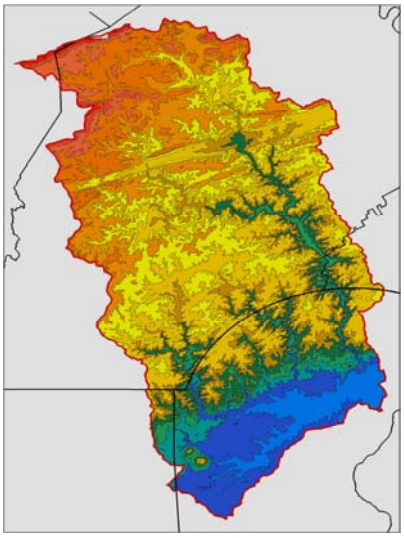
A Watershed Restoration Action Strategy (WRAS) for the Delaware Portion of the Christina Basin

"A Clean Water Strategy to Protect and Restore the Watersheds of the Brandywine, Red Clay, and White Clay Creeks and Christina River in Delaware"

June 2003



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Acknowledgements

The authors would like to acknowledge the contributions of all the members of the Christina Basin Clean Water Partnership. Special thanks is given to Nicole Minni and Vern Svatos from the University of Delaware for preparing the GIS maps and patiently responding to the numerous requests for data and maps from the public. Nigel Bradly, Anne Kitchell, and Mary Jane Middelkoop from the University of Delaware, Institute for Public Administration, Water Resources Agency provided valuable support in preparing creative graphics, tables, and text for this report.

Funding

The Section 319 of the Clean Water Act programs of the U.S. Environmental Protection Agency, Delaware Department of Natural Resources and Environmental Control, and Pennsylvania Department of Environmental Protection provided funding for the programs described in this report.

Purpose of the Report

This report provides a recommended Watershed Restoration Action Strategy (WRAS) for the Delaware portion of the Christina River Basin. The WRAS draws on information obtained from two previous reports (Christina Basin Water Quality Management Strategy Phase I and II report, May 1998 and Phase III report, August 1999) and is intended to provide a guideline for future watershed protection and restoration actions. The WRAS is also designed to interconnect with the low flow, point source Total Maximum Daily Loads (TMDLs) for the Christina Basin that were established by U.S. Environmental Protection Agency in 2002 and the high flow, nonpoint source TMDLs which are due to be set in 2004.

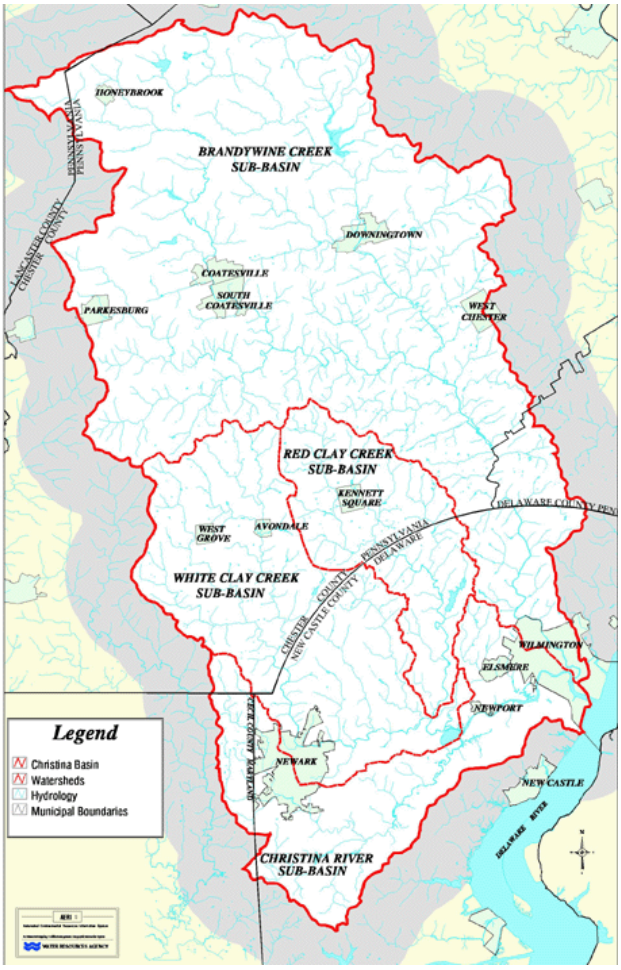
Chapter 1: The Watershed Environment

A Unique Watershed

The Christina Basin is a distinctive natural resource in Delaware. The watershed is unique in the First State because it is the:

- Only source of public surface water supply in Delaware. The streams and wells in the basin provide drinking water for over 400,000 people, which is over 70% of the population in New Castle County or 60% of the state population.
- Home to almost half of the State's citizens in the most northern and populous county in Delaware.
- Address of the first and third largest cities in Delaware: Wilmington and Newark.
- Habitat to the only six trout streams in Delaware.
- Environment of neo-tropical bird species in hilly, contiguous Piedmont forests that are found in only 3% of Delaware.
- Only watershed in Delaware to encompass three states: Delaware, Pennsylvania, and Maryland.

Figure 1.1. Base map of Christina Basin



Geography

The Christina Basin is a diverse, suburbanizing watershed with waters often under conflicting uses. Due to its desirable pastoral quality and proximity to job centers in Wilmington, West Chester, and Philadelphia; the Christina Basin has lost 15% of its open land to development since 1970. The Christina Basin is indeed a microcosm of many suburbanizing watersheds in the Delaware Valley.

The Christina River Basin:

- Occupies 565 square miles - a little larger than the size of New Castle County (Grieg, Bowers, and Kauffman, 1998)

- Includes the upper 2/3 in the headwaters of Pennsylvania and the lower third within Delaware and a small slice of Maryland

- Includes 4 major watersheds:
  - Brandywine Creek (325 sq. mi.)
  - Red Clay Creek (54 sq. mi.)
  - White Clay Creek (107 sq. mi.)
  - Christina River (78 sq. mi.)

Table 1.2. Land area of watersheds in Delaware, Pennsylvania, and Maryland

Watershed	**PA**	**DE**	**MD**	**Subtotal**
Brandywine Cr	300.14	24.58	0	324.72
Red Clay Creek	31.7	22.4	0	54.1
White Clay Creek	62.16	45.09	0	107.25
Christina River	2	67.6	8.4	78
Subtotal	396 sq. mi.	159.67 sq. mi.	8.4 sq. mi.	564.07 sq. mi.
Watershed	**PA**	**DE**	**MD**	**Subtotal**
Brandywine Cr	92%	8%	0%	100%
Red Clay Creek	59%	41%	0%	100%
White Clay Creek	58%	42%	0%	100%
Christina River	3%	87%	11%	100%
Subtotal	70%	28%	1%	

Source: Phase I and II Report, Christina Basin Water Quality Management Strategy, May 1998

- Has inter-governmental coordination challenges including:
  - 3 states: Delaware, Pennsylvania, and Maryland
  - 5 counties: Chester, Lancaster, Delaware counties in Pennsylvania, New Castle County in Delaware and Cecil County in Maryland
  - Over 60 townships, boroughs, and cities such as Elsemere, Newark, Newport, and Wilmington in Delaware and Avondale, Coatesville, Downingtown, Kennett Square, West Chester, and West Grove in Pennsylvania
  - Is the home to close to 0.5 million people in three states:

State	**Area (sq. mi.)**	**% Area**	**Population (1995)**	**% Pop.**
DE	157	28%	310,638	62%
MD	8	1%	8,039	2%
PA	400	71%	181,079	36%
Total	565	100%	499,751	100%

- Divides into three land uses of similar, but changing proportions – urban/suburban (1/3), agriculture (1/3), and open space/forests (1/3)

Figure 1.3. Land use in the Christina Basin

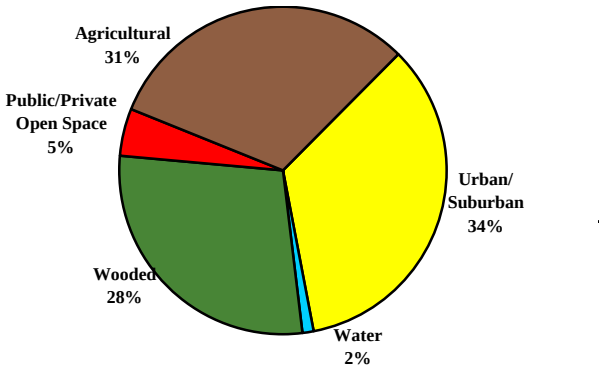
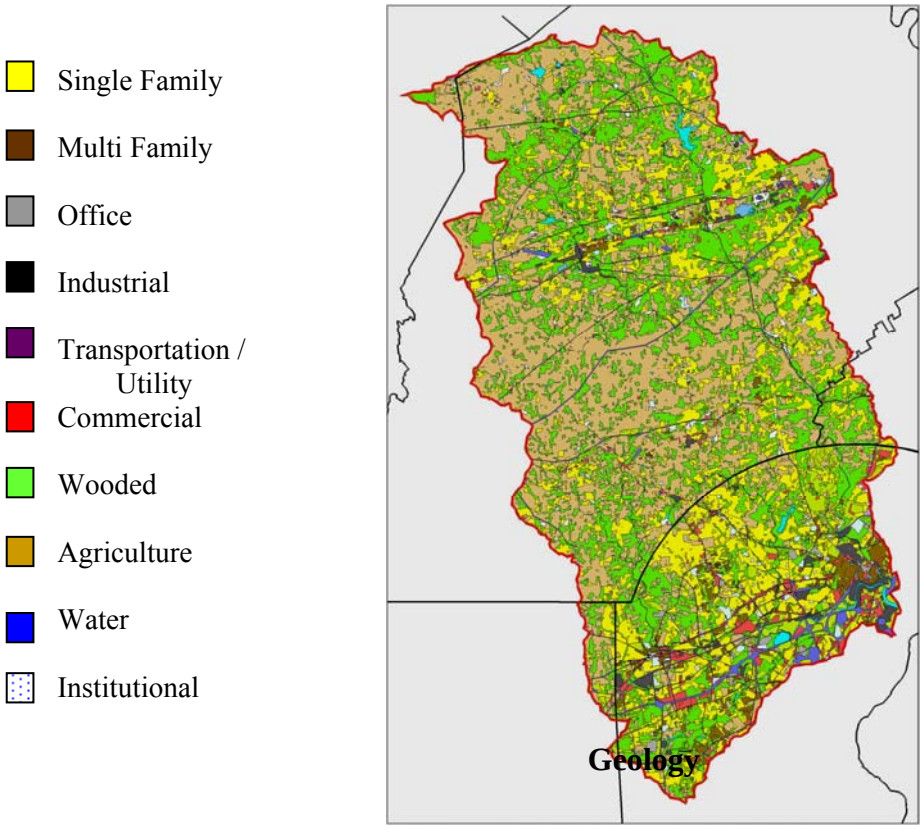


Figure 1.4. Land use designations in the Christina Basin



The Christina Basin in Delaware is perched along the fall zone, which runs along the Atlantic seaboard from Maine to Alabama (U.S. Army Corps of Engineers, 2002). The fall zone runs through a line stretched between Newark and Wilmington and separates the hilly, rocky Piedmont physiographic province from the flat, sandy Coastal Plain. North of the fall line lies the hilly Piedmont where rolling streams provide all of the surface water supply for Delaware and the Wissahickon, Wilmington, and Cockeysville formations provide some amount of

groundwater. South of the fall line is the Coastal Plain where the sand and gravel deposits provide reasonable groundwater yields. The Christina Basin occupies 90% of the Piedmont in Delaware and is the only watershed in Delaware that provides surface and groundwater supplies from the Piedmont and Coastal Plain provinces.

Water Supply

The streams and wells of the watershed provide 70% of the water supply for New Castle County and up to 40% of the water supply for Chester County. The streams and wells provide up to 100 million gallons per day (mgd) of public drinking water. The Christina Basin is the source of water supply for the following water purveyors in Delaware:

- Artesian Water Company
- City of Wilmington
- United Water Delaware
- City of Newark

Protected areas of the Christina Basin provide water storage for the following reservoirs:

- Hoopes Reservoir (2,000 mg, DE)
- Smalley's Pond (40 mg, DE)
- Marsh Creek Reservoir (7,500 mg, PA)
- Chambers Lake (350 mg, PA)
- Rock Run Reservoir (200 mg, PA)
- Struble Lake (100 mg, PA)

Recreational Resources

The streams provide a variety of primary and secondary recreational opportunities such as:

- Canoeing: The Brandywine Creek hosts many canoe and kayak enthusiasts at public boat landings and commercial liveries

- Boating: Delaware mariners own 8,400 registered boats that ply the tidal waters of the Christina River and Brandywine Creek

- Trout Fishing: Over 2,700 trout stamps are sold to anglers and 30,000 trout stocked annually along the only six trout streams in Delaware:
    - White Clay Creek above Newark
    - Upper Christina River near Newark
    - Pike Creek
    - Mill Creek
    - Beaver Run
    - Wilson Run

- Warm Water Fishing: The tidal waters of the Christina River support a striped bass fishery and spawning grounds, while the nontidal waters of the Brandywine Creek provide exceptional smallmouth bass fishing habitat.

Historic and Cultural Resources

The Christina Basin enjoys a deep historic and cultural character including:

- Battlefields: The home of two Revolutionary War battlefields: Brandywine near Chadds Ford, Pennsylvania, and Cooches Bridge near Newark, Delaware.

- Farming: The rolling hills and productive soils are conducive to horse farming near the University of Pennsylvania Veterinary College, cattle farming at the King Ranch (the largest ranch east of the Mississippi River), and increasing settlement by Amish and Mennonite farmers.

- Museums: The old water powered mills along the Brandywine (such as the Hagley Museum in Wilmington and the Brandywine Museum at Chadds Ford) are popular tourist destinations.

- Art: The Brandywine Valley is the inspiration for the "Brandywine School" and Wyeth style of art

- Gardens: The temperate and humid mid-Atlantic climate is conducive to some of the most productive public gardens in the world at Winterthur and Longwood

- Education: Many universities provide higher-level education in and about the Christina Basin including the University of Delaware in Newark, Wilmington College, Widener University School of Law and West Chester University

Economic Resources

The Christina Basin is home to the following economic sectors:

- Corporations: Wilmington and Newark are the international home of many companies including DuPont, MBNA, and W.L. Gore

- Wilmington Riverfront Revitalization: An urban renaissance along the tidal Brandywine and Christina is underway resulting in the Riverfront Arts Center, Tubman-Garrett Riverfront

Park, Riverwalk, factory store outlets, Superfund cleanup, new restaurants, the Wilmington Blue Rocks minor league baseball, and urban wetland restoration/wildlife refuge

- Port of Wilmington: The port is one of the largest importers of Chilean grapes, bananas, and automobiles nationally

- Mushroom Farms: The White Clay and Red Clay Creek watersheds are the home of the largest concentration of mushroom growers in the U.S.

Ecological and Natural Functions

The Christina Basin provides many ecological and natural functions:

- Parks: Brandywine Creek State Park near Wilmington and White Clay Creek State Park near Newark and the Marsh Creek State Park in Pennsylvania. New Castle County parks are situated at Middle Run near Newark and Delcastle Park near Wilmington.

- Conservation Areas: Large privately owned conservation areas include Woodlawn Trustees land along the Brandywine Creek, Delaware Nature Society land along the Red Clay Creek in Delaware, and Brandywine Conservancy, Red Clay Valley Association and Brandywine Valley Association holdings in Pennsylvania.

- Habitat: Contiguous forests and wetlands provide habitat for several Federal or State-listed endangered or threatened species:
    - Bog Turtle (Clemmys muhlenbergi)
    - Cerulean Warbler (Dendroica cerulea)
    - Long-tailed Salamander (Eurycea longicauda)
    - Bald Eagle (haliaeetus leucocephalas).

- Exceptional Value Waters: The Brandywine Creek above Wilmington and the White Clay Creek above Newark have more protective water quality standards through the designation by the Delaware DNREC as waters of Exceptional Recreational and Ecological Significance (ERES waters).

- Wild and Scenic Status: President Clinton and the U.S. Congress approved a U.S. National Park Serve recommendation to designate the White Clay Creek and its tributaries for Wild and Scenic status. The White Clay Creek is the only wild and scenic river in Delaware and it is the first river nationally to be protected on a watershed basis as opposed to a river segment basis.

Watershed Organizations

The people of the Christina Basin provide watershed stewardship through nonprofit organizations:

- Brandywine Conservancy (www.brandywineconservancy.org)
- Brandywine Valley Association (www.bva-rcva.org)
- Red Clay Valley Association (www.bva-rcva.org)
- Delaware Nature Society (www.delawarenaturesociety.org)
- White Clay Watershed Association (www.ccil.org/-wcwa/index.html)
- Stroud White Clay Creek Laboratory (www.stroudcenter.org)
- Christina Conservancy
- Wilmington River-City Steering Committee

More Information

Additional information regarding the Christina Basin can be obtained from the following web sites:

- University of Delaware, Institute for Public Administration, Water Resources Agency (www.wr.udel.edu)
- Delaware DNREC Whole Basin program (www.dnrec.state.de.us)
- Chester County Water Resources Authority (www.chesco.org)
- Pennsylvania Department of Environmental Protection (www.state.pa.us)
- Delaware River Basin Commission (www.state.nj.us/drbc)
- US Environmental Protection Agency (www.epa.gov/owow)
- U.S. Geological Survey (www.usgs.gov)
- Delaware Geological Survey (www.dgs.udel.edu)
- University of Delaware Spatial Analysis Lab (www.bluehen.ags.udel.edu/spatlab/)

Chapter 2: Problems, Goals, and Objectives

Water Quality Problems

The streams of the watershed in Delaware suffer from impaired water quality due to the following problems (DNREC, 1998 and USEPA, 2002):

Nutrients: 130.5 stream miles have higher than desired nitrogen and phosphorus loads, which deplete dissolved oxygen levels

Toxics (metals): 13 stream miles are impaired due to elevated zinc levels.

Bacteria (pathogens): Concentrations along 134.2 miles of stream frequently exceed the primary recreation standards for swimming of 100 colonies per 100 milliliters.

Fish Consumption Advisories: Health warnings advising against the consumption of fish have been posted along 82.2 stream miles due to PCB contaminated sediment and high PCB levels in fish tissue.

Sediment: The streams are degraded by high sediment loads which range between 311 to 975 pounds per acre annually depending on the subwatershed.

Stream Habitat: While biological diversity of the streams has been improving, 39% of the nontidal streams in the Piedmont have poor habitat due to the increased frequency and rate of runoff from urban/suburban development and rural activities (Shaver et al., 1995).

Watershed Pollution Potential

Based on the May 1998 Phase I and II watershed inventory conducted for the Christina Basin Water Quality Management Strategy, the potential sources of pollutant loads in the watershed include (in alphabetical order):

Delaware

• Combined Sewer Overflows	37 CSOs
• NPDES Wastewater Discharges	14 outfalls
• Roadways	2% of watershed in DE
• Solid Waste/Hazardous Waste/Superfund Sites	78 sites identified
• Underground Storage Tanks	763 sites identified
• Urban/Suburban Runoff	53% of watershed in DE

Pennsylvania

• Agriculture	40% of watershed in PA
• NPDES Wastewater Discharges	82 outfalls
• Roadways	2% of watershed in PA
• Urban/Suburban Runoff	27% of watershed in PA

Total Maximum Daily Loads

In 1997, Delaware and Pennsylvania consented with the U. S. Environmental Protection Agency to establish low flow and high flow Total Maximum Daily Loads (TMDLs) in the Christina Basin. The low flow (point source) TMDLs were issued by the USEPA in October 2002. USEPA expects to complete the high flow (stormwater) TMDLs by December 2004.

TMDLs are established along impaired waterways in accordance with Section 303(d) of the Federal Clean Water Act. TMDLs are determined using hydrologic and hydraulic computer models according to the following equation:

TMDL = WLA + LA + FS

TMDL = Maximum amount of a particular pollutant that can be discharged to a waterway without violating stream water quality standards

WLA = The waste load allocation from point sources such as wastewater treatment plants during low flow conditions

LA = Load allocation from nonpoint sources such as stormwater and agricultural runoff during high flow conditions

FS = Factor of safety to account for imprecision in modeling and monitoring

Delaware identified 15 stream segments on its 1998 Section 303(d) list as not meeting water quality standards for nutrients and low dissolved oxygen within the Christina Basin. Table 2.1 lists the impaired stream reaches on this list.

Table 2.1. Christina Basin stream reaches on the Delaware 1998 303(d) List

Watershed ID	Watershed Name	Subwatershed	Miles	Pollutants
B16	Brandywine Creek	Brandywine Cr. above Wilmington	9.3	nutrients
B17	Brandywine Creek	Brandywine Cr. below Wilmington	3.8	nutrients
R3	Red Clay Creek	Burroughs Run	4.5	nutrients
R4 and R5	Red Clay Creek	Red Clay Cr.at Woodale	12.8	nutrients
W5	White Clay Creek	Mill Creek	16.6	nutrients
W6	White Clay Creek	Pike Creek	9.4	nutrients
W7	White Clay Creek	Middle Run	5.8	nutrients
W8, W9, W10	White Clay Creek	White Clay Cr. below Newark	18.2	nutrients
C1	Christina River	Christina R.abv. Cooches Br.	28.3	nutrients
C4	Christina River	Little Mill Creek	12.8	nutrients, DO
C5	Christina River	Christina River below Newark	7.5	nutrients
C6	Christina River	Tidal Christina Smalley's Pond	1.5	nutrients, DO

Low Flow TMDL

In October 2002 USEPA issued the low flow TMDL for the Christina Basin. The TMDL calls for eight wastewater dischargers to reduce chemical/biological oxygen demand (CBOD5), Nitrogen (NH3-N), and Total Phosphorus (TP) loads in accordance with the amounts listed in Table 2.2. Necessary reductions in pollutant loads will be accomplished as part of renewal of NPDES discharge permits.

Table 2.2. Reduction in TMDL of nutrients and dissolved oxygen under low flow conditions in the Christina Basin.

NPDES Facility	Permit Number	Flow (mgd)	Level 1 and 2 Reduction		
			CBOD5	NH3-N	TP
East Branch Brandywine Creek					
Broad Run Sew. Co	PA0043982	.4	8%	0%	6%
Sonoco Products	PA0012815	1.028	28%	28%	28%
Downingtown Area Reg. Auth.	PA0026531	7.134	36%	36%	36%
West Branch Brandywine Creek					
PA American Water Co.	PA0026859	3.85	28%	0%	28%
NW Chester Co. Mun. Auth.	PA0044776	.6	10%	10%	10%
West Branch Red Clay Creek					
Kennett Square	PA0024058	1.1	34%	34%	34%
Sunny Dell Foods, Inc.	PA0057720-001	.05	5%	5%	5%
West Branch Christina River					
Meadowview Utilities, Inc.	MD0022641	.7	0%	69%	0%

High Flow TMDL

The U.S. Geological Survey was retained to prepare a high flow, nonpoint source TMDL watershed model for the Christina Basin using the Hydrologic Simulation Program - Fortran (HSPF). The model is designed to simulate effects of nonpoint source loads for nutrients (N and P) and suspended sediment for the high flow TMDL. The USGS prepared four subwatershed HSPF models according to the following schedule (Senior and Koerkle, 2001, 2002, and 2003):

Brandywine Creek Subwatershed	Draft Report October 19, 2001
Red Clay Creek Subwatershed	Draft Report November 1, 2002
White Clay Creek Subwatershed	Draft Report June 13, 2002
Christina River Watershed	Draft Report February 1, 2002
Christina Basin High Flow TMDL due	December 2004

Watershed Governance

Since 1995, local agencies in Delaware and Pennsylvania have coordinated the activities of the overall watershed strategy on behalf of the Christina Basin Clean Water Partnership. The Chester County Water Resources Authority and Chester County Conservation District serve as local watershed coordinators for the Pennsylvania portion of the basin. The University of Delaware, Institute for Public Administration, Water Resources Agency serves as a local coordinator for the Delaware portion of the Basin. A cooperative mix of federal, state, and local entities have served the following roles:

Watershed Coordination:	Chester County Water Resources Authority Chester County Conservation District University of Delaware, Water Resources Agency
GIS Watershed Inventory:	University of Delaware, Water Resources Agency
Stream Monitoring:	Pennsylvania Dept. of Environmental Protection Delaware Dept. of Natural Resources and Environ. Control
Stormwater Monitoring:	U.S. Geological Survey University of Delaware, College of Agriculture and Natural Resources
Total Maximum Daily Load	Delaware River Basin Commission
(TMDL) Modeling:	U.S. Environmental Protection Agency
Public Education/Outreach:	Brandywine Valley Association Red Clay Valley Association Christina Basin Task Force
BMP Implementation Projects:	Chester County Conservation District

	New Castle Conservation District
Integrated Watershed Programs:	Chester County Water Resources Authority (Water Resources Mgmt. Plan) Delaware DNREC (Piedmont Whole Basin Program)
Section 319 Funding:	Pennsylvania DEP, Bureau of Watershed Conservation Delaware DNREC, Div. of Soil and Water Conservation U.S. Environmental Protection Agency, Region III

Table 2.3. Members and organizations of the Christina Basin Clean Water Partnership

Category	Entities Represented
Policy Committee	Pennsylvania Department of Environmental Protection Delaware Department of Natural Resources and Environmental Control Delaware River Basin Commission U.S. Environmental Protection Agency, Region III
Local Co-Coordinators	Chester County Water Resources Authority, Pennsylvania Univ. of Delaware, Institute for Public Administration, Water Resources Agency Chester County Conservation District, Pennsylvania
Members	U.S. Department of Agriculture, Natural Resources Conservation Service U.S. Department of Interior, National Park Service U.S. Department of Interior, U.S. Geological Survey Chester County Board of Commissioners, Pennsylvania New Castle County Executive and Dept. of Planning, Delaware New Castle Conservation District, Delaware Brandywine Valley and Red Clay Valley Associations White Clay Watershed Association Delaware Nature Society Christina Conservancy

Mission Statement

The mission of the Christina Basin Clean Water Partnership is to conduct a cooperative, interstate effort to restore the water quality of ALL streams and tributaries in the Brandywine, Red Clay and White Clay Creeks, and Christina River watersheds of Delaware, Maryland, and Pennsylvania to fishable, swimmable, and potable status by 2015.

Goals and Objectives

To protect and improve stream water quality, the Christina Basin WRAS hopes to achieve the following goals:

Goal No. 1 – Nutrients: Substantially reduce nutrient (nitrogen and phosphorus) pollutant loads to meet the fishable water quality standards in accordance with the future Christina Basin Total Maximum Daily Loads

Goal No. 2 – Toxics: Remediate the existing sources of zinc to reduce toxics loads in accordance with Delaware water quality standards and the Christina Basin TMDLs

Goal 3 – Bacteria: Reduce bacteria loads in the streams to meet the Delaware swimmable primary recreation water quality standard of less than 100#/100 ml

Goal No. 4 – Fish Consumption Advisories: Cleanup the hazardous waste sources of PCBs to reduce loads and ultimately lift existing fish consumption advisories

Goal 5 – Sediment: Reduce total sediment loads from land and stream erosion sources to less than 250 pounds per acre per year

Goal No. 6 – Stream Habitat: Improve stream habitat to a "good" rating (above 81% for Habitat Community Index and 61% for Biological Community Index) in the Delaware portion of the Christina Basin

Table 2.4. Accomplishments of the Christina Basin Partnership since 1995

1	Developed, promulgated, and implemented a series of low-flow TMDLs
2	Conducted monitoring and modeling for development of high-flow nonpoint source (NPS) TMDLs
3	Installed over 50 agricultural Best Management Practices (BMPs)
4	Restored over 10,000 linear feet of stream banks
5	Established a Storm Water BMP Tour for municipal officials and designers
6	Engaged over 300 residential property owners in lawn management and rain barrel stewardship programs
7	Established the Christina Basin Task Force as a mechanism for stakeholder participation
8	Updated municipal comprehensive plans and zoning ordinances in dozens of municipalities to incorporate sustainable land use management strategies
9	Preserved hundreds of acres of riparian and other lands
10	Overcame issues of inconsistent policies and institutional barriers that spanned multiple jurisdictions

Chapter 3: Christina Basin Report Card

This chapter issues a report card summarizing the health of the streams and subwatersheds in the Christina Basin. Drawing from existing water quality, stream habitat, and watershed data, the report card grades the streams and subwatersheds of the Christina Basin in an "A" through "F" format. The following existing data sources were used in assessing the health of the watersheds:

1. Source Water Assessment Reports, Delaware Source Water Assessment and Protection Program (Wollaston and Kauffman, University of Delaware, Institute for Public Administration, Water Resources Agency, May 2002), including:

- City of Wilmington Public Water Supply Intake Located on the Brandywine Creek
- City of Newark Public Water Supply Intake Located on the White Clay Creek
- United Water Delaware at Stanton Public Water Supply Intake Located on the White Clay and Red Clay Creeks
- United Water Delaware Public Water Supply Intake Located on the Christina River at Smalley's Pond

2. Delaware Clean Water Act Section 303(d) List of Water Quality Limited Segments (Delaware Department of Natural Resources and Environmental Control, 1998)

3. Non-point Source Water Quality Monitoring in the Christina River Basin, Pennsylvania and Delaware (Senior and Koerkle, U. S. Geological Survey, 1997 – 1998)

4. Christina Basin Subwatershed Impervious Cover, Population Density, and Forest Cover Estimates (Greig, Bowers, and Kauffman, May 1998 and August 1999)

5. Christina Basin Watershed Indicator Report Card (Greig, Bowers, and Kauffman, August 1999)

Delaware SWAPP Data

In 1996, Congress amended the Safe Drinking Water Act (SDWA) establishing a Source Water Assessment and Protection Program (SWAPP). The program, coordinated nationally by the U.S. Environmental Protection Agency (EPA), requires all states to develop a plan for evaluating the drinking water supply sources used by public water systems in their state and then follow the plan to conduct source water susceptibility assessments. Susceptibility assessments include a determination of the watershed area that has the greatest effect on the quality of each public drinking water source and an inventory of potential contaminants within the watershed.

The University of Delaware, Institute for Public Administration, Water Resources Agency developed the Delaware SWAPP susceptibility assessments using the following methodology:

1. Delineate the source water area (watersheds) upstream of the following water supply intakes:
- City of Wilmington Water Supply Intake Located on the Brandywine Creek
- City of Newark Water Supply Intake Located on the White Clay Creek

- United Water Delaware at Stanton Water Supply Intake on the White Clay/Red Clay Creeks
- United Water Delaware Water Supply intake on the Christina River at Smalley's Pond

2. Determine the vulnerability of each intake or well to contamination

3. Identify the potential sources of contamination in the watershed area. Table 3.1 summarizes the potential sources of contamination in the watershed upstream of the water supply intakes in the Christina Basin

Table 3.1. Potential sources of contamination upstream of the water supply intakes in the Christina Basin.

	Brandywine Creek at Wilmington		**White Clay Creek at Newark**		**White Clay Creek at UWD Stanton**		**Christina River at UWD Smalley's Pond**		
	DE	**PA**	**DE**	**PA**	**DE**	**PA**	**DE**	**PA**	**MD**
Discrete Site Type									
Hazardous Substance Sites (Superfund and SIRB)	4	*	3	*	37	*	34	*	*
Underground Storage Tanks	259	*	11	2*	302	*	191	*	*
Landfills/Dumps	0	9	0	5	3	2	2	0	0
NPDES Wastewater Discharges**	3	61	2	38	9	21	0	0	2
Tire Piles	0	*	0	4	0	21	8	0	0
Hazardous Waste Generators	42	*	0	*	1	*	1	*	*
Toxic Release Inventory (TRI) Sites	2	*	0	*	150	*	81	*	*
Salvage Yards	0	*	0	*	9	*	12	*	*
Pesticide Loading, Mixing Areas	0	*	0	*	1	*	4	*	*
Large On-Site Septic Systems	0	35	0	*	0	*	0	*	*
Waste Water Spray Irrigation	1	17	0	17	0	21	0	1	*
Waste Sludge Application	0	*	0	10	0	3	0	0	*
Confined Animal Feed Operations (CAFOs)	0	*	0	*	1	*	0	*	*
Combined Sewer Overflows	0	*	0	*	0	*	0	*	*
Dredge Spoils	0	*	0	*	0	*	0	*	*
Domestic Septic Systems	0	*	0	*	0	*	0	*	*
SARA Title III Sites	*	*	*	*	*	*	*	*	*
Total	311	122	16	76	513	68	333	1	2

* *Limited or No Data Available from PA.*

4. Determine the susceptibility of the source water area to contamination by evaluating existing stream water quality data (1990 - 2001) for the following constituents:
- Nutrients (nitrate, etc.)
- Pathogens (bacteria, cryptosporidium, giardia, etc.)
- Petroleum Hydrocarbons (benzene, toluene, etc.)
- Pesticides (endrin, lindane, etc.)
- Polychlorinated biphenyls (PCBs)
- Other Organics (chloroform, etc.)

