizer and pesticide use. The SMARTYARD program also includes delivery of rain barrels to interested homeowners according to the following goals for each watershed. The Delaware Nature Society and the Appoquinimink River Association are identified as the leads.

Watershed	SMARTYARDS	Rain Barrels
C & D Canal	200	200
Augustine Creek/Silver Run	200	200
Drawyers Creek	300	300
Appoquinimink River	300	300
Blackbird Creek	100	100
Cedar Swamp	5	5
Smyrna River/Duck Creek	100	100
Chester River	10	10
Sassafras River/Cypress Branch	10	10
Sandy Branch/Great Bohemia Creek	50	50
Back Creek	200	200

R-7. Reduce Impervious Cover. Modify the New Castle County Unified Development Code to incorporate the following impervious cover reduction strategies to minimize total pavement and roof area in the watersheds:

- Narrower residential road cross-sections (24 feet wide) and road shoulders
- Shorter road lengths
- Smaller turn-arounds and cul-de-sac radii
- Permeable paving for spill over parking areas
- Smaller parking stalls and smaller parking demand ratios
- Angled one-way parking
- Clustered subdivisions with open space
- Smaller front yard setbacks
- Shared parking and driveways
- Narrower sidewalks

To provide flexible development options, the amended ordinance should contain stormwater credits that permit the impervious cover to be increased with incorporation of the following techniques:

- Disconnect rooftop runoff to splash onto lawns or infiltrate into the groundwater table.
- Reforest disturbed areas along riparian stream corridors.
- Remove existing impervious surfaces from onsite or from other watersheds.
- Acquire and protect open space offsite through conservation easements.

Summary

Watershed zoning based on impervious coverage thresholds is recommended as a measurable and scientifically defensible technique to plan for smart growth and protect stream water quantity and quality in the watersheds in southern New Castle County. Watersheds provide the natural boundaries to guide the land planning decisions that affect stream water quality, after all, watersheds know no political boundaries. The wealth of literature points to a link between the amount of impervious cover and the health of streams and watersheds. By employing these concepts in the Unified Development Code, growth can be concentrated into areas with existing development and infrastructure and away from the undeveloped watersheds. These tools are available to assist the New Castle County Department of Planning with wise land use decisions to protect water supplies in the watersheds of southern New Castle County.

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Appendix A. Area of land use by subwatershed in southern New Castle County.

