Table 2-30 – Summary of Algae Types and Frequency Detected in Wilmington's Raw Water In 2006 & 2007

Algae name	# times detected	% detected	Algae Type/Importance
Gloecystis	1	4%	Unknown
Unidentified flagellates	5	20%	Unknown
Achnanthes	1	4%	Algae growing on surfaces
Gomphonema	1	4%	Algae growing on surfaces
Microspora	1	4%	Algae growing on surfaces
Cocconeis	2	8%	Clean water algae
Navicula	6	24%	Clean water algae/filter clogging algae
Chlorella	1	4%	Filter clogging algae
Nitzschia	1	4%	Fresh water pollution algae
Lyngbya	2	8%	Fresh water pollution algae/ blue-green algae/T&O algae
Oscillatoria	1	4%	Fresh water pollution algae/ blue-green algae/T&O algae
Scenedesmus	1	4%	Surface water algae
Stauroneis	1	4%	Surface water algae
Synedra	1	4%	T & O algae

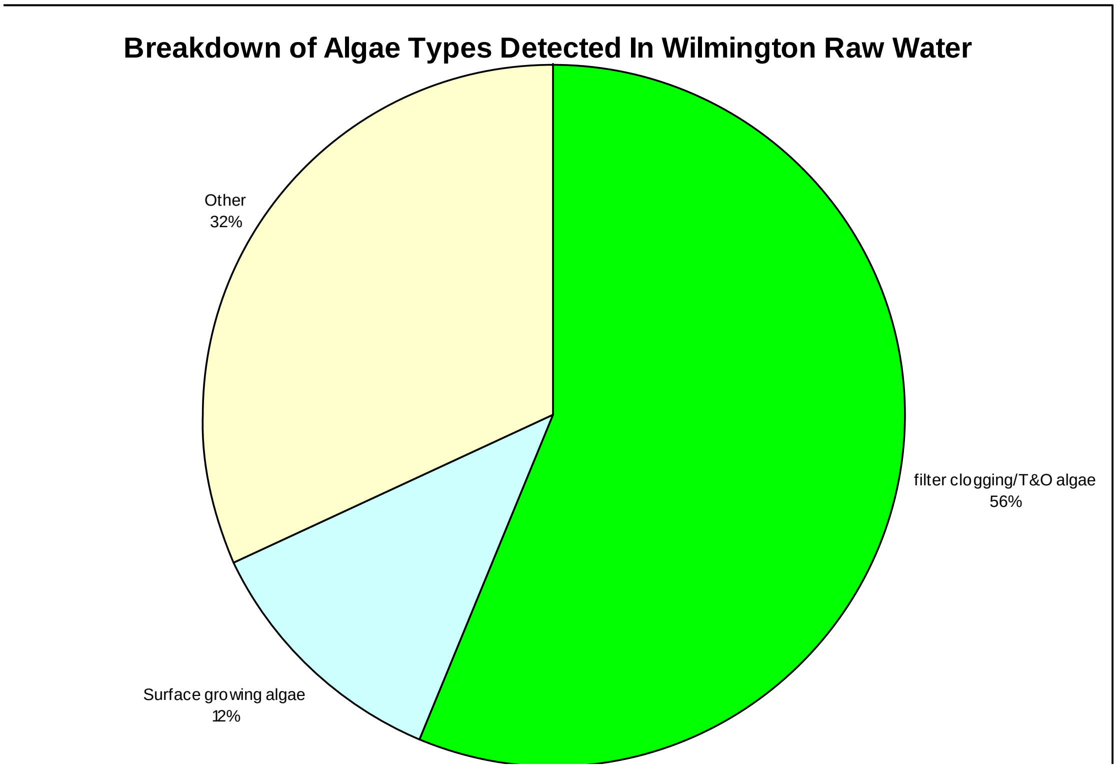


Figure 2-47 – Frequency of Algae Types Detected in the Brandywine Creek at Wilmington's Intake

2.3.12. Trace Organics

Trace organics include pharmaceuticals and personal care products. Currently some of the trace organics are being investigated for potential as endocrine disrupting compounds (EDCs). This subset of the trace organics that have been suggested to have the potential for environmental (aquatic life) or health effects at very low levels (1 – 10 ng/L) are of the most concern to water suppliers. Studies by the American Water Works Foundation show that these compounds are not easily removed by the water treatment process. New studies are currently underway to examine the toxicological relevance of these compounds in drinking water. Preliminary findings of most research on pharmaceuticals (one of the groups of trace organics) suggests that a person would need to drink 8 glasses of water per day for thousands of years to get the same dose as an infants dose of Tylenol. Thus, attention is turning towards personal care products and items such as plasticizers, flame retardants, and chemicals which mimic estrogen due to potential endocrine effects at very low concentrations. It is clear there is growing public and media pressure on the issue of Pharmaceuticals in drinking water. In March 2007, the Associated Press ran an in-depth three part investigative article on this issue. This touched off local media and political inquiries into the issue.

Before the recent media coverage of this issue, the City of Wilmington in 2007 initiated a quarterly sampling program with USGS using non standardized research analytical methods to identify trace organics in the Brandywine Creek at Chadds Ford. Part of the reason for this study was due to the fact that trace organics can serve as good tracers to identify potential sources impacting the water supply for other contaminants. For example if livestock related chemicals are found, then it lends strength to prioritizing agricultural controls. The monitoring analyzed for 54 different pharmaceutical compounds. Only 12 pharmaceuticals were detected as shown in Table 2-31. Additional monitoring will be conducted in Chadds Ford and the East and West Branch of the Brandywine Creek to help identify sources.

Table 2-31 – Pharmaceuticals Detected in the Brandywine Creek at Chadds Ford

Med identified	Description	Concentrations
Acetaminophen	Tylenol	0.014 - 0.018
Caffeine	coffee byproduct	0.016 - 0.047
Carbamazepine	anticonvulsant	0.013 - 0.046
Cotinine	nicotine byproduct	0.015
Diltiazem	blood pressure	0.003
Diphenahydramine	cold medicine / allergy	0.002
Sulfamethoxazole	antibacterial	0.016 - 0.035
Azithromycin	antibiotic - human	0.035
Roxithromycin	antibiotic - human	0.073
Sulfachloro-pyridazine	antibiotic - livestock	0.006
Tylosin	antibiotic - livestock	0.542
Trimethroprim	antibiotic - human	0.007 - 0.015

Note: Concentrations in ppb or ug/L

The preliminary results of the sampling did identify that the largest concentrations of antibiotics were from livestock suggesting agricultural runoff controls are a greater priority. The detection of the antibiotics also suggests that studies of antibiotic resistant bacteria may be useful in identifying sources of pathogens in the watershed. The expected low level identification of human medicines also confirms that wastewater discharges do contribute trace organics to the water supply and that other trace contaminants such as pathogens may have the potential to be delivered by wastewater as well downstream to Wilmington's water supply. Further study is needed upstream of Chadd's Ford to help isolate the various geographical areas and sources/activities of the trace organics.

2.3.13. Metals

Figures 2-48 to 2-50 show the observed metals data for the Wilmington intake. Zinc concentrations were the greatest during 1999. In general, zinc concentrations are greater during winter and spring and lowest during the fall. It is unknown if this is related to precipitation or release of zinc from corrosion of piping systems. None of the zinc concentrations were within a factor of 10 of the secondary MCL.

Iron concentrations were the greatest during the summer and fall when precipitation is low and water temperatures are higher and more baseflow from groundwater occurs. This results in a greater release of iron from geological formations. Iron concentrations were the highest in the spring when surface runoff was dominant. During all months of the year iron concentrations at the Wilmington intake were great enough to exceed the secondary MCL.

Based on these findings, the dominant source of iron is in crustal forms from groundwater sources, but extreme weather events can produce high iron concentrations at times. Since iron concentrations can exceed the secondary MCL in the raw water, oxidation of the iron must be conducted prior to filtration in order to remove it properly in the drinking water treatment process.

Manganese concentrations were the greatest during the late spring and early summer when surface runoff was dominant. Manganese concentrations were the lowest in the fall when precipitation is low and water temperatures are higher and more baseflow from groundwater occurs. This results in a greater release of manganese from geological formations. During all months of the year manganese concentrations at the Wilmington intake were great enough to exceed the secondary MCL.

Based on these findings, the dominant source of manganese is in surface forms impacted by runoff and precipitation. Since manganese concentrations can exceed the secondary MCL in the raw water, oxidation of the manganese must be conducted prior to filtration in order to remove it properly in the drinking water treatment process.

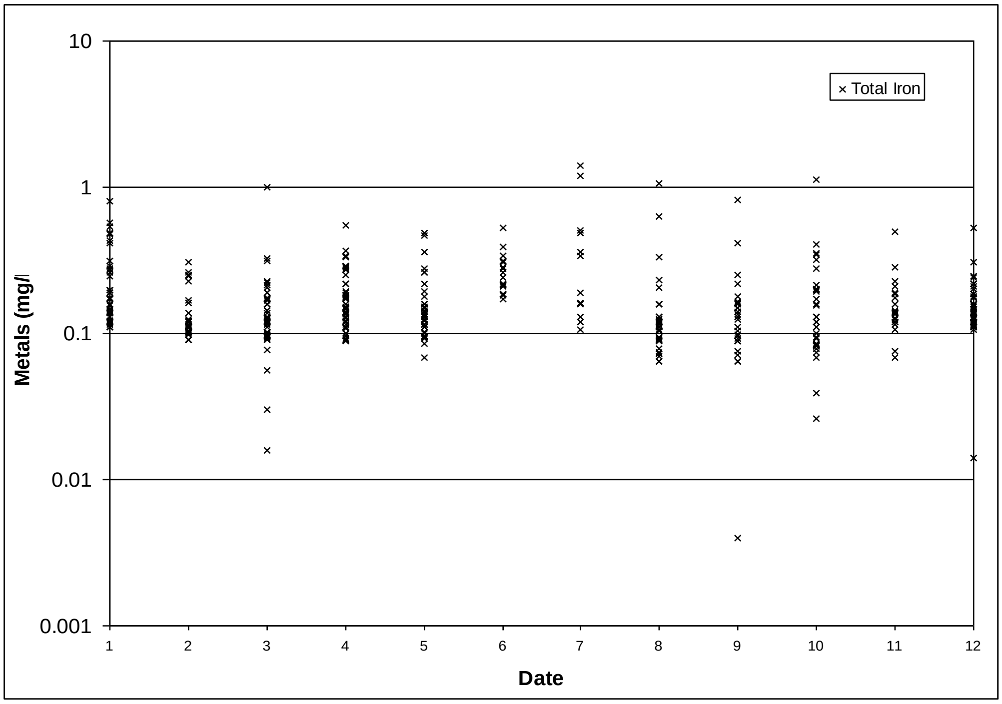


Figure 2-48 - Total Iron Concentrations in Porter Raw Water by Julian Month (1996-2007)

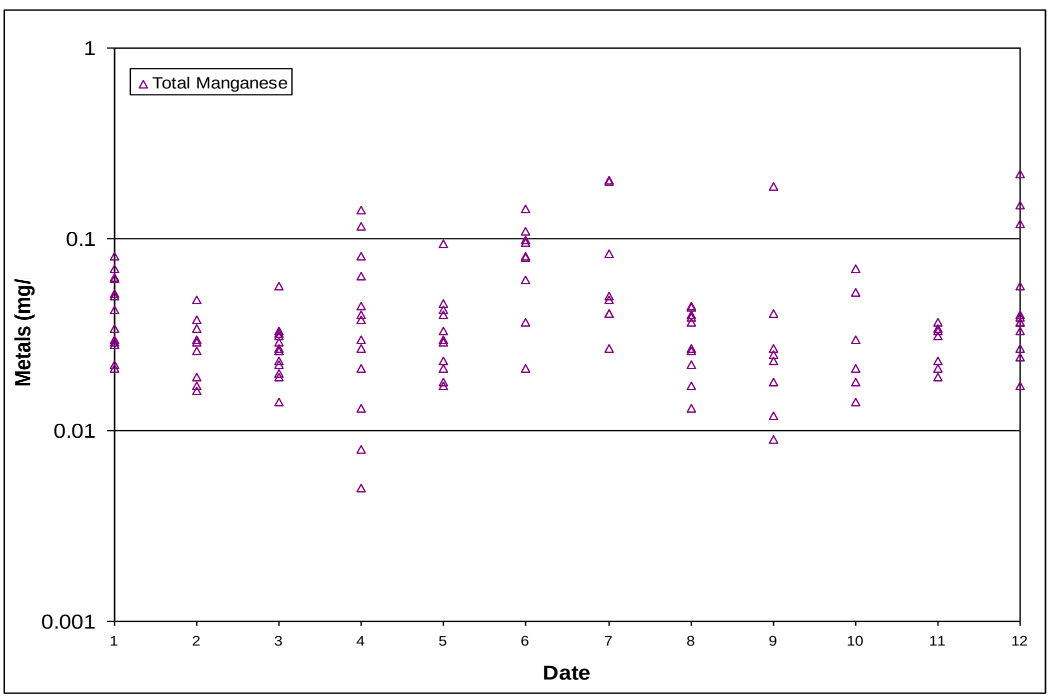


Figure 2-49 - Total Manganese Concentrations in Porter Raw Water by Julian Month (1996-2007)

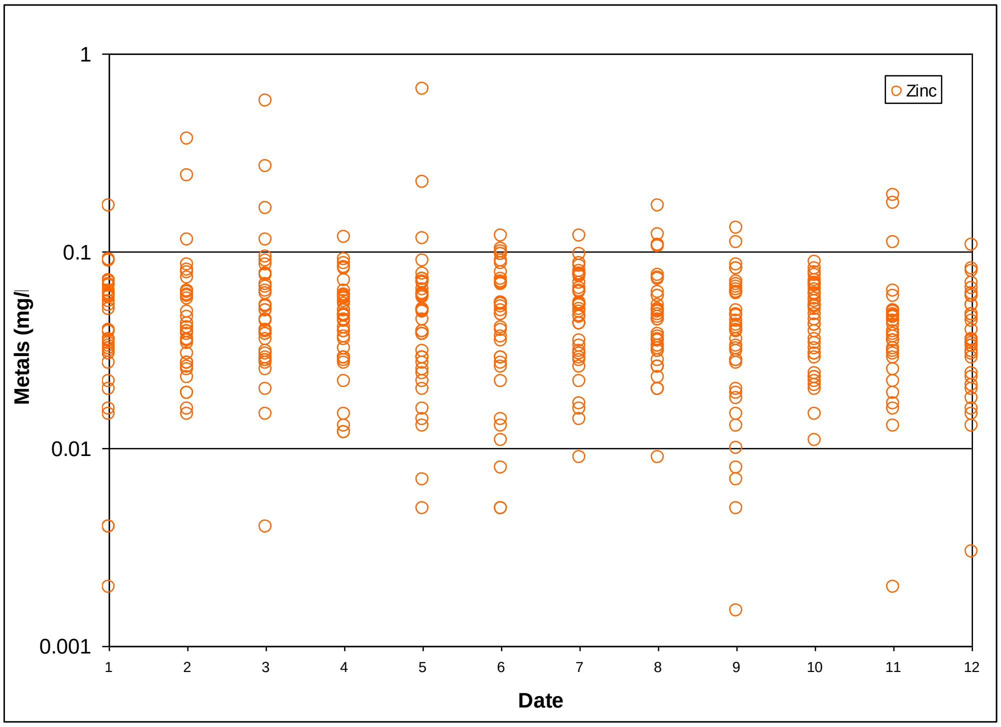


Figure 2-50 - Zinc Concentrations in Porter Raw Water by Julian Month (1996-2007)

2.3.14. Long Term Water Quality and Historical trends 1979-2007

Long term trends allow the ability to determine the past, current, and potential future water quality of the watershed and to evaluate how changes in regulation, industry, and development/land use have impacted the watershed. This is valuable information that can inform which areas of the past and current watershed protection efforts have been successful and what gaps remain.

The identification of long term trends also allows for prediction of future water quality. Specific trends for certain parameters provide identification of potential contaminant sources of concern for future mitigation and protection planning work. This data combined with the seasonal analysis (Julian calendar analysis) will provide additional perspective to contaminant issues and sources and may even provide some indication of general geographic areas within the watershed for focused data collection, monitoring, or protection/mitigation activities.

It was determined that the Lower Brandywine Creek would be the best area to receive the sum of all the changes in water quality and pollution activities in the watershed and would serve as the best starting point to identify any potential long term trends. The EPA STORET water quality data for 52 parameters for the period from 1967 to 1999 at five locations on the Lower Brandywine was obtained from DNREC in June of 2007 for long term trend analysis. The first step in this process was to determine through a simple screening process if any potential trends could be observed and comparison with trends observed in USGS studies from 1981 to 1997 in the Upper Brandywine. Once a potential trend was observed, the data was then compared to data from the City of Wilmington intake for the period from 1997 to 2007 to see if the same trend continued. This allows for a later analysis that compares the long term trends analyzed for upstream locations on the Brandywine by USGS. If the same trends for the same parameters in the lower Brandywine in Delaware match that for the upper Brandywine or a specific branch, geographical isolation of sources or land use activities for source water protection planning may be possible. The locations provided in the data from DNREC/STORET included the following five locations in Table 2-32.

Table 2-32 – Locations of DNREC/STORET Long Term Trend Data Analysis from 1967 to 1997

AGENCY	STATION	LAT	LONG	USGS HUC	LOCATION NAME
21DELAWQ	104011	394532	753315	2040205	BRANDYWINE CREEK, FOOT BRIDGE IN BRANDYWINE PARK
21DELAWQ	104021	394613	753445	2040205	BRANDYWINE, RD 279 BRIDGE, DU PONT EXP STATION
21DELAWQ	104031	394720	753432	2040205	BRANDYWINE, DU PONT STATION AT HAGLEY MUSEUM
21DELAWQ	104041	394749	753431	2040205	BRANDYWINE CREEK AT ROCKLAND BRIDGE
21DELAWQ	104051	395015	753445	2040205	BRANDYWINE CREEK AT SMITH BRIDGE

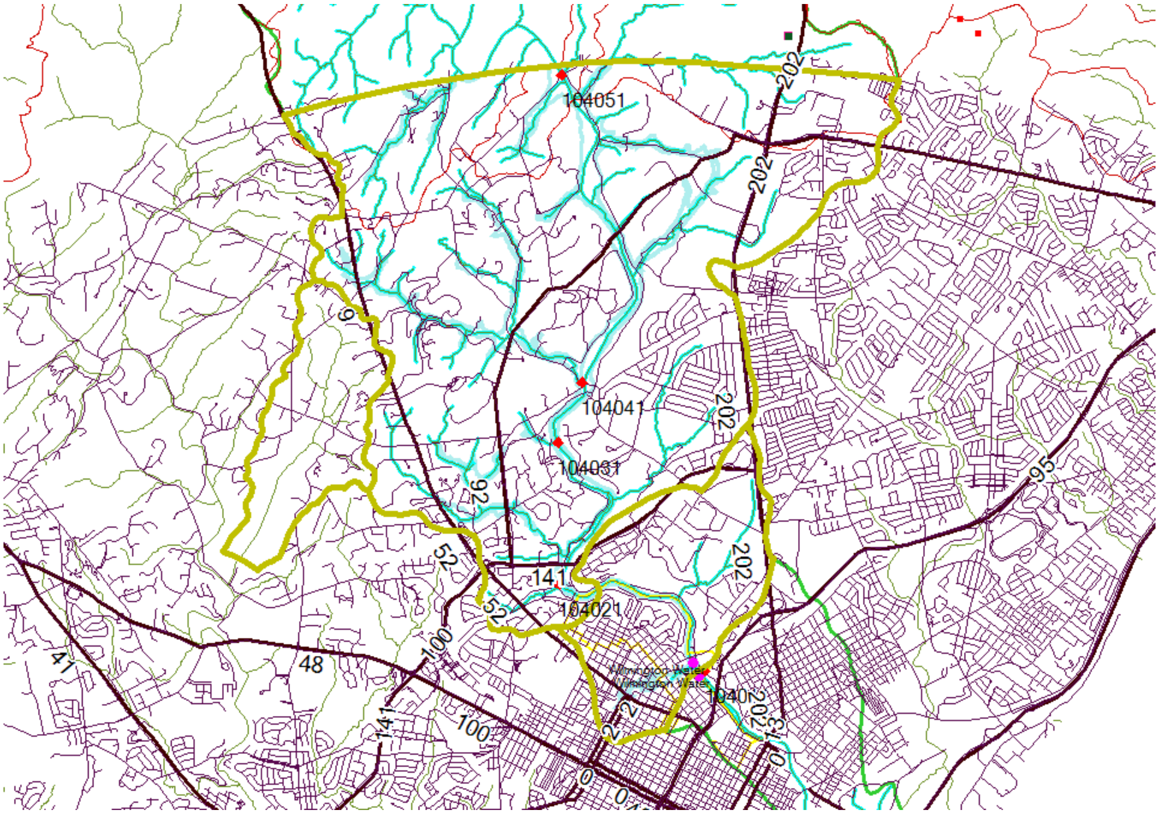


Figure 2- 51 - Sampling Locations in the Lower Brandywine Used In the Trend Analysis

As shown above the five sampling locations cover a distance of roughly 12 kilometers starting at the upstream location at the Delaware State Border, bracketing the Dupont Experimental Station, and extending down to the City of Wilmington's intakes.

Data from all five locations was pooled in order to accommodate for missing time periods in data sets and to cover seasonal gaps in monitoring. It was assumed by pooling the data that the water quality at the various locations is statistically identical or at a minimum not statistically significantly different. This assumption remains to be tested and will be tested in later phases for any significant observed trends.

A total of 52 parameters were examined for potential trends. Only 17 parameters had sufficient data and were of relevance to drinking water quality. The final parameters analyzed are provided in Table 2-33 below.

Table 2-33 – Parameters Examined for Long Term Trends in Delaware

Inorganics	Pathogens	Nutrients	Metals	Organics
Dissolved Oxygen	Enterococcus	Total phosphorus	Total Iron	Total organic carbon
pH	Fecal coliform	Total orthophosphate	Total Manganese	
Chloride	Fecal streptococcus	Ammonia (total NH_3 and NH_4)		
Conductivity		Nitrate (total NO_3 and total NO_3+NO_2)		
Alkalinity				
Hardness				
Temperature				

The analytical methods, detection limits, recovery, precision, and variability for many water quality parameters have changed substantially since 1970. Therefore, when conducting a historical trend analysis, it is important to remember that not all decreasing or increasing trends are related to real water quality changes from pollution sources and could be an artifact of the analytical process. Once trends are observed and even if plausible explanations or sources are available, future analysis will need to be conducted to determine the types and time period that different analytical methods were used and their potential impact on the observed data and trends.

Comparison of probe, field, and lab data are also always an element to consider when conducting historical trend analyses. The data from any of the three methods for the same parameter can observe similar or different trends. Therefore an understanding of the shortcomings and inaccuracies of these methods is important to determine which measurement is most likely the true measurement at the location and representative of what is occurring.

The following was observed in the Lower Brandywine from the potential trend analysis:

- Chloride and conductivity appear to have the most pronounced and continuous increasing trends from the early 1970s to current periods in the Lower Brandywine. There is no indication that this trend is "leveling off" or diminishing. As mentioned in previous analysis regarding the Wilmington intake water quality data, it appears that these concentrations are related to road salt runoff, road salt runoff accumulation in the watershed and groundwater, and potentially even the effects of increased irrigation (from landscaping, farming, sewage disposal) causing "salting" effects on surface waters.

- Alkalinity and hardness appear to have increasing trends that mirror that of chloride and conductivity, but appear to be related to groundwater and base flow changes. As mentioned in previous memos regarding analysis of Wilmington intake data, increasing alkalinity will affect the requirements for TOC removal by the Wilmington water treatment plants and have potential impacts on future water treatment designs, operations, and distribution system corrosion control approaches.

- Total phosphorus appears to be decreasing while total orthophosphate concentrations remain relatively unchanged suggesting that any improvements in phosphorus reduction in the watershed will need to be significant in order to have an effect on orthophosphate concentrations and thus ecological activities influenced by orthophosphate uptake in the water column (i.e. algal growth).

- Nitrate concentrations appear to be have increased since the 1970s, but appear to be leveling off in recent years while ammonia concentrations have decreased historically (are they stable?). This appears to be related mainly to the advent of secondary wastewater treatment since the trend starts in the mid 1980s when most sewage treatment plants were required to enact secondary wastewater treatment. TKN appears to be decreasing historically, but leveling off in recent years.

- Dissolved oxygen concentrations appear to have some limited decreasing trend since the mid 1980s. This appears to coincide with changes to secondary wastewater treatment suggesting that nitrogenous biological oxygen demand (NBOD) from upstream wastewater discharges in Pennsylvania, may have some potential role in the slightly decreasing dissolved oxygen trend in the Lower Brandywine. Future data needs to be collected to confirm these observations and determine their validity. In addition, calculations on time of travel from upstream sewage treatment plants during a variety of base flow conditions needs to be examined to determine if their sufficient time for NBOD exertion to occur. Given the variety of small and large historic mill dams and impoundments along the Brandywine, especially in the Lower Brandywine, there may be some localized NBOD effects from these impoundments "holding" water longer than main stream channel water. There are no major changes in the extremes or trends of other algae related parameters such as water temperature and pH concentrations to suggest that the downward DO trend is algae related at this time, but it does not rule out algae growth and population type as a possible factor.

- There were no discernible historical trends observed for total organic carbon, bacteria/pathogens, total iron and manganese, temperature, and pH. Trends may be occurring, but analytical method variability, analytical detection limits, analytical method changes, and frequency/seasonality of monitoring may not have been able to detect them.

Table 2-34 – Summary of Historical and Current Water Quality Trends in the Chester County Portion of the Brandywine Creek Reported in Various USGS Studies

Parameter	Historical Trend (pre-1990)	Current Trend (post 1990)	USGS Trend (1981-1997)	Potential for Negative Impacts	Notes:
Chloride	Increasing	Increasing	NA	Yes	Most notable increasing trend in watershed
Conductivity	Increasing	Increasing	Increasing	Yes	Most notable increasing trend in watershed
Alkalinity	Increasing	Increasing	NA	Yes	related to base flow changes potentially
Hardness	Increasing	Increasing	NA	Yes	related to base flow changes potentially
Total Phosphorus	Decreasing	Decreasing	Decreasing	No	
Orthophosphate	Decreasing	Stable	NA	Yes	dissolved phosphorus can impact algal growth
Nitrate	Increasing	Stable	Increasing	No	
Ammonia	Decreasing	Decreasing	Decreasing	No	
TKN	Decreasing	Stable	NA	No	
Dissolved Oxygen	Increasing	Increasing/Stable	Increasing	No	Positive trend

2.3.15. Spatial Comparison of Water Quality Trends

In addition to the Lower Brandywine Trend analysis another analysis of long term trends from 1981-1997 was conducted for Chester County (Reif, 2002). Increasing trends in nitrate and specific conductance were observed while decreasing trends in phosphorus and ammonia were observed. Increases in nitrate and specific conductance were attributed to wastewater discharge and conversion of ammonia. Decreases in phosphorus were attributed to reduced agricultural activity, improvements in wastewater treatment, and elimination of phosphates in detergents. Increases in dissolved oxygen during this period were also attributed to reduced agricultural impact and improved agricultural management and wastewater treatment improvements. Evaluation of bed sediment data suggests that pesticides have decreased or are of limited presence in the Brandywine due to reductions in agriculture use and outlawing of the substances.

Trends are not necessarily observed watershed wide homogeneously in the Brandywine Creek, but can have spatial differences. According to USGS, (Reif, 2002), statistical analysis showed 10 of 11 sites in the Brandywine observed increasing trends in specific conductance and 8 of 11 sites observed increasing trends in nitrate. Concentrations of phosphorus and ammonia went down or stayed the same at 4 of 11 and 3 of 11 sites respectively in the Brandywine from 1981-1997. The specific sites with these trends were not identified by USGS in the report.