- Metals (lead, copper, zinc, etc.)
- Other Inorganics (chloride, sodium, etc.)

Tables 3.2 through 3.6 summarize detected substances from stream water quality data sampled from 1990 through 2001.

Table 3.2. Substances detected upstream of the Brandywine Creek above Wilmington intake

Parameter	Min. Detection Level (mg/L)	50% of MCL (mg/L)	Drinking Water Standard (mg/L)	Max. Level Detected 1990-2000 (mg/L)	Date Sampled	Sampling Program	Sampling Aug. 2001 by DNREC (mg/L)
Nutrients – 3 of 3 sampled							
Nitrate Nitrogen	0.10	5	10	2.89	5/11/99	USGS	1.9
Nitrite Nitrogen	0.10	0.5	1	0.33	3/16/99	USGS	**
Total Nitrogen as Nitrate + Nitrite	0.20	5	10	5.56	7/21/98	DNREC	**
Pathogens – 5 of 5							None
Cryptosporidium		0	0	5.0	11/19/98	Wilm	**
Enterococcus (#/100 ml)		0	0	2000	10/16/95	DNREC	**
Fecal Coliform/E. Coli		0	0	195.2	2/14/00	Wilm	**
Giardia lambia		0	0	37.5	12/17/98	Wilm	**
Total Coliform Bacteria		0	0	200.5	4/11/00	Wilm	**
Petroleum Hydrocarbons 2 of 8 sampled, 0 detected							All Sampled No Detects
Pesticides - 26 of 31 sampled,1 detected							28 Sampled No Detects
Hexachlorocyclopentadie	0.001	0.025	0.05	0.1	3/15/00	Wilm	No Detect
Polychlorinated biphenyls		0.00025	0.0005	0.007501	1996	DNREC	No Detect
Other Organics – 29 of 59 sampled, 3 detected							
Bromodichloromethane	0.0005	0.00085	0.00170	0.0405	9/15/99	DNREC	No Detect
Chloroform	0.0005	0.040	0.080	0.28332	6/7/00	DNREC	No Detect
Total Trihalomethanes	0.0005	0.05	0.1	0.027	3/15/00	Wilm	**
Metals – 18 of 18 sampled,							15 Sampled
Aluminum	0.00020	0.025- 0.1	0.05 -0.2	2.946	3/14/94	DNREC	0.258
Barium	0.01	1.0	2.0	0.026	3/15/00	DNREC	No Detect
Copper	0.02	0.65	1.3	0.0385	6/12/00	DNREC	No Detect
Iron		0.15	0.30	6.437	9/17/96	DNREC	**
Lead	0.003	0.0075	0.015	0.0446	6/12/98	DNREC	No Detect
Manganese		0.025	0.05	0.2175	5/13/96	DNREC	**
Mercury	0.0002	0.001	0.002	0.0009	5/13/96	DNREC	No Detect
Silver	0.01	0.050	0.1	0.015	3/16/99	DNREC	No Detect
Zinc	0.000020	2.5	5.0	0.61	3/15/00	DNREC	No Detect
Other Inorganics – 6 of 17 sampled, 5 detected							6 Sampled
Chloride	0.005	125	250	184	11/18/96	DNREC	50
Fluoride	0.0001	0.9	1.8	0.18	9/14/99	DNREC	0.69
pH*			6.5 – 8.5	5.5 – 8.7	1/29/96	DNREC	6.2
Sulfate	0.001	125	250	230	3/16/99	Wilm	16.4
Total Dissolved Solids	0.01	250	500	190	2/16/99	Wilm	179

Table 3.3. Substances detected upstream of the White Clay Creek above Newark intake.

Historic Sampling Data Substances Detected	Minimum detection level	50% of MCL for Treated Water or Screening Level	Treated Drinking Water Standard (PMCL/SMCL;HAL/RBCL)	Untreated Water Maximum Level Detected 1990-2000	Date Sampled	Sampling Program	Current Sampling Data August 2001 Sampling by DNREC
	mg/L	mg/L	mg/L	mg/L			(mg/L)
Nutrients – 3 of 3							1 Sampled
Nitrate	0.10	5	10	3.15	5/11/99	USGS	3.9
Nitrite	0.02	0.5	1	0.031	5/11/99	USGS	**
Total Nitrogen as Nitrate + Nitrite	0.20	5	10	4.72	11/15/94	DNREC	**
Pathogens – 1 of 5 sampled							None Sampled
Enteroccocus		0	0	2000	7/21/93	DNREC	
Petroleum Hydrocarbons 0 of 8 sampled							All Sampled No Detects
Pesticides – 7 of 31 sampled, none detected							28 Sampled No Detects
Polychlorinated biphenyls (PCBs)		0.00025	0.0005	.0000576	1996	DNREC	No Detect
Other Organics 3 of 59 sampled							44 Sampled No Detects
Bromodichloromethane	0.0005	0.00085	0.00170	0.02686	9/15/99	DNREC	No Detect
Chloroform	0.0005	0.04	0.08	0.40372	6/7/00	DNREC	No Detect
Dibromochloromethane	0.0005	0.04	0.08	0.00362	3/15/00	DNREC	No Detect
Metals – 10 0f 18							15 Sampled
Aluminum	0.00020	0.025 –	0.05 -0.2	1.520	10/19/93	DNREC	No Detect
Arsenic	0.004	0.005	0.01	.00257	9/15/97	DNREC	No Detect
Copper	0.02	0.65	1.3	0.0447	4/15/96	DNREC	No Detect
Iron		0.15	0.3	2.42	10/19/93	DNREC	**
Lead	0.003	0.0075	0.015	0.00988	9/15/98	DNREC	No Detect
Manganese		0.025	0.05	0.1421	10/19/93	DNREC	**
Zinc	0.000020	2.5	5.0	0.0639	5/16/94	DNREC	No Detect
Other Inorganics 3 of 17 sampled							6 Sampled
Turbidity				21 FTU		DNREC	**
Chloride	0.005	125	250	54	1/17/95	DNREC	24
Sulfate	0.001	125	250				29.6
pH *			6.5 – 8.5	5.9 / 8.9	11/13/95-7/21/93	DNREC	8.1

Table 3.4. Substances detected upstream of the White Clay/Red Clay Creek United Water Delaware at Stanton intake.

Historic Sampling Data Substances Detected	Minimum Detection Level	50% of MCL for Treated Water or Screening Level	Treated Drinking Water Standard (PMCL/SMCL; HAL/RBCL)	Untreated Water Maximum Level Detected 1990-2000	Date Sampled	Sampling Program	Current Sampling Data August 2001 Sampling by DNREC
	mg/L	mg/L	(mg/L)	(mg/L)			(mg/L)
Nutrients – 3 of 3							
Nitrate	0.10	5	10	3.15	5/11/99	USGS	2.3
Nitrite	0.02	0.5	1	0.031	5/11/99	USGS	**
Total Nitrogen as Nitrate + Nitrite	0.20	5	10	4.98	3/11/96	DNREC	**
Pathogens – 1 of 5 sampled							None Sampled
Enteroccocus		0	0	2000	7/21/93	DNREC	**
Petroleum Hydrocarbons 0 of 8 sampled							All Sampled No Detects
Pesticides – 7 of 31 sampled, none detected							28 Sampled No Detects
Polychlorinated biphenyls (PCBs)		0.00025	0.0005	.0000576	1996	DNREC	No Detect
Other Organics - 3 of 59 sampled							44 Sampled No Detects
Bromodichloromethane	0.0005	0.00085	0.00170	0.04226	9/15/99	DNREC	No Detect
Chloroform	0.0005	0.04	0.08	0.40372	6/7/00	DNREC	No Detect
Dibromochloromethane	0.0005	0.04	0.08	0.00624	9/15/99	DNREC	No Detect
Metals – 11 of 18 sampled							15 Sampled
Aluminum	0.00020	0.025 –0.1	0.05 -0.2	8.056	5/16/96	DNREC	0.253
Arsenic	0.004	0.005	0.01	.00341	7/21/93	DNREC	No Detect
Cadmium	0.005	0.0025	0.005	0.005	9/15/99	DNREC	No Detect
Copper	0.02	0.65	1.3	0.0643	5/18/99	DNREC	No Detect
Iron		0.15	0.3	2.42	10/19/93	DNREC	**
Lead	0.003	0.0075	0.015	0.146	9/15/98	DNREC	No Detect
Manganese		0.025	0.05	0.4261	7/18/94	DNREC	**
Mercury	0.0002	0.001	0.002	0.0004	1/24/94	DNREC	No Detect
Zinc	0.000020	2.5	5.0	2.0103	5/18/99	DNREC	No Detect
Other Inorganics - 3 of 17 sampled							6 Sampled
Turbidity				50 FTU	1/24/94	DNREC	**
Chloride	0.005	125	250	136	3/16/99	DNREC	32
Cyanide		0.1	0.2				0.117
Fluoride	0.0001	0.9	1.8				0.1
Sulfate	0.001	125	250				29.6
pH *			6.5 – 8.5	5.5 / 8.9	5/27/97-7/21/93	DNREC	7.9

Table 3.5. Substances Detected upstream from the Christina River above the United Water Delaware at Smalley's Pond intake.

Historic Sampling Data Substances Detected	Minimum Detection Level	50% of MCL for Treated Water or Screening Level	Treated Drinking Water Standard (PMCL/SMCL HAL/RBCL)	Untreated Water Maximum Level Detected 1990-2000	Date Sampled	Sampling Program	Current Sampling Data August 2001 Sampling by DNREC
	mg/L	mg/L	(mg/L)	(mg/L)			(mg/L)
Nutrients - 1 of 3 sampled							
Nitrate	0.10	5	10				0.36
Total Nitrogen as Nitrate + Nitrite	0.20	5	10	4.82	5/15/95	DNREC	**
Pathogens - 1 of 5 sampled							None Sampled
Enterococcus		0	0	2000	8/15/95	DNREC	**
Petroleum Hydrocarbons - O of 8 sampled							All Sampled No Detects
Pesticides - 0 of 31 sampled							28 Sampled No Detects
Polychlorinated biphenyls (PCBs)		0.00025	0.0005	0.00001097	1996/97	DNREC	No Detect
Other Organics - 3 of 59 sampled							44 Sampled 1 Detects
Bromodichlorometh	0.0005	0.00085	0.00170	0.05268	7/21/99	DNREC	No Detect
Chloroform	0.0005	0.040	0.080	0.5812	3/15/00	DNREC	0.0007
Chloromethane	0.0005	0.0105	0.021	0.01585	6/14/99	DNREC	No Detect
Metals - 8 of 18 sampled							15 Sampled
Aluminum	0.00020	0.025 - 0.1	0.05 -0.2	2.048	1/18/95	DNREC	0.336
Arsenic	0.004	0.005	0.01	0.00184	11/18/97	DNREC	No Detect
Copper	0.02	0.65	1.3	0.0336	11/18/97	DNREC	No Detect
Iron		0.15	0.30	6.379	4/16/96	DNREC	**
Lead	0.003	0.0075	0.015	0.0141	6/12/98	DNREC	No Detect
Manganese		0.025	0.05	0.2145	6/14/94	DNREC	**
Mercury	0.0002	0.001	0.002	0.0004	3/15/94	DNREC	No Detect
Zinc	0.000020	2.5	5.0	0.155	3/15/94	DNREC	No Detect
Other Inorganics - 2 of 17 sampled							6 Sampled
Chloride	0.005	125	250	170	3/16/99	DNREC	37
Cyanide		0.1	0.2				0.22
Fluoride	0.0001	0.9	1.8				7.14
Sulfate	0.001	125	250				169
pH			6.5 – 8.5	High- 8.3 Low- 5.3	7/15/97 1/30/96	DNREC	9.7

Table 3.6. Substances sampled above the detection level in Christina Basin streams (1990 - 2001).

Contaminant Category	Brandywine Creek at Wilmington	White Clay Creek at Newark	UWD White Clay Creek at Stanton	UWD Christina River at Smalley's Pond
Above Detection Level				
Nutrients	Nitrate Nitrogen, Nitrite Nitrogen	Nitrate Nitrogen Nitrite Nitrogen	Nitrate, Nitrite, Nitrate + Nitrite	Nitrate, Total Nas Nitrate + Nitrite
Pathogens				
Petroleum Hydrocarbons				
Pesticides				
PCBs		Polychlorinated biphenyls	Polychlorinated biphenyls	Polychlorinated biphenyls
Other Organics	Trihalomethanes	Dibromochloromethane	Dibromochloromethane	
Metals	Barium, Copper, Mercury, Silver, Zinc	Arsenic, Copper, Zinc	Arsenic, Copper, Zinc	Arsenic, Copper, Mercury, Zinc
Other Inorganics	Fluoride	Chloride, Sulfate	Sulfate, Fluoride	
Above 50% Drinking Water Standard				
Nutrients	Nitrate + Nitrite			
Pathogens				
PCBs				
Pesticides				
Polychlorinated Biphenyls				
Other Organics				Chloromethane
Metals		Lead		Lead
Other Inorganics	Chloride, Sulfate		Chloride, Cyanide	Chloride, Sulfate
Above 100% Drinking Water Standard				
Nutrients				
Pathogens	Total Coliform Bacteria, Cryptosporidium, Enterococcus, Fecal Coliform/E.Coli, Giardia lambia	Enteroccocus		
Petroleum Hydrocarbons				
Pesticides	Hexachlorocyclopentadiene			
PCBs	Polychlorinated biphenyls			
Other Organics	Bromodichloromethane, Chloroform	Bromodichloromethane, Chloroform	Bromodichloromethane, Chloroform	Bromodichloromethane, Chloroform
Metals	Aluminum, Iron, Lead, Manganese	Aluminum, Iron, Manganese	Aluminum, Cadmium, Iron, Lead, Manganese	Iron, Manganese, Aluminum
Other Inorganics				Cyanide, Fluoride

USGS Non-Point Source Water Quality Monitoring Data

The United States Geological Survey (USGS) completed a stormwater monitoring project for the Christina River Basin during 1998. The monitoring characterized stormwater and nonpoint source pollutant loads from representative land uses in the Christina Basin. The sampling plan collected pollutant load data over a range of hydrologic conditions - including base flow and high flow. The pollutant data was used to calibrate a Hydrological Simulation Program-Fortran watershed model (HSPF) which will be used to simulate nonpoint source loading for a Total Maximum Daily Load (TMDL) of the Christina Basin. Table 3.7 summarizes the mean results of the USGS Stream Sampling Program in the Christina Basin in 1998 (USGS as published in Grieg, Bowers and Kauffman, 1999).

Table 3.7. Mean results of the USGS Stream Sampling Program in the Christina Basin 1998.

Stream Gage	TSS (mg/l)	Dis.Phosphorus (mg/l)	Nitrate plus Nitrite (mg/l)
White Clay Creek near Newark DE USGS station 01479000 DA = 89.1 mi.^{2}	210	0.045	1.75
Red Clay Creek near Wooddale DE USGS station 01480000 DA = 47.0 mi.^{2}	80	0.15	2.7
Brandywine Creek at Chadds Ford PA USGS station 01481000 DA = 287 mi.^{2}	100	0.04	2.2
Christina River at Cooch's Bridge DE USGS station 01478000 DA = 20.5 mi.^{2}	60	0.03	0.9

Clean Water Act Section 303 (d) List of Water Quality Limited Segments

Every two years the Delaware DNREC surveys the water quality and habitat of impaired stream segments in the Section 303 (d) List of Water Quality Limited Segments as required by the Federal Clean Water Act. Table 3.8 summarizes the data in the Christina Basin for dissolved oxygen, enterococcus bacteria, chlorophyll, nitrogen, phosphorus, aquatic life support, fish consumption advisories, biological community index and habitat community index.

Table 3.8. Christina Basin summary water quality data.

Segment	Subwatershed	Size	DO	Enteroc. Bact.	Chloro. A	Total Phosphorus	Total Nitrogen	Aquatic Life	Fish Advisory	Biology	Habitat
		(mi.)	Min. (mg/l)	G.M.	Max. (ug/l)	Max. (mg/l)	Max. (mg/l)			%BCI	%HCI
Brandywine Creek Watershed											
Tidal Brandywine Creek	B17	3.8	6.7	147	13	0.566	5.6	P (habitat)	Y	75	70
Upper Brandywine Creek from State Line to Wilmington	B16	9.3	6.2	106	16	0.743	4.9	P (habitat) & ERES & CWF	Y	75	70
Tributaries on Brandywine Creek, PA-DE Line to Christina R.	B16, B17	19.3	9.7	--	--	--	--	N (biology)	--	13	79
Red Clay Creek Watershed											
Red Clay Creek from PA-DE State Line	R4, R5	12.8	4.9	148	45	0.8	6.7	N. (zinc)	Y	38	87
Burroughs Run from PA-DE State Line	R3	4.5	8.1	109	13	0.268	3.9	P (biology)	--	38	73
All other tributaries in RCC watershed	R3, R4, R5	10.3	--	--	--	--	--	P (biology) & (habitat)	--	--	--
Hoopes Reservior (ac.)	R4	200.0	--	--	--	--	--	F	--	--	--
White Clay Creek Watershed											
White Clay Creek from PA-DE State Line	W8, W9, W10	18.2	5.9	199	16	1.17	6.5	N (zinc) & ERES (W8) & CWF (W8)	Y	50	85
Mill Creek	W5	16.6	6.6	252	11	0.752	4.5	N (habitat) & CWF	--	25	67
Pike Creek	W6	8.2	8	109	5	0.348	5.5	P (biology) & (habitat) & CWF	--	38	70
Middle Run	W7	5.8	8.1	102	24	0.19	4.6	P (biology) & (habitat)	--	50	81
Christina River Watershed											
All tributaries from the headwaters to the confluence with the Christina River	W5 -W10	14.2	--	--	--	--	--	P (biology)	--	50	92
Lower Christina River	C6	1.5	3.1	163	45	0.243	4.5	F	Y	--	--
Mid Christina River between the White Clay Cr. and Brandywine Cr.	C5, C6	8.5	4	255	131	0.233	4.2	F	Y	--	--
Tributaries on Christina River from White Clay Cr.to Brandywine Cr.	C5, C6	3.0	--	--	--	--	--	F	--	--	--
Christina River below Newark	C5	6.9	3.9	225	11	0.215	2.7	N. (biology)	Y	25	66
Tributaries from Smalleys Pond to White Clay Creek	C5, C6	3.1	--	--	--	--	--	N. (biology)	--	13	69
Tidal Christina Creek	C6	8.4	5.9	242	16	0.777	3.7	N, (biology)	Y	25	71
Belltown Run	C3	5.6	--	--	--	--	--	F	--	38	82
Muddy Run	C2	13.1	--	--	--	--	--	N (biology)	--	38	--
West Branch including Persimmon Run and Stine Haskell Branch	C1	5.3	--	--	--	--	--	F	--	--	--
Upper Christina Creek	C1	10.8	8.2	121	13	0.282	3.9	N (habitat) & CWF	--	38	58
Little Mill Creek	C4	12.8	4.8	376	8	0.268	264.2	N (biology) & (habitat)	Y	13	38
Chestnut Run	C4	2.8	--	--	--	--	--	N (biology) & (habitat)	--	38	61
Smalleys Pond (ac.)	C5, C6	30.0	3.9	225	11	0.215	2.7	F	Y	--	--
Becks Pond (ac.)	C2	25.6	--	--	--	--	--	F	--	--	--
Sunset Pond (ac.)	C3	40.0	--	--	--	--	--	N (DO)	--	--	--

Impervious Cover/Population Density/Forest Cover/Open Space Estimates

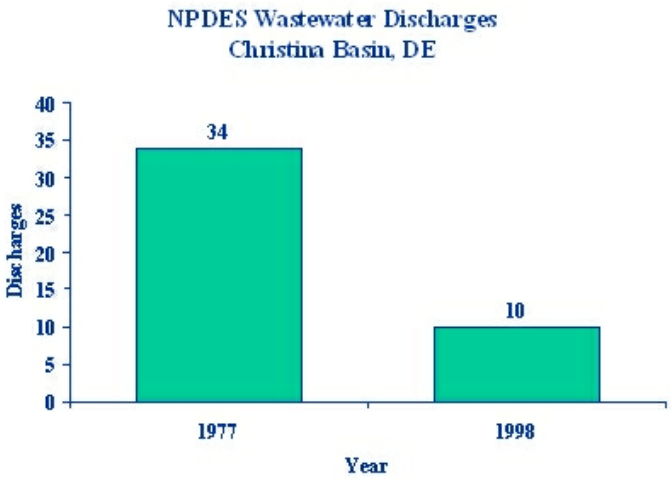
The UDWRA utilized a geographic information system to estimate impervious cover, population density, and forest cover/open space for the various subwatersheds in the Christina Basin (Grieg, Bowers, and Kauffman, 1998). Forest cover/open space includes public/private open space, wooded, and water uses. High amounts of impervious cover, population density, and total suspended solids (TSS) generally correspond to impaired stream water quality and habitat. High amounts of forested cover/open space generally correspond to good stream water quality.

Table 3.9. Christina Basin impervious cover, population density, and forest cover/open space estimates

	Area (sq. mi.)	Subwatershed Impervious	Population	Pop. Density (p./sq. mi.)	Forest Cover/Open Space	TSS Load (lb/ac./yr)
Brandywine Creek Watershed						
B16. Main Stem below Chadds Ford	26.46	13 %	16,232	613	56 %	345
B17. Main Stem through Wilmington	6.06	49 %	34,802	5,743	29 %	975
Red Clay Creek Watershed						
R3. Burroughs Run	7.11	9 %	2,280	321	27 %	481
R4. Main Stem above Wooddale	12.45	16 %	6,884	553	45 %	316
R5. Main Stem below Wooddale	7.11	32 %	17,252	2,426	25 %	506
White Clay Creek Watershed						
W5. Mill Creek	12.92	28 %	24,715	1,913	22 %	530
W6. Pike Creek	6.64	26 %	13,788	2,077	22 %	483
W7. Middle Run	3.89	10 %	5,645	1,451	45 %	428
W8. Main Stem above Newark	10.12	9 %	9,588	947	60 %	311
W9. Main Stem above Delaware Park	9.05	38 %	27,289	3,015	21 %	759
W10. Main Stem at Churchmans Marsh	5.51	48%	9,058	1,644	39 %	792
Christina River Watershed						
C1. East / West Branch above Coochs Bridge	21.06	22 %	24,198	1,149	27 %	651
C2. Muddy Run	8.66	16 %	9,919	1,145	50 %	421
C3. Belltown Run	6.43	24%	5,706	887	43 %	479
C4. Little Mill Creek	9.23	37%	33,182	3,595	27 %	654
C5. Main Stem above Smalley's Pond	10.67	30%	28,919	2,710	35 %	633
C6. Main Stem Lower Tidal	21.95	44 %	53,500	2,437	37 %	928

Christina Basin Watershed Indicators

After years of watershed management, a report card was issued on the health of the Christina Basin. The results are mixed, but there is positive news to report regarding watershed protection initiatives in the Christina Basin. The indicators that were used to develop this past report card are as follows:



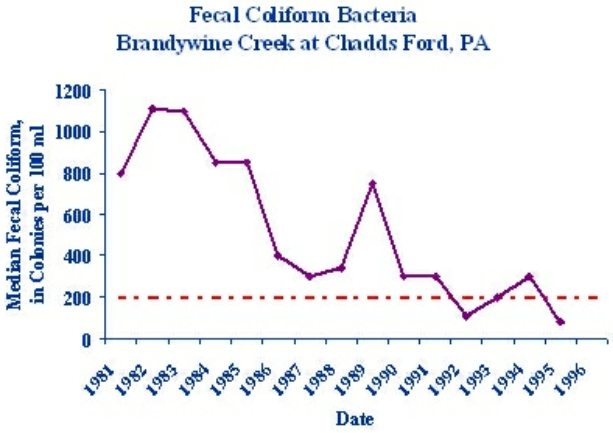
Watershed Indicator	Worse	Same	Improved	Meets Standards
DE Wastewater Discharges			☺	
Bacteria			☺	
Biological Diversity			☺	
Sediment Loads			☺	✓
Dissolved Oxygen				
-Pennsylvania			☺	✓
-Delaware	☹			
Fish Consumption Advisories	☹			
Phosphorous		😐		
Nitrogen	☹			
Zinc		😐		
Stream Habitat	☹			
Impervious Cover	☹			
Superfund Sites			☺	
Public Open Space			☺	

Wastewater Discharges

Point sources in the Christina Basin of Delaware have declined by 70% from 34 discharges in 1977 to 10 in 1999 due to regional wastewater plans implemented by the Delaware DNREC, City of Wilmington, and New Castle County governments.

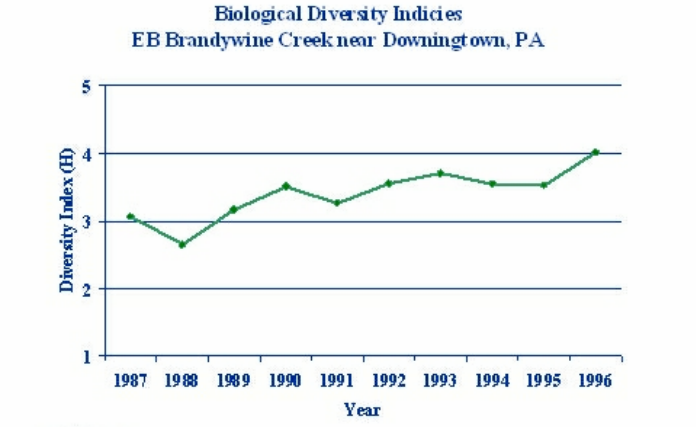
Bacteria

Median levels have decreased 10-fold along the Brandywine Creek at Chadds Ford, Pennsylvania from 1000 coliforms in 1982 to 100 in 1995 due to improved wastewater treatment technology, agriculture conservation programs, and better septic systems (CCWRA and USGS, 1996).



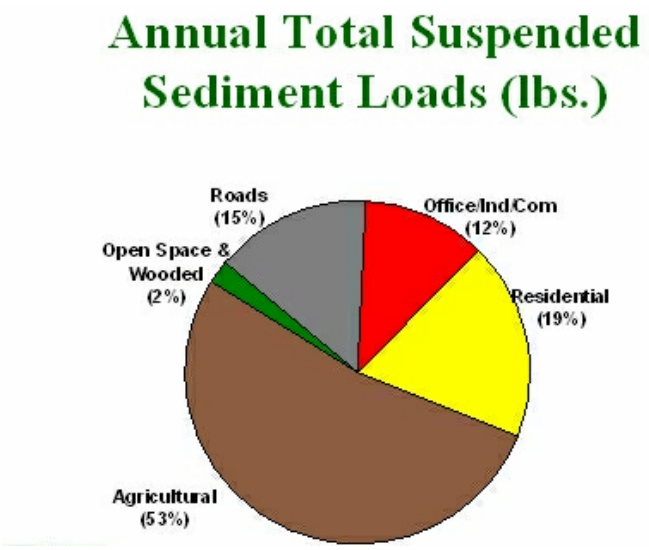
Biological Diversity

Since 1987, biological diversity indices have increased at 16 stream monitoring stations operated by the U.S. Geological Survey and the Chester County Water Resources Authority. This is a positive trend indicating that the macroinvertebrate populations are becoming healthier in the streams, possibly due to new precautions on pesticide use (CCWRA and USGS, 1996).

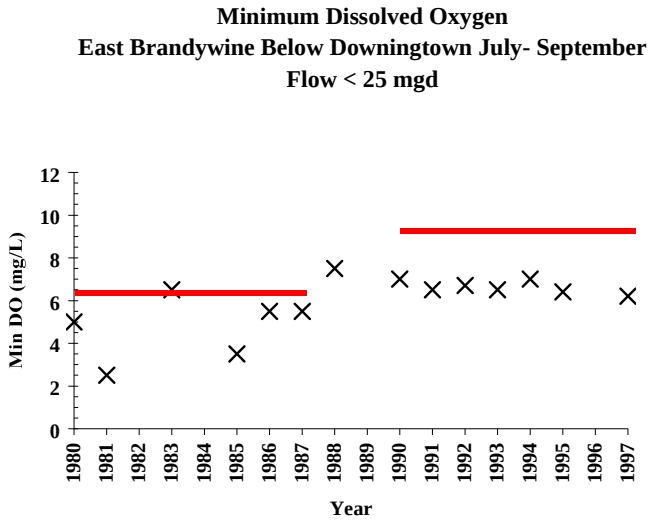


Sediment

Sediment loads have decreased slightly over the last several years, a trend that can only be improved by the Delaware Nature Society's Soil Watch Program and agriculture soil conservation projects undertaken by the Chester County Conservation District and New Castle Conservation District (DNREC, 1996).



Dissolved Oxygen



High dissolved oxygen levels are necessary for the preservation of fauna species found in streams and rivers. Dissolved oxygen levels have increased since 1990 along the Brandywine Creek due to more stringent wastewater treatment standards imposed by the Pennsylvania DEP.

Fish Consumption Advisories

Since the 1980s, 82 urban stream miles have been posted with warnings against the consumption of fish due to high levels of PCBs (DNREC, 1998). In Delaware, the Whole Basin Program has embarked on a watershed initiative to identify and mitigate the sources of PCBs in the waterways. Delaware has posted fish consumption advisories along the following stream segments in the Christina Basin:

Stream	Species	Pollutants	Advisory
Brandywine Cr (nontidal)	finfish	PCB's	Limited Consumption
Brandywine Cr. (tidal)	finfish	PCB's	No Consumption
Red Clay Cr. (all)	finfish	PCB's	No Consumption
White Clay Cr. (tidal)	finfish	PCB's	No Consumption
White Clay Cr. (d.s. Newark)	finfish	PCB's	Limited Consumption
Little Mill Creek	finfish	PCB's	No Consumption
Christina River (tidal)	finfish	PCB's	No Consumption
Christina River (nontidal Newark toSmalley's pond	finfish	PCB's	Limited Consumption

Nutrients

Concentrations of phosphorus have remained the same for several years, but levels of nitrogen have increased (DNREC 1996). In 2001, a joint Total Maximum Daily Load (TMDL) strategy was recommended by the USEPA, Delaware, and Pennsylvania that will identify reductions in nutrients from point source wastewater discharges needed to meet the standards imposed by the Federal Clean Water Act.

Toxics

Zinc levels remain the same, indicating conditions have not worsened. Both states administer Superfund programs that clean up toxic zinc pollutant sources along the Red Clay Creek in Kennett Square, Pennsylvania and National Vulcanized Fibers (NVF) Yorklyn, Delaware and

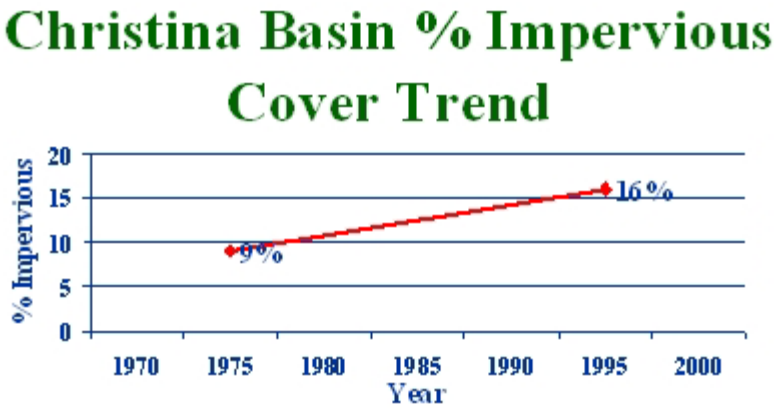
along the White Clay Creek at NVF Newark, Delaware. The Delaware DNREC developed a zinc TMDL for these two creeks in 2000.

Stream Habitat

Biological habitat has degraded over the last few decades due to increased stormwater runoff and associated siltation from development in the upstream watersheds (DNREC, 1994). Best management practices such as the City of Newark's Experimental Bioengineering Stream Restoration Project and the Mill Creek Stream Restoration project at Delaware Park Racetrack are examples of projects intended to restore the habitat of Christina Basin streams.

