# A COMPARATIVE ANALYSIS OF SOURCE WATER PROTECTION POLICIES AND REGULATIONS OF LOCAL GOVERNMENTS IN THE CHRISTINA RIVER BASIN IN DELAWARE AND PENNSYLVANIA

by

Kate E. Miller

A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Master of Science in Water Science and Policy

Spring 2014

**A COMPARATIVE ANALYSIS OF**

**SOURCE WATER PROTECTION REGULATIONS OF LOCAL**

**GOVERNMENTS IN THE CHRISTINA RIVER BASIN**

**IN DELAWARE AND PENNSYLVANIA**

by

Kate E. Miller

Approved: ________________________________________
Gerald Kauffman, Ph.D.
Professor in charge of thesis on behalf of the Advisory Committee

Approved: ________________________________________
Shreeram Inamdar, Ph.D.
Director of the Program of Water Science and Policy

Approved: ________________________________________
George Watson, Ph.D.
Dean of the College of Arts and Sciences

Approved: ________________________________________
James G. Richards, Ph.D.
Vice Provost for Graduate and Professional Education

ACKNOWLEDGMENTS

I would first like to thank Jan Bowers of the Chester County Water Resources Authority, Jake Michael of the Chester County Planning Authority, and Andrew Homesy of the University of Delaware Water Resources Agency for their support and the wealth of knowledge they allowed me to tap while completing this research. I would also like to thank the kind and incredibly helpful administrative staff in municipalities across the Christina Basin for being available to answer questions and guide me to resources that would have otherwise been beyond my reach.

My sincere gratitude goes to Jerry Kauffman and Martha Narvaez of the University of Delaware Water Resources Agency. Without their time, encouragement, and expertise, I would never have been able to complete this thesis. I am deeply indebted to them for the work that they do every day in the field of water resources, which is a constant source of inspiration for me as an aspiring water resource professional. Thanks are also given to Dr. Paul Imhoff for his wonderful insights and fresh perspective on my topic, which were an invaluable component in the completion of this research.

Finally, endless thanks to my incredible friends, family, and fiancé for the unwavering support throughout this entire process. I certainly could not have come this far, in my thesis or in life, without all of you, and I am truly grateful for all of the love and support you have shown me.

## TABLE OF CONTENTS

LIST OF TABLES ..................... vi
LIST OF FIGURES ..................... vii
ABSTRACT ..................... ix

Chapter

1 INTRODUCTION ..................... 1

1.1 Introduction to Source Water Protection ..................... 1
1.2 Research Objectives ..................... 2
1.3 Policy Implications ..................... 3

2 AN OUNCE OF PREVENTION: SOURCE WATER PROTECTION ..................... 5

2.1 Defining Source Water Protection ..................... 5
2.2 A Global History of Source Water Protection ..................... 8
2.3 The Federal Legal Framework for Source Water Protection ..................... 11
2.4 Why Local Governments? ..................... 12

3 STUDY AREA: THE INTERSTATE CHRISTINA BASIN ..................... 14

3.1 Using the Christina Basin as a Case Study ..................... 14
3.2 Geographic Context ..................... 14
3.3 Water Supply and Use ..................... 17
3.4 Demographics and Land Use ..................... 22
3.5 Water Quality ..................... 24
3.6 Basic Political Boundaries, Actors, and Agencies ..................... 26

4 THE DIFFERENCES IN GOVERNANCE STRUCTURE IN PENNSYLVANIA AND DELAWARE ..................... 32

4.1 The Role of State Governance in Interstate Watersheds ..................... 32
4.2 Delaware’s Governance Structure ..................... 33
4.3 Pennsylvania’s Governance Structure ..................... 34
4.4 Summary of Governance Structures in the Christina Basin ..................... 36
4.5 State-level Approaches to Source Water Protection in Delaware ..................... 37
4.6 State-level Approaches to Source Water Protection in Pennsylvania ..................... 39

4.7 Summary of Approaches to Source Water Protection in the Christina Basin ........ 41

5 RESEARCH METHODOLOGY ........ 42

5.1 Municipal Code and Ordinance Review ........ 42
5.2 Background Municipal Data Collection ........ 48
5.3 Scoring Matrix ........ 49
5.4 GIS Analysis of Source Water Protection and Natural Resources ........ 50
5.5 Statistical Analyses ........ 51
5.6 Surface Water Quality Analysis near Public Water Supply Intakes ........ 52

6 RESULTS ........ 57

6.1 Municipal Ordinance Review and Scores ........ 57
6.2 GIS Source Water Mapping Results ........ 67
6.3 Statistical Results: State-to-State Scores Analysis ........ 74
6.4 Statistical Results: Background and Natural Resource Correlations ........ 75
6.5 Water Quality Analysis Results ........ 82

7 SUMMARY OF FINDINGS AND RECOMMENDATIONS ........ 99

7.1 Summary of Findings ........ 99
7.2 Recommendations ........ 101
7.3 Areas of Future Research ........ 104

REFERENCES ........ 107

Appendix

A BACKGROUND AND NATURAL RESOURCE DATA ........ 113
B SOURCE WATER PROTECTION ORDINANCE SCORES ........ 120
C LAND AREA-WEIGHTED SCORE CALCULATIONS ........ 128

## LIST OF TABLES


Table 2.1: Water quality treatment scenarios .......... 7

Table 3.1: Christina Basin major public water suppliers.......... 17

Table 3.2: Public surface water withdrawals.......... 18

Table 3.3: Susceptibility of Delaware’s surface water intakes to contamination..... 25

Table 3.4: State and county areas within the basin.......... 27

Table 3.5: The state, county, and local governments of the Christina Basin .......... 30

Table 4.1: Comparison of Delaware-Pennsylvania governance structures .......... 37

Table 4.2: Comparison of state source water protection approaches .......... 41

Table 5.1: Direct and indirect source water protection checklist .......... 47

Table 5.2: Background municipal data.......... 48

Table 5.3: Water quality sites in Delaware and Pennsylvania .......... 54

Table 6.1: State and county ordinance review scores.......... 57

Table 6.2: Average county scores for direct source water protection parameters.... 61

Table 6.3: Average county scores for natural resource protection parameters......... 63

Table 6.4: Average county scores for stormwater management parameters.......... 64

Table 6.5: Average county scores for education and accessibility parameters ........ 65

Table 6.6: Municipal scores by category.......... 66

Table 6.7: Natural resources and vulnerable resources by municipality.......... 72

Table 6.8: Background correlations from nonparametric analysis.......... 76

Table 6.9: Natural resource correlations from nonparametric analysis.......... 78

## LIST OF FIGURES

Figure 3.1: The Christina Basin ........ 16

Figure 3.2: Surface and groundwater withdrawals in the Christina Basin ........ 20

Figure 3.3: Surface water source water protection areas for New Castle County ..... 21

Figure 3.4: Land use in the Christina Basin ........ 23

Figure 3.5: The organizational structure of the Clean Water Partnership ........ 28

Figure 3.6: Municipal boundaries of the Christina Basin ........ 31

Figure 4.1: Northern New Castle County WRPAs ........ 39

Figure 5.1: Example ordinance checklist ........ 43

Figure 6.1: Municipalities in the upper 50% of ordinance review scores ........ 59

Figure 6.2: Municipalities in the lower 50% of ordinance review scores ........ 59

Figure 6.3: Distribution of scores across the Christina Basin ........ 68

Figure 6.4: Natural resources in the Christina Basin ........ 70

Figure 6.5: TSS along White Clay Creek at McKee's Lane, Delaware ........ 84

Figure 6.6: TSS along White Clay Creek at Route 7 Bridge, Delaware ........ 85

Figure 6.7: TSS along Red Clay Creek at Route 4 Stanton, Delaware ........ 85

Figure 6.8: TSS along Brandywine Creek at Footbridge, Delaware ........ 86

Figure 6.9: Turbidity along Brandywine Creek at Wilmington, Delaware ........ 86

Figure 6.10: Turbidity at Rock Run Reservoir, Pennsylvania ........ 88

Figure 6.11: Turbidity along Brandywine Creek at Modena, Pennsylvania ........ 88

Figure 6.12: Turbidity along Brandywine Creek below Downingtown, Pennsylvania ........ 89

Figure 6.13: Enterococcus along White Clay Creek at McKee's Lane, Delaware...... 90

Figure 6.14: Enterococcus along White Clay Creek at Route 7 Bridge, Delaware..... 91

Figure 6.15: Enterococcus along Red Clay Creek at Route 4 Stanton, Delaware....... 91

Figure 6.16: Enterococcus along Brandywine Creek at Footbridge, Delaware........... 92

Figure 6.17: TSS along White Clay Creek at Chambers Rock Road, Delaware......... 93

Figure 6.18: TSS along Red Clay Creek at Barley Mill Road, Delaware ................... 94

Figure 6.19: TSS along Brandywine Creek at Smith Bridge, Delaware ..................... 94

Figure 6.20: Turbidity along Brandywine Creek at Chadds Ford, Pennsylvania........ 95

Figure 6.21: Enterococcus along White Clay Creek at Chambers Rock Road, Delaware........................................................................................... 96

Figure 6.22: Enterococcus along Red Clay Creek at Barley Mill Road, Delaware.... 96

Figure 6.23: Enterococcus along Brandywine Creek at Smith Bridge, Delaware....... 97

## ABSTRACT

Benjamin Franklin is credited with saying "An ounce of prevention is worth a pound of cure." Research has shown that this is certainly true when it comes to preserving the quality of public drinking water supplies. Source water protection is the active management and conservation of the sources of raw drinking water from both surface and groundwater sources. It was a major feature of the 1996 Amendments to the Federal Safe Drinking Water Act. Using the interstate Christina River Basin in Delaware and Pennsylvania as a case study, this research provides a comparative analysis of how the 58 local governments within the two states that share the basin compare in terms of direct and indirect legal protections for source water.

The results of an original ordinance review and scoring matrix show that, despite differences in governance styles and state-level regulations, there is relative consistency and fairly high levels of local protections for source water in both states across the Christina Basin. This consistency is demonstrated across four basic categories: direct source water protection; natural resource protection; stormwater management; and education and accessibility. Delaware received an average score of 13.2 (out of 20 possible points), which is not statistically different from Pennsylvania's score of 13.0. Furthermore, an analysis of water quality trends shows that, generally speaking, improving local trends for total suspended solids (TSS), turbidity, and enterococcus across the Christina Basin seem to reflect the consistently high levels of protection for water resources throughout the basin.

# Chapter 1

# INTRODUCTION

## 1.1 Introduction to Source Water Protection

Clean, safe water is vital to all life on earth, and certainly all aspects of human society. This necessity has been acknowledged since ancient times, but the manner of ensuring (as well as the threats posed to) a healthy and sustainable water supply has evolved through time. Many human activities that take place on the land have a negative impact on waterways, including those waters that serve as sources of drinking water. Fertilizers and pesticides from agriculture, contaminant-laden stormwater runoff from urban areas, bacteria from leaking septic systems, and chemical discharges from industrial sources are just some of the contaminants that, if not managed properly, can make their way into the streams, rivers, and groundwater systems that make up the public water supply system (Davies and Mazumder, 2003).

The Federal Safe Drinking Water Act of 1974 requires that public water supplies, which provide drinking water for roughly 90% of the American population (U.S. Environmental Protection Agency, 2013), be treated to certain quality standards. More often than not in the U.S., what comes out of the tap is "'finished' water, or water is that is delivered to consumers after receiving treatment" such as chlorination However, there are still some risks associated with treated water, such as exposure to "enteric pathogens, disinfection by-products (DBPs), chemical contamination, and other toxic compounds, such as those produced by cyanobacteria" (Davies and Mazumder, 2003). In order to reduce these risks, it is important to begin taking risk management steps as early in the supply chain as possible, starting at the natural level while the water that will become drinking water is still flowing in streams or through the ground.

That first link in the chain is known as source water protection. The 1996 amendments to the Safe Drinking Water Act required the states to conduct detailed assessments of their source waters and the threats to those sources. It also established a basic framework under which states and local governments could implement programs that would act upon those assessments. Where established, these programs play an important role in protecting the water supply and mitigating the risks to the public. Where such programs are absent, the opportunity for a first line of defense against harmful water contamination is missed.

## 1.2 Research Objectives

The goal of this research is to present a comparative analysis of the source water protection regulations put in place by local governments in the interstate Christina Basin watershed. This research will determine how municipalities in two states, Delaware and Pennsylvania, with very different governance structures protect a common and vital natural resource: drinking water. This geographic area is of particular interest because the State of Delaware has an active law that requires all municipalities of a given size to incorporate source water protection measures into their codes, while the State of Pennsylvania merely provides informational and technical resources to municipalities that wish to voluntarily implement source water protection programs. Delaware, as the downstream state in the watershed, has a vested interest in ensuring that its northern neighbor protects the sources of drinking water in

Pennsylvania, since much of that water in turn becomes the drinking water for thousands of residents in New Castle County, Delaware.

Using a review of all municipal ordinances within the basin and a Geographic Information System (GIS) analysis of local natural resources, this research will compare each municipality's direct and indirect source water protection regulations as they relate to one another and as they relate across state lines through the use of an original scoring matrix. The ultimate goal is to determine whether there are significant differences in the levels of protection demonstrated in each state, or if there is a general consistency in levels of protection throughout the basin. This research will also identify areas within the source water regulations that can be improved in each municipality and in the basin as a whole. Finally, water quality trends near surface water intakes for public supplies and close to the interstate border will be analyzed to begin to determine whether the codified efforts of local governments within the basin appear to be paying off.

### 1.3 Policy Implications

There is a growing body of literature dedicated to promoting the effectiveness of best management practices on protecting source waters (Hurley and Mazumder, 2013; Ainsworth and Brown, 1996; Gullick, 2003; Islam et al., 2013). However, little attention has been paid to whether or not local governments, as the primary authorities over land use within their jurisdictions, have begun incorporating these practices into their ordinances and regulations. Although highly localized, this research will attempt to fill in some of that knowledge gap, and will provide a method of analysis for future research into this subject.

This research will include an analysis of source water protection regulations as they are written in the municipal codes, and will not quantify any variances issued by local governments or any direct violations of those codes. This research will also present natural resource protection levels as they are written in the ordinances and will not account for development or land uses that were put into place prior to the adoption of the relevant ordinances and may have been grandfathered into newer zoning or land use districts.

# Chapter 2

# AN OUNCE OF PREVENTION: SOURCE WATER PROTECTION

## 2.1 Defining Source Water Protection

The term source water protection "refers to the development and implementation of policies, plans and activities to prevent or minimize the direct or indirect release of pollutants into surface or groundwater resources currently used or intended to be used in the future as sources of drinking water" (Ivey et al., 2006). Source water protection can take different forms depending on the nature of the source. "In the context of surface water (e.g., lakes, reservoirs, rivers), source water protection typically takes the form of watershed or catchment management, while for groundwater resources may focus on private wells, municipal water fields, groundwater recharge areas, or whole aquifers" (Ivey et al., 2006). Generally, these methods include conservation efforts and/or land use restrictions in sensitive natural areas that drain into source water supplies (Ernst, 2004). Some of the specific steps that can be undertaken in the name of source water protection will be discussed in depth in later chapters. However, all methods share the same common goal of preventing contaminants from reaching the water supply.

Protecting the sources of public drinking water is the first step in what is known as a multi-barrier approach to protecting the quality of drinking water. Other steps include treatment (the physical or chemical removal of pollutants and contaminants), monitoring (developing systems capable of detecting harmful contaminants if and when they reach levels that are unacceptable for consumption), and contingency planning in order to respond to contamination and restore water quality (Ivey et al., 2006). Each of these steps is important in its own right, and this research is not meant to suggest that source water protection should take the place of any other step in the multi-barrier approach. However, given the general consensus that source water protection can be cost effective and efficient at contaminant and risk reduction (Hurley and Mazumder, 2013; Ainsworth and Brown, 1996; Gullick, 2003; Islam et al., 2013), it deserves increased attention in a nation that, until relatively recently, relied overwhelmingly on water treatment facilities to protect the water flowing from taps all across the country, and it should certainly be considered as part of a holistic management strategy for the protection of drinking water.

In addition to the direct benefits to society of improved drinking water quality that poses fewer health risks, source water protection can also have economic and ancillary benefits for society. Some researchers have quantified the relationship between water quality and treatment costs (Hesson, 2005) as well as the relationship between specific land uses, like forests, and treatment costs (Ernst, 2004). The economic benefits associated with an improved source are typically the avoided costs of advanced treatment processes, and can total millions if not billions of dollars in cost savings (Alcott et al., 2013). Treating water to drinking water quality standards can be an expensive business, and protecting the source can save costs on chemicals for disinfection, upgrades for treatment facilities, and in some cases it can help prevent suppliers from needing to purchase water from external sources in order to meet their customers' demand (Hesson, 2005). Table 2.1 illustrates the number and type of treatment steps at supply facilities depending on the quality of raw source water. Each step that can be avoided by protecting the source means less money spent on water quality improvements at the treatment plant, which means lower costs to both drinking water producers and consumers.

Table 2.1: Water quality treatment scenarios

| Treatment Scenario | Location Example | Water Quality | Treatment Steps Required | Treatment Processes |
|---|---|---|---|---|
| 1.1a | New York City | Superior | 1 | Disinfection |
| 1.1b | Newark, DE | High | 4 | Flocculation<br>Clarification<br>Filtration<br>Disinfection |
| 1.2 | Stanton, DE | Moderate | 5-6 | Pre-Sedimentation<br>Flocculation<br>Sedimentation<br>Filtration<br>Disinfection |
| 1.3 | Philadelphia, PA | Poor | 8-10 | Screening<br>Pre-sedimentation<br>Sedimentation<br>Softening<br>Activated Carbon<br>Flocculation<br>Clarification<br>Sedimentation<br>Filtration<br>Disinfection |

Source: Hesson, 2005

Beyond economics, some of the ancillary benefits of source water protection include improved water quality for recreational activities like boating and swimming, as well as natural habitat for both aquatic and terrestrial creatures (Chiueh et al., 2012; Ainsworth andBrown, 1996). The Christina Basin is home to several protected species, such as the bog turtle, bald eagle, and brook trout. Improving water quality locally will improve the habitat for these creatures, which can reduce the current burden on their stressed populations. The basin also features an area of national ecological significance: the federally designated Wild and Scenic White Clay Creek, which received special protections at the turn of this past century for its exceptional scenic, natural, and recreational resources. It was the first watershed in the country to be designated in its entirety, and protecting water quality in the basin can help to preserve the overall environmental wellbeing of this regional treasure.

## 2.2 A Global History of Source Water Protection

In the early 17th century, Governor Gates of Virginia issued this proclamation to the colonists of the Jamestown settlement:

> There shall be no man or woman dare to wash any unclean linen, wash clothes…nor rinse or make clean any kettle, pot or pan, or any suchlike vessel within twenty feet of the old well or new pump. Nor shall anyone aforesaid, within less than a quarter mile of the fort, dare to do the necessities of nature, since by these…immodesties, the whole fort may be choked and poisoned (Reimold, 1998).

This decree may well have been the first source water protection law in North America. Governor Gates was sufficiently aware of natural processes to understand that activities undertaken near sources of drinking water have the potential to contaminate the supply. The outbreak of a waterborne disease certainly would have been devastating to the colonists. However, the Governor was certainly not the world's first leader to make such a connection. Consultant microbiologist Dr. Edmund Pike describes the legacy of Sextus Julios Frontinus, the imperial water commissioner for the City of Rome in the 1st century A.D. Frontinus took the city's already advanced water supply to the next level by protecting the areas around known aquifers and setting aside the purest water sources for the purpose of human consumption. It was reported by Frontinus himself that within two years, Rome was experiencing an "improved cleanliness and health of the city…purer air and the removal of the causes of pestilence" (Pike, 1999).

Although the connection between water quality and health has been understood since antiquities, contaminated water and waterborne diseases continue to plague countries all across the globe. In the 19th century London, England was ravaged by lethal outbreaks of cholera until Dr. John Snow (who would become the father of modern epidemiology) discovered the nature of transmission of the disease and traced its spread to a sewage-contaminated water supply (Jacobsen, 2008). Subsequently the British government passed a law that forced water suppliers to ensure that the drinking water they supplied to consumers was "pure and wholesome water, sufficient for all domestic uses of all inhabitants within their area" (Pike, 2008).

In the United States in the early 1900s, cities across the country began disinfecting their drinking water prior to distributing it to consumers. This led to significant decreases in illnesses and deaths brought on by waterborne diseases like cholera and typhoid, which prompted many to label water treatment as one of the major public health achievements of the century (U.S. Center for Disease Control, 1999). Because of advances in the way drinking water is treated and disinfected today, waterborne diseases are commonly associated with lesser developed nations that lack the necessary infrastructure and resources. However, this does not mean that countries like the United States are free from the dangers of contaminated drinking water. According to the U.S. Center for Disease Control, the largest outbreak of a waterborne disease recorded in this country happened in the early 1990s in Milwaukee, Wisconsin. More than 400,000 people fell ill after drinking from the city's public water supply, which had been contaminated with the parasite *Cryptosporidium*. And that was only one of thirty outbreaks across the nation related to drinking water contamination in that year alone (U.S. Center for Disease Control, 1996).

It is becoming increasingly apparent that drinking water treatment and disinfection are not enough to protect public water supplies from all contaminants all of the time. In light of this, over the past few decades several countries around the globe, including Canada and Australia, have begun initiating source water protection programs (Davies and Mazumder, 2003; Rizak et al., 2003).

In the United States, the most notable and most widely acclaimed source water protection initiative was undertaken to protect the drinking water supply for New York City. The city's water supply comes from three watersheds located upstate. Two of these watersheds, the Delaware and the Catskills, provide water that is of such consistently high quality that the U.S. Environmental Protection Agency has issued the city a filtration avoidance determination, meaning that the city can bypass many of the federally required treatment processes that are required of less pristine source waters. This has been made possible by more than a half century of source water protection programs put in place by the city, including "land stewardship in source water areas,…incentive-laden partnership-based programs [that] can support multiple resource management values," and "ongoing investment and comprehensive community engagement" in the rural Delaware and Catskills watersheds (Alcott et al., 2013). Because these two watersheds were almost completely undeveloped when the city's water supply systems were built, the City's Department of Environmental Protection was able to channel significant financial resources into protecting and preserving these areas' natural ability to filter and purify water, and it was able to prevent development and activities with the potential to degrade water quality (Ernst, 2004).

With the largest unfiltered water supply in the nation (Alcott et al., 2013), New York City is an impressive example of source water protection in the United States. However, it represents only one end of a continuum, as many areas have smaller source water protection programs, and some have no programs at all. The next section will describe the legal framework for source water protection, which will help to shed light on why source water protection efforts are not uniform across the country.

### 2.3 The Federal Legal Framework for Source Water Protection

The Federal Government has passed several laws within the past fifty years that support source water protection initiatives and overall water quality improvements. Chief among these regulations are the Clean Water Act of 1972 and the Safe Drinking Water Act of 1974.

The Federal Clean Water Act (otherwise known as the Federal Pollution Control Act) was enacted by Congress in 1972, a time when water quality in certain areas of the country was so abysmal that rivers were known to catch on fire. The Clean Water Act granted the U.S. Environmental Protection Agency (EPA) the authority to establish and enforce standards for surface water quality. The Act also prohibits the discharge of any pollutant into “waters of the United States” unless a permit is issued (U.S. Environmental Protection Agency, 2014). The Clean Water Act has been incredibly effective at reducing contamination and improving water quality across the country. However, those successes are related to discharges that the Act has given the EPA the authority to regulate, which are generally limited to discrete or point source pollution (e.g., industrial dischargers, wastewater treatment plants, etc.). Under this law, the EPA has less authority to govern nonpoint sources of pollution like agricultural and municipal runoff, which are still major causes of water impairment across the country.

The Federal Safe Drinking Water Act of 1974 is as much a public health law as it is an environmental law, since deals directly with the quality of water that can be sold to the public for as drinking water. It regulates and sets quality standards for the water distributed by public water suppliers. In addition, the Act allows for states to administer their own drinking water programs, provided that their rules and standards are at least as stringent as those of the federal government (Tiemann, 2014).

The 1996 amendments to the Act also required states to complete source water assessments for all public drinking water supplies. These assessments include delineated source water areas, an inventory of potential pollutants, and the susceptibility of the public water supply to contamination (Pontius, 1997). The goal of these assessments is to serve as the basis for source water protection plans and programs designed to minimize the risk of contamination to surface and groundwater that furnishes the public's drinking water supply. However, the implementation of source water protection programs is strictly voluntary, and the amendments have no provision that requires states to develop or implement such programs.

### 2.4 Why Local Governments?

According to Davies and Mazumder (2003), "All levels of government (local, provincial/state, and federal) bear the responsibility for setting policies to ensure the protection of our water resources and for providing instruments for the attainment of these policies." Indeed, it is certainly not a stretch to assume that source waters fall under the basic public trust doctrine, and that governments are therefore required to protect them in the name of the public good. However, Davies and Mazumder go on in their article to hint at a critical point for why local governments in particular must be actively involved in source water protection. “Drinking water sources are usually proximately located to areas they supply. Thus, impacts of industrialization, agriculture, and urbanization are closely linked to drinking water supplies” (2003).

In the U.S., land use is largely governed by local governments through zoning codes and ordinances put in place by local governments. Therefore, it falls to local governments, as the primary authorities in land use, to use that power to prevent the degradation of the sources of drinking water on which their citizens rely. It is also particularly in the realm of local governments to manage and protect source water in the Christina Basin. Delaware’s Source Water Protection Law of 2001 is a statewide rule requiring local governments to incorporate source water protection strategies into their zoning codes and ordinances where appropriate. In Pennsylvania there is no statewide law or program, but the State provides resources to local governments that wish to voluntarily implement programs or develop regulations of their own. The source water protection strategies of each state will be discussed in depth in later chapters. However, it is crucial to understand that the level of government with the greatest capacity to protect the sources of public drinking water, both nationally and more specifically in the interstate Christina Basin, is the local level.

# Chapter 3

# STUDY AREA: THE INTERSTATE CHRISTINA BASIN

## 3.1 Using the Christina Basin as a Case Study

From a physical and chemical perspective, the Nation Science Foundation's Critical Zone Observatories claim that the "Christina River Basin and its four sub-basins may be one of the best studied watersheds of its size in the nation." The basin provides an interesting case study of source water protection regulations because it is an interstate watershed with a history of water quality issues, a diverse mixture of land uses, and variations in state and local governance structure within a confined area. Additionally, this is an ideal watershed in which to study the differences in approaches to local source water protection given that the local governments in Delaware are subject to a state law regarding source water protection, while the local governments in Pennsylvania are not. One might therefore expect that the level of protection for drinking water sources would be different across state lines. This research will aim to demonstrate the validity of such a hypothesis.

The variations in governance structure and state laws will be discussed in the next chapter. This section will address the physical, political, and societal characteristics of the basin in order to provide context for this research.

## 3.2 Geographic Context

The Christina Basin is located on the border of southeastern Pennsylvania and northern Delaware. It spans 565 square miles from the foothills of the Piedmont region in southern Chester County, Pennsylvania to its outlet into the Delaware River in Wilmington, Delaware. The basin is nestled at the southern end of the Delaware River Basin, which drains a significant portion of the Mid-Atlantic region from its headwaters in New York to the Delaware Estuary.

There are four watersheds within the basin: the Brandywine Creek (325 $mi^2$); the White Clay Creek (107 $mi^2$); the Red Clay Creek (54 $mi^2$); and the Christina River (78 $mi^2$). These four watersheds can be further broken down into 38 subwatersheds, which range in size from 4 to 33 square miles (Greig et al., 1998).

The northern portion of the basin is located in the Piedmont region, which is characterized by rolling hills and valleys, while the southern portion is located in the Atlantic Coastal Plain, a relatively flat region characterized by sandy soils. The divide between these two geologic regions is located in Delaware between Newark and Wilmington (Delaware Tributary Action Teams et al., 2011). The climate of the basin is temperate and humid, with moderately cold winters and hot summers. Climate data for this area is extensive and stretches back more than a hundred years. Between 1894 and 2011, the average annual temperature in the basin was 53.6˚ Fahrenheit, and the annual average precipitation amount was roughly 45 inches (Critical Zone Observatories, n.d.). The area also has a history of various forms of extreme weather, ranging from droughts to flooding from hurricanes to ice storms.

The Delaware-Pennsylvania Christina Basin

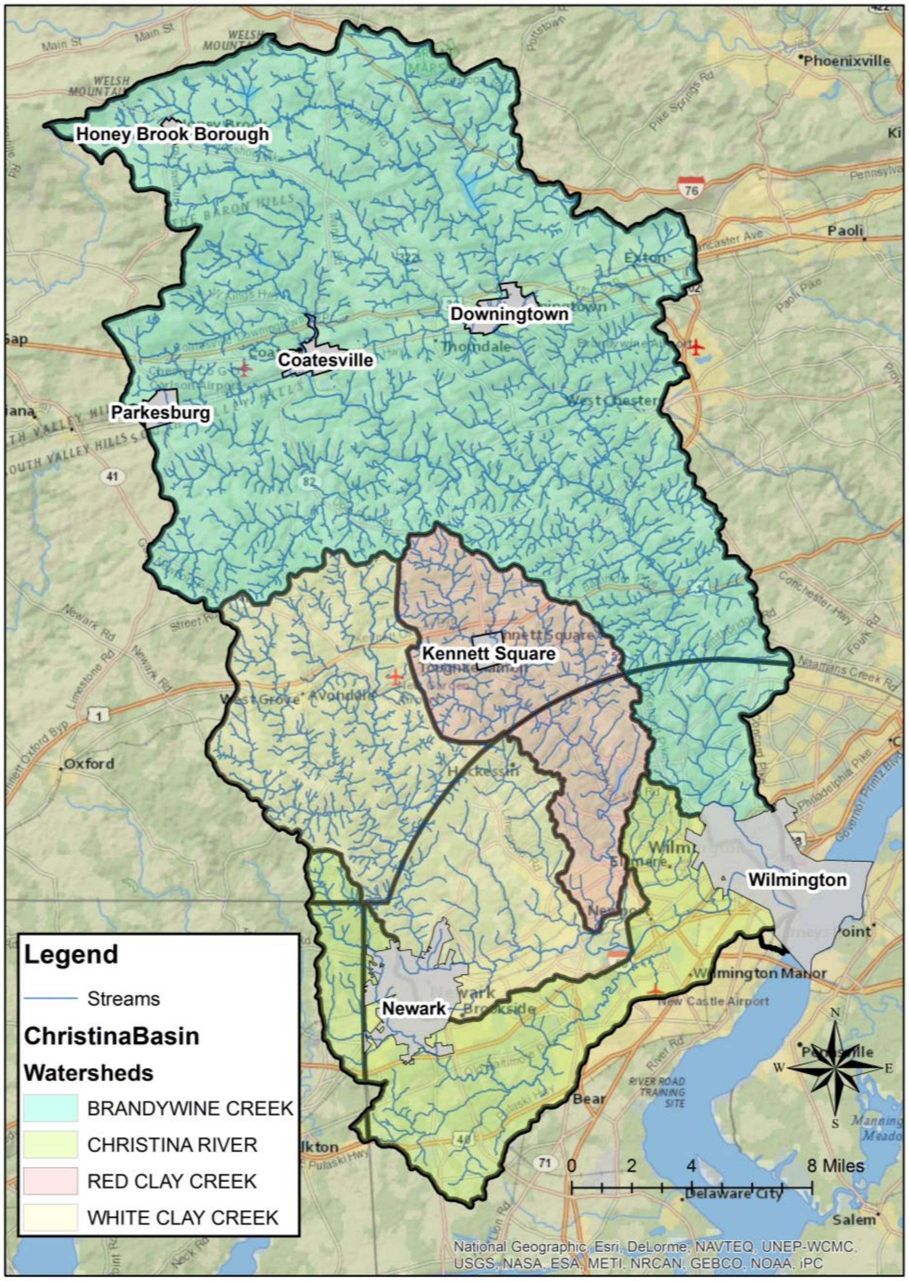


Figure 3.1: The Christina Basin

### 3.3 Water Supply and Use

The water flowing through the basin's streams and soils is among the area's most valuable (or perhaps even its most valuable) natural resources. Each day, hundreds of millions of gallons of water are drawn from the ten surface water intakes and dozens of public supply wells within the four major watersheds, which provides drinking water for 40% of the residents in Chester County, Pennsylvania and 70% of the residents of New Castle County, Delaware (Delaware Tributary Action Teams et al, 2011), roughly half a million people in all. Table 3.1 below lists the major public water suppliers within the basin.

Table 3.1: Christina Basin major public water suppliers

| **Delaware PWS** | **Pennsylvania PWS** |
|---|---|
| Artesian Water Co. | Artesian Water Co. |
| City of Newark Water Dept. | Avondale Borough Water Dept. |
| United Water Delaware | Aqua Pennsylvania Water Co. |
| City of Wilmington Water Dept. | Chester Water Authority* |
| | Downingtown Mun. Authority |
| | Honey Brook Borough Water Authority |
| | Kennett Square Municipal Water Works |
| | London Grove Mun. Authority |
| | Pennsylvania American Water Co. |
| | West Grove Borough Water Dept. |

Source: Grieg et al., 1998; Chester County Planning Commission, 2010

The Chester Water Authority is marked with an asterisk because, although the purveyor supplies drinking water to residents within the Christina Basin, the sources of that raw water are actually in the Octoraro Watershed, the basin's western neighbor.

The surface waters of the Christina Basin alone have the capacity to provide more than 100 million gallons per day in public water supplies for local residents. Table 3.2 illustrates the capacity of each public water supplier that relies on surface water intakes, and the associated annual economic value of that water.