Comparison of overall contaminant concentrations also has an impact on the trends, especially if one area of the watershed is significantly higher or lower. The West Branch and East Branch of the Brandywine have roughly similar concentrations of nitrate, though West Branch has all increasing trends of nitrate while the East Branch has some increasing trends. Specific conductance increases suggest that in addition to nitrate that sodium, chloride, and TDS may be increasing in these areas. The USGS study suggested that trends in nutrient concentrations follow a spatial pattern related to land use in Chester County.

The USGS observed most dramatic improvement in water quality were the trends for phosphorus, ammonia, and dissolved oxygen. For example, data from 3 monitoring stations since 1972 indicate the concentrations of minimum dissolved oxygen have increased over time. In 1997, there only were 3 days when the minimum concentration of dissolved oxygen was below 5.0 mg/L on the East Branch Brandywine Creek below Downingtown compared to 103 days in 1981 (Reif, 2002).

2.3.16. Comparison of Water Quality by Land use, Location, and Weather

There is no single report that compares the water quality at different locations in the watershed. This is mainly due to the fact that there are only a handful of sites where comparative data is available and usually beyond basic parameters there are less than 25 observations. Thus, a detailed statistical analysis comparing the water quality between different locations in the watershed is not a feasible exercise, but could be possible in a future effort. Therefore, it is suggested that future watershed monitoring programs become synchronized in order to conduct a geographical comparison of a variety of key parameters.

Since a true statistical comparison of various locations in the watershed was not feasible given the data management and comparison issues another method of comparison was performed utilizing comparisons from past water quality studies. The comparisons are conducted by using data and graphs from studies conducted by USGS to examine the differences in stream water quality samples in the Brandywine for different land uses and weather conditions. All graphs in this section are from the various USGS reports.

2.3.16.1. TSS and Nutrients Spatial Comparison

In previous studies (Keorkle and Senior, 2002), it has been found that the TSS during dry weather is always below 20 mg/L and usually in single digits values. Overall wet weather TSS values were roughly 100 times higher than during dry weather for all land uses except for forested lands.

During dry weather there only appears to be higher TSS in the main stem, but this could be due to the many dams and fluvialgeomorphological differences between the branches and main stem and less related to land use.

During wet weather the sampling location representative of a majority residential unsewered land use observed the highest median TSS concentrations closely followed by agricultural livestock and row crop land use/watershed station. Residential sewered and main stem mixed use lands produced substantially lower median TSS values with the lowest TSS values observed in the forested land use areas. These observations were not unexpected given that residential development and agricultural activities can create the greatest streambank encroachment, erosion, and degrading activity.

During base-flow periods agricultural row crop areas, agricultural livestock areas, and residential unsewered areas observed higher levels of nitrate over 3 mg/L. These impacts were observed further downstream at the main stem mixed use sites and appear to be dominant. Residential sewered and forested land use stations observed ranges of concentrations that were roughly similar (range: 0.5 to 2 mg/L).

During wet weather nitrate concentrations generally decreased at all sites or were not substantially different. Overall agricultural row crop, agricultural livestock, and residential unsewered continued to be the dominant land uses with the greatest nitrate concentrations compared to other locations. The manure and fertilizer runoff and local impact on groundwater from agricultural activities is an obvious source of nitrate in the stream. The source of the nitrate concentrations from residential unsewered areas is suspected to be from septic systems in failure or impacting local groundwater systems. It has been well documented in other states and within Delaware that there are a significant number of failed septic systems reported and estimated (University of Delaware, 2007).

Total and dissolved ammonia was the greatest at agricultural livestock and residential unsewered areas during base flow periods. Agricultural row crops observed the greatest increase in total and dissolved ammonia concentrations from baseflow to stormflow periods which is suspected to be mainly due to manure and fertilizer. Agricultural livestock land use also saw a slight increase in concentrations during storm flow periods. The other stations and land use did not see any increase from base flow to storm flow periods.

The agricultural livestock station observed the greatest concentrations of total and dissolved phosphorous compared to other stations. Residential sewered and forested areas observed the lowest total phosphorus concentrations during baseflow and stormflow. Residential unsewered and forested areas observed the lowest orthophosphate concentrations during baseflow and stormflow. Dissolved orthophosphate concentrations increased significantly during stormflow at livestock agricultural areas, but remained relatively unchanged at other stations. Total phosphorus increased by a factor of 10 from baseflow to stormflow periods at the agricultural livestock, agricultural row crop, and residential unsewered locations.

Overall, the data from previous studies by USGS suggests that regardless of weather condition agricultural and residential unsewered areas are major contributors of TSS and nutrients.

2.3.16.2. Bacteria Spatial Data Comparison

There has been considerable study of the bacteria concentrations and hypothesis as to its sources in the Brandywine Creek Watershed to date. However, there have not been any studies using advanced methods such as DNA fingerprinting, genetic typing, or antibiotic resistance to conclusively determine bacteria sources in the watershed. Therefore, geographical, temporal, and land use based comparisons are the only tools available to identify potential sources of bacteria.

A study by USGS (Town, 2000) was conducted that examined the elevated bacteria concentrations during base flow and stormflow to indicate pollution from point and nonpoint sources. The study concluded that during base flow, elevated bacteria concentrations in the Brandywine Creek appear to come from nonpoint sources such as contaminated ground water, or from farm animals and wildlife entering and leaving waste in the stream. It also concluded that during stormflow, land-surface runoff, a nonpoint source, is the causal agent for the elevated bacteria concentrations in all of the subbasins. This information is further corroborated by a USGS study (Cinotto, 2005) of bacteria sources in 2005 that suggested nonpoint sources as well. The Cinotto study concluded that previously suspected sources of elevated bacteria concentrations, such as wastewater treatment facilities and on-lot sewage disposal systems, were not found to directly contribute to increased bacterial concentrations observed within the study area of the West Branch Brandywine Creek. Cinotto suggested that the primary sources of elevated bacteria concentrating throughout the study area were generally found to be related to natural processes occurring within the environment and anthropogenic influences centered around urban and industrial runoff issues. The combined conclusions of these studies suggest that livestock, wildlife, or urban/suburban runoff with bacteria regrowth as the main sources of bacteria in the watershed.

The USGS study concluded (Town, 2000), that the factors affecting bacteria concentrations in the Brandywine Creek Basin include nonpoint sources, stormflow, reservoirs, and seasonality. Suspected nonpoint sources included agriculture, ground-water contamination (residential septic systems or leaking landfills), urban/residential activities, resident wildlife, and land-surface runoff. As was expected, bacteria concentrations are higher in stormflow than in base flow because the runoff washes the land surface, and overland runoff transports bacteria (mostly attached to particulates) into the stream.

The observed concentrations of bacteria in the USGS studies suggest that the West Branch has the highest base flow and storm flow concentrations of bacteria. This is suspected to be linked to the greater agricultural land use activities in the West Branch. This is further shown by USGS comparisons of median concentrations of fecal coliform bacteria from 1998 to 1999 (Table 2-35) and 1973 to 1999 where fecal coliforms were highest on the West Branch at Modena and Honey Brook and lowest on the Main stem at Chadds Ford. The East Branch at Downingtown had the greatest range in bacteria concentrations.

Table 2-35 –Comparison of Spatial and Weather Related Fecal Coliform Concentrations in the Brandywine Creek Reported by USGS (Town, 2000)

		Baseflow Fecal Coliform		Stormflow Fecal Coliform	
USGS Station ID	**Site Name**	**Range**	**Median**	**Range**	**Median**
1480300	West Branch Brandywine Creek near Honey Brook	63-10,000	4,500	1,100-610,000	12,000
1480500	West Branch Brandywine Creek at Coatesville Reservoir	2-1,800	410	3,700-16,000	7,200
1480617	West Branch Brandywine Creek at Modena	6-4,400	940	2,700-15,000	6,000
1480870	East Branch Brandywine Creek below Downingtown	80-8,000	590	1,400-12,000	4,500
1418000	Brandywine Creek at Chadds Ford	2-2,200	110	160-6,700	2,200

Source: Data reported in Town, 2000

The USGS study (Town, 2000) suggested that the tributaries on the West Branch that contribute elevated bacteria concentrations to Brandywine Creek during base flow include Birch Run, Rock Run, Doe Run, Little Broad Run, Broad Run, and Two Log Run. During stormflow, Buck Run also contributes elevated bacteria concentrations. The tributaries on the East Branch that contribute elevated bacteria concentrations to Brandywine Creek during base flow include Beaver Creek, Uwchlan Run, and Taylor Run. During stormflow, Marsh Creek, Culbertson Run, and Valley Creek were also determined to contribute elevated bacteria concentrations. Pocopson Creek, the only tributary on the main stem that was evaluated, contributed bacteria concentrations to the Brandywine Creek during base flow and stormflow.

Comparison of bacteria concentrations at sites above and below each of the three reservoirs in the Brandywine Creek Basin (Chambers Lake, Rock Run, and Marsh Creek Reservoirs) by USGS (Town, 2000) observed that bacteria concentrations in the streams that flow from the reservoirs are lower than bacteria concentrations in the streams that flow into the reservoirs. USGS suggested that this phenomenon is most likely due to the dilution of the small stream bacteria concentrations in the large volume of water in the reservoir and not due to any specific reduction mechanisms.

Seasonality plays a role in the concentration of bacteria in Brandywine Creek. During March, April, May, October, and November, water temperatures and bacteria concentrations are lower in the Brandywine Creek than during June, July, August, and September. This lends further credence to the bacteria regrowth and algae impacts on bacteria concentrations suggested by Cinotto.

The USGS that compared the impacts of different land use on bacteria concentrations showed no significant differences between fecal coliform concentrations in agricultural, forested, residential or mixed subbasins during base flow and stormflow (Town, 2000). However, sites in forested subbasins had a greater range in bacteria concentrations than did sites in agricultural, residential, or mixed subbasins. These results were in substantial contrast to the observed water quality data.

Table 2-36 –Summary of Tributaries in the Brandywine Creek Watershed with Elevated Bacteria Concentrations Reported by USGS (Town, 2000)

		Elevated Concentrations Observed During	
Tributary	**Branch**	**Baseflow**	**Wet Weather**
Birch Run	West	X	
Rock Run	West	X	
Doe Run	West	X	
Little Broad Run	West	X	
Broad Run	West	X	
Two Log Run	West	X	
Buck Run	West		X
Beaver Creek	East	X	
Uwchlan Run	East	X	
Taylor Run	East	X	
Marsh Creek	East		X
Culbertson Run	East		X
Valley Creek	East		X
Pocopson Creek	Main stem	X	X

2.4. Potential Sources of Contamination Analysis

2.4.1. Point Sources Inventory

Combining information from the states of Delaware and Pennsylvania for a comprehensive point source inventory was a challenging effort since the two states house information on different types of point sources in different places/programs and in formats that are not easily merged. Therefore, the first step in assessing the scope and location of point sources was to start with the review of the point sources from the Source Water Assessments conducted in the watershed. The Wilmington source water assessment was expected to provide the closest proximity sources and includes a 196 square-mile portion of the watershed (60%) and extends upstream starting at the Wilmington intake in Delaware and up to the first Pennsylvania intakes along the East Branch of the Brandywine Creek at West Chester and the West Branch of the Brandywine Creek at Coatesville. The Pennsylvania SWAP program conducted source water assessments upstream for the West Chester and Coatesville intakes for the remaining 129 square miles of the watershed (40%).

As described in the Delaware SWAP (University of Delaware, 2002), the delineated source water areas for surface water intakes were separated into Level 1 and Level 2 areas. The Level 1 areas were the lands closest to the main stream and its tributaries. These lands were expected to have the greatest impact on water quality. They included the Level 1A areas defined as the 100-year floodplain and erosion-prone slopes adjacent to the floodplain and the Level 1B areas defined as a buffer area of 200 feet on both sides of the stream. The erosion prone slopes were only designated on the Delaware portion of the watershed and were obtained from the New Castle County Water Resource Protection Area program developed years ago to protect public drinking water sources in New Castle County. The entire watershed area upstream of the intake is labeled as the Level 2 area (196 square miles). In the SWAP potential contaminants in the Level 2 area were important to water quality, but their impacts were considered lesser than those located in Level 1 areas because of the greater distance they must travel to enter a stream.

The Delaware Source Water Assessment Plan separated discrete sources into the following categories following a category scheme established by the State DNREC:

- Hazardous Substance Sites (Superfund and SIRB)
- Large On-Site Septic Systems
- Underground Storage Tanks/Leaking UST
- Waste Water Spray Irrigation
- Landfills/Dumps Waste Sludge Application
- NPDES Waste Water Discharges Confined Animal Feed Operations
- Tire Piles Combined Sewer Overflows
- Hazardous Waste Generators
- Dredge Spoils
- Toxic Release Inventory (TRI) Sites Domestic Septic Systems
- Salvage Yards SARA Title III Sites
- Pesticide Loading & Mixing Areas

The existence of a discrete source doesn't necessarily mean it was discharging a contaminant and even if there was a discharge that may be regulated by a permit. However, its location within a source water area may provide a threat to the drinking water source. The Delaware DNREC developed an extensive database (called the Site Index Database) of discrete sources and determined the relative risk that almost every discrete source in Delaware poses to a variety of media including surface waters.

2.4.1.1. Summary of Delaware SWAP Discrete Source Inventory

Approximately 433 point sources were identified in the 196 square mile area upstream from the Wilmington intake SWAP. In the Delaware portion of Wilmington's Brandywine Creek intake delineated source water area, which were closest to the intake, there were 24 discrete sources in the Level 1 area and 287 discrete sources in the Level 2 area (Table 2-37). In the Pennsylvania portion of this delineated source water area the contaminant inventory was incomplete. There were a total of 122 known discrete sources with the majority of them associated with wastewater or stormwater management, including NPDES discharges, spray irrigation sites, and large septic systems. There were 72 discrete sources in the Level 1 area with all but one associated with stormwater or wastewater discharges. There were 50 discrete sources in the Level 2 area. It is important to note that the inventory compiled by Delaware stopped before reaching the majority of the populated areas upstream of West Chester, Coatesville, and Downingtown since PADEP was continuing the inventory beyond that point for those intakes.

It is also important to note that many of the PA inventories did not have data available from PA and could have missed significant potential sources. An example of this missing information is aboveground and underground storage tanks (AST/UST). A brief review of the AST/UST records for Chester County identified another 1270 AST/UST that may or may not reside in the watershed. Some of these tanks have the potential to store up to 30,000 gallons of chemicals including fuel oil, gasoline, diesel fuel, and hazardous substances. Section 3 in this report will discuss the potential impacts from accidents and tanks. From the upstream SWAP reports the total point sources in the entire watershed upstream of Wilmington is most likely double that reported in the Wilmington SWAP.

Table 2-37 – Summary of Delaware SWAP Discrete Source Inventory

Discrete Site Type	Brandywine Creek at Wilmington		DE		PA		
	DE	PA	Level 1	Level 2	Level 1	Level 2	total
Hazardous Substance Sites(Superfund and SIRB)	4	*	1	3	*	*	4
Underground Storage Tanks	259	*	19	240	*	*	259
Landfills/Dumps	0	9	0	0	1	8	9
NPDES Wastewater Discharges**	3	61	3	0	61	**	64
Tire Piles	0	*	0	0	*	*	0
Hazardous Waste Generators	42	*	0	42	*	*	42
Toxic Release Inventory (TRI) Sites	2	*	1	1	*	*	2
Salvage Yards	0	*	0	0	*	*	0
Pesticide Loading, Mixing Areas	0	*	0	0	*	*	0
Large On-Site Septic Systems	0	35	0	0	7	28	35
Waste Water Spray Irrigation	1	17	0	1	3	14	18
Waste Sludge Application	0	*	0	0	*	*	0
Confined Animal Feed Operations (CAFOs)	0	*	0	0	*	*	0
Combined Sewer Overflows	0	*	0	0	*	*	0
Dredge Spoils	0	*	0	0	*	*	0
Domestic Septic Systems	0	*	0	0	*	*	0
SARA Title III Sites	*	*	*	*	*	*	0
Total	311	122	24	287	72	50	433

* Limited or No Data Available from PA.

Table 2-38 provides a list of the point source types identified in the other source water assessments for water intakes upstream of Wilmington. The evaluation of top priority sources of pollution from the prior SWAP reports in Section 1.3 shows that upstream discharges were the most important point sources due to their potential for impact during dry weather and plant failures/accidents. The reports all gave storage tanks and other point sources lower priority over non-point sources such as urban/suburban stormwater runoff, agricultural runoff, and transportation corridor accidents. These rankings were created by program officers with on the ground field knowledge of the facilities and thus are considered the best available information and judgement related to their potential for concern. Though the ranking schemes were based on a number of factors, emergency planning prioritization for these point sources should be conducted that will prioritize which sites may have the greatest impact during an emergency/accident that has a low likelihood of occurrence, but a high potential impact. This separate emergency prioritization would be used for emergency planning purposes only, but may help aid in regulatory inspection programs and notification requirements in permits and improved first responder training and education.

Combining the point source inventory information from the upstream SWAPs and the other available GIS coverages from PA and DE, the total estimated number of relevant point sources is 706 (See Table 2-39). This is almost twice the original estimate of point sources in the Wilmington SWAP in 2002. The location of these potential sources is in Figure 2-52.

Table 2-38 – Summary of SWAP Point Source Inventories for the Brandywine Creek Watershed

SWAP	Wilmington	Downingtown	Coatesville	West Chester	Total
UST	259	24	8		291
TRI	2	3	0		5
RCRIS	42	16	6		64
PWS ID'd	0	19	19		38
NPDES/PCS	64	6	1		71
Mines	0	1	4		5
Superfund/SIRB	4				4
Landfills/Dumps	9				9
Spray Irrigation	18				18
Septic Systems	35				35
TOTAL	433	69	38	325	865

Table 2-39 – Summary of SWAP Point Source Inventories for the Brandywine Creek Watershed from Available GIS Coverages

Discrete Site Type	PA part of COW SWAP GIS	DE part of COW SWAP GIS	PA UST GIS coverage (via WRA)*	PA NPDES GIS coverage (via WRA)**	PA HWG GIS coverage via WRA	PA Water Resources GIS Coverage (via WRA)	subtotal
Hazardous Substance Sites(Superfund and SIRB)		4					4
Underground Storage Tanks		148	109				257
Landfills/Dumps	12						12
NPDES and Wastewater Discharges	129	3		93		22	247
Tire Piles							0
Hazardous Waste Generators		41			3		44
Toxic Release Inventory (TRI) Sites		2					2
Salvage Yards							0
Pesticide Loading, Mixing Areas							0
Large On-Site Septic Systems	35					77	112
Waste Water Spray Irrigation	20			7			27
Waste Sludge Application							0
Confined Animal Feed Operations (CAFOs)				1			1
Combined Sewer Overflows							0
Dredge Spoils							0
Domestic Septic Systems							0
SARA Title III Sites							0
						Total	706

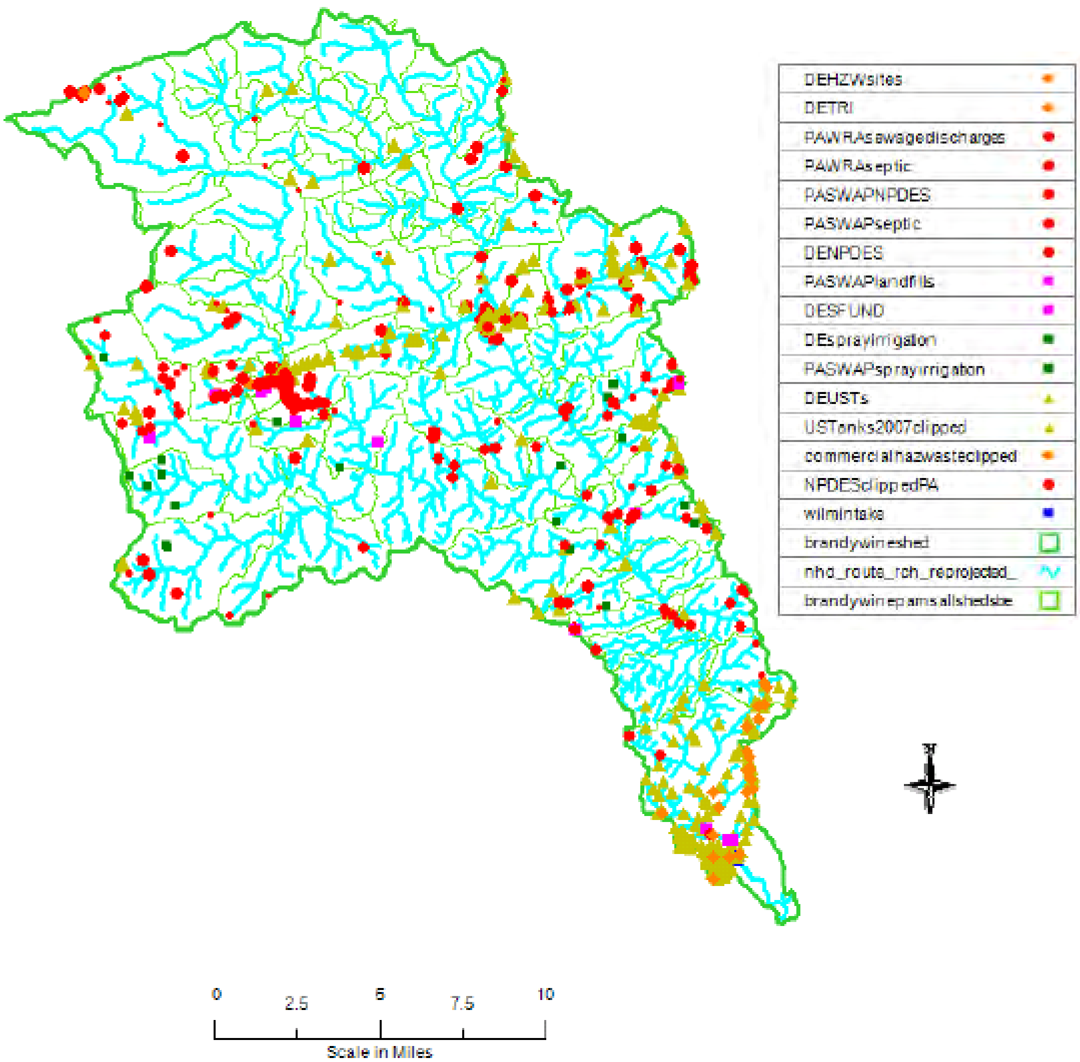


Figure 2-52 – Location of Potential Point Sources in the Brandywine Creek Watershed

2.4.1.2. NPDES Dischargers

In the source water assessments were 64 known discharges with NPDES permits in the watershed as of 2003. The largest 30 NPDES dischargers are shown in Table 2-39. Figure 2-52 shows their location. The total volume discharged to the watershed in 1998 was estimated to be 5.3 billion gallons per year or 12.9 million gallons per day on average.

Point sources can have some effect on the water quality in the watershed during baseflow periods. Under certain conditions NPDES discharges have been reported to make up over 15% of the flow in the Brandywine Creek (BVA, 1999). These discharges cannot be ignored since they affect the baseline water quality in the watershed during non rain event influenced period (roughly 60% of the year).

Though NPDES discharges have permit requirements to reduce specified pollutants to prevent water quality problems, the NPDES and TMDL process of the Clean Water Act does not specifically regulate many of the same water quality parameters that are regulated by the Safe Drinking Water Act. For example, *Cryptosporidium* does not have a federal or state water quality standard though water suppliers are regulated based upon the concentrations in their raw water. Many of the emerging contaminants that water suppliers are concerned about are not regulated by any state and federal agencies in the region including taste and odor compounds, pharmaceuticals, and personal care products. Regardless of the gaps between the CWA and SDWA, the NPDES process does provide opportunities and mechanisms to ultimately address nutrients, TSS, TDS, and TOC from point sources and provides some limited and indirect improvements towards excessive algal growth, taste and odor compounds, and pathogens.

When examining all dischargers, proximity is also an important factor for potential impact on a downstream water intake. According to the GIS coverages, only the Dupont Experimental Station NPDES discharge is within or near 1 mile from the Wilmington intake. The next closest NPDES discharge is 4 miles upstream from the intake at Winterthur. Five miles upstream the Greenville Country Club is the third closest NPDES. The largest concentration of major dischargers is located along or near the Route 30 corridor, including Malvern, Downingtown, and Coatesville.

Of the 92 NPDES dischargers identified in Pennsylvania a detailed breakdown by Standard Industrial Classification is provided. As shown in Table 2-40 the majority of discharger in PA (34 or 37%) is sewage system facilities.

Table 2-40 –The Top 30 Largest NPDES Dischargers in the Brandywine Creek Watershed 1998

Subbasin	Dischargers Name	Type	flow limit (MGD)	1994-1998 average (MGD)
West Branch	Northwest Chester County STP	STP	0.6	0.433
West Branch	Tel Hai Rest Home STP	STP	0.055	0.044
West Branch	Coatesville City Authority - WTP	IND	0.14	0.073
West Branch	Lukens Steel no. 1 and no. 16	IND	1	0.76
West Branch	Coatesville City Authority - STP	STP	3.85	2.87
West Branch	South Coatesville Borough STP	STP	0.39	0.224
West Branch	Parkesburg Borough Authority STP	STP	0.7	0.263
West Branch	Lincoln Crest Mobile Home Park STP	STP	0.036	0.038
West Branch	Embreeville Center STP	STP	0.2	0.059
East Branch	Indian Run Mobile Home Park STP	STP	0.0375	0.037
East Branch	Little Washington Wastewater Company STP	STP	0.0531	0.042
East Branch	Eaglepoint Development STP	STP	0.015	0.001
East Branch	PA Turnpike Service Plaza STP	STP	0.05	0.014
East Branch	Uwchlan Township Municipal Authority STP	STP	0.475	0.033
East Branch	Pepperidge Farm	IND	0.144	0.021
East Branch	Downingtown Area Regional Authority	STP	7.134	5.4

East Branch	Sonoco Products	IND	1.028	0.806
East Branch	Broad Run Sewer Company STP	STP	0.4	0.26
East Branch	West Chester Borough - Taylor Run STP	STP	1.8	1.27
East Branch	Philadelphia Suburban Water- Ingrams Mill	WTP	0.369	0.137
Main stem	Radley Run Mews STP	STP	0.032	0.017
Main stem	Radley Run Country Club STP	STP	0.017	0.008
Main stem	Birmingham/TSA STP	STP	0.04	0.0107
Main stem	Birmingham Township STP	STP	0.15	0.05
Main stem	Knights Bridge/Villa at Painters STP	STP	0.045	0.021
Main stem	Menhenhall Inn STP	STP	0.022	0.011
Main stem	Unionville - Chadds Ford Elementary School	STP	0.0063	0.0027
Main stem	Winterthur STP	STP	0.025	0.011
			total (MGD)	total (MGD)
			18.8	12.9

Source: Keorkle and Senior, 2002

Table 2-41 – Summary of SIC Codes for 92 NPDES Dischargers in PA

# of facilities	Standard Industrial Classification
34	SEWERAGE SYSTEMS
5	GASOLINE SERVICE STATIONS
4	PRIVATE HOUSEHOLDS
3	REFINED PETROLEUM PIPELINE
3	INDUSTRIAL INORGANIC CHEMICALS
2	PHYSICAL FITNESS FACILITIES
2	UNSUPPORTED PLSTICS FILM/SHEET
2	CANNED FRUITS, VEG, PRES, JAM
2	COMMERCIAL PHYSICAL RESEARCH
2	INORGANIC PIGMENTS
2	PLSTC MAT./SYN RESINS/NV ELAST
2	GLASS CONTAINERS
2	HOTELS AND MOTELS
2	WATER SUPPLY
2	MUSEUMS AND ART GALLERIES
1	MOTOR VEHICLES & CAR BODIES
1	ALKALIES AND CHLORINE
1	ANALYTICAL INSTRUMENTS
1	ASPHALT FELT AND COATINGS
1	BLAST FURN/STEEL WORKS/ROLLING
1	BREAD & OTHER BAKERY PRODUCTS
1	BUSINESS SERVICES, NEC
1	CANNED SPECIALTIES
1	EATING PLACES
1	ELECTRICAL SERVICES

1	ELEMENTARY & SECONDARY SCHOOLS
1	INDUST. ORGANIC CHEMICALS NEC
1	IRON AND STEEL FORGINGS
1	NATURAL GAS LIQUIDS
1	OPER OF DWELL OTHER THAN APART
1	VOCATIONAL SCHOOLS, NEC
1	PAPERBOARD MILLS
1	PETROLEUM BULK STATIONS & TERM
1	SERVICES, NEC
1	PETROLEUM REFINING
1	REFUSE SYSTEMS
1	READY-MIXED CONCRETE
1	OIL FIELD MACHINERY

2.4.1.3. Underground Storage Tanks

Underground and Aboveground Storage Tanks can store large quantities of toxic chemicals that if directly released into the Brandywine Creek would result in potential water intake closures. According to records, there are 504 tanks in Delaware and 154 in PA upstream of the Wilmington intake (total 658 tanks). The types of tanks vary significantly, but a majority in Delaware and PA are commercial or gas station related (See tables 2-42 and 2-43). Though many tanks are reported, not all tanks are active. In PA, less than half of the 504 reported tanks are in a status that may be considered active or potentially active in the future (see Table 2-44).