Impervious Cover

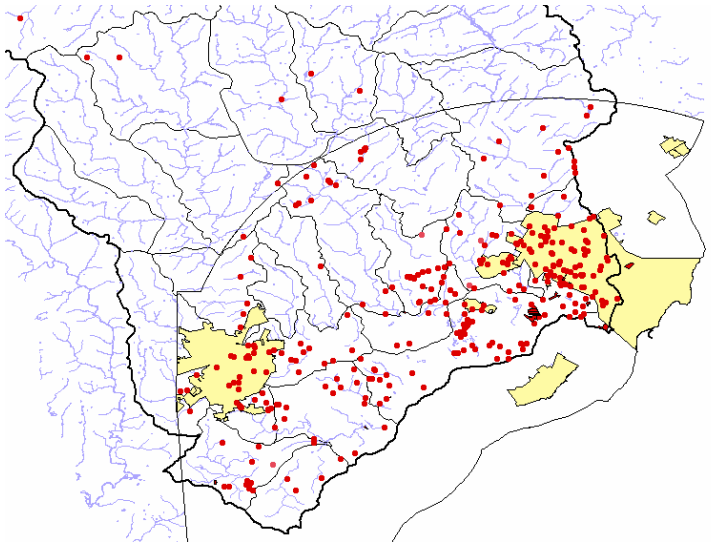
Impervious cover (the amount of buildings and pavement in the watershed) has increased from 9% in 1975 to 16% in 1995 due to suburban growth. An increase in impervious surface coverage is often correlated with an increase in population and population growth. The population in the Christina Basin has increased 21% from 412,000 in 1970 to 500,000 in 1995. Recent scientific literature indicates that important environmental parameters such as stream habitat, wetlands, water quality, and trout streams become impaired when the impervious cover in a watershed exceeds a threshold of 10 to 15%.



The percent impervious cover in the Christina River Basin has increased from 9% in 1975 to 16% in 1995.

Superfund Sites

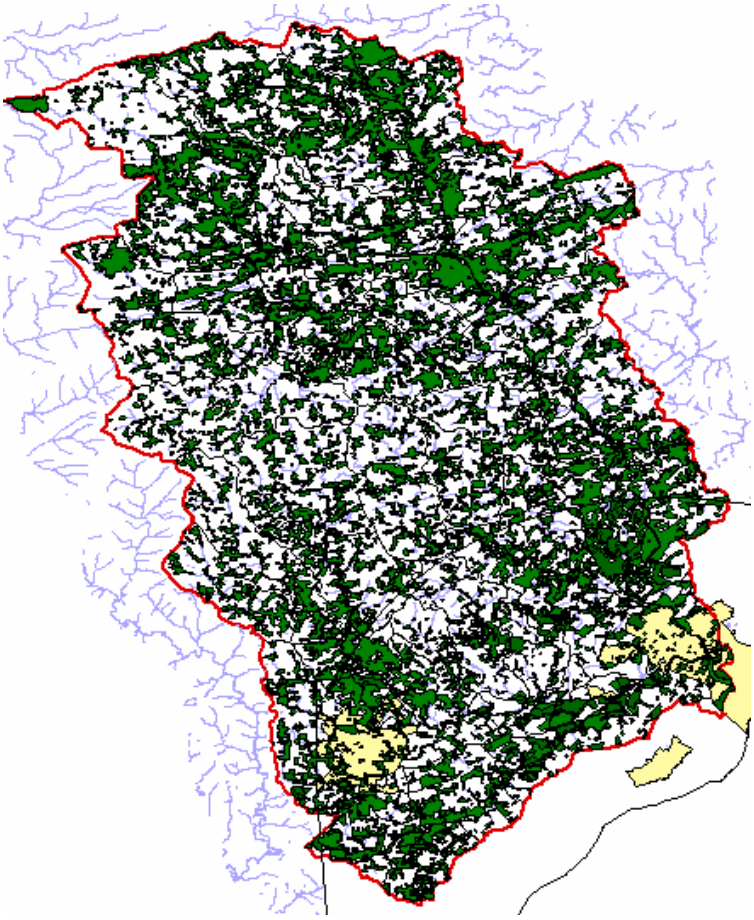
While many of these contaminant sources have been identified since the 1970s, many have been cleaned up in recent years. The Pennsylvania DEP and USEPA are nearing closure on the Strasburg Landfill Superfund site in the Brandywine watershed. The Delaware DNREC has recently announced the closure of the Diamond State Salvage and Wilmington Coal Gas Superfund sites



along the tidal Christina River in Wilmington and is completing the remediation of Superfund sites at NVF Newark and Newark Lumber within the White Clay Creek watershed.

Open Space

Both states have acquired large amounts of public open space, which provide multi-objective watershed protection benefits. The Delaware DNREC has assembled large tracts of state park land in the White Clay Creek and Brandywine Creek watersheds, including the recent acquisition of the Judge Morris Property in the Pike Creek watershed. Non-profit watershed and environmental organizations such as the Brandywine Conservancy, Brandywine Valley Association, Red Clay Valley Association, Delaware Nature Society, White Clay Watershed Association, and the Woodlawn Trustees all actively manage open conservation lands in the Christina Basin.



Christina Basin Report Card

This section presents a report card that summarizes the health of the subwatersheds in the Delaware portion of the Christina Basin according to measurements of existing stream water quality, habitat, and watershed characteristics.

This method employs the water quality ladder approach, which helps the public understand how different pollutants affect water quality (Smith and Desvousages, 1986). The top of the ladder corresponds to the best possible water quality (Grade = A). The bottom of the ladder indicates the worst possible water quality (grade = F). The following ladder will be used to grade the water quality of each of the subwatersheds in the Delaware portion of the Christina Basin:

Grade	Water Quality	Basis of Rating
A	Excellent	So pure one could drink water from stream.
B	Good	Meets fishable/swimmable standards, supports cold water trout fishery
C	Average	Clean enough to support warm water fishery, not swimmable.
D	Unsatisfactory	Polluted, okay for boating not swimming or fishing
F	Poor	Polluted, has raw sewage and floating trash

Christina Basin watershed report card grades are assigned according to 19 water quality, habitat, and watershed health indicators. Grading criteria were derived from the following sources:

Stream Water Quality

- Total Nitrogen: Public Drinking Water Standards (DE Div. of Public Health, 2002)
- Total Phosphorus: Section 303 (d) Report (DE DNREC, 1998)
- Chlorophyll: Chesapeake Chlorophyll-a Criteria (Chesapeake Bay Program, 2002)
- Copper: Public Drinking Water Standards (DE Div. of Public Health, 2002)
- Lead: Public Drinking Water Standards (DE Div. of Public Health, 2002)
- Zinc: Public Drinking Water Standards (DE Div. of Public Health, 2002)
- Dissolved Oxygen: DE Surface Water Quality Standards (DE DNREC, 2002)
- Enterococcus Bacteria: Public Drinking Water Standards (DE Div. of Public Health, 2002)
- Total Suspended Solids: Public Drinking Water Standards (DE Div. of Public Health, 2002)

Stream Habitat

- Aquatic Life Support: Section 303 (d) Report (DE DNREC, 1998)
- Waters of Exceptional Recreational and Ecological Significance (ERES): Section 303 (d) Report (DE DNREC, 1998)
- Cold Water Fishery: Section 303 (d) Report (DE DNREC, 1998)
- Fish Consumption Advisories: Section 303 (d) Report (DE DNREC, 1998)
- Biological Community Index: Section 303 (d) Report (DE DNREC, 1998)
- Habitat Community Index: Section 303 (d) Report (DE DNREC, 1998)

Watershed Health

- Delaware Hazardous Substance Sites: Source Water Protection Reports (Wollaston and Kauffman, 2002)
- Watershed Imperviousness: Rapid Watershed Planning Handbook (Center for Watershed Protection, 1998)
- Population Density: Phase III Christina Basin Report (CCCD, CCWRA, UDWRA, 1999)
- Forest/Open Space Cover: Forest Cover, Impervious Surface Area and the Mitigation of Urbanization Impacts in King County, WA, 2000

Tables 3.10, 3.11, and 3.12 provide the criteria used to assign watershed grades. For instance, if the peak nitrogen level in a particular watershed is undetected, the grade would be an "A" (excellent). If the peak nitrogen level exceeded the drinking water standard 10 mg/L, the grade for this parameter would be a "D" (unsatisfactory). The overall grade for a particular subwatershed is the mean of the grades assigned for the 19 indicators.

Table 3.13 provides a listing of the individual grades for each subwatershed. The composite grade for the Delaware portion of the Christina Basin is “C” (average) signifying that there is an opportunity to improve watershed health through a Watershed Restoration Action Strategy outlined in the next chapters. Table 3.14 provides a listing of the overall grades for water quality, habitat, and watershed health indicators for the subwatersheds studied.

Final watershed letter grade is based on the following scale:

A	= 4.0 – 3.68	C	= 2.0 – 1.68
A-	= 3.67 – 3.34	C-	= 1.67 – 1.34
B+	= 3.33 – 3.01	D+	= 1.33 – 1.01
B	= 3.00 – 2.68	D	= 1.00 - .68
B-	= 2.67 – 2.34	D-	= .67 - .34
C+	= 2.33 – 2.01	F	= < .34

Table. 3.10. Criteria to assign watershed grades.

	Water Quality	Total Nitrogen	Total Phosphorus	Chlorophyll	Copper	Lead	Zinc	Dissolved Oxygen	Enterococcus Bacteria	Total Suspended Solids	Stream Habitat	Aquatic Life Support	ERES	Cold Water Fishery	Fish Consumption Advisory	Biological Community Index	Habitat Community Index	Watershed Health	Del. Hazardous Substance Sites	Watershed Imperviousness	Population Density	Forest / Open Space Cover
A	**Excellent**	‹0.50 mg/L	‹0.10 mg/L	<3 ug/L	‹0.065 mg/L	‹0.001 mg/L	‹.25 mg/L	>6.750 mg/L	‹10 mg/L	‹25 mg/L	**Excellent**	full support	yes	yes	none	> 80	91 to 100	**Excellent**	0	‹8%	‹250 sq mi	›75%
B	**Good**	0.50 to 5.00 mg/L	0.10 to 1.00 mg/L	3.1 to 7.0 ug/L	0.065 to 0.650 mg/L	0.001 to 0.008 mg/L	0.25 to 2.50 mg/L	4.501 to 6.750 mg/L	10 to 100 mg/L	25 to 250 mg/L	**Good**	-	-	-	-	61 to 80	81 to 90	**Good**	1 to 5	8.1% to 15%	251 to 500 sq mi	45.1% to 75%
C	**Average**	5.01 to 10.00 mg/L	1.01 to 2.00 mg/L	7.1 to 25.0 ug/L	0.651 to 1.300 mg/L	0.009 to 0.016 mg/L	2.51 to 5.00 mg/L	2.251 to 4.500 mg/L	101 to 200 mg/L	251 to 500 mg/L	**Average**	partial support	no	no	partial	41 to 60	61 to 80	**Average**	6 to 10	15.1% to 25%	501 to 1000 sq mi	25.1% to 45%
D	**Unsatisfactory**	10.01 to 15.00 mg/L	2.01 to 3.00 mg/L	25.1 to 50.0 ug/L	1.301 to 1.950 mg/L	0.016 to 0.023 mg/L	5.01 to 7.50 mg/L	.225 to 2.250 mg/L	201 to 300 mg/L	501 to 750 mg/L	**Unsatisfactory**	-	-	-	-	21 to 40	31 to 60	**Unsatisfactory**	11 to 30	25.1% to 40%	1000 to 1500 sq mi	10% to 25%
F	**Poor**	›15.00 mg/L	›3.00 mg/L	> 50.0 ug/L	›1.950 mg/L	›0.023 mg/L	›7.50 mg/L	< .225 mg/L	›300 mg/L	›750 mg/L	**Poor**	non-support	-	-	full	< 20	0 to 30	**Poor**	> 30	›40%	›1500 sq mi	‹10%

Table 3.11. Preliminary watershed grading measurements.

	B16. Brandywine Creek above Wilmington	B17. Brandywine Creek below Wilmington	R3. Burroughs Run	R4. Red Clay Creek above Woodale	R5. Red Clay Creek below Wooddale	W5. Mill Creek	W6. Pike Creek	W7. Middle Run	W8. White Clay Creek above Newark	W9. White Clay Creek below Newark	W10. White Clay Creek Tidal	C1. Upper Christina River above Cooches Bridge	C2. Muddy Run	C3. Belltown Run	C4. Little Mill Creek	C5. Christina River below Newark	C6. Tidal Christina below Smalley's Pond
Total Nitrogen (mg/L)	4.9	5.6	3.9	6.7	6.7	4.5	5.5	4.6	6.5	6.5	6.5	3.9	-	-	264.2	2.7	3.7
Total Phosphorus (mg/L)	.743	.566	.268	.8	.8	.752	.348	.19	1.17	1.17	1.17	.282	-	-	.268	.215	.777
Chlorophyll (ug/L)	16	13	13	45	45	11	5	24	16	16	16	13	-	-	8	11	45
Maximum Copper (mg/L)	.0385	-	-	-	-	-	-	-	.0447	-	.0643	-	-	-	-	.0336	-
Maximum Lead (mg/L)	.0446	-	-	-	-	-	-	-	.00988	-	.146	-	-	-	-	.0141	-
Maximum Zinc (mg/L)	.61	-	-	-	-	-	-	-	.0639	-	2.010	-	-	-	-	.155	-
Dissolved Oxygen (mg/L)	6.2	6.7	8.1	4.9	4.9	6.6	8	8.1	5.9	5.9	5.9	8.2	-	-	4.8	3.9	3.1
Enterococcus Bacteria (mg/L)	106	147	109	148	148	252	109	102	199	199	199	121	-	-	376	225	242
Total Suspended Solids (mg/L)	345	975	481	316	506	530	483	428	311	759	792	651	421	479	654	633	928
Aquatic Life Support	P	P	P	N	N	N	P	P	N	N	N	N	N	F	N	N	F/N *
Exceptional Recreational and Ecological Significant Waters	ERES	NO	NO	NO	NO	NO	NO	NO	ERES	NO	NO	NO	NO	NO	NO	NO	NO
Cold Water Fishery	CWF	NO	NO	NO	NO	CWF	CWF	NO	CWF	NO	NO	CWF	NO	NO	NO	NO	NO
Fish Consumption Advisories	PC	NC	C	NC	NC	C	C	C	C	PC	NC	C	C	C	NC	PC	NC
Biological Community Index	75	75	38	38	38	25	38	50	50	50	50	38	38	38	13	25	25
Habitat Community Index	70	70	73	87	87	67	70	81	85	85	85	58	-	82	38	66	71
Delaware Hazardous Sites (Superfund and SIRB)	-	4	-	-	-	-	-	-	3	-	37	-	-	-	-	34	-
Watershed Imperviousness	13	49	9	16	32	28	26	10	9	38	48	22	16	24	37	30	44
Population Density	613	5743	321	553	2426	1913	2077	1451	947	3015	1644	1149	1145	887	3595	2710	2437
Forest/Open Space Cover	56	29	27	45	25	22	22	45	60	21	39	27	50	43	27	35	37

* Note: Portions of this segment of stream are designated as both fully-supporting and non-supporting.

Table 3.12. Watershed grades per criteria.

	B16. Brandywine Creek above Wilmington	B17. Brandywine Creek below Wilmington	R3. Burroughs Run	R4. Red Clay Creek above Woodale	R5. Red Clay Creek below Wooddale	W5. Mill Creek	W6. Pike Creek	W7. Middle Run	W8. White Clay Creek above Newark	W9. White Clay Creek below Newark	W10. White Clay Creek Tidal	C1. Upper Christina River above Cooches Bridge	C2. Muddy Run	C3. Belltown Run	C4. Little Mill Creek	C5. Christina River below Newark	C6. Tidal Christina below Smalley's Pond
Total Nitrogen	**B**	**C**	**B**	**C**	**C**	**B**	**C**	**B**	**C**	**C**	**C**	**B**	**-**	**-**	**F**	**B**	**B**
Total Phosphorus	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**B**	**C**	**C**	**C**	**B**	**-**	**-**	**B**	**B**	**B**
Chlorophyll	**C**	**C**	**C**	**D**	**D**	**C**	**B**	**C**	**C**	**C**	**C**	**C**	**-**	**-**	**C**	**C**	**D**
Maximum Copper	**A**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**A**	**-**	**A**	**-**	**-**	**-**	**-**	**A**	**-**
Maximum Lead	**F**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**C**	**-**	**F**	**-**	**-**	**-**	**-**	**C**	**-**
Maximum Zinc	**B**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**A**	**-**	**B**	**-**	**-**	**-**	**-**	**A**	**-**
Dissolved Oxygen	**B**	**B**	**A**	**B**	**B**	**B**	**A**	**A**	**B**	**B**	**B**	**A**	**-**	**-**	**B**	**C**	**C**
Enterococcus Bacteria	**C**	**C**	**C**	**C**	**C**	**D**	**C**	**C**	**C**	**C**	**C**	**C**	**-**	**-**	**F**	**D**	**D**
Total Suspended Solids	**C**	**F**	**C**	**C**	**D**	**D**	**C**	**C**	**C**	**F**	**F**	**D**	**C**	**C**	**D**	**D**	**F**
Aquatic Life Support	**C**	**C**	**C**	**F**	**F**	**F**	**C**	**C**	**F**	**F**	**F**	**F**	**F**	**A**	**F**	**F**	**A/F**
Waters of Exceptional Recreational and Ecological Significance	**A**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**A**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**
Cold Water Fishery	**A**	**C**	**C**	**C**	**C**	**A**	**A**	**C**	**A**	**C**	**C**	**A**	**C**	**C**	**C**	**C**	**C**
Fish Consumption Advisories	**C**	**F**	**A**	**F**	**F**	**A**	**A**	**A**	**A**	**C**	**F**	**A**	**A**	**A**	**F**	**C**	**F**
Biological Community Index	**B**	**B**	**D**	**D**	**D**	**D**	**D**	**C**	**C**	**C**	**C**	**D**	**D**	**D**	**F**	**D**	**D**
Habitat Community Index	**C**	**C**	**C**	**B**	**B**	**C**	**C**	**B**	**B**	**B**	**B**	**D**	**-**	**B**	**D**	**C**	**C**
Delaware Hazardous Sites (Superfund and SIRB)	**-**	**B**	**-**	**-**	**-**	**-**	**-**	**-**	**B**	**-**	**F**	**-**	**-**	**-**	**-**	**F**	**-**
Watershed Imperviousness	**B**	**F**	**B**	**C**	**D**	**D**	**D**	**B**	**B**	**D**	**F**	**C**	**C**	**C**	**D**	**D**	**F**
Population Density	**C**	**F**	**B**	**C**	**F**	**F**	**F**	**D**	**C**	**F**	**F**	**D**	**D**	**C**	**F**	**F**	**F**
Forest/Open Space Cover	**B**	**C**	**C**	**C**	**C**	**D**	**D**	**B**	**B**	**D**	**C**	**C**	**B**	**C**	**C**	**C**	**C**
TOTAL GRADE	**B$^-$**	**C**	**B$^-$**	**C**	**C$^-$**	**C**	**C$^+$**	**B$^-$**	**B**	**C$^-$**	**C$^-$**	**C$^+$**	**B$^-$**	**B$^-$**	**D$^+$**	**C**	**C$^-$ / D$^+$**

Table 3.13. Report card summarizing stream water quality.

Subwatershed	Grade	Watershed Health	Watershed Impervious	Notes
B16. Brandywine Creek above Wilmington	**B$^-$**	Good	13 %	Exceptional Recreational Ecological Significance Two tributaries are cold water trout streams. Biological Community Index of 75%. Higher amounts of forests/open space. Source of potable water for Wilmington.
B17. Brandywine Creek below Wilmington	**C**	Average	49 %	Combined sewer overflow discharges. Full fish consumption advisory. High watershed impervious and pop.density.
R3. Burroughs Run	**B$^-$**	Good	9%	Protected by Burroughs Run Preserve. No fish consumption advisory. Low watershed impervious and pop. density. Biological Community Index of 38%.
R4. Red Clay Creek above Wooddale	**C**	Average	16 %	Full fish consumption advisory. Non-supported for aquatic life. Habitat Community Index of 87%.
R5.Red Clay Creek below Wooddale	**C$^-$**	Average	32 %	Full fish consumption advisory Non-supported for aquatic life High watershed impervious and pop.density.
W5. Mill Creek	**C**	Average	28 %	Supports put and take cold water trout fish. No fish consumption advisory. Non-supported for aquatic life. High watershed impervious and pop.density.
W6. Pike Creek	**C$^+$**	Average	26 %	Supports put and take cold water trout fish. No fish consumption advisory. High watershed impervious and pop.density.
W7. Middle Run	**B$^-$**	Good	10 %	Protected by Middle Run Preserve. No fish consumption advisory. Low watershed impervious. Higher amounts of forests/open space.
W8. White Clay Creek above Newark	**B**	Good	9 %	Exceptional Recreational Ecological Significance Supports put and take cold water trout fish Low watershed impervious. Higher amounts of forest/open space. Source of potable water for City of Newark
W9. White Clay Creek below Newark	**C$^-$**	Average	38 %	Non-supported for aquatic life. High watershed impervious and pop.density.
W10. White Clay Creek Tidal	**C$^-$**	Average	48%	Full fish consumption advisory. High watershed impervious and pop.density. Several Superfund and SIRB sites.
C1. Upper Christina River above Cooches Bridge	**C$^+$**	Average	22 %	Supports put and take cold water trout fish. No fish consumption advisory. Non-supported for aquatic life.
C2. Muddy Run	**B$^-$**	Good	16 %	No fish consumption advisory. Non-supported for aquatic life. Higher amounts of forest/open space.
C3. Belltown Run	**B$^-$**	Good	24%	Fully supported for aquatic life. No fish consumption advisory. Biological Community Index of 38%.
C4. Little Mill Creek	**D$^+$**	Unsatisfactory	37%	Only 13% of biological habitat intact. Full Fish consumption advisory. High watershed impervious and pop.density.
C5. Christina River below Newark	**C**	Average	30%	Several Superfund and SIRB sites. High watershed impervious and pop.density.
C6. Tidal Christina River below Smalley's Pond	**C-/ D$^+$**	Average/ Unsatisfactory	44 %	Combined sewer overflow discharges. Full fish consumption advisory. High watershed impervious and pop.density.
Average Grade = C				

Table 3.14. Report card summarizing indicator quality.

Indicator	Grade	Sources of Impairment
Stream Water Quality	**B$^-$**	
Total Nitrogen	**C$^+$**	Fertilizer, wastewater treatment, failing septic systems
Total Phosphorus	**B**	Fertilizer, wastewater treatment, failing septic systems
Chlorophyll	**C**	Fertilizer, wastewater treatment, failing septic systems
Copper	**A**	Natural deposits, sewage treatment
Lead	**D**	Brake linings, wastewater treatment
Zinc	**A$^-$**	Industries
Dissolved Oxygen	**B$^+$**	High nutrient loads
Enterococcus Bacteria	**C$^-$**	Leaking septic systems, manure
Total Suspended Solids	**D$^+$**	Erosion from agriculture, land development and stream banks
Stream Habitat	**C**	
Aquatic Life Support	**D$^+$/ D**	Point and nonpoint sources of pollution
Waters of Exceptional Recreational and Ecological Significance	**C$^+$**	Brandywine Creek above Wilmington and White Clay Creek above Newark are ERES waters
Cold Water Fishery	**B$^-$**	Urbanization in watersheds
Fish Consumption Advisories	**C$^+$**	High PCB and Zinc levels in fish tissue
Biological Community Index	**C$^-$**	Urbanization in watersheds
Habitat Community Index	**C$^+$**	Urbanization in watersheds
Watershed Health	**C$^-$**	
Delaware Hazardous Substance Sites (Superfund and SIRB)	**C$^-$**	Legacy from industrial development
Watershed Imperviousness	**C$^-$**	Urban and suburban development
Population Density	**D**	Urban and suburban development
Forest / Open Space	**C$^+$**	Agricultural and Urban/Suburban development
Average Grade = C		

Chapter 4: Priority Watersheds of the Christina Basin

Methodology

The 565 square-mile Christina Basin includes four major watersheds and 38 subwatersheds occupying five counties in three states. There is a need to prioritize the watersheds to focus funding and implement best management practices depending on whether the goal is to protect or restore existing stream water quality in a particular watershed. The subwatersheds of the Christina Basin were prioritized according to the following four-step process:

Step 1: Characterize the watershed based on land use
Step 2: Identify existing water quality
Step 3: Compute the watershed pollution potential
Step 4: Prioritize the watershed for protection or restoration BMPs

Step 1: Characterize the Watershed Based on Land Use

The watershed health of the Christina Basin was characterized by the following factors:

- Total suspended sediment loads (Table 4.4.): TSS contributes to water quality problems in the Christina Basin. Estimates of annual TSS loads are provided for each subwatershed according to three watershed pollution potential classes:
    - Low (0 to 400 lb/ac/yr)
    - Medium (401 to 600 lb/ac/yr)
    - High (over 600 lb/ac/yr)

- Percent impervious cover (Figure 4.5.): This is a key indicator of watershed and stream health. Many studies indicate water quality, biological habitat, wetlands, and trout fisheries become increasingly impaired when the impervious cover in a watershed exceeds 10 to 15 percent. Estimates of impervious cover are derived for each subwatershed according to three pollution potential classes:
    - Low (0 to 10 % impervious)
    - Medium (11 to 20 %)
    - High (over 20 %)

- Percent agriculture (Figure 4.6.): The extent of agriculture in subwatersheds without soil and water conservation plans can also affect stream water quality. The percentage of agricultural land in each subwatershed is classified by pollution potential:
    - Low (0 to 20 % agricultural land)
    - Medium (21 to 40 %)
    - High (over 40%)
- Percent wooded areas (Figure 4.7.): Highly wooded watersheds usually exhibit good stream health. The percentage of wooded land is categorized for each subwatershed according to pollution potential:

- Low (over 30 % wooded land)
- Medium (21 to 30 %)
- High (0 to 20%)

Step 2: Identify Existing Water Quality

The next step is to assess existing stream water quality from the following sources:

- Fish Consumption Advisories (Table 4.1): Pennsylvania and Delaware have posted fish consumption advisories along the following stream segments in the Christina Basin:

Table 4.1. Fish consumption advisories in the Christina Basin

State	Stream	Species	Pollutants	Advisory
PADEP	Brandywine Cr. (Chadds Ford)	Eel	PCBs	No Consumption
PADEP	WB Brandywine (Coatesville)	Eel	PCBs,Chlordane	No Consumption
PADEP	Red Clay Cr. (all)	White Sucker	PCBs,Chlordane	No Consumption
DNREC	Brandywine Cr (nontidal)	finfish	PCBs	Limited Consumption
DNREC	Brandywine Cr. (tidal)	finfish	PCBs	No Consumption
DNREC	Red Clay Cr. (all)	finfish	PCBs	No Consumption
DNREC	White Clay Cr. (tidal)	finfish	PCBs	No Consumption
DNREC	White Clay Cr. (d.s. Newark)	finfish	PCBs	Limited Consumption
DNREC	Little Mill Creek	finfish	PCBs	No Consumption
DNREC	Christina River (tidal)	finfish	PCBs	No Consumption
DNREC	Christina River (nontidal Newark to Smalley's pond)	finfish	PCBs	Limited Consumption

- Designated Uses: Delaware assigns designated uses for stream segments according to dissolved oxygen in the stream water quality standards:

Dissolved Oxygen Criteria	Avge. D.O. (mg/l)	Min. D.O. (mg/l)
Fresh Water	5.5	4.0
Cold Water Fish (Put and Take Trout)	6.5	5.5
Exceptional Recreational or Ecological Significance, White Clay Creek	6.5	5.5
Exceptional Recreational or Ecological Significance, Brandywine Creek	5.5	4.0

- Impaired Stream Segments (Figure 4.9.): Both states have designated impaired stream segments as required by the USEPA through Section 303(d) of the Clean Water Act. The stream segments were identified as being impaired for the following pollutants:

Pennsylvania: Organic enrichment/Low Dissolved Oxygen, Nutrients (N and P), and BacteriaDelaware: Low Dissolved Oxygen, Nutrients (N and P), Toxics (zinc), and Bacteria

Step 3: Compute the Watershed Pollution Potential

Using the sediment load, impervious cover, agricultural land data, wooded land data, designated use and fish consumption advisories, the watershed pollution potential of each subwatershed is computed according to the criteria in Table 4.2. Subwatersheds with a medium or high pollution potential have a goal of improving water quality through retrofitting, restoration, and reforestation BMPs (3 R's). Subwatersheds with a low pollution potential have a goal of protecting existing water quality through prevention, preservation, and protection BMPs (3 "P"s).

Table 4.2. Watershed pollution potential in the Christina Basin.

Watershed Pollution Potential	BMP Implementation Strategies	Goal	TSS Load (lb/ac./ yr.)	% Impervious	% Agriculture	% Wooded	Stream Water Quality	Fish Consumption Advisory
HIGH	Remediation Retrofitting Restoration Reforestation	Improve Water Quality	>600	>20	>40	0 - 20	Not Supported for Aquatic Life,Wildlife or Water Supply	No Consumption of Selected Finfish
MEDIUM	Conservation	Improve Water Quality	401 - 600	11 - 20	21 - 40	21 - 30	Not Supported for Swimming, Fishing, Boating or Water Sports	Limited Consumption of Finfish
LOW	Prevention Preservation Protection	Protect Water Quality	0 - 400	0 - 10	0 - 20	>30	Exceptional Recreational or Ecological Significance, Cold Water Trout Fishery	Unlimited Consumption of Finfish or not Tested but Presumed Safe

Tables 4.3 and 4.4 summarize the watershed pollution potential for each of the 38 subwatersheds in the Christina Basin.

Table 4.3. Watershed pollution potential data

ID	Subwatershed	TSS Load (lb/ac./yr)	% Imperviou s	% Agriculture	% Wooded	Designated Uses	Fish Consumption Advisory	Watershed Pollution Potential
	Brandywine Creek							
B16	Main Stem below Chadds Ford	345 (L)	13 (M)	17 (L)	34 (L)	P/ ERES	NC/ LC	LOW
B17	Main Stem through Wilmington	975 (H)	49 (H)	2 (L)	14 (H)	P	NC	HIGH
	Red Clay Creek							
R3	Burrough's Run	481 (M)	9 (L)	42 (H)	25 (M)	P	UC	MEDIUM
R4	Main Stem above Wooddale	316 (M)	16 (M)	15 (L)	35 (L)	N	NC	LOW
R5	Main Stem below Wooddale	506 (M)	32 (H)	1 (L)	13 (H)	N	NC	HIGH
	White Clay Creek							
W5	Mill Creek	530 (M)	28 (H)	11 (L)	12 (H)	N/ CWF	UC	HIGH
W6	Pike Creek	483 (M)	26 (H)	8 (L)	13 (H)	P/ CWF	UC	HIGH
W7	Middle Run	428 (M)	10 (L)	30 (M)	12 (H)	P	UC	MEDIUM
W8	Main Stem above Newark	311 (L)	9 (L)	20 (L)	54 (L)	ERES/ CWF	UC	LOW

W9	Main Stem above Delaware Park	759 (H)	38 (H)	9 (L)	10 (H)	N	LC	HIGH
W10	Main Stem at Churchmans Marsh	792 (H)	48 (H)	4 (L)	13 (H)	N	NC	HIGH
	Christina River							
C1	East/West Branch above Coochs Bridge	651 (M)	22 (H)	28 (M)	21 (M)	N/ CWF	UC	HIGH
C2	Muddy Run	421 (M)	16 (M)	15 (L)	38 (L)	N	UC	LOW
C3	Belltown Run	479 (M)	24 (H)	9 (L)	34 (L)	F	UC	MEDIUM
C4	Little Mill Creek	654 (H)	37 (H)	1 (L)	14 (H)	N	NC	HIGH
C5	Main Stem above Smalley's Pond	633 (H)	30 (H)	10 (L)	27 (M)	N	LC	HIGH
C6	Main Stem Lower Tidal	928 (H)	44 (H)	2 (L)	13 (H)	F	NC	HIGH
Watershed Pollution Potential: High (H), Medium (M), Low (L)								
Designated Uses = Supported (F), Partially Supported (P), Non-Supported (N), Exceptional Recreation or Ecological Significance (ERES), Cold Water Fishery (CWF), Warm Water Fishery (WWF), High Quality (HQ), Exceptional Value (EV), or Designated Watershed (DW).								
Fish Consumption Advisory: No Consumption (NC), Limited Consumption (LC), Unlimited Consumption (UC)								

Step 4: Prioritize the Watershed for Protection or Restoration BMPs

The final step is to prioritize the subwatersheds in the Christina Basin for three types of protection or restoration strategies:

Preservation/Protection Subwatersheds: These relatively undeveloped "green" subwatersheds have generally healthy water quality, particularly in the headwater tributaries, due to low amounts of impervious surfaces (less than 15%) and high amounts of forested and open space lands (over 30%). These healthy watersheds have few contaminant sources such as wastewater discharges and hazardous waste sites. The strategy here is to keep the green subwatersheds green and maintain existing good water quality through protection, prevention, and preservation BMPs.

Urban/Suburban Restoration Subwatersheds: These watersheds are more urbanized with greater amounts of impervious surfaces (more than 20%) and lower amounts of forested and open space land (less than 10%). Water quality in these more developed watersheds is generally impaired. These restoration subwatersheds have many contaminant sources such as wastewater discharges and hazardous waste sites. The strategy here is to restore these brown watersheds and improve water quality through restoration, retrofitting, and reforestation BMPs.