Table 3.2: Public surface water withdrawals

| State | County | Purveyor | Watershed | Capacity (mgd) | Water Rate ($/1000 gal) | Annual Value |
|---|---|---|---|---|---|---|
| DE | New Castle | City of Wilmington | Brandywine | 44 | $4.88 | $78,372,800 |
| DE | New Castle | City of Newark | White Clay | 3 | $5.92 | $6,482,400 |
| DE | New Castle | United Water DE | White Clay, Christina River | 36 | $6.28 | $82,519,200 |
| PA | Chester | PA American Co. | Brandywine | 6 | $9.21 | $20,169,900 |
| PA | Chester | Downingtown MUA | Brandywine | 2.5 | $7.65 | $6,980,625 |
| PA | Chester | Aqua America PA | Brandywine | 6 | $10.27 | $22,491,300 |
| | | | | **97.5** | | **$217,016,225** |

Source: Greig et al., 1998; Cruz and Miller, 2013

Clearly, public drinking water supplies represent a crucial and valuable natural resource within the region. On an annual basis it is a $215 million dollar industry for surface water supplies alone. Figure 3.2 illustrates the distribution of wells and intakes across the basin used by public water suppliers.

Figure 3.3 shows the areas of the Christina Basin in Delaware that contribute specifically to the county's public water supply surface intakes. Areas in yellow represent municipal boundaries. Areas in white represent the total area that drains (and therefore has the potential to contribute contaminants from land uses and activities) to the water bodies that supply thousands of Delawareans with their drinking water. All of the City of Newark and portions of New Castle County and the City of Wilmington are encompassed in this area. The towns of Elsmere and Newport lie beyond the extent of the contributing area, meaning that land uses and activities within this area have minimal potential to impact the quality or quantity of water at these intakes. Although not shown on this map, the contributing area upstream of the surface water intakes extends north to encompass the entire Pennsylvania portion of the basin.

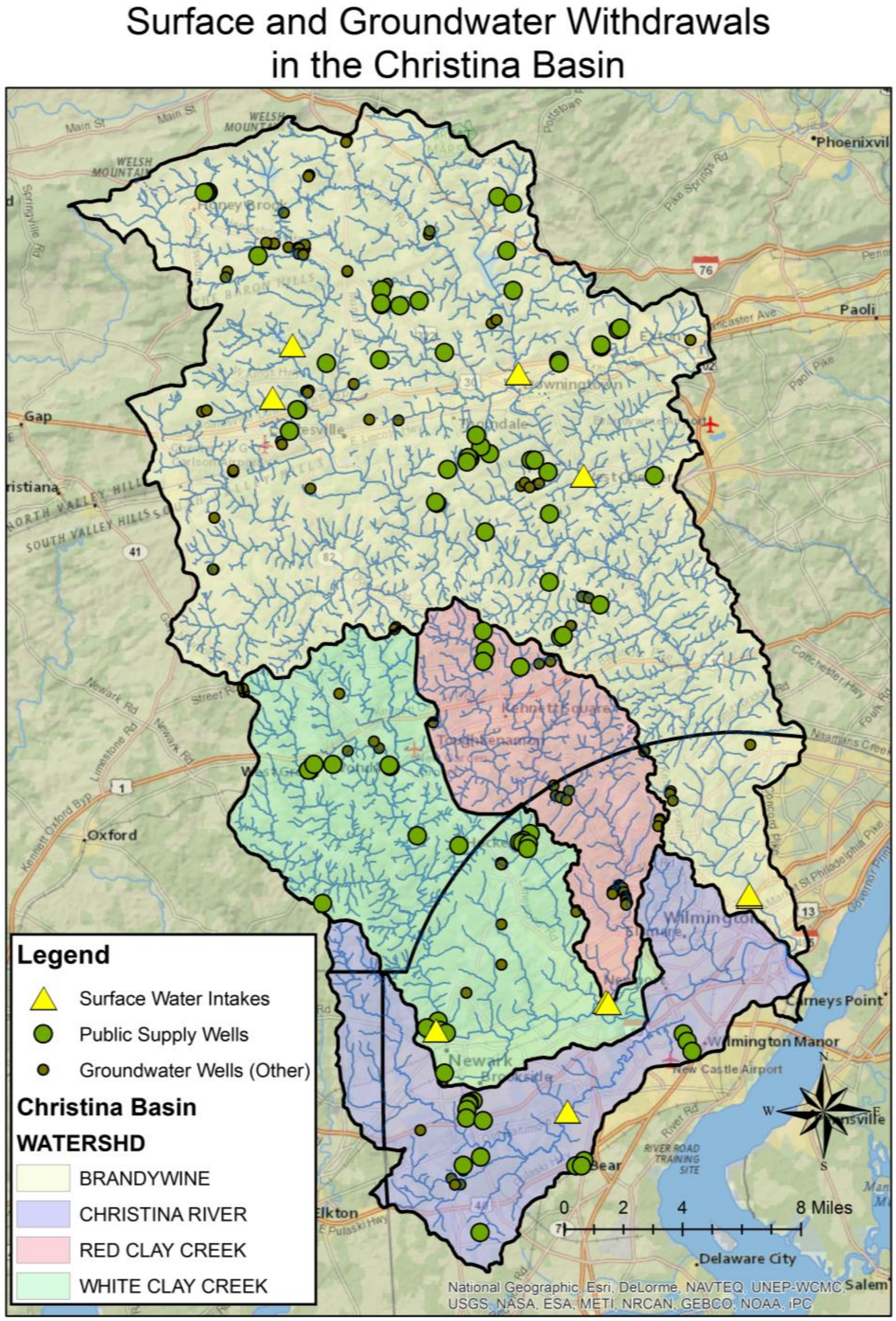


Figure 3.2: Surface and groundwater withdrawals in the Christina Basin

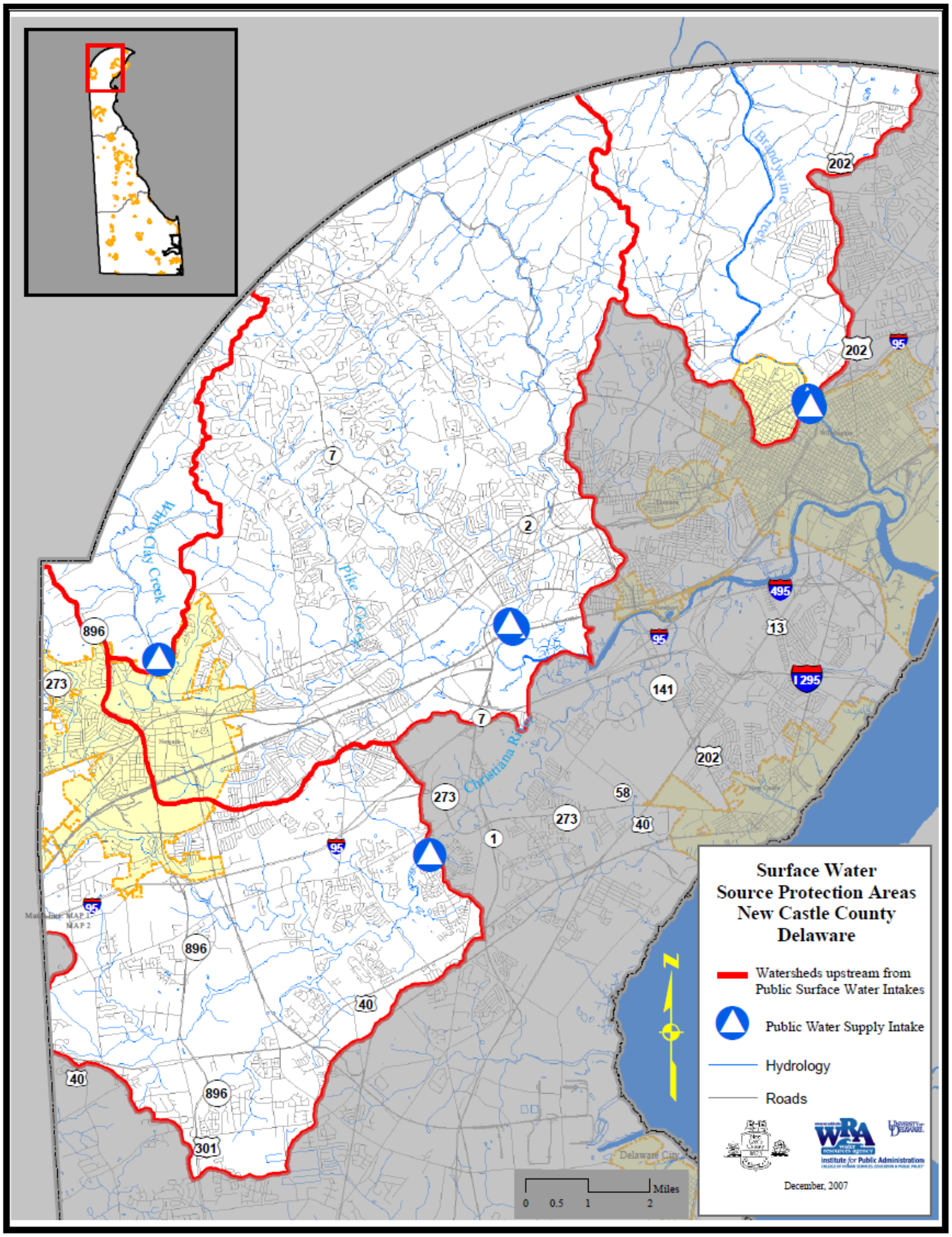


Figure 3.3: Surface water source water protection areas for New Castle County

### 3.4 Demographics and Land Use

Located between the major metropolitan cities of Philadelphia and Washington D.C., the Christina Basin is home to more than half a million people. The population of the basin at the 2010 Census was 591,000, an increase of 42,000 people (or about 8%) from the year 2000. The average population density in the basin is more than 1,000 persons per square mile, although this is not a uniform distribution, as some areas are significantly more urbanized and built up than others (Delaware Tributary Action Teams et al, 2011).

Land use in the basin is fairly evenly distributed between three major categories: agriculture; urban/suburban; and open space/forested lands. Each of these categories represents roughly a third of total land usage (Cruz and Miller, 2014). However, as with population density, the distribution of land use type is not uniform across the basin. Generally speaking, the Pennsylvania portion of the basin is covered with a greater percentage of agriculture and open space or forests, while the portion in Delaware is more heavily urbanized (Delaware Tributary Action Teams et al, 2011).

There have been no drastic land use changes over time, but there has been an overall increase in urbanized areas, particularly in the White Clay and Christina River watersheds. Agriculture has declined fairly steeply in these watersheds, and at a smaller scale in the Brandywine and Red Clay Watersheds (Delaware Tributary Action Teams et al, 2011).

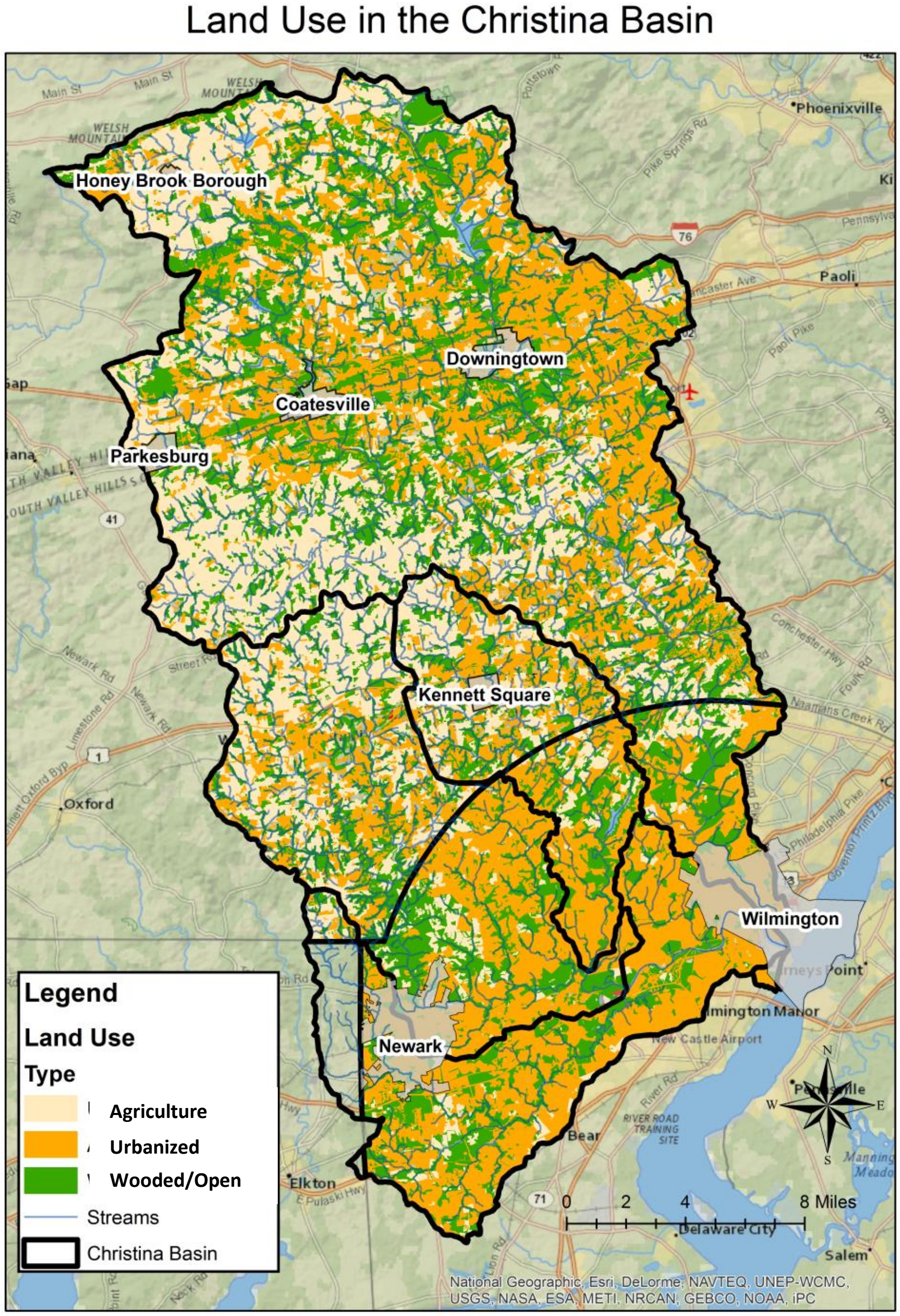


Figure 3.4: Land use in the Christina Basin

### 3.5 Water Quality

The area that makes up the Christina Basin has been inhabited and developed by humans for thousands of years. This human interaction with the environment has always had some impact on water quality within the basin. However, as the basin has become more populated and the amount of land under natural cover has decreased to give way to agricultural or urbanized uses, water quality has become an issue of increasing concern. Many common land uses have the potential to contribute to water contamination in the basin, including: transportation corridors; residential and commercial developments; industrial sites; landfills; cemeteries; and agricultural areas. The susceptibility of source waters to contamination depends on a variety of physical and geographic factors, and some sources are naturally more vulnerable than others. As an example of this, Table 3.3 illustrates the susceptibility of the surface water intakes in the Christina Basin in Delaware to a variety of common contaminants, as reported by their individual source water assessments. Those assessments were completed in 2002 by the University of Delaware in compliance with the 1996 amendments to the Federal Safe Drinking Water Act.

The source water assessments for the surface water intakes in the Pennsylvania Christina Basin vary in their content and formatting depending on the author of each individual report, but overall each report provides similar information on the potential sources of contamination to the public drinking water supply, and how vulnerable the public supply is to each potential contaminant. Source water assessments for every public drinking water provider are available online and in print through each provider.

Table 3.3: Susceptibility of Delaware's surface water intakes to contamination

| Susceptibility Matrix for Surface Waters in Delaware | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Metals** | **Other Inorganics** | **Nutrients** | **Pathogens** | **Petroleum Hydro-carbons** | **Pesticides** | **PCBs** | **Other Organics** |
| **Smalley's Pond, DE (United Water DE)** | Exceeds Standards (7) | Exceeds Standards (7) | High (5) | High (5) | High (5) | High (5) | High (5) | High (5) |
| **Stanton, DE (United Water DE)** | Exceeds Standards (7) | Exceeds Standards (7) | High (5) | High (5) | High (5) | High (5) | High (5) | High (5) |
| **White Clay Creek, DE (City of Newark)** | Exceeds Standards (7) | High (5) | High (5) | High (5) | High (5) | High (5) | High (5) | High (5) |
| **Hoopes Reservoir, DE (City of Wilmington)** | Exceeds Standards (7) | Moderate (4) | Low (3) | Low (3) | Low (3) | Low (3) | Low (3) | Low (3) |
| **Brandywine Creek, DE (City of Wilmington)** | Exceeds Standards (7) | Exceeds Standards (7) | Very High (6) | Very High (6) | Very High (6) | High (5) | High (5) | High (5) |

Understanding actual contamination is as important as understanding the susceptibility to or potential for contamination. Various contaminants have historically been identified in the surface waters of the Christina Basin. They include excess levels of nitrogen, phosphorus, bacteria, and sediment, as well as some heavy metals and hazardous organic compounds (Greig et al., 1998). The presence of these contaminants compromises the ability of the water bodies in which they are present to fulfill their designated uses. These designated uses are associated with specific water quality levels necessary for activities like boating, fishing, and swimming, as well as for waters that furnish the public water supply. In the first decade of the 21st century, Delaware and Pennsylvania were forced to establish Total Maximum Daily Loads (TMDLs) for the dozens of impaired stream segments within the basin in order to address some of the most pressing contaminant issues (Delaware Tributary Action Teams et al, 2011). These TMDLs, which for this specific area require reductions in levels of bacteria, nitrogen, and phosphorus, are essentially pollution diets that limit or cap the amount of a given pollutant allowed in a water body at a given time, regardless of the source of pollution.

Surface waters are not the only water bodies of concern. According to a groundwater study conducted by the USGS, the Chester County Water Resources Authority, and the Chester County Health Department, a host of contaminants were found in surveyed wells within the county between 1980 and 1998. Some, like chloride, formaldehyde, antibiotics, and detergents, were found in concentrations above natural conditions. Others, like nitrates, pesticides, and volatile organic compounds (specifically trichloroethylene, or TCE) were found in concentrations that exceed water quality standards set by the U.S. Environmental Protection Agency (Senior and Koerkle, 2003).

While some of the contaminants found in the waters of the basin are from point sources like wastewater treatment plants and industrial discharges, those are fairly well regulated and controlled. Nonpoint source pollution, like stormwater runoff from municipal and agricultural areas, is a growing problem within the basin and across the country. Because of its diffuse nature, this type of pollution is much more difficult to regulate and manage. However, it can be done through land use controls and the installation of best management practices (BMPs), which help to slow down and potentially stop the transport of contaminants from their place of origin to water bodies of concern.

### 3.6 Basic Political Boundaries, Actors, and Agencies

As an interstate watershed, the Christina Basin presents an interesting case study in managing water quality across political boundaries. The basin covers major portions of Chester County, Pennsylvania and New Castle County, Delaware, as well as small areas of Delaware and Lancaster counties in Pennsylvania and a sliver of land in Cecil County, Maryland. Table 3.4 describes the area of the basin within each state.

Table 3.4: State and county areas within the basin

| **State/County** | **Area (sq. mi.)** | **% of Basin** |
|---|---|---|
| Pennsylvania | 400.2 | 70.8% |
| Chester County, PA | 388.3 | 68.7% |
| Delaware County, PA | 9.1 | 1.6% |
| Lancaster County, PA | 2.8 | 0.5% |
| Delaware | 156.3 | 27.7% |
| New Castle County, DE | 156.3 | 27.7% |
| Maryland | 8.4 | 1.5% |
| Cecil County, MD | 8.4 | 1.5% |
| **Total** | **564.5** | **100%** |

Source: Greig et al., 1998

There are 65 political entities operating within the basin, including three states, five counties, 58 municipalities, and the Delaware River Basin Commission (DRBC), which through an interstate compact has some authority over water use and protection in the areas in the larger Delaware River Basin.

Beyond the governmental organizations with regulatory power over their respective jurisdictions, there is the Christina Basin Clean Water Partnership and its associated Task Force (formerly known as the Christina Basin Water Quality Management Committee). This group is a collaborative effort by public and private interests within the basin that the DRBC established to help achieve water quality goals through stakeholder involvement and BMP implementation. For roughly two decades, the Partnership has worked on projects ranging from rain garden installation and stream restoration to agricultural conservation, with the overall goal of

…be[ing] one of the first watersheds in the Delaware Valley to be restored to Clean Water Act fishable and swimmable goals and serve as an example of what can be achieved when governments and two states cooperate with progressive policies to restore the environment (Kaffman, 2009).

Without a doubt, these efforts have contributed both directly and indirectly to increases in source water quality throughout the basin. The organizational structure of this initiative, as well as the groups and organizations involved, are described below in Figure 3.5.

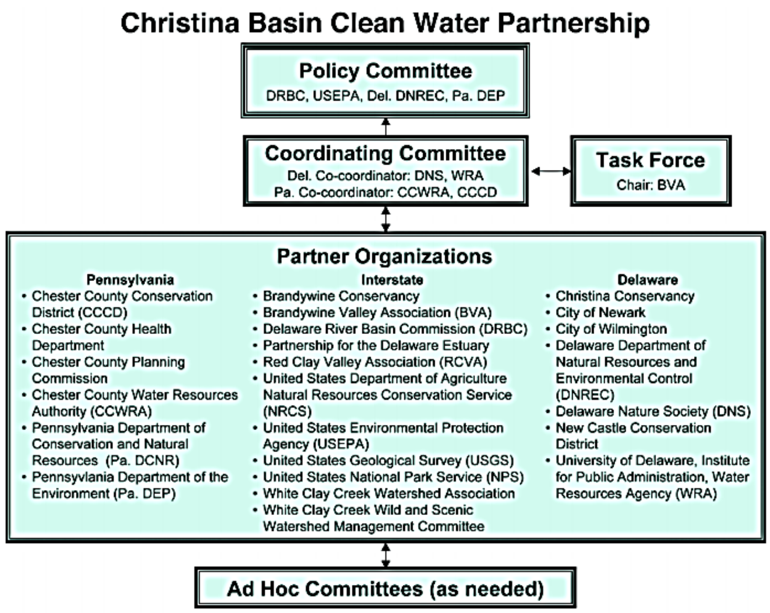


Figure 3.5: The organizational structure of the Clean Water Partnership

Another interstate watershed organization operating within the basin is the Wild and Scenic White Clay Creek Management Program. As mentioned earlier, the White Clay Creek watershed, which is a subwatershed within the Christina Basin, was the first to be designated in its entirety as a Wild and Scenic River by the federal government. This organization works in both Delaware and Pennsylvania to conserve and preserve the invaluable natural resources that led to the watershed's designation in 2000. Programs include BMP installation in local housing developments, education and outreach with local stakeholders, and open space preservation initiatives (Wild and Scenic White Clay Creek Management Program, 2013).

There are also a dozen or more nonprofit organization with varying missions that all relate in some way to protecting and enhancing local water quality. Some, like the Brandywine Conservancy, work directly with local governments to protect natural resources. Others, like the Stroud Water Research Center and the University of Delaware Water Resources Agency, have the capacity to provide technical information and support should local governments seek it out.

It should be noted that, for the purposes of this research, the tiny sliver of the basin in Maryland has been excluded from analysis and the following chapters will focus exclusively on Delaware and Pennsylvania.

Table 3.5: The state, county, and local governments of the Christina Basin

| Pennsylvania | | Delaware | Maryland |
|---|---|---|---|
| **Chester County** | Londonderry | **New Castle County** | **Cecil County** |
| **Cities/Boroughs -** | London Grove | **Towns -** | Elkton |
| Avondale | New Garden | Elsmere | |
| Coatesville | Newlin | Newport | |
| Downingtown | New London | **Cities -** | |
| Honey Brook Borough | Penn | Newark | |
| Kennett Square | Pennsbury | Wilmington | |
| Modena | Sadsbury | | |
| Parkesburg | Thornbury | | |
| South Coatesville | Upper Uwchlan | | |
| West Chester | Pocopson | | |
| West Grove | Valley | | |
| **Townships -** | Wallace | | |
| Birmingham | West Bradford | | |
| Caln | West Brandywine | | |
| East Bradford | West Caln | | |
| East Brandywine | West Fallowfield | | |
| East Caln | West Goshen | | |
| East Fallowfield | West Marlborough | | |
| East Marlborough | West Nantmeal | | |
| East Nantmeal | West Sadsbury | | |
| East Whiteland | West Vincent | | |
| Franklin | West Whiteland | | |
| Highland | Westtown | | |
| Honey Brook | **Delaware County** | | |
| Kennett | Bethel | | |
| London Britain | Chadds Ford | | |
| Londonderry | Concord | | |
| London Grove | **Lancaster County** | | |
| New Garden | Salisbury | | |

Source: Greig et al., 1998

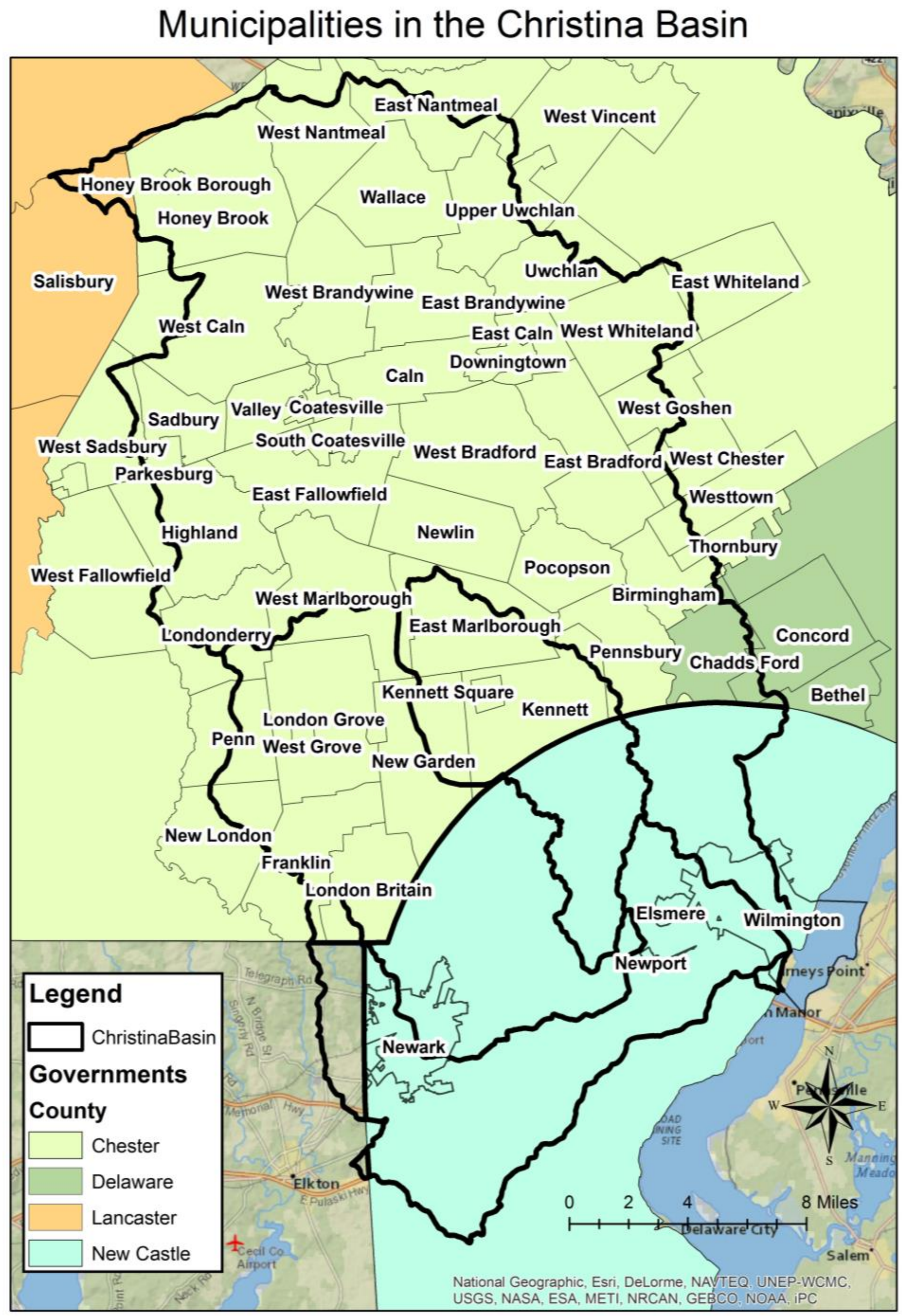


Figure 3.6: Municipal boundaries of the Christina Basin

# Chapter 4

# THE DIFFERENCES IN GOVERNANCE STRUCTURE IN PENNSYLVANIA AND DELAWARE

## 4.1 The Role of State Governance in Interstate Watersheds

Water has no regard for arbitrary political borders, and its only master is gravity. As Kauffman (2002) notes, if the boundaries of the states in this nation were based on natural watershed boundaries, there would be no issues or conflicts regarding interstate resource management. However, that is generally not the case in this country, and it is certainly not the case in the Christina Basin. As such, states that share common waters must cooperate with one another in order to manage resources in ways that benefit both upstream and downstream users.

Managing shared water resources between states has not always been a simple or conflict-free task. There are dozens of interstate water agreements and compacts throughout the country that have arisen as a result of conflicts between upstream and downstream user states. These agreements and compacts address the entire spectrum of both water quality and water quantity issues (Mittal, 2007). The Delaware River Basin, in which the Christina Basin is nestled, is home to one of the oldest and most successful interstate river basin compacts in the nation's history. The compact and its resulting commission were established in the mid-20th century as a result of litigation over water allocation between the states in the basin.

Even the Christina Basin has experienced interstate conflict over water resources. "During the early 1990's, Pennsylvania and Delaware had disagreements regarding the administration of water quality standards on both sides of the line in the Christina Basin. Perhaps conflicts in water issues are deeply rooted since the words ‘rival’ and ‘river’ are both derived from the Latin rivalis meaning ‘one using the same stream as another’” (Kauffman et al., 1999).

In addition to variations in laws and regulations between states that share watersheds, basic differences in governance structures can play a large role in the approach each state takes to managing the resources within its own borders. This chapter will give a brief overview of the governance structures in Delaware and Pennsylvania, and discuss the implications of those governance structures on source water protection in the Christina Basin.

### 4.2 Delaware’s Governance Structure

The governance structure in Delaware is less complex and contains fewer classifications than its northern neighbor, which is an interesting distinction because Delaware was actually a part of Pennsylvania during the Colonial era. What is today known as Delaware was formerly known as the three “Lower Counties” of Pennsylvania. Those three counties had a separate assembly from the one in what is modern-day Pennsylvania, and were relatively self-governing (Mack, 1990). The spilt from the “Upper Counties” came in 1776 when the representatives of the Lower Counties made the decision to separate themselves not only from the Royal Government of Britain, but also from Pennsylvania as well (“Delaware Declares Independence,” 2014). Subsequent to this separation from its northern neighbor, Delaware became the first state to sign the Declaration of Independence, sealing its place in history and its nickname as the “First State.”

To this day, the state is still divided into the three counties that were once a part of Pennsylvania. There are 57 municipal incorporated governments scattered across the state. They are self-governing units with their own laws and systems of government separate from that of the county, and they are not subject to the rules and regulations of the counties. All land outside of the jurisdiction of those municipal governments is unincorporated, and is therefore subject to the laws and jurisdiction of the county in which it is located. The majority of the state is unincorporated land, and this is certainly true for the portion of the state in the Christina Basin. Of the 158 square miles of land in the Delaware portion of the basin, roughly 88% is under the jurisdiction of New Castle County. The other 12% is divided among the four municipal governments of Wilmington, Newark, Newport, and Elsmere. In this way, the potential for inconsistencies in source water protection regulations is relatively low, since the physical distribution of governments dictates that 88% of the Delaware Christina Basin is subject to a single set of source water protection laws.

### 4.3 Pennsylvania's Governance Structure

The governance structure of the Commonwealth of Pennsylvania has its origins in colonial times. After receiving the land from the King of England in the 17th century, William Penn divided it up into various units of local governments based on the existing system in England. These governments included counties, boroughs, cities, townships, and towns (Pennsylvania Township News, 2007).

The basic governance structure in Pennsylvania is a tiered system. Each Pennsylvania resident lives within one of the state's 67 counties. Below the county level, there are the local governments: 1,547 townships, 960 boroughs, and 56 cities. Collectively, they make up the 2,563 municipal governments of the state. These categories of government can be broken down into classes (typically based on population size). However, there is relatively little difference in powers and authorities between the different types and classes, so this research will refer to them collectively as “local governments” or “municipalities.”

Both state and county laws apply to local governments in Pennsylvania. However, PA Act 247 (otherwise known as the Municipalities Planning Code) gives local governments primary authority to establish and regulate land uses within their jurisdictions through comprehensive plans, zoning codes, and land use and subdivision ordinances (Pennsylvania Department of Community and Economic Development, 2001).

One of the characteristics of Pennsylvania that sets it apart from many neighboring states is that all land within the state is incorporated and under the jurisdiction of one of the multitudes of local governments. Each local government has the right to establish its own land use laws. This has important implications source water protection regulations in the Christina Basin. The largest municipality in the Pennsylvania portion is Salisbury Township in Lancaster County, with a total area of 41.9 square miles, while the smallest municipality is the Borough of Modena in Chester County, at a mere 0.3 square miles in total area. The average size of a municipality in the Pennsylvania Christina Basin is roughly 11 square miles. This means that, on average, a person could drive 11 miles from any point in this area and end up in a different municipality that has a different set of ordinances governing land use and source water protection from the point at which they started. Put another way, it is possible that, because the Christina Basin encompasses 49 Pennsylvania municipalities, there could be 49 completely different sets of ordinances that impact source waters in this portion of the basin alone. From this perspective, one can see that the potential for inconsistencies in source water protection in the Pennsylvania portion of the basin is high.

### 4.4 Summary of Governance Structures in the Christina Basin

Table 4.1 provides an executive summary of the differences and similarities of the governance structures in Delaware and Pennsylvania. It shows that the primary difference between the two states in terms of structure is the powers and jurisdiction of the county level governments. The other major difference, as cited in the previous chapter, is the difference in the sheer number of government units between the two states. Because there is no unincorporated land in Pennsylvania, there are 53 local governments in that state, compared with only four local governments in Delaware.