ID	Subwatershed	Drainage Area (Acres)	Drainage Area (Sq.Mi.)	Single Family Residential	Multi Family Residentt.	Industrial	Transportation	Commercial	Institution	Recreation	Wooded	Agriculture	Water	Wetland	Vacant/Barren	Public/Private Open Space
Chesapeake Bay																
	C & D Canal A															
CD1	C& D Canal West	6150.2	9.6	1307.0	48.1	0.0	55.0	0.0	11.7	4.2	1179.5	1592.4	271.3	805.0	161.1	2030.8
	Back Creek															
BC1	Back Creek	4821.9	7.5	1302.6	2.3	0.0	60.1	16.0	0.0	205.1	190.6	2649.1	52.7	170.7	171.9	493.3
	Sandy Branch															
SB1	Bohemia River	3056.0	4.8	558.0	0.0	0.0	7.1	0.0	0.0	0.0	208.3	2013.4	34.3	123.8	111.2	31.2
SB2	Sandy Branch	2785.7	4.4	197.0	0.0	0.0	0.0	37.8	0.0	0.0	207.5	2220.4	6.4	108.8	7.8	309.2
	Sassafras River															
SS1	N. Br. Sassafras River	911.7	1.4	35.6	0.0	0.0	0.0	0.0	0.0	0.0	175.7	299.9	9.1	393.9	0.0	29.0
SS2	S. Br. Sassafras River	4082.0	6.4	173.5	0.0	0.0	0.0	40.8	0.0	0.0	363.3	3063.9	0.0	449.0	0.0	67.7
	Cypress Branch															
CY1	Cypress Branch	10219.9	16.0	993.3	0.0	0.0	0.0	0.0	2.2	0.0	1690.1	3178.5	47.1	4308.7	0.0	3295.3
Delaware River																
	C & D Canal B															
CD2	Lums Pond	3817.7	6.0	717.9	0.0	0.0	81.0	11.0	14.4	207.0	1159.3	589.4	439.0	231.6	37.1	2760.9
CD3	C & D Canal East	7939.0	12.4	1168.0	0.0	8.3	85.7	84.7	82.3	16.5	841.5	3323.7	942.4	640.0	258.4	3061.3
CD4	Scott's Run	4168.1	6.5	239.9	0.0	54.5	115.3	10.3	0.0	0.0	457.6	2900.3	45.5	303.8	39.6	221.0
CD5	1000 Acre Marsh	4788.2	7.5	308.9	0.0	0.0	1.9	0.0	0.0	0.0	432.4	1595.8	774.2	1576.4	80.4	1238.3
	Augustine/Silver Run															
AS1	Augustine Creek	5051.5	7.9	888.0	0.0	0.0	146.2	14.3	0.0	1.8	445.2	2431.0	205.9	913.0	0.0	1266.2
AS2	Silver Run	2370.0	3.7	568.5	0.0	0.0	43.6	14.2	0.0	29.1	121.0	826.0	63.3	688.9	0.0	1003.1
	Drawyer's Creek															
DR1	Shallcross Lake	4658.4	7.3	690.2	0.0	0.0	0.0	34.7	21.2	0.0	418.7	3027.6	111.6	309.9	44.6	714.1