Of the tanks in PA, an analysis was conducted of 220 tanks with more detailed information available. Of those only 112 tanks were considered active, in use, or exempt from state law. Of those tanks approximately 78% were gas or diesel fuel tanks. The remaining 12% held a variety of chemicals (see table 2-45). The size of the tanks ranged from 100 gallons to 20,000 gallons (see table 2-46). The largest tanks reaching 15,000 to 20,000 gallons tended to be for aviation gas, fuel oil, diesel fuel, kerosene, gasoline, and jet fuel. The largest hazardous substance tank was 1,000 gallons. Hazardous substances of unknown types were stored either at Sunoco market terminal in Exton or at Scott Honda.

Tanks ranged from 4 to over 76 years old in PA (see Table 2-47). The oldest tanks were located at Zekes. Almost all of the Delaware USTs are within 5 miles of the Wilmington intake suggesting that any direct releases from these tanks would have the potential for immediate impacts on Wilmington's water supply. There is a large concentration of USTs on the west side of the main stem Brandywine within 1 to 2 miles of the intake. The next largest concentration of storage tanks is located generally around 20 miles from the Wilmington intake. This is still within a close enough distance to assume that dilution will be limited and impacts would appear within a day of the accident at Wilmington's intake depending on flow and rainfall. The information in the PADEP records for storage tanks indicates there is no last date of inspection for some of the older tanks. Therefore older tanks that have not been inspected in the past decade should be a priority for inspection.

Table 2-42 – Types of Storage Tanks in Delaware Portion of the Brandywine Creek

Major Type	Number	Percentage
Agricultural	1	1%
Automotive	30	21%
Commercial/Retail/Services	33	23%
Educational	3	2%
Government	11	8%
Health Care	9	6%
Industrial	4	3%
Recreation	2	1%
Religious	12	8%
Residential	39	27%
Unknown	1	1%
Total	145	

Table 2-43 – Types of Storage Tanks in Pennsylvania Portion of the Brandywine Creek

Facility Type	Number	Percentage
Aviation	4	1%
Agricultural	4	1%
Manufacturing/Industrial	121	24%
Gas Station	128	25%
Gas Storage	5	1%
Other	19	4%
Oil Supplier	34	7%
Government	48	10%
Retails/Commercial	64	13%
Services	1	0%
Transportation	9	2%
Unavailable	1	0%
Unknown (for stds conv only)	65	13%
Utilities/Sanitary Services	1	0%
Total	504	

Table 2-44 – Storage Tank Status in Pennsylvania Portion

Tank Type	Number	Percentage
Active	1	0%
Closed w/out permit	200	40%
Currently in use	109	22%
Exempt from State Law	98	19%
Permanently Closed in Place	8	2%
Removed	72	14%
Temporarily out of use	8	2%
Transferred	3	1%
Unregulated Removed	5	1%
Total	504	

Table 2-45 – Types of Substances Reported in Active Storage Tanks in PA

Type	Number	Percent
Aviation gas	1	1%
Diesel	40	22%
Gas	102	56%
Heating Oil	8	4%
Hazardous Substance	3	2%
Jet Fuel	3	2%
Kerosene	10	5%
New Motor Oil	1	1%
Other	12	7%
U.S. Dept. Of Labor Regulated	3	2%
Total	**183**	

Table 2-46 – Amount of Substances Stored in Tanks in PA Upstream of Wilmington's Intake

Parameter	Minimum tank size (gallons)	Maximum tank size (gallons)
Aviation Gas	15,000	15,000
Diesel	500	20,000
Gas	550	15,000
Heating Oil	12,000	20,000
Hazardous Substances	350	1,000
Jet Fuel	15,000	15,000
Kerosene	1,000	20,000
New Motor Oil	2,000	2,000
Other	3,000	5,000
U.S. Dept. Of Labor Regulated	300	2,000

Table 2-47 – Storage Tank Ages in PA (for tanks that had ages provided)

Parameter	Age (years)
min	4
max	76
average	19
Std.dev.	11.7
Count	**102**

2.4.1.4. Spray Irrigation and Large On-Site Septic Systems

Spray Irrigation and Large On-Site Septic Systems represent the potential for large concentrated areas of groundwater influence from sewage. Also spray irrigation has the potential to impact surface waters from runoff. Both activities are monitored and permitted by state and federal agencies to ensure they do not impact streams. In some cases, these facilities are required or preferred by regulators instead of direct discharge to the Brandywine Creek directly. Therefore, the potential for an immediate impact from these facilities is unlikely, but long term studies and monitoring are necessary to ensure as these options are more heavily utilized instead of direct discharge that they remain effective.

According to Delaware records, there is only 1 spray irrigation system in the Delaware portion of the Brandywine Creek Watershed. There are 20 identified spray irrigation systems in Pennsylvania. There were 35 large on-site septic systems identified in the PA drainage area during the Wilmington SWAP. Another 77 potential large on-site systems were identified further upstream in PA in its Significant Water Resources GIS coverage. Only limited information is available regarding these facilities and actual size and flow rates were not provided. No stakeholder information suggested significant concerns from any specific spray irrigation or on-site septic systems.

2.4.1.5. Residential Septic Systems

A residential septic system is actually a broad category that includes traditional or modern septic systems, cesspools, and seepage pits. The difference between these systems is significant from a contaminant mitigation perspective. A traditional septic system utilizes a solids settling tank and soil absorption field usually involving a piping manifold system. A cesspool is the older technology prior to septic tanks. A cesspool is a large box that drains either through the bottom or sides into the ground. The design and operation of cesspools leads to significantly less treatment, higher failure, and more interaction with groundwater (University of Delaware, 2007). It is assumed that most septic systems in Delaware have on average a 1,000 gallon capacity. Most cesspool systems due to failures and additional tank installations can have an average 2,000 gallon capacity. Traditional or modern septic systems may provide greater nutrient and bacteria reduction and operate longer, but still can be a potential source of contamination since both effluents contains pathogens and nutrients in excessive amounts.

Residential septic systems have long been suspected sources of nutrients and bacteria in watershed studies nationwide *(*University of Delaware, 2007*)*. A study by USGS identified unsewered residential areas as having higher loads of sediment and nutrients compared to other residential land uses Keorkle and Senior, 2002). The interaction between surface flow and groundwater contributions especially during low flow periods combined with the low nutrient removal by septic systems suggests that cumulatively septic systems may actually play some role as a more diffuse non-point source than as a direct point source discharge individually. Due to these concerns, New Castle County has restricted septic system placement on steep slopes. *(*University of Delaware, 2007*)*

A number of efforts have been conducted to estimate the amount of septic systems and their operational status in the watershed. The most comprehensive evaluation is summarized in the Bacteria and Sediment TMDL for the Christina Watershed and is provided below in Table 2-48 (USEPA, 2006).

An estimated 587 septic systems are located in the Delaware portion of the Brandywine Creek Watershed. DNREC estimates that all of these systems are actually cesspools with a 10.9% failure rate. In the Chester County portion of the watershed, site-specific information on the locations or numbers of septic systems was not available. However, the worst case assumption is to use the entire number of septic systems estimated for Chester County since most of Chester County drains into the Brandywine Creek Watershed. Using 2005 estimates, there were at most potentially about 55,200 septic systems in the Chester County portion of the basin. The failure rate for these systems is roughly one known failure for every two newly permitted systems. It is less than the 10.9% failure rate for Delaware's cesspool system, but over 1%. Other failure rates for septic systems in Delaware ranged from 2.9% to 11.2%. It is assumed that the failure rate in the watershed ranges from 1 to 10.9% depending upon location.

A worst case analysis can be conducted to provide some perspective on the overall potential impacts on septic systems. Assuming a typical household generates 10–15 pounds of nitrogen per year and 1–2 pounds of phosphorus per year and there are 55,200 septic systems in the Brandywine Creek, the septic systems will generate 250-376 tons of nitrogen and 15 to 50 tons of phosphorous per year. If this is assumed to enter the creek annually it still only makes up 2 to 4% of the total phosphorous and nitrate annual loads for the entire watershed that were estimated by USGS in 1998. Compared to other point sources septic systems only are 10 to 15% and 1 to 2% of the point source load from NPDES dischargers for nitrogen and phosphorus respectively. Thus during baseflow periods septic systems are not currently the dominant point source potential impact on intake water quality.

Table 2-48 – Census Data for Septic System Estimates

Septic System Estimate	Location New Castle County	 Chester County	Source
2004 DNREC Estimate of Septic Systems in Christina River Basin	1,713	-----	USEPA, 2006
2005 Estimated Number of Septic Systems in Christina River Basin	1,650	55,200	USEPA, 2006
2005 Estimated Number of Malfunctioning Septic Systems in Christina River Basin	17	552	USEPA, 2006
2005 Estimated failure rate	1.03%	1.00%	
1990 Estimated septic tanks or cesspools countywide	12,142	50,396	University of Delaware, 2007
Estimated # of Septic Systems in Delaware Portion of Brandywine Creek	587	-----	University of Delaware, 2007
Estimated failure rate for septic systems in Brandywine Creek	10.90%	-----	University of Delaware, 2007
Range of failure rates for Christina basin and subbasins	2.9 - 11.2% (7.2 avg)	------	University of Delaware, 2007

2.4.1.6. Hazardous Waste, Toxic Release Inventory, Landfills, and Contaminated Sites

There are activities, facilities, and sites in the watershed that may generate, release, store, discharge, or release toxic and hazardous substances. Most of these places are regulated or monitored under the Toxic Release Inventory (TRI), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or Superfund program, or Resource Conservation and Recovery Act (RCRA). Facilities reported by the TRI system can generate or discharge toxic substances into the air, land, or water. CERCLA or Superfund is a program that monitors and cleans up the most contaminated lands that directly release or threaten to release hazardous substances. RCRA facilities are regulated the framework for the proper management of hazardous and nonhazardous solid waste including controlling hazardous waste from the time it is generated units its ultimate disposal – in effect, from "cradle to grave".

In the watershed upstream of the Wilmington intake there are 61 known facilities that are regulated under the previously mentioned programs, 2 from TRI, 3 from CERCLA, 3 Commercial hazardous waste generators in Pennsylvania, 41 hazardous waste generators in Delaware, and 12 landfills in Pennsylvania. It is important to note that being listed in these programs does not necessarily mean the facility is releasing or discharging a toxic or hazardous substance upstream from the water intake. In most situations, facilities in these programs are heavily monitored to prevent such events from occurring. In order to determine their potential for impact on the intake the permit compliance status, status of remediation, and mitigation requirements should be evaluated. At the very minimum, these are facilities that notification and communication protocols should be established between Wilmington and the facility. The following Toxic Release Inventory and Superfund facilities are located immediately upstream from the Wilmington Intake:

<u>Toxic Release Inventory Facilities</u>

Dupont Experimental Station

Wilmington Piece Dye

<u>Superfund (CRCLA) Sites</u>

Bancroft Mills

Dupont Exp. Station

Container Corp.

2.4.1.7. Combined Sewer Overflows

A combined sewer system is a system that has both stormwater and sanitary sewage combined in one conveyance pipe instead of two separate pipes. During dry weather a combined sewer does not discharge into the local waterbody. During wet weather, the flow in the pipe can exceed the carrying capacity of the collection system and discharge via an overflow into a nearby stream or river, this is called a combined sewer overflow (CSO). The nature of the discharge is a mixture of urban stormwater runoff and sanitary sewage. Thus, it naturally has been reported to contain high concentrations of pathogens and other contaminants compared to other wet weather sources. Elimination of discharges of untreated sewage and combined sewers upstream from drinking water intakes is a major goal of most regulatory programs.

The Rockford Road CSO is located in the City of Wilmington in the Rockford Park neighborhood immediately upstream of the Wilmington intakes on the opposite side of the Brandywine Creek from the Wills intake for Porter Filter Plant and Hoopes and on the same side of the Brandywine Creek as the Brandywine Filter Plant raceway. The City of Wilmington has an initiative underway to eliminate the Rockford Road CSO by removing the stormwater from the combined system to a new separate stormwater system.

2.4.1.8. Transportation Crossings & Pipelines

There are several major highway and railroad bridge crossings immediately upstream of the intake and along major branches of the Brandywine Creek. The railroads and highways also run parallel along the main stem and branches of the Brandywine Creek on winding roads that are subject to accidents near the water. Trucks on highways can transport toxic chemicals, petroleum substances, and fertilizers. An accident in one of these sensitive locations could result in the release of anywhere from a few gallons to several thousand gallons of material into the Brandywine Creek. Railroad crossings also represent a similar concern given the wide variety of chemicals transported in large quantities across and along the creek. The I-95 bridge, Route 30, and Route 100 road crossings represent the crossings with the greatest vulnerability, while the Route 100 sections that parallel the main stem is the greatest water supply vulnerability from a truck accident. The railroad crossing near I-95 and along the Route 30 corridor and lines that run along the main stem and West Branch to Coatesville are the areas of greatest water supply vulnerability from a railroad accident.

A number of natural gas and petroleum pipelines are located running throughout the watershed. Accidental releases due to pipeline breaks represent a potential source. However, the herbicide spraying to maintain the pipeline right of ways and other maintenance or clearing activities also represent a potential source of contamination.

A full listing of all relevant point sources is provided in Appendix A.

2.4.2. Upstream Discharges & Baseflow impacts

There were 64 known discharges with NPDES permits in the watershed as of 2003. The top 30 NPDES dischargers were provided in the previous section. The total volume discharged to the watershed in 1998 was estimated to be 5.3 billion gallons per year or 12.9 million gallons per day on average. This is different from the cumulative maximum permitted discharges of 19.23 million gallons per day.

Point sources can have some effect on the water quality in the watershed during baseflow periods. Under certain conditions NPDES discharges have been reported to make up over 15% of the flow in the Brandywine Creek (BVA, 1999). These discharges cannot be ignored since they affect the baseline water quality in the watershed during non rain event influenced period (roughly 60% of the year).

The sewage discharge in the year 2100 was projected for the watershed using a population of 213,000 persons and an average discharge of 12.9 MGD as the current status and the projected population of 384,000 persons. It was projected that the future sewage discharges in the watershed by 2100 are projected to almost double to 23.2 MGD. This suggests that during non rainfall periods that the NPDES discharges in the future could make up 30% of the baseflow especially if this increase in discharges is associated with increased withdrawals from the basin. The water quality impacts from the contaminant loads associated with the additional sewage discharges would need to be offset by increased wastewater treatment or land application if the pollutant loads to the watershed from point sources are not to increase.

A cursory review of discharge applications and dockets recently permitted by regulating agencies for the Brandywine Creek watershed suggests that nutrient load reductions are already being prescribed via additional treatment or land application for some dischargers in the watershed. However, these increased regulatory requirements may not address the issues of contaminants that appear to fall between the gaps linking CWA and SDWA. The ability of regulatory initiatives for point sources in the watershed to address emerging contaminants will need to be examined.

2.4.3. Point Source Loadings

The loads of the priority contaminant groups were estimated to determine their relative potential impact on intake concentrations at the Wilmington intake under average, maximum, and future maximum wastewater discharges. These estimates were to provide under a conservative "worst case" of the potential significance of these discharges. Table 2-49 summarizes the total annual loads of the various contaminants of concern. Table 2-50 provides a summary of the potential impacts at the Wilmington intake in relation to regulatory and operational impact thresholds as well as a comparison with the concentrations currently observed at the intake. Table 2-51 provides an estimate of the percentage of the regulatory threshold or observed concentrations at the Wilmington intake that could be related to NPDES discharges/point sources. These data suggest that NPDES discharges have the most potential for impact on regulatory thresholds for *Cryptosporidium*. The NPDES discharges also have the potential to be a significant portion of the average concentration of TOC and nitrate at the Wilmington intake. However, though the wastewater discharges may have the potential to be a significant contributor of TOC, the type and fraction of natural organic matter in the TOC is more important than the amount. For example, natural runoff with certain types of vegetation may contribute a more specific or potent natural organic matter with a higher disinfection by product potential than water with an equal or greater amount of TOC in wastewater. In the future under certain conditions, NPDES discharges could have the potential to be a significant portion of the average ammonia concentration at the Wilmington intake as well.

Table 2-49 – Annual Estimated Loads of Various Contaminants of Concern

		Annual Load of Total Wastewater Discharges at	
Parameter	**units**	**19.2 MGD**	**23.2 MGD**
Nitrate*	tons/yr	638.8	1149.8
Ammonia*	tons/yr	12.5	22.5
Phosphorus*	tons/yr	24.3	43.7
fecal coliform**	cfu/yr	5.3E+13	6.4E+13
Cryptosporidium**	oocysts/yr	2.7E+11	3.2E+11
TOC**	tons/yr	663.1	801.3

* load estimated by Keorkle and Senior, 2002

** load estimated using average or maximum effluent concentrations

Table 2-50 – Intake Impacts of Wastewater Discharges

Parameter	STP Effluent Discharge (MGD)	STP effluent concentration used	Units	Estimated intake concentration	Units	Regulatory limit / Operational impact threshold	average / max observed at intake
Crypto-sporidium	12.9	1	oocysts/L	0.04	oocysts/L	0.075	0.065/0.88
Crypto-sporidium	19.2	1	oocysts/L	0.06	oocysts/L	0.075	0.065/0.88
Crypto-sporidium	23.2	1	oocysts/L	0.07	oocysts/L	0.075	0.065/0.88
fecal coliform	12.9	200	cfu/100mL	79	cfu/100mL	N/A	182/2419 (E.coli)
fecal coliform	19.2	200	cfu/100mL	118	cfu/100mL	N/A	182/2419 (E.coli)
fecal coliform	23.2	200	cfu/100mL	142	cfu/100mL	N/A	182/2419 (E.coli)
TOC	12.9	25	mg/L	0.99	mg/L	4 / 8	2.5/7.69
TOC	19.2	25	mg/L	1.47	mg/L	4 / 8	2.5/7.69
TOC	23.2	25	mg/L	1.78	mg/L	4 / 8	2.5/7.69
Nitrate	12.9	10	mg/L	0.95	mg/L	10	2.1/3.6
Nitrate	19.2	10	mg/L	1.42	mg/L	10	2.1/3.6
Nitrate	23.2	10	mg/L	2.55	mg/L	10	2.1/3.6
Phosphorus	12.9	0.1	mg/L	0.04	mg/L	N/A	0.3/2.2 (Ortho-P)
Phosphorus	19.2	0.1	mg/L	0.05	mg/L	N/A	0.3/2.2 (Ortho-P)
Phosphorus	23.2	0.1	mg/L	0.10	mg/L	N/A	0.3/2.2 (Ortho-P)
Ammonia	12.9	1	mg/L	0.02	mg/L	0.1	0.1/0.9
Ammonia	19.2	1	mg/L	0.03	mg/L	0.1	0.1/0.9
Ammonia	23.2	1	mg/L	0.05	mg/L	0.1	0.1/0.9

* assumes an annual flow of 505.7 cfs in the Brandywine Creek at Wilmington and 100% mixing for concentration estimates

Table 2-51 – Estimated Potential Impact and Contribution of Point Sources to Wilmington's Intake Concentrations for Various Contaminants

Parameter	STP Effluent Discharge (MGD)	Estimated intake concentration	**% reg threshold**	**% max or avg conc at intake**	**Note**
Crypto	12.9	0.04	53%	4%	reg/avg
Crypto	19.2	0.06	78%	7%	reg/avg
Crypto	23.2	0.07	95%	8%	reg/avg
fecal coliform	12.9	79	40%	3%	reg/max
fecal coliform	19.2	118	59%	5%	reg/max
fecal coliform	23.2	142	71%	6%	reg/max
TOC	12.9	0.99	25%	40%	reg/avg
TOC	19.2	1.47	37%	59%	reg/avg
TOC	23.2	1.78	44%	71%	reg/avg
Nitrate	12.9	0.40	10%	45%	reg/avg
Nitrate	19.2	1.42	14%	67%	reg/avg
Nitrate	23.2	2.55	26%	121%	reg/avg
Phosphorus	12.9	0.00	40%	13%	reg/avg
Phosphorus	19.2	0.05	54%	18%	reg/avg
Phosphorus	23.2	0.10	97%	32%	reg/avg
Ammonia	12.9	0.04	20%	20%	reg/avg
Ammonia	19.2	0.03	28%	28%	reg/avg
Ammonia	23.2	0.05	50%	50%	reg/avg

(orange)	color denotes potential for impact on regulatory or operational threshold or a significant factor
(yellow)	color denotes potential for impact on average intake concentration

2.4.4. Non Point Sources Inventory

Nonpoint source (NPS) pollution, unlike pollution from point sources, comes from many distributed sources in the watershed. NPS pollution is caused by runoff from ground cover. As the runoff flows over the ground surfaces, it picks up and carries away natural and human-made pollutants, finally depositing them into streams and rivers. These pollutants include:

- Excess fertilizers, herbicides, and insecticides from agricultural lands and residential areas;
- Oil, grease, metals, and toxic chemicals from urban runoff and energy production;
- Sediment from improperly managed construction sites, destabilized streambanks, crop and forest lands, and eroding streambanks;
- Salt from irrigation practices and road de-icing materials
- Metals from acid mine drainage from abandoned mines;
- Bacteria and nutrients from livestock, pet wastes, and wildlife
- Atmospheric deposition and hydromodification are also considered sources of nonpoint source pollution. An example of atmospheric deposition is from PCBs. An example of hydromodification is streambank erosion due to channelization and downcutting of streams from urban stormwater runoff.

The impacts from non-point source runoff are usually categorized into Urban/Suburban Runoff, Agricultural Runoff, and Wildlife/Forest Runoff related impacts.

2.4.4.1. Urban/Suburban Stormwater

Urban and suburban stormwater runoff can contain various metals, nutrients, pathogens, organic chemicals, and sediment. In addition to these constituents, the high flow velocities from urban runoff can actually create significant erosion of streambanks and scour significant deposits of contaminated sediments. Though some data suggests the runoff from areas with more than 40% impervious cover can result in metal levels in streams that are toxic, the most significant damage is caused by flow. Flow not only erodes the streambank and downcuts the main channel, it also scours the streambed eliminating aquatic life habitat embedding the streambed from deposits that essentially choke out the chance for life to establish and sustain in the streambed. From a drinking water perspective there is a growing amount of reports in literature that urban and suburban runoff can actually produce trace organic waste contaminants such as PBDEs and other compounds that are not easily removed by water treatment and represent a potential human health concern.

Therefore, the prevention of stormwater runoff and management of stormwater runoff through proper treatment is the most important activity that can be undertaken.

2.4.4.2. Agriculture Activities

Agricultural lands are estimated to make up 39% of the land cover in the Brandywine Creek Watershed. Census data from the USDA in 2002 suggests that approximately one quarter of the land is croplands, one quarter is pasture, and the remaining half is undetermined. Recently the TMDL report by USEPA (USEPA, 2006) classified 84% of the agricultural land use in the Brandywine as row croplands and the remaining 16% was livestock pasture areas. The type of agricultural use and proximity to the stream is extremely important when prioritizing the mitigation of agricultural land uses. The location and concentration of animal feeding and watering activities, barnyards, and manure application can all be important in the loading of pathogens and pharmaceuticals from a particular livestock operation. The tilling or no-tilling, riparian buffers, fertilizer and manure applications for croplands can have a significant impact on the sediment, nutrients, pesticides/herbicides, and pharmaceuticals that reach the stream from cropland operations.

The inventories of livestock in Chester County and New Castle County from the last three agricultural census periods are shown in Table 2-52. As shown there are approximately 766,000 livestock in Chester and New Castle County. Assuming that the livestock is divided evenly in the counties and using the percentage of the counties that drain into the Brandywine Creek Watershed, there is potentially 580,000 livestock in the Brandywine Creek Watershed. If there are roughly 213,000 people living in the Brandywine watershed, this suggests that there are more than 2 livestock animals per person living in the watershed. Thus, the waste from a population of animals that can create more fecal material than humans creates a situation of untreated sewage/animal waste that is an order of magnitude greater than human contributions that are typically treated. It should be noted that over 90% of the livestock included poultry. Removing the poultry from the potential livestock, there are potentially 32,000 cattle, pigs, horses, sheep, and lambs in the watershed. Again, given these larger animals can produce ten times more fecal material than humans on a daily basis they would represent the same potential fecal production as 320,000 people. Most importantly this waste is not treated and in most cases spread in the watershed for fertilizer or potentially concentrated near or into streams. Other than fecal coliform bacteria there is data suggesting that neonatal livestock actually can produce pathogen levels such as *Cryptosporidium* at levels that are even more significant than adult livestock or humans. For example a young calf could produce the equivalent daily load of *Cryptosporidium* as 100 adult cows or 1,000 immunocompromised humans (Crockett, 2007).

Table 2-52 - Livestock Inventories from 2002 USDA Agricultural Census & Estimated in the Brandywine Creek Watershed by EPA

	USDA Countywide Census Data 2002		EPA Estimate for Watershed	
Category	**Chester County**	**New Castle County**	**Chester County**	**New Castle County**
Cattle and calves	41,878	2,665	5286 / 31900 *	633 / 1736 *
Hogs and Pigs	12,860	86	6,540	280
Poultry	696,361		740,480	220,308
Horses	8,597	833	5,293	737
Sheep	2,856	366	2,580	222
Total	**762,552**	**3,950**	**792,079**	**223,916**

Source: USEPA, 2006

2.4.4.3. Wildlife

Wildlife also generates bacteria on the land surfaces and in streams. Wild animals are also assumed to be the only source of bacteria on forested land. A precise estimate of the number of wild animals in the Brandywine Creek is not available. Wild animal populations were estimated based on animal densities in the EPA TMDL report (USEPA, 2006). Based on these values it is estimated there are approximately 71,715 wild animals in the watershed. Surprisingly, these estimates suggest that 60% of the wild animals are located in row crop lands and 32% are in forested lands in the watershed. The number of wild animals is roughly 10% of the estimated number of livestock in the watershed. Removing poultry from the watershed estimate, wildlife is approximately twice the number of animals estimated for cattle, horse, and pig livestock in the watershed.

Table 2-53 – Estimated Location of Wild Animals in the Brandywine Watershed

Wild Animal	Row crop (total # animals)	Livestock (total # animals)	Forest (total # animals)	total # wild animals in watershed
Ducks	3,192	612	1,027	4,831
Geese	5,320	1,020	-	6,340
Deer	-	714	3,595	4,309
Beaver	532	102	1,027	1,661
Raccoons	266	51	514	831
Other	34,048	3,264	16,432	53,744
Total	43,358	5,763	22,594	71,715

Source: USEPA, 2006

2.4.4.4. Domestic Pets

Domestic pets are potential sources of bacteria in a similar way as wildlife. Cats and dogs can contribute fecal material within the watershed that may find its way into surface waters. This source is more likely in more populated areas where large numbers of pets (and abandoned pets) tend to be found.