Table 4.1: Comparison of Delaware-Pennsylvania governance structures

| | **Delaware** | **Pennsylvania** |
|---|---|---|
| **State** | -Has primary legal and legislative authority over all counties, cities, towns, and unincorporated lands | -Has primary legal and legislative authority over all counties, cities, boroughs, townships, and towns |
| **County** | -Number of Christina Basin counties = 1<br><br>-Has legal jurisdiction over all unincorporated land within its borders under the state<br><br>-Has primary authority for creating rules and regulations regarding land use | -Number of Christina Basin counties = 3<br><br>-Has some authority over cities, townships, borough, and towns within its jurisdiction, generally concerning public health, welfare, and the courts |
| **Local** | -Number of Christina Basin municipalities = 4<br><br>-Has legal jurisdiction under the state but independent of the county for all lands within its borders.<br><br>-Has primary authority for creating rules and regulations regarding land use | -Number of Christina Basin municipalities = 53<br><br>-Has primary authority for creating rules and regulations regarding land use within its jurisdiction |

## 4.5 State-level Approaches to Source Water Protection in Delaware

At the state level in Delaware, source water protection is addressed by the Source Water Protection Law of 2001, which requires counties and municipalities with year-round populations above 2,000 to delineate areas crucial to the quality of both ground and surface source water, and regulates the human activities and land uses that can occur within those areas. In addition, it requires the Department of Natural Resources and Environmental Control (DNREC) to provide these counties and municipalities with the assistance they need to comply with the law. This technical assistance has been provided in part through a comprehensive manual on source water protection under the new law, authored by the University of Delaware Water Resources Agency.

Essentially, the Delaware law requires that municipalities incorporate the findings of the source water assessments that were federally mandated by the Safe Drinking Water Act's 1996 amendments into local land use ordinances and codes. Figure 4.1, provided by the University of Delaware Water Resources Agency (2001) shows the designated water resource protection areas (WRPAs) identified in northern New Castle County under the law. These areas are to receive elevated levels of land use protection from both county and local governments.

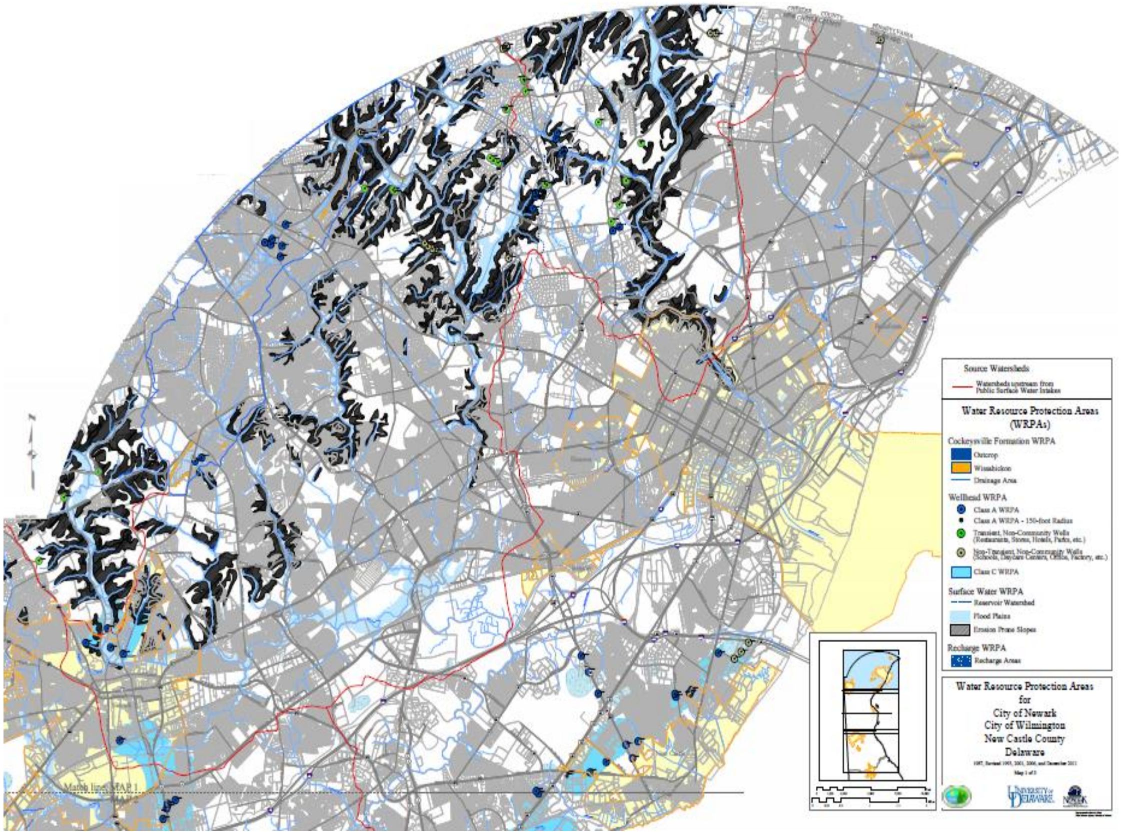


Figure 4.1: Northern New Castle County WRPAs

Though the law does not specifically define the changes to local land uses, the comprehensive manual put forth by the University of Delaware Water Resources Agency describes a variety of land use management techniques, best management practices, and model source water protection ordinances that local governments can use.

### 4.6 State-level Approaches to Source Water Protection in Pennsylvania

The 1968 amendments to the Pennsylvania Constitution state in Section 27 of Article 1 that "Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustees of these resources the Commonwealth shall conserve and maintain them for the benefit of all the people." In addition, the State's Municipalities Planning Code "has been amended several times to encourage local governments to address valuable natural and cultural resources such as agricultural lands, wetlands, floodplains, historic and water supply resources" (Pennsylvania Department of Community and Economic Development, 2001).

However, there is currently no state law requiring county or local governments to implement source water protection or wellhead protection programs. There are a variety of factors that underlie the absence of a statewide law, and those are difficult to quantify without delving into social science research and interviewing state law makers. A possible reason for the lack of a state law is that Pennsylvania is such a large state with highly diverse political and economic interests that passing a comprehensive environmental bill might be more difficult than in a smaller, more homogeneous state like Delaware. In addition, the current boom in natural gas drilling in the Marcellus Shale regions of the state may have created a disincentive for the development of a state source water protection law, as the regulations and restrictions under the law may restrict natural gas production efforts. These explanations are based primarily on personal observations, and further research into the reasons why the state government has been silent on source water protection may be beneficial in the future.

The Pennsylvania Department of Environmental Protection provides technical and informational support for those communities that voluntarily choose to implement such programs, but by and large that is the extent of State level involvement in source water protection initiatives. It is up to each individual municipal government to decide whether or not they wish to implement their own program.

## 4.7 Summary of Approaches to Source Water Protection in the Christina Basin

Table 4.2 on the following page provides an executive summary of the differences between Pennsylvania and Delaware in their approaches to source water protection. These differences in state approaches combined with the differences in governance structures set the stage for this research. The subsequent chapters will strive to show whether or not there is consistency in levels of direct and indirect source water protection at the local level across the basin, despite the many differences between the two states encompassed by it.

Table 4.2: Comparison of state source water protection approaches

| Delaware | Pennsylvania |
|---|---|
| • Source Water Protection Law of 2001<br>• Requires incorporation of source water assessment findings (per the Federal Safe Drinking Water Act amendments of 1996) into local land use ordinances | • No statewide law regarding source water protection<br>• Technical and informational assistance from the State Department of Environmental Protection available for local governments that voluntarily choose to implement a program |

# Chapter 5

# RESEARCH METHODOLOGY

## 5.1 Municipal Code and Ordinance Review

All local government and county ordinances within the basin (except for Cecil County, Maryland which was excluded) were reviewed and their direct and indirect source water regulations were quantified using an original source water checklist. This checklist was developed after reviewing relevant literature regarding model source water ordinances (U.S. EPA, 2013) and similarly-formatted stormwater ordinance reviews (Water Resources Agency for New Castle County, 1998; South Carolina Department of Health and Environmental Control, N.D.; New Jersey Department of Environmental Protection, 2004). Figure 5.1 gives an example of the format and wording of a stormwater municipal regulations checklist developed by the New Jersey Department of Environmental Protection as part of its Stormwater Best Management Practices Manual (2004). This basic style and formatting, as well as some of the relevant content, was used to inform the ordinance checklist for this research.

**D. Riparian Buffers**

Municipalities may have existing buffer and/or floodplain ordinances that require the protection of vegetation adjacent to streams. Municipalities should consult existing regulations adopted by the Department to ensure that riparian buffer or floodplain ordinances reflect the requirements of the Department within these areas. The municipality should consider conservation restrictions and allowable maintenance to ensure the preservation of these areas.

❑ Yes ❑ No Is there a stream buffer or floodplain ordinance in the community?

❑ Yes ❑ No Is the ordinance consistent with existing state regulatory requirements?

❑ Yes ❑ No Does the ordinance require a conservation easement, or other permanent restrictions on buffer areas?

❑ Yes ❑ No Does the ordinance identify or limit when stormwater outfall structures can cross the buffer?

❑ Yes ❑ No Does the ordinance give detailed information on the type of maintenance and/or activities that is allowed in the buffer?

New Jersey Stormwater Best Management Practices Manual • Appendix B: Municipal Regulations Checklist • February 2004 • Page B-2

Figure 5.1: Example ordinance checklist

The majority of the data for this research was extracted from the zoning, land use and subdivision, and stormwater ordinances within the larger codes of each municipality. For New Castle County in Delaware, the Unified Development Code (most recently amended in January 2014) provided the majority of the data for the county. Also of significant importance was the State of Delaware Sediment and Stormwater Regulations (effective January 2014) which informed the majority of the stormwater data for municipalities within the State, as well as the Chester County Health Department Rules and Regulations On Water Well Construction and Individual and Semi-Public Water Supplies (Chapter 500), which informed the majority of the source water protection data for the municipalities in that county.

The checklist (Table 5.1) identifies four categories of source water-related regulations: direct source water protection; natural resource protection; stormwater management; and education and accessibility.

The first category addressed by this checklist review is direct source water protection. Obviously, a source water protection ordinance is the most direct indicator of a municipal source water protection program. This ordinance may be broad and encompass many different regulations; however, it is assumed that the municipalities with such ordinances have dedicated efforts into identifying source water areas and made conscious decisions to protect those areas in some manner.

The number of public supply wells within the basin far surpasses the number of surface water withdrawals, so it was particularly important to examine the protections that focus on groundwater resources. These included: wellhead buffer ordinances, which restrict land uses around the point where water is withdrawn for public supplies in order to protect the quality of groundwater; septic system siting regulations, since these systems can pose an elevated risk to groundwater if they are improperly installed or begin to fail; and the protection of areas of significant groundwater recharge, since these areas are typically at an increased risk of conveying pollutants into groundwater resources. Regulating activities and development near these areas in particular can have a direct impact on minimizing the potential for contamination (New England Interstate Pollution Control Commission, n.d.).

The final three categories in the checklist review deal with indirect source water protection. These are initiatives that are typically broader environmental rules and regulations that aren't solely put in place to protect drinking water sources, but their establishment does indirectly contribute to a safer, better protected water supply. Those parameters are described in terms of their benefits to source waters below.

The natural resource areas discussed in the table were chosen to be part of this analysis because they either serve as barriers to or conduits for contaminants reaching waterways. Riparian buffers, protected floodplains, wooded areas, wetlands, and wetland buffers can all provide ecosystem services that benefit drinking water quality, including slowing down and encouraging the infiltration, filtration, and uptake of runoff waters (Water Resources Agency for New Castle County et al., 1998). Karst or carbonate features are geologic features that are porous by nature and can act as an easy conduit for pollutants to infiltrate into the groundwater system. Restricting potentially harmful land uses or activities in these areas can help prevent contamination (Drew and Holtz, 1999). Similarly, restricting land uses and activities on steep slopes (generally those with a gradient of 15% or more) can minimize erosion and keep sediments, which are a costly contaminant to remove at water treatment facilities, out of the drinking water supply (Water Resources Agency for New Castle County et al., 1998).

Stormwater runoff is particularly important to the quality of raw drinking water because it is often the carrier of contaminants over land and into waterways and groundwater. Stormwater management typically focuses on two techniques: minimizing and/or mitigating runoff (Water Resources Agency for New Castle County et al., 1998). Requiring stormwater runoff rates for new construction to be reduced to pre-developed levels and requiring at least some form of treatment for that runoff can protect water quality by mimicking natural hydrologic conditions.

Similarly, reducing the amount impervious cover in both critical areas and across the municipality can encourage infiltration and reduce the overall amount of runoff with the capacity to carry pollutants into waterways. One simple but powerful example of impervious cover management can be demonstrated by establishing low minimum parking stall areas. It is typical for municipalities to set minimum standards for stall sizes for both off and on-street parking. A parking stall with dimensions of 9 feet by 18 feet has a total area of 162 sq. feet. In comparison, a parking stall with minimum dimensions of 10 feet by 20 feet (as is required in some municipalities) has a total area of 200 sq. feet. This is a difference of 38 sq. feet of impervious cover per parking space.

The final category in this checklist briefly quantifies each municipality's efforts to educate their citizenry about water quality issues and the local regulations in place that influence them. Access to information and educational materials is a crucial component of source water protection because it allows local citizens, who are ultimately drinking water consumers, to make themselves more knowledgeable on the subject and to make informed decisions regarding their own actions relating to water quality. The availability of municipal ordinances online also provides a level of transparency so that landowners and residents can understand is required of them, and so that they can be aware of what regulations are already in place should they decide to advocate for stronger protections.

Table 5.1: Direct and indirect source water protection checklist

| Source Water Protection Ordinance Checklist | |
|---|---|
| **Direct Source Water Protection** | **Rating** |
| Does the municipality have a source water protection ordinance? | Yes/No SW areas (1)<br>No (0) |
| If a wellhead buffer ordinance is in place, how wide is the buffer area required to be? | No buffer (0), 1-250 ft (0.5)<br>≥ 250 ft /No wells (1) |
| Are there specific prohibited activities and uses within the buffer? | Yes/No wells (1)<br>No/No buffer (0) |
| Are there regulations or ordinances governing the placement of septic systems near wellheads? | Yes/No wells (1), No (0) |
| Do the ordinances define special protections or restrictions in groundwater recharge areas? | Yes (1), No (0) |
| **Natural Resource Protection** | **Rating** |
| Does the municipality have specific protections for karst/carbonate areas? | Yes (1), No (0) |
| Does the municipality have a wetland buffer ordinance, and how wide is the buffer area required to be? | No buffer (0), 1-25 ft (0.25)<br>26-50 ft (0.5), 51-74 ft (0.75)<br>≥ 75ft (1) |
| Is there a stream buffer ordinance in place, and how wide is the buffer area required to be? | No buffer (0), 1-20 ft (0.25)<br>21-40 ft (0.5), 41-74 ft (0.75)<br>≥ 75ft (1) |
| Do the ordinances restrict or prohibit development within the 100 year floodplain? | Prohibit (1), Restrict (0.5)<br>No restrictions (0) |
| Do the ordinances call for the preservation of wooded areas or trees? | Yes (1), No (0) |
| Do the ordinances protect steep slopes, and at what gradient do land use restrictions or prohibitions begin for steep slope areas? | No protections (0)<br>≥ 25% (0.25), 16-24% (0.5)<br>≤ 15% (1) |
| Does the ordinance list allowable and prohibited uses for open space? | Yes (1), No (0) |
| **Stormwater Management** | **Rating** |
| Is there a stormwater ordinance that requires runoff from new development to be reduced to pre-development conditions? | Yes (1), No (0) |
| Is stormwater from new development required to be treated for quality (either through natural, chemical, or engineered means) before it leaves the lot or enters a natural water body? | Yes (1), No (0) |
| What is the impervious cover standard/maximum in critical areas like floodplains, stream buffers, wetland buffers, etc., calculated as a percentage of the total lot area? | No standard (0), ≥ 50% (0.1)<br>35-49% (0.25) , 20-34% (0.5)<br>11-19% (0.75), ≤ 10% (1) |
| What is the impervious cover standard/maximum in all zoning districts throughout the municipality, calculated as a percentage of the total lot area? | No standard (0), ≥ 50% (0.1)<br>35-49% (0.25) , 20-34% (0.5)<br>11-19% (0.75), ≤ 10% (1) |
| Is the required minimum parking stall area 162 sq. feet (9 by 18 feet) or less? | Yes (1), No (0) |
| **Education and Accessibility** | **Rating** |
| Does the municipality have a website? | Yes (1), No (0) |
| Does the municipality have their codes available online? | Yes (1), Partially (0.5)<br>No (0) |
| Does the municipality have information about water quality (drinking water, stormwater, etc.) available on their website? | Yes (1), No (0) |

## 5.2 Background Municipal Data Collection

In an effort to determine if there are any underlying characteristics that can serve as predictors for how well a municipality's ordinances act to directly and indirectly protect source water (as measured by the scoring matrix described in the next section), the following information was collected for each municipality. This data was then set aside to be incorporated into the statistical analysis.

Table 5.2: Background municipal data

| Parameter | Unit of Measurement | Data Source |
| --- | --- | --- |
| Size of Municipality | sq. mi. | University of Delaware Water Resources Agency |
| Population | Persons | U.S. Census 2010 |
| Population Density | Persons per sq. mile | U.S. Census 2010 |
| Population Growth Rate | % change | U.S. Census 2010 |
| Urban Population | % of total population | City-Data.com |
| General Fund Budget | Dollar amount | Municipal websites/personal contact |
| Median Household Income | Dollar amount | American Community Survey (2008-2012) |
| High School Education or higher | % of total population | American Community Survey (2008-2012) |
| Public Water Supply Surface Intake/Groundwater Well | Present within the municipality: Yes/No | University of Delaware Water Resources Agency, Chester County Water Resources Authority |
| Agricultural Land Use (aggregated crop land, agricultural uses, pastures, etc.) | % of total municipal area | University of Delaware Water Resources Agency, Chester County Planning Commission, Delaware Valley Planning Commission, Pennsylvania Spatial Data Access Clearinghouse |
| Urbanized Land Use (aggregated residential, commercial, built-up, industrial, etc.) | % of total municipal area | University of Delaware Water Resources Agency, Chester County Planning Commission, Delaware Valley Planning Commission, Pennsylvania Spatial Data Access Clearinghouse |

## 5.3 Scoring Matrix

Each checklist item or question is worth up to 1 (one) point in the associated scoring matrix. Items that quantify specific distances or other numerical data may be broken into gradations where partial points are awarded. For items where more than one answer was selected (e.g., impervious cover standards in critical and non-critical areas), the point values for each recorded answer were averaged together. For the direct source water protection category, a full point was awarded for the relevant checklist items to those municipalities who have no land areas that contribute to or impact source waters (i.e., Newport and Elsmere in Delaware) and to those without any public water supply wells. This was done in order to avoid penalizing municipalities for not having ordinances that are actually unnecessary within their borders. The same logic was also used to amend the scores for municipalities where certain natural resources were absent. Table 6.7 in the following chapter lists the total area or presence of each natural resource in each municipality. This data was used to identify those municipalities whose scores needed to be amended to reflect the absence of one or more natural resources.

Because this research is attempting to quantify only the presence or absence of regulatory source water protection measures and not the effectiveness of any such measures, no value-laden weighting system based on the strength of any given effort has been applied to these scores.

Once all of the ordinance data was collected, the answers were converted into scores based on the values outlined in the tables in the previous section. The scores were then totaled by category and across the entire dataset and set aside for statistical analysis. In order to provide a comparison to these raw scores, the calculated scores were then adjusted by the municipalities' total land area within the watershed. This was done in order to better understand the impact of municipal size (particularly in Delaware, where New Castle County covers 88% of the basin within that state) on the overall level of source water protection.

## 5.4 GIS Analysis of Source Water Protection and Natural Resources

Mapping of geographic, political, and natural features was completed using ESRI ArcGIS software (version 10) in order to supplement the ordinance data. All of the layer data for the State of Delaware was provided by the University of Delaware Institute for Public Administration Water Resources Agency. The layer data for Pennsylvania was provided by the Chester County Water Resources Authority, the Chester County Department of Computing and Information Services, and the Pennsylvania Spatial Data Access (PASDA) clearinghouse provided by the Pennsylvania State University.

Maps of the watershed with the appropriate physical boundaries were generated in order to provide spatial context for the region. Then, the scores associated with the ordinance data were uploaded to the ArcGIS program and joined to the municipalities layer in order to visually represent the distribution of scores across the basin.

In an effort to better understand how the language and content of the ordinances impact the natural resources located within a municipality's jurisdiction, six natural resources were mapped across the basin. Those resources, followed by the units they were measured in, were: woodlands (acres); wetlands (acres); steep slopes (acres); floodplains (acres); stream miles (miles); and karst features (present or not).

The ordinance data was cross-referenced with the natural resources layer and used to identify those municipalities where a natural resource was present but a related ordinance to protect it was not. The total area, mileage, or presence of each unprotected resource (if any) was then compiled for each municipality. The goal of this analysis was to determine where and how much of each natural resource might be vulnerable to degradation or destruction because it is not protected by the language of the ordinances.

It is important to note that, with the exception of wetlands (which come from a single National Wetlands Inventory layer), it cannot be assumed that the area of these natural resources or the definitions under which they were created are identical across state boundaries. There is no single protocol for the development of natural features in GIS software, and the creators of these layers (and therefore their methods) may not be the same. However, since there are no multi-state layers available that would represent a guaranteed uniform methodology, this analysis assumes that the definitions and calculated areas are similar enough in their outcomes that they can be compared to one another in order to form a more complete picture about resource availability within the basin.

### 5.5 Statistical Analyses

Three separate statistical analyses were performed using JMP 11 Desktop Software from SAS Institute Inc. The questions that each analysis sought to answer were as follows:

1. Are the collective average scores of each state statistically different from one another?
2. Do any of the parameters collected as "background" data correlate with the municipal scores, and therefore serve as potential predictors or motivators of source water protection regulations?

3. Do any of the natural resources identified as part of the GIS analysis correlate with the municipal scores, and therefore serve as potential predictors or motivators of source water protection regulations?

For the state to state comparison in the first analysis, the results of the scores were separated into categories (Pennsylvania and Delaware), and then they were compared to one another using a two-tailed Students t-test using the null hypothesis that the scores of the two states were not statistically different from one another and an $\alpha$ (or probability) cutoff value of 0.05. This test was also performed on the land area-weighted scores.

The process for the final two analyses was exactly the same. First, each of the parameters in the municipal background data was compared to the municipal scores through multivariate analyses using both pairwise (Pearson's r) and nonparametric (Spearman's $\rho$) correlation analyses, both with an $\alpha$ value of 0.05. For parameters with normally distributed data, the results from the pairwise analysis were used to assess the strength of any apparent correlations. For those parameters where data was not normally distributed, the results from the nonparametric analysis took precedence. This process was then repeated, but the background data was swapped out for the total area/mileage/presence of natural resources and features in each municipality as quantified by the GIS analysis.

### 5.6 Surface Water Quality Analysis near Public Water Supply Intakes

Existing water quality data from sites that are proximately located to surface water intakes in the basin were collected and analyzed for trends over time. While these data cannot be directly linked to the source water regulations of the municipalities, this analysis is meant to serve as a supplement to the ordinance review and indicate whether those regulations, along with complementary federal, state, and voluntary programs, are impacting the quality of local source waters. Due to the complex nature of groundwater contaminant transport, this analysis includes only surface water quality.

The sites used in this analysis were chosen based on their proximity to public water supply surface intakes (either in streams or reservoirs) and the availability of data on water quality. Several additional sites were chosen for their location on the Pennsylvania-Delaware border. The sites in each state are listed in Table 5.3 on the following page.

Table 5.3: Water quality sites in Delaware and Pennsylvania

| Site | Watershed | Proximity to Intake | Data Source |
|---|---|---|---|
| **Delaware** | | | |
| Station 105171 at McKee's Lane | White Clay Creek | 1 mile downstream City of Newark's Papermill WTP | DNREC (2006-2012) |
| Station 105011 at Rte. 7 Bridge | White Clay Creek | 1/4 mile upstream of United Water Delaware's Stanton WTP | DNREC (1995-2008) |
| Station 103011 at Rte. 4 Stanton | Red Clay Creek | 1/3 mile upstream of United Water Delaware's Stanton WTP | DNREC (1995-2012) |
| Station 104011 at Foot Bridge in Brandywine Park | Brandywine Creek | Just downstream from Wilmington's Porter WTP and just upstream from Wilmington's Brandywine WTP | DNREC (1995-2012) |
| Gage 01481500 at Wilmington | Brandywine Creek | 1 mile upstream from Wilmington's Porter WTP and from Wilmington's Brandywine WTP | USGS (2006-2014) |
| Station 105031 at Chambers Rock Road, | White Clay Creek | Stateline station | DNREC (1995-2012) |
| Station 103041 at Barley Mill Road | Red Clay Creek | Stateline station | DNREC (1995-2012) |
| **Pennsylvania** | | | |
| Station 104051 at Smith's Bridge | Brandywine Creek | Stateline station | DNREC (1995-2012) |
| Rock Run (Coatesville) Reservoir | Rock Run (Brandywine Creek Tributary) | At reservoir intake | PA American Water Co. (2006-2013) |
| Gage 01480617 at Modena | Brandywine Creek (West Branch) | 4.3 miles downstream from the Rock Run Reservoir | USGS (2005-2014) |
| Gage 01480870 below Downingtown | Brandywine Creek (East Branch) | Just north of the intake for the Aqua Pennsylvania West Chester Intake on the Brandywine | USGS (2005-2014) |
| Gage 01481000 at Chadds Ford | Brandywine Creek | Stateline station | USGS (2005-2014) |

Discussions with drinking water professionals led Hurley et al. (2012) to conclude that the three essential water quality parameters to study for source waters that will ultimately be chlorinated (a common disinfection method) were E. coli, total organic carbon (TOC), and turbidity. According to Hurley and Mazumder (2013), when measured together "these three parameters capture aspects of microbial risk, disinfection byproduct formation risk, and treatment interference and aesthetic concerns."

The turbidity data to which Hurley et al. (2012) refer is an analysis of sediment in the water column. There are two different ways to quantify that sediment, and the methods used by Delaware and Pennsylvania are not consistent across state lines. Turbidity data is collected at some of the U.S. Geological Survey (USGS) stream gage stations in Pennsylvania and a few gages in Delaware, while data on total suspended solids (TSS) is collected at water quality monitoring stations installed and maintained by the Department of Natural Resources and Environmental Control in Delaware.

There are different reasons for collecting TSS versus turbidity data. TSS is a direct measure of sediment in the water column and is therefore more accurate, but it is an expensive process that is typically cost prohibitive of any monitoring on a basis more frequent than monthly. On the other hand, measuring turbidity is an indirect way of analyzing sediment concentrations though the use of underwater light scattering technologies and sensors. This is used as a proxy for TSS since it is less expensive, and measurements can be taken in real-time on a daily basis, or in some cases even more frequently (Susfalk et al., 2008).

TSS data was available for all sites in Delaware, and turbidity was available for one of the state's stations. Turbidity data was available for all of the sites in Pennsylvania. Data on enterococcus, a type of bacteria that can cause medical conditions such as urinary tract infections and diverticulitis (Fisher andPhillips, 2009) was available at the monitoring stations in Delaware and was used as a substitute parameter for E. coli. Enterococcus can be found in the fecal matter of both humans and animals, and is thought to be a stable indicator of other disease-causing bacteria in the water column. Unfortunately no data was available in either state on TOC, so this work does not present an analysis of that water quality component.

Each set of water quality data was analyzed in Microsoft Excel using a basic correlation matrix to determine the presence of trends over time, and a calculated $R^2$ value was used to determine the strength of the trend.

# Chapter 6

# RESULTS

## 6.1 Municipal Ordinance Review and Scores

The results collected from reviewing the ordinances of each municipality (as well as relevant state or county regulations) were compiled and the results converted into scores. For the sake of brevity and formatting, only summary tables are included in this chapter. The raw data tables for both results and scores for each municipality are available in the appendices.

A state to state and county to county comparison of scores is provided in Table 6.1 below. The maximum achievable score for any municipality was 20 points.

Table 6.1: State and county ordinance review scores

| State | # of Local Governments | Raw Average Score | Land Area-Weighted Average Score | Range of Raw Scores |
|---|---|---|---|---|
| Pennsylvania | 53 | 13.0 | 12.8 | 8.0 – 16.9 |
| Chester Co. | 49 | 13.0 | 12.9 | 8.0 – 16.9 |
| Delaware Co. | 3 | 12.5 | 12.2 | 10.8 – 13.5 |
| Lancaster Co. | 1 | 10.0 | 10.0 | 10.0 |
| Delaware | 5 | 13.2 | 15.9 | 9.9 – 16.3 |

The average score and the range of scores for each level of government show that the municipalities in Delaware have a very slight edge over the municipalities in Pennsylvania in source water protection regulations. Chester County is not far behind

Delaware in terms of average score. Chester County also demonstrates the widest range of scores that includes both the highest and lowest scores in the entire Basin. Delaware County and Lancaster County have lower averages, although there are so few municipalities represented from these counties in the basin that it does little to alter the average score for the state of Pennsylvania overall.

The land area-weighted average scores of each county and state tell a slightly different story than the raw scores. In Delaware, the average score jumps from 13.2 to 15.9. This accounts for the fact that New Castle County covers more than 88% of the basin in Delaware and is one of the highest scoring local governments in the basin. Therefore, in this case the weighted score is more likely to give an accurate representation of the distribution of source water protection regulations in the Delaware portion of the basin. In Pennsylvania, the change in score is barely noticeable from the raw score to the adjusted score. This is because the spatial distribution of municipalities in Pennsylvania is more uniform than in Delaware, and so land-area weighting has less of an impact on the overall scores.

The overall rankings for each municipality as they compare with one another are displayed in the Figures 6.1 and 6.2.

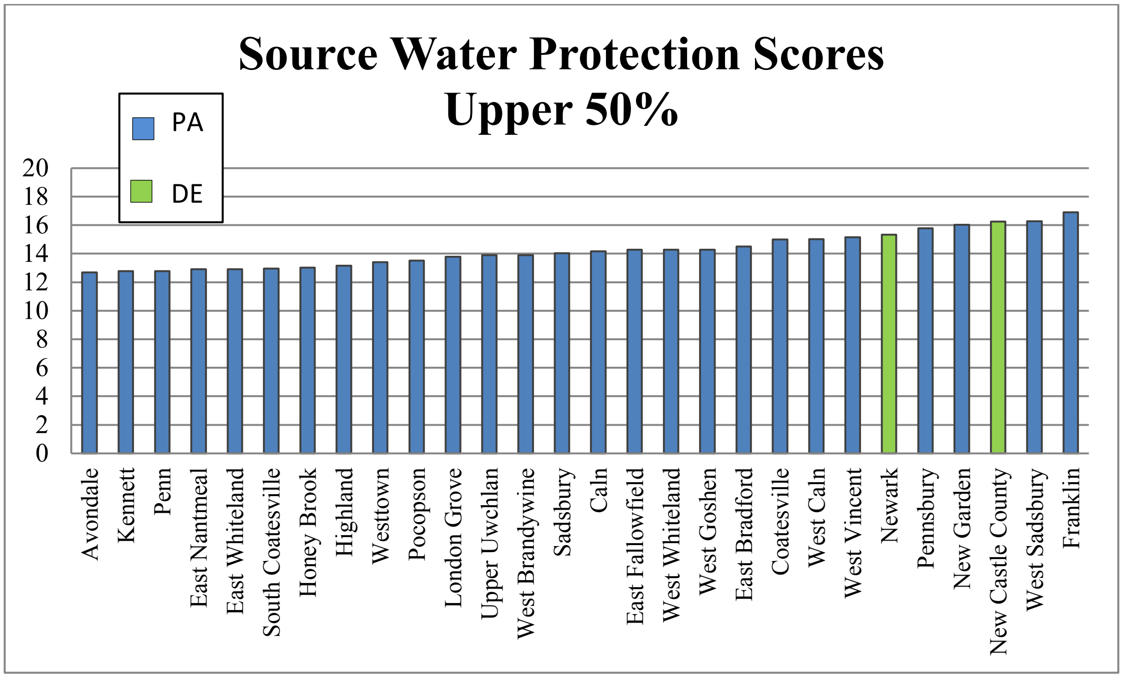


Figure 6.1: Municipalities in the upper 50% of ordinance review scores

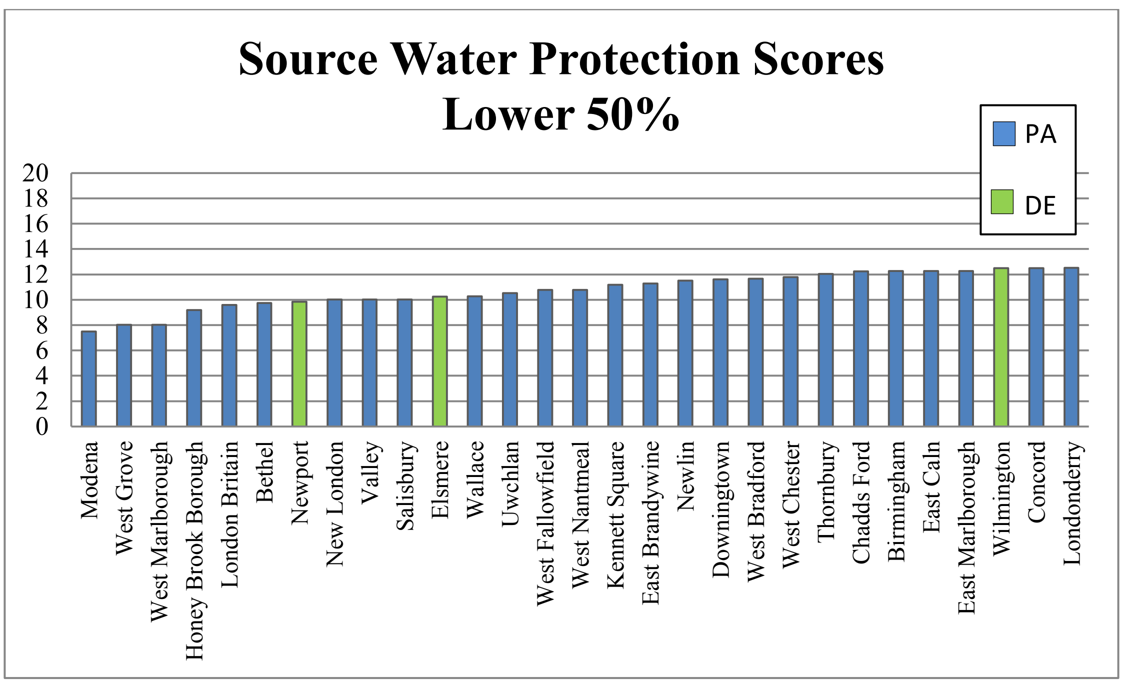


Figure 6.2: Municipalities in the lower 50% of ordinance review scores

The following set of tables depicts the average score in each county for all of the twenty ordinance checklist parameters. The charts are divided based on the four categories in the ordinance review: direct source water protection; natural resource protection; stormwater management; and education and accessibility. The highest possible score for each parameter is 1. The averages presented in these tables were calculated by summing the total point values by parameter for all of a county's municipalities and then dividing that value by the total number of municipalities in the county.