DR2	Doves Nest	3902.1	6.1	914.0	182.6	47.1	87.7	104.3	13.5	201.2	252.5	1421.9	88.6	239.3	157.9	520.2
DR3	Main Stem Drawyers	1313.8	2.1	151.6	0.0	0.0	104.0	0.0	0.0	0.0	168.2	518.4	98.4	209.8	0.0	200.1
	Appoquinimink River															
AQ1	Deep Creek	2170.5	3.4	125.4	9.5	91.1	65.9	129.2	42.8	0.0	64.8	1434.3	43.6	37.8	114.4	32.9
AQ2	Silver Lake	2009.3	3.1	343.2	8.7	0.0	0.0	38.5	99.4	0.0	125.4	1264.3	49.0	31.9	48.9	131.8
AQ3	Appoquinimink Confluence	4277.6	6.7	718.4	15.8	0.0	228.2	86.2	41.7	0.0	478.6	1739.4	248.2	646.7	60.6	965.9
AQ4	Main Appoquinimink	3016.4	4.7	92.8	0.0	0.0	1.1	0.0	0.0	0.0	23.3	899.5	329.8	1669.9	0.0	1493.2
AQ5	Wiggin's Mill	2688.3	4.2	260.2	0.0	4.5	0.0	14.4	0.9	0.0	236.4	2033.3	46.4	85.6	4.5	366.8
AQ6	Noxontown Lake	3511.5	5.5	381.5	0.0	0.0	47.8	28.8	55.0	0.0	634.2	1874.5	231.1	227.1	28.0	4.0
AQ7	Hangman's Run	2695.2	4.2	301.6	0.0	0.0	16.7	0.0	0.0	0.0	101.3	1477.6	86.9	542.7	164.4	473.0
	Blackbird Creek															
BB1	N. Br. Blackbird Creek	4750.0	7.4	825.7	0.0	7.7	3.1	26.6	6.4	0.0	1159.1	1802.7	15.5	867.6	28.2	948.7
BB2	S. Br. Blackbird Creek	7098.0	11.1	945.4	7.0	0.0	237.7	72.1	0.0	0.0	1951.7	2513.4	66.1	1204.6	58.4	1865.0
BB3	Main Stem Blackbird Crk	5343.2	8.3	284.5	17.0	0.0	13.7	0.0	0.0	0.0	771.2	2554.4	206.6	1469.7	16.1	2584.1
BB4	Fishing Creek	3445.9	5.4	2.1	0.0	0.0	0.0	0.0	0.0	0.0	56.7	551.4	312.4	2523.4	0.0	3057.8
	Cedar Swamp															
CS1	Cedar Swamp	5248.1	8.2	17.2	0.0	0.0	11.9	0.0	0.0	4.7	276.5	1951.0	232.4	2754.6	0.0	4855.8
	Smyrna River															
SM1	N. Br. Above Clayton	13631.4	21.3	2095.9	67.4	105.1	50.3	177.7	164.6	0.0	634.0	8559.7	103.7	1505.0	0.0	1605.4
SM2	S. Br. Smyrna River	17576.7	27.5	906.8	7.1	0.0	274.6	32.6	215.1	0.0	2835.7	7663.3	374.1	5010.2	229.5	2673.7
SM3	Main Stem Smyrna River	7568.0	5.2	395.1	0.0	0.0	136.2	76.4	215.7	0.0	916.5	4026.9	133.2	1682.4	0.0	1997.6
SM4	Tidal Smyrna River	10008.7	0.0	511.4	0.0	0.0	138.1	0.0	0.0	0.0	1919.7	3639.2	240.2	3327.9	209.2	3730.0