As reported by EPA in the TMDL report (USEPA, 2006), a national study American Pet Products Manufactures Association reported that 39.1 percent of households own at least one dog and 32.1 percent own at least one cat. The average number of dogs per dog-owning household is 1.41, and the average number for cats is 2.4 per cat-owning household. There are an estimated 149,812 households in the Christina River Basin (USEPA, 2006). Based on the APPMA national study, approximately 58,576 households own dogs and 48,090 households own cats. Using these values produces an estimate of 82,593 dogs and 115,415 cats within the Christina River Basin (see Table 2-54). Assuming the Brandywine Creek is approximately 57% of the Christina River Basin, a rough estimate of cats and dogs is 65,787 and 47,078 respectively. The total number of cats and dogs is 112,865 pets which is roughly 15% of the estimated animals in the watershed as shown in Tables 2-55 and 2-56.

Table 2-54 – Estimated Numbers of Cats and Dogs in the Christina and Brandywine Watersheds

Pet	Christina	Brandywine
cats	115,415	65,787
dogs	82,593	47,078

Table 2-55 – Estimated Numbers of Animals in the Brandywine Watershed

animal type	total estimated # in Brandywine Watershed
cats&dogs	112,865
wild animals	71,715
livestock	579,317
livestock w/out poultry	31,667
total # animals	763,896
total # animals w/out poultry	216,247

Table 2-56 – Detailed Breakdown of Estimated Numbers of Animals in the Brandywine Watershed

animal category	animal	Total estimated # in Brandywine Watershed
livestock	beef cattle	3,374
livestock	dairy cattle	19,173
livestock	swine (hogs)	3,887
livestock	poultry	547,649
livestock	horses	3,437
livestock	sheep	1,597
livestock	other ag animals	200
wild	Ducks	4,831
wild	Geese	6,340
wild	Deer	4,309
wild	Beaver	1,661
wild	Raccoons	831
wild	Other wild animals	53,744
pets	cats	65,787
pets	dogs	47,078
	Total	**763,896**

2.4.5. Non Point Source Loadings

The multitude of non-point sources requires a series of loading analysis aimed at identifying the priority non-point sources as they relate to impacts on the Wilmington intake. These analyses include comparisons of landuse types to identify specific types of non-point source activities to control. It also includes analysis of the animal contributions to non-point source contaminants in order to prioritize within a given landuse (ex. Agricultural), which types of animal practices are more important to mitigate/control. A final analysis is also conducted to geographically prioritize the subsheds that have the largest non-point source contributions of contaminants for focused implementation plan development at the clustered parcel and first order stream level. It also identifies key subsheds that currently have low non-point source loadings and should be examined for detailed prioritization plan activities.

2.4.5.1. Land Use Type Estimates

As shown below in Table 2-57 the priority land use type depends upon the potential contaminant concern. For example, the estimates suggest that agricultural row crop lands are the dominant source of nitrogen, phosphorus, and sediment from non-point sources in the watershed. However, from a pathogen perspective, agricultural livestock, urban and sewered residential areas are dominant sources. Residential and urban areas and agricultural row crop areas had the highest contributions of Total Organic Carbon.

Table 2-57 – Summary of Load Portions Attributed to Different Land Use Types in the Brandywine Creek Watershed

		% annual Load				
Land Use/Surrogate	**Cryptosporidium**	**Fecal Coliform**	**TOC**	**Nitrogen**	**Phosphorous**	**TSS**
Residential-septic	10%	0%	12%	7%	6%	3%
Residential sewer	18%	33%	16%	7%	5%	3%
Urban	12%	21%	14%	4%	3%	2%
Agricultural - livestock	24%	0%	4%	4%	7%	15%
Agricultural - row crop	8%	0%	15%	62%	68%	52%
Agricultural - mushroom	0%	0%	0%	0%	0%	0%
Forested	0%	0%	9%	2%	3%	2%
Open	0%	0%	2%	2%	1%	1%
Wetland water	0%	0%	0%	0%	0%	0%
Undesignated	1%	0%	1%	2%	0%	18%
Impervious-residential	14%	24%	12%	5%	4%	2%
Impervious-urban	13%	23%	15%	5%	4%	2%

Note: Data estimated merged with data from Keorkle and Senior, 2002

2.4.5.2. Animal Non Point Source Contributions

As noted above the agricultural livestock and urban/residential land uses were considered the dominant sources of pathogens. However, it does not provide information as to which sources within those land uses are potential priorities for mitigation. Using estimated fecal production and concentrations in animal feces reported in literature (USEPA 2006, Crockett, 2007). An estimate of the relative contribution of fecal coliforms and *Cryptosporidium* in the watershed is available in Tables 2-58 and 2-59. Using these estimates dairy cattle and especially dairy calves are potentially the greatest contributors of pathogens to these land uses and a primary source for control. Pigs, dogs, and geese were estimated to be the other secondary major sources for control and mitigation on a subshed basis depending upon water quality measurements and available land uses. Further confirmation using DNA fingerprinting and microbial source tracking methods for bacteria and *Cryptosporidium* should be conducted to confirm these estimates.

Table 2-58 – Animal Contributions of Fecal Coliform in the Brandywine Watershed

animal category	Animal	Total estimated # in Brandywine	fecal coliform production (cfu/animal/day)	fecal coliform production (cfu/day)	% fecal coliform production
livestock	beef cattle	3,374	1.04E+11	3.51E+14	9%
livestock	dairy cattle	19,173	1.01E+11	1.94E+15	51%
livestock	swine (hogs)	3,887	1.08E+10	4.20E+13	1%
livestock	Poultry	547,649	1.36E+08	7.45E+13	2%
livestock	Horses	3,437	4.20E+08	1.44E+12	0%
livestock	Sheep	1,597	1.20E+10	1.92E+13	1%
livestock	other ag animals	200	3.81E+10	7.59E+12	0%
wild	Ducks	4,831	2.43E+09	1.17E+13	0%
wild	Geese	6,340	4.90E+10	3.11E+14	8%
wild	Deer	4,309	5.00E+08	2.15E+12	0%
wild	Beaver	1,661	2.50E+08	4.15E+11	0%
wild	Raccoons	831	1.25E+08	1.04E+11	0%
wild	Other wild animals	53,744	1.05E+10	5.62E+14	15%
pets	Cats	65,787	4.09E+09	2.69E+14	7%
pets	Dogs	47,078	4.09E+09	1.93E+14	5%
	Total	**763,896**		**3.78E+15**	

Table 2-59 – Animal Contributions of *Cryptosporidium* in the Brandywine Watershed

Animal category	Animal	Total estimated # animals in Watershed	median oocysts/ day total	% of total median	max oocysts/ day total	% of total max
livestock	beef cattle	3,374	2.0E+07	0%	2.0E+07	0%
livestock	beef calves	337	2.0E+08	0%	2.0E+08	0%
livestock	dairy cattle	19,173	7.7E+07	0%	7.7E+07	0%
livestock	dairy calves	1,917	5.8E+12	98%	5.8E+12	95%
livestock	swine (hogs)	3,887	7.3E+09	0%	1.2E+11	2%
livestock	poultry	547,649	0.0E+00	0%	0.0E+00	0%
livestock	horses	3,437	3.1E+08	0%	3.1E+08	0%
livestock	sheep	1,597	3.7E+07	0%	1.5E+10	0%
livestock	other ag animals	200	0.0E+00	0%	0.0E+00	0%
wild	Ducks	4,831	3.5E+07	0%	1.6E+09	0%
wild	Geese	6,340	4.5E+09	0.1%	7.8E+09	0.1%
wild	Deer	4,309	9.8E+06	0%	9.8E+06	0%
wild	Beaver	1,661	1.9E+05	0%	1.9E+05	0%
wild	Raccoons	831	5.1E+06	0%	8.4E+06	0%
wild	Other wild animals	53,744	6.1E+06	0%	6.1E+06	0%
pets	cats	65,787	1.3E+08	0%	1.3E+08	0%
pets	dogs	47,078	1.3E+11	2%	1.3E+11	2%
	Total	766,151	5.90E+12		6.03E+12	

2.4.5.3. Subwatershed Loading Comparisons

An analysis was conducted to estimate the loading of various contaminants by subwatershed in order to provide a relative basis from which to assign geographical priorities for various contaminants of concern to Wilmington's water intake. The USEPA TMDL and USGS HSPF study (USEPA, 2004 and Keorkle and Senior, 2002) provided the basis for the subwatershed land uses. Loadings were estimated for phosphorus, nitrogen, and sediment by multiplying the event mean concentrations provided in the TMDL and USGS documents (lbs/acre/yr) times the acres of the various landuses for the appropriate segments as provided by the USGS. Loadings for TOC, fecal coliform, and *Cryptosporidium* were calculated by multiplying event mean concentrations for each land use subtype times the land use subtype for each reach and summing them together for a total load for the reach. Loads were calculated annually on a total load for each subwatershed. Loads were also calculated to determine a per square mile total annual load for each subwatershed since all of the subwatersheds are different sizes and thus would lead to potential improper comparison.

As shown in Table 2-60, the greatest loadings typically came from throughout the West Branch of the Brandywine Creek and its tributaries mainly due to agricultural land use with some focus in the Coatesville area. The West Branch and its tributaries were high for all contaminant categories including nutrients, sediment, pathogens, and TOC. Only the sections of the East Branch including Downingtown, Exton, and West Chester appeared as areas with high potential loadings for TOC, fecal coliforms, and *Cryptosporidium*.

The West Branch of the Brandywine Creek at Honey Brook was estimated to produce the greatest loads of sediment and *Cryptosporidium*. The West Branch of the Brandywine Creek in the Coatesville area was identified as having high loads of TOC, fecal coliforms, and *Cryptosporidium*. The West Branch of the Brandywine Creek in the Pocopson Township area was identified as having high potential phosphorous loadings. Significant tributaries to the West Branch such as Buck Run and Doe Run were identified as areas with high nutrients and sediment loading.

The East Branch of the Brandywine Creek at Downingtown was identified as an area of high loadings for TOC, fecal coliform, and *Cryptosporidium*. The tributaries to the East Branch at Taylor Run in the West Chester, West Goshen, and E. Bradford townships were identified as high loading areas for fecal coliform only. Valley Creek in the Exton area of the watershed including West Whiteland and East Bradford townships was another high loading area for pathogens and TOC. Beaver Creek in East and West Brandywine and Caln townships had high loadings for TOC and fecal coliforms.

In the Lower Brandywine Creek, the main stem area draining New Castle County just outside of Wilmington on the east side of the main stem Brandywine was identified for high TOC and pathogen loadings as well.

Table 2-60 - Priority Subwatersheds of Greatest Relative Annual Loads of Various Contaminants in the Brandywine Watershed

Subbasin name	Shed	TP	N	TSS	TOC	Fecal	Crypto
West Branch Brandywine Creek	1			X			
West Branch Brandywine Creek	5				X	X	X
West Branch Brandywine Creek	8	X					
East Branch Brandywine Creek	12				X	X	X
East Branch Brandywine Creek/Taylor Run	14						
Upper & Lower Buck Run	20	X					
Upper Doe Run	21	X	X	X			
Lower Doe Run	22	X	X	X			
Trib to Valley Creek	28				X		X
Valley Creek	29					X	
Beaver Creek	30						
Lower Main stem Brandywine	34			X	X	X	X

shaded are high by total annual load

As shown in Table 2-61, the lowest loadings came from throughout the watershed usually focused in areas of low human population. However, these areas may coincide with areas of high loadings due to agricultural activity and suggest potential synergy areas for restoration and preservation work to be combined. In fact, three "synergy" areas were identified; these include Doe Run, Buck Run, and the West Branch of the Brandywine Creek in the Pocopson Township area.

The typical areas were identified as areas for continued preservation including the Chadds Ford township area, headwaters of the Upper Marsh Creek/Struble Lake Area, headwaters of the Upper Marsh Creek/Marsh Creek Reservoir Area, and West Caln township/Hibernia Reservoir Area. The majority of lowest loadings were for pathogens and TOC. However, generally low loadings are observed across all contaminant categories in these areas.

Tributaries such as Pocopson Creek, Birch Run, and Indian Run were also identified as potential preservation areas for low pathogen and TOC loadings. Broad Run, Birch Run, and Marsh Creek/Lyons Run were identified for preservation for low nutrients and TSS loadings.

The low nutrients and TSS loadings for some areas was due to the fact that they are heavily urbanized and would appear to have a low load as an artifact of the calculation method. However, these urban areas are not viable land preservation areas.

Overall, preservation of headwater areas in Honey Brook, West Nantmeal, East Nantmeal, Wallace, West Caln, and Upper Uwchlan appear to be the best areas for focused clustered parcel preservation of forested and open lands of first and second order tributaries.

Preservation of agricultural lands in Honey Brook, Highland, Sadsbury, Londonderry, W. Marlborough and E. Fallowfield townships appear to be the best areas for focused clustered farm parcel preservation of first and second order tributaries.

The Lower East and West Branches at East and West Bradford and Newlin townships are potential preservation areas. Main stem preservation areas should continue to be focused on the Chadds Ford, Pocopson and Pennsbury areas.

Table 2-61- Priority Subwatersheds of Lowest Relative Annual Loads of Various Contaminants in the Brandywine Watershed

Subbasin name	Shed	TP	N	TSS	TOC	Fecal	Crypto
West Branch Brandywine Creek	4	X	X	X			
West Branch Brandywine Creek	7						X
West Branch Brandywine Creek	8				X	X	X
East Branch Brandywine Creek	9				X	X	
East Branch Brandywine Creek/Indian Run	10						X
East Branch Brandywine Creek	12						
Brandywine Creek	17						X
Beaver Creek-2	18	X					
Upper Doe Run	21				X	X	
Lower Doe Run	22				X	X	
Lower Buck Run	23				X	X	
Trib to Broad Run-2	24	X		X			
Broad Run-2	25						
Marsh Creek/Lyons Run	26		X				
Pocopson Creek	31						X
Birch Run	32	X	X			X	
Upper Marsh Creek	35				X	X	

shaded are low by total annual load

Note: loads were examined as % avg. load by square mile

2.4.6. Comparison of Point & Non Point Source Loadings

Point sources represent a potential source of contamination that has the opportunity to be addressed and controlled through various mechanisms by the City of Wilmington. It is also important to put the contribution of point sources for contaminants in perspective to non point sources so their importance can be examined. The best example of an available comparison was conducted by USGS for the Brandywine Creek TMDL. As shown in Table 2-62, non-point sources of nutrients, especially phosphorus, make up the majority of most nutrient contaminant loads. In Table 2-63, the annual estimated loads using alternative calculation methods suggest that in general non point sources are the dominant source of all contaminants that impact the Wilmington intake.

Table 2-62 - Summary of Contaminant Loads Estimated by USGS 1994 – 1998 (tons)

	Nitrate	**Ammonia**	**Phosphorus**
Nonpoint	6,050	139	1,574
Point	2,555	50	97
Total	8605	189	1671
2000 Estimate of total load proportion between point and non point sources			
Nonpoint	70%	74%	94%
Point	30%	26%	6%
2100 Estimate of total load proportion with point source increase from 12.9 to 23.2 mgd and no change in nonpoint load			
Nonpoint	57%	61%	90%
Point	43%	39%	10%

Source: Keorkle and Senior, 2002

Table 2-63 - Comparison of Annual Loads from Point and Non-Point Sources

Source	Phosphorus	Nitrogen	TSS	TOC	fecal coliform	*Cryptosporidium*
Non-point	88%	61%	100%	79%	100%	78%
Point Source*	12%	39%	0%	21%	0%	22%
Point Source 2020**	20%	53%	0%	24%	0%	26%

* is conservative estimate using 19.2 MGD (all NPDES dischargers at permit limit)

* is conservative estimate for growth in 2020 using 23.2 MGD (all NPDES dischargers at permit limit)

Though some data suggests that point sources may not appear to be the dominant sources of certain types of pollution in the watershed, they may still be important potential sources of contamination and could impact water intake quality under specific conditions. When it is not raining, some non-point source originating pollutants are not present and point sources are the only source of a particular contaminant. *Cryptosporidium*, pharmaceuticals, and organic waste contaminants are good examples of these situations. For example, a *Cryptosporidium* outbreak such as the one in the summer/fall of 2007 represented the conditions where a large loading of *Cryptosporidium* in the watershed had the potential to impact water quality at the intakes downstream. Another example is the case of a malfunction or treatment failure at an upstream discharger. This may result in large quantities of raw sewage discharged to the stream. Toxic spills and industrial discharges can also cause impacts on wastewater discharges that may need to be considered.

Though the previous examples represented acute situations, chronic events can happen that impact downstream water quality. For example, a discharger can have a discharge of a chemical or compound at trace levels that is sporadic and difficult to detect or trace. An example of these types of events in the Brandywine would be the discharge of a taste and odor compound such as trichloroanesol or a compound that once it enters the stream can be converted to a form that represents a water quality impact.

3. Section 3 - Prioritization of Potential Sources and Identification of Restoration & Protection Projects

3.1. Priority Issues in the Watershed

Based on the water quality analysis and technical data presented in Section 2, the priority contaminant groups in the watershed that impact water quality and water supply for the City of Wilmington were ranked in the following order:

- *Cryptosporidium* & pathogens
- Turbidity
- Disinfection by product pre-cursors (surrogate: Total Organic Carbon)
- Sodium & chloride
- Algae/ Nutrients
- Trace Organics
- Baseflow (though flow is not a regulated contaminant it affects dilution of contaminants)

The priority sources of these contaminants are a wide varying range of activities. Within each major source type a priority issue is identified by contaminant group in Table 3-1.

Table 3-1 – Contaminant Sources and Priority Issues

Contaminant Source	Priority issue	Contaminants Addressed
Agriculture	Dairy Farms, cows in stream, manure management	*Cryptosporidium*, pathogens, nutrients, turbidity, disinfection by products, trace organics (antibiotics)
Wastewater	Raw and untreated sewage discharges, outbreaks	*Cryptosporidium*, pathogens, trace organics, baseflow
Urban/Suburban Runoff	Road Runoff, Streambank erosion	Turbidity, sodium & chloride, baseflow
Riparian buffer removal	Streambank erosion	Disinfection by products, turbidity

3.2. Prioritization Methodology

The prioritization of sources was divided into a number of separate elements because the priority of a source depends upon many factors including the potential vulnerability, susceptibility, and possibility of a potential source to impact the water supply. Some sources have impacts that are continuous with chronic impacts and take a long time to lead to a threshold change in water quality. Meanwhile, some sources only have impacts during very infrequent and unlikely events but lead to immediate, acute impacts that could cause the closure of the water intake or treatment changes.

These situations are further complicated by wet and dry weather conditions. There are also the water quality impacts during dry weather periods which are almost 300 days per year while during wet weather periods dry weather sources do not have a dominant influence. As discussed in section 2, over 2/3 of all the different annual contaminant loads were due to non-point or wet weather sources. However, their impact on water treatment may be limited compared to things that impact water quality during dry weather. (It is understood that wet weather runoff can result in dry weather water quality impacts after a storm and sediment has settled).

Given these situations choosing an overall "top" priority source depends on the perspective of time and weather conditions. Most water quality managers will choose to give the immediate impacts the greatest priority, while some will give the source with greatest potential impact the greatest priority. These choices are both right given the various perspectives and needs of the water utility at a given time and the resources involved.

However, it is still necessary to prioritize these sources in some logical fashion to determine which actions are necessary in the short and long term to mitigate future impacts on water quality.

A number of prioritizations were conducted to provide priority lists based on the situation, condition, and time perspective. The point sources prioritization approach assumes only dry weather water quality impacts on a routine daily continuous basis and based on low likelihood accidental spill impacts. Point source prioritization was then based upon the distance from the intake, the discharge flow or amount stored at a given facility. Individual contaminant ranking was not necessary since there is no way to choose which contaminant (microbial, toxics, or organics) is more important since the water treatment process is equally vulnerable to specific elements of these general classes. The way these prioritizations should be used is so that emergency planning and response communications can be prioritized and mitigated using the low likelihood high impact rankings and so long term source water protection issues can be addressed via the constant daily discharge rankings. Higher ranked NPDES dischargers may need to be considered for long term support for upgrades to tertiary treatment or ultraviolet light disinfection for protection of Wilmington's intake against pathogens.

Non-point sources tend to be long term chronic sources, though they can have acute impacts during severe or unique wet weather periods. Non-point sources were prioritized based on the overall load contribution and loading per square mile. A distance factor was not included since during a storm event most pollutants can reach the Wilmington intake between a few hours to less than a day thus a relatively immediate impact. A cross contaminant group ranking was then determined using weighting factors based on the priority a given contaminant group is to the Wilmington intake. This information was then used to identify priority cluster areas for mitigation of non-point sources for agricultural runoff. This information was also used to help prioritize forested areas for preservation. Sub-priority areas were based on field investigations and other information provided by stakeholders and local studies.

This same approach coupled with landuse and riparian buffer characteristics was used to determine the lowest impact areas and identify sub priority areas of high priority for preservation. This allowed the non-point source impacts can be broken into the urban/suburban stormwater runoff, agricultural mitigation, or forest preservation priorities. The priority clusters for agriculture and preservation (forested) areas were identified in the most detail. However urban/suburban stormwater impacts are the most costly and difficult to address and mitigate. Therefore, this plan acknowledges that for urban/suburban areas the current MS4, TMDL, and stormwater ordinances are the frameworks for addressing these areas and any prioritization of urban/suburban stormwater influence is addressed via this framework and therefore prioritization of these areas has already been conducted by regulatory agencies.

All priority areas and issues were compared to the findings of previous planning efforts and reports. This provided some relative check to identify any differences with previous efforts by stakeholders and how the SWP Plan builds on those efforts.

3.3. Prioritization Results – Point Sources

Starting with over 600 point sources upstream from Wilmington's intake a final list of 344 active facilities was identified for priority ranking. The classes of priority were broken into High, Medium-High, Medium, and Low. Figure 3-1 shows the breakdown of the classes based on the overall point source score to show where the dividing lines were set between classes based on statistical breakpoints. A total of 37 facilities were determined to be of "High" priority for emergency response planning and source water protection activities. Another 34, 78, and 194 facilities were determined to be considered "Medium-High", "Medium", and "Low" priority respectively. Of the "High" ranked facilities, only three sites were a Superfund, TRI, or Hazardous Waste Generation sites. Over half of the "High" ranked facilities were storage tanks and the other half were NPDES dischargers. Other "High" ranked point sources in the table include a Combined Sewer Overflow outfall and locations of potential vulnerability to transportation accidents. Table 3-2 lists the recommended emergency response preparation activities to be conducted by the Wilmington SWP staff for the various priority levels. The High ranked transportation accident areas require special activity not listed in Table 3-2 which includes meeting with emergency response agencies responsible for spill and accident notification, response, and cleanup in the vulnerable areas and establishing communication protocols. Figure 3-2 identifies the location of the High ranked facilities and Table 3-3 provides the listings for the High and Medium High ranked facilities upstream of Wilmington's intake.

Figure 3-1 – Priority Point Source Ranking Characterization of Scores and Classification

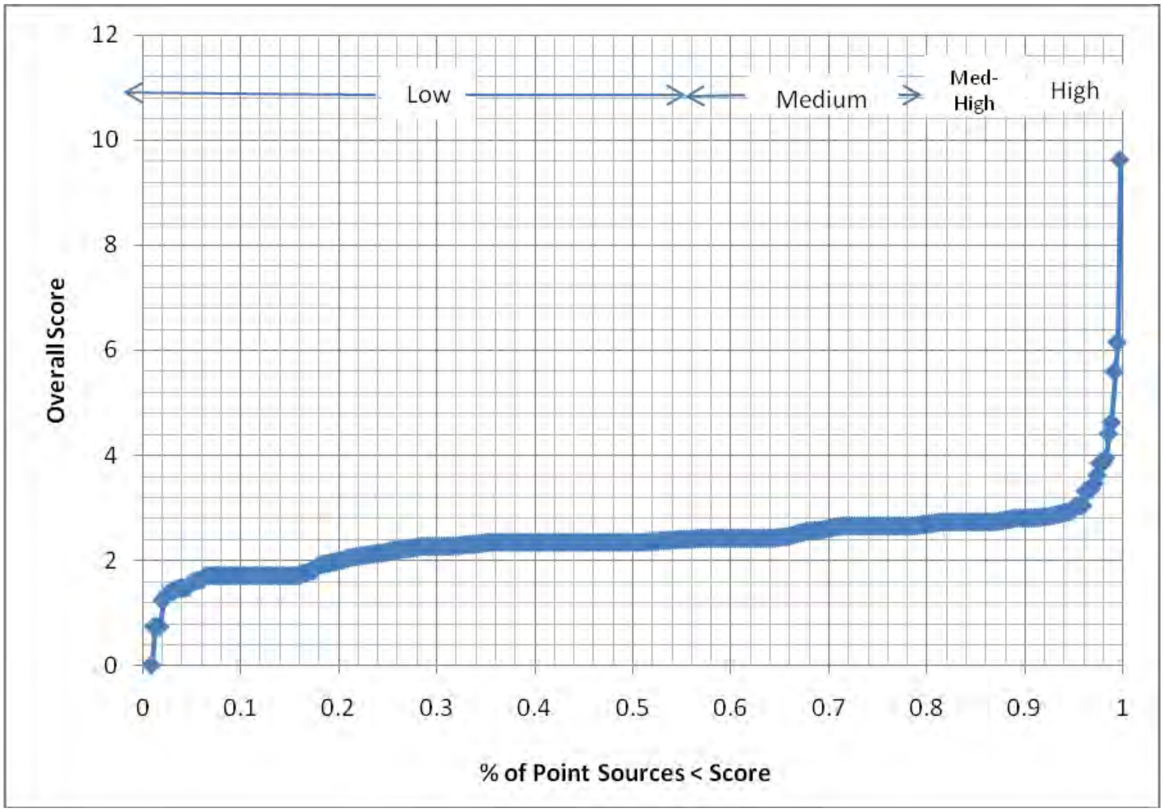


Table 3-2 – Priority Point Source Recommended Emergency Response Preparation Activities

Point Source Priority	Visit Frequency	Update contact information	Locational / Monitoring Information	Water Quality Impact Preparation
High	Once per year	Check bi-annually	Identify outfalls, detailed location maps, locate sampling points	Conduct estimates of water quality impacts from releases under various extreme scenarios (loss of treatment, full release), estimate and verify time of travel, monitor disease rates
Medium High	Every 2 years	Annually	Identify outfalls, detailed location maps, locate sampling points	Conduct estimates of water quality impacts from releases under various extreme scenarios (loss of treatment, full release), estimate and verify time of travel, monitor disease rates
Medium	Every 3 years	Every 3 years	Identify outfalls only	Conduct estimates using a predetermined worst case screening accident scenario, refine distance estimates, develop low flow and high flow TOT estimates
Low	Every permit cycle	Every permit cycle	Identify outfalls only	Conduct estimates using worst case screening scenario, refine estimates, develop low flow & high flow TOT estimates

Note: High priority transportation accidents will require a separate activity related to emergency response education, communication, and preparation from that provided in the table above.