For the direct source water protection set of scores, the state law in Delaware is clearly evident in the State's results for having a source water protection ordinance. Three out of the five local governments (New Castle, Newark, and Wilmington) have ordinances that directly address the issue, as the law requires. The two municipalities in Delaware that do not have such an ordinance are outside of the boundaries of any identified source water protection area, and neither have any public water supply wells within their jurisdictions. Wilmington, Delaware also has no public supply wells within its jurisdiction.

In Chester County, the high average value for wellhead buffers and wellhead buffer protection is the result of a county level health code law (Chester County Health Code Ch. 500: Water, Nuisances, Sewage and Liquid Waste). A handful of municipalities in the county have their own wellhead buffer standards incorporated into their codes, but the county law takes precedence over all municipalities in regulating activities and land uses around all public water supply wells. This extends even to the 31 municipalities in the County that have no public supply wells.

The basin's four municipalities within Pennsylvania's Delaware and Lancaster Counties are largely without any direct source water protection regulations written into their ordinances. This is certainly reflected in the absence of a source water ordinance. However, there are no public supply wells in these municipalities, and so their scores have been amended so they are not penalized for the absence of wellhead-related ordinances.

Table 6.2: Average county scores for direct source water protection parameters

| Average County Scores: Direct Source Water Protection | | | | |
|---|---|---|---|---|
| **Parameter** | **Delaware** | **Pennsylvania** | | |
| | **NCC** | **ChesCo** | **DelCo** | **LanCo** |
| Source water protection ordinance | 1.0 | 0.0 | 0.0 | 0.0 |
| Wellhead buffer area (ft) | 0.9 | 0.9 | 1.0 | 1.0 |
| Wellhead buffer prohibited uses and activities | 1.0 | 1.0 | 1.0 | 1.0 |
| Septic system regulations near wellheads | 0.6 | 1.0 | 1.0 | 1.0 |
| Recharge ordinance | 0.4 | 0.1 | 0.0 | 0.0 |

For the natural resource protection category, the most protected of the natural resources (as measured by the highest total scores across the basin) under the ordinances were floodplains, steep slopes, and trees/wooded areas. The first two are not surprising since protecting these areas is as much a health and safety issue as an environmental because of the hazards of flooding and erosion that undermines physical structures (Pennsylvania also has Act 166, which requires local municipalities to regulate activities and development within the floodplains). However, the high level of protection trees/wooded areas, as well as stream buffers which weren't far behind in terms of overall score, seems to imply a general consensus across state lines in the basin that protecting natural resources is an important component of land use regulations. The overall score for the protection of karst/carbonate geological features is also high, which implies that there are strong protections in place across the board for areas that have limestone features (which is an important distinction since these scores were amended to avoid penalizing those areas without limestone).

Less than half of the municipalities have language in their ordinances that requires the establishment of wetland buffers. This could be because there are federal regulations (Section 404 of the Clean Water Act) and state regulations (The Subaqueous Lands Act in Delaware and the Dam Safety and Waterway Management Rules and Regulations in Pennsylvania) that regulate and protect most wetlands. In light of this, municipal officials may feel that the wetlands within their jurisdictions are sufficiently protected by national and state laws and therefore extra local protections are unnecessary. However, in a nation that still loses tens of thousands of wetland acres each year in spite of federal laws (NCSU Water Quality Group, n.d.), an added layer of protection might not be unnecessary after all.

Table 6.3: Average county scores for natural resource protection parameters

| Average County Scores: Natural Resource Protection | | | | |
|---|---|---|---|---|
| **Parameter** | **Delaware** | **Pennsylvania** | | |
| | **NCC** | **ChesCo** | **DelCo** | **LanCo** |
| Karst/ carbonate protections | 0.8 | 0.8 | 1.0 | 0.0 |
| Wetland buffer width (ft) | 0.2 | 0.4 | 0.4 | 0.0 |
| Stream buffer width (ft) | 0.6 | 0.8 | 0.5 | 0.0 |
| 100 year floodplain development restricted or prohibited | 0.6 | 0.8 | 0.8 | 0.5 |
| Tree/ wooded area protection ordinance | 0.6 | 0.9 | 0.7 | 1.0 |
| Steep slopes gradient protection | 0.6 | 0.8 | 0.4 | 1.0 |
| Open space allowed/ prohibited uses | 0.6 | 0.7 | 1.0 | 1.0 |

For the stormwater management category, the analysis of stormwater ordinances comes at an interesting transitional time for the local governments in the Christina Basin. A similar stormwater inventory was performed on this area in 1998 (Greig, et al., 1998). However, the past year has brought changes to local stormwater management in both states.

In Delaware, the State's Sediment and Stormwater Regulations (7 DE Admin. Code 5101) were revised in late 2013 to include new requirements for impervious surface area reductions (or supplementary BMP installation), as well as increases in runoff reduction requirements and a "no adverse impact" requirement for stormwater runoff entering water bodies.

Scores are also high for stormwater management in Pennsylvania. The Stormwater Management Act 167 (1978) requires that stormwater mitigation plans be developed and implemented for designated watersheds that are at an increased risk of degradation from stormwater runoff, including the Christina Basin (PA Department of Environmental Protection, 2010). In mid-2013, Chester County finished developing its

Act 167 plans for all watersheds within its borders, and the County is currently working with municipalities to incorporate these new regulations into their local ordinances and codes (Chester County Water Resources Authority, 2013). Because the percentage of the basin in neighboring Delaware County is so low, the county government has chosen to defer to the watershed plans developed by Chester County (Delaware County Planning Commission, n.d.) and, although it is not directly expressed, Lancaster County will presumably do the same for the sliver of the watershed that is located within its borders.

In total, although stormwater scores are already high across the basin, one might reasonably expect that, if this analysis were to be revisited in the next year or two, these scores might actually be higher as local municipalities incorporate the new regulations and program requirements into their ordinances.

Table 6.4: Average county scores for stormwater management parameters

| **Average County Scores: Stormwater Management** | | | | |
|---|---|---|---|---|
| **Parameter** | **Delaware** | **Pennsylvania** | | |
| | **NCC** | **ChesCo** | **DelCo** | **LanCo** |
| Pre-developed runoff conditions | 1.0 | 0.9 | 1.0 | 1.0 |
| Stormwater treatment | 1.0 | 0.8 | 0.0 | 0.0 |
| Critical area impervious cover standards | 0.3 | 0.2 | 0.0 | 0.0 |
| General zoning districts impervious cover standards | 0.1 | 0.4 | 0.0 | 0.5 |
| Parking stall area less than 162 sq. feet | 0.4 | 0.3 | 0.7 | 0.0 |

The final category in the ordinance review was education and accessibility. Across the board, almost every single municipality has a website, which is a good starting point for distributing information to local citizens. Many municipalities use third party web servers to host their municipal ordinances online so that residents have easy access to them. Some municipalities have chosen to scan the local code book and upload it directly to their home website. A handful of municipalities in Chester County do not make their codes available online at all, and so they must be contacted directly (sometimes requiring a Right-to-Know form) in order to gain access to the codes.

The availability of information on drinking water, stormwater, or general water quality generally parallels one of two factors: either the municipality has a water department or authority and is responsible for providing consumers with information on their drinking water, or the municipality has a Municipal Separate Storm Sewer System (MS4) permit that requires an education and outreach component.

Table 6.5: Average county scores for education and accessibility parameters

| **Average County Scores: Education and Accessibility** | | | | |
|---|---|---|---|---|
| **Parameter** | **Delaware** | **Pennsylvania** | | |
| | **NCC** | **ChesCo** | **DelCo** | **LanCo** |
| Municipal Website | 1 | 1.0 | 1 | 1 |
| Codes online | 0.9 | 0.8 | 1 | 1 |
| Water info on web | 0.6 | 0.7 | 1 | 0 |

Provided on the following pages is a summary table of the scores for each municipality, both by category and in total.

Table 6.6: Municipal scores by category

| Municipality | State | County | Direct SWP | Nat. Res. | Storm-water | Edu & Access | Raw Score | Score (%) |
|---|---|---|---|---|---|---|---|---|
| Franklin | PA | ChesCo | 2.8 | 7.0 | 4.2 | 3.0 | 16.9 | 84.5% |
| New Castle County | DE | NCC | 4.0 | 6.5 | 3.8 | 2.0 | 16.3 | 81.3% |
| West Sadsbury | PA | ChesCo | 4.0 | 7.0 | 4.3 | 1.0 | 16.3 | 81.4% |
| Coatesville | PA | ChesCo | 3.0 | 6.3 | 3.8 | 3.0 | 16.0 | 80.0% |
| New Garden | PA | ChesCo | 2.8 | 6.0 | 4.3 | 3.0 | 16.0 | 80.1% |
| Pennsbury | PA | ChesCo | 3.0 | 7.0 | 3.3 | 2.5 | 15.8 | 78.9% |
| Newark | DE | NCC | 3.5 | 5.3 | 3.6 | 3.0 | 15.3 | 76.7% |
| East Fallowfield | PA | ChesCo | 3.0 | 7.0 | 2.3 | 3.0 | 15.3 | 76.4% |
| West Goshen | PA | ChesCo | 3.0 | 6.0 | 3.3 | 3.0 | 15.3 | 76.4% |
| West Vincent | PA | ChesCo | 4.0 | 7.0 | 2.1 | 2.0 | 15.1 | 75.7% |
| Sadsbury | PA | ChesCo | 3.0 | 6.5 | 4.5 | 1.0 | 15.0 | 75.1% |
| West Caln | PA | ChesCo | 2.8 | 6.0 | 4.3 | 2.0 | 15.0 | 75.1% |
| Upper Uwchlan | PA | ChesCo | 2.8 | 5.8 | 3.4 | 3.0 | 14.9 | 74.5% |
| East Bradford | PA | ChesCo | 3.0 | 6.0 | 2.5 | 3.0 | 14.5 | 72.5% |
| Pocopson | PA | ChesCo | 2.8 | 5.5 | 3.3 | 3.0 | 14.5 | 72.6% |
| Westtown | PA | ChesCo | 3.0 | 6.0 | 2.4 | 3.0 | 14.4 | 72.0% |
| West Whiteland | PA | ChesCo | 2.8 | 5.0 | 3.5 | 3.0 | 14.3 | 71.4% |
| Caln | PA | ChesCo | 3.0 | 6.0 | 2.2 | 3.0 | 14.2 | 70.9% |
| Highland | PA | ChesCo | 4.0 | 7.0 | 3.1 | 0.0 | 14.1 | 70.7% |
| East Nantmeal | PA | ChesCo | 3.0 | 6.0 | 3.4 | 1.5 | 13.9 | 69.5% |
| West Brandywine | PA | ChesCo | 2.8 | 4.8 | 3.4 | 3.0 | 13.9 | 69.5% |
| London Grove | PA | ChesCo | 2.8 | 5.0 | 3.0 | 3.0 | 13.8 | 68.9% |
| Penn | PA | ChesCo | 3.0 | 6.5 | 2.3 | 2.0 | 13.8 | 68.9% |
| Wilmington | DE | NCC | 4.0 | 4.5 | 2.0 | 3.0 | 13.5 | 67.5% |
| Concord | PA | DelCo | 3.0 | 5.5 | 2.0 | 3.0 | 13.5 | 67.5% |
| Birmingham | PA | ChesCo | 3.0 | 3.8 | 3.5 | 3.0 | 13.3 | 66.4% |
| East Caln | PA | ChesCo | 2.8 | 5.0 | 2.5 | 3.0 | 13.3 | 66.4% |
| Chadds Ford | PA | DelCo | 3.0 | 5.3 | 2.0 | 3.0 | 13.3 | 66.3% |
| Honey Brook | PA | ChesCo | 3.0 | 4.8 | 3.3 | 2.0 | 13.0 | 65.1% |
| South Coatesville | PA | ChesCo | 3.0 | 4.5 | 3.5 | 2.0 | 13.0 | 64.8% |
| Thornbury | PA | ChesCo | 3.0 | 5.8 | 1.3 | 3.0 | 13.0 | 65.2% |
| East Whiteland | PA | ChesCo | 3.0 | 5.5 | 2.4 | 2.0 | 12.9 | 64.5% |
| Kennett | PA | ChesCo | 3.0 | 4.5 | 2.3 | 3.0 | 12.8 | 63.9% |
| West Chester | PA | ChesCo | 2.8 | 3.8 | 3.3 | 3.0 | 12.8 | 63.9% |

Table 6.6 continued

| Municipality (cont.) | State | County | Direct SWP | Nat. Res. | Storm-water | Edu & Access | Raw Score | Score (%) |
|---|---|---|---|---|---|---|---|---|
| Avondale | PA | ChesCo | 2.8 | 4.8 | 2.2 | 3.0 | 12.7 | 63.4% |
| West Bradford | PA | ChesCo | 2.8 | 4.5 | 2.4 | 3.0 | 12.7 | 63.3% |
| Downingtown | PA | ChesCo | 3.0 | 3.5 | 3.1 | 3.0 | 12.6 | 63.0% |
| Londonderry | PA | ChesCo | 3.0 | 5.0 | 2.5 | 2.0 | 12.5 | 62.6% |
| Parkesburg | PA | ChesCo | 3.0 | 4.3 | 2.3 | 3.0 | 12.5 | 62.7% |
| East Marlborough | PA | ChesCo | 2.8 | 5.0 | 1.5 | 3.0 | 12.3 | 61.4% |
| Kennett Square | PA | ChesCo | 3.0 | 4.0 | 2.2 | 3.0 | 12.2 | 60.9% |
| West Fallowfield | PA | ChesCo | 3.0 | 4.8 | 2.5 | 1.5 | 11.8 | 58.9% |
| Newlin | PA | ChesCo | 2.8 | 4.8 | 2.0 | 2.0 | 11.5 | 57.5% |
| Uwchlan | PA | ChesCo | 3.0 | 3.3 | 2.3 | 3.0 | 11.5 | 57.7% |
| Elsmere | DE | NCC | 4.0 | 2.3 | 2.0 | 3.0 | 11.3 | 56.3% |
| East Brandywine | PA | ChesCo | 2.8 | 4.0 | 1.5 | 3.0 | 11.3 | 56.4% |
| Valley | PA | ChesCo | 2.8 | 4.8 | 2.5 | 1.0 | 11.0 | 55.1% |
| West Nantmeal | PA | ChesCo | 3.0 | 3.5 | 2.3 | 2.0 | 10.8 | 53.9% |
| Bethel | PA | DelCo | 3.0 | 3.8 | 1.0 | 3.0 | 10.8 | 53.8% |
| London Britain | PA | ChesCo | 3.0 | 5.0 | 0.6 | 2.0 | 10.6 | 52.9% |
| Wallace | PA | ChesCo | 3.0 | 4.8 | 0.5 | 2.0 | 10.3 | 51.4% |
| Honey Brook Boro | PA | ChesCo | 3.0 | 3.0 | 2.2 | 2.0 | 10.2 | 50.9% |
| New London | PA | ChesCo | 3.0 | 2.5 | 1.5 | 3.0 | 10.0 | 50.1% |
| Salisbury | PA | LanCo | 3.0 | 3.5 | 1.5 | 2.0 | 10.0 | 50.1% |
| Newport | DE | NCC | 4.0 | 2.3 | 2.1 | 1.5 | 9.9 | 49.3% |
| West Grove | PA | ChesCo | 2.8 | 2.8 | 1.5 | 2.0 | 9.0 | 45.1% |
| Modena | PA | ChesCo | 3.0 | 2.5 | 1.0 | 2.0 | 8.5 | 42.5% |
| West Marlborough | PA | ChesCo | 3.0 | 3.5 | 1.5 | 0.0 | 8.0 | 40.1% |

## 6.2 GIS Source Water Mapping Results

Once all of the municipal ordinance review scores were compiled, the scores were uploaded as a spreadsheet into ArcMap 10 software and linked to the existing municipalities GIS layer to create the map in Figure 6.3, which shows the geographic distribution of scores across the basin.

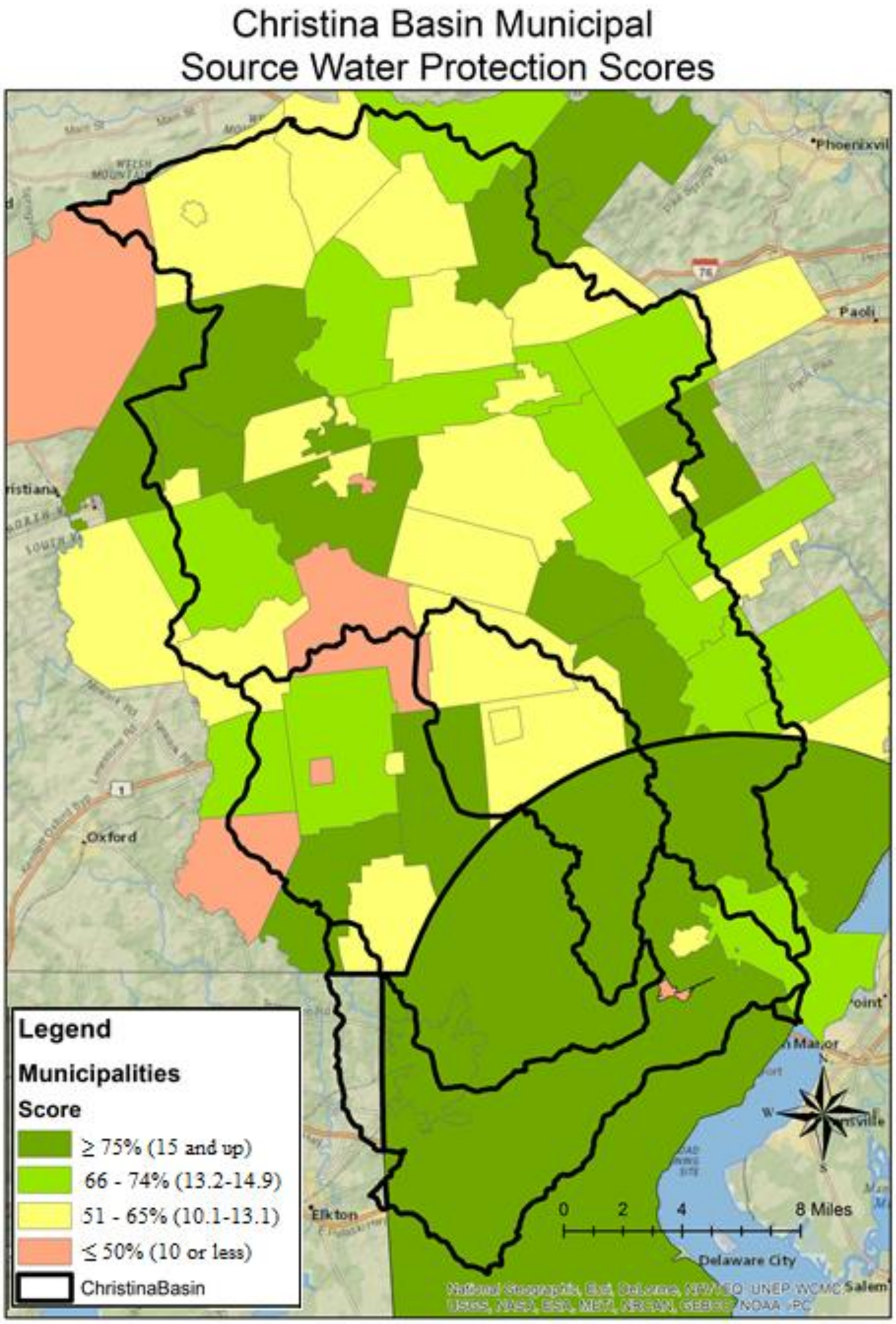


Figure 6.3: Distribution of scores across the Christina Basin

In Delaware, the majority of the land within the basin is under the jurisdiction of New Castle County, which is one of the highest scoring local governments in the region. Of the municipalities, Newark is also very high scoring. Wilmington scores moderately well, while Newport and Elsmere are lower scoring municipalities.

On the Pennsylvania side of the basin, the majority of large municipalities in Pennsylvania appear to have relatively high scores, especially around the outer edges of Chester County. There is a strip of moderate to lower scoring municipalities running down the center of the County, as well as at each of the western corners of the Pennsylvania extent of the basin. On the whole, however, all but a handful of municipalities have scores above 50%.

Because the presence of natural resources across the basin is an integral part of this analysis, the map in Figure 6.4 on the following page illustrates the distribution of woodlands, wetlands, streams, floodplains, and steep slopes across the basin. (Karst features are not displayed on the map due to irreconcilable inconsistencies in the measurement units of data between the two states. However, their presence or absence in each municipality was quantified in the analysis.)

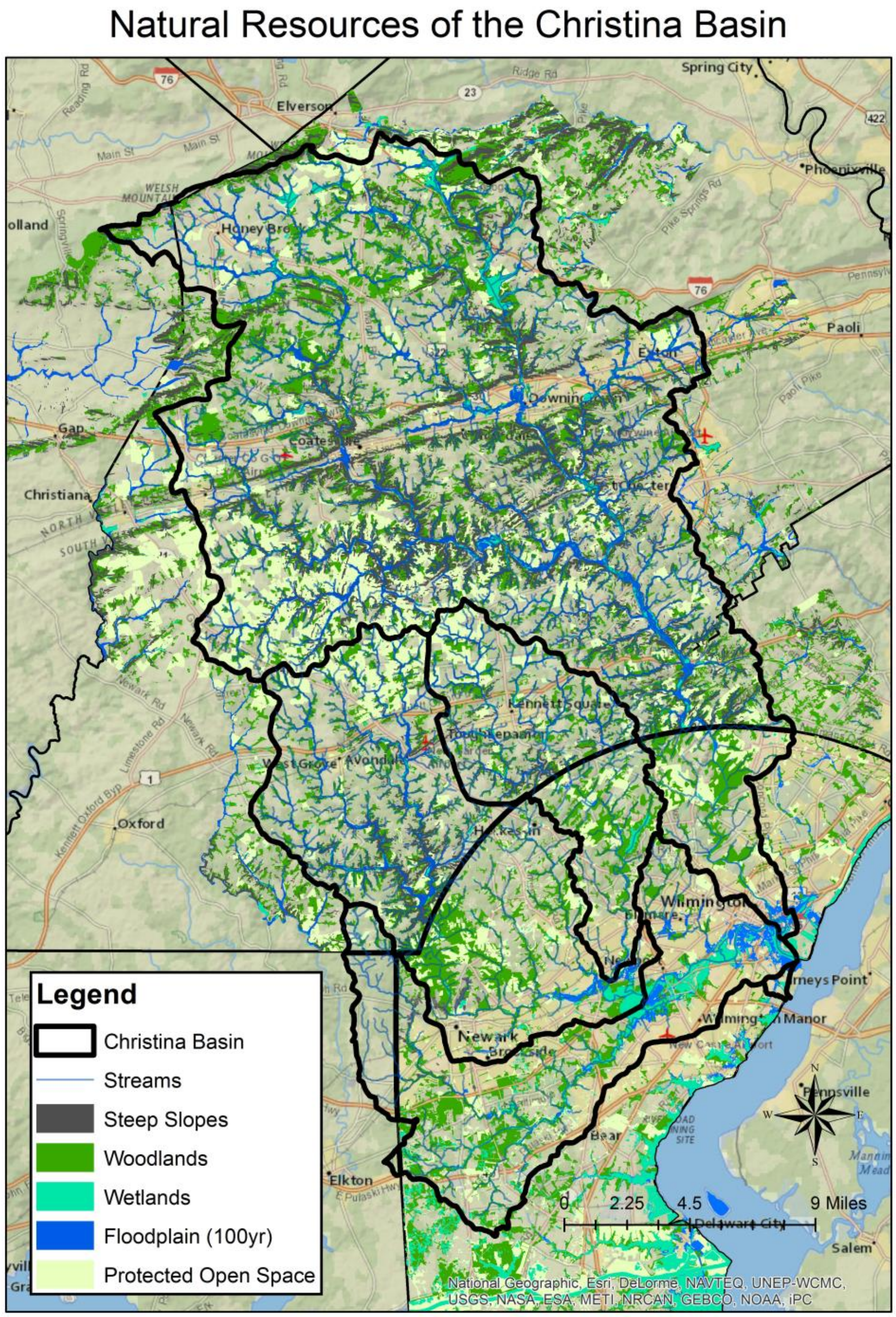


Figure 6.4: Natural resources in the Christina Basin

The final component of the GIS analysis was to identify and quantify natural resources in each municipality that are not protected by the language of the ordinances in their respective jurisdictions. The table below presents the results of this analysis. Data marked in red represents the area/mileage/presence of a natural resource that is unprotected by the ordinances.

When interpreting the following table, there are two important notes to keep in mind. First, in the steep slopes column, numbers shown with an asterisk refer to those municipalities where only very steep slopes, usually above 20-25% gradient, are protected, as opposed to steep slopes with a 15% gradient. Second, for stream mile values marked in red, the ordinances have no requirements for stream buffers.

Table 6.7: Natural resources and vulnerable resources by municipality

| Municipality | State | Wooded (ac) | Wetlands (ac) | Steep Slopes (ac) | Floodplain (ac) | Streams (mi) | Karst |
|---|---|---|---|---|---|---|---|
| New Castle County | DE | 40,184.97 | 46,103.44 | 6,594.02 | 61,747.54 | 1,285.56 | Yes |
| Elsmere | DE | 78.73 | 15.17 | 0.01 | 263.89 | 2.46 | No |
| Newark | DE | 898.10 | 135.60 | 289.80 | 681.68 | 19.75 | Yes |
| Newport | DE | 0.01 | 33.16 | 0.01 | 114.43 | 2.13 | Yes |
| Wilmington | DE | 112.34 | 863.69 | 0.01 | 3,288.28 | 31.92 | No |
| Avondale | PA | 37.45 | 15.77 | 67.25 | 102.69 | 2.67 | Yes |
| Coatesville | PA | 231.99 | 7.05 | 560.71 | 122.46 | 2.75 | No |
| Downingtown | PA | 157.65 | 49.45 | 96.53 | 322.89 | 6.41 | Yes |
| Honey Brook Boro | PA | 0.01 | 3.25 | 0.01 | 0.0 | 0.43 | No |
| Kennett Square | PA | 36.58 | 8.78 | 25.62 | 35.40 | 2.22 | No |
| Modena | PA | 104.60 | 2.09 | 198.71* | 59.93 | 1.53 | No |
| Parkesburg | PA | 104.55 | 2.91 | 136.64 | 50.79 | 2.83 | Yes |
| West Chester | PA | 16.95 | 0.01 | 20.07 | 58.70 | 2.42 | No |
| Birmingham | PA | 840.51 | 128.94 | 438.02* | 599.75 | 25.14 | No |
| Caln | PA | 1,711.92 | 140.17 | 1,115.98 | 546.24 | 22.79 | Yes |
| East Bradford | PA | 2,755.32 | 389.77 | 2,015.87 | 1,368.13 | 54.07 | No |
| East Brandywine | PA | 2,025.77 | 84.92 | 1,092.12 | 404.38 | 34.01 | No |
| East Caln | PA | 535.53 | 79.34 | 538.08 | 140.86 | 4.94 | Yes |
| East Fallowfield | PA | 3,255.40 | 72.15 | 2,750.55 | 545.28 | 42.50 | No |
| East Marlborough | PA | 1,694.70 | 119.36 | 334.00 | 531.93 | 49.70 | Yes |
| East Nantmeal | PA | 4,787.47 | 446.00 | 2,227.98 | 828.13 | 44.68 | No |
| East Whiteland | PA | 1,431.64 | 42.98 | 524.84 | 354.30 | 18.66 | Yes |
| Franklin | PA | 2,218.62 | 117.72 | 936.84 | 605.79 | 58.06 | No |
| Highland | PA | 2,125.49 | 69.14 | 1,039.93 | 365.53 | 47.64 | No |
| Honey Brook | PA | 3,892.27 | 643.36 | 1,016.63 | 1,464.21 | 69.07 | No |
| Kennett | PA | 2,679.94 | 213.39 | 822.07 | 645.72 | 53.45 | Yes |
| London Britain | PA | 2,489.80 | 93.56 | 1,297.17 | 549.92 | 40.17 | No |
| London Grove | PA | 2,049.78 | 216.19 | 464.76 | 769.69 | 59.14 | Yes |
| Londonderry | PA | 1,446.06 | 40.97 | 320.69 | 430.23 | 36.53 | No |
| New Garden | PA | 2,007.77 | 163.46 | 981.45 | 451.76 | 54.33 | Yes |
| New London | PA | 1,826.67 | 117.08 | 574.09 | 559.33 | 49.50 | No |
| Newlin | PA | 2,959.20 | 221.34 | 2,253.45 | 955.80 | 47.93 | No |
| Penn | PA | 944.88 | 102.08 | 18.67 | 239.28 | 31.71 | Yes |
| Pennsbury | PA | 2,208.90 | 134.01 | 1,014.28 | 532.81 | 38.43 | No |
| Pocopson | PA | 1,288.24 | 148.13 | 841.22 | 745.38 | 34.92 | No |
| Sadsbury | PA | 979.22 | 65.18 | 250.44 | 356.15 | 16.72 | Yes |
| South Coatesville | PA | 494.61 | 6.41 | 546.26* | 57.79 | 4.02 | No |

Table 6.7 continued

| Municipality | State | Wooded (ac) | Wetlands (ac) | Steep Slopes (ac) | Floodplain (ac) | Streams (mi) | Karst |
|---|---|---|---|---|---|---|---|
| Thornbury | PA | 484.21 | 44.24 | 193.07 | 284.06 | 13.24 | No |
| Upper Uwchlan | PA | 1,789.10 | 711.49 | 950.61 | 1,057.16 | 38.43 | No |
| Uwchlan | PA | 1,214.97 | 93.83 | 559.77 | 78.15 | 28.93 | No |
| Valley | PA | 1,240.69 | 12.94 | 1,107.67 | 146.05 | 16.49 | Yes |
| Wallace | PA | 3,417.53 | 298.32 | 718.41 | 429.03 | 32.04 | No |
| West Bradford | PA | 3,995.78 | 99.41 | 2,902.13 | 488.83 | 53.13 | Yes |
| West Brandywine | PA | 2,463.14 | 125.08 | 484.89 | 488.07 | 38.05 | Yes |
| West Caln | PA | 4,996.47 | 200.21 | 1,412.47 | 804.79 | 61.23 | No |
| West Fallowfield | PA | 2,088.10 | 74.79 | 20.07 | 408.71 | 49.45 | No |
| West Goshen | PA | 1,085.52 | 133.41 | 1,152.57 | 591.66 | 29.34 | No |
| West Grove | PA | 32.81 | 1.75 | 284.34* | 0.04 | 0.92 | No |
| West Marlborough | PA | 2,131.85 | 106.85 | 9.07 | 898.58 | 56.77 | Yes |
| West Nantmeal | PA | 2,628.78 | 243.59 | 1,314.53 | 671.01 | 40.51 | Yes |
| West Sadsbury | PA | 1,343.81 | 136.69 | 536.31 | 548.81 | 25.92 | Yes |
| West Vincent | PA | 4,009.61 | 212.46 | 544.61 | 459.58 | 46.85 | No |
| West Whiteland | PA | 1,586.92 | 153.18 | 1,996.97 | 986.28 | 36.43 | Yes |
| Westtown | PA | 879.43 | 111.81 | 927.46 | 320.26 | 30.11 | No |
| Bethel | PA | 947.87 | 23.93 | 279.31 | 48.40 | 2.38 | No |
| Chadds Ford | PA | 2,139.10 | 202.34 | 1,071.21* | 388.66 | 23.97 | No |
| Concord | PA | 2,401.02 | 81.55 | 608.33 | 250.71 | 29.72 | No |
| Salisbury | PA | 4,443.16 | 122.08 | 1,725.68 | 1,046.95 | 42.17 | Yes |
| **Total** | | **35,933.5** | **54,286.0** | **0,204.3** | **91,292.9** | **2,997.3** | **23** |
| **Vulnerable** | | **4,978.7** | **2,088.3** | **1,603.7** | **1,076.0** | **257.3** | **13** |
| **% Vulnerable** | | **4%** | **4%** | **3%** | **1%** | **9%** | **57%** |

As the table above demonstrates, karst features are the natural resource least protected by the ordinances. Woodlands are the resource with the greatest square acreage at risk, while the percentage of un-buffered stream miles is highest of all of the vulnerable resources. It should be noted that for wetlands, although more than two thousand acres are considered vulnerable under this analysis because they are not addressed by the municipal ordinances, they are protected under state and national regulations that prevent the dredging and filling of identified wetlands. However, as mentioned in an earlier chapter, enforcing a second layer of protection for this natural resource is never a bad practice, since despite the national protections thousands of acres of wetlands continue to be lost annually.