Appendix B. Percentage of land use by subwatershed in southern New Castle County.

ID	Subwatershed	Drainage Area (Acres)	Drainage Area (Sq.Mi.)	Single Family Residential	Multi Family Residential	Industrial	Transportation	Commercial	Institution	Recreation	Wooded	Agriculture	Water	Wetland	Vacant/Barren	Public/Private Open Space
Chesapeake Bay																
	C & D Canal A															
CD1	C & D Canal West	6150.2	9.6	21.3	0.8	0.0	0.9	0.0	0.2	0.1	19.2	25.9	4.4	13.1	2.6	33.0
	Back Creek															
BC1	Back Creek	4821.9	7.5	27.0	0.2	0.0	1.0	0.3	0.0	4.3	4.0	54.9	1.1	3.5	3.6	10.2
	Sandy Branch															
SB1	Bohemia River	3056.0	4.8	18.3	0.0	0.0	0.2	0.0	0.0	0.0	6.8	65.9	1.1	4.1	3.6	1.0
SB2	Sandy Branch	2785.7	4.4	7.1	0.0	0.0	0.0	1.4	0.0	0.0	7.4	79.7	0.2	3.9	0.3	11.1
	Sassafras River															
SS1	N. Br. Sassafras River	911.7	1.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	2.1	3.6	0.1	4.7	0.0	0.3
SS2	S. Br. Sassafras River	4082.0	6.4	4.3	0.0	0.0	0.0	1.0	0.0	0.0	8.9	75.1	0.0	11.0	0.0	1.7
	Cypress Branch															
CY1	Cypress Branch	10219.9	16.0	9.7	0.0	0.0	0.0	0.0	0.0	0.0	16.5	31.1	0.5	42.2	0.0	32.2
Delaware River																
	C & D Canal B															
CD2	Lums Pond	3817.7	6.0	18.8	0.0	0.0	2.1	0.3	0.4	5.4	30.4	15.4	11.5	6.1	1.0	72.3
CD3	C and D Canal East	7939.0	12.4	14.7	0.0	0.1	1.1	1.1	1.0	0.2	10.6	41.9	11.9	8.1	3.3	38.6
CD4	Scotts Run	4168.1	6.5	5.8	0.0	1.3	2.8	0.2	0.0	0.0	11.0	69.6	1.1	7.3	0.9	5.3
CD5	1000 Acre Marsh	4788.2	7.5	6.5	0.0	0.0	1.9	0.0	0.0	0.0	9.0	33.8	16.2	32.4	1.7	25.9
	Augustine/Silver Run															
AS1	Augustine Creek	5051.5	7.9	17.6	0.0	0.0	2.9	0.3	0.0	0.0	8.8	48.1	4.1	18.1	0.0	25.1
AS2	Silver Run	2370.0	3.7	24.0	0.0	0.0	1.8	0.6	0.0	1.2	5.1	34.9	2.7	29.1	0.0	42.3
	Drawyers Creek															
DR1	Shallcross Lake	4658.4	7.3	14.8	0.0	0.0	0.0	0.7	0.5	0.0	9.0	65.0	2.4	6.7	1.0	15.3
DR2	Dove's Nest	3902.1	6.1	2.3	0.5	0.1	0.2	0.3	0.0	0.5	0.6	3.6	0.2	0.6	0.4	1.3
DR3	Main Stem Drawyers	1313.8	2.1	11.5	0.0	0.0	7.9	0.0	0.0	0.0	12.8	39.5	7.5	16.0	0.0	15.2
	Appoquinimink River															
AQ1	Deep Creek	2170.5	3.4	5.8	0.4	4.2	3.0	6.0	2.0	0.0	3.0	66.1	2.0	1.7	5.3	1.5
AQ2	Silver Lake	2009.3	3.1	17.1	0.4	0.0	0.0	1.9	4.9	0.0	6.2	62.9	2.4	1.6	2.4	6.6
AQ3	Appoquinimink Confluence	4277.6	6.7	16.8	0.4	0.0	5.3	2.0	1.0	0.0	11.2	40.7	5.8	15.1	1.4	22.6
AQ4	Main Appoquinimink	3016.4	4.7	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.8	29.8	10.9	55.4	0.0	49.5
AQ5	Wiggins Mill	2688.3	4.2	9.7	0.0	0.2	0.0	0.5	0.0	0.0	8.8	75.6	1.7	3.2	0.2	13.6
AQ6	Noxontown Lake	3511.5	5.5	10.9	0.0	0.0	1.4	0.8	1.6	0.0	18.1	53.4	6.6	6.5	0.8	0.1
AQ7	Hangmans Run	2695.2	4.2	301.6	0.0	0.0	16.7	0.0	0.0	0.0	101.3	1477.6	86.9	542.7	164.4	473.0
	Blackbird Creek															
BB1	N. Br. Blackbird Creek	4750.0	7.4	17.4	0.0	0.2	0.1	0.6	0.1	0.0	24.4	38.0	0.3	18.3	0.6	20.0
BB2	S. Br. Blackbird Creek	7098.0	11.1	13.3	0.1	0.0	3.3	1.0	0.0	0.0	27.5	35.4	0.9	17.0	0.8	26.3
BB3	Main Stem Blackbird Crk	5343.2	8.3	5.3	0.3	0.0	0.3	0.0	0.0	0.0	14.4	47.8	3.9	27.5	0.3	48.4
BB4	Fishing Creek	3445.9	5.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.6	16.0	9.1	73.2	0.0	88.8
	Cedar Swamp															
CS1	Cedar Swamp	5248.1	8.2	0.3	0.0	0.0	0.2	0.0	0.0	0.1	5.3	37.2	4.4	52.5	0.0	92.6
	Smyrna River															
SM1	N. Br. Above Clayton	13631.4	21.3	15.4	0.5	0.8	0.4	1.3	1.2	0.0	4.7	62.8	0.8	11.0	0.0	11.8
SM2	S. Br. Smyrna River	17576.7	27.5	5.2	0.0	0.0	1.6	0.2	1.2	0.0	16.1	43.6	2.1	28.5	1.3	15.2
SM3	Main Stem Smyrna River	7568.0	5.2	5.2	0.0	0.0	1.8	1.0	2.9	0.0	12.1	53.2	1.8	22.2	0.0	26.4
SM4	Tidal Smyrna River	10008.7	0.0	5.1	0.0	0.0	1.4	0.0	0.0	0.0	19.2	36.4	2.4	33.3	2.1	37.3