Agricultural BMPs: These watersheds are largely rural with high percentages of agricultural land (more than 40%) and are primarily in the PA portion of the basin. The strategy in these rural watersheds is to improve water quality implemented through a variety of Chester County Conservation District and USDA Natural Resources Conservation Service agricultural restoration programs.

The subwatershed prioritization is completed by combining the four steps: (1) watershed characterization, (2) existing water quality, (3) watershed pollution potential, and (4) assigning a protection or restoration strategy. Table 4.4 recommends a protection or restoration strategy for the subwatersheds in the Delaware portion of the Christina River Basin and Figure 4.11 shows a map depicting where each restoration strategy should be implemented.

Table 4.4. Recommended Christina Basin watershed protection or restoration strategies

Subwatershed	Area (sq. mi.)	Existing % Impervious Cover (1995)	Forested / Open Space (1995)	BMP Strategy
B16. Brandywine Creek above Wilmington	27	13 %	34 %	**P - Open Space Protection**
B17. Brandywine Creek through Wilmington	6	49 %	14 %	**R - Urban Restoration**
R3. Burroughs Run	7	9%	25%	**P - Open Space Protection**
R4. Red Clay Creek above Wooddale	12	16 %	35 %	**P - Open Space Protection**
R5.Red Clay Creek below Wooddale	7	32 %	13 %	**R - Suburban Restoration**
W5. Mill Creek	13	28 %	12 %	**R - Suburban Restoration**
W6. Pike Creek	7	26 %	13%	**R - Suburban Restoration**
W7. Middle Run	4	10 %	12 %	**P - Open Space Protection**
W8. White Clay Creek above Newark	10	9 %	54 %	**P - Open Space Protection**
W9. White Clay Creek below Newark	15	38 %	13 %	**R - Suburban Restoration**
W10. White Clay Creek Tidal	6	48 %	13 %	**R - Urban Restoration**
C1A. Upper Christina River PA/MD	8	8 %	31%	**P - Open Space Protection**
C1. Upper Christina River ab. Cooches Br.	13	22 %	21 %	**R - Suburban Restoration**
C2. Muddy Run	9	16 %	38 %	**P - Open Space Protection**
C3. Belltown Run	6	24%	34%	**P - Open Space Protection**
C4. Little Mill Creek	9	37%	14 %	**R - Urban Restoration**
C5. Christina River below Newark	11	30%	27%	**R - Suburban Restoration**
C6. Tidal Christina R. below Smalley's Pond	22	44 %	13 %	**R - Urban Restoration**

Figure 4.5. Total suspended sediment loads (lb/ac/yr).

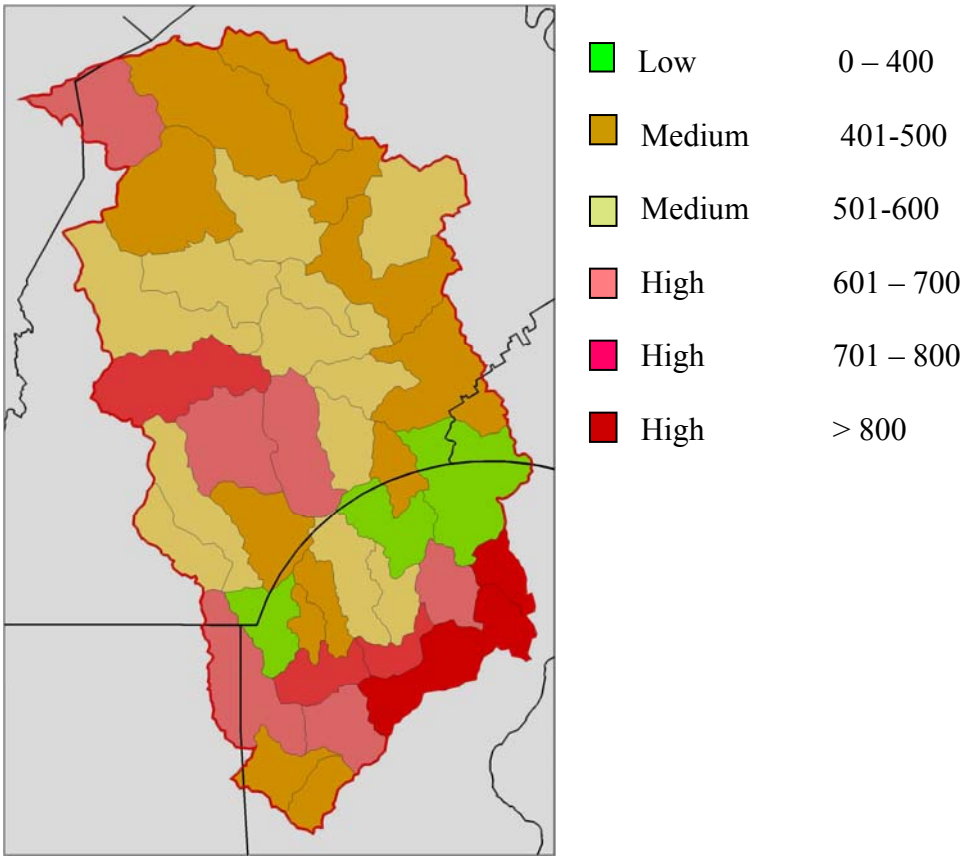


Figure 4.6. Percent impervious cover.

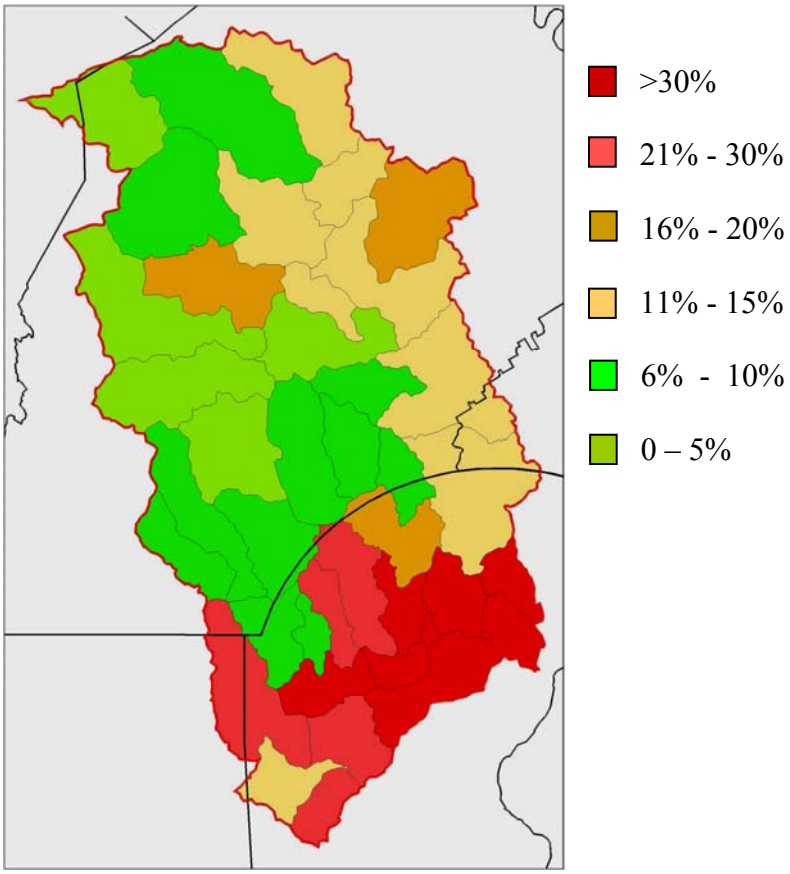


Figure 4.7. Percent agricultural area.

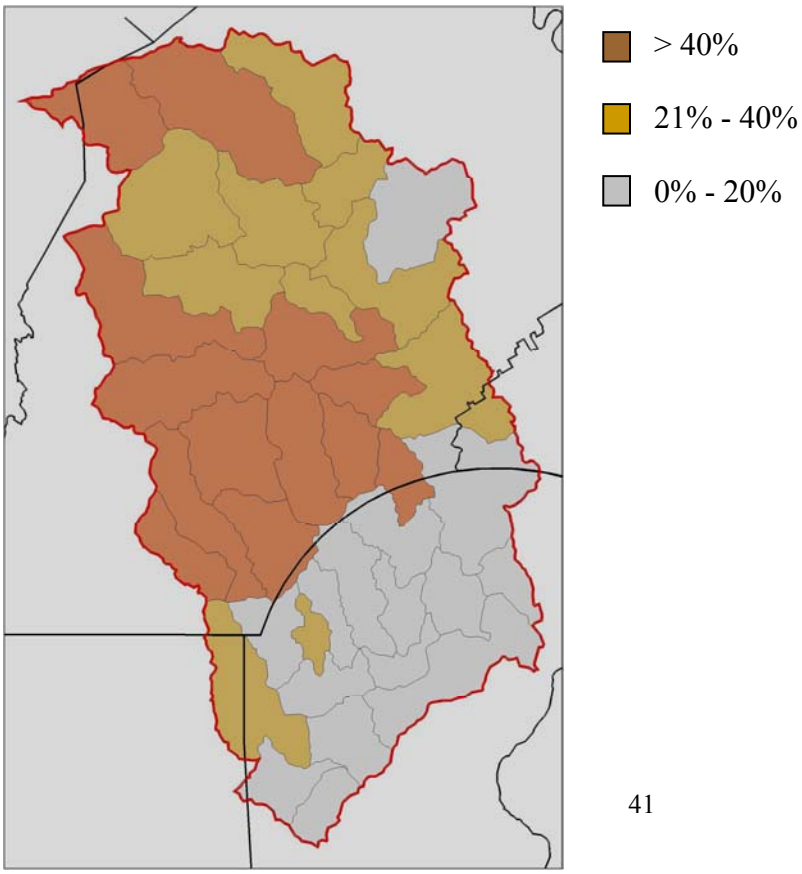
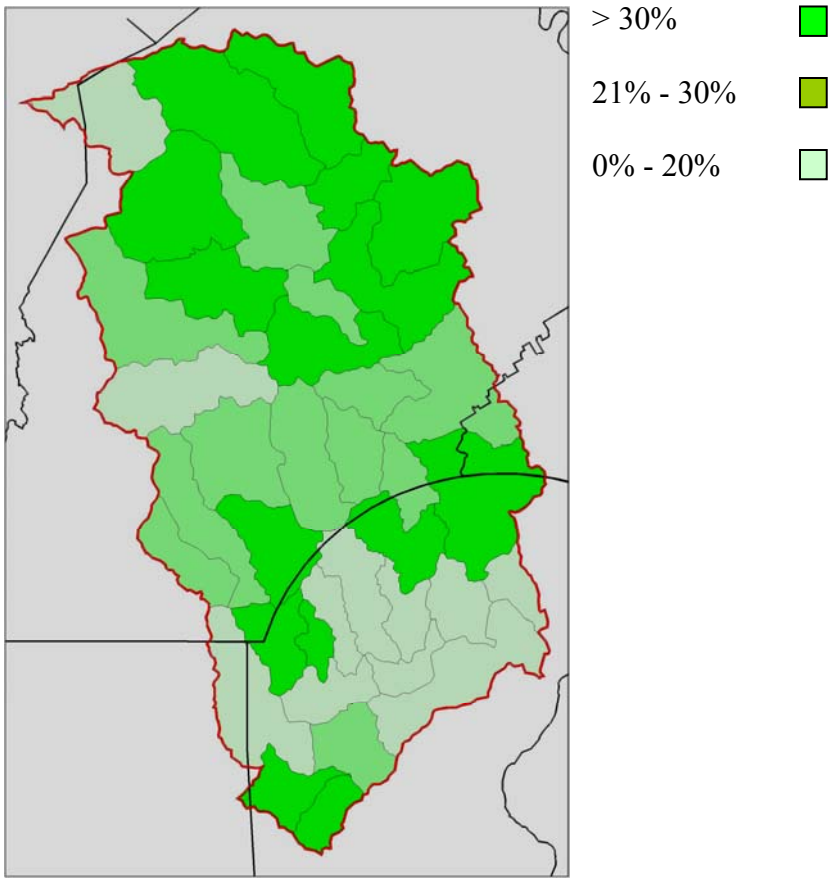


Figure 4.8. Percent wooded area.



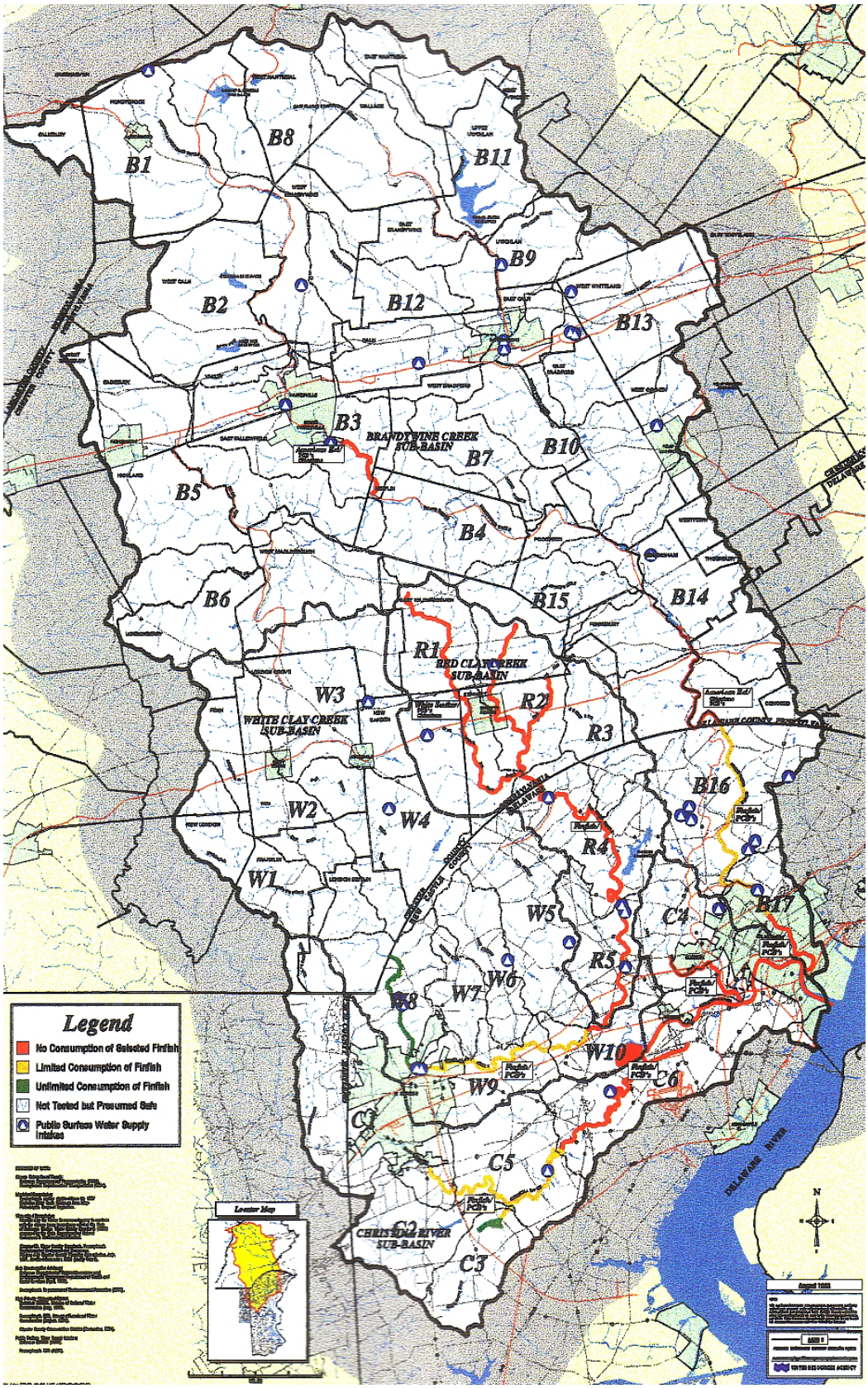


Figure 4.9. Fish consumption advisories.

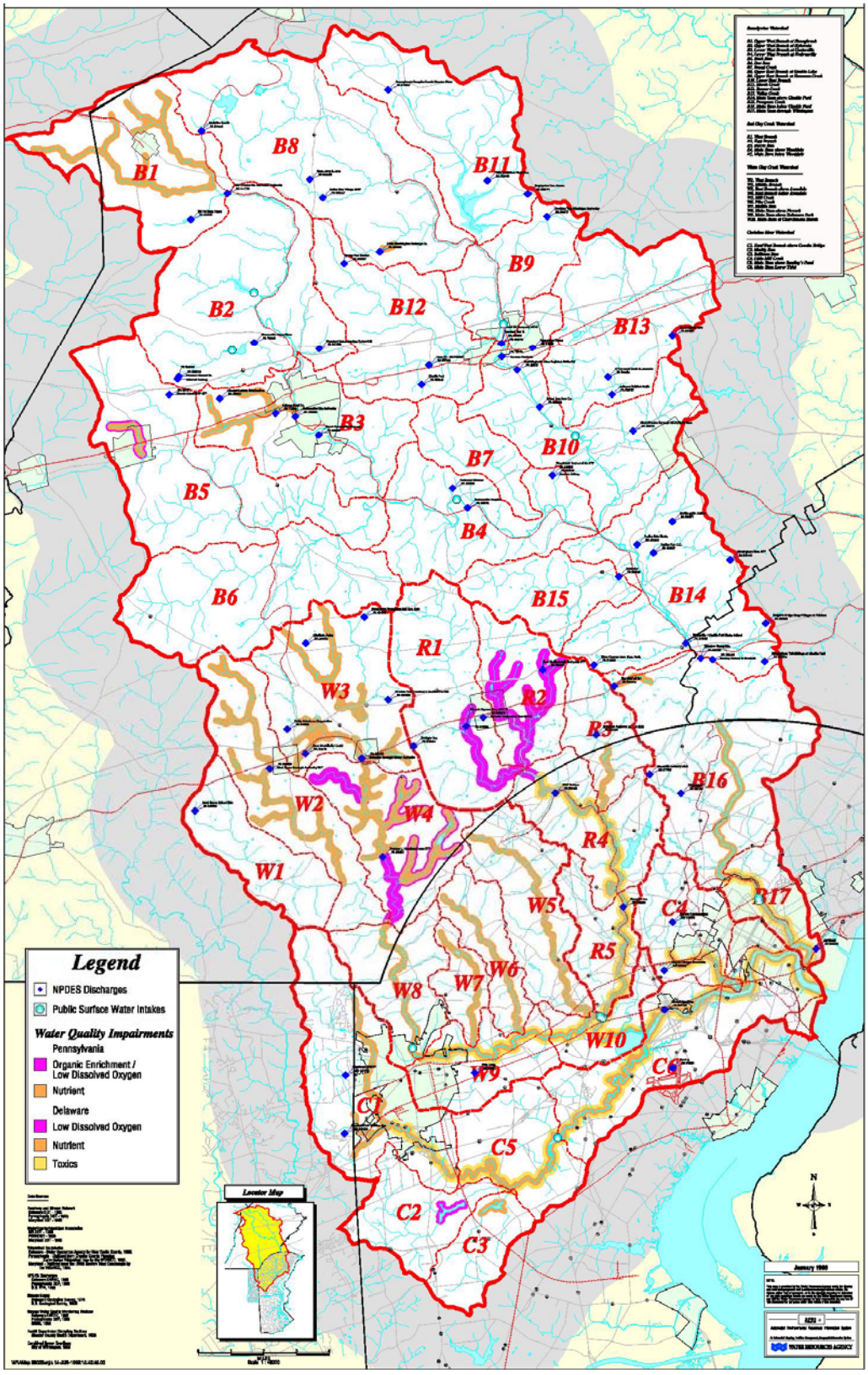
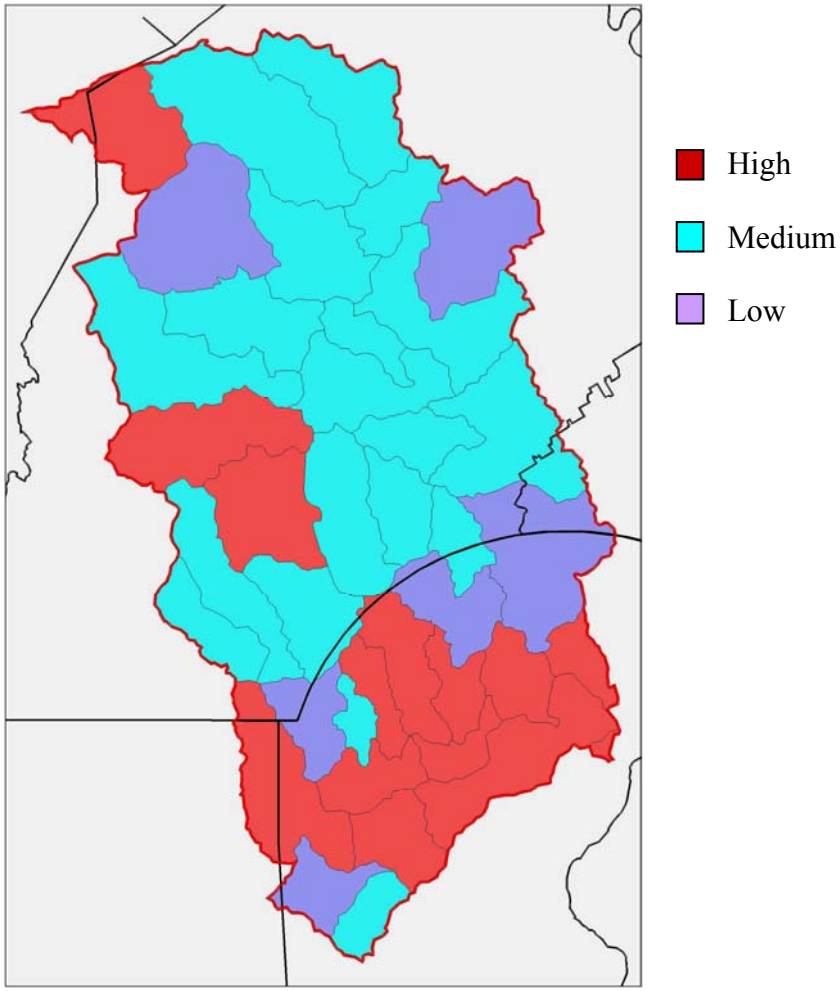


Figure 4.10. Impaired stream segments.

Figure 4.11. Watershed pollution potential.



Chapter 5: Recommended Watershed Restoration Action Strategy

Protection and restoration of the waters of the Christina Basin is a big job that will take years of work by many. Various members of the Christina Basin Clean Water Partnership will be appointed as "BMP Champions" to take the lead on implementing the various BMP strategies discussed below. BMP Champions will be requested to develop a schedule with milestones and report back quarterly to the committee regarding the progress of the BMP initiatives. The following Watershed Restoration Action Strategy (WRAS) is recommended to protect and restore the waters and the watersheds of the Christina Basin in Delaware by the year 2015.

Preservation/Protection Watershed BMPs

These relatively undeveloped "green" watersheds generally have healthy water quality due to low amounts of impervious surfaces, few contaminant sources, and high overall amounts of forested and open spaces. The strategy for these areas is to keep "green" watersheds as they are and maintain existing good water quality through the following preservation/protection Best Management Practices:

- P1. Acquire and Conserve Open Space
- P2. Retain Conservation Easements
- P3. Minimize Impervious Cover in New Developments
- P4. Amend Stormwater Ordinances
- P5. Implement Agricultural Conservation BMPs
- P6. Coordinate with Nonprofit Watershed Organizations
- P7. Administer SMARTYARD Program for Homeowners
- P8. Expand Public Education Outreach Programs

P-1. Acquire and Conserve Open Space: Prioritize funding to acquire 6,000 acres of public open space, particularly forested tracts and headwater streams adjacent to the Brandywine Creek State Park, White Clay Creek State Park, Middle Run Preserve, Sunset Lake and Becks Pond. Representatives from the Delaware DNREC - Division of Parks and Recreation, the New Castle County Department of Special Services, and the City of Newark Department of Parks and Recreation would be appointed as the Open Space BMP champions for this initiative.

P-2. Retain Conservation Easements: Continue to seek opportunities to acquire 2000 acres of conservation easements for the preservation of open space especially near the Woodlawn Trustees parcels in the Brandywine Valley, near the White Clay Creek State Park, and near the Delaware Nature Society in the Red Clay Valley. The Brandywine Valley Association/Red Clay Valley Association and the Delaware Nature Society would be appointed as the Conservation Easement BMP champions for this initiative.

P-3. Minimize Impervious Cover: Amend the existing New Castle County Unified Development Code to establish an impervious cover threshold of 15 to 20 percent in watershed zoning districts for any new development in the Brandywine, Red Clay, White Clay Creeks and Christina River

watersheds that are upstream from the only four drinking water intakes in New Castle County and hold the only six trout streams in Delaware. The University of Delaware Water Resources Agency and New Castle County would be appointed as the Impervious Cover BMP champions. The following subwatersheds would be included as water resource protection areas under the provisions of the Unified Development Code:

Subwatershed	**Impervious**
B16 - Brandywine Creek above Wilmington	13%
R3 - Burroughs Run	9%
R4 - Red Clay Creek above Wooddale	16%
W7 - Middle Run	10%
W8 - White Clay Creek above Newark	9%
C2 - Muddy Run	16%

P-4. Amend Stormwater Ordinances: To be consistent with upstream townships in Pennsylvania, amend the New Castle County and City of Newark Drainage Codes to assume a predevelopment "meadow" condition (curve number) for stormwater calculations for new subdivisions. The University of Delaware Water Resources Agency, New Castle County, and City of Newark would be appointed as the Stormwater Ordinance BMP champions.

P-5. Implement Agricultural Conservation BMPs: Prioritize existing U.S. Department of Agriculture, Conservation Reserve Enhancement Program (CREP), WHIP, WRP, and EQIP funds for nutrient management, grassed waterways, crop rotation and filter strips, manure storage and stream fencing at 15 farms in the remaining agricultural watersheds of the Christina Basin in Delaware. 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 would be appointed as the Agricultural BMP champions. The following subwatersheds have agricultural lands that exceed 10% of the watershed area:

Subwatershed	**Agricultural Land**
B16 - Brandywine Creek above Wilmington	17%
R3 - Burroughs Run	15%
W7 - Middle Run	30%
W8 - White Clay Creek above Newark	20%
C2 - Muddy Run	15%

P-6. Coordinate with Nonprofit Watershed Organizations: Coordinate with the stewardship and stream watch programs of the nonprofit watershed organizations such as:

- Delaware Nature Society - Soil Watch and Stream Watch
- Brandywine Valley Association - Stream Watch
- Brandywine Conservancy - Land Stewardship
- Red Clay Valley Association - Advocacy
- White Clay Watershed Association - Stream Watch
- Christina Conservancy - Advocacy

- Coalition for Natural Stream Valleys

The Delaware Nature Society and Brandywine Valley Association would be appointed as Nonprofit Watershed Organization BMP champions.

P-7. SMARTYARD Home Lawn Care Program: Work with landscape designers and the Delaware Nature Society to provide incentive to and assist homeowners to plant water friendly native landscaping to conserve water and reduce fertilizer and pesticide use. The SMARTYARD program would include delivery of rain barrels to interested and qualified homeowners according to the following goals:

Watershed	**SMARTYARDS**	**Rain barrels**
Brandywine Creek	100	300
Red Clay Creek	100	250
White Clay Creek	100	250
Christina River	200	200

The Delaware Nature Society and the University of Delaware Water Resources Agency would be appointed as SMARTYARD BMP champions.

P-8. Public Education and Outreach: Expand the public outreach program though the following techniques:

- Water bill and brochure inserts to the Newark, Wilmington, Artesian Water Company, and United Water Delaware water bills
- Watershed road signs at 18 locations entering the Christina Basin along DELDOT highways
- Watershed brochures delivered at University of Delaware Football Games (capacity 22,000), U of D basketball games (capacity 5,000) and Wilmington Blue Rock Minor League Baseball games (capacity 5,000)
- Update the Christina Basin website at the U of D homepage (www.wr.udel.edu)
- Obtain or develop an email mailing list to broadcast word about the Christina Basin
- Develop press releases to the Wilmington News Journal and the Philadelphia Inquirer, TV Channel 12, and WILM radio
- Sponsor a 5k race though the White Clay Creek State Park highlighting the watershed
- Watershed Education Module - Accomplished with Middle School Teachers by the DE Department of Education and the UD Math and Science Education and Research Center

The Delaware Nature Society, Brandywine Valley Association, the University of Delaware Water Resources Agency would be appointed as the Public Outreach BMP champion.

Table 5.1. Protection/preservation watershed BMPs in the Christina Basin

WRAS Implementation BMP	Goal	BMP Champions	Timing
P1. Acquire/Conserve Open Space	6000 acres	DNREC, New Castle County, City of Newark	TBD
P2. Retain Conservation Easements	2000 acres	Delaware Nature Society Brandywine Valley Association	TBD
P3. Minimize Impervious Cover	1 ordinance 6 subwatersheds	UD Water Resources Agency, New Castle County	TBD
P4. Amend Stormwater Ordinances	2 ordinances	UD Water Resources Agency, New Castle County, City of Newark	TBD
P5. Implement Agricultural Conservation BMPs	15 Farms 6 subwatersheds	USDA NRCS, New Castle Cons. District, Delaware Nutrient Management Commission	TBD
P6. Coordinate w/ Nonprofit Watershed Organizations	7 organizations	Delaware Nature Society Brandywine Valley Association	TBD
P7. Administer SMARTYARD Program for Homeowners	500 lawns 1000 rainbarrels	UD Water Resources Agency Delaware Nature Society	TBD
P8. Expand Public Outreach Program	9 components	Delaware Nature Society Brandywine Valley Association UD Water Resources Agency	TBD

*TBD – To be determined by individual watershed BMP champions

Restoration/Retrofitting Watershed BMPs

These developed watersheds have generally poor water quality due to higher amounts of impervious surfaces, low overall amounts of forested and open space, and higher densities of contaminant sources.

Restoration subwatersheds have characteristics of (a) low percentages (< 10%) of wooded land, (b) high percentages (> 20%) of impervious cover, (c) relatively poor water quality, and (d) many contaminant sources such as wastewater discharges and hazardous waste sites.

The strategy is to restore the "brown" watersheds and improve existing impaired water quality through the implementation of the following restoration and retrofitting Best Management Practices:

- R-1. Cleanup Superfund, Hazardous Waste, Leaking Underground Tank (LUST) Sites
- R-2. Abate the Combined Sewer Overflows (CSOs)
- R-3. Continue Wilmington Riverfront Development Efforts
- R-4. Continue Sewer Repair/Septic Elimination Projects
- R-5. Restore Stream and Riparian Corridors
- R-6. Reforest Watersheds and Headwaters
- R-7. Retrofit Stormwater Quality Basins
- R-8. Eliminate Remaining NPDES Discharges

R-1. Cleanup Superfund, Hazardous Waste and LUST Sites: Establish an abatement schedule to prioritize the remediation of 40 Superfund, Hazardous Waste, and LUST sites in the Delaware portion of the watershed. First priority for remediation should be given to the hazardous waste sites above the 4 drinking water intakes in the watersheds of the Brandywine, Red Clay Creek, White Clay Creek, and Christina River. The Delaware DNREC -Division of Air and Waste Management is identified as the BMP Champion for this initiative.

Watershed	**Existing Hazardous Waste Sites**
Brandywine Creek above Wilmington	311
White Clay Creek above Newark	16
Red Clay/White Clay Creeks above Stanton	513
Christina River above Smalley's Pond	333

R-2. Abate the Combined Sewer Overflows (CSOs): In accordance with the recommendations of the Wilmington CSO Task Force and the Christina Basin High Flow TMDLs (due 2004), implement storage, conveyance, and treatment strategies to remove 85% of the combined sewer overflows at 37 locations along the Brandywine Creek and Christina River. The City of Wilmington Department of Public Works is identified as the BMP Champion for this initiative.

R-3. Riverfront Development Efforts: Coordinate with Riverfront Development Corporation efforts to clean up and restore the riverfront and revitalize with the waterfront park, path, offices, restaurants, and shops along the Brandywine Creek and Christina River in Wilmington. A representative of the state/privately funded Riverfront Development Corporation will be requested to act as the BMP Champion for this initiative.

R-4. Continue Sewer Repair/Septic Elimination Projects: Continue ongoing program to repair 30 miles of sanitary sewers and eliminate 500 failing septic systems in the New Castle County regional wastewater system. The New Castle County Department of Special Services will be requested to act as the BMP Champion for this initiative.

R-5. Restore Stream and Riparian Corridors: Restore 20 miles of stream and riparian corridors using techniques such as bioengineering and wetland restoration. The Delaware DNREC Division of Soil and Water Conservation and Whole Basin Program will be requested to act as the BMP Champions for stream restoration.