### 6.3 Statistical Results: State-to-State Scores Analysis

Since comparing the source water protection regulations between the states was the ultimate goal of this research, the first statistical analysis compared the average scores of Pennsylvania and Delaware. A student's t-test was performed with the null hypothesis ($H_0$) that there is no statistical difference between the two average scores. The test results returned a p-value of 0.72, which is far above the probability threshold of 0.05. This indicates that the null hypothesis cannot be rejected, and that the average scores between Pennsylvania and Delaware are not statistically different. A quick assessment of those average scores (DE=13.2, PA=13.0) shows that, even without the use of statistical tests, the average scores between the two states are incredibly similar. This is a very surprising finding given that the municipalities in Delaware are under the authority of a statewide source water protection law while all efforts in municipalities in Pennsylvania are implemented voluntarily.

It is important to note that the analysis described above gives each municipality equal weight when calculating and analyzing the raw average scores. This does not account for the fact that New Castle County, with one of the highest scores in the basin (16.3 out of 20), covers 88% of the Delaware portion of the basin. Therefore, this analysis may not perfectly reflect the "situation on the ground" in Delaware involving the level and coverage of source water protection regulations, which is to say that the Delaware portion of the basin may actually be better protected as a whole than its average score implies. For these reasons, the student's t-test was repeated using the land-area weighted average of the two states. These averages, as described in Table 6.1, were: Delaware = 15.9 and Pennsylvania = 12.8. The t-test results indicate that, although these numbers appear to be different from one another, it cannot be said that they are statistically different. The p-value calculated by this test was a 0.34, well above the probability threshold of 0.05 required to reject the null hypothesis that these scores are statistically the same.

### 6.4 Statistical Results: Background and Natural Resource Correlations

In addition to comparing the scores of each state to one another, this research sought to identify any predictive or common municipal characteristics that correlate with higher source water protection scores. Two sets of parameters, background data and natural resources data, were compared to scores through a series of multivariate analyses. First, each dataset was compared to the scores for the entire Basin, and then the analysis was repeated but the data and scores were separated by state.

Information on eleven parameters was collected to make up the background dataset. These parameters included:

- Municipal size ($mi^2$)
- Population (2010)
- Population density (people/ $mi^2$)
- Population growth rate (2000-2010)
- Urban population (%)
- Municipal general fund budget
- Median household income
- High school education (%)
- Public surface/groundwater intake
- % Land use – agricultural
- % Land use - urbanized

The only parameter with normally distributed data for the entire Basin was % land use-urbanized, so this parameter was tested against the scores using a pairwise correlation analysis (Pearson's correlation coefficient). The rest of the parameters had data that were not normally distributed, and so were tested against the scores using a nonparametric correlation analysis (Spearman's correlation coefficient). Pearson's r and Spearman's ρ are both coefficients of correlation and can be interpreted in roughly the same manner, since both represent the relationship between the parameter of interest and the score. For the purposes of this analysis, a coefficient value below 0.39 is considered to represent a weak relationship between the two variables, a coefficient value of 0.4 – 0.59 is considered a moderate relationship, and any coefficient values above 0.6 represent a strong relationship between the parameters.

The results of the pairwise correlation analysis produced no statistically significant results. The statistically significant ($\alpha < 0.05$) results from the nonparametric analyses are provided in Table 6.9 below.

Table 6.8: Background correlations from nonparametric analysis

| **Delaware & Pennsylvania** | | |
|---|---|---|
| **Parameter** | **Spearman ρ** | **Prob>\|0.05\|** |
| Population | 0.41 | 0.0016 |
| General Fund Budget | 0.30 | 0.0274 |
| MS4 Permit | 0.29 | 0.0290 |
| Size (mi2) | 0.28 | 0.0323 |
| **Pennsylvania** | | |
| **Parameter** | **Spearman ρ** | **Prob>\|0.05\|** |
| Population | 0.32 | 0.0179 |
| MS4 Permit | 0.31 | 0.0354 |

Almost all of the statistically significant correlations associated with the background data are considered to be weak relationships. For the whole basin, the strongest of these relationships was with population. This moderate correlation coefficient indicates that source water protection scores tend to rise as the total population of a municipality rises. When put together with the weaker correlations, we see that larger, more populous municipalities with larger budgets (and therefore increased financial and organizational capacity) tend to exhibit higher source water protection scores. There is also a weak but significant correlation between high scores and MS4 municipal stormwater permits. This is a logical connection because a stormwater permit would most likely be incorporated into the municipality's ordinances, which would have been captured in the ordinance review and scoring matrix under the stormwater management category.

When the scores and this set of parameters are compared for Pennsylvania alone, the number of statistically significant parameters is cut in half. Municipal size and budget no longer present statistically significant correlations, leaving only population and MS4 permits as significant positive correlations with scores. The results for the State of Delaware have been discarded since the sample size (n=5) is considered too small for the results to be interpreted as practically significant.

The second dataset that was run through the correlation analyses was based on the natural resources data collected in the GIS analysis. The parameters included in this dataset were:

- Karst/carbonate features
- Stream miles
- Wetlands
- Floodplains
- Woodlands
- Steep Slopes
- Protected Open Space

Data for wetlands, floodplains, woodlands, steep slopes, and protected open space were quantified in two ways. The raw acreage per municipality was included in the dataset, as was the total acreage of each resource as a percent of the total area of the municipality. None of the parameters had data with normal distributions, and so the nonparametric correlation analysis was used exclusively. The statistically significant results from that analysis are summarized in Table 6.10 below.

Table 6.9: Natural resource correlations from nonparametric analysis

| **Pennsylvania** | | |
|---|---|---|
| **Parameter** | **Spearman ρ** | **Prob>\|ρ\|** |
| Stream miles | -0.38 | 0.0068 |
| Protected Open Space (acres) | -0.28 | 0.0446 |

None of the natural resource parameters were statistically significant across both states in the basin. However, a strange result emerged in Pennsylvania. The statistical results indicate that there is a significant negative correlation between total stream miles and source water protection scores, as well as between total acreage of protected open space and source water protection scores. This finding is somewhat counterintuitive, and no readily available information exists to explain these relationships. It is possible that these correlations are spurious (meaning that despite showing significant correlations, these variables have no direct causal connection), and that there is likely some unidentified factor that is influencing these relationships. Total stream miles and total protected open space acreage are highly correlated with one another ($\rho = 0.78$, prob = 0.0001), and so it is possible that the same underlying factor could explain both negative relationships. Unfortunately, this research is unable to identify that factor.

One speculative explanation for the negative relationship between protected open space and source water protection scores is that officials in municipalities with large areas of protected open space may feel less compelled to develop protective ordinances since many natural resources and resources areas are already protected in these open space areas. However, to confirm this it would be necessary to speak with local officials in those municipalities to see if such factors influenced the development (or lack thereof) of relevant ordinances. It is much harder to explain the negative correlation between stream miles and source water protection scores. Studying the hydrogeology and the dendritic patterns in this area as it relates to the boundaries of the municipalities may be of interest in future research, but will not be explored in this work.

It is important to note that there are most likely factors not captured by this analysis that influence how well municipalities use their ordinances to protect source water. Conversations with local experts from the New Castle County Planning Department, the Chester County Water Resources Authority, and the Chester County Planning Commission have shed light on what some of those factors might be.

Despite the fact that the statistical data for Delaware had to be discarded, there are some inferences that can be made about the factors that influence source water protection. In Delaware, the greatest predictor or motivator of local source water protection regulations is likely to be the presence of source water contributing areas (SWCAs). As mentioned earlier, the State Source Water Protection Law of 2001 requires municipal governments to incorporate the findings of local source water assessments into their zoning codes and ordinances. Newark and New Castle County both have SWCAs and high scores, while Newport and Elsmere have no SWCAs and low scores. All four of these municipalities are following the law, but the law applies to them differently based on the geographic distribution of source water areas.

In Delaware then, Wilmington is somewhat of an anomaly, since the city has SWCAs and only ranks in the middle of municipalities across the basin in terms of total score. The City has incorporated the results of the local source water assessment into its ordinances, but not to the extent that Newark and New Castle County have. One possible explanation for this inconsistency (and a component not analyzed through this research) involves the era in which intensive urbanization took place. In Wilmington (and in the town of Newport as well), the majority of the municipality's land area has been highly built up and urbanized for more than a century, pre-dating the modern environmental movement and many of the city's current land use codes. Industrial areas were constructed in what today would be considered stream buffer zones, and wetlands were drained or dredged to make way for residential development (Delaware Coastal Programs, n.d.). As such, it is possible that source water protection ordinances (and environmental ordinances in general) may be weaker in municipalities like Wilmington because the natural resource areas they would protect have already been compromised or developed into more urbanized land uses. This factor may also play a role in some of the older, more urbanized municipalities in Pennsylvania, and further research into this vein of study may be beneficial.

In Pennsylvania, there is no state level source water protection law, but the source water protection scores in the Pennsylvania Christina Basin are still fairly high across the board. High stormwater protection scores as a result of the State's stormwater management law (Act 167). However, this does not fully explain relatively high scores, particularly in the areas of the basin in Chester County. It has been suggested that this may in large part be due to what Bill Gladden, the former head of the Chester County Planning Commission referred to as the county's "culture of conservation" (Conway, 2008). For many years, wealthy families in the county owned large estates that were predominantly occupied by open space, and these landowners were very active in protecting the natural resources on their properties. One of the historically dominant land uses in the county is horse farming, which has also lent itself to the preservation of open space throughout the county. As the population of the region continues to grow, some of this land is being bought up, subdivided, and converted into residential or other urbanized land uses. However, according to personal communications with Jan Bowers, the Director of the Chester County Water Resources Authority, there is still "a huge commitment to natural resources protection in the County" in the local ordinances that remains as a legacy of the large estates and their environmentally-minded land owners.

This seems to imply that the level of source water protection regulations found in Chester County might not be generalizable to other counties in Pennsylvania. The handful of municipalities in the Pennsylvania Christina Basin that are outside of Chester County do tend to have lower overall source water protection scores.

However, this research does not include a large enough sample of municipalities in other Pennsylvania counties to reach any conclusions on how Chester County might compare to surrounding counties in the State.

### 6.5 Water Quality Analysis Results

The final component of this research was to examine water quality near the public water supply surface intakes in the basin in both states, as well as water quality along the state border. The water quality parameters of interest in this analysis were total dissolved solids (TSS), turbidity, and enterococcus in Delaware, and turbidity in Pennsylvania. The following figures show the trends for those parameters at each of the sites of interest over time, beginning with the datasets that represent sediments (turbidity and TSS) and finishing with those that represent bacteria (enterococcus). The data that is proximally located near surface water intakes is presented first, followed by data from the state line stations. The green line on the graphs indicates the year (1996) in which the Safe Drinking Water Act amendments that required states to complete source water assessments was passed.

The graphs below show the data gathered by Delaware Department of Natural Resources and Environmental Control (DNREC) water quality monitoring stations near surface water intakes in the State. The order of the graphs moves from east to west, from Newark to Wilmington.

The TSS data available at the McKee's Lane station, which is roughly a mile downstream from a surface water intake for the City of Newark, represents a relatively short time frame. Although the data show a barely perceptible upward trend in TSS in the water column, a longer dataset would be needed to confirm or refute this trend.

The Route 7 Bridge station above United Water Delaware's White Clay Creek intake and the Route 4 Stanton station above United Water Delaware's Red Clay Creek intake are within about a mile of one another, but they measure water quality in two different streams. The data from the Route 7 Bridge station on the White Clay Creek indicates a slight upward trend in TSS, while the Route 4 Stanton station data show a stable (if barely imperceptible downward) trend in TSS concentrations.

Finally, the DNREC Brandywine Creek Footbridge station, which is located between two of the City of Wilmington's surface water intakes, shows a noticeably decreasing trend in TSS over a span of nearly twenty years, although the $R^2$ value indicates that the trend is not a very strong one. The USGS gage at Wilmington provides sediment to compliment the DNREC station data. The USGS gage data indicates no noticeable trend in sediment concentrations, but this is a relatively short dataset and for the purposes of this analysis the DNREC station will be considered more reliable since the period of record is longer.

There is no standard for TSS in Delaware. The standard in neighboring New Jersey is 40mg/L for non-trout streams (Ten Towns Great Swamp Watershed Management Committee, 2002). Although there are a handful of data points above the 40mg/L threshold at each monitoring site, the annual medians recorded at these stations in Delaware are well below this threshold.

There is no state standard for turbidity in surface waters in Delaware or in Pennsylvania, although for potable water supplies turbidity is not to exceed 100 ntu (U.S. Environmental Protection Agency, 2004). None of the data points for either of the stations shown above come close to that standard for the time frame in which the data were collected. However, this seems to be a relatively loose standard, as some other states have standards as low as 10 ntu for drinking water supplies (Minnesota Pollution Control Agency, 2008).

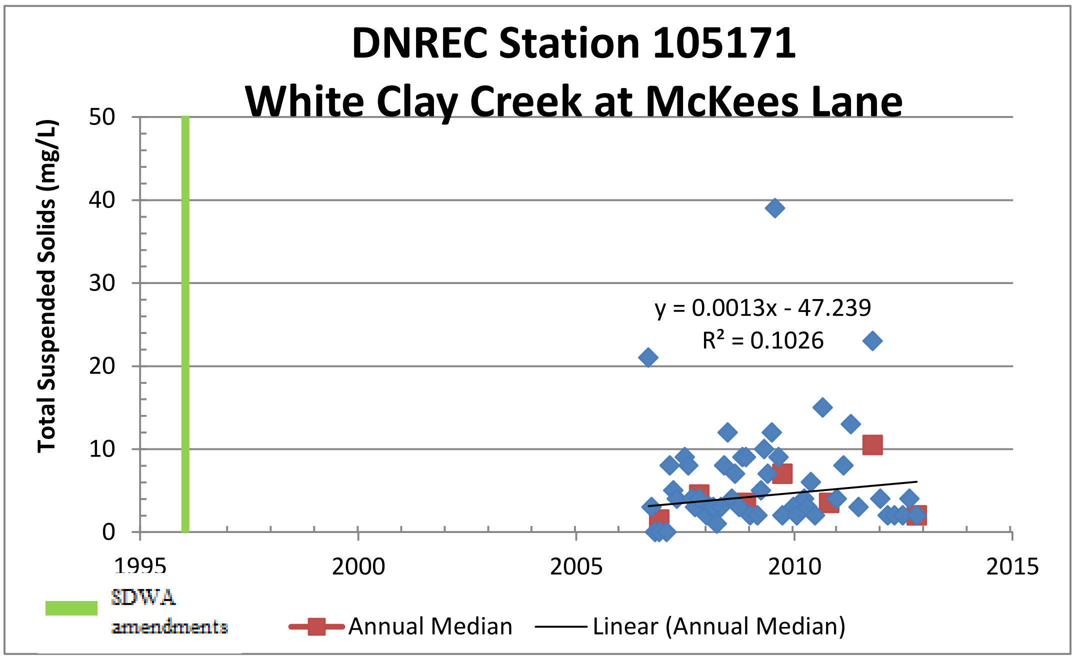


Figure 6.5: TSS along White Clay Creek at McKee’s Lane, Delaware

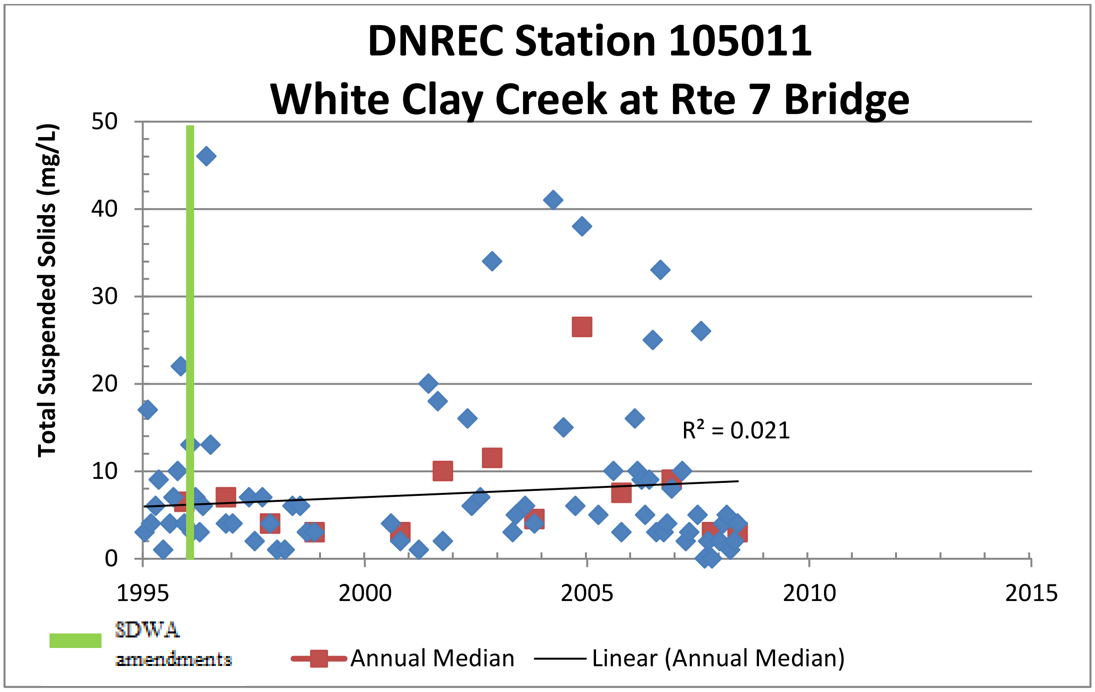


Figure 6.6: TSS along White Clay Creek at Route 7 Bridge, Delaware

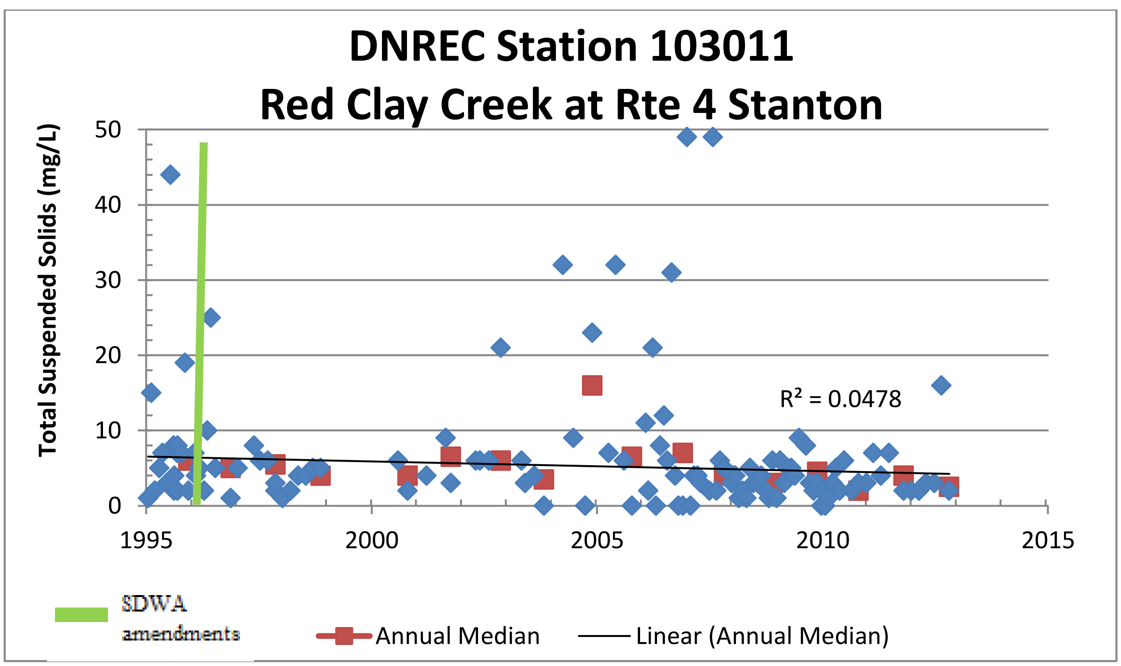


Figure 6.7: TSS along Red Clay Creek at Route 4 Stanton, Delaware

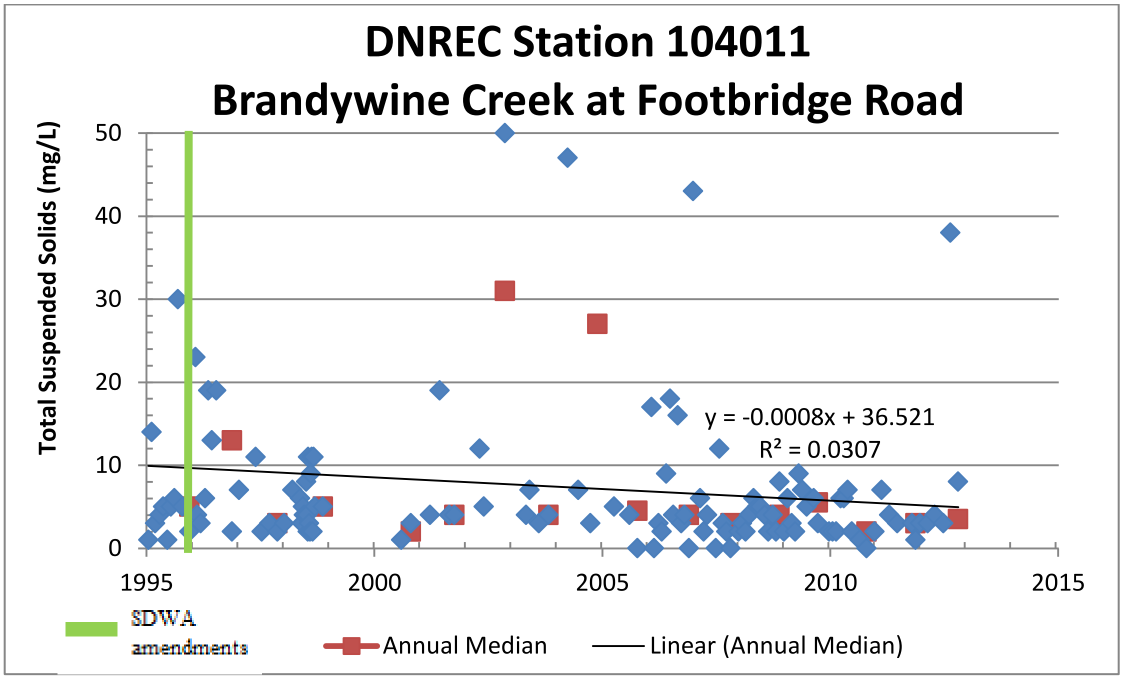


Figure 6.8: TSS along Brandywine Creek at Footbridge, Delaware

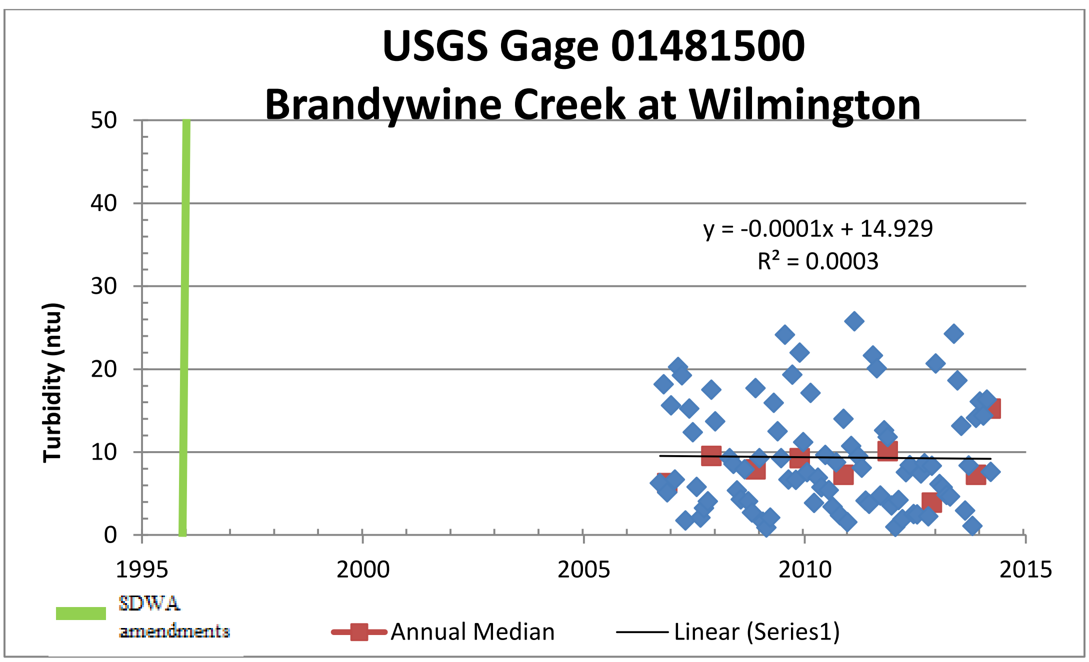


Figure 6.9: Turbidity along Brandywine Creek at Wilmington, Delaware

Data on turbidity was only available in Pennsylvania from 2006 until 2013 for the Rock Run Reservoir, from 2005 until 2014 for the USGS gage at Modena, and from 2006 until 2014 for the USGS gage below Downingtown. All three sets of data represent daily values that have been converted into monthly averages.

The Rock Run Reservoir, also known as the Coatesville Reservoir, serves as a primary source of water supplies for the Pennsylvania American Water Company. The data shows that there is an increasing trend in turbidity over time at this intake, which could present a costly problem for the water supplier. However, the time series represented by this data is relatively short, and data from prior years would be required to make any assertions about whether or not this is an actual trend in water quality. The same basic principle applies to the data from the USGS gages at Modena and below Downingtown. At Modena, there is a relatively strong decline in turbidity over time downstream from the Rock Run Reservoir, and there is a weak decline in turbidity at the gage below Downingtown, which is upstream of the intake for the Chester Water Authority. However, more data would be beneficial in determining if this improvement in water quality is an actual trend over time.

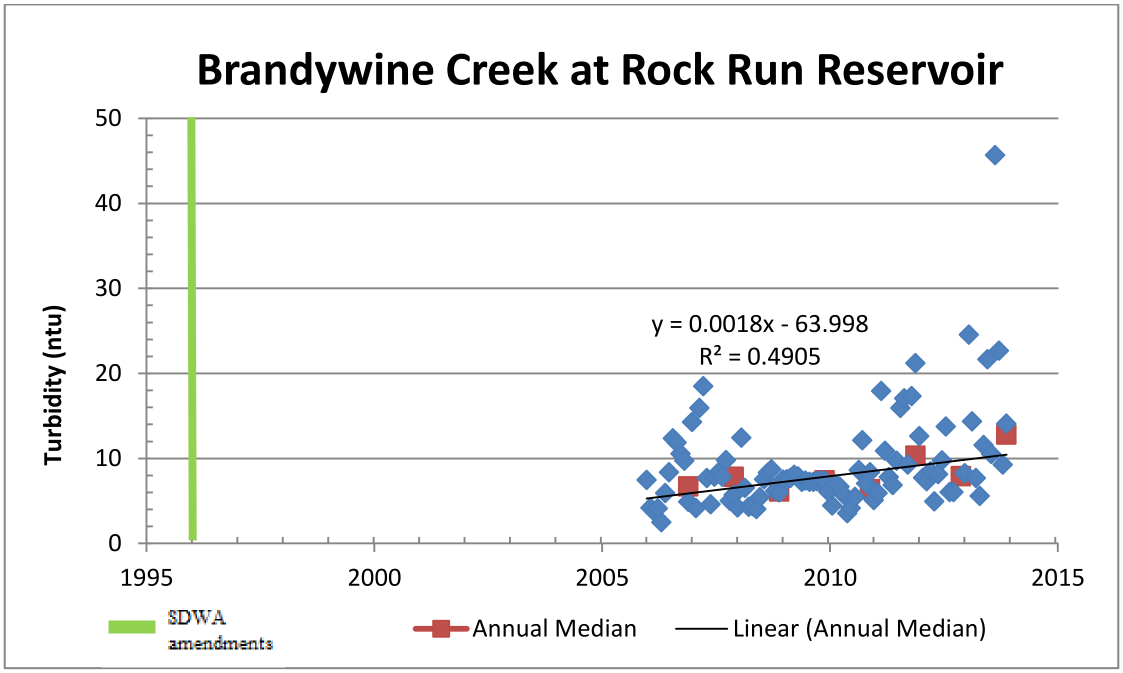


Figure 6.10: Turbidity at Rock Run Reservoir, Pennsylvania

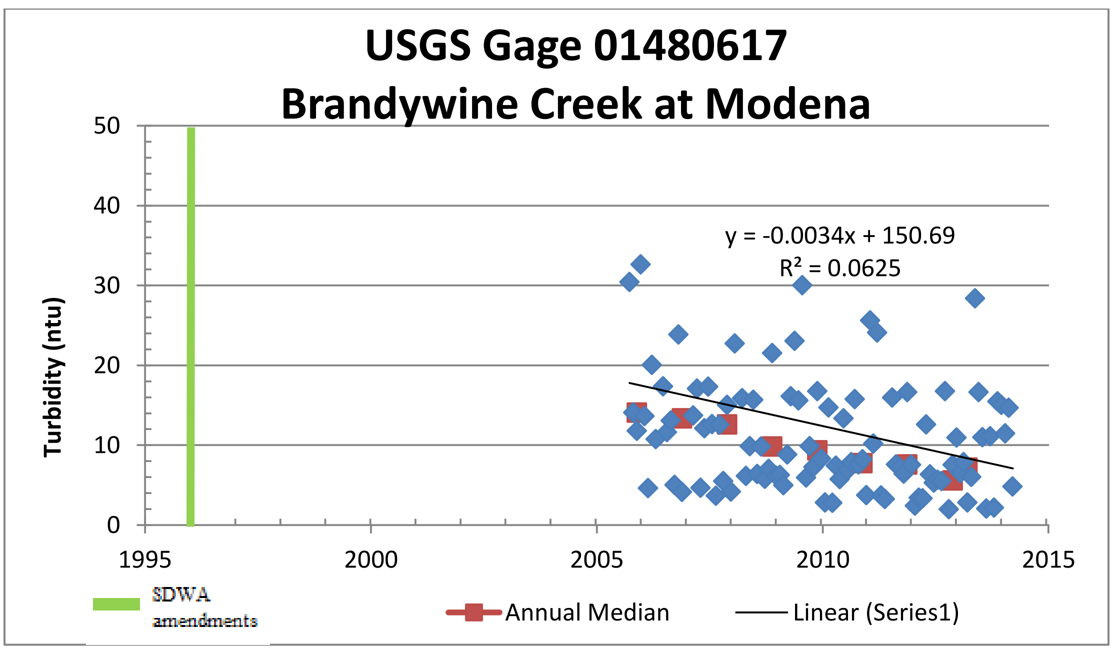


Figure 6.11: Turbidity along Brandywine Creek at Modena, Pennsylvania

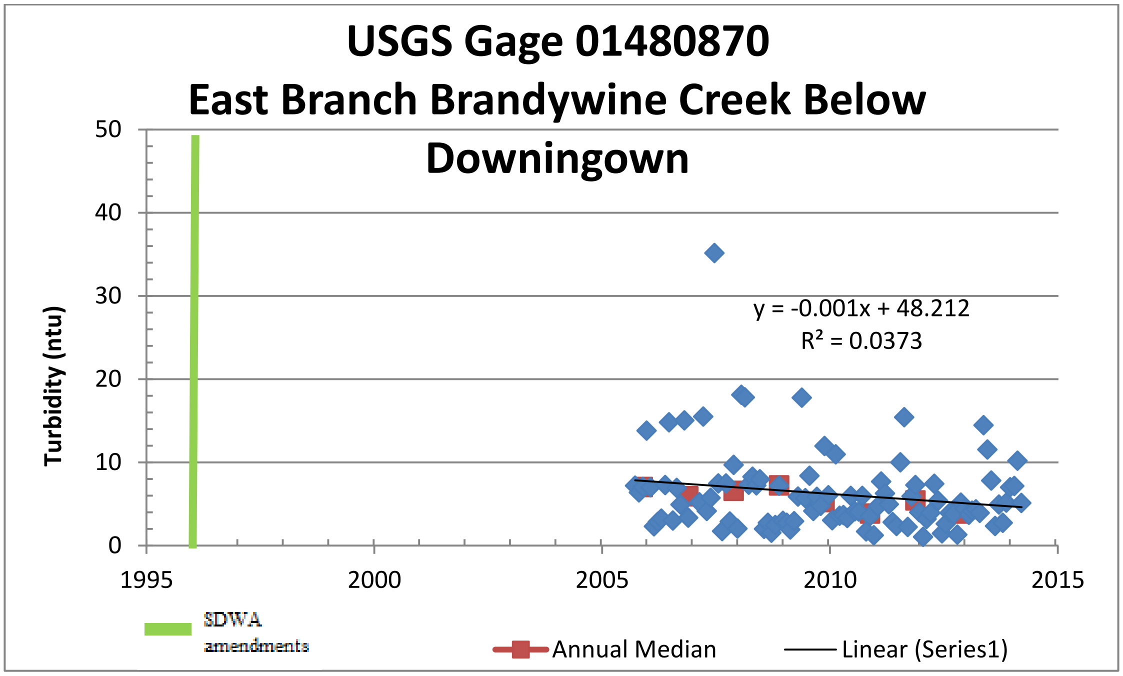


Figure 6.12: Turbidity along Brandywine Creek below Downingtown, Pennsylvania

The next set of graphs depicts the concentrations of enterococcus (bacteria) at the same water quality monitoring stations in Delaware that were used for the TSS and turbidity analyses. The State of Delaware standard for enterococcus in surface waters is 100 cfu/100mL. Levels above this can pose a threat to human health for people that come in close contact with or ingest the water.