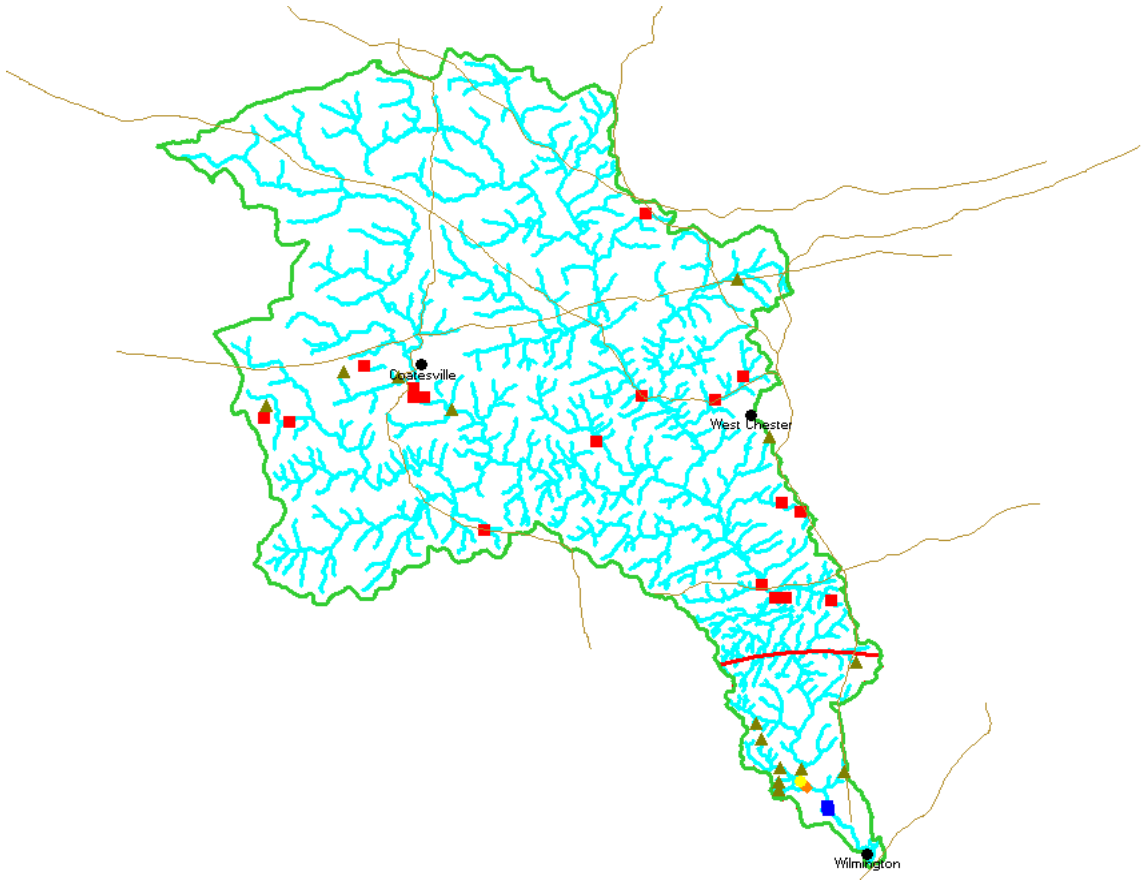


Figure 3-2 – Location of High Ranked Point Sources Upstream of the Wilmington Intake

Table 3-3 – Top Priority Point Sources Upstream of the Wilmington Intake

			NPDES	NPDES	NPDES	UST	UST		
MASTER ID	Site Name	SITE TYPE	NPDES type	Flow (MGD)	Intake Distance (miles)	Capacity (gallons)	Substance Stored	Overall score	Rank
COW-0001	City of Wilmington Rockford Road CSO	Combined Sewer Overflow	CSO	NA	< 1	NA			High
COW-0002	Tanker Truck Accidents from I-95, Route 100 and 30	Transportation Accident	None	NA	< 1 - 10	NA	Petroleum/ Toxics		High
COW-0003	Railroad Accidents from bridge crossing and along main stem Brandywine roads	Transportation Accident	None	NA	< 1 - 10	NA	Petroleum/ Toxics		High
COW-0004	Accidents from Pipeline Crossings on the Brandywine	Transportation Accident	None	NA	> 20	NA	Petroleum/ Toxics		High
PA0026531	Downingtown Area Regional Authority	PCS/NPDES	ATP2	7.134	20.1			9.63	High
PA0026859	Coatesville City Authority	PCS/NPDES	ATP1	3.85	27.5			6.16	High
6437	Dupont Experimental Station	SFUND & TRI						5.60	High
7107	Ei Dupont Experimental Station	HW_Gen & TRI						4.64	High
PA0026018	West Chester Borough Mua/Taylor Run	PCS/NPDES	MUN	1.8	15.1			4.42	High
569614	Zekes Hc Sheeler	AST				20000	Heating Oil	3.95	High

			NPDES	NPDES	NPDES	UST	UST		
MASTER ID	Site Name	SITE TYPE	NPDES type	Flow (MGD)	Intake Distance (miles)	Capacity (gallons)	Substance Stored	Overall score	Rank
508704	Reilly & Sons	AST				20000	Heating Oil	3.86	High
508704	Reilly & Sons	AST				20000	Diesel Fuel	3.86	High
569614	Zekes Hc Sheeler	AST				12000	Heating Oil	3.63	High
569614	Zekes Hc Sheeler	AST				8000	Kerosene	3.47	High
569614	Zekes Hc Sheeler	AST				20000	Heating Oil	3.37	High
517410	Jc Hayes	AST				20000	Heating Oil	3.33	High
517410	Jc Hayes	AST				20000	Kerosene	3.33	High
4161	Brandywine Raceway Assoc Inc	UST						3.05	High
4400	Hagley Museum & Library	UST						3.05	High
593737	Petrocon	AST				4000	Kerosene	3.05	High
DE0021768	Winterthur Museum	PCS/NPDES	STP	0.025	0.0			3.03	High
PA0043982	Broad Run Sewer Co.	PCS/NPDES	ATP2	0.4	18.2			2.94	High
PA0053449	Birmingham Twp. Stp	PCS/NPDES	STP	0.15	8.9			2.93	High
6644	Bancroft Mills	SFUND						2.92	High
593737	Petrocon	AST				550	Gas	2.91	High
PA0054917	Uwchlan Twp. Municipal	PCS/NPDES	STP	0.475	23.3			2.89	High

			NPDES	NPDES	NPDES	UST	UST		
MASTER ID	Site Name Authority	SITE TYPE	NPDES type	Flow (MGD)	Intake Distance (miles)	Capacity (gallons)	Substance Stored	Overall score	Rank
PA0055476	Birmingham TSA/Ridings At Chadds Ford	PCS/NPDES	STP	0.04	6.4			2.88	High
511023	Texaco 100250	UST				12000	Gas	2.87	High
PA0024473	Parkersburg Borough Authority Wwtp	PCS/NPDES	STP	0.7	33.5			2.86	High
PA0055484	Keating, Herbert & Elizabeth	PCS/NPDES	SRD	0.0005	6.4			2.84	High
PA0055085	Winslow, Nancy	PCS/NPDES	SRD	0.0005	6.4			2.84	High
PA0030848	Unionville - Chadds Ford Elem. School	PCS/NPDES	STP	0.0063	7.0			2.83	High
PA0057011	Thornbury Twp./Bridlewood Farms Stp	PCS/NPDES	STP	0.0773	10.2			2.82	High
1542	Chester Cnty Airport	AST				15000	Aviation Gas	2.82	High
1542	Chester Cnty Airport	AST				15000	Jet Fuel	2.82	High
4830	Carpenter Estates	UST						2.82	High
3682	Dupont Winterthur Museum	UST						2.82	High
5086	Estate Of Neil H Keough J	UST						2.82	High

			NPDES	NPDES	NPDES	UST	UST		
MASTER ID	Site Name	SITE TYPE	NPDES type	Flow (MGD)	Intake Distance (miles)	Capacity (gallons)	Substance Stored	Overall score	Rank
5040	Lanphear Property Albert	UST						2.82	High
4838	St Joseph On The Brandywine	UST						2.82	High
4198	Wilmington Country Club	UST						2.82	High
PA0036200	Radley Run Mews	PCS/NPDES	STP	0.032	8.9			2.81	Medium High
PA0031097	Radley Run C. C.	PCS/NPDES	STP	0.017	8.9			2.79	Medium High
511023	Texaco 100250	UST				10000	Diesel Fuel	2.79	Medium High
511023	Texaco 100250	UST				10000	Gas	2.79	Medium High
569163	Longwood Gardens	AST				6000	Diesel Fuel	2.76	Medium High
PA0056120	Schindler	PCS/NPDES	SRD	0.0005	9.5			2.76	Medium High
4986	A Felix Dupont	UST						2.74	Medium High
4666	Alapoccas Maintenance Base	UST						2.74	Medium High
4374	Alexis I Dupont Middle School	UST						2.74	Medium

			NPDES	NPDES	NPDES	UST	UST		
MASTER ID	Site Name	SITE TYPE	NPDES type	Flow (MGD)	Intake Distance (miles)	Capacity (gallons)	Substance Stored	Overall score	Rank
									High
4674	Bayard Sharp Estate	UST						2.74	Medium High
3604	Brandywine Commons	UST						2.74	Medium High
3838	Concord Pike Gulf	UST						2.74	Medium High
4744	Craven Property	UST						2.74	Medium High
3611	Dupont Experimental Station	UST						2.74	Medium High
4865	Hank Blacks Foreign Car	UST						2.74	Medium High
5076	Henry Property John	UST						2.74	Medium High
6089	Laird Property	UST						2.74	Medium High
4280	Lincoln Towers	UST						2.74	Medium High
5077	Norwood Property	UST						2.74	Medium High

			NPDES	NPDES	NPDES	UST	UST		
MASTER ID	Site Name	SITE TYPE	NPDES type	Flow (MGD)	Intake Distance (miles)	Capacity (gallons)	Substance Stored	Overall score	Rank
4114	Porter Filter Plant	UST						2.74	Medium High
6229	Reed Property	UST						2.74	Medium High
4557	Ross Holden	UST						2.74	Medium High
6135	Stonesgate Retirement Community	UST						2.74	Medium High
6105	Thornton Property	UST						2.74	Medium High
4620	Widener University	UST						2.74	Medium High
4386	Wilmington Piece Dye Company	UST						2.74	Medium High
4878	Woodlawn Trustees Inc	UST						2.74	Medium High
PA0056171	Mcglaughlin, Jeffrey	PCS/NPDES	SRD	0.0005	10.8			2.73	Medium High
PA0036897	South Coatesville Borough	PCS/NPDES	ATP1	0.39	26.9			2.72	Medium High
511023	Texaco 100250	UST				8000	Gas	2.71	Medium

			NPDES	NPDES	NPDES	UST	UST		
MASTER ID	Site Name	SITE TYPE	NPDES type	Flow (MGD)	Intake Distance (miles)	Capacity (gallons)	Substance Stored	Overall score	Rank
									High
515503	Thorndale Exxon	UST				10000	Gas	2.71	Medium High
573143	Sunoco 0013 6804	UST				8000	Gas	2.70	Medium High
569511	Sunoco 0318 3209	UST				12000	Gas	2.69	Medium High

3.4. Priority Non-Point Source Areas – Subwatershed Rankings

Loading Scores were calculated using the following equation which incorporated the relative magnitude of the load per square mile for a given subwatershed, the overall load contribution to the entire watershed, and the percentage of the subwatershed that is forested. As a watershed is more forested and its loadings are smaller in the overall watershed loading and compared to the average subwatershed it received a lower ranking.

The individual contaminant load score was calculated using the following formula:

(1-% forested) X ratio of contaminant load per square mile for subshed/average contaminant load per square mile for all subsheds X % of total watershed load for contaminant

The overall contaminant load score was calculated into loading scores, the average loading score and the weighted loading score. The average loading score is just the average of all the contaminant load scores to provide an overall gage of the total contaminant loading from a given subwatershed. The weighted loading score is a weighted average calculated based on the priority of the contaminant group as described earlier in this section. The weightings given to the various individual contaminants are as are provided in Table 3-4.

Table 3-4 – Weightings for Contaminant Groups for Overall Rankings

Total Phosphorus	Nitrogen	Total Suspended Solids	Total Organic Carbon	Fecal coliform	*Cryptosporidium*
0.15	0.15	0.05	0.25	0.05	0.35

Table 3-5 below provide a summary of the ten watersheds with the greatest weighted loading score and their land use attributes/characteristics. As expected, the subwatersheds with the greatest loading scores tended to have either the highest amount of urban/residential or agricultural lands in the watershed. Figure 3-3 shows their location in the watershed.

Table 3-6 provides the individual, average, and weighted contaminant loading scores for all 35 subwatersheds in the Brandywine Creek Watershed.

Table 3-5 – Top Ten Areas with Greatest Overall Combined Weighted Pollutant Loadings in the Brandywine Watershed

Reach #	Stream Name	weighted avg score	% Agricultural - Pasture Hay	% Agricultural - Row Crops	% Ag land total	% forested	Urban / Residential total	Impervious total
34	Lower Brandywine Creek	0.612334	0%	2%	2%	14%	62%	29%
29	Valley Creek	0.592378	0%	21%	21%	35%	33%	13%
30	Beaver Creek	0.516642	0%	32%	32%	30%	33%	9%
20	Upper Buck Run	0.323445	6%	53%	59%	25%	13%	3%
28	Trib. To Valley Creek	0.210492	0%	3%	3%	21%	67%	23%
14	Brandywine Creek East Br.	0.203494	0%	32%	32%	30%	32%	9%
19	Brandywine Creek	0.199628	0%	4%	4%	17%	34%	9%
27	Marsh Creek	0.186072	9%	21%	29%	34%	26%	3%
33	Rock Run	0.169321	4%	38%	42%	30%	21%	4%
15	Brandywine Creek	0.165557	0%	41%	41%	17%	34%	7%

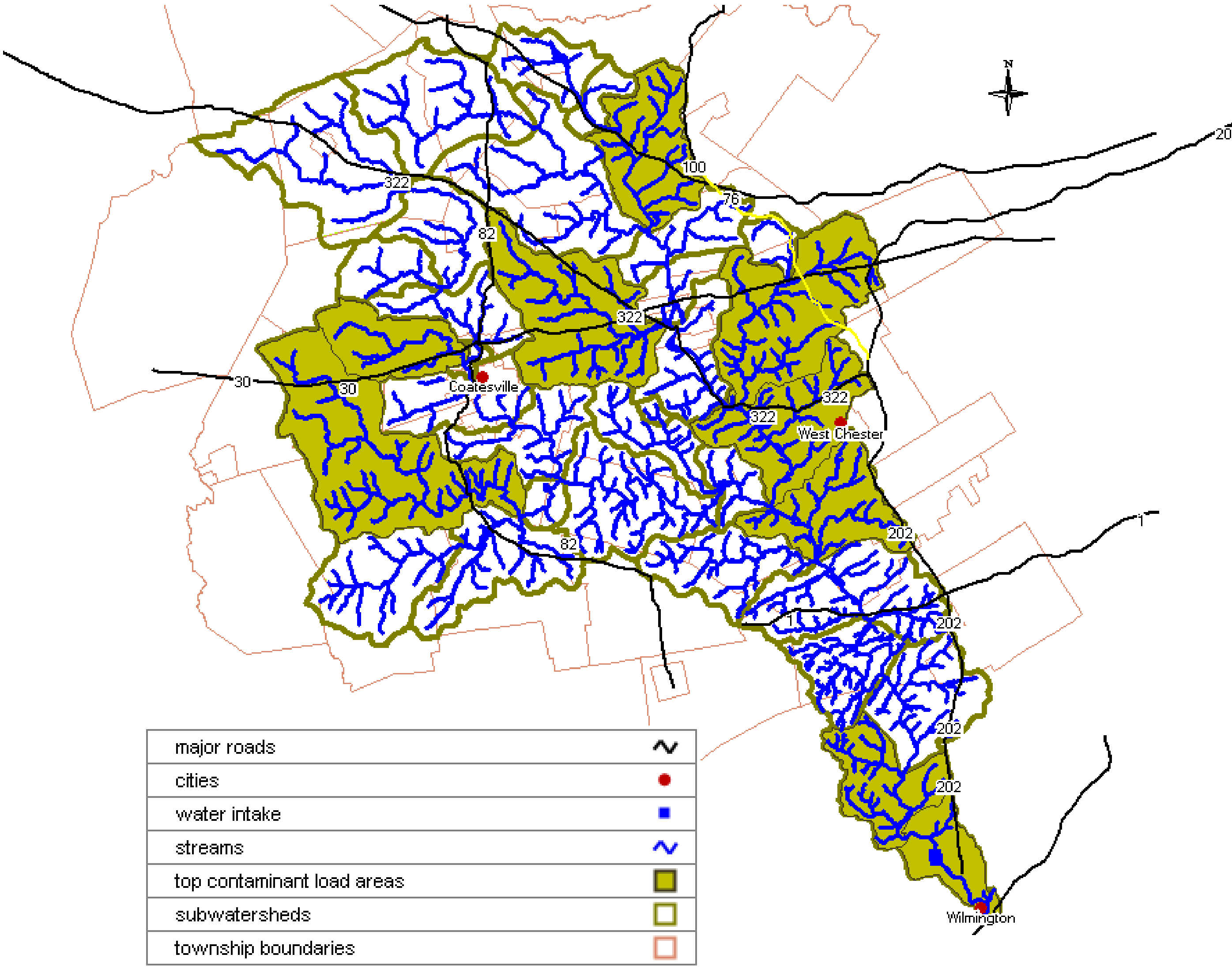
Table 3-6 – Individual, Average, and Weighted Pollutant Loading Scores in the Brandywine Watershed

Reach #	Stream Name	% forested	TP score	Nitrogen score	TSS score	TOC score	Fecal score	Crypto score	Average score	weighted avg score
34	Lower Brandywine Creek	14%	0.018	0.031	0.077	0.231	0.210	1.523	0.348	0.612334
29	Valley Creek	35%	0.034	0.041	0.056	0.122	0.124	1.548	0.321	0.592378
30	Beaver Creek	30%	0.046	0.051	0.055	0.078	0.074	1.360	0.277	0.516642
20	Upper Buck Run	25%	0.096	0.091	0.046	0.017	0.018	0.823	0.182	0.323445
28	Trib. To Valley Creek	21%	0.008	0.009	0.017	0.084	0.099	0.518	0.122	0.210492
14	Brandywine Creek East Br.	30%	0.034	0.031	0.034	0.065	0.066	0.493	0.120	0.203494
19	Brandywine Creek	17%	0.011	0.019	0.029	0.051	0.049	0.510	0.111	0.199628
27	Marsh Creek	34%	0.013	0.015	0.013	0.005	0.007	0.513	0.094	0.186072
33	Rock Run	30%	0.020	0.017	0.012	0.009	0.010	0.458	0.088	0.169321
15	Brandywine Creek	17%	0.040	0.034	0.028	0.035	0.035	0.407	0.097	0.165557
22	Lower Doe Run	18%	0.066	0.060	0.020	0.002	0.002	0.356	0.084	0.145226
31	Pocopson Creek	22%	0.032	0.026	0.014	0.005	0.004	0.364	0.074	0.138237
21	Upper Doe Run	17%	0.064	0.059	0.019	0.001	0.002	0.332	0.079	0.135781
9	Upper Brandywine Creek East Br.	33%	0.024	0.031	0.019	0.003	0.007	0.350	0.072	0.132808
35	Upper Marsh Creek	34%	0.011	0.011	0.006	0.001	0.002	0.312	0.057	0.113301
16	Brandywine Creek	39%	0.018	0.015	0.014	0.013	0.010	0.279	0.058	0.107207

Reach #	Stream Name	% forested	TP score	Nitrogen score	TSS score	TOC score	Fecal score	Crypto score	Average score	weighted avg score
18	Brandywine Creek	38%	0.011	0.021	0.021	0.012	0.011	0.252	0.055	0.097674
25	Broad Run	30%	0.016	0.013	0.010	0.010	0.009	0.247	0.051	0.094048
5	Brandywine Creek West Br.	35%	0.018	0.019	0.032	0.095	0.093	0.158	0.069	0.090974
13	Brandywine Creek East Br.	48%	0.007	0.009	0.014	0.031	0.030	0.205	0.049	0.084071
32	Birch Run	53%	0.003	0.003	0.003	0.001	0.001	0.194	0.034	0.069324
10	Brandywine Creek East Br.	40%	0.029	0.024	0.016	0.008	0.006	0.158	0.040	0.066394
12	Brandywine Creek East Br.	39%	0.006	0.005	0.008	0.034	0.037	0.152	0.040	0.065486
11	Brandywine Creek East Br.	36%	0.014	0.012	0.012	0.023	0.023	0.153	0.039	0.064974
1	Upper Brandywine Creek West Br.	20%	0.043	0.070	0.049	0.009	0.028	0.092	0.049	0.055263
7	Brandywine Creek West Br.	38%	0.032	0.026	0.012	0.004	0.003	0.064	0.023	0.032711
17	Brandywine Creek	49%	0.007	0.006	0.004	0.002	0.002	0.082	0.017	0.031411
6	Brandywine Creek West Br.	35%	0.015	0.013	0.009	0.005	0.005	0.064	0.019	0.028649
24	Trib. To Broad Run	8%	0.001	0.001	0.001	0.003	0.003	0.057	0.011	0.02119
26	Marsh Creek	60%	0.001	0.001	0.001	0.001	0.001	0.053	0.010	0.01926
3	Brandywine Creek West Br.	40%	0.008	0.007	0.006	0.004	0.004	0.030	0.010	0.014264
8	Brandywine Creek West Br.	25%	0.016	0.013	0.005	0.001	0.001	0.024	0.010	0.012931
2	Brandywine Creek West Br.	46%	0.006	0.006	0.006	0.004	0.005	0.021	0.008	0.011008

Reach #	Stream Name	% forested	TP score	Nitrogen score	TSS score	TOC score	Fecal score	Crypto score	Average score	weighted avg score
23	Lower Buck Run	49%	0.003	0.003	0.001	0.000	0.000	0.022	0.005	0.008468
4	Brandywine Creek West Br.	69%	0.000	0.000	0.000	0.001	0.001	0.002	0.001	0.001058

Figure 3-3 – Top Contaminant Loading Score Areas in the Brandywine Creek



3.4.1. Priority Non-Point Sources –Priority Cluster Areas for Agricultural Mitigation

The priority cluster areas for agriculture were identified based on an analysis conducted of the potential *Cryptosporidium* loadings of livestock in the watershed (see Tables 3-7 and Figure 3-4). *Cryptosporidium* is the most important contaminant group of all the contaminant groups with turbidity being a second priority. Using the livestock and wildlife estimates provided in the USEPA Bacteria TMDL, an analysis was conducted that estimated the livestock loadings based on animal type (see Tables 3-8 and 3-9). From this analysis, it was determined that the most important animals in terms of *Cryptosporidium* loadings into the watershed were dairy calves and cows. Based on interviews and communication with the Chester County Conservation District it was determined that the highest concentration of dairy farms were in the Honey Brook township area of the West Branch of the watershed. A windshield survey of the Honey Brook farming areas was conducted with the Chester County Conservation district to confirm and prioritize dairy farming areas based on dairy cows in the stream as the highest priority. Areas where cows were observed in the stream or known to be in the stream were estimated and a series of farm parcel clusters along tributaries and the West Branch of the Brandywine Creek was identified for future mitigation. These were broken into four different clusters with clusters 1 and 3 given the greatest priority based on cows in the stream and potential cooperation/synergy with existing stakeholder efforts (See Figure 3-5). Information regarding the cost estimates is provided in section 7.4. Clusters 2 and 4 were given second priority for implementation after clusters 1 and 3 are completed. These findings complement the recommendations of the CCCD and the Christina Basin partnership and the TWIG grant. Those studies suggested Honey Brook Township, Buck Run, and Doe Run as the highest priorities for agricultural mitigation. These findings identify a strong synergy between the stakeholders in the watershed priorities and the priorities for protection of Wilmington's water supply.

Mitigation of cows in the stream near the Wilmington intake is also a priority, but cannot be specified at the cluster level using the prioritization approach. Thus, any cows in the stream near the Wilmington intake in New Castle County and near the main stem including its tributaries such as the Pocopson Creek should be evaluated and prioritized for cluster areas similar to the Honey Brook analysis. An analysis is currently being conducted by the Brandywine Conservancy that will prioritize these agricultural areas where livestock are in the stream in New Castle County.

Table 3-7 – Brandywine Subwatersheds Ranked by *Cryptosporidium* Loading

Reach #	Stream Name	Crypto score	% Agricultural - Pasture Hay	% Agricultural - Row Crops	% Agricultural land total	% forested
29	Valley Creek	1.548	0%	21%	21%	35%
34	Lower Brandywine Creek	1.523	0%	2%	2%	14%
30	Beaver Creek	1.360	0%	32%	32%	30%
20	Upper Buck Run	0.823	6%	53%	59%	25%
28	Trib. To Valley Creek	0.518	0%	3%	3%	21%
27	Marsh Creek	0.513	9%	21%	29%	34%
19	Brandywine Creek	0.510	0%	4%	4%	17%
14	Brandywine Creek East Br.	0.493	0%	32%	32%	30%
33	Rock Run	0.458	4%	38%	42%	30%
15	Brandywine Creek	0.407	0%	41%	41%	17%
31	Pocopson Creek	0.364	0%	49%	49%	22%
22	Lower Doe Run	0.356	8%	71%	79%	18%
9	Upper Brandywine Creek East Br.	0.350	27%	27%	54%	33%
21	Upper Doe Run	0.332	8%	69%	76%	17%
35	Upper Marsh Creek	0.312	12%	36%	48%	34%
16	Brandywine Creek	0.279	0%	26%	26%	39%
18	Brandywine Creek	0.252	2%	19%	21%	38%
25	Broad Run	0.247	0%	41%	41%	30%
13	Brandywine Creek East Br.	0.205	0%	14%	14%	48%
32	Birch Run	0.194	16%	16%	32%	53%
10	Brandywine Creek East Br.	0.158	0%	36%	36%	40%
5	Brandywine Creek West Br.	0.158	0%	19%	19%	35%
11	Brandywine Creek East Br.	0.153	0%	33%	33%	36%
12	Brandywine Creek East Br.	0.152	0%	11%	11%	39%

1	Upper Brandywine Creek West Br.	0.092	46%	22%	68%	20%
17	Brandywine Creek	0.082	0%	27%	27%	49%
6	Brandywine Creek West Br.	0.064	4%	36%	40%	35%
7	Brandywine Creek West Br.	0.064	0%	49%	49%	38%
24	Trib. To Broad Run	0.057	0%	3%	3%	8%
26	Marsh Creek	0.053	7%	20%	26%	60%
3	Brandywine Creek West Br.	0.030	7%	23%	30%	40%
8	Brandywine Creek West Br.	0.024	0%	62%	62%	25%
23	Lower Buck Run	0.022	5%	44%	49%	49%
2	Brandywine Creek West Br.	0.021	9%	19%	28%	46%
4	Brandywine Creek West Br.	0.002	0%	15%	15%	69%

Table 3-8 – Top 12 Brandywine Subwatersheds Ranked by *Cryptosporidium* Score and Livestock Land use

Reach #	Stream Name	Crypto score	% Agricultural - Pasture Hay	% Agricultural - Row Crops	% Agricultural land total	% forested
1	Upper Brandywine Creek West Br.	0.092	46%	22%	68%	20%
9	Upper Brandywine Creek East Br.	0.350	27%	27%	54%	33%
32	Birch Run	0.194	16%	16%	32%	53%
35	Upper Marsh Creek	0.312	12%	36%	48%	34%
2	Brandywine Creek West Br.	0.021	9%	19%	28%	46%
27	Marsh Creek	0.513	9%	21%	29%	34%
22	Lower Doe Run	0.356	8%	71%	79%	18%
21	Upper Doe Run	0.332	8%	69%	76%	17%
3	Brandywine Creek West Br.	0.030	7%	23%	30%	40%
26	Marsh Creek	0.053	7%	20%	26%	60%
20	Upper Buck Run	0.823	6%	53%	59%	25%
23	Lower Buck Run	0.022	5%	44%	49%	49%

Table 3-9 - Final Ranking of Subwatersheds for Agriculture Incorporating Factors for Dairy Farms and Cows in Stream