R-6. Reforest Watersheds and Headwaters: Reforest 2000 acres of watershed land and headwater streams in the Delaware portion of the Christina Basin. The Delaware Nature Society and the New Castle Conservation District will be requested to act as the BMP Champions for the reforestation initiative.

R-7. Retrofit Stormwater Quality Basins: Amend the City of Wilmington, City of Newark and New Castle County Development Codes to require retrofitting of stormwater management ponds for water quality functions during urban redevelopment projects. Find opportunities to retrofit existing stormwater basins and convert them into stormwater quality ponds. The New Castle County Department of Land Use and City of Newark Department of Public Works are identified as the BMP Champions.

R-8. Eliminate Remaining NPDES Discharges: Seek opportunities to eliminate or consolidate the 10 remaining NPDES wastewater discharges in Delaware and the 2 remaining discharges in the Maryland portions of the Christina Basin. The Delaware DNREC - Division of Water Resources, Discharges Section is identified as the BMP Champion.

Table 5.2. Restoration watershed BMPs in the Christina Basin

WRAS Implementation BMP	Goal	BMP Champion	Timing
R1. Clean-up Superfund, Hazardous Waste, and LUST Sites	40 sites	DNREC Division of Air and Waste Management	TBD*
R2. Abate Combined Sewer Overflows	37 CSOs	City of Wilmington	TBD
R3. Continue Riverfront Development Efforts	5 acres	Riverfront Development Corporation	TBD
R4. Continue Sewer Repair/Septic Elimination Projects	30 miles	New Castle County Dept. of Special Services	TBD
R5. Restore Stream and Riparian Corridors	6 miles	DNREC Division of Soil and Water Conservation and DNREC Whole Basin Program	TBD
R6. Reforest Watersheds and Headwaters	1,200 acres	Delaware Nature Society New Castle Cons. District	TBD
R7. Retrofit Stormwater Quality Basins	10 Ponds	City of Newark New Castle County	TBD
R8. Eliminate Remaining NPDES Discharges	10 Discharges	Delaware DNREC Division of Water Resources	TBD

*TBD – To be determined by individual watershed BMP champions

Tables 5.3. and 5.4. show conceptual-level costs associated with the suggested protection/preservation and restoration actions that are to occur in the subwatersheds. Table 5.5. indicates the relationship of the BMPs to the overall watershed goals. Potential sources of federal funding for the Christina Basin WRAS are illustrated in Table 5.6.

Table 5.3.

Protection and Preservation Subwatershed BMP Cost

Christina Basin Watershed Restoration Action Strategy

Implementation Action	Unit Cost	**Brandywine Cr.** above Wilmington B16 No.	**Red Clay Cr.** Above Wooddale R3 and R4 No.	**White Clay Creek** Middle Run W7 No.	**White Clay Creek** above Newark W8 No.	**Christina River** above Cooches Br C1A No.	**Christina River** Muddy Run C2 No.	**Christina River** Belltown Run C3 No.	Subtotal No.	Subtotal Cost	Watershed Champion
P1. Acquire Open Space	$60,000/ac	2000	1000	500	1000	500	500	500	6000	360000000	*DNREC-DPR, NCC Parks, City of Newark*
P2. Retain Conservation Easements	$10,000/ac	500	200	200	500	200	200	200	2000	20000000	*BVA, DNS*
P3. Minimize Impervious Cover in New Developments									2 ordinances in 6 watersheds		*NCC, University of Delaware IPA-WRA*
P4. Amend the Stormwater Ordinance									2 ordinances		*City of Newark, NCC, University of Delaware IPA-WRA*
P5. Implement Agricultural Conservation BMP's	10,000/farm	4	4	2	2	1	1	1	15 farms	150000	*USDA-NRCS, NCCD*
P6. Coordinate with Nonprofit Watershed Organizations									60 organizations		*DNS, BVA*
P7. Administer SMARTYARD Program for Homeowners	300 / home	100	100	50	50	100	50	50	500	150000	*DNS, University of Delaware IPA-WRA*
P8. Expand Public Education Outreach											*University of Delaware IPA-WRA, DNS, BVA*
Subtotal		2604	1304	752	1552	801	752	752		380300000	

Table 5.4.

Restoration Subwatershed BMP Cost

Christina Basin Watershed Restoration Action Strategy

Implementation Action	Unit Cost	Brandywine Cr.	Red Clay Cr.	White Clay Creek		Christina River			Subtotal No.	Subtotal Cost	Watershed Champion
		below Wilmington	below Woodale	Mill Creek/Pike Creek	below Newark	above Cooches Br.	Little Mill Creek	above Smalley's Pond/Tidal			
		B17	R5	W5/W6	W9/W10	C1B	C5	C4/C6			
		No.	No.	No.	No.	No.	No.	No.			
R1. Cleanup Superfund, Hazardous Waste and LUST Sites	100,000	10	5	0	10	0	5	10	40 sites	4,000,000	*DNREC Division of Air and Waste*
R2. Abate Combined Sewer Overflows	4,000,000	19	0	0	0	0	0	19	37 CSOs	148000000	*City of Wilmingtion*
R3. Continue Wilmington Riverfront Development	5000000/mile	1	0	0	0	0	0	1	2 miles	10000000	*Riverfront Development Corporation*
R4. Continue Sewer Repair/Septic Elimination Projects	1,000,000/mile	5	5	5	5	0	5	5	30 miles	30000000	*NCC - Department of Special Services*
R5. Restore Stream and Riparian Corridors	1,000,000	0	1	2	1	1	0	1	6 miles	6000000	*DNREC Whole Basin Program*
R6. Reforest Watersheds and Headwaters	10,000/acre	200	200	200	200	200	0	200	1,200 acres	12000000	*DNS, NCCD*
R7. Retrofit Stormwater Quality Basins	20,000	1	1	2	1	2	2	1	10 ponds	200000	*City of Newark, NCC*
R8. Eliminate Remaining NPDES Discharges	2,000/ outfall	2	3	0	1	0	2	2	10 outfalls	20000	*DNREC - Divison of Water Resources*
Subtotal		238	215	209	218	203	14	239		210,220,000	

Table 5.5. Relationship of WRAS BMPs to watershed goals. Christina Basin WRAS.

RELATIONSHIP OF BMPS TO WATERSHED GOALS	GOAL 1 NUTRIENTS	GOAL 2 TOXICS	GOAL 3 BACTERIA	GOAL 4 FISH CONSUMPT. ADVISORY	GOAL 5 SEDIMENT	GOAL 6 STREAM HABITAT
PROTECTION/PRESERVATION WATERSHEDS						
P1. Acquire/Conserve Open Space	■	■			■	■
P2. Retain Conservation Easements	■	■			■	■
P3. Minimize Impervious Cover	■				■	■
P4. Amend Stormwater Ordinances	■	■			■	■
P5. Implement Agricultural Conservation BMPs	■		■		■	■
P6. Coordinate w/ Nonprofit Watershed Organizations	■	■	■	■	■	■
P7. Administer SMARTYARD Program for Homeowners	■				■	■
P8. Expand Public Outreach Program	■	■	■	■	■	■
RESTORATION WATERSHEDS						
R1. Clean-up Superfund, Hazardous Waste, and LUST Sites		■		■		
R2. Abate Combined Sewer Overflows		■	■	■	■	
R3. Continue Riverfront Development Efforts		■		■	■	■
R4. Continue Sewer Repair/Septic Elimination Projects	■		■			
R5. Restore Stream and Riparian Corridors			■		■	■
R6. Reforest Watersheds and Headwaters	■				■	■
R7. Retrofit Stormwater Quality Basins	■		■		■	■
R8. Eliminate Remaining NPDES Discharges	■	■	■			

Table 5.6. Potential sources of federal funding. Christina Basin WRAS.

Federal Funding Program	Requested Funding Per Year	10-Year Total Funding Request
USDA PL 566 Brandywine Creek Watershed Supplement	$ 1,150,000	$ 11,500,000
USDA PL 566 Red and White Clay Creek Watershed Plan	$ 650,000	$ 6,500,000
USDA CRP/Conservation Reserve Enhancement Program	$ 1,000,000	$ 10,000,000
USEPA Section 104(b)(3)	$ 600,000	$ 6,000,000
USEPA Brownfields (Prioritize DE for funding)	TBD*	TBD*
USEPA Superfund (Prioritize DE for funding)	TBD*	TBD*
USEPA Watershed Initiative (3 year grant)**	$ 430,000	$ 1,339,500
USDOI/NPS Federal Wild and Scenic Rivers Program	$ 500,000	$ 5,000,000
USDOI Land and Water Conservation Fund	$ 1,000,000	$ 10,000,000
Total Federal Funding Request	**$ 5,330,000**	**$ 50,339,500**

* To Be Determined

**In May 2003, USEPA Administrator Christine Whitman announced the award of a $1 million Watershed Initiative Grant to the Christina Basin Clean Water Partnership. The Christina Basin grant was the top ranked application out of over 170 applications submitted from watersheds all over the United States. The Watershed Initiative Grant will be applied to a series of agriculture, stormwater, and native landscaping (SMARTYARD) BMP projects in the Delaware and Pennsylvania portions of the Christina Basin.

Chapter 6: WRAS Progress in Delaware

While the recommendations of the Watershed Restoration Action Strategy (WRAS) for the Delaware portion of the Christina Basin are new, progress on these BMPs is not. For years, many agencies and entities have implemented WRAS BMPs in the Christina Basin under the auspices of individual programs. The Delaware DNREC owns many acres of open space at the Brandywine Creek and White Clay Creek State Parks and is cleaning up Superfund and hazardous waste sites along with the Christina Riverfront revitalization effort at Wilmington. The Delaware Nature Society holds many acres of conservation easements in the Red Clay Creek watershed donated by the public. The New Castle Conservation District has funded many streamside restoration and stormwater pond retrofitting projects. While these BMP projects and programs were conducted incrementally, they count as "progress" toward the implementation of an overall Christina Basin WRAS Strategy in anticipation of the upcoming, high flow, stormwater TMDLs in 2004.

This chapter describes the progress to date on the following WRAS initiatives in the Delaware portion of the Christina Basin.

Preservation/Protection Watershed BMPs

These relatively undeveloped “green” watersheds have generally healthy water quality due to low amounts of impervious surfaces and contaminant sources, and high overall amounts of forested and open spaces. The strategy for these areas is to keep the “green” watersheds "green" as they are and maintain existing high water quality through following the preservation/protection Best Management Practices:

- P1. Acquire and Conserve Open Space
- P2. Retain Conservation Easements
- P3. Minimize Impervious Cover in New Developments
- P4. Amend the Stormwater Ordinance
- P5. Implement Agricultural Conservation BMPs
- P6. Coordinate with Nonprofit Watershed Organizations
- P7. Administer SMARTYARD Program for Homeowners
- P8. Expand Public Education Outreach Programs

Restoration/Retrofitting Watershed BMPs

These developed watersheds have generally poor water quality due to high amounts of impervious surfaces, high densities of contaminant sources, and low overall amounts of forested and open spaces. The strategy for these watersheds is to restore the "brown" watersheds and improve existing impaired water quality through the implementation of the following restoration and retrofitting Best Management Practices:

- R-1. Cleanup Superfund, Hazardous Waste and LUST Sites
- R-2. Abate the Combined Sewer Overflows (CSOs)
- R-3. Wilmington Riverfront Development Efforts
- R-4. Continue Sewer Repair/Septic Elimination Projects
- R-5. Restore Stream and Riparian Corridors
- R-6. Reforest Watersheds and Headwaters
- R-7. Retrofit Stormwater Quality Basins
- R-8. Eliminate Remaining NPDES Discharges

Christina Basin Watershed Restoration Action Strategy (WRAS)

P1. Acquire and Conserve Open Space

White Clay Creek State Park - Over the last three years, the DNREC added 11 tracts of land totaling about 1,000 acres to the White Clay Creek State Park. Now comprising 3,372 acres, White Clay Creek State Park offers a range of recreational opportunities including trout fishing, hiking, wading, and bird watching while protecting the watershed. The park, along with adjacent Middle Run Natural Area, and the White Clay Creek Preserve in Pennsylvania, form a 5,000 acre green area in the White Clay Valley north of Newark.

Brandywine Creek State Park - The DNREC has assembled over 933 acres of open space for the state park perched in the Brandywine Creek hills north of Wilmington. The Brandywine Creek State Park provides trout fishing, bass fishing, canoeing, and kayak opportunities in the creek and its Wilson Run and Rocky Run tributaries. Along with the adjacent holdings of the privately owned Woodlawn Trustees Preserve, the state park provides more than 1100 acres of protected land along the Brandywine Creek which is the source of drinking water for the City of Wilmington.

Dayett Mills, Upper Christina River - The State of Delaware purchased 27 acres along the Upper Christina River to preserve one of the oldest mills in Delaware. The open space near Newark protects the historic stream valley, which includes a land grant from William Penn and the site of the Revolutionary War battle at Cooches Bridge.

Middle Run Natural Area - In a series of strategic acquisitions, New Castle County has purchased 815 acres of open space for this county park in the Middle Run Valley. Approximately 45% of the Middle Run watershed is protected by this county open space.

Carousel Park - New Castle County operates the over 200 acre park in the middle of the suburbanizing Mill Creek watershed near DE Route 7. This green space protects several tributaries of Mill Creek which is a put and take trout stream.

Valley Garden Park, Hoopes Reservoir - The City of Wilmington acquired the holdings for this 78 acre park in the 1930's to protect the Hoopes Reservoir watershed. The park open space protects Delaware's only drinking water reservoir.

Open Space Inventory – Approximately $14,260,000 was spent by the Delaware DNREC in the Brandywine Creek sub-basin to maintain 380 acres of open space. The Christina River sub-basin has 341 acres of open space at a cost of $8,030,000. The largest amount of open space, 2231 acres, is found in the White Clay Creek sub-basin at a cost of $52,040,792.

Figure 6.1. White Clay Creek State Park.

Christina Basin Watershed Restoration Action Strategy (WRAS)

P2. Retain Conservation Easements

Woodlawn Trustees Preserve - The Woodlawn Trustees have preserved 1100 acres of open space in the Brandywine Valley. Together with the adjoining Brandywine Creek State Park, over 2033 acres of open space are dedicated for watershed protection, hiking, mountain biking, canoeing, and fishing.

Delaware Nature Society Burrows Run Preserve – The Burrows Run Preserve was donated to the Delaware Nature Society by the late Margaretta and Crawford Greenewalt. The Preserve provides a habitat for 70 nesting bird, 19 fish, 20 butterfly and over 450 plant species.

Frederick Family/Whitely Farms Natural Area - The Frederick Family donated three conservation easements totaling 89 acres to the Delaware Nature Society in the White Clay Creek Valley Natural Area. The natural area protects the pristine Turkey Run and scenic forest and wetlands bordering the White Clay State Park.

Lefren Family Conservation Area - The Lefren Family donated ten acres to the Delaware Nature Society in the Red Clay Creek natural stream corridor.

Lunger Family Conservation Easement - Mrs. Lunger donated a conservation easement in the Burrows Run watershed to the Delaware Nature Society. The 31-acre easement preserves a tributary to Burrows Run, which flows downstream to the 352 acre Delaware Nature Society's Burrows Run preserve.

Flint Woods Preserve - The Flint family donated a 44-acre easement to the DNS in the Brandywine Valley.

University of Delaware - The UD owns 102 acres of forest and open space at the Laird Campus, Agriculture Farm, and Judge Morris tracts near the Newark campus in the White Clay watershed.

DuPont Corporation - At the Haskell Research Center in the Upper Christina River watershed near Newark and the Experimental Station in the Brandywine Creek watershed near Wilmington, the DuPont corporation maintains 640 acres of private open space.

Smith Bridge Road – The family of the late Sophie du Pont May has donated a conservation easement to the Delaware Nature Society on 30 acres of farmlands, woodlands and wetlands along Smith Bridge Road. The property contains a spring fed tributary to the Brandywine Creek, a grove of mature forest, steep slopes, rare Delaware plants, and scenic rolling farmland.

Winterthur easement – Winterthur's board of trustees signed a conservation easement with the Brandywine Conservancy to protect 982 acres of the estate from development.

Figure 6.2. Woodlawn Trustees Easement.

Christina Basin Watershed Restoration Action Strategy (WRAS)

P3. Minimize Impervious Cover in New Developments

New Castle County Water Resource Protection Area (WRPA) Ordinance

Since the early 1990s, two Delaware governments in the Christina Basin have administered zoning ordinances that utilize impervious cover thresholds to protect sensitive water resources areas during new development. New Castle County and the City of Newark have adopted Water Resource Protection Area (WRPA) ordinances to protect the quantity and quality of ground and surface water supplies. In New Castle County, WRPAs are protected as overlay zoning districts. In Newark, the WRPAs are protected as part of the city water code.

Impervious Cover Thresholds

In New Castle County, overlay zoning ordinances limit the impervious surface coverage for new development to a maximum of 10% to 20% in the following WRPAs:

- Cockeysville Limestone Aquifer
- Cockeysville Drainage Area
- Wellhead Areas
- Recharge Areas
- Hoopes Reservoir Watershed

A new single-family development within the Reservoir WRPA zoning district is limited to a maximum impervious cover of 10% that equates to a gross density of 2 to 3 dwellings per acre. Two of the WRPAs, the Cockeysville Drainage Area and the Hoopes Reservoir, include their respective drainage areas so impervious cover thresholds already protect at least two watersheds in the Christina Basin in Delaware.

Figure 6.3. Hoopes Reservoir Water Resource Protection Area.

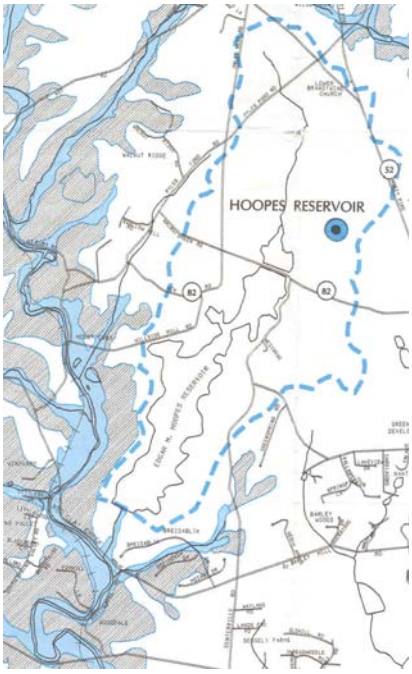
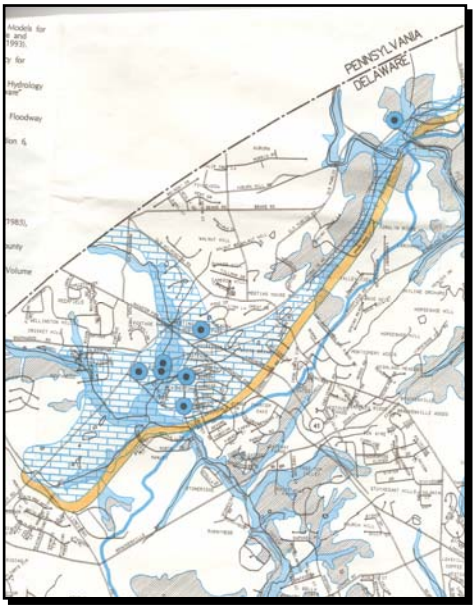


Figure 6.4. Cockeysville Aquifer Water Resource Protection Area.



Christina Basin Watershed Restoration Action Strategy (WRAS)

P4. Amend Stormwater Ordinances

DNREC Stormwater and Sediment Ordinance - In 1991, DNREC adopted a stormwater ordinance that is designed to control the quantity and quality of stormwater runoff flowing from new development. The ordinance provides criteria for the 2-, 10-, 25-, 50-, and 100-year storm events.

DNREC Conservation Design Manual - In 1998, DNREC wrote a manual that recommends various infiltration and stormwater design practices such as infiltration basins, native landscaping, wetlands restoration, buffers, cluster development, and impervious cover minimization practices.

New Castle County Unified Development Code - In 1997, New Castle County adopted a code which provides minimum criteria to protect sensitive areas such as floodplains, steep slopes, forests, wetlands, and riparian buffer area. The code requires protection of open space (50% to 100%) in these sensitive watershed areas.

New Castle County Council is considering amendments to the Unified Development Code which include stormwater amendments such as buffer strips, clustering and infiltration practices for new development.

Figure 6.5. Traditional large lot development.

Figure 6.6. Conservation / open space development.

Source: Arendt, 1996.

Christina Basin Watershed Restoration Action Strategy (WRAS)

P5. Implement Agricultural Conservation BMPs

USDA-NRCS and NCD Agriculture BMPs - In 1997, the USDA NRCS and New Castle Conservation District installed the following agricultural conservation practices in the Christina Basin through the Red Clay - White Clay PL83-566 program, Environmental Quality Incentive Program (EQIP), and the Conservation Reserve Program (CRP):

Red/White Clay Creeks PL83-566 Program

Hay Planting	42.5 ac.
Nutrient Management Plans	19.0 ac.
Riparian Buffer Restoration	>1.0 ac.

EQIP

Agriculture Waste Structure
Spray Irrigation System

Conservation Reserve Program

Private Lands (Buffers)	224 ac.

District Cost-share Program

Stream Bank Stabilization
Wetland Pond Installation
Manure Storage/Pasture Management

Conservation Practices

Tree Planting	45 ac.
Intensive Grazing/Waterway	30 ac.

Delaware Nutrient Mgmt. Commission - Starting in the summer of 2000, owners with 10 or more acres must follow a nutrient management plan. Those having 8 or more animal units (AU) must follow an animal waste management plan. 8AU =8 cattle, 7 horses, 3200 chickens, or 40 sheep.

Hy-point Dairy Waste Storage System - During 1998, the USDA-NRCS and NCCD installed a waste storage structure on the northern New Castle dairy in the Brandywine Creek watershed that provides 3-months storage for spent milk products. The treated wastewater is used for irrigation on hay crops, which are harvested regularly to remove excess nitrogen and phosphorus from the soils.

UD Farm Stream Fencing Conservation Cost-Share - The New Castle Conservation District installed a conservation cost-share project along the Cool Run Tributary to the White Clay Creek at the University of Delaware farm in Newark. The project included putting up fences to keep livestock from the stream and planting trees to establish a riparian buffer to reduce nitrogen and shade the stream.

Conservation Management Plans - Experienced conservation planners work with state and federal agencies to develop conservation management plans for agricultural lands through Piedmont Whole Basin Management Program.

Surface Water Nutrient Loading – Specialists evaluate non-point source nutrients from lawn care and golf courses and develop management plans to help prevent surface water pollution.

Figure 6.7. UD Cool Run Tributary stream fencing.

Christina Basin Watershed Restoration Action Strategy (WRAS)

P6. Coordinate w/ Nonprofit Watershed Organizations

Annual Christina River Cleanup - Each April, the Christina Conservancy sponsors a cleanup of the Christina River watershed. Volunteers from Boy Scouts, Girl Scouts, corporations and citizens groups venture to the river to remove trash for a spring cleaning. Main focus areas include the Wilmington Riverfront, Churchman's Marsh, White Clay Creek State Park, and the Upper Christina River at Dayett Mills.

DNS Soil Watch Program -The Delaware Nature Society obtained a grant from the William Penn Foundation to run a well-received Soil Watch program. Eight developers at 14 sites have signed up to become Soil Stewards, which indicates a commitment to maintain sound soil erosion and sediment controls during and after construction. To become a Soil Steward, builders voluntarily pledge to: (1) install and maintain erosion and sediment controls as defined on an approved plan, (2) provide time for a Soil Watch presentation to the contractor's staff, and (3) provide access for a Soil Watch Coordinator to inspect soil erosion and sediment controls.

DNS Reforestation - The DNS sponsors a program at the Burrows Run Preserve in the Red Clay Creek watershed to increase awareness of how young people can take action to improve stream corridors and protect our drinking water supply. More than 50 students have participated in the program where they evaluate stream habitat, assess the stream buffers, and plant trees and shrubs in designated reforestation areas in the valley.

DNS Macroinvertebrate Surveys - DNS volunteers conduct annual quantitative surveys of the White Clay/Red Clay Creek watersheds.

White Clay Watershed Association - Stream Watch volunteers have been monitoring the quality of the White Clay Creek for over ten years. Volunteers monitor macroinvertebrates along the White Clay Creek at several sites, including sites 20, 21, and 22 in Delaware.

Red Clay Valley Association - The RCVA collects acorns, hickory nuts, and beech nuts to plant seedlings and reforest the banks of the Red Clay Creek near Yorklyn. The nuts are gathered by volunteers and dried before broadcasting the seeds along the reforestation sites.

Delaware Stream Watch – The Delaware Nature Society received a $3,600 minigrant for the purchase of equipment (including physical /chemical kits, waders, D-nets, German filter funnels, hand lenses, alkalinity and nitrate test kits and culture media) to supplement the Delaware Stream Watch program co-sponsored by the DNS and the Delaware Department of Natural Resources and Environmental Control. Delaware Stream Watch provides natural resource education and trains volunteers to carry out stream monitoring at 150 sites on Delaware River tributaries in the state.

Christina Basin Watershed Restoration Action Strategy (WRAS)

P7.Administer SMARTYARD Program to Homeowners

Backyard Conservation Kit - The New Castle Conservation District distributes Backyard Conservation kits to homeowners interested in creating stormwater marshes and beneficial habitat on their property.

SMARTYARDS Native Landscaping – The University of Delaware Water Resources Agency, Delaware Nature Society, and URS Inc. used a grant from USEPA, DNREC, and Pennsylvania DEP to provide free landscape design and plants to install water friendly native plant gardens for citizens within the White Clay Creek and Christina River subwatersheds of the Christina Basin. Twenty households participated in the program at a cost of $20,000. Species of trees, shrubs and groundcover used included such examples as Red Maple, Flowering Dogwood, Dwarf Azalea and Black eyed Susan.

Rain Barrels – Approximately 150 rain barrels were distributed by the University of Delaware Water Resources Agency throughout the White Clay Creek and Christina River Watershed with a grant from the USEPA, DNREC and Pennsylvania DEP. At no cost to the participant, the project provided a means to collect rain water to be used for activities such as watering plants and lawns. Some observations made by participants included the following:

"I've gained a better appreciation of how much water I've used in the past in outdoor watering, and how easy it is to reduce that amount."

"I like being involved in the conservation of water and wish I had 50 rain barrels!"

"It's a great way to save water – the water is free and I wish I had another rain barrel."

Figure 6.8. Example of a rain barrel.

Figure 6.9. SMARTYARDS Native Landscaping Project Plant Species.

Figure 6.10. Example of a SMARTYARD (Year 1).

Christina Basin Watershed Restoration Action Strategy (WRAS)

P8.Expand Public Education and Outreach Programs

Christina Basin Task Force - The Christina Basin Task Force is a public outreach arm that provides a forum for discussion among organizations that represent the four watersheds in the basin.

Christina Basin Bus Tour - The Christina Basin Task Force sponsors an annual tour of the basin in September in order to review BMP demonstration projects and conservation practices.

Christina Basin Brochure/Newsletter - The BVA publishes a brochure and newsletter summarizing the interstate Christina Basin Strategy. Over 10,000 copies of the brochure have been distributed at public meetings, conferences, by mail, and in water bill stuffers.

Basin Scapes Homeowners Guides - The BVA publishes a series of guides that advocate environmentally sound landscapes benefiting people, wildlife and the Christina Basin.

Christina Basin Conference - The RCVA and Delaware Nature Society hosted an Interstate Christina Conference in June 1999 at the Ashland Nature Center where over 160 people heard presentations about Basin TMDLs.

Christina Basin Web Site - The University of Delaware Water Resources Agency created a web site (www.wr.udel.edu) hosting the Christina Clean Water Strategy. The web site includes published watershed maps and reports with hyper-links to dozens of collaborating agencies and entities.

Christina Basin Road Signs - The UD Water Resources Agency received funding for the DNREC and DELDOT to erect 18 colorful road signs alerting over 100,000 motorists daily that they are "Entering the Christina River Basin".

Christina Basin Poster - Graduate students at the UD Water Resources Agency designed a 2-sided poster that summarizes the uses, the problems, the issues, and recommended solutions in the Christina Basin.

Storm Drain Stenciling – The Partnership for the Delaware Estuary, city of Wilmington and DNREC provided the opportunity for citizens to help mark over 5,000 Wilmington storm drains with the warning "No Dumping, Drains to the River".

Kalmar Nyckel Shipyard Challenge Program - The Delaware Estuary Program awarded a grant to the Kalmar Nyckel Shipyard to further expand the watershed education program that introduces inner-city youth to the industrial influences on water quality, wetland environments, stream ecology, and sewage treatment.

7th Grade Watershed Training - The DNREC Whole Basin Program, Delaware Department of Education, and the University of Delaware Math and Science Education and Research Center sponsor a watershed training module that every 7th grade public school student is required to take. Over 35 teachers and 500 middle school students have successfully completed the watershed curriculum in the last three years.

Figure 6.11. 7th grade watershed teachers

Christina Basin Watershed Restoration Action Strategy (WRAS)

R1.Cleanup Superfund, Hazardous Waste & LUST Sites

DNREC Superfund Program - Since 1990, the USEPA and DNREC have cleaned many Superfund sites, leaking underground storage tanks, and hazardous waste sites in the Christina Basin including:

Tidal Brandywine Creek/Christina River

DE 1084. AMTRAK Operations Center - 1.9 ac. remediated at the Pusey & Jones Shipyard

DE 1085. Madison Street Ext. - Contaminated soils removed near Martin Luther King Blvd

DE 1116. Riverfront Park - 2 acres of petroleum soils and groundwater remediated at the new riverfront park

DE 1044. CSX - 2.4 acres remediated to remove petroleum and organic solvents

DE 244 Rogers Corner Dump - Site remediated at corner of Route 13 and I-495

DE-199. NVF-Newark Company Site (Timothy's Restaurant)- The 20 acre brownfields site contained a fiber mill along the White Clay Creek downstream from Paper Mill Road. Deposits of zinc and oil were removed from stream bed sediments and soils. Leaking underground storage tanks were removed. The creek-side site is being renovated with the construction of a restaurant and condominiums as part of the Newark downtown renaissance.

DE-0163. Del Chapel Place (University Courtyard)- This 8.5 acre site with a small tributary of the White Clay Creek flowing through it was a fiber factory near downtown Newark dating to 1907. The soils and stream were contaminated with zinc, arsenic and organic chemicals and were renovated by removing the contamination and constructing private student housing for University students.

Dupont Co. Cleanup – The Dupont Co. engineered an 8-year cleanup of a hazardous waste site on the Christina River in Newport. On the 120-acre former Dupont site, 57,000 cubic yards of contaminated sediments from the Christina River were removed at a cost of $42 million.

PCBs in Piedmont Streams – There is a focused effort through the Delaware Piedmont Whole Basin Management Program in the lower Christina River to develop a pollution control strategy for PCBs that will lead to reduced human health and ecological risks.

Site Index Database - Statewide identification of potential contaminant sources with the Piedmont Whole Basin Management Program (e.g., UST, Superfund, Animal Feeding Operations, NPDES, Landfills, etc.).

Figure 6.12. Former NVF Superfund site along White Clay Creek at Newark.

Christina Basin Watershed Restoration Action Strategy (WRAS)

R2. Abate Combined Sewer Overflows (CSOs)

Wilmington CSO Abatement Strategy - Older cities like Wilmington have a combined sewer system that carries both sanitary sewage and stormwater. The city operates 37 CSOs in the urban, lower Christina Basin. Approximately 62% of the City of Wilmington is drained by a combined sewer system. The CSOs include:

- 19 CSOs to Brandywine Creek
- 15 CSOs to Christina River
- 2 CSOs to Silverbrook Run
- 1 CSO to Little Mill Creek

What has Been Done to Date? - The City has implemented CSO control programs such as:

- USEPA nine minimum controls such as daily inspection of CSOs, street cleanup programs, and nets at CSO 30 to catch floatables
- Upgrade the Wilmington Wastewater Treatment plant from 90 mgd to 134 mgd
- Improve the capacity and modify pump controls at the 11th Street pump station
- Develop West Side facility plans to reduce discharge from CSOs 27, 28, and 29
- Install a netting system and raise the regulating weir at CSO 30

Long Term CSO Control Plan (LTCP) - The City prepared a long term plan to control 85% of the CSO volume by 2010. The LTCP recommends:

Nonstructural Improvements

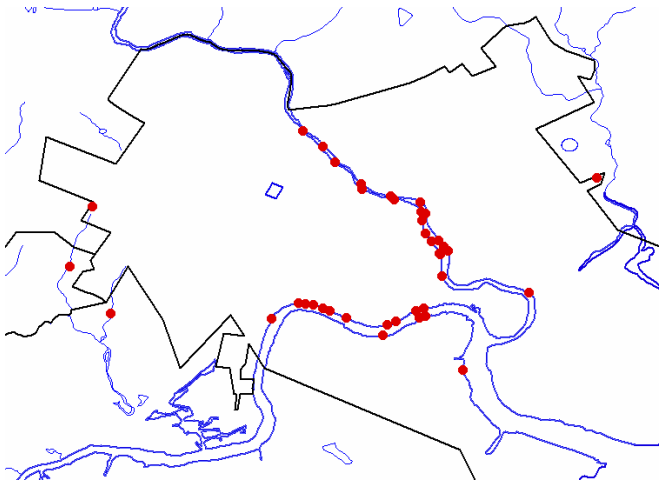
- Inspect and repair tide gates city wide
- Assess performance of floatables control
- Initiate GIS mapping of sewers.