As with the TSS data, the enterococcus data from the McKee's Lane station represents a time frame that is too limited to make any real informed judgments about water quality trends. All three of the other Delaware stations exhibit a distinct and noticeable downward trend in enterococcus concentrations over time. Although there are still months where the average enterococcus values exceed the water quality standard, the general trends at these stations are promising, and show that, at least for this parameter, water quality has been improving over time.

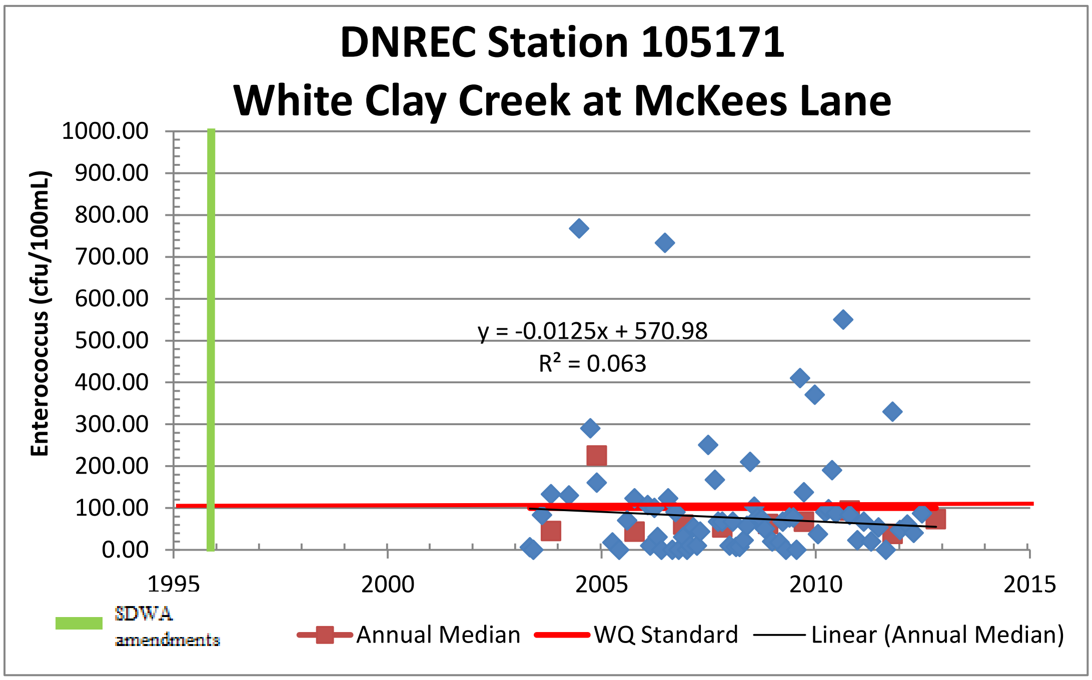


Figure 6.13: Enterococcus along White Clay Creek at McKee's Lane, Delaware

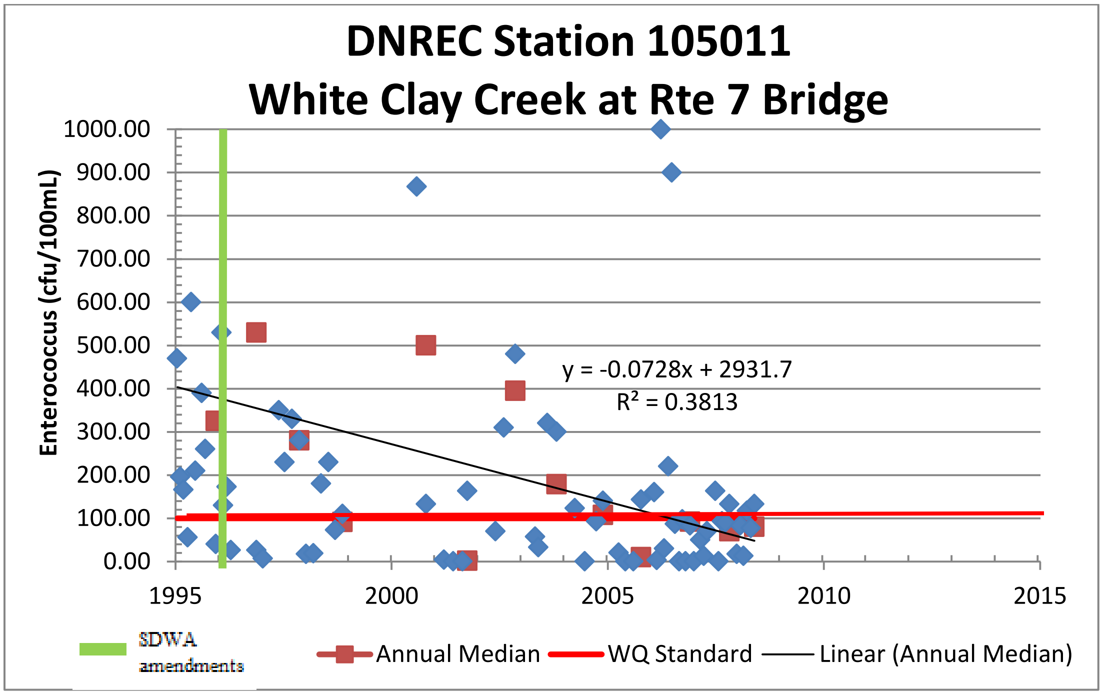


Figure 6.14: Enterococcus along White Clay Creek at Route 7 Bridge, Delaware

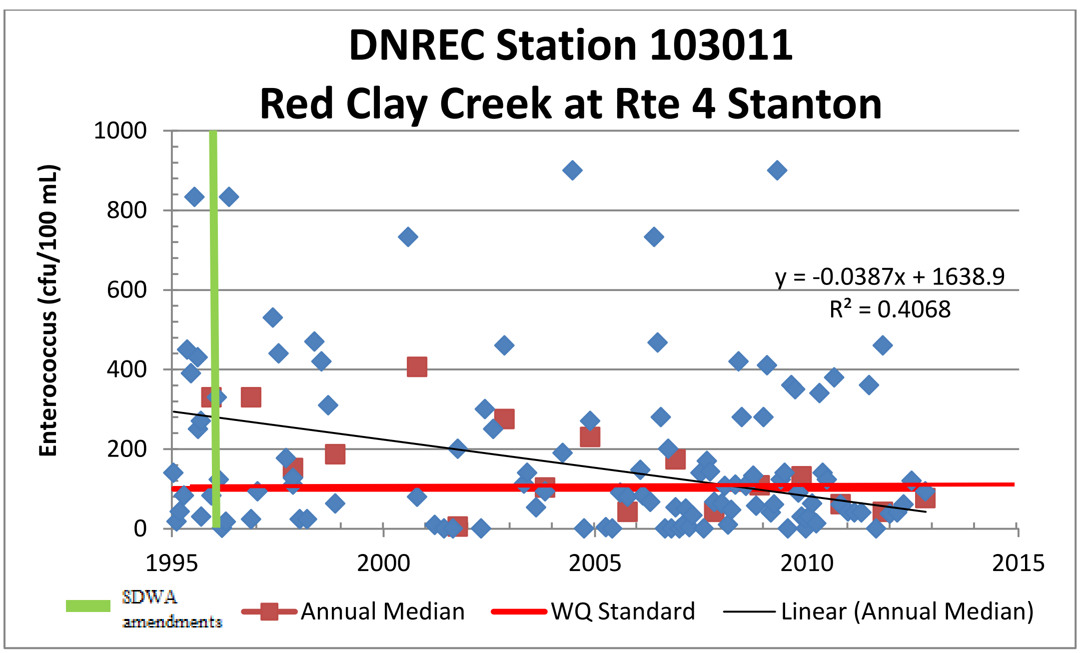


Figure 6.15: Enterococcus along Red Clay Creek at Route 4 Stanton, Delaware

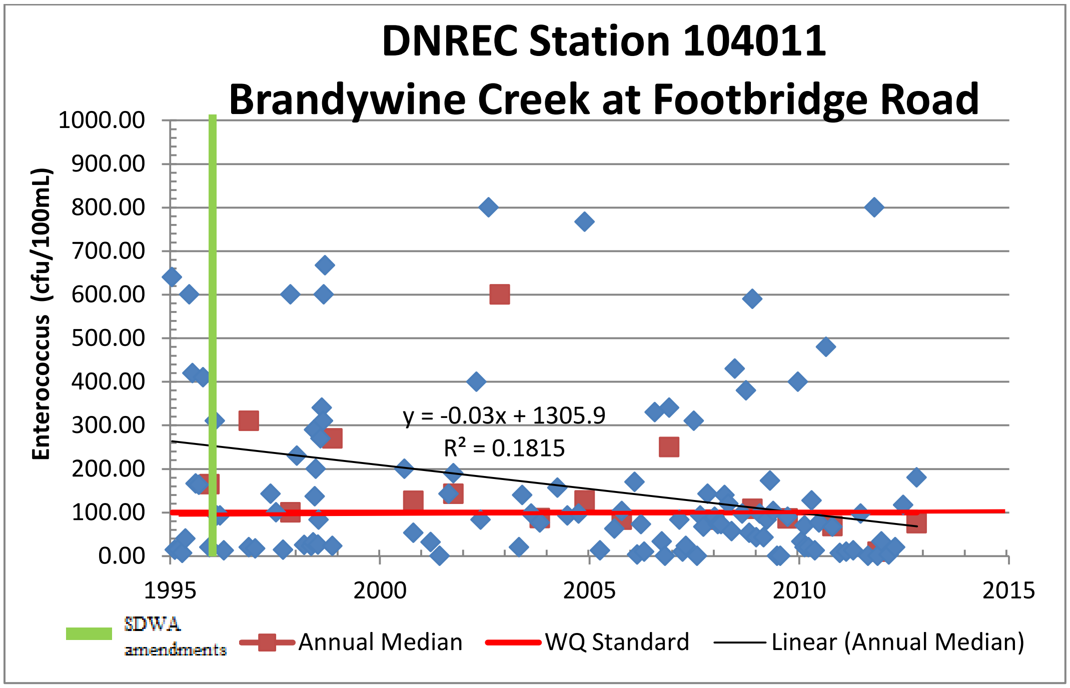


Figure 6.16: Enterococcus along Brandywine Creek at Footbridge, Delaware

Finally, water quality data from three stations in Delaware and one station in Pennsylvania (turbidity data only) that are close to the state line were examined in order to assess whether or not there are any trends over time in the quality of water flowing into Delaware from Pennsylvania. That data is provided in the graphs on the following pages.

Each of the state line stations exhibits a downward trend in the concentrations of TSS and turbidity over the past two decades. That trend is most prevalent in the Brandywine and White Clay Creek stations, while the trend at the station in the Red Clay Creek is almost stable. None of these trends are particularly strong, but they do appear to be moving in the right direction. It should also be noted that a new gage has recently been installed by the USGS near the Delaware-Pennsylvania state border. It is

USGS Gage 10478245 on the White Clay Creek at Strickersville, Pennsylvania. This gage station began collecting data in December 2013. The current period of record is far too short to be analyzed for trends, but turbidity data will be collected continuously at this gage in the future, and so this data will be available for future analyses.

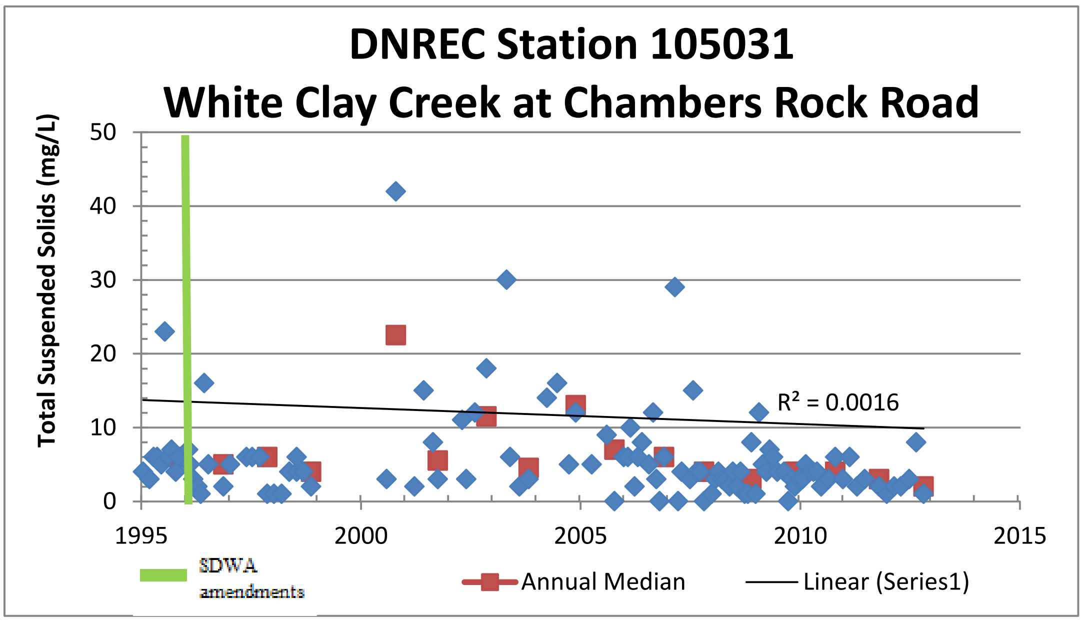


Figure 6.17: TSS along White Clay Creek at Chambers Rock Road, Delaware

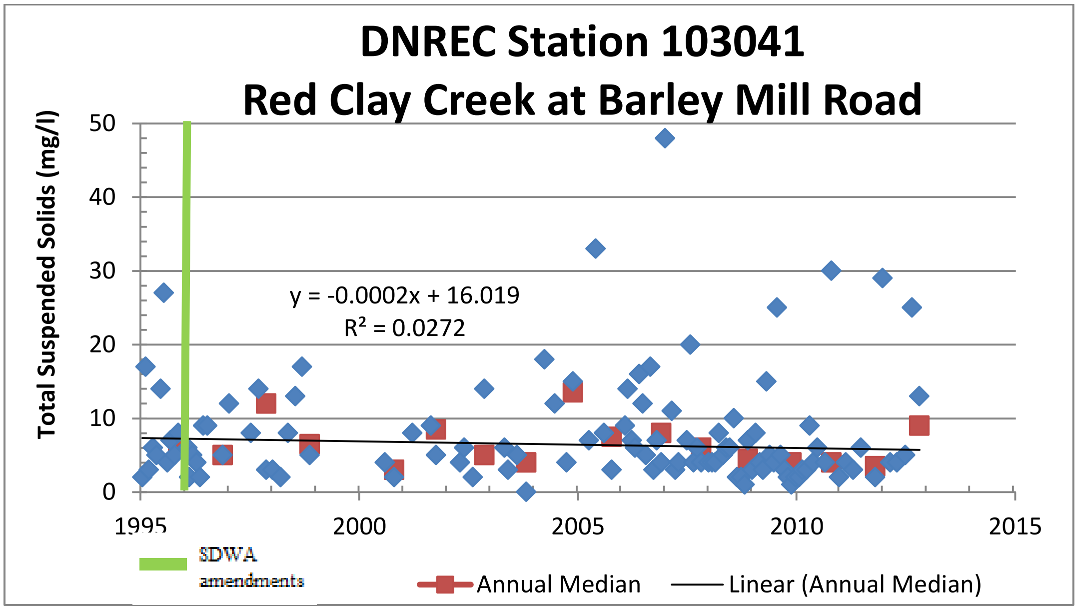


Figure 6.18: TSS along Red Clay Creek at Barley Mill Road, Delaware

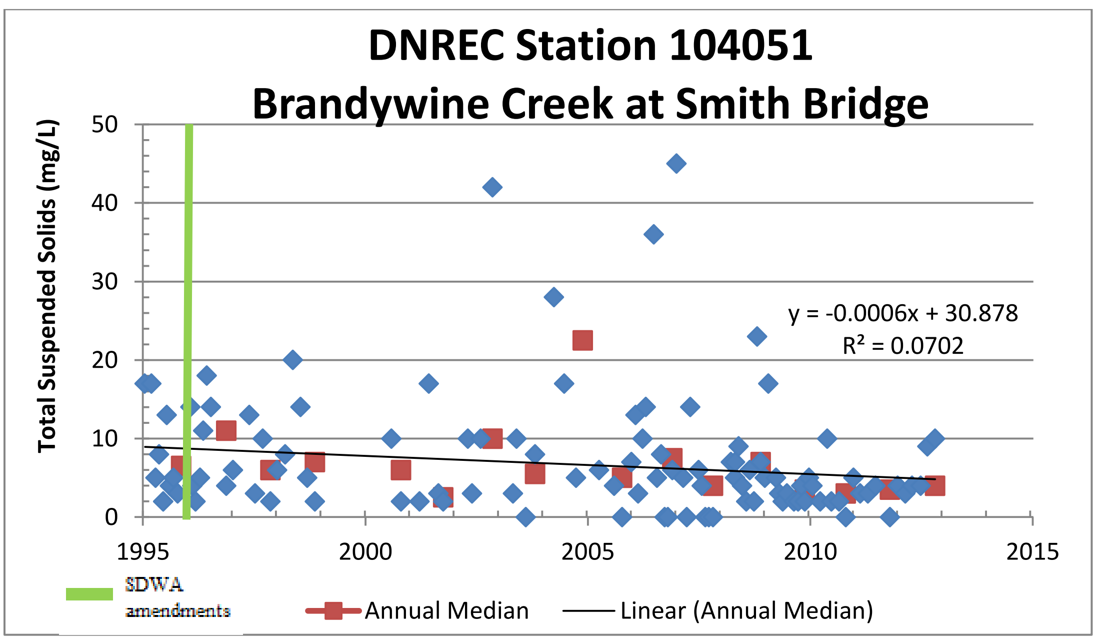


Figure 6.19: TSS along Brandywine Creek at Smith Bridge, Delaware

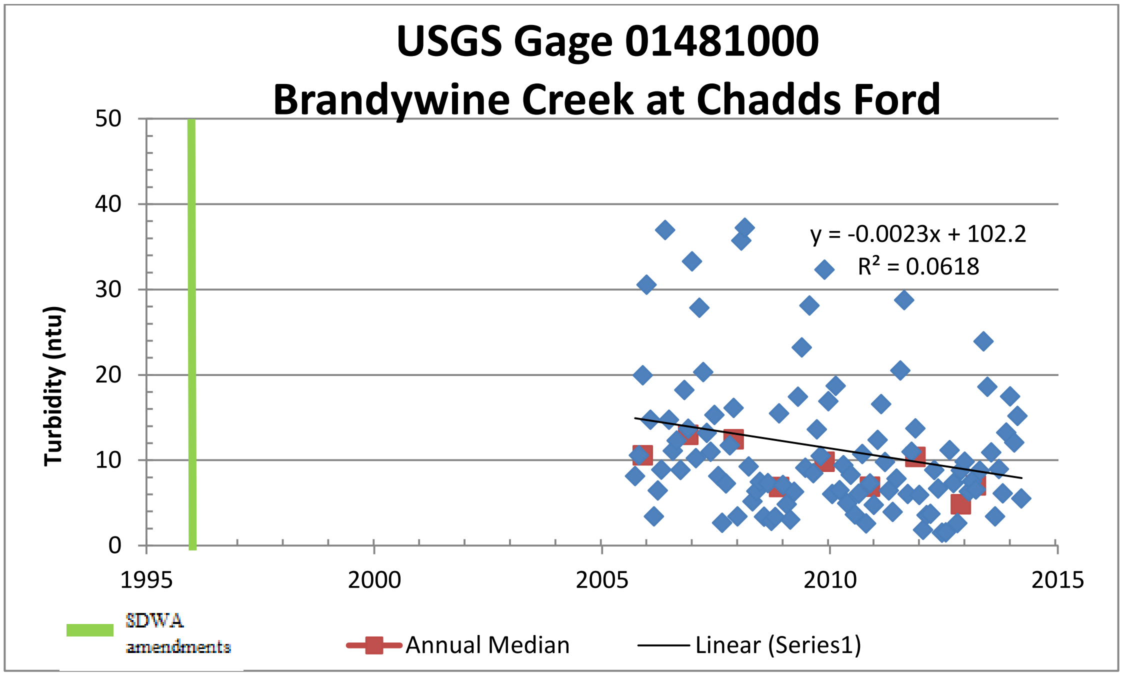


Figure 6.20: Turbidity along Brandywine Creek at Chadds Ford, Pennsylvania

As with TSS, the enterococcus data from the state line stations all exhibit a noticeable downward trend in bacteria concentrations over time. These trends are stronger and clearer than those for TSS, and certainly seem to indicate that, in terms of bacteria, water quality flowing from Pennsylvania into Delaware tends to be cleaner now than it was twenty years ago.

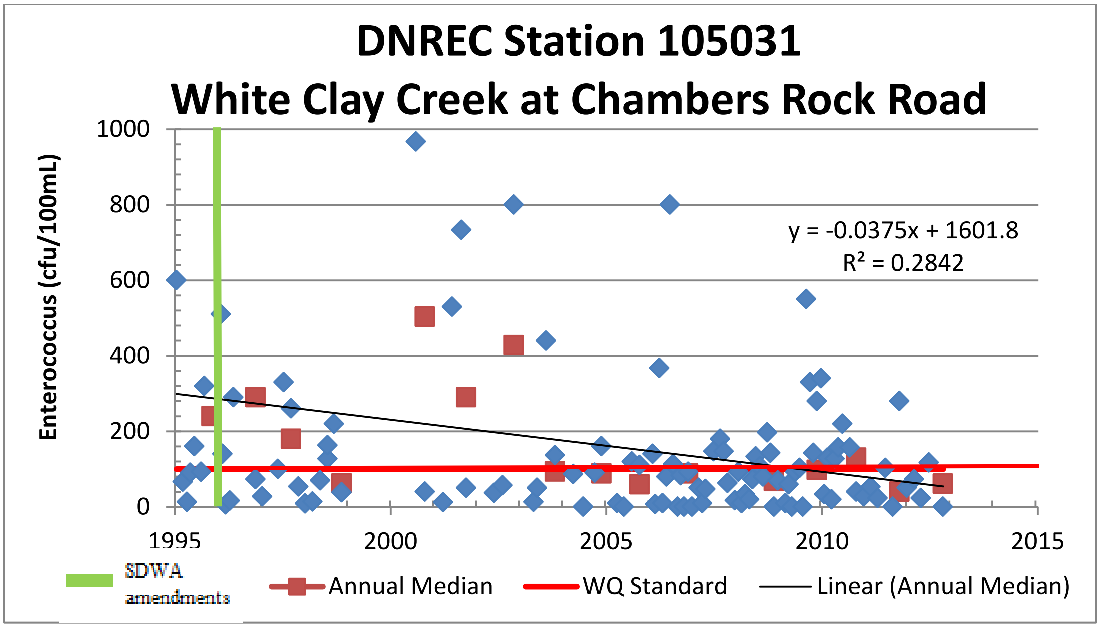


Figure 6.21: Enterococcus along White Clay Creek at Chambers Rock Road, Delaware

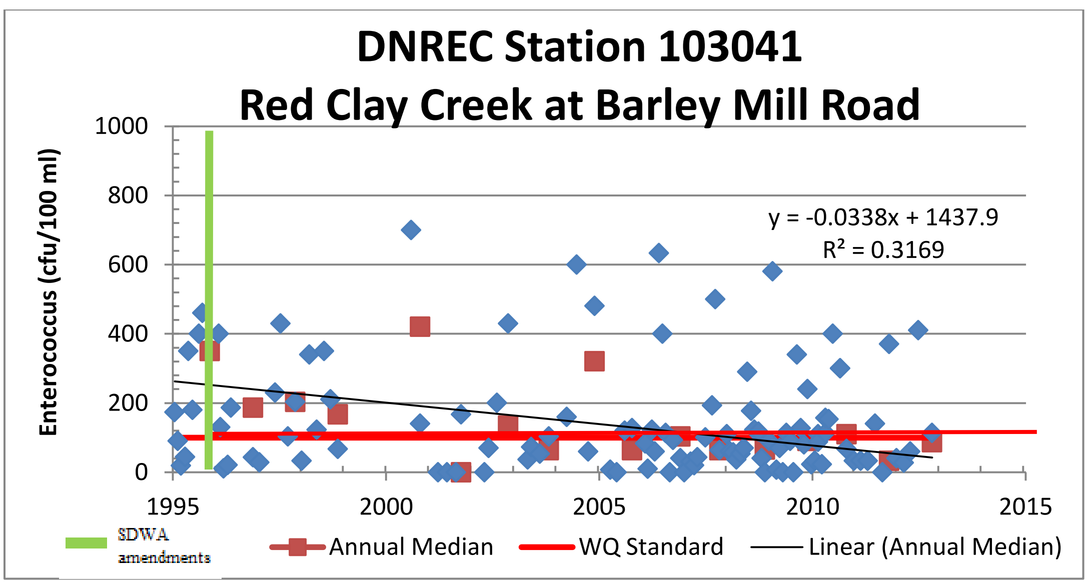


Figure 6.22: Enterococcus along Red Clay Creek at Barley Mill Road, Delaware

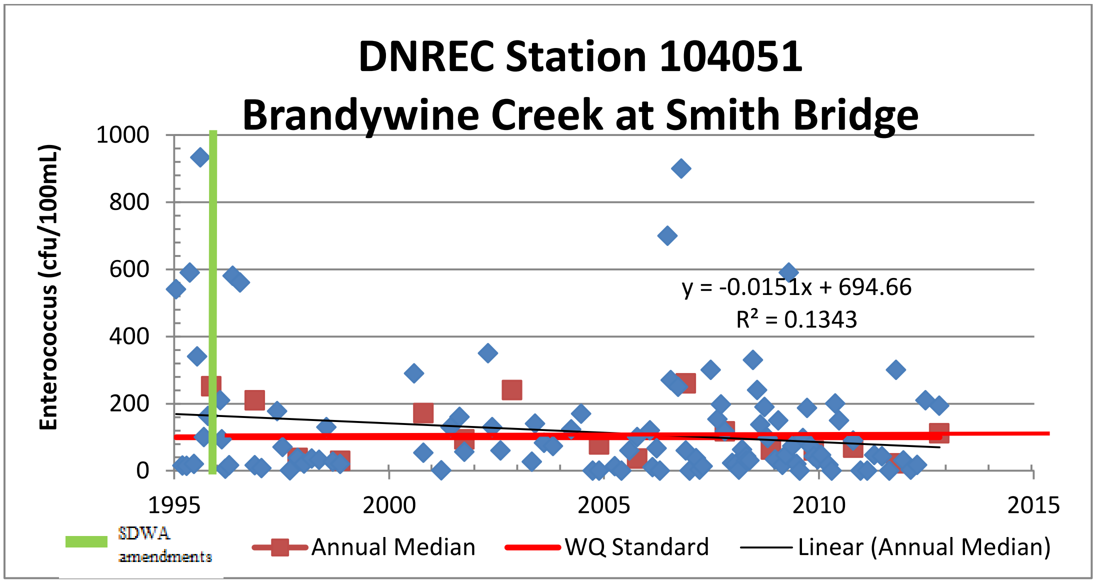


Figure 6.23: Enterococcus along Brandywine Creek at Smith Bridge, Delaware

Across all of the datasets there are high monthly outliers in certain years. According to USGS peak streamflow data at the Wilmington gage, outliers that appear in 2000 or 2006 may be due to high precipitation (and therefore high flows) throughout the watershed. Hurricanes, large storm events, or particularly rainy seasons have the potential to carry more contaminants into waterways than is typical of drier months. Another potential explanation for some of the outliers presented in the charts above is that the majority of the gages and stations have periods during which data collection was halted or infeasible. These periods are usually brief and are unique to each gage or station. Under the principles of averaging, the absence of those data points may lead to disproportionately high values or outliers as presented on the graph.

Ideally, this data would be studied using flow-weighted Seasonal Kendall analyses in order to determine the influence of seasonal weather patterns on these trends. Currently that type of analysis is beyond the scope of this research, but it should be considered in future works.

Overall for all of the sites where there was a record of data long enough from which to draw conclusions, water quality in the basin appears to be improving over time. These improvements may be slight, but they are improvements nonetheless. While this is not necessarily the direct result of source water protection ordinances put in place by local governments, it does seem to show that efforts by local governments, as well as other organizations and programs throughout the basin, are having a positive impact on water quality. In short, while there is certainly room for improvement to accelerate the gains in water quality, things are moving in the right direction for source water in the basin.

# Chapter 7

# SUMMARY OF FINDINGS AND RECOMMENDATIONS

## 7.1 Summary of Findings

The previous chapters in this work review the direct and indirect source water protection ordinances put in place by local governments in the Christina Basin and examine how the municipalities in each state compare to one another. There were four major areas of findings in this research, and they are each described in turn below.

Comparison of the states: Overall, despite the lack of a state law or program involving source water protection, the municipal review scores indicate that the Pennsylvania portion of the Christina Basin, with an overall score of 13.0, is on par with the Delaware portion of the basin (average score = 13.2) in terms of levels of source water protection ordinances. At first glance, these numbers are very similar, and statistical analyses confirm that they cannot be confidently assumed to be different from one another. Even with land-area weighting to account for the fact that New Castle County (a high scoring local government) covers more than 88% of the basin in Delaware, the recalibrated scores (Delaware = 15.9, Pennsylvania = 12.8) are still not statistically different from one another. This fairly high level of consistency across the basin lends itself to the protection of this entire area as a single watershed unit, which research has shown is the most efficient level at which to manage water resources. There are pockets of low scoring regions within the basin, but they are surprisingly few and far between, with only 10% of municipalities scoring at 50% or below on the ordinance review.

GIS analysis: The results of the GIS analyses for the basin indicate that, in terms of total resource area, woodlands and un-buffered stream miles are the basin's most vulnerable natural resources. This means that there were large tracts of woodlands and stretches of streams without protections under the ordinances of their respective municipalities. Karst/carbonate features were also left vulnerable due to a lack of ordinance protections in the municipalities where these features are present.

Statistical analyses: The statistical analysis within this research indicates that generally, higher scores tend to correlate with larger, more populous municipalities with larger annual budgets across the basin. While it is impossible to suggest that lower scoring municipalities become larger, wealthier, or more populous in order to improve their scores, it does demonstrate that source water protection is not inherently anti-growth from an economic or demographic perspective. Furthermore, one of the benefits of using regulatory measures through local ordinances to protect sources of drinking water is that municipalities can use one another's existing ordinances as templates to update and strengthen their own. A strange result emerged out of the statistical analyses based on the natural resources data in Pennsylvania, which indicated that acreage of protected open space and total stream miles are both negatively correlated with source water protection scores. The cause of these relationships is not well understood, but it may be explainable by factors currently beyond the scope of this research.

Water quality trend analysis: Using local water quality as a loose measure of source water protection success, the general trend across the basin seems to be that water quality for major parameters like bacteria and sediment are improving. While the direct and indirect source water protection ordinances quantified by this research cannot be proposed as the causal factor in this positive trend, it certainly indicates that these efforts have not been in vain.

Though the results of this research cannot be directly generalized to surrounding watersheds and river basins, the underlying methodology could certainly be applied to any interstate watershed within the region in order to assess the consistency of source water protection initiatives in interstate Basins. Certainly, the results of this research seem to indicate that a state source water law is not the only means to encourage the regulatory protection of drinking water sources. Voluntary efforts do exist at the local level, and those efforts do appear to have a positive impact on the health and quality of source waters in the region. This is an especially important alternative in states like Pennsylvania, whose large size and diverse demographics might make it more difficult to garner the support for a statewide law than in a smaller state like Delaware.

### 7.2 Recommendations

The data collected and the conclusions reached through this research have led to the development of five recommendations for improving the level of source water protection across the basin, especially in areas where they are currently weak.

Targeting areas for ordinance updates: This research provides a first step in identifying where source water protection ordinances are strong within the basin, and where they are weak. Using this knowledge, direct efforts can be made to target the areas where the ordinances are currently the weakest. However, in addition to targeting weak ordinances, the data and conversations with local experts indicate that all weak ordinances may not be created equally. Some areas with weaker ordinances, like Newport, Delaware, have little potential to improve overall source water quality in the basin, even if their ordinances were completely revised. Efforts should be more specifically targeted in those areas where the potential for gains from updating the ordinances is highest. In particular, this means municipalities that are still largely un-urbanized, but are growing at a rapid pace or have the potential for rapid population growth. Protecting the open spaces and natural resources in these areas through revised and updated ordinances are likely to have the greatest gains for source water quality in the basin. Because the revision of ordinances is a project that has inherent time and cost considerations, focusing the efforts to the places where the benefits will be greatest is the most efficient way to use the limited resources available in the basin.

Increased natural resource protection: This research also shows that the natural resources most vulnerable to degradation or contamination due to a lack of ordinance protections are un-buffered streams and woodlands. Both of these resources have the potential to substantially impact the quality of source waters (both surface and groundwater), and so working with municipalities to improve protections for these resources where they are weak may be a good place to start with ordinance revisions.

Financial incentives: The process of updating ordinances and implementing best management practices is not without financial costs. However, there are some innovative financing strategies that are currently being studied in the basin. The William Penn Foundation has recently awarded a grant for the completion of a feasibility study of the potential for upstream-downstream water quality investing in the basin, also known as a water fund, to be undertaken by The Nature Conservancy and the University of Delaware Water Resources Agency. This project will analyze the potential “for downstream beneficiaries to invest in upstream conservation and restoration measures designed to secure freshwater resources -- both quality and quantity -- for people and nature" (University of Delaware Office of Communication and Marketing, 2014). As an economic mechanism, a water fund is an ideal way to allow downstream water users to financially incentivize the protection and enhancement of upstream water supplies, where in the absence of incentives the capacity or motivation to do so may be low or nonexistent.

Utilizing new model ordinances: Currently, the Brandywine Conservancy is collaborating with the Chester County Planning Commission in Pennsylvania to develop a database of local environmental ordinances and a series of individual model ordinances regarding each individual natural resource. Once this database is completed, these organizations will begin coordinating outreach efforts to strengthen the environmental ordinances in Chester County, many of which include the indirect source water protection ordinances quantified by this research. Change is certainly coming to the basin, and that change appears to be quite positive. Re-evaluating the status of the basin's ordinances in the next five or ten years may be beneficial to understand the evolution of source water protection locally.