Appendix C. Excerpts from State of Delaware 2004 Combined Watershed Assessment Report (305(b)).

Table III-4 2004 Station Summary Statistics

Station	Segment	Segment Description	Station Location	Minimum DO Attainment			Average DO Attainment			
				# samples	# samples below min	Min DO Attainment	# samples	10th %tile UCL	Average Salinity	Avg. Attainment
109091	DE 010-001-01	Lower Appoquinimink River	Confluence with Delaware River	20	0	1	10	5.55	5.1	1
109121	DE 010-001-01	Lower Appoquinimink River	Rt. 9 Bridge	20	2	5	10	3.85	4.5	5
109141	DE 010-001-01	Lower Appoquinimink River	Mouth of East Br. Drawyer Creek	20	2	5	10	3.3	4.1	5
109041	DE 010-001-02	Upper Appoquinimink River - Odessa	Rt. 13 Bridge	21	2	5	11	3.5	2.4	5
109051	DE 010-001-02	Upper Appoquinimink River - Odessa	Rt. 299 Bridge, Odessa	20	4	5	10	3.4	3.0	5
109151	DE 010-001-02	Upper Appoquinimink River - Odessa	Above West Br. Drawyer Creek	20	3	5	10	3.405	3.7	5
109171	DE 010-001-02	Upper Appoquinimink River - Odessa	MOT Gut (Appo Gut) - West Bank	20	3	5	10	3.3	3.2	5
109071	DE 010-001-03	Lower Appoquinimink River - Drawyer Creek	Drawyer Creek, Rt 13	20	1	1	10	4.21	2.4	5
109201	DE 010-001-03	Lower Appoquinimink River - Drawyer Creek	Tributary of Drawyer Creek at Marl Pit Rd.	13	0	1	9	I.D.	0.0	3
109211	DE 010-001-03	Lower Appoquinimink River - Drawyer Creek	Drawyer Creek above Shallcross Lake at Ceder Lane Rd.	9	0	1	5	I.D.	0.0	3
109221	DE 010-002-01	Upper Appoquinimink - Wiggins Mill Pond Branch	Downstream of Wiggins Mill Pond at Rt. 71	8	1	1	4	I.D.	0.0	3
109231	DE 010-002-01	Upper Appoquinimink - Wiggins Mill Pond Branch	Upstream of Wiggins Mill Pond at Grears Corner Rd.	8	1	1	5	I.D.	0.0	3
109081	DE 010-002-02	Upper Appoquinimink, Deep Creek To Confluence With Silver	Deep Creek Branch at Rt. 71 Bridge (Middletown Nat	4	0	1	4	I.D.	0.0	3
109241	DE 010-002-02	Upper Appoquinimink, Deep Creek To Confluence With Silver	Deep Creek at DE Rt. 15	7	0	1	4	I.D.	0.0	3
109251	DE 010-002-02	Upper Appoquinimink, Deep Creek To Confluence With Silver	Deep Creek above Silver Lake at Rt. 71	9	0	1	5	I.D.	0.0	3
109131	DE 010-L01	Noxontown Pond	Noxontown Pond Overflow, Rd 38	20	0	1	10	7.2	0.1	1
109031	DE 010-L02	Silver Lake	Silver Lake Overflow, Rd 442	19	0	1	10	8.6	0.1	1
109191	DE 010-L03	Shallcross Lake	Shallcross Lake Overflow	20	0	1	10	5.5	0.1	1
114011	DE 020-001	Lower Army Creek	Rt. 9	20	4	5	9	I.D.	0.0	3

Table III-4 2004 Station Summary Statistics

Station	Segment	Segment Description	Station Location	Minimum DO Attainment			Average DO Attainment			
				# samples	# samples below min	Min DO Attainment	# samples	10th %tile UCL	Average Salinity	Avg. Attainment
114041	DE 020-001	Lower Army Creek	No name trib. At Rt. 13 near Airport Ind. Park	4	0	1	3	I.D.	0.0	3
114021	DE 020-002	Upper Army Creek	Rt. 13 Bridge	19	1	1	8	I.D.	0.0	3
114051	DE 020-002	Upper Army Creek	No name trib. At Rt. 40 near Airport Ind. Park	3	0	1	2	I.D.	0.0	3
110031	DE 030-001	Lower Blackbird Creek	Blackbird Landing	7	2	5	4	I.D.	0.0	3
110041	DE 030-001	Lower Blackbird Creek	Rt. 9 Taylors Bridge	20	3	5	8	I.D.	0.0	3
110011	DE 030-002	Upper Blackbird Creek	Blackbird Station	6	0	1	3	I.D.	0.0	3
110021	DE 030-002	Upper Blackbird Creek	Rt. 13 (Northern Branch	20	2	5	8	I.D.	0.0	3
110101	DE 030-002	Upper Blackbird Creek	Rd. 472	7	0	1	4	I.D.	0.0	3
110111	DE 030-002	Upper Blackbird Creek	Barlow Br	7	0	1	4	I.D.	0.0	3