Structural Improvements

- Construct underground retention basins at
  CSOs 28 and 29 (Silverbrook)
  CSOs 24 and 25 (Brandywine Creek)
  CSO 27 (Silverbrook)
  CSOs 4a and 4b (Brandywine Creek)
- Partial separation of combined sewers
- Expand pumping capacity
- Use inflatable dams for in-pipe storage.

Cost - The estimated construction cost for the CSO improvements are $113.7 M to be financed with city sewer/water, federal, and state funds.

Figure 6.13. Combined Sewer Overflow Locations.



Christina Basin Watershed Restoration Action Strategy (WRAS)

R3. Wilmington Riverfront Development Efforts

Brandywine Creek Vessel Removal - The Brandywine River Conservancy provided funding to the NCCD to remove two derelict vessels from the tidal Brandywine Creek near Wilmington to make the river safer and more attractive.

Russell W. Peterson Urban Wildlife Refuge - The DNREC and the Riverfront Development Corporation announced plans to transform 225 acres of tidal marshland along the Christina River in Wilmington into an urban wildlife refuge. The wetland restoration will anchor the upstream end of the Christina River revitalization efforts.

Riverfront Development Corporation - The RDC was created by the Delaware General Assembly in June 1995 to carry out a 25-year, $1 billion vision to revitalize 500 acres along the Christina and Brandywine Rivers in Wilmington. The riverfront revitalization plan includes such completed amenities as:

- Riverfront Arts Center
- Factory Discount Shopping
- Restaurants
- Riverfront Park
- River Walk
- Wildlife Wetland Refuge
- Kalmar Nyckel Shipyard
- Wilmington Blue Rocks Baseball Stadium
- Wilmington Rowing Club Boathouse

The objective is to attract commerce and business to the riverfront and at the same time the revitalization stimulates riverfront restoration, CSO, and Superfund site cleanups.

Superfund Cleanups - During revitalization, the DNREC and USEPA completed a comprehensive environmental cleanup of the Amtrak, Amer, and boatyard superfund sites.

River Walk Biofiltration - The designers of the new 1.5 mile River Walk built in a series of biofiltration basins along the Christina riverfront to treat runoff before entering the river.

River Debris Cleanup - The aesthetic qualities of the River Walk and shops are important to visitors so a river debris clean up program is in effect to remove trash and floatables from the tidal Christina River.

Economic and Environmental Revitalization - While these projects improve the recreational and commercial appeal of the waterfront, they have also triggered Superfund cleanup and combined sewer overflows initiatives, which can improve water quality of the Brandywine and Christina River.

Figure 6.14. Wilmington Riverfront revitalization.

Christina Basin Watershed Restoration Action Strategy (WRAS)

R4. Continue Sewer Repair/Septic Elimination Projects

New Castle County Sewer Rehabilitation - Since 1990, the New Castle County Department of Special Services has rehabilitated 18 miles of sanitary sewer in the following watersheds:

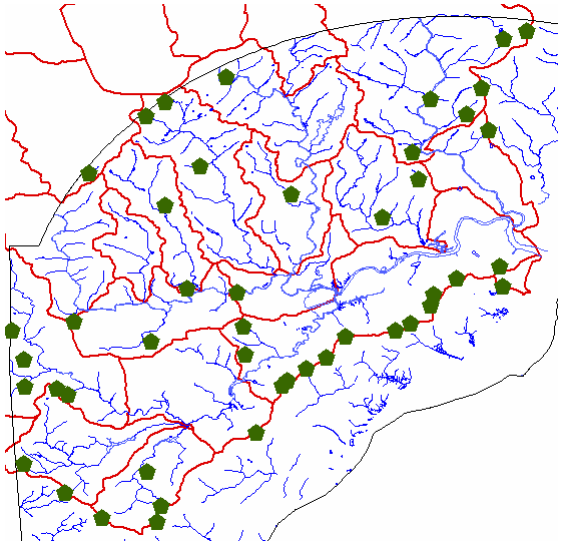
Brandywine Creek	10 miles
Red Clay Creek	8 miles
White Clay Creek	0 miles
Christina River	0 miles

New Castle County Septic Relief - The New Castle County Department of Special Services has eliminated over 200 failing septic systems in the following Cristina Basin watersheds:

Brandywine Creek
Red Clay Creek
White Clay Creek
Christina River

Domestic Septic Mapping- Identification of non-point pollutant septic sources and locations of all domestic septic systems through the Piedmont Whole Basin Management Program.

Figure 6.15. New Castle County sewer rehabilitation map



Christina Basin Watershed Restoration Action Strategy (WRAS)

R5. Restore Stream and Riparian Corridors

Newark Bioengineering Project - In 1996, the City of Newark installed an experimental stream restoration project along 500 feet of the Upper Christina River in Rittenhouse Park. The USDA Natural Resources Conservation Service and the New Castle Conservation District designed the vegetated geogrid, brush mattress, and double fiber roll bioengineering techniques used.

Wilmington Rattlesnake Run Project - The NCCD and the Wilmington Nature Office cooperated on a project to restore the stream corridor in a picturesque section of Brandywine Park. The stream restoration project incorporated a series of pools and riffle sections in a ravine near the Brandywine Creek at Wilmington water supply intake.

Mill Creek Stream Bioengineering Project - The DNREC is restoring 1000 linear feet of degraded stream at Delaware Park racetrack using geomorphological concepts. The project includes reshaping the creeks dimension and profile and planting 57,600 square feet of riparian vegetation and 7,200 square feet of non-tidal wetland habitat.

Ball Run at All Saints Cemetery – Coastal Design and Construction, Inc. restored approximately 2,100 feet of the Ball Run Stream with funding provided by DNREC, All Saints Cemetery, New Castle County and New Castle Conservation District. Instream structures such as rock cross veins, rock j-veins, grade control structures, boulder stabilization, rock check dams, and stilling basins were put into place to try to recreate a natural stream channel.

Mill Creek Greenway -The New Castle Conservation District extended the Mill Creek Greenway from Limestone Road to the Delcastle Recreation Area. A path was installed for bicycling and hiking.

Three Little Bakers – The Delaware Department of Natural Resources and Environmental Control plans to restore Pike Creek, one of the more degraded streams in the Christina Basin with a watershed imperviousness of 29%.

Riparian Corridor Inventory - Walking and boating along 300 miles of streams in the Piedmont Basin is done to collect environmental information and identify priority areas for protection and restoration through the Piedmont Whole Basin Management Program.

Figure 6.16. Mill Creek before restoration.

Figure 6.17. Mill Creek after restoration.

R6. Reforest Watersheds and Headwaters

Pike Creek Christian School - Cost share funds were used to repair a severe erosion problem on the slopes of the Middle Run. The area was protected with a sediment basin and stabilization planted by Brandywine Nurseries.

Terraces at Iron Hill Open Space - The NCCD planted trees and shrubs in the community open space in the Christina River watershed.

Girl Scouts Restore Birch Run Meadow - The Delaware Estuary Program awarded a grant to the Girl Scouts to restore Birch Run meadow in the Red Clay Creek watershed near Hockessin, Delaware. The Scouts will, with the assistance of the US Fish and Wildlife Service, restore the meadow to its natural vegetation and install trail markers identifying native plant and animal life.

Pike Creek Stream Buffer Initiative - The NCCD and volunteers lined drainage swales with grasses, shrubs, and trees in the Yorktowne and Thistleberry Farms subdivisions to control stormwater runoff and improve water quality.

Winterthur - At one of the most popular gardens in the U.S., Winterthur has planted a native landscaped meadow, which serves to protect the Wilson Run, a trout-laden tributary to the Brandywine Creek.

Burrows Run Preserve - Delaware Nature Society volunteers planted 1,395 trees on 352 acres in Burrows Run to increase the riparian buffer.

Upland Forest Protection - Comparison of aerial photography and land-use cover data with historical data was used to identify old growth forests.

Middle Run Preserve Reforestation Effort - The Delaware Nature Society and New Castle County reforested almost 65 acres of land in the Middle Run Preserve with 16,235 trees planted, 250 shrubs and 20,000 tree seeds.

Friends of White Clay Creek State Park Wildlife Habitat Restoration - In October 2000, Friends and DNREC reforested a nine-acre field in the Possum Hill Section of White Clay Creek State Park. About 175 volunteers planted 800 trees to extend the natural forest. The volunteers planted 15 different native trees to be compatible with the surrounding forest with appropriate understory plants.

Wilmington/Newark Urban Forest Management - The US Forest Service awarded a grant to the Delaware Center for Horticulture to carry out an urban reforestation plan in the two largest cities in the Christina Basin.

Figure 6.18. Winterthur Native Meadow.

Christina Basin Watershed Restoration Action Strategy (WRAS)

R7. Retrofit Stormwater Quality Basins

Dayett Mills Christina River Dam Stabilization - The New Castle Conservation District reinforced the millrace dam along the Upper Christina River with a layer of shotcrete. The historic Dayett Mills Dam diverts water to the millrace and serves to capture sediment loads from the upstream watershed.

DNREC Stormwater Contractor Certification - DNREC sponsors an annual Sediment and Stormwater Management Contractor Certification Program in April. The Delaware Sediment and Stormwater Regulations require that all construction projects should have a certified sediment and stormwater contract onsite.

DNREC Sediment and Stormwater Certified Construction Reviewer - DNREC offers annual training to individuals who wish to qualify as certified Construction Reviewers as specified in the Delaware Sediment and Stormwater Regulations Section 12.

White Chapel Storm Water Basin - NCCD retrofitted the existing storm water basin at White Chapel along Cool Run, a tributary to the White Clay Creek. The basin was expanded to provide more detention time, allowing sediments to filter out before discharging. The riparian buffer downstream was restored to provide shade and cooler stream temperatures.

Brader Elementary School Pond- USDA - NRCS converted the school grounds into a wetland pond and bird sanctuary in the Christina River watershed.

Independence School Wetland - The New Castle Conservation District completed a wetland on school grounds and students planted wetland plants. The wetland collects stormwater runoff from the buildings, parking lots, and fields before it can reach Pike Creek.

Carousel Pond Rehabilitation - The New Castle Conservation District rehabilitated the pond and dam at the New Castle County Carousel Park in the Pike Creek watershed.

Hockessin Glen Stormwater Basin Retrofit- NCCD helped Hockessin Glen residents perform maintenance to stabilize the outlet pipe and plant trees and shrubs around the pond.

Coverdale Farm Restoration - This project by DNS restores ponds with native vegetation and adds a boardwalk to conduct scientific experiments without disturbing the banks.

Figure 6.19. University of Delaware stormwater wetland retrofit

Christina Basin Watershed Restoration Action Strategy (WRAS)

R8.Eliminate Remaining NPDES WastewaterDischarges

Delaware NPDES Wastewater Discharges - These point source discharges in the Delaware portion of the Christina Basin have declined by 70% from 34 discharges in 1977 to 10 in 1999 due to regional wastewater plans implemented by the Delaware DNREC, City of Wilmington, and New Castle County governments. Most of the discharges were removed by consolidating flows into the Northern New Castle County regional sewer system. Some of the discharges were removed due to business and industry closures. Of the remaining 10 NPDES discharges, 2 are wastewater outfalls and 8 are stormwater or cooling water outfalls. The remaining Delaware discharges in the Christina Basin include:

Brandywine Creek

Amtrak	Stormwater
Winterthur Museum	Wastewater

Red Clay Creek

Haveg/Amtek	Cooling Water
Hercules	Cooling Water
Greenville Country Club	Wastewater

White Clay Creek

FMC Corp	Stormwater

Christina River

General Motors	Stormwater
DuPont Chestnut Run	Stormwater
Ciba Geigy Corp.	Cooling Water
Boeing	Stormwater

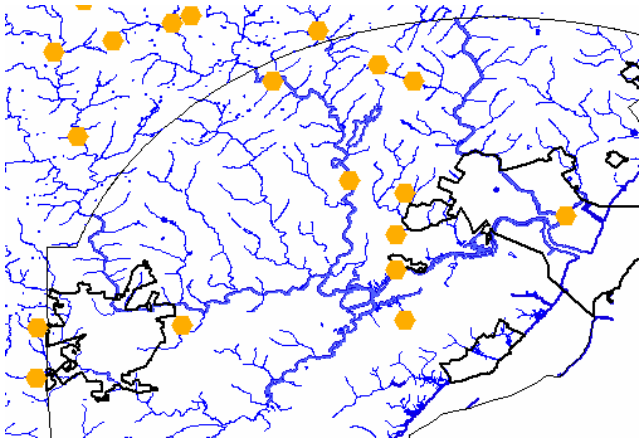
Christina Basin Point Source TMDL Model - In January 2001, the US Environmental Protection Agency announced the promulgation of Total Maximum Daily Loads (TMDLs) for the point source discharge for low flow conditions in the Christina Basin. According to the TMDL, all ten of the Delaware discharges in the basin are meeting stream water quality standards, therefore no reductions in wastewater loads are required.

The TMDLs will require nitrogen reductions to two wastewater discharges directly across the state line in Cecil County, Maryland along the Christina River at:

Highlands WWTP	
Meadowview Utilities	69% reduction

Reductions to these Maryland discharges will improve water quality along the Christina River in Delaware.

Figure 6.20. NPDES Wastewater Discharges.



References

Arendt, R.G. 1996. Conservation Design for Subdivisions: A Practical Guide to Creating Open Space Networks. Island Press.

Chesapeake Bay Program. Chesapeake Bay Chlorophyll-a Criteria. www.chesapeakebay.net. Accessed April 15, 2003.

Delaware Department of Natural Resources and Environmental Control. 1996. Preliminary Assessment of Water Quality Data for the Christina Basin.

Delaware Department of Natural Resources and Environmental Control. 1997. Piedmont Basin Preliminary Assessment Report.

Delaware Department of Natural Resources and Environmental Control. March 1998. Tentative Determination for State of Delaware (1998) Clean Water Act Section 303 (d) List of Waters Needing TMDLs.

Delaware Department of Natural Resources and Environmental Control. 2002. Surface Water Quality Standards.

Delaware Division of Public Health. Revised March 31, 1991 and 2002 and as amended. State of Delaware Regulations Governing Public Drinking Water Systems.

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

Greig, D., J. Bowers, and G. Kauffman. August 1999. Phase III Report Christina River Basin Water Quality Management Strategy. Chester County Conservation District, Chester County Water Resources Authority, and University of Delaware Water Resources Agency.

King County, Washington. 2000. Forest Cover, Impervious Surface Area and the Mitigation of Urbanization Impacts in King County, WA.

Senior, L. A. and E. H. Koerkle. October 2001. Draft Report Simulation of Streamflow and Water Quality in the Brandywine Creek Subbasin of Christina River Basin, Pennsylvania and Delaware, 1994-1998. United States Geological Survey.

Senior, L. A. and E. H. Koerkle. February 2002. Draft Report Simulation of Streamflow and Water Quality in the Christina River Subbasin and Overview of Simulations in Other Subbasins of the Christina River Basin, Pennsylvania, Maryland, and Delaware, 1994-1998. USGS.

Senior, L. A. and E. H. Koerkle. June 2002. Draft Report Simulation of Streamflow and Water Quality in the White Clay Creek Subbasin of Christina River Basin, Pennsylvania and Delaware, 1994-1998. United States Geological Survey.

Senior, L. A. and E. H. Koerkle. November 2002. Draft Report Simulation of Streamflow and Water Quality in the Red Clay Creek Subbasin of Christina River Basin, Pennsylvania and Delaware, 1994-1998. United States Geological Survey.

Smith,V. K. and W. H. Desvousges. 1986. Measuring Water Quality Benefits. Boston: Kluwer Nijhoff Publishing.

United States Environmental Protection Agency Region III. January 19, 2001; revised October 2002. Total Maximum Daily Loads of Nutrients and Dissolved Oxygen Under Low-Flow Conditions in the Christina River Basin, Pennsylvania, Delaware, and Maryland.

United States Army Corps of Engineers. July 2002. Christina River Watershed Pennsylvania, Delaware, and Maryland Expedited Reconnaissance Report 905(b) Analysis.

Wollaston, M. and G. Kauffman. May 2002. Source Water Assessment of the United Water Delaware Public Water Supply Intake Located on the Christina River at Smalley's Pond. Prepared by the University of Delaware, Institute for Public Administration, Water Resources Agency for the Delaware Department of Natural Resources and Environmental Control.

Wollaston, M. and G. Kauffman. May 2002. Source Water Assessment of the City of Wilmington Edgar M. Hoopes Reservoir. Prepared by the University of Delaware, Institute for Public Administration, Water Resources Agency for the Delaware Department of Natural Resources and Environmental Control.

Wollaston, M. and G. Kauffman. May 2002. Source Water Assessment of the United Water Delaware at Stanton Public Water Supply Intake Located on the White Clay and Red Clay Creeks. Prepared by the University of Delaware, Institute for Public Administration, Water Resources Agency for the Delaware Department of Natural Resources and Environmental Control.

Wollaston, M. and G. Kauffman. May 2002. Source Water Assessment of the City of Newark, Delaware Public Water Supply Intake Located on the White Clay Creek. Prepared by the University of Delaware, Institute for Public Administration, Water Resources Agency for the Delaware Department of Natural Resources and Environmental Control.

Wollaston, M. and G. Kauffman. May 2002. Source Water Assessment of the City of Wilmington, Delaware Public Water Supply Intake Located on the Brandywine Creek. Prepared by the University of Delaware, Institute for Public Administration, Water Resources Agency for the Delaware Department of Natural Resources and Environmental Control.

United States Geological Survey with the Chester County Water Resources Authority. 1995. Organochlorine Compound Concentrations and Trends in Benthic-Invertebrate Communities in Selected Stream Reaches in Chester County, Pennsylvania.

United States Geological Survey with the Chester County Water Resources Authority. 1996. Fecal Coliform Bacteria Historic Trends for Brandywine Creek Basin, 1981 through 1996.

Appendix A: Stream Water Quality Sampling Data. Delaware Source Water Protection Reports, May 2002

	Minimum detection level	Treated Drinking Water Standard /Risk Based Screening Level	Maximum Recorded Level (1990-2001) Brandywine Creek at Wilmington	Maximum Recorded Level (1990-2001) White Clay Creek at Newark	Maximum Recorded Level (1990-2001) White Clay Creek at UWD Stanton	Maximum Recorded Level (1990-2001) Christina River at Smalley's Pond
Parameter	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Nutrients						
Nitrate Nitrogen	0.10	10	2.89(5/11/99)	3.9(8/6/01)	3.15 (5/11/99)	.36 (8/6/01)
Nitrite Nitrogen	0.10	1	0.03(3/16/99)	0.031(5/11/99)	0.031 (5/11/99)	
Total Nitrogen	0.20	10	5.56(7/21/98)	4.72(11/15/94)	4.98 (3/11/96)	4.82(5/15/95)
Pathogens						
Cryptosporidium		0	5.0(11/19/98)			
Enterococcus (#/100 ml)		0	2000(10/16/95)	2000(7/21/93)	2000(7/21/93)	2000(9/15/99)
Fecal Coliform/E. Coli		0	195.2 (2/14/00)			
Giardia lambia		0	37.5 (12/17/98)			
Total Coliform		0	200.5 (4/11/00)			
Petroleum						
Benzene	0.0005	0.005	0.0005 U (3/15/00)			
Ethylbenzene	0.0005	0.7	0.0001 U (3/15/00)			
MTBE	0.0005	0.010				
Toluene	0.0005	1				
Xylene	0.0005	10.0				
o-xylene						
m-xylene						
p-xylene						
Pesticides						
2,3,7,8-TCDD (Dioxin)		3x10^-8				
2,4,5-TP (Silvex)	0.0005	0.05	0.0001 U (3/15/00)			
2,4-D	0.0005	0.07	0.0001 U (3/15/00)			
Alachlor	0.00001	0.002	0.0001 U (3/15/00)	0.002U	0.002U	
Aldicarb		0.003	0.0005 U (3/15/00)			
Aldicarb Sulfone		0.002	0.0004 U (3/15/00)			
Aldicarb Sulfoxide		0.004	0.0005 U (3/15/00)			
Atrazine	0.0007	0.003	0.0001 U (3/15/00)			
Benzo(a)pyrene	0.001	0.0002	<0.00002 U (3/25/99)			

Carbofuran		0.04	0.0009 U (3/15/00)	0.0030U	0.0030U	
Chlorodane		0.002				
Dalapon	0.0005	0.2	0.001 U (3/15/00)			
Di(2-		0.4				
Di(2-		0.006				
Dinoseb	0.0005	0.007	0.0001U (3/15/00)			
Diquat		0.02	0.0004 U (3/15/00)			
Endothall		0.1	0.009 U (3/15/00)			
Endrin	0.0001	0.002	0.00001 U (3/15/00)	0.0001U	0.0001U	
Ethylenedibromide		0.00005				
Glyphosphate		0.7	0.006 U (3/15/00)			
Heptachlor	0.00005	0.0004	0.00004 U (3/15/00)	0.00005U	0.00005U	
Heptachlor epoxide	0.0005	0.0002	0.00002 U (3/15/00)	0.00005U	0.00005U	
	Minimum detection level	Treated Drinking Water Standard (PMCL/SMCL;HAL/RBCL)/ Risk Based Screening Level	Maximum Recorded Level (1990-2001) Brandywine Creek at Wilmington	Maximum Recorded Level (1990-2001) White Clay Creek at Newark		Maximum Recorded Level (1990-2001) Christina River at Smalley's Pond
Parameter	(mg/L)	(mg/L)	(mg/L)	(mg/L)		(mg/L)
Pesticides (con't)						
Hexachlorobenzene	0.001	0.001	0.0001 U (3/15/00)			
Hexachlorocyclopenta	0.001	0.05	0.1 (3/15/00)			
Lindane		0.0002	0.000004 U (9/14/99)			
Methoxychlor	0.0005	0.04	0.0001 U (3/15/00)	0.00005U	0.00005U	
Oxamyl (Vydate)		0.2	0.001 U (3/15/00)			
Pentachlorophenol	0.0005	0.001	0.00004 U 3/16/99			
Picloram	0.0005	0.5	0.0001 U (3/15/00)			
Simazine	0.0005	0.004	0.00007 U (3/15/00)			
Toxaphene	0.001	0.003	0.001 U (3/15/00)	0.005U	0.005U	
Polychlorinated		0.0005	0.007501 (1996)	0.0000576	0.0000576	0.00001097(1996/97)
Other Organics						
2-chlorotoluene	0.0005	1.2	0.0002 U (3/115/00)			
4-chlorotoluene	0.0005	1.2	0.0002 U (3/115/00)			
Bromoform	0.0005	0.08	0.0002U (8/6/01)		.0003U (8/6/01)	
Bromobenzene	0.0005		0.0002 U (3/15/00)			
Bromochloromethane	0.0005		0.0002 U (3/15/00)			

Bromodichloromethan	0.0005	.00170	0.0405 (9/15/99)	0.02686(9/15/99)	0.04226(9/15/99)	0.05268(7/21/99)
Bromomethane	0.0005	.085	0.0005 U (3/15/00)			
n- Butylbenzene	0.0005	2.4				
Sec-butylbenzene	0.0005	2.4				
Tert-butylbenzene	0.0005	2.4				
Carbon tetrachloride	0.0005	0.005	0.0001 U (3/15/00)			
Chloroethane	0.0005	.036	0.0005 U (3/15/00)			
Chloroform	0.0005	0.080	0.28332 (6/7/00)	.40372(6/7/00)	0.40372(6/7/00)	0.5812(3/15/00))
Chloromethane	0.0005	0.021	0.0005 U (3/15/00)			
Dibromochloromethan	0.0005	0.080	0.00675 (9/15/99)	.00362(3/15/00)	0.00624(9/15/99)	0.01585(6/14/99)
Dibromochloropropan		0.0002				
Dibromomethane	0.0005		0.0001 U (3/15/00)			
Dichlorodifluorometha	0.0005	3.5	0.5 U (3/15/00)			
Foaming Agents		0.5				
Hexachlorobutadiene	0.0005	2.4	0.0002 U (3/15/00)			
Bis (2-chloroethyl)	0.0005	0.009				
Isopropylbenzene	0.0005	6.6				
4-Isopropyltoluene	0.0005		0.0001 U (3/15/00)			
Monchlorobenzene		0.1				
Naphthalene	0.0005	0.065	0.0002 U (3/15/00)			
o-Dichlorobenzene	0.0005	0.6				
p-Dichlorobenzene	0.0005	0.075				
Propylbenzene		0.007				
Styrene	0.0005	0.1	0.0002 U (3/15/00)			
Dichloromethane		0.005				
Tetrachloroethylene	0.0005	0.005				
Total Trihalomethanes	0.0005	0.1	0.027 (3/15/00)			
Trichloroethylene	0.0005	0.005				
Trichlorofluoromethan	0.0005	13.0	0.0005 U (3/15/00)			
Trichloropropane	0.0005					
Vinyl Chloride	0.0005	0.002	0.0002U (3/15/00)			
	Minimum detection level	Treated Drinking Water Standard (PMCL/SMCL;HAL/RBCL)/ Risk Based Screening Level	Maximum Recorded Level (1990-2001) Brandywine Creek at Wilmington	Maximum Recorded Level (1990-2001) White Clay Creek at Newark	Maximum Recorded Level (1990-2001) White Clay Creek at UWD Stanton	Maximum Recorded Level (1990-2001) Christina River at Smalley's Pond
Parameter	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)

Other Organics						
Cis-1,2-		0.07				
Trans-1,2-	0.0005	0.1				
1.1 Dichloroethylene		0.007				
1,1-Dichloroethane	0.0005	8.0	0.0001 U (3/15/00)			
1,1 –Dichlororopene	0.0005					
1,2-Dibromo-3-chlorop	0.001	.00047	0.0002 U (3/15/00)			
1,2-Dibromoethane	0.0005	.0000075	0.0001 U (3/15/00)			
1,2-Dichloroethane	0.0005	0.005	0.0001 U (3/15/00)			
1,2-Dichloropropane	0.0005	0.005	0.0001 U (3/15/00)			
1,3-dichlorobenzene						
1,3- dichloropropane	0.0005					
Cis-1,3-Dichloroprope	0.0005	0.0044	0.0001 U (3/15/00)			
Trans-1,3-Dichloropro	0.0005	0.044				
2,2-Dichlorpropane	0.0005		0.0005 U (3/15/00)			
1,1,1,2-	0.0005	0.005	0.0001 U (3/15/00)			
1,1,2 –Trichloroethane	0.0005	0.005				
1,1,1 - Trichloroethane		0.2				
1,1,2,2-	0.0005	0.005				
1,2,3-	0.0005					
1,2,3 –	0.0005	0.000053				
1,2,4-trichlorobenzene	0.0005	0.07	0.0002 U (3/15/00)			
1,2,4-	0.0005	0.120				
1,3,5-	0.0005	0.120				
Metals						
Aluminum	0.00020	0.05 -0.2	2.946 (3/14/94)	1.520(10/19/93)	8.056(5/16/96)	2.048(1/18/95)
Antimony	0.007	0.006	0.0002 U (3/15/00)			
Arsenic	0.004	0.01	0.003 U (3/14/94)	0.00257(9/15/97)	0.00341(7/21/93)	0.00184(11/18/97)
Barium	0.01	2.0	0.026 (3/15/00)			
Beryllium	0.002	0.004	0.0002 U (3/15/00)			
Cadmium	0.005	0.005	0.002U (3/16/99)		0.005(9/15/99	
Chromium	0.01	0.1	0.002U (3/16/99)			
Copper	0.02	1.3	0.0385 (6/12/00)	0.0447(4/15/96)	0.0643(5/18/99)	0.0336(11/18/97)
Iron		0.30	6.437 (9/17/96)	2.42(10/19/93)	2.42(10/19/93)	6.379(4/16/96)
Lead	0.003	0.015	0.0446 (6/12/98)	0.00988(9/15/98)	0.146(3/16/99)	0.0141(6/12/98)
Manganese		0.05	0.2175 (5/13/96)	0.1421(10/19/93)	0.4261(7/18/94)	0.2145(6/14/94)
Mercury	0.0002	0.002	0.0009 (5/13/96)	<0.0002 U(5/2/00)	0.0004(1/24/94)	0.0004(3/15/94)

Nickel	0.040	0.1	0.0029U (3/15/00)	<0.040 U(8/15/94)	<0.040 U(8/15/94)	0.040 U(6/19/95)
Selenium	0.005	0.05	0.002 U (3/15/00)	<0.005 U(8/15/94)	<0.005 U(8/15/94)	0.005 U(6/19/95)
Silver	0.01	0.1	0.015 (3/16/99)			0.010 U(6/19/95)
Sodium			14 (9/14/99)			
Thallium	0.000005	0.002	0.0002 U (3/15/00)			
Zinc	0.000020	5.0	0.61 (3/15/00)	0.0639(5/16/94)	2.0103(5/18/99)	0.155(3/15/94)
Other Inorganics						
Asbestos		7.0 MF/L				
Chloride	0.005	250	184 (11/18/96)	54.0(1/17/95)	136(3/16/99)	170(3/16/99)
Color						
Corrosivity		See Regs				
Cyanide		0.2				.22 (8/6/01)
	Minimum detection level	Treated Drinking Water Standard (PMCL/SMCL;HAL/RBCL)/ Risk Based Screening Level	Maximum Recorded Level (1990-2001) Brandywine Creek at Wilmington	Maximum Recorded Level (1990-2001) White Clay Creek at Newark	Maximum Recorded Level (1990-2001) White Clay Creek at UWD Stanton	Maximum Recorded Level (1990-2001) Christina River at Smalley's Pond
Parameter	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Other Inorganics						
Fluoride	0.0001	1.8	0.69 (8/6/01)			7.14 (8/6/01)
pH		6.5 – 8.5	5.5 (1/29/96) – 8.7 (11/15/93)	5.9(11/13/95)- 8.9(7/21/93)	5.5(5/27/97) - 8.9(7/21/93)	5.3(1/30/96) - 9.7(8/6/01)
Sulfate	0.001	250	230 (3/16/99)	25.7 (8/6/01)	29.6 (8/6/01)	169(8/6/01)
Total Dissolved Solids	0.01	500	190	225 (8/6/01)	106/153(8/6/01)	
Turbidity (FTU)		See Regs	101 (8/15/94)	21	50(1/24/94)	
Cesium 134		See Regs				
Gross Particle Activity		15 pci/l				
Iodine 131		See Regs				
Radon		Regs Pend.				
Radium 226 and 228		5 pci/l				
Strontium		8 pci/l				
Tritium		20,000 pci/l				