Reach #	Stream Name	Ag mitigation load/land score	Dairy livestock factor (H, M, L, U)	Diary Score	Ag mitigation combined score
1	Upper Brandywine Creek West Br.	0.93	H	3	3.93
9	Upper Brandywine Creek East Br.	0.63	H	3	3.63
35	Upper Marsh Creek	0.32	H	3	3.32
22	Lower Doe Run	0.25	M	2	2.25
23	Lower Buck Run	0.10	M	2	2.10
31	Pocopson Creek	0.09	M	2	2.09
32	Birch Run	0.36	L	1	1.36
2	Brandywine Creek West Br.	0.19	L	1	1.19
19	Brandywine Creek	0.13	L	1	1.13
18	Brandywine Creek	0.11	L	1	1.11
16	Brandywine Creek	0.07	L	1	1.07
17	Brandywine Creek	0.02	L	1	1.02
29	Valley Creek	0.39	U	0	0.39
34	Lower Brandywine Creek	0.38	U	0	0.38
30	Beaver Creek	0.34	U	0	0.34
20	Upper Buck Run	0.32	U	0	0.32
27	Marsh Creek	0.31	U	0	0.31
21	Upper Doe Run	0.24	U	0	0.24
33	Rock Run	0.20	U	0	0.20
3	Brandywine Creek West Br.	0.16	U	0	0.16

Reach #	Stream Name	Ag mitigation load/land score	Dairy livestock factor (H, M, L, U)	Diary Score	Ag mitigation combined score
26	Marsh Creek	0.14	U	0	0.14
28	Trib. To Valley Creek	0.13	U	0	0.13
14	Brandywine Creek East Br.	0.12	U	0	0.12
15	Brandywine Creek	0.10	U	0	0.10
6	Brandywine Creek West Br.	0.10	U	0	0.10
25	Broad Run	0.06	U	0	0.06
13	Brandywine Creek East Br.	0.05	U	0	0.05
10	Brandywine Creek East Br.	0.04	U	0	0.04
5	Brandywine Creek West Br.	0.04	U	0	0.04
11	Brandywine Creek East Br.	0.04	U	0	0.04
12	Brandywine Creek East Br.	0.04	U	0	0.04
7	Brandywine Creek West Br.	0.02	U	0	0.02
24	Trib. To Broad Run	0.01	U	0	0.01
8	Brandywine Creek West Br.	0.01	U	0	0.01
4	Brandywine Creek West Br.	0.00	U	0	0.00

Figure 3-4 – Priority Areas for Agricultural Mitigation To Protect Wilmington's Water Supply

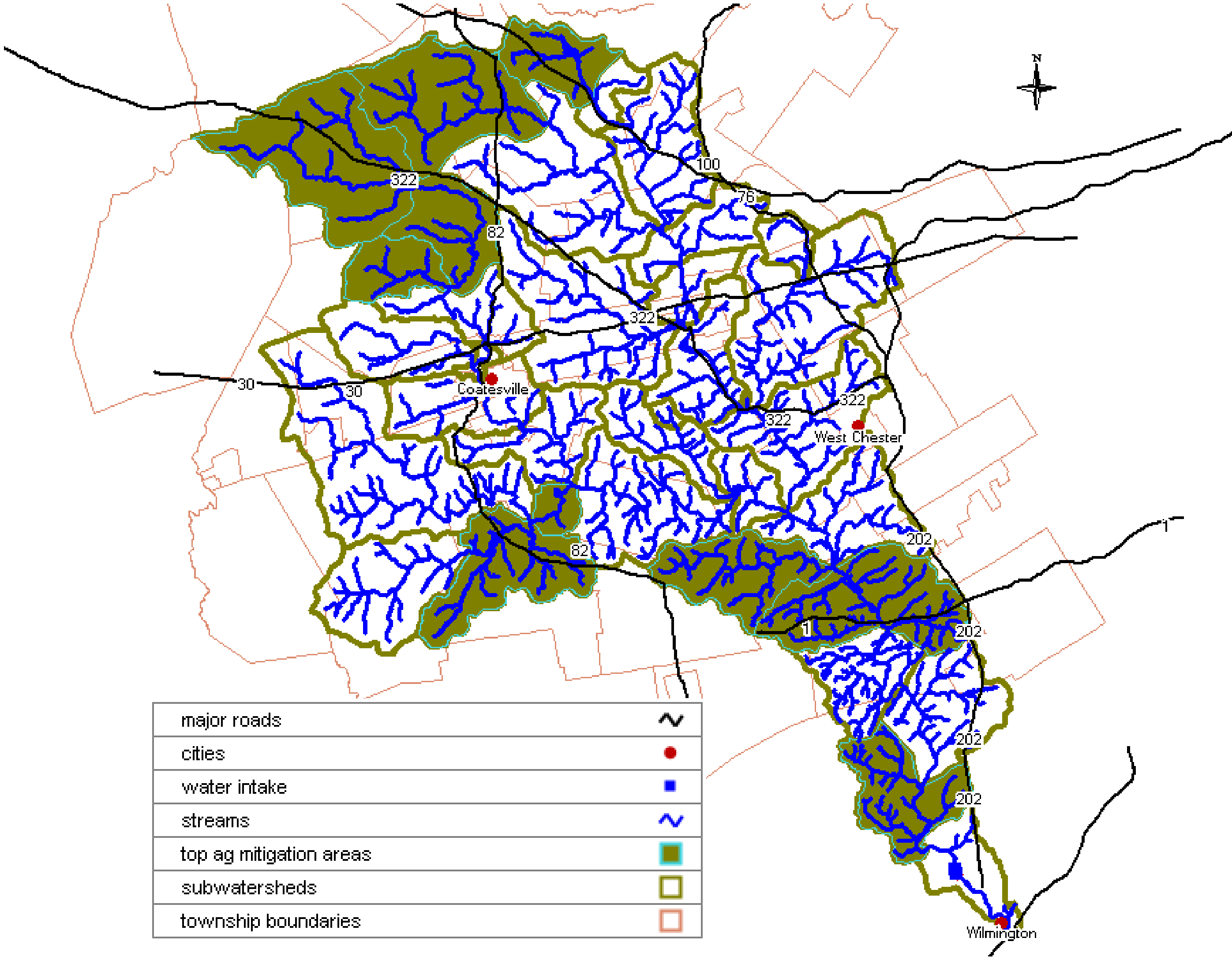
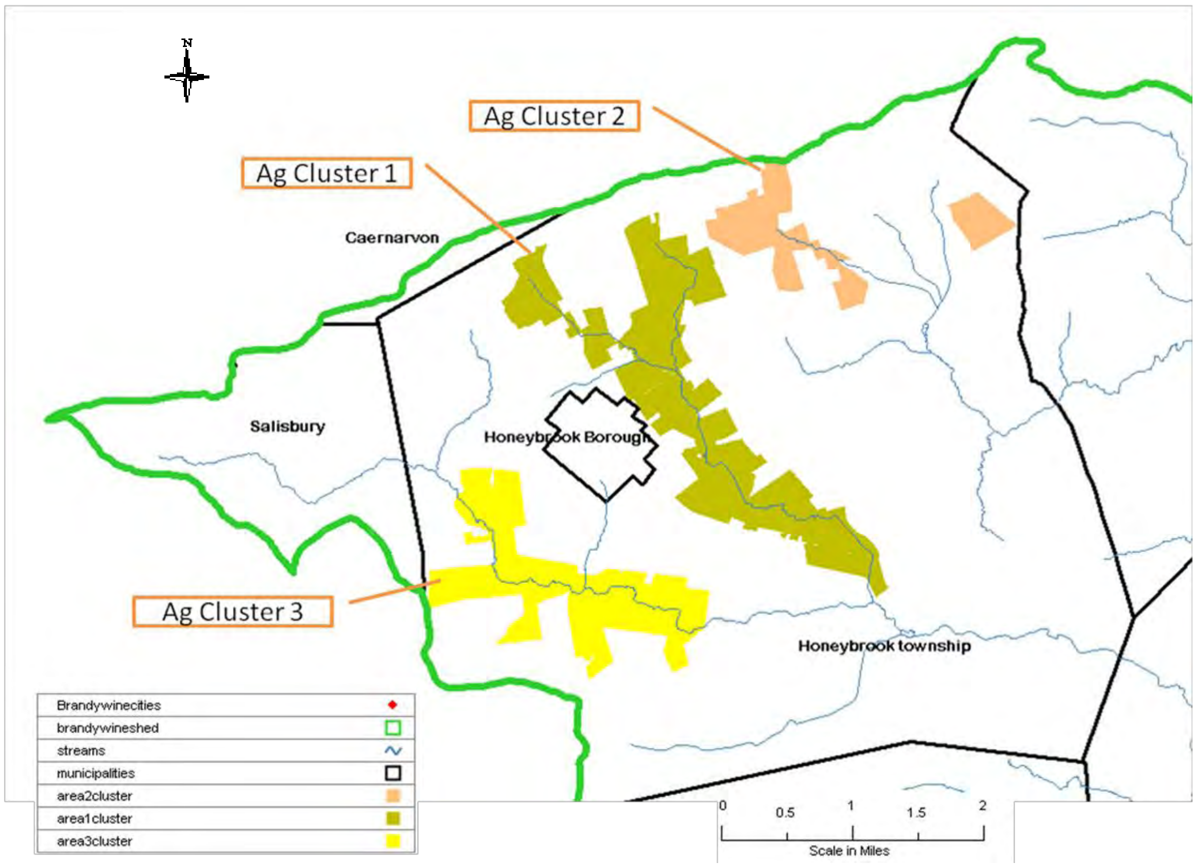


Figure 3-5 – Location of Honey Brook Farm Clusters for Top Priority Agricultural Mitigation Activities to Protect Wilmington's Water Supply



3.4.2. Priority Areas For Stormwater Mitigation

The priority areas for stormwater were ranked by using the weighted contaminant loading scores, the percentage of impervious land, and the percentage of urban/residential land in a subwatershed to determine an overall stormwater score. An initial stormwater load score was calculated as follows:

Stormwater load score = % urban&residential land use + 2 X % impervious land use + 2 X weighted average contaminant loading score

Then additional land use and ordinance factors were used to calculate an overall stormwater mitigation score as follows:

Overall stormwater mitigation score = (%urban&residential land use to % agricultural land ratio + % urban&residential land use to % forested land ratio) / 10 + stormwater load score - ordinance factor

Based on this scoring system the top watersheds were identified in Tables 3-10 and 3-11 and Figure 3-6. In each of the subwatersheds specific mitigation activities will need to be identified. For example in subwatershed 15, there is already a mitigation project underway with the Brandywine Valley Watershed Association for Plum Run and Radley Run. In subwatershed 34, partnerships with New Castle County and the continued implementation of the WRPA ordinance and Wilmington's proposed WRPA ordinance are critical activities to addressing stormwater in addition to the movement to impervious cover parcel based stormwater billing in this area of Delaware. In the East Branch subwatersheds, specifically in the Valley Creek and Beaver Creek subwatersheds (including their tributaries), increased stringency of stormwater ordinances for development and retrofitting of existing basins for additional infiltration is recommended as an interim step until a stormwater utility can be established in these areas. These areas would also be priority areas to focus any watershed based reforestation programs.

Subwatersheds 12, 13, and 19 also have dual priorities. Subwatersheds 12 and 13 are also priority areas for forest preservation in addition to stormwater mitigation. The synergy of riparian forest preservation and open space preservation in these areas to prevent the worsening of stormwater issues will also help towards laying groundwork for stormwater mitigation projects. These subwatersheds also represent a good opportunity to merge reforestation efforts with forest preservation efforts for a greater overall improvement.

In Subwatershed 19, it is a stormwater priority area and an agricultural mitigation priority area due to the close proximity to the Wilmington intake and thus any activities in or near the stream, floodplain, or waterways have a direct and immediate negative potential impact on Wilmington's water quality.

Table 3-10 - Top Watersheds for Stormwater Mitigation

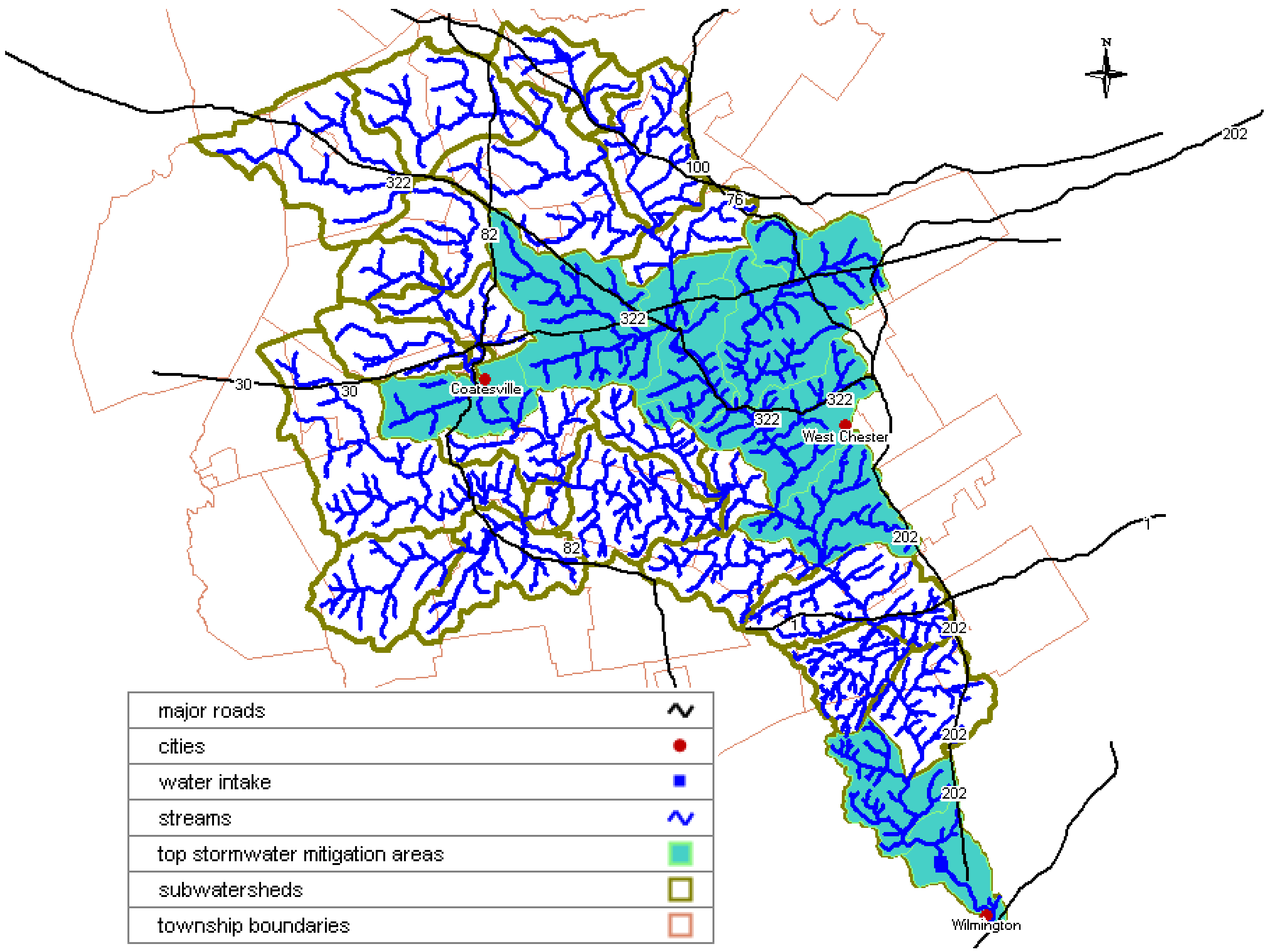
Subwatershed /Reach #	Stream Name	% Ag land total	% forested	Urban / Residential total	Impervious total	Overall Stormwater Mitigation Score
34	Lower Brandywine Creek	2%	14%	62%	29%	5.75
24	Trib. To Broad Run	3%	8%	88%	10%	4.74
28	Trib. To Valley Creek	3%	21%	67%	23%	4.11
29	Valley Creek	21%	35%	33%	13%	2.03
19	Brandywine Creek	4%	17%	34%	9%	1.94
30	Beaver Creek	32%	30%	33%	9%	1.75
12	Brandywine Creek East Br.	11%	39%	45%	13%	1.36
5	Brandywine Creek West Br.	19%	35%	39%	16%	1.19
14	Brandywine Creek East Br.	32%	30%	32%	9%	1.12
15	Brandywine Creek	41%	17%	34%	7%	1.09
13	Brandywine Creek East Br.	14%	48%	31%	10%	0.95

Table 3-11 – Ranking of Subwatersheds for Stormwater Mitigation in the Brandywine Creek

Reach #	Stream Name	% Ag land total	% forested	Urban / Residential total	Impervious total	Overall Stormwater Mitigation Score
34	Lower Brandywine Creek	2%	14%	62%	29%	5.75
24	Trib. To Broad Run	3%	8%	88%	10%	4.74
28	Trib. To Valley Creek	3%	21%	67%	23%	4.11
29	Valley Creek	21%	35%	33%	13%	2.03
19	Brandywine Creek	4%	17%	34%	9%	1.94
30	Beaver Creek	32%	30%	33%	9%	1.75
12	Brandywine Creek East Br.	11%	39%	45%	13%	1.36
5	Brandywine Creek West Br.	19%	35%	39%	16%	1.19
14	Brandywine Creek East Br.	32%	30%	32%	9%	1.12
15	Brandywine Creek	41%	17%	34%	7%	1.09
13	Brandywine Creek East Br.	14%	48%	31%	10%	0.95
20	Upper Buck Run	59%	25%	13%	3%	0.91
27	Marsh Creek	29%	34%	26%	3%	0.86
16	Brandywine Creek	26%	39%	33%	5%	0.86
31	Pocopson Creek	49%	22%	27%	3%	0.79
33	Rock Run	42%	30%	21%	4%	0.76
25	Broad Run	41%	30%	27%	6%	0.72
11	Brandywine Creek East Br.	33%	36%	26%	7%	0.68
18	Brandywine Creek	21%	38%	19%	5%	0.62
3	Brandywine Creek West Br.	30%	40%	28%	4%	0.54
10	Brandywine Creek East Br.	36%	40%	22%	3%	0.53
6	Brandywine Creek West Br.	40%	35%	23%	4%	0.48
2	Brandywine Creek West Br.	28%	46%	24%	4%	0.47

9	Upper Brandywine Creek East Br.	54%	33%	8%	1%	0.42
17	Brandywine Creek	27%	49%	17%	4%	0.41
35	Upper Marsh Creek	48%	34%	9%	2%	0.40
32	Birch Run	32%	53%	14%	2%	0.39
21	Upper Doe Run	76%	17%	5%	1%	0.37
4	Brandywine Creek West Br.	15%	69%	14%	5%	0.36
22	Lower Doe Run	79%	18%	3%	1%	0.35
26	Marsh Creek	26%	60%	13%	3%	0.31
1	Upper Brandywine Creek West Br.	68%	20%	8%	2%	0.28
7	Brandywine Creek West Br.	49%	38%	10%	2%	0.25
8	Brandywine Creek West Br.	62%	25%	11%	2%	0.24
23	Lower Buck Run	49%	49%	0%	0%	0.02

Figure 3-6 - Priority Areas for Stormwater Mitigation To Protect Wilmington's Water Supply



3.4.3. Priority Non-Point Sources – High Priority Geographical Areas for Preservation

Tables 3-12 & 3-13 and Figures 3-7 and 3-8 show the high priority subwatershed areas for agricultural and forest preservation. These were calculated using the following metrics and scores.

Preservation score = ((1 - % urban/residential land) * 2) + (% forested land * %agricultural row crops land * 0.5) - (weighted contaminant load score * 2)

Ag preservation score = IF(%row crops land>0.04,1,0) + IF(% agricultural land total >0.3,1,0) + IF(weighted contaminant load score<0.1,1,0)

Forest preservation score = IF(weighted contaminant load score <0.1,0.5,0) + IF(weighted contaminant load score <0.01,0.5,0) + IF(% forested land>0.3,1,0) + IF(% urban/residential land <0.2,1,0)

Water supplier benefit score = # of water intakes downstream that benefit from the preservation in a given subwatershed

Overall Preservation Score = forest preservation rank + water supplier benefit score

Using these various scores the top subwatersheds were ranked by overall preservation score. This information was also compared with the agricultural preservation score to identify "synergy areas" where forest preservation activities could be synchronized with agricultural mitigation and preservation activities (Table 3-14). As shown the subwatersheds #9 and 35, the Upper Marsh Creek and Upper East Branch (including Perkins Run and Indian Run shown in Figure 3-9), are two high priority subwatersheds for forest preservation, agricultural preservation, and agricultural mitigation. Thus these areas serve as top priority areas for preservation activities due to the multiple potential partners and funding sources and greater chances for success. Second tier top priority areas included subwatersheds 4 (W. Branch at Coatesville), 12 (E. Branch), and 13 (E. Branch). Second tier top priority forested preservation areas include the lower section of the Upper East Branch (subwatersheds 12 & 13) and the West Branch at Coatesville (subwatershed 4).

Since most of the high priority and second priority areas for preservation were in the Upper East Branch of the Brandywine Creek, efforts to identify even smaller subwatersheds for further prioritization were conducted. Detailed priority cluster areas were determined by working with the Brandywine Conservancy. Existing prioritization of preservation areas have been conducted for the Upper East Branch (UEB) as part of a DCNR study in 2004. The Upper East Branch priority cluster is also one of the areas with the greatest potential. In the UEB study the top priority subwatersheds in the Upper East Branch for forested stream corridor preservation were Upper Marsh Creek, Perkins Run, and Indian Run (especially the North Branch) see Figure 3-10. Using the riparian buffer gap areas and estimates from this report specific areas and costs were used to estimate and determine how preservation of the forested areas could be achieved to protect the water supplies of the watershed. More information on the costs and metrics of progress are in section 7.

Table 3-12 – Top Priority Areas for Forest Preservation for Long Term Protection of Wilmington's Water Supply

Preservation Priority	Reach #	Stream Name	Ag preservation rank (0-3, 3 best)	Forest preservation rank (0-3,3 best)	Type of Preservation	Water Supplier benefit score	Overall Preservation Score
Primary	**26**	Marsh Creek	2	2.5	Synergy w/ag efforts	3	5.5
Primary	**35**	Upper Marsh Creek	2	2	Synergy w/ag efforts	3	5
Primary	**9**	Upper Brandywine Creek East Br.	2	2	Synergy w/ag efforts	3	5
Primary	**11**	Brandywine Creek East Br.	2	1.5	Synergy w/ag efforts	3	4.5
Primary	**10**	Brandywine Creek East Br.	2	1.5	Synergy w/ag efforts	3	4.5
Secondary	**13**	Brandywine Creek East Br.	1	1.5	Forest / riparian corridor	3	4.5
Secondary	**12**	Brandywine Creek East Br.	1	1.5	Forest pres	3	4.5
Secondary	**4**	Brandywine Creek West Br.	1	3	Forest pres	1	4

Table 3-13 – Top Priority Areas for Agricultural Preservation

Reach #	Stream Name	Ag preservation rank (0-3, 3 best)	Forest preservation rank (0-3,3 best)	Water Supplier benefit score	Overall Preservation Score
3	Brandywine Creek West Br.	3	1.5	2	3.5
1	Upper Brandywine Creek West Br.	3	1.5	2	3.5
32	Birch Run	3	2.5	2	4.5
23	Lower Buck Run	3	3	1	4
33	Rock Run	2	0	1	1
22	Lower Doe Run	2	1	1	2
21	Upper Doe Run	2	1	1	2
20	Upper Buck Run	2	1	1	2
25	Broad Run	2	1.5	1	2.5

Table 3-14 – Ranking of Areas for Agricultural and Forest Preservation in the Brandywine Creek for Water Supply Protection

Reach #	Stream Name	Ag preservation rank (0-3, 3 best)	Forest preservation rank (0-3,3 best)	Water Supplier benefit score (0-4, 4 best)	Overall Preservation Score
26	Marsh Creek	2	2.5	3	5.5
35	Upper Marsh Creek	2	2	3	5
9	Upper Brandywine Creek East Br.	2	2	3	5
32	Birch Run	3	2.5	2	4.5
13	Brandywine Creek East Br.	1	1.5	3	4.5
12	Brandywine Creek East Br.	1	1.5	3	4.5
11	Brandywine Creek East Br.	2	1.5	3	4.5
10	Brandywine Creek East Br.	2	1.5	3	4.5
23	Lower Buck Run	3	3	1	4
4	Brandywine Creek West Br.	1	3	1	4
18	Brandywine Creek- main stem downstream of Smith's Bridge	1	2.5	1	3.5
17	Brandywine Creek – main stem	1	2.5	1	3.5

Reach #	Stream Name	Ag preservation rank (0-3, 3 best)	Forest preservation rank (0-3,3 best)	Water Supplier benefit score (0-4, 4 best)	Overall Preservation Score
	to Smith's Bridge				
7	Brandywine Creek West Br.	2	2.5	1	3.5
5	Brandywine Creek West Br.	1	1.5	2	3.5
3	Brandywine Creek West Br.	3	1.5	2	3.5
1	Upper Brandywine Creek West Br.	3	1.5	2	3.5
25	Broad Run	2	1.5	1	2.5
8	Brandywine Creek West Br.	2	1.5	1	2.5
6	Brandywine Creek West Br.	2	1.5	1	2.5
2	Brandywine Creek West Br.	2	1.5	1	2.5
29	Valley Creek	0	1	1	2
27	Marsh Creek	1	1	1	2
22	Lower Doe Run	2	1	1	2
21	Upper Doe Run	2	1	1	2
20	Upper Buck Run	2	1	1	2

Reach #	Stream Name	Ag preservation rank (0-3, 3 best)	Forest preservation rank (0-3,3 best)	Water Supplier benefit score (0-4, 4 best)	Overall Preservation Score
16	Brandywine Creek	0	1	1	2
14	Brandywine Creek East Br.	1	1	1	2
24	Trib. To Broad Run	1	0.5	1	1.5
34	Lower Brandywine Creek	0	0	1	1
33	Rock Run	2	0	1	1
31	Pocopson Creek	1	0	1	1
30	Beaver Creek	1	0	1	1
28	Trib. To Valley Creek	0	0	1	1
19	Brandywine Creek	0	0	1	1
15	Brandywine Creek	1	0	1	1

Figure 3-7 - Priority Areas for Forest Preservation To Protect Wilmington's Water Supply

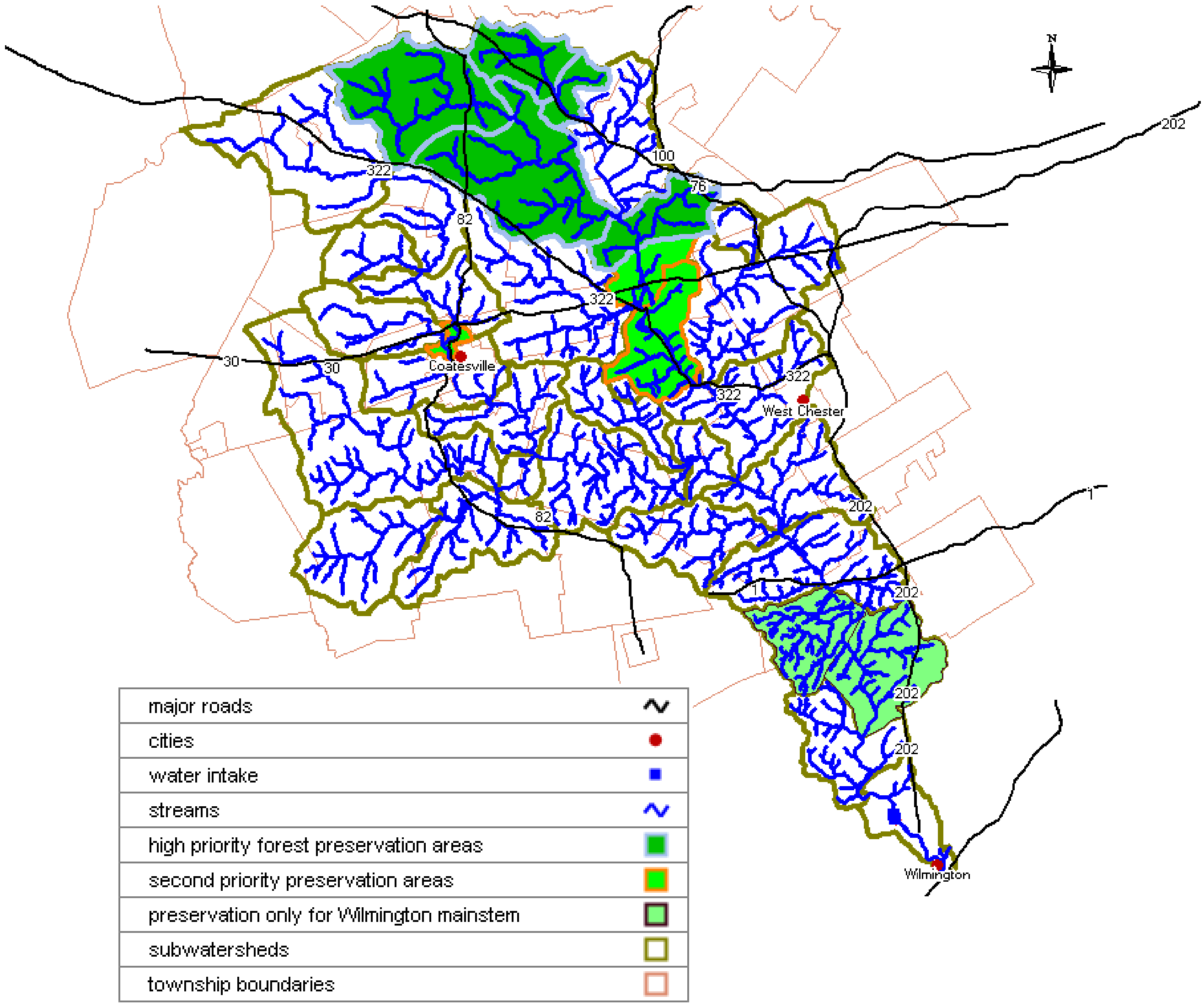


Figure 3-8 - Priority Areas for Agricultural Preservation To Protect Wilmington's Water Supply