Increased monitoring: Increasing the capacity of the basin states to conduct real time water quality monitoring for more parameters at more sites is a crucial component to understanding whether the efforts currently underway are having an impact. There should be increased monitoring of turbidity, enterococcus, and total organic carbon (TOC) at gages and monitoring stations across the basin. Specifically, the most important sites for this kind of data collection are: the Red Clay Creek at Wooddale, Delaware (turbidity and TOC); the Red Clay Creek at Kennett Square, Pennsylvania (turbidity, enterococcus, and TOC); the White Clay Creek at Strickersville, Pennsylvania (enterococcus and TOC); the White Clay Creek near

Newark, Delaware (turbidity, enterococcus, and TOC); and the Christina River at Cooch's Bridge in Delaware (turbidity, enterococcus, and TOC). These sites were selected to their proximity to local source water intakes, and improved monitoring at these specific sites would not only improve the dataset for trend analysis, but the increased real time monitoring could serve as a beneficial early warning system for local water suppliers should harmful contaminants find their way into water bodies upstream of source water areas.

Over the next decade the water quality dataset for this region will also grow to be significantly larger than it is right now. This will allow for an expanded analysis of and more concrete assertions regarding water quality trends as they relate to source water protection regulations.

### 7.3 Areas of Future Research

In the Christina Basin there are some weak to moderate correlations between background municipal characteristics (size, population, etc.), natural resources (stream miles, protected open space, etc.) and overall source water protection scores. However, these correlations do not tell the whole story about what factors influence how well a municipality's ordinances protect the sources of its drinking water. Factors like the era of intensive infrastructure and historical land ownership data may be beneficial areas of future research, both in the basin and outside of it, in order to determine whether or not these factors play a greater role than the parameters identified by this research. More research is also needed in further understanding the counterintuitive negative relationship between stream miles, protected open space, and source water scores in order to determine whether or not there is a currently unidentified factor that underlies these seemingly spurious relationships.

Another extension of this research that may be beneficial in understanding the underlying strength of the existing source water ordinances would be to quantify the number of variances issued by each municipality that allow for these ordinances to be circumvented. The data presented in this research assumes that the ordinances are enforced exactly as they are written, but this may not be the case in all municipalities, and it is possible that there may be variation in levels of enforcement in the same way that there are variations in levels of protective ordinances.

Other areas of future research involve expanding the area of analysis to include surrounding interstate basins in order to assess whether or not the Christina Basin is an anomaly among its watershed neighbors, or if the findings detailed in this research are generalizable to a wider set of river basins.

The results of this research demonstrate that, although not completely uniform, there is a level of consistency in source water protection regulations across the basin. From a management perspective, this makes identifying key areas for improvement more straight forward, and it also provides a framework of reference for what strong local source water protection initiatives look like.

More generally, it implies that there are many paths that local governments can take to protecting the sources of drinking water for their citizens. That path does not always have to be through mandates from the state, as this research demonstrates that voluntary efforts at the local level can also be successful. However, to further these efforts, some interstate coordination may be required in order to disseminate information and focus initiatives in a manner that works best for each individual municipality. Fortunately, such interstate leadership (through the Christina Basin Water Quality Management Committee, the University of Delaware Water Resources

Agency, and the Chester County Water Resources Authority, among others) already exists in the Christina Basin.

Clearly, protecting the sources of water that contribute to the public water supply is an enormously important task for any society. Here in the Christina Basin, such efforts are well under way. Although there is still progress to be made, the overall trend is a consistently positive one, and the basin can certainly serve as an example and a success story for other interstate watersheds within the region and across the country.

## REFERENCES


Ainsworth, S., Brown, H., and Jehn, P. (1996). "How's the water?" Public Management, 2(2), 15–20.

Alcott, E., Ashton, M. S., and Gentry, B. S. (Eds.). (2013). "Natural and Engineered Solutions for Drinking Water Supplies." Boca Raton, FL: CRC Press.

Chen, S. (2008). "From Community-based Management to Transboundary Watershed Governance." Development, 51(1), 83–88. doi:10.1057/palgrave.development.1100445

Chester County Planning Commission. (2010). "Community Water Supply System." West Chester, PA. Retrieved from http://www.chesco.org/DocumentCenter/View/3296

Chester County Water Resources Authority. (2013). "PA Act 167 Stormwater Management Plans." Retrieved April 04, 2014, from http://www.chesco.org/index.aspx?NID=758

Chiueh, P.-T., Shang, W.-T., and Lo, S.-L. (2012). "An integrated risk management model for source water protection areas." International Journal of Environmental Research and Public Health, 9(10), 3724–39. doi:10.3390/ijerph9103724

"Constitution of the Commonwealth of Pennsylvania." (1968). Harrisburg, PA: Commonwealth of Pennsylvania.

Conway, T. (2008, April). "Battle of the Brandywine Redux." Mainline Today. Retrieved from http://www.mainlinetoday.com/core/pagetools.php?pageid=6376&url=/Main-Line-Today/April-2008/FRONTLINE-Neighborhood/&mode=print

Critical Zone Observatories. (n.d.). "Christina River Basin Critical Zone Observatory." Retrieved March 31, 2014, from http://criticalzone.org/christina/infrastructure/field-area/christina-river-basin/

Cruz-Ortiz, C., and Miller, K. (2014). "The Economic Value of the Christina Basin." Newark, DE.

Davies, J.-M., and Mazumder, A. (2003). “Health and environmental policy issues in Canada: the role of watershed management in sustaining clean drinking water quality at surface sources.” Journal of Environmental Management, 68(3), 273–286. doi:10.1016/S0301-4797(03)00070-7

Delaware Coastal Programs. (n.d.). “Special Area Management Plan - A Plan for the Revitalization of South Wilmington.” Retrieved April 06, 2014, from http://www.dnrec.delaware.gov/coastal/Pages/WilmingtonSAMP.aspx

Delaware County Planning Commission. (n.d.). “Act 167 Stormwater Management Plans.” Retrieved April 04, 2014, from http://www.co.delaware.pa.us/planning/environmental/act167.html

“Delaware declares independence.” (2014). The History Channel website. Retrieved 2:00, April 22, 2014, from http://www.history.com/this-day-in-history/delaware-declares-independence.

Delaware Tributary Action Teams, University of Delaware, and Delaware Department of Natural Resources and Environmental Control. (2011). “Christina Basin Pollution Control Strategy.” Dover, DE.

Drew, D., and Holtz, H. (1999). “Karst Hydrogeology and Human Activities: Impacts, Consequences and Implications.” (p. 332). Brookfield, VT: A.A. Balkema Publishers.

Emelko, M. B., Silins, U., Bladon, K. D., and Stone, M. (2011). “Implications of land disturbance on drinking water treatability in a changing climate: demonstrating the need for ‘source water supply and protection’ strategies.” Water Research, 45(2), 461–72. doi:10.1016/j.watres.2010.08.051

Ernst, C. (2004). “Land Conservation and the Future of America’s Drinking Water: Protecting the Source.”

Fisher, K., and Phillips, C. (2009). “The ecology, epidemiology and virulence of Enterococcus.” Microbiology (Reading, England), 155(Pt 6), 1749–57. doi:10.1099/mic.0.026385-0

Froemke, P. (2012). “Nationwide Assessment of Nonpoint Source Threats to Water Quality.” BioScience, 62(2), 136–146. doi:10.1525/bio.2012.62.2.7

Greig, D., Bowers, J., and Kauffman, G. J. (1998). “Phase I and II Report: Christina River Basin Water Quality Management Strategy.” Newark, DE.

Gullick, R. W. (2003). “AWWA’s Source Water Protection Committee outlines how to maintain the highest quality source water.” Journal of the American Water Works Association, 95(11), 36–42.

Hesson, M. D. (2005). “The Economic Efficiency of Watershed Management Concerning Drinking Water Supply in the White Clay Creek Watershed in Pennsylvania and Delaware.” University of Delaware.

Homsey, A., and Kauffman, G. J. (2007). “Report on Source Water Protection for the Surface Water Intakes in New Castle County.”

Hurley, T., and Mazumder, A. (2013). “Spatial scale of land-use impacts on riverine drinking source water quality.” Water Resources Research, 49(3), 1591–1601. doi:10.1002/wrcr.20154

Hurley, T., Sadiq, R., and Mazumder, A. (2012). “Adaptation and evaluation of the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) for use as an effective tool to characterize drinking source water quality.” Water Research, 46(11), 3544–52. doi:10.1016/j.watres.2012.03.061

Interstate Council on Water Policy. (2002). “Interstate River Basin Organization Source Water Protection Survey.” Washington, D.C.

Islam, N., Sadiq, R., Rodriguez, M. J., and Francisque, A. (2013). “Evaluation of source water protection strategies: a fuzzy-based model.” Journal of Environmental Management, 121, 191–201. doi:10.1016/j.jenvman.2013.02.022

Ivey, J. L., de Loë, R., Kreutzwiser, R., and Ferreyra, C. (2006). “An institutional perspective on local capacity for source water protection.” Geoforum, 37(6), 944–957. doi:10.1016/j.geoforum.2006.05.001

Jacobsen, K. H. (2008). “Introduction to Public Health.” Sudbury, MA: Jones and Bartlett Publishers.

John, M., Catherine, V., Jeffrey, L., and Andrews, L. (2005). “Linking Water Quality To The Watershed: Developing Tools for Source Water Protection.” Journal of the American Water Works Association, 97(9), 62.

Kauffman, G. J. (2009). “Clean Water is Good Business in the Christina Basin.” Newark, DE.

Kauffman, G. J., Corrozi, M. B., and Vonck, K. J. (2006). “Imperviousness : A Performance Measure Of A Delaware Water Resource Protection Area

Ordinance.” Journal of the American Water Resources Association, 19716, 603–615.

Kauffman, G. J., Greig, D., and Bowers, J. (1999). “Phase III Christina Basin Water Quality Management Strategy.”

Mack, J. (Ed.). (1990). “The Encyclopedia of Colonial and Revolutionary America.” New York City, NY: Sachem Publishing Associates, Inc.

Minnesota Pollution Control Agency. (2008). “Turbidity: Description, Impact on Water Quality, Sources, Measures.” St. Paul, MN. Retrieved from http://www.pca.state.mn.us/index.php/view-document.html?gid=7854

Mittal, A. K. (2007). “Interstate Compacts: An Overview of the Structure and Governance of Environment and Natural Resource Compacts.” Washington, D.C.

Montgomery, J. (2014, January 19). “Vulnerability of Delaware’s water sources in the spotlight.” The News Journal.

NCSU Water Quality Group. (n.d.). “Major Causes of Wetland Loss and Degradation.” WaterShedss. Retrieved April 04, 2014, from http://www.water.ncsu.edu/watershedss/info/wetlands/wetloss.html

New England Interstate Water Pollution Control Commission. (n.d.). “Protecting Drinking Water Sources in Your Community, A New Source Water Protection Tool for Municipal Officials.” Lowell, MA.

New Jersey Department of Environmental Protection. (2004). “New Jersey Stormwater Best Management Practices Manual.”

PA Department of Environmental Protection. (2010). “The Pennsylvania Stormwater Management Act 167 Planning Program.” Harrisburg, PA. Retrieved from ftp://ftp.dot.state.pa.us/public/Bureaus/BOMO/3930-FS-DEP1840.pdf

Patrick, R. J. (2009). “Source water protection in a landscape of ‘New Era’ deregulation.” The Canadian Geographer / Le Géographe Canadien, 53(2), 208–221. doi:10.1111/j.1541-0064.2009.00254.x

Pennsylvania Department of Community and Economic Development. (2001). “Local Land Use Controls in Pennsylvania: Planning Series #1.” Harrisburg, PA.

“Pennsylvania Municipalities: In a Class by Themselves.” (2007, March). Pennsylvania Township News.

Pike, E. B., Drive, R. H., and Common, S. (1999). “Drinking water supply- a backward look into the future.” The Environmentalist, 9, 5–9.

Pontius, F. W. (1997). “Overview of SDWA source water protection programs.” Journal of the American Water Works Association, 89(11), 22–24.

Reimold, R. J. (1998). “Watershed Management: Practices, Policies, and Coordination.” New York: McGraw-Hill.

Rizak, S., Cunliffe, D., Sinclair, M., Vulcano, R., Howard, J., Hrudey, S., andCallan, P. (2003). “Drinking water quality management: a holistic approach.” Water Science and Technology: A Journal of the International Association on Water Pollution Research, 47(9), 31–6. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12830937

Roberson, J. A. (2011). “What’s next after 40 years of drinking water regulations?” Environmental Science and Technology, 45(1), 154–60. doi:10.1021/es101410v

South Carolina Department of Health and Environmental Control. (n.d.). “Code and Ordinance Worksheet.”

Susfalk, R. B., Fitzgerald, B., and Knust, A. M. (2008). “Suspended Solids in the Upper Carson River, Nevada.”

Ten Towns Great Swap Watershed Management Committee. (2002). “Water Quality Standards for the Great Swamp Watershed.”

Tiemann, M. (2014). “Safe Drinking Water Act (SDWA): A Summary of the Act and Its Major Requirements.” Washington, D.C.

U.S. Center for Disease Control. (1996). “Surveillance for Waterborne-Disease Outbreaks -- United States, 1993-1994.” Morbidity and Mortality Weekly Report, 45(SS-1), 1–33.

U.S. Center for Disease Control. (1999). “Achievements in Public Health, 1900-1999: Control of Infectious Diseases.” Morbidity and Mortality Weekly Report, 48(29), 621–629.

U.S. Environmental Protection Agency. (2004). “Sediment-Related Criteria for Surface Water.” Washington, D.C.

U.S. Environmental Protection Agency. (2013a). "Model Ordinance Language: Ground and Surface Water Protection Overlay District Example Ordinance." Retrieved October 12, 2013, from http://water.epa.gov/polwaste/nps/mol7.cfm

U.S. Environmental Protection Agency. (2013b). "Public Drinking Water Systems Program." Retrieved from http://water.epa.gov/infrastructure/drinkingwater/pws/index.cfm

U.S. Environmental Protection Agency. (2014). "Summary of the Clean Water Act." Retrieved April 04, 2014, from http://www2.epa.gov/laws-regulations/summary-clean-water-act

U.S. General Accounting Office. (1999). "Safe Drinking Water Act: Progress and Challenges in Implementing the 1996 Amendments." Washington, D.C.

University of Delaware Office of Communications and Marketing. (2014, April 8). "Watershed Investment." UDaily. Newark, DE. Retrieved from http://www.udel.edu/udaily/2014/apr/wra-nature-040814.html

University of Delaware Water Resources Agency. (2002a). "Source Water Assessment of the City of Newark, Delaware Public Water Supply Intake Located on the White Clay Creek."

University of Delaware Water Resources Agency. (2002b). "Source Water Assessment of the City of Wilmington Edgar M. Hoopes Reservoir."

University of Delaware Water Resources Agency. (2002c). "Source Water Assessment of the City of Wilmington, Delaware Public Water Supply Intake Located on the Brandywine Creek."

University of Delaware Water Resources Agency. (2002d). "Source Water Assessment of the United Water Delaware at Stanton Public Water Supply Intake Located on the White Clay and Red Clay Creeks."

University of Delaware Water Resources Agency. (2002e). "Source Water Assessment of the United Water Delaware Public Water Supply Intake Located on the Christina River at Smalleys Pond."

Wild and Scenic White Clay Creek Management Program. (2013). "Wild and Scenic White Clay Creek." Retrieved April 20, 2014, from www.whiteclay.org

Yanggen, D. A., and Webendorfer, B. (1991). "Groundwater Protection through Local Land-Use Controls." Madison, WI: University of Wisconsin Extension.

## Appendix A

## BACKGROUND AND NATURAL RESOURCE DATA

| Background Municipal Data: Population Information | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Municipality** | **State** | **County** | **Size** | **Pop.** | **Pop. Density** | **Pop. Growth** | **Pop. Urban** |
| New Castle County | DE | NCC | 494.0 | 538,479 | 1,090 | 7.6 | 0.95 |
| Elsmere | DE | NCC | 1.0 | 6,131 | 6,131 | 5.7 | 1.00 |
| Newark | DE | NCC | 8.9 | 31,454 | 3,534 | 12.2 | 1.00 |
| Newport | DE | NCC | 0.4 | 1,055 | 2,573 | -6.0 | 1.00 |
| Wilmington | DE | NCC | 17.0 | 70,851 | 4,168 | -2.3 | 1.00 |
| Avondale | PA | ChesCo | 0.5 | 1,265 | 2,530 | 14.2 | 1.00 |
| Birmingham | PA | ChesCo | 6.5 | 4,208 | 647 | -0.3 | 0.83 |
| Caln | PA | ChesCo | 8.8 | 13,817 | 1,570 | 16.0 | 1.00 |
| Coatesville | PA | ChesCo | 1.9 | 13,100 | 6,895 | 22.0 | 1.00 |
| Downingtown | PA | ChesCo | 2.2 | 7,891 | 3,587 | 4.0 | 1.00 |
| East Bradford | PA | ChesCo | 15.1 | 9,942 | 658 | 5.7 | 0.88 |
| East Brandywine | PA | ChesCo | 11.4 | 6,742 | 591 | 15.8 | 0.95 |
| East Caln | PA | ChesCo | 3.7 | 4,838 | 1,308 | 69.3 | 0.99 |
| East Fallowfield | PA | ChesCo | 15.7 | 7,449 | 474 | 44.4 | 0.77 |
| East Marlborough | PA | ChesCo | 15.6 | 7,026 | 450 | 11.2 | 0.88 |
| East Nantmeal | PA | ChesCo | 16.4 | 1,803 | 110 | 0.9 | - |
| East Whiteland | PA | ChesCo | 11.0 | 10,650 | 968 | 14.1 | 0.95 |
| Franklin | PA | ChesCo | 13.2 | 4,352 | 330 | 13.0 | 0.25 |
| Highland | PA | ChesCo | 17.2 | 1,272 | 74 | 13.1 | - |
| Honey Brook | PA | ChesCo | 25.4 | 7,647 | 301 | 21.8 | 0.22 |
| Honey Brook Boro | PA | ChesCo | 0.5 | 1,713 | 3,426 | 33.1 | 1.00 |
| Kennett | PA | ChesCo | 15.5 | 7,565 | 488 | 17.3 | 0.60 |
| Kennett Square | PA | ChesCo | 1.1 | 6,072 | 5,520 | 15.2 | 1.00 |
| London Britain | PA | ChesCo | 9.9 | 3,139 | 317 | 12.2 | 0.50 |
| London Grove | PA | ChesCo | 17.2 | 7,475 | 435 | 42.0 | 0.69 |
| Londonderry | PA | ChesCo | 11.3 | 2,149 | 190 | 31.7 | - |
| Modena | PA | ChesCo | 0.3 | 535 | 1,783 | -12.3 | 1.00 |
| New Garden | PA | ChesCo | 16.2 | 11,984 | 740 | 31.9 | 0.89 |
| New London | PA | ChesCo | 11.9 | 5,631 | 473 | 22.9 | 0.47 |
| Newlin | PA | ChesCo | 12.0 | 1,285 | 107 | 11.7 | - |

| Municipality (cont.) | State | County | Size | Pop. | Pop. Density | Pop. Growth | Pop. Urban |
|---|---|---|---|---|---|---|---|
| Parkesburg | PA | ChesCo | 1.2 | 3,593 | 2,994 | 6.5 | 1.00 |
| Penn | PA | ChesCo | 9.6 | 5,364 | 559 | 90.7 | 0.50 |
| Pennsbury | PA | ChesCo | 10.0 | 3,604 | 360 | 3.0 | 0.55 |
| Pocopson | PA | ChesCo | 8.4 | 4,582 | 545 | 36.8 | 0.71 |
| Sadsbury | PA | ChesCo | 6.2 | 3,570 | 576 | 38.3 | 0.72 |
| South Coatesville | PA | ChesCo | 1.7 | 1,303 | 766 | 30.7 | 1.00 |
| Thornbury | PA | ChesCo | 3.9 | 3,017 | 774 | 12.7 | 0.83 |
| Upper Uwchlan | PA | ChesCo | 11.7 | 11,227 | 960 | 63.9 | 0.92 |
| Uwchlan | PA | ChesCo | 10.4 | 18,088 | 1,739 | 9.1 | 1.00 |
| Valley | PA | ChesCo | 6.0 | 6,794 | 1,132 | 32.8 | 0.96 |
| Wallace | PA | ChesCo | 12.1 | 3,458 | 286 | 6.7 | 0.04 |
| West Bradford | PA | ChesCo | 18.7 | 12,376 | 662 | 14.9 | 0.88 |
| West Brandywine | PA | ChesCo | 13.4 | 7,394 | 552 | 3.4 | 0.88 |
| West Caln | PA | ChesCo | 21.8 | 9,014 | 413 | 27.8 | 0.19 |
| West Chester | PA | ChesCo | 1.8 | 18,461 | 10,256 | 3.4 | 1.00 |
| West Fallowfield | PA | ChesCo | 18.1 | 2,566 | 142 | 3.3 | - |
| West Goshen | PA | ChesCo | 12.0 | 21,866 | 1,822 | 6.7 | 1.00 |
| West Grove | PA | ChesCo | 0.6 | 2,854 | 4,757 | 7.6 | 1.00 |
| West Marlborough | PA | ChesCo | 17.1 | 814 | 48 | -5.2 | - |
| West Nantmeal | PA | ChesCo | 13.5 | 2,170 | 161 | 6.8 | - |
| West Sadsbury | PA | ChesCo | 10.7 | 2,444 | 228 | 0.0 | 0.52 |
| West Vincent | PA | ChesCo | 17.8 | 4,567 | 257 | 44.1 | 0.01 |
| West Whiteland | PA | ChesCo | 13.0 | 18,274 | 1,406 | 10.8 | 1.00 |
| Westtown | PA | ChesCo | 8.7 | 10,827 | 1,244 | 4.6 | 0.99 |
| Bethel | PA | DelCo | 5.7 | 8,791 | 1,542 | 36.9 | 1.00 |
| Chadds Ford | PA | DelCo | 8.7 | 3,640 | 418 | 14.8 | 0.42 |
| Concord | PA | DelCo | 13.7 | 17,231 | 1,258 | 73.5 | 0.97 |
| Salisbury | PA | LanCo | 41.9 | 11,062 | 264 | 10.5 | 0.28 |

| Background Municipal Data: Demographic Information | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Municipality** | **State** | **County** | **Budget ($)** | **Median House Income ($)** | **High School Edu.** | **MS4** | **Well/ Intake** | **LU Urban (%)** | **LU Ag (%)** |
| New Castle County | DE | NCC | 248,190,104 | 64,670 | 89% | 1.00 | 1.00 | 32% | 22% |
| Elsmere | DE | NCC | 3,153,587 | 47,016 | 76% | 1.00 | - | 84% | 0% |
| Newark | DE | NCC | 43,532,428 | 51,184 | 96% | 1.00 | 1.00 | 75% | 7% |
| Newport | DE | NCC | 1,517,770 | 39,318 | 74% | 1.00 | - | 100% | 0% |
| Wilmington | DE | NCC | 145,540,837 | 39,761 | 82% | 1.00 | 1.00 | 52% | 0% |
| Avondale | PA | ChesCo | 900,000 | 58,036 | 52% | 1.00 | 1.00 | 46% | 14% |
| Birmingham | PA | ChesCo | 2,062,670 | 168,550 | 98% | 1.00 | - | 45% | 25% |
| Caln | PA | ChesCo | 6,269,536 | 66,457 | 92% | 1.00 | - | 54% | 6% |
| Coatesville | PA | ChesCo | 10,120,657 | 34,625 | 79% | 1.00 | - | 70% | 0% |
| Downingtown | PA | ChesCo | 9,000,000 | 53,024 | 89% | 1.00 | - | 65% | 5% |
| East Bradford | PA | ChesCo | 3,982,043 | 117,276 | 97% | 1.00 | 1.00 | 39% | 26% |
| East Brandywine | PA | ChesCo | 6,495,935 | 104,339 | 97% | 1.00 | 1.00 | 40% | 17% |
| East Caln | PA | ChesCo | 2,505,428 | 90,107 | 97% | 1.00 | 1.00 | 60% | 1% |
| East Fallowfield | PA | ChesCo | 2,784,475 | 89,836 | 94% | 1.00 | - | 26% | 37% |
| East Marlborough | PA | ChesCo | 1,799,480 | 106,022 | 96% | 1.00 | 1.00 | 31% | 46% |
| East Nantmeal | PA | ChesCo | 814,150 | 97,500 | 90% | - | - | 12% | 35% |
| East Whiteland | PA | ChesCo | 14,183,930 | 91,144 | 94% | 1.00 | - | 62% | 6% |
| Franklin | PA | ChesCo | 1,687,316 | 122,527 | 94% | 1.00 | 1.00 | 27% | 41% |
| Highland | PA | ChesCo | 598,700 | 50,903 | 80% | - | - | 4% | 75% |
| Honey Brook | PA | ChesCo | 1,016,484 | 67,348 | 79% | 1.00 | 1.00 | 16% | 54% |
| Honey Brook Boro | PA | ChesCo | 1,489,325 | 72,829 | 90% | - | - | 74% | 19% |
| Kennett | PA | ChesCo | 3,095,200 | 105,280 | 97% | 1.00 | - | 37% | 28% |
| Kennett Square | PA | ChesCo | 4,529,100 | 60,030 | 63% | 1.00 | - | 80% | 4% |
| London Britain | PA | ChesCo | 4,275,000 | 118,309 | 96% | 1.00 | - | 28% | 28% |
| London Grove | PA | ChesCo | 3,450,090 | 90,433 | 89% | 1.00 | 1.00 | 24% | 49% |
| Londonderry | PA | ChesCo | 503,969 | 97,625 | 89% | - | - | 13% | 65% |
| Modena | PA | ChesCo | - | 45,938 | 81% | 1.00 | - | 50% | 8% |
| New Garden | PA | ChesCo | 4,415,100 | 113,736 | 82% | 1.00 | 1.00 | 36% | 35% |
| New London | PA | ChesCo | 1,500,000 | 116,319 | 90% | 1.00 | - | 32% | 38% |
| Newlin | PA | ChesCo | 419,968 | 106,500 | 93% | 1.00 | 1.00 | 11% | 48% |
| Parkesburg | PA | ChesCo | 2,909,91 | 64,831 | 85% | 1.00 | - | 76% | 10% |
| Penn | PA | ChesCo | - | 74,205 | 92% | 1.00 | - | 30% | 49% |
| Pennsbury | PA | ChesCo | 1,284,996 | 120,795 | 98% | 1.00 | - | 33% | 28% |
| Pocopson | PA | ChesCo | 1,654,876 | 141,875 | 89% | 1.00 | 1.00 | 30% | 36% |
| Sadsbury | PA | ChesCo | 1,739,760 | 73,925 | 91% | 1.00 | - | 29% | 43% |
| South Coatesville | PA | ChesCo | - | 46,696 | 89% | 1.00 | - | 41% | 7% |
| Thornbury | PA | ChesCo | 1,688,353 | 128,077 | 97% | 1.00 | - | 52% | 12% |
| Upper Uwchlan | PA | ChesCo | 4,882,029 | 156,482 | 99% | 1.00 | 1.00 | 45% | 14% |
| Uwchlan | PA | ChesCo | 12,227,000 | 107,098 | 97% | 1.00 | - | 64% | 11% |

| Municipality (cont.) | State | County | Budget ($) | Median House Income ($) | High School Edu. | MS4 | Well/ Intake | LU Urban (%) | LU Ag (%) |
|---|---|---|---|---|---|---|---|---|---|
| Valley | PA | ChesCo | 1,500,000 | 75,313 | 90% | 1.00 | 1.00 | 47% | 12% |
| Wallace | PA | ChesCo | 1,953,000 | 111,400 | 96% | 1.00 | - | 28% | 21% |
| West Bradford | PA | ChesCo | 2,587,700 | 103,389 | 98% | 1.00 | 1.00 | 33% | 25% |
| West Brandywine | PA | ChesCo | 2,440,000 | 81,477 | 95% | 1.00 | 1.00 | 37% | 29% |
| West Caln | PA | ChesCo | 1,980,000 | 72,059 | 91% | 1.00 | 1.00 | 29% | 31% |
| West Chester | PA | ChesCo | 33,713,989 | 45,071 | 90% | 1.00 | 1.00 | 90% | 0% |
| West Fallowfield | PA | ChesCo | 951,815 | 58,657 | 86% | - | - | 8% | 72% |
| West Goshen | PA | ChesCo | 14,642,468 | 93,397 | 95% | 1.00 | - | 76% | 3% |
| West Grove | PA | ChesCo | 1,342,000 | 67,778 | 84% | 1.00 | 1.00 | 89% | 3% |
| West Marlborough | PA | ChesCo | 364,850 | 84,375 | 91% | - | - | 2% | 77% |
| West Nantmeal | PA | ChesCo | 1,481,042 | 64,361 | 91% | - | - | 16% | 50% |
| West Sadsbury | PA | ChesCo | 807,855 | 69,079 | 82% | 1.00 | - | 19% | 59% |
| West Vincent | PA | ChesCo | 2,435,000 | 121,528 | 95% | 1.00 | - | 20% | 40% |
| West Whiteland | PA | ChesCo | 10,064,254 | 94,695 | 97% | 1.00 | 1.00 | 62% | 11% |
| Westtown | PA | ChesCo | 6,606,946 | 116,984 | 98% | 1.00 | - | 60% | 16% |
| Bethel | PA | DelCo | 1,903,428 | 115,063 | 97% | 1.00 | - | 57% | 4% |
| Chadds Ford | PA | DelCo | 1,210,885 | 108,869 | 98% | 1.00 | - | 34% | 22% |
| Concord | PA | DelCo | 3,536,403 | 84,953 | 93% | 1.00 | - | 52% | 9% |
| Salisbury | PA | LanCo | 1,859,700 | 61,662 | 64% | - | - | 11% | 70% |

*In the table above, a 1.00 indicates that the municipality has that parameter (either an MS4 permit or a surface/well intake) within their jurisdiction.