Appendix B: Piedmont Basin Water Quality Data, 303 (d) Report			Designated Uses Support								Assessment Type (miles)			
											Monitored		Evaluated	
Segment	Subwatershed	Size (mi.)	Primary Contact	Secondary Contact	Aquatic Life	ERES	Public Water Supply	Agricultural Supply	Industrial Supply	Harvestable Shellfish/ Cold Water Fishery	Physical/ Chemical	Biology/ Habitat	Physical/ Chemical	Biology/ Habitat
Brandywine Creek Watershed														
Lower Brandywine Creek	B17	3.8	--	F	P. (habitat)		--	--	F	--	3.8	3.8	0	0
Upper Brandywine Creek from State Line to Wilmington	B16	9.3	N. (Bact.)	F	P (habitat)	F	F	F	F	--	9.3	8	0	1.3
All tributaries on Brandywine Creek PA-DE Line to the confluence with the Christina River	B16, B17	19.3	--	F	N (biology)	--	F	F	F	F	0	8.9	19.3	10.5
Red Clay Creek Watershed														
Red Clay Creek from Pennsylvania State Line	R4, R5	12.8	N. (Bact.)	F	N. (zinc)	--	F	F	F	P (Temp)	12.8	12.8	0	0
Burroughs Run from DE-PA State Line	R3	4.5	N. (Bact.)	F	P. (biology)	--	F	F	F	--	2.6	4.2	1.9	0.2
All other tributaries located in the watershed but not on the mainstem	R3, R4, R5	10.3	--	F	P (biology) & (habitat)	--	F	F	F	--	0	3.9	10.3	6.4
Hoopes Reservior (ac.)	R4	200.0	N. (Bact.)	F	F	--	F	F	F	--	0	0	200 ac.	0
White Clay Creek Watershed														
White Clay Creek from DE-PA State Line	W8, W9, W10	18.2	N. (Bact.)	F	N (zinc)	N	F	F	F	P (Temp)	15.6	16.2	2.6	2
Mill Creek	W5	16.6	N. (Bact.)	F	N. (habitat)	--	F	F	F	F	8.3	3.3	8.3	13.3
Pike Creek	W6	8.2	N. (Bact.)	F	P (biology) & (habitat)	--	F	F	F	F	5.4	6.1	2.8	2.2
Middle Run	W7	5.8	N. (Bact.)	F	P (biology) & (habitat)	--	F	F	F	--	4.5	4	1.3	1.8
Christina River Watershed														
All tributaries from the headwaters to the confluence with the Christina River	W5 - W10	14.2	--	F	P (biology)	--	F	F	F	--	0	6.1	14.2	8.1
Lower Christina River	C6	1.5	--	F	F	--	--	--	F	--	1.5	0	0	0
Mid Christina River between the confluences of White Clay Creek and Brandywine River	C5, C6	8.5	--	F	F	--	--	--	F	--	7.5	0	1	0
Tributaries on the Christina River between White Clay Creek and Brandywine Creek	C5, C6	3.0	--	F	F	--	F	F	F	--	0	0	3	0
Christina River below Newark	C5	6.9	--	F	N. (biology)	--	F	F	F	--	6.3	6.4	0.6	0.5
Tributaries from Smalleys Pond overflow to White Clay Creek	C5, C6	3.1	--	F	N. (biology)	--	F	F	F	--	0	1	3.1	2.1
Tidal Christina Creek	C6	8.4	N. (Bact.)	F	N. (biology)	--	F	F	F	--	8.4	6	0	2.4
Belltown Run	C3	5.6	N. (Bact.)	F	P. (biology) & (habitat	--	F	F	F	--	0	5.1	5.6	0.5
Muddy Run	C2	13.1	N. (Bact.)	F	P. (biology)	--	F	F	F	--	8	5.9	5.1	7.2

West Branch including Presimmon Run and Stine Haskell Branch	C1	5.3	N. (Bact.)	F	F	--	F	F	F	F	0	0	5.3	0
Upper Christina Creek	C1	10.8	N. (Bact.)	F	N (habitat)	--	F	F	F	--	8.3	4	2.5	6.9
Little Mill Creek	C4	12.8	N. (Bact.)	F	N (biology) & (habitat)	--	F	F	F	--	5.1	9.7	7.8	3.2
Chestnut Run	C4	2.8	N. (Bact.)	F	N (biology) & (habitat)	--	F	F	F	--	0	1.5	2.8	1.4
Smalleys Pond (ac.)	C5, C6	30.0	N. (Bact.)	F	F	--	F	F	F	--	30.0 ac.	0	0	0
Becks Pond (ac.)	C2	25.6	N. (Bact.)	F	F	--	F	F	F	--	0	0	25.6 ac.	0
Sunset Pond (ac.)	C3	40.0	N. (Bact.)	F	N (DO)	--	F	F	F	--	0	0	40 ac.	0

Segment	Subwatershed	Size	Assessed Parameters (Conventional Pollutants)															
			DO (mg/l) (Standard = 5.5 mg/l)				pH (Standard 6.5-8.5)				Temperature ('C) (Standard = 86F or 30C)				Enteroc. Bact. (Standard = 100#/100 mL)			
			Max.	Min.	Avg.	S.D.	Max.	Min.	Avg.	S.D.	Max.	Min.	Avg.	S.D.	Max.	Min.	G.M.	S.D.
Brandywine Creek Watershed																		
Lower Brandywine Creek	B17	3.8	13.5	6.7	9.9	1.9	8.1	5.7	7.087	0.592	24	0	10.8	8.2	2000	9	147	759
Upper Brandywine Creek from State Line to Wilmington	B16	9.3	12.8	6.2	9.2	1.8	8.5	5.5	7.093	0.657	23	0	11.6	7.9	2000	3	106	656
All tributaries on Brandywine Creek from the headwaters at PA-DE Line to the Christina River	B16, B17	19.3	15.8	9.7	13	2	7.5	7	7.3	0.2	17.5	3	9.5	5	--	--	--	--
Red Clay Creek Watershed																		
Red Clay Creek from Pennsylvania State Line	R4, R5	12.8	12.3	4.9	9.1	1.8	8.3	5.8	7	0.6	24	0	10.5	8	2000	4	148	716
Burroughs Run from Pennsylvania State Line Run	R3	4.5	14.2	8.1	11.3	2	7.6	6.1	6.8	0.5	21	0	9.4	7.4	2000	1	109	729
All other tributaries located in the watershed but not on the mainstem	R3, R4, R5	10.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hoopes Reservior	R4	200.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
White Clay Creek Watershed																		
White Clay Creek from Pennsylvania State Line	W8, W9, W10	18.2	14.3	5.9	10	2.2	7.7	5.5	6.8	0.5	24	0	10.1	8	2000	6	199	765
Mill Creek	W5	16.6	14.2	6.6	10.9	2.3	7.4	5.5	6.7	0.5	22.1	0	8.9	8	2000	24	252	809
Pike Creek	W6	8.2	16.1	8	11.6	2.4	7.7	6.2	7	0.4	21.8	0	9.6	7.5	2000	4	109	674
Middle Run	W7	5.8	14.5	8.1	11.2	2	7.6	6.1	6.7	0.4	21.9	-0.1	9.3	7.6	2000	3	102	792
Christina River Watershed																		
All tributaries from the headwaters to the confluence with the Christina River	W5 - W10	14.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lower Christina River	C6	1.5	13.1	3.1	8	2.5	8.3	5.1	7.1	0.7	28	1	12.5	9	2000	3	163	667
Mid Christina River between the White Clay Creek and Brandywine River	C5, C6	8.5	12.8	4	8.5	2.2	8.9	5.7	7.1	0.8	28	1	11.5	9	2000	3	255	738
Tributaries on the Christina River between the White Clay Cr. and Brandywine Cr.	C5, C6	3.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Christina River below Newark	C5	6.9	13	3.9	8.2	2.3	8.3	5.3	7	0.7	28	1	11.2	8.7	2000	7	225	776
Tributaries from Smalleys Pond overflow to White Clay Creek	C5, C6	3.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tidal Christina Creek	C6	8.4	11.4	5.9	8.7	2	8.1	5.2	6.9	0.8	28	1	11.7	8.6	2000	7	242	788
Belltown Run	C3	5.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Muddy Run	C2	13.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

West Branch including Presimmon Run and Stine Haskell Branch	C1	5.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Upper Christina Creek	C1	10.8	14.4	8.2	11.1	2	7.3	6.1	6.7	0.4	21.9	-0.1	10.2	7.5	2000	8	121	792
Little Mill Creek	C4	12.8	12.8	4.8	9	2.6	8.6	5.7	7.1	0.7	26	1	11.1	8.3	2000	26	376	791
Chestnut Run	C4	2.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Smalleys Pond	C5, C6	30.0	13	3.9	8.2	2.3	8.3	5.3	7	0.7	28	1	11.2	8.7	2000	7	225	776
Becks Pond	C2	25.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sunset Pond	C3	40.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Segment	Subwatershed	Size (mi.)		Assessed Parameters (Nutrients, Toxins, and Others)											
				Total Nitrogen (mg/l)				Total Phosphorous (mg/l)				Chlorophyll-a (ug/l)			
				Max.	Min.	Avg.	S.D.	Max.	Min.	Avg.	S.D.	Max.	Min.	Avg.	S.D.
Brandywine Creek Watershed															
Lower Brandywine Creek	B17	3.8		5.6	2.6	3.5	0.8	0.566	0.036	0.167	0.163	13	1	5	4
Upper Brandywine Creek from State Line to Wilmington	B16	9.3		4.9	2.4	3.6	0.7	0.743	0.02	0.172	0.171	16	1	5	4
All tributaries on Brandywine Creek from the headwaters at PA-DE Line to the confluence with the Christina River	B16, B17	19.3		--	--	--	--	--	--	--	--	--	--	--	--
Red Clay Creek Watershed															
Red Clay Creek from Pennsylvania State Line	R4, R5	12.8		6.7	2.7	4.3	0.1	0.8	0.065	0.213	0.151	45	1	6	8
Burroughs Run from Pennsylvania State Line Run	R3	4.5		3.9	1.8	2.5	0.6	0.268	0.012	0.043	0.063	13	1	3	3
All other tributaries located in the watershed but not on the mainstem	R3, R4, R5	10.3		--	--	--	--	--	--	--	--	--	--	--	--
Hoopes Reservior	R4	200.0		--	--	--	--	--	--	--	--	--	--	--	--
White Clay Creek Watershed															
White Clay Creek from Pennsylvania State Line	W8, W9, W10	18.2		6.5	2.8	4.3	1.0	1.17	0.02	0.134	0.185	16	1	5	4
Mill Creek	W5	16.6		4.5	1.7	2.8	0.9	0.752	0.008	0.103	0.178	11	1	3	2
Pike Creek	W6	8.2		5.5	1.9	2.9	0.8	0.348	0.004	0.047	0.082	5	1	3	2
Middle Run	W7	5.8		4.6	1.6	2.7	0.9	0.19	0.005	0.044	0.042	24	1	6	5
Christina River Watershed															
All tributaries from the headwaters to the confluence with the Christina River	W5 - W10	14.2		--	--	--	--	--	--	--	--	--	--	--	--
Lower Christina River	C6	1.5		4.5	1.4	2.8	0.6	0.243	0.046	0.13	0.053	45	1	13	13
Mid Christina River between the confluences of White Clay Creek and Brandywine River	C5, C6	8.5		4.2	1.7	2.9	0.7	0.233	0.054	0.125	0.053	131	1	29	40
Tributaries on the Christina River between the confluences of White Clay Creek and Brandywine Creek	C5, C6	3.0		--	--	--	--	--	--	--	--	--	--	--	--
Christina River below Newark	C5	6.9		2.7	1.3	1.8	0.4	0.215	0.018	0.079	0.054	11	1	4	3
Tributaries from Smalleys Pond overflow to White Clay Creek	C5, C6	3.1		--	--	--	--	--	--	--	--	--	--	--	--
Tidal Christina Creek	C6	8.4		3.7	1.6	2.4	0.5	0.777	0.012	0.151	0.24	16	1	4	4
Belltown Run	C3	5.6		--	--	--	--	--	--	--	--	--	--	--	--
Muddy Run	C2	13.1		--	--	--	--	--	--	--	--	--	--	--	--

West Branch including Presimmon Run and Stine Haskell Branch	C1	5.3		--	--	--	--	--	--	--	--	--	--	--	--
Upper Christina Creek	C1	10.8		3.9	2.3	3.0	0.5	0.282	0.004	0.047	0.066	13	1	4	3
Little Mill Creek	C4	12.8		264.2	1.1	19.5	65.4	0.268	0.01	0.058	0.068	8	1	3	2
Chestnut Run	C4	2.8		--	--	--	--	--	--	--	--	--	--	--	--
Smalleys Pond	C5, C6	30.0		2.7	1.3	1.8	0.4	0.215	0.018	0.079	0.054	11	1	4	3
Becks Pond	C2	25.6		--	--	--	--	--	--	--	--	--	--	--	--
Sunset Pond	C3	40.0		--	--	--	--	--	--	--	--	--	--	--	--

Appendix C: List of Participants in the Christina Basin Rain Barrel Program

Address	City	ST	ZIP
1 Goodsir St.	Newark	DE	19702
5 Donegal Woods	Newark	DE	19702
1754 Otts Chapel Rd.	Newark	DE	19702
528 Sparrow Court	Newark	DE	19702
152 Bartly Drive	Newark	DE	19702
101 Barrett Run Rd.	Newark	DE	19702
11 Deer Run Dr.	Newark	DE	19702
3283 Frazer Rd.	Newark	DE	19702
58 Flinthill Drive	Newark	DE	19702
28 Charles Pointe	Newark	DE	19702
51 Danvers Circle	Newark	DE	19702
5 Cynthia Road	Newark	DE	19702
Brackenville and Barley Mill Roads	Hockessin	DE	19707
40 Raphael Rd.	Hockessin	DE	19707
226 Jeffrey Drive	Middletown	DE	19709
302 Vassar Drive	Newark	DE	19711
91 W. Park Place	Newark	DE	19711
19 Farmingdale Lane	Newark	DE	19711
32 Kells Ave	Newark	DE	19711
4 Darien Road	Newark	DE	19711
34 Covered Bridge Lane	Newark	DE	19711
604 Apple Road	Newark	DE	19711
405 Apple Rd	Newark	DE	19711
723 Harvard Lane	Newark	DE	19711
15 Ferncliff Rd.	Newark	DE	19711
128 Pinedale Rd.	Newark	DE	19711
908 Baylor Drive	Newark	DE	19711
21 Covered Bridge Lane	Newark	DE	19711
108 Briar Lane	Newark	DE	19711
1003 Lafayette Road	Newark	DE	19711
115 Panarama Dr.	Newark	DE	19711
24 Decker Drive	Newark	DE	19711
15 Amherst Dr	Newark	De	19711
229 Aronimink Dr.	Newark	DE	19711
307 N. Dillwyn Rd	Newark	DE	19711
106 Tanglewood Lane	Newark	DE	19711
14 Hempsted Drive	Newark	DE	19711
301 Bent Lane	Newark	DE	19711
303 Vassar Drive	Newark	DE	19711
11 North Wynwyd Drive	Newark	DE	19711
6 W. Chapel Hill Dr	Newark	DE	19711
733 Harvard Lane	Newark	DE	19711
503 Cambridge Dr	Newark	DE	19711

113 Panarama Drive	Newark	DE	19711
26 Beagle Club Way	Newark	DE	19711
112 Tanglewood Lane	Newark	DE	19711
201 Radcliffe Lane	Newark	DE	19711
620 New London Rd.	Newark	DE	19711
278 Beverly Rd.	Newark	DE	19711
15 Townsend Rd	Newark	DE	19711
808 Dallam Road	Newark	DE	19711
809 N.Country Club Dr	Newark	DE	19711
216 Vassar Drive	Newark	DE	19711
440 Terrapin Lane	Newark	DE	19711
51 E. Mill Station Dr	Newark	DE	19711
6 Fir Ct.	Newark	DE	19711
19 Covered Bridge Lane	Newark	DE	19711
803 Baylor Drive	Newark	DE	19711
103 Lena Drive	Newark	DE	19711
189 Madison Drive	Newark	DE	19711
914 Rockmoss Avenue	Newark	DE	19711
708 North Country Club Drive	Newark	DE	19711
17 South Dillwyn Road	Newark	DE	19711
609 Apple Road	Newark	DE	19711
272 S. Chapel St. #4	Newark	DE	19711
308 Winterthur Lane	Newark	DE	19711
13 Fox Lane	Newark	DE	19711
107 Bent Lane	Newark	DE	19711
9 Chippenham Dr.	Newark	DE	19711
1005 Lakeside Dr.	Newark	DE	19711
12 Farmingdale Lane	Newark	DE	19711
812 Dallam Road	Newark	DE	19711
160 Forest Lane	Newark	DE	19711
138 Timberline Dr.	Newark	DE	19711
245 S. Dillwyn Rd	Newark	DE	19711
41 Bridleshire Road	Newark	DE	19711
910 Aster Avenue	Newark	DE	19711
17 Vassar Drive	Newark	DE	19711
2 Tufts Lane	Newark	DE	19711
806 Dallam Road	Newark	DE	19711
700 Cambridge Dr	Newark	DE	19711
321 Tamara Circle	Newark	DE	19711
205 Lasalle Way	Newark	DE	19711
105 Ruth Ellen Ct. S.	Newark	DE	19711
88 Kells Avenue	Newark	DE	19711
2 Green Meadow Ct	Newark	DE	19711
18 Henderson Hill Road	Newark	DE	19711
47 N. Fawn Drive	Newark	DE	19711
909 Baylor Drive	Newark	DE	19711

1012 Baylor Drive	Newark	DE	19711
302 Beverly Rd.	Newark	DE	19711
20 Woodshaw Rd.	Newark	DE	19711
727 Havard Lane	Newark	DE	19711
15 Ferncliff Road	Newark	DE	19711
13 Vassar Dr.	Newark	DE	19711
9 Hempsted Drive	Newark	DE	19711
350 Wallace Dr	Newark	DE	19711
University Women's Club	Newark	DE	19711
32 Carriage Lane	Newark	DE	19711
12 Firechase Circle	Newark	DE	19711
16 Longwood Lane	Newark	DE	19711
8 Creek Bend Court	Newark	DE	19711
1 Nottingham Rd.	Newark	DE	19711
274 Beverly Rd.	Newark	DE	19711
709 Swarthmore Dr. (Binns)	Newark	DE	19711
106 Radcliffe Drive	Newark	DE	19711
33 Somerset Lane	Newark	DE	19711
324 Tamara Circle	Newark	DE	19711
2 Chapel Hill Dr.	Newark	DE	19711
4 Haywood Court	Newark	DE	19711
1003 Lakeside Dr.	Newark	DE	19711
7 Hempsted Drive Fairfield	Newark	DE	19711
20 Sunset Road	Newark	DE	19711
7 South Dillwyn Road	Newark	DE	19711
5 Radcliffe Dr	Newark	DE	19711
551 Terrapin Lane	Newark	DE	19711
9 Briar Lane	Newark	DE	19711
207 Grantham Pl.	Newark	DE	19711
609 Durso Drive, Harmony Hills	Newark	DE	19711
104 Tanglewood Lane	Newark	DE	19711
802 Dallam Road	Newark	DE	19711
701 Dallam Road	Newark	DE	19711
729 Harvard Lane	Newark	DE	19711
3 S. Dillwyn Rd	Newark	DE	19711
194 Starr Road	Newark	DE	19711
12 Amherst Dr	Newark	De	19711
306 N. Dillwyn Rd.	Newark	DE	19711
1014 Baylor Drive	Newark	DE	19711
13 Montague Rd.	Newark	DE	19713
420 Willa Road	Newark	DE	19711
20 Vassar Drive	Newark	DE	19711
409 Apple Road	Newark	DE	19711
24 Nightengale Circle	Newark	DE	19711
814 Dallam Rd	Newark	DE	19711
24 Somerset Ln.	Newark	DE	19711

29 Blue Fox Court	Newark	DE	19711
416 Longfield Rd	Newark	DE	19713
32 Arizona State Drive	Newark	DE	19713
15 Furman Court	Newark	DE	19713
315 Deefield Rd.	Newark	DE	19713
14 Laurel Lane	Newark	DE	19713
1 Michigan St. Dr	Newark	DE	19713
47 Lynch Farm Drive	Newark	DE	19713
34 Merry Rd. Brookside	Newark	DE	19713
9 Burkwood Drive	Newark	DE	19713
427 Stanley Plaza Blvd.	Newark	DE	19713
129 Garrett Road	Newark	DE	19713
410 Longfield Rd.	Newark	DE	19713
304 N. Dillwyn Rd.	Newark	DE	19713
318 Lark Drive	Newark	DE	19713
857 Broadfield Drive	Newark	DE	19713
417 Lark Dr.	Newark	DE	19713
16 Jamison St.	Newark	DE	19713
704 Brook Drive	Newark	DE	19713
5 Michigan State Drive	Newark	DE	19713
110 Beeson Ave	Wilmington	DE	
905 East Matson Run Pkwy.	Wilmington	DE	19802
1408 Lovering Ave.	Wilmington	DE	19806
1517 W. 9th St.	Wilmington	DE	19806
1410 Hamilton St.	Wilmington	DE	19806
4817 Pennington Ct.	Wilmington	DE	19808
2 Biltmore Ct. Breckinridge	Wilmington	DE	19808
	Lewes	DE	19958
1176 Irishtown Rd.	North East	MD	21901

Appendix D: Results of Christina Basin Rain Barrel Survey

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Introduction

The University of Delaware, Institute for Public Administration, Water Resources Agency distributed approximately 166 rain barrels to homeowners throughout the White Clay Creek and Christina River watersheds near Newark, Delaware. The U.S. Environmental Protection Agency, Delaware Department of Natural Resources and Environmental Control, and Pennsylvania Department of Environmental Protection provided funds for the rain barrel program through a Clean Water Act Section 319 grant. Over the summer of 2002, the project provided free rain barrels to interested homeowners to collect rain water to be used for activities such as watering plants and lawns. The rain barrel program continues to be a part of an implementation strategy carried out by the Christina Basin Clean Water Partnership: a cooperative effort between the states of Delaware and Pennsylvania.

The purpose of the rain barrel program is to encourage water conservation and provide a forum for watershed education and community participation. As the summer of 2002 coincided with a record-breaking drought in northern Delaware, homeowners had newfound opportunities to store water in between the infrequent rainstorms. The rain barrels became the focus of a public education effort where friends, neighbors, and family heard of the program and expressed interest in obtaining their own rain barrel. Delivery of rain barrels to various neighborhoods encouraged community participation in neighborly watershed management as the public tried to do their part to conserve water. The interest in the rain barrel program by homeowners outpaced the available funds by at least a 3 to 1 margin.

The rain barrels are 50 gallons in capacity and were recycled by the vendor from Greek pepper barrels. The barrels were steam cleaned and holes were drilled for the various outlet fittings. A screened cover was installed on the top of the barrel to keep out debris, insects and leaves. The rain barrels were delivered via truckload or parcel service at a cost of $50 to $60 per barrel from the vendor:

> Brett Anderson, Midwest Internet Sales
> Phone: 877-888-5609
> Email: info@midwestinternetsales.com Web: http://www.rainbarrelsandmore.com

Throughout the fall and winter of 2002, a survey was distributed to all participants to summarize their opinions on the experience of having a rain barrel. Within this report are included the compiled results of the surveys.

Methods

In order to tabulate the data from the 71 surveys received, the answers were divided into categories and transferred into a spreadsheet that was used to determine the results. The following questions were used in the survey:

1. Where did you learn of the Christina Basin Rain Barrel Program?

2. Did you collect rainwater in any fashion before participating in the Christina Basin Rain Barrel Program?

3. Describe in a few sentences how you have connected your rain barrel in your yard.

4. Were there any problems in constructing your rain barrel system? If so, please explain.

5. How many gallons of water (estimated) have you collected since you received your rain barrel?

6. What have you used your saved water to do?

7. Have you had any problems with the appearance of your rain barrel? If so, please explain and provide preferences for other colors.

8. Do you feel posting the "Participant in Christina Basin Rain Barrel Program" sign was helpful? Any concerns or comments?

9. Overall, are you pleased with your rain barrel?

10. What have you learned from the experience of having a rain barrel?

Results

Figure 1 shows the different places that participants heard about the Rain Barrel Program. In order from most to least used method of recruitment was newspaper/radio (25%), civic association newsletter (18%), neighbor/co-worker/friend (14%), University of Delaware Water Resources Agency (10%), Master Gardeners Program (9%) and mail, Delaware Nature Society, water utility bill and other (6% each).

Only 30% of those with a rain barrel had collected rain water before while it was the first time for 70% as seen in Figure 2.

Figure 3 summarizes the connection devices used to set-up the rain barrels. Eighty-two (82%) of those surveyed put the barrel directly under the downspout, 10% used multiple barrels or collection devices, 7% used an interconnection device from the downspout to the barrel and 1% used a different technique.

While 62% of individuals had no problems with the construction of their barrels, 35% had difficulties with the sealing and valves and 3% had parts missing as displayed in Figure 4.

Figure 5 quantifies the number of gallons of water collected from the rain barrel since installation. Six people estimated 0 –99 gallons collected, twenty seven estimated 100- 199,

eleven estimated 200 – 299, seven estimated 300 – 399, five estimated 400- 499, one estimated 500 – 599, four estimated 600 and over and eight were unsure as to how much they collected.

Figure 6 shows that 57% of survey participants used the water they saved to water plants, shrubs or trees, 33% watered gardens, 2% watered lawns and 8% used the water for other purposes.

While 83 % of people did not mind the appearance of their rain barrel, 17% did mind the appearance as summarized in Figure 7.

If the color of the rain barrels was to change as in Figure 8, 66% would like it to be green, 28% would prefer brown and 6% like white.

Figure 9 describes answers to the question: "Was posting the Christina Basin Rain Barrel Program Participant sign helpful?" Thirty-four individuals answered the question yes, 17 said no, 6 were not sure and 11 did not post a sign.

Every single person (100%) surveyed agreed that they were pleased with their rain barrels in Figure 10.

Figure 11 categorizes the most popular responses to the lessons learned from using a rain barrel. Twenty-five participants were surprised at how much water they collected, 17 thought it was great to reduce water usage during the drought, 16 were so pleased they would like another and 7 were surprised at how easy the process was.

Conclusions

Several conclusions can be made from the results of the Christina Basin rain barrel surveys. First of all, with 100% of those surveyed being pleased with their rain barrels, it can be concluded that the program has started as a success. The best methods of recruiting individuals for the program seem to be newspaper/radio advertisements, civic association newsletters and by word of mouth. The majority of those participating had no prior knowledge or experience with using a rain barrel.

The set-up of the rain barrel provided only a few problems with sealing and valves for some while the majority of individuals had no problems. The most popular method of set-up was to place the rain barrel directly under the downspout. In terms of the estimation of gallons of water collected from using the rain barrels, most people accumulated between 100 – 199 gallons while a few collected as much as 600 gallons. The most common use of rain water was to water plants, shrubs and trees while watering gardens was the next most popular.

The appearance of the rain barrel was not an issue of complaint by an overwhelming majority of people but if a color change was available, green was the choice. Most people found the posting of the “Christina Basin Rain Barrel Program Participant” sign to be helpful. Almost everyone surveyed learned something from the process of owning a rain barrel with the most common comments being surprise at how much water could be collected, a feeling that they can help to reduce water usage during drought conditions and a desire to obtain other rain barrels.

Figure 1: Where did you learn of the Christina Basin Rain Barrel Program?

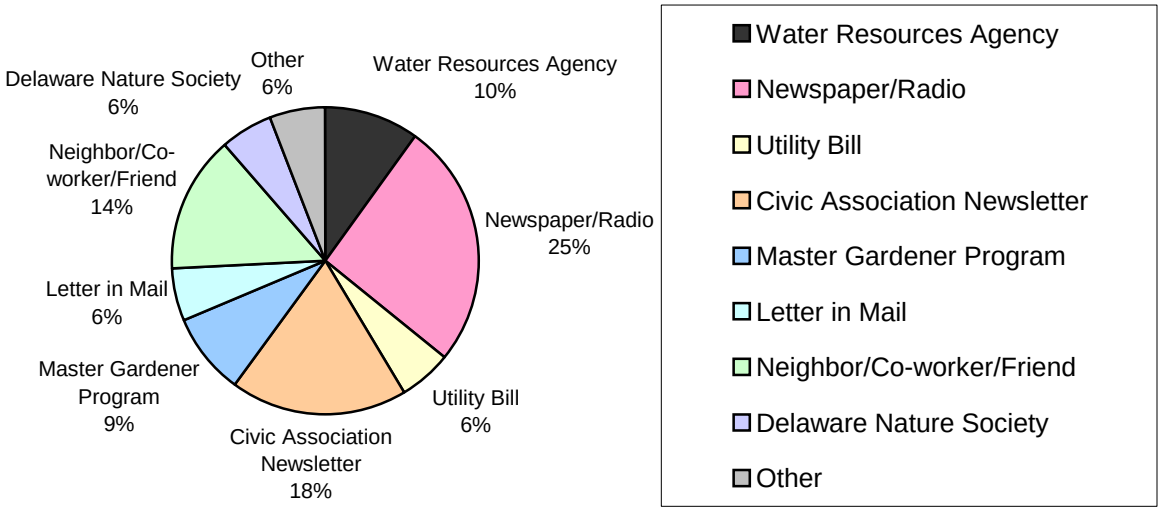


Figure 2 : Have you ever collected rainwater before?

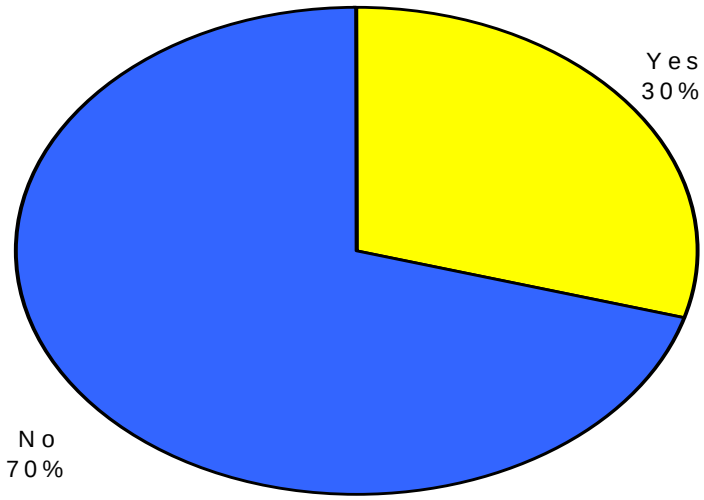


Figure 3 : How is your rainbarrel connected?

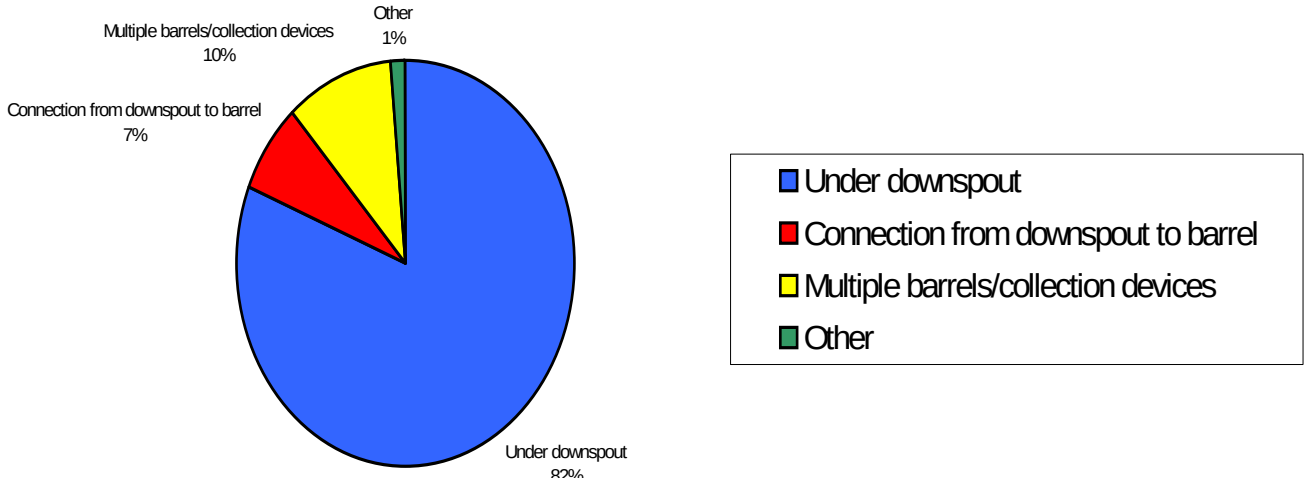


Figure 4 : Did you have any problems with the construction of your waterbarrel?

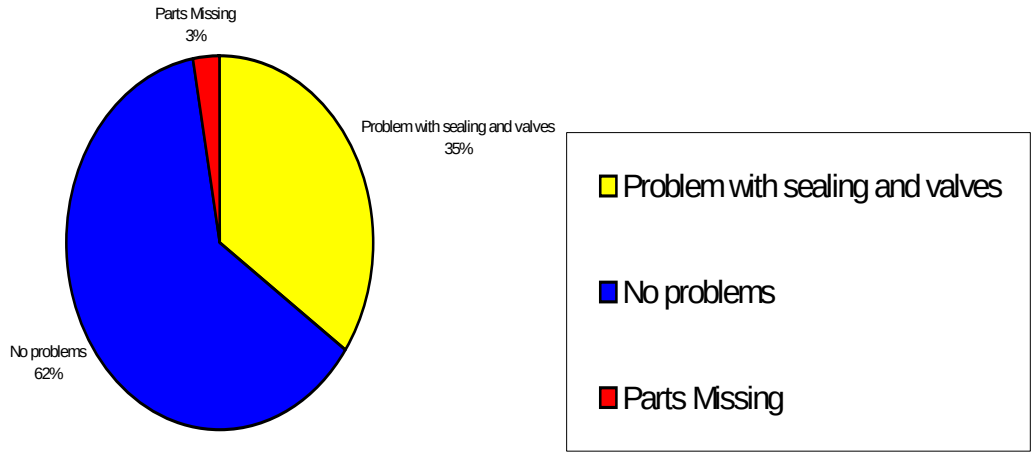


Figure 5 : How many gallons of water have you collected since receiving your rainbarrel?