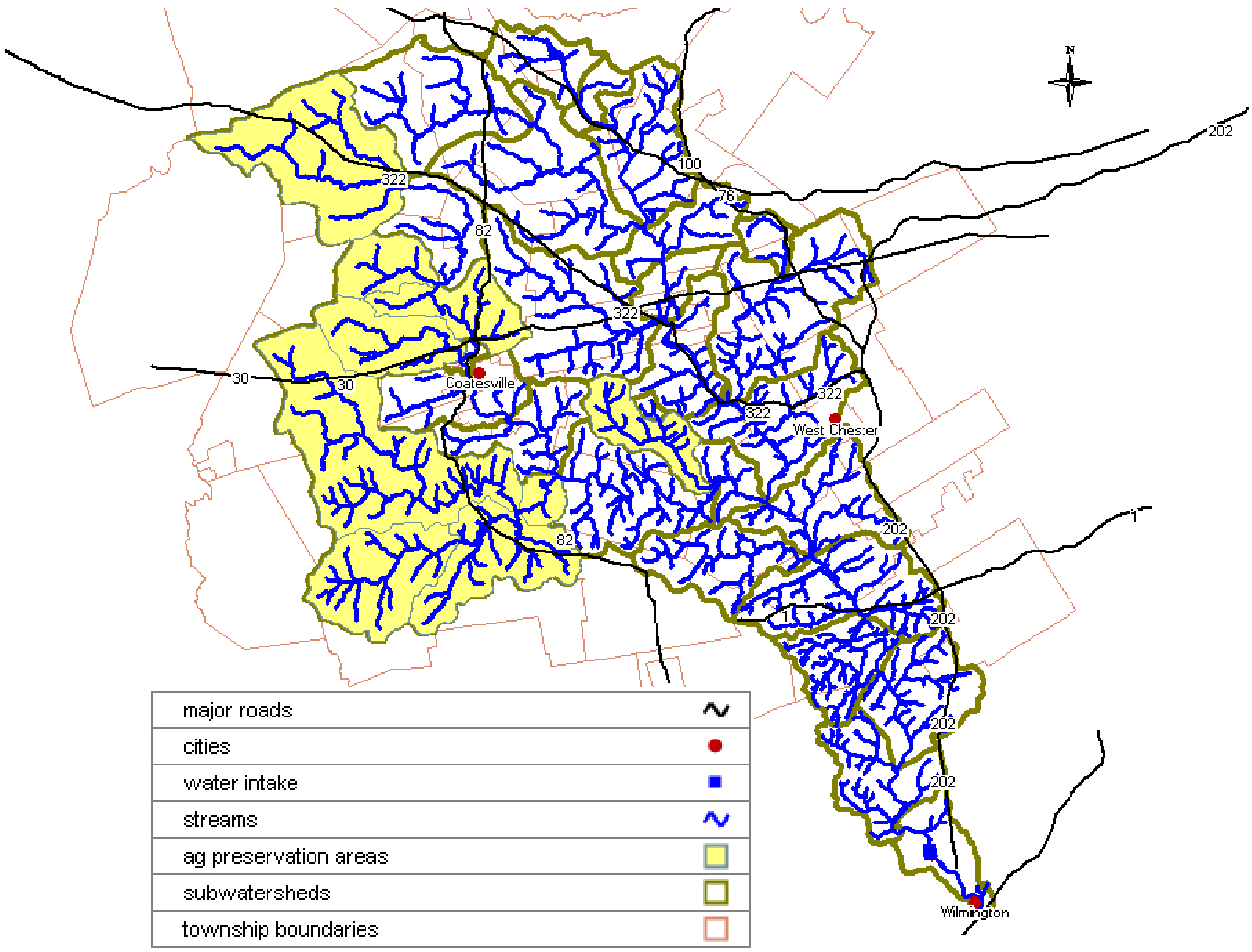
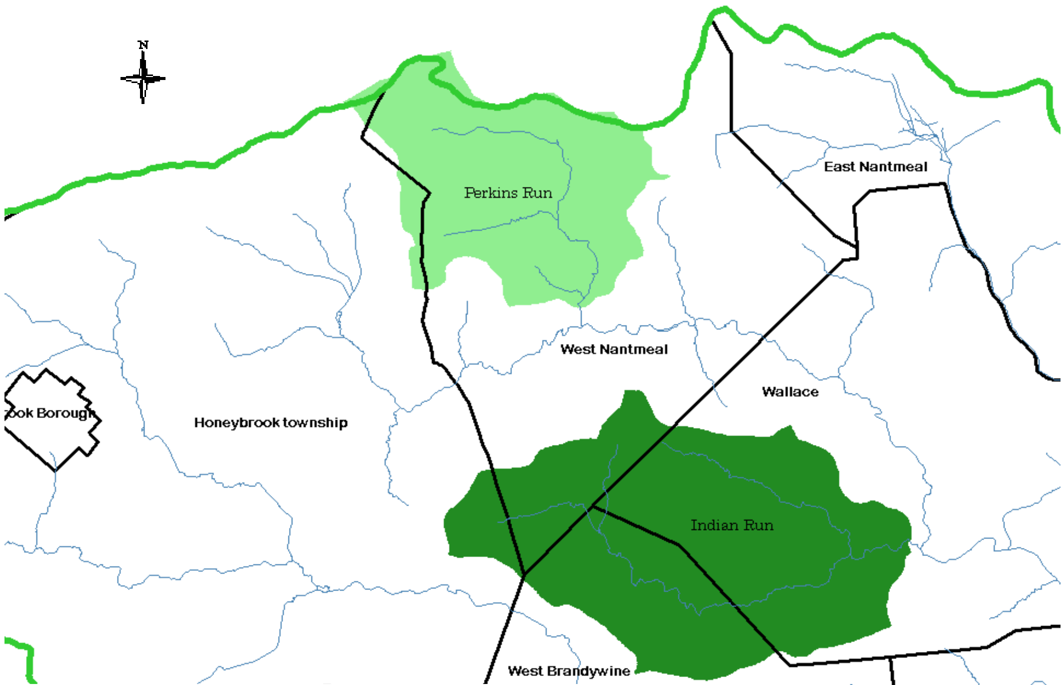


Figure 3-9 – Perkins Run and Indian Run Top Forest Preservation Priority Areas to Protect Wilmington's Water Supply



Brandywinecities	◆
brandywineshed	□
streams	∿
municipalities	□
perkins run	■
indian run	■

Figure 3-10 – Stream Corridor Preservation Priorities in the Upper East Branch – (used with permission from the Brandywine Conservancy Watershed Conservation Plan, 2004)

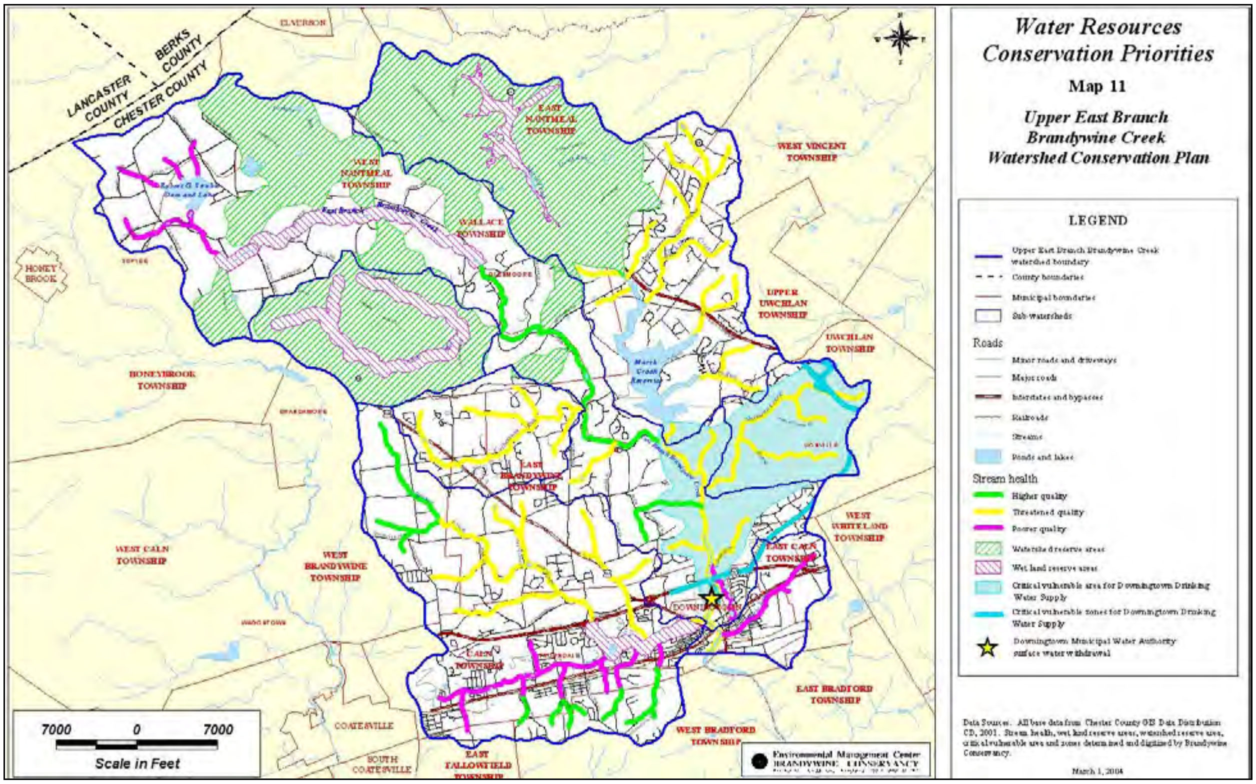


Figure 3-11– Map of Overlapping Priority Areas

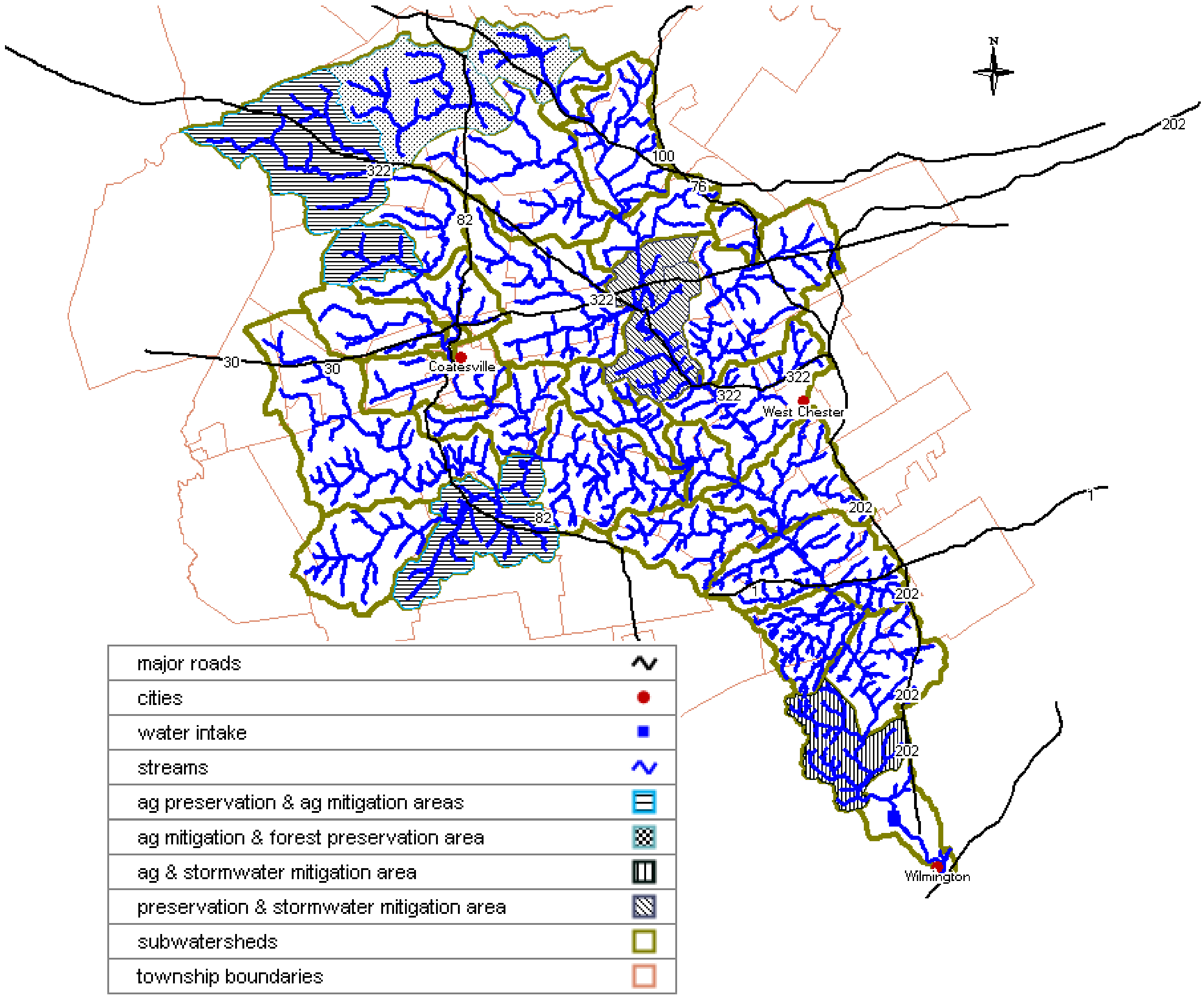


Figure 3-12 – Top Agricultural and Stormwater Mitigation Areas to Protect Wilmington's Water Supply

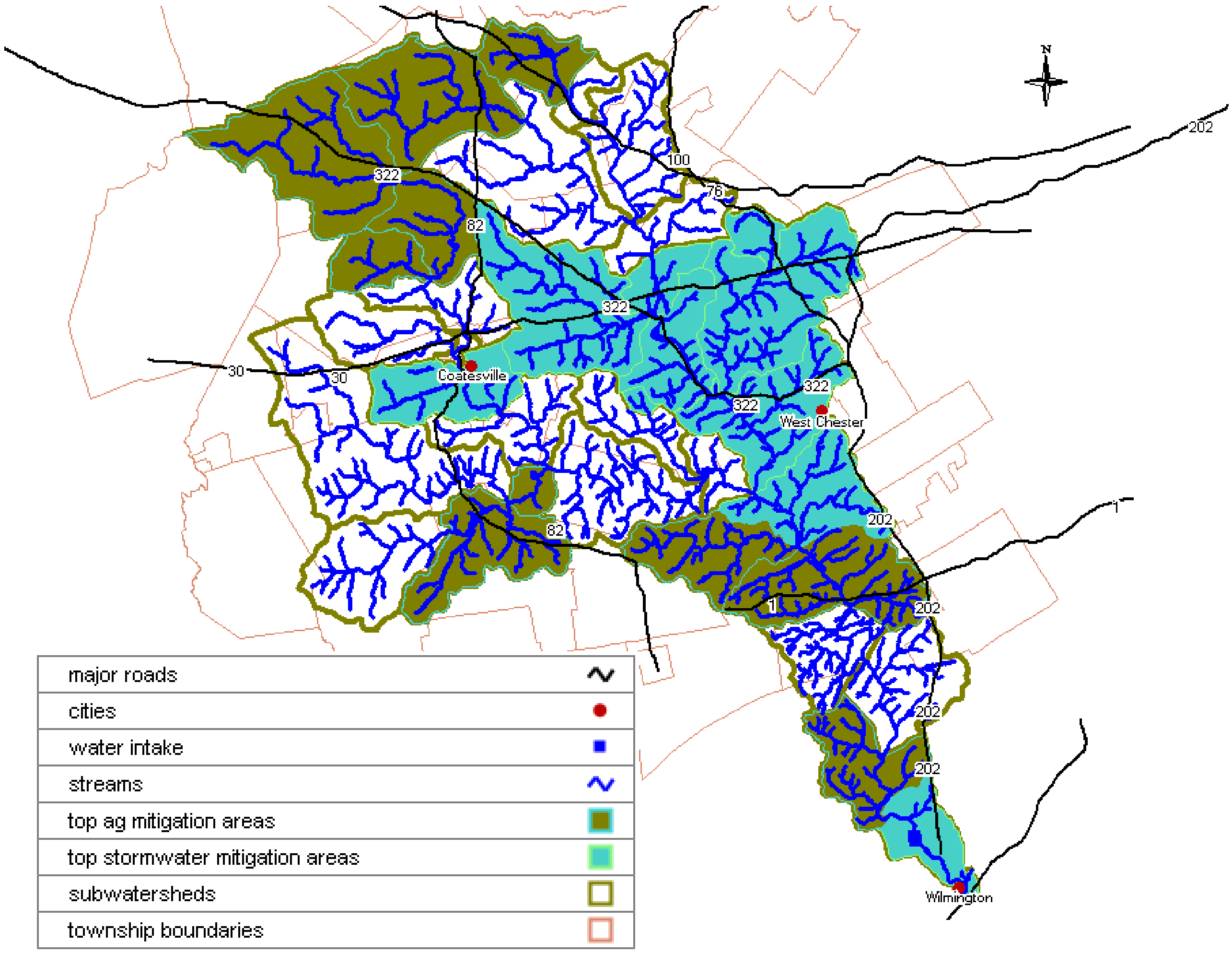
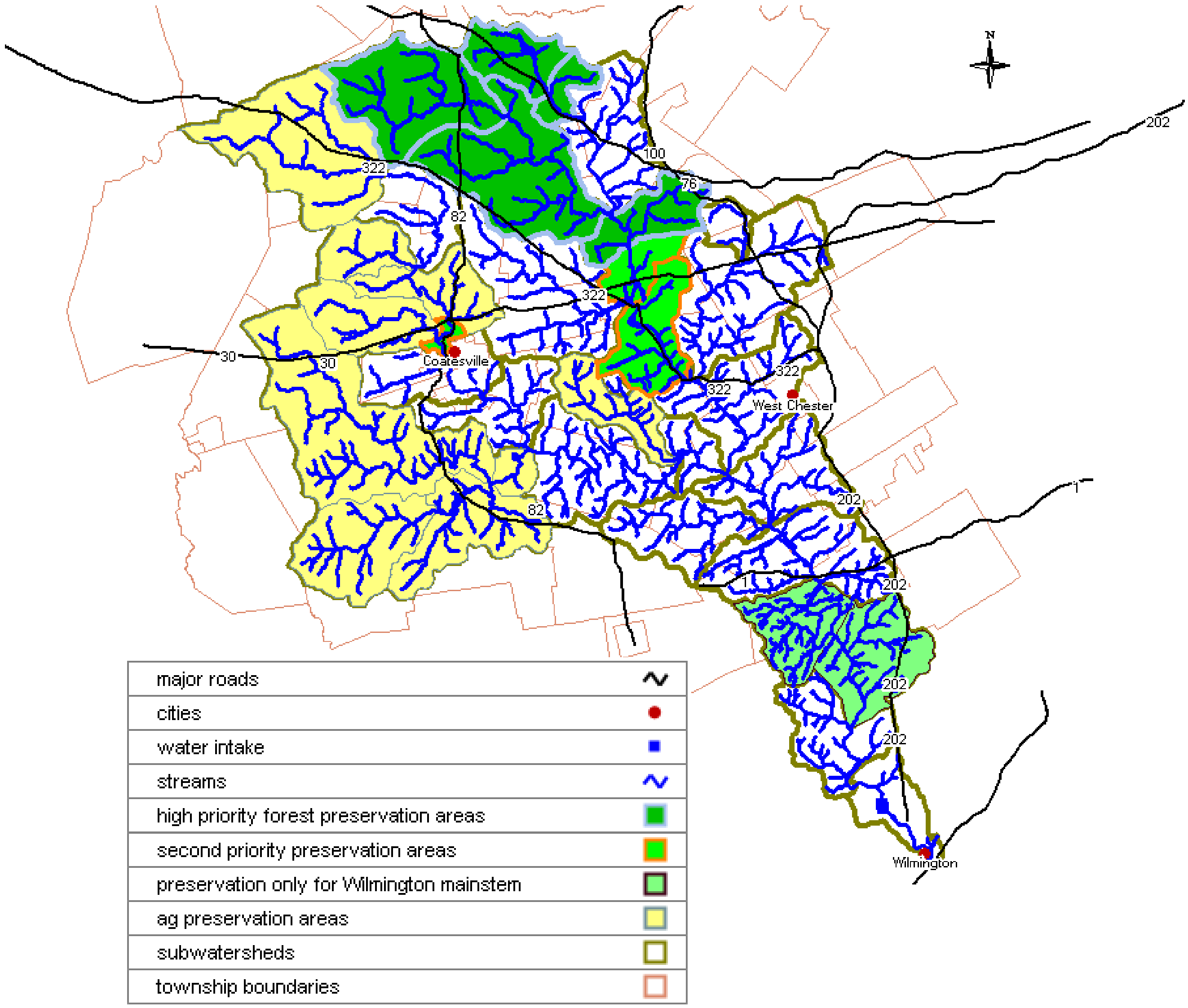


Figure 3-13 – Agricultural and Forest Preservation Priority Areas to Protect Wilmington's Water Supply



3.4.4. Priority Non-Point Sources – High Priority Geographical Areas for Riparian Buffer Restoration, Reforestation, and Preservation

In the previous section, preservation of prioritization of forested riparian buffers in largely pristine areas was discussed. However, in many cases it is difficult within any given parcel to just preserve the riparian buffer because it is intermittently disturbed by various human activities past and present. Therefore, it is more realistic to assume that any riparian buffer preservation activities will need to be conducted in conjunction with riparian buffer reforestation and restoration. Also, since a similar analysis to that conducted for the Upper East Branch of the Brandywine Creek has not been conducted watershed wide, only limited information is available or needs to be created for other areas of the watershed.

With this limited information a limited screening for prioritization to identify additional clusters or prioritize amongst the remaining priority was conducted using forested areas, current area preserved/protected and including factors such as proximity to the Wilmington intake. This created the ability to prioritize the areas on the main stem Brandywine to the Wilmington intake for preservation. Using these factors, preservation on the West branch was determined to only be feasible in combination with agricultural preservation and stream corridor efforts on a case by case basis given the dominant impacts of and opportunities with agriculture and agricultural preservation (see Figures 3-11 to 3-13). The remaining areas in the Lower Main stem Brandywine below Chadds Ford and into New Castle County were determined to be the most important of the secondary preservation areas due to their location immediately upstream of the Wilmington intake.

Examining the area along the main stem of the Brandywine in more depth, it appears the area above Smith's Bridge is either protected by existing parks/open space, railways or roadways that create a limited buffer to development along or near the stream and thus provide some limited preservation along the stream. Therefore, riparian buffer preservation, reforestation, and restoration in the Lower Main stem will need to be focused on opportunities and priorities within the tributaries to the main stem. Within the Lower Main stem a general screening for prioritization of preservation areas were identified below Chadds Ford to the PA border by examining the current protected and preserved lands, the potential for connection of forested stream corridors within tributaries to the lower mainsteam and overall existing forested stream corridors within the tributaries. Based on this analysis the following tributaries were ranked as shown in Table 3-15. The results suggest that the completion of forest preservation in Ramsey Run, Rocky Run/Hurricane Run, and Beaver Creek and Craigs Mill Run should be completed first. Given the amount of land in this area attributed to golf courses these may be good initial starting areas for riparian buffer restoration and preservation efforts.

The only tributary to the main stem not included in this analysis was Pocopson Creek due to its large size compared to the other tributaries and proximity to the confluence of the East and West Branches of the Brandywine Creek. Field surveys of the Pocopson Creek have identified cows in the stream, some large continuous tracks of fully buffered stream sections, and large continuous tracks of stream in agricultural lands. Given on the ground observations as compared to the desktop values, the Pocopson Creek should be considered as an additional area for agricultural preservation work coordination with the recommended agricultural mitigation and reforestation efforts.

Given the results of the screening a more in depth analysis was conducted to obtain more detailed information. The Brandywine Conservancy donated staff time to this effort and conducted a GIS analysis that identified areas of potential riparian buffer gaps, protected lands, and lower main stem area was then evaluated for specific tributaries and areas for future preservation or reforestation efforts within Delaware or near the PA border. It is important to acknowledge that the following part of this section was compiled, analyzed, produced, and published by the Brandywine Conservancy (Anderson, 2008) and was extremely useful to the future prioritization of riparian buffer efforts in the Lower Brandywine main stem.

The land use and land cover within the Delaware portion of the watershed used in the analysis was based on a statewide land use layer produced in 2007. From this coverage it was determined that single family dwellings are the single largest land use/cover type (24 percent), followed by deciduous forest (22 percent). Farmland comprised 12 percent of the Delaware portion of the watershed and is concentrated west of Route 202 near the Pennsylvania border as mentioned earlier near Smiths Bridge (see Figure 3-14 and Table 3-16). A relatively high proportion (10 percent) of land is in recreational use (golf courses and state, city, and county parks). Portions of four golf courses fall within the Delaware portion of the watershed, including the Biderman Golf Course near Winterthur and the golf courses at Brandywine Country Club, Wilmington Country Club, and Dupont Country Club. The opportunities at golf courses related to riparian buffers are discussed later in this section.

Figure 3-15 shows the 2007 land use and land cover within riparian buffers, defined as areas of land within 100 feet of a stream centerline or body of water. Roughly 1,636 acres of land or 11% of the total Delaware portion of the watershed is within the 100 foot buffer. Of the 1,636 acres of land within riparian buffers, 45 percent is in forest cover. The next greatest land use/land cover type within riparian buffers is single family dwellings (17 percent), followed by farmland (9 percent), urban/built-up (8 percent), and recreational (8 percent). Such variability suggests that any program aimed at reforesting or improving management of all buffer lands should be designed to reach small-lot landowners as well as larger estate, farmland, and institutional landowners.