Table III-4 2004 Station Summary Statistics

Station	Segment	Segment Description	Station Location	Minimum DO Attainment			Average DO Attainment			
				# samples	# samples below min	Min DO Attainment	# samples	10th %tile UCL	Average Salinity	Avg. Attainment
108031	DE 090-001	Chesapeake And Delaware Canal From Maryland Line To Delaware	Summit Bridge	20	0	1	9	I.D.	0.0	3
108111	DE 090-L01	Lums Pond	Lums Pond Boat Ramp	20	0	1	9	I.D.	0.0	3
112011	DE 100-001	Cypress Branch	Cypress Branch at Delaney Corner (Rt. 40) Bridge	9	2	5	4	I.D.	0.0	3
112021	DE 100-001	Cypress Branch	Sewell Branch at Rd. 95	19	4	5	8	I.D.	0.0	3
112581	DE 100-001	Cypress Branch	Cypress Branch at Morris Road (Rt. 477) Bridge	9	3	5	4	I.D.	0.0	3

Table III-4 2004 Station Summary Statistics

Station	Segment	Segment Description	Station Location	N Attainment			P Attainment			Bacterial Attainment			ERES Use Support
				# samples	N LCL 90th %tile	N Attainment	# samples	P LCL 90th %tile	P Attainment	# samples	B LCL 90th %tile	Bacterial Attainment	
114041	DE 020-001	Lower Army Creek	No name trib. At Rt. 13 near Airport Ind. Park	4	ID	3	4	ID	3	4	ID	3	--
114021	DE 020-002	Upper Army Creek	Rt. 13 Bridge	19	2.849	5	18	0.149	5	19	733	5	--
114051	DE 020-002	Upper Army Creek	No name trib. At Rt. 40 near Airport Ind. Park	3	ID	3	3	ID	3	3	ID	3	--
110031	DE 030-001	Lower Blackbird Creek	Blackbird Landing	7	ID	3	7	ID	3	7	ID	3	--
110041	DE 030-001	Lower Blackbird Creek	Rt. 9 Taylors Bridge	20	2.289	5	18	0.298	5	20	340	5	--
110011	DE 030-002	Upper Blackbird Creek	Blackbird Station	6	ID	3	6	ID	3	6	ID	3	--
110021	DE 030-002	Upper Blackbird Creek	Rt. 13 (Northern Branch	20	2.103	5	18	0.17	5	20	2000	5	--
110101	DE 030-002	Upper Blackbird Creek	Rd. 472	7	ID	3	7	ID	3	7	ID	3	--
110111	DE 030-002	Upper Blackbird Creek	Barlow Br	7	ID	3	7	ID	3	7	ID	3	--

Table III-4 2004 Station Summary Statistics

Station	Segment	Segment Description	Station Location	N Attainment			P Attainment			Bacterial Attainment			ERES Use Support
				# samples	N LCL 90th %tile	N Attainment	# samples	P LCL 90th %tile	P Attainment	# samples	B LCL 90th %tile	Bacterial Attainment	
108031	DE 090-001	Chesapeake And Delaware Canal From Maryland Line To Delaware	Summit Bridge	20	2.448	5	18	0.16	5	20	53	1	--
108111	DE 090-L01	Lums Pond	Lums Pond Boat Ramp	20	1.658	5	18	0.083	5	20	88.5	1	--
112011	DE 100-001	Cypress Branch	Cypress Branch at Delaney Corner (Rt. 40) Bridge	9	ID	3	9	ID	3	9	ID	3	--
112021	DE 100-001	Cypress Branch	Sewell Branch at Rd. 95	19	2.982	5	19	0.2755	5	19	600	5	--
112581	DE 100-001	Cypress Branch	Cypress Branch at Morris Road (Rt. 477) Bridge	9	ID	3	9	ID	3	9	ID	3	--

Appendix D. Impervious cover estimates obtained for each land use class from hand digitization.

Land Use	Subwatershed	Percent Impervious
Single Family	Back Creek	15
Single Family	C & D West	19
Single Family	Doves Nest	19
Single Family	Main Stem Drawyers	13
Single Family	1000-Acre Marsh	25
Multi-Family	Back Creek	46
Multi-Family	C & D West	26
Multi-Family	Doves Nest	33
Multi-Family	Main Stem Drawyers	N/A
Multi-Family	1000-Acre Marsh	N/A
Commercial	Back Creek	69
Commercial	C & D West	N/A
Commercial	Dove's Nest	62
Commercial	Main Stem Drawyers	N/A
Commercial	1000-Acre Marsh	N/A
Transportation	Back Creek	40
Transportation	C & D West	33
Transportation	Doves Nest	46
Transportation	Main Stem Drawyers	42
Transportation	1000-Acre Marsh	39