| Natural Resource Municipal Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Municipality** | **State** | **County** | **Wooded (ac)** | **Wetland (ac)** | **Steep Slopes (ac)** | **Flood-plain (ac)** | **POS (ac)** | **Karst** | **Streams (mi)** |
| New Castle County | DE | NCC | 40,184.9 | 46,103.4 | 6,594.0 | 61,747.5 | 63,383.7 | 1.00 | 61,644.3 |
| Elsmere | DE | NCC | 78.73 | 15.17 | 0.01 | 263.89 | 85.50 | - | 2.46 |
| Newark | DE | NCC | 898.10 | 135.60 | 289.80 | 681.68 | 792.53 | 1.00 | 19.75 |
| Newport | DE | NCC | - | 33.16 | 0.01 | 114.43 | 20.76 | 1.00 | 2.13 |
| Wilmington | DE | NCC | 112.34 | 863.69 | 0.01 | 3,288.28 | 522.89 | - | 31.92 |
| Avondale | PA | ChesCo | 37.45 | 15.77 | 67.25 | 102.69 | 9.93 | 1.00 | 2.67 |
| Birmingham | PA | ChesCo | 157.65 | 49.45 | 96.53 | 322.89 | 103.26 | 1.00 | 6.41 |
| Caln | PA | ChesCo | 0.01 | 3.25 | 0.01 | - | 5.59 | - | 0.43 |
| Coatesville | PA | ChesCo | 104.60 | 2.09 | 198.71 | 59.93 | 8.95 | - | 1.53 |
| Downingtown | PA | ChesCo | 16.95 | 0.01 | 20.07 | 58.70 | 42.37 | - | 2.42 |
| East Bradford | PA | ChesCo | 840.51 | 128.94 | 438.02 | 599.75 | 734.30 | - | 25.14 |
| East Brandywine | PA | ChesCo | 1,711.92 | 140.17 | 1,115.98 | 546.24 | 304.67 | 1.00 | 22.79 |
| East Caln | PA | ChesCo | 2,755.32 | 389.77 | 2,015.87 | 1,368.13 | 3,045.15 | - | 54.07 |
| East Fallowfield | PA | ChesCo | 2,025.77 | 84.92 | 1,092.12 | 404.38 | 811.45 | - | 34.01 |
| East Marlborough | PA | ChesCo | 535.53 | 79.34 | 538.08 | 140.86 | 103.79 | 1.00 | 4.94 |
| East Nantmeal | PA | ChesCo | 3,255.40 | 72.15 | 2,750.55 | 545.28 | 3,260.37 | - | 42.50 |
| East Whiteland | PA | ChesCo | 1,694.70 | 119.36 | 334.00 | 531.93 | 3,068.37 | 1.00 | 49.70 |
| Franklin | PA | ChesCo | 4,787.47 | 446.00 | 2,227.98 | 828.13 | 4,379.97 | - | 44.68 |
| Highland | PA | ChesCo | 1,431.64 | 42.98 | 524.84 | 354.30 | 249.63 | 1.00 | 18.66 |
| Honey Brook | PA | ChesCo | 2,218.62 | 117.72 | 936.84 | 605.79 | 1,887.60 | - | 58.06 |
| Honey Brook Boro | PA | ChesCo | 2,125.49 | 69.14 | 1,039.93 | 365.53 | 6,047.23 | - | 47.64 |
| Kennett | PA | ChesCo | 3,892.27 | 643.36 | 1,016.63 | 1,464.21 | 1,828.93 | - | 69.07 |
| Kennett Square | PA | ChesCo | 2,679.94 | 213.39 | 822.07 | 645.72 | 930.09 | 1.00 | 53.45 |
| London Britain | PA | ChesCo | 2,489.80 | 93.56 | 1,297.17 | 549.92 | 2,100.03 | - | 40.17 |
| London Grove | PA | ChesCo | 2,049.78 | 216.19 | 464.76 | 769.69 | 2,296.85 | 1.00 | 59.14 |

| Municipality (cont.) | State | County | Wooded (ac) | Wetland (ac) | Steep Slopes (ac) | Flood-plain (ac) | POS (ac) | Karst | Streams (mi) |
|---|---|---|---|---|---|---|---|---|---|
| Londonderry | PA | ChesCo | 1,446.06 | 40.97 | 320.69 | 430.23 | 3,654.04 | - | 36.53 |
| Modena | PA | ChesCo | 2,007.77 | 163.46 | 981.45 | 451.76 | 502.31 | 1.00 | 54.33 |
| New Garden | PA | ChesCo | 1,826.67 | 117.08 | 574.09 | 559.33 | 701.54 | - | 49.50 |
| New London | PA | ChesCo | 2,959.20 | 221.34 | 2,253.45 | 955.80 | 4,112.31 | - | 47.93 |
| Newlin | PA | ChesCo | 944.88 | 102.08 | 18.67 | 239.28 | 254.87 | 1.00 | 31.71 |
| Parkesburg | PA | ChesCo | 2,208.90 | 134.01 | 1,014.28 | 532.81 | 2,000.82 | - | 38.43 |
| Penn | PA | ChesCo | 1,288.24 | 148.13 | 841.22 | 745.38 | 1,181.65 | - | 34.92 |
| Pennsbury | PA | ChesCo | 979.22 | 65.18 | 250.44 | 356.15 | 1,003.39 | 1.00 | 16.72 |
| Pocopson | PA | ChesCo | 494.61 | 6.41 | 546.26 | 57.79 | 9.64 | - | 4.02 |
| Sadsbury | PA | ChesCo | 484.21 | 44.24 | 193.07 | 284.06 | 245.06 | - | 13.24 |
| South Coatesville | PA | ChesCo | 1,214.97 | 93.83 | 559.77 | 78.15 | 507.83 | - | 28.93 |
| Thornbury | PA | ChesCo | 1,240.69 | 12.94 | 1,107.67 | 146.05 | 119.74 | 1.00 | 16.49 |
| Upper Uwchlan | PA | ChesCo | 3,417.53 | 298.32 | 718.41 | 429.03 | 1,336.03 | - | 32.04 |
| Uwchlan | PA | ChesCo | 3,995.78 | 99.41 | 2,902.13 | 488.83 | 1,720.63 | 1.00 | 53.13 |
| Valley | PA | ChesCo | 2,463.14 | 125.08 | 484.89 | 488.07 | 775.28 | 1.00 | 38.05 |
| Wallace | PA | ChesCo | 4,996.47 | 200.21 | 1,412.47 | 804.79 | 2,388.13 | - | 61.23 |
| West Bradford | PA | ChesCo | 2,088.10 | 74.79 | 20.07 | 408.71 | 3,815.54 | - | 49.45 |
| West Brandywine | PA | ChesCo | 1,085.52 | 133.41 | 1,152.57 | 591.66 | 124.79 | - | 29.34 |
| West Caln | PA | ChesCo | 32.81 | 1.75 | 284.34 | 0.04 | 23.26 | - | 0.92 |
| West Chester | PA | ChesCo | 2,131.85 | 106.85 | 9.07 | 898.58 | 7,911.25 | 1.00 | 56.77 |
| West Fallowfield | PA | ChesCo | 2,628.78 | 243.59 | 1,314.53 | 671.01 | 2,295.59 | 1.00 | 40.51 |
| West Goshen | PA | ChesCo | 1,343.81 | 136.69 | 536.31 | 548.81 | 1,300.51 | 1.00 | 25.92 |
| West Grove | PA | ChesCo | 4,009.61 | 212.46 | 544.61 | 459.58 | 1,739.92 | - | 46.85 |
| West Marlborough | PA | ChesCo | 1,586.92 | 153.18 | 1,996.97 | 986.28 | 853.24 | 1.00 | 36.43 |
| West Nantmeal | PA | ChesCo | 879.43 | 111.81 | 927.46 | 320.26 | 321.51 | - | 30.11 |
| West Sadsbury | PA | ChesCo | 947.87 | 23.93 | 279.31 | 48.40 | 33.79 | - | 2.38 |

| Municipality (cont.) | State | County | Wooded (ac) | Wetland (ac) | Steep Slopes (ac) | Flood-plain (ac) | POS (ac) | Karst | Streams (mi) |
|---|---|---|---|---|---|---|---|---|---|
| West Vincent | PA | ChesCo | 2,139.10 | 202.34 | 1,071.21 | 388.66 | 1,676.20 | - | 23.97 |
| West Whiteland | PA | ChesCo | 2,401.02 | 81.55 | 608.33 | 250.71 | 938.85 | - | 29.72 |
| Westtown | PA | ChesCo | 4,443.16 | 122.08 | 1,725.68 | 1,046.95 | 3.21 | 1.00 | 42.17 |
| Bethel | PA | DelCo | 231.99 | 7.05 | 560.71 | 122.46 | 66.04 | - | 2.75 |
| Chadds Ford | PA | DelCo | 36.58 | 8.78 | 25.62 | 35.40 | 53.82 | - | 2.22 |
| Concord | PA | DelCo | 104.55 | 2.91 | 136.64 | 50.79 | 21.64 | 1.00 | 2.83 |
| Salisbury | PA | LanCo | 1,789.10 | 711.49 | 950.61 | 1,057.16 | 1,693.57 | - | 38.43 |

*In the table above, a 1.00 in the "karst" column indicates that the municipality has one or more karst/carbonate features within their jurisdiction.

# Appendix B

## SOURCE WATER PROTECTION ORDINANCE SCORES

| **Municipal Scores: Direct Source Water Protection (SWP)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Municipality** | **State** | **County** | **SWP Ord.** | **Wellhead buffer area (ft)** | **Wellhead buffer prohibited uses and activities** | **Septic system regulations near wellheads** | **Recharge Ord.** | **Total Score (max: 5)** |
| New Castle County | DE | NCC | 1 | 1 | 1 | 0 | 1 | **4.0** |
| Elsmere | DE | NCC | 1 | 1 | 1 | 1 | 0 | **4.0** |
| Newark | DE | NCC | 1 | 0.5 | 1 | 0 | 1 | **3.5** |
| Newport | DE | NCC | 1 | 1 | 1 | 1 | 0 | **4.0** |
| Wilmington | DE | NCC | 1 | 1 | 1 | 1 | 0 | **4.0** |
| Avondale | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| Birmingham | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Caln | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Coatesville | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Downingtown | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| East Bradford | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| East Brandywine | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| East Caln | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| East Fallowfield | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| East Marlborough | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| East Nantmeal | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| East Whiteland | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Franklin | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| Highland | PA | ChesCo | 0 | 1 | 1 | 1 | 1 | **4.0** |
| Honey Brook | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Honey Brook Boro | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Kennett | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Kennett Square | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| London Britain | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| London Grove | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| Londonderry | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Modena | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| New Garden | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |

| Municipality (cont.) | State | County | SWP Ord. | Wellhead buffer area (ft) | Wellhead buffer prohibited uses and activities | Septic system regulations near wellheads | Recharge Ord. | Total Score (max: 5) |
|---|---|---|---|---|---|---|---|---|
| New London | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Newlin | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| Parkesburg | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Penn | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Pennsbury | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Pocopson | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| Sadsbury | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| South Coatesville | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Thornbury | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Upper Uwchlan | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| Uwchlan | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Valley | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| Wallace | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| West Bradford | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| West Brandywine | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| West Caln | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| West Chester | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| West Fallowfield | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| West Goshen | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| West Grove | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| West Marlborough | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| West Nantmeal | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| West Sadsbury | PA | ChesCo | 0 | 1 | 1 | 1 | 1 | **4.0** |
| West Vincent | PA | ChesCo | 0 | 1 | 1 | 1 | 1 | **4.0** |
| West Whiteland | PA | ChesCo | 0 | 0.75 | 1 | 1 | 0 | **2.8** |
| Westtown | PA | ChesCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Bethel | PA | DelCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Chadds Ford | PA | DelCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Concord | PA | DelCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| Salisbury | PA | LanCo | 0 | 1 | 1 | 1 | 0 | **3.0** |
| (Standard) | | | 1 | 1 | 1 | 1 | 1 | **5.0** |

| Municipal Scores: Natural Resource Protection | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Municipality** | **State** | **County** | **Karst/ Carbonate ord.** | **Wetland buffer width (ft)** | **Stream buffer width** | **100 yr floodplain restricted** | **Tree/ wooded area ord.** | **Steep slopes ord.** | **Open space allowed/ prohibited uses** | **Total Score (max: 7)** |
| New Castle County | DE | NCC | 1 | 0.5 | 1 | 1 | 1 | 1 | 1 | **6.5** |
| Elsmere | DE | NCC | 0 | 0 | 0.75 | 0.5 | 0 | 0 | 0 | **1.3** |
| Newark | DE | NCC | 1 | 0.5 | 0.75 | 1 | 1 | 1 | 0 | **5.3** |
| Newport | DE | NCC | 0 | 0 | 0.75 | 0.5 | 0 | 0 | 1 | **2.3** |
| Wilmington | DE | NCC | 0 | 0 | 0 | 0.5 | 1 | 1 | 1 | **3.5** |
| Avondale | PA | ChesCo | 1 | 0.5 | 0.75 | 0.5 | 1 | 1 | 0 | **4.8** |
| Birmingham | PA | ChesCo | 0 | 0 | 0.5 | 1 | 1 | 0.25 | 0 | **2.8** |
| Caln | PA | ChesCo | 1 | 0.5 | 1 | 0.5 | 1 | 1 | 1 | **6.0** |
| Coatesville | PA | ChesCo | 0 | 1 | 0.75 | 0.5 | 1 | 1 | 1 | **5.3** |
| Downingtown | PA | ChesCo | 0 | 0 | 0 | 1 | 1 | 0.5 | 0 | **2.5** |
| East Bradford | PA | ChesCo | 1 | 0.5 | 1 | 1 | 1 | 0.5 | 1 | **6.0** |
| East Brandywine | PA | ChesCo | 0 | 0 | 1 | 1 | 1 | 1 | 0 | **4.0** |
| East Caln | PA | ChesCo | 0 | 0 | 0 | 1 | 1 | 1 | 1 | **4.0** |
| East Fallowfield | PA | ChesCo | 0 | 1 | 1 | 1 | 1 | 1 | 1 | **6.0** |
| East Marlborough | PA | ChesCo | 1 | 0 | 1 | 1 | 1 | 1 | 0 | **5.0** |
| East Nantmeal | PA | ChesCo | 0 | 1 | 1 | 1 | 1 | 1 | 0 | **5.0** |
| East Whiteland | PA | ChesCo | 1 | 0 | 0.5 | 1 | 1 | 1 | 1 | **5.5** |
| Franklin | PA | ChesCo | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **7.0** |
| Highland | PA | ChesCo | 0 | 1 | 1 | 1 | 1 | 1 | 1 | **6.0** |
| Honey Brook | PA | ChesCo | 0 | 0.25 | 1 | 0.5 | 1 | 1 | 1 | **4.8** |
| Honey Brook Boro. | PA | ChesCo | 0 | 1 | 0 | 0 | 0 | 0 | 1 | **2.0** |
| Kennett | PA | ChesCo | 0 | 0.5 | 1 | 1 | 1 | 1 | 0 | **4.5** |
| Kennett Square | PA | ChesCo | 0 | 0 | 0 | 1 | 1 | 1 | 0 | **3.0** |
| London Britain | PA | ChesCo | 0 | 0 | 0.5 | 0.5 | 1 | 1 | 1 | **4.0** |
| London Grove | PA | ChesCo | 1 | 0 | 1 | 1 | 0 | 1 | 1 | **5.0** |
| Londonderry | PA | ChesCo | 0 | 0.5 | 1 | 0.5 | 1 | 1 | 1 | **5.0** |
| Modena | PA | ChesCo | 0 | 0 | 0.75 | 0.5 | 0 | 0.25 | 0 | **1.5** |
| New Garden | PA | ChesCo | 0 | 1 | 1 | 1 | 1 | 1 | 1 | **6.0** |
| New London | PA | ChesCo | 1 | 0 | 0 | 0.5 | 0 | 1 | 0 | **2.5** |
| Newlin | PA | ChesCo | 0 | 0.5 | 0.75 | 1 | 1 | 0.5 | 1 | **4.8** |
| Parkesburg | PA | ChesCo | 1 | 0 | 0.75 | 0.5 | 1 | 1 | 0 | **4.3** |
| Penn | PA | ChesCo | 0 | 0.5 | 1 | 1 | 1 | 1 | 1 | **5.5** |
| Pennsbury | PA | ChesCo | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **7.0** |
| Pocopson | PA | ChesCo | 0 | 0 | 1 | 0.5 | 1 | 1 | 1 | **4.5** |
| Sadsbury | PA | ChesCo | 0 | 0.5 | 1 | 1 | 1 | 1 | 1 | **5.5** |
| South Coatesville | PA | ChesCo | 0 | 0.5 | 0.75 | 1 | 1 | 0.25 | 1 | **4.5** |
| Thornbury | PA | ChesCo | 0 | 1 | 0.75 | 1 | 1 | 1 | 0 | **4.8** |

| Municipality (cont.) | State | County | Karst/ Carbonate ord. | Wetland buffer width (ft) | Stream buffer width | 100 yr floodplain restricted | Tree/ wooded area ord. | Steep slopes ord. | Open space allowed/ prohibited uses | Total Score (max: 7) |
|---|---|---|---|---|---|---|---|---|---|---|
| Upper Uwchlan | PA | ChesCo | 0 | 0 | 0.75 | 1 | 1 | 1 | 1 | **4.8** |
| Uwchlan | PA | ChesCo | 0 | 0 | 0.75 | 0.5 | 1 | 0 | 0 | **2.3** |
| Valley | PA | ChesCo | 0 | 0.5 | 0.75 | 0.5 | 1 | 1 | 0 | **3.8** |
| Wallace | PA | ChesCo | 0 | 0.5 | 0.75 | 0.5 | 1 | 1 | 1 | **4.8** |
| West Bradford | PA | ChesCo | 0 | 0 | 1 | 1 | 0 | 0.5 | 1 | **3.5** |
| West Brandywine | PA | ChesCo | 0 | 0.25 | 1 | 0.5 | 1 | 1 | 1 | **4.8** |
| West Caln | PA | ChesCo | 0 | 1 | 1 | 1 | 1 | 1 | 1 | **6.0** |
| West Chester | PA | ChesCo | 0 | 0.5 | 0.75 | 0.5 | 0 | 0 | 1 | **2.8** |
| West Fallowfield | PA | ChesCo | 0 | 0.25 | 0 | 0.5 | 1 | 1 | 1 | **3.8** |
| West Goshen | PA | ChesCo | 0 | 0 | 1 | 1 | 1 | 1 | 1 | **5.0** |
| West Grove | PA | ChesCo | 0 | 0 | 0.5 | 0 | 0 | 0.25 | 1 | **1.8** |
| West Marlborough | PA | ChesCo | 0 | 0 | 1 | 0.5 | 1 | 1 | 0 | **3.5** |
| West Nantmeal | PA | ChesCo | 0 | 0.5 | 0 | 1 | 1 | 1 | 0 | **3.5** |
| West Sadsbury | PA | ChesCo | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **7.0** |
| West Vincent | PA | ChesCo | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **7.0** |
| West Whiteland | PA | ChesCo | 1 | 0 | 1 | 1 | 1 | 1 | 0 | **5.0** |
| Westtown | PA | ChesCo | 0 | 0 | 1 | 1 | 1 | 1 | 1 | **5.0** |
| Bethel | PA | DelCo | 0 | 0 | 0.75 | 1 | 0 | 0 | 1 | **2.8** |
| Chadds Ford | PA | DelCo | 0 | 0.25 | 0.75 | 1 | 1 | 0.25 | 1 | **4.3** |
| Concord | PA | DelCo | 0 | 1 | 0 | 0.5 | 1 | 1 | 1 | **4.5** |
| Salisbury | PA | LanCo | 0 | 0 | 0 | 0.5 | 1 | 1 | 1 | **3.5** |
| (Standard) | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **7.0** |

| Municipal Scores: Stormwater Management | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Municipality** | **State** | **County** | **Reduce to pre-developed conditions** | **Stormwater treatment** | **Critical area imperv. cover standards** | **General imperv. cover standards** | **Parking stall area ≤162 sq. feet** | **Total Score (max: 5)** |
| New Castle County | DE | NCC | 1 | 1 | 0.8 | 0.0 | 1 | **3.8** |
| Elsmere | DE | NCC | 1 | 1 | 0.0 | 0.0 | 0 | **2.0** |
| Newark | DE | NCC | 1 | 1 | 0.6 | 0.0 | 1 | **3.6** |
| Newport | DE | NCC | 1 | 1 | 0.0 | 0.1 | 0 | **2.1** |
| Wilmington | DE | NCC | 1 | 1 | 0.0 | 0.0 | 0 | **2.0** |
| Avondale | PA | ChesCo | 1 | 1 | 0.0 | 0.2 | 0 | **2.2** |
| Birmingham | PA | ChesCo | 1 | 1 | 1.0 | 0.5 | 0 | **3.5** |
| Caln | PA | ChesCo | 1 | 1 | 0.0 | 0.2 | 0 | **2.2** |
| Coatesville | PA | ChesCo | 1 | 1 | 0.8 | 0.0 | 1 | **3.8** |
| Downingtown | PA | ChesCo | 1 | 1 | 0.0 | 0.1 | 1 | **3.1** |
| East Bradford | PA | ChesCo | 1 | 1 | 0.0 | 0.5 | 0 | **2.5** |
| East Brandywine | PA | ChesCo | 1 | 0 | 0.0 | 0.5 | 0 | **1.5** |
| East Caln | PA | ChesCo | 1 | 1 | 0.0 | 0.5 | 0 | **2.5** |
| East Fallowfield | PA | ChesCo | 0 | 1 | 0.8 | 0.5 | 0 | **2.3** |
| East Marlborough | PA | ChesCo | 1 | 0 | 0.0 | 0.5 | 0 | **1.5** |
| East Nantmeal | PA | ChesCo | 1 | 1 | 0.0 | 0.4 | 1 | **3.4** |
| East Whiteland | PA | ChesCo | 1 | 1 | 0.0 | 0.4 | 0 | **2.4** |
| Franklin | PA | ChesCo | 1 | 1 | 0.8 | 0.4 | 1 | **4.2** |
| Highland | PA | ChesCo | 1 | 1 | 0.6 | 0.5 | 0 | **3.1** |
| Honey Brook | PA | ChesCo | 0 | 1 | 0.8 | 0.5 | 1 | **3.3** |
| Honey Brook Boro | PA | ChesCo | 1 | 1 | 0.0 | 0.2 | 0 | **2.2** |
| Kennett | PA | ChesCo | 0 | 1 | 0.8 | 0.5 | 0 | **2.3** |
| Kennett Square | PA | ChesCo | 1 | 0 | 0.0 | 0.2 | 1 | **2.2** |
| London Britain | PA | ChesCo | 0 | 0 | 0.0 | 0.6 | 0 | **0.6** |
| London Grove | PA | ChesCo | 1 | 1 | 0.6 | 0.4 | 0 | **3.0** |
| Londonderry | PA | ChesCo | 1 | 1 | 0.0 | 0.5 | 0 | **2.5** |
| Modena | PA | ChesCo | 1 | 0 | 0.0 | 0.0 | 0 | **1.0** |
| New Garden | PA | ChesCo | 1 | 1 | 0.8 | 0.5 | 1 | **4.3** |
| New London | PA | ChesCo | 1 | 0 | 0.0 | 0.5 | 0 | **1.5** |
| Newlin | PA | ChesCo | 1 | 1 | 0.0 | 0.0 | 0 | **2.0** |
| Parkesburg | PA | ChesCo | 1 | 1 | 0.0 | 0.3 | 0 | **2.3** |
| Penn | PA | ChesCo | 1 | 1 | 0.0 | 0.3 | 0 | **2.3** |
| Pennsbury | PA | ChesCo | 1 | 1 | 0.8 | 0.5 | 0 | **3.3** |
| Pocopson | PA | ChesCo | 1 | 1 | 0.8 | 0.5 | 0 | **3.3** |
| Sadsbury | PA | ChesCo | 1 | 1 | 1.0 | 0.5 | 1 | **4.5** |
| South Coatesville | PA | ChesCo | 1 | 1 | 0.0 | 0.5 | 1 | **3.5** |
| Thornbury | PA | ChesCo | 1 | 0 | 0.0 | 0.3 | 0 | **1.3** |

| Municipality (cont.) | State | County | Reduce to pre-developed conditions | Stormwater treatment | Critical area imperv. cover standards | General imperv. cover standards | Parking stall area ≤162 sq. feet | Total Score (max: 5) |
|---|---|---|---|---|---|---|---|---|
| Upper Uwchlan | PA | ChesCo | 1 | 1 | 0.0 | 0.4 | 1 | **3.4** |
| Uwchlan | PA | ChesCo | 1 | 1 | 0.0 | 0.3 | 0 | **2.3** |
| Valley | PA | ChesCo | 1 | 1 | 0.0 | 0.5 | 0 | **2.5** |
| Wallace | PA | ChesCo | 0 | 0 | 0.0 | 0.5 | 0 | **0.5** |
| West Bradford | PA | ChesCo | 1 | 1 | 0.0 | 0.4 | 0 | **2.4** |
| West Brandywine | PA | ChesCo | 1 | 1 | 0.0 | 0.4 | 1 | **3.4** |
| West Caln | PA | ChesCo | 1 | 1 | 0.8 | 0.5 | 1 | **4.3** |
| West Chester | PA | ChesCo | 1 | 1 | 0.0 | 0.3 | 1 | **3.3** |
| West Fallowfield | PA | ChesCo | 1 | 0 | 0.0 | 0.5 | 1 | **2.5** |
| West Goshen | PA | ChesCo | 1 | 1 | 0.0 | 0.3 | 1 | **3.3** |
| West Grove | PA | ChesCo | 1 | 0 | 0.0 | 0.5 | 0 | **1.5** |
| West Marlborough | PA | ChesCo | 1 | 0 | 0.0 | 0.5 | 0 | **1.5** |
| West Nantmeal | PA | ChesCo | 1 | 1 | 0.0 | 0.3 | 0 | **2.3** |
| West Sadsbury | PA | ChesCo | 1 | 1 | 0.8 | 0.5 | 1 | **4.3** |
| West Vincent | PA | ChesCo | 1 | 0 | 0.6 | 0.5 | 0 | **2.1** |
| West Whiteland | PA | ChesCo | 1 | 1 | 0.0 | 0.5 | 1 | **3.5** |
| Westtown | PA | ChesCo | 1 | 1 | 0.0 | 0.4 | 0 | **2.4** |
| Bethel | PA | DelCo | 1 | 0 | 0.0 | 0.0 | 0 | **1.0** |
| Chadds Ford | PA | DelCo | 1 | 0 | 0.0 | 0.0 | 1 | **2.0** |
| Concord | PA | DelCo | 1 | 0 | 0.0 | 0.0 | 1 | **2.0** |
| Salisbury | PA | LanCo | 1 | 0 | 0.0 | 0.5 | 0 | **1.5** |
| (Standard) | | | 1 | 1 | 1.0 | 1.0 | 1 | **5.0** |

| Municipal Scores: Education and Accessibility | | | | | | |
|---|---|---|---|---|---|---|
| **Municipality** | **State** | **County** | **Municipal Website** | **Ordinances available online** | **Water info. on web** | **Total Score (max: 3)** |
| New Castle County | DE | NCC | 1 | 1 | 0 | **2.0** |
| Elsmere | DE | NCC | 1 | 1 | 1 | **3.0** |
| Newark | DE | NCC | 1 | 1 | 1 | **3.0** |
| Newport | DE | NCC | 1 | 0.5 | 0 | **1.5** |
| Wilmington | DE | NCC | 1 | 1 | 1 | **3.0** |
| Avondale | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| Birmingham | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| Caln | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| Coatesville | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| Downingtown | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| East Bradford | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| East Brandywine | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| East Caln | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| East Fallowfield | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| East Marlborough | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| East Nantmeal | PA | ChesCo | 1 | 0.5 | 0 | **1.5** |
| East Whiteland | PA | ChesCo | 1 | 1 | 0 | **2.0** |
| Franklin | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| Highland | PA | ChesCo | 0 | 0 | 0 | **0.0** |
| Honey Brook | PA | ChesCo | 1 | 1 | 0 | **2.0** |
| Honey Brook Boro | PA | ChesCo | 1 | 1 | 0 | **2.0** |
| Kennett | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| Kennett Square | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| London Britain | PA | ChesCo | 1 | 0 | 1 | **2.0** |
| London Grove | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| Londonderry | PA | ChesCo | 1 | 1 | 0 | **2.0** |
| Modena | PA | ChesCo | 1 | 1 | 0 | **2.0** |
| New Garden | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| New London | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| Newlin | PA | ChesCo | 1 | 1 | 0 | **2.0** |
| Parkesburg | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| Penn | PA | ChesCo | 1 | 0 | 1 | **2.0** |
| Pennsbury | PA | ChesCo | 1 | 0.5 | 1 | **2.5** |
| Pocopson | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| Sadsbury | PA | ChesCo | 1 | 0 | 0 | **1.0** |
| South Coatesville | PA | ChesCo | 1 | 0 | 1 | **2.0** |
| Thornbury | PA | ChesCo | 1 | 1 | 1 | **3.0** |

| **Municipality (cont.)** | **State** | **County** | **Municipal Website** | **Ordinances available online** | **Water info. on web** | **Total Score (max: 3)** |
|---|---|---|---|---|---|---|
| Upper Uwchlan | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| Uwchlan | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| Valley | PA | ChesCo | 1 | 0 | 0 | **1.0** |
| Wallace | PA | ChesCo | 1 | 0 | 1 | **2.0** |
| West Bradford | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| West Brandywine | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| West Caln | PA | ChesCo | 1 | 1 | 0 | **2.0** |
| West Chester | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| West Fallowfield | PA | ChesCo | 1 | 0.5 | 0 | **1.5** |
| West Goshen | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| West Grove | PA | ChesCo | 1 | 0 | 1 | **2.0** |
| West Marlborough | PA | ChesCo | 0 | 0 | 0 | **0.0** |
| West Nantmeal | PA | ChesCo | 1 | 1 | 0 | **2.0** |
| West Sadsbury | PA | ChesCo | 1 | 0 | 0 | **1.0** |
| West Vincent | PA | ChesCo | 1 | 1 | 0 | **2.0** |
| West Whiteland | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| Westtown | PA | ChesCo | 1 | 1 | 1 | **3.0** |
| Bethel | PA | DelCo | 1 | 1 | 1 | **3.0** |
| Chadds Ford | PA | DelCo | 1 | 1 | 1 | **3.0** |
| Concord | PA | DelCo | 1 | 1 | 1 | **3.0** |
| Salisbury | PA | LanCo | 1 | 1 | 0 | **2.0** |
| (Standard) | | | 1 | 1 | 1 | **3.0** |

## Appendix C

## LAND AREA-WEIGHTED SCORE CALCULATIONS

| Municipality | State | County | Raw Score | Area in WS (sq. mi) | % of Basin | % of Basin by State | Weighted Score |
|---|---|---|---|---|---|---|---|
| New Castle County | DE | NCC | 16.3 | 138.39 | 24.5% | 87.7% | 14.24 |
| Elsmere | DE | NCC | 10.3 | 0.99 | 0.2% | 0.6% | 0.06 |
| Newark | DE | NCC | 15.3 | 9.19 | 1.6% | 5.8% | 0.89 |
| Newport | DE | NCC | 9.9 | 0.46 | 0.1% | 0.3% | 0.03 |
| Wilmington | DE | NCC | 12.5 | 8.84 | 1.6% | 5.6% | 0.70 |
| Avondale | PA | ChesCo | 12.7 | 0.48 | 0.1% | 0.1% | 0.02 |
| Birmingham | PA | ChesCo | 12.3 | 6.22 | 1.1% | 1.6% | 0.19 |
| Caln | PA | ChesCo | 14.2 | 8.95 | 1.6% | 2.2% | 0.32 |
| Coatesville | PA | ChesCo | 15.0 | 1.86 | 0.3% | 0.5% | 0.07 |
| Downingtown | PA | ChesCo | 11.6 | 2.23 | 0.4% | 0.6% | 0.06 |
| East Bradford | PA | ChesCo | 14.5 | 15.33 | 2.7% | 3.8% | 0.56 |
| East Brandywine | PA | ChesCo | 11.3 | 11.23 | 2.0% | 2.8% | 0.32 |
| East Caln | PA | ChesCo | 12.3 | 3.67 | 0.6% | 0.9% | 0.11 |
| East Fallowfield | PA | ChesCo | 14.3 | 15.65 | 2.8% | 3.9% | 0.56 |
| East Marlborough | PA | ChesCo | 12.3 | 15.50 | 2.7% | 3.9% | 0.48 |
| East Nantmeal | PA | ChesCo | 12.9 | 7.20 | 1.3% | 1.8% | 0.23 |
| East Whiteland | PA | ChesCo | 12.9 | 0.60 | 0.1% | 0.1% | 0.02 |
| Franklin | PA | ChesCo | 16.9 | 8.77 | 1.6% | 2.2% | 0.37 |
| Highland | PA | ChesCo | 13.1 | 13.51 | 2.4% | 3.4% | 0.45 |
| Honey Brook | PA | ChesCo | 13.0 | 22.69 | 4.0% | 5.7% | 0.74 |
| Honey Brook Boro | PA | ChesCo | 9.2 | 0.47 | 0.1% | 0.1% | 0.01 |
| Kennett | PA | ChesCo | 12.8 | 15.51 | 2.7% | 3.9% | 0.50 |
| Kennett Square | PA | ChesCo | 11.2 | 1.07 | 0.2% | 0.3% | 0.03 |
| London Britain | PA | ChesCo | 9.6 | 9.79 | 1.7% | 2.5% | 0.24 |
| London Grove | PA | ChesCo | 13.8 | 17.31 | 3.1% | 4.3% | 0.60 |
| Londonderry | PA | ChesCo | 12.5 | 8.64 | 1.5% | 2.2% | 0.27 |
| Modena | PA | ChesCo | 7.5 | 0.35 | 0.1% | 0.1% | 0.01 |
| New Garden | PA | ChesCo | 16.0 | 16.09 | 2.8% | 4.0% | 0.65 |
| New London | PA | ChesCo | 10.0 | 3.59 | 0.6% | 0.9% | 0.09 |

| Municipality (cont.) | State | County | Raw Score | Area in WS (sq. mi) | % of Basin | % of Basin by State | Weighted Score |
|---|---|---|---|---|---|---|---|
| Newlin | PA | ChesCo | 11.5 | 12.08 | 2.1% | 3.0% | 0.35 |
| Parkesburg | PA | ChesCo | 12.5 | 1.26 | 0.2% | 0.3% | 0.04 |
| Penn | PA | ChesCo | 12.8 | 4.88 | 0.9% | 1.2% | 0.16 |
| Pennsbury | PA | ChesCo | 15.8 | 10.21 | 1.8% | 2.6% | 0.40 |
| Pocopson | PA | ChesCo | 13.5 | 8.42 | 1.5% | 2.1% | 0.29 |
| Sadsbury | PA | ChesCo | 14.0 | 6.22 | 1.1% | 1.6% | 0.22 |
| South Coatesville | PA | ChesCo | 13.0 | 1.80 | 0.3% | 0.5% | 0.06 |
| Thornbury | PA | ChesCo | 12.0 | 0.72 | 0.1% | 0.2% | 0.02 |
| Upper Uwchlan | PA | ChesCo | 13.9 | 9.07 | 1.6% | 2.3% | 0.32 |
| Uwchlan | PA | ChesCo | 10.5 | 7.47 | 1.3% | 1.9% | 0.20 |
| Valley | PA | ChesCo | 10.0 | 5.99 | 1.1% | 1.5% | 0.15 |
| Wallace | PA | ChesCo | 10.3 | 11.94 | 2.1% | 3.0% | 0.31 |
| West Bradford | PA | ChesCo | 11.7 | 18.51 | 3.3% | 4.6% | 0.54 |
| West Brandywine | PA | ChesCo | 13.9 | 13.25 | 2.3% | 3.3% | 0.46 |
| West Caln | PA | ChesCo | 15.0 | 17.05 | 3.0% | 4.3% | 0.64 |
| West Chester | PA | ChesCo | 11.8 | 1.33 | 0.2% | 0.3% | 0.04 |
| West Fallowfield | PA | ChesCo | 10.8 | 0.55 | 0.1% | 0.1% | 0.01 |
| West Goshen | PA | ChesCo | 14.3 | 4.70 | 0.8% | 1.2% | 0.17 |
| West Grove | PA | ChesCo | 8.0 | 0.67 | 0.1% | 0.2% | 0.01 |
| West Marlborough | PA | ChesCo | 8.0 | 17.06 | 3.0% | 4.3% | 0.34 |
| West Nantmeal | PA | ChesCo | 10.8 | 10.03 | 1.8% | 2.5% | 0.27 |
| West Sadsbury | PA | ChesCo | 16.3 | 1.60 | 0.3% | 0.4% | 0.07 |
| West Vincent | PA | ChesCo | 15.1 | 0.67 | 0.1% | 0.2% | 0.03 |
| West Whiteland | PA | ChesCo | 14.3 | 12.25 | 2.2% | 3.1% | 0.44 |
| Westtown | PA | ChesCo | 13.4 | 1.75 | 0.3% | 0.4% | 0.06 |
| Bethel | PA | DelCo | 9.8 | 0.26 | 0.0% | 0.1% | 0.01 |
| Chadds Ford | PA | DelCo | 12.3 | 8.10 | 1.4% | 2.0% | 0.25 |
| Concord | PA | DelCo | 12.5 | 1.19 | 0.2% | 0.3% | 0.04 |
| Salisbury | PA | LanCo | 10.0 | 2.90 | 0.5% | 0.7% | 0.07 |