Table 3-15 – Priority Lower Main stem Tributaries for Protection & Preservation Efforts

Tributary	Total Length (km)	Length needing forest/open space	length w/forest/open space	% protected	% unprotected	L or R side looking upstream	sequence from intake	protection score
Ramsey Run	1.4	0.7	0.7	50%	50%	R	2	1.30
Rocky Run/Hurricane Run	4.8	0.9	3.9	81%	19%	R	1	1.09
Beaver Creek	15	4.7	10.3	69%	31%	R	3	1.01
Craigs Mill Run	8.2	3.2	5	61%	39%	L	4	0.99
Ring Run	8.7	4.3	4.4	51%	49%	L	7	0.79
Harvey Run	16.3	6.1	10.2	63%	37%	R	6	0.77
Wilson Run	2.7	0.45	2.25	83%	17%	R	5	0.67
Bennetts Run	10.9	4.5	6.4	59%	41%	L	9	0.51
Brinton Run	5.2	1.1	4.1	79%	21%	R	8	0.41

Figure 3-16 and Table 3-17 shows that close to 40 percent of land within the Delaware portion of the Brandywine Creek watershed is in some form of protection, whether eased or owned by a land trust, public agency, nonprofit organization, or homeowners association. “Protection status” does not speak to the management of these lands for water quality purposes (i.e. protected lands may not have adequate riparian forest buffers), but generally indicates that they are off-limits to future residential or commercial development. With close to 40 percent of the watershed in some form of protection, targeted outreach to, and/or program implementation through, a few key land trusts (including the Brandywine Conservancy), nonprofits, and government agencies could have far reaching positive impacts on water quality.

Figure 3-17 shows that close to 16 percent of protected lands within the Delaware portion of the Brandywine Creek watershed is within the 100 foot buffer. Of the 1,636 acres of land within riparian buffers, roughly 56 percent is in some form of protection. This strengthens the need for targeting outreach to and/or implementing best management practices in cooperation with the owners and easement holders of protected lands. As presented in Figure 3-17, these lands generally offer greater opportunity for buffer reforestation and enhancement. Such an approach may also prove more cost-effective than a program aimed at all riparian buffer landowners.

Based on these results an effort to get even more detailed forested land use information for stream buffer restoration was conducted. Higher resolution data captured from aerial photographs and limited ground-truthing in 2002 indicates that roughly 32 percent of the Delaware portion of the watershed is forested, more than the amount identified with the coarser land use/land cover data presented in Figure 3-18 based on 2007 data. Comparison of the two land cover datasets indicates that this older one may potentially be more accurate. Therefore, it is used as the basis for the final riparian buffer forested cover and prioritization analysis depicted in Figures 3-18 and 19 and Tables 3-18.

As shown in Figure 3-20 nearly 60 percent of the land within riparian buffers is forested. This exceeds the estimate presented in Figure 3-17. Roughly 30 percent of riparian buffers are not forested and not developed, suggesting that close to one-third of riparian buffers in the Delaware portion of the watershed (484 acres) could be reforested or enhanced.

Synthesizing information presented in Figures 3-15 through 3-19, Figure 3-20 identifies potential gaps in riparian forest cover throughout the Delaware portion of the watershed. All tax parcels with gaps in riparian forest cover are highlighted, with the top 30 ranked by the acreage of non-forested riparian buffer area per parcel. These 30 parcels – in some cases owned by the same landowner – contain 277 acres of non-forested riparian buffer land, roughly 57 percent of all non-forested riparian buffer land in the Delaware portion of the watershed. Agriculture, including hay, row crops, and pasturage, is the most common land use of the top 30 (11 parcels), followed by golf courses (6 parcels) and parks (5 parcels). Twenty of the top 30 “reforestation opportunity parcels” are in some form of protection.

The two top priority riparian reforestation areas appear to be the Wilson Run Cluster (areas 1, 5, 8, 16, 20) and the Smith Bridge Road Agricultural Corridor Cluster (areas 4, 5, 11, 14, 17, 22, 28) which includes the Beaver Creek, Ramsey Run, and unnamed tributary (see

Table 3-19 and Figure 3-20). Both of these clusters of parcels only involve a handful of landowners and already possess some protected lands suggesting they may be open to riparian buffer restoration efforts. Also, these clusters possess a variety of land uses. The Smith Bridge Road Cluster is mostly agricultural land with cows in the headwater streams. The Wilson Run Cluster is mostly gardens, but also has a significant golf course area. These both represent opportunities to pilot and demonstrate how better management of riparian corridors at golf courses and agricultural lands on headwater tributaries can be conducted effectively for watershed wide application.

Within the two major clusters, the greatest priority areas are areas 1, 5, 8, and 28 due to the presence of cows in the stream or other activities that could have a direct impact on water quality at Wilmington's intake. In the future, actions to verify these gaps and meet with the key stakeholders/property owners to determine ways to improve the riparian buffers within these key parcels will need to be determined. Also, future watershed monitoring by COW may want to focus on establishing a baseline at these top priority tributaries so as riparian buffer improvements are made they can be measured and quantified.

Table 3-16 – Land Use within the Delaware Portion and 100 ft Riparian Buffer of the Brandywine Creek Watershed (Source: Brandywine Conservancy, 2008)

Land Use/Land Cover Type	Acres	% of Watershed	Acres	% of Riparian Buffer Area
Single Family Dwellings	3,566.8	24.30	256.8	15.69
Multi Family Dwellings	165.6	1.13	2.9	0.17
Mobile home Parks/Courts	22.4	0.15	0.0	0.00
Commercial	1,098.0	7.48	70.9	4.33
Junk/Salvage Yards	*8.8*	*0.06*	3.2	0.20
Retail Sales/Wholesale/Professional Services	*1,089.1*	*7.42*	67.7	4.14
Industrial	114.5	0.78	10.6	0.64
Transportation/Communication	346.4	2.36	19.7	1.20
Highways/Roads/Access roads/Freeways/Interstates	*248.1*	*1.69*	5.2	0.32
Parking Lots	*11.1*	*0.08*	0.3	0.02
Railroads	*87.2*	*0.59*	14.1	0.86
Utilities	*0.0*	*0.00*	0.0	0.00
Mixed Urban or Built-up Land	1,476.9	10.06	130.9	8.00
Mixed Urban or Built-up Land	*621.4*	*4.23*	16.2	0.99
Other Urban or Built-up Land	*855.5*	*5.83*	114.8	7.01
Institutional/Governmental	623.6	4.25	34.9	2.13
Recreational	1,474.7	10.05	129.9	7.94
Farms, Pastures, and Cropland	1,778.1	12.12	144.5	8.83
Cropland	*1,579.2*	*10.76*	132.6	8.11
Farmsteads and Farm Related Buildings	*72.0*	*0.49*	7.0	0.43
Idle Fields	*32.1*	*0.22*	0.0	0.00
Pasture	*94.8*	*0.65*	4.8	0.30
Rangeland	47.4	0.32	10.0	0.61
Herbaceous Rangeland	*37.3*	*0.25*	4.5	0.27
Mixed Rangeland	*10.2*	*0.07*	5.6	0.34
Deciduous Forest	3,289.2	22.41	726.2	44.39
Evergreen Forest	11.4	0.08	0.2	0.01
Mixed Forest	33.5	0.23	1.4	0.09
Shrub/Brush Rangeland	40.3	0.27	8.3	0.51
Man-made Reservoirs and Impoundments	87.5	0.60	10.4	0.63
Open Water	231.4	1.58	29.9	1.83
Bays and Coves	*31.4*	*0.21*	3.1	0.19
Non-tidal Open Water	*7.2*	*0.05*	5.5	0.34
Waterways/Streams/Canals	*192.8*	*1.31*	21.3	1.30
Emergent Wetlands - tidal and non-tidal	36.5	0.25	21.4	1.31

Land Use/Land Cover Type	Acres	% of Watershed	Acres	% of Riparian Buffer Area
Non-tidal Emergent Wetland	*22.5*	*0.15*	13.7	0.84
Tidal Emergent Wetland	*14.0*	*0.10*	7.8	0.47
Non-tidal Forested Wetland	16.0	0.11	11.1	0.68
Non-tidal Scrub/Shrub Wetland	2.4	0.02	1.0	0.06
Tidal Shoreline	2.1	0.01	1.6	0.10
Transitional (incl. cleared, filled, and graded areas)	211.9	1.44	13.7	0.84

Table 3-17 – Summary of Protected Lands within the Delaware Portion and 100 ft Riparian Buffer of the Brandywine Creek Watershed (Source: Brandywine Conservancy, 2008)

Protected Land Type	Acres	% of Watershed	Acres within Riparian Buffer	% of Riparian Buffer Area	Riparian/ Watershed
Lands Owned or Eased by Land Trusts	2009.1	13.7	312.9	19.1	16%
Public Lands	1921.3	13.1	301.8	18.4	16%
Non-Profit Institution Lands	1715.6	11.7	291.1	17.8	17%
Homeowners Association Lands	36.4	0.3	12.1	0.7	33%
Sum	5682.4	38.8	917.9	56.1	16%

Table 3-18 – Summary of Final Forested Lands within the Delaware Portion and 100 ft Riparian Buffer of the Brandywine Creek Watershed (Source: Brandywine Conservancy, 2008)

Land Cover Type	Acres	% of Watershed	Acres *(of Riparian Buffer)*	% of Total Buffer
Developed	2,984.3	20.3	128.5	7.9
Forested	4,621.7	31.5	978.5	59.8
Non-Forested	6,678.0	45.5	484.3	29.6
Water/Wetland	325.1	2.2	41.8	2.6
Missing data*	70.9	0.5	2.9	0.2
Sum	14,680.0	100.0	1,636.0	100.0

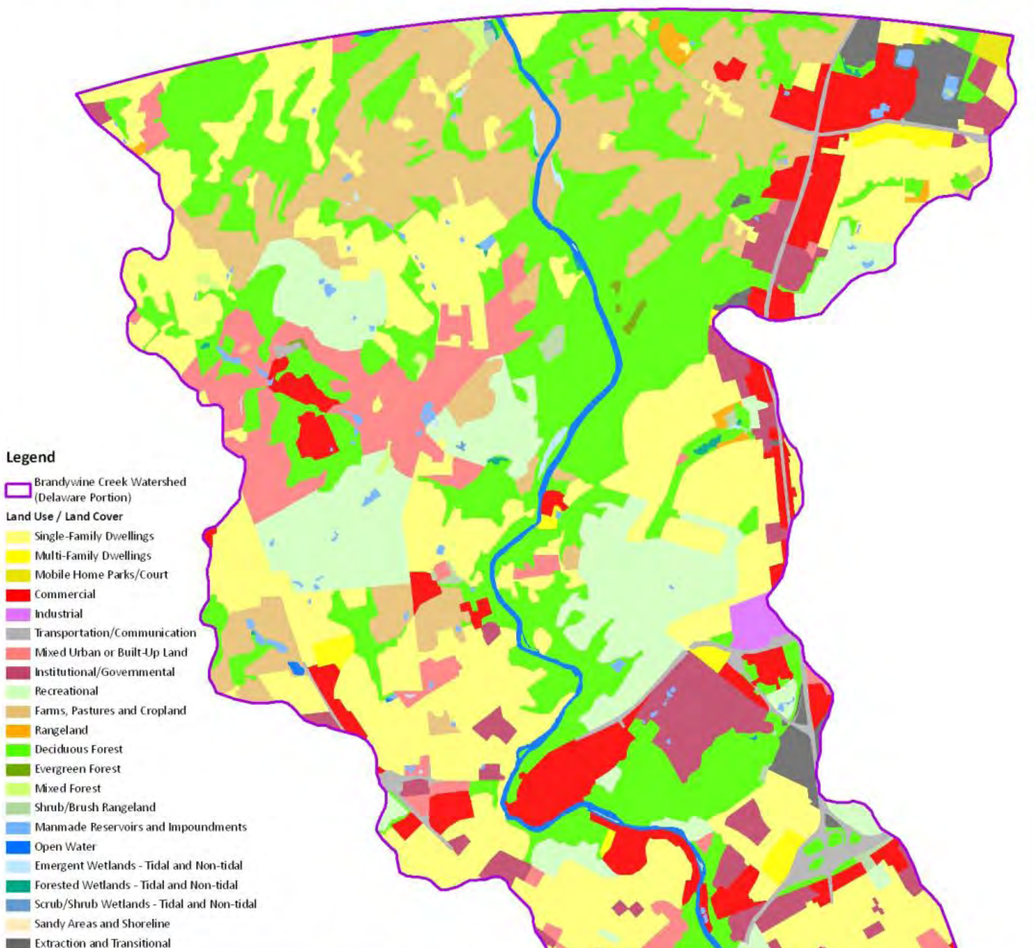
**The land cover layer does not match the Brandywine Creek watershed boundary due to differences in data collection*

Table 3–19 - Priority Areas for Riparian Buffer Restoration in New Castle County – (Source: Brandywine Conservancy, 2008)

Rank	Non-Forested Buffer Acreage	Land Use*	Protected^	Notes
1	38.57	Institutional/Agriculture	Yes	hay
2	25.84	Golf Course	No	
3	17.44	Agriculture	Yes	mixed
4	15.99	Golf Course	No	
5	15.34	Agriculture	No	mixed
6	13.67	Institutional (Hospital)	Yes	
7	10.77	Agriculture	Yes	hay
8	9.76	Golf Course	No	
9	9.63	Park	Yes	
10	8.59	Agriculture	Yes	crops
11	8.48	Institutional/Agriculture	Yes	hay
12	7.71	Institutional (Museum)	Yes	
13	7.48	Agriculture	Yes	mixed
14	7.00	Residential (HOA land)	Yes	
15	6.53	Golf Course	Yes	
16	6.50	Agriculture	Yes	mixed
17	6.41	Golf Course	No	
18	5.52	Golf Course	Yes	
19	5.37	Agriculture	No	crops/dairy production
20	5.29	Agriculture	Yes	hay/horses
21	5.01	Residential (HOA land)	Yes	
22	4.97	Park	Yes	
23	4.91	Institutional (College)	No	
24	4.56	Agriculture	Yes	mixed
25	4.48	Park	Yes	
26	4.43	Park	Yes	
27	4.39	Commercial	No	
28	4.33	Park	Yes	
29	4.11	Residential	No	
30	3.77	Agriculture	No	hay/horses

Figure 3-14

Land Use/Land Cover, Delaware Portion of the Brandywine Creek Watershed, 2007



Land Use/Land Cover Type	Acres	% of Watershed
Single Family Dwellings	3,566.8	24.30
Multi Family Dwellings	165.6	1.13
Mobile home Parks/Courts	22.4	0.15
Commercial	1,098.0	7.48
Junk/Salvage Yards	*8.8*	*0.06*
Retail Sales/Wholesale/Professional Services	*1,089.1*	*7.42*
Industrial	114.5	0.78
Transportation/Communication	346.4	2.36
Highways/Roads/Access roads/Freeways/Interstates	*248.1*	*1.69*
Parking Lots	*11.1*	*0.08*
Railroads	*87.2*	*0.59*
Utilities	*0.0*	*0.00*
Mixed Urban or Built-up Land	1,476.9	10.06
Mixed Urban or Built-up Land	*621.4*	*4.23*
Other Urban or Built-up Land	*855.5*	*5.83*
Institutional/Governmental	623.6	4.25
Recreational	1,474.7	10.05
Farms, Pastures, and Cropland	1,778.1	12.12
Cropland	*1,579.2*	*10.76*
Farmsteads and Farm Related Buildings	*72.0*	*0.49*
Idle Fields	*32.1*	*0.22*
Pasture	*94.8*	*0.65*
Rangeland	47.4	0.32
Herbaceous Rangeland	*37.3*	*0.25*
Mixed Rangeland	*10.2*	*0.07*
Deciduous Forest	3,289.2	22.41
Evergreen Forest	11.4	0.08
Mixed Forest	33.5	0.23
Shrub/Brush Rangeland	40.3	0.27
Man-made Reservoirs and Impoundments	87.5	0.60
Open Water	231.4	1.58
Bays and Coves	*31.4*	*0.21*
Non-tidal Open Water	*7.2*	*0.05*
Waterways/Streams/Canals	*192.8*	*1.31*
Emergent Wetlands - tidal and non-tidal	36.5	0.25
Non-tidal Emergent Wetland	*22.5*	*0.15*
Tidal Emergent Wetland	*14.0*	*0.10*
Non-tidal Forested Wetland	16.0	0.11
Non-tidal Scrub/Shrub Wetland	2.4	0.02
Tidal Shoreline	2.1	0.01
Transitional (incl. cleared, filled, and graded areas)	211.9	1.44

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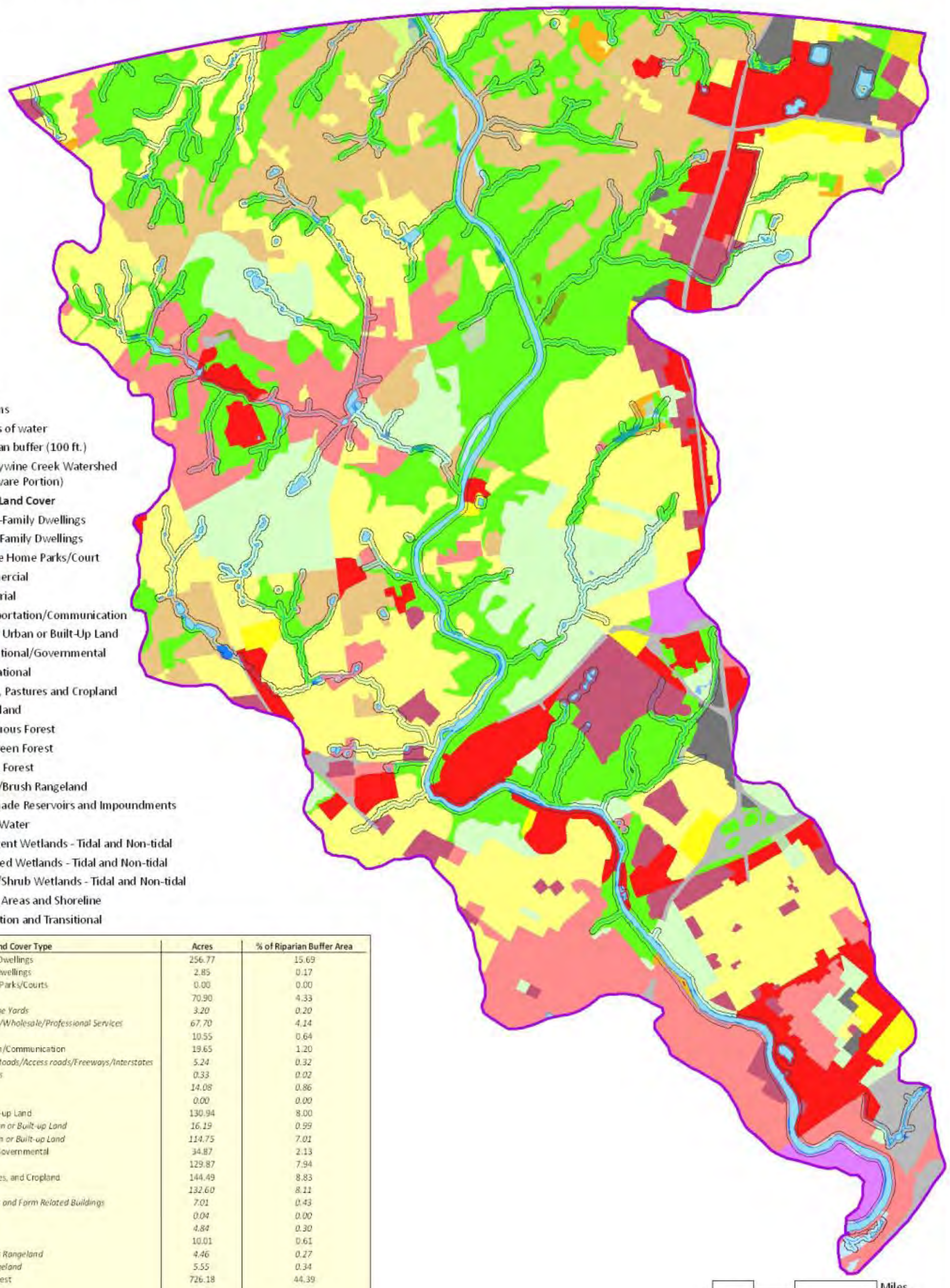
***Data Sources**: Watershed boundary (HUC 10) from DNREC, 1998. Land use/land cover from Delaware Office of Management and Budget, 2008.*

Created: October 9, 2008. Revised November 20, 2008.

Figure 3-15

Land Use/Land Cover and Riparian Buffers, Delaware Portion of the Brandywine Creek Watershed, 2007



Legend

- Streams
- Bodies of water
- Riparian buffer (100 ft.)
- Brandywine Creek Watershed (Delaware Portion)

Land Use / Land Cover

- Single-Family Dwellings
- Multi-Family Dwellings
- Mobile Home Parks/Court
- Commercial
- Industrial
- Transportation/Communication
- Mixed Urban or Built-Up Land
- Institutional/Governmental
- Recreational
- Farms, Pastures and Cropland
- Rangeland
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Shrub/Brush Rangeland
- Manmade Reservoirs and Impoundments
- Open Water
- Emergent Wetlands - Tidal and Non-tidal
- Forested Wetlands - Tidal and Non-tidal
- Scrub/Shrub Wetlands - Tidal and Non-tidal
- Sandy Areas and Shoreline
- Extraction and Transitional

Land Use / Land Cover Type	Acres	% of Riparian Buffer Area
Single Family Dwellings	256.77	15.69
Multi Family Dwellings	2.85	0.17
Mobile Home Parks/Courts	0.00	0.00
Commercial	70.90	4.33
Junk/Salvage Yards	*3.20*	*0.20*
Retail Sales/Wholesale/Professional Services	*67.70*	*4.14*
Industrial	10.55	0.64
Transportation/Communication	19.65	1.20
Highways/Roads/Access roads/Freeways/Interstates	*5.24*	*0.32*
Parking Lots	*0.33*	*0.02*
Railroads	*14.08*	*0.86*
Utilities	*0.00*	*0.00*
Urban or Built-up Land	130.94	8.00
Mixed Urban or Built-up Land	*16.19*	*0.99*
Other Urban or Built-up Land	*114.75*	*7.01*
Institutional/Governmental	34.87	2.13
Recreational	129.87	7.94
Farms, Pastures, and Cropland	144.49	8.83
Cropland	*132.60*	*8.11*
Farmsteads and Farm Related Buildings	*7.01*	*0.43*
Idle Fields	*0.04*	*0.00*
Pasture	*4.84*	*0.30*
Rangeland	10.01	0.61
Herbaceous Rangeland	*4.46*	*0.27*
Mixed Rangeland	*5.55*	*0.34*
Deciduous Forest	726.18	44.39
Evergreen Forest	0.24	0.01
Mixed Forest	1.40	0.09
Shrub/Brush Rangeland	8.31	0.51
Man-made Reservoirs and Impoundments	10.35	0.63
Open Water	29.88	1.83
Bays and Coves	*3.10*	*0.19*
Non-tidal Open Water	*5.49*	*0.34*
Waterways/Streams/Canals	*21.29*	*1.30*
Emergent Wetlands - tidal and non-tidal	21.42	1.31
Non-tidal Emergent Wetland	*13.67*	*0.84*
Tidal Emergent Wetland	*7.75*	*0.47*
Non-tidal Forested Wetland	11.05	0.68
Non-tidal Scrub/Shrub Wetland	0.98	0.06
Tidal Shoreline	1.59	0.10
Transitional (incl. cleared, filled, and gra	13.73	0.84

0 0.25 0.5 1 Miles

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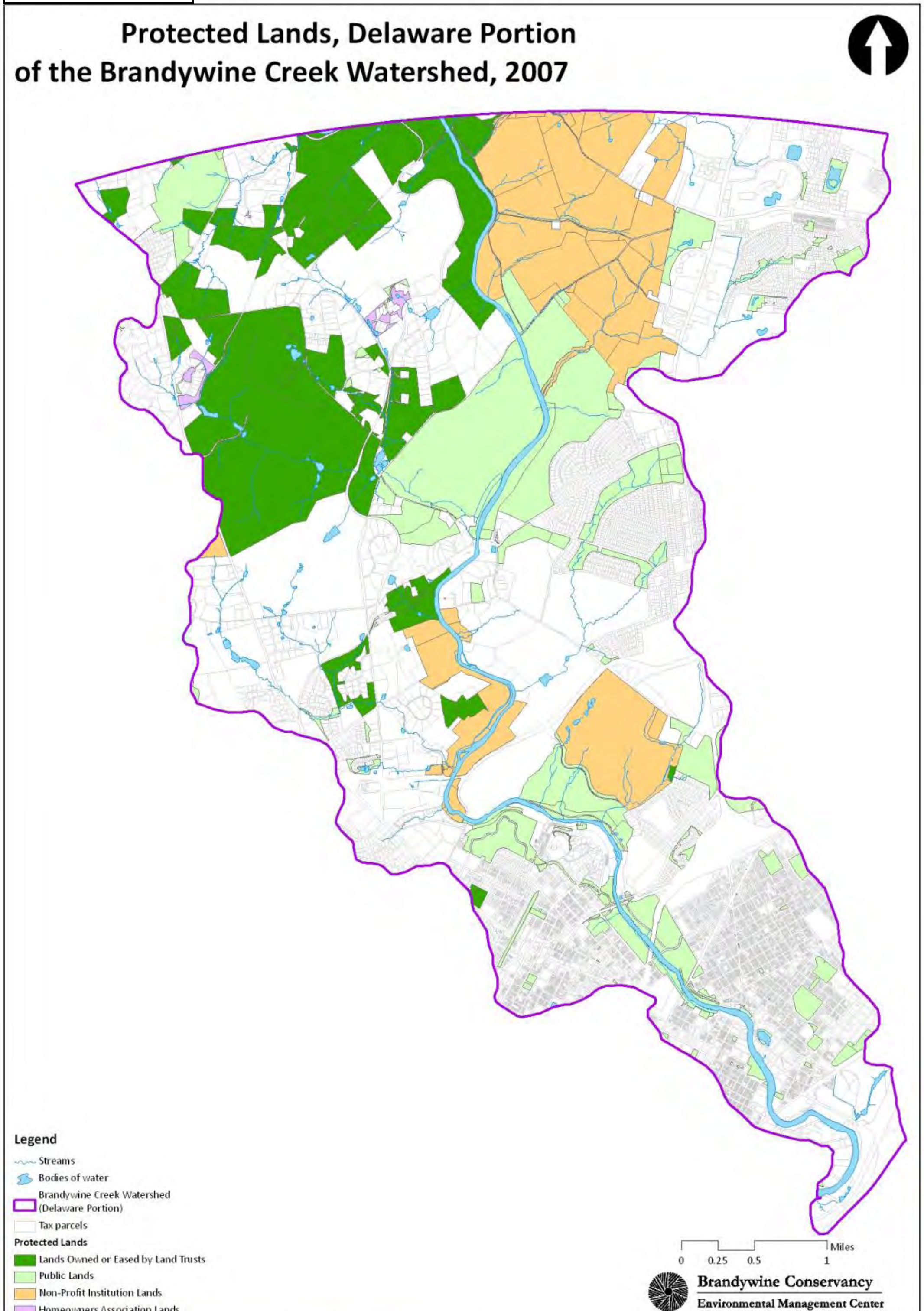
***Data Sources**: Watershed boundary (HUC 10) from DNREC, 1998. Land use/land cover from Delaware Office of Management and Budget, 2008. Streams created by Brandywine Conservancy (9/2008) from layers provided by USGS, Delaware Nature Society, and New Castle County, DE.*

Created: October 9, 2008. Revised November 20, 2008.

Figure 3-16

Protected Lands, Delaware Portion of the Brandywine Creek Watershed, 2007



Protected Land Type	Acres	% of Watershed
Lands Owned or Eased by Land Trusts	2009.1	13.7
Public Lands	1921.3	13.1
Non-Profit Institution Lands	1715.6	11.7
Homeowners Association Lands	36.4	0.3
Sum	5682.4	38.8

***Data Sources**: Watershed boundary (HUC 10) from DNREC, 1998. Protected Lands from Brandywine Conservancy, 2007. Streams created by Brandywine Conservancy (9/2008) from layers provided by USGS, Delaware Nature Society, and New Castle County, DE. Tax parcels from New Castle County Department of Land Use, 2007.*

Created: October 9, 2008. Revised November 20, 2008.