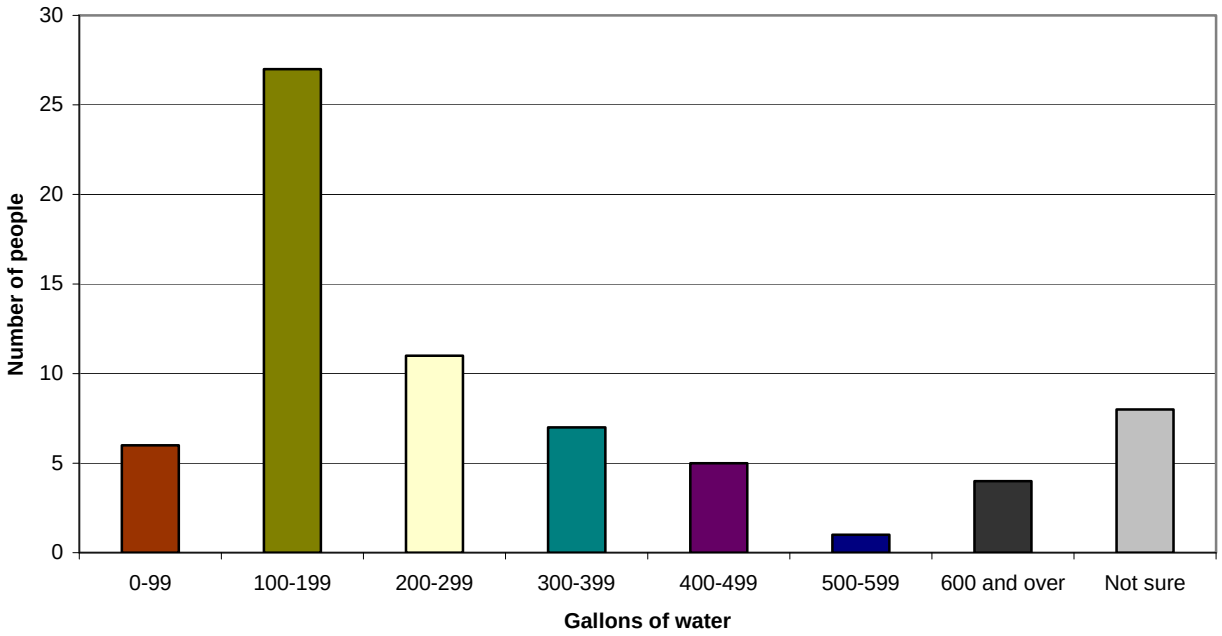


Figure 6 : What have you used your saved water to do?

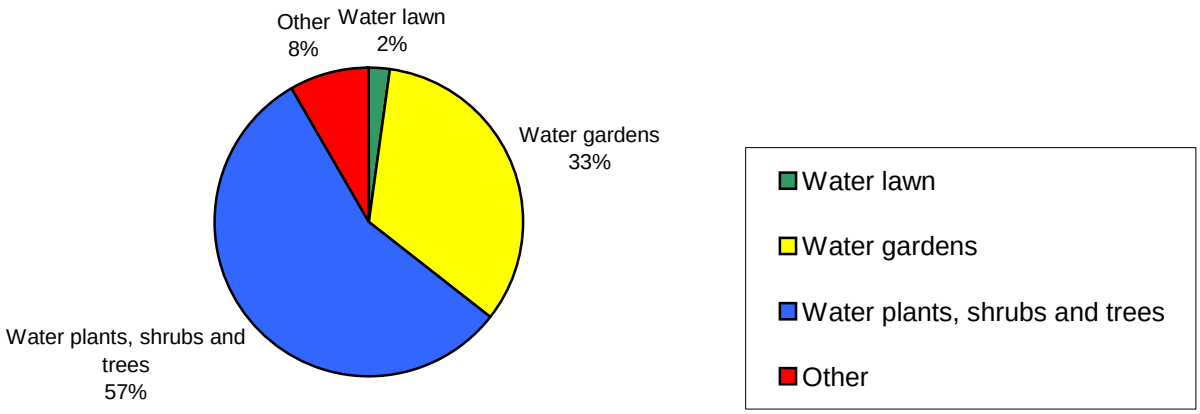


Figure 7 : Do you mind the appearance of your rain barrel?

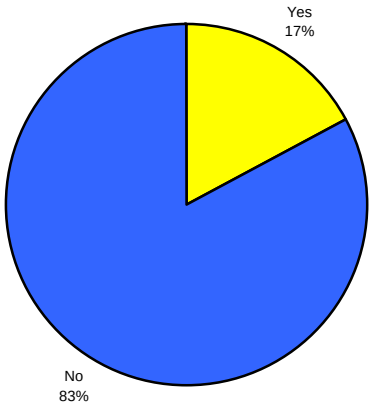


Figure 8 : What color rain barrel would you prefer?

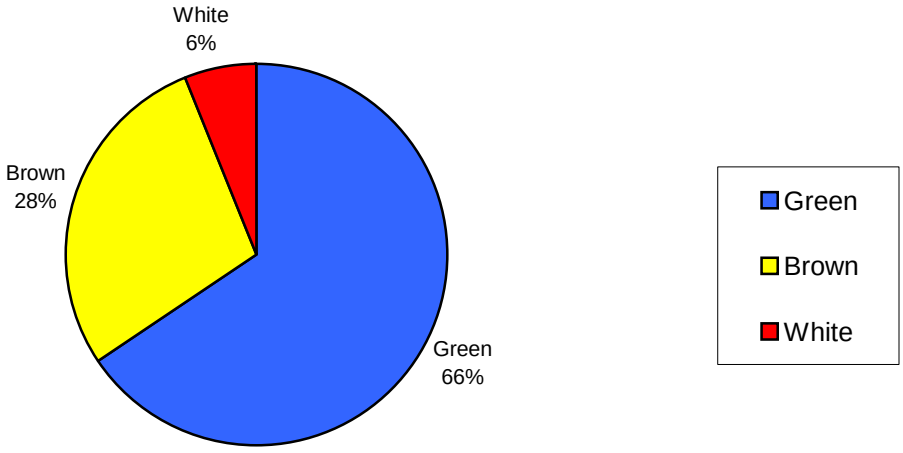


Figure 9 : Was posting the "Participant in Christina Basin Rain Barrel Program" sign helpful?

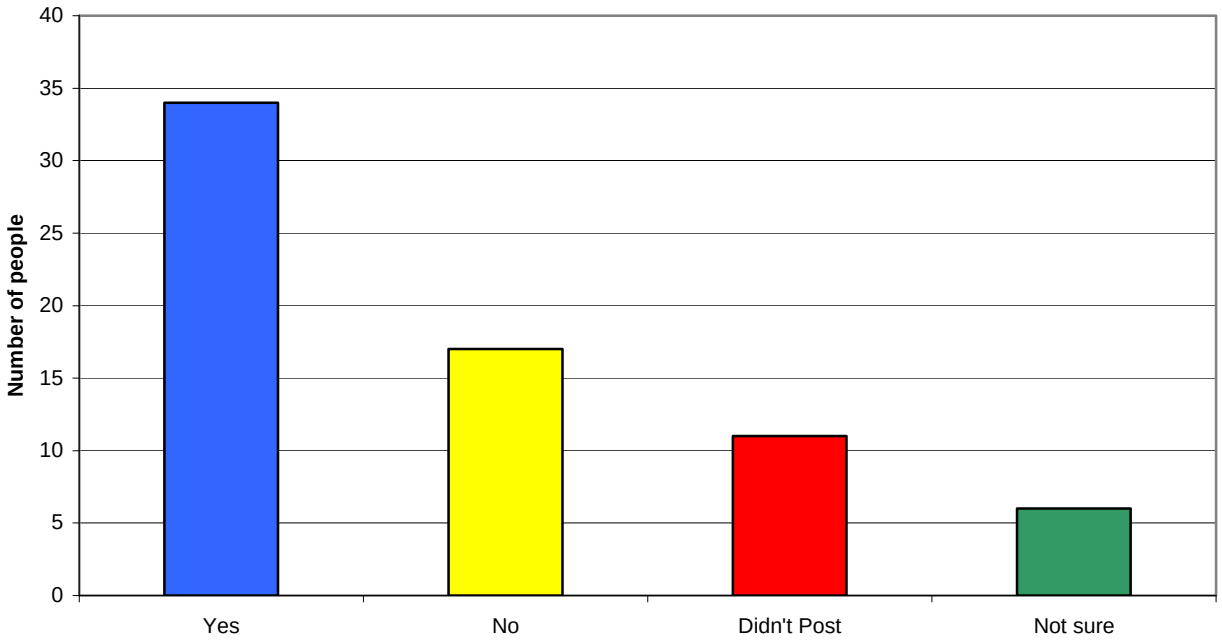
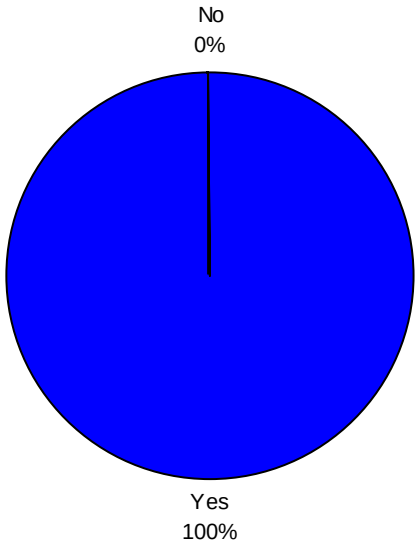


Figure 10 : Overall, are you pleased with your rain barrel?



Appendix E: SMARTYARD Water-Friendly Lawn Care Education in the Christina Basin

The University of Delaware Water Resources Agency received a $20,000 grant from the Delaware DNREC Section 319 of the Clean Water Act Program to establish and implement a suburban landscapes BMP program to assist lawn-owners to manage lawns and yards in an environmentally sound manner. Water quality benefits will occur from these BMPs as measureable by the number of yards and acres planted with water-friendly vegetation and the number of gallons of roof runoff annually redirected for infiltration to the groundwater. The greater benefit will be that of increased public awareness, education, and participation in watershed stewardship. It is hoped that community use of conservation landscaping techniques will increase as residents learn from the demonstration projects in their neighborhood.

Two subcontractors contractors were retained to assist with the program. URS Corp. ($10,000) was retained to develop three conceptual landscape design plans depending on sunlight, shade, drainage and other concerns. The Delaware Nature Society ($10,000) was retained to coordinate the program, select homeowners, and distribute the native plants to the homeowners. Homeowners that meet minimum criteria were also certified by the National Wildlife Foundation Backyard habitat Program. Homeowners were given signs, birdbaths, and birdhouses to increase the habitat value of their SMARTYARD.

Twenty interested homeowners were selected to plant low impact, basin scape water conservation landscaping, rain gardens, and fertilizer and pesticide-free grasses for retrofitting at urban and suburban dwellings. In October 2002, each participating homeowner in the SMARTYARD project received a free landscape design plan and free distribution of up to $300 worth of native plantings, trees, and shrubs, and assistance with tips on planting and maintaining the water friendly landscaping. As a condition of the program, the homeowner will participate in a 50% cost share agreeing to install and maintain landscaping and install a sign on the property educating the public about these conservation landscaping practices. The homeowners were selected based on the following criteria:

- Watershed - priority watersheds are the White Clay Creek and Upper Christina River near Newark
- Age of Home - equal distribution between young and mature neighborhoods.
- Eagerness to participate and spread the word

Homeowners were recruited through announcements (see below) at the University of Delaware Ag Field Day and by Delaware Nature Society newsletter.

SIGN UP FOR THE SMARTYARD PROJECT!

Would you like to plant water-friendly landscaping on your lawn?

Would you like to conserve and protect our drinking water supplies?

Would you like to save time cutting your lawn?

Would you like to save fertilizer and pesticide lawn care costs?

Do you live in the Christina Basin in the following watersheds?

The Brandywine Creek
The Red Clay Creek
The White Clay Creek
The Christina River

Then sign up for the Christina Basin SMARTYARD project.

Using a grant from the USEPA and the Delaware DNREC and Pennsylvania DEP, the University of Delaware Water Resources Agency will provide you with free landscape design and plants to install a rain garden on a portion of your lawn. A rain garden includes native plants and flowers that require minimal watering and little or no chemical fertilizers. SMARTYARDs are offered as an experimental program to demonstrate that thoughtful homecare practices can used to protect streams and aquifers.

As part of your participation, you would agree to post a small, aesthetically pleasing sign on you lawn announcing the SMARTYARD program.

If you are interested in the program, please phone, fax, or email the Delaware local coordinator of the Christina Basin Clean Water Partnership at:

Gerald Kauffman
University of Delaware
Institute for Public Administration-Water Resources Agency
DGS Annex Academy Street
Newark, DE 19716 **302-831-4929** **fax: 302-831-4934**
jerryk@udel.edu **www.wr.udel.edu**

SMARTYARD Participants			
Address	City	State	Zip
416 Longfield Rd	Newark	DE	19713
1 Goodsir St.	Newark	DE	19702
12 Farmingdale Lane	Newark	DE	19711
17 Anglin Dr.	Newark	DE	19713
318 Lark Drive	Newark	DE	19713
17 Wrangler Road	Newark	DE	19711
107 Bent Lane	Newark	DE	19711
1014 Baylor Drive	Newark	DE	19711
27 Willow Creek Lane	Newark	DE	19711
604 Apple Road	Newark	DE	19711
908 Baylor Drive	Newark	DE	19711
11 North Wynwyd Drive	Newark	DE	19711
33 Somerset Lane	Newark	DE	19711
20 Sunset Road	Newark	DE	19711
5 Michigan State Drive	Newark	DE	19713
307 N. Dillwyn Rd	Newark	DE	19711
301 Bent Lane	Newark	DE	19711
205 LaSalle Way	Newark	DE	19711
3 Birchgrove Road	Newark	DE	19702
308 Winterthur Lane	Newark	DE	19711
47 N. Fawn Drive	Newark	DE	19711
UDWRA DGS Annex Academy Street	Newark	DE	19711
708 N. Country Club Drive	Newark	DE	19711

SMARTYARD Native Plant Species and Price List

Name: Gerald Kauffman (University of Delaware IPA Water Resources Agency (831-4929)

Type	Plant name	Common Name	Concept	size	Price	Quantity
Tree	Acer rubrum	Red Maple	A	4-5', 3gal	23.00	1
Tree	Betula nigra	River Birch	A	7gal, 4-8'; 1"cal	45.00	1
Tree	Fraxinus pennsylvanica	Green Ash	A	7gal, 4-8'; 1"cal	45.00	1
Tree	Liriodendron tulipifera	Tuliptree	A	7gal, 4-8'; 1"cal	45.00	1
Tree	Quercus rubra	Red Oak	A	3-5', 5gal	35.00	1
Tree	Amelanchier canadensis	Shadblow Serviceberry	B	5gal, 3-4'	40.00	1
tree	Chionanthus virginicus	Fringetree	B	3gal	30.00	1
tree	Cornus florida	Dogwood	B	5gal, 3-4'	35.00	1
Tree	Carpinus caroliniana	American Hornbeam	B	5 gal	35.00	1
tree	Sassafras albidum	Sassafras	B	5gal	16.00	1
tree	Betula nigra	River Birch	C	7gal, 4-8'; 1"cal	45.00	
tree	Ilex opaca	American Holly	C	1gal	15.00	
tree	Juniper virginiana	Red Cedar	C	2gal,2-3'	24.00	
tree	Nyssa sylvatica	Black Gum	C	7gal, 4-8'; 1"cal	45.00	
tree	Quercus palustris	Pin Oak	C	7gal, 4-8'; 1"cal	45.00	
shrub	Aronia arbutifolia	Red Chokeberry	A	3gal, 3-4'	17.00	1
shrub	Ilex verticillata	Winterberry Holly	A	3gal, 2-3'	20.00	1
shrub	Lindera benzoin	Spicebush	A	18-24"	9.00	1
shrub	Vaccineum corymbosum	Highbush Blueberry	A	2gal, 18-24"	17.00	1
shrub	Viburnum dentatum	Southern Arrowwood	A	18-24"	9.00	1
shrub	Myrica pennsylvanica	Northern Bayberry	B	3 gal	20.00	1
shrub	Hamamalis virginiana	Witchhazel	B	1gal, 12-18"	9.00	1
shrub	Prunus maritima	Beach Plum	B	2gal	14.00	1
shrub	Rhododendron atlanticum	Dwarf azalea	B	24-30", B&B	60.00	1
shrub	Viburnum acerifolium	Mapleleaf viburnum	B	2-3', B&B	50.00	1
shrub	Clethra alnifolia	Sweet Pepperbush	C	3gal, 2-3'	25.00	
shrub	Ilex glabra	Inkberry Holly	C	3gal, 2-3'	20.00	

shrub	Itea virginica	Virginia Willow	C	3gal, 2-3'	18.00	
shrub	Rhododendron viscosum	Swamp Azalea	C	18-24", B&B	50.00	
shrub	Viburnum prunifolium	Smooth Blackhaw	C	1gal	10.00	
Ground cover	Adiantum pedatum	Maidenhair Fern	A	1gal	6.00	1
Ground cover	Asclepias incarnata	Swamp Milkweed	A	1gal	6.00	1
Ground cover	Aster novae-angliae	New England Aster	A	1gal	6.00	1
Ground cover	Iris versicolor	Blue flag Iris	A	1gal	6.00	1
Ground cover	Polystichum acrosticoides	Christmas Fern	A	1gal	6.00	1
groundcover	Asclepias tuberosa	Butterflyweed	B	1gal	6.00	1
groundcover	Chrysopsis mariana	Maryland golden Aster	B	1qt	3.50	1
groundcover	Solidago caesia	Bluestem Goldenrod	B	1 qt	3.50	1
groundcover	Rudbeckia f. 'Goldsturm'	Black-eyed Susan	B	1gal	6.00	1
groundcover	Vaccinium angustifolium	Lowbush Blueberry	B	1gal	14.00	1
groundcover	Yucca filamentosa	Common Yucca	B	2gal	14.00	1
groundcover	Asclepias incarnata	Swamp Milkweed	C	1gal	6.00	1
groundcover	Aster puniceus	Swamp Aster	C	1qt	3.50	1
groundcover	Lobelia siphilitica	Great Blue Lobelia	C	1gal	6.00	1
groundcover	Penstemon digitalis	Tall White Beardtongue	C	1gal	6.00	1
groundcover	Rudbeckia laciniata	Cutleaf Coneflower	C	1gal	6.00	1
groundcover	Vernonia noveboracensis	New York Ironweed	C	1 gal	6.00	1

Concept "A"

	Light Preference	Moisture Preference	Approximate Height	Approximate Spread	Wildlife Value
TREES (approximate cost - $40)					
Red maple **Acer rubrum**	☼	M-PD	40-60’	40-60’	Seeds and sap used by chickadees, robin, cardinal, finches, chipmunk and deer; young red maples are favorite nesting sites for prairie warbler. Brilliant red fall foliage.
River birch **Betula nigra**	◐	M-PD	50-75’	40-60’	Fruit, sap and buds used by ducks, nuthatches, chickadees, finches, fox sparrow, and rabbit.
Green ash *Fraxinus pennsylvanica*	☼	PD	50-60’	25-30’	Seeds and foliage used by finches, grosbeaks, wood duck, red-winged blackbird, squirrel, and deer.
Tuliptree *Liriodendron tulipifera*	☼	M	70-90’	35-50’	Seeds, sap and nectar used by chickadees, woodpeckers, cardinal, finches, hummingbirds, and honeybees. Exceptionally large and old trees approach 180 feet in height.
Northern red oak *Quercus rubra*	☼	M	50-75’	40-50’	Acorns are very important food source used by quail, turkey, grouse, ducks, woodpeckers, bluejay, thrashers, towhee, nuthatch, squirrel, chipmunk, raccoon, gopher, opossum, and deer.
SHRUBS *(approximate cost - $20)*					
Red chokeberry *Aronia arbutifolia*	◐	M	6-12’	3-5’	Berries and buds eaten by grouse, chickadee, cedar waxwing, meadowlarks and squirrel. Red berries persist throughout the winter.
Winterberry holly ***Ilex verticillata***	●	M-PD	6-10’	6-10’	Berries used by woodpeckers, cedar waxwing, thrushes, finches, cardinal, chickadees, and deer. Bright red berries add splash of color to the winter. Need one male holly for fruit.
Spicebush *Lindera benzoin*	●	M-PD	6-12’	6-12’	Berries used by thrushes, catbird, and kingbird.
Highbush Blueberry *Vaccinium corymbosum*	◐	M-PD	6-10’	8-12’	Berries, foliage and twigs used by robin, orioles, tanagers, squirrel, and other small mammals.
Southern arrowwood *Viburnum dentatum*	◐	M-PD	5-12’	6-10’	Berries and foliage used by turkey, cedar waxwing, brown thrasher, squirrel, deer, red fox, and chipmunk.
GROUNDCOVER **(approximate cost - $5)**					
Northern maidenhairfern *Adiantum pedatum*	●	M	2’	1’	Woodlands. Produces very delicate, attractive fronds.
Swamp milkweed *Asclepias incarnata*	☼	M-PD	3-4’	1’	Important nectar source for butterflies; host plant for Monarchs.
New england aster *Aster novae angliae*	☼	M-PD	4-6’	1’	Attractive wildflower for wet meadows and pond edges. Attracts butterflies.
Blueflag iris ***Iris versicolor***	◐	PD	3-4’	6-8”	Ponds. Nectar attracts butterflies and other insects. Shoots consumed by muskrat.

Light Preference
☼ = Full sun
◐ = Partial Shade
● = Shade

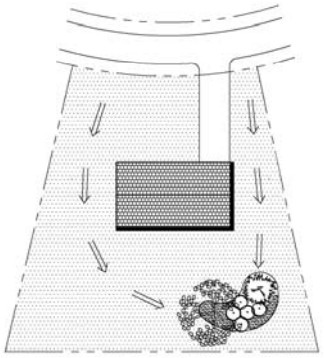
Moisture Preference
PD = Poorly drained
M-PD = Moist to poorly drained
M = Moist
M-WD = Moist to well drained
WD = Well drained

Concept "B"

	Light Preference	Moisture Preference	Approximate Height	Approximate Spread	Wildlife Value
TREES (approximate cost - $40)					
Downy serviceberry *Amelanchier canadensis*	◐	M	15-25’	6-10’	Berries and twigs used by thrushes, brown thrasher, catbird, woodpeckers, orioles, tanagers, robin, junco, cardinal, beaver, squirrel, and deer.
Fringetree **Chionanthus virginicus**	◐	M	20-35’	15-30’	Berries used by rabbit and deer. Large drooping clusters of white flowers.
Flowering dogwood ***Cornus florida***	◐	M-WD	15-30’	15-30’	Berries and nectar used by quail, woodpeckers, cedar waxwing, vireos, cardinal, songbirds, squirrel, rabbit, other small mammals, and butterflies. May be a small tree.
American hornbeam *Carpinus caroliniana*	◐	M	20-40’	20-40’	Seeds and buds used by wood duck, quail, beaver, squirrel, and deer.
Sassafras *Sassafras albidum*	◐	M-WD	35-50’	25-40’	Fruit used by quail, catbird, flycatchers, mockingbird, and pileated woodpecker.
SHRUBS (approximate cost - $20)					
Northern Bayberry ***Myrica pennsylvanica***	◐	WD	6-8’	5-12’	Berries used by quail, bluebird, catbird, tree swallow, and yellow-rumped warbler. Popular in candle-making.
American witch hazel *Hamamelis virginiana*	●	M	12-20’	20-25’	Seed and twigs used by grouse and deer, fruit used by songbirds and small mammals.
Beach plum *Prunus maritima*	☼	WD	3-6’	3-6’	Fleshy edible fruits used by deer and other mammals. Shrubs may be blanketed in blooms at flowering time.
Dwarf azalea *Rhododendron atlanticum*	●	M	3-6’	3-6’	Beautiful clusters of fragrant white flowers attract insects. Another common name is coast azalea.
Mapleleaf viburnum *Viburnum acerifolium*	●	M	4-6’	3-4’	Berries used by upland gamebirds, songbirds, large and small mammals.
GROUNDCOVER (approximate cost - $5)					
Butterfly Milkweed *Asclepias tuberosa*	☼	WD	1’	1’	Meadows; important nectar source for butterflies (host plant for Monarchs). Flower color highly variable: orange, red or yellow.
Maryland Golden Aster *Chrysopsis mariana*	☼	WD	1-2’	1’	Open woods and meadows. Produces bright yellow aster-like heads, nearly an inch across.
Blackeyed Susan ***Rudbeckia fulgida***	☼	M-WD	2’	2’	Meadows. Attracts butterflies, bees and other beneficial insects.
Early lowbush Blueberry Vaccinium angustifolium	●	WD	1’	1’	Berries, foliage and twigs used by robin, orioles, tanagers, squirrel, and other small mammals.
Sweet Goldenrod ***Solidago caesia***	●	M-WD	3’	1-2’	Open woodlands and edges. This species has a history of medicinal use by Native Americans. The State Herb of Delaware. Herbage has an anise fragrance when crushed.

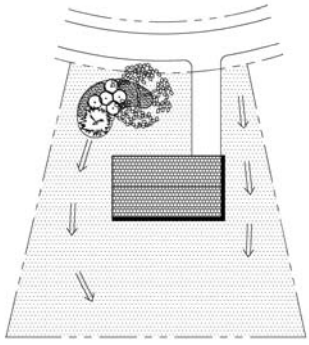
Concept "C"

TREES (approximate cost - $40)					
River birch ***Betula nigra***	◐	M-PD	50-75’	40-60’	Fruit, sap and buds used by ducks, nuthatches, chickadees, finches, fox sparrow, and rabbit.
American holly ***Ilex opaca***	◐	M-PD	40-50’	18-40’	Fruits used extensively by bluebird, catbird, mockingbird, robin, thrasher, also used to lesser extent by pileated woodpecker, wild turkey, thrushes and other songbirds.
Red cedar *Juniperus virginiana*	☼	M-WD	40-50’	8-20’	Berry-like cones eaten by many songbirds, upland gamebirds, small mammals, and hoofed browsers.
Black gum ***Nyssa sylvatica***	◐	M	30-50’	20-30’	Berries used by wood duck, thrushes, woodpeckers, eastern kingbird, cedar waxwing, and squirrel.
Pin oak *Quercus palustris*	☼	PD	50-75’	25-40’	Acorns are very important food source used by quail, turkey, grouse, ducks, woodpeckers, bluejay, thrashers, towhee, nuthatch, squirrel, chipmunk, raccoon, gopher, opossum, and deer. Also does well on upland soils.
SHRUBS (approximate cost - $20)					
Sweet pepperbush ***Clethra alnifolia***	◐	M-PD	5-8’	4-6’	Nectar used by hummingbirds, butterflies and other insects. Produces fragrant cluster of white flowers.
Inkberry ***Ilex glabra***	●	M-PD	6-8’	8-10’	Berries used by woodpeckers, cedar waxwing, thrushes, finches, cardinal, chickadees, and deer.
Virginia willow **Itea virginica**	●	PD	4-6’	3-5’	Nectar used by butterflies and other insects; fruit infrequently used by waterbirds, songbirds, gamebirds, and small mammals.
Swamp azalea *Rhododendron viscosurn*	◐	M-PD	4-6’	3-8’	Leaves and nectar used by butterflies, other insects, hummingbirds, and deer.
Smooth blackhaw *Vibumum prunifolium*	●	M	12-15’	8-12’	Berries and foliage used by turkey, cedar waxwing, brown thrasher, squirrel, deer, red fox and chipmunk.
GROUNDCOVER (approximate cost - $5)					
Swamp aster ***Aster puniceus***	☼	M-PD	4-6’	1-2’	Attractive wildflower for wet meadows and pond edges. Attracts butterflies.
Great blue lobelia *Lobelia cardinalis*	◐	M	1-2’	1’	Wet meadows. Attractive spike of blue flowers.
Tall white beardtongue *Penstemon digitalis*	☼	M	1-2’	1’	Meadows. Attracts butterflies and other insects.
Cutleaf coneflower *Rudbeckia laciniata*	◐	PD	3-4’	3’	Wet meadows and moist edges. Attracts butterflies and other insects.
New York Ironweed *Veronica noveboracensis*	☼	M-PD	5-6’	2’	Wet meadows, attracts butterflies and other nectar feeding insects.



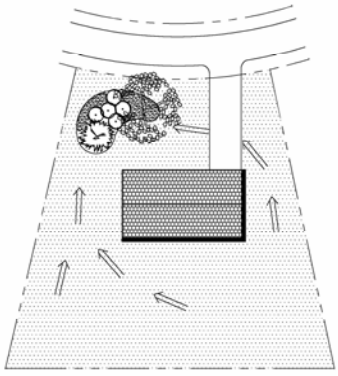
CONCEPT 'A'

DRAINAGE GENERALLY FROM FRONT YARD TO BACK YARD WITH GARDEN PLACED IN MORE MOIST CONDITIONS IN THE BACK.



CONCEPT 'B'

DRAINAGE GENERALLY FROM FRONT YARD TO BACK YARD WITH GARDEN PLACED IN DRYER CONDITIONS IN THE FRONT.



CONCEPT 'C'

DRAINAGE GENERALLY FROM THE BACK YARD TO THE FRONT YARD WITH GARDEN PLACED IN MORE MOIST CONDITIONS IN THE FRONT.

Additional information can be found at:

National Wildlife Federation, www.nwf.org
Wild Ones, www.for-wild.org
ENature, www.enature.com

Other references include:

The Flora of Delaware: An Annotated Checklist by William A. McAvory and Karen A. Bennett

Delaware Native Plants for Landscaping and Restoration: Recommended Species for the Property Owner and Land Steward by the Delaware Native Plant Society (* used as reference in above tables)

SITING PROCEDURE

You will need to decide if your Backyard Habitat garden will be placed where your yard is more apt to be moist or dry. To do this, you need to understand how your yard drains. Ideally you could walk around your yard when it is raining to see which way the water flows. However, this isn't always necessary as most every yard has either a natural pitch or a man-made slope (or both) that is steep enough to be seen simply by observing. Other indications would be a stream or storm inlet as properties will always drain toward these. And don't forget to note the locations of the roof gutter downspouts.

A good understanding of how sun and shade affect your yard is also be needed. Observing your yard throughout a summer day is the best way to determine this. Don't forget to factor in your neighbors' yards as trees that are small today could become quite large in the future. Conversely, your neighbor could also remove a large tree. Best to discuss plans.

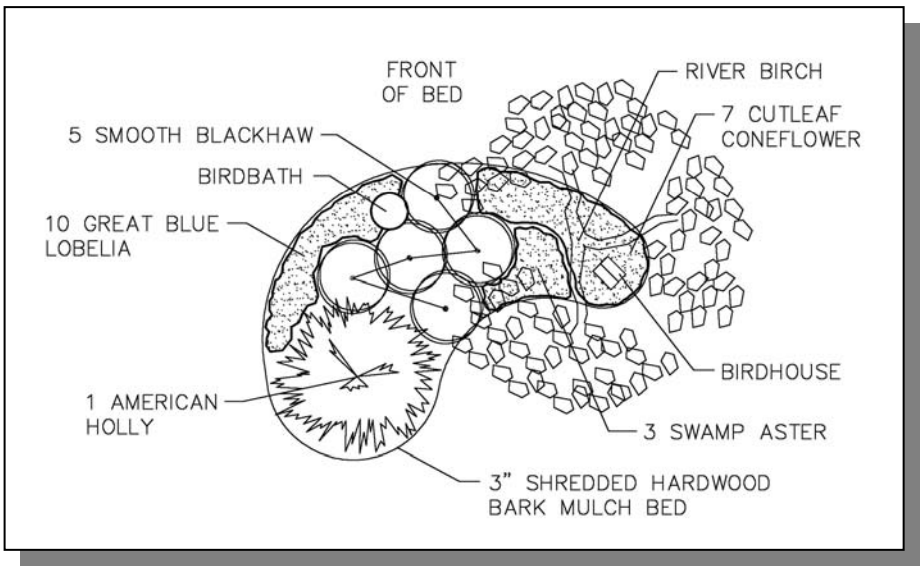
Knowledge of your yard's soils is also advised. The Cooperative Extension at the University of Delaware's Agriculture Department will analyze soils for a nominal cost. All you need to do is supply a sample. They can be contacted at 831-2667.

Many homeowners find that it is wise to prepare a rough map of their yard showing the information described above in an attempt to help identify the best locations for Backyard Habitat gardens. Examples are shown.

After an optimum location is picked, the last step is to select plant materials from the matrix for each of the three concepts. The matrices are intended to be a guide. Homeowners can mix and match between matrices. Trees should be installed in accordance with the guidelines in "Trees, Selection, Care and Planting" by the Delaware Cooperative Extension.

Generally, a Backyard Habitat garden requires an area approximately 15' x 20'. The size of the planting bed will be determined by the approximate spread of the plant material selected.

Optimum benefit will be reached when species are grouped tightly together.



Example Garden